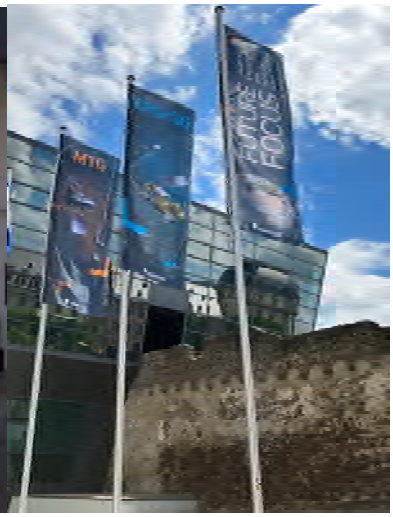
User Days 2022 on MTG and EPS-SG Report



Doc.No. : EUM/MTGUP/DOC/22/1330338
Issue : v3 e-signed
Date : 30 November 2022
WBS/DBS :

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SYNTHESIS

For improving Earth system monitoring and prediction, there is massive innovation potential in the next-generation EUMETSAT satellite missions of the Meteosat Third Generation (MTG) and EPS Second Generation (EPS-SG) programmes. Research and development (R&D) will be essential to fully unlock this potential. The discussions with users, developers and academia at the 2022 MTG and EPS-SG User Days provided a unique opportunity to identify *key R&D priorities* and match them against current plans within EUMETSAT, including its Satellite Application Facilities (SAFs). These priorities are described in the section "SUMMARY of Key Findings".

The User Days also identified items requiring *additional R&D support from the entire community* since they are not, or only partly, addressed in current EUMETSAT plans (such as: PDIP, CSDP, Scientific Roadmaps, SAF CDOP-4 plans). The items are displayed in **Table 1**, grouped into three categories:

1. New developments to enhance user uptake of satellite-based products
2. R&D on improving existing or developing new satellite-based products
3. R&D on underpinning knowledge

Background

EUMETSAT organised the User Days on its next-generation satellite programmes Meteosat Third Generation (MTG) and EUMETSAT Polar System Second Generation (EPS-SG) as an in-person event on 31 May – 2 June 2022 in Darmstadt, Germany. This event brought together users of EUMETSAT data from the national hydrometeorological services and other operational agencies and from the R&D community from Member States, as well as manufacturers of software and hardware. In this first community gathering organised by EUMETSAT after the Covid break, we had 153 external participants from 32 countries (28 member states). The event demonstrated a great team effort of EUMETSAT Secretariat and the SAFs. Sixty-one people working at EUMETSAT attended, not all of them for the full event.

The aim of the event was to:

- ascertain the readiness of operational services in the member states for MTG-I launch and
- identify the opportunities and challenges the novel MTG and EPS-SG data bring for R&D and relevant application areas.

The event highlighted innovative data processing and visualisation techniques in a technical exhibition with participation by five companies and EUMETSAT (data services, user support). The SAF described their CDOP-4 plans related to MTG and EPS-SG in a poster exhibition. The agenda, presentations, SAF posters and preliminary reports from the roundtable discussion groups are available in the meeting website: EUMETSAT User Days 2022 on MTG and EPS-SG and, for EUMETSAT-internal users, here.

Table 1: Items identified at the 2022 User Days requiring additional R&D support from the entire community since they are not, or only partly, addressed in current EUMETSAT plans

1. New developments to enhance user uptake of satellite-based products	2. R&D on improving existing or developing new satellite-based products	3. R&D on underpinning knowledge
• **Develop (integrated) nowcasting tools** using uncertainty information to guide forecasts • More research on handling of **spatial and temporal errors** for use of high-resolution data in NWP • Explore the value of providing model-based O-B analyses to forecasters for very-short range NWP • Analyse fire-related operational forecasting and risk management chains and assess **added value of fire products** such as Fire Radiative Power • **Visualise complex new products**, e.g., 4D weather cube, lightning, 3MI-based • Provide online monitoring tools of the instruments on the EUMETSAT website, showing status and basic parameters (a user-friendly, public CHART; example is NOAA STAR ICVS) • **Systematic assessment of EUMETSAT/SAF climate data record portfolio** in light of evolving needs for timely, regional/locally relevant information and following UNFCCC and the IPCC needs • **Develop cloud infrastructure (e.g., through the European Weather Cloud) to improve data accessibility**, particularly improving data availability and the user experience.	• Develop **merged, multi-sensor, multi-mission (synergy) NRT products** exploring physics-based as well as statistical AI/ML approaches, leading to better consistency and quality (coverage and accuracy) • Develop consistent and uncertainty-characterised multi-mission **climate data records** (L1, L2), taking into account different spatial resolutions, overpassing times and observation conditions, e.g., combining all geostationary ring platforms and enhance this with polar-orbiter data into a global radiance dataset • Develop **all-weather global products** over land, sea ice, and snow cover **using microwave observations** • Additional research to **understand cloud microphysics and phase in severe storms**, using Lightning Imager (LI) and the Ice Cloud Imager (ICI) • Research into **of the development of improved precipitation products** (rain rate, accumulated rainfall) including for more accurate estimates of intense precipitation, shallow precipitation, liquid/solid precipitation (combining data from sensors on MTG, EPS-SG and on other missions such as GPM in a unified retrieval concept) • More research on **fire-related emission estimates** of GHG, trace gases, aerosols based on satellite products and complementary data • More research needed on **inferring cloud vertical information** to meet demanding aviation requirements, in synergy with active instruments (e.g., EarthCARE) • More research needed **on cloud microphysics dynamics** during convection using rapid scan imagery and new FCI 1.3μm and 2.2μm channels sensitive to thin cirrus clouds and cloud phase • Improve night-time tracking of aerosols and cloud microphysics, incl. using ML-based techniques, e.g., by tracking plume objects or creating daytime-like imagery using night-time IR bands • Research into developing a prototype peroxyacetyl nitrate (PAN) concentration product derived from TIR as a facilitator of long-range transport of pollutants (e.g.,NOx) • Make available a "**sandbox" for flexible product prototyping, testing and feedback**	• As a pre-condition to realise the innovation potential of MTG and EPS-SG missions in many application areas, instigate developments to address **gaps in radiative transfer (RT) models** across the full spectral range and observation conditions • Improve **observation operators and surface emissivity models** (over land/sea/sea-ice/snow) to support coupled assimilation, retrievals • Synergy of MTG 4D Weather Cube data for severe weather prediction: **investigate km to sub-km scale processes governing convection** (initiation in particular), cloud microphysics, lightning and hail formation using 4DWC and other data • Promote and support long-term investment in fiducial reference measurements with full uncertainty characterisation over diverse environments • Develop OSSE runs for the assimilation of atmospheric chemistry products to establish data assimilation approaches (L1 vs L2 assimilation, thinning, super-obbing, filtering, etc.) • Better understand cloud-aerosol radiative interaction by creating a collection of cases of poor forecasts due to the presence of dust, and learn from the statistics (focus on Mediterranean area). • Establish uncertainty characterisation based on metrology principles for all instruments throughout the value adding chain starting with the L0-> L1 data processing.

SUMMARY OF KEY FINDINGS

The following tables summarise the salient points arising from the discussions at the 2022 EUMETSAT User Days on MTG and EPS-SG, in particular from the Roundtable discussions. The full reports from the Roundtable discussions are available in Annex I.

Salient points of general nature

Finding	Proposed way forward
About 60% of EUMETSAT Member state national meteorological and hydrological services (NMHS) have declared technical readiness to receive and visualise data from MTG-I1, and have built scientific capacity to exploit the data	Publicize success stories. Targeted user preparation support provided to NMHS lagging behind
Next-generation satellite missions bring significant improvement and novelty but also increasing complexity and some proliferation of products, therefore a strong need for: 1. Application-specific product guidance for users, fitness-for-purpose information, and training and visualization tools (e.g., 3D winds, lightning) 2. Synergy Products[1] – to exploit multitude of missions and their coverage – for example aerosol products from 3MI, UVNS, METimage, IASI-NG from LEO; FCI, UVN, IRS from GEO; merged nowcasting products, combining satellite and surface-based humidity 3. flexible prototype product generation and testing mechanisms (e.g., of synergy products) 4. engaging with a widening and evolving community of users and developers (e.g., surface modellers, data scientists, land surface and biogeochemistry)	1. User portal and Application guides; Training and user engagement framework 2. Identify priorities, through Scientific Roadmaps; generate prototypes 3. This goes beyond agreed baselines: mechanisms and funding to be discussed internally, potentially via the R&D call mechanism for the European Weather Cloud 4. Create mechanisms for interaction with these broader communities (1)-(4) with full involvement of the EUMETSAT Satellite Application Facilities (SAFs)
Data availability through Cloud services and Web Mapping Services (WMS) layers is needed for many more products, esp. in nowcasting, climate, and marine applications	Feedback to the evolution of EUMETSAT data services

[1] In many discussions, participants raised the need for synergy products. The area receives the highest R&D interest of users to simplify exploitation of data from multiple missions or within the global constellation, across spectral ranges and orbits (see Annex V: Pre-event survey responses by participants. Synergy is not an end in itself, but to facilitate uptake and maximise information content. It is intended to improve products for users, and to reduce the diversity and complexity of the existing product suites. Several open questions remain, however:

- At what level are products combined - level: L1, L2, or higher, and how are they represented (data cube,'')?
- Terminology needs to be clarified: "merging", "fusing", "combining", "integrating" all mean "synergy"?
- Physical consistency across products is important, e.g., clouds-aerosol-precipitation, snow water equivalent and passive MW radiances.

Early dissemination of pre-operational data will be beneficial for many user communities, such as NWP centres	To be considered in the commissioning plans of MTG and EPS-SG
Create mechanisms, processes and tools for rapid, flexible interaction with users of products, enabling users to propose changes and new ideas	Via the EUMETSAT User Portal Create a cluster of R&D groups that support studies, product evaluations
Concern by some users about adequate timeliness of products mainly for nowcasting, fire detection (FCI products), assimilation in local area models (ocean winds, 3D winds)	Manage user expectations Identify exact user aspirations and explore options to accelerate processing and dissemination
As a pre-condition to realise the huge innovation potential for many application areas, address gaps in radiative transfer (RT) models and surface properties across the full spectral range covered by the MTG and EPS-SG instrumentation; spectroscopy; cloud, aerosol and surface radiative properties, geometries; performance in an NRT context from UV to MW including polarisation	Instigate developments based on a gap analysis and building on existing databases NWPSAF has plans to upgrade RTTOV for NWP Priorities related to cal/val to be addressed by EUMETSAT roadmaps
Availability, access, and sustainment of ground-based network data for validation, verification, and product development	Partly addressed in EUMETSAT roadmaps
• Engagement with the EC on HorizonEurope work programme effective and ongoing (confirmed by EC statement at event) • Stronger engagement with national R&D bodies and funding agencies related to R&D and exploitation of MTG and EPS-SG data	• Continue engaging and inform Member states on opportunities as needed • Share User Days findings with key R&D entities • Dedicated reflection on how to engage more effectively with national R&D actors

Salient points from Roundtable discussions

Roundtable NWP

Finding	Proposed way forward
Progress required on the handling of horizontal and temporal errors to unlock the potential in time and space resolution improvements.	Preparatory IRS-related study by ECMWF using GIIRS in global NWP. Build on EUMETSAT research fellowship on IRS impact on convection-permitting model. Further research essential to advance these areas. Massive upgrading of infrastructure required to handle data flow/working memory challenges.
Cloud and aerosol information from MTG/EPS-SG warrants significant advances in model developments thus significantly improving weather forecasts. This requires fundamental research to exploit the full spectral range, viewing geometries and resolutions.	Several studies ongoing or planned for looking at the characterisation of cloud and aerosols from MTG and EPS-SG observations.
Cover the spectral range of MTG and EPS-SG from UV to MW in terms of radiative transfer models, treatment of clouds, surface properties, and aerosols as well as geometries, polarisation. Gaseous atmosphere RT is sufficient in MW. Performance of the models needs to be sufficient for operational purposes. Measurements of surface emissivity to cover full range of frequencies, covering all surface types, taking into account the treatment of surfaces (Lambertian vs. specular). Investigate whether BRDF libraries are sufficient. Validation of RT models: Is it sufficient to do RT model intercomparison only? NWP users are interested in verification efforts to understand the differences between models and observations	NWPSAF is planning the development of RTTOV to fulfil the requirements for MTG and EPS-SG (NWPSAF CDOP-4), this includes: updated transmittance data sets using latest spectroscopy data across full spectrum; improve cloud and aerosol scattering capability; fully polarised version; update land surface emissivity atlases and ocean emissivity models Instigate additional developments and research based on a gap analysis and building on existing databases Priorities related to cal/val to be addressed by EUMETSAT roadmaps
Very short range NWP: support forecasters by providing O-B results, ideally a tool that can integrate a group of instruments and send QC alarms to forecasters	Explore the value of O-B (observed minus background analysis) with forecasters
NWP centres need test datasets in BUFR and early access to pre-operational data.	Make delivery of MTG FCI ASR and AMV test data in BUFR a priority. Same for EPS-SG for all BUFR data that are assimilated in NWP
Online monitoring tools of the instruments on the EUMETSAT website, showing status and basic parameters (examples of NOAA STAR ICVS; a user-friendly CHART)	Follow up on recommendation by MWS SAG

Roundtable Nowcasting

Finding	Proposed way forward
Investigate MTG "4D weather cube" information content on low-level moisture, winds, cloud microphysics for nowcasting CI, storm development, tracking compared to other information sources (surface-based etc.) Investigate statistical and/or ML-based modelling of complex processes, e.g., severe weather activation, drizzle, freezing rain, fog	NWCSAF evolution of convection, humidity & stability, lightning products. Feasibility studies on 3D winds, based on IASI demonstrational product (cf. Scientific Roadmap Wind Products). Study on convective updraft detection based on FCI RSS data planned for 2023. Evaluate results of 3 EUMETSAT research fellowships. More research needed on: (1) synergy in 4DWC and complementary data for severe weather prediction. (2) km to sub-km scale processes governing convection (convective initiation in particular), cloud microphysics, lightning and hail formation using 4DWC and other data
Develop metrics to quantify impact of satellite products on nowcasting; use convective initiation as one candidate parameter	• Generate common verification datasets from all relevant sources, e.g. in a European field campaign (e.g., Olympic Games, using ESWD); • Generate sandbox environment for testing NWC tools (e.g., in the EWC) and agree on common skill scores for benchmarking; • Develop "community challenges" • Use RSS experiments with MTG-I1 as one data source
Establish common code base for nowcasting software tools, ultimately to develop a shared European nowcasting tool(s)	Build on "Nowcasting on EWC" discussion group, using Pytroll as a model of collaboration
Augment product validation methods to account for nowcasting-related rare events; quantify product uncertainty and develop methods (incl. ML-based) to use uncertainty in forecasting tools	Develop nowcasting tools that use uncertainty information to guide forecasts
Combine nowcasting-related products into the development of a storm severity indicator tool	Pursue development of integrated nowcasting tools

Roundtable Climate

Finding	Proposed way forward
Systematic assessment of EUM portfolio in light of evolving needs for timely, regional/locally relevant information provision while maintaining the principle "understand the past - monitor the present - predict the future". The measurements from MTG and EPS-SG become most useful in the climate context if they are connected to the past and if the analysis of past measurements can be improved with new knowledge coming from new measurements.	EUMETSAT climate user engagement and product planning process to address this.
Link satellite datasets to downstream users with increasing awareness that users may need information and not data, document integrated user value chains and provide last-mile support to users, e.g., on auxiliary data (DEM, …) for joint use with CDR	EUMETSAT climate user engagement activity will address this, with stronger link to applications and services also at national level, UNFCCC adaptation/mitigation agenda, IPCC (cf. results of "Shaping the future – EUMETSAT support to climate services" 2022 workshop)
Generation of climate data records (FCDR, ICDR, and CDR) remains important, including from combinations of instruments from the entire constellation; data rescue and producing fundamental climate data records (FCDR) for historic instruments is very useful. CDRs from valuable NRT products (e.g., ice products) might be created, being cognisant of the portfolio of other agencies being aware of potential competition and duplication. Consistency across products is essential (e.g., clouds-aerosol-precipitation). Use combinations of instruments in different orbits (e.g., LEO-GEO), at high-low spatial resolution for addressing specific science questions. In addition, sharpen awareness on the increasing quality of global and regional reanalysis to not risk usefulness of satellite products.	Systematic assessment of EUMETSAT CDR portfolio; providing a holistic view for EUMETSAT including the SAF network; more joint product planning across the SAF network and with the Secretariat to remain competitive at global scale; wider engagement in international partnerships
Develop uncertainty estimates at all levels of Climate Data Records and propagate uncertainty from L1 to the end products. This shall allow to express improvements of measurements over time in a time series stitched together from missions over several decades.	Inclusion of activities in the Sec Climate Service Development Plan and SAF work plans. Adding educational elements to training activities on metrology and concepts for uncertainty estimates.
Infrastructure and Data Access: having infrastructure such as the European Weather Cloud (EWC) to work with large amounts of data is essential. Access to all EUM data in suitable formats is required. User friendliness needs to be improved by establishing a Platform-as-a-Service and more targeted documentation.	Ensure accessibility to all needed EUM data; Generate the PaaS layer of the EWC following user demands as planned in the EWC medium-term resource plan. Generate targeted documentation on EWC to improve user experience; Support to the EUMETSAT Data Tailor needs enhancement with more specific examples

Roundtable Atmospheric Chemistry

Finding	Proposed way forward
Improve boundary layer retrievals of tropospheric ozone by combined UV/IR use from S-5 and IASI-NG, for its importance to air quality and inference of tropospheric foldings	AC SAF plans to undertake feasibility study exploiting synergy between IASI-NG and S-5, combining the UV and TIR to generate ozone profile product
Aim for peroxyacetyl nitrate (PAN) concentration prototype product derived from TIR as a facilitator of long-range transport of pollutants such as NOx	Research needed to develop this prototype product
Given large number of S4/S5 products, prioritize validation of products according to maturity, availability of independent validation data, and highest priority to users (NO2, O3 total column, for example); make use of selected "supersites" (e.g. deployed as ARM or Cloudnet) with ground-based composition as well as profiling / radiation monitoring; involve CAMS during commissioning and the use of assimilated products to support validation In addition to overall product accuracy, validation needs to cover Spatial / temporal (seasonal) variability of the product performance. Dependence on the time-of-day (S-4) Validation of uncertainty estimates Information to users on product quality and product limitations need to be provided throughout the mission lifetime – product quality monitoring	To be addressed in S-4/S-5 Cal Val plan; publish validation results. Provide information to user community via User Portal Make Analysis Ready Data available
Synergetic UV and IR retrievals for new products to be considered, e.g., SO2, CO, NH3, and for products under development such as S-5 CH4 and NO2, use of aerosol information from 3MI could improve the accuracy	The need for synergetic product retrievals and the prerequisites will continue to be identified and addressed in the scientific roadmaps and some of these will be followed up by studies (e.g. Support trace gas retrieval from S4 and S5 with cloud information from METImage and FCI; Temperature profile information from IASI-NG and IRS) AC SAF plans the development of Aerosol Direct Radiative Effect retrievals based on synergy between S5 and 3MI
Information on application-based products at the level of data access portal so that products can be identified and explored with thematic application guidance Provide different products on a common grid / format / units / as analysis ready data (ARD), and define what information should go into such datasets (metadata, quality flags, geolocation	This will be addressed in the User Portal and training activities as part of the AC User Engagement framework EUMETSAT is part of a CEOS WG to define the information going into ARD datasets.

Assimilation; priority for CAMS is NO2 and other species and for ECMWF NWP is L1 radiances for Ozone and aerosols. OSSEs using proxy data to establish the data assimilation approaches (thinning, super-obbing, observation filtering, L1 vs L2 assimilation etc.). Requirements on data include the provision of reliable error characterization and averaging kernels	Together with CAMS and other user communities (e.g., Météo-France, CERFACS), prepare OSSEs using proxy data to establish data assimilation approaches.
Reprocessing of climate datasets would require a coordination with ECMWF to integrate into the future reanalysis and with AC-SAF	Continue the coordination with ECMWF and SAFs
Investigate the added value of satellite fire detection and monitoring products (active fire, FRP, burned area) in nowcasting the fire activity, and in estimating fire-related emissions. This could be important information to mobilise emergency & safety teams, warn the population etc.	Fire-related product development and user engagement by EUMETSAT HQ LSASAF and ACSAF, and CAMS Analyse added value of fire products such as Fire Radiative Power in fire-related operational forecasting and risk management chains More research on fire-related emission estimates based on satellite products and complementary data

Roundtable Aerosols and Clouds

Finding	Proposed way forward
Cloud products: Research on cloud vertical information, e.g., more accurate inference of cloud top height (e.g., 10hPa precision for aviation), cloud base, microphysical quantities	More accurate cloud top temperature height retrievals for multi-layer clouds, cloud base and thickness, expected in next phase of NWCSAF, and in EUMETSAT plans. More research needed on inferring cloud vertical information to meet demanding aviation requirements; including use of active instruments (e.g., EarthCARE)
Use of statistical information, textural and spatial structure, high temporal resolution mainly during convective development, e.g. for better knowledge of convective initiation, glaciation speed, rate of change of particle size; enhance detection of thin cirrus clouds to improve cloud type classification	Study on convective updraft detection based on FCI RSS data planned for 2023. Evaluate EUMETSAT research fellowships using FCI More research needed on cloud microphysics dynamics during convection using rapid scan imagery and new FCI 1.3um and 2.2um channels sensitive to thin cirrus clouds and cloud phase
Better estimates of cloud optical depth and cloud effective radius based on synergy products, for improving Earth radiation budget products highly important for solar energy estimates and electrical grid forecasts	Addressed in EUMETSAT plans (HQ, NWCSAF and CMSAF)

Focus product improvements /validation on difficult situations (severe storms, polar regions) Generate probabilistic cloud masks with confidence levels, since binary mask does not meet all user needs	To be considered as part of FCI and METimage cal/val plans Probabilistic cloud masks in plans of CMSAF
Aerosol products: For modelling and research, focus on vertical profiles (layer height), type (dust, ash, smoke), and diurnal evolution for tracking plumes Improve nighttime tracking of aerosols and cloud microphysics, incl. using ML-based techniques, e.g., by tracking plume objects or creating daytime-like imagery using night-time IR bands Improve uncertainty estimates in aerosol products which is a strong requirement by modellers Develop platform-based and GEO-LEO aerosol synergy products, and air quality products in synergy with ground-based networks	 Exploit rapid repeat cycle of new geostationary products (FCI, Sentinel-4). Exploit 3MI for retrieving aerosol profile information, and joint retrievals of aerosol (layer, type) and directional land surface parameters. Studies planned Research studies required in this area Assign uncertainty estimates to aerosol products based on cal/val results. Studies planned Cross-calibrate sensors, and harmonise radiative transfer models and aerosol type definitions. Studies planned
Aerosol-cloud interaction: Improved aerosol products over clouds, and potentially under clouds, using synergy in particular from EPS-SG; use FCI 1.38um channel and 3MI for aerosol-cloud discrimination, including for retrievals at cloud edge and for semi-transparent clouds Better understand cloud-aerosol radiative interaction by creating a collection of cases of poor forecasts due to the presence of dust, and learn from the statistics	 Studies planned Create and analyse case database, with focus on Mediterranean area

Roundtable Atmospheric Winds

Finding	Proposed way forward
Enhanced AMV products from geostationary orbit: 1. Extension of AMVs from FCI Rapid Scan Service, including for higher-resolution AMVs 2. Extension of AMV generation into high latitudes. With improved spatial resolution of FCI, there is a reduced distortion at the edge of the disk. 3. Better usage of cloud parameters (such as cloud depth, cloud base, OCA/MOCA products) for AMV retrievals 4. Stereo height assignment as an opportunity to estimate cloud height	1. To be realised with MTG-I2. Tests planned during MTG-I1 commissioning. 2. Further investigation required 3. EUMETSAT (NWCSAF, HQ) have plans to pursue this 4. To be explored following operations of the full MTG constellation, possibly through NWCSAF visiting scientist
Investigate the use of Aeolus data to better characterize the height assignment problem and improve the setting of the AMV altitude	Comparisons of Aeolus winds against common AMVs extracted from passive satellite imagery to continue
Characterise wind errors, in particular for data assimilation: separation of tracking errors vs. height assignment errors	EUMETSAT investigating the use of new feature tracking methods, and potential use of correlation surfaces
3D winds demonstrational product: Further development needed to support nowcasting tasks such as convective initiation and early storm warning (derivation of level convergence/high level divergence and vertical wind shear in the lowest layer up to 3000m)	Feedback on the usage of 3D winds from users is needed. Demonstrational products under development. Additional research needed to investigate the potential of 3D winds products in NWP and nowcasting

Roundtable Land

Finding	Proposed way forward
Develop all-weather global products using microwave observations in addition to infrared and visible data, very important for land surface temperature and snow cover. All-weather is a major challenge for products derived from IR and optical sensors	Need for further research to develop all-weather development of all-sky microwave products
Need for consistent and unbiased multi-mission time series (for L1 and L2 products), that account for different spatial resolutions, overpassing times and observation conditions (spectral responses, observing incidence angle etc.). Possibly with time varying error bars. From SEVIRI to FCI, ASCAT to SCA, from SSM/I to MWI	EUMETSAT climate user engagement activity to address this. Scientific studies need to be undertaken for extending the data records to meet the expected requirements
Ensure consistency among surface products (e.g., snow cover, snow water equivalent, and albedo)	Further research needed for developing synergistic, consistent retrieval algorithms.
Land surface applications are quite varied and thus there are a variety of satellite base land surface products catering to these applications provided by different groups and agencies with variable levels of accessibility and difference in temporal and spatial resolutions and coverage	Guidance through user portal would support this need by - Documenting changes between consecutive versions of products Cloud infrastructure to improve data accessibility, and to explore multi-sensor approach
Coupled assimilation in NWP community requires improvements in the representation of land surface variables and development of adequate operators over all types of land surfaces is essential	Improve observation operators and surface emissivity models (over land/sea/sea-ice/snow) to support coupled assimilation, retrievals
Land surface product developers have to deal with diverse information content of upcoming satellite data (e.g., IR vs MW) and thus have to resort to new algorithm strategies and multi mission observations. Merged or multi mission products may lead to significant increase in the quality of land surface products in terms of coverage and/or accuracy	Physically based and statistical AI/ML approaches should be considered and combined; Where no reliable RT models exists, ML/AI methodologies should be explored; Cloud infrastructure development should explore multi-sensor, multi-mission approaches
Long-term investment in high quality reference sites with harmonised observation data over diverse environments should be actively promoted	To be addressed in EUMETSAT roadmaps

Roundtable Marine and Sea Ice

Finding	Proposed way forward
Observation operator and surface emissivity model development required to use the data (assimilation, retrieval) from MWI, MWS; covering all frequency ranges; for heterogeneous scenes (land/sea/sea ice)	Build on Snow Microwave RT model (SMRT) and community framework; partly addressed in OSISAF plans
Display of SCA winds in GeoWeb, EUMETView	ASCAT winds are part of EUMETView, this will be continue for SCA as part of data services upgrade
Develop ocean color products based on FCI (water turbidity, chl-a), address atmospheric correction problem in higher latitudes (Baltic Sea)	EUMETSAT study initiated
Crosscutting Climate: • Reprocessing of heritage data which is noisy and poorly calibrated • Training for users on understanding uncertainties • CDRs for winds: how to merge old sensors with the new capabilities of the new sensors • SST focusing on CDR for each sensor • Continuation of sea ice CDRs	OSI SAF plans to addresses wind, SST and sea ice CDRs.
Information on timeline of product development to support the readiness of downstream users: outcomes of science studies, upcoming product enhancements	This information will be provided as part of the User Portal
Needs for Synergy products: Sea ice edge characterization: MWI + scatterometer Snow/ice thickness: MWI and other sensors (IR, altimeter) Sea Surface Temperature: MW+LEO IR+GEO IR	The development of these synergy products are addressed in OSI-SAF plans
RFI is recognised as a problem for microwave SST retrievals in coastal regions, some mitigation options in L1 processing. Validation and assessment of RFI impact is needed for new missions	Users to raise RFI issues via their ITU national representative
Validation: Scatterometer winds: no in-situ measurements of extreme winds – ongoing discussion with the in-situ community Availability of trusted buoys, sea ice surface temperature drifters Multi-sensor match up databases	This is in discussion with in-situ community in the context of EPS-SG Cal/Val planning

Roundtable Precipitation and Hydrology

Finding	Proposed way forward
Accuracy of satellite-based precipitation estimation especially in rapidly evolving situations is a challenge, particularly in the absence of surface-based radar networks; use of future missions to improve accuracy is highly important for civil protection purposes	Identified in plans of the EUMETSAT SAFs for Nowcasting and for Hydrology, based on FCI, LI, MWI and other mission data , and including the use of ML/AI techniques
Research on LI to understand storm microphysics, presence of graupel etc.; the LI-ICI synergy for frozen precipitation needs to be understood to realise the full potential	Additional research to understand cloud microphysics and phase in severe storms, using MTG Lightning Imager (LI) and synergy with the Ice Cloud Imager (ICI). An HSAF Day-2 product is planned to estimate rain rate from LI
Exploitation of new channels of MTG and EPS-SG (e.g., ICI) to improve detection of precipitation and improve the accuracy of precipitation products (intense precipitation, shallow precipitation, phase). Merged products of MTG and EPS-SG, and with other global missions are needed to fill gaps (CIMR, EPS-Sterna, EarthCare, FY-3 etc.)	EUMETSAT SAFs (Nowcasting, Hydrology) to pursue plans for improving precipitation products. Additional research and development needed on the merging of products from different sensors, incl. using ML techniques both in retrieval and assimilation process Engage with IPWG
Continue space-based precipitation radar missions as critical reference for the constellation of precipitation-related missions	Engage with partners in IPWG and CGMS to promote continuity
Improve the estimation of rainfall over land from scatterometer-derived soil moisture estimates. Since precipitation is retrieved from soil moisture accumulated over time, approaches to take into account the time scale need to be considered.	Identified as part of the Hydrology SAF plans; to be assessed as part of the GEWEX precipitation assessments
Explore indirect validation of products within applications, e.g., within hydrological application value chains modelling river discharge, as an alternative to classical precipitation product validation	Identified as part of the Hydrology SAF plans for impact studies and hydrological validation
For high latitude precipitation retrievals, snow cover and sea-ice characteristics need to be physically consistent	Hydrology SAF plan adaptation of algorithms for snowfall retrieval to MWI; ICI-based MW microphysical product retrievals planned (NWCSAF); see also Land SAF plans

Conclusions and Way Forward

The User Days format was highly beneficial and allowed in-depth, open exchange with our core user community. We are considering similar events for Marine and Atmospheric Composition on the Copernicus side in future.

User engagement is effective but needs continuing attention beyond launch & commissioning. It needs to be sustained through application/theme-specific user engagement plans. Engaging with R&D contacts established at User Days has been successful, but could be raised to a higher level through more intense interaction with the R&D community in Member states.

The report provides major input provided for an R&D agenda on next-generation data in Europe which we hope will bear fruit within the community, including within EUMETSAT over the coming years that we deploy the next-generation satellites in space. Tapping into the innovation potential provided by next-generation data will advance our understanding and ability to predict the Earth system, for the benefit of society and protection of life and property.

ANNEX I: MEETING RECORD AND ROUNDTABLE REPORTS

MEETING RECORD

On **Day 1**, in the **Opening and Welcome Addresses**, **Joachim Saalmüller** welcomed participants and introduced objectives and logic of the meeting. The User Days have a key role in bringing together the community of EUMETSAT data users, and provide a step-stone on the road to readiness for MTG-I1 data. **Phil Evans** (DG EUMETSAT) emphasized the massive opportunities arising from the next-generation MTG and EPS-SG programmes, noting that weather, climate and related environmental applications are ever more important to society. Users are fundamental to EUMETSAT, and benefits are only realised when they can exploit data to their full potential ("if users cannot flourish, we cannot flourish"). He recognised the challenges faced by users to prepare for the new missions and the key role of the SAFs as facilitators. **Bozena Lapeta** (MTGUP User Group) and **Stefanie Hollborn** (NWP Core User Group) welcomed participants and outlined their expectations from the event – exchange with colleagues, receiving updates from EUMETSAT, discussing R&D challenges. **Paolo Ruti** evoked scientific and technological drivers influencing Earth observation, and their meaning for the EUMETSAT community.

Bojan Bojkov described MTG and EPS-SG in a European research and development context, and quoted examples for the research potential in novel data from next-generation missions. These include severe storm prediction, deriving precipitation from soil moisture data, and in estimating emissions of atmospheric constituents. **Jochen Grandell** briefed on the status of the MTG programme, stressing that in addition to preparing the launch and commissioning of MTG-I1, work is in parallel ongoing on MTG-S, e.g. integration tests and cal/val of instruments. **Rosemary Munro** updated participants on the EPS-SG programme.

Hans-Peter Lüttenberg (DLR) addressed the development of METimage as a customer-furnished item on the Metop-SG A satellites, making a contribution to nowcasting, NWP and land surface monitoring. **Carole Deniel (CNES)** emphasized the importance of IASI-NG for NWP, atmospheric composition monitoring and climate studies. On behalf of Toni Tolker-Nielsen, **Didier Martin (ESA)** described the Copernicus Sentinel-4, -5 and Sentinel-5p precursor missions as a game-changer for monitoring atmospheric chemistry and climate, with key input to the Copernicus Atmospheric and Climate Change services. **Stephan Bojinski, Sreerekha Thonipparambil** and **Federico Fierli** informed about user preparation activities for the next-generation missions along the following themes: information and communication, training, test data, science support to users, and ensuring data access.

The **session on R&D priorities and perspectives on MTG and EPS-SG** brought together agencies that are supporting R&D activities related to Earth observation. In addition to investigation and operational experience gained with MTG and EPS-SG data by meteorological and hydrological services in Member states, it is clear that additional R&D efforts are required to fully understand and exploit the data, especially the novel mission data such as LI, 3MI, and ICI. In addition, our data is addressing the actual or potential use by an expanding range of user communities and Member state institutions. To effectively demonstrate the introduction of the data into their context, e.g., the land surface modelling community using METimage and 3MI, or the data science community investigating AI/ML methods based on the new data, additional R&D support would be a facilitator. The SAFs have an important role here as actors or facilitators in such support.

A pre-event survey among participants confirmed scientific and technical understanding of MTG and EPS-SG as the biggest challenge for users, followed by data access and. The two most interesting R&D aspects of next-generation data for participants are synergy of products and understanding of Earth system processes (see Figs in Annex).

Paolo Ruti raised perspectives on what should be done to coordinate R&D priorities over the coming 5 years and link them to next-generation EUMETSAT data. Fast tracking the link between science and

solutions for global challenges is an imminent need, given the high relevance of weather and climate information for WEF risk assessments, and the context of the European Green Deal and the Digital agenda for Europe. **Philippe Tulkens (European Commission)** provided challenges and perspectives for Earth Observations in supporting the implementation of the European Green Deal. He stressed that Horizon Europe was strongly engaged in supporting the advancement of Earth observation, and that these data and services were of high important to achieve the objectives of the European Green Deal. He invited participants to look at the many opportunities in Horizon Europe work programme including in Cluster 5: Climate, Energy, Mobility, and Cluster 6: Food, Bioeconomy, Natural Resources, Agriculture, and Environment. Copernicus and Destination Earth are both major programmes supporting Earth observation and Earth system modelling. He also mentioned the EU Missions as a set of placed-based activities rooted in research and innovation but going well beyond, towards deployment in areas of great public interest. **Vincent-Henri Peuch (ECMWF/CAMS)** recognised the transition to truly Earth system modelling, not only addressing weather or air pollution, and the major contribution of MTG and EPS-SG data to the "digital twin of the Earth". Secondly, he recognised the acceleration of R2O, recalling that NWP took 40-50 years to emerge as real operational force outperforming human forecasters; air pollution and ocean modelling took 20 years; and monitoring GHG in the order of 10 years. More hand-in-hand R2O and O2R is required for further advances. Thirdly, the necessity of EO-based activities to address all following three tiers:

1) Earth Observations themselves (including retrievals)
2) Generic processing services (like ECMWF, CAMS…) involving assimilation and modelling
3) "Customisation" applications (tailoring the output of (2) to specific users or clients, which could be downscaling, turning figures into indicators or reports… to deliver fit-for-purpose solutions)

The many instruments on MTG and EPS-SG will provide a major step forward, provided questions around radiative transfer can be addressed. From a CAMS perspective, there is complementarity among (i) L2 products generated in CAMS services; products generated elsewhere and then ingested into CAMS; individual products. **Mike Rast (International Space Science Institute)** presented ISSI as a platform to fund R&D investigation on EO and on other space science aspects. ISSI also supports proposal-based R&D networking activities on specific topics of interest.

The R&D discussion was structured along nine thematic Roundtables, facilitated by co-moderators and rapporteurs: Nowcasting, NWP, Climate, Precipitation and Hydrology, Atmospheric Chemistry, Aerosols and Clouds, Land Surface, Atmospheric Winds, and Marine & Sea Ice. In a pre-event survey, participants expressed interest in all of these, with Nowcasting, NWP, Aerosols and Clouds, Precipitation and Hydrology, and Climate being of highest interest (see Fig. in Annex). Participants could freely choose their participation in the Roundtables on Day 2. By means of introduction, **Roundtable co-moderators** (see Annex X for a listing) presented their R&D briefs with key topics and lead questions to the audience in session 1.10.

The Technical Exhibition featured booths by the following entities: (see Annex and https://cdn.eventsforce.net/files/ef-xnn67yq56ylu/website/30/userdays2022_exhibition.pdf)

All SAFs presented posters with highlights from their current and future (CDOP-4) activities addressing the use of data from MTG and EPS-SG (see https://cdn.eventsforce.net/files/ef-xnn67yq56ylu/website/30/userdays2022_1.1_safposters.zip).

Roundtable sessions were held on **Day 2** all day. Co-moderators presented preliminary reports from the Roundtables in plenary on Day 3. The final reports from the Roundtables are provided in Annex I.

On **Day 3**, the MTGUP User Group, NWP Core User Group and MTGUP Advisory Group held a meeting to discuss user preparation topics.

In a session on data visualisation, **Marc Rautenhaus (University of Hamburg) and Tim Hewson (ECMWF)** presented an approach to visualise meteorological data and satellite data in 3D using the Met.3D package developed mainly for atmospheric research, but also used in research aircraft flight

planning. With its integration into MetView used by the ECMWF analysis section, Met.3D is becoming a community software. It requires GPU-enabled workstations. They showed examples of 3D visualisation of winter storm Eunice in ERA-5. **Sauli Joro and Andrea Meraner** demonstrated the use of sift/pytroll for fast display of FCI radiances and imagery, including fast zoom in and out, segmentation, and overlays.

In a concluding session, **Bozena Lapeta** (MTGUP User Group), **Stefanie Hollborn** (NWP Core User Group, **Paolo Ruti** and **Joachim Saalmüller** reflected on their main findings from the User Days. How users can deal with and benefit from the complexity of next-generation data was a key observation. What EUMETSAT can do to facilitate this process, to untap the potential innovation in the new data. There are tremendous opportunities to take the next innovation cycle in weather prediction, and more R&D will be needed to facilitate this.

FULL REPORTS FROM ROUNDTABLES

ROUNDTABLE NWP REPORT

Session 1: Radiative Transfer

Radiative transfer is the physical basis for exploiting the EPS-SG + MTG observations (mapping them into physical space). The discussions pointed out that the exploitation of microwave in NWP has matured over the years over land, sea-ice but consistent treatment of clouds remains to be missing. These advancements also needs to be extended first to infrared and then to other parts of the spectrum.

Surface: Over surface, there is a potential for using the model parameters as input to the RT models. Fast RT scheme are needed to get surface parameters over difficult surfaces like land/ice/snow. There is work on the OSI-SAF to interface SMRT with RTTOV. Similar efforts are also needed over land surfaces in order to join the atmosphere to the land surface and to retrieve biogeophysical parameters. It was mentioned by one MOSAIC campaign data provides emissivity measurements for frequencies up to 80-90 GHz over sea-ice, but there may be a gap over sea-ice for higher frequencies. Met Office sampled emissivities up to 664 GHz by aircraft over sea-ice, but it was difficult to get enough on-the-ground measurements of the snow density. Similar gaps may exist in the BRDF libraries. There is also a need to consider frequency dependent surface characterisation and whether specific surface need to be treated Lambertian or specular. A survey of where we stand in terms of RT, for all frequencies, over all surface types, would help to identify priorities for development. Are the current BRDF data libraries sufficient? Snow is nearly Lambertian at high frequencies (microwave) and becomes near specular, as it gets wet, so for the visible it is doubtful that we have enough characterization available.

Clear sky: In the area of clear sky RT, preparation in the microwave regions seems sufficient. However, preparatory studies for sub mm instruments are needed.

PC RT: Further development of Principle Component radiative transfer models depends on the assimilation framework for high frequency hyperspectral data. There are no major knowledge gaps that would delay the progress, but maintaining the two RT models under development takes away resources from other efforts.

RT Model validation: Users are interested in RT model validation through model intercomparison or field campaigns. Campaigns are helpful to understand the differences between models and observations. To understand the observation, we need to understand the real world that we seek to measure. Dedicated campaigns while necessary, they also need good design. A more thorough exploitation of O-Bs, especially in relation to campaign and well-characterised observations, would be helpful to build and close error/uncertainty budgets.

To summarise the discussions in this topic, it is necessary to do systematic inventory, and discussion with the SAFs to ensure all EPS-SG+MTG instruments and frequencies are covered by RT models on day 1. Outcome of the inventory will direct future developments of RT models

Session 2: Assimilation

Business as usual (acknowledging the competition of resources to implement the instruments that come into play now) will lead to a significant under-realisation of the benefits of EPS-SG. Understanding the proportion of the EPS data that we do not yet use can be considered as an indicator of this.

Cloud and Aerosol Screening: Cloud and aerosol detection are still needed in NWP: only the very large amounts are easy to detect in NWP, smaller amounts are not. There are two possible approaches to make the best use of the data. a. The current method of using the instruments to filter out data affected by clouds/aerosols, and b. extract information about these aerosols and clouds and assimilate the information into models. The second is a longer-term prospect but it will deliver higher value over the long run. The current method for cloud and aerosol detection is looking at radiative effects in O-B space, but it needs to be investigated to understand whether machine-learning approaches would lead to new developments.

Efficient use of high-resolution data: Temporal error correlations are not understood; hence, temporal thinning needs to be performed until understanding the correlations and how to work with them. Errors can be inflated, but still have data flow / working memory challenges with volume. Side note from rapid update assimilation of radar data - working at 5 minutes is too fast (never stop spinning up) half hour to hour seems to be better.

One possibility to handle the horizontal error correlations is to down-weight the data, and still use them all, without thinning. However, this is only feasible if storage and computing are not limiting factors. This is very different from dealing with retrievals such as AMVs, as each datum has different error characteristics, in which case one is better off picking the best datum rather than use them all. To conclude, working with horizontal correlated errors is complicated but there is enough clarity. One interesting question that was raised is whether using less than 1% of the data still a successful outcome. While of course this is not, but the general view is that the problems are well identified.

Working on the horizontal and temporal errors will enable to unlock the time and space resolution improvements - directly addressing Destination Earth, and high resolution (NWP) forecasting of short-term weather:

- Assessing these error structures in the first place
- Developing methods in data assimilation to exploit this information

Very-short range NWP: The possibility of computing O-B on the bench (without/before assimilation) can be a quick way to quickly identify how the model is behaving. Forecasters cannot look at all the instruments separately, but O-Bs computed for groups of instruments can guide them into where the observations start to differ from the forecast trajectory. This would be an extension of the automatic QC alarms that are already disseminated (although not in real-time), and currently only back to data producers. However, this would need to work across models (forecasters have multiple models available).

The questions is whether this would this be useful to forecasters. One needs to get information from operational meteorologists on what the challenges are where the seamless approach would make a clear difference. Is it even possible given the short timescale nonlinear processes? This would be a possible side benefit of continuous data assimilation (continuous ingest). A side remark is also made that such assessment would mostly be helpful in linear scenarios, but may fail in cases of discontinuous or fast-developing processes.

Observation errors: The progress on basic elements such as observation errors and RT remains clearly insufficient to make full use of the EPS-SG and MTG data by the time these data are available, and the NWP users indicate they are now on track for an under-utilisation. The current prognostic is to use much less than 1% of the data and yet to try and get some positive impact. The capacity to work with huge data volumes is not there at present. Considering the effects of climate change improvements in forecasts should be quicker than a day per decade.

Questions were raised as to whether the community feel that all the necessary information is readily available to address the topic of observation errors and are there parameters that would need to be included in the observation record to help characterise instrument errors.

Situation dependent observation errors were discussed and there was a call for more systematic stratification of error estimates against instrument parameters. Triple collocations are helpful to better understand error characteristics, even if the method is not perfect. Machine learning was proposed to explore the parameters that influence observation error. The relative error partition between observation error and model errors are to be considered for situation dependency. Bias characterization will be important for the new instruments, using the O-B departures and trying to tie them to physical causes.

On whether the knowledge of observation errors could be of interest to other users, it was mentioned that the current systematic and random error estimates (bias corrections and specified obs. error) are not perfect and could be misused or contaminate important applications if users were to rely on them.

Exploitation of clouds and aerosols information from the new instruments: On the use of products like cloud extent, cloud liquid water in NWP, the general remark is that current NWP data assimilation systems are better suited at assimilated radiances than 'products'. The reason is that NWP tries to follow a physical approach in the assimilation, and, in doing so, lead progress in modelling by identifying issues and fixing them in the model. A direct use of the products may not allow to fuel such a second (slower) loop of improvements in modelling. There is a perception at present that product assimilation would lead to parameter estimation and take away efforts to improve physical models. Such products, however, are useful for model / assimilation scheme validation. In addition, studies by Météo-France on updating cloud fields with observations has showed an impact in the short range.
The fact that for the first time a satellite system will fly with such a broad range of spectral properties, and not in an experimental framework, but working operationally and covering many different types of conditions in a short time calls for targeted research in this area. This will lead to a better understanding of cloud microphysics leading to improvement in cloud process understanding and parameterization for both weather and climate modelling.

Value of aerosols for NWP: A question to address is if there are plans in place to bridge the gap towards improving aerosols specifications in NWP, beyond the classical air quality applications.
Aerosols are important from the radiative angle, and attempts have been made to use the CAMS products into other (local) models. ECMWF running comparison experiments between core model and CAMS model to explore requirements for aerosol assimilation and handling, with the hope of identifying a few selected aerosol parameters that are important to include in the ECMWF NWP model.

Coupled Data Assimilation: For the Earth system approach and coupled interfaces, new satellite data provides an opportunity to progress in terms of getting the lower trop. channels used and providing the initial conditions for the boundary interface. There are scale challenges as the scale of the model is much finer than the microwave observations. Moreover, surface models are mostly one dimensional. Modelling the footprint of the observations may assist in reconciling the different horizontal scales of information. (Subject of fellowship at DWD).

Impact studies on MTG + EPS-SG data: OSSEs in advance and OSEs when the data arrive are expensive, but worth the effort. FSOIs are also to be foreseen to estimate the impact of the new data. Getting

an indicator in the model space is helpful and straightforward, but in order to cement the benefit of new data societal impact studies have to be undertaken, which are more difficult.

Session 3: Observation monitoring and system verification

Observation monitoring: NWP Centres request to receive the data as early as possible, quickly after launch for cal/val even when it is still being worked on. Real Time monitoring - instrument parameter monitoring (instrument temperature etc.) at the producer side is essential and a recommendation by MWS SAG has already been made.

EUMETSAT supports a number of fiducial reference measurements which is important. Information on the plans of validation campaigns, what validation has been done and what information is available on the FRMs and campaigns - across themes / application areas have to be made known.
In addition to reference quality observations, reference quality observation operators may be useful.
Regarding the large data volumes foreseen for IRS, there is a day-1 solution in place, but maybe there is a need for further discussion in the MAG for further discussion for day-2 (radiances). Working collaboratively in EWC is an option to consider.

ROUNDTABLE NOWCASTING REPORT

1.1 How to read this document

This report compiles the result of the discussions held in the Nowcasting (NWC) roundtable during the MTG and EPS-SG User Preparation Days. They were held during two sessions of one and a half hour in the afternoon of June 1st 2022. This document is divided in two sections. The first one explaining the preparatory work done before the meeting and the second one detailing the outcome of the round-table.

The round-table results are, in turn, subdivided in three sub-sections for each one of the topics being discussed. The first sub-section, entitled “General discussion” details the discussion that happened live during the round-table. The second sub-section explains what the Rapporteurs and Moderators understand as the “Highlights” of the discussion with the goal of identifying where R&D investments are needed and driving future work in each of the particular areas of interest. A third sub-section is added with “Additional Comments” and advises coming exclusively from Rapporteurs and Moderators.

1.2 Preparatory Work

Rapporteurs and Moderators consulted before the meeting, to identify the meteorological phenomena and possible topics for discussions with the NWC community. The meteorological phenomena listed for attention were:

1. Precipitation
2. Deep convection
3. Fog
4. Turbulence
5. Others. High-latitudes specific weather. The fires topic was added during the discussions as a phenomenon worthy of being connected to Nowcasting activities.

Within the main topics selected for discussion, some particular areas of interest where listed to trigger the discussion among the participants. These topics and areas of interest are:

1. Verification and Evaluation

a) Develop verification/validation techniques: compare products, develop common metric, etc.
   i. Development of metrics to verify satellite date based products
   ii. Development of metrics to quantify the impact of satellite on Nowcasting/Forecasting quality
   iii. Using common verification dataset, and an environment to run “benchmarking” tests
b) Evaluation of satellite based products in operational use

2. Technical Aspects
   a) Common development of techniques and software
      i. Software contributions with a free software license such that others can benefit
      ii. Software portable to other institutions as possible
      iii. Technical standards
      iv. Timeliness of products to be suitable for real-time use in Nowcasting, Warning, data assimilation
      v. Provide information of uncertainty of measurements
      vi. Potential of using ML/AI methods
   b) Sandbox environment
      i. Sandbox environment to compare nowcasting tools and products, in controlled experiments
      ii. Prototypes in the EWC; common tool (e.g. ADAGUC, ESSL Display tool)
   c) Formed a Nowcasting EWC discussion group (contact xcalbeta@aemet.es, Vesa.Nietosvaara@eumetsat.int). See also Convection Working Group NWC EWC presentation.
   d) Foster Development
      i. Via: contests, Visiting Scientists, Fellows, other?

3. Detection, Nowcasting, Forecasting
   a) Use synergy of satellite data with ground-based measurements to obtain a picture as complete as possible of the present atmospheric condition
      i. Combination of satellite, radar, Commercial Microwave Links (CML), rain gauge for precipitation
      ii. Combination of satellite, station data for temperature and WV
      iii. Radar, lighting detection, cloud camera, radiosondes, wind profiles, lidar, SYNOP station,...) and other data sources (crowd-sourced data, ...)
      iv. Uncertainty and/or probabilistic determination, consistency
   b) Use full potential of satellite data in otherwise data-sparse areas
      i. Consistency analysis
   c) Real-time monitoring & probabilistic short-term forecasting of phenomena
      i. Improve on Convective Initiation, T and WV analysis
      ii. Dynamics of storms: analyse winds at top of clouds, anvils, lightning to model storms, “non spin-up” model assimilation?
   d) Combined methods
      i. Observation extrapolation
      ii. Seamless: observation-based physical ensemble/probabilistic nowcasting and NWP-based forecasting
      iii. Round-table discussion results on Verification and evaluation

1.3 Round-table Discussion

1.4 Validation and Evaluation

1.4.1 Verification/Validation of satellite products

General Discussions

- Satellite products developers do perform large validation. However, they usually come as bulk statistics, not always applicable to NWC-critical situations. Nowcasting-specific situations are often linked to comparatively rare meteorological events. Hence, it is difficult to have statistically representative number of cases.
- Satellite product developers should (and often do) perform statistical verification. It should be paid attention that the verification methods are developed in a way to best access the quality of the products with respect to what the products are aiming at.
- There are often not sufficient independent measurements representative of NWC-relevant situations that can be used as reference observations for product verification. E.g., the radiosondes network is sparse; the synoptic launches may not necessarily occur in relevant weather and are also several hours away from typical Polar satellite overpasses. On contrast, lightning detection networks provide a wider coverage and continuous measurements.
- ESSL maintains a catalogue of severe weather, which was considered an excellent starting point. How to collect/share reference observations in those situations and augment the database?
- The estimation and documentation of product properties (strengths and limitations e.g. in vertical resolution, applicability under specific meteorological situations…) is essential in order for the forecasters to use them in an informed manner.
- There are no standard common metrics to verify nowcasting products. Different skills scores are used across the Met Services.

Highlights

- Build dedicated validation sets for NWC purposes, which would also represent common benchmark for the community
    - ESSL maintains a descriptive catalogue of severe weather occurrence, which the group considers an excellent starting point. However, those report databases can only provide information on “positive” events. No report in the database does not necessarily mean that no event occurred.
    - How to collect/share reference observations in those situations and augment the database?
    - The potential of intensive *in situ* campaigns in NWC-relevant periods (convection, sting jet…) to contribute to the above objective should be evaluated. The design would require further thoughts.
    - The above should consider pan-European scale and super-sites components as well as agile instruments to be dynamically deployed upon weather event precursors and developments.
    - It should be discussed whether data from previous intensive observation periods of convective weather performed in recent years e.g. in southern UK, Corse (France), southern Germany/western France, eastern Germany, can be accessed an used for verification efforts or whether the analysis of the design of those campaigns can provide useful insights on how new *in situ* campaigns should be designed.
- Collaborative public observation database should be further explored to complete the database and validation reference.
- Knowledge exchange and collaboration should be further fostered among EUMETSAT and NMHS on designing, implementing, applying and interpreting verification methodologies. This should

also include work towards establishing common metrics that can be used to verify existing and new products.

Additional Comments

- It should be noted that ESSL's database is private and it is not publicly available free of charge.
- Super-sites, similar to ARM sites in the US is probably the best option in order to have proper validation ground based datasets. An alternative, limited in scope with respect to the super-sites, would be to perform campaigns.
- Increased cooperation between EUMETSAT and NMHS should be sought to have a common set of validation datasets. The International Wind Working Group is a good example.

1.4.2 Quantitative evaluation of the benefit of satellite products for forecasting severe weather?

General Discussions

- There are no standard commonly accepted approaches to evaluate a product's usefulness in operational forecasting context. Different practices are used across the Met Services.
- It is difficult to reach statistically significant evaluation sample of the usefulness, as this cannot be performed by the forecasters while busy in their duties. And since nowcasting is usually important for high-impact weather events which are rare and thus no large number of cases occur per season.
- ESSL sometimes organises blind tests in real forecasting context as part of their test beds. Team A/B are provided with different datasets to formulate forecasts, which are manually evaluated the next day. Case studies are also organised in the different NMHS. However, the evaluation samples remain small and mostly yield subjective/qualitative feedback from the users to the products developers.
- It is crucial to train and explain the new products as an informed use is integral to the usefulness of the products. The experience through e.g. EUMeTrain and at ESSL test beds is very beneficial e.g. the recent training with IASI L2 profiles in view of IRS, the geostationary NWC SAF products and other experiences

Highlights

- Comparisons including short-range numerical forecasts, observation-based nowcasting (e.g. using radar data), combined methods, satellite products and independent ground/in situ measurements is encouraged to further contribute to the usefulness evaluation.
- Knowledge exchange and collaboration should be further fostered among EUMETSAT and NMHS on designing, implementing, and analysing evaluation approaches. This should also include work towards establishing common best practices that can be used to evaluate existing and new products.
- Training on products, with an emphasis on new products should be further organised. It is conditional to the products usefulness.
- Rapid scan episodes during the commissioning of MTG-I1 are needed, to validate and prepare for the RSS provided by MTG-I2.

Additional comments

- **Increased cooperation between EUMETSAT and NMHS should be sought for a final end-user evaluation of the products. Testbeds are a good starting point.**

1.4.3 Provision and use of products uncertainties

General Discussions

- The quantification of the product uncertainties (static and random) is essential in order for the forecasters to use them in an informed manner.
- In general, it has become more common to provide uncertainty estimates along with the satellite geophysical products.
- If proven, forecasters can make use of products uncertainties, if reliable and scene-dependent. E.g. good experience made at ESSL with IASI L2 temperature and humidity products was cited: the uncertainty was a scalar pertaining to the lower troposphere, the uncertainty profile under development would help further the utilisation of the satellite sounding.
- Products uncertainties help modulate the confidence with the information used in assessing the probability of severe scenario, and hence in issuing warnings.
- Uncertainties are important for data fusion, when heterogeneous products (remote sensing spectral range, retrieval methodology…) are combined together.
- Machine learning can handle uncertainty estimates in the input data. Semi-automatic expert system could account for uncertainties provided along with geophysical products (whether satellite- or ground-based actually), e.g. to help
    - identifying areas needing special forecasting attention;
    - pointing forecasters to which data layers to focus on first among the 20+ satellite products available

Highlights

- The data producers should generalise the provision of uncertainty estimates and very importantly, should provide information on the significance/reliability of these uncertainty estimates.
- The application developers should further investigate effective visualisation of uncertainties in operational contexts, given the rising amount of information available.
- Further research and development should be dedicated to AI/ML techniques, which is a promising avenue to process the growing wealth of information from satellite data with the future programmes (new missions, additional imager channels, dense 4D atmospheric information…).

Additional Comments

- Uncertainties or probabilities should ideally be included when developing a product.

1.5 Technical developments

General Discussions

- Large positive consensus around the European Weather Cloud (EWC), which constitutes an « excellent opportunity for collaborative work » across Met services and research teams.
- It will allow NRT experiments, ensuring homogeneous ground and evaluation metrics e.g. in view of organising intercomparison studies or public challenges/contests to advance science, promote the products and activity, attract new players etc.
- The NWC-SAF S/W is installed at the EWC, aiming routine production on best effort (not operational scope), including streams of model data (atm. and surface) and visualisation facility (ADAGUC). It is noted that this is considered very helpful both in terms of centralized data access/streams as well as for product comparisons.
- The ESSL Data Viewer is being installed on the EWC. The group indicated interest including access to the severe weather catalogue.
- The question of the scalability and hence sustainability of the facility was raised if too many teams run semi-operational algorithms and software. At this moment in time, this should not be taken as a roadblock.

Highlights

- Ground-based and *in situ* data (radar, lightning, ground GPS TCWV, SYNOP stations…) should be streamed to the EWC
- In this context as well, it is recommended to bridge the gap between data scientists and the communities of meteorologists, remote sensing scientists and forecasters to take full advantage of AI/ML in order to exploit the data and visualize information.

Additional Comments

- A path towards an integrated Nowcasting facility, installed in the EWC should be pursued. The initial steps taken towards the installation of software and visualization tools in the EWC is the first step in this direction.
- It should be noted that currently EUMETSAT is restricting the license to distribute medium sized datasets (two/three years SEVIRI data) to the AI/ML community for research purposes.

1.6 Detection, Nowcasting, Forecasting

1.6.1 Synergies, e.g., satellite-satellite, satellite-ground

General Discussions

- The amount of satellite information is growing. All individual geophysical products cannot be realistically scrutinised and exploited while in forecast shift.
- Synergy between different satellite sensors to provide a common meteorological product should be pursued.
- Some exploratory work has started in different groups, to blend ground- and satellite-information, or to prepare for synergetic NIR-TIR retrievals. The 0.9 micron channel in MTG FCI is a good example of this.
- Fusion between different products to give a common one should be pursued. Combination of surface station based humidity and temperature with satellite soundings is one example. Fusion of radar precipitation and satellite precipitation is another one.
- A combination of products to provide a final Nowcasting product indicating the severity of a situation should be pursued. A product like ProbSevere should be developed.

Highlights

- The synergy microwave+infrared sounding has well established operational heritage now (e.g. EUMETSAT IASI L2 or NOAA/NASA AIRS and CrIS L2 sounding).
- The synergy would be most beneficial if done upfront, in aggregating the geophysical information from different satellite missions (synergetic L2, L2-fusion etc.)
- It is essential to accelerate further the study of synergetic imager+sounder processing. In particular, to exploit the potential of the 0.9µm band of FCI and METimage, to complement the humidity sounding (resp. from IRS and IASI-NG) near surface. The potential of fine scale horizontal structures in the humidity fields enabled by the high-resolution imagers (subpixel info to the sounders) in connection with the satellite profiles should be studied.
- The satellite-ground synergy should be further studied, considering the intrinsic limitations of satellite sounders near surface.
- The potential of ground-GPS TCWV for NWC should be explored. EUMETNet coordinates 2000+ stations in Europe. Forecasters could use it to evaluate large-scale humidity patters, or in case of disagreements between numerical models or between model and satellite data. (It was noted that EUMETNet TCWV is used for validation and monitoring of IASI L2 products already, and is in the plans for METimage L2 cal/val and monitoring).

Additional Comments

- Combination of products from different measurements should be pursued. Particularly for hyperspectral sounders/surface stations and rain gauges/radar/satellite precipitation.
- A kind of ProbSevere product should be developed.

1.6.2 Understanding the atmospheric processes and anticipating developments

General Discussions

- The experience of the forecaster is critical to interpret the data, as the processes but also the model and products characteristics can be very specific to a given region. This knowledge is not easily transferred or put down in an algorithm.
- Automatising detection of areas needing attention is promising, but the accurate prediction of actual convective initiation remains very challenging.
- Considering well established and widely used automatise detections, it was reminded that some markers commonly used for severe weather (cold-U, overshooting-top, etc.) are not necessarily associated with the occurrence of a severe storms below the clouds. Conversely, some dramatic storms were not necessarily associated with these markers.
- LI will further contribute to the analysis of storm top features.
- The cloud microphysics topic has been overlooked in the past years, as priority was given to analysing and monitoring storm top features like e.g. overshooting-tops (OTs). Cloud microphysics is critical to understand the strength of updraft, storm intensity…
- OTs and above anvil cirrus plumes will be much better resolved with next generation imagers. This is a key info to forecasters. It should also facilitate application of automatic detection algorithms. However, word of caution, the higher spatio-temporal resolution (e.g. with FCI) will resolve the "buoyancy bubbling" from the anvil dynamics, which may give wrong impression of denser OTs occurrences.
- Up to know the low resolution of satellite observations compared to radar observations have made satellite observations less useful/relevant. Perhaps this can change with FCI and its increased temporal and spatial resolution.

Highlights

- The convective initiation is an excellent candidate for community efforts, to better forecast and harmonise practices. Synergy crucial to allow for high detection efficiency and few false alarms.
- Explore further the statistical modelling of severe weather activation, exploiting the full diversity of observables from all future missions (MTG + EPS-SG), also exploiting the temporal information
- Investment should be made in developing quality-controlled training sets for ML, for which understanding the physical processes behind remains a key.
- The physics of the weather processes should be further studied, with further investments in exploiting the full information account of various different observation types, the theoretical and numerical modelling, as well as with *in situ* campaigns.
- The high spatio-temporal resolution of FCI shall be exploited to study the water vapour fields preceding convection initiation.
- The ability to characterize low-level convergence with MTG should be studied, in particular whether also the depth of the convergence zone can be evaluated e.g. with the 3D winds from IRS.
- Further studies are necessary to exploit the cloud microphysics potential of the new FCI channels, in particular towards cloud microphysics profiling using a combination of channels.
- Foster exchanges between experienced forecasters and developers: profit from forecasters knowledge and their "meteorological thinking" while on operational nowcasting duties; try to translate and use this knowledge as best as possible while develop new algorithms and products
- The Nowcasting community is strongly encouraged to exchange further and also to document/publish knowledge and practices on e.g.:
  - Nowcasting in operations
  - The perceived strength and limitations of existing and new data sets

- Product and algorithm development
- Understanding and interpretation of different data and products at hand.

- It should be further studied, including upfront of their commissioning, how future missions can help better forecasting the dynamics of storms, including in anticipation of their occurrence.

Additional Comments

- Usually all arguments related to the "holy grail" for satellite meteorology, the Convective Initiation product, lead to a better knowledge of the storm physical dynamics. Any work moving in this direction should be prioritized. One example: the determination of cloud microphysics in the vertical scale (as much as the sensor allows).

1.6.3 NWC relevant atmospheric phenomena

Highlights

- Due to the high relevance of this phenomena and also due to the imminence of MTG-I launch, the forecasting of convective storm and the geostationary and imagery perspectives constituted a large part of the discussions. However, all considerations in this report can be applied to both GEO and LEO platforms.
- A number of non-convective phenomena with potential severe impact on population and society are also within nowcasting responsibilities, with improved capabilities expected from the future missions.
- The drizzle initiation is difficult to detect with ground radars. Forecasting freezing rain is also very challenging. It should be studied if/how future satellite products can be beneficial.
- Fog dissipation: very good experience of better forecasting of fog dissipation is being made with ABI. For instance in San Francisco area, more frequent plane landing authorisations have been enabled, with high positive impact on economy. Strong benefits are expected along these lines with the high FCI spatio-temporal resolution and the new WV channels. Further studies and promotion of the products potential would be beneficial.
- Atmospheric turbulence: can they be monitored given the upcoming improvements in spatio-temporal resolution?
- Sting jet storms: Some preliminary studies in Shapiro-Kayser cyclones using IASI T/q products have been made at DWD, showing the potential for tracking stratospheric intrusion (dry air + ozone descent) with sounders. In particular with IRS, this should be a valuable complement to the traditional imagery. More studies should be performed to feed back to the products development and share possible guidelines within the forecaster community.
- Fire in Nowcasting. EUMETSAT already has excellent fire products. It should be brought to the users as quickly as possible with a timeliness useful for Nowcasting.
- Fire: further to the fire detection and monitoring (performed by other application groups), recent studies indicate that satellite products can help to better nowcast the meteorological configurations potentially intensifying the fire activity. This could be important information to mobilise emergency & safety teams, warn the populations etc. Correlation between fire intensification and dry/ozone intrusions have been observed. This information could be accessible from space. Further studies on this are encouraged.
- Can future missions help better forecasting the dynamics of e.g. downdraft, sand & dust storms?
- Future development plans shall also include arctic/polar phenomena.

ROUNDTABLE CLIMATE REPORT

The climate round table discussed along five major items:

- Assessment of climate change (including extremes) and its impacts
- Climate mitigation and adaptation strategy
- Climate science leading to improved understanding
- Climate prediction and projection
- Event attribution

In all of the above areas, there is a tendency that more local information is needed pointing to the need of higher resolution measurements. The temporal perspective for the discussion was 5-20 years, which is roughly at the relevant scales for climate variability and change.

Needs for Climate Data Records and future evolution of products

The balance of needed products between those needed for climate change assessment and mitigation and adaptation will likely change and the EUMETSAT product portfolio is not necessarily well prepared for it. In general, understanding the past, monitor the presence, and forecast the future most likely remains the guiding principle. Past remains important to provide temporal context to more recent data. The planned addition of Interim Climate Data Records at low latency becomes important for evaluating events with high societal relevance, e.g., recent heat wave in Pakistan and India. Timely availability of data with high resolution and a more complete set of surface data matters as well.

The roundtable confirmed the absolute need for Fundamental Climate Data Records (FCDR) to generate Climate Data Records (CDR). It was noted that reprocessed Level 1 data not necessarily establish an FCDR. The EUMETSAT Secretariat has introduced a new nomenclature separating into FDR and FCDR, the first being best record per instrument but not cross-calibrated using a reference. The roundtable discussed a climate compliance label but came to no conclusion.

Satellite data rescue and producing FCDR for historic instruments is seen very useful, e.g., ESMR (Electrically Scanning Microwave Radiometer), SMMR etc. Also an early start of reprocessing for a new mission after the commissioning phase is seen useful.

The usage of instrument combinations is underdeveloped, e.g., similar instruments in different orbits but also combinations of LEO/GEO, high/low spatial resolution for specific scientific questions, e.g., link permafrost to methane emission, should be assessed and, if useful, implemented. Partnership with other agencies would help to realise.

There is also a clear demand to improve consistency across products, e.g., for clouds-aerosol-precipitation or FAPAR-LAI-albedo, etc.

For the combination of old and new observations it could be attractive to work on concepts to express improvement via uncertainty estimates implemented at all levels of produced data and propagated to the end product.

Awareness needs to be increased to the fact that Climate and other Environmental Services are looking for best products worldwide. EUMETSAT including its SAF network needs to be strong in such global competition. A systematic assessment of the EUMETSAT CDR portfolio is advisable to prepare for the future. A specific look at valuable NRT products that could be turned into CDRs and ICDRs could be part of the consideration. This includes a consideration of the integration of other satellite and non-satellite data that becomes more important, e.g., drones, handheld devices. For the support of mitigation and adaptation, a big portfolio of consistent datasets is needed, e.g. for AFOLU (Agriculture Forest and Land Use), Land Use and Land Use Change and Forestry (LULUCF), atmosphere and oceans monitoring, etc.

Constructing products needs to focus more on downstream usage, e.g. assessing crop losses using satellite data works and may provide links to insurance questions (see IPCC AR6 WG-II), etc.
Participants confirmed that engagement of users with products coming from new measurement capabilities is important, e.g., cloud properties derived from AVHRR and lidar measurements.

The uncertainty approach mentioned above may help with that. Is the user ready to engage with such new products? This requires improved user engagement for enhanced products.

Retrieval and/or reanalysis output – what is needed in the future

User day participants are convinced that both will be needed for the foreseeable future for several reasons. Reanalysis products are acknowledged to be of good value and play an increasing role in state of the climate assessments, and other applications. However, the quality of reanalysis depends on variable considered. On the positive side, spatio-temporal sampling is much better in reanalysis but still diurnal cycles are less good.

The temporal stability of a climate data record is key to assess decadal and centennial variability and singleinstrument-type series may perform better compared to reanalysis. In addition, a retrieval scheme may offer more control for individual variables.

High temporal and spatial resolution is also important, e.g., for land surface applications such as fires. This is better delivered by satellite data, e.g., MTG FCI products. However, downscaling methods can be effective and higher resolution reanalysis at km scale is coming as well.

Finally, satellite products may be easier to use, e.g., products for solar energy compared to extract such information from model outputs. However, toolboxes as part of data stores are increasingly able to reduce data volume, e.g. to allow extracting a figure that contains the needed information.

Infrastructure needs and data usage

The roundtable confirmed that bringing users to the data in cloud infrastructure such as the European Weather Cloud is essential to cope with future data volumes. Nonetheless the experiences with the EWC are mixed. Users see its great potential demonstrated by a couple of use cases, but the use must be facilitated since many users have no experience in administering a Cloud environment. The development towards Platform as a Service is seen as good. More generally the documentation needs to be enhanced.

With regards to data access, the roundtable participants asked for tools to work with large amounts of data and see this as essential to be provided by EUMETSAT. Particularly, local users for local studies need easy access. It was noted that there is a tendency that users care more for easy access rather than quality. This is an issue that could be overcome by providing easier access to high quality data. In addition, users need easier access to auxiliary data such as topography, e.g., for downscaling of precipitation from a global data record.

The existence of multiple products for the same parameter needs better explanation to avoid confusion among the users. Within Europe, very similar products for certain variables are available from EUMETSAT, ESA and Copernicus Services. It is seen necessary to readdress the responsibilities of agencies and to explain better why these products exist and what their particular usage is.

Users also required a facilitation of the combination of EUMETSAT data with other data at national scale. Better guidance on product usage is needed, since the benefits of similar but different products are often unclear to users. Information on data usage and quality might be improved by better organising available information, e.g., by linking datasets with scientific results from data quality assessments. It might also be helpful to link to the products considered in such assessments.

The diversity of data formats is seen critical. Formats compatible with downstream tool are required. The EUMETSAT Data Tailor software support needs enhancement with more specific examples.

ROUNDTABLE ATMOSPHERIC CHEMISTRY REPORT

There were about 15 +-3 people attending the Atmospheric Chemistry Roundtable discussions. The discussion was structured to focus on four main topics, namely

1. Application domains & additional species of interest
2. Calibration/Validation
3. Data provision and access
4. Data assimilation - reprocessing

Application domains & additional species of interest:

Regarding application domains, as a general statement, it was mentioned that it is considered important to widen the focus from looking at individual products to a variety of products relevant for thematic sectors, such as the agricultural sector, impacted by various topics such as land, air quality, weather …: The example given was the impact of wildfires ozone emissions as well as dust deposition from sandstorms on crops/agriculture as well as on air quality.

As a potential new species of interest, peroxyacetyl nitrate (PAN) concentrations were mentioned. PAN is more stable than ozone and facilitates the long-range transport of pollutants such as NOx into remote regions. The possibility of such retrieval from thermal infrared measurements. should be explored, building on the heritage from MIPAS or TES (see Figure 1).

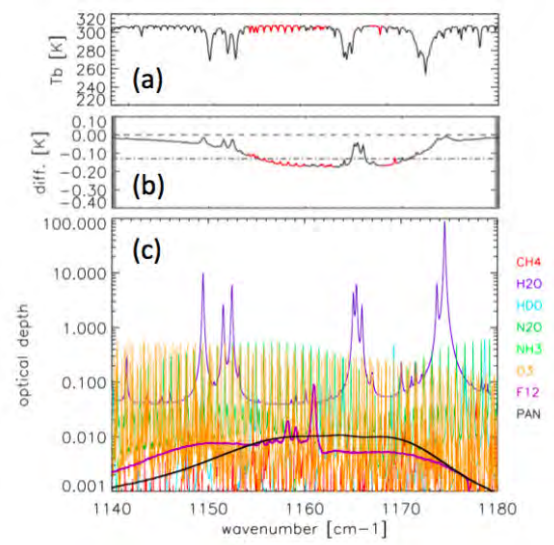

Figure 1: (a) Simulated TES spectrum in the PAN spectral region. (b) Brightness temperature difference for simulations with and without PAN. (c) Optical depth contributions for the dominant interfering species in this spectral region. Figure taken from Payne et al. 2014

Another discussion topic was the retrieval of tropospheric ozone. Possible use cases for this product include:

- Detection of tropopause foldings (downward mixing of stratospheric air) – this requires a reliable tropospheric column in the mid-latitudes.
- It is of high interest for air-quality, however the potential for quantification of near surface ozone is limited

Regarding products already in the planning, it was discussed whether the OClO product (S5, AC-SAF) will be good enough for source detection.
The possibility of synergistic UV and IR retrieval to improve boundary layer estimates was considered (e.g. Sentinel-4 / IRS Synergy). See Figure 2 for an example for GOME-2 and IASI discussed in Cuesta et al., 2013. The possible use of AI-based inference methods was mentioned.

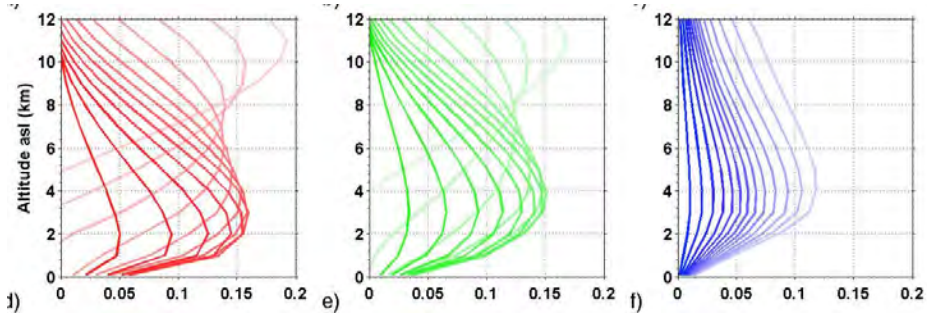

Figure 2: Typical examples of Averaging Kernels between the surface and 12 km a.s.l. for (left) IASI + GOME-2, (middle) IASI only, and (right) GOME-2 only ozone retrieval methods, over land. Figure taken from Cuesta et al, 2013.

Synergistic retrievals using IR and UVNS data could be exploited for additional species (e.g. SO2, CO, Ammonia (NH3)). Both the interest in and feasibility of such retrievals need to be clarified, possibly at the level of science studies.
Regarding the improvement of existing or under-development products, the synergistic use of observations to improve the accuracy of, e.g., S5 CH4, NO2 retrievals was proposed by using aerosol information from 3MI.

Calibration/Validation:

The session was started by recalling that the validation of Sentinel-4 and 5 is under preparation at EUMETSAT and a specific input on general strategy and methods was solicited from the experts present in the room. It was discussed that in view of the large number of L2 products from S4 and S5 and the complex task of commissioning and validating them, a prioritisation of products and staggered release will be necessary. The prioritization shall be a trade-off among (1) the most mature (2) the ones where independent validation datasets available and (3) the ones of highest interest for users - NO2 and Ozone total column were mentioned as the logical candidates for the highest priority candidates.
Regarding issues, the availability of reference data was mentioned. The users voiced a warning about the availability, quality and stability of ground-based data, which is not a given and not fully under control by EUMETSAT. Furthermore, the possibly low numbers of observations effectively available (e.g. for NO2 Pandonia, CO2) was a concern, as well as the geographical distribution of the ground-based data which in many cases is not fully representative of the reality, if for instance pollution hotspots are not fully covered. EUMETSAT's strategy is to rely on consolidated EU and worldwide networks (NDACC, DOAS, ACTRIS, Pandonia, TCCON, AERONET) and make use of selected "supersites" (e.g. deployed as ARM or Cloudnet) with ground-based composition as well as profiling / radiation monitoring. However, the importance of the mentioned topics was generally acknowledged.

There was a recommendation to validate L1 radiances in addition to L2 geophysical parameters by making use of vicarious calibration, using ground-based hyperspectral measurements + RTM at selected sites. Both for L1 and L2, satellite - satellite intercomparison is necessary and to be consolidated.
The need for the involvement of CAMS during the commissioning phase and the possible use of assimilated products to support validation was mentioned and the importance of this activity was generally agreed.
It was moreover announced that the near-real-time monitoring of level-2 products by comparing them to independent data is foreseen and will possibly be part of the data serving (e.g., Data Store).
In addition to overall product accuracy, it was stressed that the validation needs to cover:

- Spatial / temporal (seasonal) variability of the product performance.
- Dependence on the time-of-day (Sentinel-4)
- Validation of uncertainty estimates

It was mentioned that it might be an option to make use of AI in the automated validation and product quality evaluation process for, e.g., identifying biases caused by cross-correlations with auxiliary data issues, such as the presence of snow cover/ice which is not properly reflected in the surface type AUX data.

Data provision:

The question of how to provide the information on validation results / product quality / product limitations to users is recognized as crucial. This needs to be ensured throughout the mission lifetimes and updated continuously. The following points were mentioned in particular:

- The provided information should consist of quality monitoring information, combined with easy-to-access information for users.
- It was recommended to extract key information from detailed Product User Guides and provide the information in a condensed way as guidance for users about fitness for purpose for various applications.
- Similarly, it was recommended to extract key results from detailed validation reports and associate these to the products access point.
- Users asked for the demonstration of usefulness/applications of the products. It was recommended to point users to case studies. In general, it is not easy for users to make use of products of same species from different sensors. It is therefore important to explain the differences, strengths, weaknesses.
- These points constitute an action for the data store - data user portal.

As a general point, data serving was considered crucial and was a specific focus of the discussion. Regarding the chunking of the EPS-SG (L1 and) L2 products, the following clarifications were given:

- The data will be provided in NetCDF in chunks of few minutes and disseminated via EUMETCast.
- If requested by a user, longer time spans of data will be provided via the Data Store as a zip of several of these granules. However, there will be no concatenated orbit files.
- There is no concept of separated NRT and offline products.

This concept was accepted, even if a higher configurability was identified as a potential future feature for the Data Store (e.g. using Data Tailor).
The Data Store shall also grant the access to existing datasets - also outside EUMETSAT (e.g. CAMS / C3S) making use for instance of APIs.
The exploitation of different products - (e.g. NO2) - shall also be served at the level of the Data portal

- e.g. provide different products on a common grid / format / units / as analysis ready data (ARD)
- EUMETSAT is working on prototypes for provision of datacubes.
- There is a specific need to define which are the mandatory information to be provided with ARD data (e.g. metadata, quality flags, geolocation …) – EUM is part of a CEOS WG to define this and input is needed.
- Products can be identified and explored with thematic application guidance - tackled in the Data User Portal - one additional example to be included is extreme events with relevance for climate (e.g. dust - abrupt emissions etc.)

Participants stated the usefulness of Jupyter Notebooks to support users. This is already tackled in EUMETSAT / Copernicus actions in training but is to be expanded and updated.
Webinars / Training are seen as crucial to inform users about quality and “do’s and dont’s”.

Data Assimilation/ integration in models / reprocessing

The priorities and perspectives for Data Assimilation were discussed: The priority for assimilation for CAMS/ AQ models is NO2 (+ other species) while for ECMWF NWP it is mainly L1 radiances for Ozone and soon for aerosols.

CAMS service evolution is object of a specific project with:

- Progress on Data assimilation for Sentinel4 - Proxy with GEMS and OSSEs approach.
- Pragmatic use of data in assimilation using data thinning / super-observations / observation filtering
- IRS L1 radiances for ozone (possibly L1 for aerosol)

Further on the question of L1 vs L2 assimilation, it was mentioned that Météo-France conducts assimilation experiments of L1 radiances for ozone / IRS. CERFACS assimilate radiances.
It was stressed that the requirements on the data include the provision of reliable error characterization and averaging kernels. It was recalled that the products optimally suited for Data Assimilation may be different from user-targeted products (e.g. trop ozone is not well suited for assimilation)
As a clarification, it was explained that data assimilation in the field of atmospheric composition is following two approaches – The initial value problem and the inverse modelling for emissions, where the latter needs a longer assimilation window.
It was mentioned that NH3 and fast reacting species assimilation have different constraints compared to other assimilation, mainly due to their reactivity and non-uniformity. There is currently a Horizon CAMS service evolution which intends to progress with data assimilation with S4.
For the long term monitoring, the reanalyses are taking into account the inter-calibration to reduce the differences between instruments. The global reanalysis ERA6 (2023) will contain dynamic Atmopshere+ocean, whereas the ERA7 (2029) will add the aerosols and will extend the reanalyses back to the 80s and possibly using the level 1.
It was mentioned that regional reanalysis would be very useful as well.
Regarding the topic of reprocessing of GOME-2, IASI it was recalled that the timing of reprocessing needs to be coordinated with the needs of CAMS/ECMWF as the plan for reanalysis starts years in advance. AC-SAF also needs time for development of their part in the chain.
AC-SAF plans to release a long CDR on surface UV, covering period from the beginning of 1980 up to date – Other CDRs are tied to the METOP years and reprocessing.
Regarding NWP reanalysis, it was explained that model systematic errors can be characterized with the current observing systems and this knowledge can be used to remove/reduce systematic errors in the pre-satellite era. No such activities are happening in CAMS.

Recommendations :

The thematic (support to air quality, emergency, science, trends and variability) and users (from services to academia and value-adders) are well identified. It is recommended to take into account likely enlargement of the user's groups and dimension due to Sentinel-4 and 5. **The thematic division (eg Atmosphere / Ocean / Climate) is not reflecting sectors and these may be addressed specifically (e.g. providing aggregations of products for agriculture).**

Specific "experiments" are also sought (e.g. evaluate retrieval of new species as PAN, synergistic retrieval as GEO/LEO or combined spectral for ozone) – for this **science studies** would be an optimal framework.

Validation – it is advised to properly evaluate **the availability of reference datasets, to implements a combined – harmonized approach within Copernicus. This include visibility to users (e.g. validation**

portal) and provision of validation outcomes (e.g. validation reports). The integration of the community at different stages (e.g. key users as CAMS from the commissioning to the wider community through announcement of opportunity). Validation methods may be flexible enough to integrate novel tools (e.g. artificial intelligence algorithms for biases identification)

Data access is felt as crucial and strong recommendation was formulated to provide **Analysis Ready Data extraction at the data access point level** (e.g. Data Store) to facilitate the usage and aggregation. This also addressed the need to interoperate data from different missions. **Moreover, the access to external datasets** can be sought (e.g., ECMWF analyses, forecasts) and this may be implemented with similar APIs at the user level.

Data guidance and training is requested. More specifically a "fitness for purpose" to guide users on the choice of products versus application is deemed as essential. Training is seen also as key tool making use also of self-paced and online methods.

Reprocessing of climate datasets would require a **coordination with ECMWF needs** to integrate the future reanalysis (e.g., ERA6 / integrated ERA7). This coordination may also include input from AC-SAF reprocessing needs.

ROUNDTABLE AEROSOLS AND CLOUDS REPORT

General structure

The round table "Aerosols and Clouds" was structured in three blocks, in order to provide to the users a complete framework to discuss their challenges and ideas. The first block addressed the topic of single-sensor and synergy cloud products. The second block was devoted to single-sensor and synergy aerosol products. The third block was dedicated to cloud/aerosol interactions and to the radiative transfer within aerosols and clouds.

Initial survey about the audience

At the beginning of the round table, a survey was conducted to understand the specific interests of the audience in the generic cloud/aerosol topic (see Fig. 1 below). The domain of activity of the users attending the round table was mainly research, followed by operational services. Many of users described themselves as products providers as well. The audience voiced their current challenges as mainly focused on the topics of multilayer clouds, desert dust, and convection for multiple and often overlapping purposes. The applications of highest interest were nowcasting, followed by climate, and a variety of other applications such as NWP, air pollution, and hydrology.

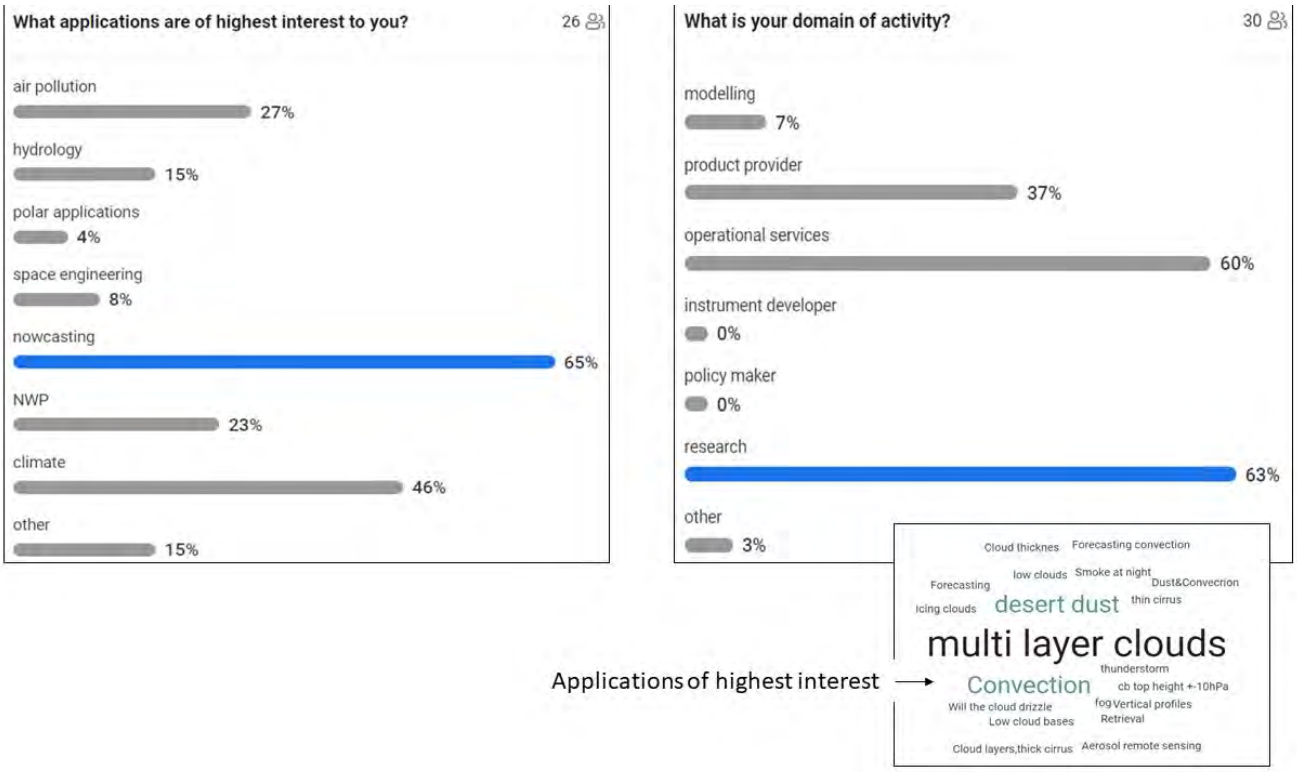

Figure 3: Results of the user survey conducted at the "Aerosols & Clouds" round table.

Session 1: Cloud Products

The discussion covered both single-sensor and synergy cloud products. The main priorities identified within the cloud community can be summarised in three points:

- The knowledge of the cloud vertical information (presence of multilayers, profiling of microphysical parameters, accurate cloud top height for convection studies, accurate base height and presence of supercooled water for aviation applications).
- The exploitation of high-temporal resolution observations for nowcasting, convection development, as additional information within retrieval algorithms etc.
- The improvement of the retrievals for the most challenging situations (Polar Regions, severe convection, etc.).

Sub-session 1.1: Single-sensor Cloud Products

The essential parameters required by the users remain cloud masks, cloud type, cloud top/base height and cloud microphysics. However, each user requires different accuracy for the same parameter, depending on the specific application.

In the case of cloud mask, it was found that a binary cloud mask does not cover the requirements of all the users. Some users expressed their preference for a probabilistic mask with, for example, confidence levels, because it allows flexibility (i.e., tuning of the detection) depending on the application. This product is of

critical importance for NWP and has many applications in different fields (land, cloud/aerosol retrievals, trace gases, lightning, etc.).
Within the cloud type, the correct identification of thin cirrus clouds is critical, especially in connection with deep convection. The rapid cooling of cloud tops can be masked by the presence of thin cirrus, generating false alarms in the detection of convection initiation. Moreover, the cloud type is a necessary information for specific/more accurate retrievals of cloud properties.
The need for an increased accuracy in cloud top height is clear and paramount in many different fields, such as to correctly portray convective initiation or for deriving atmospheric motion vectors. As an example, the level of precision of this product required within the aviation community is identified to be 10 hPa, which is very challenging depending on the cloud type. , Similarly, the knowledge of cloud base height is of special relevance for aviation, and the cloud geometrical thickness contains very important information for precipitation products and other applications. Herein, the identification of multi-layer clouds is challenging.
Cloud microphysical quantities, i.e. cloud optical depth (COT), cloud effective radius (CRE), liquid/ice water path, is important information for many aspects such as the radiative budget, aerosol-cloud interaction and precipitation development. To improve precipitation prediction and retrieval, the correct depiction of cloud microphysics is required, mainly through particle size and particle type. Tiny ice particles around convective cores are a challenging example. Aviation users are also in need of the vertical information on the cloud, especially to be able to identify where icing conditions exist. While ideally products should be available as vertical profile moving towards two-layer retrieval schemes is seen as the next step. The challenge of extending COT retrievals to nighttime due to the lack of visible channels and decreased temperature was discussed by the users.
The Earth Radiation Budget (ERB) products are important for climate applications and modelling, and for solar energy estimations and forecast of electrical grid needs. Because ERB products are often based on COT and CRE estimates, the users are interested in better COT/CRE estimates based on synergy products. In this context, ERB products act also as validation and crosschecking references.
Finally, three opportunities were identified as able to improve in general the existing cloud products: (i) the enhanced use of statistical information, (ii) the utilisation of texture and spatial structures and (iii) the exploitation of temporal information. The statistical information of longer time scales allows for a better understanding of microphysical processes and a more statistic-based forecasting approach, for example for the identification of the type of severe weather. Texture information would widen the scope away from a single pixel and enable a more comprehensive cloud characterisation The temporal information increases the knowledge on e.g. convective initiation, speed of glaciation, rate of change of particle size, distinction between snow and clouds, etc. All three opportunities could benefit from machine learning methods.

Sub-session 1.2: Synergy Cloud Products

The main objective of this session was to identify the synergy products the community is more interested in, and discuss their specific applications. Clearly the users are interested in having the best possible product for their application, rather than a variety of them with limited information depending on the provider/retrieval approach. Synergy products are definitively the step forward allowing a significant improvement of the performance of existing products (e.g. combining on EPS-SG the spectral information from METimage with the microwave information from ICI, and the polarisation from 3MI). For this reason, it is a requirement that each new/synergy product has an appropriate description of the differences with respect to other similar products of the same type/name and for which application it is best suited. With this approach, the users can select the appropriate product that fulfils their specific needs.
Users are most interested in satellite/ground-based synergy. It allows for a better knowledge of many processes but is challenging from both the scientific and the organizational point of view (which synergies are most interesting, how to provide a platform where these merged products can be disseminated and made available to users, etc.). Synergy products based on the combination of GEO/LEO observations are seen as an interesting opportunity to better understand cloud processes and microphysics with respect to particle size distribution, vertical extent, cloud top height uncertainties, precipitation, etc.
Given the large opportunities and high data amounts training of users on how to use the new products comprehensive training and easy to handle visualization tools are essential for the users.

Session 2: Aerosol Products

Sub-session 2.1: Single-sensor Aerosol Products

The main users for the aerosol products are the modelling and the research communities. The main product remains the aerosol optical depth, but both aerosol type and height are highly relevant.
The aerosol layer height (ALH) knowledge is necessary for forecasting. Nevertheless, ALH does not have a clear definition and, for this reason, the aerosol vertical profile could be a better product. This need of an aerosol vertical profile should be addressed with the next generation of aerosol products. The current IASI-based vertical profile is strongly dependent on surface temperatures, which makes IASI-based aerosol detection latitude dependent. The product that is most widely used in forecasting is the dust RGB. Its lack of information on the layer height creates ambiguities. Within the climate modelling community, the ALH in combination of single scattering albedo (SSA) provides a better constraint for the models.
The monitoring of transport plumes requires not only the knowledge of the aerosol height, but also that of the aerosol type, including different types of dust, ash, smoke, etc. The rapid revisit time of the next GEO products will be extremely useful in the monitoring and tracking of aerosol plumes and aerosol forecasting. The volcanic ash and dust storm characterisation will see an improvement too. However, there is a need for night-time observations of all aerosol types, especially in the case of smoke, which is currently only existent for dust. An idea to improve the monitoring is through the creation and tracking of plume objects themselves. This makes the retrieval easier because the approximate location of the plume is known beforehand. This multi-temporal information will allow also estimations of aerosol mass emitted per unit of time, which are essential in the case of biomass burning.
The aerosol type itself is also fundamental for the modelling perspective, since the correct hygroscopicity of the aerosols is an essential parameter for the models. In this respect, the dust aerosol emissions at high latitudes have different characteristics than the dust emissions from the Saharan desert, which should also be better considered in the retrieval.
New sensors such as 3MI will drastically improve the remote sensing of aerosol properties. However, it is necessary to hold a good description of the aerosols that need to be identified. 3MI will also allow for the detection of aerosol over clouds. In combination with IASI, it will yield an even better characterisation of the aerosol layer. Aerosols over clouds can also be detected from a GEO orbit, compensating the lower precision in the retrieval with a higher temporal resolution. There is high potential of assimilating 3MI-derived aerosol products in the CAMS forecast because of the better characterisation of aerosol height and model.
Finally, all aerosol products should also all include the associated uncertainty, which is strongly required by modellers, for example, but currently not really well-defined, nor homogeneous. Unfortunately, the provision of errors is not a topic as advanced as the products themselves. There is the opportunity to provide better characterisation of uncertainties that, in turn, improves the results associated with the assimilated product.

Sub-session 2.2: Synergy Aerosol Products

The aerosol synergy products are useful to cover the needs of the users. The possible synergies can be grouped in three main blocks:

- Platform-based synergies, through combination of 3MI, UVNS, METimage, and IASI-NG on EPS-SG. This unprecedented suite of instruments should allow the improvement of aerosol characterisation. An analogous combination for MTG can be done using FCI, IRS, and UVN.
- GEO-LEO synergy, using the improved aerosol characterisation from 3MI to enhance the retrieval of aerosol optical depth derived from FCI. This could be done by propagating the information from the 3MI retrievals to update the GEO products. The models can then benefit from the so-called

GEO ring (a constellation of GEO satellites evenly spaced to cover to full globe) for quasi-global coverage.
- Synergy with the ground-based network (e.g. AERONET or PM25) and/or models. Air quality is very challenging from satellite, so this can be better constrained locally using ground-based measurements.

To support the development of synergistic products, it is instrumental to consider the harmonisation of the radiometry from the different sensors (e.g. cross-calibration) as well as some aspects of the retrieval (e.g. RTM, aerosol models, etc.).

Session 3: Cloud/Aerosol interactions

This session was focused on the retrieval of aerosols over clouds and/or clouds over aerosols, as well as aerosol-cloud interactions. The discussion was addressed toward the main capabilities of the new generations of satellites and sensors, and the challenges associated with them.
From a user perspective, the RGB images are a main tool for analysis. Still, they present several problems due to the simultaneous presence of aerosols and clouds: temperatures from models are higher than the real ones because of dust presence, precipitation of convection is overestimated, etc. A better detection and forecast of dust and its concentration is a crucial parameter, together with its timing with respect to convective initiation, because it affects the cloud particle size, the amount of precipitation, the strength of convection, etc.
EPS-SG and MTG measurements will provide the capability to derive aerosols over clouds, and potentially cloud properties under aerosols. Most of this work has already been demonstrated by using the A-train constellation, with an existing methodology today. Nevertheless, synergy measurements from, in particular, the EPS-SG instruments have the capability to improve these products. The validations in MTG and EPS-SG context can be carried out using CALIPSO, Aeolus, and EarthCARE.
Among the possible synergy products, those including the use of the 1.38 µm water vapour absorption band can be exploited to improve cloud/aerosol discrimination. The band presents difficulties in scenes with thick aerosols and thin cirrus. However, the EPS-SG 3MI instrument has the capability to provide the polarisation content necessary to discriminate cirrus and aerosols, since spherical and non-spherical particles behave differently.
The radiative interaction between clouds and aerosols presents more difficulties than the discrimination, and while the latter has proven methodologies as mentioned above, the former has not yet been fully demonstrated. Retrievals at the cloud edge and semi-transparent clouds present specific challenges in this regard. An opportunity to improve the knowledge of the cloud-aerosol interaction is to create collections of cases where the forecasts are wrong due to the presence of dust, build a database and learn from the statistics. These situations are common in Mediterranean areas. Since the MTG/IRS instrument will provide the humidity and temperature profile in these areas, it will be possible to establish correlations with the forecast.

Session 4: Radiative transfer (aerosol/cloud)

In order to produce synergistic products it is necessary to simulate all instruments in a consistent manner. The RTM chosen should be fast enough for an NRT operation context, include polarization, and cover the full range from UV to microwave wavelengths. The description of the atmosphere should be consistent, both in terms of ancillary data (as will be the case for EPS-SG) and in the description of the optical properties of aerosols and clouds.
Scenes with extreme view angles such as the edges of the GEO disks, high sun zenith angles at sunset/sunrise, etc. are of high interest but non-sphericity effects must be properly accounted for. However, most of RTMs present limitations in this respect today.

It is not clear whether 3-dimensional RTM are beneficial for operational retrievals, since the degrees of freedom are too high for NRT applications. However, 3D effects should be taken into account for instrument synergies and for instruments with large footprints such as the microwave sensors. A possible solution is to parameterise the 3D effects.
RTTOV is identified as a reliable RTM, especially well-suited for the IR range. It has the added value that the number of users is very large. It can be in many aspects considered the reference RTM, yet it is not fast enough for NRT retrievals in domains where scattering matters.

Session 5: Additional Questions

During the discussion, some user raised additional questions not covered in the discussion described in the previous sections.

- The MTG/EPS-SG sensors and their synergy may allow the development of new products, with additional information, such as flags indicating whether a given cloud is already precipitating.
- In the climate context, the same algorithms have to be applied to the new sensor for consistency of climate data records. It is then advantageous for the users/developers of climate products to have transfer functions for heritage bands during transition period.

Recommendations

EUMETSAT takes notes of the following top recommendations emerged from the overall discussion held at the Aerosols & Cloud Roundtable:

- Data handling (access, processing, visualisation, formats, standards, tools, etc.):
    - Because MTG and EPS-SG will provide an all-new suite of products, including synergy products, it is of paramount importance to provide to the user the proper training on these products and the tools to visualize and explore them.
    - During the transition period from MSG to MTG and from EPS to EPS-SG, transfer functions for heritage bands should be provided to allow the application of existing climate algorithms to the new sensors.

- New products and synergy products: among all possible new products from MTG and EPS-SG, the following are of special interest for the users:
    - Synergy products combining satellite and ground-based measurements.
    - New products providing information on whether a given cloud is already precipitating.
    - Generate products providing temporal information on the dynamic evolution of cloud or aerosol parameters
    - Night-time aerosol product

- ML/AI aspects: the users acknowledge that the use of machine learning algorithms and neural networks can provide improvements in the following aspects:
    - Statistical analyses of large collections of, for example, cloud objects, aerosol plume objects, in order to derive properties and extract evolution parameters.
    - Improvement of cloud microphysics retrievals and RGBs over night (e.g., using cloud structure/texture to infer properties at night or improve daytime retrievals, creating daytime-like images from night-time IR bands, etc.).
    - Tentative retrieval of CAPE (Convective Available Potential Energy).

ROUNDTABLE ATMOSPHERIC WINDS REPORT

The roundtable discussion was moderated by Régis Borde of EUMETSAT and Javier García-Pereda of AEMET/NWCSAF, and it was reported by Marie Doutriaux-Boucher and Alessandro Burini of EUMETSAT. The session was split in two parts; in the first part the discussion was dedicated to the extraction of atmospheric winds, and in the second part to the use of atmospheric winds. Eleven people attended the first part, and nineteen people attended the second one.

Session 1: Extraction of atmospheric winds

The next generation of satellites will allow the production of atmospheric winds at higher spectral, temporal and spatial resolutions. Atmospheric Motion Vectors (AMVs) will be extracted using FCI and MetImage imagers onboard MTG-I and EPS-SG satellites since day 1. In a second round, 3D winds will be retrieved using IRS/IASI-NG sounders.
The discussion was organised around five main points:

- **Enhanced MTG and EPS-SG wind products with higher temporal/spatial resolution**

Considering geostationary AMVs, EUMETSAT will provide day-1 AMV products at full disk resolution every 30 minutes, and the NWCSAF will provide to its users the software to generate regional AMVs at higher temporal and spatial resolution for every satellite slot (every 10 minutes in MTG-I nominal mode). Continuity is preserved: MTG-I/FCI AMV extraction will be similar to what is now done for MSG/SEVIRI. A potential change is the additional use with MTG-I/FCI of 3.9µm channel during nighttime that will allow getting more information at nighttime.
An optimal use of high-resolution visible channels for good detection of small-scale winds, and good distributions of AMVs at medium and low levels have been requested by the users.

Rapid scan mode AMVs will also be extracted with MTG-I/FCI. Rapid scan AMVs will be available only for the second MTG-I satellite, but some tests will be in place during the first MTG-I satellite commissioning phase. They will allow observing rapidly evolving phenomena, for example convection, for which a good tracking of cells and a good evaluation of the lower atmospheric levels is especially requested by the users.

As an example of use, NOAA comments the "1-minute super rapid scan" configuration used with GOES satellites for hurricanes. However, this option is not applicable to normal scenarios. Here, the spatial resolution is a limiting factor for fixing the tracking interval between the two images used for AMV extraction (a minimum tracking interval dependent on satellite resolution is needed so that displacements of tracers can actually be detected between the two satellite images). For the moment, calculation of AMVs every 2.5 minutes with images separated 10 minutes seems to be a good compromise.

The improved temporal resolutions will be a big revolution in terms of data production, although the impact on the users is still not clear. No major challenges are however foreseen on the computing side caused by the increase of data size and frequency. Parallelization of AMV code is discussed with the users, and possibly considered for coming versions.

For low-orbiting satellites, the major improvement of EPS-SG/METimage will be the usage of METimage water vapour channels that will settle the loss of MODIS polar water vapour AMVs. The current operational EUMETSAT dual capabilities need more than one EPS-SG satellite; to bridge the gap, a dual AMV product with Metop/AVHRR by EUMETSAT, or the NWCSAF polar AMV software for several polar radiometers can be considered.

Some suggestions were provided here by the users. On one side, it is possible to extend geostationary AMV production to higher latitudes (current limit with MSG is 65° latitude), as the spatial resolution of MTG-I/FCI increases with respect to the one of MSG/SEVIRI, and so there is a reduction of distortions near the edge of the Earth disk.
On another side, Aeolus data can be used to better characterize the height assignment problem and improve the setting of the AMV altitude.

- **Product and satellite changes**

Two recommendations regarding product or satellite changes have been defined by the International Wind Working Group[2] (IWWG):
- To provide a 9-month overlap period when transitioning to a new generation of satellite and for major derivation changes. For like-for-like satellite changes, a 3-month overlap period is considered sufficient.
- To communicate upcoming significant changes in product provision several months in advance. An important remark has been made by the roundtable attendants: it is required that the correct and needed information is clearly and timely communicated to the corresponding users, to avoid processing issues.

[2] http://cimss.ssec.wisc.edu/iwwg/iwwg.html

- **Options than can be tested/implemented in AMV calculation**

AMV production can be improved with the new generation of sensors. Three main aspects were discussed on this:

- Better usage of cloud parameters:
  Currently, AMV retrieval is assuming in general that the top of the cloud is the driver for winds, but this is not always the case. New cloud information can be used; in particular, it should be possible to use the cloud depth (as NWCSAF AMV software is starting to do) and the cloud base inside the height assignment process. At EUMETSAT, OCA product (MOCA for polar) will be exploited for additional cloud and cloud microphysics information. Difficult cases remain however with multilevel situations.
- Better characterization of wind errors:
  The error characterisation is important in particular for data assimilation. The separation of tracking errors from height assignment errors is seen as a basic element. The usage of the surface correlation will help to compute a horizontal displacement error.
- Cloud height estimation:
  Stereo height assignment can be an opportunity for an improved estimation of cloud height, being based on a completely geometrical process without any type of other assumptions. However, the fact that it is only available for small regions observed at the same time by two satellites, and the fact that different satellites have different scanning processes, are seen as important limitations for its implementation and use. This is so seen as a secondary step following the full MTG operational readiness.

- **Ensure commonality in the definition/derivation of AMVs from new generation imagers**

The IWWG community has defined an “AMV common Quality Index (QI)” and an “AMV common BUFR sequence” for common use by all AMV products, for a more homogeneous use of different sources of AMV data. This is being currently implemented by the different AMV producers. It will be available for the products generated by the new sensors.

The existing Quality Index continues to be used for quality screening, but NWP centres are looking for new and better ways to characterize errors. Due to this, AMV producers will provide further information on the AMV derivation, which will be evaluated for enhanced AMV quality. Besides, considering the capabilities of the new sensors, the AMV quality strategy will be revisited to include smaller scale/higher resolution information.

- **Synergy with wind products from new methods and instruments**

It will be possible to derive 3D wind information from MTG-S/IRS derived fields (radiances and/or vertical profiles). There is a high potential interest from users for MTG-S/IRS 3D winds at full resolution for nowcasting applications, with specific interests in convection and aviation.

3D winds is presently a demonstrational product for EUMETSAT and the NWCSAF will consider to provide also a demonstrational product during the current CDOP-4 phase (2022-2027), which needs further investigation and interaction with the user community. Current prototype for this is the EUMETSAT IASI 3D wind optical flow product with 19 vertical levels, based on humidity information at lower levels and ozone information at higher levels. The vertical sampling has been briefly discussed, stating that the actual 19 levels represent most probably only six or seven real atmospheric flows, with interpolation in between.

In a second round of development, the potential derivation of level convergence/high level divergence and vertical wind shear in the lowest layer up to 3000 metres are seen as important information for convection initiation and early storm warning in nowcasting tasks (although this might be tricky to be measured with the 3D winds).

The user feedback on the usage of 3D winds is important for the producers. In particular, the number of levels on which wind profiles will be provided is still an open question.

Session 2: Usage of atmospheric winds

The second session of the roundtable was addressing the usage of the AMVs. The discussion was articulated around three themes:

- **Use of atmospheric winds in NWP models**

The Met Office (with the whole NWP community) has prepared a document to summarise the requirements for wind products in global and regional NWP models. The document is ready and published on the International Winds Working Group (IWWG) web page[3]. The EUMETSAT day-1 AMV products will be based on this document. The NWCSAF AMV software will also consider using these requirements once published.
Further experimentation might be useful regarding target size and tracking interval, to produce the best product for global and regional applications. Some existing experience regarding thinning/super-obbing may be relevant, but dedicated experimentation is still required.

It is noteworthy that the frequency of AMV provision will increase with the new generation of satellites. However, this is not seen as a challenge by the NWP community for the AMV assimilation. Different perspectives are considered in different centres related to the impact of this in global models and high-resolution regional models.
For example, half-hourly AMV products are interesting for ECMWF, but the benefit is not clear; it depends on how data are used, and how these are correlated spatially: correlation inside AMV data is an issue. The testing of more frequent AMV data can be attempted, but open points arise in how they should be treated.
Considering the 3D winds in NWP assimilation, they should be compared in regional models and assessed versus other wind products, with high dependence on how data are used in the specific regional model, depending on the assimilation schema.

- **Monitoring activities**

The NWPSAF (Met Office and ECMWF) provides a very valuable operational AMV monitoring[4]. It offers a real-time description of satellite wind observations used in NWP models, monthly AMV monitoring and AMV analysis reports. The current summary of satellite winds used in different NWP centres can also be found in their web page[5].
The activities will continue in the new CDOP-4 phase, in which the DWD will also contribute to AMV monitoring.

[3] http://cimss.ssec.wisc.edu/iwwg/Docs/AMVconfiguration_v3_Apr22.pdf
[4] https://nwp-saf.eumetsat.int/site/monitoring/winds-quality-evaluation/amv/
[5] https://nwp-saf.eumetsat.int/site/monitoring/winds-quality-evaluation/amv/amv-use-in-nwp

- **Climate: satellite wind climate data record (CDR)**

The information for existing and planned AMV climate data records (CDRs) are available in the CEOS-CGMS Essential Climate Variables (ECV) inventory[6]. The inventory version 4.0 is the latest available release from October 2021. A next release is foreseen at the end of Q3 2022.
It is clear that:

- 40 years of GEO & LEO AMVs start to be long enough for AMV CDR;
- There is a proven value for climate global and regional reanalysis;
- The AMV CDRs can be used to better understand atmospheric climate patterns and their time evolution;
- There is a clear need to extend AMV CDR with the new era of satellites to come;
- Specific options are needed for some phenomena (i.e. extreme winds, tropical cyclones), which are considered with difficulties inside currently reprocessed datasets.

The continuity of the AMV CDR time series is the key factor for any climate application.

From this discussion, there are some open points:

- Should climate products be based on individual datasets from different AMV centres or a global AMV product (option to use NWCSAF/HRW with all its satellites)?
- Is there any need for a combined AMV climate product? (LEO + GEO)?
- Is there a need for new wind CDRs to be reprocessed: e.g. 3D winds using past and future sensors?
- Climate centres should provide some more insight on the value of long-term AMV reprocessing

Conclusion and Recommendations

- There was a high interest from the users for the new AMV products. The continuity with the current generation of product is important but the novelty should be exploited at maximum.
- The usage of new cloud information will be useful for AMV day-2 products.
- The monitoring of AMV is important. The “Quality Index” definition should/will evolve with the venue of the new sensors.
- There is a high interest for the higher resolution AMVs. It will increase the gain of information for convection initiation and monitoring.
- The water vapor AMVs from METimage will settle the loss of MODIS water vapour AMVs.
- There is a high interest for the demonstrational 3D winds from the sounders instruments. That will open a new era in the winds community. It will allow new important outputs such as the wind convergence and the wind shear.
- The climate data records (CDRs) should continue with the new generation of sensors.

[6] https://climatemonitoring.info/ecvinventory/

ROUNDTABLE LAND SURFACE REPORT

Introduction

The Land Surface Roundtable held during the MTG + EPS-SG User Days counted with a significant number of participants (more than 40, at least during part of this session), representing a diverse community, who highlighted the relevance of observations provided by satellites operated by EUMETSAT for a wide range of land surface applications. The discussions focused on the use of surface sensitive top-of-atmosphere observations, covering spectral ranges from optical to microwave, as well as passive and active sensors. The roundtable covered seven sub-themes, which are described below. However, since most of the major concerns raised during the roundtable relate to more than one of those topics, the overall outcome is not presented for each individual theme, but instead we summarize the overarching discussions and recommendations. Finally, it should be noted that, although the discussions focused on land surface products and applications, as identified below, it is widely acknowledged that there are clear links to all other thematic roundtables, with many of the issues discussed being relevant to Hydrology, Numerical Weather Prediction, or Climate, amongst others.

Sub-Theme 1: Surface Temperature and Emissivity

- Estimation of LST and emissivity over complex surface types (e.g., snow, sea-ice, desert) covering all spectral ranges
- Atmospheric correction algorithms (e.g., aerosols, clouds)
- Synergies between different instruments: IR and micro-wave
- Requirements for climate/multi-annual variability assessment studies – Multi-mission.

Sub-Theme 2: Surface Reflectance and Albedo

- Albedo & BRDF - Improve estimations over all surface types and under difficult atmospheric conditions
- Albedo & BRDF algorithm approaches: ML, physical retrieval of surface reflectance and AOD
- Synergies between different instruments (e.g., METimage, 3MI)
- Requirements for climate/multi-annual variability assessment studies – Multi-mission.

Sub-Theme 3: Vegetation and wild fires, and land use

- Vegetation type, state/health (LAI, FAPAR, NDVI, SIF), Above Ground Biomass and Above Ground Carbon
- Land use and land use change
- Canopy water content: current status; opportunities opened by EPS-SG (METImage; synergies with other sensors)
- Burned area – requirements for medium-resolution products; multi-mission products
- Fire hotspots and Fire Radiative Power: requirements; way forward
- Fire Risk

Sub-Theme 4: Soil Moisture

- Soil moisture from micro-wave passive and active sensors – EPS-SG and Copernicus synergies
- Disentangling Soil moisture – vegetation – surface temperature
- Mapping surface water

Sub-Theme 5: Snow Products

- Snow products from passive and active microwave and optical sensors – synergies among EPS-SG sensors (METImage, MWI, MWS);

- Facing time and space variability of snow properties (e.g., wetness, density, grain size, layering); freezing and thawing
- Snow under vegetation
- Snow water equivalent and snow depth

Sub-Theme 6: Land Surface Processes: Energy-Water-Carbon Exchange

- Evapotranspiration
- Turbulent Energy Fluxes
- Downward shortwave/longwave radiation fluxes in this context
- Gross Primary Production
- Net ecosystem exchange
- Fire emissions (Fire Radiative Power and fuel consumption)

Sub-Theme 7: Assimilation of surface products and surface sensitive radiances in Models

- Operators
- Snow Cover, Snow depth, snow water equivalent
- Surface soil moisture
- Land Surface Temperature
- Vegetation (LAI, SIF, VOD), Albedo

Land Surface Applications

The applications of satellite observations over land are the driver for the development of remote sensing land surface products. Such applications cover a very wide range of topics, namely:

- Agriculture and Forestry
- Assessment/mapping of extreme events (droughts, heat waves)
- Urban monitoring
- Numerical Weather Prediction (NWP) – model enhancement and assessment
- Climate applications

This list is by no means complete, but highlights the diversity of user requirements covering a large range of spatial and time resolutions, which pose challenges to data and product providers. On the other hand, there are already many satellite products available, e.g., Land Surface Temperature (LST), albedo, or vegetation products and indices being provided by different groups or agencies, with variable levels of accessibility, with differences in temporal and spatial resolutions, area and temporal coverages, or accuracies.

NWP models can benefit from land surface satellite products in different ways, from benchmarking to improve the representation of land surface processes to assimilation of land sensitive observations and land products.

Challenges

The selection of available land surface satellite products for the different applications is perceived as a real challenge by users, who often resort to data accessibility and “ease of use” as main criteria to effectively choose the datasets. Guidance is needed and the advent of new missions, such as MTG, EPS-SG and respective products, will only add to such requirements, including the clear documentation of changes between consecutive versions of products and between products derived from consecutive missions/sensors (e.g., MSG/SEVIRI and MTG/FCI).

Many of the user requirements for land surface applications can only be met through the combination of observations from different satellites and sensors, from both geostationary and polar-orbiting platforms such as those operated by EUMETSAT, including Copernicus, and third-party data.

The NWP community is moving towards coupled assimilation, requiring improvements in the representation of land surface variables and the development/improvement of adequate operators (emphasis on microwave frequencies) over all types of land surfaces.

Opportunities

Existing cooperation between different data providers (e.g., SAFs/EUMETSAT, ESA) can be further strengthened and can lead to better documentation in a simple and standardized way to describe product characteristics, target applications and the complementarities among different products.

Cloud infrastructures can be explored to significantly improve data accessibility. Moreover, cloud infrastructures offer the means to explore multi-sensor observations: these can foster collaborative work either from current/past satellites as well as the development of truly multi-sensor products.

The use of surface-sensitive observations, including new instruments such as ICI/EPS-SG, may significantly improve surface/near surface variables in NWP models. The development of coupled surface and atmosphere operators, over the full frequency range is strongly recommended. In parallel, there is the need to improve land surface operators (converting land surface variables into satellite observations), especially over complex surfaces, to enhance the exploitation of surface-sensitive channels for these environments. Statistical/machine learning approaches are welcome to overcome the problem of physically-based emissivity models.

Land Surface Products Development

The degree of complexity between satellite observations and land surface variables is diverse: for example, the information content for LST in thermal infrared window channels is very high, while the relationship between snow water equivalent and passive microwave can be challenging. This implies that very different approaches – algorithm and observations wise – must be taken into account. Indeed, the role of existing and forthcoming observations to address different land surface products together with new algorithm strategies, making use of physically-based radiative transfer models or new machine learning/artificial intelligence methodologies were the subject of the discussion within most sub-themes of the roundtable.

Other topics widely discussed concerned the need to address new paradigms in product development, including the use of multi-mission products, multiple observation sources (satellite and in situ), and the need to go towards all-weather retrievals. Regarding the latter, while acknowledging that satellite observations may lack surface information under certain conditions (e.g., cloud-covered areas), gaps in the data products may be a strong limitation for many applications.

Challenges

Developers of land surface products must deal with the diverse information content and therefore resort to new algorithm strategies and multi-mission observations. The retrieval of gap-free (all-weather) products is a major challenge, for products derived from optical and IR sensors.

Validation of land surface products is often a real challenge given the lack of in situ reference data.

Opportunities

"All weather" global products, in particular land surface temperature and snow cover, will benefit from the use of microwave observations (e.g., MWI/EPS-SG, MWS/EPS-SG) in addition to infrared and visible data (e.g., FCI/MTG, METimage/EPS-SG).

Merging or fusion of multi-mission data (e.g., MTG and EPS-SG sensors, similar sensors operated by different agencies, or METimage and 3MI to improve albedo and vegetation indices) may lead to a significant increase in the quality of land surface products (regarding coverage and/or accuracy). The merging can be done at levels 1 or 2, depending on the variable to be retrieved and on the observations. Ideally, merging at level 1 would be preferred, although practical issues must be considered.

The combination of different observations/products can be further extended and approaches that exploit the synergies between surface and atmospheric products are strongly encouraged, e.g.: snow water equivalent estimates could benefit from snowfall observations; precipitation and soil moisture are obviously closely linked.

Given the wide range of available and foreseen observations, physically-based retrievals and statistical "ML/AI" approaches should be both considered and, whenever possible combined. For some environments, no reliable consistent radiative transfer model across frequencies (e.g., snow in the microwave) – emerging ML/AI new methodologies can be further explored for these cases.

Climate – a Long-Term Perspective

A number of topics discussed during the roundtable concerned the use of satellite data and products for long-term monitoring and are presented here, regardless of their relevance for near-real-time products and applications. It is acknowledged that EUMETSAT missions, with sustained operations over long periods and ensuring continuity among different satellite generations, are particularly well-positioned for the long-term monitoring of the Climate System in general, and of land surfaces in particular.

Challenges

Despite the continuity effort between consecutive EUMETSAT missions, ensuring consistent and unbiased multi-mission time series (for level 1 and 2 products) is far from trivial, especially when taking into account different spatial resolutions, overpass times and observation conditions (spectral response function, observing incidence angles, amongst others). Efforts to inter-calibrate the satellite data at level 1 should be strongly promoted, including the earlier satellite mission to provide the longest possible time series (for instance ESMR, to SMRR, to SSM/I, SSMIS, AMSR, and soon MWI).

Validation of climate (and near real time) land surface products is absolutely essential and the availability of reference, high standard and sustained in time in situ observations should be actively promoted by the satellite community.

The study of land surface processed generally involves the analysis of different variables obtained from satellite observations, eventually complemented by model fields. However, although the consistency among the various datasets is essential (e.g., between vegetation products and albedo, or between snow cover, snow water equivalent and albedo), this is often not guaranteed.

Opportunities

The full-time record, from SEVIRI to FCI, or ASCAT to SCA, or SMMR, to SSM/I to MWI, must be fully explored. The development of consistent and unbiased multi-mission products (e.g., based on those pairs of sensors) should pursued, preferably making use of all valuable information (e.g. without discarding new

channels) and with time-varying error bars. Such time series are key for climate applications, including reanalysis (C3S), but it is paramount that the consistency between climate time series and near real time products is ensured. Indeed, the suite of available observations should be explored to derive a range of products, beyond land surface variables, that close and allow the monitoring of the water, energy and carbon cycles.

The temporal coverage of EUMETSAT satellite missions and their ensured continuity make these observations highly valuable for the development of Climate Data Records and for climate assessment studies in general. The complementarity between satellite observations, modelling, and in situ measurements should be recognized as a major asset in this regard, and the respective observations and modelling communities are strongly encouraged to work together.

Summary of Main Recommendations:

Data Accessibility

- Data accessibility and usability must be given highest priority to promote the use of the most appropriate datasets/products for each application, preferably making use of cloud infrastructures.
- Following frequently expressed user needs, it is recommended to provide guidance in the selection of land surface products for specific applications, as well as to clearly document the changes between consecutive versions of products, or concerning follow-on mission products.
- Cloud infrastructures should also be considered as an opportunity to obtain multiple observations and products, but also to promote the development of multi-product applications, providing access to the necessary tools to merge / fuse high resolution observations at regional scales.

Land Surface Products Evolution

- It is recognised that some user requirements for land surface applications can only be met through the use of multi-sensor/multi-platform observations, including different sensors on-board EPS-SG, on MTG and EPS-SG, or others. Cloud infrastructures should also be regarded as an opportunity and further explored for that purpose.
- New approaches to resolve the different levels of information in top-of-atmosphere observations, or to allow or improve, retrievals under difficult conditions (e.g., complex surfaces, heavy aerosol loads, or cloudy conditions), combining optical and micro-wave observations, or physically-based and machine learning methodologies.
- In situ measurements are absolutely essential in remote sensing applications, namely for
    - (i) The Evaluation of the products;
    - (ii) Integration and assimilation in the product retrieval;
    - (iii) Training of the statistical retrieval for complex variables.

  Long-term investment in high quality reference sites, with harmonised observation data over diverse environments should be actively promoted.

Long-term products and Datasets

- It is strongly recommended to develop consistent and unbiased time series developed from multi or follow-on missions (e.g., MSG and MTG; for both levels 1 and 2 products), that account for different spatial resolutions, overpassing times and observation conditions (e.g., spectral responses, observing

incidence angles). Such datasets should preferably take into account all available information/channels and be provided with time-varying error bars.
- Consistency among various surface products (e.g., LAI and albedo, or snow cover, snow water equivalent and albedo) is also strongly recommended to allow their use in comprehensive studies of the evolution of land surfaces and land surface processes.
- Beyond the consistency among land surface products, satellite-derived products should be considered as a whole and be developed/assessed with the goal of closing the water, energy, and carbon cycle budgets, for their wider use to monitor the Climate System.

ROUNDTABLE MARINE AND SEA ICE REPORT

Session / Subsession 1: Sea Ice

This session began with an introduction from Rasmus Tonboe (DMI). He covered: requirements for sea ice data from the new missions; how to exploit the data; uncertainty and validation; CDRs and what we want for the future; as well as perspective on combined and new products. He highlighted the following priorities: continuation of provision; NWC applications; operational oceanography; climate monitoring.

Rasmus highlighted the Science plan from MWI-ICI showing a gap in research above 100GHz (freshwater sea ice; scattering models).
It was noted that OSI SAF follows the GCOS requirements for ECVs.

Main discussion points
Synergies:
Questions were raised on possible synergies for sea thickness between the L-band radiometer and CIMR, as well as with Sentinel-1. S-1 products are not so mature. Focus on this, as CIMR will only come after 2025.
For EPS-SG MWI plus Scatterometer will be used for sea ice edge characterisation.
Models:
Research is needed to be able to assimilate radiances. Discussion was had around the use of the Snow Microwave Radiative Transfer Model (SMRT) – observation operator. SMRT is supported by ESA but is a community initiative. Higher frequencies in particular need further modelling. SMRT was recognised as a platform for sharing this code etc. and is open to new modules.
Use of Mosaic campaign:
Instruments used did not focus on higher frequencies, but still relevant.
Resolution:
There is a wealth of data to improve products using combination of scatterometers towards sea ice. However, there are resource limits and many face challenges in fully exploiting the data we already have.
Combined scatterometer radiometry products would benefit from the higher resolution.
Enhancing the spatial resolution of the microwave radiometer (incl Noise) products would be good. Noise is not such an issue – good contrast between water and ice. So better spatial resolution should be achievable.
Sea ice emissivity and temperature
Emissivity products are not used a lot. How can they be more useful? How could this product be used in models? What are the observation operator development priorities? There is still a need to exploit the existing data e.g. AMSU at lower frequencies
In the next phase (CDOP-4), OSI SAF has some resources to work further in model development (observational parameters). SMRT was again raised as an appropriate framework within which this development could occur.
The question was raised on whether AI could be used for approximation. However, for this you still need SMRT simulations. There are ongoing experiments about the layers needed to resolve temperature profiles.

CDRs

Good collaboration with CCI and EUMETSAT – SMMR/SSMI/SSMIS data – now mature CDRs (interim release 2) fulfilling requirements from GCOS and all fully validated with peer review documentation. Users need to get used to using the uncertainties within the data. Going back as well as forward – using Nimbus back in to 70's.

Combining products
SMOS and CryoSat sea ice thickness is an example. Move from the OSI SAF to combine, drift, thickness etc. Is this what the user community wants?
Should L-band and altimetry sea ice thickness be provided by OSI-SAF or is it better for users to combine data themselves through their models.

Is there a need for snow/ice thickness (MWI and other sensors)? - Yes.

Interest in products for Baltic – but narrow for microwave sensors. Need to fix problem of observation operators in heterogeneous scenes (mix land/water).

Integration of data directly into Earth System models might be better than combined products.
Considering cross-SAF interactions, question was posed whether other products e.g. direct readout data (NWP SAF package) are needed. In the short-term, there are no plans to use direct readout MWI in the sea ice products.

Challenges / Opportunities

- **Coordination of use/integration with SMRT framework**
- **Training for users on uncertainty usage**
- **Synergy with Sentinel-1 and later CIMR.**
- **Improving resolution of microwave products.**

Session / Subsession 2: Wind

Main discussion points
OSI SAF is processing scatterometer data from seven satellites. There is the problem of not having in-situ measurements in the extremes; ongoing discussions with the in-situ community.
Improving the quality of coastal winds – ongoing enhancements and SCA is expected to improve the current product with increased resolution and accuracy. There will be new opportunities to exploit Doppler products on SCA to detect ocean surface motion (similar Sentinel-1).
Pytroll community are ready to use all scatterometer winds; for Baltic Sea community, the enhanced coastal winds will be very beneficial.
Forecasters are using Diana to view data, but will be switching to GeoWeb. To encourage use by forecasters it is important to offer a visualisation based on a web map service, OGC or other standard that should be adopted.
Challenges / Opportunities

- **Timescale of availability of wind products**
- **Reporting of calibration.**
- **Gridded L3/4 wind and stress which corrects NWP errors is generated as part of the Sea surface wind TAC. Looking for users of these data to test the new product.**
- **Web map service for winds – needed. But have not tested EUMETView yet.**
- **Concern about CDRs for winds when you have sensors with new capabilities. How to merge these?**

Session / Subsession 3: Sea Surface temperature

Main discussion points

Harmonisation of products (EUMETSAT OSI SAF and Copernicus; GHRSST community) L2 and L3: skin, sub-skin and depth; plus algorithms and brightness temperatures. Collaboration between OSI SAF and CMEMS to provide coverage; formatting; algorithms; analysis ready data.

Consistency with sea ice temperature products – should these be separate or combined separate or combined? No preference was stated.

Cal/Val and Fiducial reference measurements – improving the reference measurements, TRUSTED buoys and sea-ice surface temperature drifters.

Forecasters like to see SST data in the morning to prepare for the day – if linking to algae blooms etc. Need to consolidate users' timeliness relative to applications.

Fitness for purpose and guidance information is needed to ensure users are aware of the products to use. This will also be highlighted in upcoming GHRSST meeting on training requirements.

CDR issue with new sensors - same for SST? For SST will be mainly focusing on CDRs for each sensor, and to use the new capabilities to also look at uncertainties in older sensors/records.

Interference, particularly a problem for coastal region, is a problem for microwave SST retrievals. L1 processing of microwave instruments – is there already flagging procedure for the interference? Some mitigation options are being implemented in the processing of the data, tbc, once the data start to flow how these can be tuned. In addition, an issue with 5G for scatterometer and future C-band missions like CIMR. Users should signal concerns with RFI via their ITU national representatives.

Are there records of RFI contamination? During cal/val, RFI assessment campaigns may be made over some regions. (this is a question for Markus Dreis, the EUMESTAT RF expert).

Merged product (beyond OSTIA) to come? MW from LEO and IR from LEO and GEO. The community recognises the need to improve these products. Diurnal changes; horizontal resolution.

Synergies – IASI-NG and MWS are being planned for cloud detection, however currently not planned for SST.

Match-up databases are being planned/used to assist in validation – efforts started to build multi-sensor match-up databases. Efforts to coordinate the process within GHRSST, with the aim of creating a common software. This might align with the needs on how to deliver uncertainty.

Using the future satellite data to make past (CDR) measurements better, has this been considered?

Key reference sensor SLSTR (using AVHRR or IASI IR to bridge the gap)

Salinity and SST as a potential synergy? Ocean/Atmosphere interchange would benefit from salinity measurements (as well as others – Ad's examples of 'process' views).

Challenges / Opportunities

- **Interference in the coastal zone.**
- **Improvements in resolution of merge products.**
- **Salinity and SST synergy**

Session / Subsession 4: Ocean Colour

Main discussion points

Question in the first day plenary session on ocean colour products from EPS-SG/MTG. There was interest in such products and a wish for EUMETSAT to pursue these. To continue the discussion in the round tables – EUM is initiating a study to develop ocean colour products from MSG / MTG. The plans are to have evaluation and test products for users of water turbidity from MSG and additional chlorophyll from MTG. What is the application of OC from FCI? Previous research into turbidity and sediments. Temporal evolution of the ocean is very interesting.

Interest for support for ocean modellers for geostationary OC products.
Potential concern for Baltic atmospheric correction for OC from geostationary orbit (high satellite zenith angle)
Really should push for synergy with other sensors to get around some of the shortcomings of the current state of geostationary OC.

Challenges / Opportunities

- Gap filling of current OC products
- Use of current polar orbiting OC to overcome shortcomings of geostationary OC.
- Concerns around atmospheric correction under high solar zenith angles.

Crosscutting Topics:

Validation and evaluation (reference observations, etc.)

Main discussion points

Challenges / Opportunities

Do users need support to meet requirements for providing uncertainty estimates (alongside satellite products, and/or alongside in situ data)?

Climate aspects (long-term datasets, full error characterisation etc.)

Main discussion points

Challenges / Opportunities

CDR issue with new sensors – wind and same for SST? For SST will be mainly focusing on CDRs for each sensor, and to use the new capabilities to also look at uncertainties in older sensors/records.

Data handling (access, processing, visualisation, formats, standards, tools, etc.)

Main discussion points

Challenges / Opportunities

Need for WMS for different layers. Perhaps need to arrange testing and feedback on EUMETView options/for future developments.

ML/AI aspects

Main discussion points

- Potential use of AI in sea ice emissivity related modelling approaches.

Challenges / Opportunities

- Still need physical models (SMRT etc.) as input for AI approaches
- Open services – making sure products are available through view services like WMS/WFS/WCS etc. Providing online access through cloud services.

Cross-cutting Topics

Main discussion points
Challenges / Opportunities
One point coming out of the Precipitation/Hydrology session is: what is the timeframe that we are looking at? Is it MTG 4 or is it something foreseen in a shorter timeframe. We should try to frame any future detailed discussions with time and resources in mind. This could be a recommendation for future dialogues. They have also picked up on how inform the user community about the outcome of the science studies and the upcoming product enhancements (ones already planned, but not communicated). Downstream users need to know this timeline to help their readiness.
In the Climate session, (Rasmus was present): Desire to take advantage of the heritage data from earlier missions. Given the poor calibration and noise in the old data, reprocessing of these data would be beneficial. Could this be coordinated/reprocessed by EUMETSAT?
Mapping requirements of timeliness to applications – probably a broad theme. Might be useful in a 'fitness for purpose' framework.
Issue with climate level studies without climate quality products. What other axes? What are the parameters needed to be combined for different processes/application? E.g. tropical convergence. Related products? Ocean-atmosphere? El Nino?
User support and training – fitness for purpose – users do not always use the correct product e.g. climate quality data. Any step the improve this is worthwhile. How can we do this better? Develop a tree – CDR, time range, uncertainties, coupling of ocean-atmosphere, etc. Include the 'processes' to better understand how the data can be used 'thematic/application'.
Rob – guidance on GCOS data. How to understand what is achievable, from the data, and what is required by the user. Not all CDRs are real CDRs, quality and applicability are important.

Recommendations:

Any recommendations that emerge from the Roundtable discussion.

- Data availability through cloud and WMS etc. layers is needed across all product streams.
- Fitness for purpose framework needs developing along with communication of these for different products/under relevant thematics. Particularly relevant for CDRs and any 'long time series' products.
- Tool to maintain constant interactions with users for ideas/changes needed would be useful. Need to continue the dialogue and take it further with the user community and to formulate a process for capturing future dialogues, analysing and responding to the feedback and creating change.

ROUNDTABLE PRECIPITATION AND HYDROLOGY REPORT

Introduction to discussions:

Benefits from the current generation precipitation products

Main discussion points

- *On what application do you focus on (spatial and temporal scales of interest? => for processes understanding / for modelling and forecasting / for hydrological applications / for NRT applications / for climate applications / water and risks management (droughts, floods, landslides) / others (e.g., agriculture, food security))*
- *At what spatial/temporal scale are you using the precipitation product for your application?*
- *Are you using the products over ocean and/or over land? (Over complex terrain?)*
- *What kind of errors are the most problematic for your application? (Detection of precipitation? detection of phase? (Liquid or frozen), estimation of intensity? (Light versus heavy precipitation), precipitation microphysics details? (e.g. particle size distributions)*

Challenges / Opportunities

Accuracy of precipitation estimation especially in rapidly evolving and/or fast-moving events is a challenge, especially in regions not covered by ground radar networks or over ocean. Use of future missions to improve accuracy of precipitation amount and resolution would be particularly important for civil protection purposes. Monitoring of severe (e.g. convective) events is expected to be improved with MTG (including data from lightning imager) and EPS-SG. With MTG data products from the Rapid Scan Service there will be the possibility to catch the fast-moving storms giving large quantities of precipitation over small areas should be improved.
Quantifying precipitation over complex terrain is challenging, since orographic precipitation enhancement leads to very heterogeneous precipitation fields.
Shallow precipitation and precipitation phase represent another challenge. Concerning shallow precipitation, EPS-SG will contribute to its quantification (MWI and ICI in particular), but the resolution of the passive MW sensors is a limitation, as well as the radiometric contribution from surface emissivity (snow/ice and land).
Additionally, identification of precipitation type aloft and at the ground, together with the consistency of microphysical assumptions were identified as points requiring attention.

Session / Subsession 2:

Benefits from the synergy between instruments onboard EPS-SG and MTG

Main discussion points

- *Soil moisture information from the scatterometers (SCA) => Correction of false alarms in blended products? Soil moisture to rain algorithms? What could be the synergy between MWI, ICI and SCA?*
- *Snow cover information from VIS/IR imagers (FCI and METIMAGE) and low frequency MW channels => Better surface characterization for improving retrievals?*
- *Convective activity characterization from the Lightning Imager => associated intense precipitation?*
- *Better constraints on cloud and precipitation environment from MTG/IRS => In most blended satellite product, a single IR channel is used, toward usage of multispectral IR for precipitation?*
- *Multi-resolution instruments, footprint matching, issues, and opportunities?*

Challenges / Opportunities

Current algorithms can already benefit from all the channels that have a heritage of current platforms (e.g. frequencies between 18 and 183 GHz), although a few channels are not fully exploited yet (e.g. temperature sounding channels).

First operational (Day-1) activities for EPS-SG and MTG:
- HSAF will provide algorithm for microwave (polar) and this will be implemented in NWCSAF products generation.
- NWCSAF plans MW microphysical products retrieval from the ICI instrument; this could be particularly useful at high latitudes.

The SAF CDOP-4 is already ensuring some flexibility in improving EPS-SG and MTG Day-1 products, but this is a long-term development that will lead to improved Day-2 products – still lot of research to be done. (e.g. exploitation of sub-millimetre frequencies with ICI).

Several synergies will be very interesting to explore:
Synergy with SCA: Soil moisture to rain algorithms are quite relevant over land. The studies that have been performed so far aim at correcting false alarms from the combined products with this information. Exploring this synergy for studying evaporation over oceans may be interesting as well but has not been explored so far.
A big challenge for this particular synergy is the issue of time scale – precipitation has to be retrieved from the soil moisture accumulated over time – the timeline has to be accounted for. In some areas it is a very effective approach, but cannot be used everywhere (e.g., flooded areas).
Synergy with LI: LI will provide information which is not necessarily directly connected to surface precipitation but to microphysics (distribution of ice, graupel in the cloud). LI will also bring a lot of information about developing storms and convective areas. There will be a product from LI in H-SAF but also in Day-2 products in which it is planned to use lightning information.
Synergy with ICI: ICI will provide information sensitive to cloud ice, which will be very valuable, in particular for high-latitude precipitation. It will also be interesting to relate with LI measurements and precipitation. AWS will fly in the 2024-2025 time frame with 325 GHz channels that could be used in preparation of ICI. This kind of observations will be new from space and therefore challenging to use.

Session / Subsession 3:

Benefits from the synergy with other missions

Main discussion points

- *More direct information on precipitation from active instruments (CloudSat/EarthCare, GPM Core, AOS) => needed for training of cloud and precipitation retrieval databases -> Synergies?*
- *How to benefit from the detailed vertical information but low spatial resolution of polarimetric RO for improving precipitation products.*
- *Tackling the beam-filling problem of microwave imagers with high-resolution observations (CIMR over ocean (or for very deep convection).*
- *Background surface characterization (including snow cover and sea ice) at high resolution (synergy of EPS-SG and CIMR) for improving precipitation retrieval (e.g., high latitudes, coastal areas).*
- *Intercalibration of instruments for climate records (products and reanalysis).*

Challenges / Opportunities
Merged precipitation products are usually derived from a constellation of sensors. EPS-SG will be an important contribution to the fleet of microwave sensors and MTG as well for the geo-ring of infrared sensors. It was highlighted during the discussion that some sensors which are already in space are not used yet in many precipitation products. Usage of the full fleet of microwave instruments should therefore be fostered as most as possible (e.g. use of FY platforms, underexploited in current products) in order to derive the best precipitation estimates.
The role of the Copernicus Imaging Microwave Radiometer (CIMR) was discussed. It has different orbit (dawn-dusk) from Metop-SG, allowing for synergy especially in the Arctic region. CIMR can give information on soil moisture, SST, salinity of the surface layer, total WV, observing the sea-atmosphere

interface, wind vector information, sea ice and other cryosphere-related geophysical parameters. The high resolution of CIMR for channels at Ku, Ka and W bands will provide very relevant information on precipitation and convective cores which has not been observed before at the low microwave frequencies.
For precipitation monitoring, reference products are often provided by spaceborne radar. In this respect, GPM and the planned Atmosphere Observing System (AOS) missions are very important. It was therefore highlighted in the discussion that the future availability of EarthCare data is critical to avoid gaps in space radar coverage (EarthCare is most suitable for low rain rates than high rain rates like GPM).

Session / Subsession 4:

Benefits from the latest algorithm developments of AI/ML techniques

Main discussion points

- *Do the AI/ML techniques better extract the information content within observations? (e.g. non linearities?) Example of GPROF for low rain rate improvements, snowfall retrieval at high latitudes (SLALOM), and future EPS-SG day-1 and day-2 products.*
- *Need for high-quality training datasets (observational datasets not available for new missions / new channels -> joined effort to provide large datasets based on simulations?)*
- *Do the AI/ML techniques facilitate synergies by better handling multiple inputs (including usage of multispectral VIS/ IR channels for MTG-based products)?*

Challenges / Opportunities

ML/AI techniques are becoming very popular in the precipitation community. It helps to handle multiple sources of data both on retrieval side and the assimilation process (e.g. exploiting multispectral instruments). It is also very useful to handle large training datasets (e.g. 25 years of precipitation radar data with TRMM/PR and GPM/DPR)
Exploitation of ML can help in the most challenging situations – i.e. monitoring of precipitation over snow-covered land or over ice. It is also important to reduce false alarms in the classification between stratiform and convective precipitation.
However, before using ML, detailed data analysis needs to be performed. Tuning is essential including careful training to correctly capture and represent extreme events.

Session / Subsession 5

Validation and evaluation (reference observations, etc.)

Main discussion points

In the absence of a dense ground network of rain gauges or radars, satellite precipitation products are the only alternative to monitor the situation. It is not about the competition between different observation networks, but merging the information from various complementary networks.
A lot of efforts have been invested into comparing the retrieved products with ground network data in order to document the differences and highlight weaknesses and strengths of satellite rainfall products. However, in some cases, validation exercises are difficult to perform. For example using rain gauges as reference can represent quite a challenge due to the well-known spatial representativeness issue.
One alternative validation kind, called indirect validation, was discussed and represents an interesting alternative which should be encouraged. It consists in using the products within an application and validating the outputs of the application instead of the rainfall quantity itself. The main example which was given is in hydrology when the experts do not compare products versus reference data but the impact of product into river discharge.

Key Remarks :

1. Coordination between SAFs provides added value and can lead to improvements of in the tailoring of the precipitation products for the end users.
2. Effort should be put in improving and exploiting merging of information coming from different sources in an appropriate ways (e.g. ground data, radar, satellite...)
3. Synergy between MTG and EPS-SG instruments is already planned and should be further fostered in order to provide improved merged products to the users (e.g. research on ICI).
4. It is necessary to continue the reference missions. Future availability of space radar data (EarthCare data, AOS data) is critical to avoid gaps in space radar coverage.
5. The future of the passive microwave constellation is a concern in the precipitation and hydrology community. In particular current planning for third party missions is not fully clear at the moment. MWI/ICI/MWS/AWS (and CIMR at a later stage) will provide a long term contribution to the constellation.

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Marčev	Angel	IHMS of Montenegro
Marcucci	Francesca	CoMet-Operational Center for meteorology
Marcucci	Adriana	Italian Air Force - Operational Centre for Meteorology

Marseille	Jan-Gert	KNMI
Martin	Didier	ESA
Matsangouras	Ioannis	HNMS
McCorkel	Joel	NASA
McNally	Tony	ECMWF
Mehr	Thomas	CGI Deutschland
Meirink	Jan Fokke	KNMI
Melfi	Davide	Italian Air Force Met Service - COMet
Meraner	Andrea	EUMETSAT
Merše	Janko	Slovenian Environment Agency (ARSO)
Miechurska	Sylwia	EUMETSAT
Mihulet	Eugen	National Meteorological Administration, Romania
Mikulas	Branislav	IBL Software Engineering
Moisselin	Jean-Marc	METEO-FRANCE
Monteiro	Isabel	KNMI
Munro	Rosemary	EUMETSAT
Myrvoll	Lotte Kroer	Kongsberg Defence & Aerospace
Navickaitė	Katrina	Lithuanian Hydrometeorological Service
Nedelcev	Ondrej	Czech hydrometeorological institute
Nietosvaara	Vesa	EUMETSAT
Nisi	Luca	MeteoSwiss
O'Brien	Enda	Irish Centre for High-End Computing (ICHEC)
O'Carroll	Anne	EUMETSAT
Öztopal	Ahmet	Istanbul Technical University
Panegrossi	Giulia	Institute of Atmospheric Sciences and Climate (ISAC) - National Research Council of Italy (CNR)
Pāps	Kristiāns	Latvian Environment, Geology and Meteorology Centre
Pekná	Stanislava	IBL Software Engineering
Peuch	Vincent-Henri	ECMWF
Phillips	Pepe	EUMETSAT
Piontek	Dennis	Deutsches Zentrum für Luft- und Raumfahrt
Poelman	Dieter	Royal Meteorological Institute of Belgium
Poli	Paul	EUMETSAT
Portabella	Marcos	Institute of Marine Sciences (ICM-CSIC)
Preusker	Rene	FU-Berlin Weltraumwissenschaften
Prigent	Catherine	Cnrs - Observatoire De Paris
Proud	Simon	Rutherford Appleton Laboratory / National Centre for Earth Observation
Puca	Silvia	Italian Civil Protection
Pucik	Tomas	European Severe Storms Laboratory
Raspaud	Martin	SMHI
Rast	Michael	ISSI

Rautenhaus	Marc	Universität Hamburg
Riedi	Jérôme	University of Lille
Ripodas	Pilar	AEMET
Roca	Rémy	CNRS
Roebeling	Rob	EUMETSAT
Roquet	Hervé	Météo-France
Rosati	Valentina	Italian Air Force Met Service
Ruti	Paolo	EUMETSAT
Rutkowski	Artur	Institute of Meteorology and Water Management (IMGW-PIB)
Saalmüller	Joachim	EUMETSAT
Scheidgen	Peter	CGI Deutschland B.V. & Co. KG
Schüller	Lothar	EUMETSAT
Schulz	Jörg	EUMETSAT
Setvak	Martin	Czech Hydrometeorological Institute
Shenolikar	Justin	EUMETSAT
Služenikina	Jekaterina	Estonian Environment Agency
Smiljanic	Ivan	EUMETSAT
Spezzi	Loredana	EUMETSAT
Spray	Justin	Polar Media
Stankunavicius	Gintautas	Vilnius university
Stastka	Jindrich	Czech hydrometeorological institute
Stoffelen	Ad	Royal Netherlands Meteorological Institute (KNMI)
Stoycheva	Anastasiya	National Institute of Meteorology and Hydrology
Strajnar	Benedikt	Slovenian Environment Agency
Strandgren	Johan	EUMETSAT
Strelec Mahovic	Natasa	EUMETSAT
Struzik	Piotr	Institute of Meteorology and Water Management - NRI
Suhonen	Elli	Finnish Meteorological Institute
Sunda	Michela	EUMETSAT
Sundström	Anu-Maija	Finnish Meteorological Institute
Thonipparambil	Sreerekha	EUMETSAT
Tonboe	Rasmus	Denmark's Technical University
Trigo	Isabel	IPMA - Instituto Portugues do Mar e da Atmosfera
Trojakova	Alena	Czech Hydrometeorological Insitute
Tubbs	Robert	Met Office
Tulkens	Philippe	European Commission
Ugorenko	Jevgeņijs	Latvian Environment, Geology and Meteorology Centre
Ungur	Madalina	EUMETSAT
Vahter	Ilona	Estonian Environment Agency
Valachová	Michaela	Czech Hydrometeorological Institute

Vandenbussche	Sophie	Royal Belgian Institute for Space Aeronomy
Vanoni	Giancarlo	TECNAVIA SA
Vaštšenko	Aleksei	Estonian Environment Agency
Vazquez Navarro	Margarita	EUMETSAT
Verhoef	Anton	Royal Netherlands Meteorological Institute (KNMI)
Vidot	Jerome	Météo-France/CNRM/CNRS
Viticchie	Bartolomeo	EUMETSAT
Wang	Ping	Royal Netherlands Meteorological Institute
Wannop	Sally	EUMETSAT
Wapler	Kathrin	Deutscher Wetterdienst
Watts	Philip	EUMETSAT
Wirth	Andreas	ZAMG

List of Roundtable co-moderators and rapporteurs

RoundTable	**Moderators**	**Rapporteurs**
Nowcasting and VSRF	Xavier Calbet Kathrin Wapler	Thomas August Johan Strandgren
NWP	Christina Köpken-Watts Tony McNally	Mark Higgins Paul Poli
Marine and Sea Ice	Estelle Obligis Hervé Roquet	Hayley Evers-King Sally Wannop
Land Surface	Isabel Trigo Catherine Prigent	Carla Barroso
Aerosols and Clouds	Aerosol part: Bertrand Fougnie Xavier Ceamanos Cloud part: Jérôme Riedi Susanne Crewell	Ivan Smiljanic Margarita Vazquez-Navarro Loredana Spezzi
Atmospheric Chemistry	Federico Fierli Anu-Maija Sundstrom	Rasmus Lindstrot Dorothee Coppens
Climate	Rémy Roca Rainer Hollmann	Jörg Schulz Christine Träger-Chatterjee
Precipitation and Hydrology	Christophe Accadia Philippe Chambon	Vesa Nietosvaara Natasa Strelec-Mahovic
Atmospheric Winds	Régis Borde Javier Garcia-Pereda	Marie Doutriaux-Boucher Alessandro Burini

Programme team

Paolo Ruti, Chief Scientist
Paul Counet, Head of Strategy Comm & Int. Relations
Jochen Grandell, MTG Programme Scientist
Rosemary Munro, EPS-SG Programme Scientist
Joachim Saalmueller, Head of User Support & Climate Services
Bojan Bojkov, Head of Remote Sensing and Products Div.
Isabelle Kling, Head of Communications
Sally Wannop, User Relations Manager
Mark Higgins, Training Manager
Lothar Schueller, SAF Network Manager
Stephan Bojinski, MTG User Preparation Manager
Sreerekha Thonipparambil, EPS-SG User Preparation Manager

Logistics team

Stephan Bojinski, MTG User Preparation Manager
Sreerekha Thonipparambil, EPS-SG User Preparation Manager
Sally Wannop, User Relations Manager
Clemence Benamer, Communications & Launch Events Assistant
Sylwia Miechurska, Admin. Assistant, Conf. & event Coordin.
Regina Hoefenmayer, User Training Administrator

List of exhibition booths

TECNAVIA
EUMETSAT Data Services; MTG and EPS-SG
EUMETSAT SIFT
Pytroll
Kongsberg Defence & Aerospace Space Ground Systems
Meteo France
IBL
University of Hamburg/ECMWF
Irish Centre for High-End Computing (ICHEC)
CPI/Orbital Systems
CGI

Website link

https://www.eventsforce.net/eumetsat/frontend/reg/thome.csp?pageID=12681&eventID=30

ANNEX III: AGENDA

EUMETSAT User Days 2022 on MTG and EPS-SG

31 May 2022 *Plenary session in Room Spectrum A all day*

	08:00 – 09:00	*Registration (Early registration on 30 May 2022, 17:00-18:00 at Darmstadtium CC)*
1.1	09:00 – 09:20	**Opening and Welcome addresses** *Phil Evans, Director-General, EUMETSAT* *Sean Burns, Director of Operations and Services to Users, EUMETSAT* *Bozena Lapeta, MTGUP User Group, IMGW, Poland* *Stefanie Hollborn, NWP Core User Group and DWD, Germany* *Paolo Ruti, Chief Scientist, EUMETSAT* *Joachim Saalmüller, Head of User Services and Climate, EUMETSAT*
1.2	09:20 – 09:40	**Research potential of EUMETSAT Next-Generation Missions** *(Bojan Bojkov, Head of Remote Sensing and Products Division, EUMETSAT)*
1.3	09:40 – 09:55	**MTG Programme Status** *(Jochen Grandell, MTG Programme Scientist, EUMETSAT)*
1.4	09:55 – 10:10	**EPS-SG Programme Status** (Rosemary Munro, *EPS-SG Programme Scientist, EUMETSAT)*
	10:10 – 10:40	Coffee break
1.5	10:40 – 10:55	**METimage** *(Hans-Peter Lüttenberg, Head of Dept. Earth Observation, DLR)*
1.6	10:55 – 11:10	**IASI-New Generation** (*Carole Deniel, Atmospheric Programme Manager, CNES*)
1.7	11:10 – 11:25	**Sentinel-4 and -5** *(Didier Martin, Project Manager for Sentinel-5, ESA)*
1.8	11:25 – 11:40	**User Preparation for Next-Generation Missions MTG and EPS-SG** *(Stephan Bojinski, MTGUP Project Manager; Sreerekha Thonipparambil, EPS-SG UP Project Manager; Federico Fierli, Atmospheric Composition User Preparation; EUMETSAT)*
	11:40-12:00	Group photo
	12:00-13:30	Lunch break
1.9	13:30 – 14:45	**R&D priorities and perspectives on satellite missions MTG and EPS-SG** 13:30-13:35 Benefits of R&D investments in Earth Observation *(Paolo Ruti, Chief Scientist, EUMETSAT)* 13:35-13:50 Challenges and perspectives for Earth Observations in supporting the implementation of the European Green Deal *(Philippe Tulkens, Head of Unit on Climate and Planetary Boundaries, DG Research and Innovation, European Commission)* 13:50-14:45 Panel discussion moderated by *Paolo Ruti, EUMETSAT*, with: • *Philippe Tulkens (European Commission)* • *Vincent-Henri Peuch (ECMWF/CAMS)* • *Michael Rast (International Space Science Institute, Switzerland)*
1.10	14:45 – 16:00	**Introduction to Roundtable discussions on 1 June** 14:45-15:00 Climate Science and Policy Context for EO and Introduction to Climate Roundtable *(Jörg Schulz, Rémy Roca, Rainer Hollmann)* 15:00-16:00 Nowcasting *(Xavier Calbet, Kathrin Wapler)* NWP *(Christina Köpken-Watts, Tony McNally)* Aerosols and Clouds *(Bertrand Fougnie, Xavier Céamanos, Jérôme Riedi, Susanne Crewell)* Atmospheric Chemistry *(Federico Fierli, Anu-Maija Sundstrom)* Atmospheric Winds *(Régis Borde, Javier Garcia-Pereda)* Land *(Isabel Trigo, Catherine Prigent)* Marine and Sea Ice *(Anne O'Carroll, Hervé Roquet)* Precipitation and Hydrology *(Christophe Accadia, Philippe Chambon)*
1.11	16:00 – 18:00	Coffee break **and Technical Exhibition & SAF Posters**
	18:00	Icebreaker

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EUMETSAT User Days 2022 on MTG and EPS-SG

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1 June 2022 *Roundtables (in break-out rooms)*

as of 08:00 *Information desk open*

Room:	Spectrum A	Spectrum B	Spectrum C	Aurum	Palladium
09:00 – 10:30	Aerosols & Clouds	Land	Marine & Sea ice	Atmospheric Chemistry	Atmospheric Winds
10:30 – 10:45	Coffee break				
10:45 – 12:15	Aerosols & Clouds	Land	Precipitation & Hydrology	Atmospheric Chemistry	Atmospheric Winds
12:15 – 14:00	Lunch break				
14:00 – 15:30	Nowcasting	NWP	Precipitation & Hydrology	Climate	Aerosols & Clouds
15:30 – 15:45	Coffee break				
15:45 – 17:15	Nowcasting	NWP	Marine & Sea ice	Climate	
17:15	End of Day 2				
17:45	Social event: Walking tour to Mathildenhöhe UNESCO World Heritage Site (registration required)				
19:30	Dinner				

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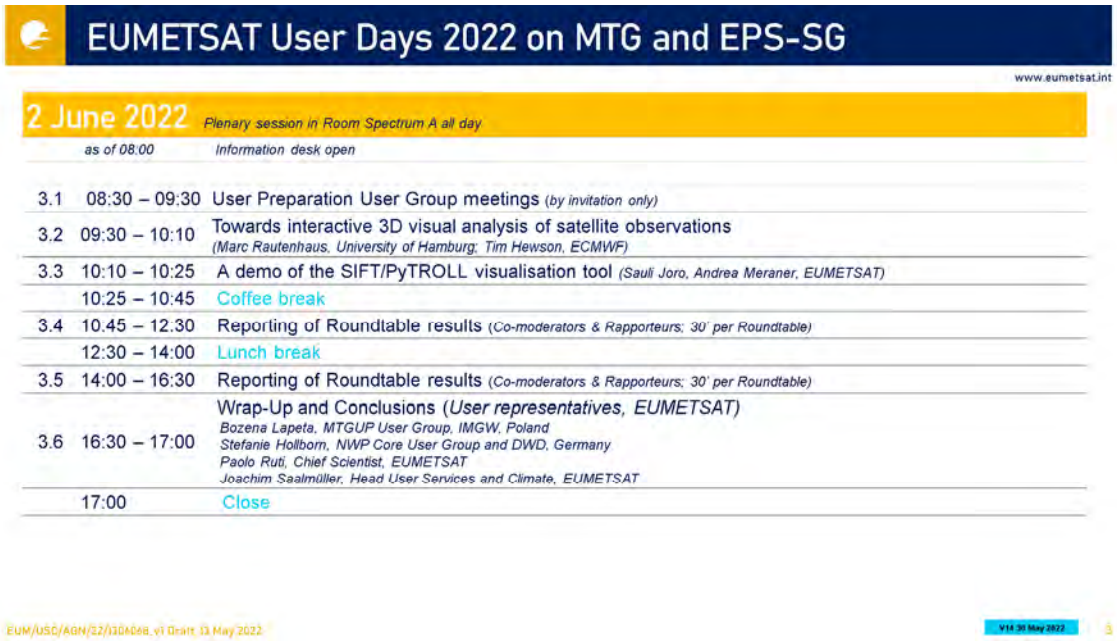

EUMETSAT User Days 2022 on MTG and EPS-SG

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2 June 2022 *Plenary session in Room Spectrum A all day*

	as of 08:00	*Information desk open*
3.1	08:30 – 09:30	User Preparation User Group meetings *(by invitation only)*
3.2	09:30 – 10:10	Towards interactive 3D visual analysis of satellite observations *(Marc Rautenhaus, University of Hamburg; Tim Hewson, ECMWF)*
3.3	10:10 – 10:25	A demo of the SIFT/PyTROLL visualisation tool *(Sauli Joro, Andrea Meraner, EUMETSAT)*
	10:25 – 10:45	Coffee break
3.4	10.45 – 12.30	Reporting of Roundtable results *(Co-moderators & Rapporteurs; 30' per Roundtable)*
	12:30 – 14:00	Lunch break
3.5	14:00 – 16:30	Reporting of Roundtable results *(Co-moderators & Rapporteurs; 30' per Roundtable)*
3.6	16:30 – 17:00	Wrap-Up and Conclusions (*User representatives, EUMETSAT)* *Bozena Lapeta, MTGUP User Group, IMGW, Poland* *Stefanie Hollborn, NWP Core User Group and DWD, Germany* *Paolo Ruti, Chief Scientist, EUMETSAT* *Joachim Saalmüller, Head User Services and Climate, EUMETSAT*
	17:00	Close

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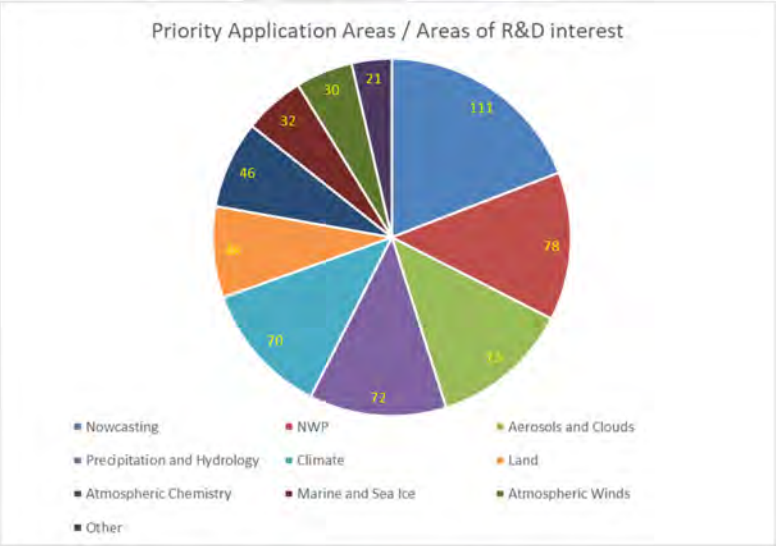
ANNEX IV: MEMBER STATE RESPONSES ON R&D AGENCIES AND PRIORITIES

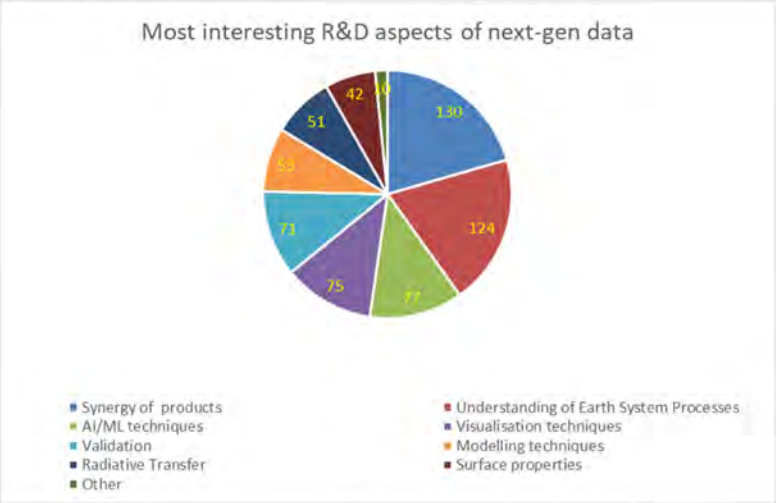
User Days MTG & EPS-SG 2022 - Member State reponses on engaging national R&D funding agencies, and R&D priorities		
Member state	Institution	National EO-related R&D priorities; comments
Belgium	BELSPO, DG Recherche et Espace	
Bulgaria	National Science Fund	Priority on seamless prediction supporting early warnings and DRR; dynamic and thermodynamic process in atmosphere; aerosol and cloud microphysics and modelling; air quality; synergy products
	Ministry of Science and Education	
	State Agency for Research and Innovation	Funding of technological programmes, themes such as digitisation, Green Deal
Finland	Business Finland	Items of importance: - Aerosol and cloud microphysics, and modelling - Surface characterisation (land, snow, ice, fires, ocean surface) - Atmospheric composition and air quality - Synergy products using next-generation EUMETSAT and Copernicus instruments - Development of AI/ML techniques for EO and/or meteorological applications - Climate records: how to use past high-resolution observation data to downscale reanalysis information to neighborhood scales to enable this scale for climate predictions
	Ministry of Agriculture and Forestry Finland	
	Ministry of the Environment Finland	
France	CNRS - INSU (Institut National des Sciences de l'Univers)	CNRS-INSU is the French research institute of CNRS in charge of earth and universe sciences. In particular, it manages an annual AO for research projects related to atmosphere and ocean sciences
	CNES	French space agency is supporting scientific activities related to earth observation satellites via the funding of PhDs and research projects, with an annual Announcement of opportunity
Germany	Hans Ertel Centre for Weather Research (HErZ; jointly supported by DWD and academia)	Priority on seamless prediction supporting early warnings and DRR, and related engagement of R&D agencies SINFONY project (seamless integrated forecasting system) Address potential funding agencies not only by the important met phenomena 'severe convective storms, heavy rainfall' and floods, but rather more specifically by our strategy on seamless prediction. HErZ: https://journals.ametsoc.org/view/journals/bams/97/6/bams-d-13-00227.1.xml?tab_body=pdf
	Deutsche Forschungsgemeinschaft (DFG) Deutsches Zentrum für Luft- und Raumfahrt (DLR) - Projektträger (PT) Forschungszentrum Jülich (FZJ-PT)	
Hungary	National Research, Development and Innovation Office (NKFIH) Horizon Europe Nat Contact Point on Cluster 6: Food, Bioeconomy, Nat Resources, Agriculture and Environment Name of institute: Nemzeti Kutatasi, Fejlesztesi es Innovacios Hivatal	Agriculture, floods, air pollution, early warning systems, climate change
	Lechner Nonprofit Kft.	
	ELKH Institute for Earth Physics and Space Sciences Name of institute: ELKH Földfizikai es Urtudomanyi Intezet	
Lithuania	Agency for Science, Innovation and Technology	All topics listed in letter relevant Highest priority on (i) seamless prediction supporting early warnings and DRR, (ii) synergy products using EUM and COPER data
Luxembourg	Luxembourg National Research Fund (FNR)	Flood hazard and prediction projects Sustainable and responsible development Climate change: energy efficiency, smart energy management; resilient eco- and agrosystems (sub-topics: resilient water systems; env monitoring; transition towards sustainability: energy efficiency)
	Luxembourg Institute of Science and Technology	
Norway	Norwegian Research Council	EO-related R&D topics of particular national importance are as already indicated on your list, with a special focus on polar areas and high latitudes
	Norwegian Environment Agency	
	Norwegian Space Agency	
Poland	National Centre for Research and Development (NCBiR)	Key areas of research: - Land surface monitoring (actual state vs multi-annual means) - Atmospheric chemistry and air quality monitoring - Convective activity - Risks of flooding / drought
	National Science Centre (NCN)	
	Polish Space Agency (POLSA)	
Sweden	FORMAS - Government research council for sustainable development (https://formas.se/en)	Heavy and sustained rainfall events. Forecasting of Aircraft icing. Wintertime road conditions - monitoring and forecasting. Forecasting and monitoring fog and low clouds (both related to air traffic control and road maintenance). Snow melt and flooding. Algae blooming and water quality near coasts and lakes. Water level-monitoring - inland water bodies. Sea Ice monitoring - Baltic Sea. Wild fires in a changing climate. Spatial-temporal climate change impacts on agriculture and forestry
	Vinnova - Sweden Innovation Agency	
	Swedish National Space Agency www.rymdstyrelsen.se/en/	

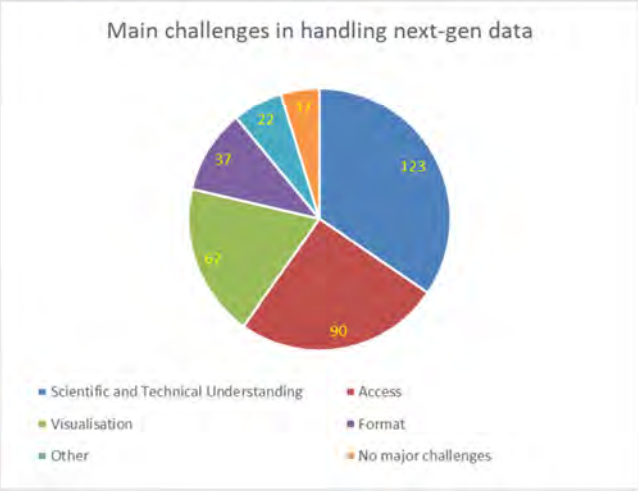
Switzerland	Swiss National Science Foundation https://www.snf.ch/en	None indicated
	Swiss Space Office https://www.sbfi.admin.ch/sbfi/en/home/research-and-innovation/space.html	
	ESA Business Incubation Centre https://www.esabic.ch	
	The International Space Science Institute https://www.issibern.ch	
	Space Innovation https://space-innovation.ch	
	Innosuisse http://www.innosuisse.ch/inno/de/home.html	
United Kingdom	STFC Rutherford Appleton Laboratory	

ANNEX V: PRE-EVENT SURVEY RESPONSES BY PARTICIPANTS

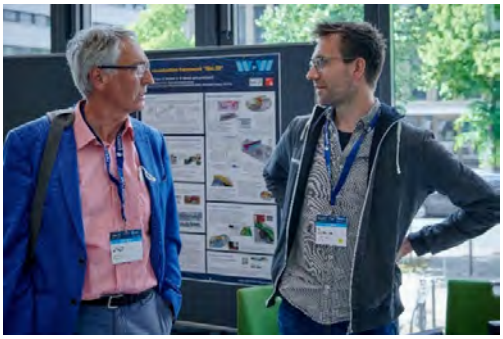
Multiple choices were possible in each question.



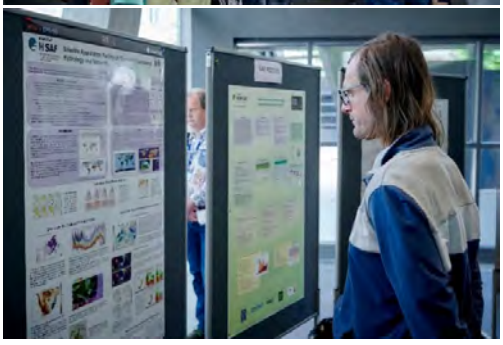




ANNEX VI: IMPRESSIONS









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