Preparation of MTG era: status of simulation of MTG-S/IRS data.

***first** scientifically realistic synthetic MTG-I/FCI and MTG-S/IRS data generated with RTTOV-13.0*

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Index of presentation

Main changes since last IRS MSG on June 2020:

- ✓ Change of RTTOV version to **RTTOV-13.0**. Updated PGE00s NWCSAF vMTG to **RTTOV-13.0**
  - ❑ It has allowed to generate **the first scientifically realistic synthetic MTG-I/FCI and MTG-S/IRS dataset**
    - Synthetic MTG-I/FCI data with operational ECMWF on IR FCI grid (2 km x 2 km)
    - Synthetic MTG-S/IRS data with operational ECMWF on 2x2 boxes of IR FCI grid (4 km x 4 km)
    - Synthetic IASI data with operational ECMWF on 2x2 boxes of IR FCI grid (4 km x 4 km)

- ✓ Exploration of the use of ECMWF with better spatial resolution than the operational
  - ❑ Synthetic MTG-S/IRS simulations with ECMWF **h3f7** experiment
  - ❑ Some issues found

- ✓ Exploration of the use of Harmonie NWP model.
  - ❑ Need to combine Harmonie with ECMWF and some NWCSAF ancillary fields to build input
  - ❑ Synthetic MSG, MTG-I/FCI and MTG-S/IRS simulations with Harmonie

- ✓ Combined use of IRS with FCI and NWCSAF products

Updated PGE00s programs to RTTOV-13.0 and ECMWF operational model to generate the *first scientifically realistic synthetic MTG-I/FCI and MTG-S/IRS data*

The set of GEO-PGE00-* programs was updated in 2020 to NWC SAF vMTG_STRR (1st version with **MTG-I/FCI grid projection** support) and it has been migrated now to **use RTTOV13.0** *(previously made with RTTOV-12.3 2020)*.

GEO-PGE00-VISIR generates **high quality simulation of MTG-I/FCI** (or other imager instruments) **clear and cloudy BTs or reflectance.**

GEO-PGE00-hyper used **now** to make high quality simulation of **MTG-S/IRS** and **IASI** clear and cloudy BTs

First version of PGE00 programs that allows simultaneous generation of synthetic MTG-I/FCI, MTG-S/IRS and IASI radiance on MTG-I/FCI grid.

PGE00 programs are highly modular and configurable. They are written in C and Fortran-90 (the core of the process is Fortran-F90).

PGE000 can be used at same time as NWP 4D (presure, time, longitude, latitude) interpolator of NWP GRIB files to satellite positions.

The main options are:

- ✓ The window size for processing in boxes of **M x M** pixels.
- ✓ optional writing: all pixels or just a clear pixels or a set of pixels.
- ✓ To write the profiles at the different steps: a) just read at hybrid level, b) interpolated/extrapolated at RTTOV pressure levels (or user's set of fixed pressure levels in case PGE00 with simple modifications), c) after temporal interpolation, d) using a cloud mask (or a set of predefined pixels), d) calculation of BTs for different satellites.

PGE00 is currently an AEMET internal tool

PGE00 programs and operational ECMWF model for MTG simulations.

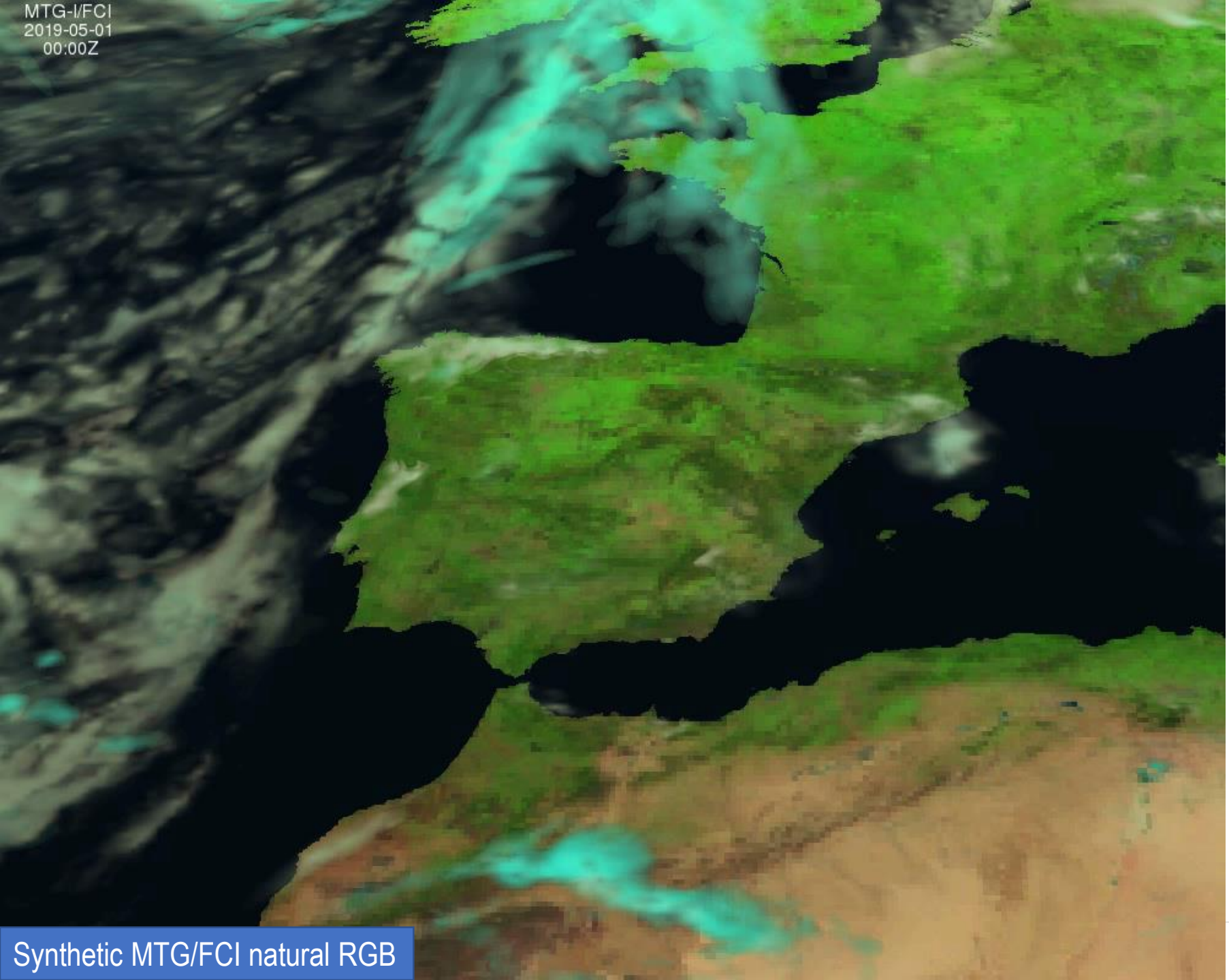
Output files are binary files with Nx * Ny records for each position on the FOR (1x1 for FCI and 2x2 for IRS) on IR FCI grid (2x2 km at nadir).

Each record contains:

- ✓ $radiance_{clear}$,
- ✓ $radiance_{cloudy}$,
- ✓ Profiles from NWP at the 54 RTTOV levels: T/q/ozone/cc/clwc/cwic/u/v
- ✓ Surface fields from NWP: P_{sfc}, T_{sfc}, T2m, q2m
- ✓ Ancillary fields: longitude, latitude, topography, sun angles and GEO satellite angles at 0º.

Operational ECMWF hybrid GRIB files between *t+00* to *t+24* hours range forecast (every 1 hour) with 0.1º x 0.1º from 2019-05-01 00Z run.

In order to have data on 24 hours it is used 75º solar zenith angle during night.



Synthetic MTG/FCI natural RGB

Synthetic MTG-I/FCI data

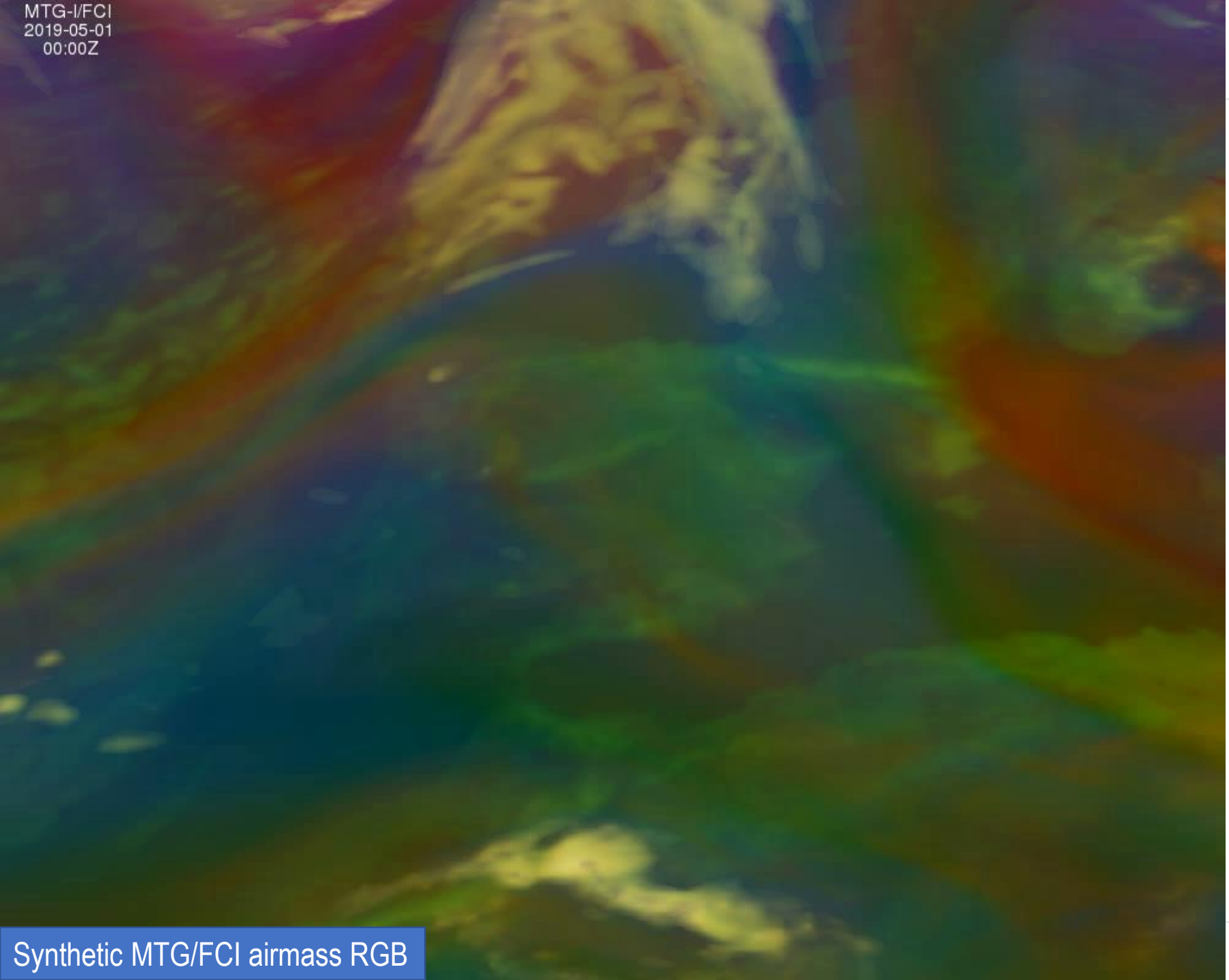
synthetic MTG-I/FCI natural RGB
2019-05-01

synthetic MTG-I/FCI dataset

- ✓ FCI 16 channels
- ✓ VIS and IR clear and cloudy radiances.
- ✓ case study 2019-05-01
- ✓ **every 10 minutes.**
- ✓ **144 slots from 00:00Z to 23:50Z**
- ✓ at IR FCI resolution (2x2 km nadir)
- ✓ Region: 1000 x 800 pixels

(displayed at 90%x90% size, images scaled between minimum and maximum of every images, in order to have data on 24 hours it is used 75º solar zenith angle during night)

Loop available in an AVI file in this NWC SAF web page



Synthetic MTG/FCI airmass RGB

Synthetic MTG-I/FCI data

synthetic MTG-I/FCI air mass RGB
2019-05-01

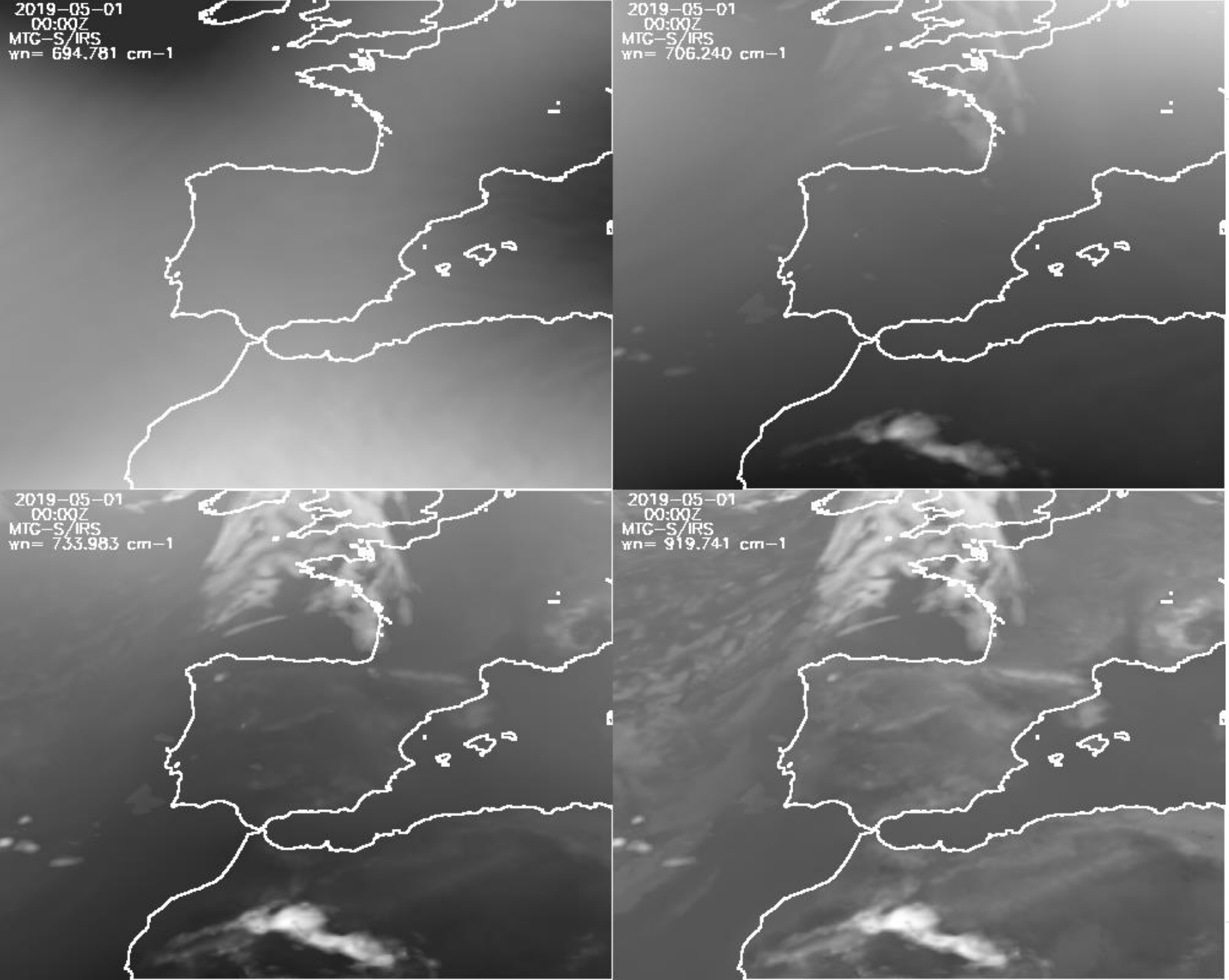
synthetic MTG-I/FCI dataset

- ✓ case study 2019-05-01
- ✓ FCI 16 channels (VIS and IR)
- ✓ **every 10 minutes.**
- ✓ **144 slots from 00:00Z to 23:50Z**
- ✓ at IR FCI resolution (2x2 km nadir)
- ✓ Region: 1000 x 800 pixels

(displayed at 90%x90%)

Loop available in an AVI file in this NWC SAF web page

Synthetic MTG-S/IRS data



MTG-S/IRS nearest to IASI channels at 695, 706, 734 and 919.5 cm^{-1}. The wavenumbers has been selected in CO_2 branch to provide top to down view in the atmosphere.

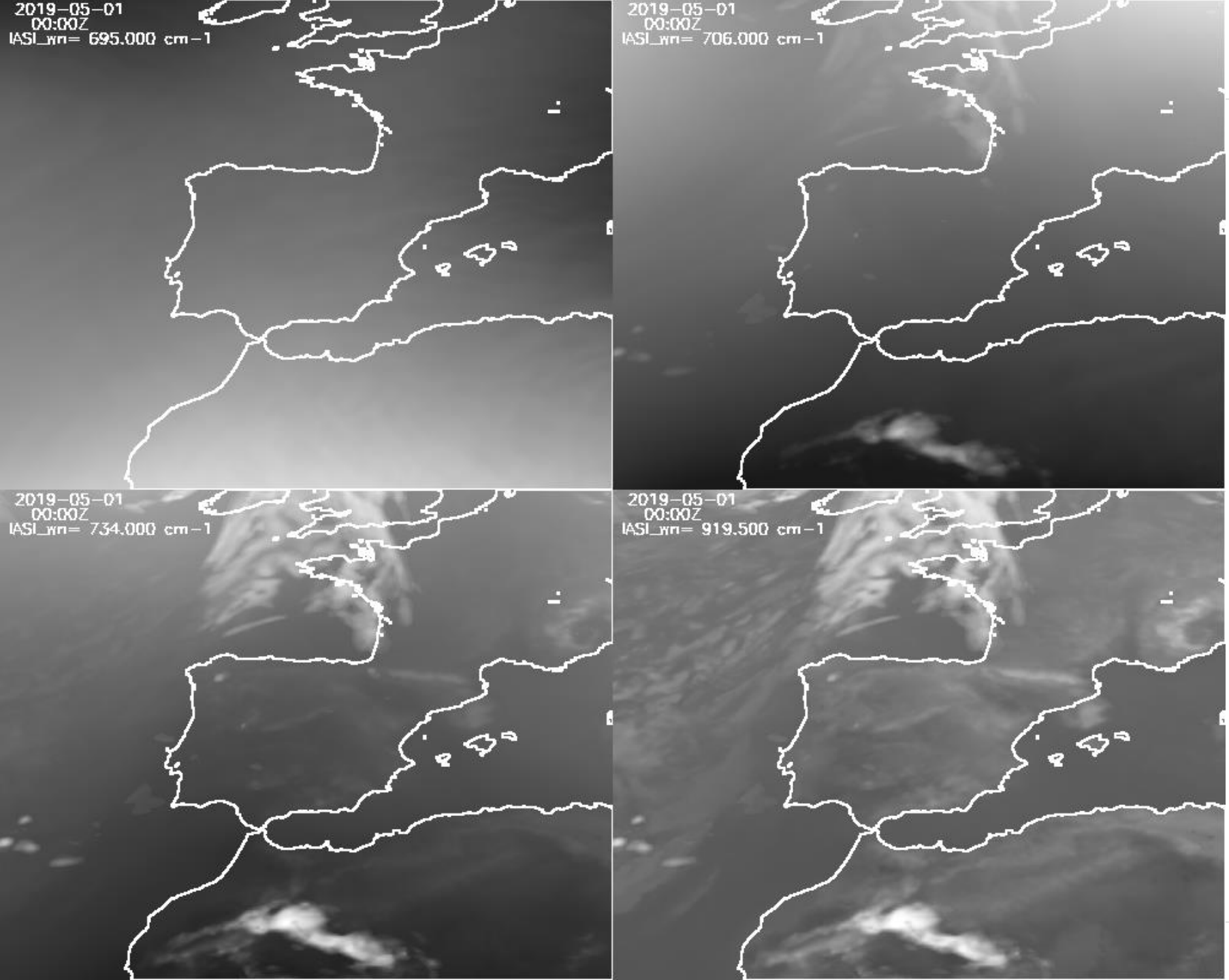
synthetic MTG-S/IRS on MTG-I/FCI projection 2019-05-01

synthetic IRS dataset

- ✓ case study 2019-05-01
- ✓ MTG-S/IRS 1960 channels
- ✓ every 30 minutes.
- ✓ **48 slots from 00:00Z to 23:30Z**
- ✓ at boxes **2x2** pixels IR FCI resolution => similar to theoretical IRS spatial resolution (**4x4** km nadir)
- ✓ Region: 500 x 400 pixels

See animated GIF in this NWC SAF web page

Synthetic IASI data



IASI channels at 695, 706, 734 and 919.5 cm^{-1}. The wavenumbers has been selected in CO_2 branch to provide top to down view in the atmosphere.

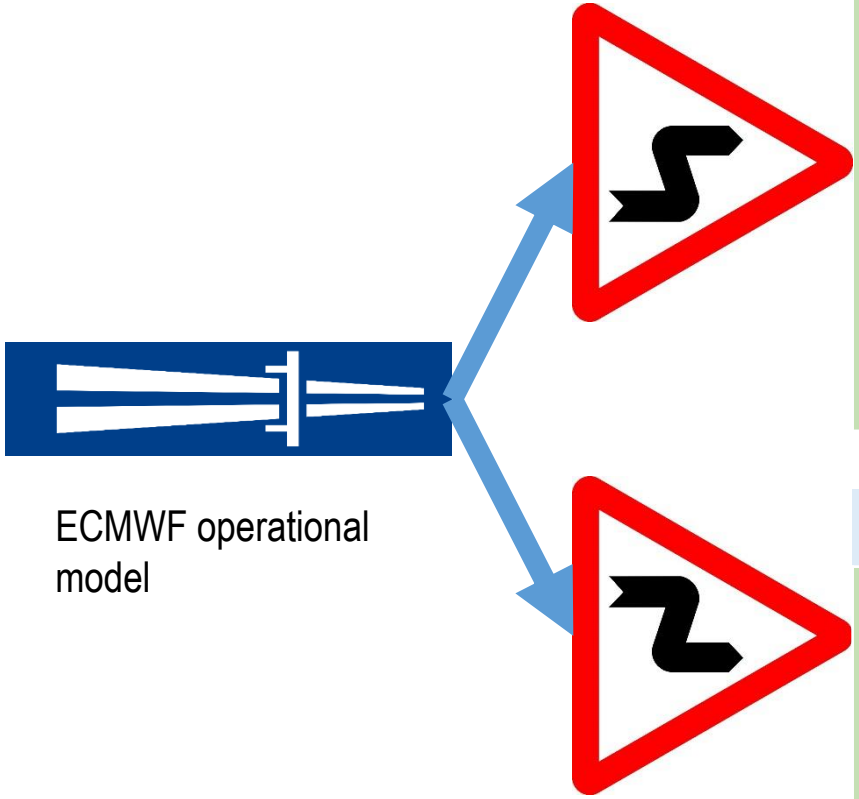
synthetic IASI on MTG-I/FCI projection 2019-05-01

synthetic IASI dataset

- ✓ case study 2019-05-01
- ✓ IASI 8461 channels clear and cloudy.
- ✓ **every 30 minutes.**
- ✓ **48 slots from 00:00Z to 23:30Z**
- ✓ at boxes **2x2** pixels IR FCI resolution => similar to theoretical IRS spatial resolution (**4x4** km nadir)
- ✓ Region: 500 x 400 pixels

See animated GIF in this NWC SAF web page

Exploration of ways to improve resolution



ECMWF operational model

Experiment ECMWF h3f7

Pros:

- ✓ Better spatial resolution on clouds

Cons:

- ✓ Only available every 3 hours.
  - **Not suitable for loops.**
- ✓ Not all variables are in MARS on hybrid levels.
  - **Need to complete with ones from operational model**
- ✓ Nature run limit the dates available
- ✓ Run at 1.4 km resolution ***but in MARS is available aggregated at 9 km resolution***

Local NWP model Harmonie

Pros:

- ✓ Very good spatial resolution **(≈ 2.5 km).**
- ✓ Every 1 hour. With possibilities to have every 15 minutes.

Cons:

- ✓ Only limited area domain.
  - **Not suitable for full disk simulation.**
- ✓ Not all variables.
  - **Need to complete ozone with a global model (ECMWF)**
- ✓ Need to complete levels above 10 hPa.

MTG simulations with experiment ECMWF h3f7

ECMWF h3f7 experiment

Seasonal (4-months) **nature run at 1.4km resolution**, ***aggregated to 9km***. A Baseline for Global Weather and Climate Simulations at 1 km Resolution, data is aggregated/truncated to 9km, and avail 3-hourly. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020MS002192

Start Date: 2018-11-01
expver: h3f7
class: rd

Information provided by X. Abellan (ECMWF User's Service)

MARS Catalogue

Time (1 values)	anoffset (1 values)	Step (961 values)	Level (137 values)	Parameter (6 values)
00:00:00	9	2853	1	Fraction of cloud cover
		2856	2	Specific cloud ice water content
		2859	3	Specific cloud liquid water content
		2862	4	Specific humidity
		2865	5	Specific rain water content
		2868	6	Specific snow water content
		2871	7	
		2874	8	
		2877	9	
		2880	10	

Only available every 3 hours.

- **Not suitable for loops.**

Not all variables available on hybrid model levels

Changed the input to read the combination of the GRIBs file from h3f7 experiment and operational ECMWF model

h3f7	Oper
q	T
CC	ozone
CLWC	
CIWC	

Modified PGE00 hyper version for use combination of h3f7 experiment and ECMWF operational

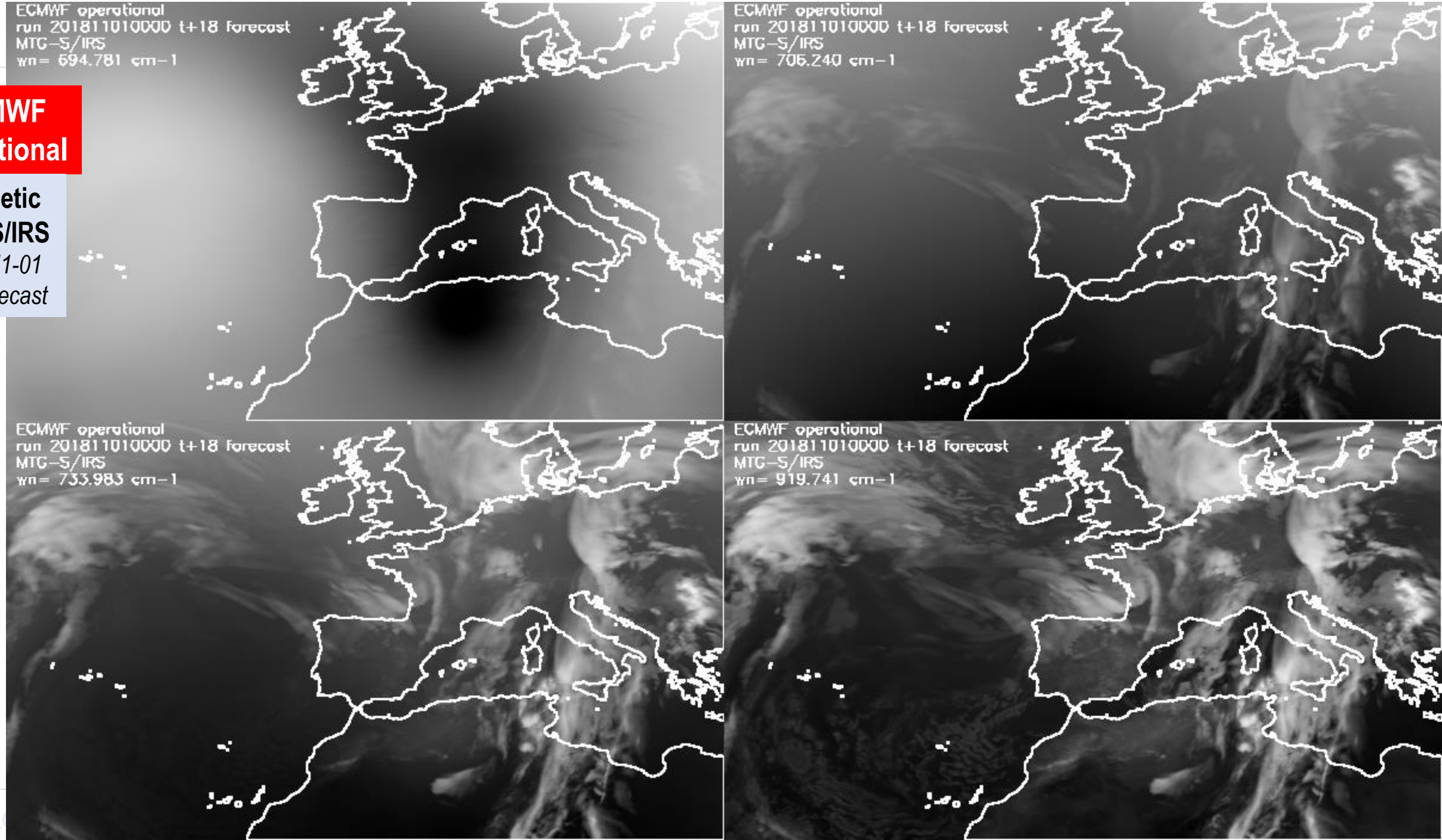
- ✓ Tested only in hybrid levels on ECMWF grid using an intermediate development version of the latest PGE00 on GEO grids and in RTTOV pressure levels.
- ✓ Adaptation of the input to PGE00 version in FCI grid in future if the ECMWF GRIBs improve in future.

ECMWF operational

synthetic MTG-S/IRS

2018-11-01

18Z forecast

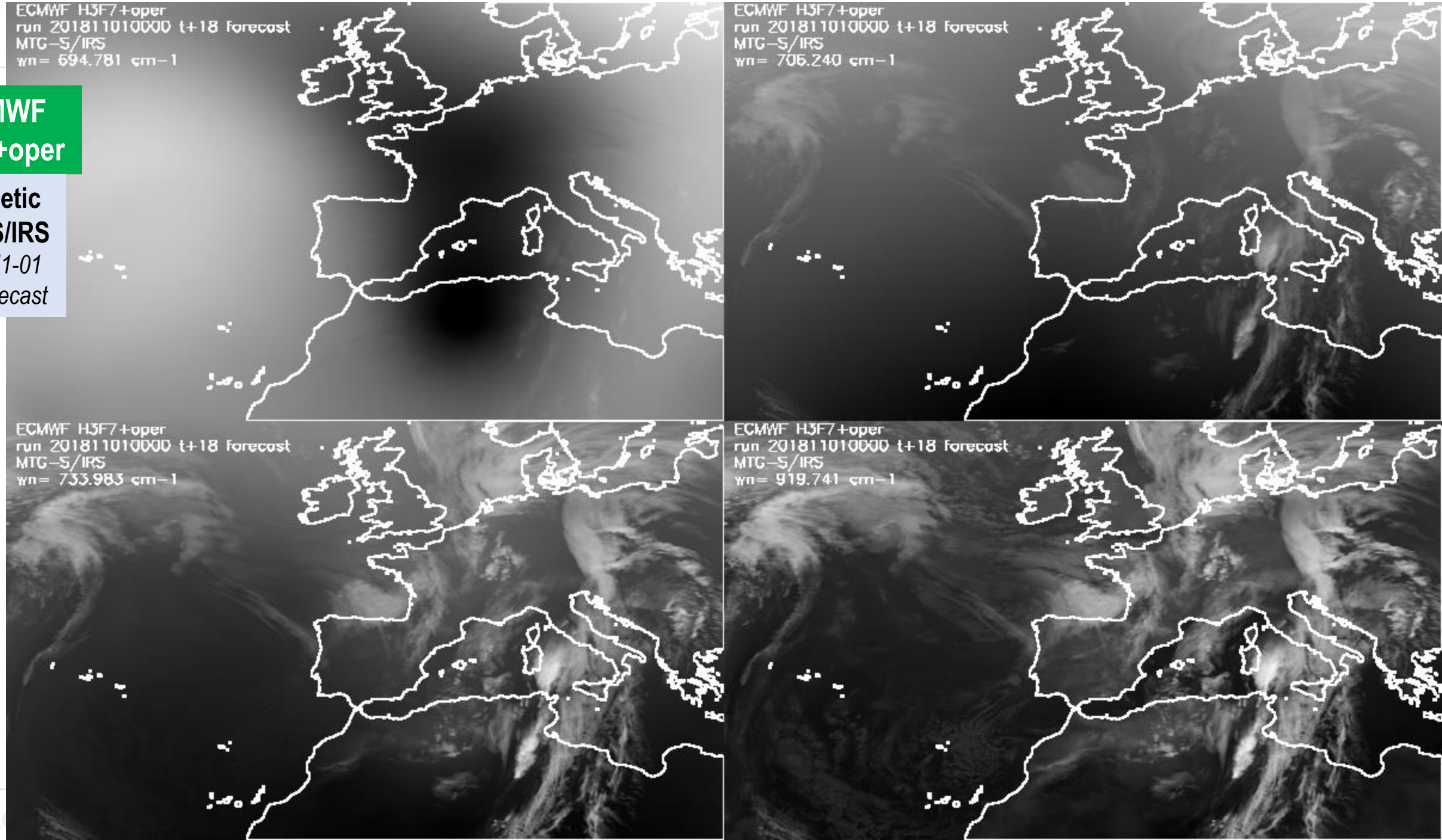


ECMWF H3F7+oper

synthetic MTG-S/IRS

2018-11-01

18Z forecast



MTG simulations with experiment AEMET Harmonie

AEMET Harmonie model

- ✓ Lambert projection grid of 2.5 km x 2.5 km resolution on grid rotated 5º
- ✓ 65 hybrid levels from Psfc to 10 hPa.
- ✓ Here have been used reprojected GRIBs files on grid 0.025 º x0.025º
- ✓ Dimensions: 1170 x 700

Changed the input to read the combination of binary with data from Harmonie, operational ECMWF model and NWCSAF ancillary fields

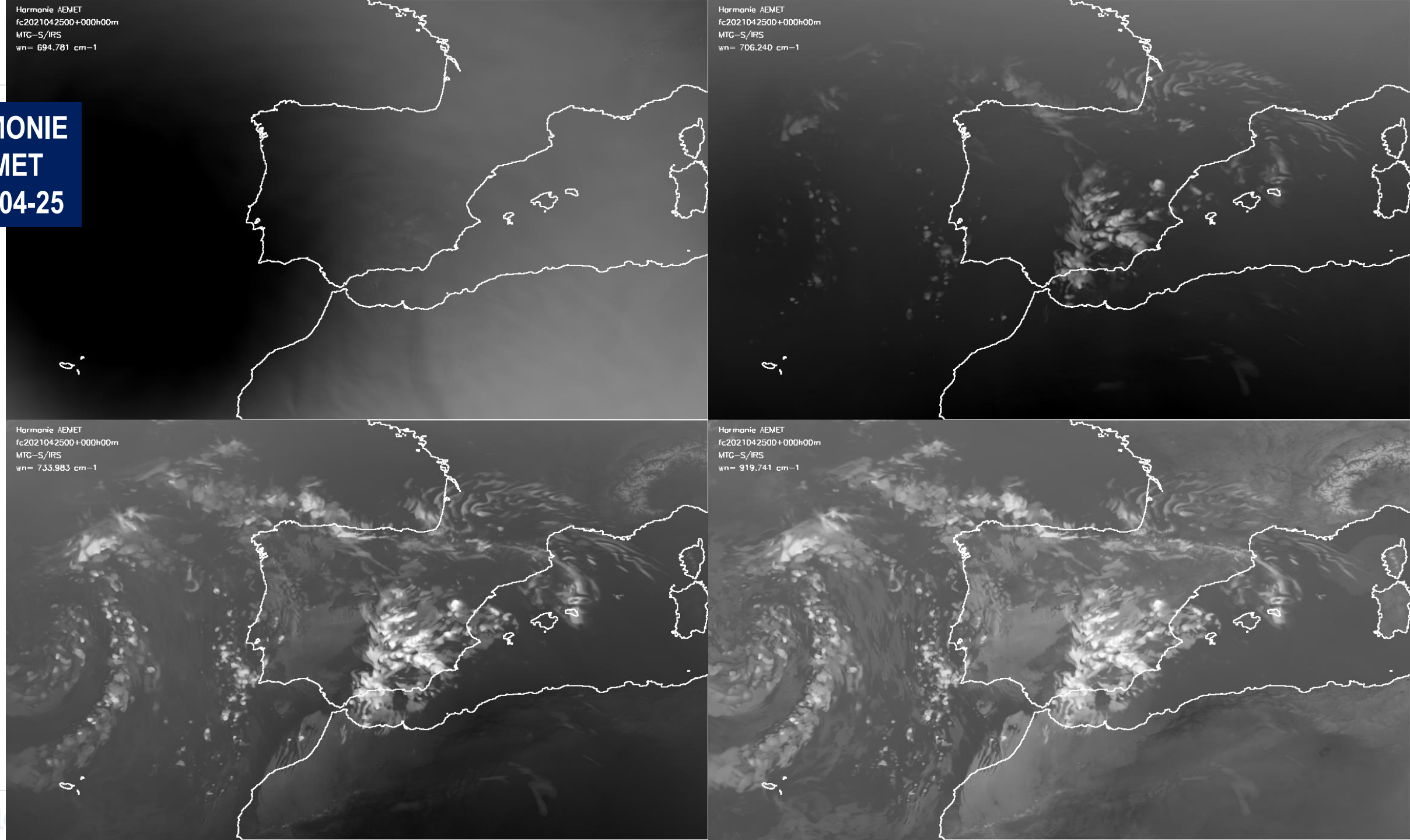
Harmonie AEMET	ECMWF Oper
T	ozone
q	
CC	
CLWC	
CIWC	

Modified PGE00 hyper version for use combination of Harmonie, ECMWF operational and NWCSAF

- ✓ Changed the input to read a binary file with the combination of Harmonie in the 65 hybrid levels, ECMWF operational (only ozone profile interpolated to Harmonie pixels and hybrid levels) and some NWCSAF GEO ancillary fields.
- ✓ Tested only in hybrid levels of Harmonie using an intermediate development version of the PGE00 on GEO grids and in RTTOV pressure levels.
- ✓ Future improvements:
  - ✓ Added some levels from ECMWF por levels above 10 hPa.
  - ✓ Adaptation of the input to PGE00 version in FCI or MSG grid.

Harmonie GRIBs files courtesy of Javier Calvo and María Diez (NWP Area of AEMET)

HARMONIE AEMET 2021-04-25



Combination of FCI and IRS

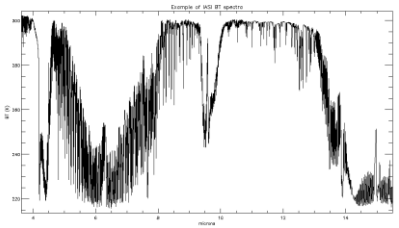
Revisit 2021: MTG-IRS and IASI RGBs with MSG RGBs heritage

Which is the synthetic IASI channel nearest to every synthetic MSG IR channel?

2017 training and validation dataset

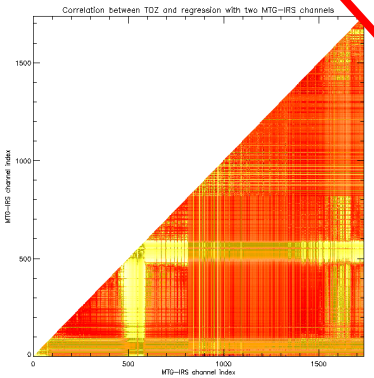
IASI RTTOV coefficients

IASI 8461 channels



Pending further tests to publish equivalent IASI ⇔ MSG table

correlation analysis between synthetic RTTOV IASI or MTG-IRS and MSG-SEVIRI channels



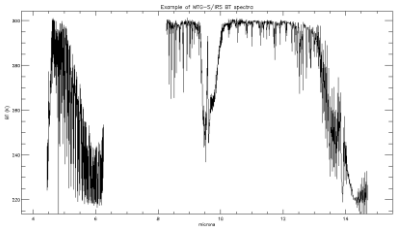
MSG RTTOV coefficients

MSG BTs

Search of IASI and **MTG-IRS** channels with lower mean square error and greatest correlation versus MSG-SEVIRI channels using 2017 training and validation dataset for MSG full disc region and **RTTOV-13.0**

IRS RTTOV coefficients

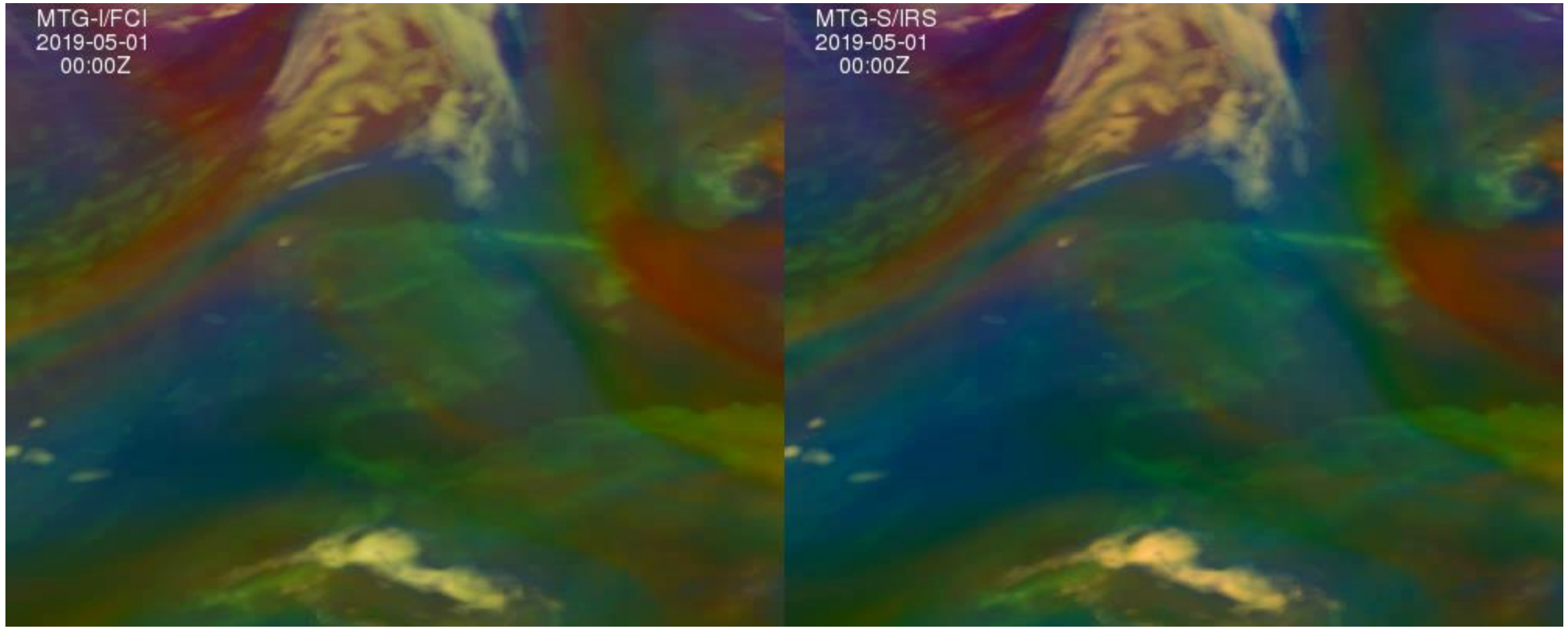
IRS 1960 channels



Pending further tests to publish equivalent IRS ⇔ MSG table

This approach was used in 2010 to create the first synthetic IRS air mass RGB

Comparison of MTG-I/FCI and MTG-S/IRS temporal resolution



MTG-I/FCI air mass RGB with synthetic RTTOV cloudy

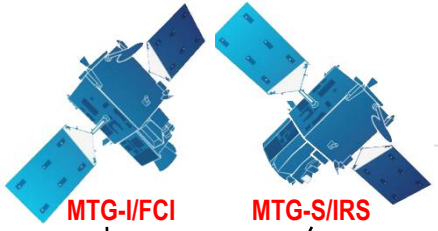
At 2x2 boxes every 10 minutes

MTG-S/IRS air mass RGB

every 30 minutes

Loop available in an AVI file in this NWC SAF web page

NWC SAF IRS SERVICES



MTG L1

MTG L2

L1 processing → **L2 processing**

EUMETSAT headquarters

EUMETCast

IRS L2 → sSHAI_ES service → ES IRS L2

IRS L1 PC → qIRS service → IRS L1 BT

sSHAI → NWCSAF IRS L2

FCI L1

LI

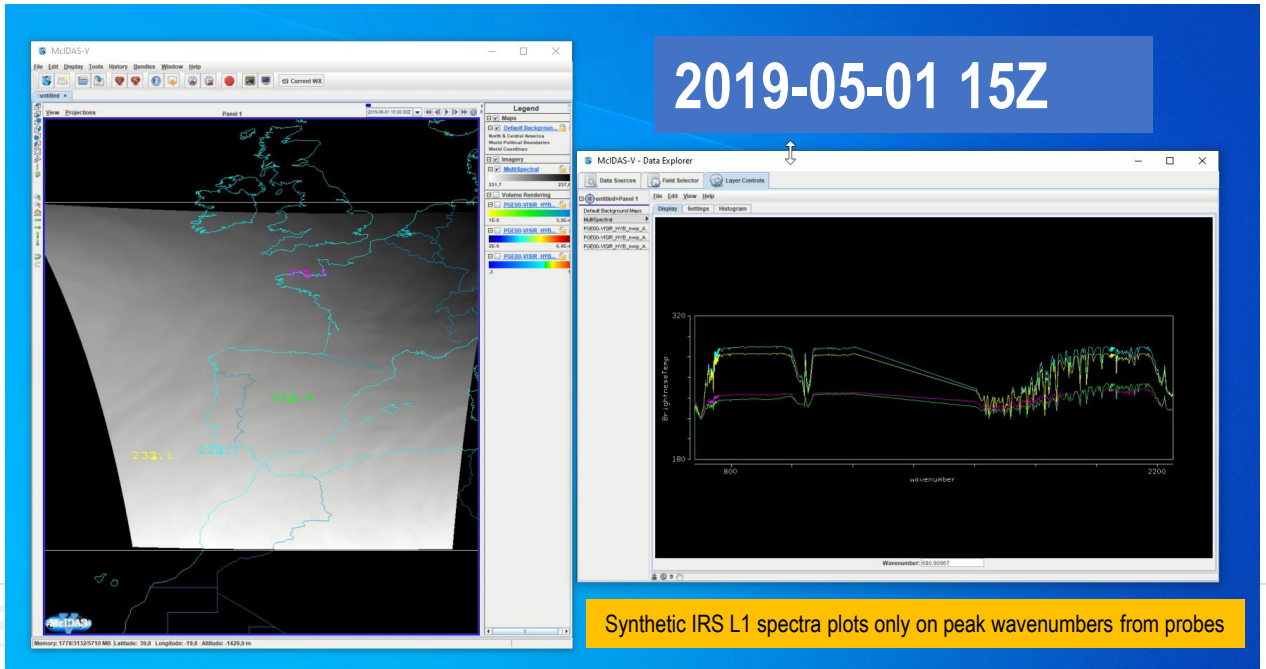
NWC SAF GEO → NWC SAF MTG-I L2

NWP

Obs(radar, synop)

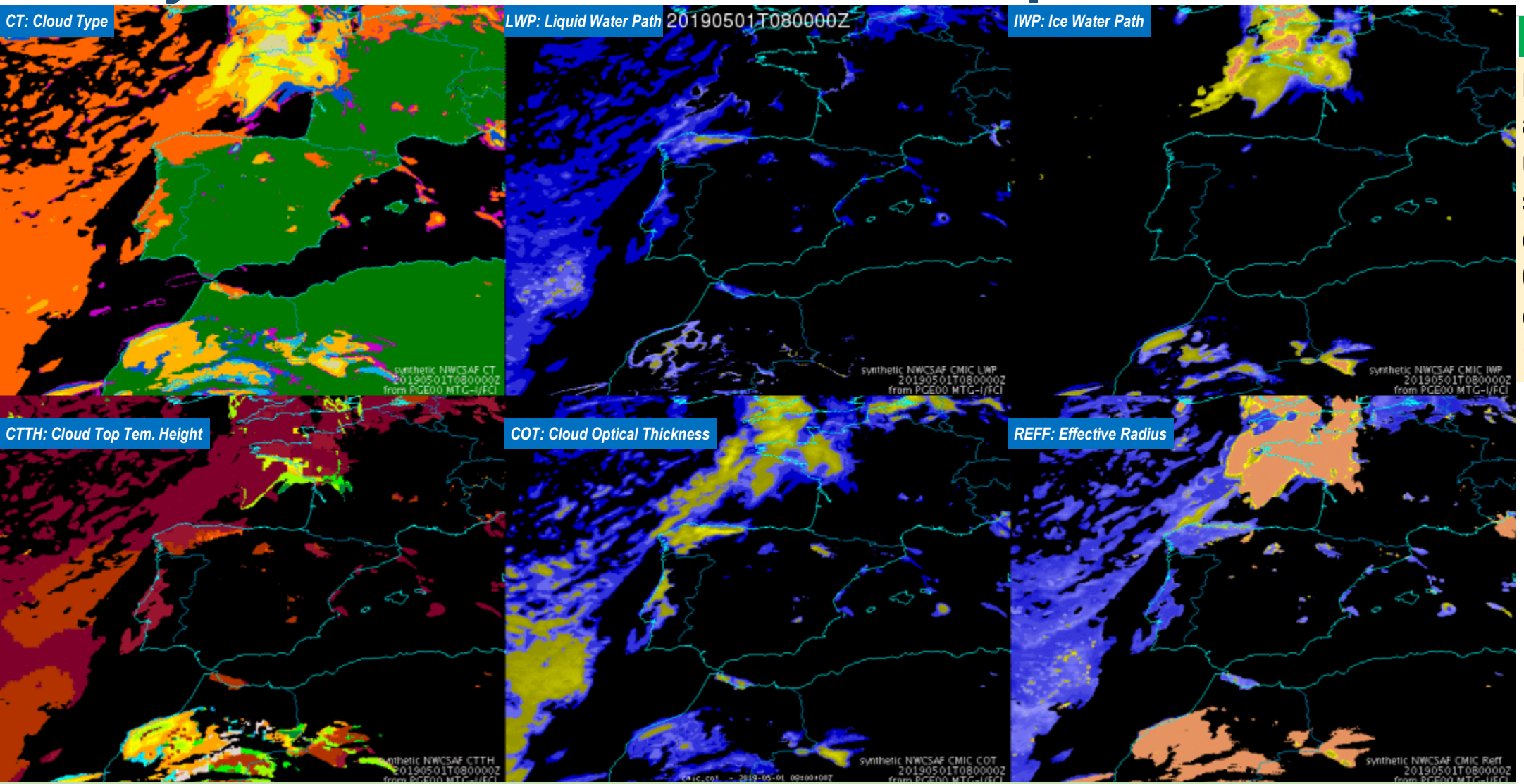
User 4D Weather data cube in NWC SAF region of interest

User tools



Synthetic IRS L1 spectra plots only on peak wavenumbers from probes

Synthetic MTG-I/FCI used as input of NWC SAF PGEs



Updated to version RTTOV-13.0

NWC SAF CT, CTTH and CMIC generated using as inputs the synthetic MTG-I/ FCI data 1st May 2019 from 00:00Z to 23:50Z with cloudy PGE00 **RTTOV-13.0** simulation.

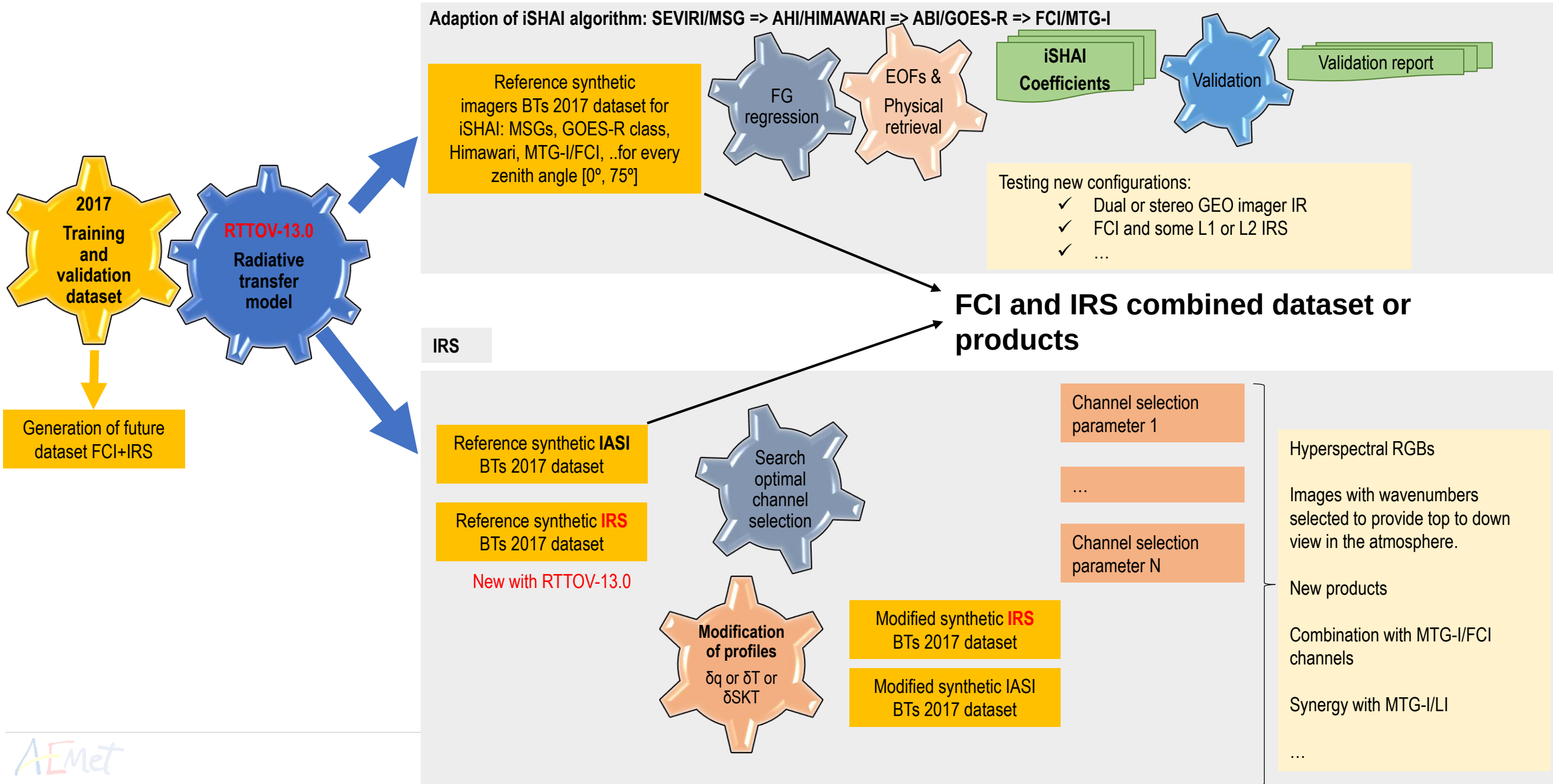
Images generated with McIDAS-V from the NWCSAF netCDF files. Later combined and created animated gifwith with Image-Magick.

The idea is to use the profiles of T, q, CC (cloudiness), LWP, IWP etc to compare the outputs of the products with the "truth" used as input to RTTOV; the McIDAS-V will allow to do it interactively.

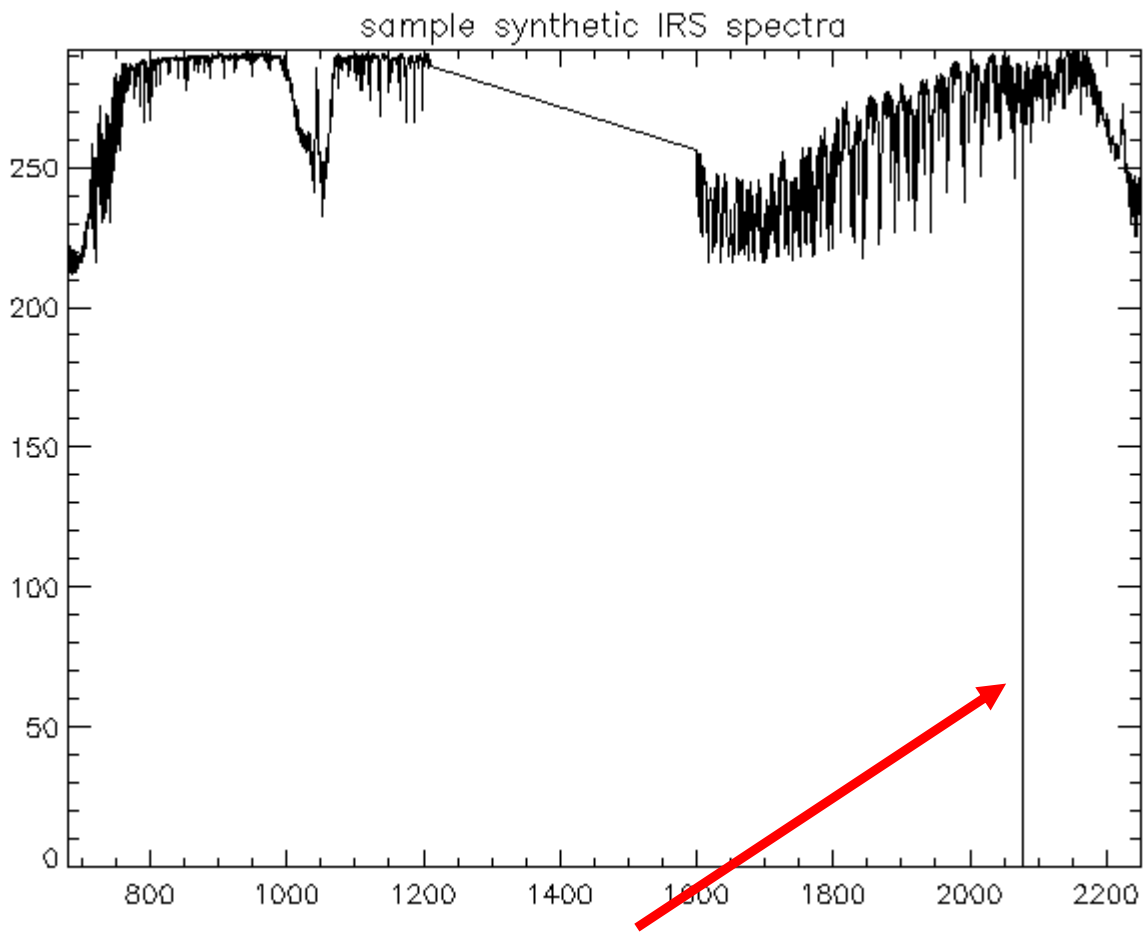
As a proof of concept it has been using as input to some NWCSAF PGEs the **synthetic FCI data version with RTTOV-13.0**.

- ✓ It has been used an IDL program to read the PGE00 synthetic binary files and to replace data on the binary raw files on *$SAFNWC/tmp/Sat_data* from a "real" slot.
- ✓ First result of several PGEs (CMA/CT/CTTH/CMIC) are available in this this link of the NWCSAF.

PGE00_1d: use of iSHAI training and validation dataset



MTG-S/IRS RTTOV-13.0 coefficients



Bad BT at channel 1672+1 wavelength 2077.28cm-1

There is a new MTG-S/IRS coefficient with Hamming apodization no tested yet.

rtcoef_mtg_1_irs-atbd-2mopd_o3.H5

Summary, conclusions and future developments

Preparation for MTG-I/FCI and MTG-S/IRS

MTG-I/FCI and MTG-S/IRS should be considered as just one facility. It is needed to explore all the synergies between both instrument and with MTG-I/LI.

The use of programs like PGE00 allows to generate synthetic test datasets from ECMWF hybrid oper GRIB files. ***It could be improved the simulations but:***

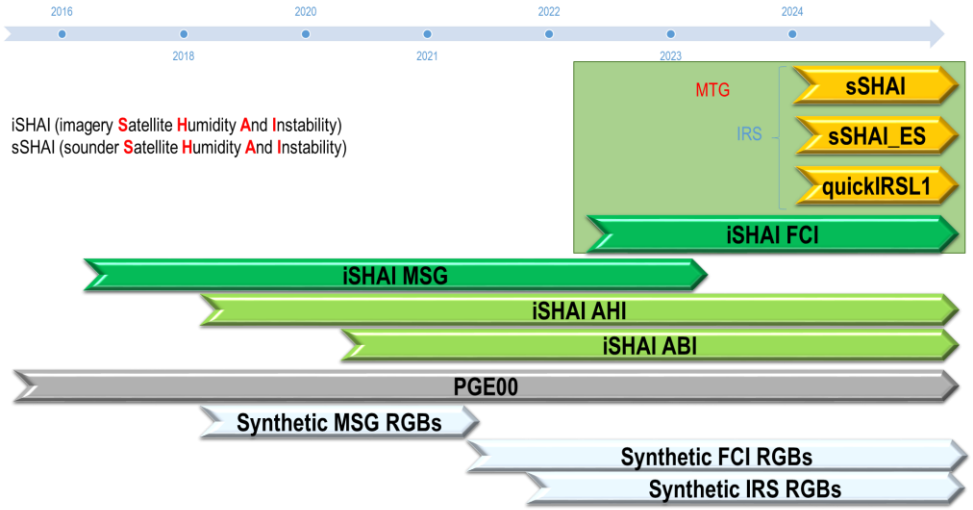
- ***ECMWF 1.4 km resolution experiment are aggregated to 9 km in MARS and very 3hours and lack of some fields***
- ***local NWP model must be complement with some global (ECMWF) NWP fields***

These synthetic test data could be used to explore ideas, as new products from new FCI channels and from IRS. These test data could be used to explore ideas as Optical flows. Using the (u,v) 4D-interpolated profiles.

SHAI family will allow to exploit the synergy of MTG-I/FCI, MTG-S/IRS and NWP for the monitoring of key ingredients in pre-convective situations. Local 4D data cube generation and exploitation to cover the gap between EUMETSAT formats and the used for users' tools.

Validation and datasets generation is a continuous and important task.

- Creation of collocated NWP, IASI and IRS, SEVIRI->FCI L1 and L2 dataset
- Generation and/or get synthetic IRS L1 data.
- Training and validation of local statistical retrieval



Research to operations (R2O) in MTG era:

- ✓ it is needed that software and processing chains must be available.
- ✓ R2O needs also that user's tools and automatic graphical processing should be able to use iSHAI and PGE00 files. **Here it has been used McIDAS-V as demonstrator tool** for interactive comparison and 3D use of proxy IRS-L2 and comparison with NWP.
- ✓ A lot of slight different products will be generated: it should be needed to develop some kind of integration tools for integration of L1 and L2 products.
- ✓ A high number of slight different products with different times generation allows be used for seamless nowcasting systems.
- ✓ NWCSAF software is installed and executed on the user side of EUMETCast. This avoid bandwidth constraints and it is ideal for generation of 4D cube dataset locally by the users.
- ✓ Generalization of RGB tool: **RGB technique could be used for display of combination of 3 fields generated with functions of L1 and L2 outputs** (not only channels or difference of channels).

TO BE CONTINUED …..

Thanks for your attention !

Questions ? Any feedback is welcome !

Direct link iSHAI MTG page

Direct link to presentation on pptx format

References

http://www.nwcsaf.org/AemetWebContents/ReferenceSystem/GEO/HTMLContributions/iSHAI/references.html