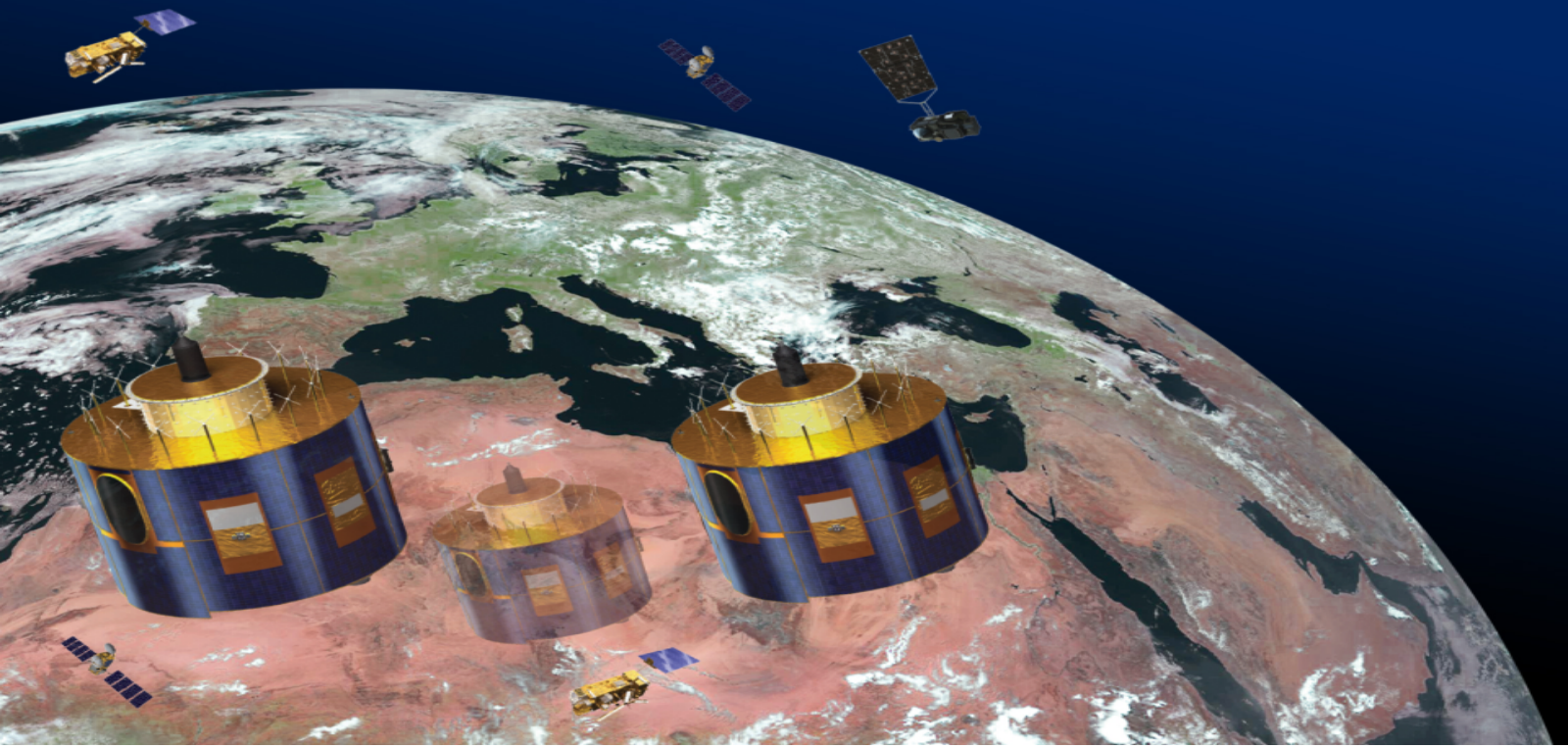
MTG-IRS L2 update

Thomas August, Tim Hultberg,
C. Goukenleuque, O. Samain, A. Burini



Two presentations

1. Prototype products development
2. Algorithms options – ATBD/User feed-back

Background & objectives

Specify a viable Day-1 baseline for IRS L2;
In time for MTG ground segment procurement;
Yielding accurate products with useful coverage.

- ✓ mature algorithms
- ✓ proven products
- ✓ CPU-affordable

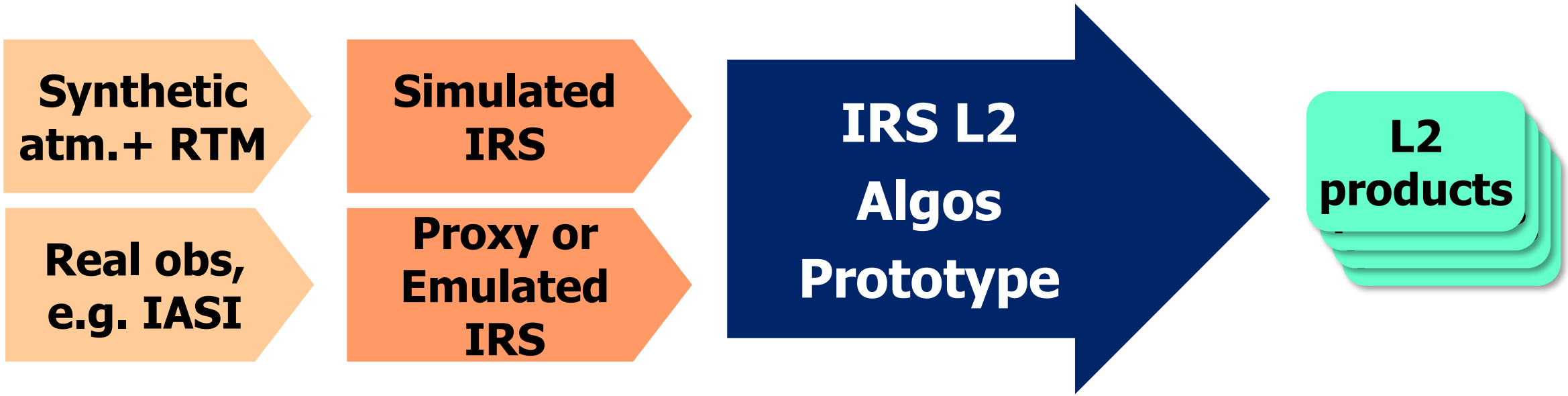
- ➔ re-use and adapt IASI L2 operational concept
- ➔ understand limitations and mission specificities
- ➔ define Day-1 & Day-2 scopes ; identify studies

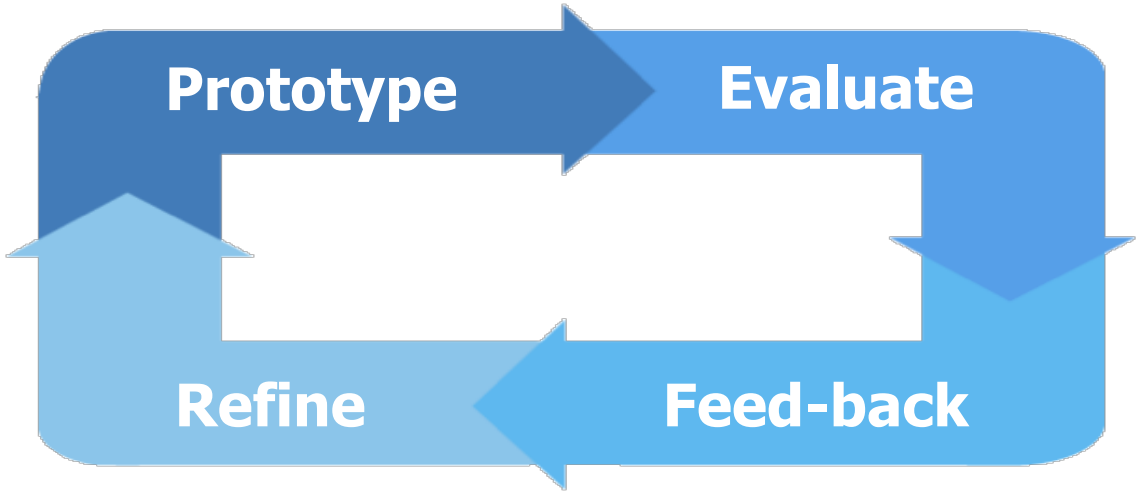
Status summary

- ✓ ATBD written following the approach presented to DTF, MB, SWG Sept.' 2017, MAG Oct. 2017, MTG SIR part.2
- ✓ Processor specifications written from the ATBD
- ✓ Prototyping started, PWLR^3 training and retrieval modules implemented for most parameters already

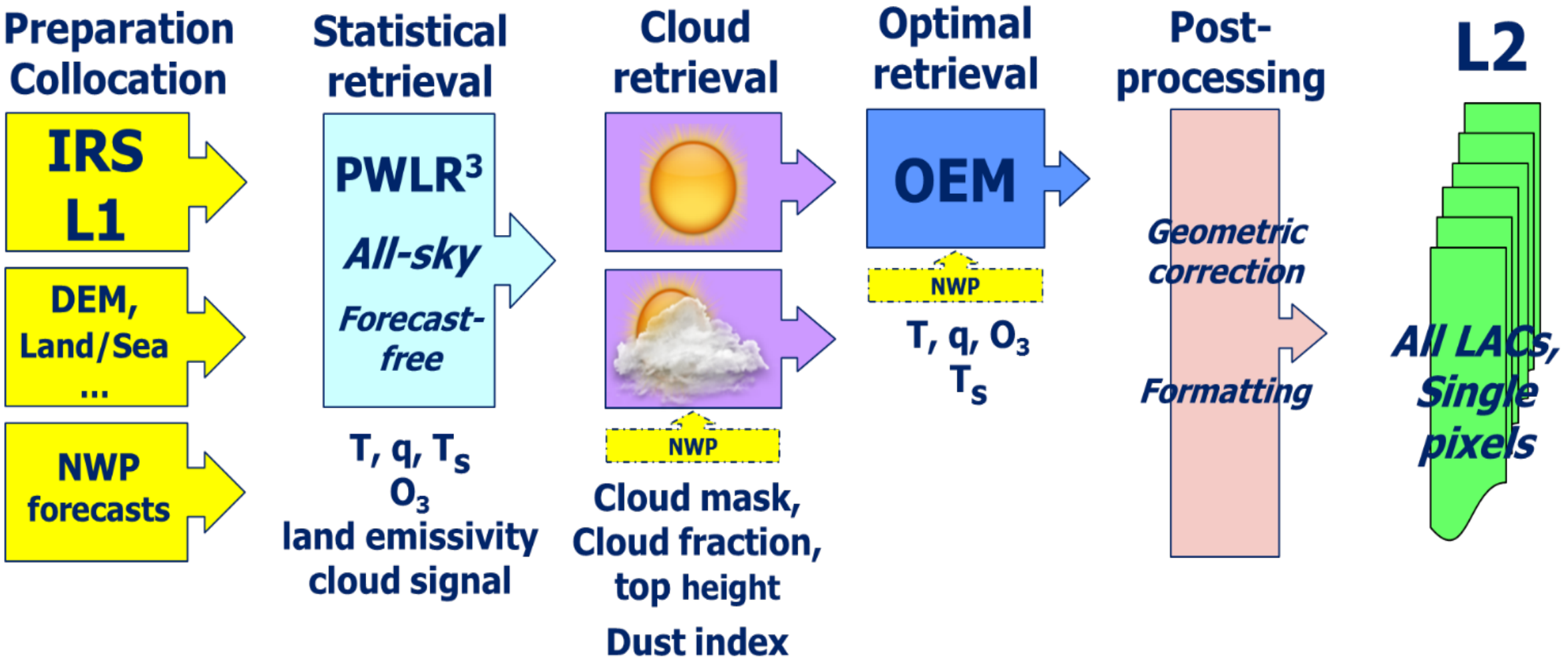
- ➢ Detailed description, document to MAG for review

Prototype products and development

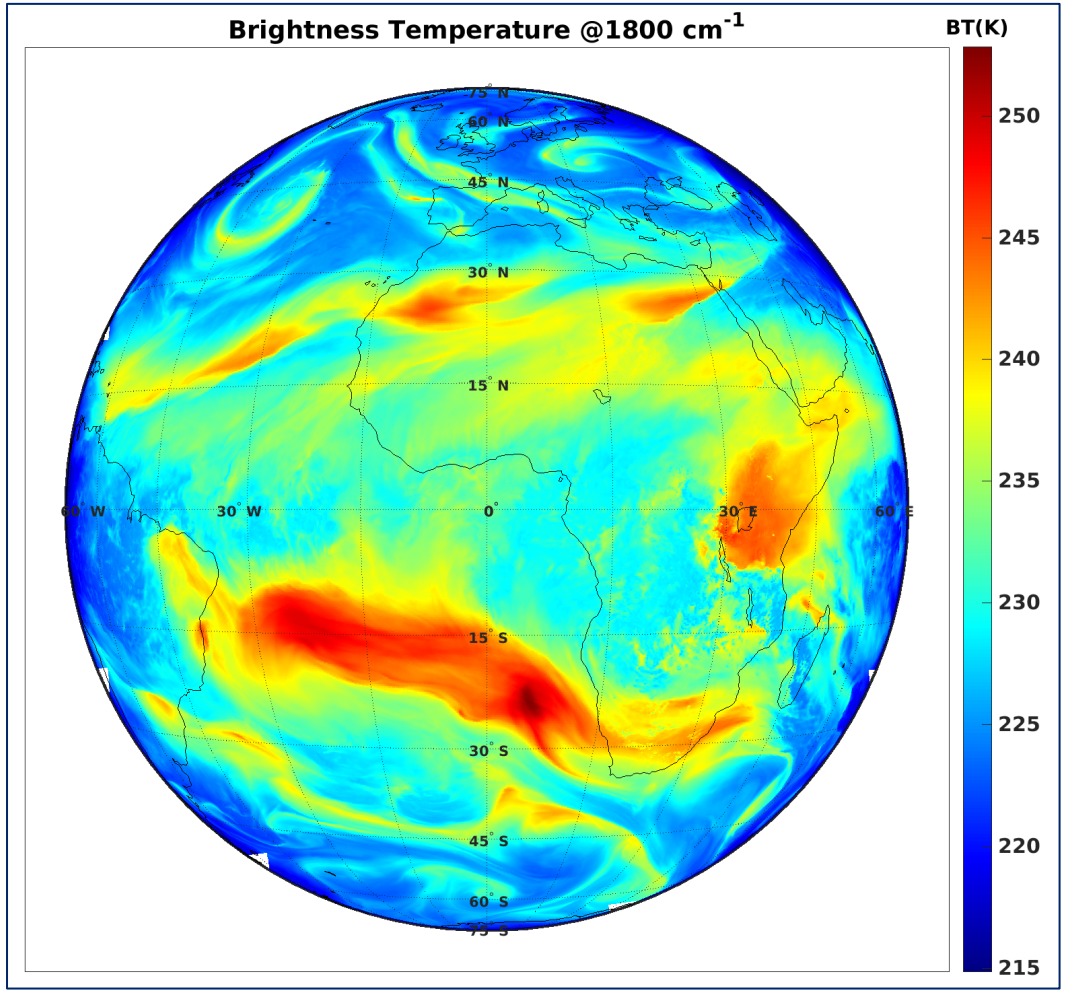




Processor overview



IRS training set – Status MAG Oct 2017

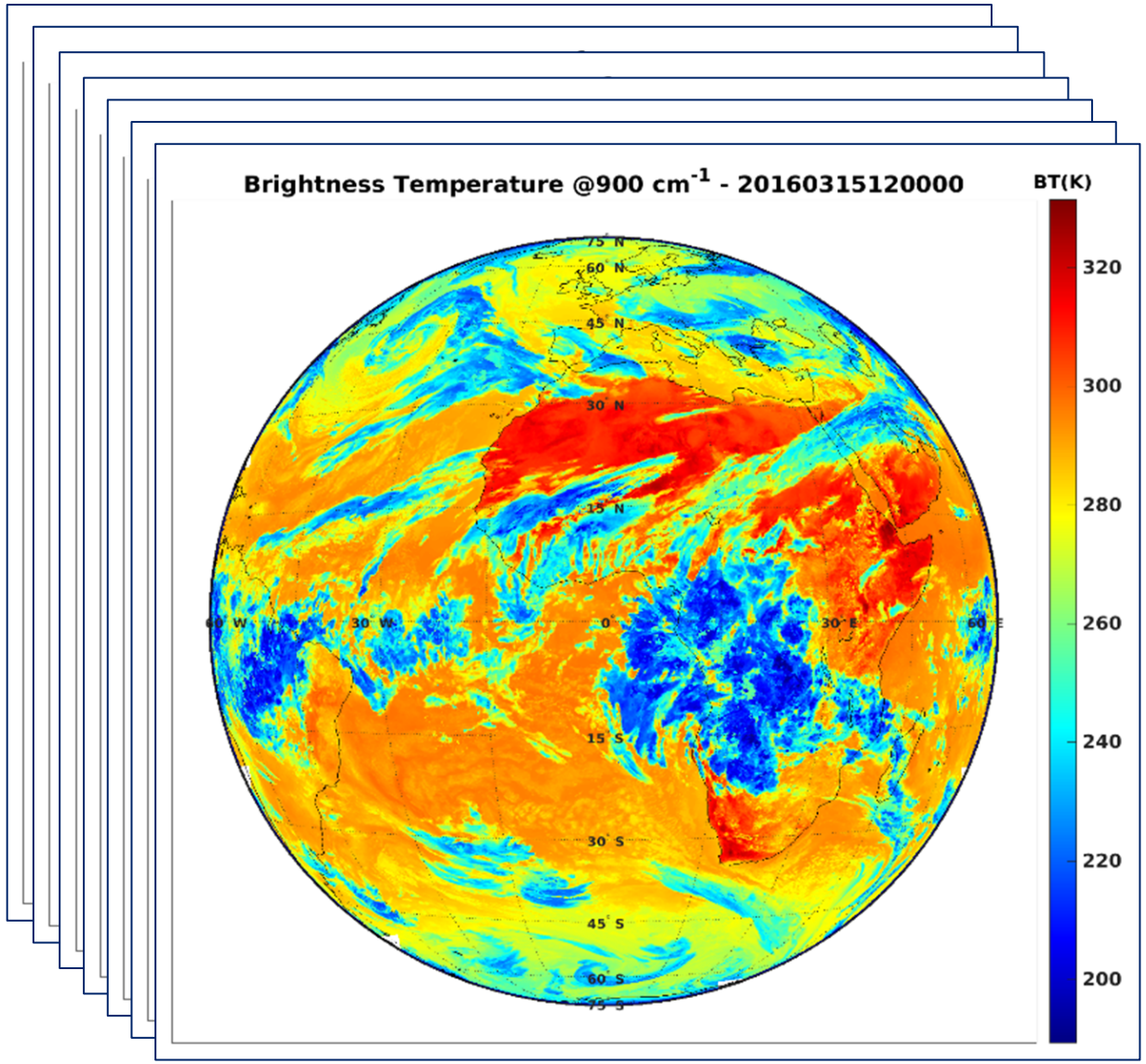


- ✓ **ECMWF fields**
- ✓ **Realistic dwells and slanted profiles**
- ✓ **Clear-sky radiances**
- ✓ **RTTOV-IRS extended to 85° satellite zenith** *(special request to NWP-SAF)*
- ✓ **1 disk**

➔ **Support prototyping development**

➔ **Viewing angle sensitivity study**

IRS training set – Status MAG May 2018



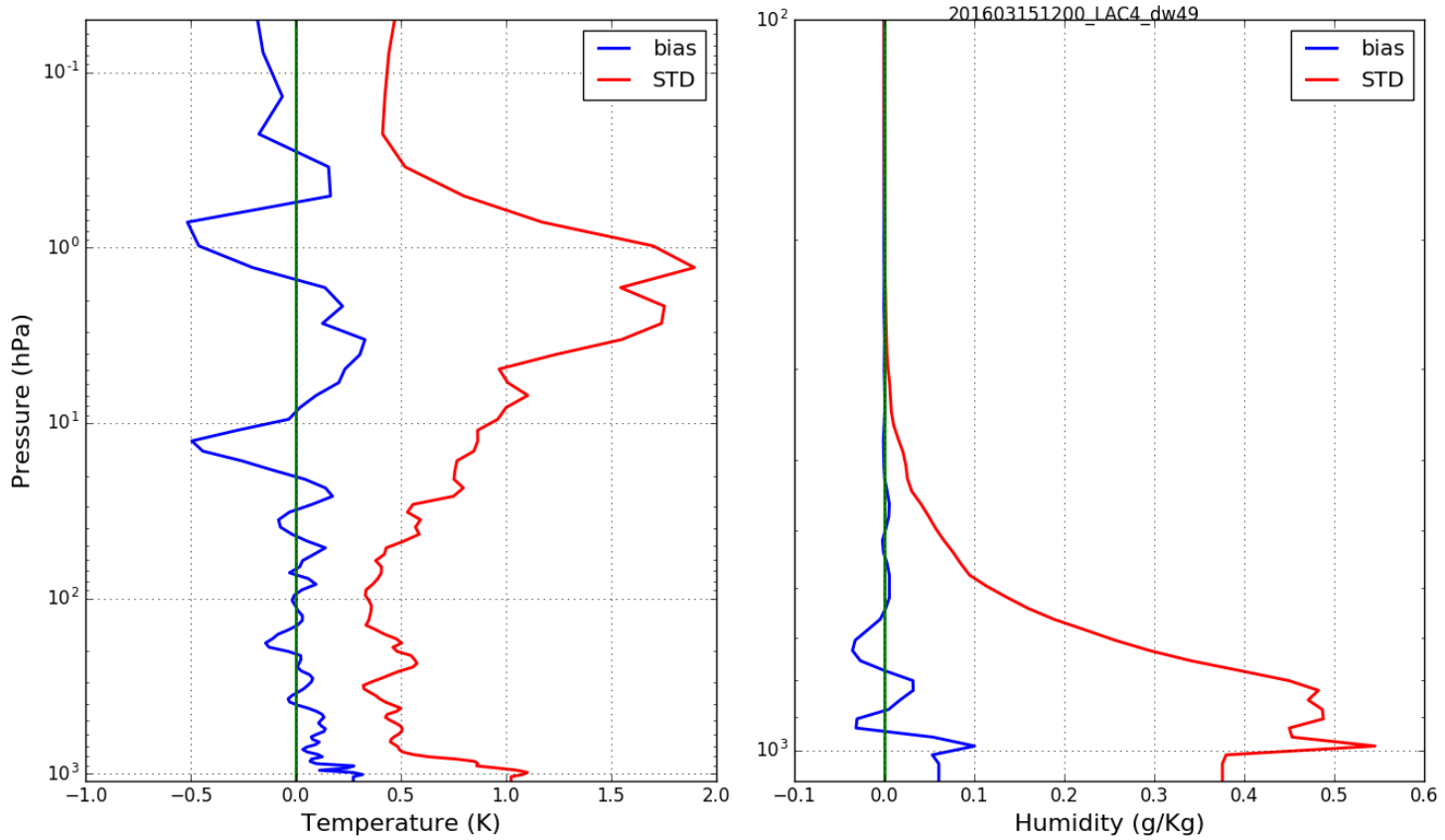
- ✓ **ECMWF fields**
- ✓ **Realistic dwells and slanted profiles**
- ✓ **Clear & cloudy simulated radiances**
- ✓ **RTTOV-IRS extended to 85° satellite zenith** *(special request to NWP-SAF)*
- ✓ **Hourly disks, one full day**

➔ **Support prototyping development**

➔ **Viewing angle sensitivity study**

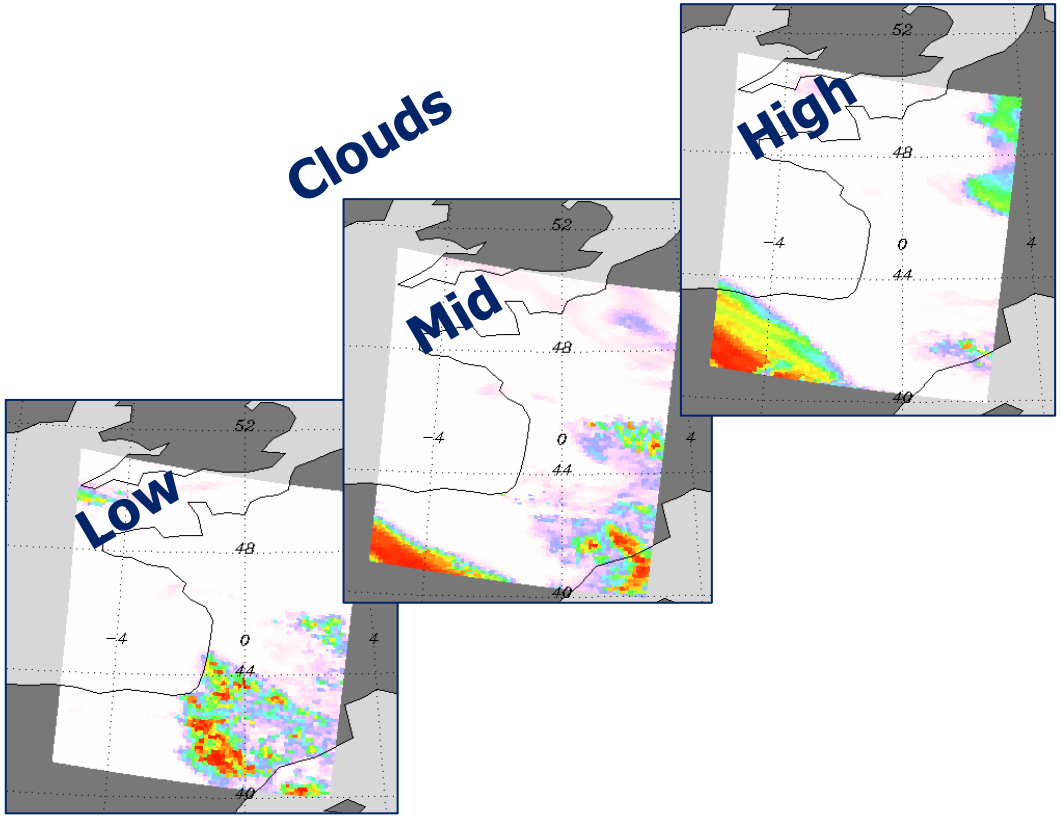
IRS PWLR^3 prototype – current status

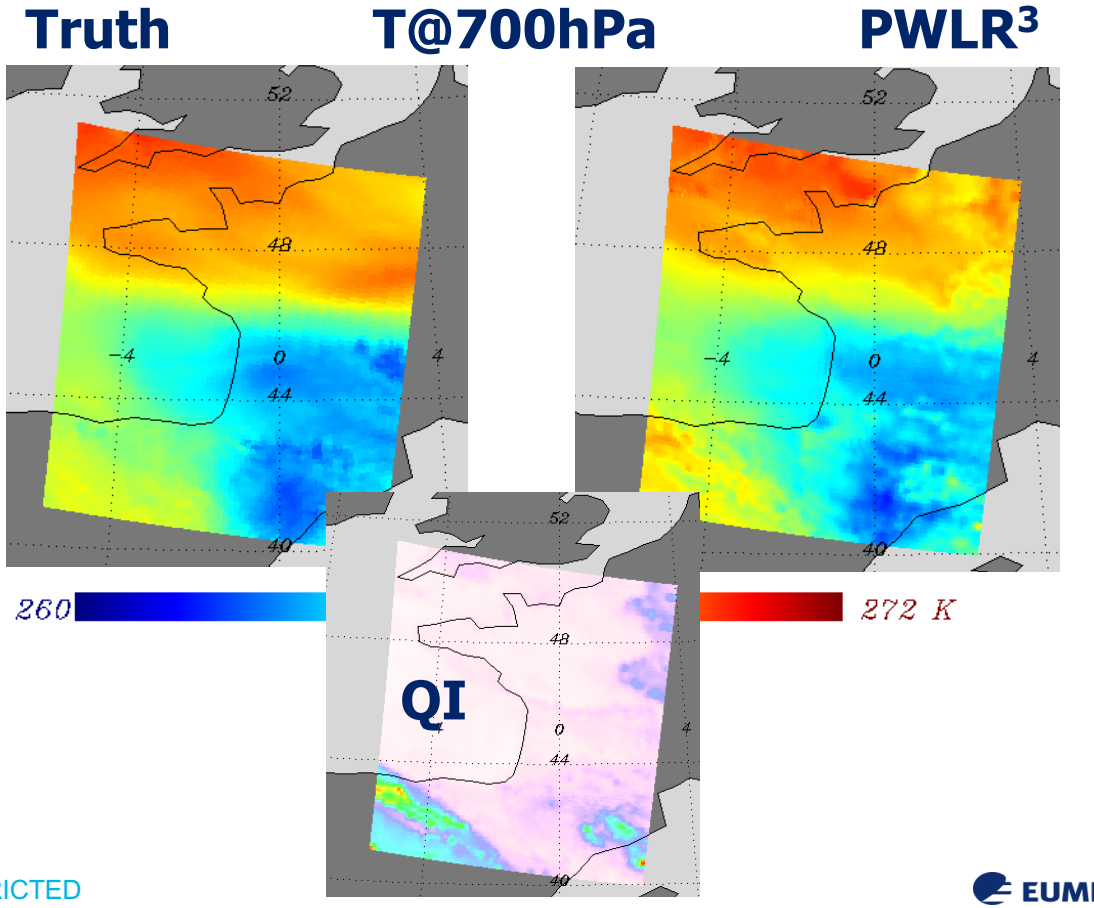
- ✓ ATBD → Specifications → Prototype
- ✓ Training module and retrieval function for T, q, O_3, T_s, emissivity + QI
- ✓ First set of coefficients
- ✓ **Full dwell** in **~1 minute** CPU-time *(non-optimised prototype S/W)*



IRS PWLR^3 prototype – current status

- ✓ ATBD → Specifications → Prototype
- ✓ Training module and retrieval function for T, q, O_3, T_s, emissivity + quality indices
- ✓ First set of coefficients
- ✓ **Full dwell** in **~1 minute** CPU-time *(non-optimised prototype S/W)*





Study: assimilation of IASI L2 (IR-only) at ECMWF

Study with IR-only products:

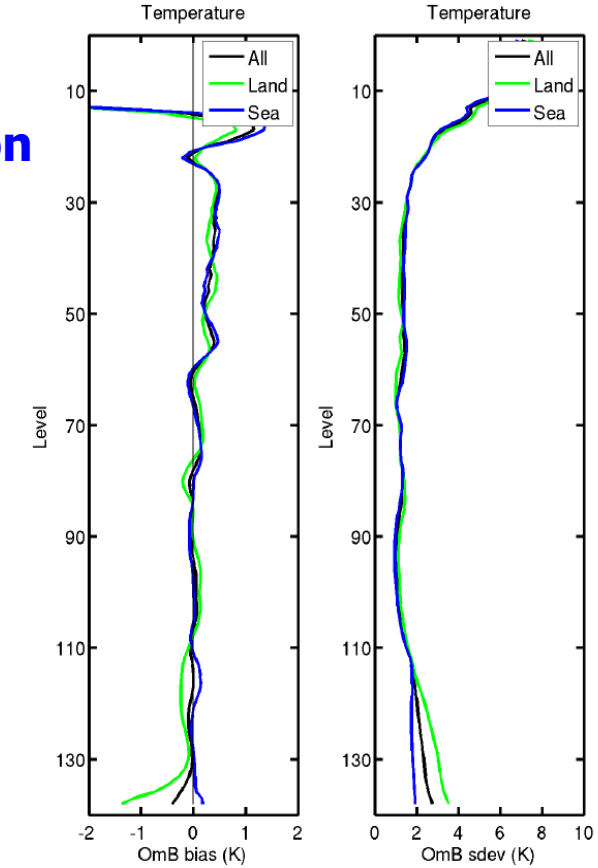
- ✓ **Kicked-off**
- ✓ **Ingest system completed**

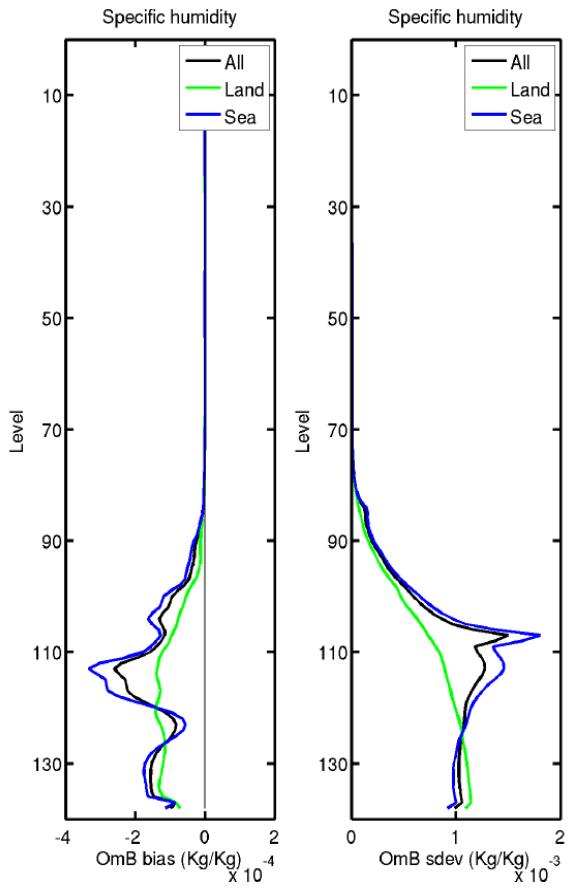
Next steps:

- ➢ **Monitoring: error characterisation**
- ➢ **Set-up QC strategy**
- ➢ **Assimilation experiments**
- ➢ **Full year dataset, 2017**

Example: O – B statistics

No QC filtering yet: all pixels retained, including fully cloudy and "bad" retrievals





Results: K. Salonen (ECMWF)

Summary

Prototyping started

- ✓ PWLR^3 in nominal configuration works
- ✓ 1’ / full dwell with non-optimised code

Coming next

- ➢ Release specifications for procurement
- ➢ Develop prototype further → feed-back to specifications
- ➢ Study IRS specifics, including with proxy real observations
- ➢ Day-2 products…

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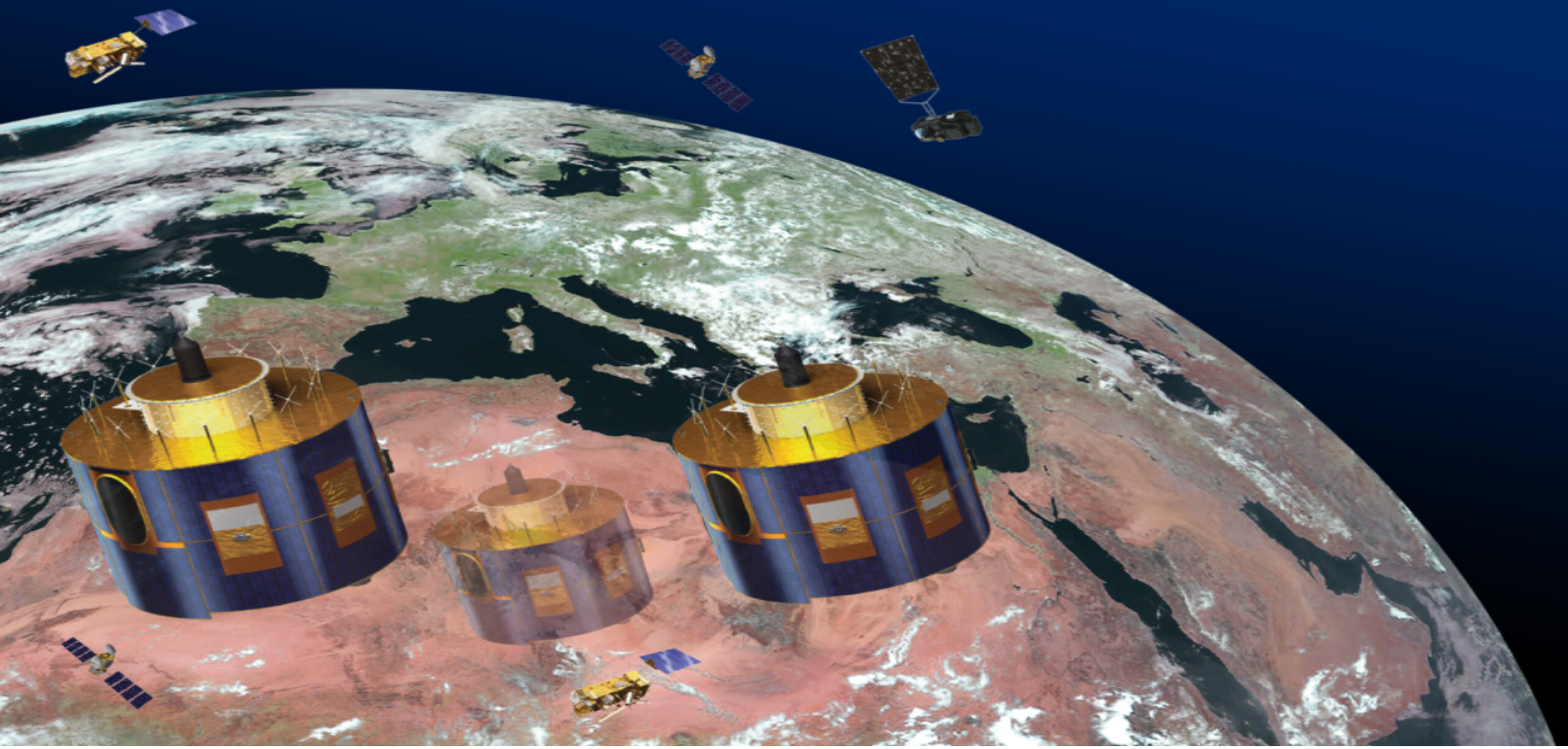
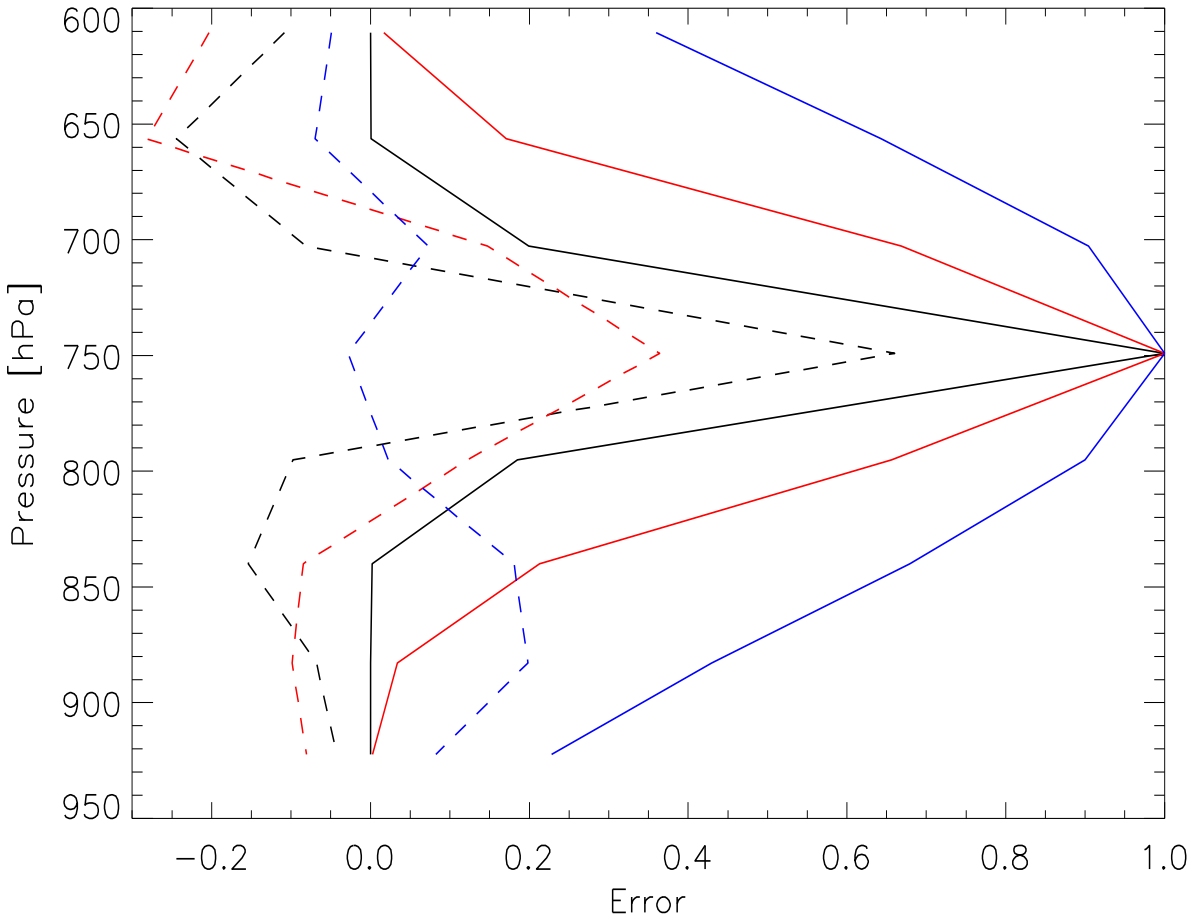
Which *a priori* ?



Fine structures *(not "seen" by IRS)* from prior to posterior



Propagation of prior structures (solid) into posterior retrieval (dash)
From MTG-IRS discussion paper, April 2011

Principles well understood and acknowledged

What is the “IASI-approach” for IRS?

The “IASI-approach” includes:

- Advanced use of PCA (rec’d radiances) to maximise information content (products quality) and optimise dimensionalities (affordable CPU) as well as numerical stability
- A statistical all-sky method, followed by physical retrievals of clouds and clear-sky profiles
- Algorithms proven in operations for EPS/IASI to generate atmospheric, cloud and surface products.

Historically FCT-free by User requirements in EPS.

✓ **Successfully tested with ECMWF forecasts in view of MTG-IRS.**

OEM *a priori* - The IRS L2 ATBD includes two options

PWLR^3

and

NWP

OEM

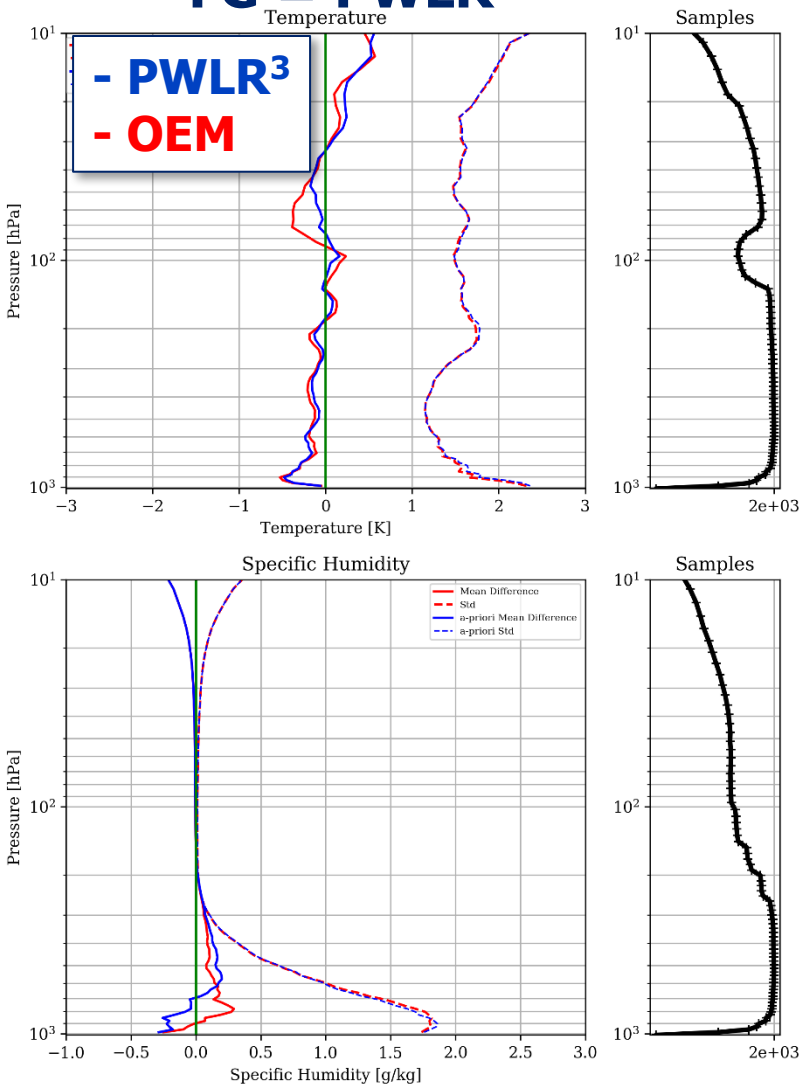
Variational retrieval

+

Choice of *a priori* — A reminder slide from MAG Oct'17

5 Wednesdays in June-July 2017 vs radiosondes (±3h ; <50km)

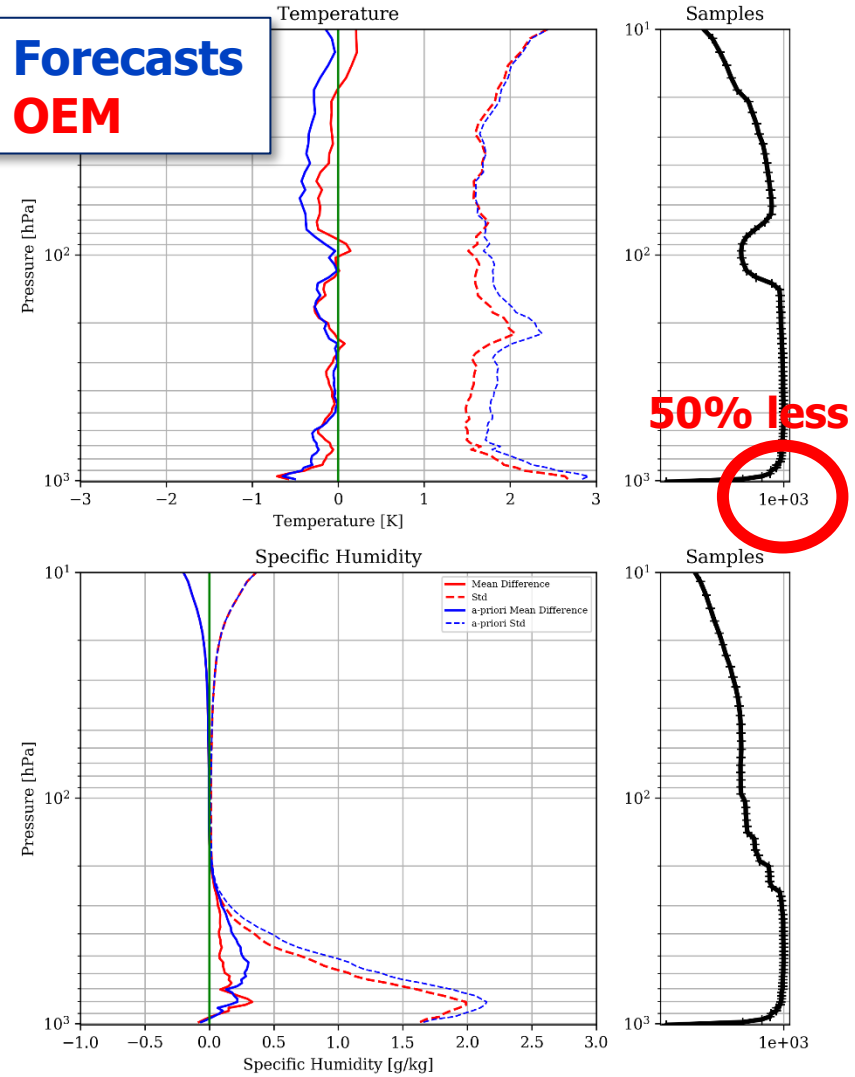
FG = PWLR³



IASI L2 PPF:

- Is FCT-free (EPS requirement)
- Can successfully process NWP forecasts (MTG assumption)
- Posterior stays close to prior if accurate *a priori*
- Some resilience to inaccurate *a priori* but not as good as stand-alone OEM(PWLR³)
- Brings independent accurate information

FG = 9h-outdated FCT

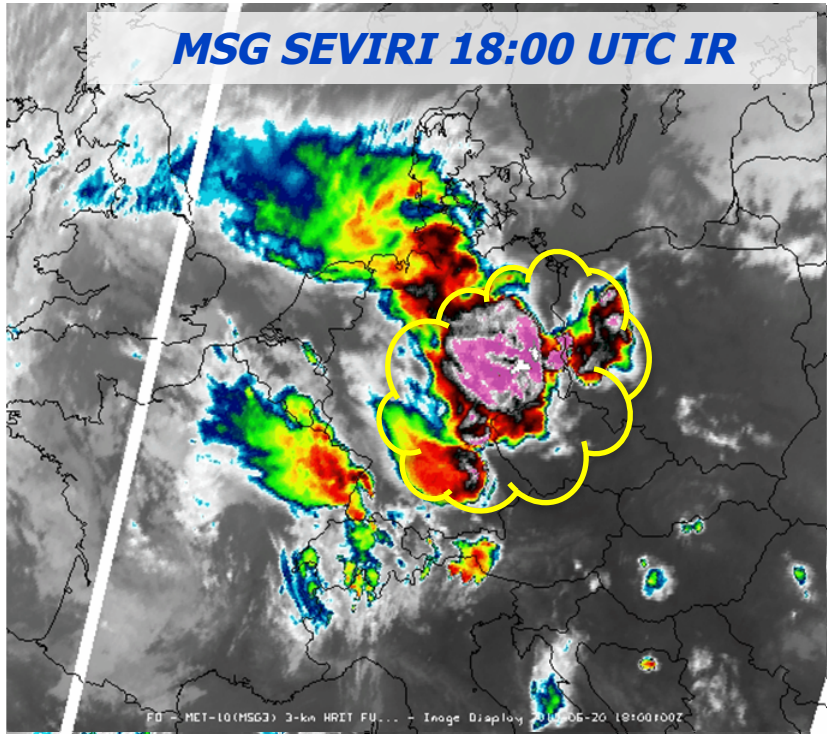


Tracking instability with IASI L2 products

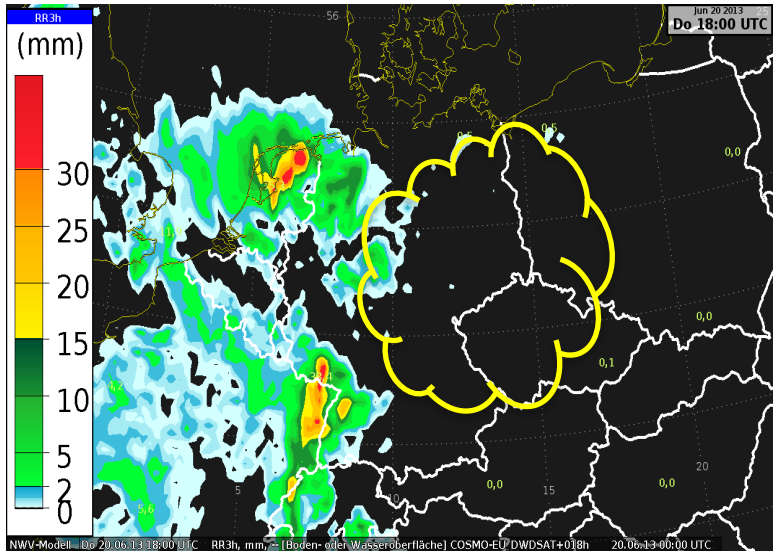
Central Europe Flooding 20 June 2013

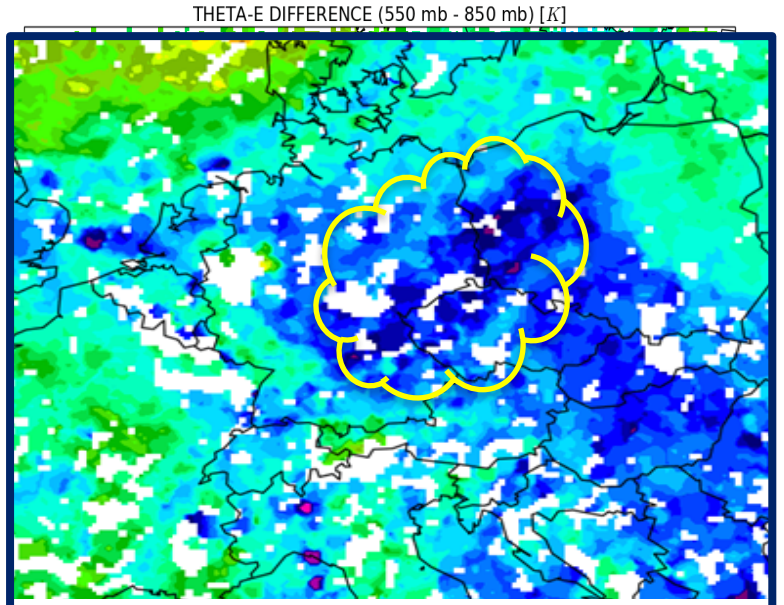
"Using hyper-spectral sounding products to improve forecasts of the pre-convective environment as a prelude to MTG-IRS"

R. Petersen, L. Cronce, (U. Wisconsin)
Keynote, EUMETSAT User Conference 2014

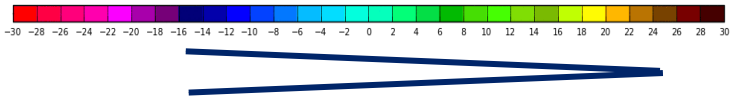


COSMO_EU 00Z forecast 18 UTC



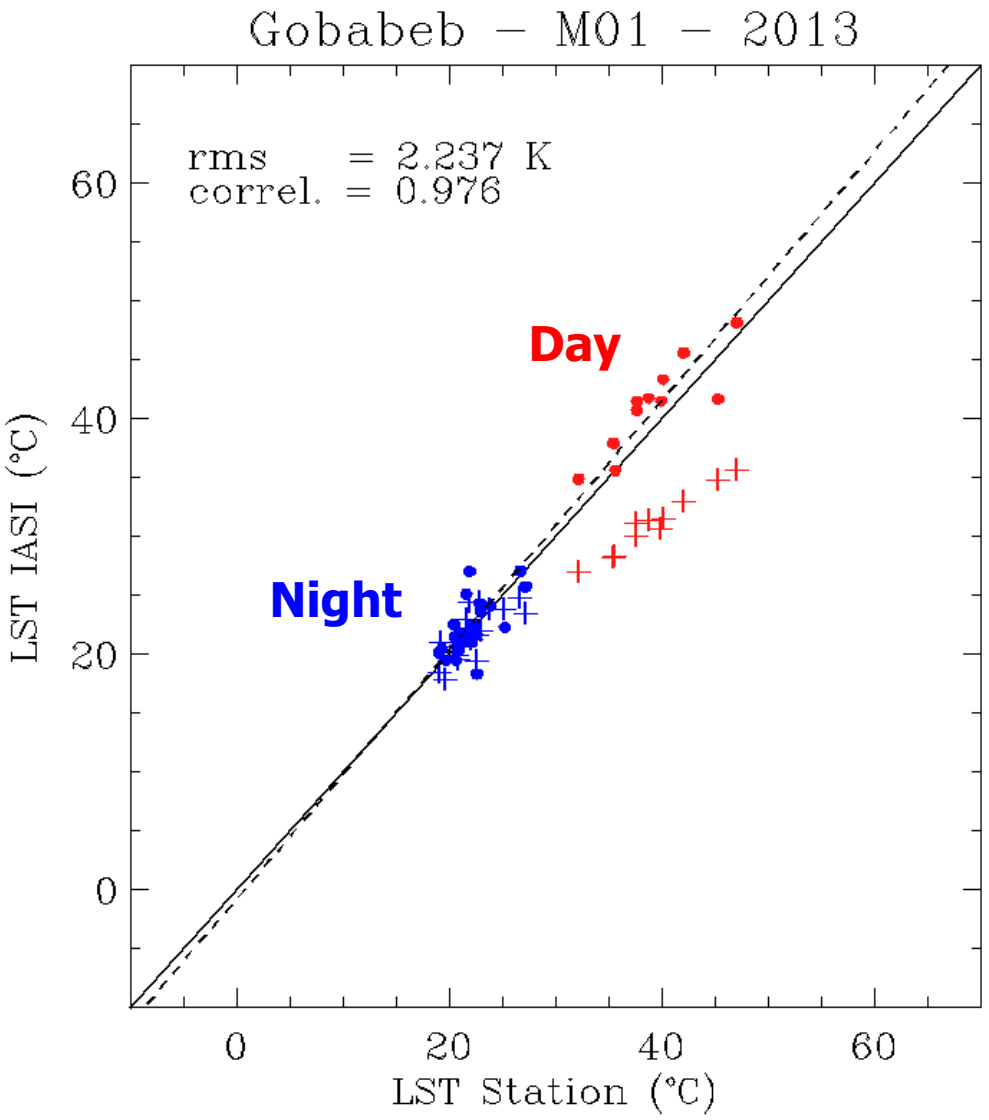


IASI L2 v6 Morning
+
NearCast at 18:00



Instability

Land surface temperature



- **IASI L2**
  + Forecasts

Results: B. Theodore in "IASI-B Validation report", EUM/TSS/REP/13/684650

But HSIR vertical resolution has limitations…

Forecast-free PWLR^3

+ All-sky
+ Full disk
+ Sounding quality
+ Relatively CPU-light, Timeliness
+ Provides independent/complementary information

Limitations *(intrinsic to IR sounders)*

- Smooth profiles → some vertical structures not accessible
- Lower sensitivity in BDL

Subsequent OEM

- Clear-sky, CPU-intensive
- With forecasts: fine-scale structures can complement the retrievals. Errors or model information may also be carried over ➔ desired for NWC, AMV?
- With PWLR^3: Refines first-guess and stays FCT-independent - smoother profiles.

Feed-back summary from CWG, Studies…

- Strong interest for FCT-free products, complementary info
- Request for continuous fields (clear and cloudy)
- Request for clear identification of L2 ≠ NWP, important info
- L2 provide observations between upper-air sonde launches

➢ But satellite profiles are smooth

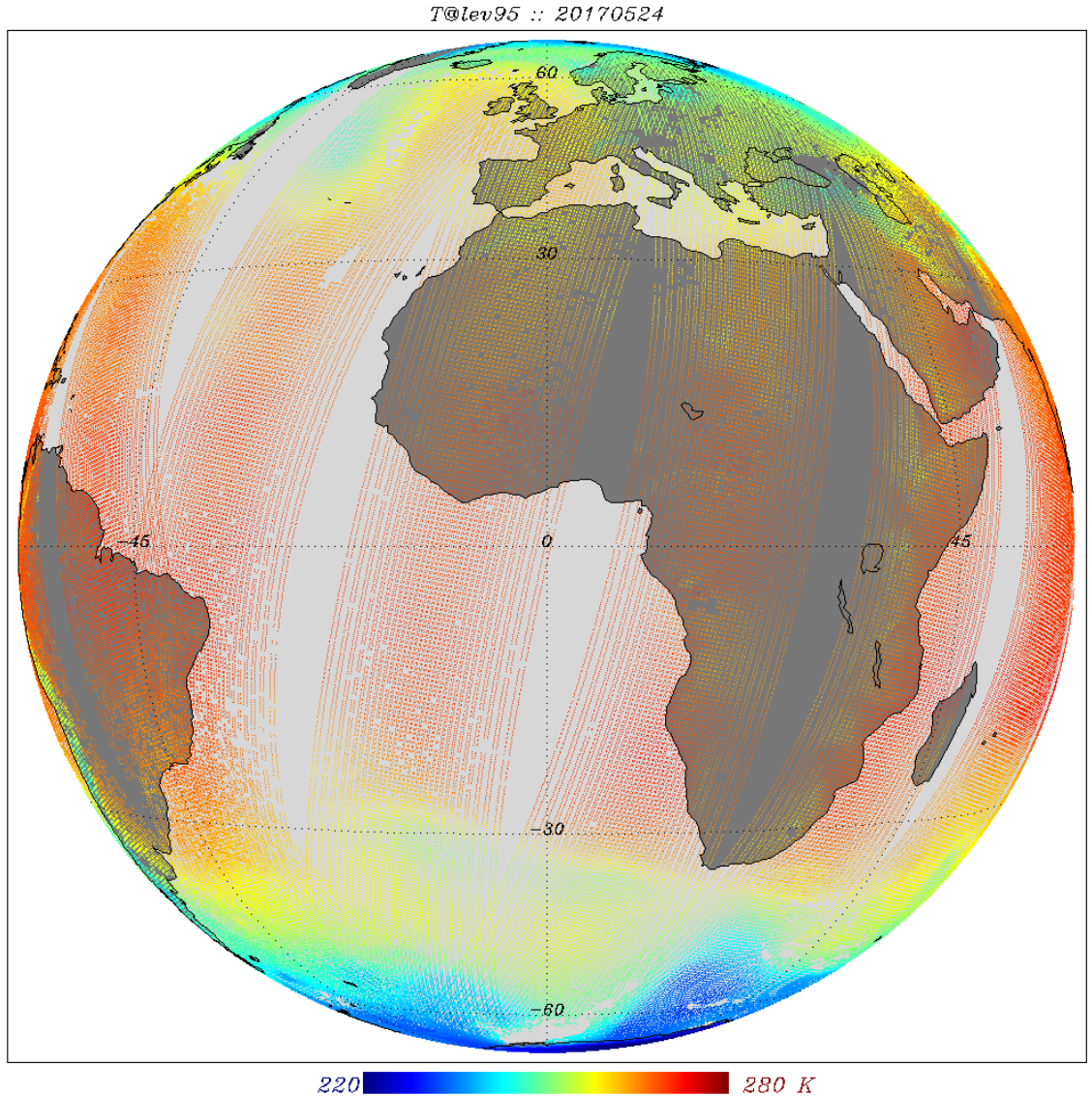
- Need to characterise performances in the lower layers
- Instability indices have smaller dynamic – *how to handle them?*
- Simple guide and quality information required – *both-way learning*
- Complement L2 with surface air measurements?

‼ Parallax effects from GEO need attention !!

Clear-sky / All-sky yields with IASI (IR-only)

24 May 2017

All-sky PWLR^3



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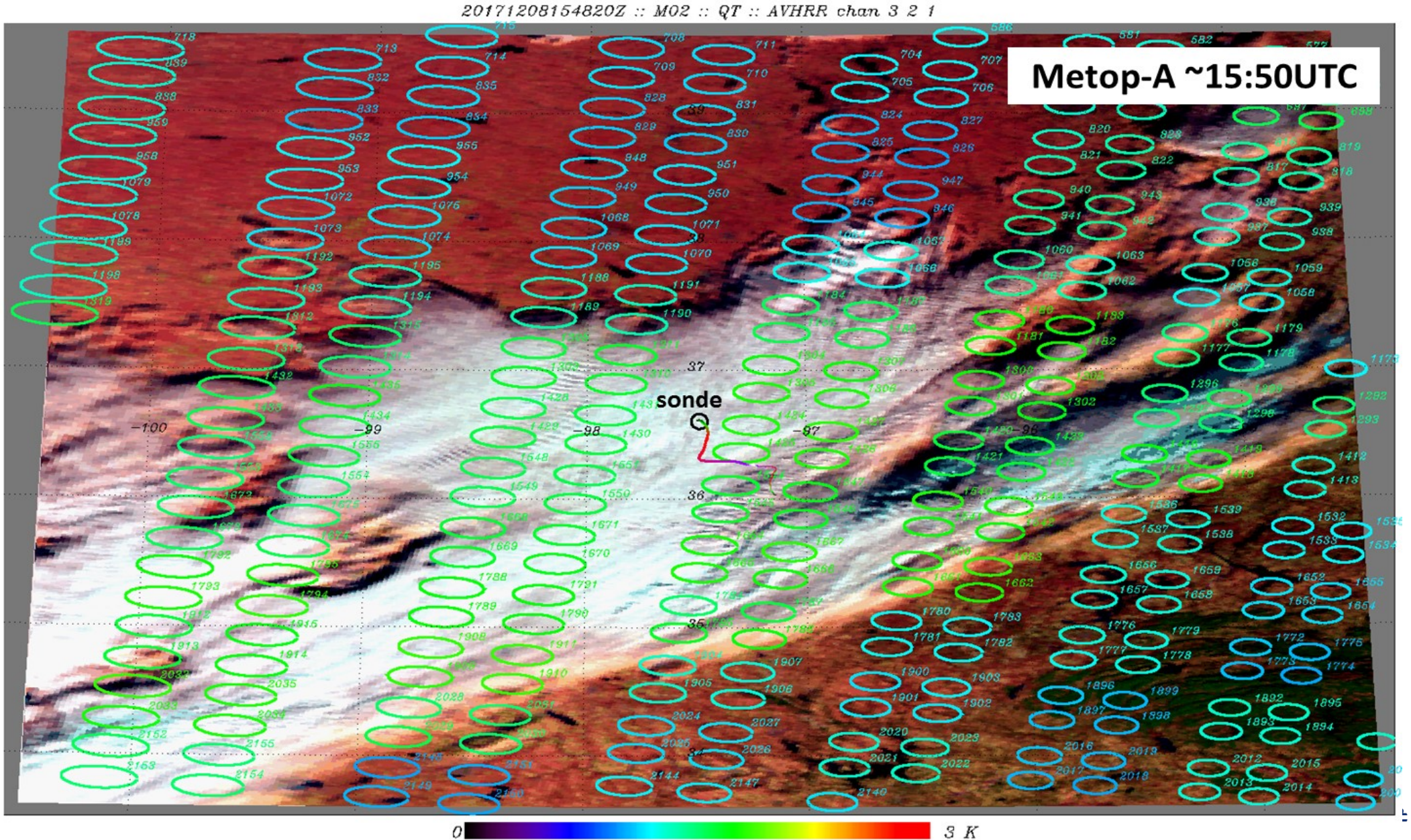
FCT-free option?

Users are expressing needs for independent products for their applications.
How best to provide a complementary information to the forecasts, that meets their requirements?

- ✓ Consolidate further the products validation, in particular in the low troposphere
- ✓ Case studies
- ✓ Assess potential and learn practical aspects of handling real products, together with Users

➔ some examples

Assessing PWLR^3 *all-sky* profiles and quality indicators



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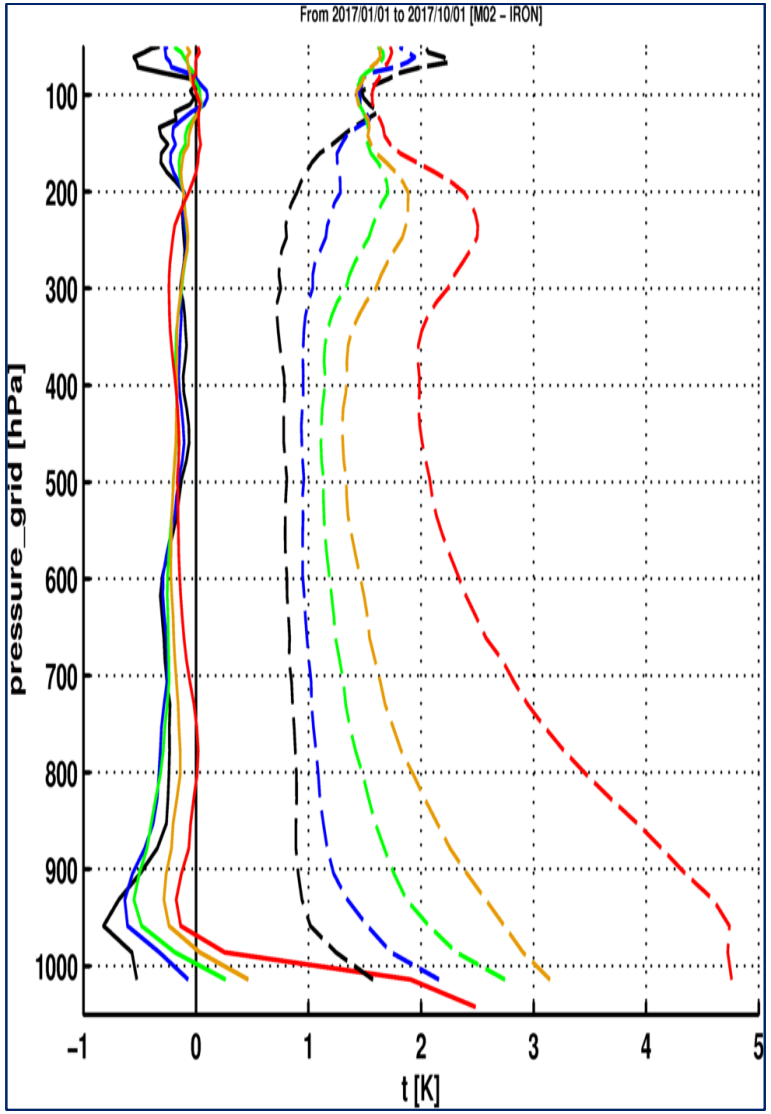
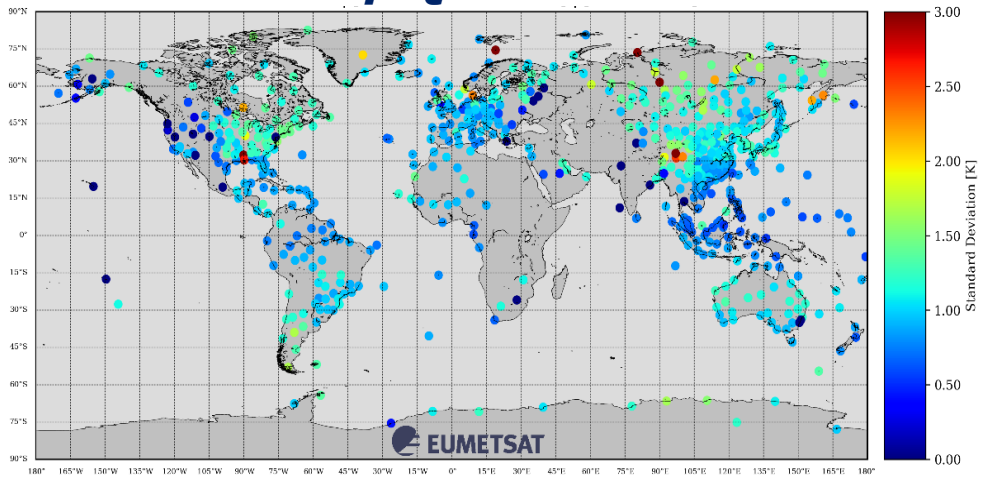
Quality indicator significance *vs* sondes [IGRA]

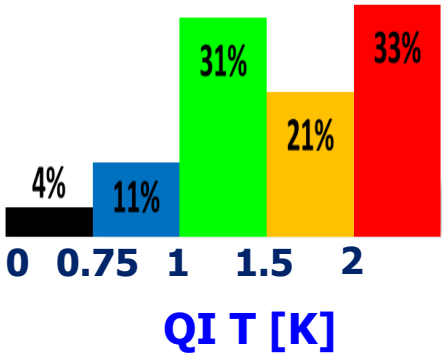
IR-only



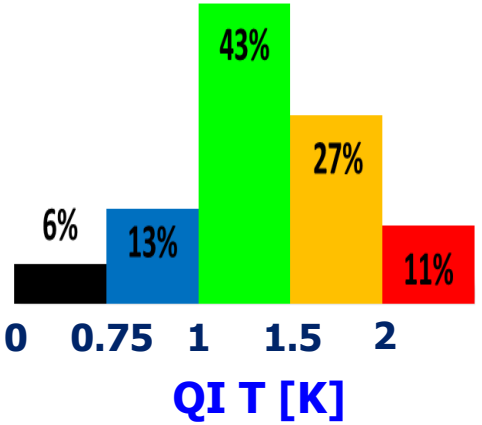
Jan. – Oct. 2017
< 50km ; < 3h
Match-up QC still needed



IR-only

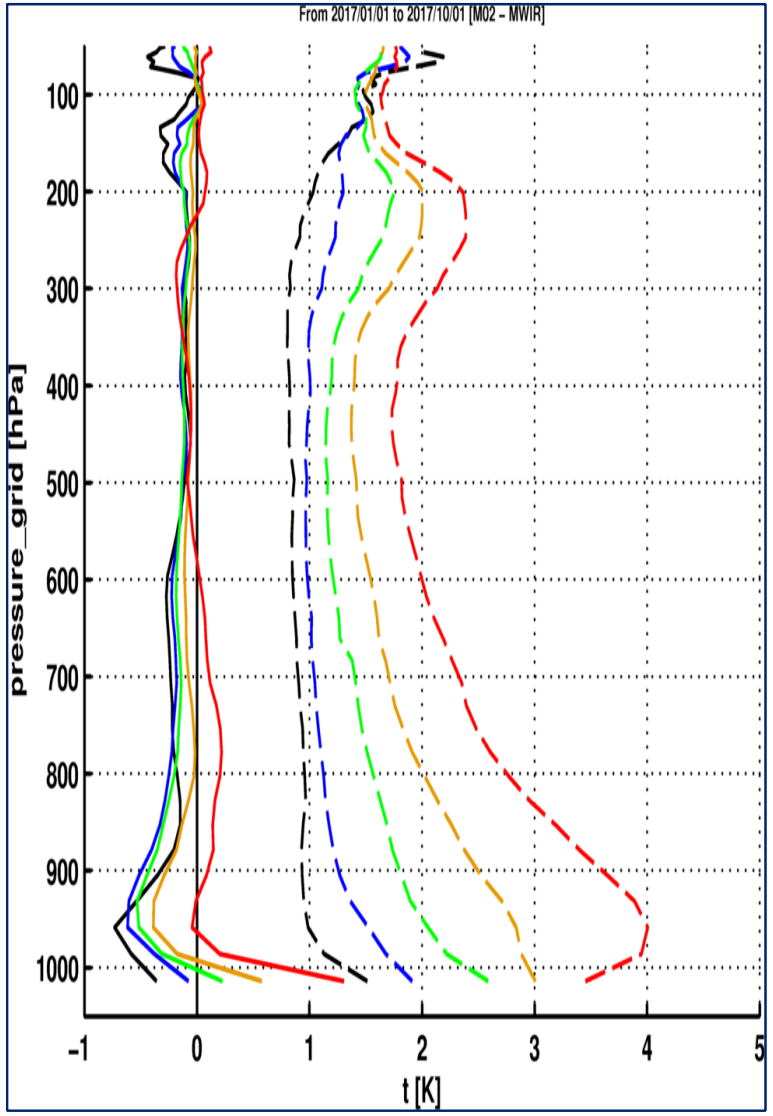


MW+IR

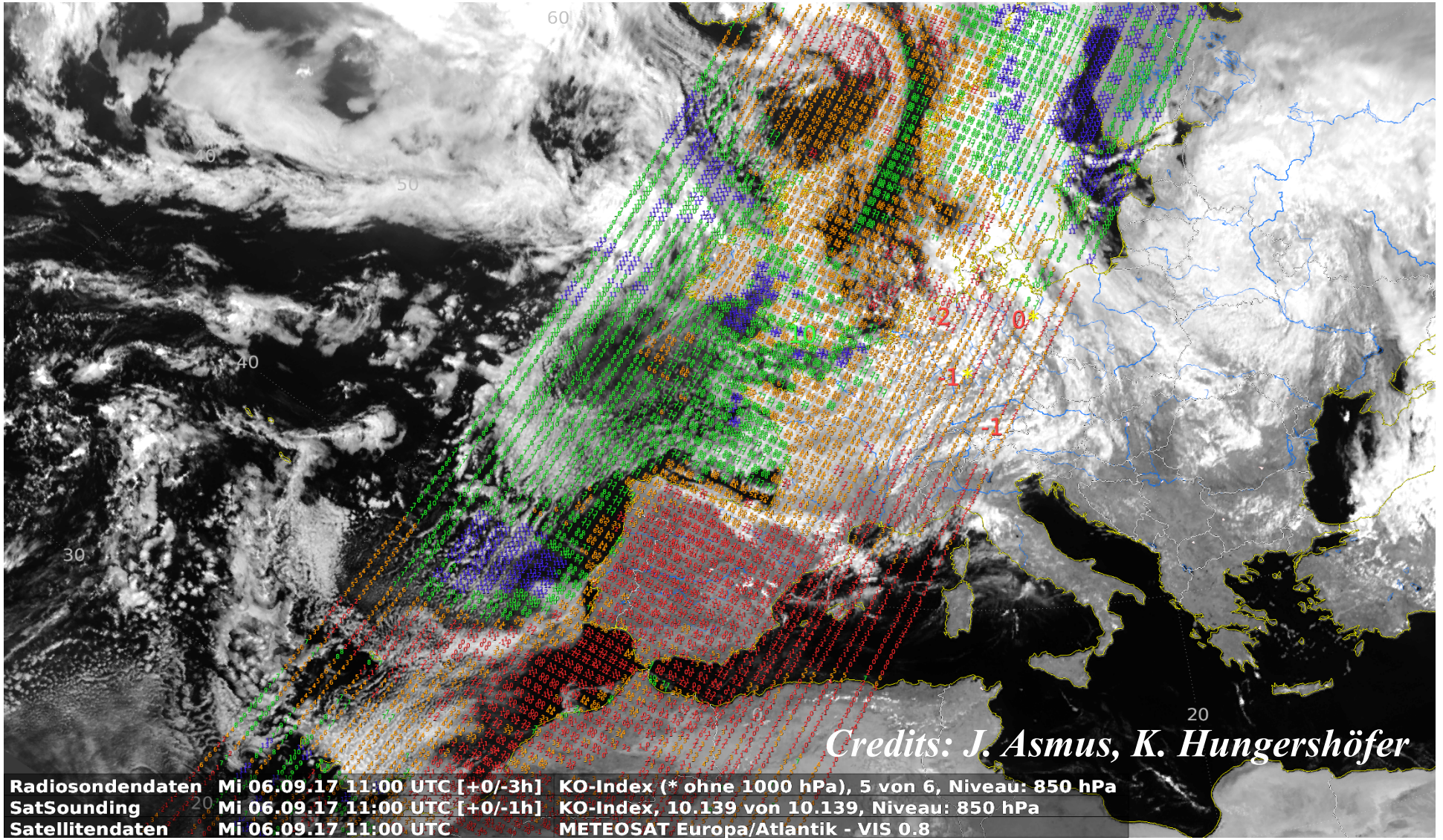


Error estimate in troposphere

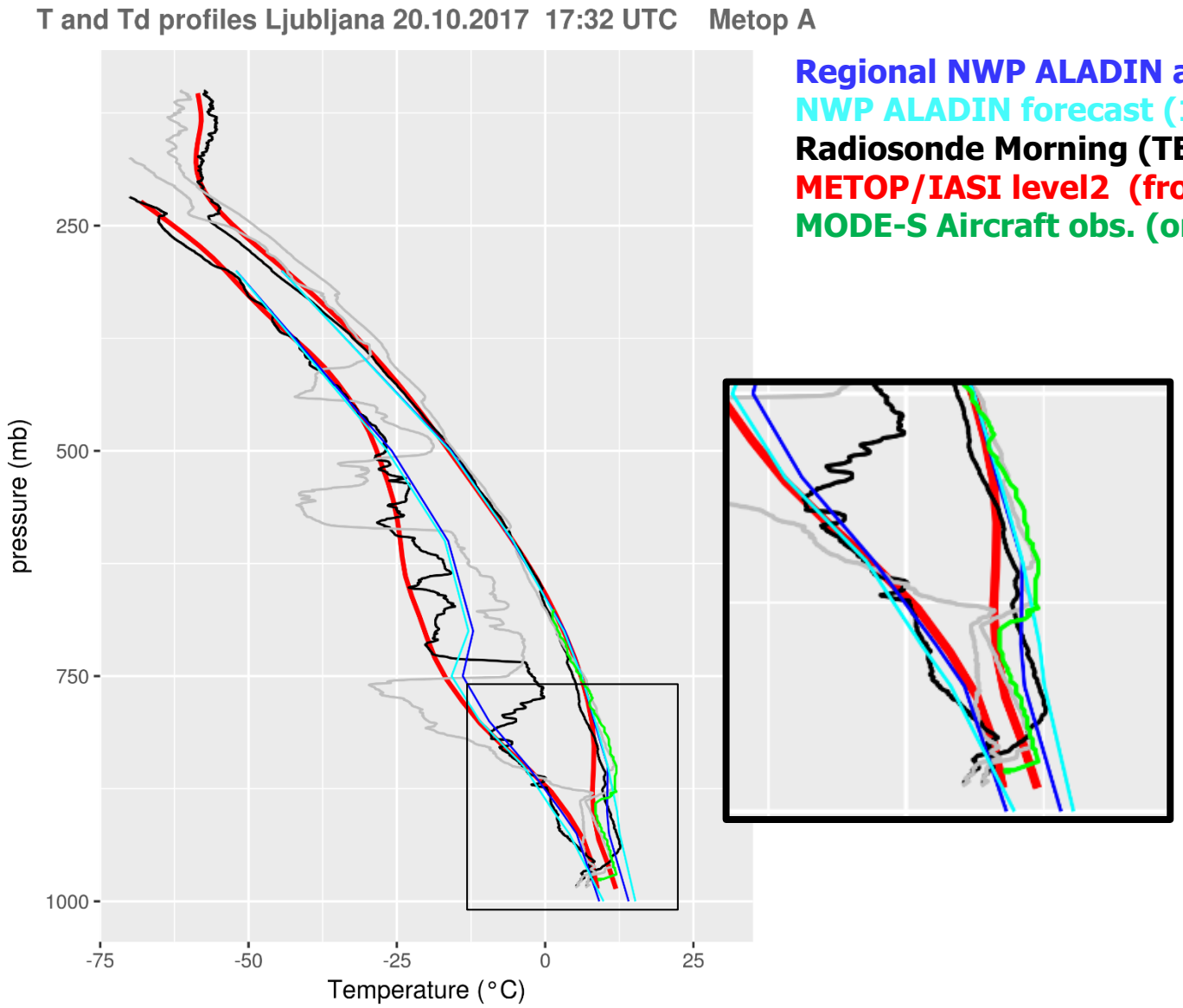
MW+IR



KO index from IASI L2 monitored at DWD with NinJo



Case study Ljubljana 20 November 2017 – *work in progress*



Regional NWP ALADIN analyses (ANA_),**
NWP ALADIN forecast (15 UTC+3 hours = GUE)
Radiosonde Morning (TEMP) and next day (NEXT_TEMP)*
METOP/IASI level2 (from the archive, over Ljubljana ~19 UTC)
MODE-S Aircraft obs. (only T ~19 UTC) – the most relevant in-situ reference

First results:
IASI/level2 T and Td profiles, does not capture the exact elevated temp. inversion (see MODE-S), however the info on „constant" temp layer is very well seen and is beneficial for the forecaster. It gives added value to the current NWP info (NWP on the plot is without assimilation of IASI level 1 – but will be soon checked for this case)

*** Please, be aware that radiosonde data are from the morning (5 UTC) and do not represent the time of METOP overpass.**
**** Be aware that ALADIN analyse is available 1-2h after 18 UTC.**

Credits: Mateja Irsic, ARSO

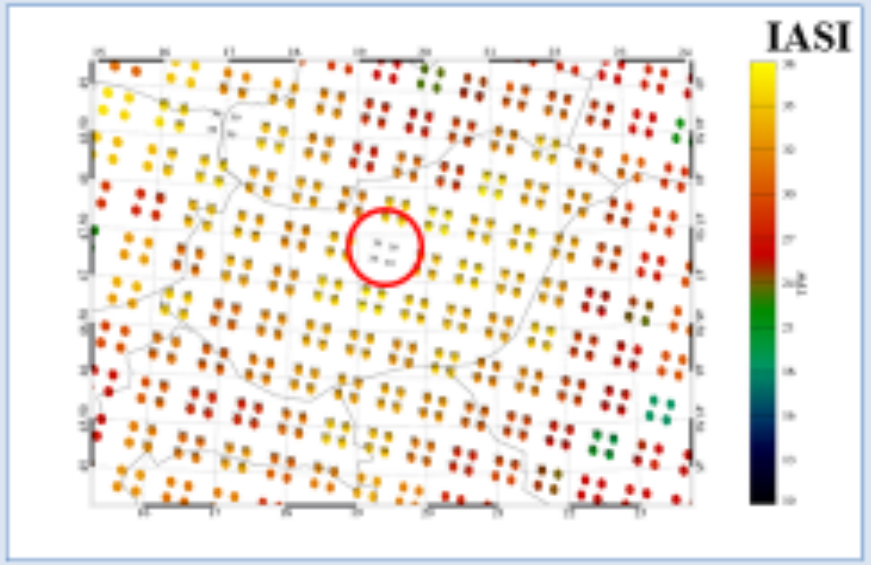
AGENCIJA RS ZA OKOLJE

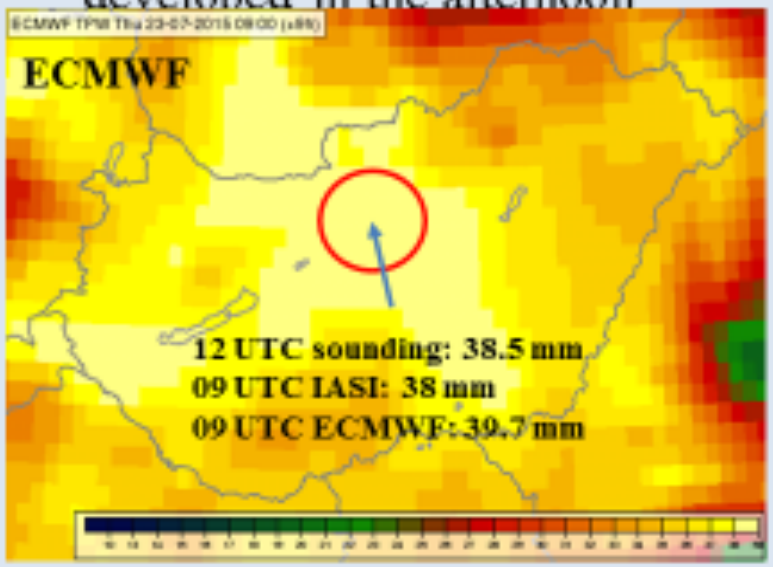
Study: potential of IASI L2 for Nowcasting (OMSZ)

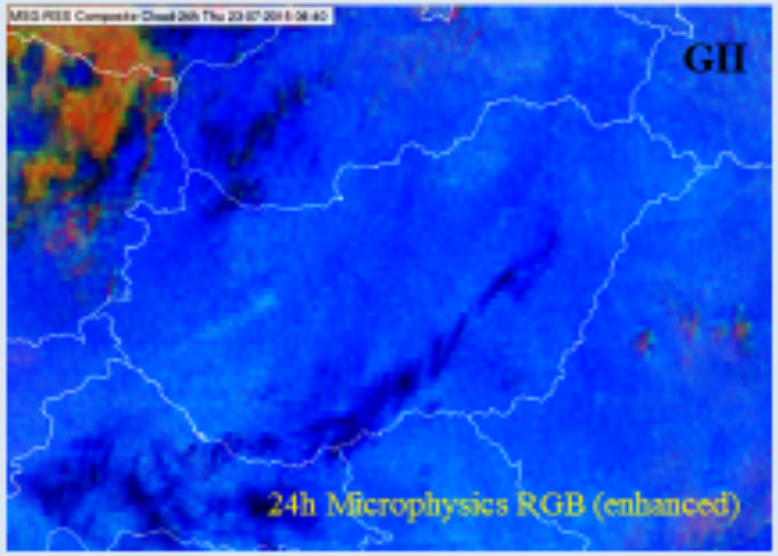
"Possible usage of IASI L2 profiles in Nowcasting", Z. Kocsis et al. CWG Workshop 2018

Humidity, TPW

- High TPW were predicted this day
- High TPW is also found in Budapest 12UTC sounding, where the IASI indicated the maximum at 09 UTC
- Multicell thunderstorms developed in the afternoon





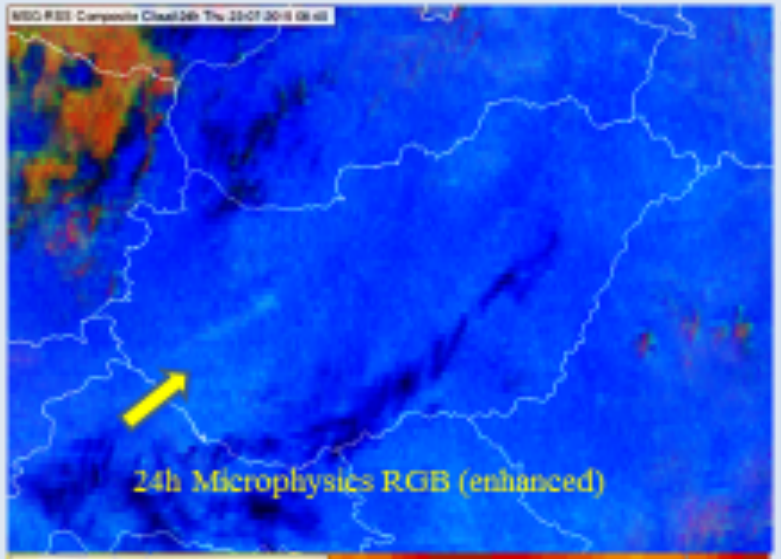


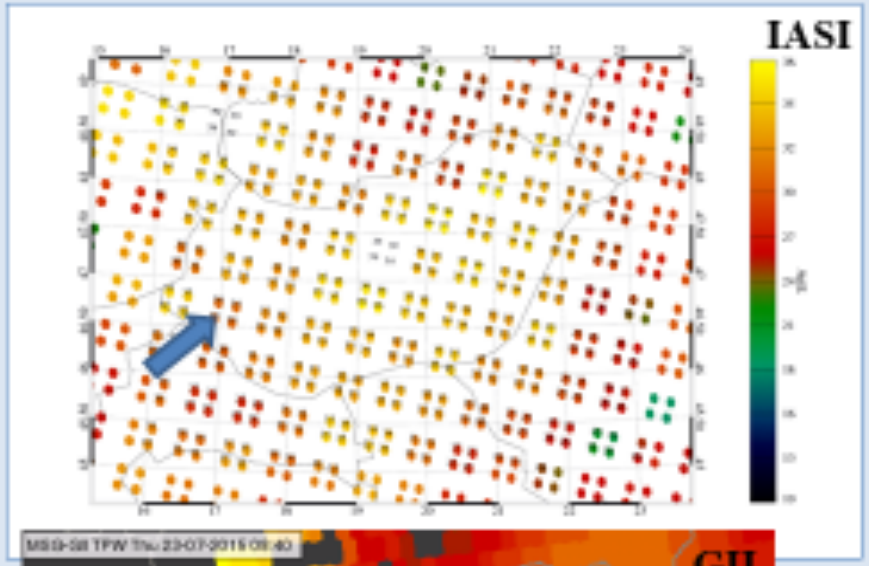
Study: potential of IASI L2 for Nowcasting (OMSZ)

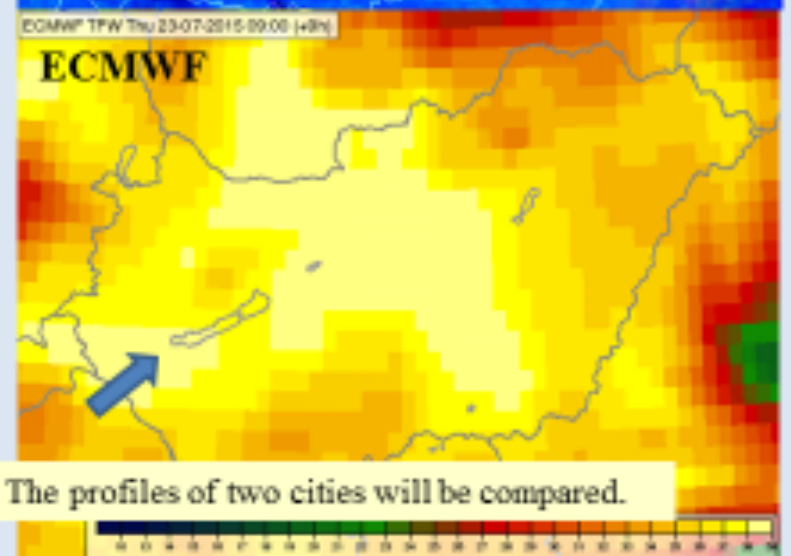
"Possible usage of IASI L2 profiles in Nowcasting", Z. Kocsis et al. CWG Workshop 2018

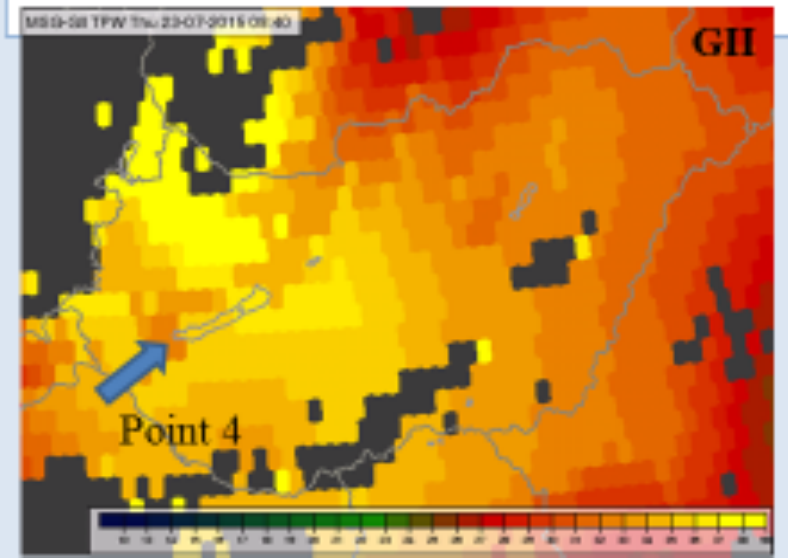
Humidity, TPW

The IASI derived TPW at 'Point 4' was lower than the ECMWF forecasted one. GII also decreased here the forecast. The RGB image shows dryer environment here.









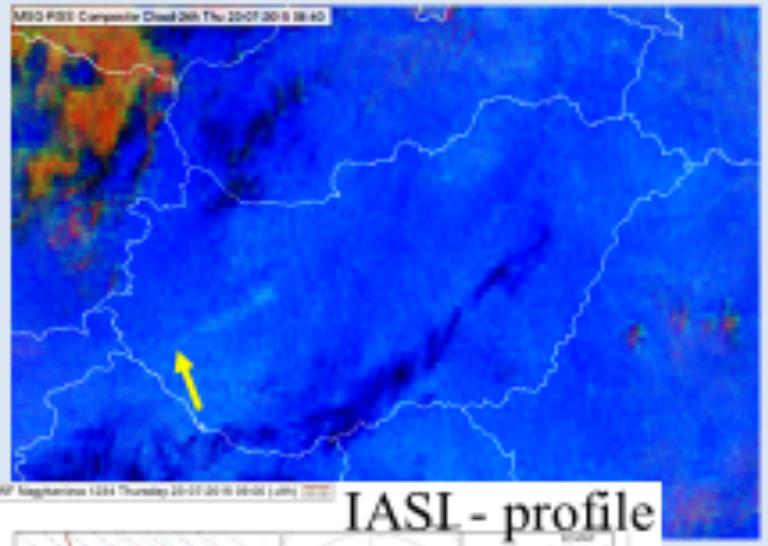
The profiles of two cities will be compared.

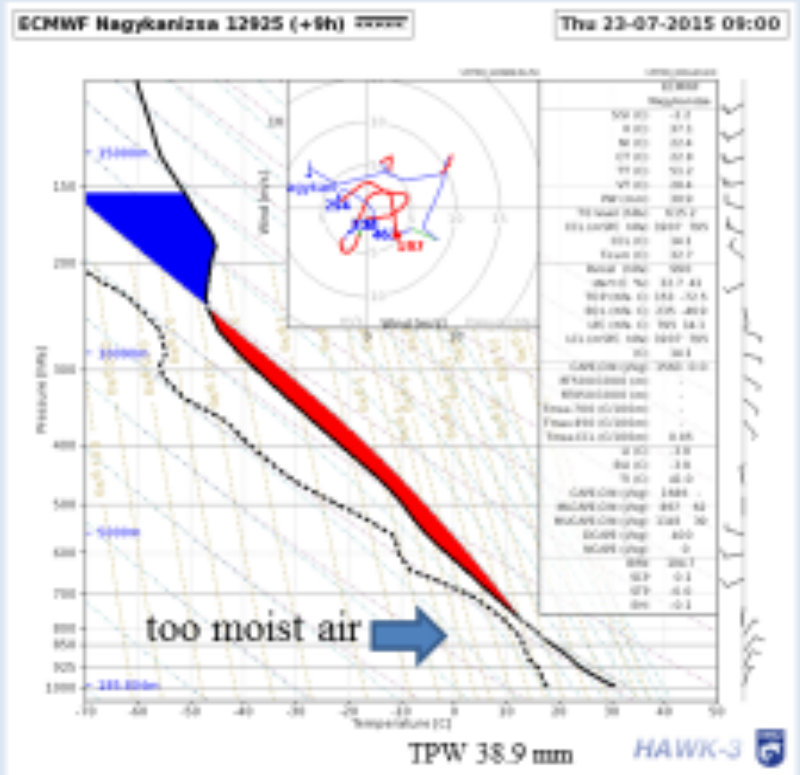
Study: potential of IASI L2 for Nowcasting (OMSZ)

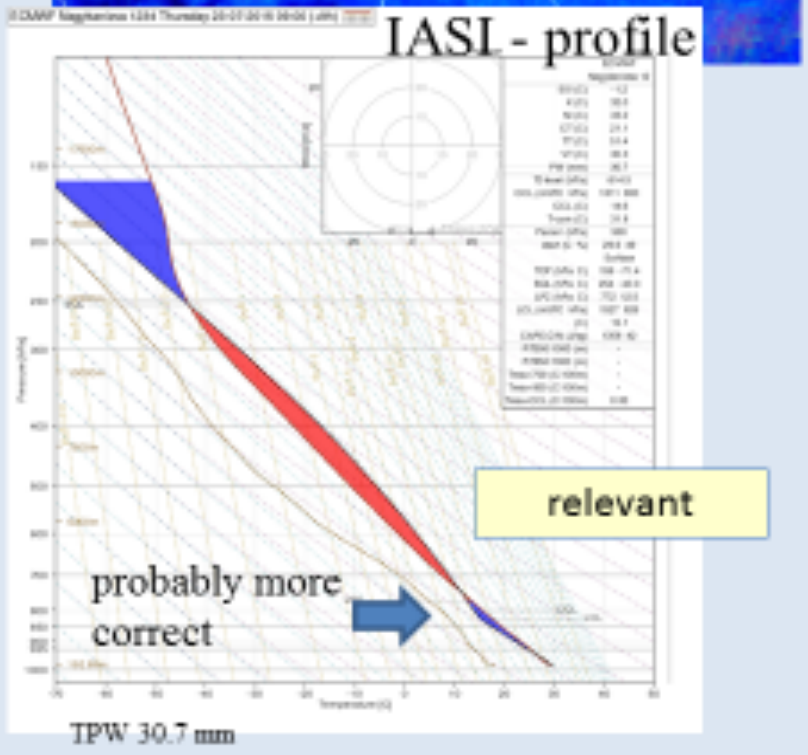
"Possible usage of IASI L2 profiles in Nowcasting", Z. Kocsis et al. CWG Workshop 2018

Evaluation – point 4

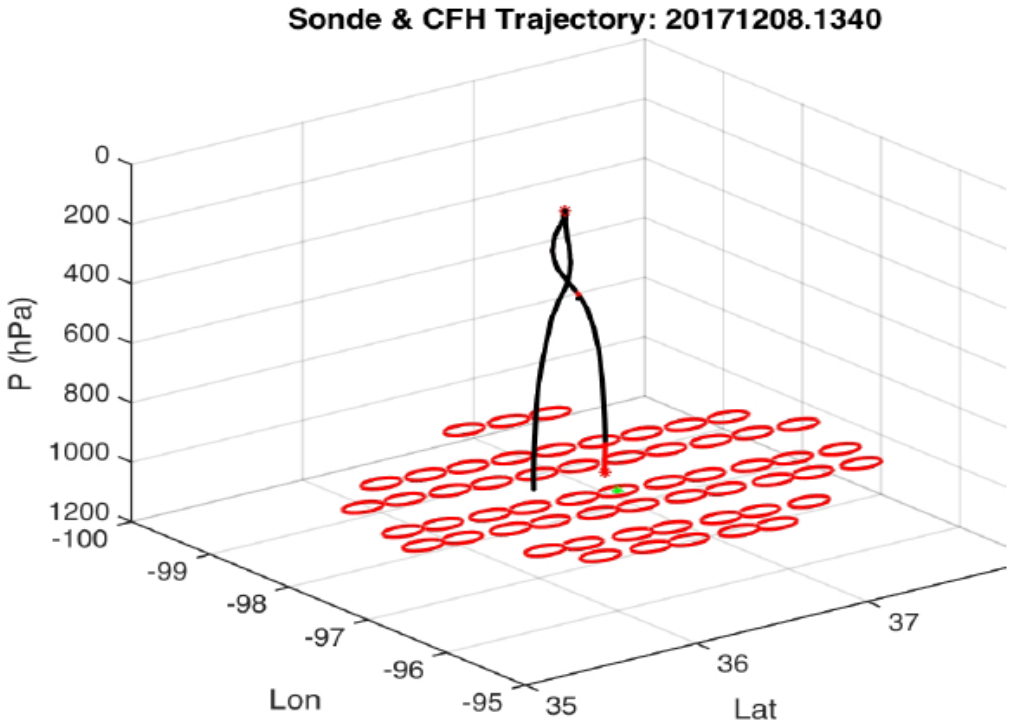
- IASI profile is less moist at 800 hPa
- The 24h Microphysics RGB indicated relatively dry air (green component: BT10.8-BT8.7), this agrees with IASI profile
- The thunderstorms in this area were short-lived,

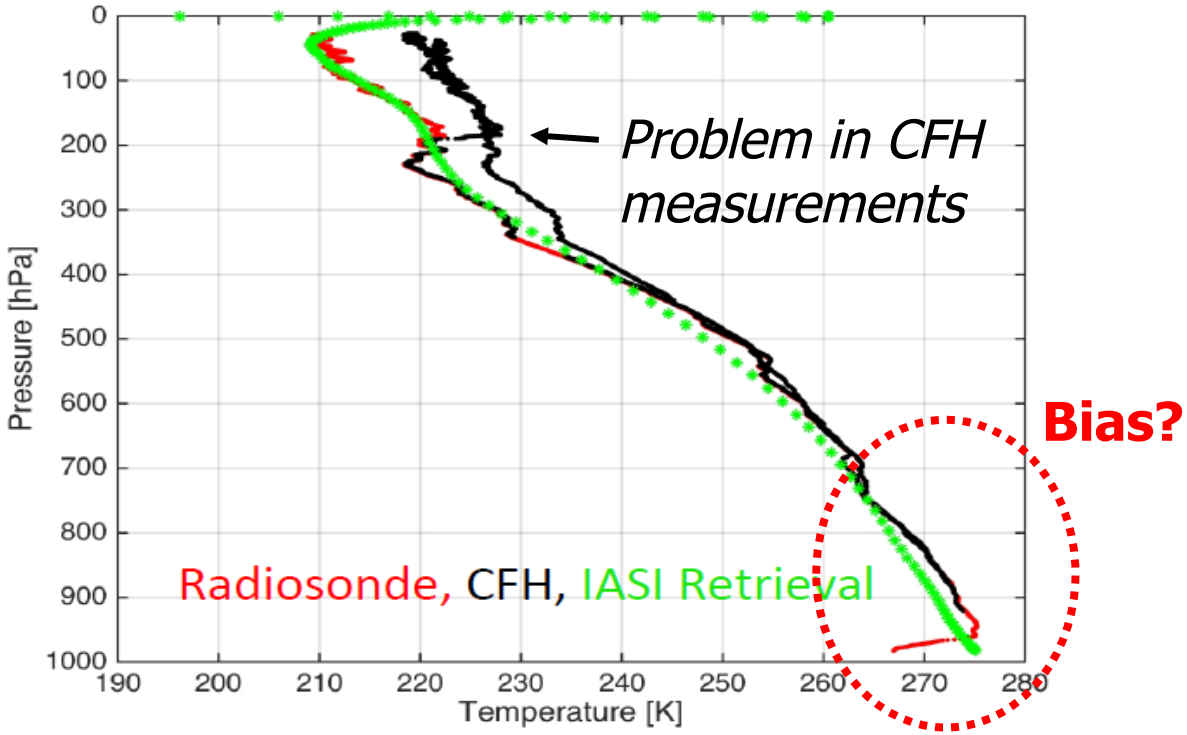






Future Work – Assessing IASI Retrievals using CFH at SGP



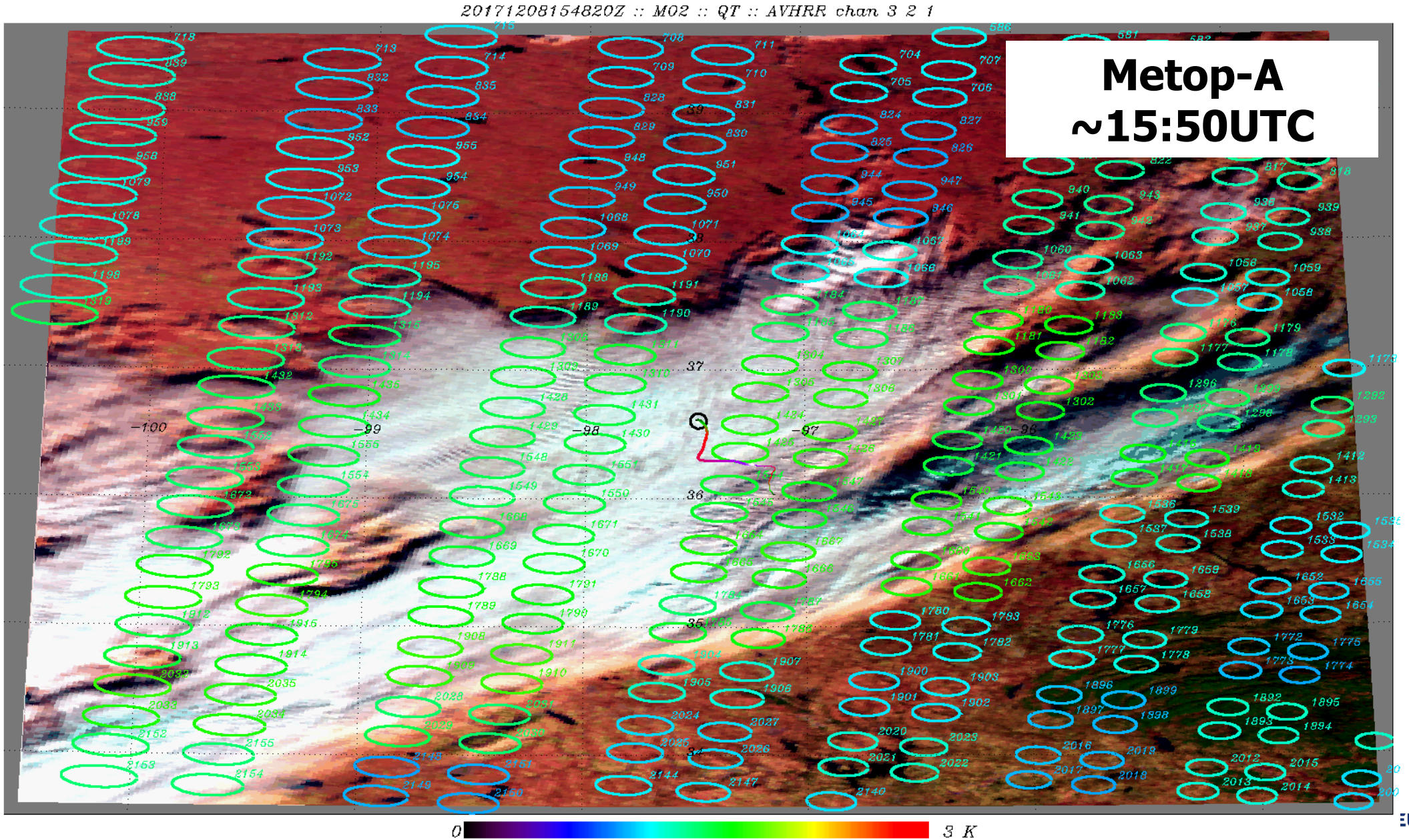


- CFH sampling ascent and descent

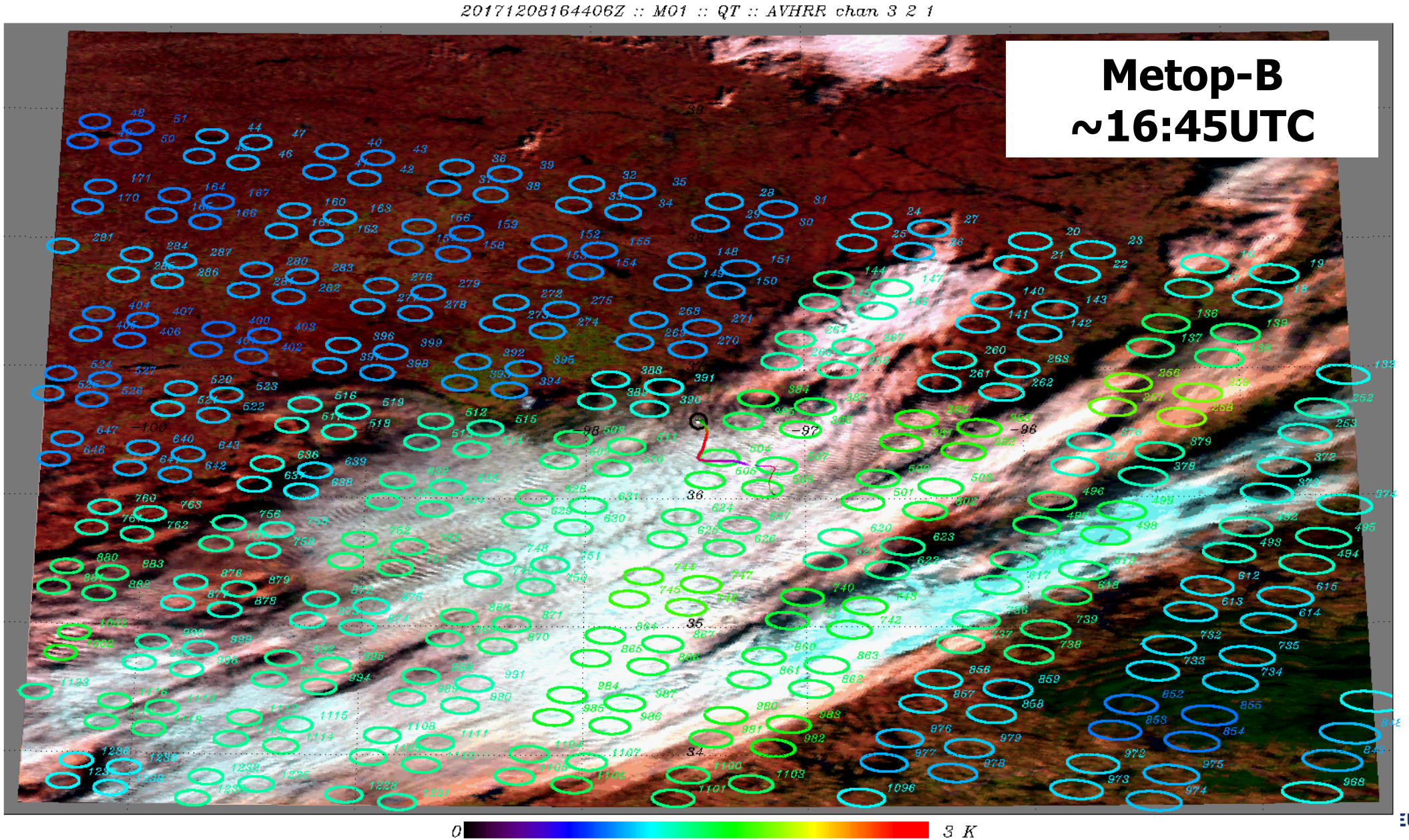
- Build statistically significant dataset of CFH launches coordinated w/METOP A&B
- Care must be taken assess 'closest' IASI footprint
- Use retrieval uncertainties

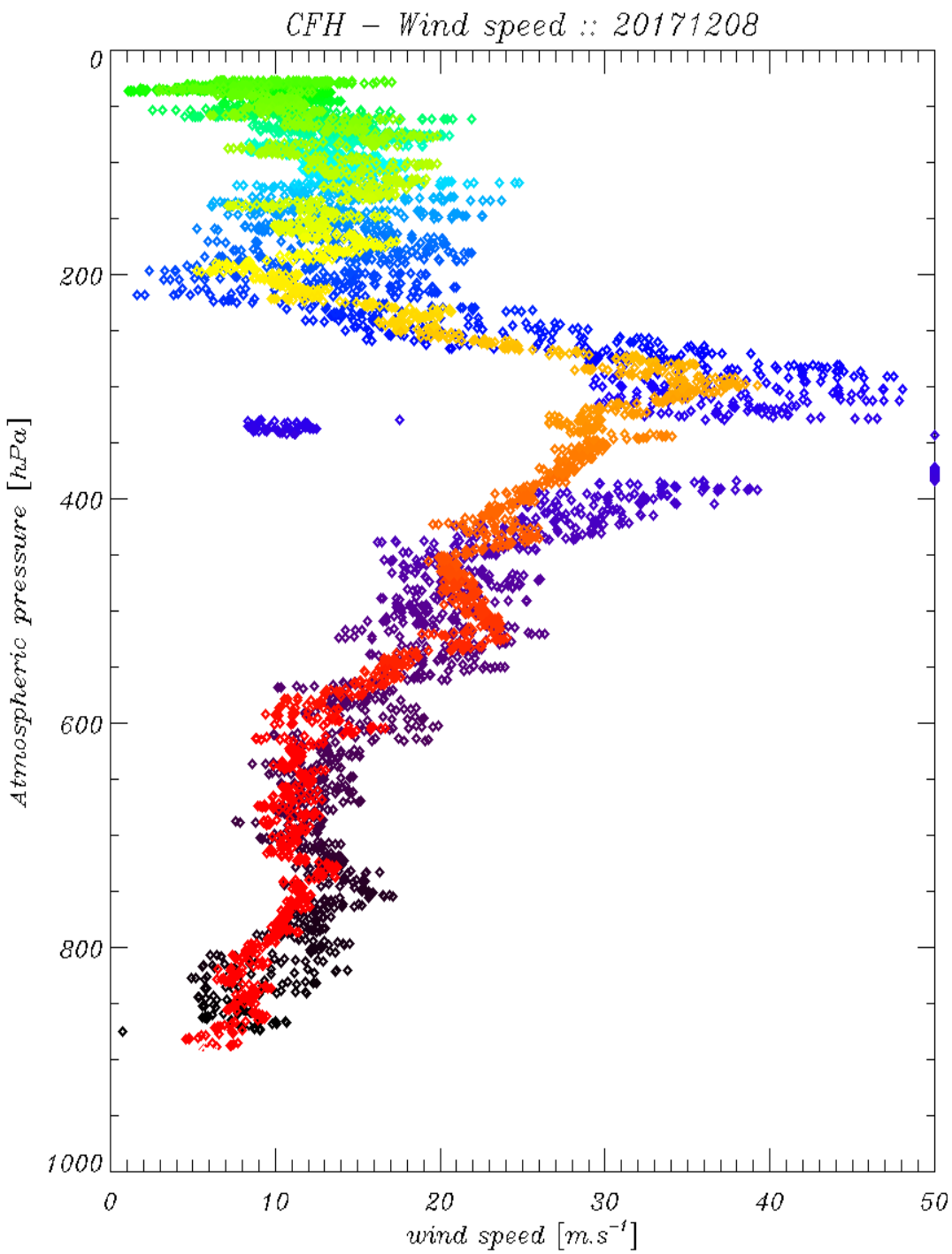
May 2018
Visiting Scientist
Lori Borg (U. Wisc.)
PI JPSS radiosondes programme

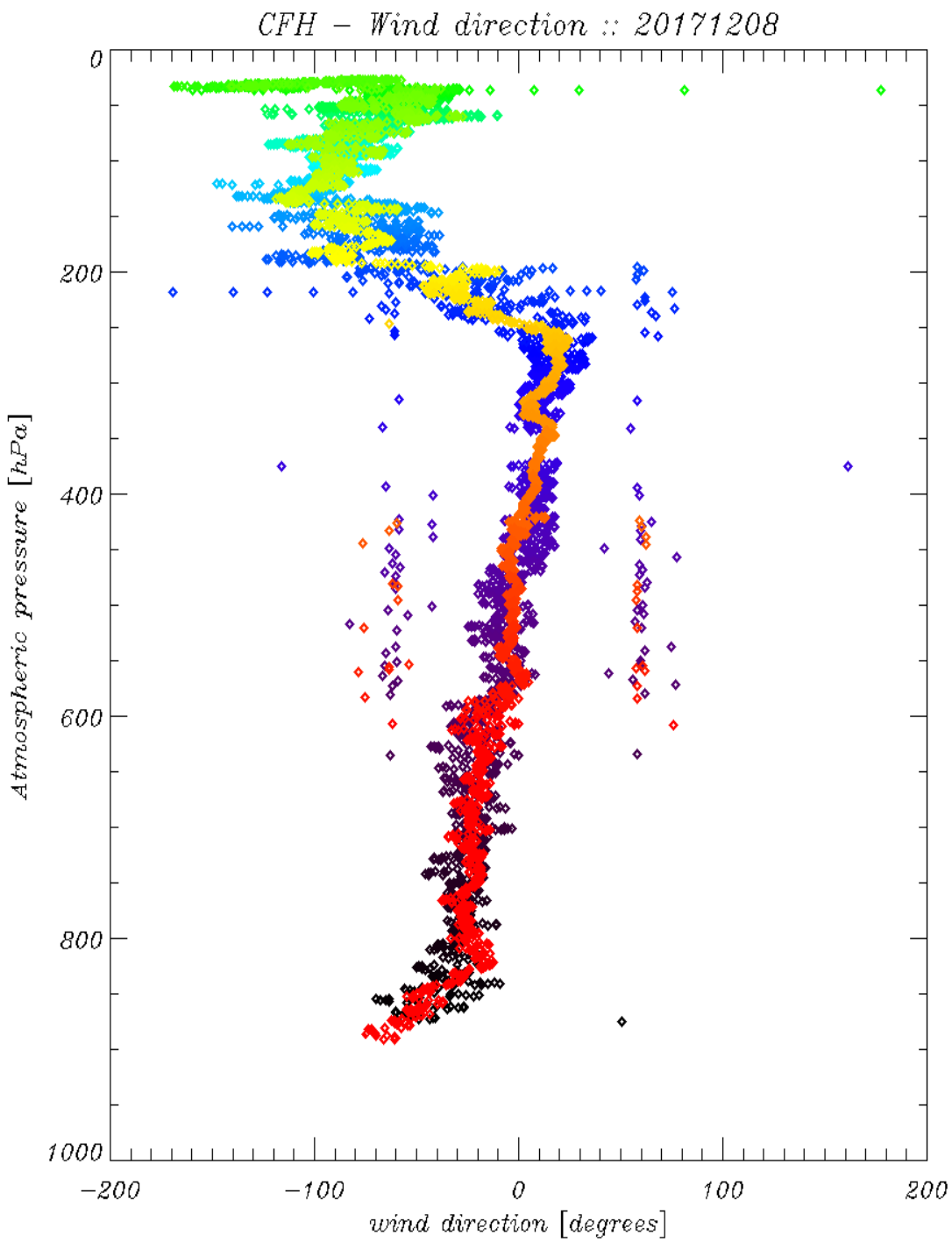
Performance assessment in the lower troposphere



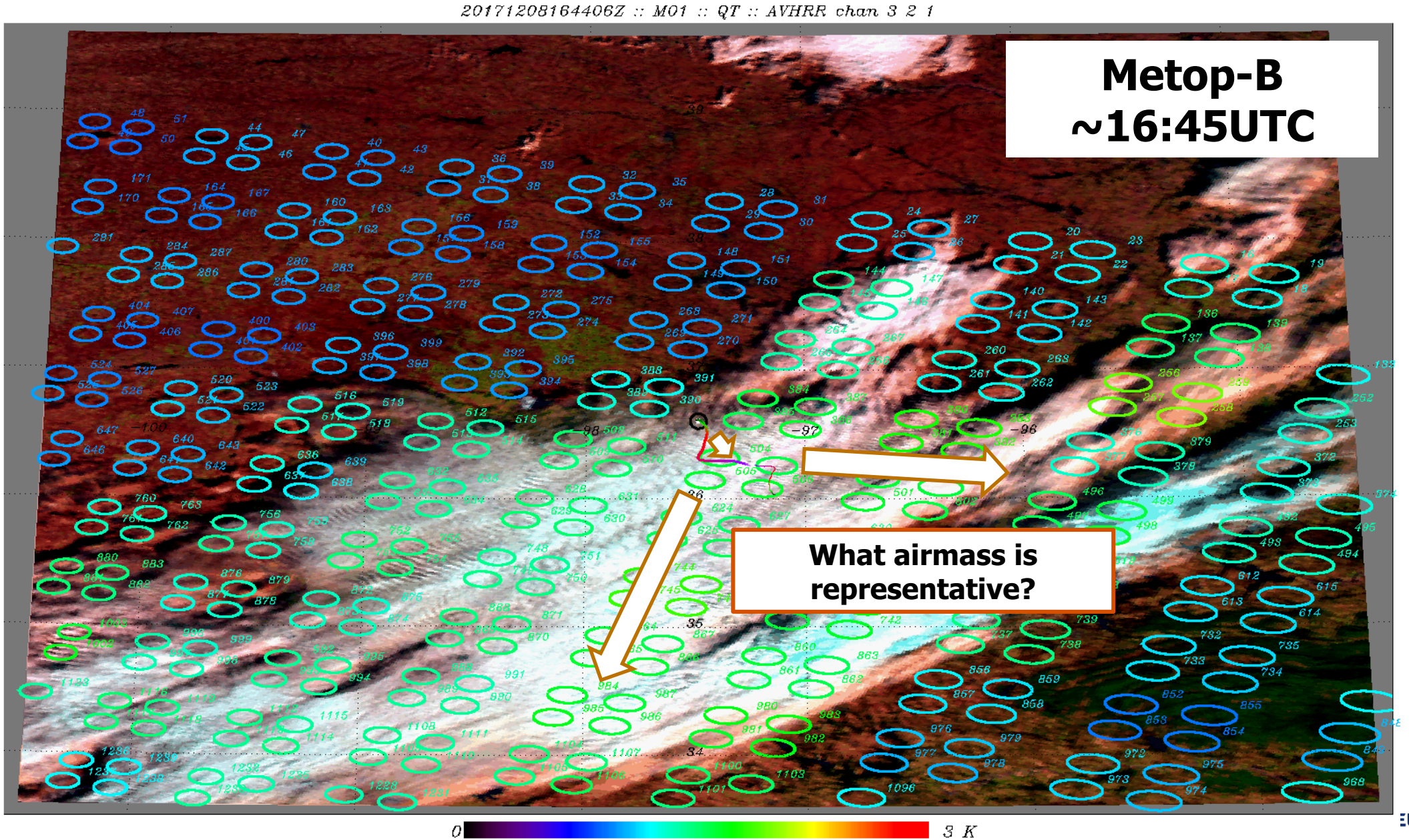
Performance assessment in the lower troposphere

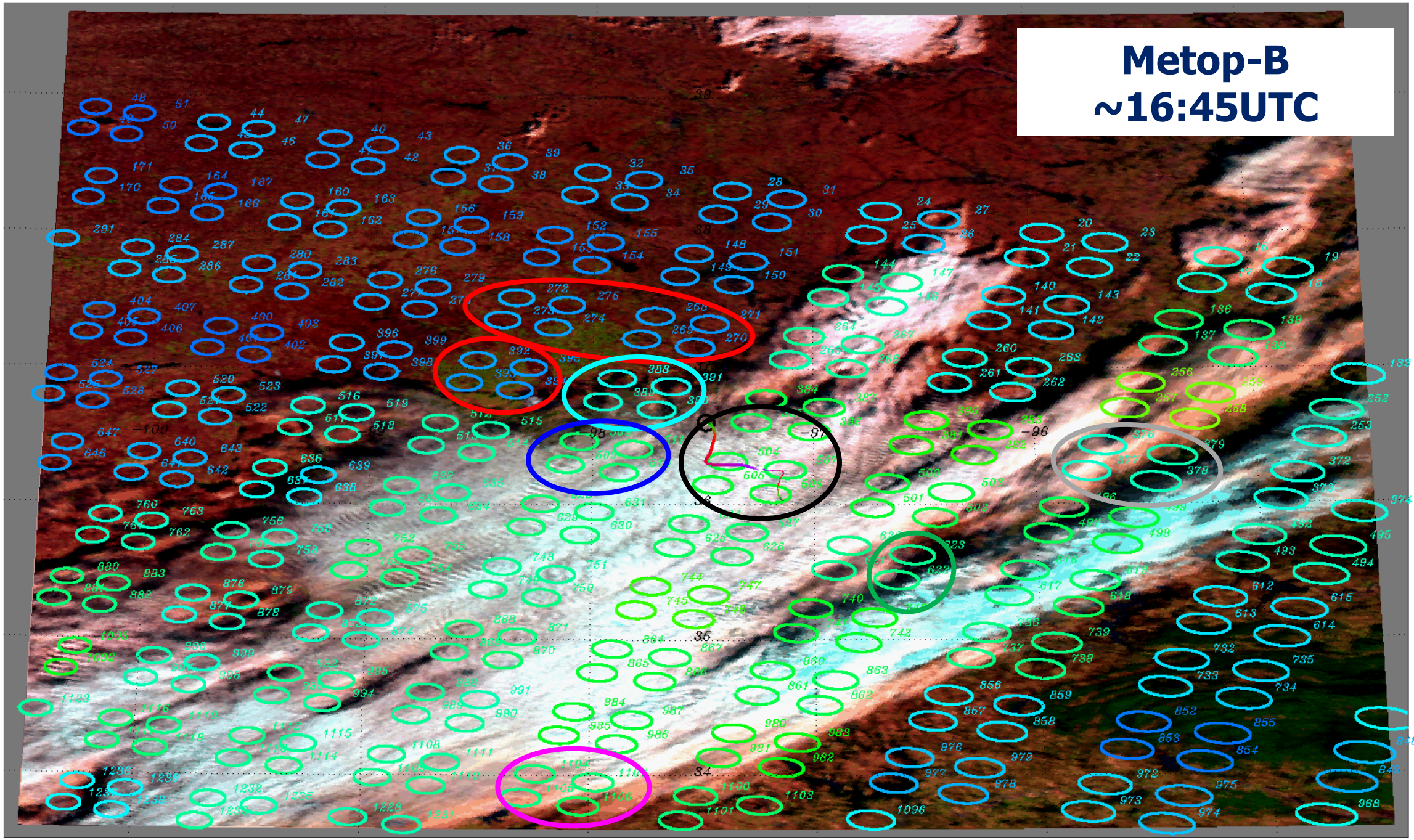


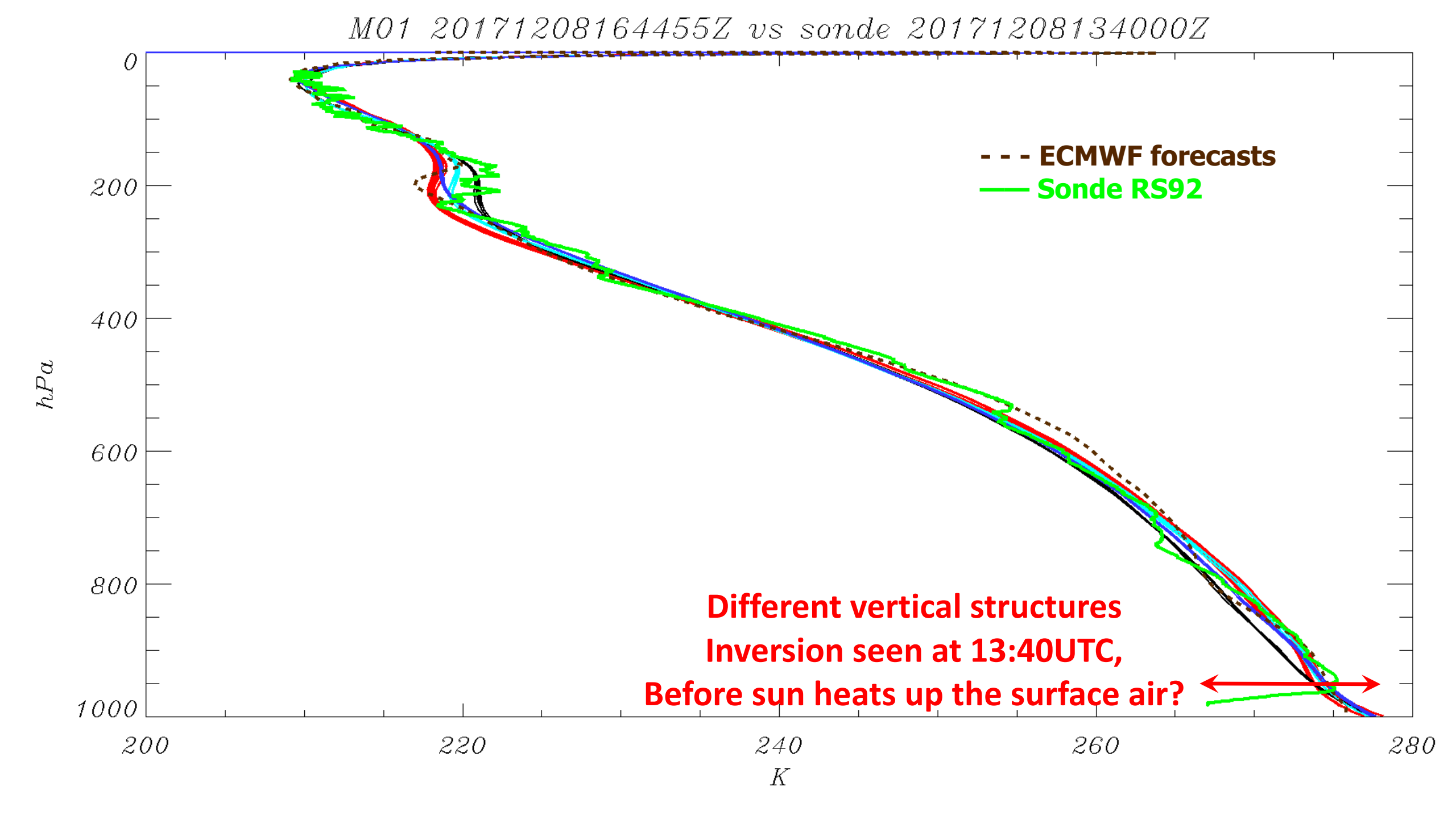

CFH – Wind speed :: 20171208
Atmospheric pressure [hPa]
0
200
400
600
800
1000
0
10
20
30
40
50
wind speed [m.s^{-1}]

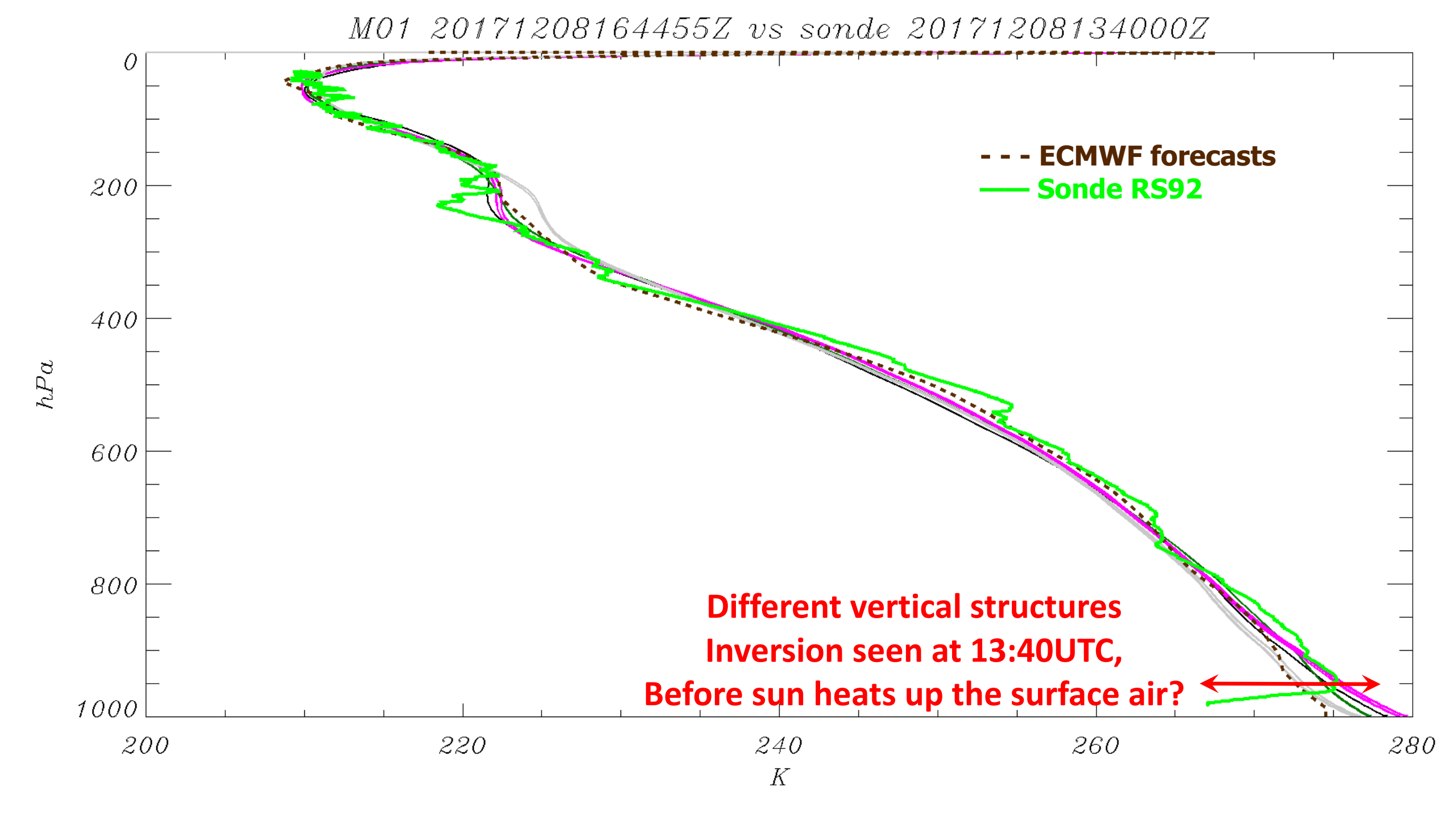

CFH – Wind direction :: 20171208
Atmospheric pressure [hPa]
0
200
400
600
800
1000
−200
−100
0
100
200
wind direction [degrees]

Performance assessment in the lower troposphere

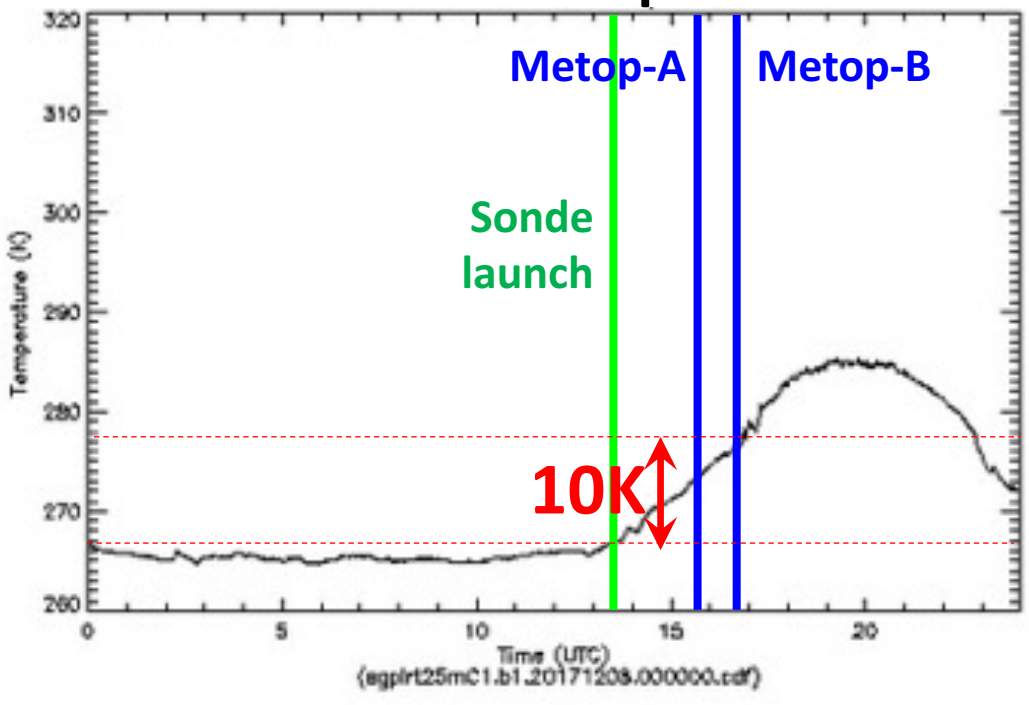



201712081644O6Z :: M01 :: QT :: AVHRR chan 3 2 1
Metop-B
~16:45UTC
0
3 K

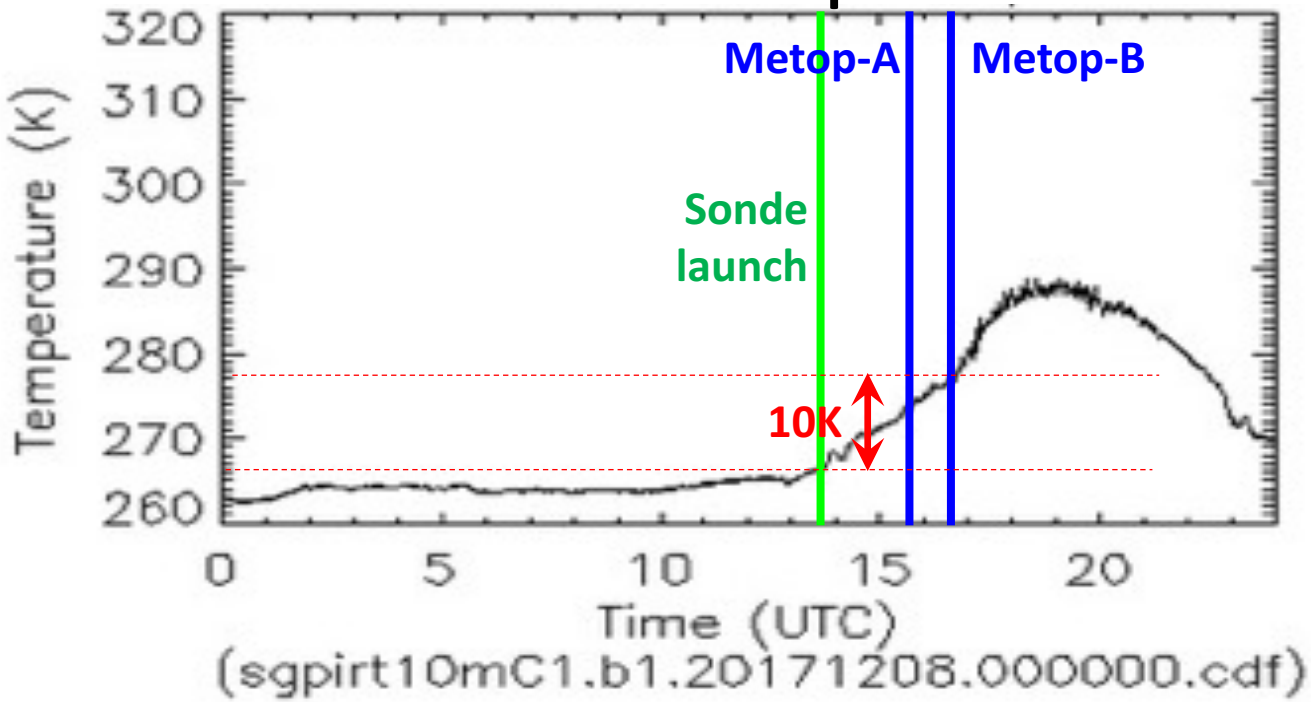

M01 20171208164455Z vs sonde 20171208134000Z
0
200
400
600
800
1000
hPa
200
220
240
260
280
K
- - - ECMWF forecasts
—— Sonde RS92
Different vertical structures
Inversion seen at 13:40UTC,
Before sun heats up the surface air?

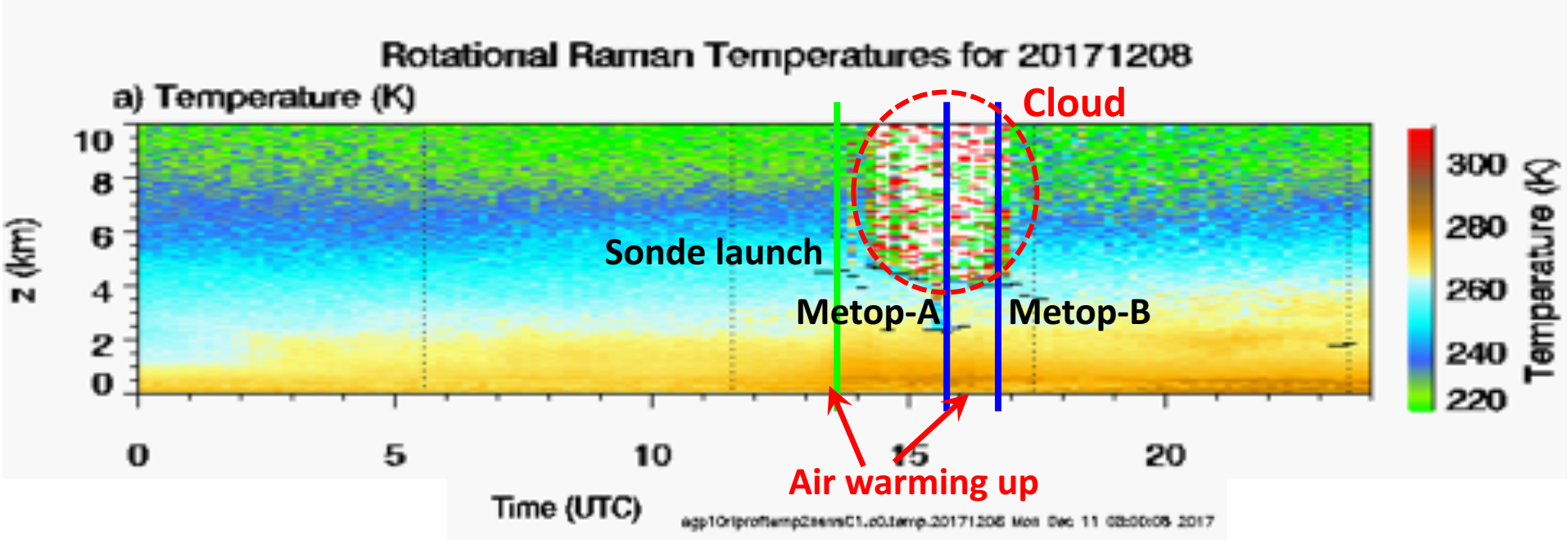

M01 20171208164455Z vs sonde 20171208134000Z
0
200
400
600
800
1000
hPa
200
220
240
260
280
K
- - - ECMWF forecasts
Sonde RS92
Different vertical structures
Inversion seen at 13:40UTC,
Before sun heats up the surface air?

10m air temperature

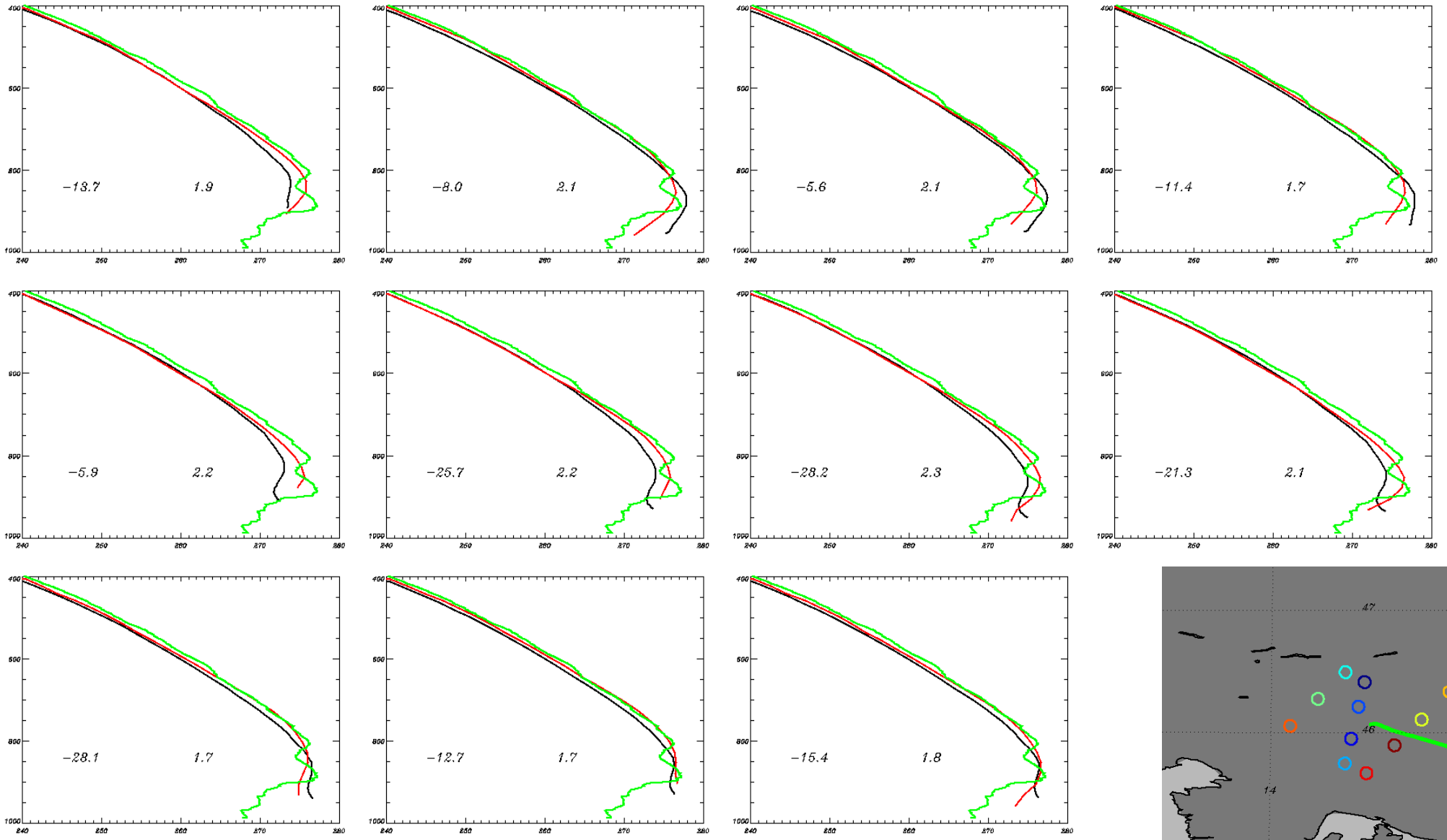


25m air temperature



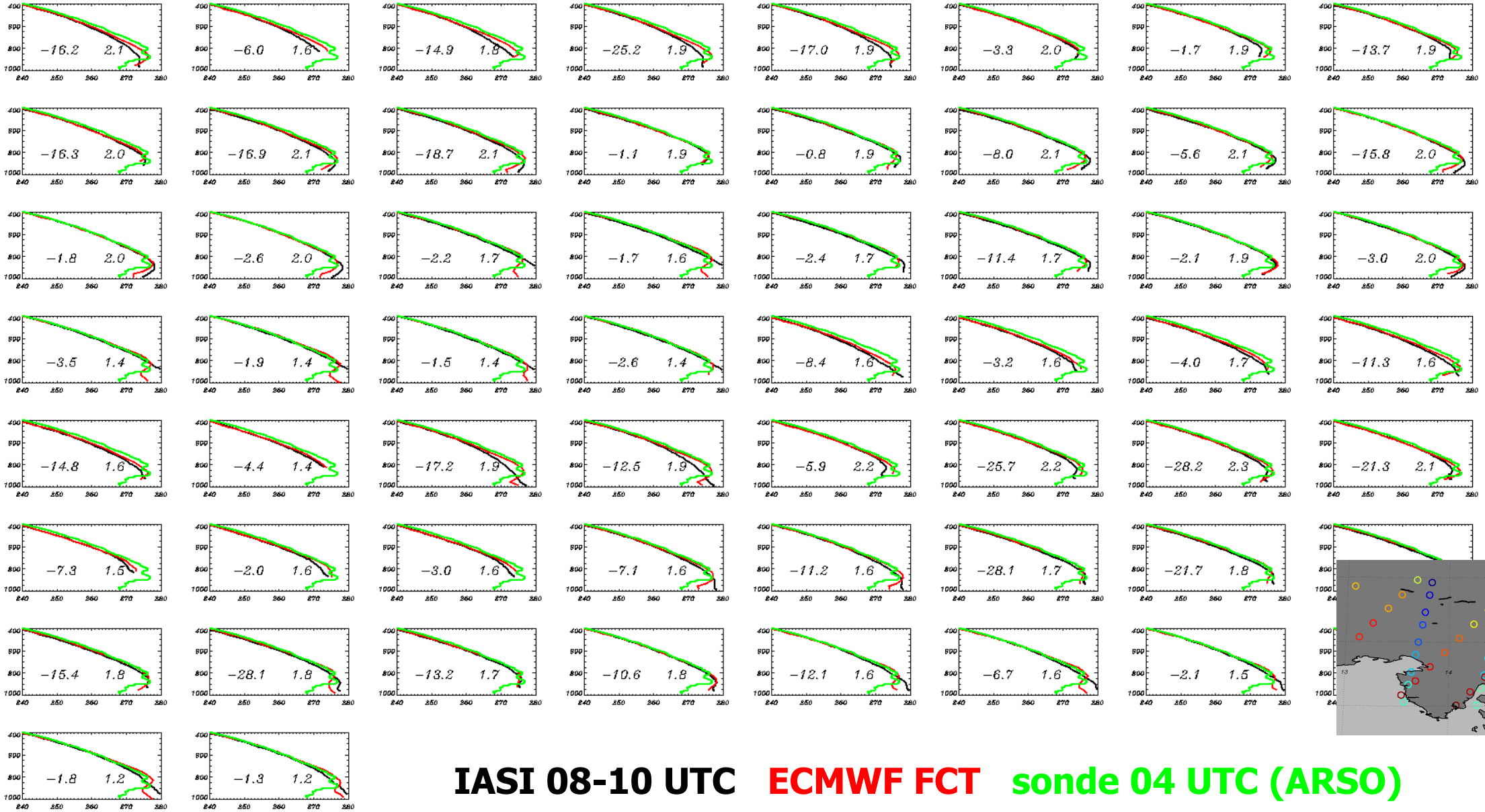


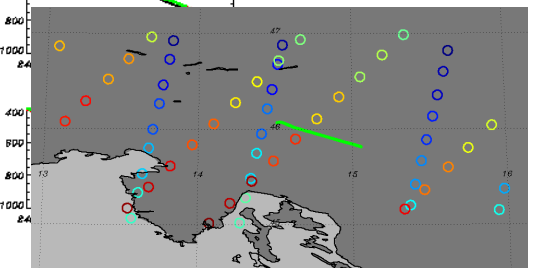
Surface elevated inversion – Ljubljana 20180216



- IASI 08-10 UTC
- ECMWF FCT
- sonde 04 UTC (ARSO)

Surface elevated inversion – Ljubljana 20180216





IASI 08-10 UTC **ECMWF FCT** **sonde 04 UTC (ARSO)**

EUMETSAT

Summary

Prototyping started

- ✓ PWLR^3 in nominal configuration works
- ✓ 1’ / full dwell with non-optimised code

Consolidated the validation of IASI IR-only

- ✓ Good quality and coverage
- ✓ Meaningful quality indicators (uncertainty estimate)

Interactions with users

- ✓ Case and systematic studies of using HSIR L2 ongoing
- ✓ Signs of added-value with existing products, but… to be further assessed

ATBD includes OEM with NWP forecasts as prior

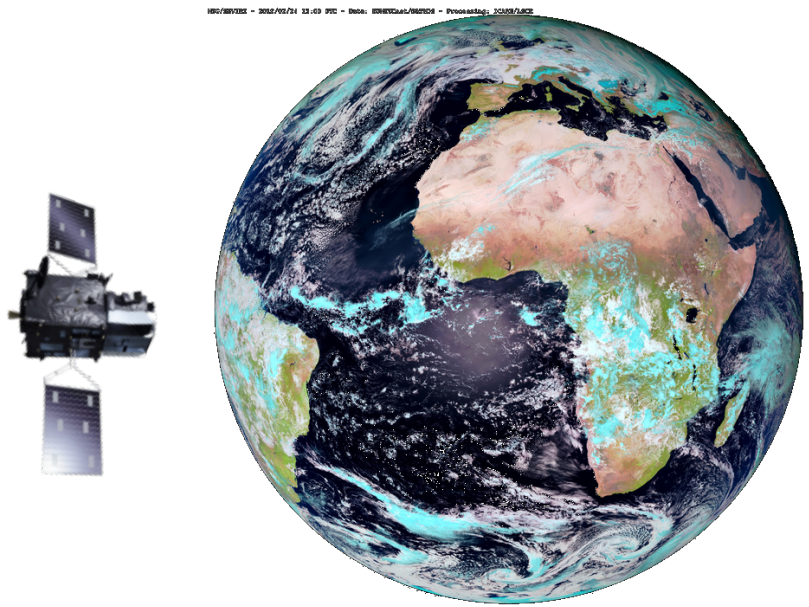
- ✓ NWP prior works with IASI algorithm heritage (rec’d rads, channel selection)
- ✓ Error characterisation with PWLR^3 studied already ➔ IASI Conference 2016

➔ Operational processor procurement can start

Next steps

- **Release specifications for ground-segment procurement**
- **Assess further potential/practical aspects of L2 products in particular for nowcasting, in close collaboration with the Users**
  - Other reference data/methodology to validate the products in low troposphere
  - More case studies and systematic investigations, using IASI L2 in IR-only mode
  - ESSL: storm database + testbed experiment
  - MAG members invited to contribute with assessment and relevant cases

    reminder: EARS-IASI L2 regional service, L2 products within 15-30'
- **User Requirements**
  - Products definition: what quantities? include instability indices? …
  - Required precision, vertical sampling/resolution
  - Auxiliary: inversions, differences *vs* NWP, quality indices, error estimates
  - FCT dependency…



Thank you !

Questions ?

Spare

PWLR: Vertical resolution, uncertainty estimate

Retrieval noise + **Smoothing error**

$$S_n = G S_y G^T \qquad S_s = (I - A) C_x (I - A)^T$$

where

$G = d\tilde{x} / dy$ **is the gain matrix**

$A = GK = (d\tilde{x} / dy)(dy / dx) = d\tilde{x} / dx$ ***aka*** **Averaging Kernels (AK)**

It is often heard that AK can only be derived from an OEM, with the well-known equations from Rodgers, 2000. It is less known that they can in fact be computed for statistical retrievals as well. In particular, in the case of a regression:

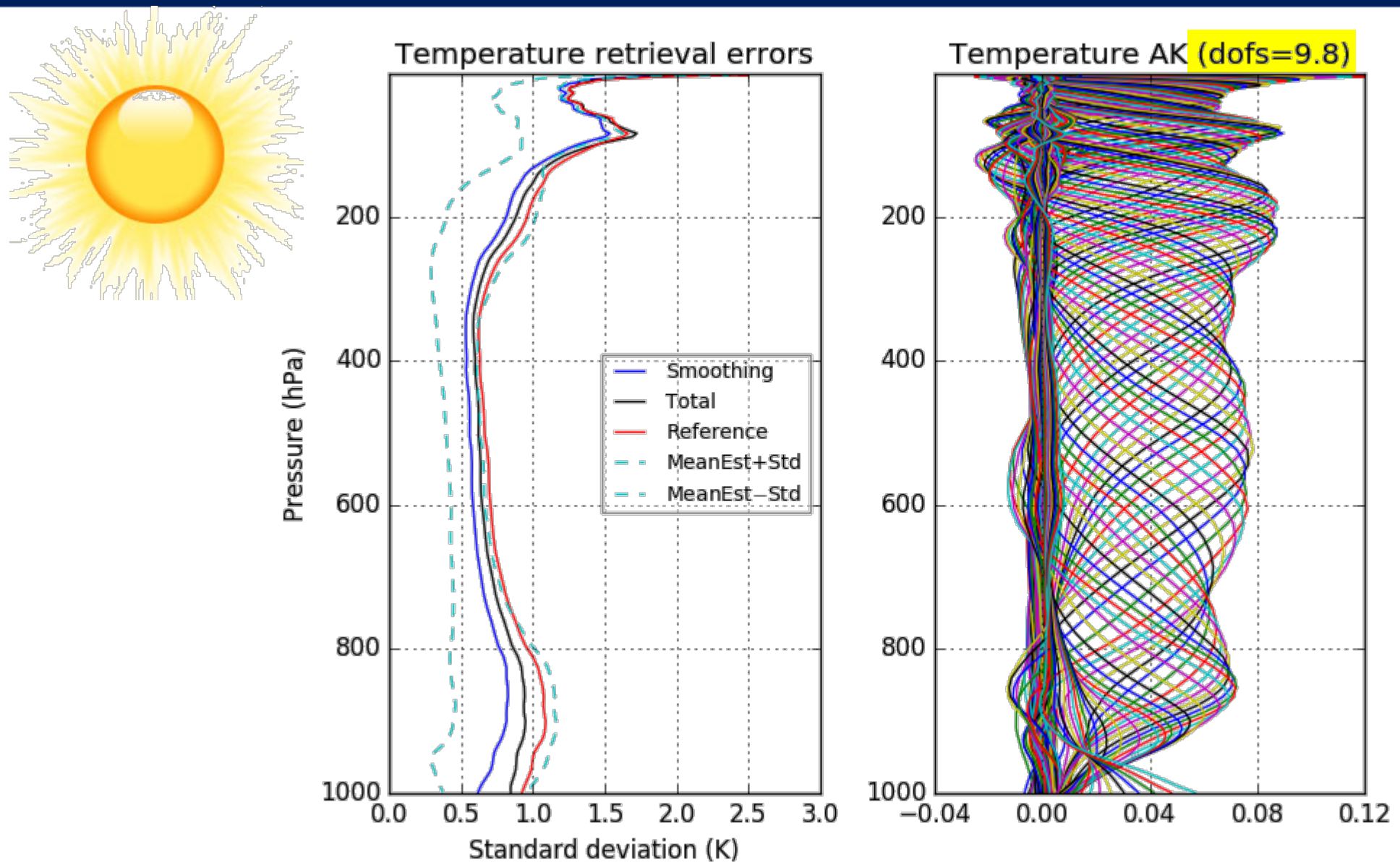
$$x \approx \bar{x} + G(y - \bar{y})$$

The gain matrix G is actually the regression coefficients from measurements to state

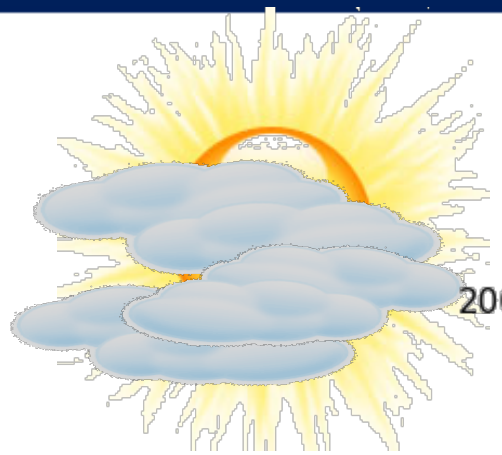
$$y \approx \bar{y} + K(x - \bar{x})$$

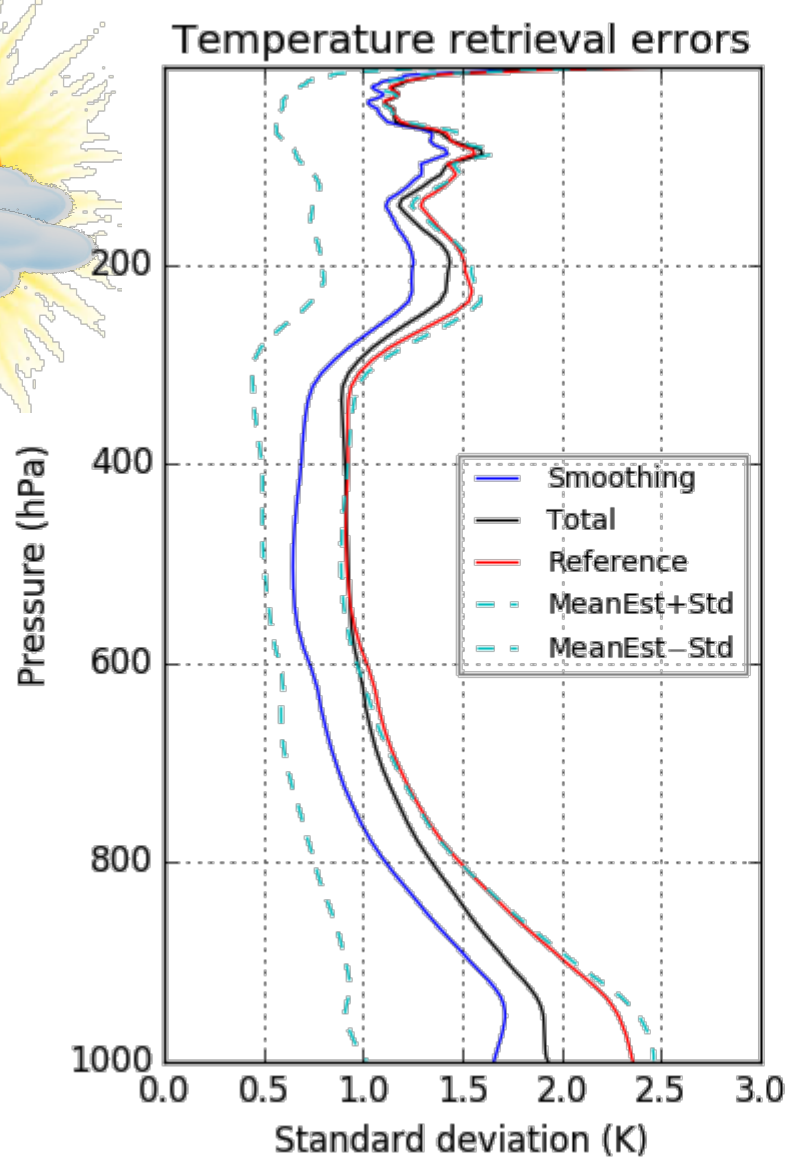
The Jacobians K could in theory be computed with an RTM. But it is time-consuming and is problematic in cloudy pixels. They can alternatively be derived by regression from the training set.

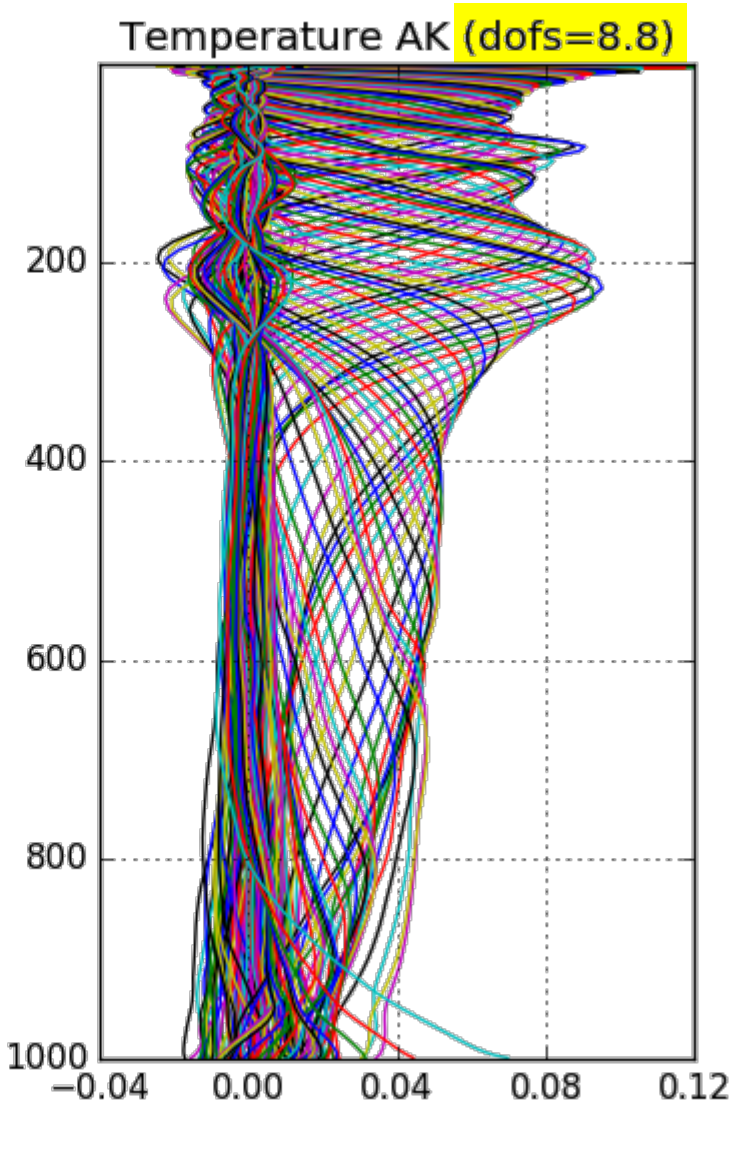
PWLR AK :: Temperature (clear) 137 levels



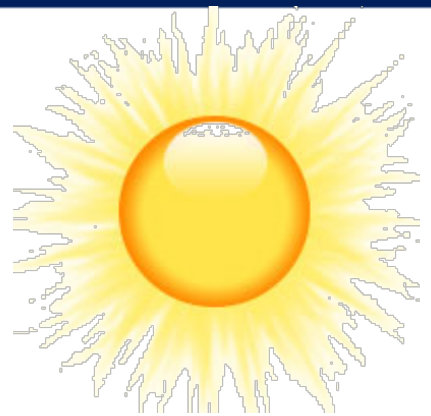
PWLR AK :: Temperature (cloudy) 137 levels

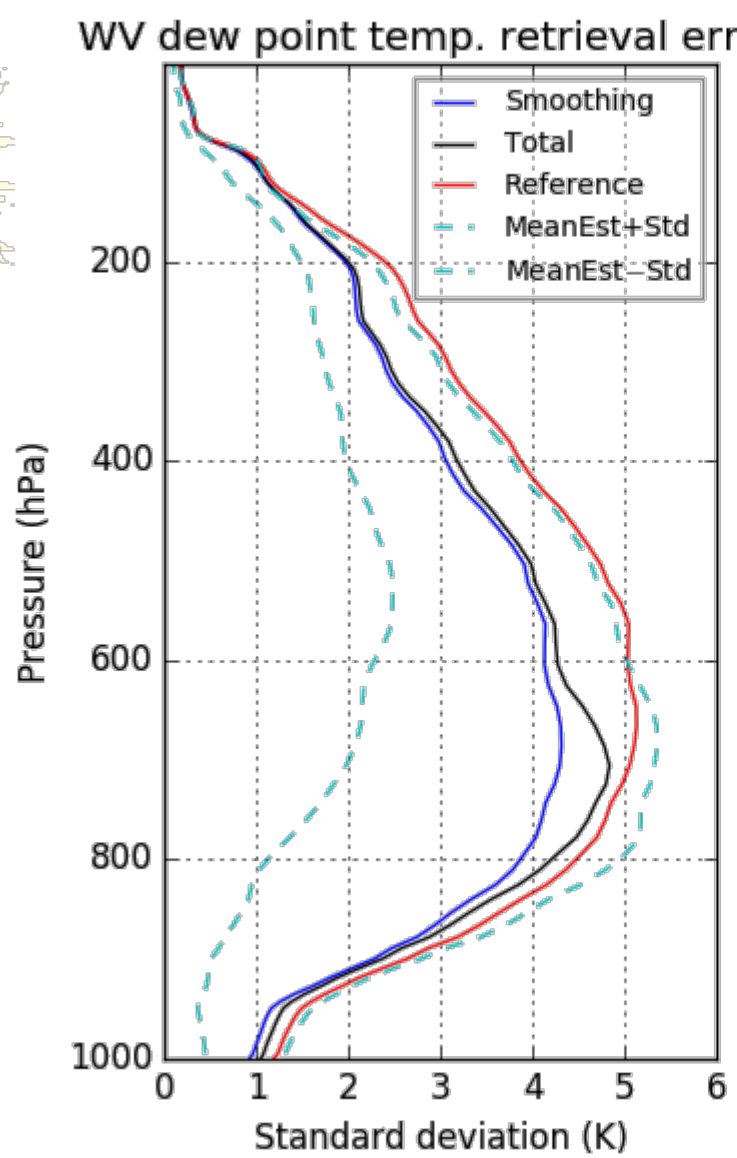


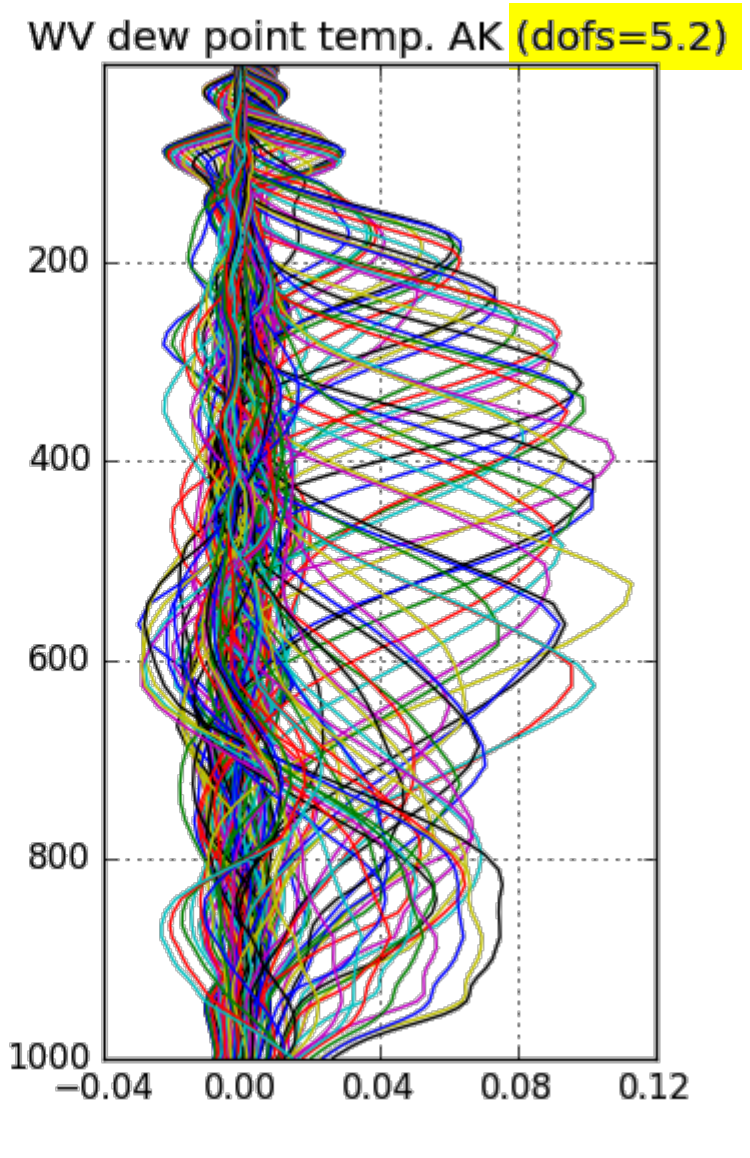




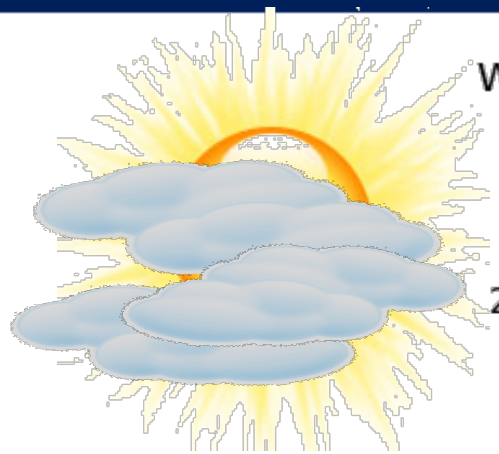
PWLR AK :: Water-Vapour (clear) 137 levels

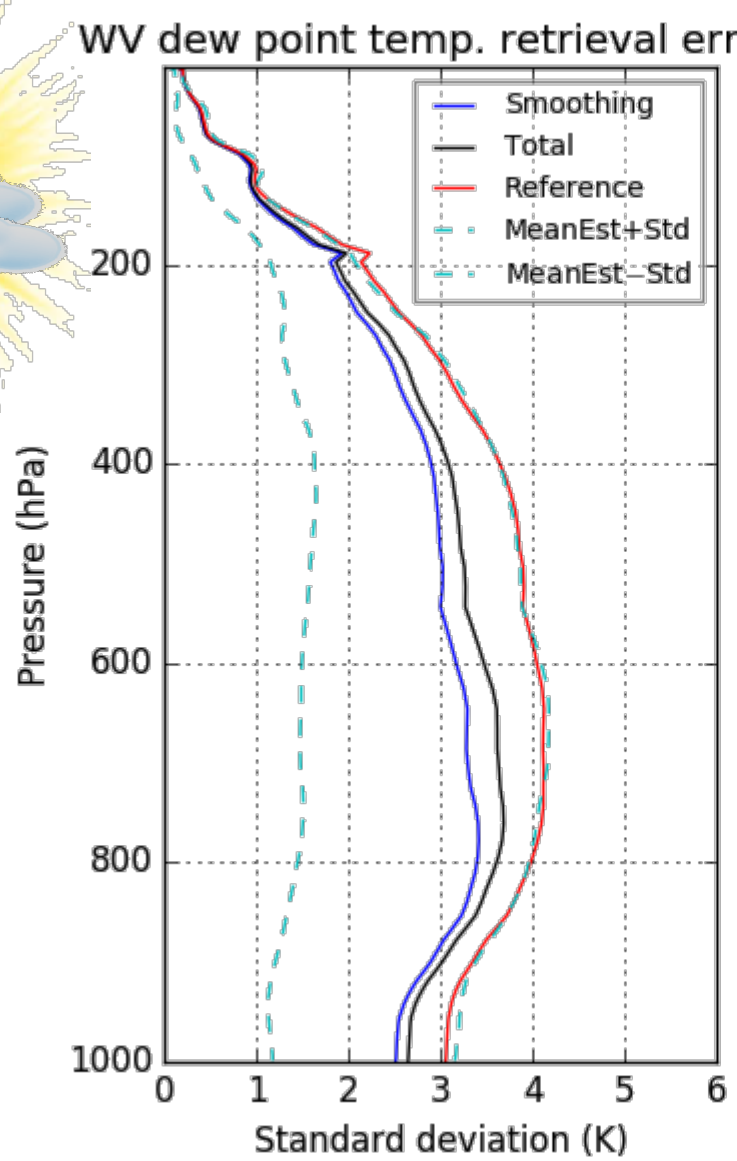


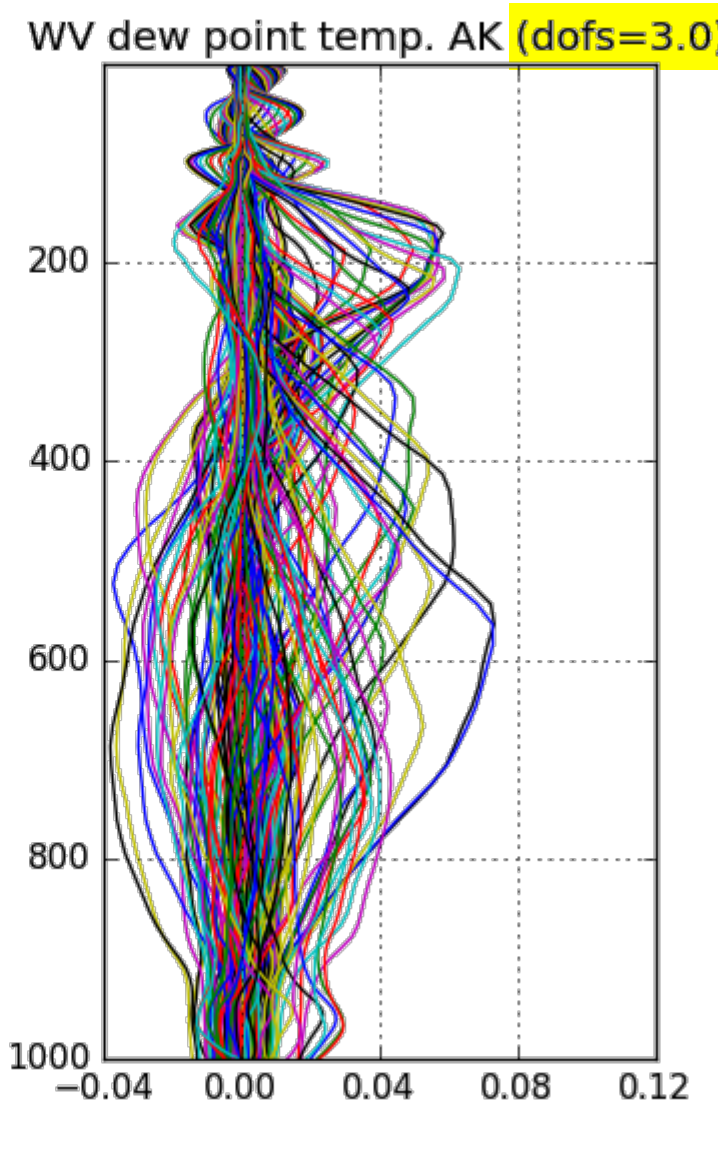




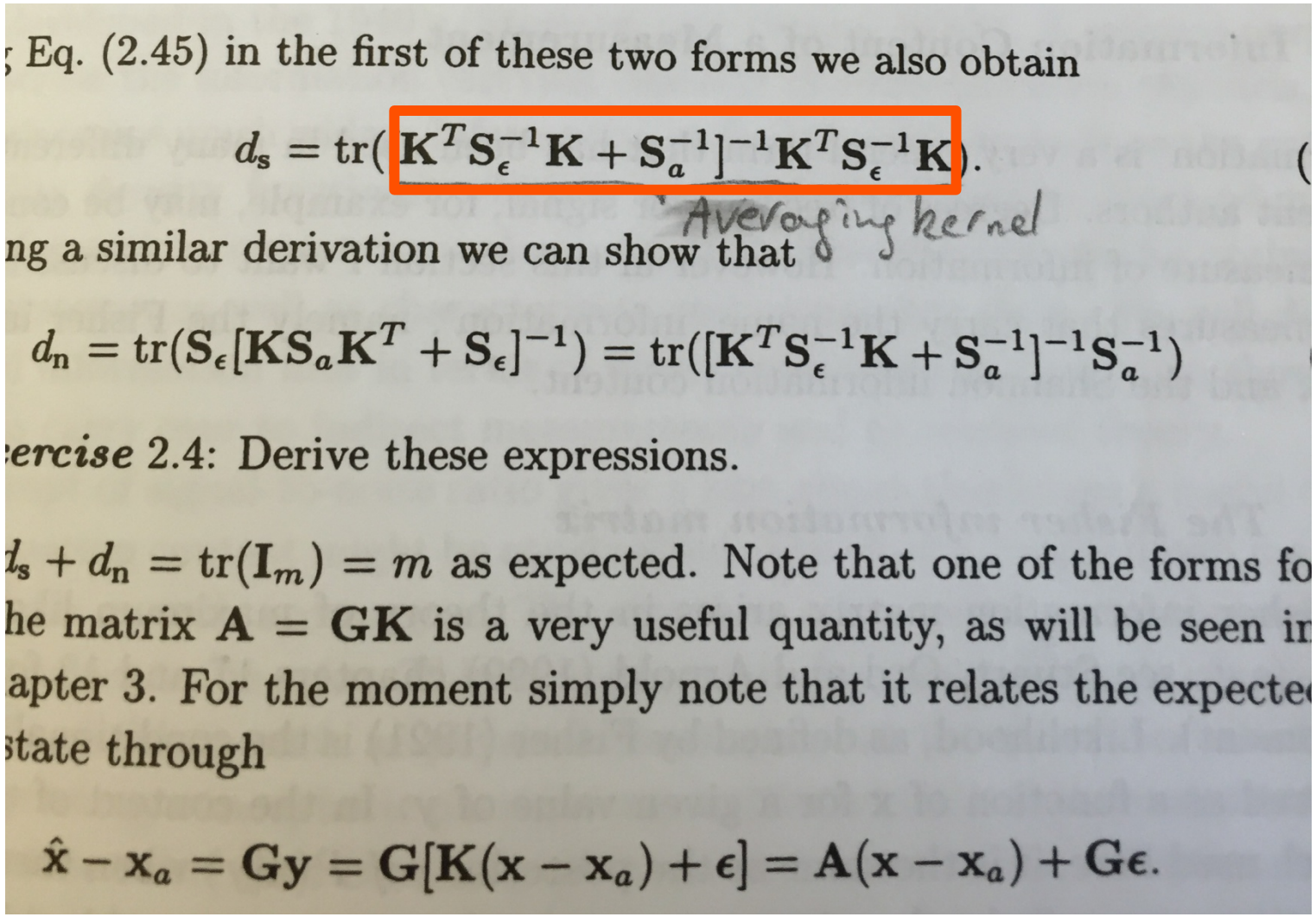
PWLR AK :: Water-Vapour (cloudy) 137 levels







2. Two words on the information content



Eq. (2.45) in the first of these two forms we also obtain

$$d_s = \mathrm{tr}(\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K} + \mathbf{S}_a^{-1}]^{-1}\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K}).$$

Averaging kernel

ng a similar derivation we can show that

$$d_n = \mathrm{tr}(\mathbf{S}_\epsilon[\mathbf{K}\mathbf{S}_a\mathbf{K}^T + \mathbf{S}_\epsilon]^{-1}) = \mathrm{tr}([\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K} + \mathbf{S}_a^{-1}]^{-1}\mathbf{S}_a^{-1})$$

ercise 2.4: Derive these expressions.

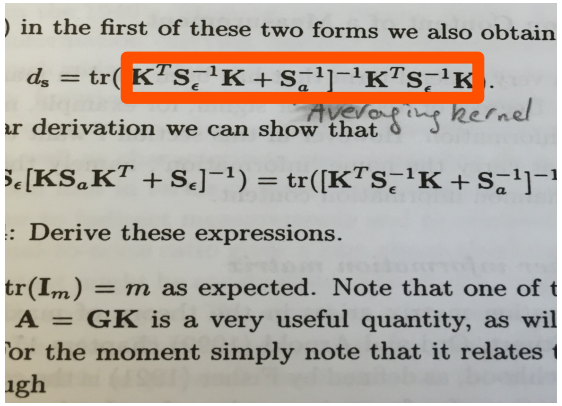
$d_s + d_n = \mathrm{tr}(\mathbf{I}_m) = m$ as expected. Note that one of the forms fo
he matrix $\mathbf{A} = \mathbf{GK}$ is a very useful quantity, as will be seen in
apter 3. For the moment simply note that it relates the expecte
state through

$$\hat{\mathbf{x}} - \mathbf{x}_a = \mathbf{G}\mathbf{y} = \mathbf{G}[\mathbf{K}(\mathbf{x} - \mathbf{x}_a) + \epsilon] = \mathbf{A}(\mathbf{x} - \mathbf{x}_a) + \mathbf{G}\epsilon.$$

C. Rodgers, 2000

Averaging Kernel with OEM(PWLR^3) - Temperature

A^{OEM} computed after Rodgers, 2000


) in the first of these two forms we also obtain

$d_s = \mathrm{tr}([\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K} + \mathbf{S}_a^{-1}]^{-1}\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K})$.

Averaging kernel

ır derivation we can show that

$\mathbf{S}_\epsilon[\mathbf{K}\mathbf{S}_a\mathbf{K}^T + \mathbf{S}_\epsilon]^{-1}) = \mathrm{tr}([\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K} + \mathbf{S}_a^{-1}]^{-1}$

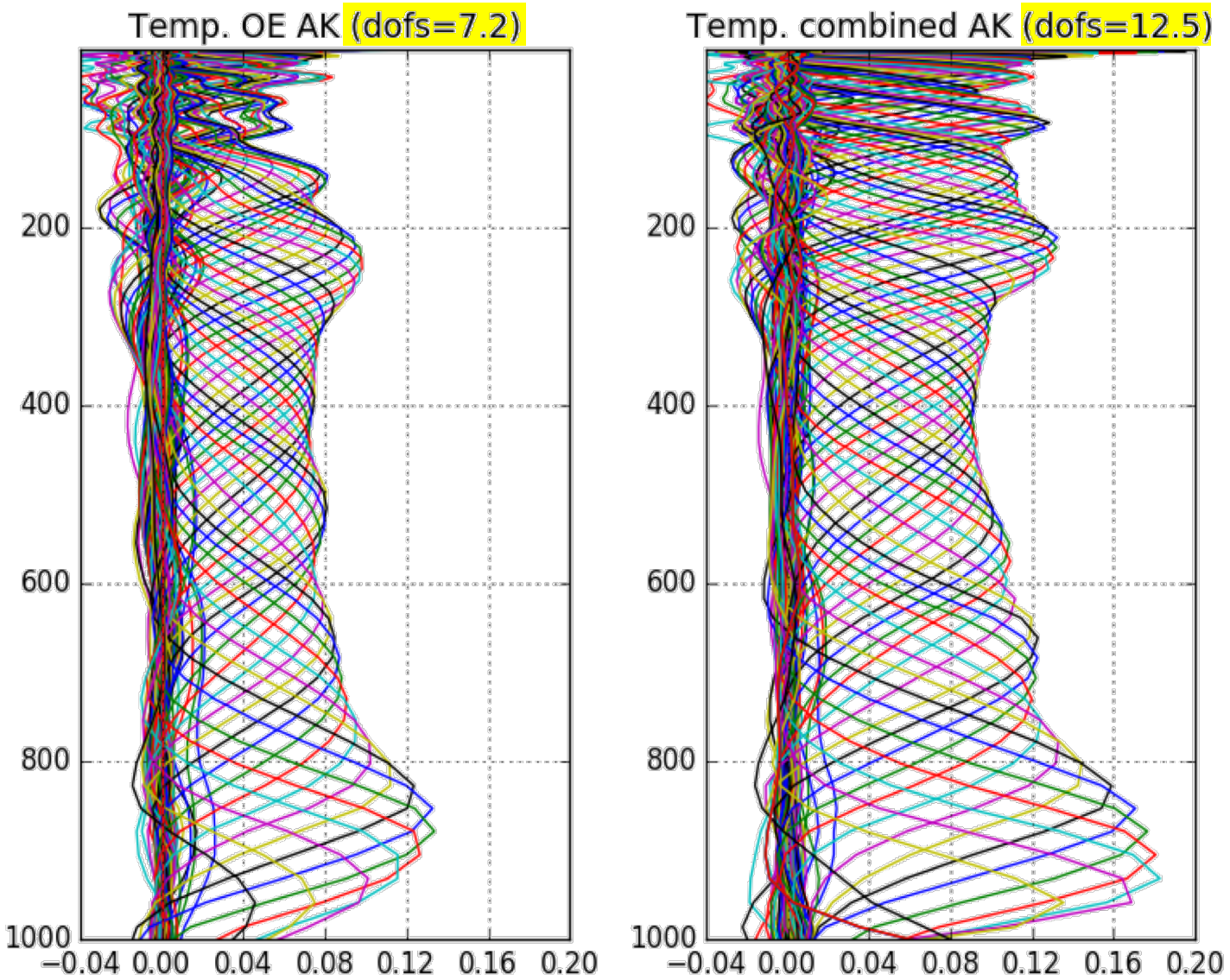
: Derive these expressions.

$\mathrm{tr}(\mathbf{I}_m) = m$ as expected. Note that one of t

$\mathbf{A} = \mathbf{GK}$ is a very useful quantity, as wil

or the moment simply note that it relates

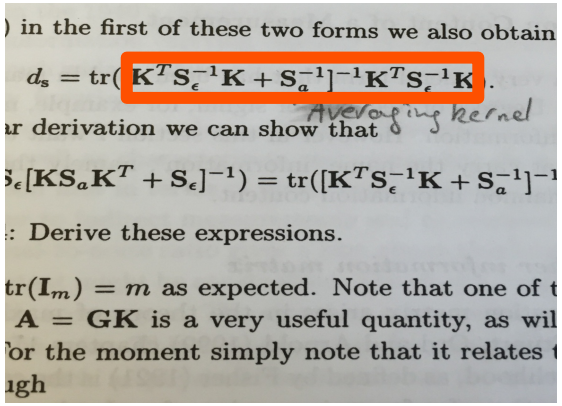
ugh



A^{TOTAL} = A^{OEM} + $(I-A^{OEM})\,A^{PWLR}$

Averaging Kernel with OEM(PWLR^3) - Humidity

A^{OEM} computed after Rodgers, 2000


) in the first of these two forms we also obtain

$d_s = \mathrm{tr}([\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K} + \mathbf{S}_a^{-1}]^{-1}\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K})$.

Averaging kernel

ır derivation we can show that

$\mathbf{S}_\epsilon[\mathbf{K}\mathbf{S}_a\mathbf{K}^T + \mathbf{S}_\epsilon]^{-1}) = \mathrm{tr}([\mathbf{K}^T\mathbf{S}_\epsilon^{-1}\mathbf{K} + \mathbf{S}_a^{-1}]^{-1}$

: Derive these expressions.

$\mathrm{tr}(\mathbf{I}_m) = m$ as expected. Note that one of t

$\mathbf{A} = \mathbf{GK}$ is a very useful quantity, as wil

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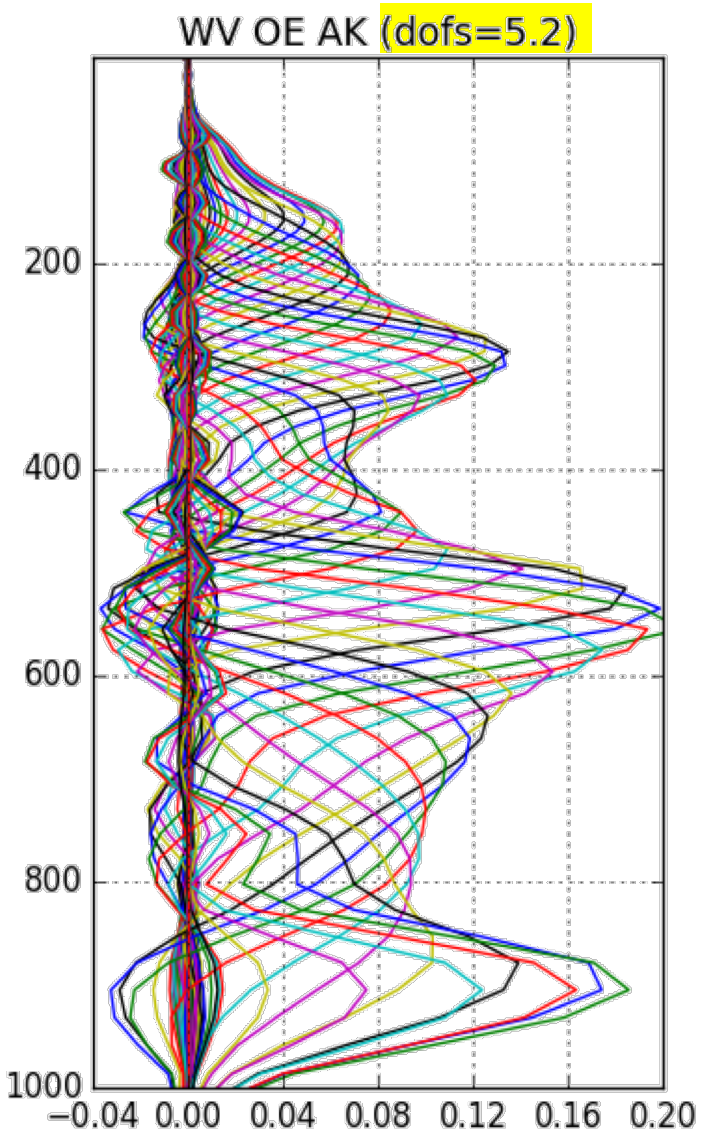
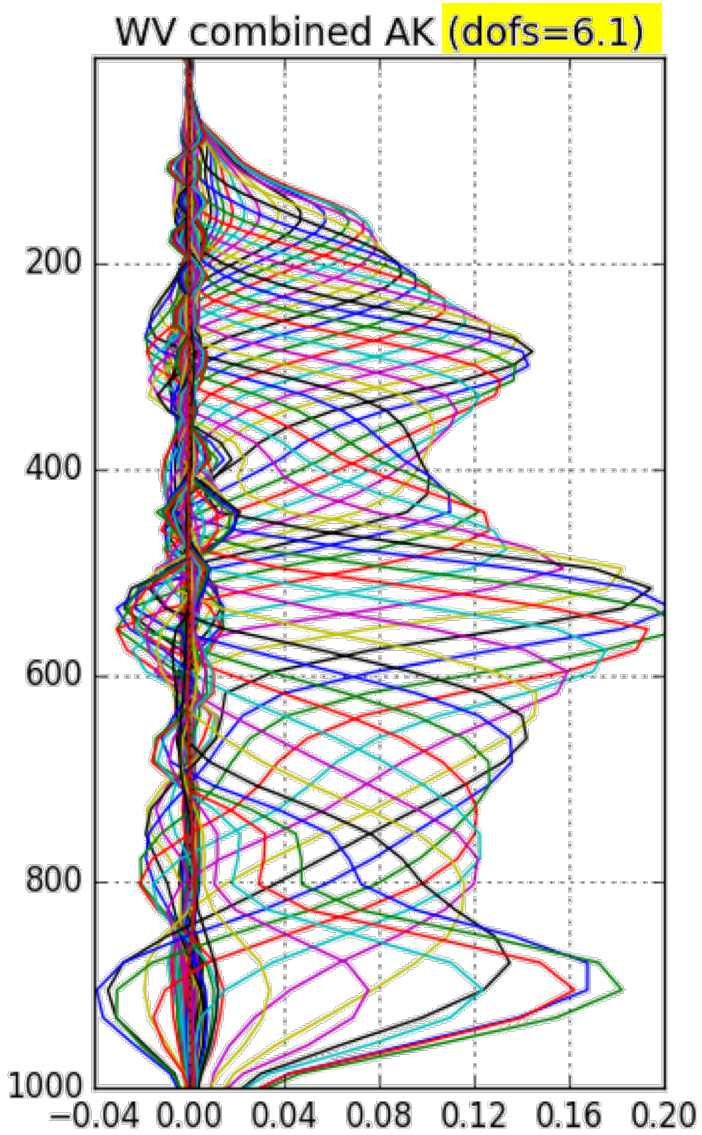
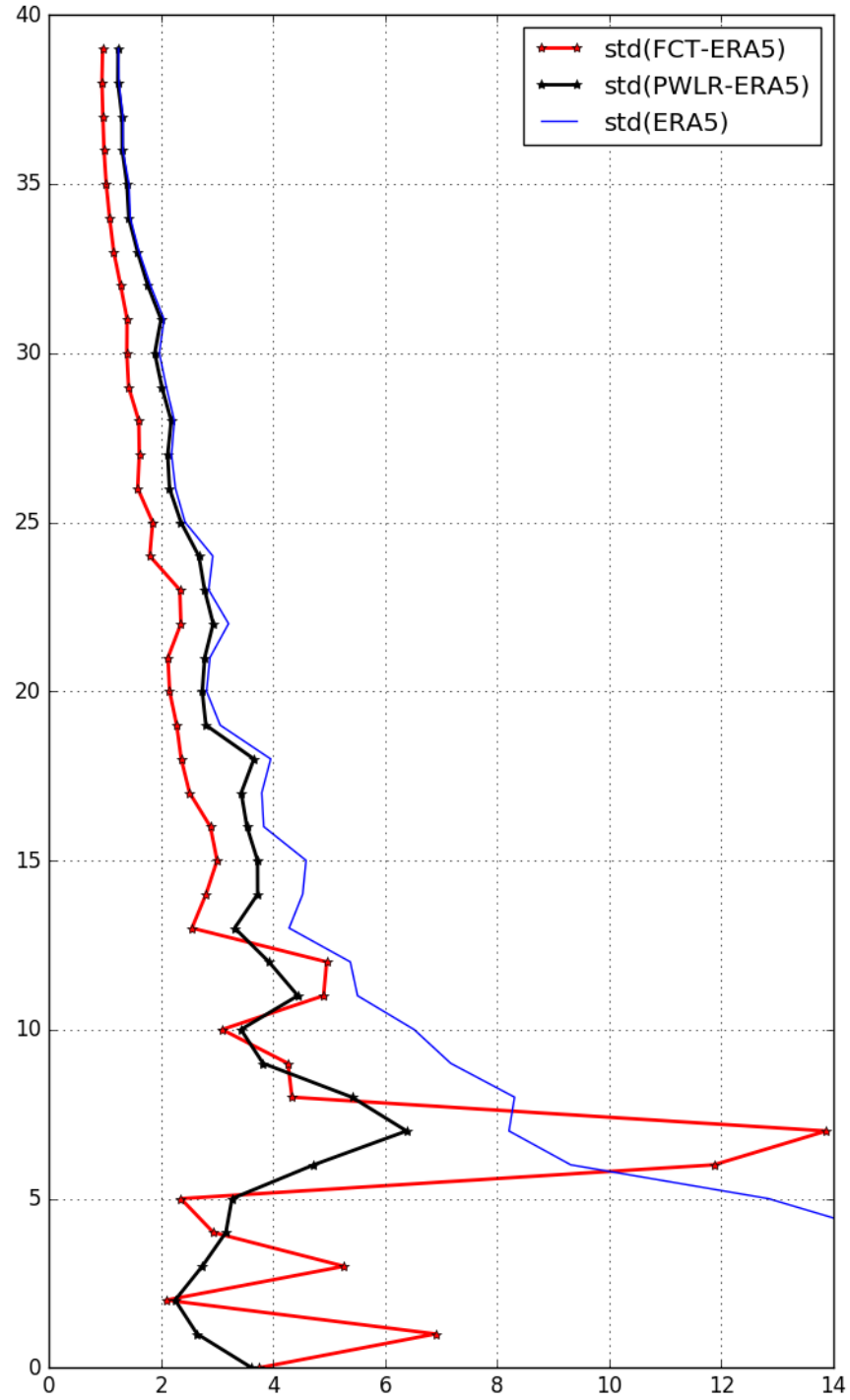


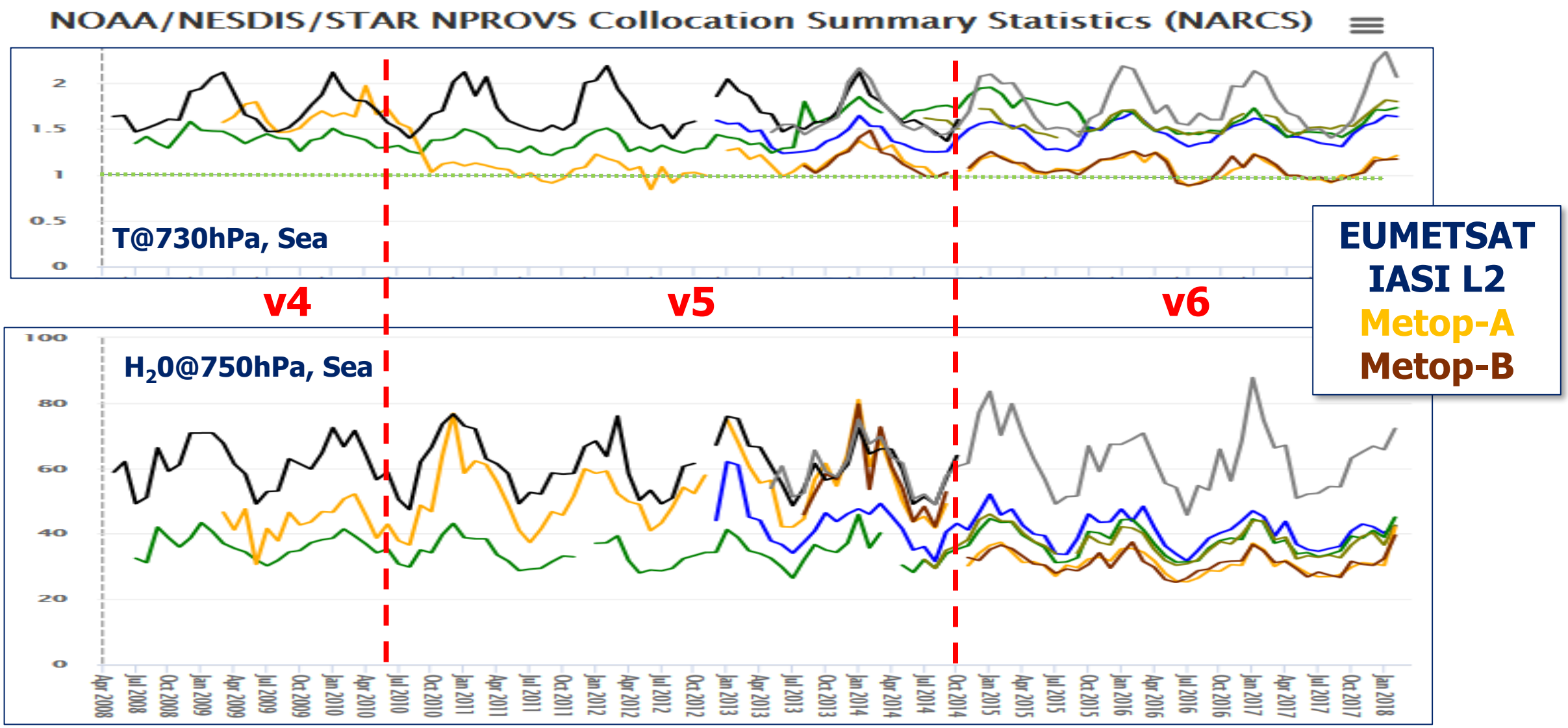


A^{TOTAL} = A^{OEM} + $(I\text{-}A^{OEM})\,A^{PWLR}$

Vertical structures



A brief history of IASI L2 algorithms evolutions



https://www.star.nesdis.noaa.gov/smcd/opdb/nprovs/

Credits: B. Sun, T. Reale (NOAA)