

Satellite Data Assimilation at ECMWF

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ECMWF

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Numerical Weather Prediction (NWP) is essential to state of the art weather forecasts.

NWP is gaining **one day in skill** for early warning of weather events **every 10 years**.

NWP is an **initial state problem**. An accurate and balanced initial state needs **Accurate, Complete** and **Global** observations and sophisticated data assimilation systems. **The largest impact comes from satellite data.**

Though its impact in NWP via Data Assimilation (as well as in other ways) **satellite data is critically important to our everyday lives as well as the social and economic health of our countries.**



ECMWF – organisation

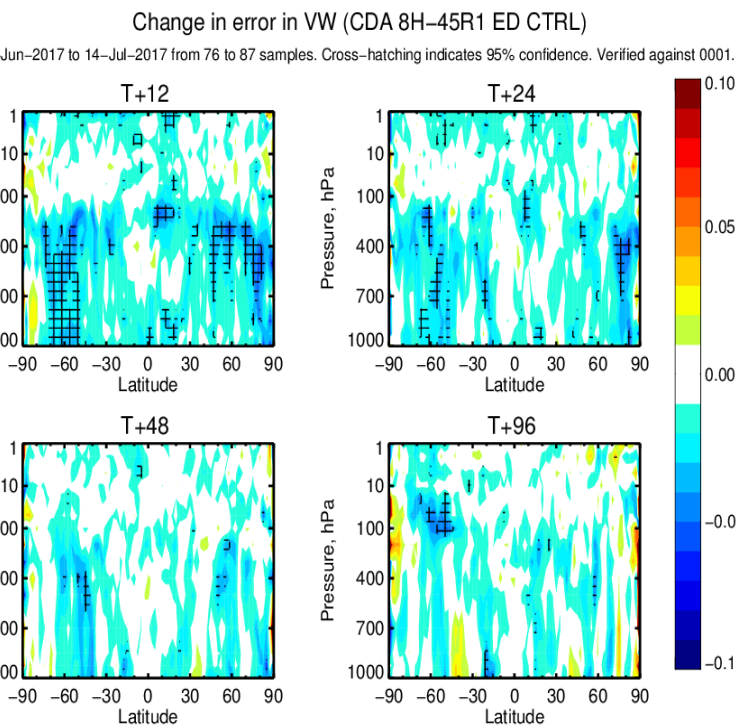
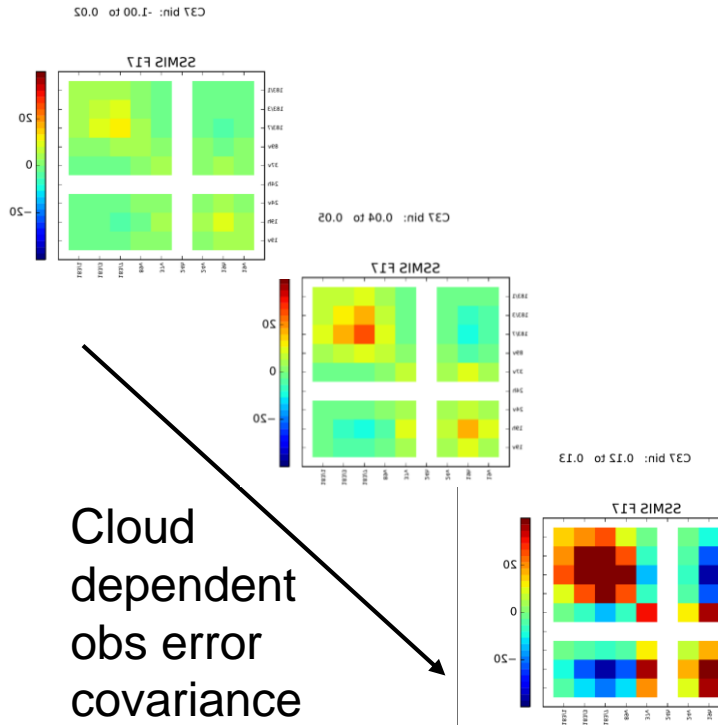
- Established in 1975
- 350 staff from more than 30 countries.
- One of the six members of the Co-ordinated Organisations (other five = NATO, CoE, ESA, OECD and EUMETSAT).
- Based in Reading, United Kingdom.

ECMWF – NWP system

- 50 Ensemble members, with ~18 km resolution plus high resolution member ~ 9km.
- Ensemble forecasts re-centred on high resolution run.
- Spectral model (1279 modes). Spectral transform to cubic octahedral grid for physics, orography
- 4D-Var data assimilation (see next slide)
- ECMWF also as a “product generation suite” to generate specific products for users
 - Deliver of basic NWP products to Member States
 - Derived products from ensemble e.g. Extreme Forecast Index – probability of extreme events with respect to model climatology
 - Met data products for Space Agencies
- Goal: 5 km ensemble, earth system based approach, coupled systems (DA and model)

Data assimilation – more details

- 4D-Var incremental formulation
- Wavelet B (Fisher and Andersson 2001) based on 25 (soon 50) member ensemble of 4D-Vars (Bonavita *et al.* 2012) at half resolution with perturbed observations and perturbed physics.
- DA “inner loop” done three (soon four) times to handle non-linearity: important for “all-sky” observations.



Cloud dependent obs error covariance

Benefit of “late” observations

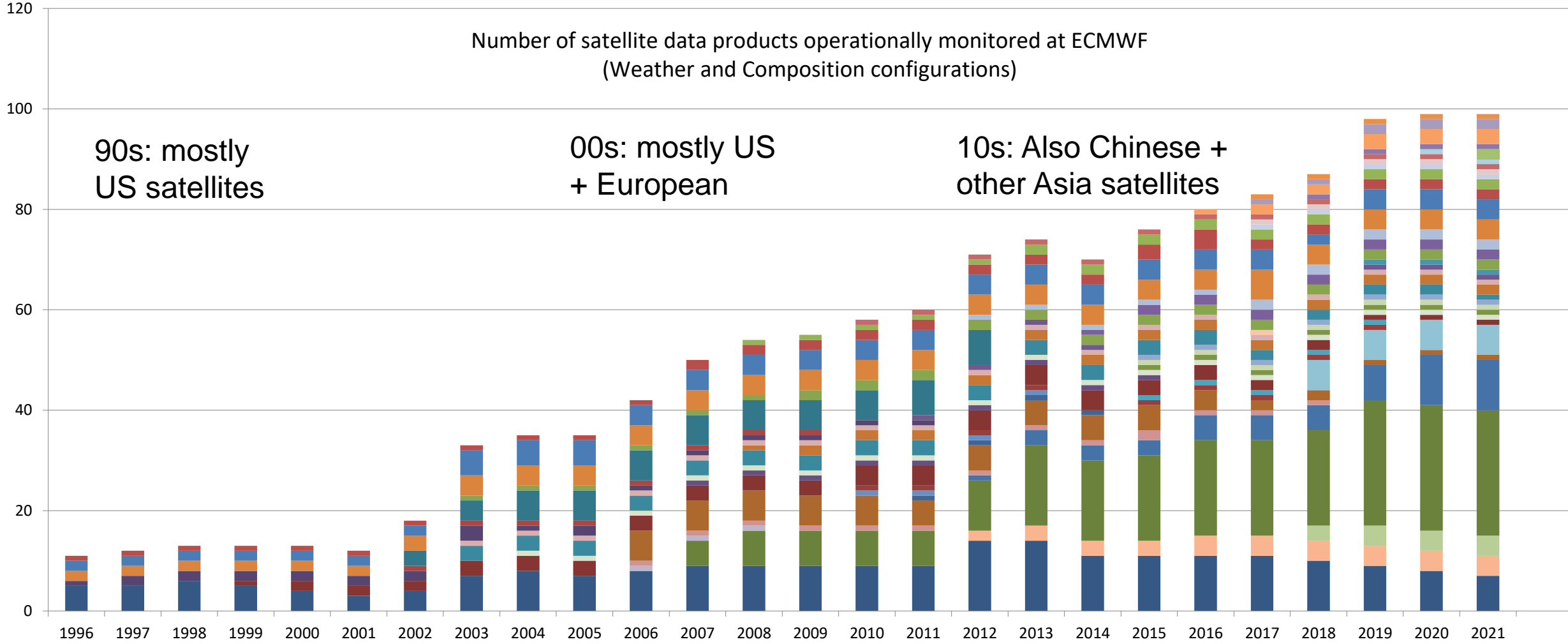
Benefit of 4 outer loops

Number of satellite data products operationally monitored at ECMWF (Weather and Composition configurations)

90s: mostly
US satellites

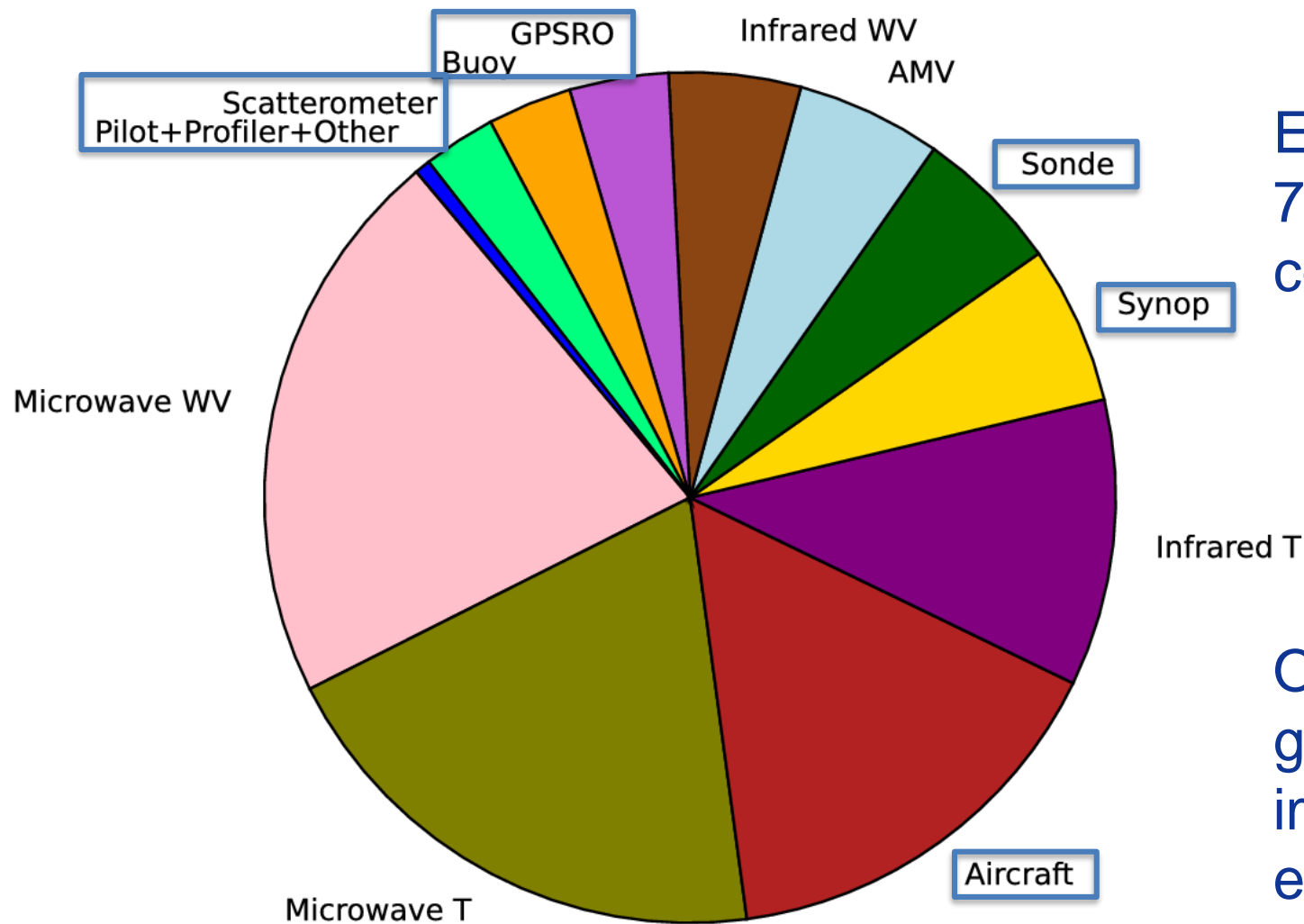
00s: mostly US
+ European

10s: Also Chinese +
other Asia satellites



- | | | | | | | | | |
|-----------------|-----------|--------------|-----------|------------|----------|------------|-------------|----------|
| POES | Suomi-NPP | JPSS | Metop | FY3 | CHAMP | GRACE | COSMIC | COSMIC-2 |
| CNOFS | SAC-C | TERRASAR-X | TANDEM-X | DMSP | TRMM | Windsat | GCOM-W/C | GPM |
| Megha Tropiques | AQUA | AURA | TERRA | ERS-1/2 | QuikSCAT | Oceansat | RapidSCAT | HY2 |
| ENVISAT | JASON | Saral/Altika | Cryosat | Meteosat | GOES | Himawari | FY2+4 | COMS1 |
| INSAT-3D | SMOS | SMAP | EarthCARE | ADM Aeolus | GOSAT | Sentinel 3 | Sentinel 5p | OCO-2 |

Weather observations: relative importance in ECMWF system

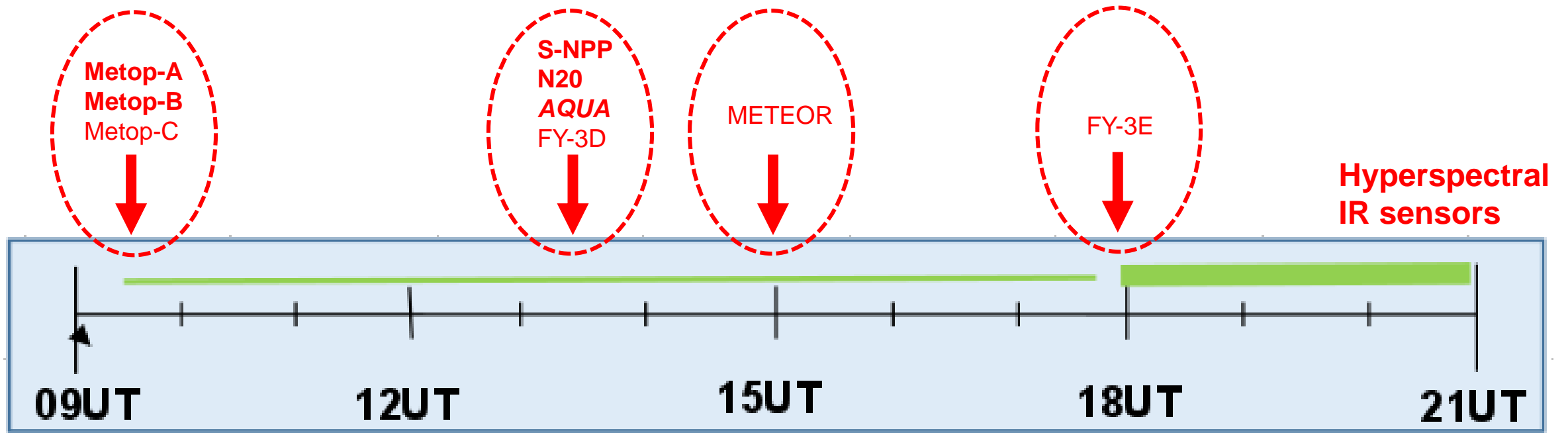


ECMWF FSOI February 2018:
70% of 24h forecast impact
comes from satellite data

Overall temperature obs give
greatest impact, but note how
important humidity obs are now
e.g. MWHS-2

FY-3E in Early Morning is very important to NWP centres and others

BOLD = ECMWF already have data; *Italics* = data available but end of life expected soon



09UT

12UT

15UT

18UT

21UT

MW sensors

↑
METOP-A
METOP-B
FY3C

↑
N20
GCOM
AQUA
FY3B
S-NPP
FY-3D

↑
N18
METEOR

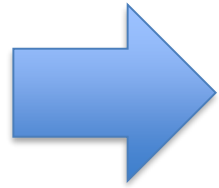
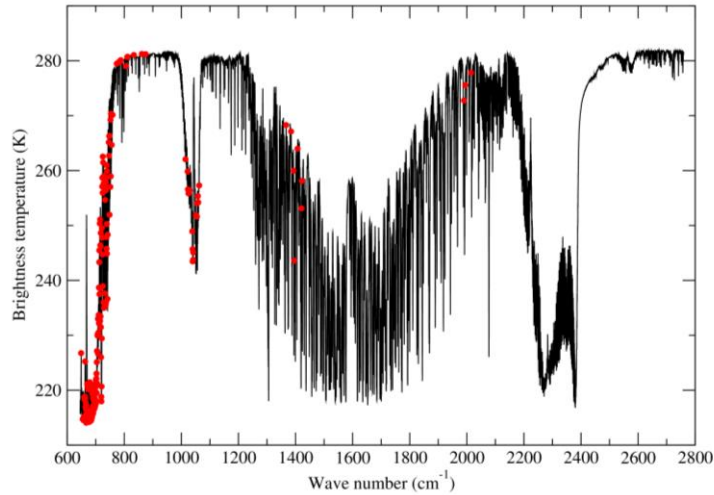
↑
N15
FY-3E
DMSP

← GPM and M-T →



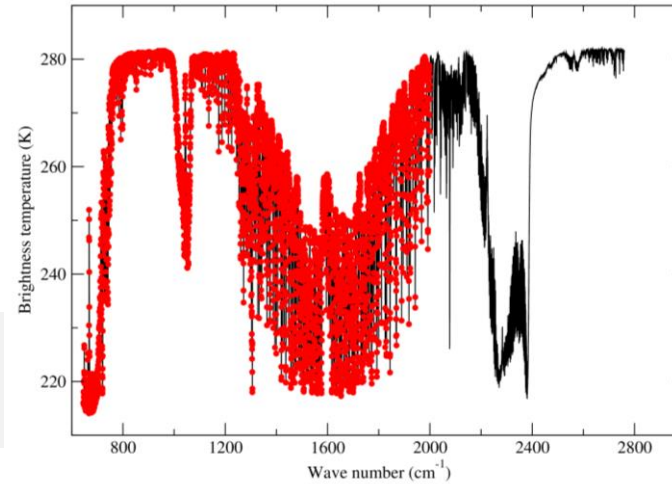
ECMWF is learning how to fully use hyperspectral IR

The 191 operational IASI channels



Assimilating 400 reconstructed radiances

Information of 5421 IASI channels

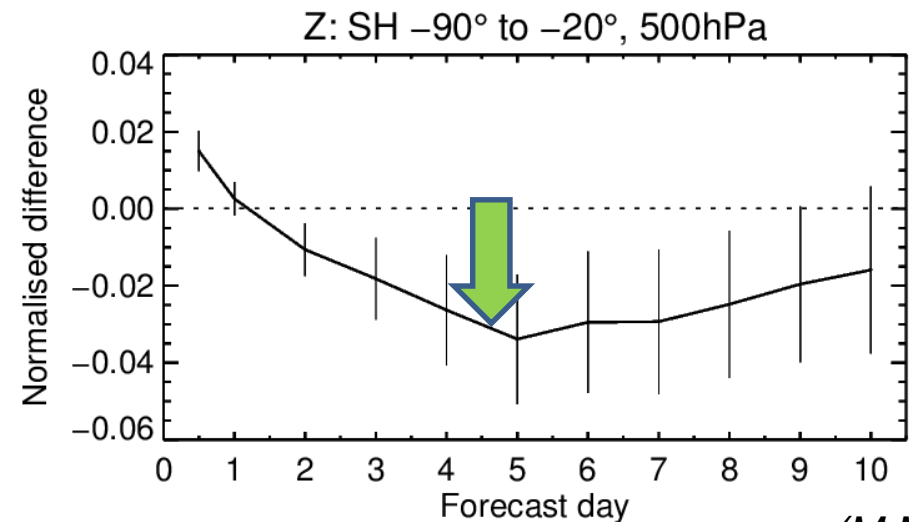
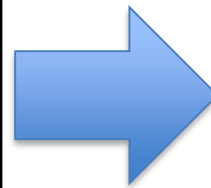


This is particularly important for **GIIRS** on **FY4** and **IRS** on **MTG**, but will also improve use of **HIRAS** on **FY3**, **IASI** on **Metop**, **CrIS** on **JPSS** and **IKFS2** on **Meteor**.

Improvement (compared to operational IASI radiance baseline assimilation) in SH forecasts of 500hPa geopotential height

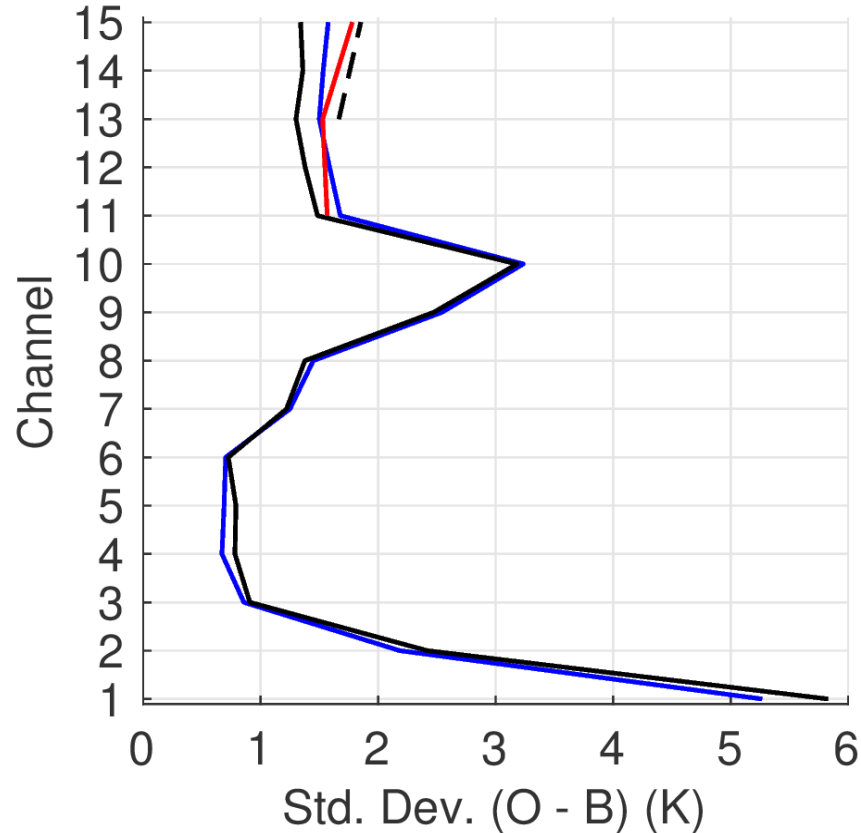
Assimilating the full IASI LW/MW spectrum via 400 reconstructed radiances:

Latest results show PCA-RR gives a very large increase in impact of IR radiances.



FY-3D and FY-3C data – quality is good, **FY-3C used operationally by ECMWF!**

StDev O – B after bias correction

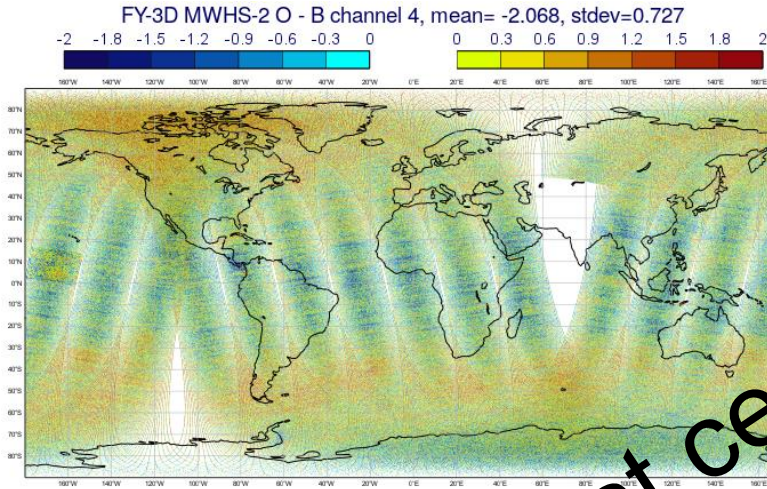


- FY-3D biases are similar to FY-3C MWHS-2.
- Standard deviation for FY-3D is similar to other state of the art instruments e.g. FY-3C MWHS-2 and MHS instruments.
- When the CMA commissioning ends and data is available in near real time ECMWF will begin extended monitoring and testing of FY-3D data and expect to begin operational use in 2019

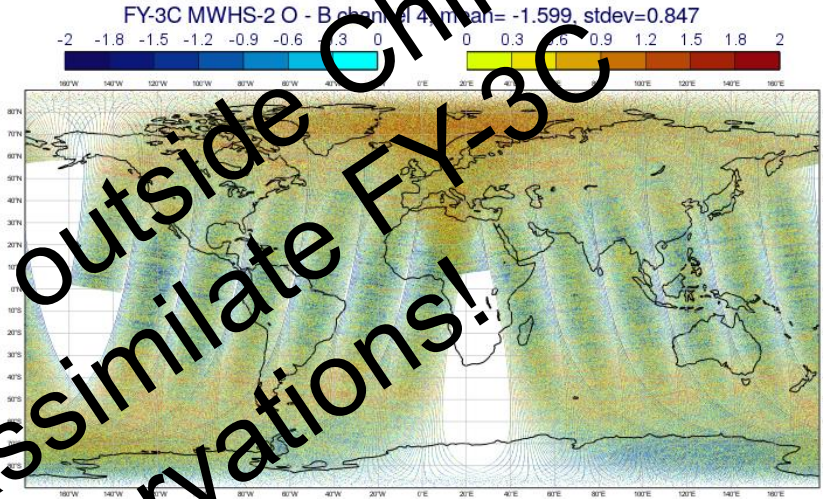
— fy3d mwhs2 — fy3c mwhs2 — metop-A mhs - - - noaa-19 mhs

World first by CMA NSMC! 118 GHz data in space. A remarkable achievement!

FY-3D MWHS-2

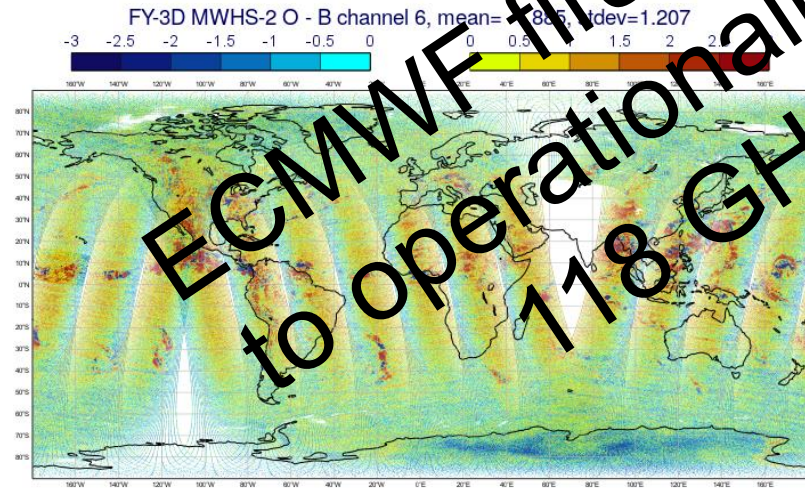


FY-3C MWHS-2

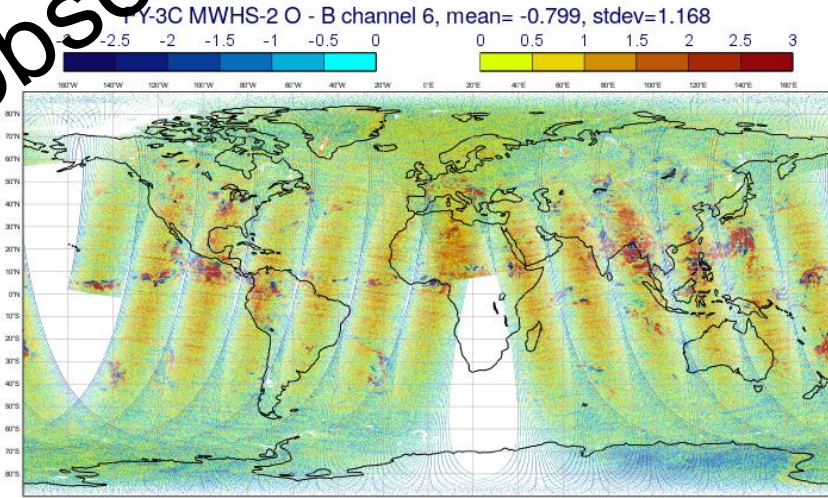


118.75 +/- 0.3

FY-3D MWHS-2 O - B channel 6, mean= -0.855, stdev=1.207



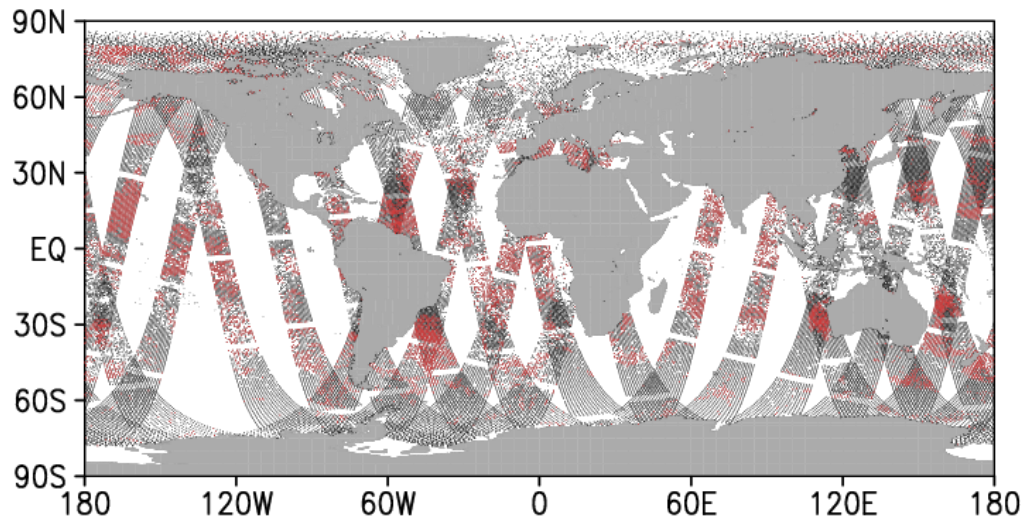
FY-3C MWHS-2 O - B channel 6, mean= -0.799, stdev=1.168



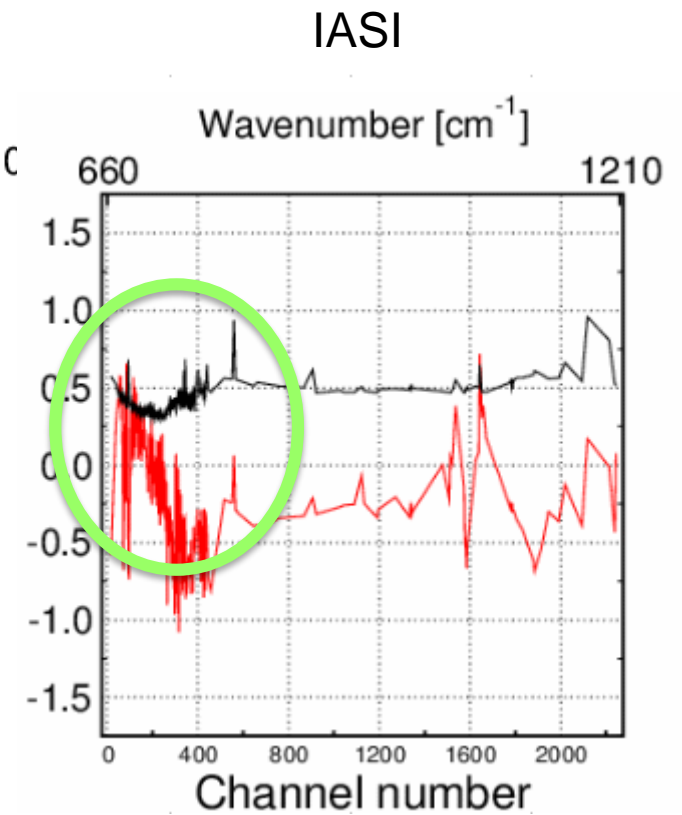
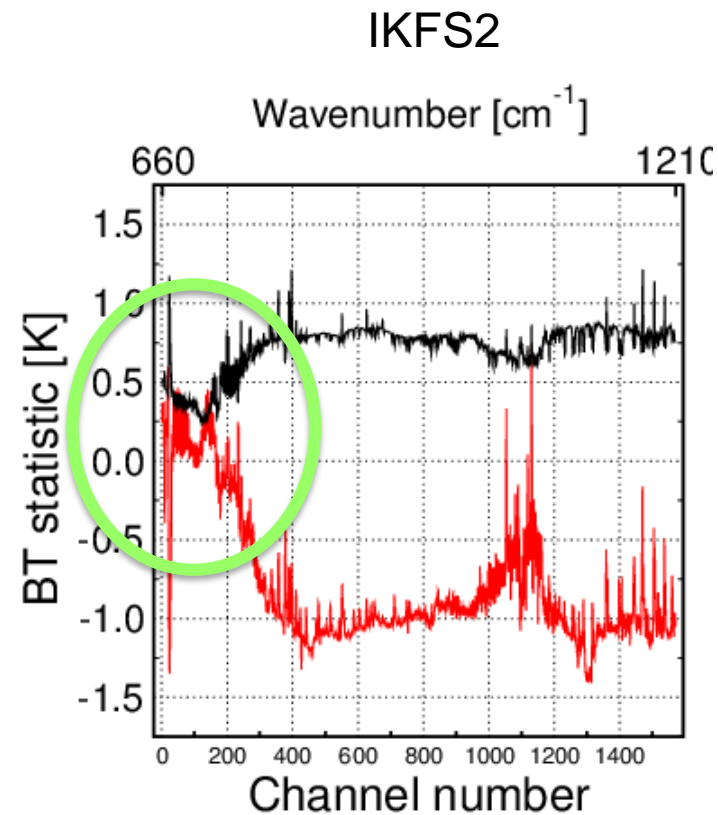
118.75 +/- 1.1

ECMWF also evaluates new obs from Russia:

The hyperspectral IR (IKFS2 on the Meteor satellite) is encouraging:



11885 clear IKFS2 observations in the two 12-hour windows of 30 January 2018

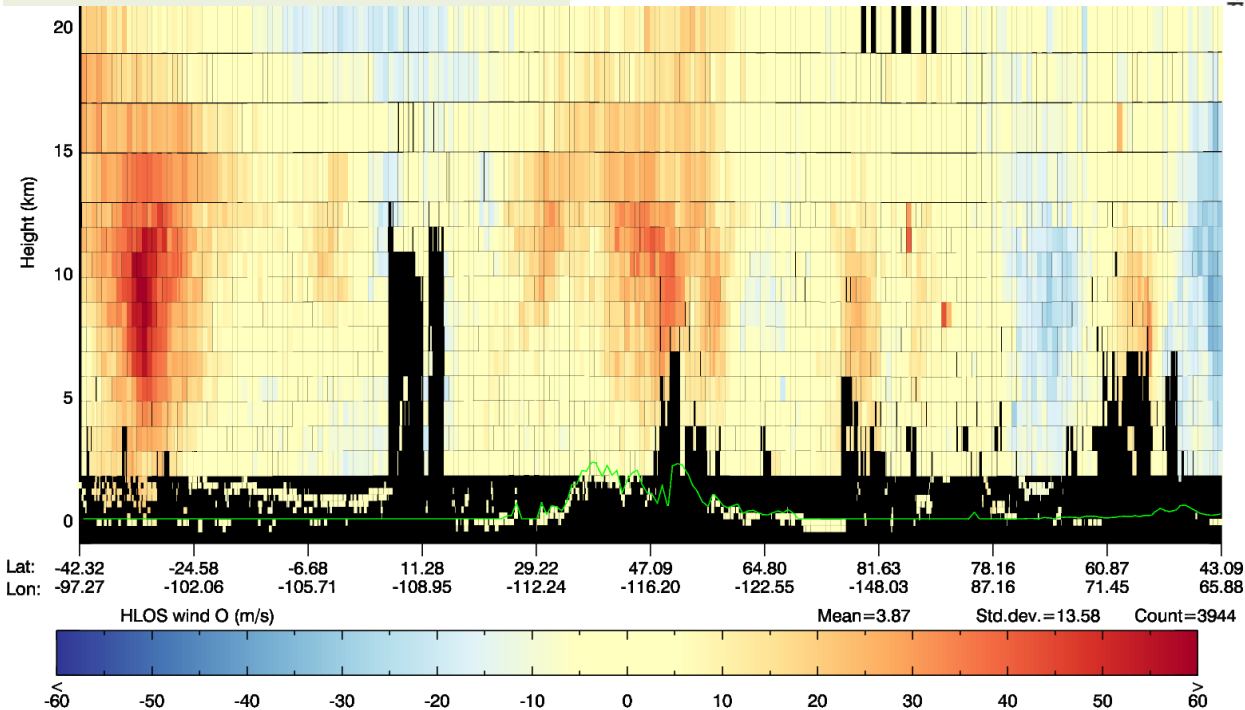


ECMWF also evaluate research observations

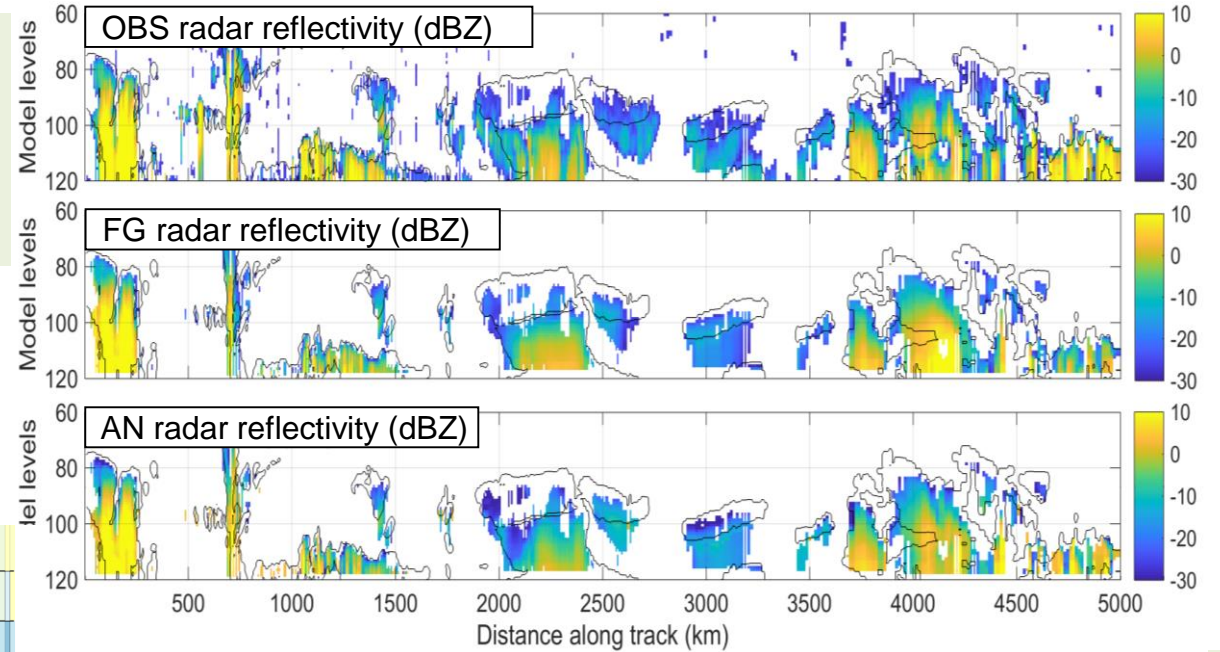


Direct 4D-Var assimilation of cloud lidar in an all-sky framework!
World first.

Rennie and Isaksen



Situation: 20070801 00 UTC



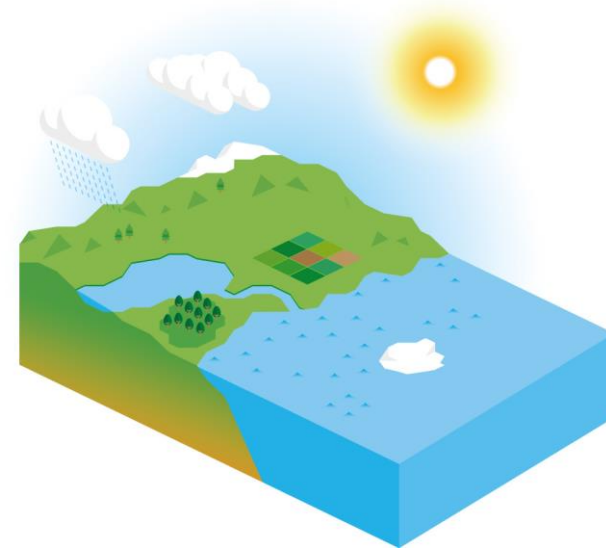
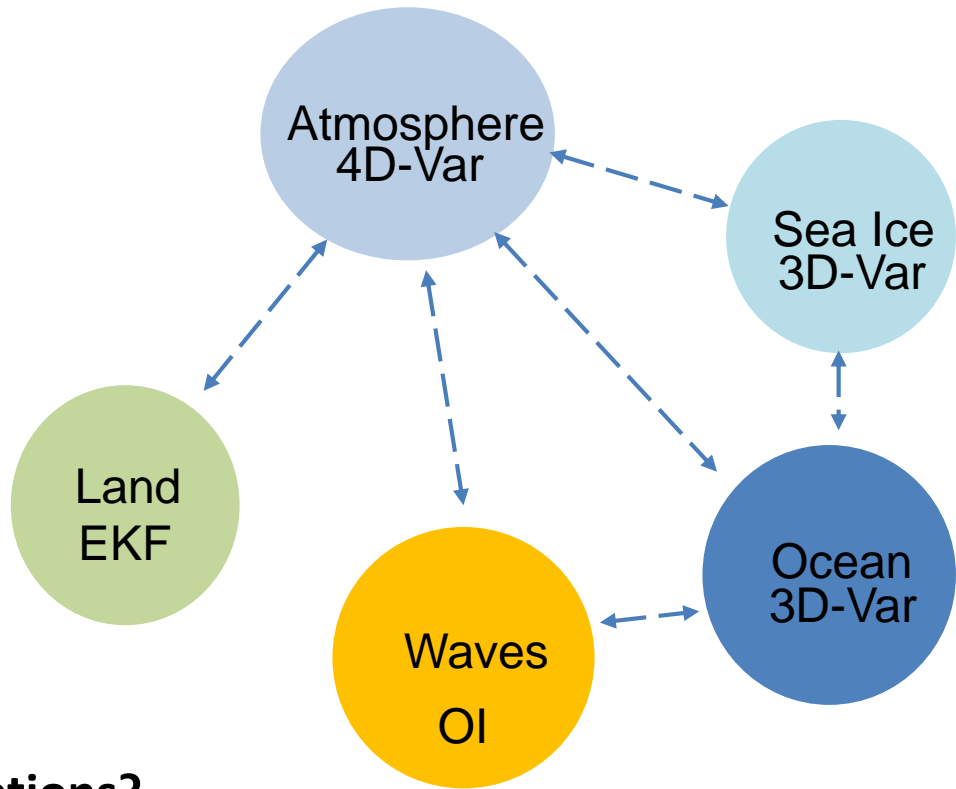
Janiskova and Fielding

Beginning evaluation of Aeolus winds – wind products generated at ECMWF less than two weeks after launch!



Coupled assimilation strategy: changes the role of observations

Coupled assimilation to initialise coupled forecasts in our operational systems



Options?

Weak, quasi-strong, strong, observation operator ...what does it all mean!

Delayed coupling

Real time coupling

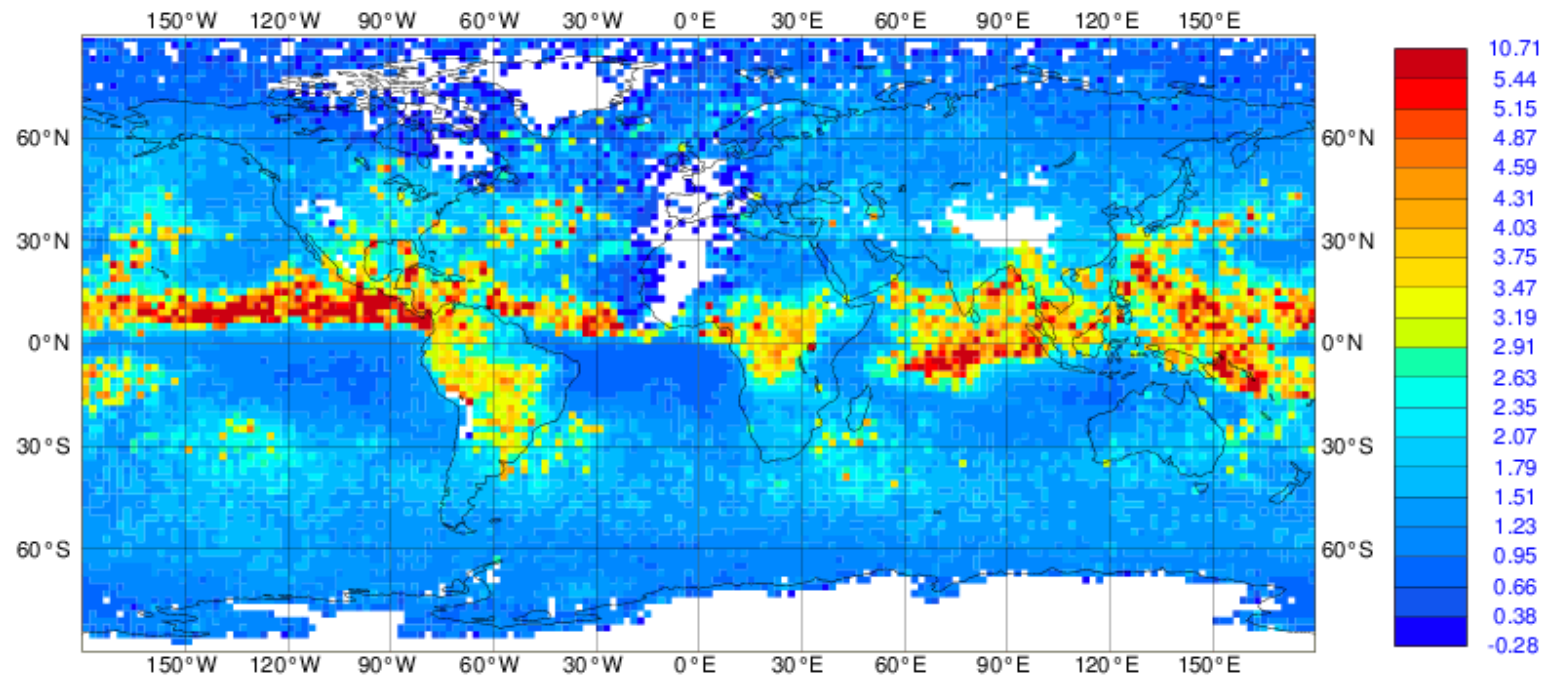
Fully coupled error covarinces

“Interface observations”
Sensitive to more than one component

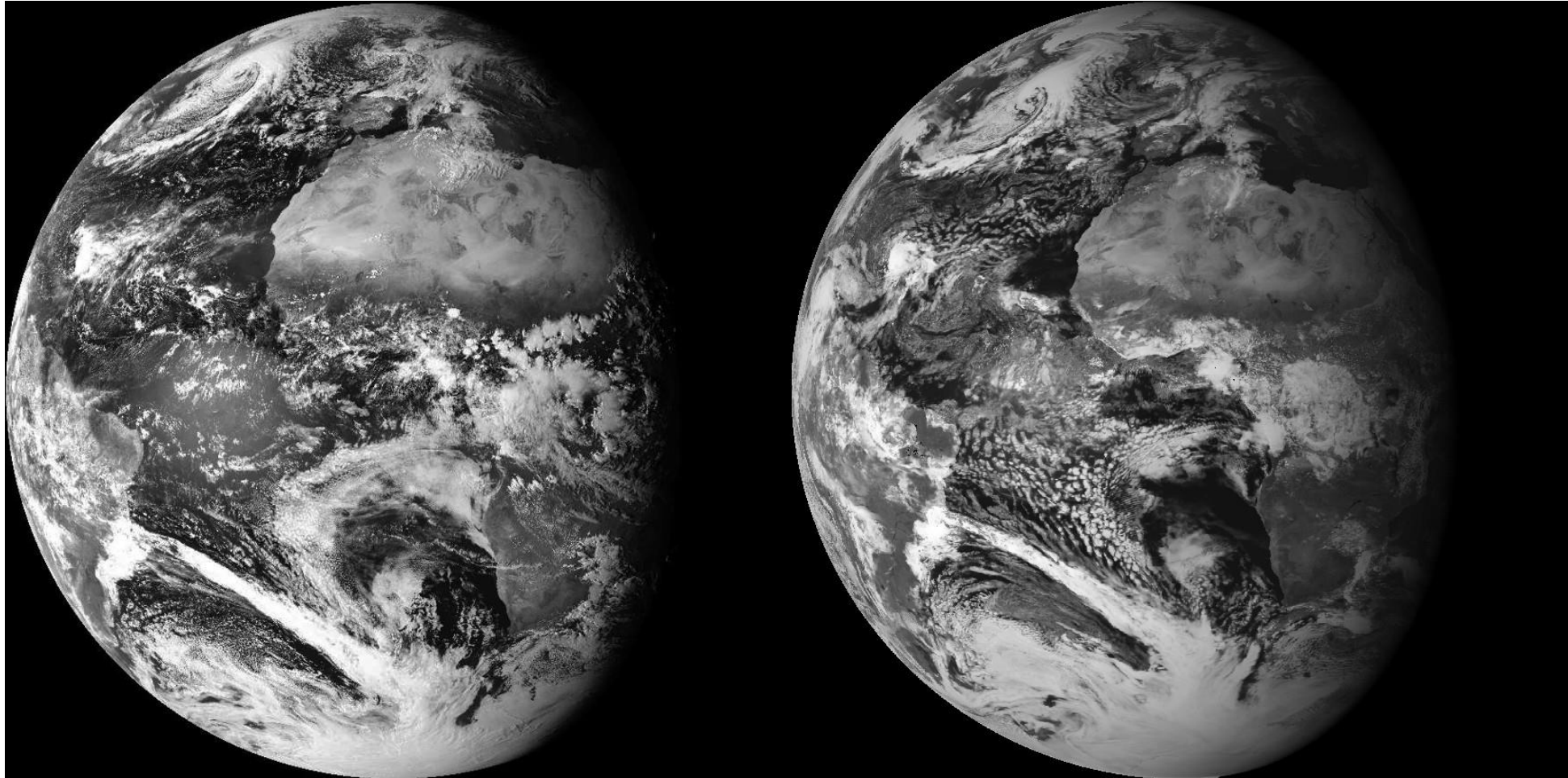
Satellite data now assimilated over many land areas and in “all-sky mode”

e.g. Channel 12 (183 GHz water vapour) of MWHS-2 from FY-3C

STATISTICS FOR RADIANCES FROM FY-3C/MWHS2
STDV OF FIRST GUESS DEPARTURE (USED)
DATA PERIOD = 2018-09-13 21 - 2018-10-19 21
EXP = 0001, CHANNEL = 12
Min: 0.000 Max: 10.434 Mean: 1.821
GRID: 2.00x 2.00



ECMWF would like to start assimilating visible data



Which is real?

Conclusion: satellite data is vital for accurate NWP

Take away satellite data – no Hurricane Florence and no typhoon MangKhut.

With satellite data they are accurately forecast many days before landfall.

