ECMWF - Future perspectives for time horizon 2040+

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ECMWF

With special thanks to Tony McNally (Head Earth System Assimilation at ECMWF) and many other ECMWF colleagues

ESA's questions

- Which future operational or scientific users' needs will drive the definition of future system-of-systems?
- What should our European Earth Observation Ecosystem look like in 2040+?
- How do commercial Earth Observation data providers fit into the overall picture?

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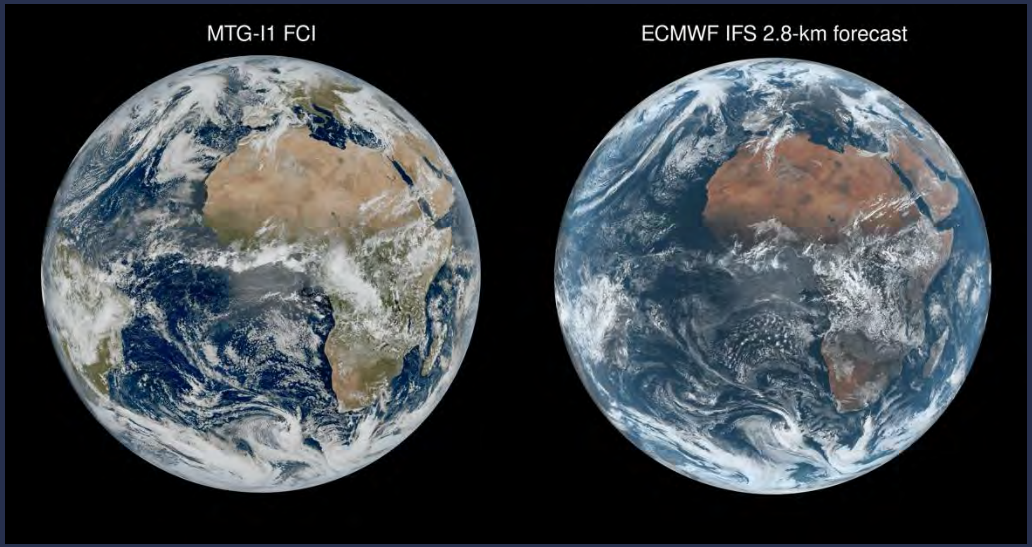
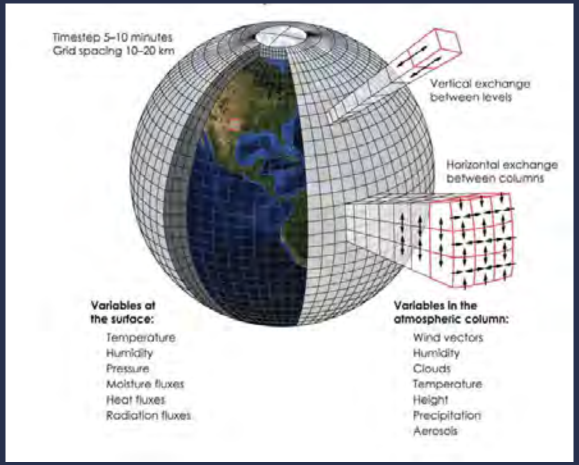
Recent evolutions in NWP…resolution and complexity

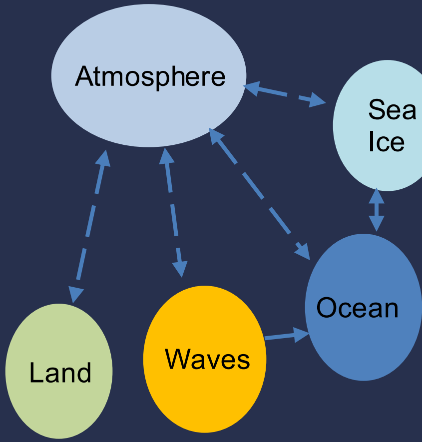
- Physics-based global NWP models have evolved to ever higher spatial resolution (km scale) and levels of complexity (i.e. full Earth system).

- This is very exciting! …but presents some extreme challenges for DA / OBS to provide initial conditions of the required detail and accuracy for the required model parameters.

Real satellite observations | ECMWF 2.8km DestinE model







Thanks to Tony McNally and Patricia de Rosnay

Which future operational or scientific users' needs will drive the definition of future system-of-systems?

THE STRENGTH OF A COMMON GOAL

ECMWF

STRATEGY 2025–2034

Our Vision:

World-leading monitoring and predictions of the Earth system enabled by cutting-edge physical, computational and data science, resulting from a close collaboration between ECMWF and the members of the European Meteorological Infrastructure, will contribute to a safe and thriving society

ECMWF in 2035:

- Innovating at the cutting edge of physical, computational and data science for environmental monitoring and prediction
- Delivering forecast tools and products of unprecedented quality, exploiting data-driven methods anchored on physics-based modelling
- Integrated in and collaborating with the wider European meteorological community to deliver maximum value to society

Our Mission: Deliver global numerical weather predictions focusing on the medium-range and monitoring of the Earth system to and with our Member States

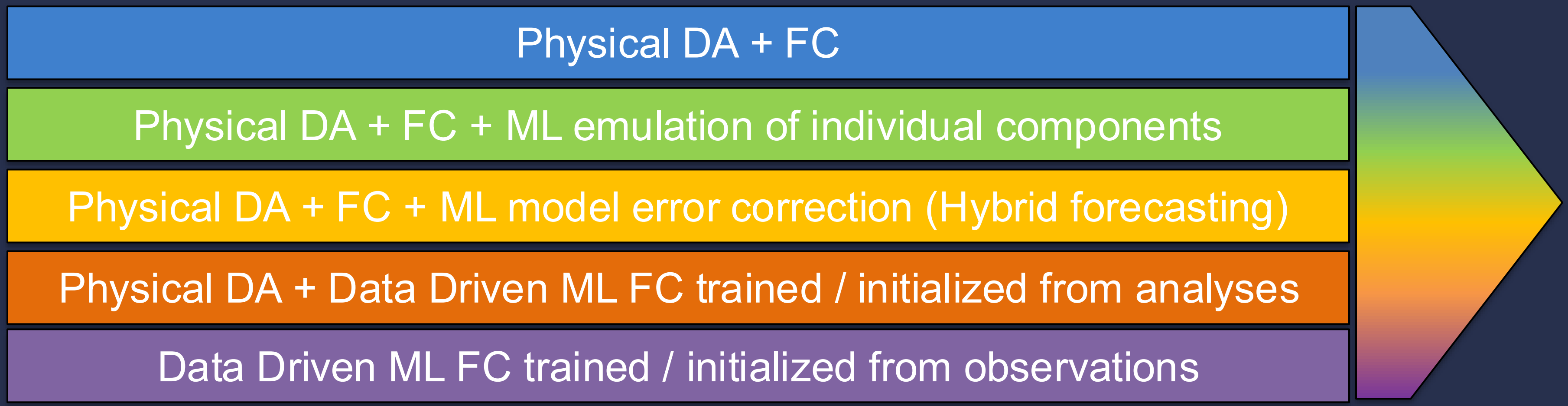
Strategic Pillars and Actions:

Science & Technology	Impact	Organisation & People
Improve use of observations & Earth system data assimilation	Meet users' needs & deliver world-leading quality products	Increase organisational performance, resilience & effectiveness
Improve seamless Earth system models	Optimise provision & sharing of data, tools & resources	Enable a thriving multi-site environment with an emphasis on sustainability
Exploit high-performance computing, technology & computational science for numerical weather prediction	Enhance partnerships, training & communications	
Harness artificial intelligence/machine learning for data-driven forecasting		
Optimise system design & enhance flow from research to operations & vice versa		

Strategic development threads of the ECMWF NWP system

Strategic drivers: ➡

- Performance (accuracy / delivery to users)
- Resource landscape (HPC, skills, partnerships)
- Long-term operational sustainability of approach
- Maintaining support of member state activity



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What should our European Earth Observation Ecosystem look like in 2040+?

Some high-level thoughts

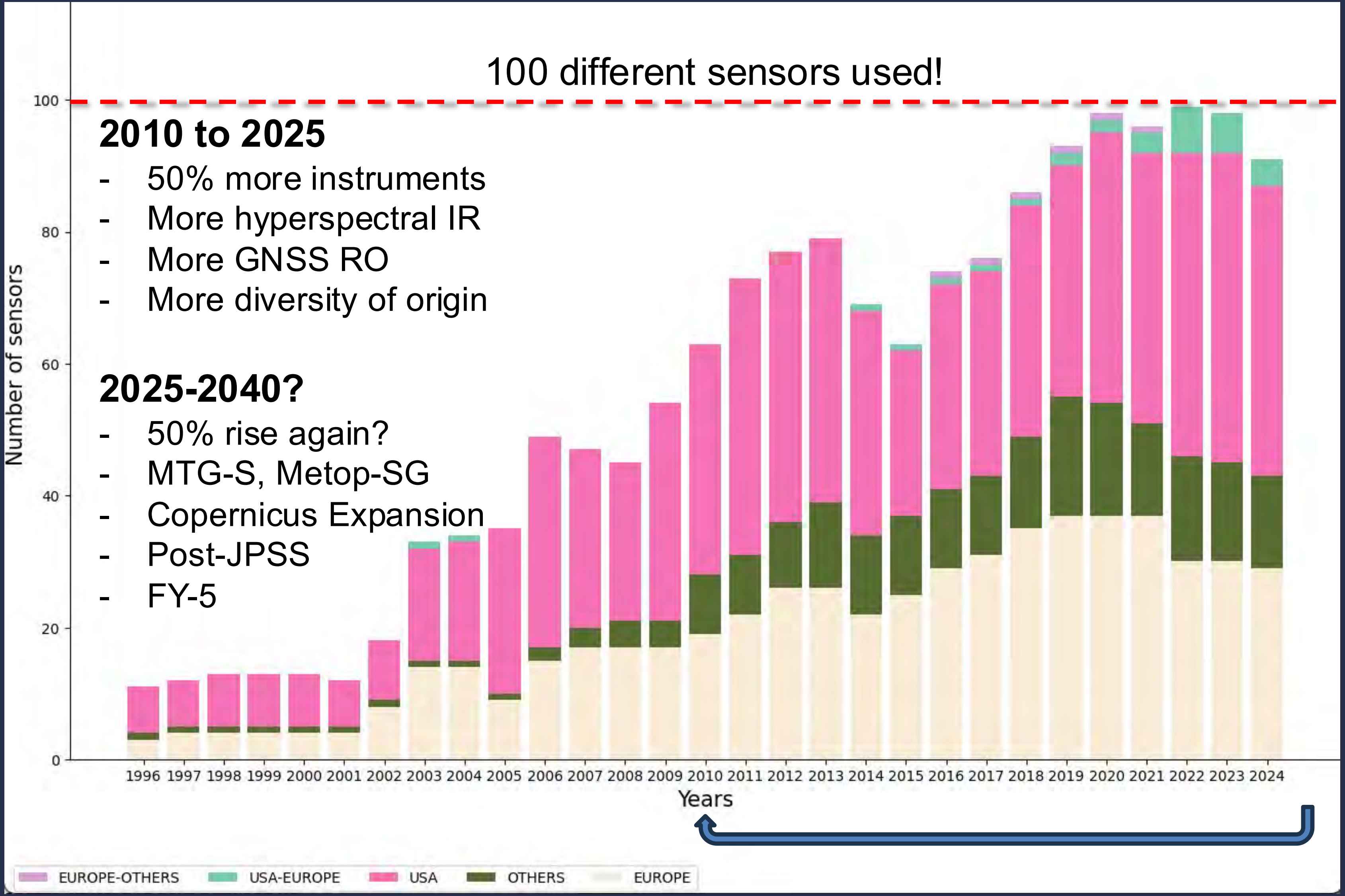
Observations (and compute power) are the only fundamental resource in our business
Who provides the observations is potentially subject to change
Who uses the observations is potentially subject to change
Which observations are needed is potentially subject to change

…our predictive horizon for the above has been significantly reduced by the advent of private sector space and AI/ML

(in other words 2040+ feels a long way off now!)

Thanks to Tony McNally

Origin of satellite used at ECMWF



USA
AQUA
AURA
C-NOFS
CORIOLIS
COSMIC2
COSMIC
DMSP
GOES
JPSS
PlanetIQ
POES
QuikSCAT
SAC-C
SMAP
TERRA

OTHERS
COMS-1
FY2
FY3
GCOM
GPM
HIMAWARI
HY2
INSAT-3D
KOMPSAT-5
MTSAT
OceanSat-2
SARAL
TRMM

EUROPE
Aeolus
CHAMP
CRYOSAT
ENVISAT
ERS
JASON
METEOSAT
METOP
Sentinel
SMOS
TanDEM-X
TerraSAR-X

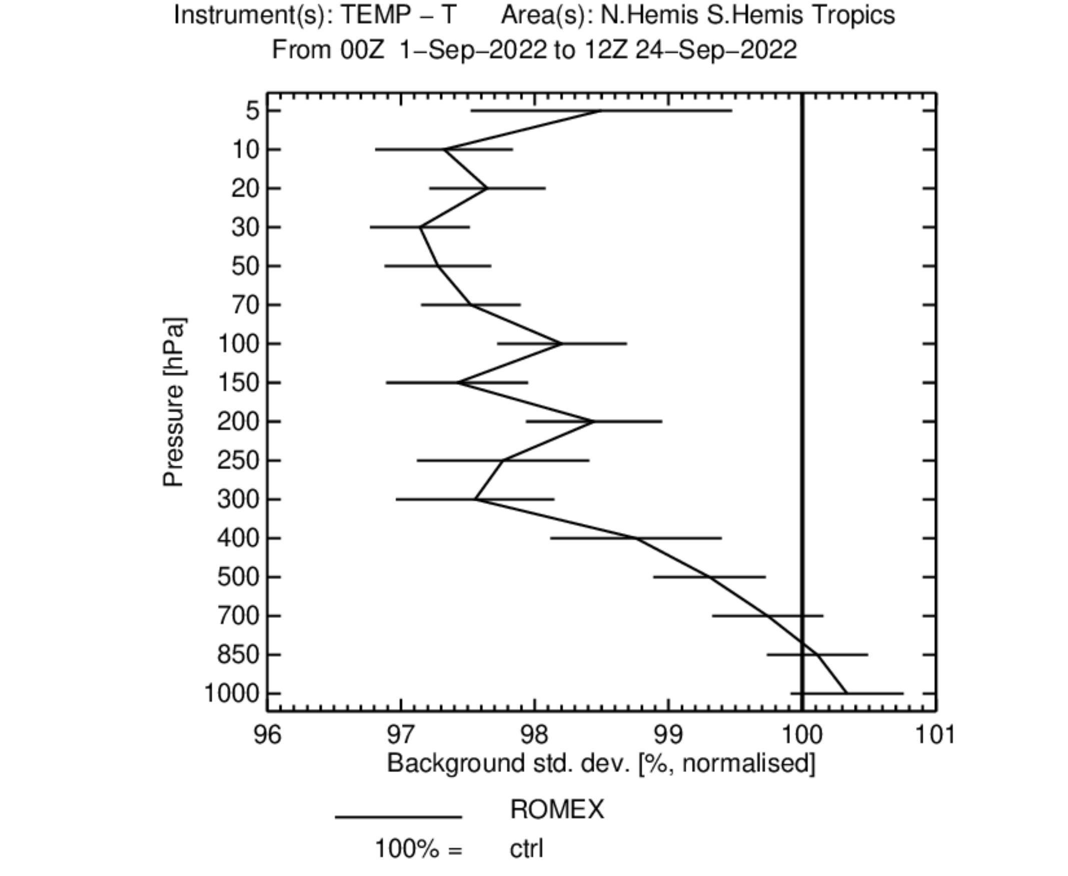
USA-EUROPE
GRACE
JASON
Sentinel-6A
SPIRE-Lemur-3U
SPIRE

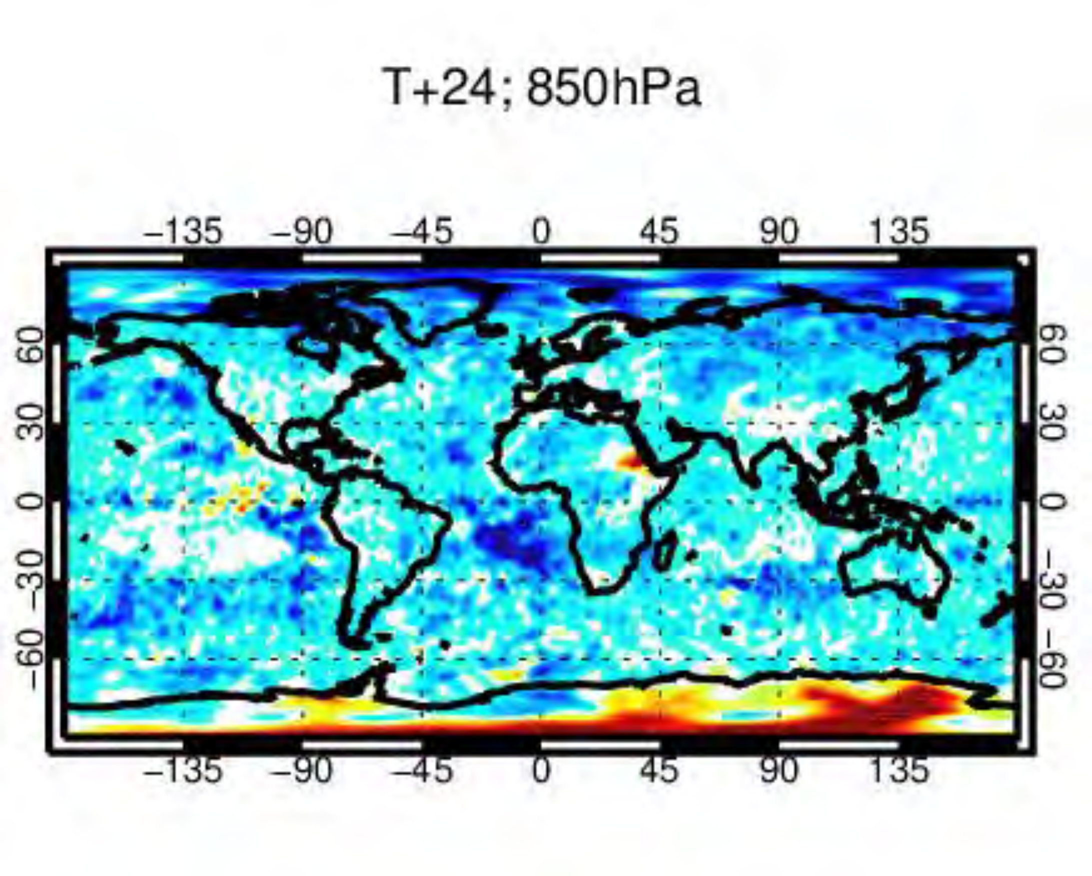
EUROPE-OTHERS
MEGHA-TROPIQUES

Thanks to Tony McNally

How much data do we need ? …ROMEX

- Highly-significant impact of the full additional ROMEX data-set on top of present RO data
- Experiments continue to examine linearity of impact improvement with OBS numbers

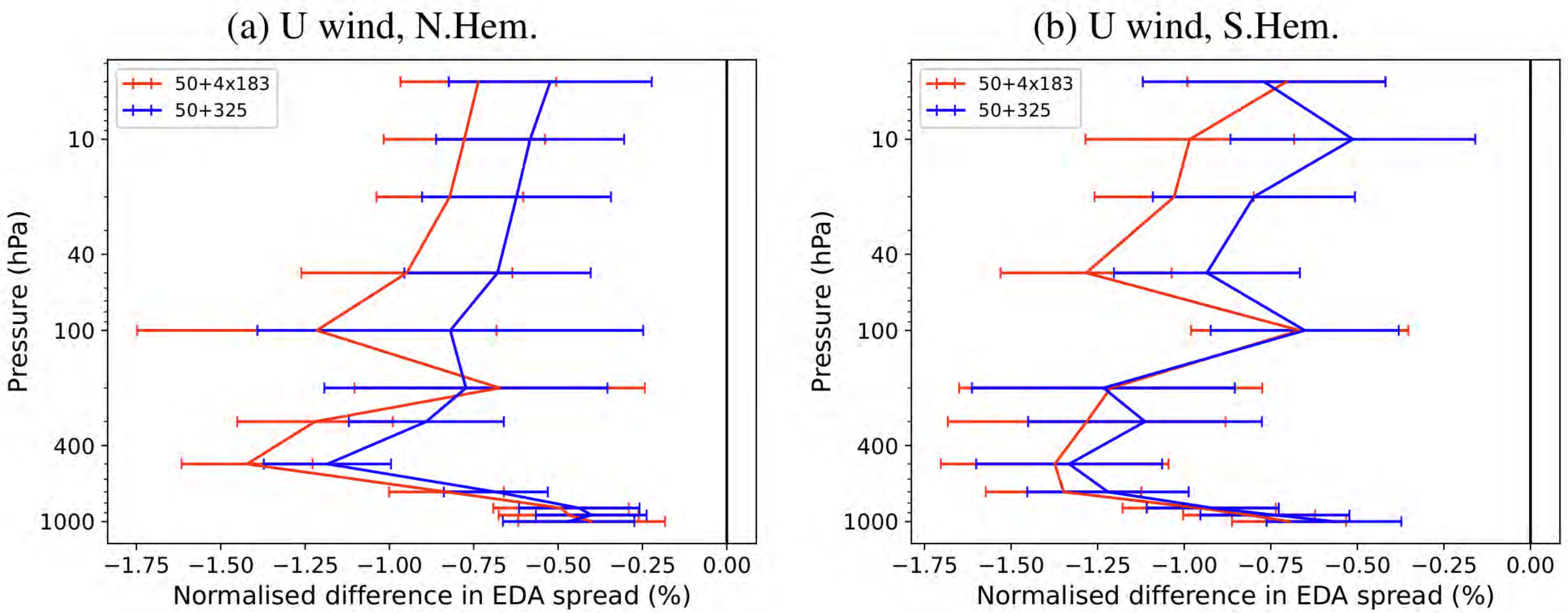




Thanks to Tony McNally, Katrin Lonitz and Sean Healy

Assessing the new EPS-Sterna 325 GHz humidity channels in the EDA

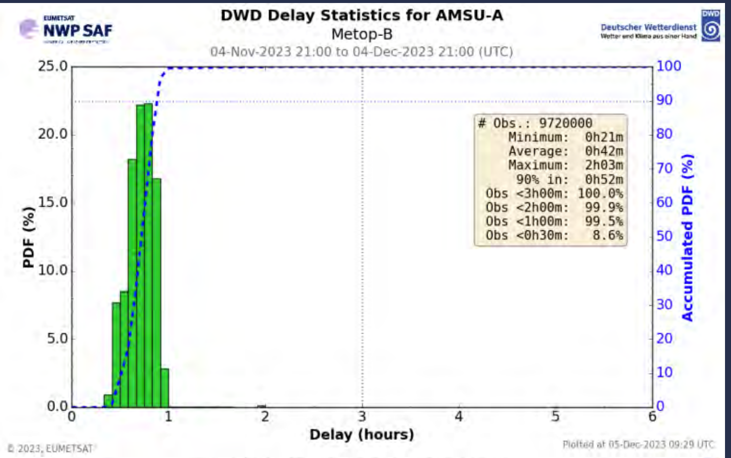
- The new 325 GHz humidity channels from EPS-Sterna give a similar impact as corresponding 183 GHz channels when added to the temperature-sounding channels.
- First time these channels are used in NWP – still lots to learn!

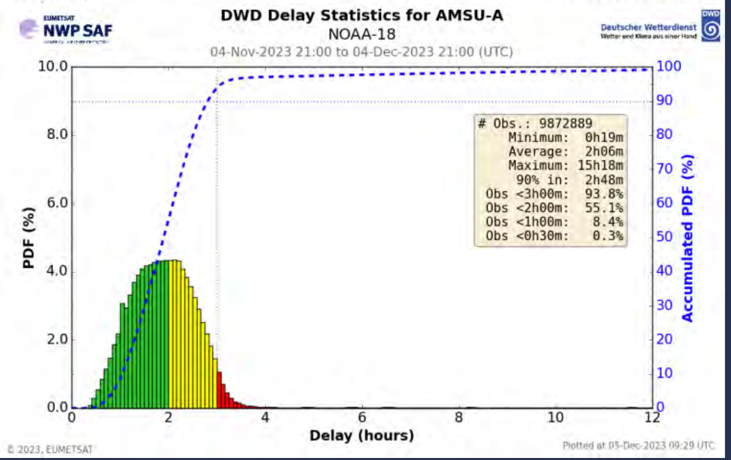


Thanks to Katie Lean and Niels Bormann

Forecast impact of data timeliness

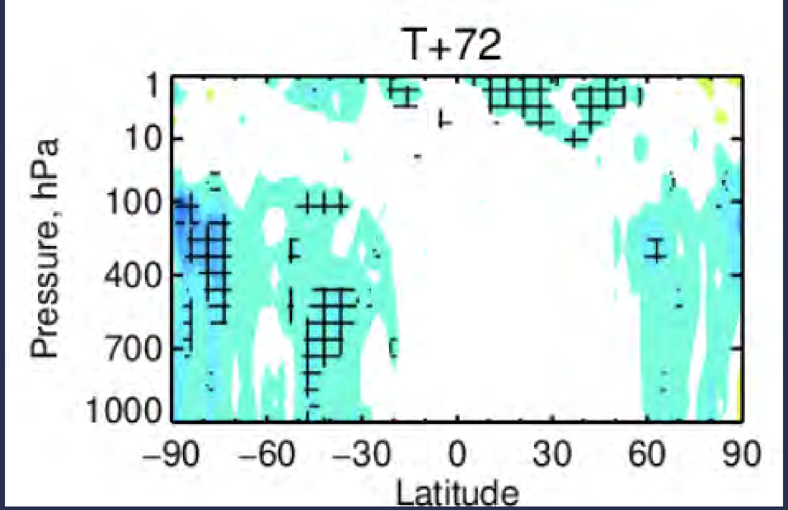
- End of window observations are the most recent and informative of the current state of the Earth System
- Since the introduction of Continuous DA, ECMWF is able to exploit observations made very close to the assimilation window end…as long as they arrive in time!!



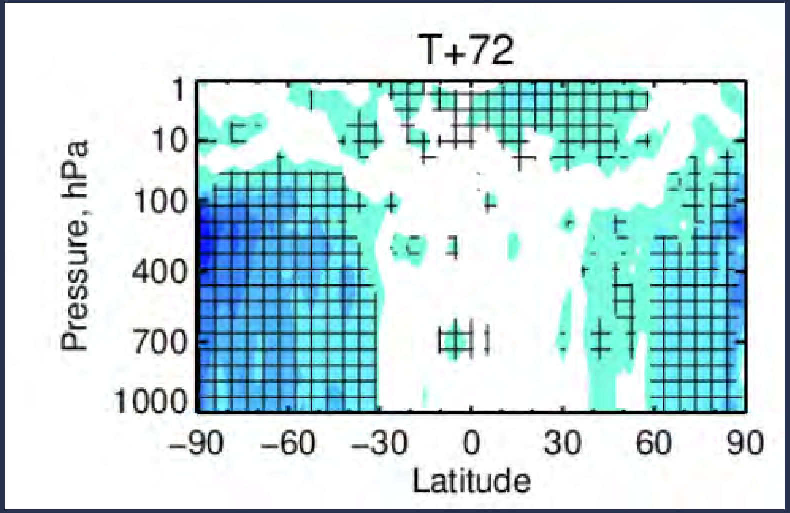


The impact of observation timeliness on forecast skill can be of the same order as adding a new satellite!

50 min vs 100 min
(1 vs 2 polar down links)



20 min vs 100 min
(1 polar down link vs DbNet)



Thanks to Peter Lean and Niels Bormann

Interface Observations

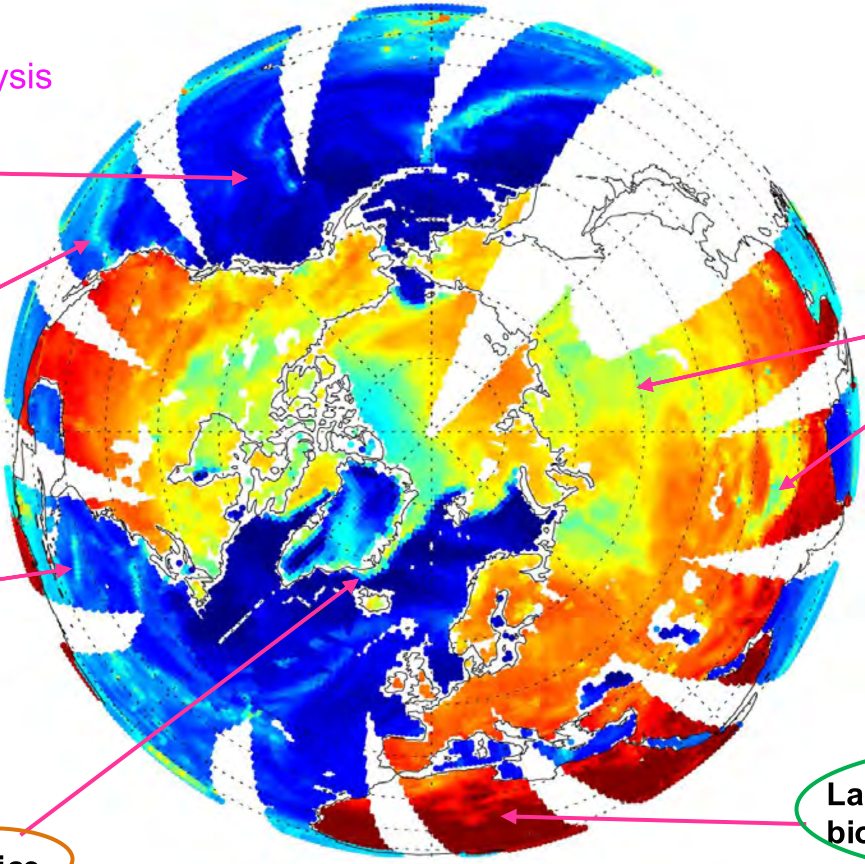
SSMIS F-17 channel 13 (19 GHz, v)
Microwave brightness temperatures
3rd December 2014

Assimilated in
atmospheric analysis

Ocean waves, wind,
skin temperature

Atmospheric
water vapour
and temperature

Cloud and
precipitation



Not used yet but
could be in snow DA

Snow cover

Not yet used, but
could be in land DA

Land surface temperature,
biomass, soil moisture

At ECMWF used via
third party L4 (OSTIA)

Sea-ice

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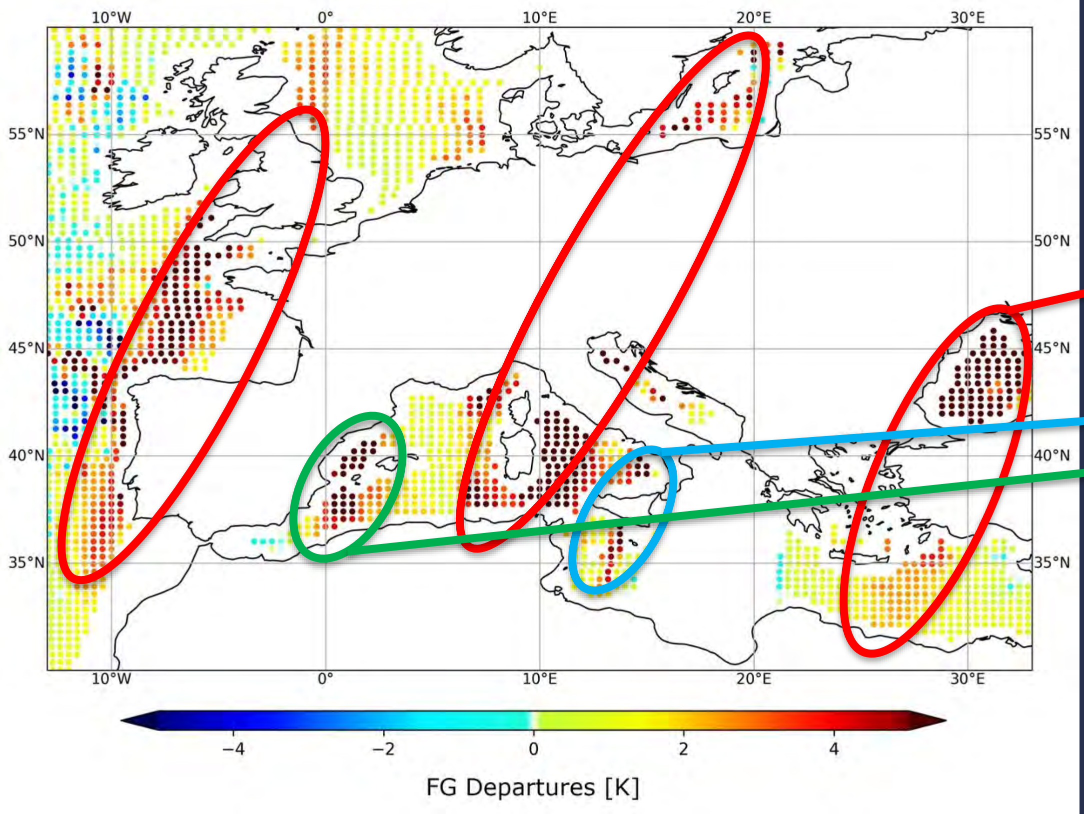
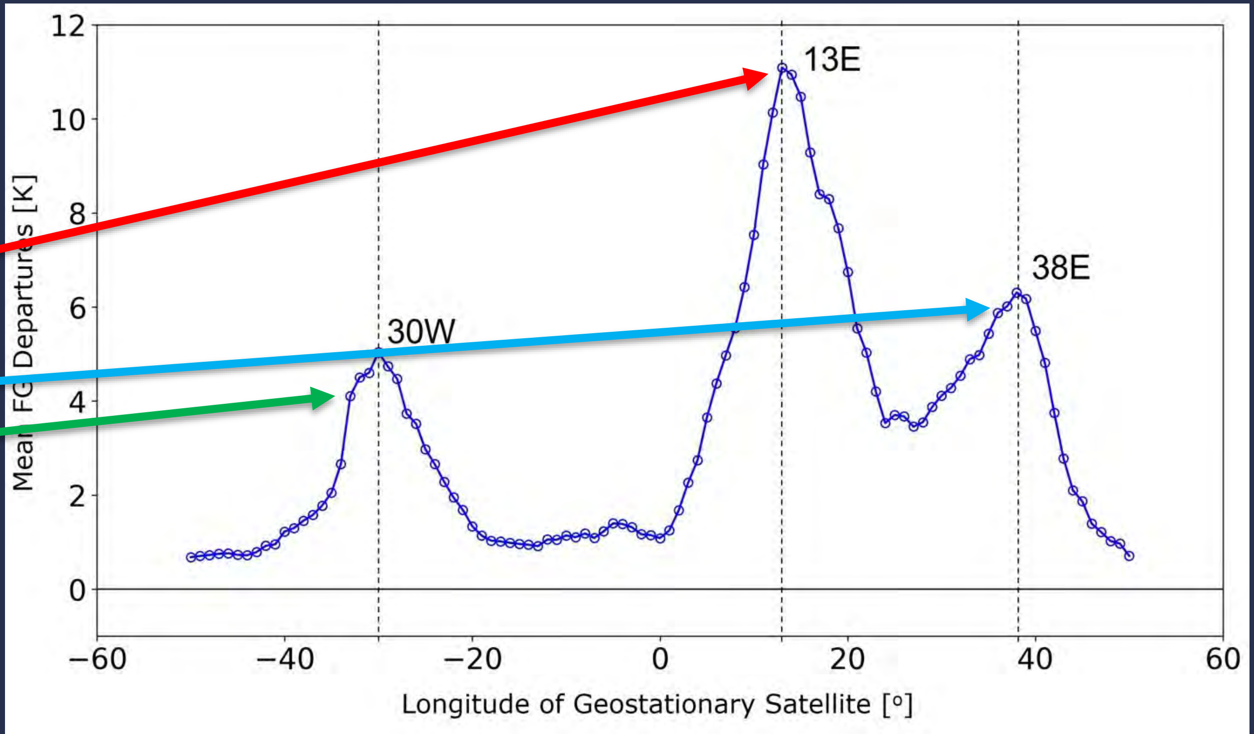
Thanks to Alan Geer

RFI detection and mitigation

RFI caused by reflections of signals from direct broadcast satellites in geostationary orbit – clearly visible in background departures at 10 GHz.

We can identify where the relevant satellites are by calculating the glint for a given satellite position and analysing the background departures.





Thanks to Tracy Scanlon and Alan Geer

ML Forecasts directly from observations:

The AI-DOP system learns an internal representation of the atmosphere purely from historical records of raw observations


DATA DRIVEN WEATHER FORECASTS TRAINED AND INITIALISED DIRECTLY FROM OBSERVATIONS

A PREPRINT

Anthony McNally Christian Lessig Peter Lean Eulalie Boucher Mihai Alexe

Ewan Pinnington

Florian Pinault

European Centre

arXiv:2407.15586v1 [physics.ao-ph] 22 Jul 2024

GRAPHDOP: TOWARDS SKILFUL DATA-DRIVEN MEDIUM-RANGE WEATHER FORECASTS LEARNT AND INITIALISED DIRECTLY FROM OBSERVATIONS

A PREPRINT

Mihai Alexe Eulalie Boucher Peter Lean Ewan Pinnington Patrick Laloyaux

Anthony McNally Simon Lang Matthew Chantry Chris Burrows Marcin Chrust

Florian Pinault Ethel Villeneuve Niels Bormann Sean Healy

European Centre for Medium-Range Weather Forecasts (ECMWF)

December 20, 2024

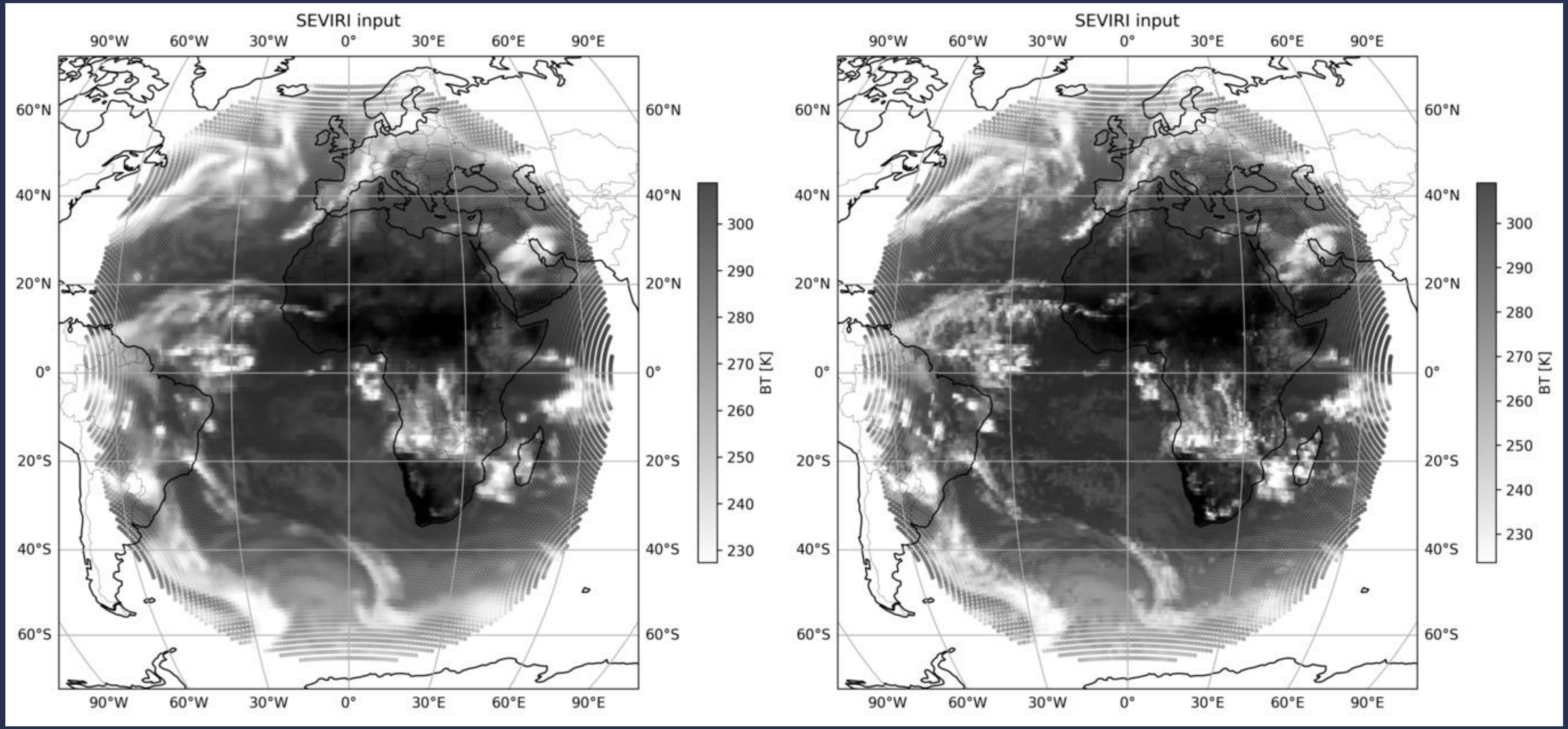
ABSTRACT

We introduce GraphDOP, a new data-driven, end-to-end forecast system developed at the European Centre for Medium-Range Weather Forecasts (ECMWF) that is trained and initialised exclusively from Earth System observations, with no physics-based (re)analysis inputs or feedbacks. GraphDOP learns the correlations between observed quantities - such as brightness temperatures from polar orbiters and geostationary satellites - and geophysical quantities of interest (that are measured by conventional observations), to form a coherent latent representation of Earth System state dynamics and physical processes, and is capable of producing skilful predictions of relevant weather parameters up to five days into the future.

1 Introduction

arXiv:submit/6084865 [physics.ao-ph] 20 Dec 2024

AI-DOP model | Target real observations



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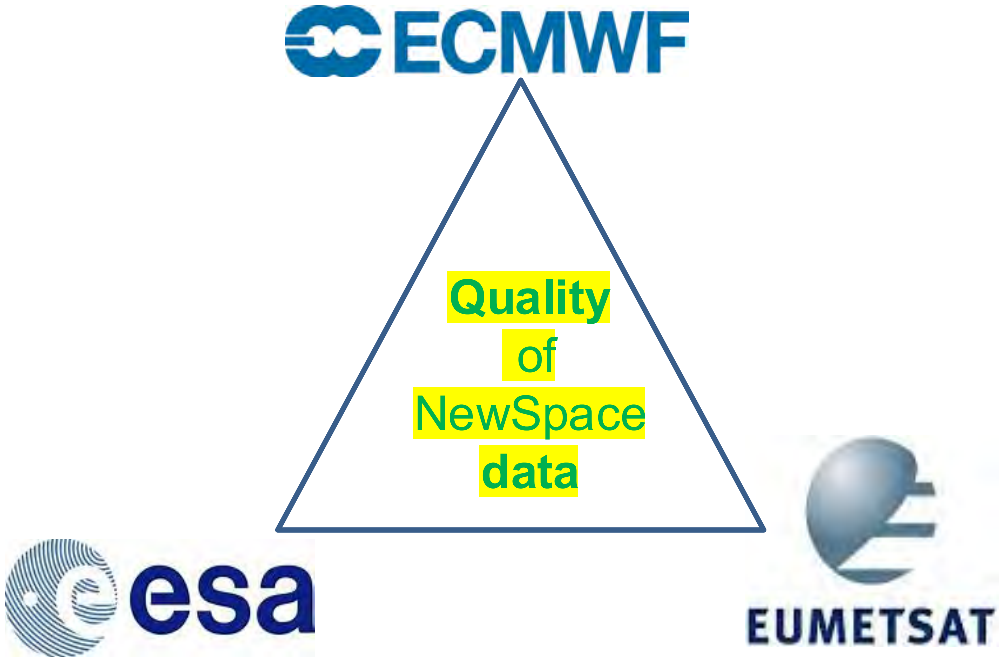
Who provides the observations is potentially subject to change

Expanded access to space for the private sector observation deployment is likely to accelerate

Space-based observation deployment (for NWP) being influenced by GEO return, technology demonstration or artificial market forces is likely to reduce

Private sector OBS players may move away from selling OBS and instead keep unique measurements to add USP value to their own commercial forecast services

AI/ML will democratize access to NWP for low cost OBS providers



New Space

WMO position paper on requirements: providing guidance to all sectors

- Share (1)
- Document instrument (2) and algorithms (4)
- Engage (3)
- Timeliness, format and tools (5)
- Pre-operational test data (6)
- Data Archives (7)
- Plan for future follow-on (8)
- SI traceability (9)
- Maintain beyond life if possible (10)

Happy users

This best practice is largely followed by the main space agencies whose data is widely used and critically important in global NWP

Strategy?

Agility to react to potentially rapid evolutions and deliver observations (ESA, EUMETSAT and others) that are actually needed (and have a robust mechanism to evaluate these needs).

To examine critically what is the verified added value of Space Agencies and NWP processing instead of somebody else doing it…prioritizing resources on these areas.

Consider that users may be evolving towards wanting raw data and tools and not products.

Thanks to Tony McNally