Importance of satellite data for ECMWF and its Copernicus Services

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Acknowledgements: Joaquin Munoz-Sabater, Stephen English, Tony McNally, Thomas Haiden, Vincent-Henri Peuch, the ECMWF team…

and the Copernicus Service component providers!

ECMWF

ECMWF - European co-operation at its best: deliverables

- Global numerical weather forecasts
- Supercomputing & data archiving
- Education & training programme

- EU activities: *Operating the Copernicus Climate Change and Atmosphere Monitoring Services, and contributing EFAS and FIRE to the Copernicus Emergency Management Service*

Model development, cycles and strategy

The strategy and its goals are always taken into account when decisions are taken: '*… European weather for a month ahead'.*

ECMWF
STRATEGY 2016–2025
THE STRENGTH OF A COMMON GOAL

EXECUTIVE SUMMARY

GOALS BY 2025

To provide forecast information needed to help save lives, protect infrastructure and promote economic development in Member and Co-operating States through:

Research at the frontiers of knowledge to develop an integrated global model of the Earth system to produce forecasts with increasing fidelity on time ranges up to one year ahead. This will tackle the most difficult problems in numerical weather prediction such as the currently low level of predictive skill of European weather for a month ahead.

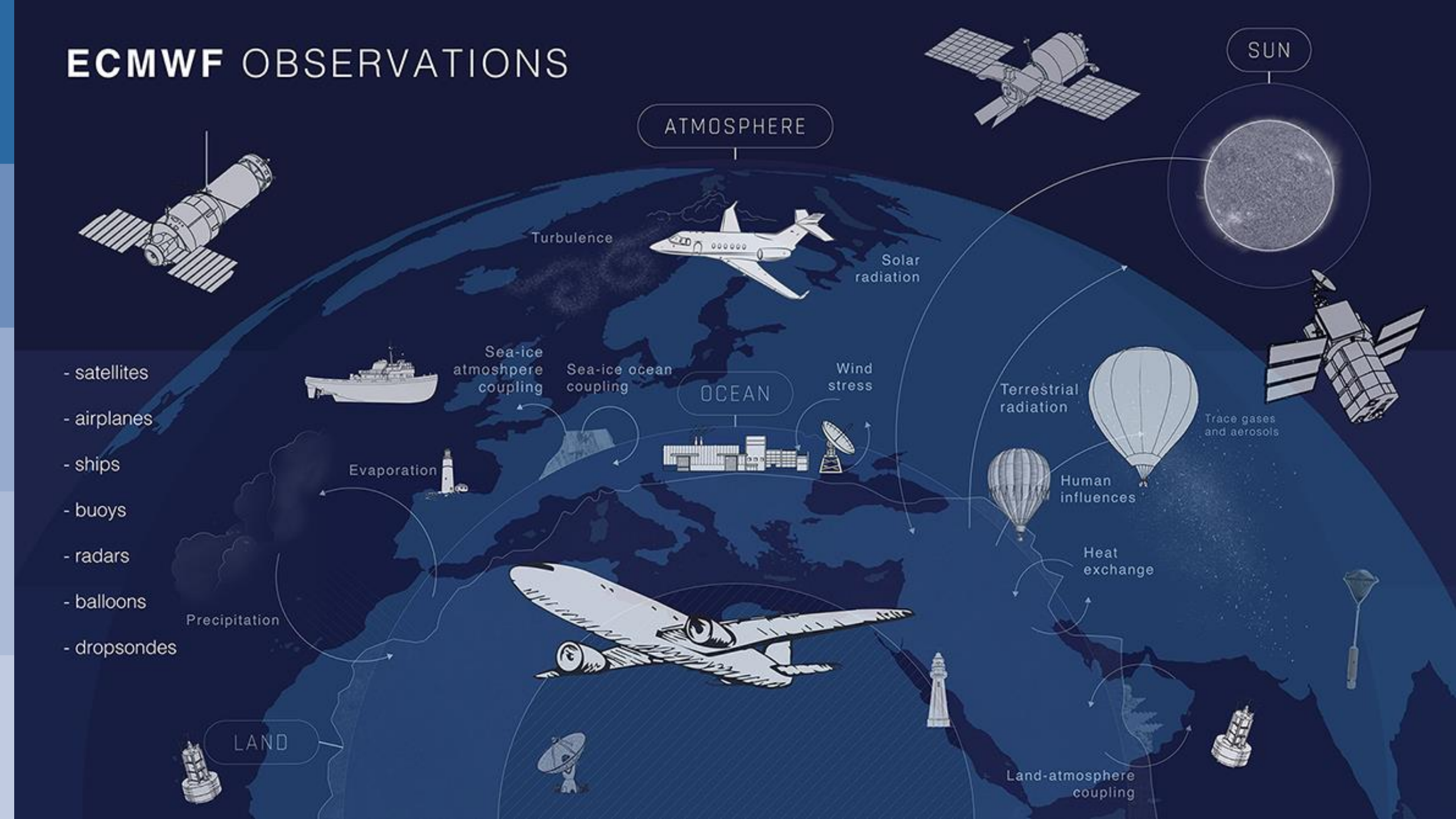
Operational ensemble-based analyses and predictions that describe the range of possible scenarios and their likelihood of occurrence and that raise the international bar for quality and operational reliability. Skill in medium-range weather predictions in 2016, on average, extends to about one week ahead. By 2025 the goal is to make skilful ensemble predictions of high-impact weather up to two weeks ahead. By developing a seamless approach, we also aim to predict large-scale patterns and regime transitions up to four weeks ahead, and global-scale anomalies up to a year ahead.

THE STRENGTH OF A COMMON GOAL

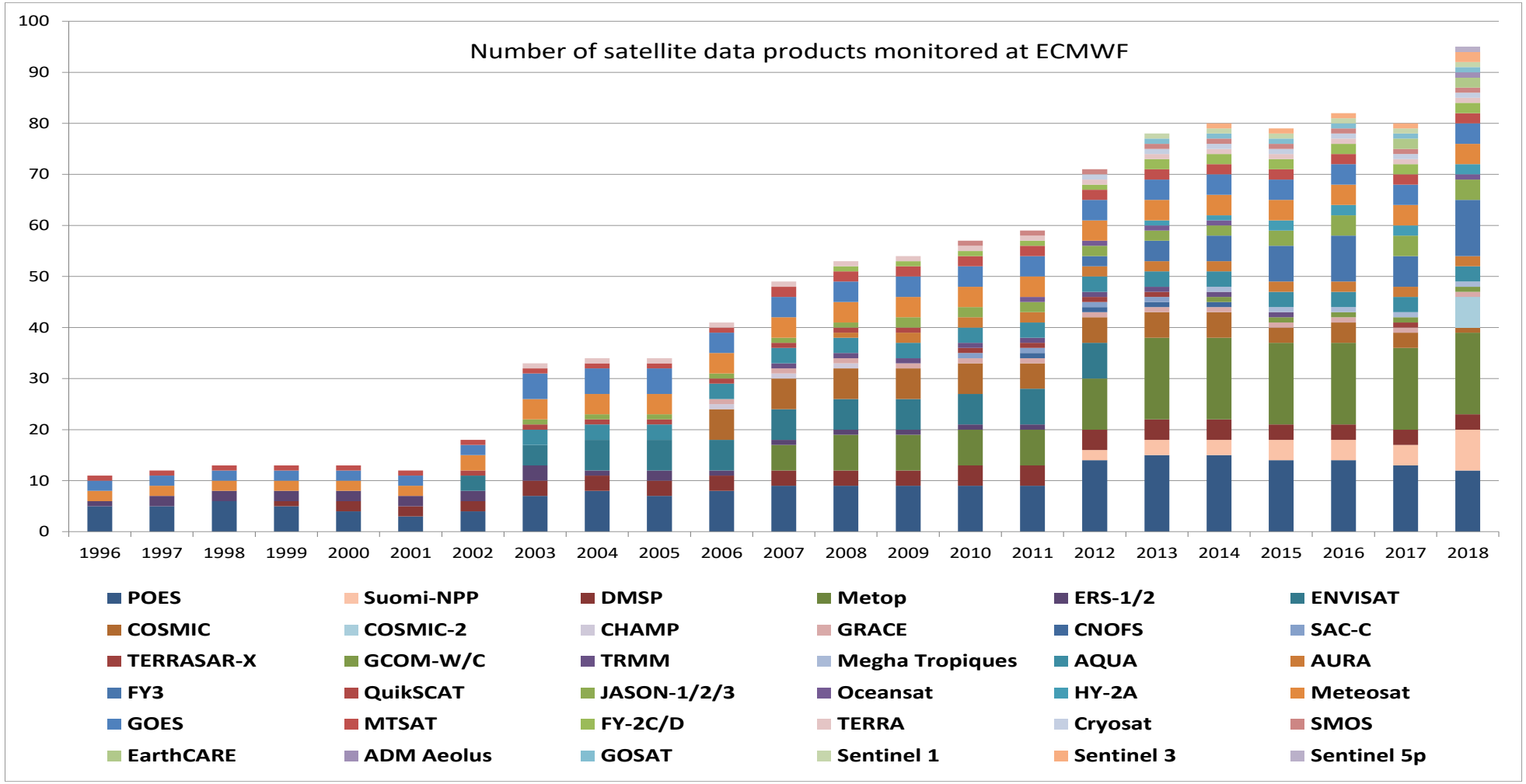
How do we achieve these goals?

- Observations
- High resolution ensemble
- Earth-system
- Scalability
- People and Collaborations

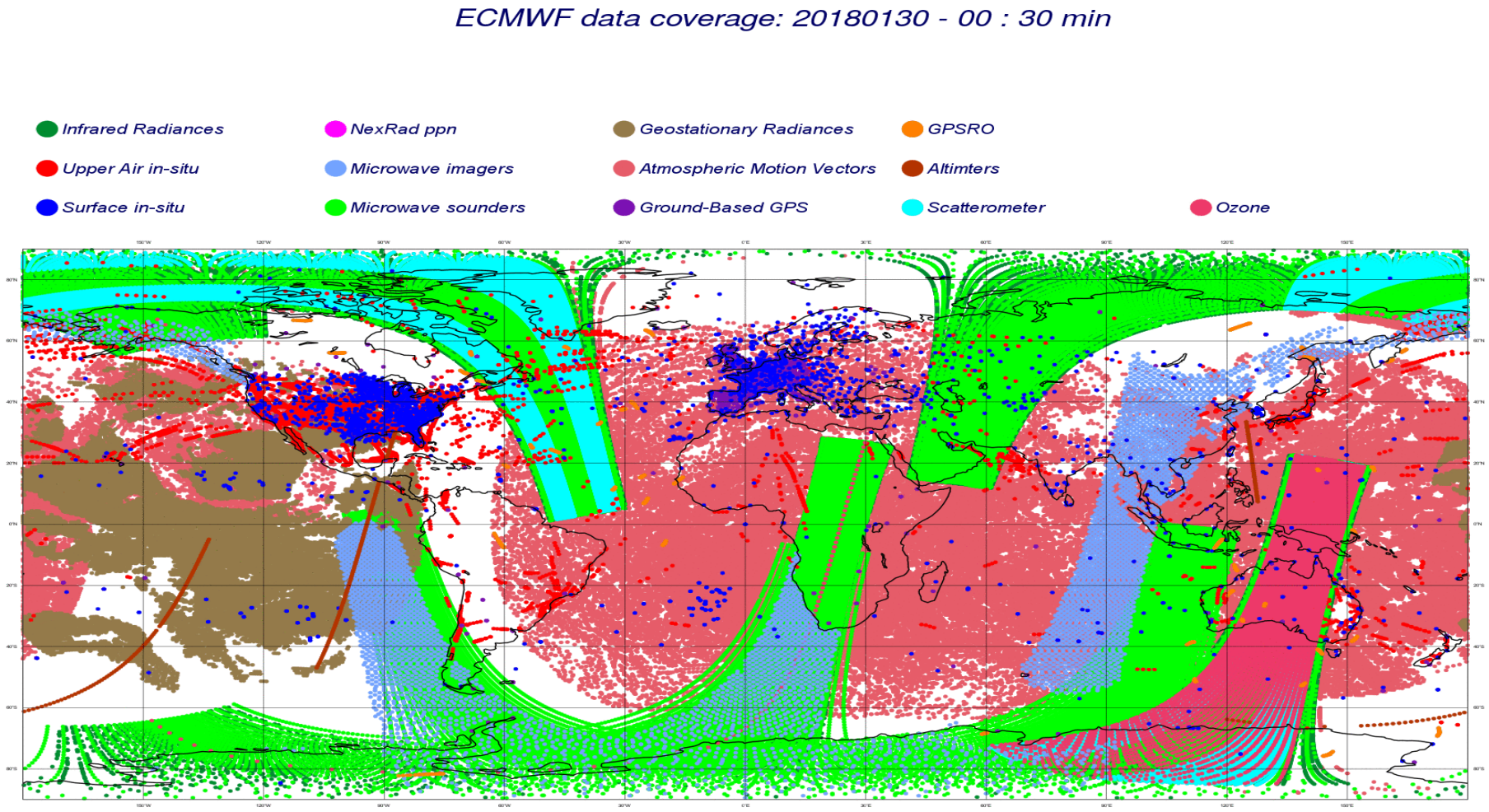
ECMWF OBSERVATIONS



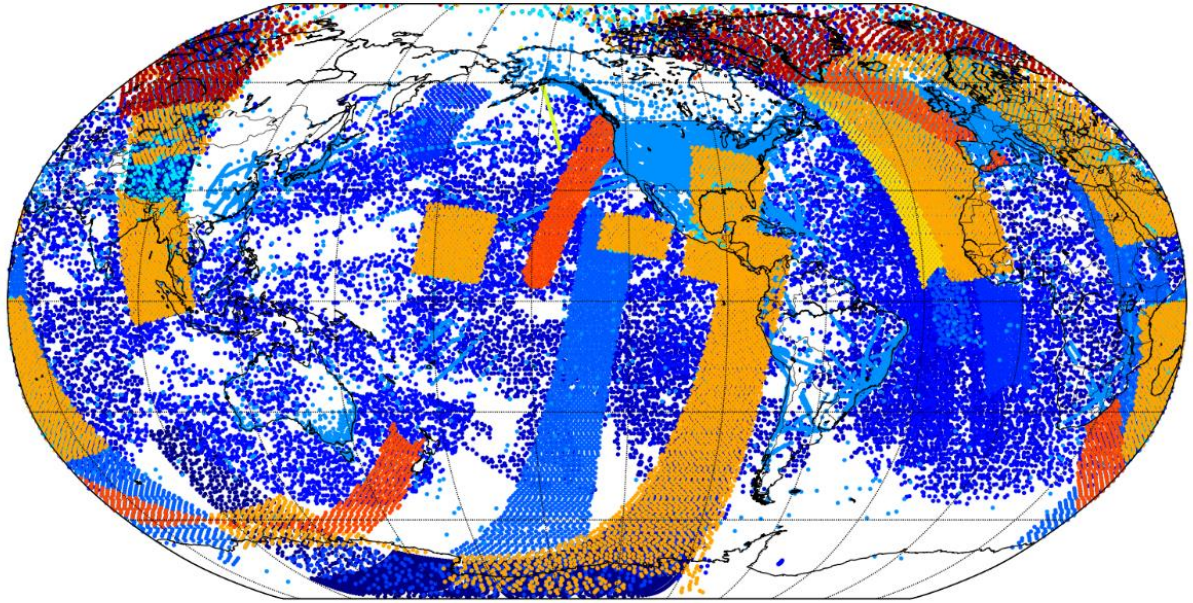
ECMWF & satellite data



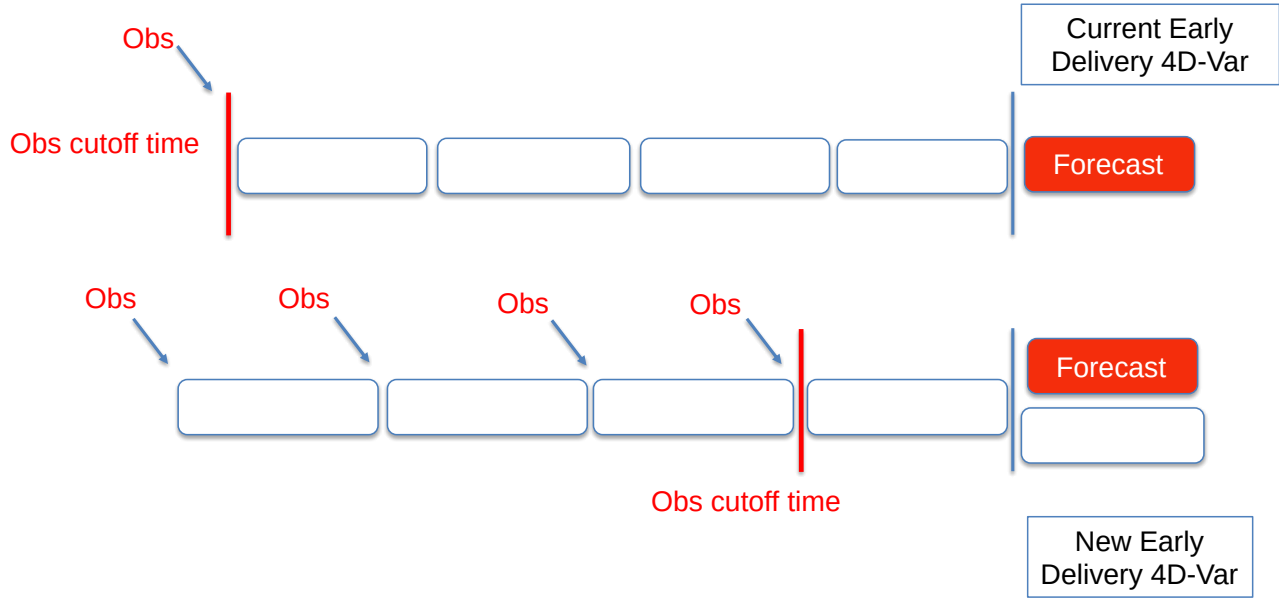
Data coverage: 24 hour of data in the ECMWF system



Data Assimilation at the heart of improving the exploitation of observations

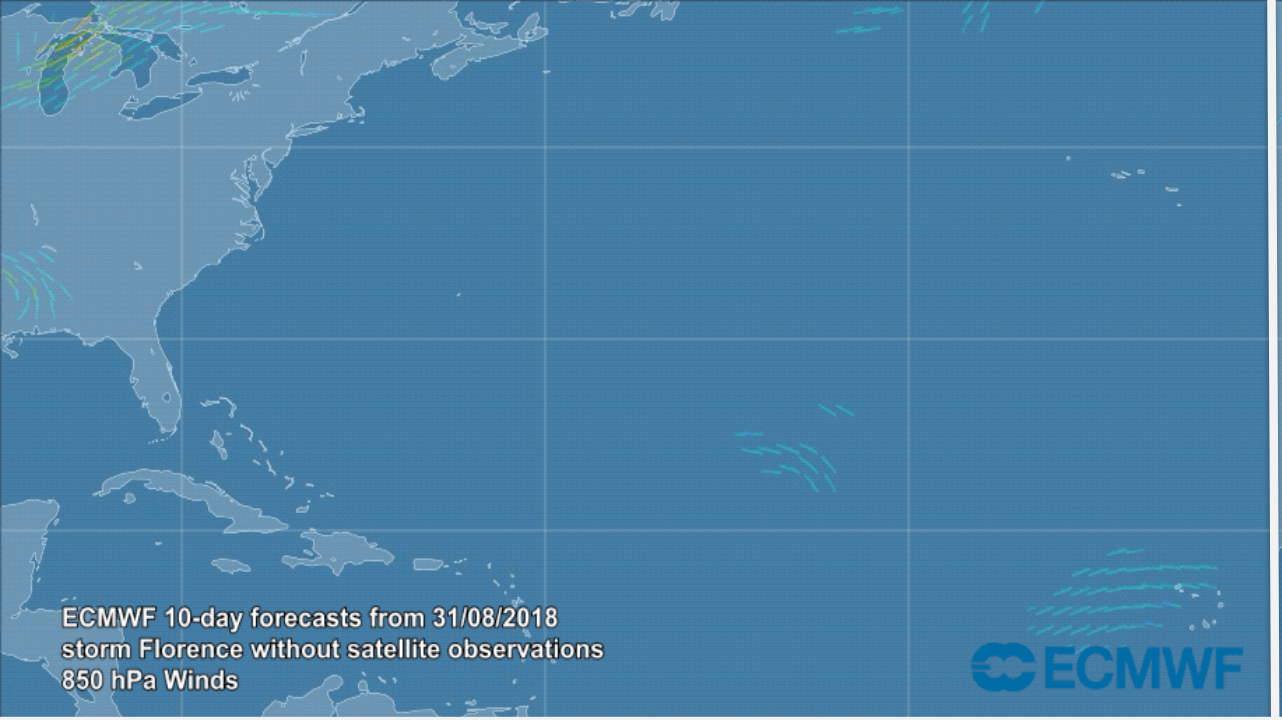


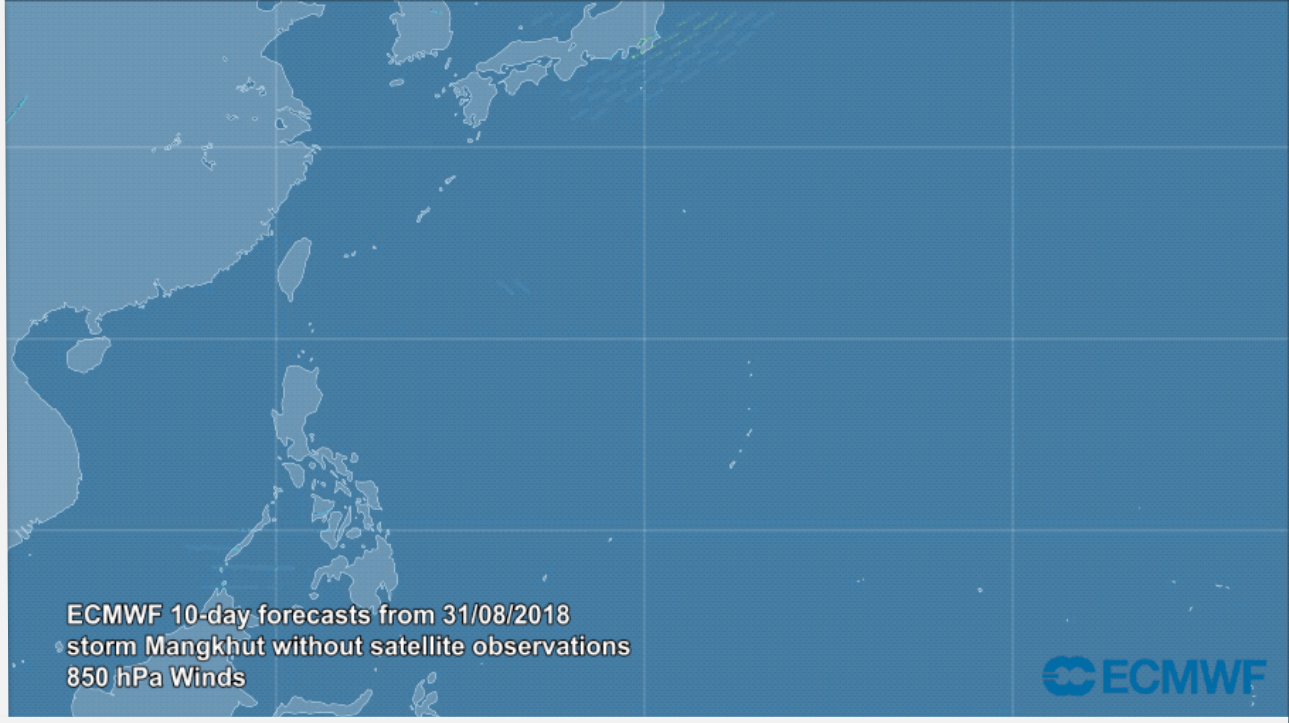
Extra observations assimilated in Continuous DA configuration

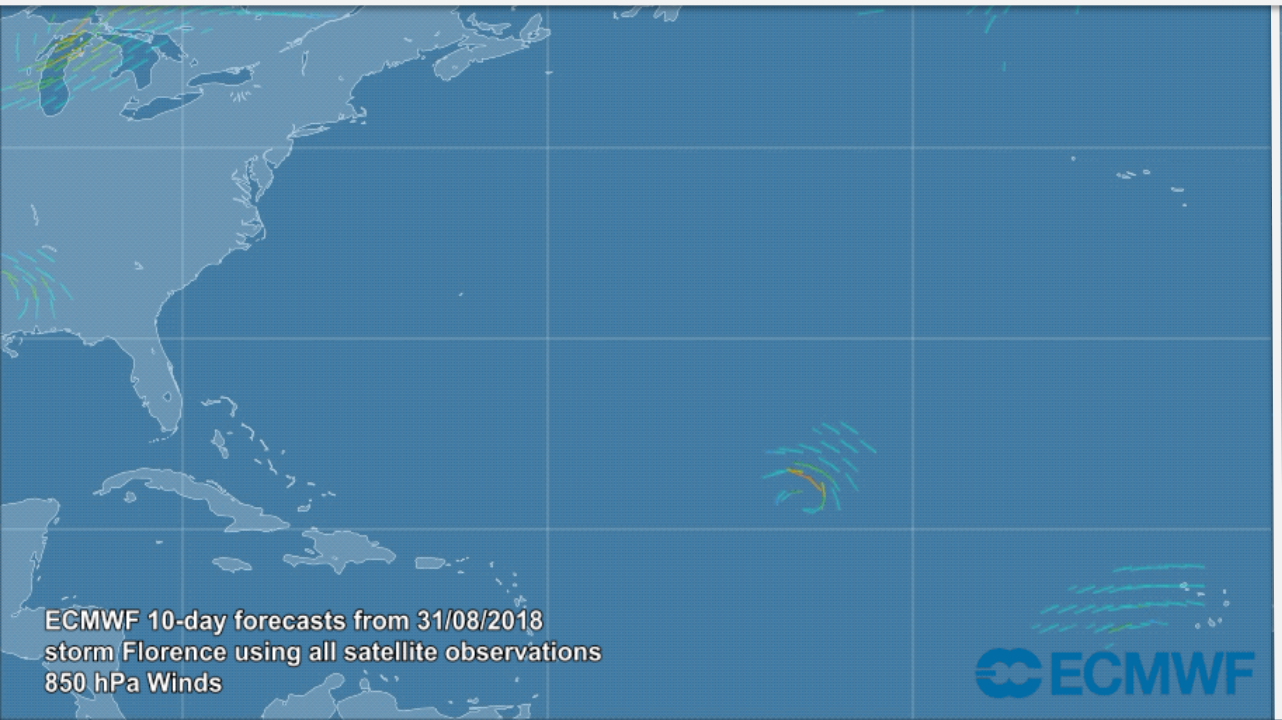


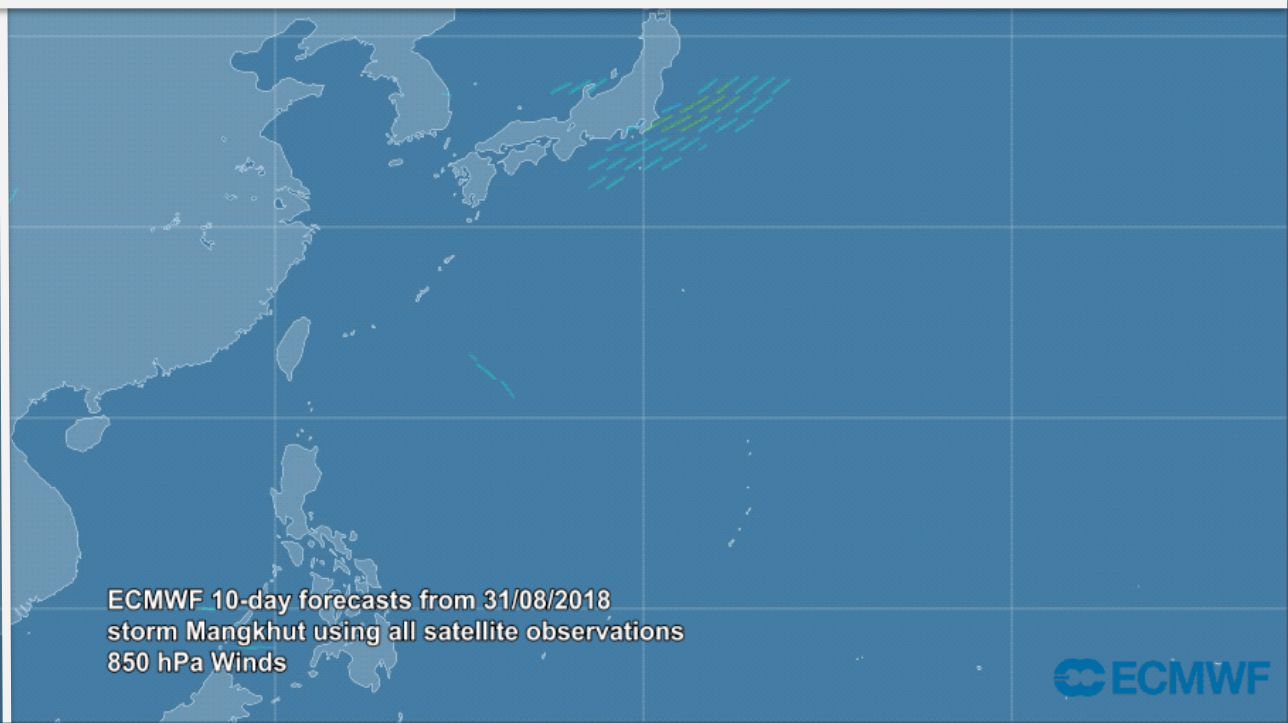
Why satellite observations matter:

The cases of Florence and Mangkhut, 2018

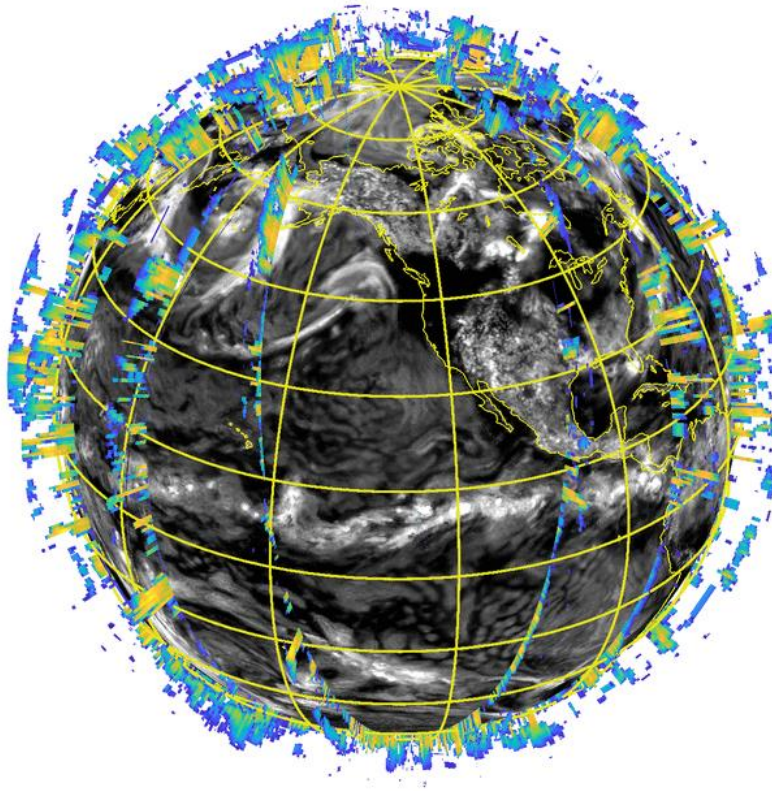

ECMWF 10-day forecasts from 31/08/2018
storm Florence without satellite observations
850 hPa Winds
ECMWF


ECMWF 10-day forecasts from 31/08/2018
storm Mangkhut without satellite observations
850 hPa Winds
ECMWF

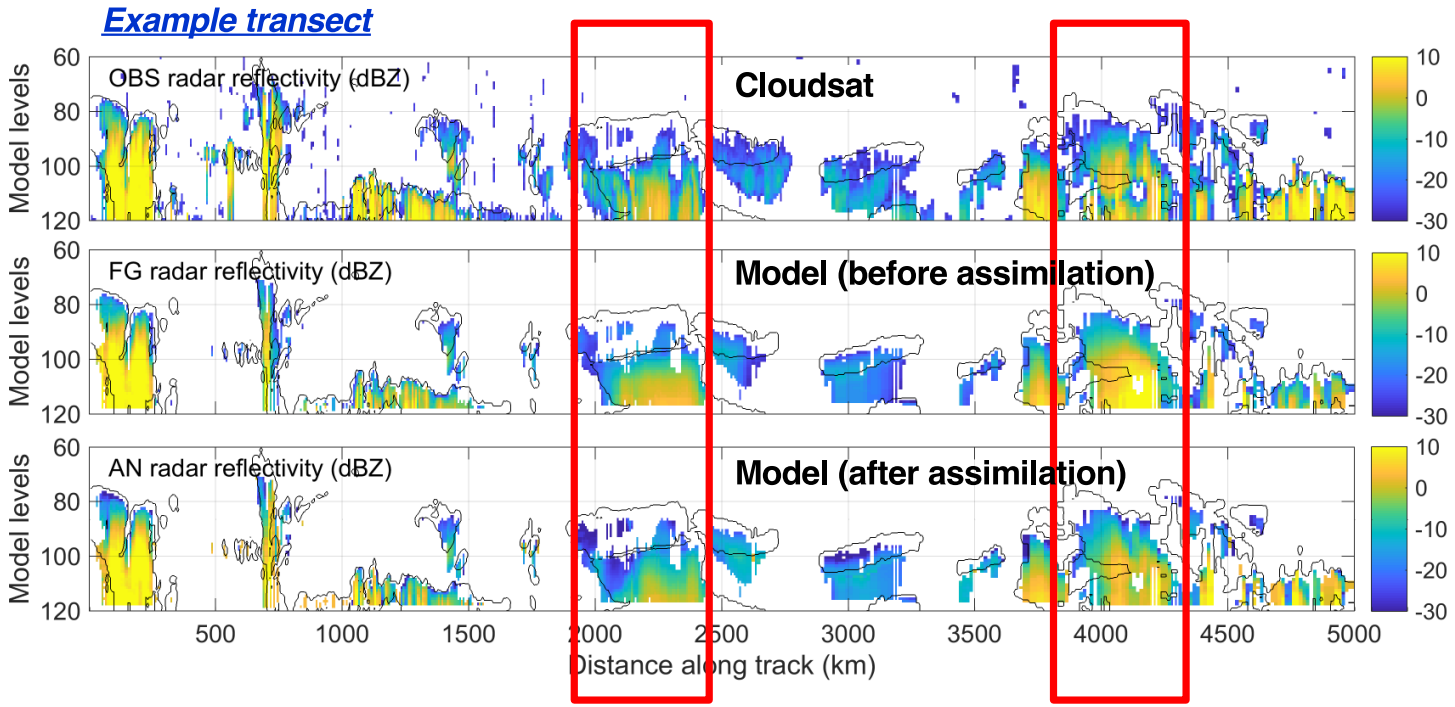

ECMWF 10-day forecasts from 31/08/2018
storm Florence using all satellite observations
850 hPa Winds
ECMWF


ECMWF 10-day forecasts from 31/08/2018
storm Mangkhut using all satellite observations
850 hPa Winds
ECMWF

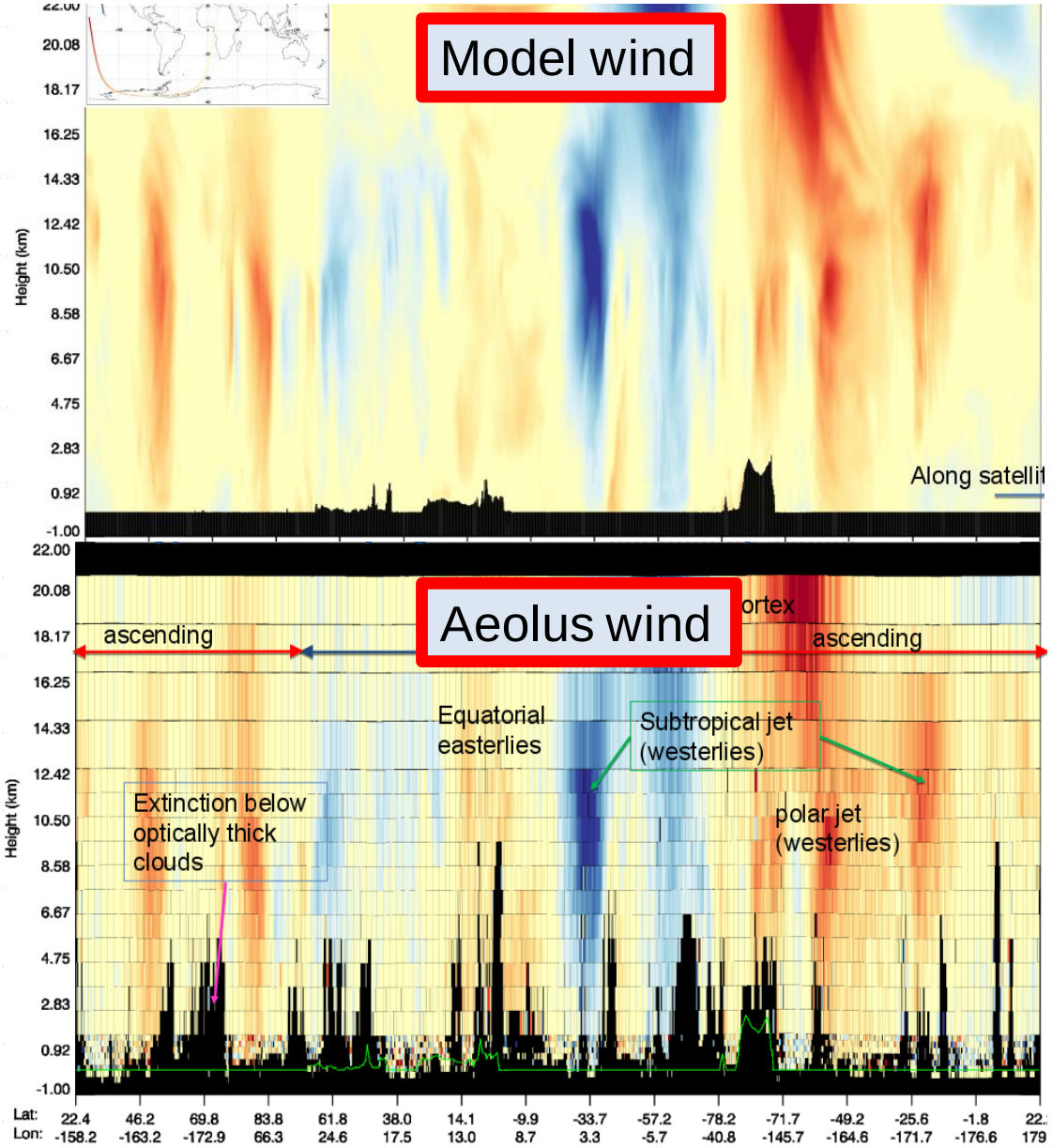
Advancing assimilation of novel instruments:
First-ever direct 4D-Var assimilation of space-borne cloud radar and lidar in NWP



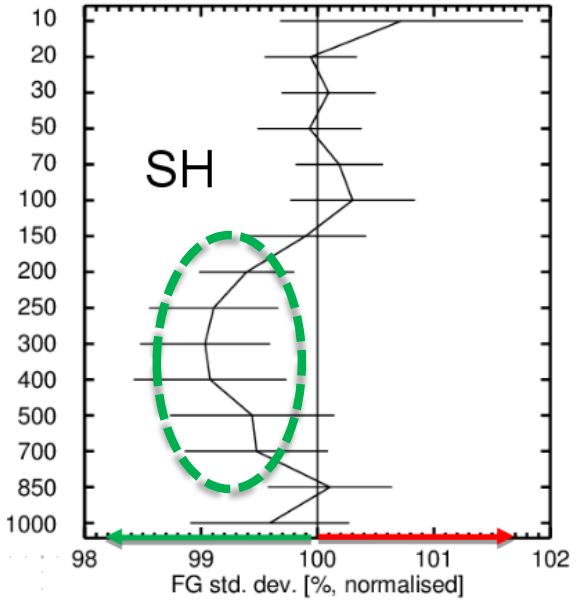
12 hour Cloudsat coverage on model cloud field

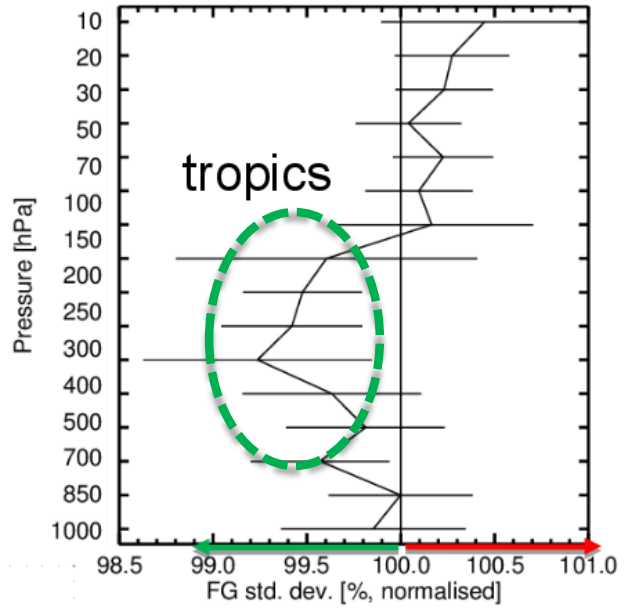


Advancing assimilation of novel instruments:
Aeolus concept successfully demonstrated !

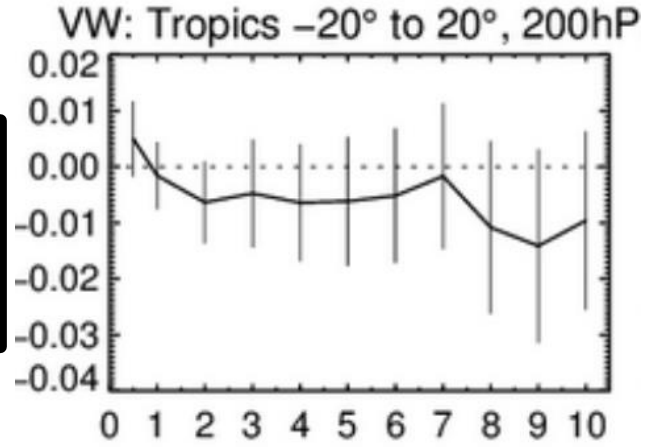


Preliminary assimilation experiments suggests that Aeolus HLOS already improves the ECMWF wind analysis vs independent radiosonde and aircraft observations



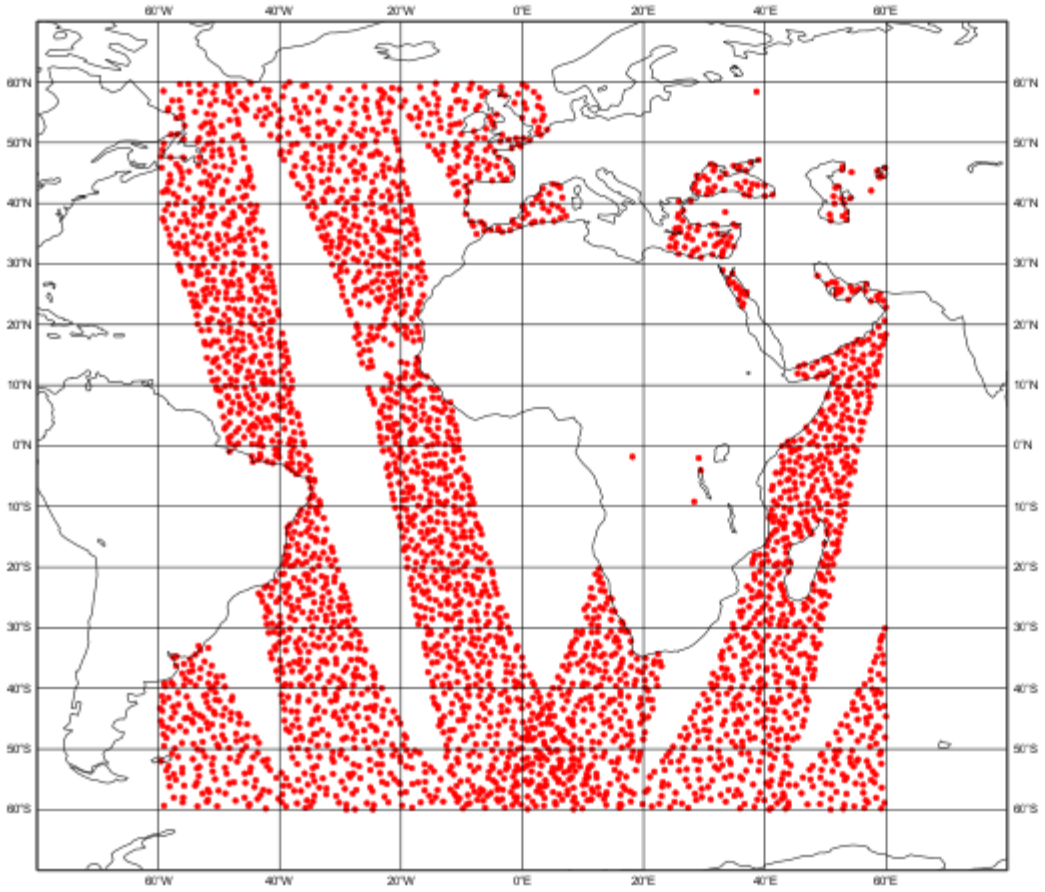


And in the 2 months tested so far there is a small but positive impact of medium-range wind forecasts



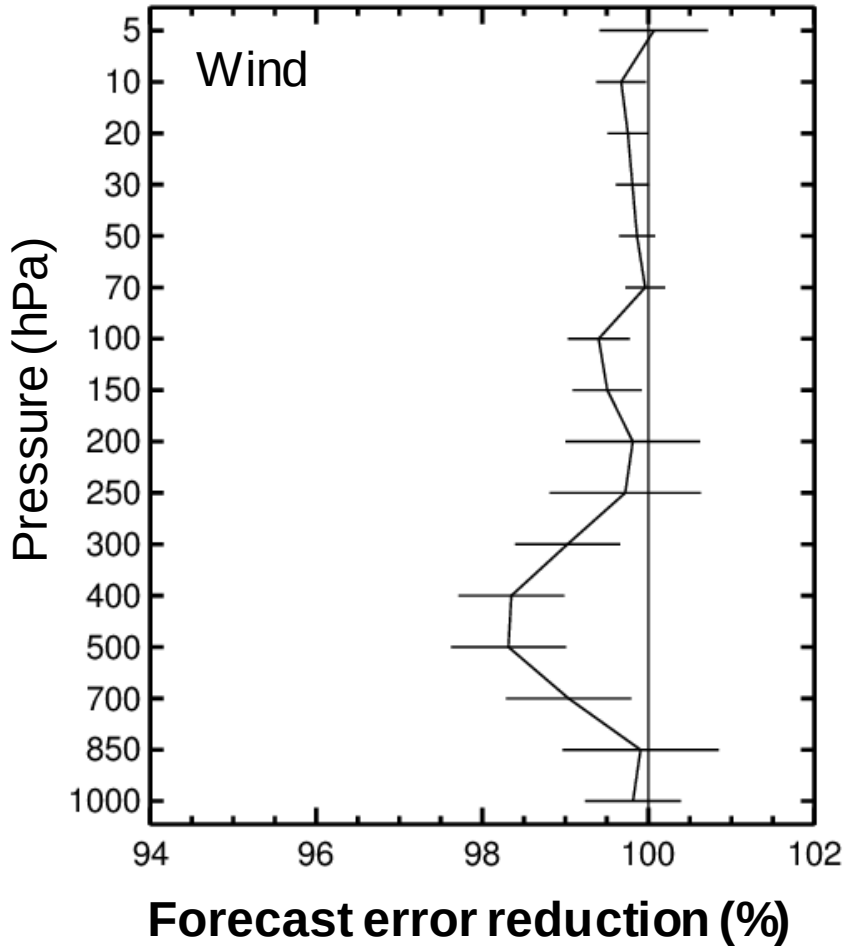
Advancing assimilation of novel instruments:
Impact of future MTG-IRS -- Wind impact increases with better time sampling

Approximate representation of MTG-IRS disk



Metop-A

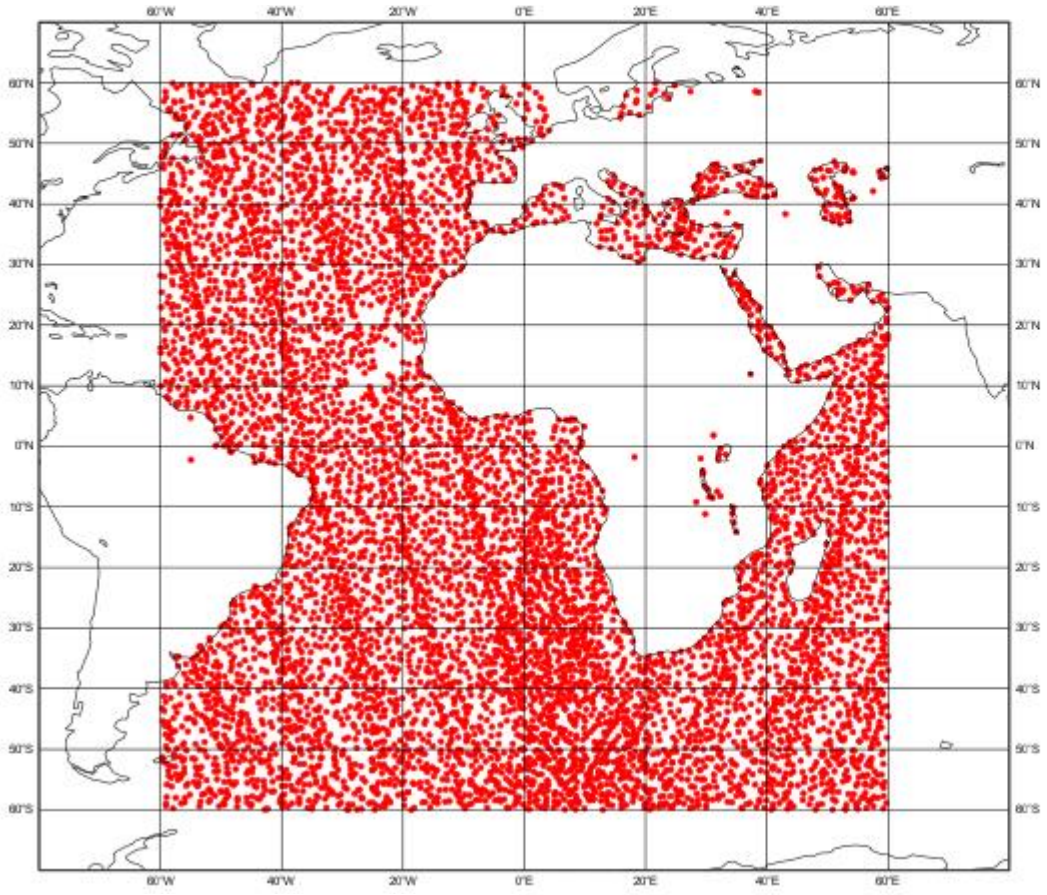
CTL: Conv + AMSU-A
EXP: CTL + Metop-A IASI



Kirsti Salonen

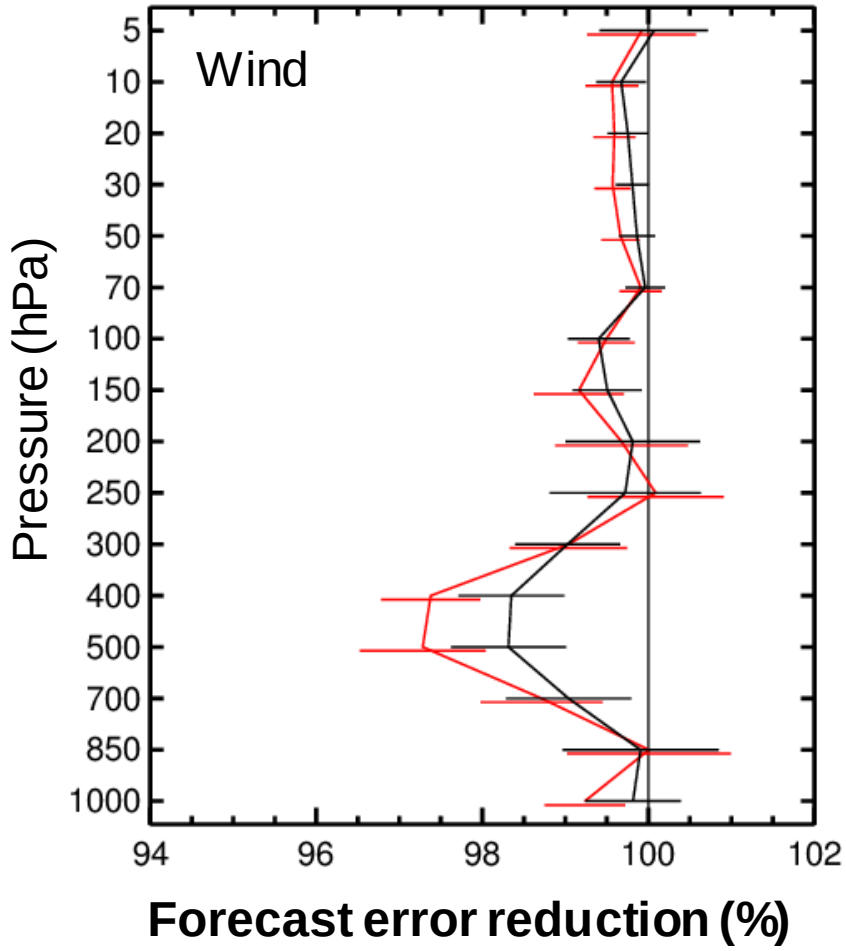
Advancing assimilation of novel instruments:
Impact of future MTG-IRS -- Wind impact increases with better time sampling

Approximate representation of MTG-IRS disk



Metop-A Metop-B

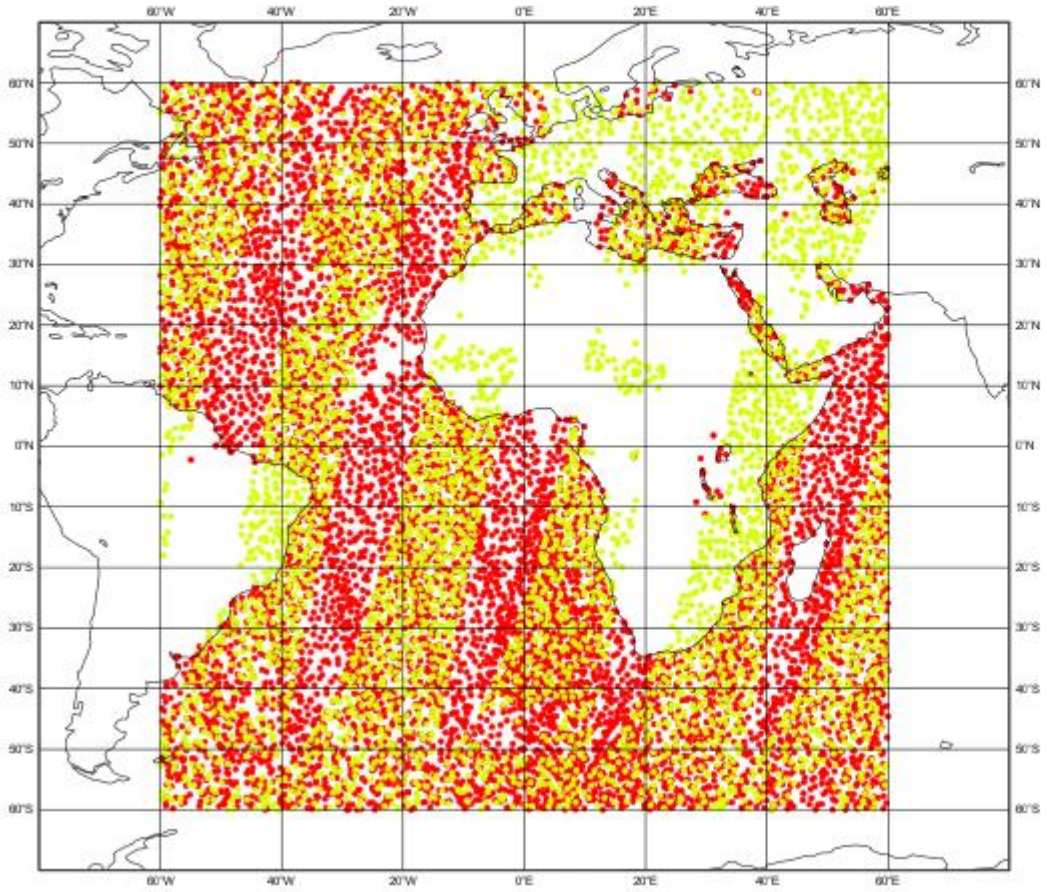
CTL: Conv + AMSU-A
EXP: CTL + 2 IASI



Kirsti Salonen

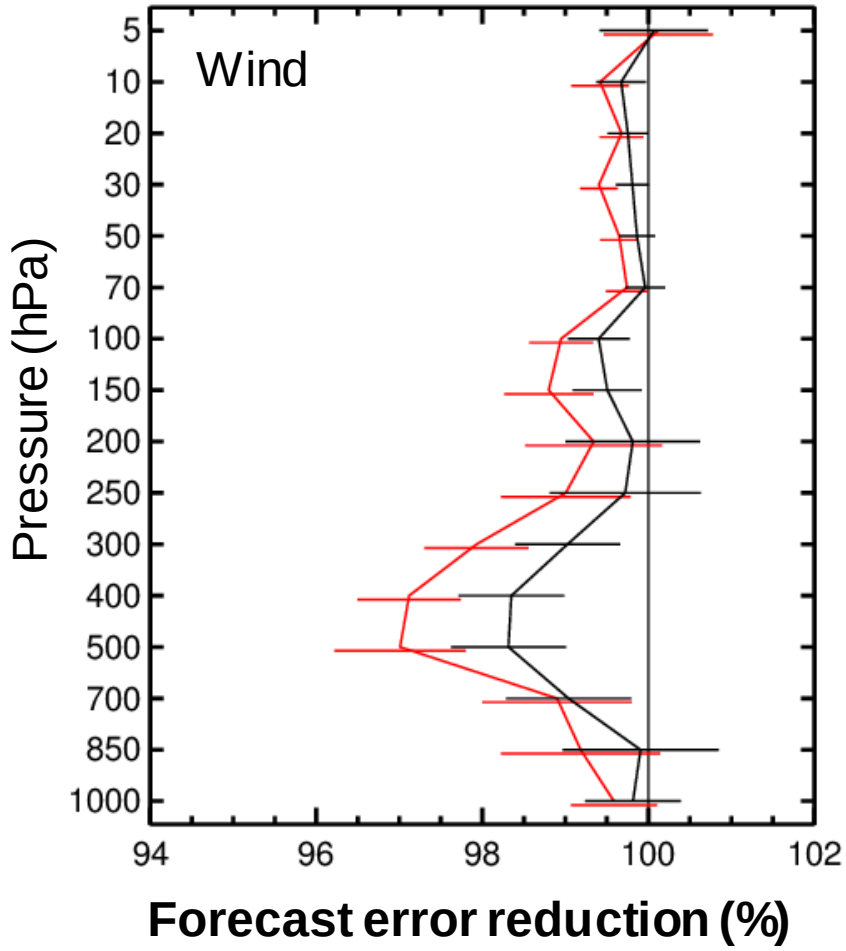
Advancing assimilation of novel instruments:
Impact of future MTG-IRS -- Wind impact increases with better time sampling

Approximate representation of MTG-IRS disk



Metop-A Metop-B CrIS

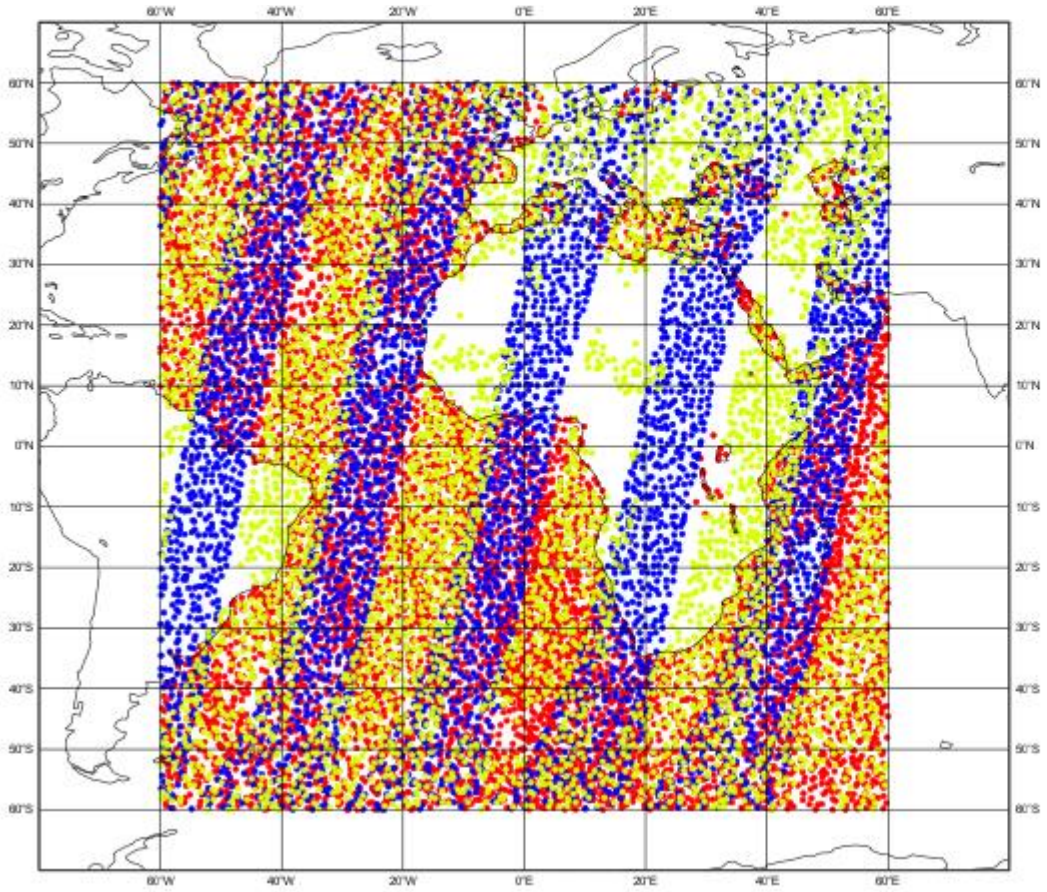
CTL: Conv + AMSU-A
EXP: CTL + 2 IASI + CrIS



Kirsti Salonen

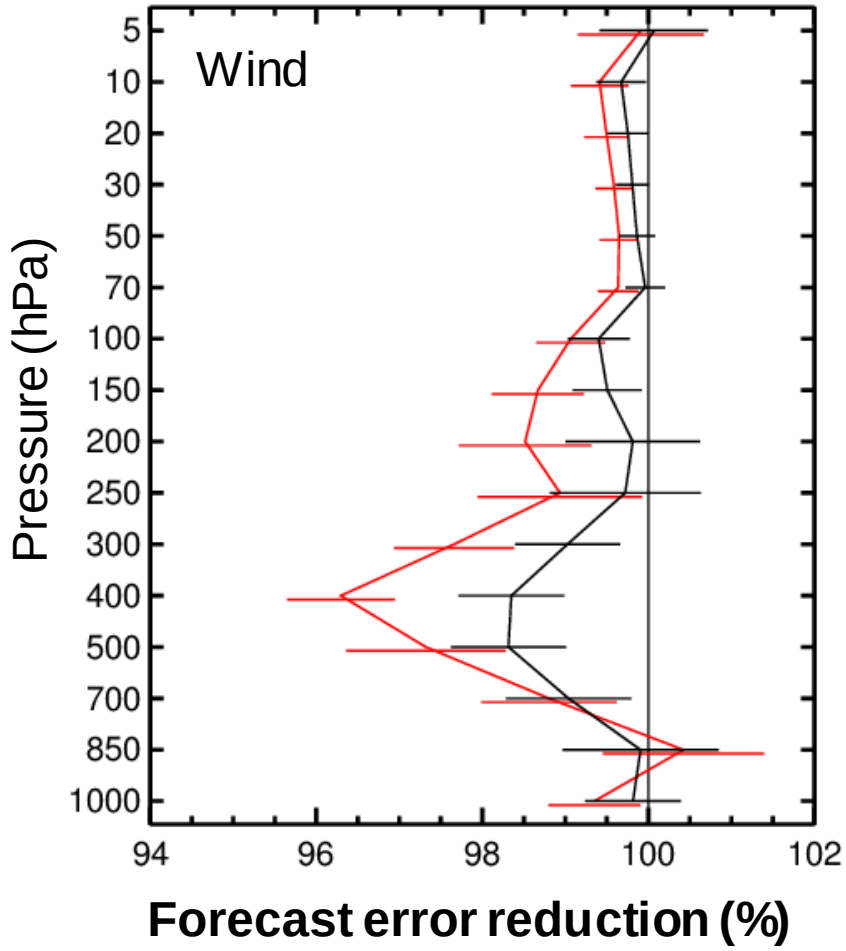
Advancing assimilation of novel instruments:
Impact of future MTG-IRS -- Wind impact increases with better time sampling

Approximate representation of MTG-IRS disk



Metop-A Metop-B CrIS AIRS

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI + CrIS + AIRS

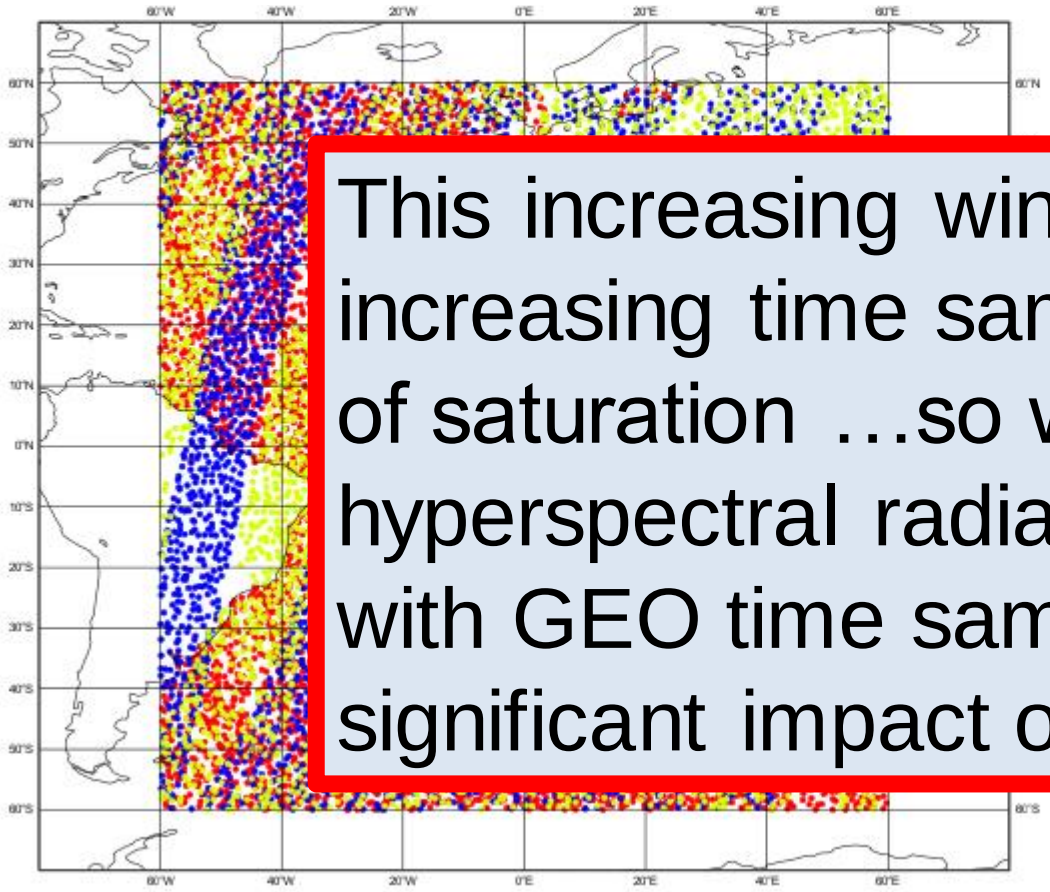


Kirsti Salonen

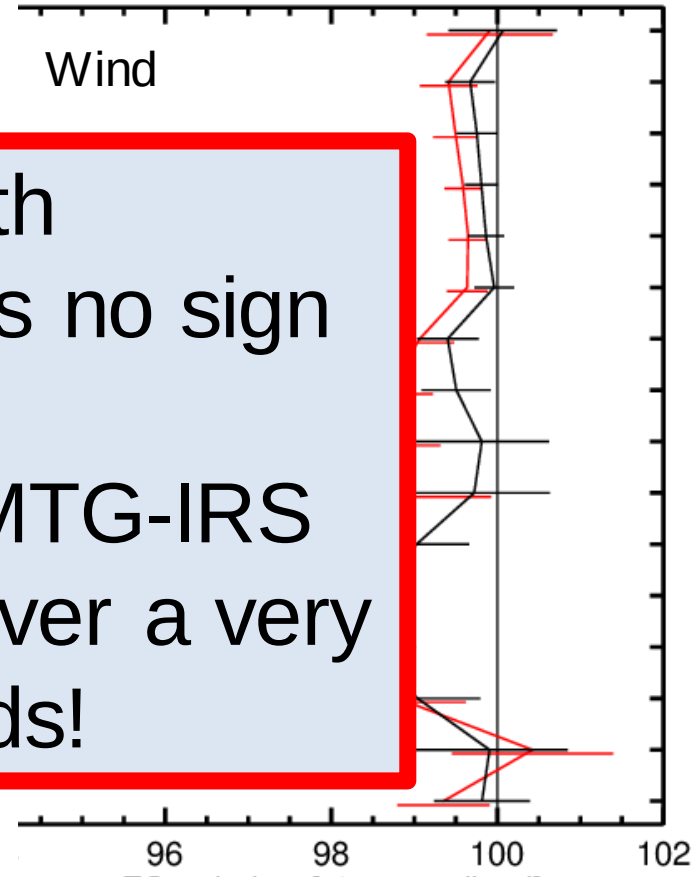
Advancing assimilation of novel instruments:
Impact of future MTG-IRS -- Wind impact increases with better time sampling

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI + CrIS + AIRS

Approximate representation of MTG-IRS disk



Metop-A Metop-B CrIS AIRS



Forecast error reduction (%)

This increasing wind impact with increasing time sampling shows no sign of saturation …so we expect hyperspectral radiances from MTG-IRS with GEO time sampling to deliver a very significant impact on NWP winds!

Satellite Data for model verification

- CM SAF surface radiation data (SARAH-ICDR) have become a cornerstone of the operational forecast validation at ECMWF
- CM SAF data spatially extends the information provided through SYNOP observations

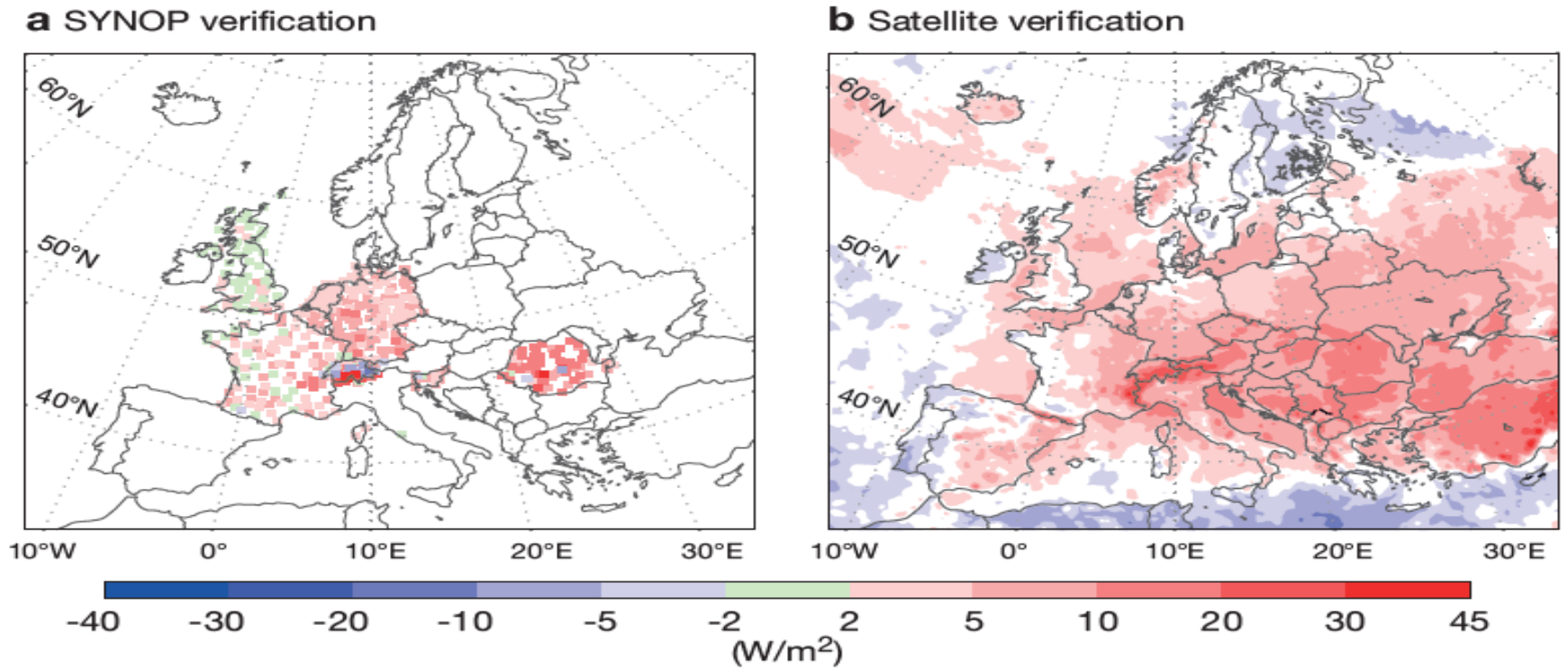


FIGURE 4 Bias in downward surface solar radiation (24-hour averages) at forecast day 2 in November–December–January 2017/18 from (a) verification against SYNOP and (b) verification against the corresponding satellite product from the Climate Monitoring Satellite Application Facility (CM SAF).

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Thomas Haiden

C3S
Copernicus
Climate Change Service

THE EUROPEAN UNION COPERNICUS PROGRAMME AND ITS CLIMATE CHANGE AND ATMOSPHERE MONITORING SERVICES

CAMS
Copernicus
Atmosphere Monitoring
Service

Copernicus
Europe's eyes on Earth

European Commission

ECMWF

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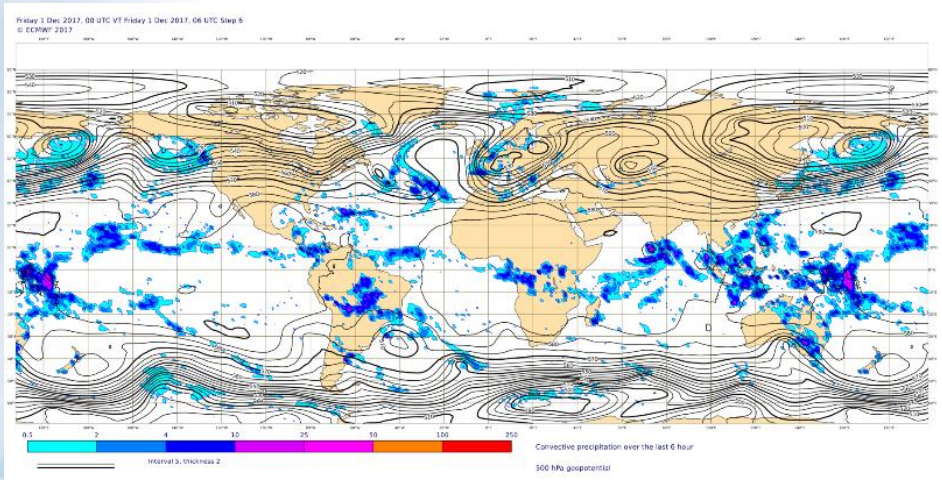
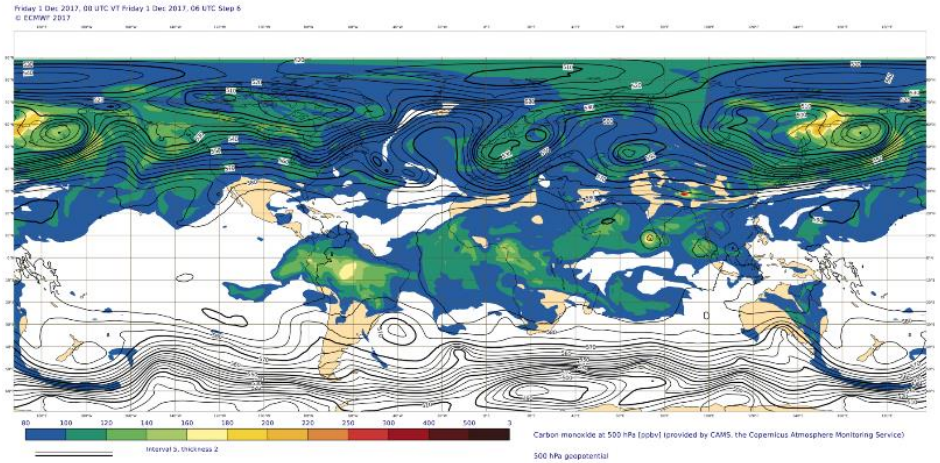
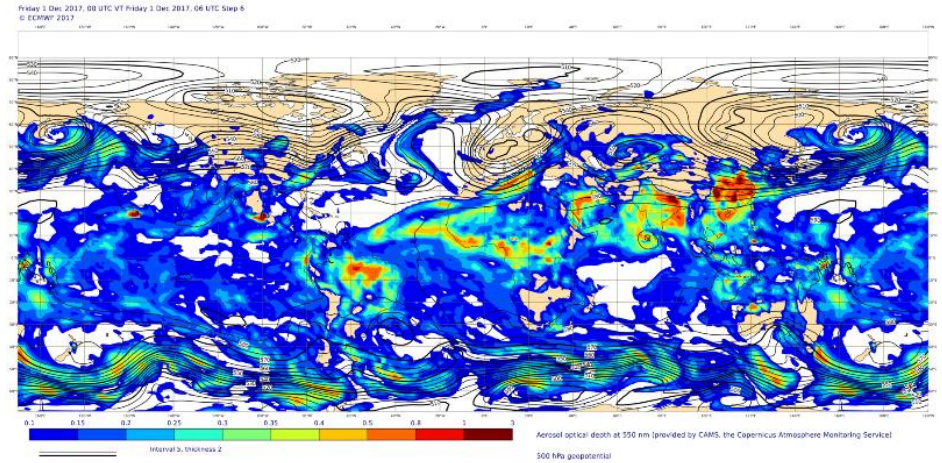
CAMS IFS CONFIGURATION

Atmosphere Monitoring





CO



AOD

ECMWF's NWP forecasting system (IFS) has been extended with atmospheric composition variables and relevant observations. Over **70 satellite instruments** are used daily.

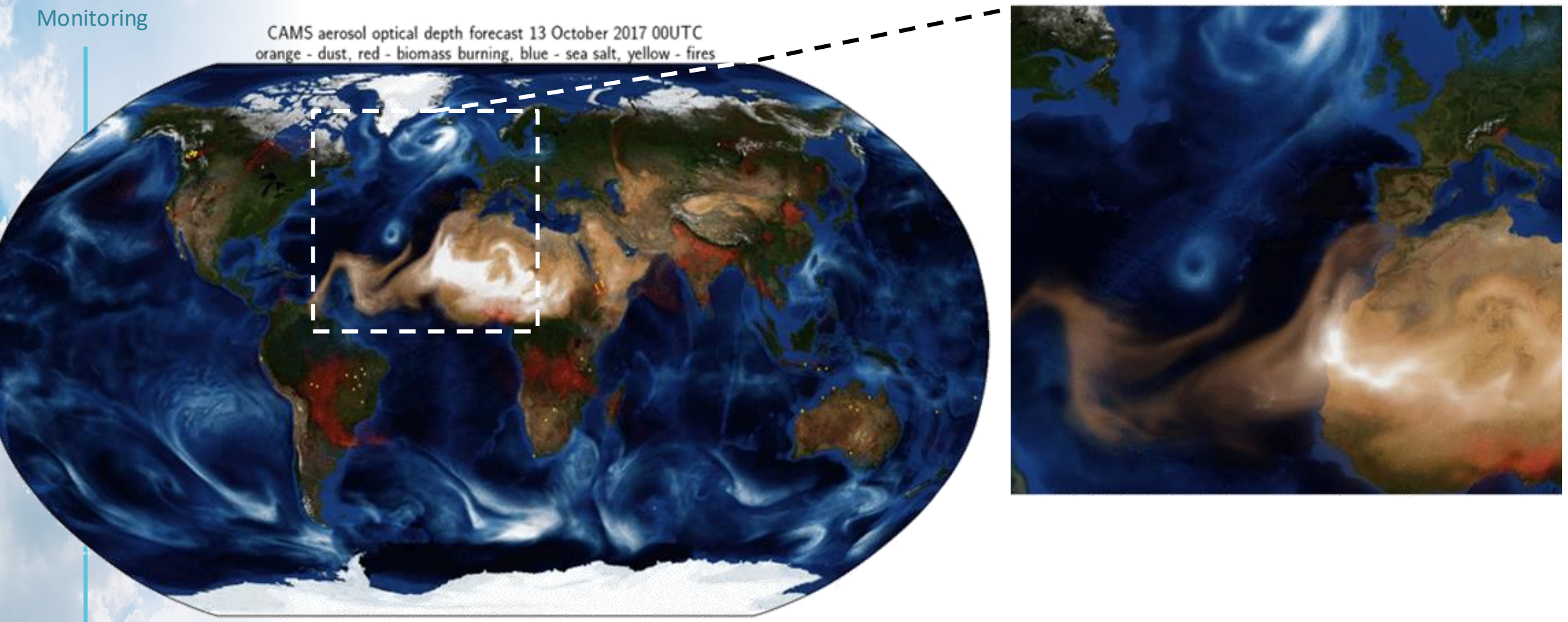
Species	Instruments
O_3	**OMI**, **SBUV**, **GOME-2**, **MLS**, **OMPS**, S5p
CO	**IASI**, **MOPITT**, S5p
NO_2	**OMI**, GOME-2, S5p
SO_2	**OMI**, **GOME-2**, S5p
Aerosol	**MODIS**, **PMAp**, VIIRS, S3
CO_2	**GOSAT**, OCO-2
CH_4	**GOSAT**, **IASI**, S5p

Operational 5-day forecasts twice a day at **40 km resolution** and 60 levels.

ECMWF Copernicus Europe's eyes on Earth European Commission

CAN I TRUST CAMS PRODUCTS? AN EXAMPLE.

Atmosphere Monitoring

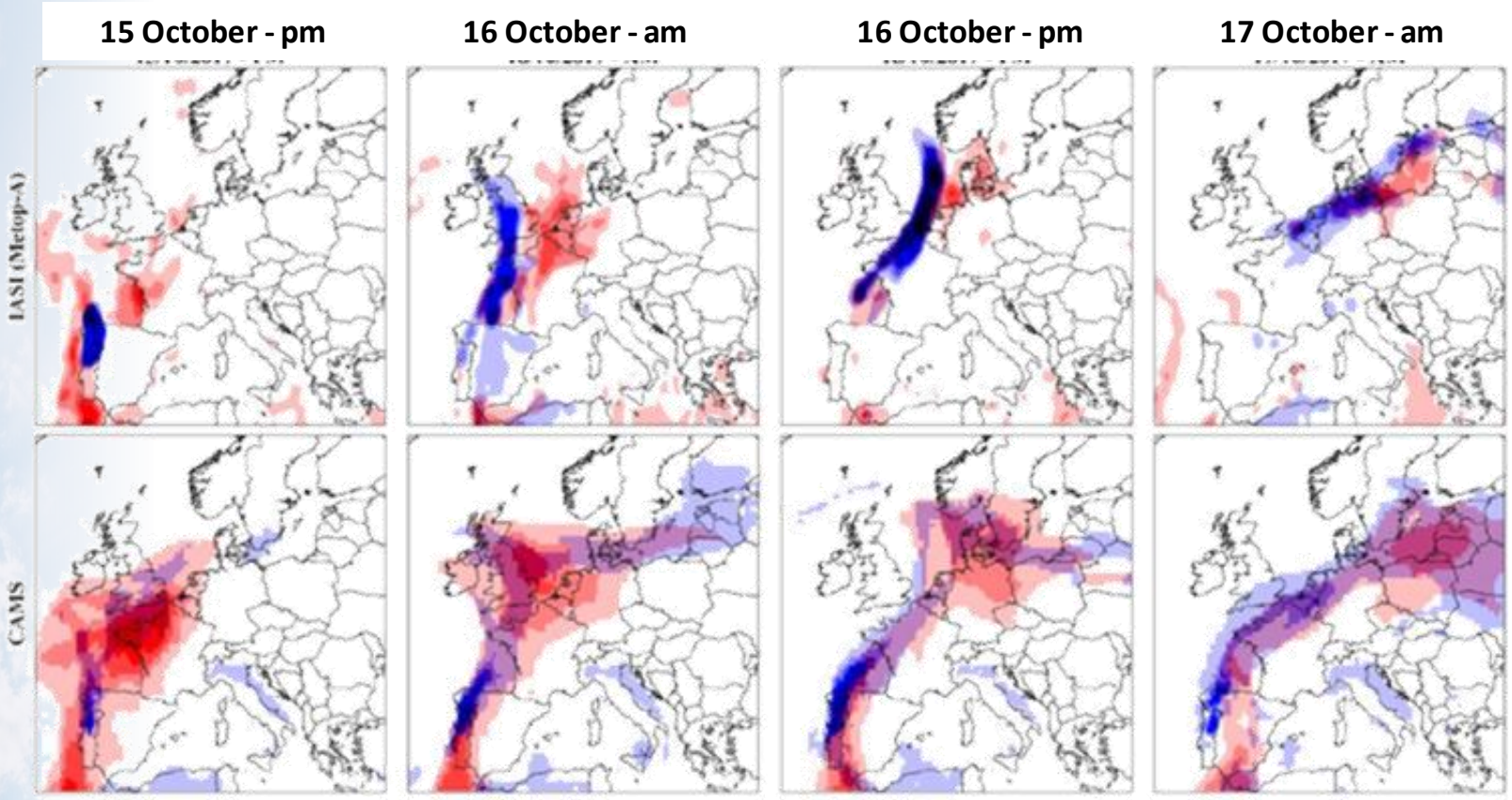


CAMS AOD forecasts initialized on 13 October 2017. Storm Ophelia transported a mixture of smoke, dust and sea salt aerosol across Europe leading to the sun appearing red and to yellow skies.

ECMWF Copernicus Europe's eyes on Earth European Commission

Atmosphere Monitoring

HURRICANE OPHELIA AND CAMS AEROSOL FORECASTS



IASI observations
Dust
NH_3

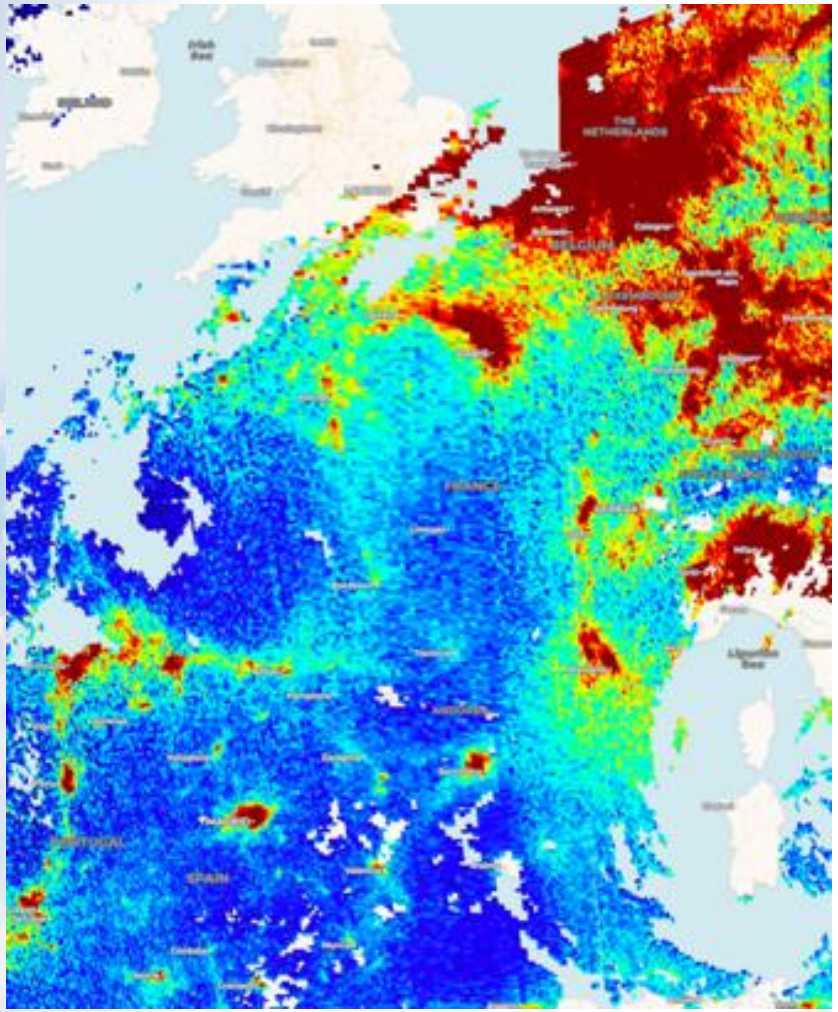
CAMS AOD contributions
Dust
Biomass burning

Figure c/o L. Clarisse (ULB) from Clerbaux et al.

- Ophelia winds advected Saharan dust closely followed by smoke from fires in Portugal and NW Spain across northern Europe over several days from 16 October.
- Near-real time monitoring of the event by CAMS showed excellent agreement with NRT IASI observations of dust and ammonia.

ECMWF Copernicus Europe's eyes on Earth European Commission

Uptake of Sentinel-5P in CAMS



Example: NO_2 tropospheric column from Copernicus Sentinel-5P (7/10/2018)

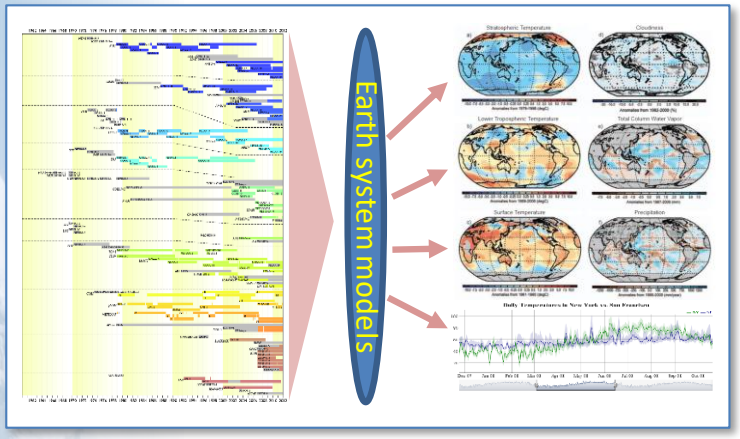
A year after launch, thanks to excellent collaboration with ESA and entities in charge of Level-2 processing, 6 products are already used in the CAMS system.

Operations @ECMWF could start on the same day as ESA released officially each product.

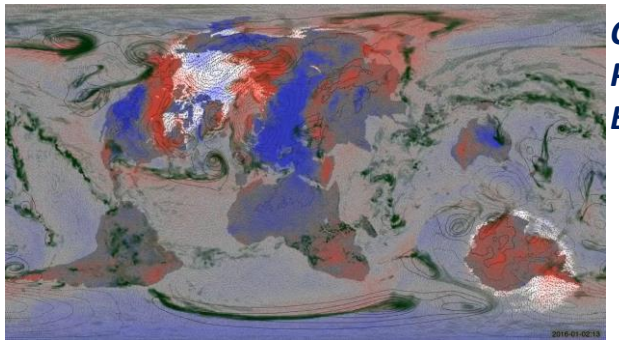
Species	Status	Since
Ozone	Operational assimilation	4/12/2018
NO_2	Operational monitoring	11/07/2018
CO	Operational monitoring	22/11/2018
SO_2	Off-line monitoring	22/11/2018
HCHO	Off-line monitoring	22/11/2018
CH_4	Off-line monitoring	22/11/2018

Climate Change

C3S portfolio

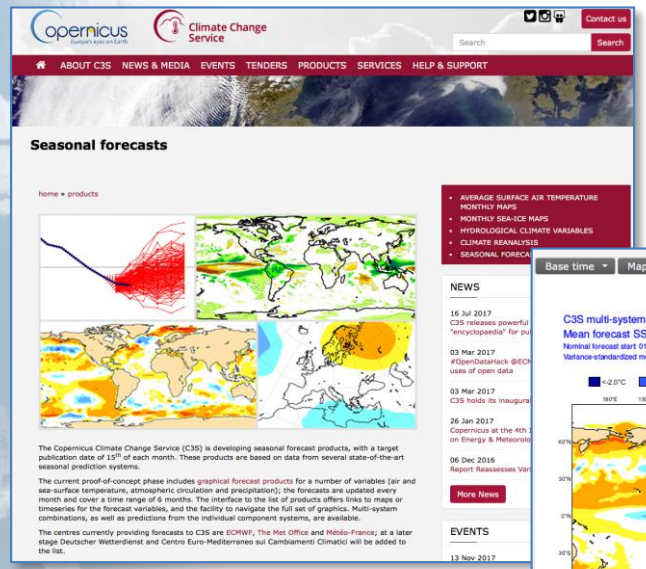


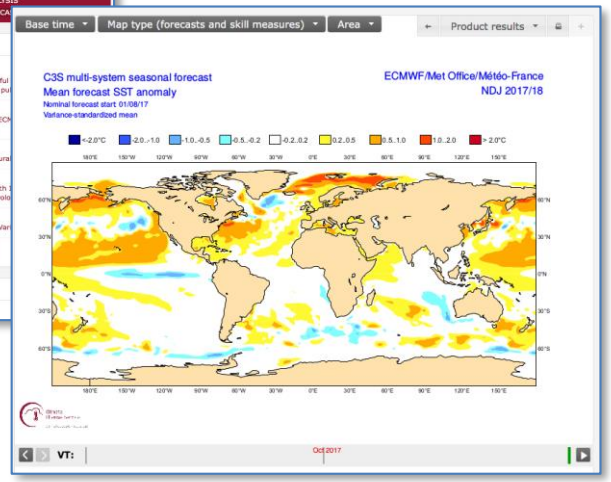
Observations, climate data records and climate Reanalyses



Courtesy: Philip Brohan

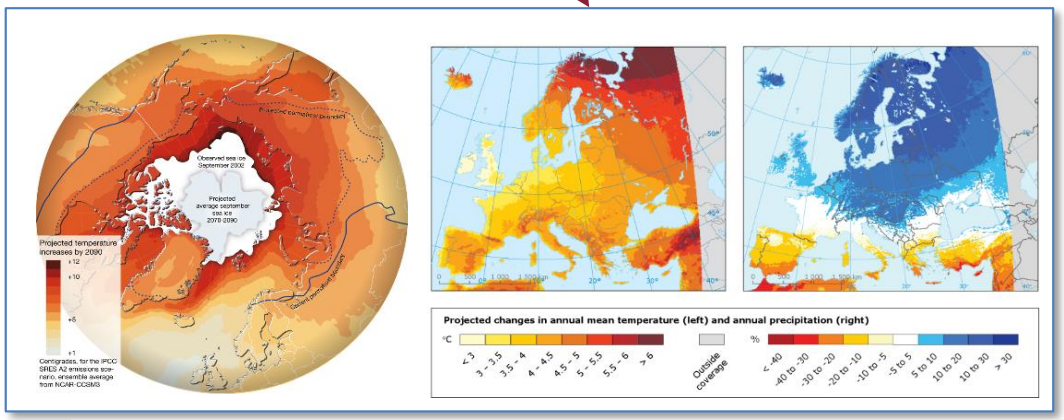
Seasonal forecast data and products





Climate model simulations

Sectoral climate impact indicators



http://climate.copernicus.eu

ECVs evolution in C3S (satellite data)

Climate Change

			C3S_312a				
				C3S_312b			
		GCOS	2017	2018	2019	2020	2021
Atmospheric physics							
	Precipitation	4.3.5		Lot 1			
	Surface Radiation Budget	4.3.6					
	Water Vapour	4.5.3					
	Cloud Properties	4.5.4					
	Earth Radiation Budget	4.5.5					
Atmospheric composition							
	Carbon Dioxide	4.7.1	Lot 6		Lot 2		
	Methane	4.7.2	Lot 6				
	Ozone	4.7.4	Lot 4				
	Aerosol	4.7.5	Lot 5				
Ocean							
	Sea Surface Temperature	5.3.1	Lot 3		Lot 3		
	Sea Level	5.3.3	Lot 2				
	Sea ice	5.3.5	Lot 1				
	Ocean Colour	5.3.7					
Land hydrology & cryosphere							
	Lakes	6.3.4			Lot 4		
	Glaciers	6.3.6	Lot 8				
	Ice sheets and ice shelves	6.3.7					
	Soil moisture	6.3.16	Lot 7				
Land biosphere							
	Albedo	6.3.9	Lot 9		Lot 5		
	Land Cover	6.3.10					
	Fraction of Absorbed Photosyntheti	6.3.11	Lot 9				
	Leaf Area Index	6.3.12	Lot 9				
	Fire	6.3.15					
			2017	2018	2019	2020	2021

Coordination with CM-SAF / ROM SAF / ESA CCI / Uni. Maryland / NASA / NOAA

Coordination with ESA-CCI and other national projects, CAMS

Coordination with ESA-CCI, CMEMS

Coordination with ESA-CCI, GloboLakes, Arc-Lake, HydroWeb

Coordination with ESA-CCI, CGL, QA4ECV, LSA-SAF

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Copernicus Europe's eyes on Earth

ECMWF

Climate Change

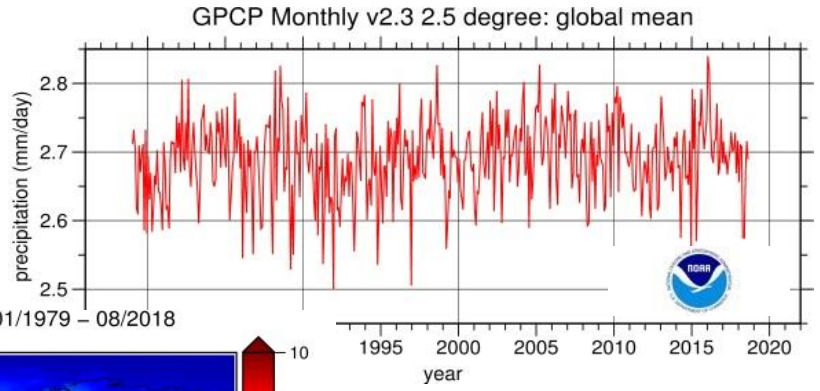
ECV products derived from observations C3S_312b-Lot1

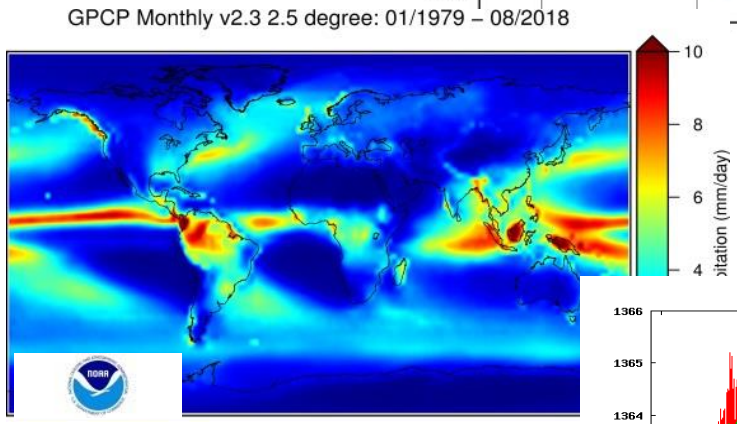
Addresses the following five Essential Climate Variables (ECVs):

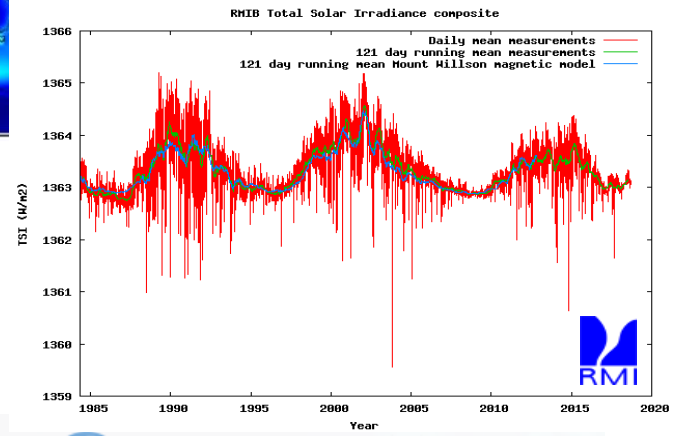
- precipitation
- surface radiation budget
- water vapour
- cloud properties and
- Earth radiation budget.

Several Thematic Climate Data Records (TCDRs) and Interim Climate Data Records (ICDRs) to be brokered and to be generated for C3S, associated with all services to provide an easy access via the Climate Data Store (CDS). For all ECVs, and largely consistent with the provided TCDRs, respective ICDRs will be provided.

TCDR examples:







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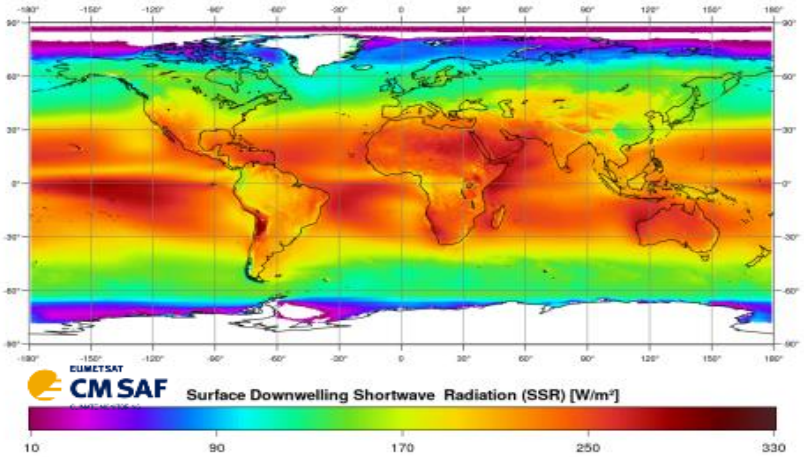
CM SAF Contributions to C3S: TCDRs

In more detail, CM SAF TCDRs are addressing

- ECV surface radiation budget

  CLARA-A2 surface radiation



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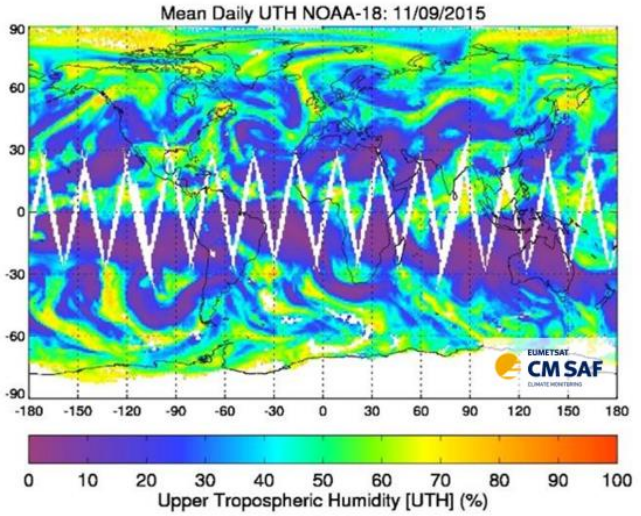
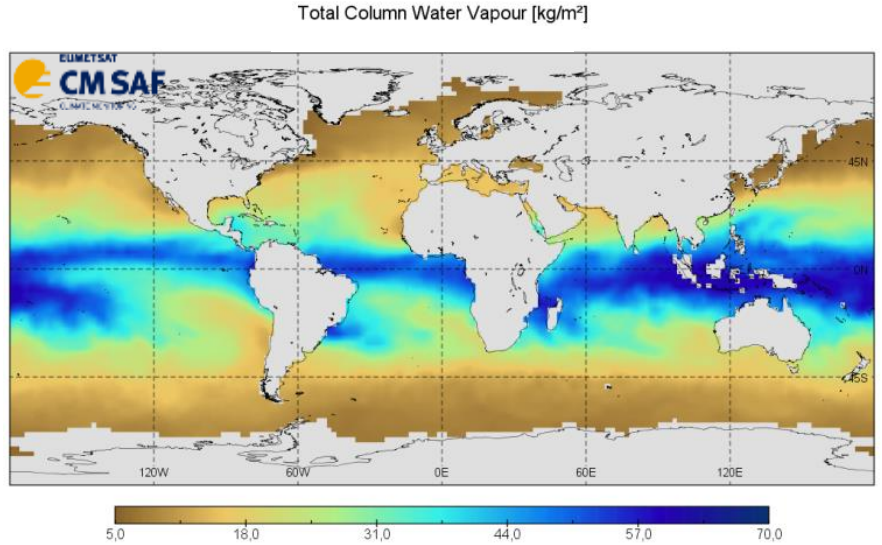
- ECV water vapour

  Total Column Water Vapour (HOAPS)

  Upper Tropospheric Humidity





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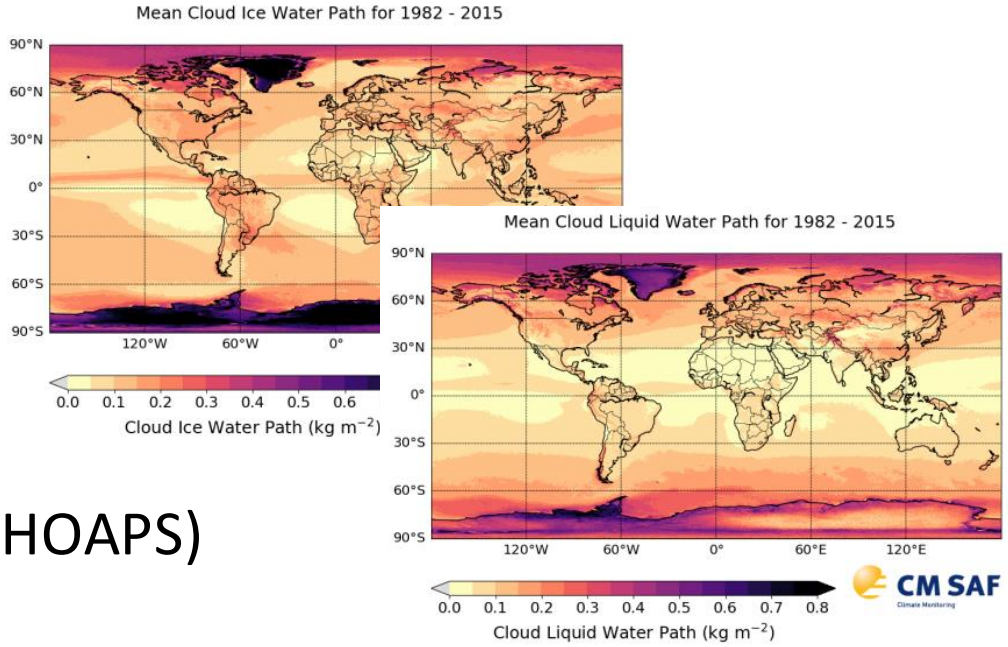
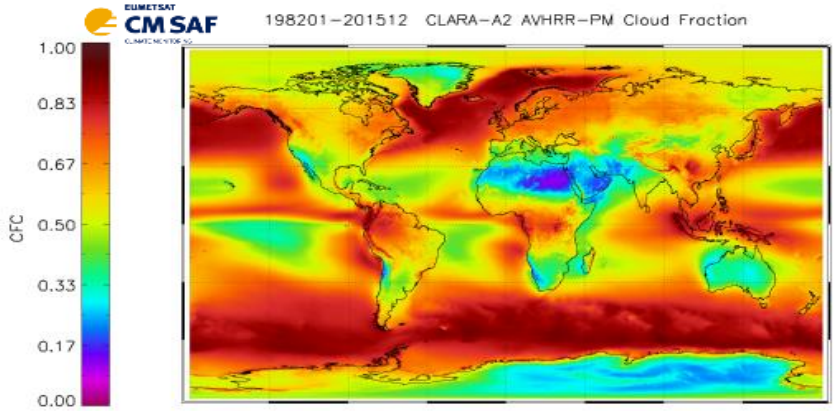
  Upper Tropospheric Humidity

- ECV cloud properties

  CLARA-A2 cloud properties





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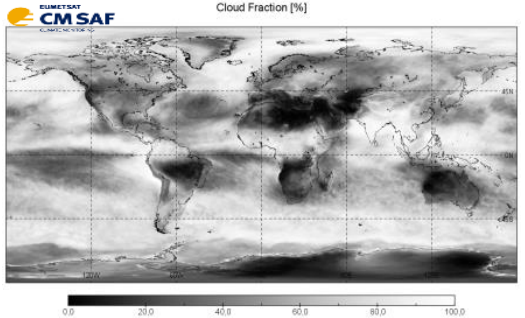
CM SAF Contributions to C3S: ICDR

The TCDR's have been delivered and will become visible via the CDS shortly

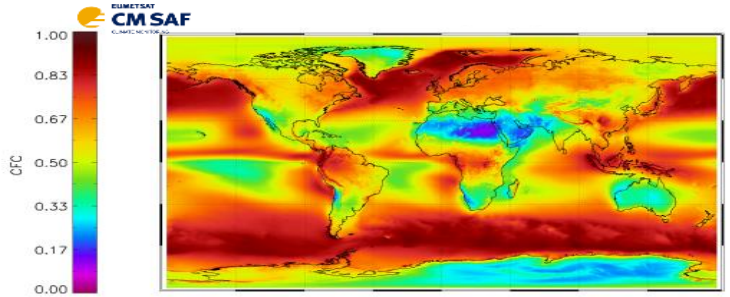
Through EQC C3S will provide Feedback to CM SAF products

For the ECV's **Surface Radiation** & **Cloud Properties**, C3S will rely on the ICDRs generated at CM SAF as soon as they become available (Q3/Q4 2019)

TCDR: Long-Term average



ICDR: Latest data



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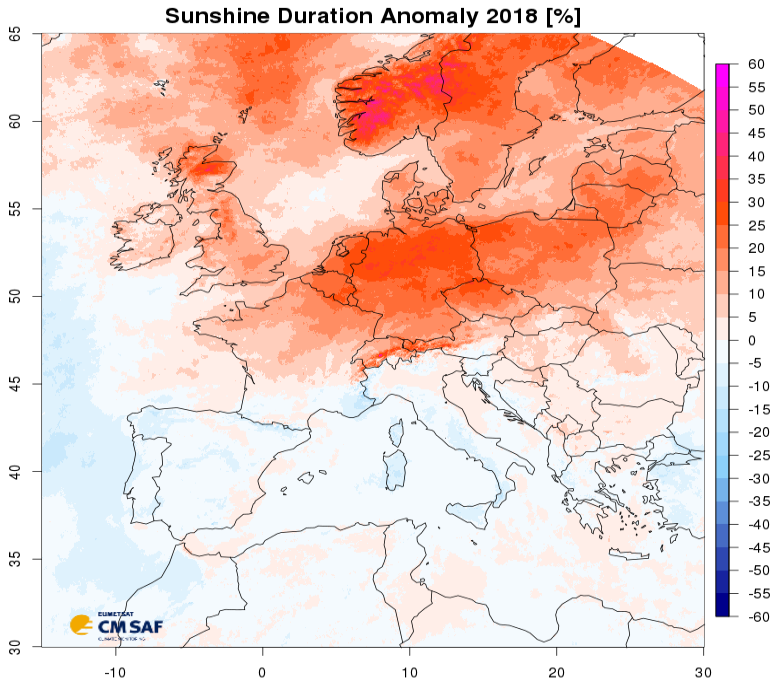
CM SAF Contributions to C3S

Support to European State of the Climate 2018

-> CM SAF Sunshine Duration for Europe

Sunshine duration in 2018 was exceptionally high across many parts of Europe. Some areas of central and northern Europe experienced up to 40% more sunshine hours than average, and in Germany it was the sunniest year on record. Only in southern Europe was sunshine duration below average.



The complete report is available online:
climate.copernicus.eu/ESOTC

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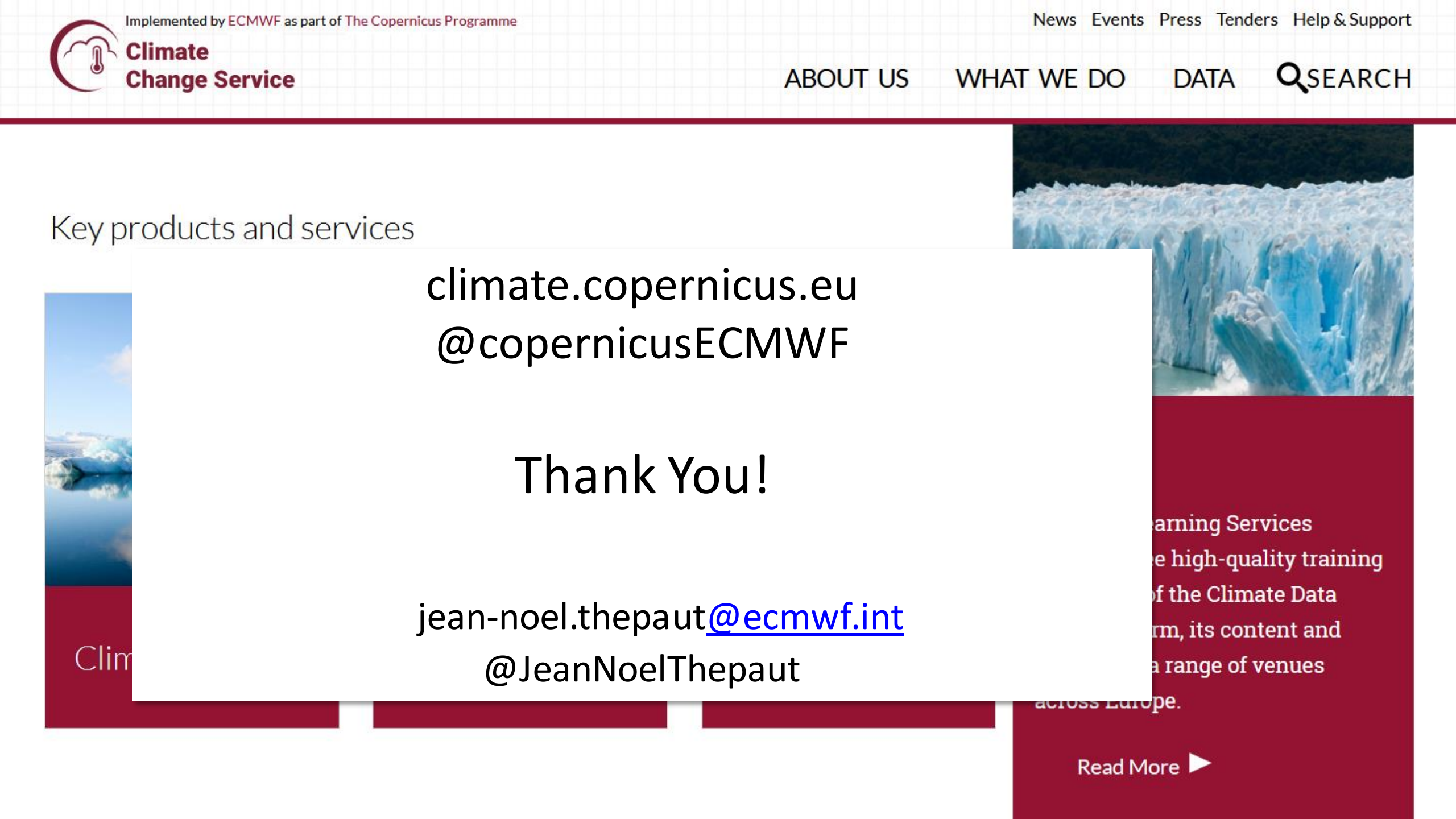
Conclusions

- Satellite Observations are key for ECMWF core NWP:
  - Model development
  - Model validation
  - Model initialization
  - Model verification
- ECMWF strategy and partnerships push R&D to increase the exploitation of satellite data and maximize their benefit
- Copernicus Services further the critical importance of satellite products in many application areas
- Collaboration within Europe is a multiplying factor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