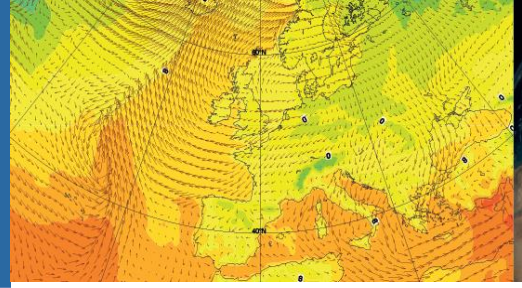




ECMWF: research developments and future plans

Irina Sandu

ECMWF, Shinfield Park, RG2 9AX, Reading, UK

ECMWF 2016-2025 strategy: overview

Forecast targets by 2025:

- Ensemble predictions of **high impact weather** up to two weeks ahead
- Seamless approach, aiming towards predictions of **large scale patterns and regime transitions** up to four weeks ahead and **global-scale anomalies** up to a year ahead

Research goals by 2025:

- Research at frontiers of knowledge
- Ensemble-based analyses and predictions that raise the international bar for quality and operational reliability reaching a 5 km horizontal resolution

Together - More collaboration:

- Partnering with universities, NMS, research institutes – OpenIFS
- Pooling expertise to improve scalability

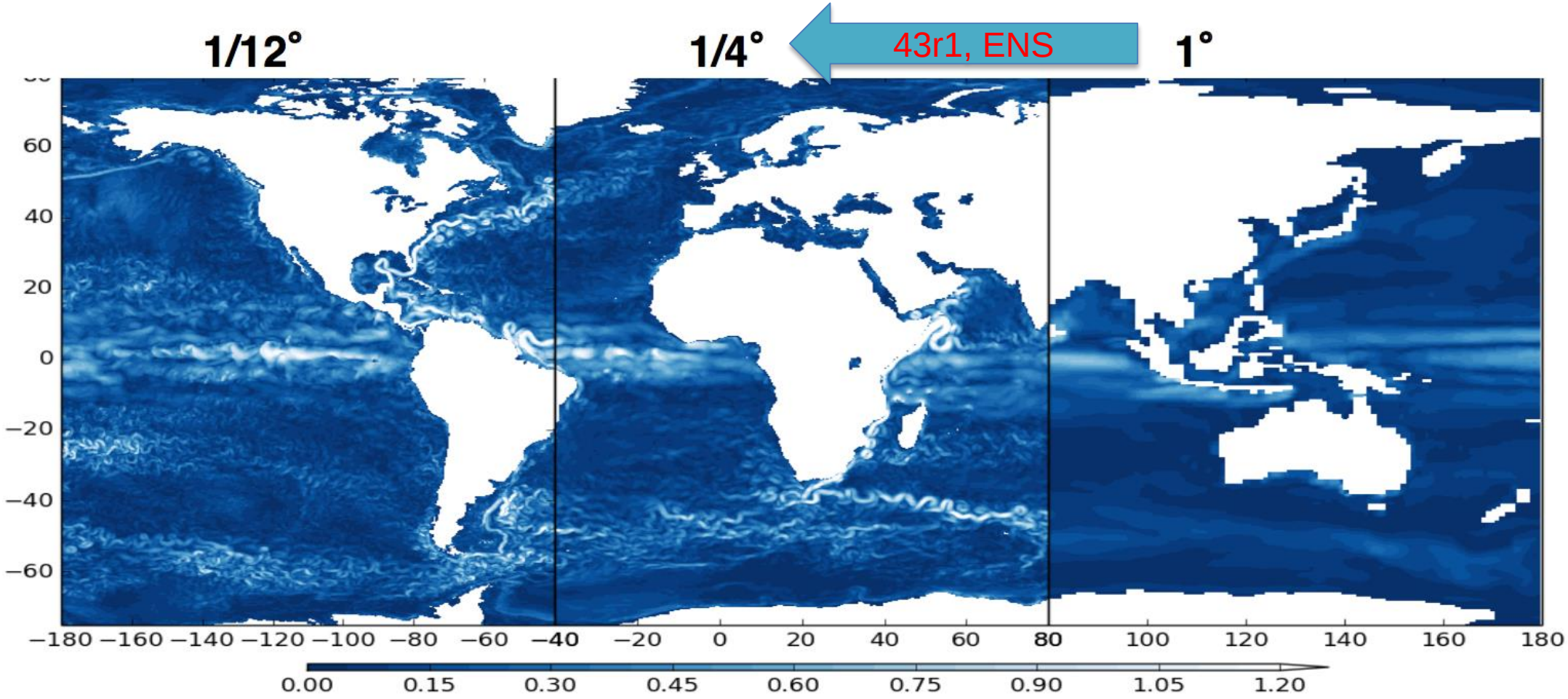
Continued support:

Dedicated HPC, software, and data resources for Member States
Advanced training

Outline

1. Highlights of the most recent model upgrade (22 Nov 2016 - CY43R1)
2. On-going R&D activities and challenges (Cy43R3 and beyond….)

Ocean surface currents at various resolutions



Eddy resolving

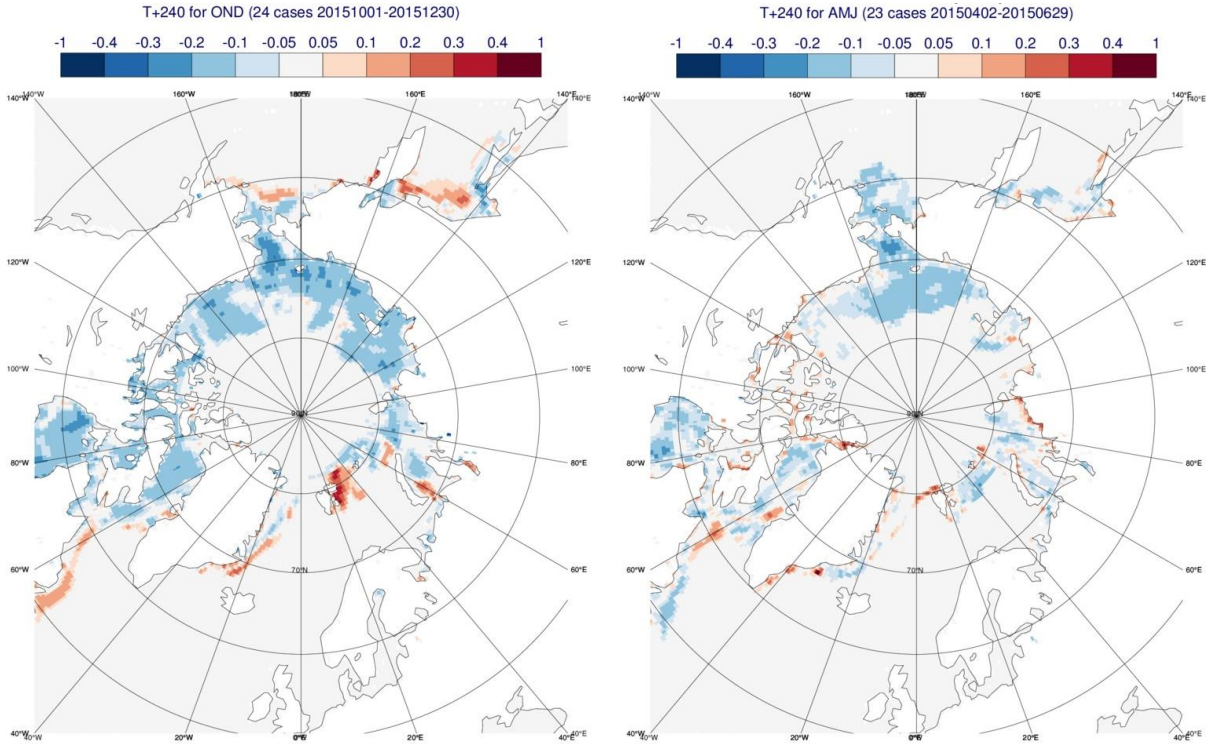
Eddy permitting

Eddy parameterising

Ocean and sea ice (Nov 2016 – CY43R1)

Increased horizontal and vertical resolution of the ocean (0.25 degrees, 75 levels) and prognostic sea ice

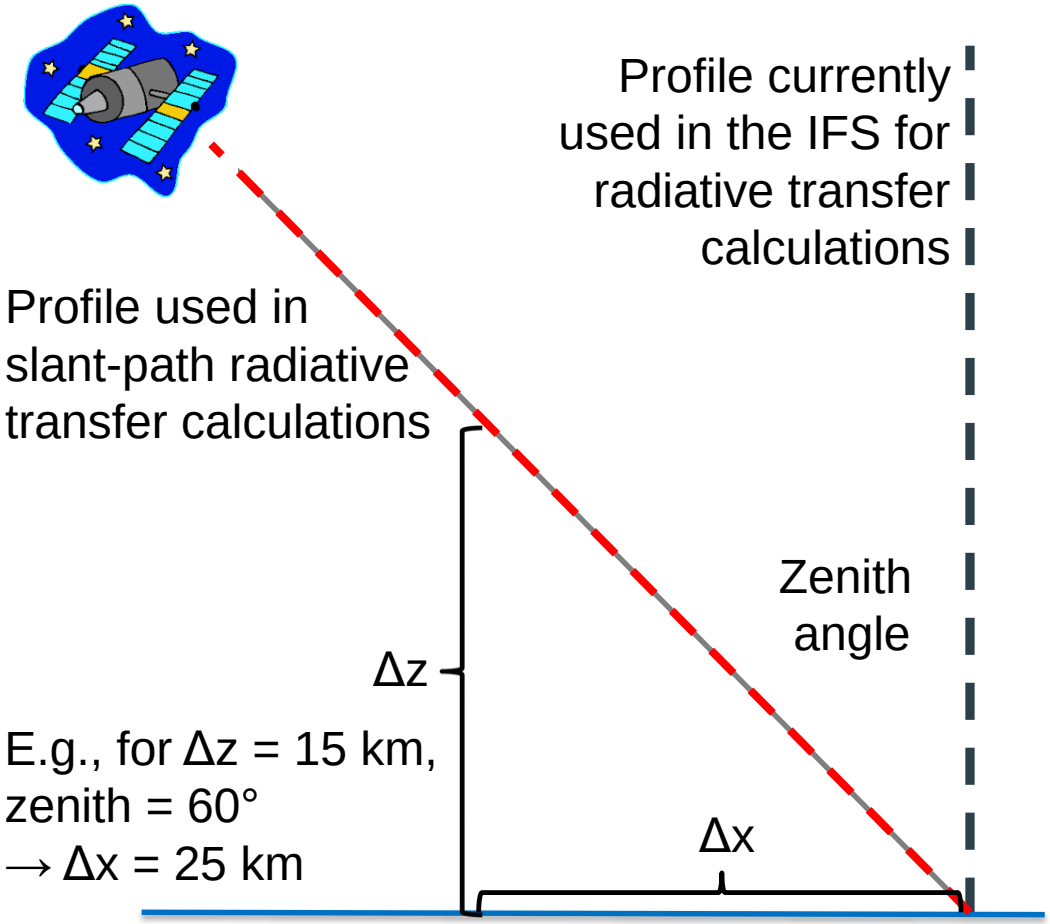
RMSE sea ice fraction at day 10



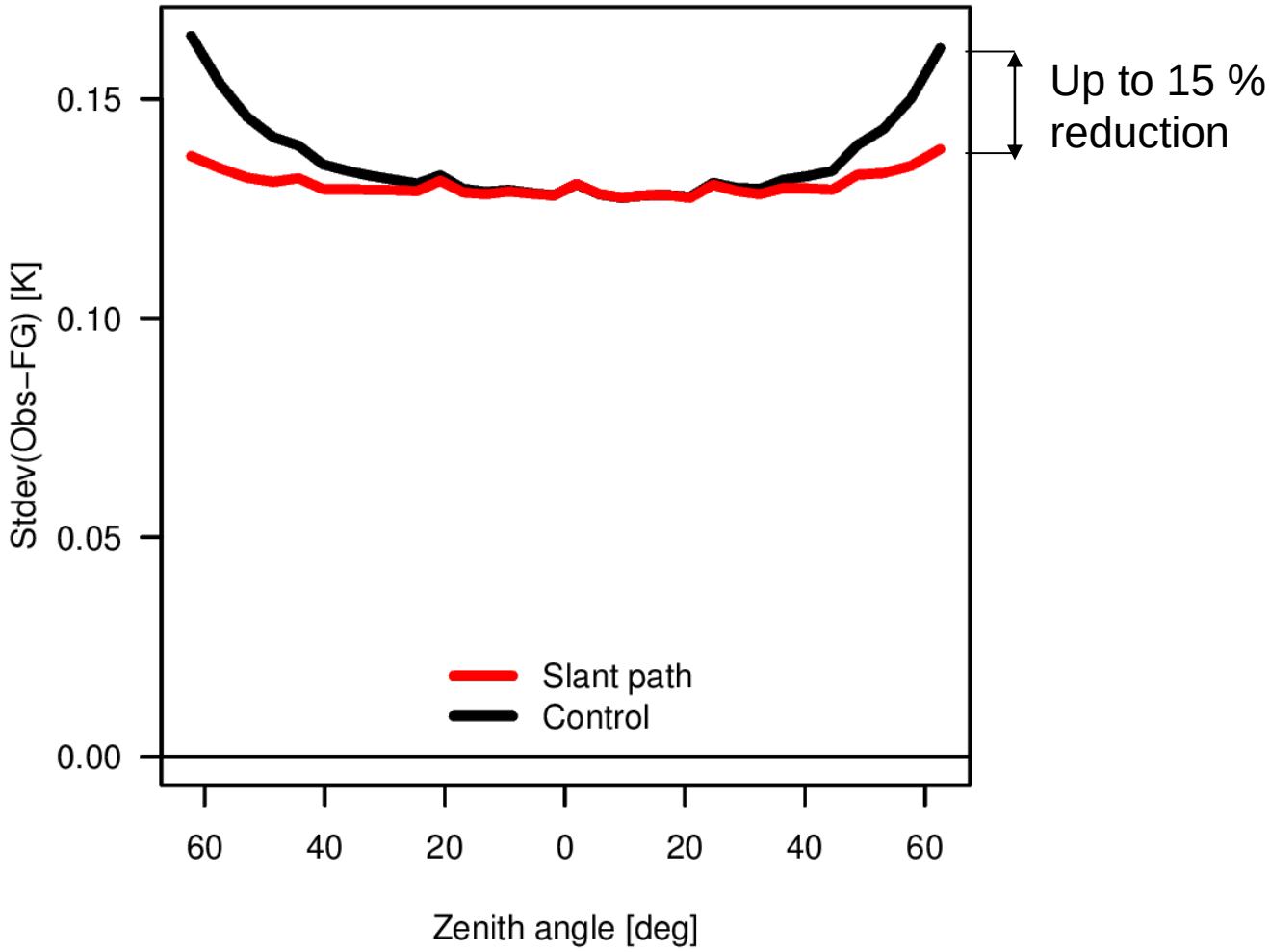
Oct – Nov – Dec

Apr – May – Jun

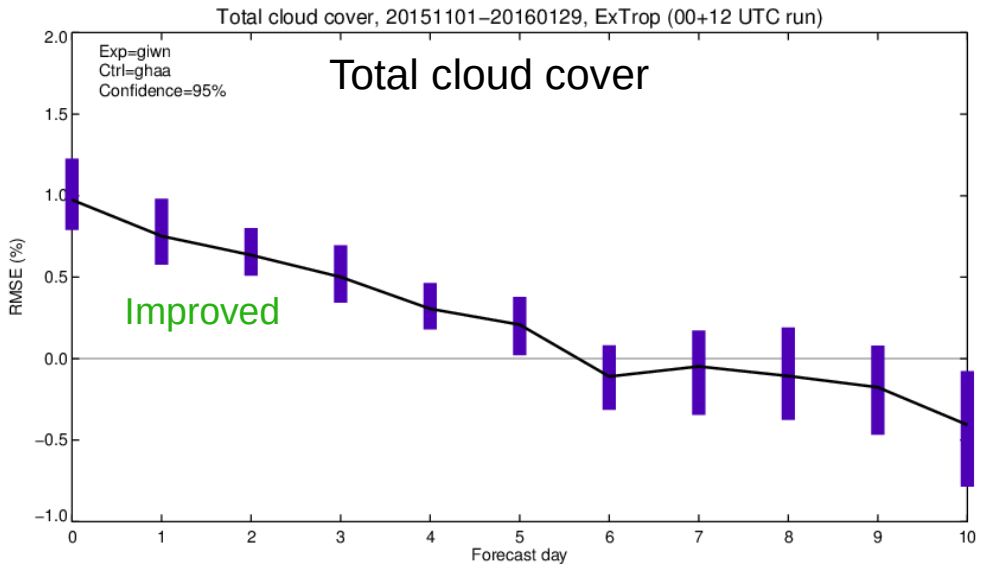
Slant-path radiative transfer for satellite based sounders

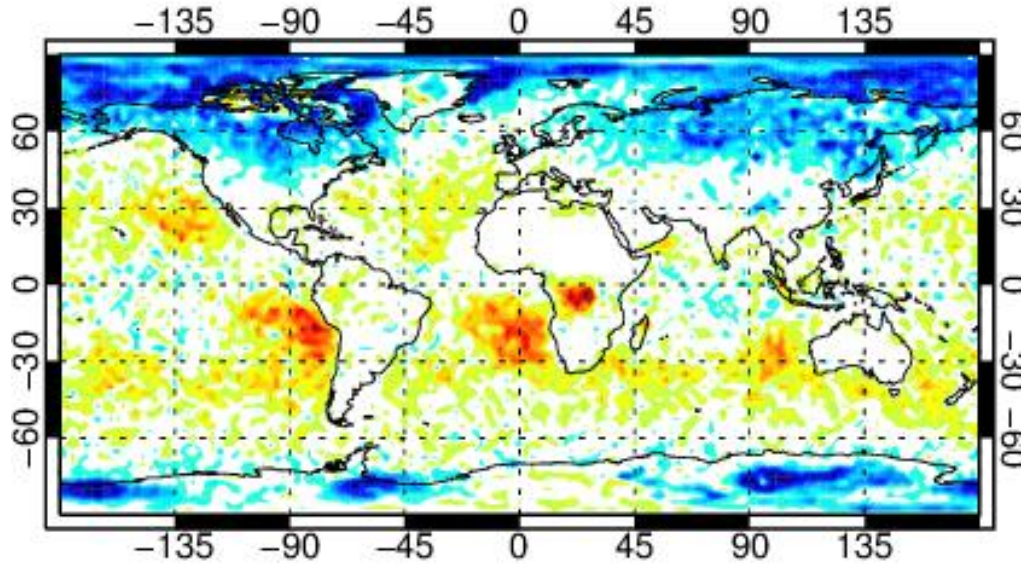


Effect on departure statistics:
E.g., stdev(Obs-FG), ATMS, channel 9, by scan-position



Improvement in low level clouds





ECMWF

Outline

1. Highlights of the most recent model upgrade (22 Nov 2016 - CY43R1)
2. On-going R&D activities and challenges (Cy43R3 and beyond….)

11 July 2017 - CY43R3 – Highlights

MOD

Glaciation of convective cloud occurs down to colder temperatures (down to -38°C)
Faster radiation scheme with reduced noise and more accurate longwave radiation transfer
New aerosol climatology based on CAMS aerosol re-analysis including dependence on RH
Visibility calculation consistent with new aerosol climatology

OBS

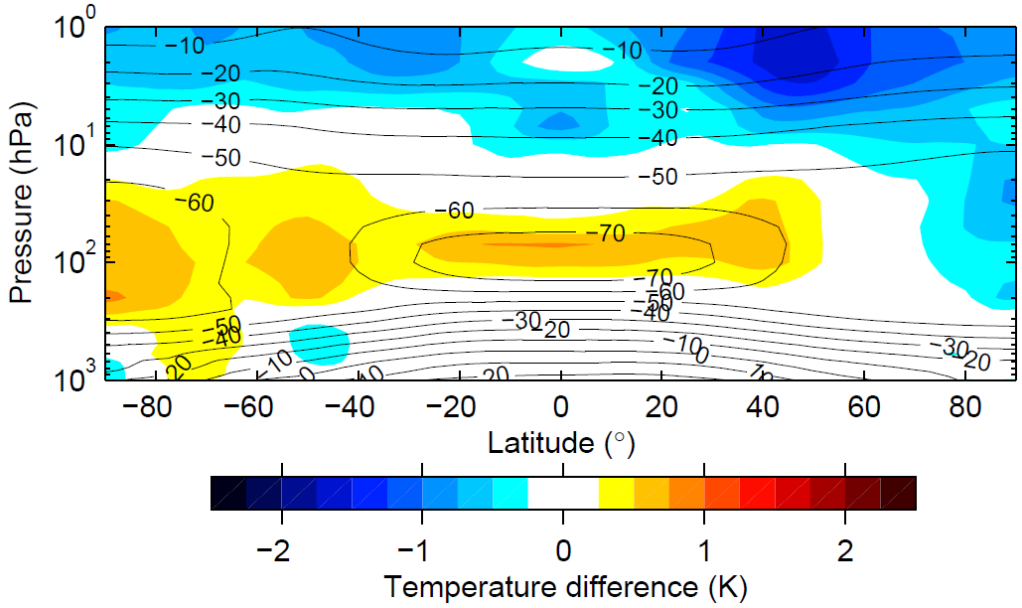
Increased use of microwave humidity data by adding SAPHIR and GMI 183 GHz channels
Activation of 118 GHz channels over land from MWHS-2 instrument on-board FY-3C
Harmonised data usage over land and sea-ice for microwave sounders
Improved screening of infrared observations for high concentrations of HCN from wildfires
Improved quality control for radio occultation observations and radiosonde data

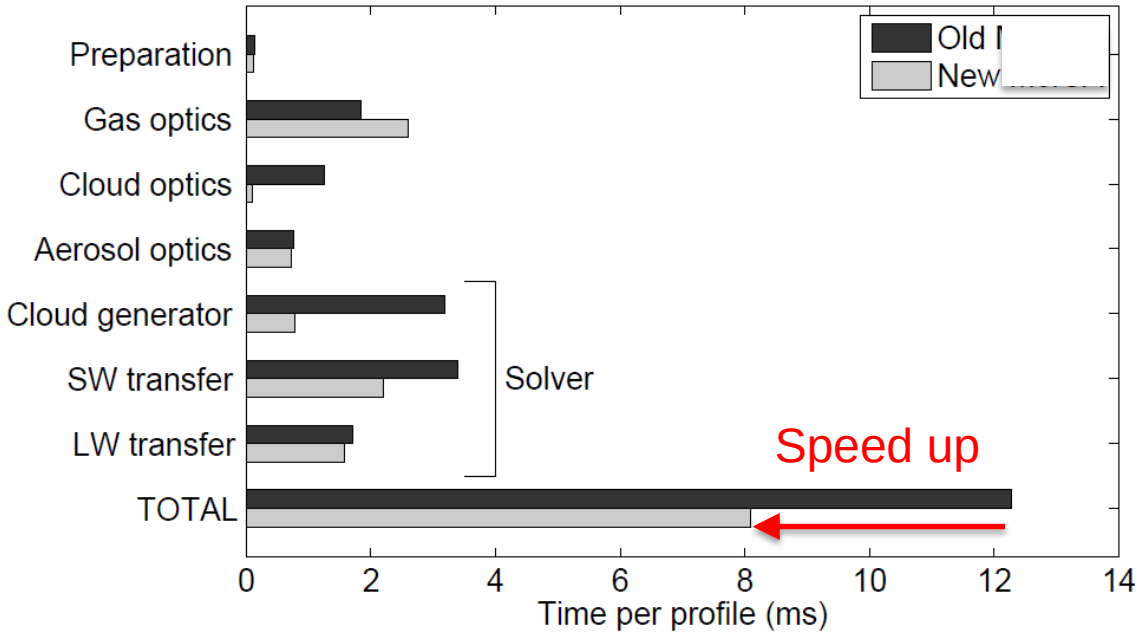
DA

Improved humidity background error variances directly from the EDA like for all other variables
Improved **tropical cyclone structures** via revised wavelet filtering of background error variances and revised quality control of drop-sonde wind observations in 4D-Var

New radiation scheme (ECRAD)

- Flexible and modular: easy to test future changes (16000 lines of code)
- Better solution to longwave equations improves stratosphere
- 31-34% faster

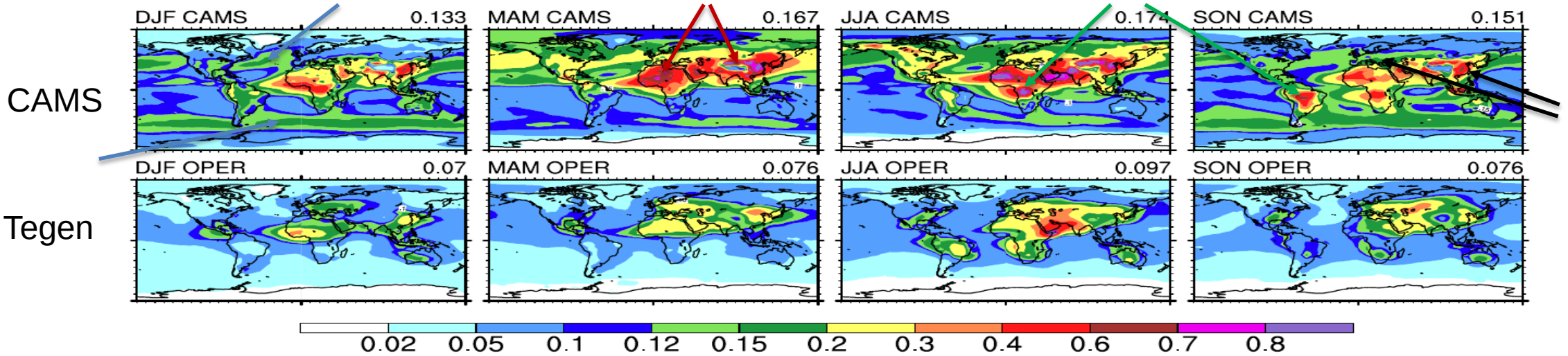




Hogan and Bozzo, TM787, 2017

Climatological AOD at 550 nm distribution

CAMS vs operational climatology (based on Tegen et al. 1997)



- Aerosol climatology computed using the CAMS-Interim reanalysis (Flemming et al. 2016)
- Some highlights:
  - Larger Sea Salt radiative forcing (~1 W/m^2 more reflection at TOA over oceans)
  - Changes in biomass burning seasonal cycle (up to 20 W/m^2 difference in total SW absorption locally)
  - Changes in dust distribution, higher on Sahara and Taklamakan, lower on Indian Ocean and Australia
  - Anthropogenic emissions lower over Europe, higher over E Asia
- Limited impact on large scale circulation
- Improvement on the summer monsoon over Indian ocean due to better dust radiative forcing

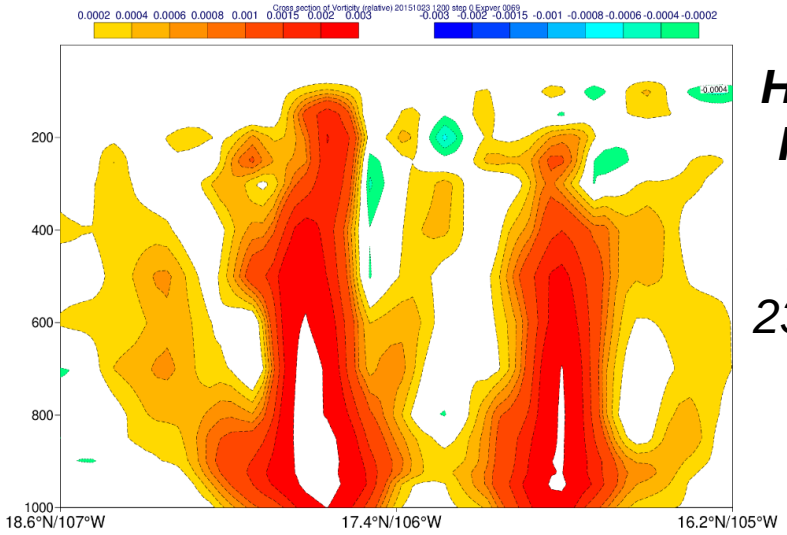
ECMWF

Bozzo et al., 2017, TM801

Tropical Cyclone Initialization

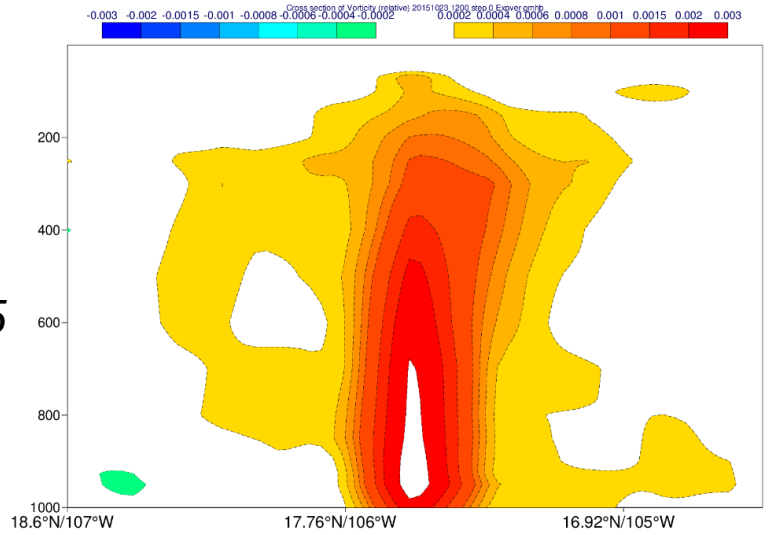
- **Adaptive observation error for dropsonde winds** leading to more cautious observation use.
- **Smoother filtering of EDA background error variances** through spectral truncation to T159 followed by **a new wavelet signal-to-noise filter**.

Before…



Hurricane Patricia: *Vorticity analysis 23/10/2015 12 UTC*

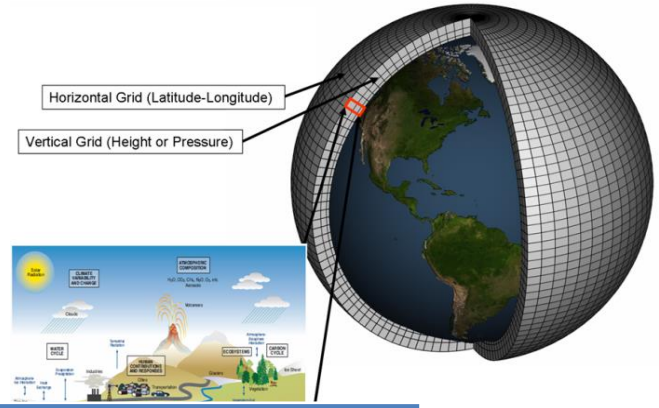
…after



Just some of the forthcoming challenges...

- Scalability
- DA science (oper & reanalysis; maximize use of in situ and satellite obs, algorithms, EDA, higher res inner loops)
- Increased coupling (land/ocean)
- Physical processes (resolved and unresolved)
- Uncertainty – parameter perturbations, ENS, EDA
- Predictability and seamless ensembles (EDA/ENS/monthly/seasonal)
- Climate monitoring, ERA-Interim replacement: ERA5

The Scalability Challenge



	Observations	Models
Today: Volume	20 million = **2×10^7**	5 million grid points 100 levels 10 prognostic variables = **5×10^9**
Type	98% from 60 different satellite instruments	physical parameters of atmosphere, waves, ocean

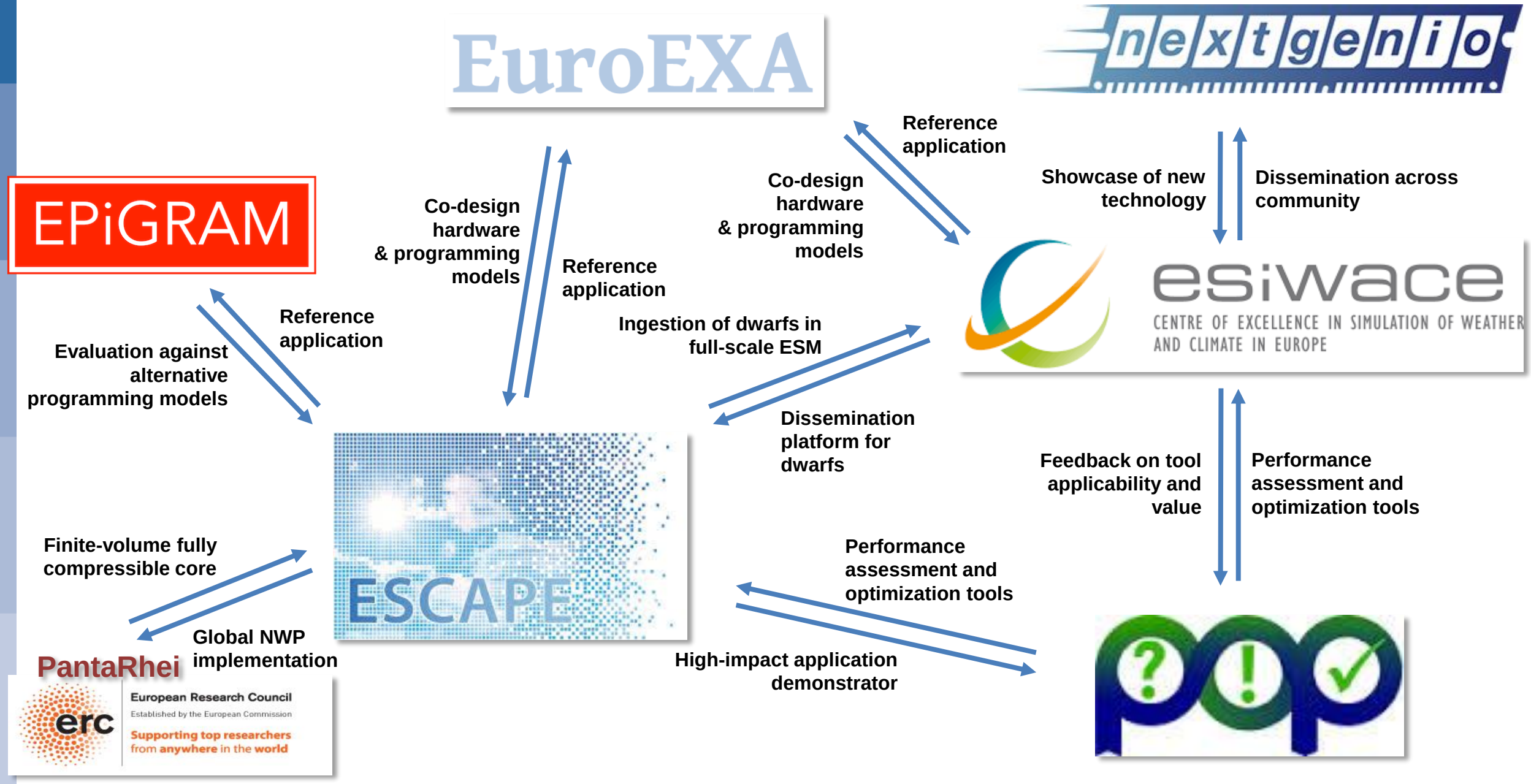
	Observations	Models
Tomorrow: Volume	200 million = **2×10^8**	500 million grid points 200 levels 100 prognostic variables = **1×10^{13}**
Type	98% from 80 different satellite instruments	physical and chemical parameters of atmosphere, waves, ocean, ice, vegetation

→ Factor 10 per day

→ Factor 2000 per <u>time step</u>

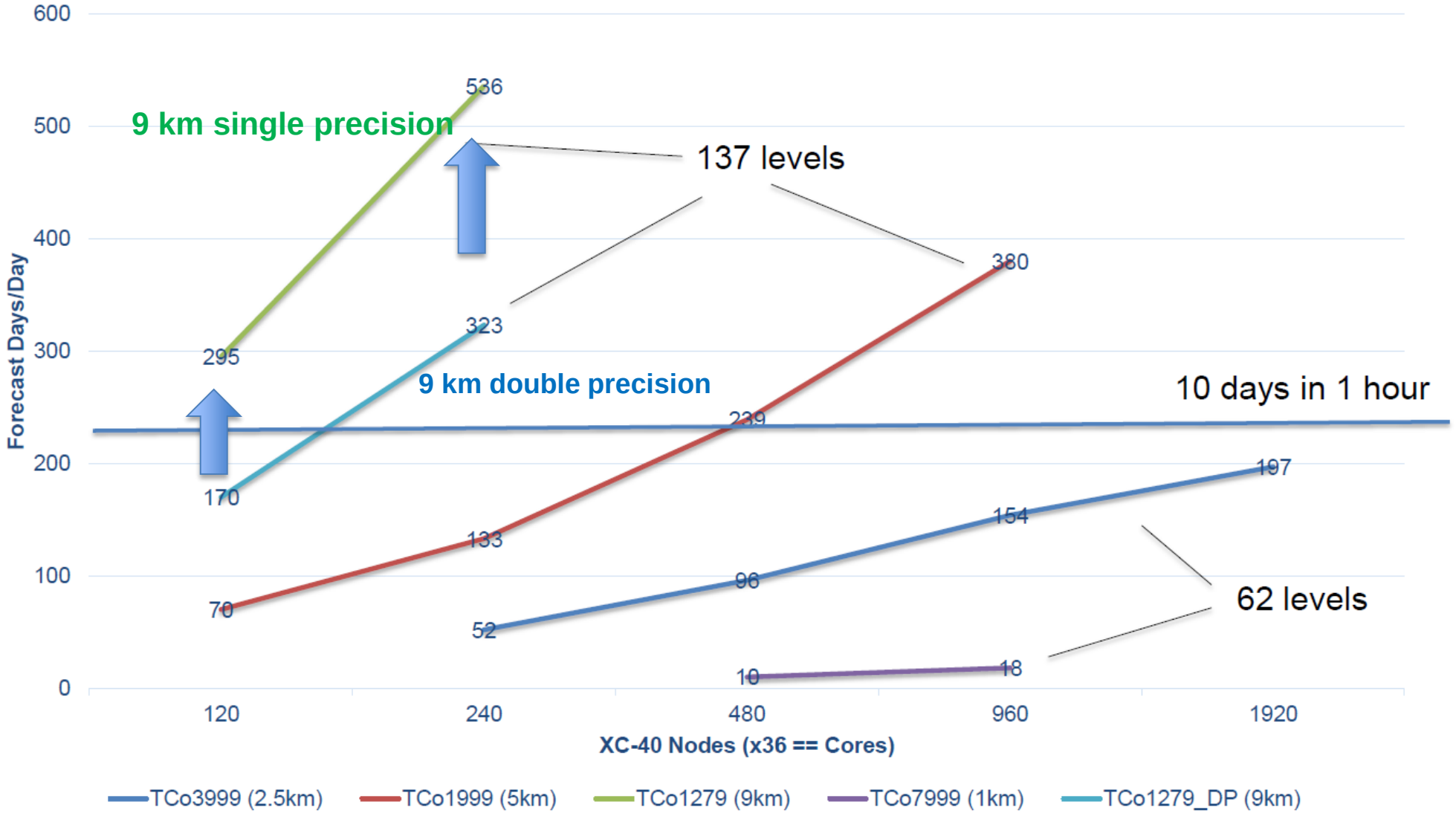
(10-day forecast today = 1440 time steps, but more time steps with increased resolution)

Scalability Program & H2020



ESiWACE: Single precision IFS

Funded by the European Union



Just some of the forthcoming challenges...

- Scalability
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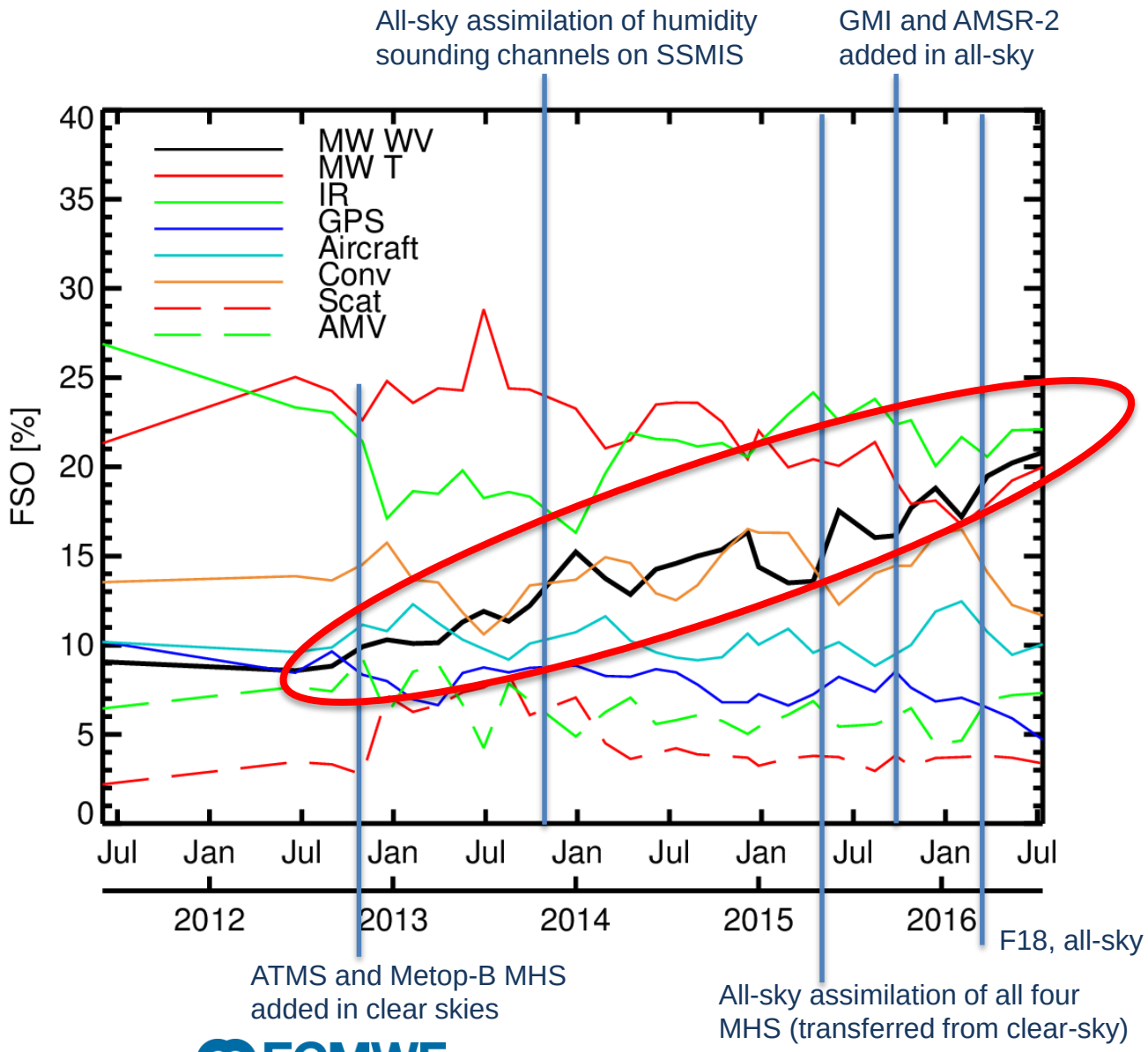
- Increased coupling (land/ocean)
- Physical processes (resolved and unresolved)
- Uncertainty – parameter perturbations, ENS, EDA
- Predictability and seamless ensembles (EDA/ENS/monthly/seasonal)
- Climate monitoring, ERA-Interim replacement: ERA5

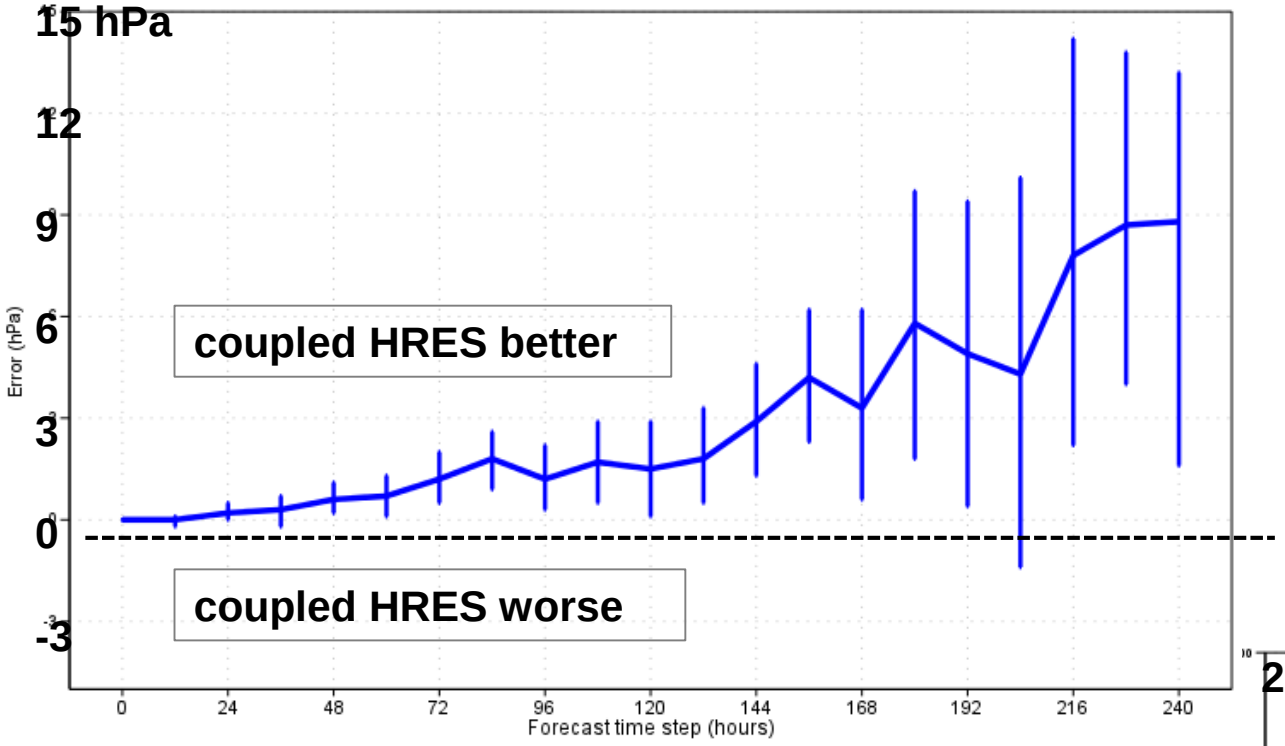
Observation changes: the rise of all-sky!



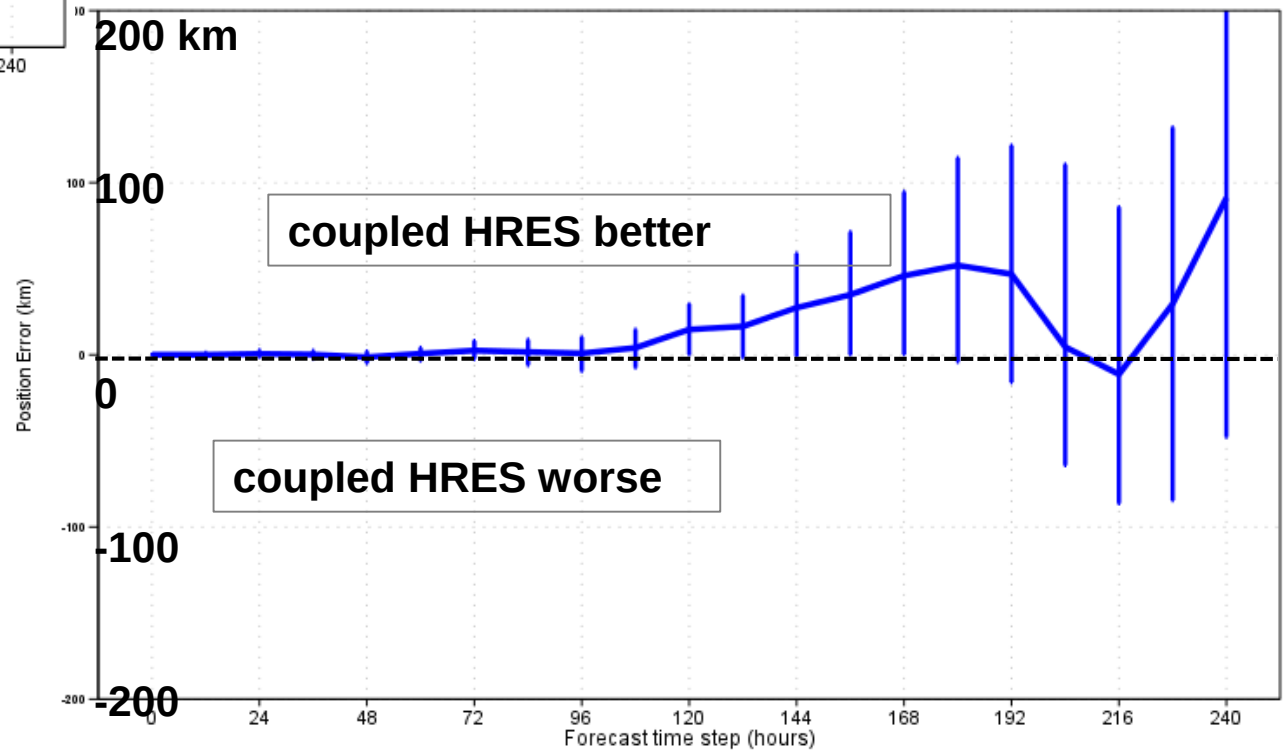
- Growing importance of microwave humidity observations (MHS, ATMS, MWHS-2, SSMIS, AMSR2, GMI, SAPHIR).
- Extending this to infrared water vapour information.
- Revisiting all-sky microwave temperature observations.
- Also investigating radar, lidar, and possible lightning observations (EarthCARE, Aeolus, GOES-R, MTG).

F18, all-sky over snow, MWHS-2

Improvement of tropical cyclones



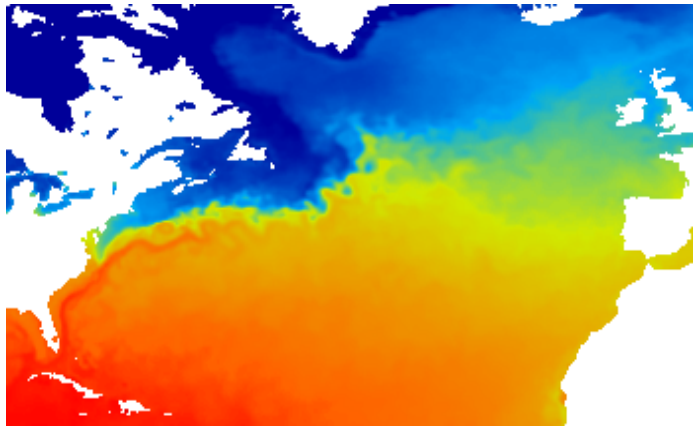
Difference of the mean absolute intensity errors (hPa)
VT: 2016-05 to 2017-01 (homogeneous samples/all basins)
Bars: 95% confidence interval



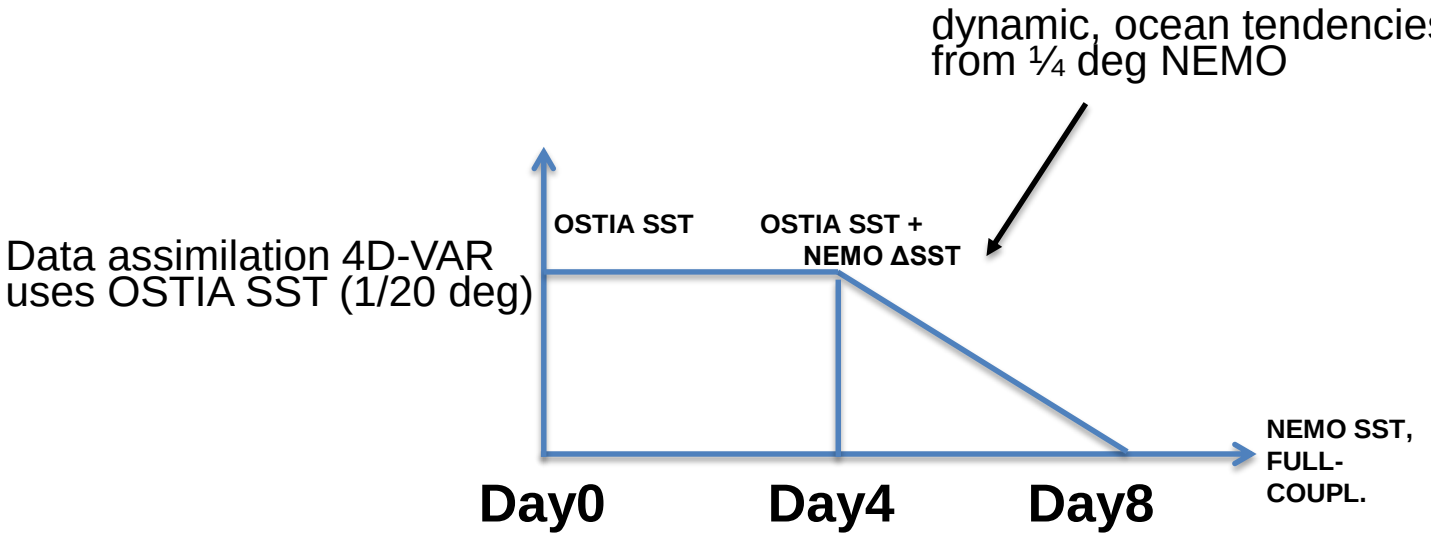
Difference of the mean position error (km)
VT: 2016-05 to 2017-01 (homogeneous samples/all basins)
Bars: 95% confidence interval

Thermal coupling of ocean – the concept of partial coupling

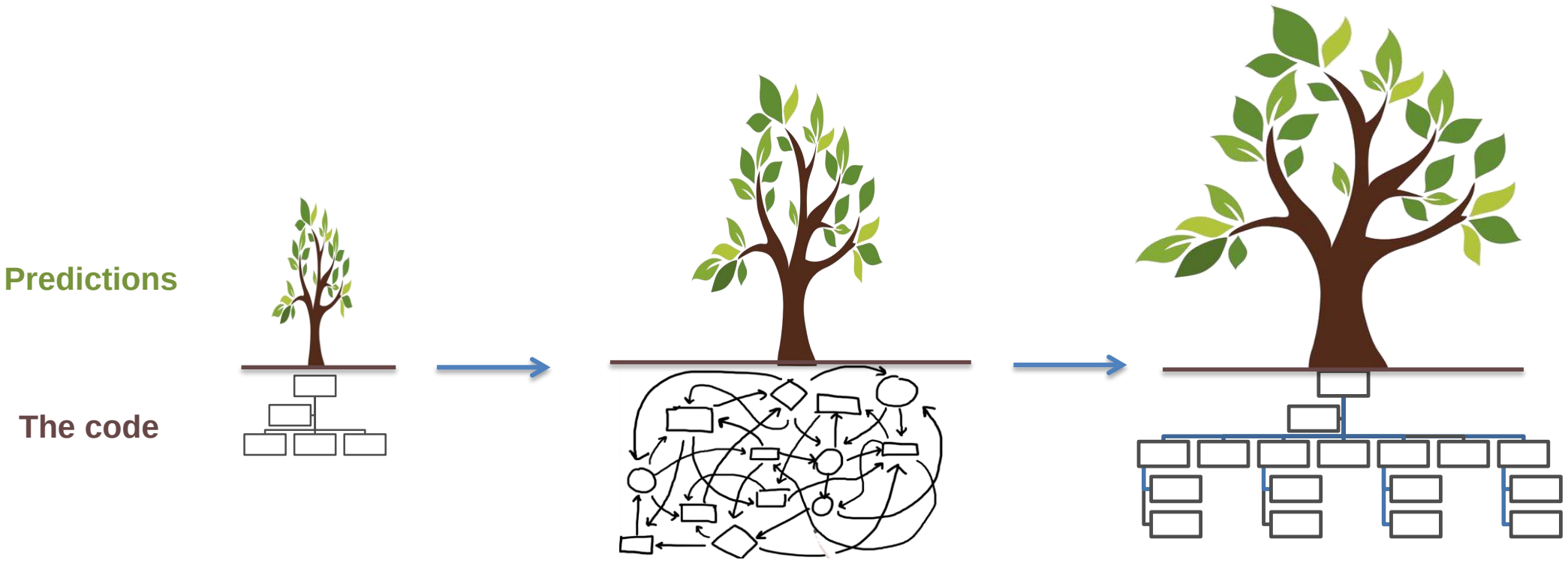
Coupled ocean-atmosphere simulations are exposed to the problem of initial shock as the atmosphere and the rest of earth surface is not yet in balance with the ocean.



OSTIA 1/20 deg (5km) SST field has details of the eddies not resolved by ocean models (at 0.25 degrees)



A cleaner interaction between the physical parameterizations representing moist processes



- Software entropy – increasing disorder with time
- Becomes difficult to understand how different parts of the code are interacting
- Numerical algorithm can be far from optimal (important for solution and code efficiency)
- Need an integrated system that is as simple as possible, **but no simpler**

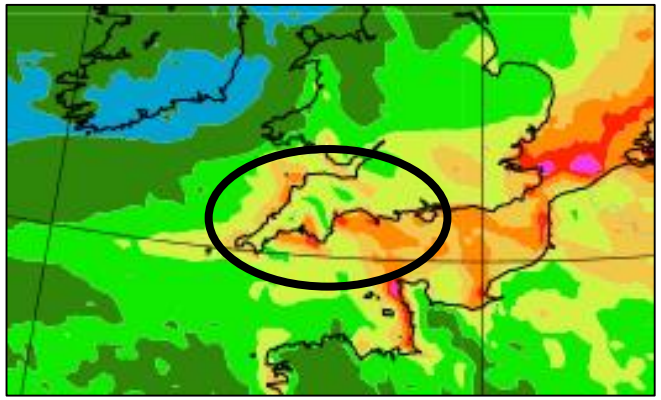
→ **Concerted effort to understand and simplify moist processes interactions in the IFS**

Improvements in precipitation along coast lines for prolonged shallow precipitating stratiform cloud events

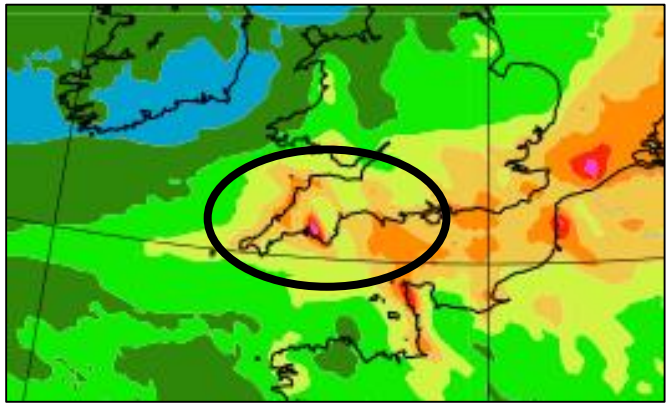
Example case study 20 June 2016 00Z

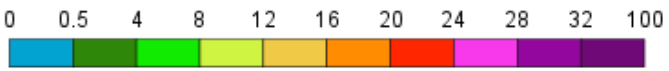
24hr forecast accumulated precipitation (mm)

Operational (43r1/43r3)

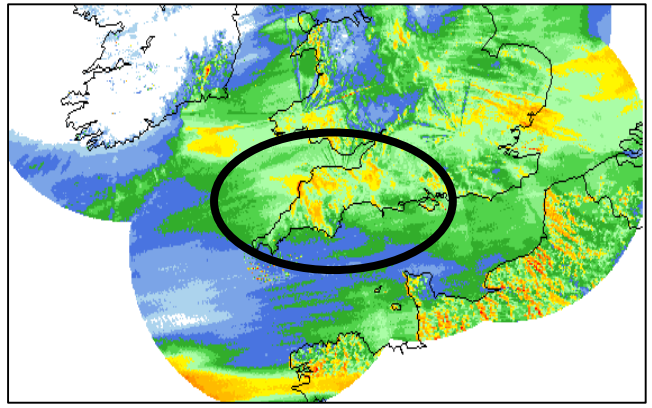


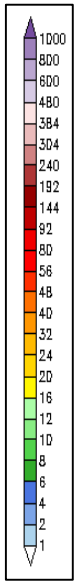
Improved warm-rain microphysics numerics (45r1)





UK radar



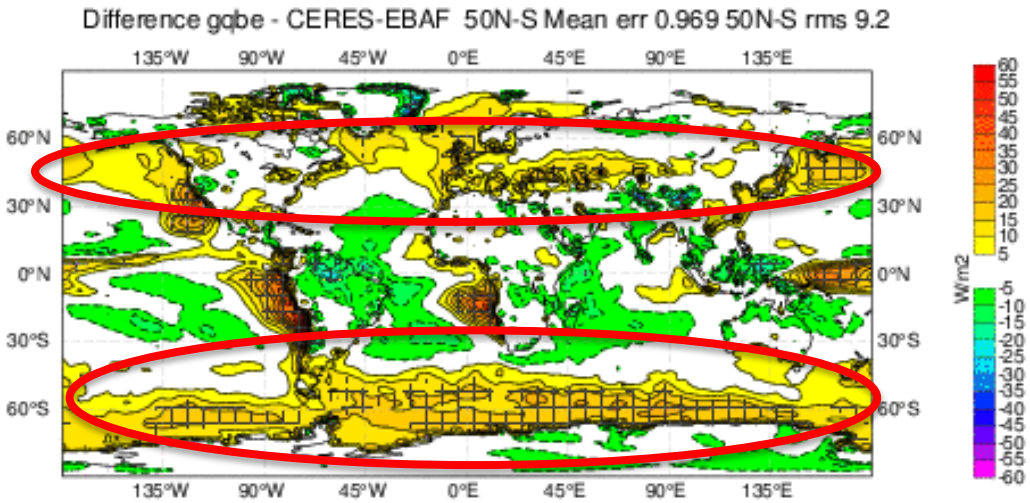


In these situations (which occur occasionally), the precipitation is no longer off the coast, but inland with maxima over orography, in much better agreement with the observations

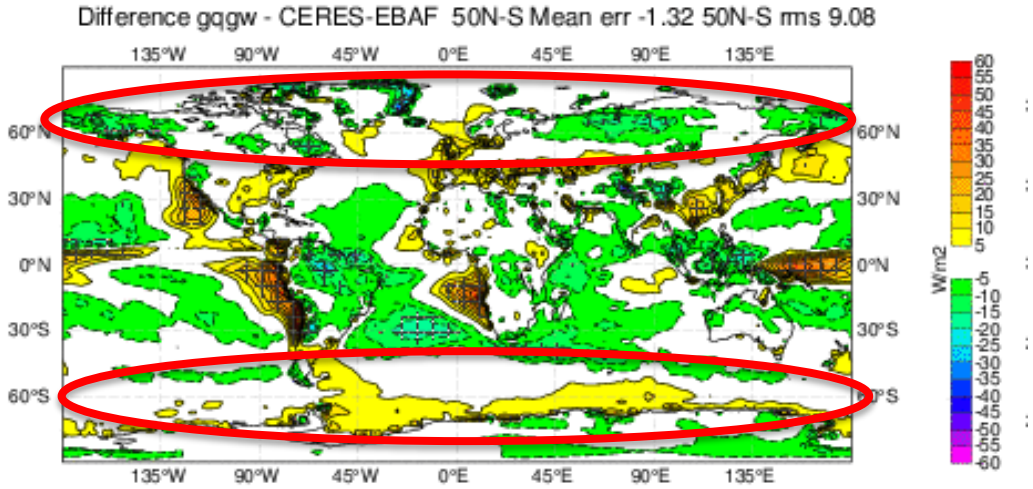
Improving the SW radiation biases through improved mixed phase in convection and consistency with prognostic cloud scheme

Focus: not reflective enough storm tracks, liquid phase in cold air outbreaks

Cy43r1



cloud + convection changes for 45r1

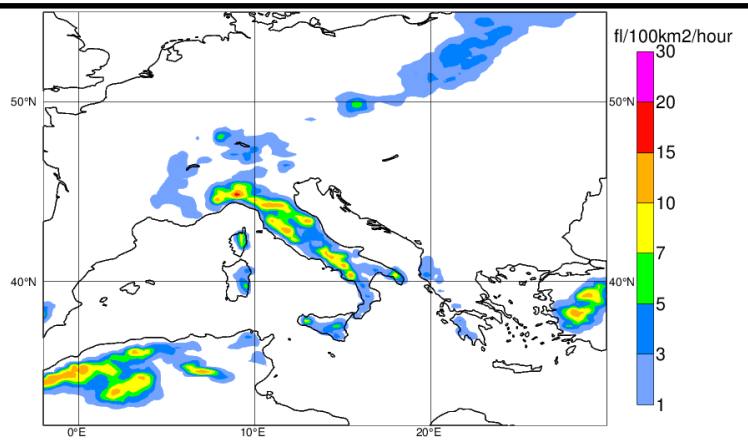


ECMWF

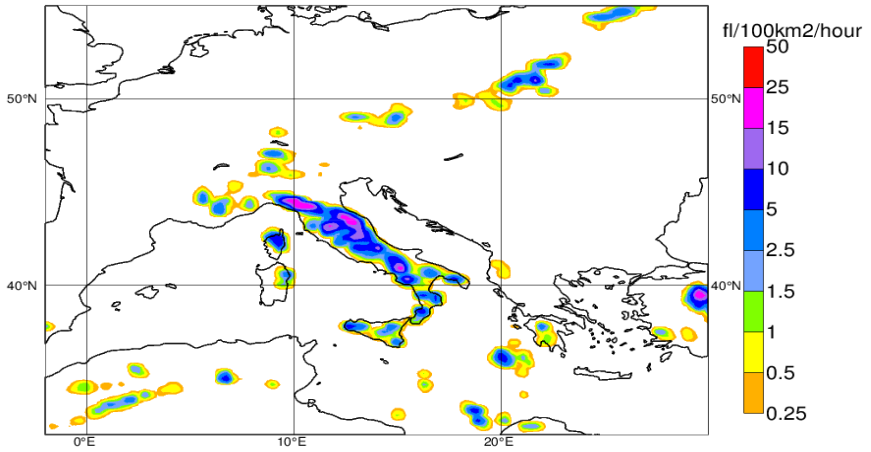
Future products: **Lightning in the Ensemble Prediction System**

Example of 15h EPS global forecasts (31 members) from 9 Aug 2015 at 00Z.

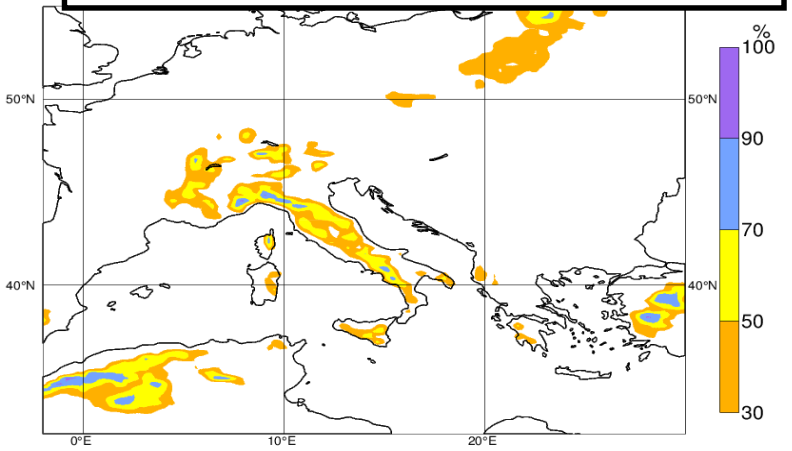
EPS mean f_T (over all members)



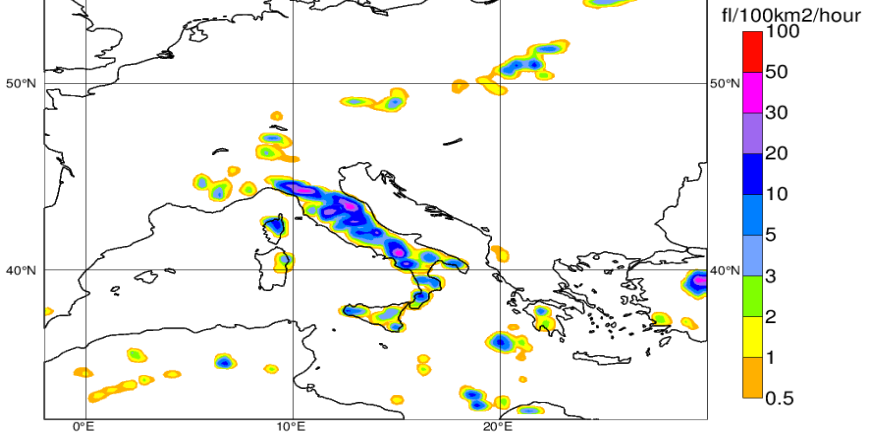
ATDnet obs



Prob (f_T > 1 flash/100 km²/h)

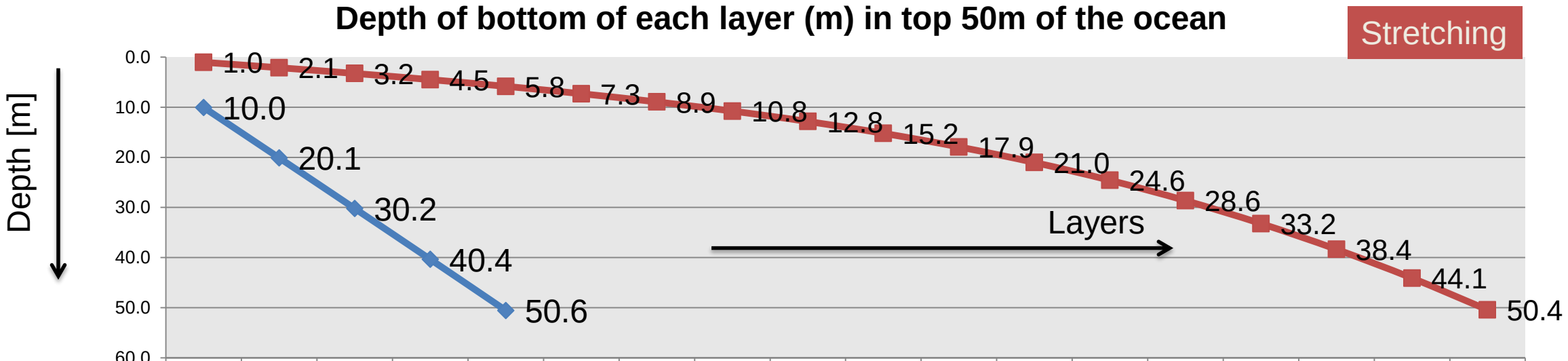


GLD360 obs



Extras

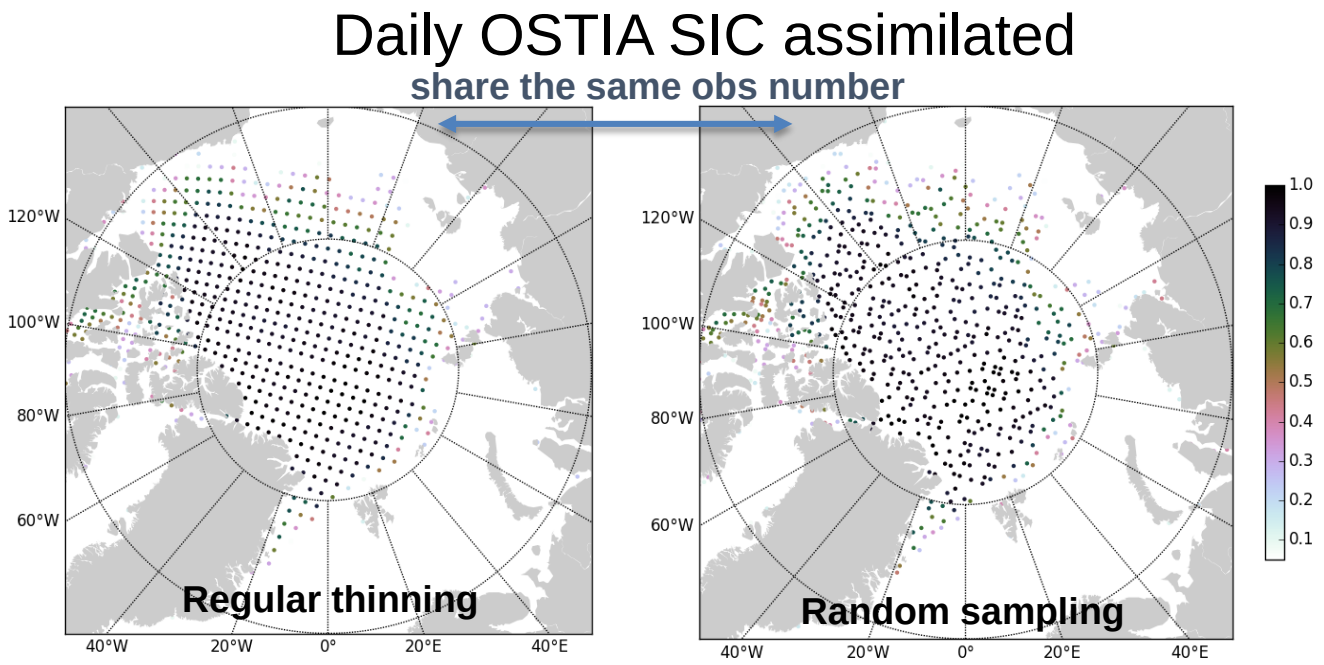
Vertical layers in the ocean column for ORCA1_Z42 and ORCA025_Z75

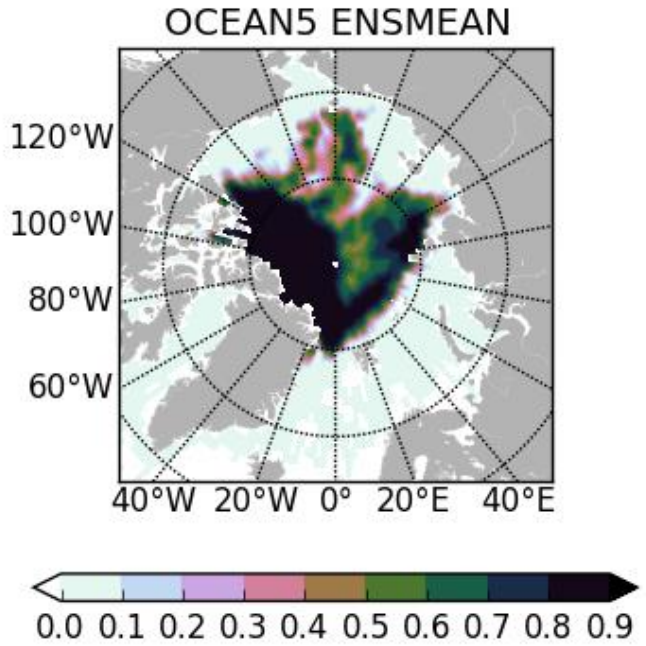


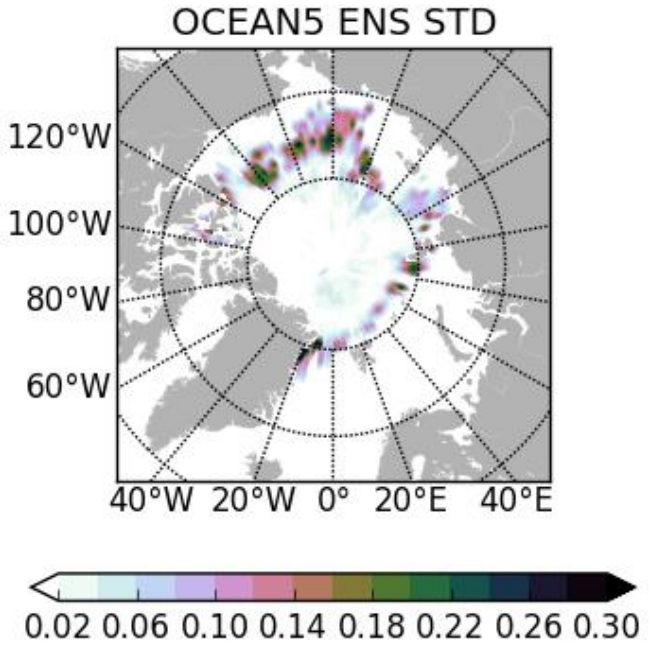
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORCA1_Z42	10.0	20.1	30.2	40.4	50.6													
ORCA025_Z75	1.0	2.1	3.2	4.5	5.8	7.3	8.9	10.8	12.8	15.2	17.9	21.0	24.6	28.6	33.2	38.4	44.1	50.4

OCEAN5: new (¼°;z75) NEMOVAR

In OCEAN5 spread is achieved by selecting different observations in each member, rather than perturbing all observations.







Production Streams (Cy41r2, TL639/TL319):

NRT: 2505 (HRES), 2506 (EDA) (was 2443/2445)

(June) Dec 2014 – Sept 2016

2010: 2502 (HRES), 2501 (EDA)

Jan 2009 – Jul 2014

2000: 2504 (HRES), 2503 (EDA)

Jan 1999 – Aug 2004

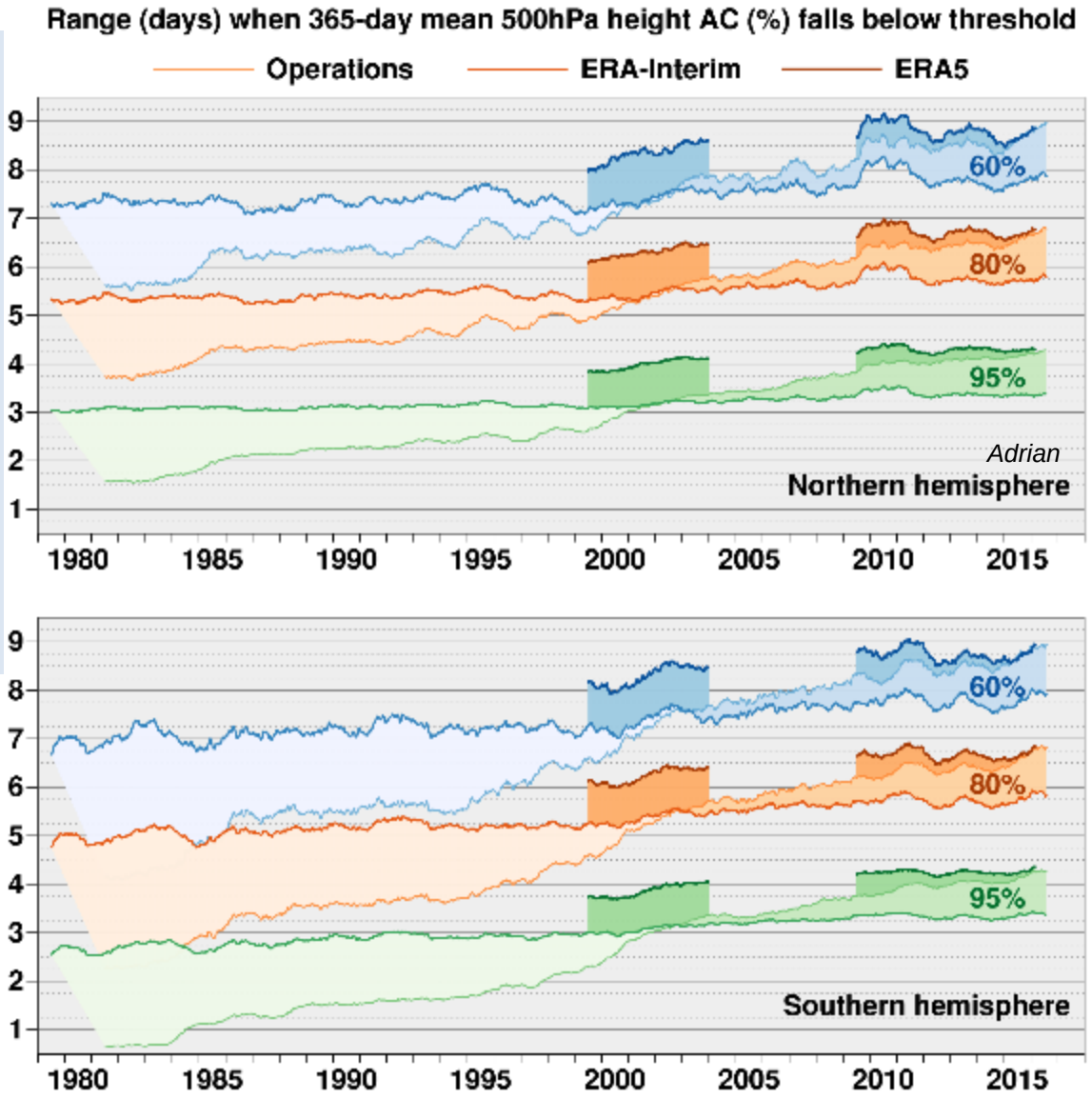
1990: 2928 (HRES), 2929 (EDA), starting

Troposphere looks very promising

Stratosphere: some issues with trends

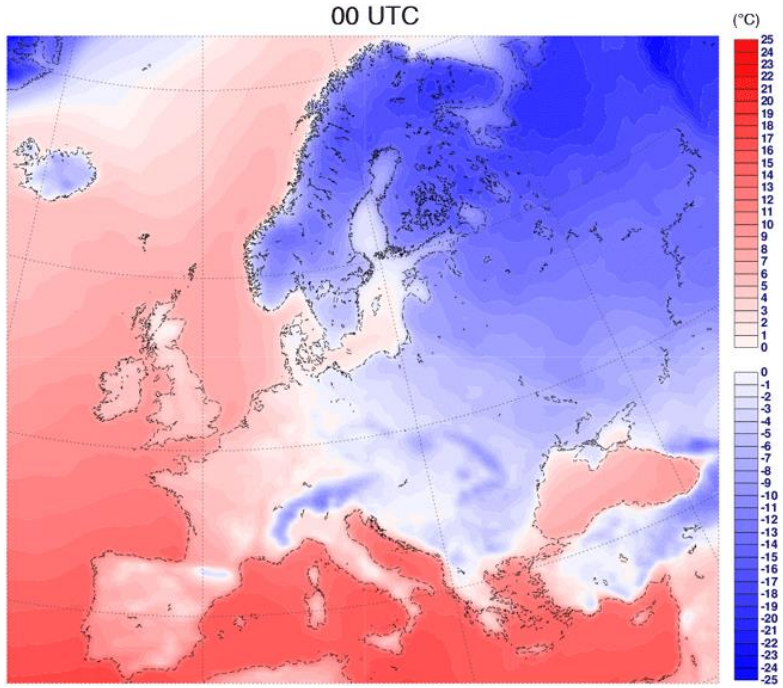
Mesosphere: unrealistic tropical jet (41r2)

1979: issues over southern hemisphere



A two-months *test data set* is available (expver=0012)

- Full resolution, 31km, hourly and 62km-ensemble 3-hourly
- Jan-Feb 2016
- *https://climate.copernicus.eu/climate-reanalysis*



Q2 2017: public release 2010 – 2016

- Includes observation feedback

Q3 2017: 2016 – timely updates

- ERA5: Updates with about 2-months delay (final product)
- ERA5T: Updates with short delay (<1 week, preliminary product)

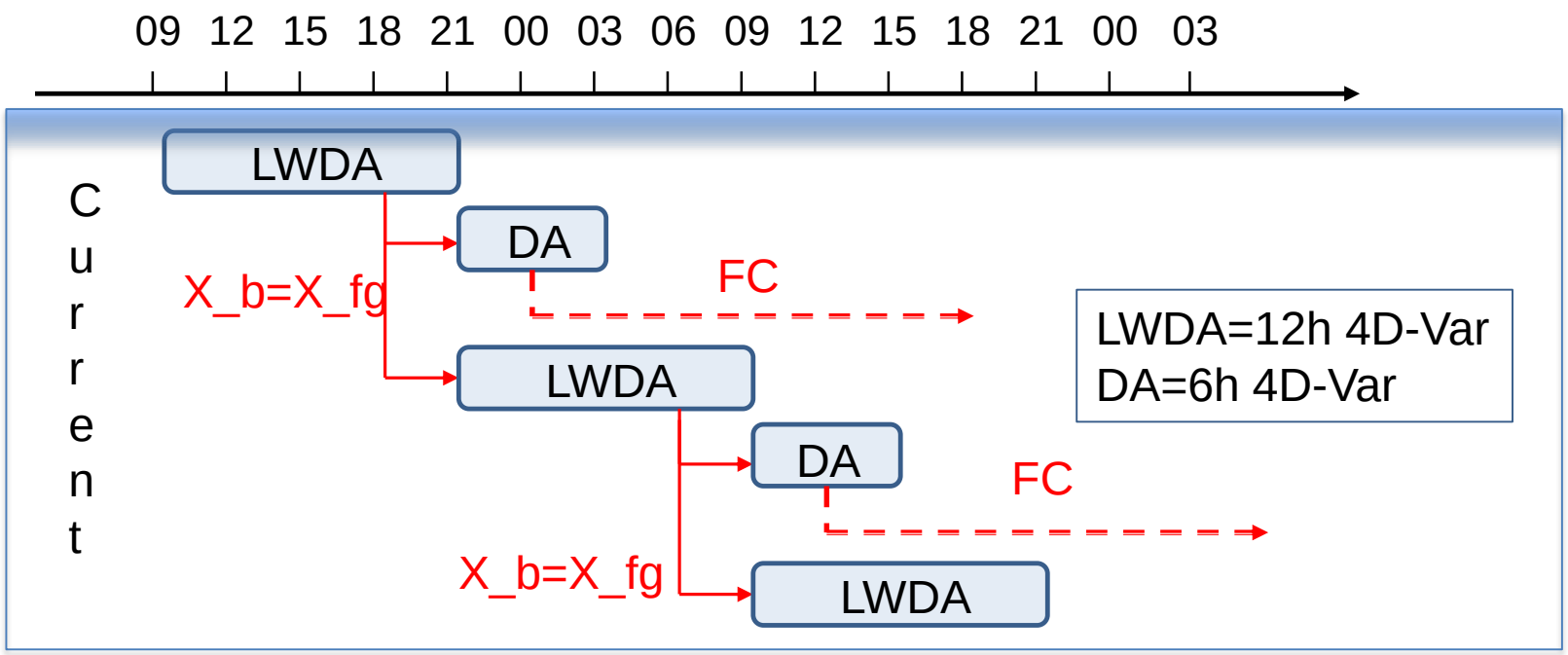
Q2 2018: Release 1979 – 2009:

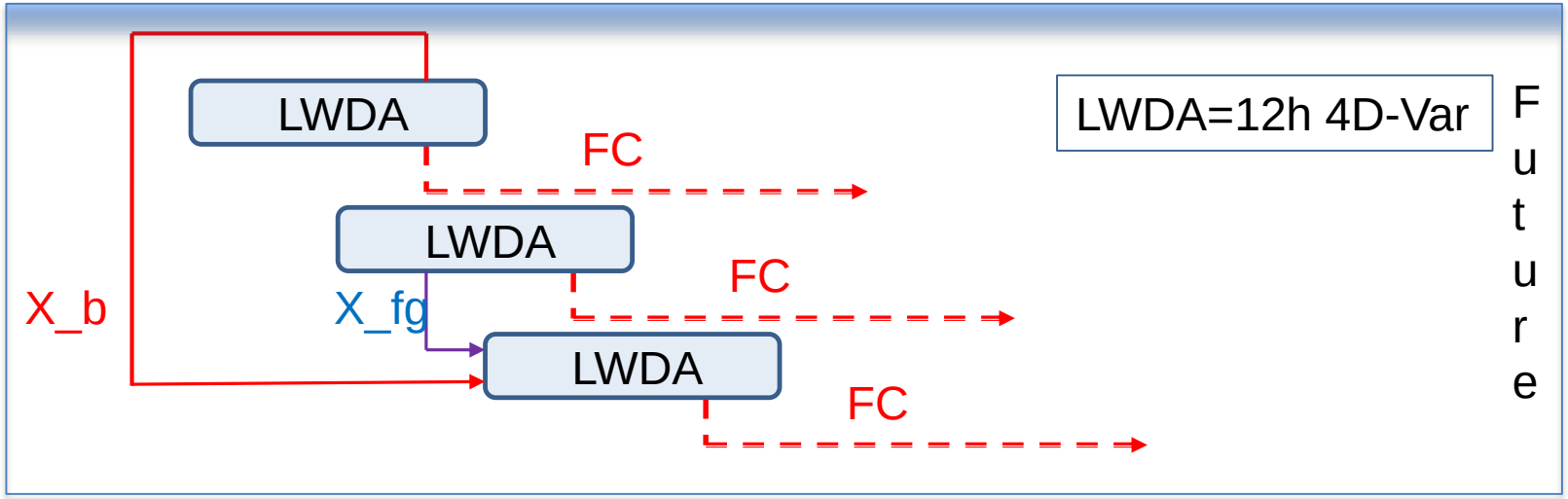
- Continue ERA5 timely updates
- Continue ERA-Interim for another 6 months

2018: integration of ERA5 back-extension to 1950

CERA-SAT: (*Dinand*) 8-year long coupled CERA system at the ERA5 EDA resolution is currently being produced as a first step towards the preparation of ERA6

Improving 4D-Var: Overlapping windows





Will try to make this invisible to users.
Targeting e-suite in 2018.

- Currently complex operational suite.
- The proposed framework does not introduce correlations between background and observation errors.
- Framework for increasing the assimilation window length, and “quasi-continuous” DA.