Global weather prediction at ECMWF: progress and plans

Andy Brown and colleagues

ECMWF, Shinfield Park, Reading, UK

THE STRENGTH OF A COMMON GOAL

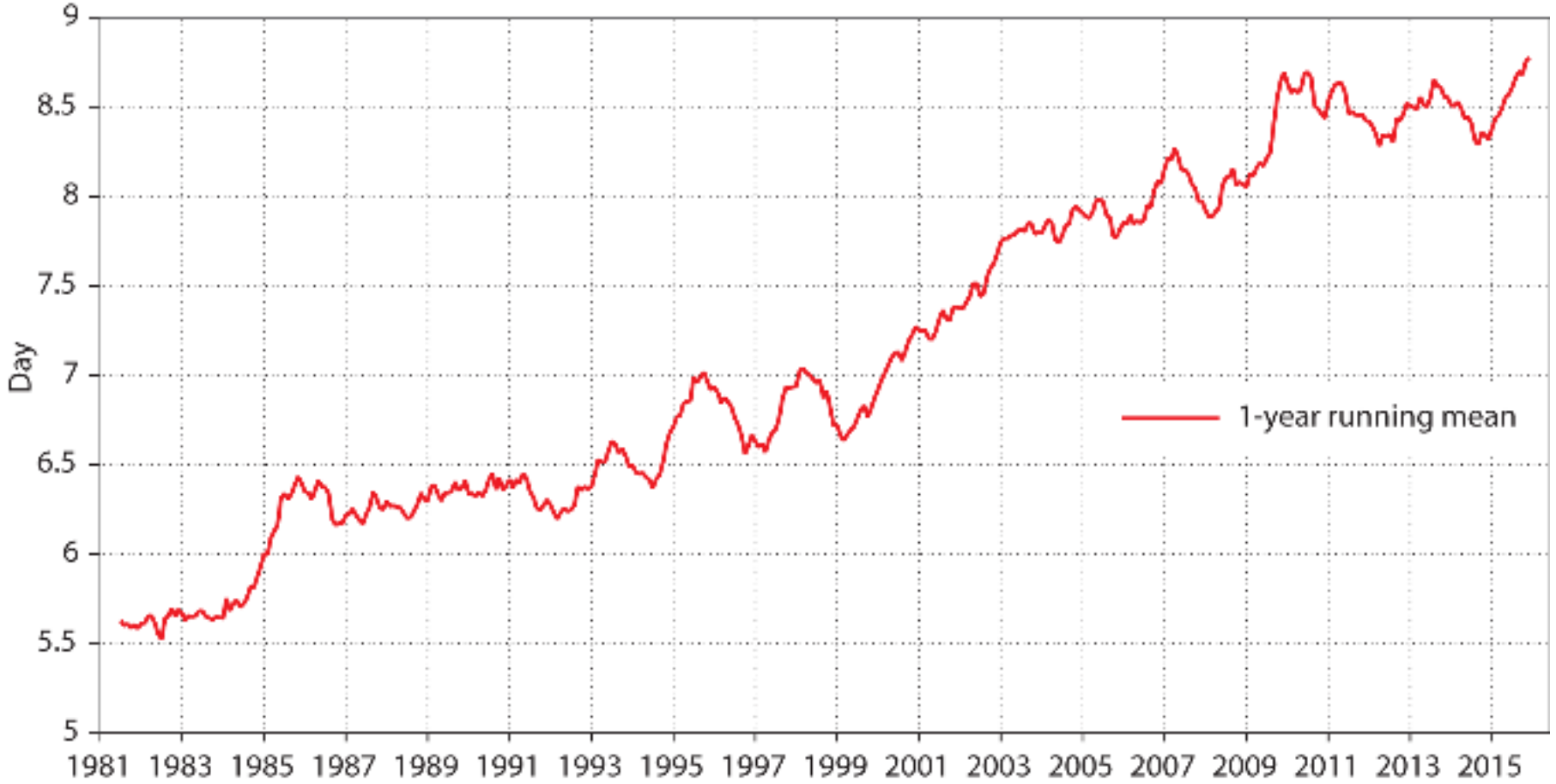
ECMWF's purpose is to develop a capability for medium-range weather forecasting and to provide such weather forecasts to the Member and Co-operating States

ECMWF is complementary to the National Meteorological Services and works with them in research, numerical weather predictions, supercomputing and training.

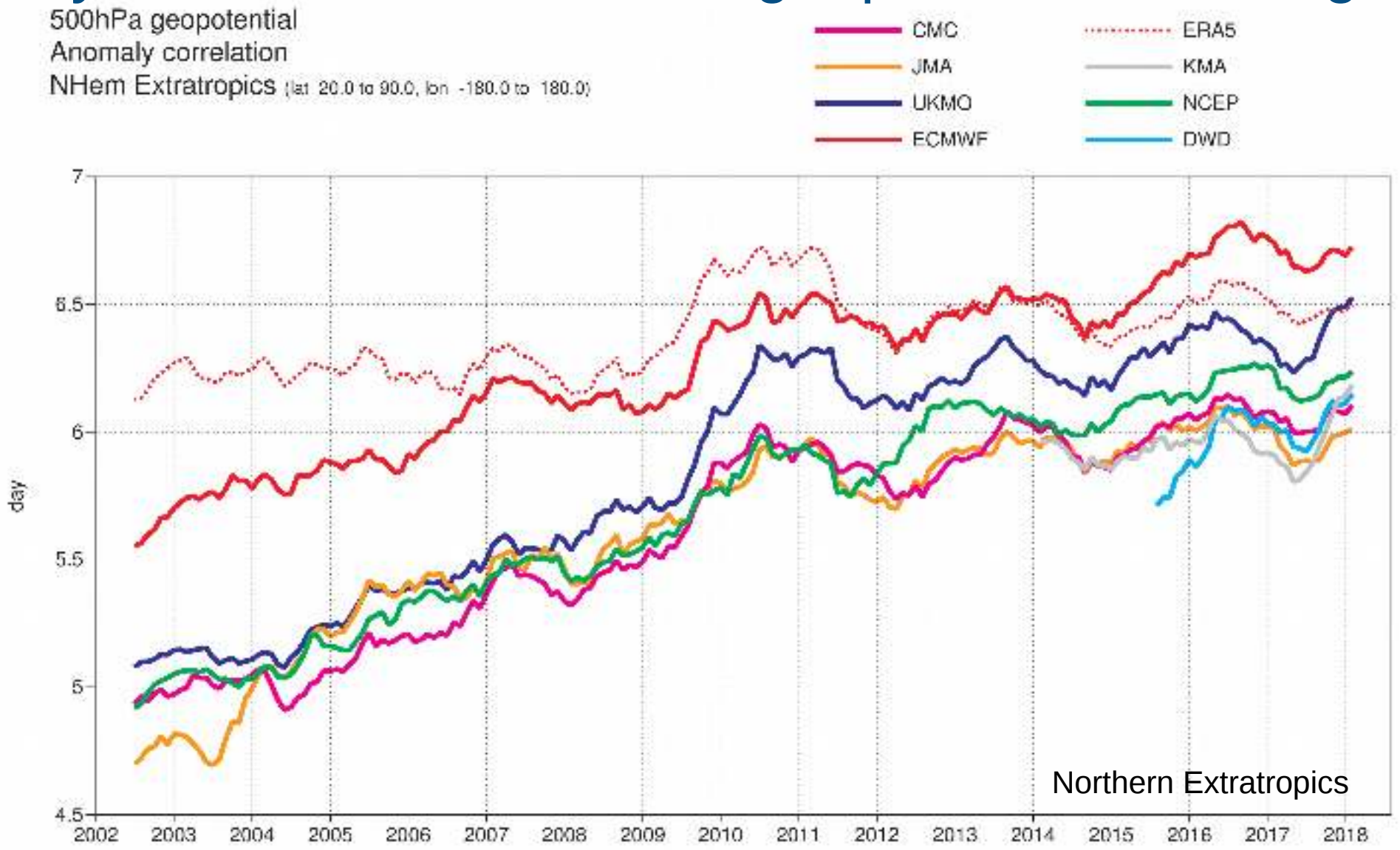

20 YEARS OF 4DVAR
20
25
25 YEARS OF ENSEMBLE FORECASTING

THE STRENGTH OF A COMMON GOAL

Evolution of ECMWF medium-range skill over the past 35 years



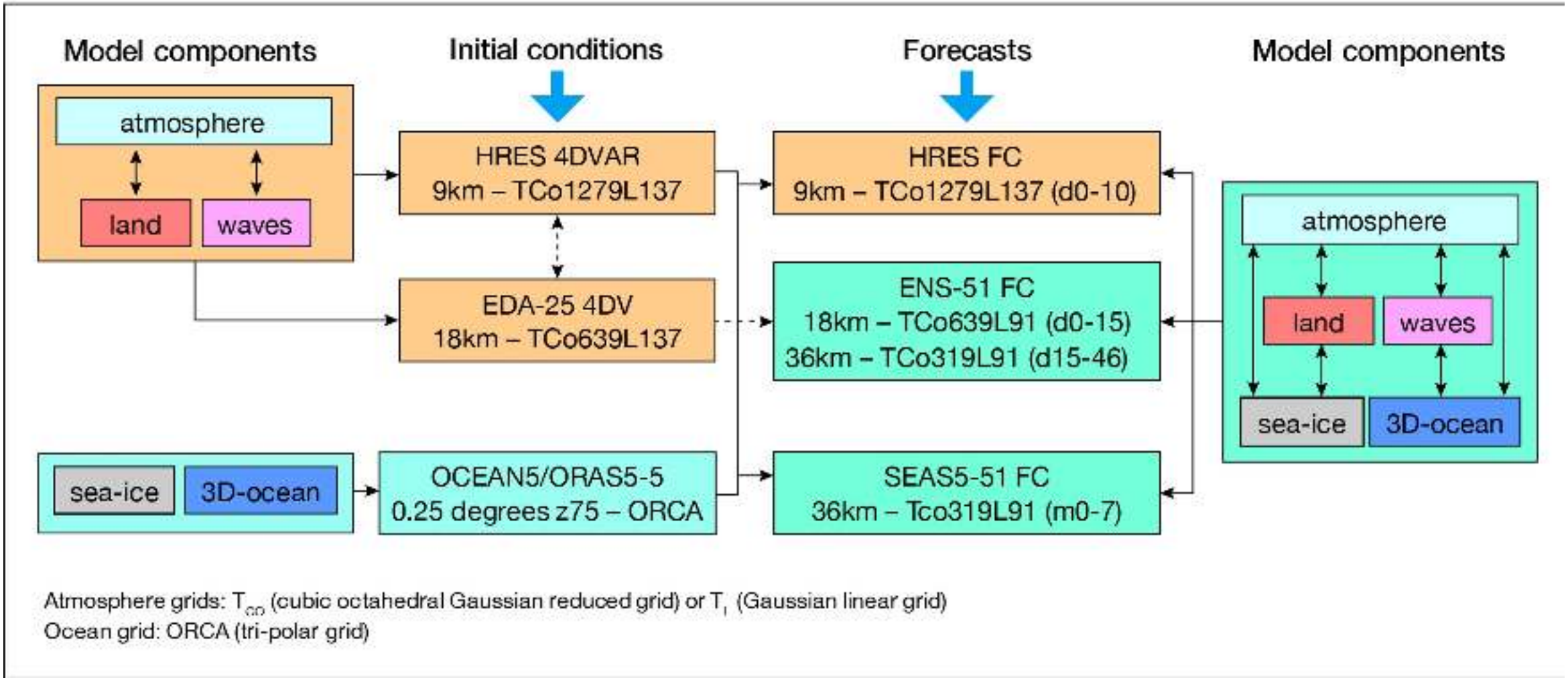
Anomaly correlation of 500 hPa geopotential reaching 80%



THE STRENGTH OF A COMMON GOAL

New emphasis: Percentage of large 2m temperature errors in the ensemble

The ECMWF suites (July 2018)



THE STRENGTH OF A COMMON GOAL

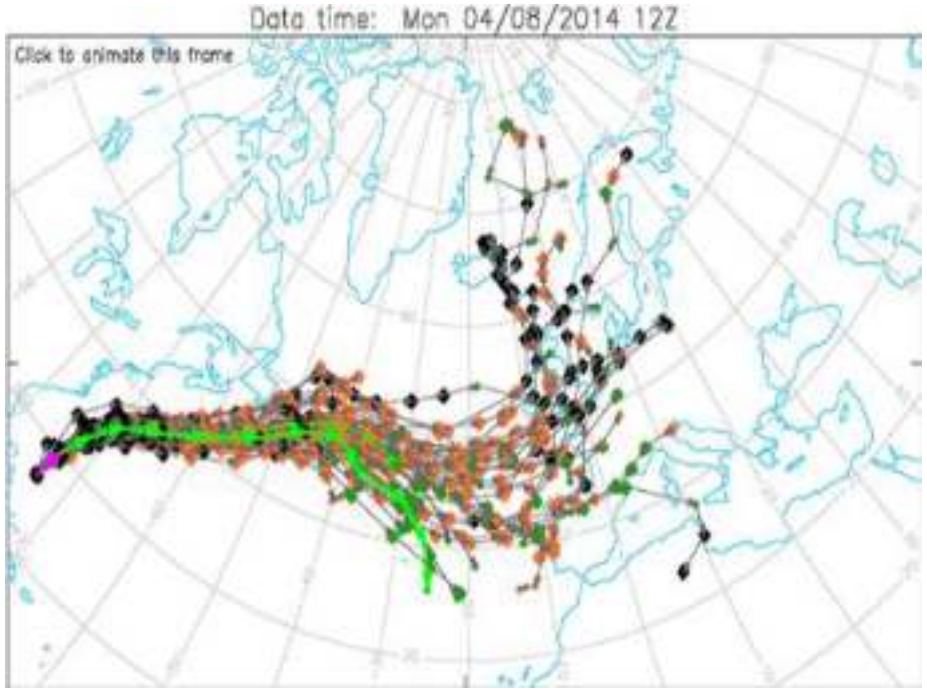
Forecast targets by 2025

- 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

THE STRENGTH OF A COMMON GOAL

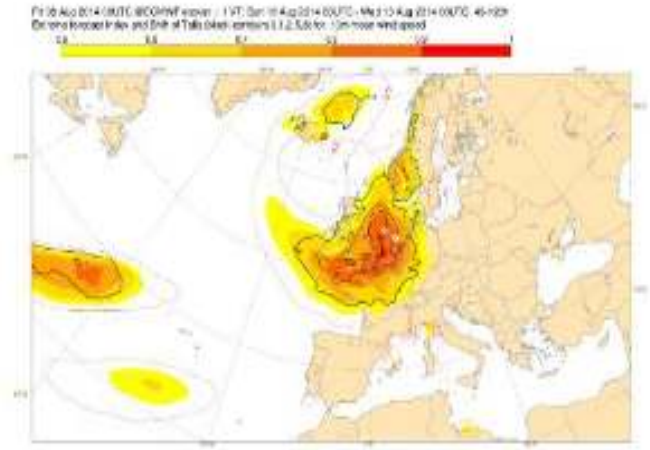
The size of the challenge # 1

Severe weather: Hurricane Bertha



The difficulty: Sharp ensembles two weeks ahead

6-9 days



2-5 days

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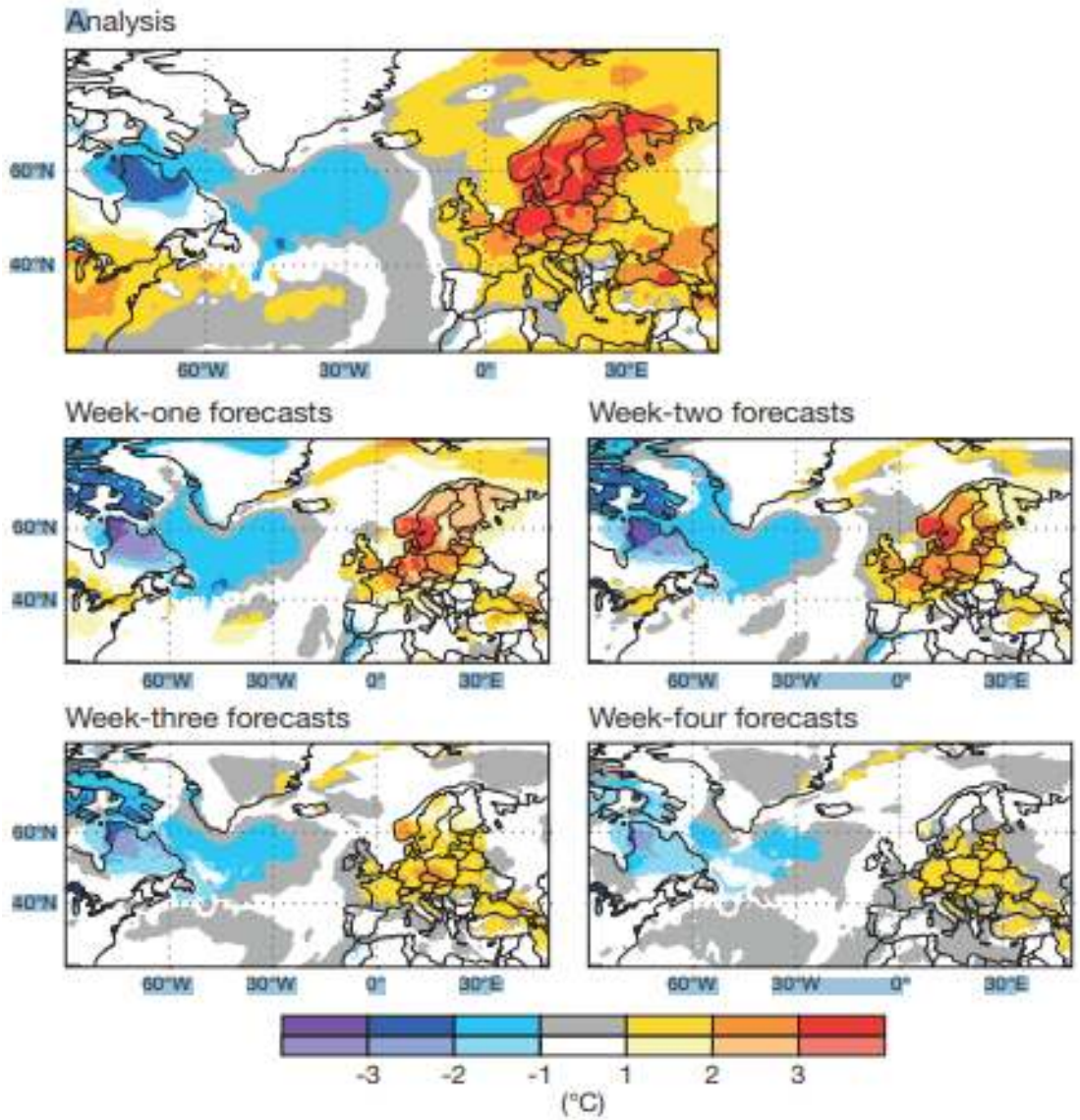
The size of the challenge # 2

Summer heatwave over Europe

2m Temperature,
7 May – 12 August 2018



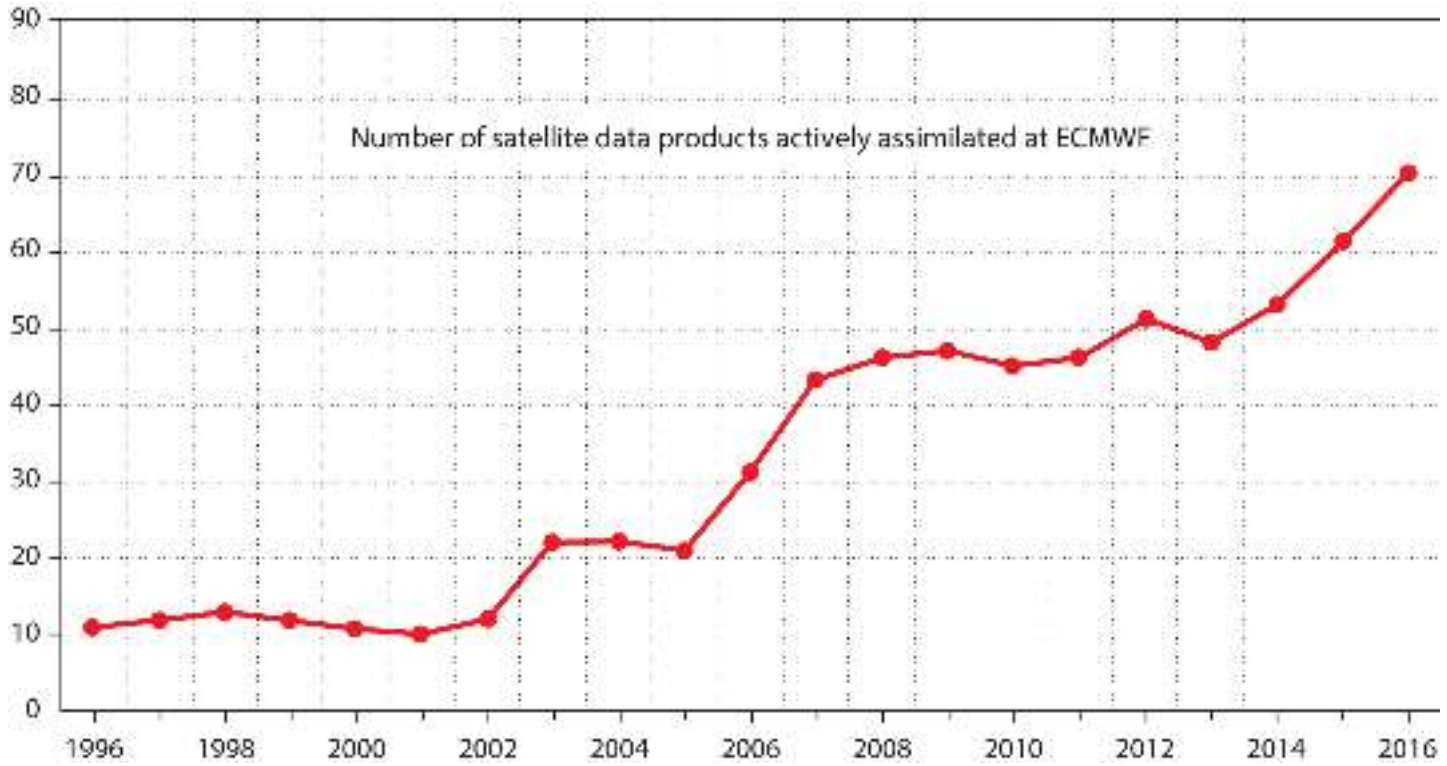
THE STRENGTH OF A COMMON GOAL

How do we achieve these goals?

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

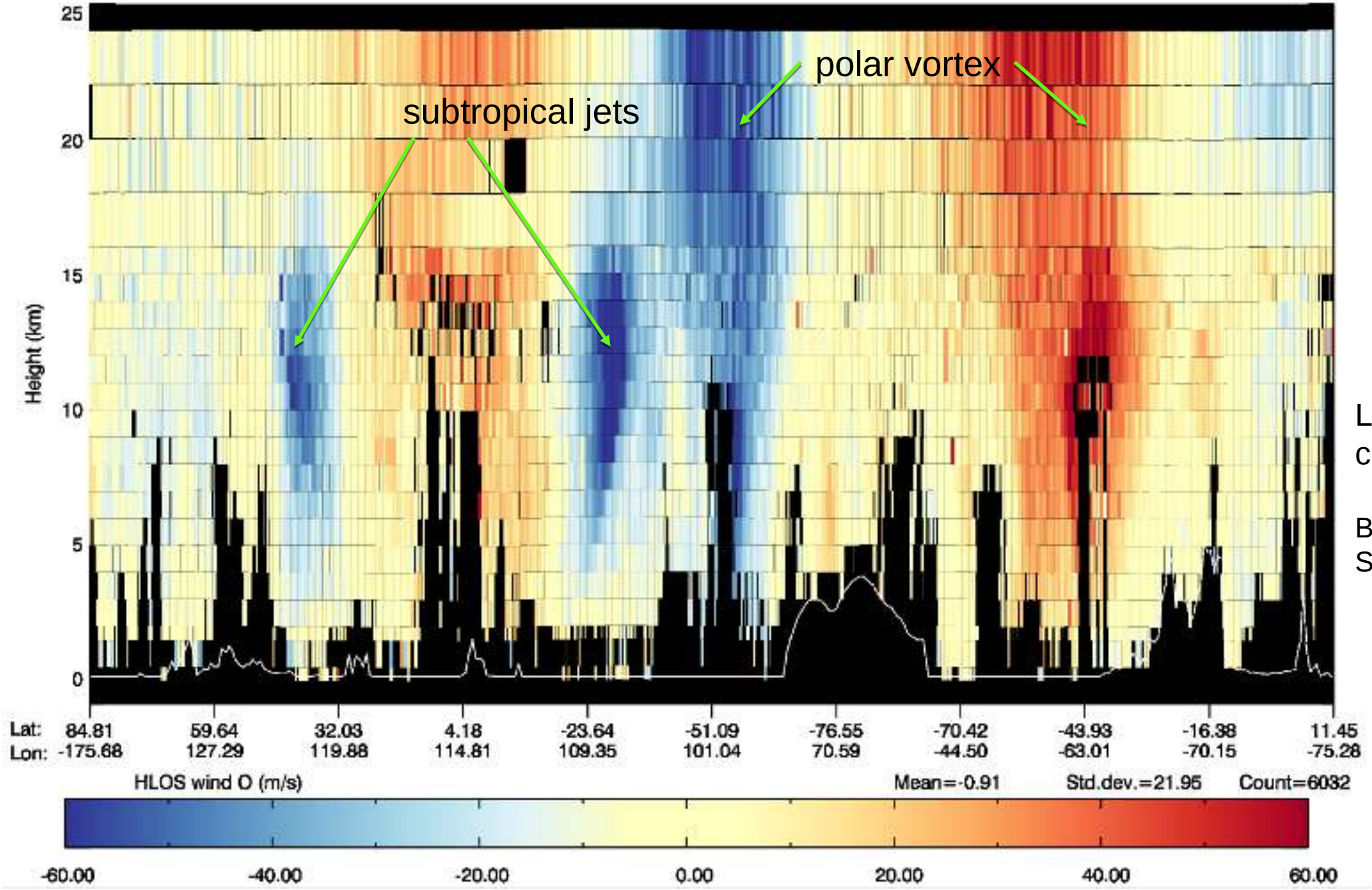
THE STRENGTH OF A COMMON GOAL

Use of satellite data at ECMWF



ECMWF processes an average of 40 million observations every day, from over 70 instruments. Collaboration with sister organisation EUMETSAT, and also ESA, CMA, JMA, NASA, NOAA among others ensures that ECMWF has access to the observations meteorology requires.

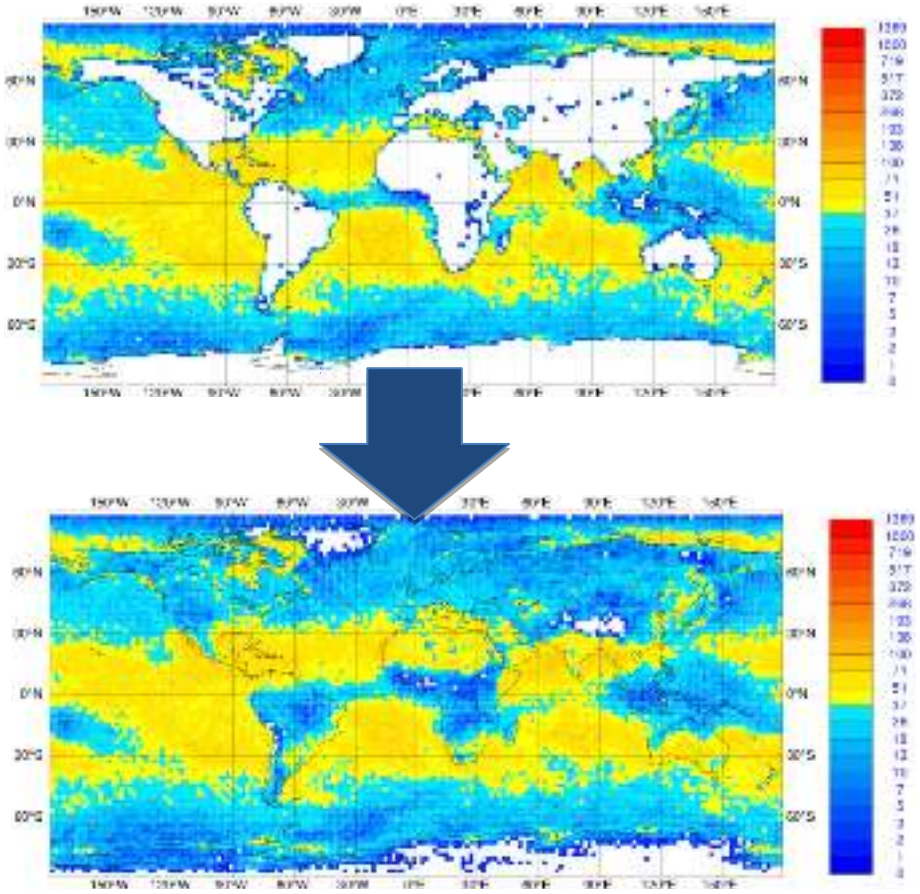
AEOLUS: wind observations from space



Level-2B Rayleigh-clear HLOS wind

Bias vs model ~ 4m/s
Stdev ~ 4.5m/s

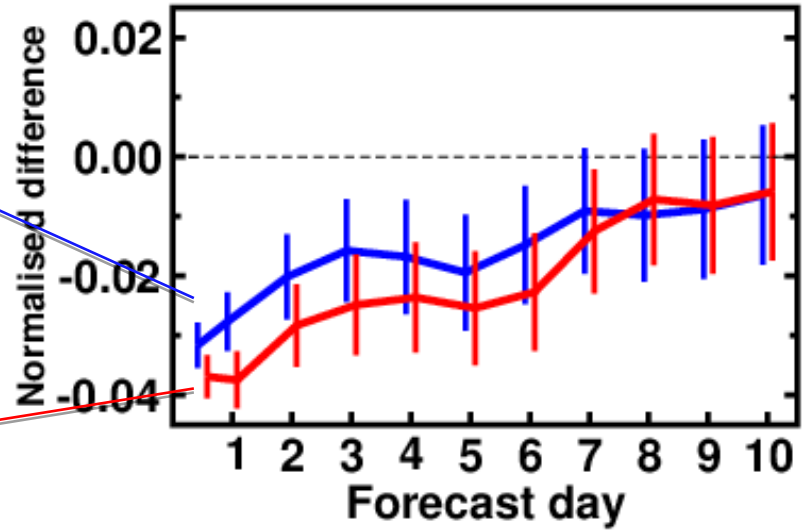
Increased used of hyperspectral infrared sounders over land



Impact of IR radiances in ***Cy43r3***

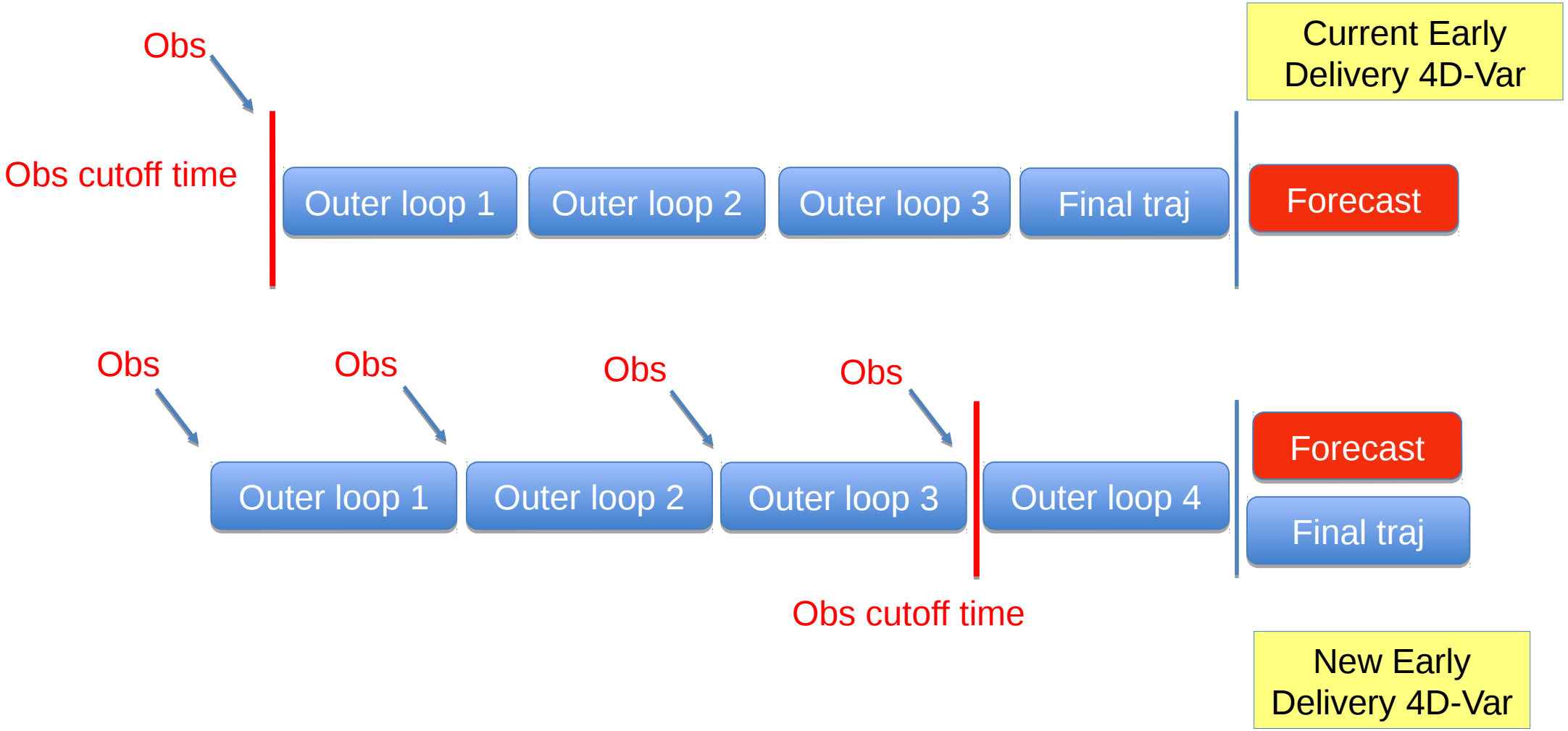
Impact of IR radiances in ***Cy45r1***

N.Hem. Z500 (RMSE)



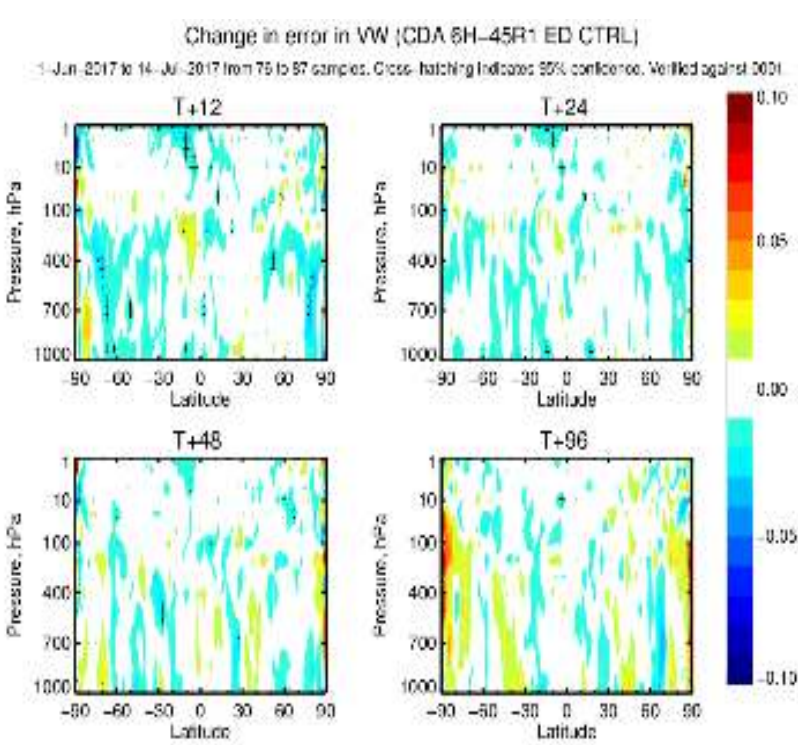
Activation of tropospheric IR data over land increased magnitude of forecast error reduction due to IR sounders by 50%

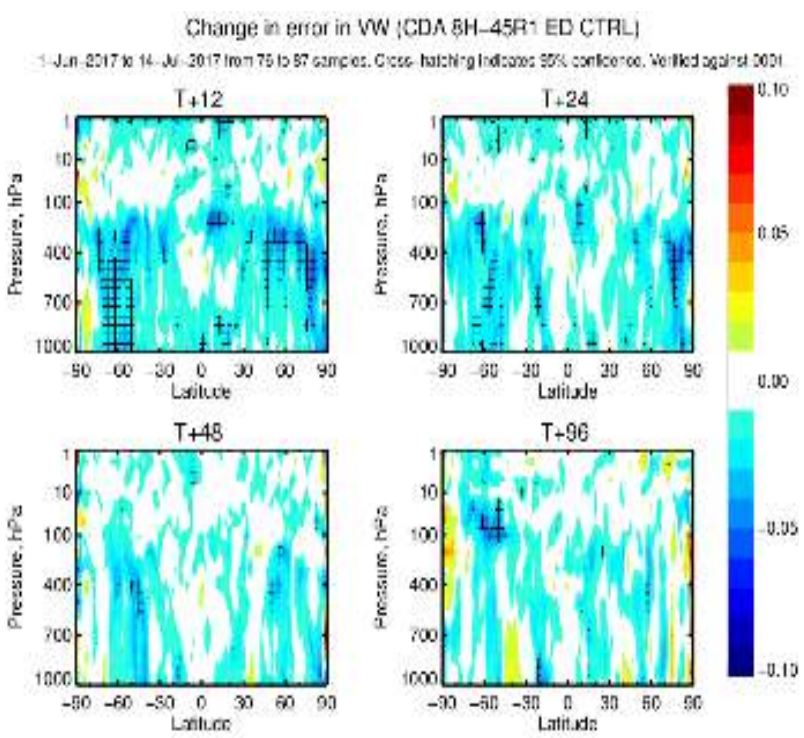
46r1: Continuous data assimilation

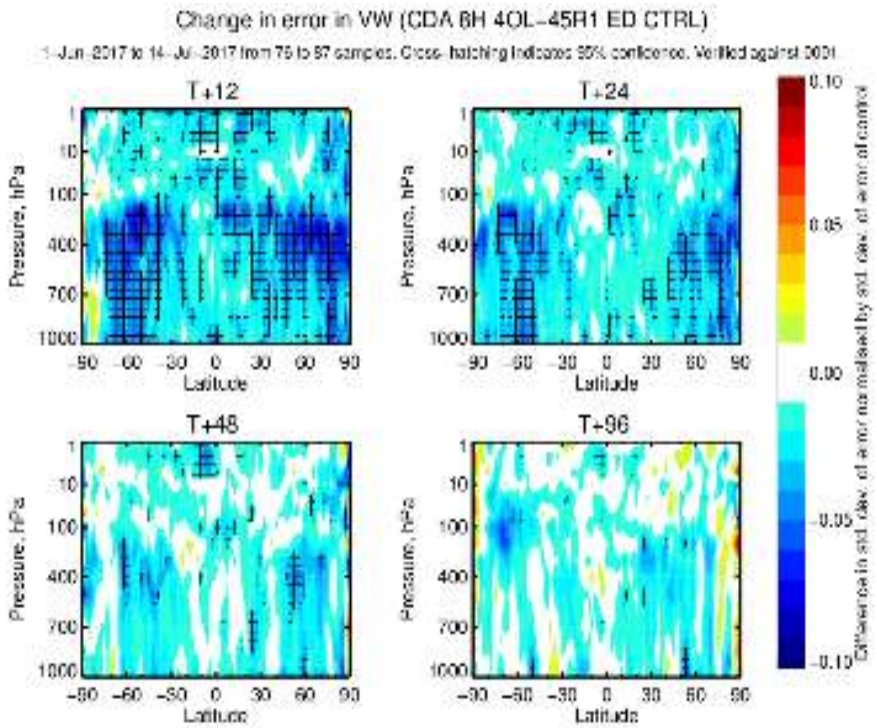


Continuous DA

- **Preliminary results (Wind Vector error stdev, 1/6/17 – 14/7/17)**





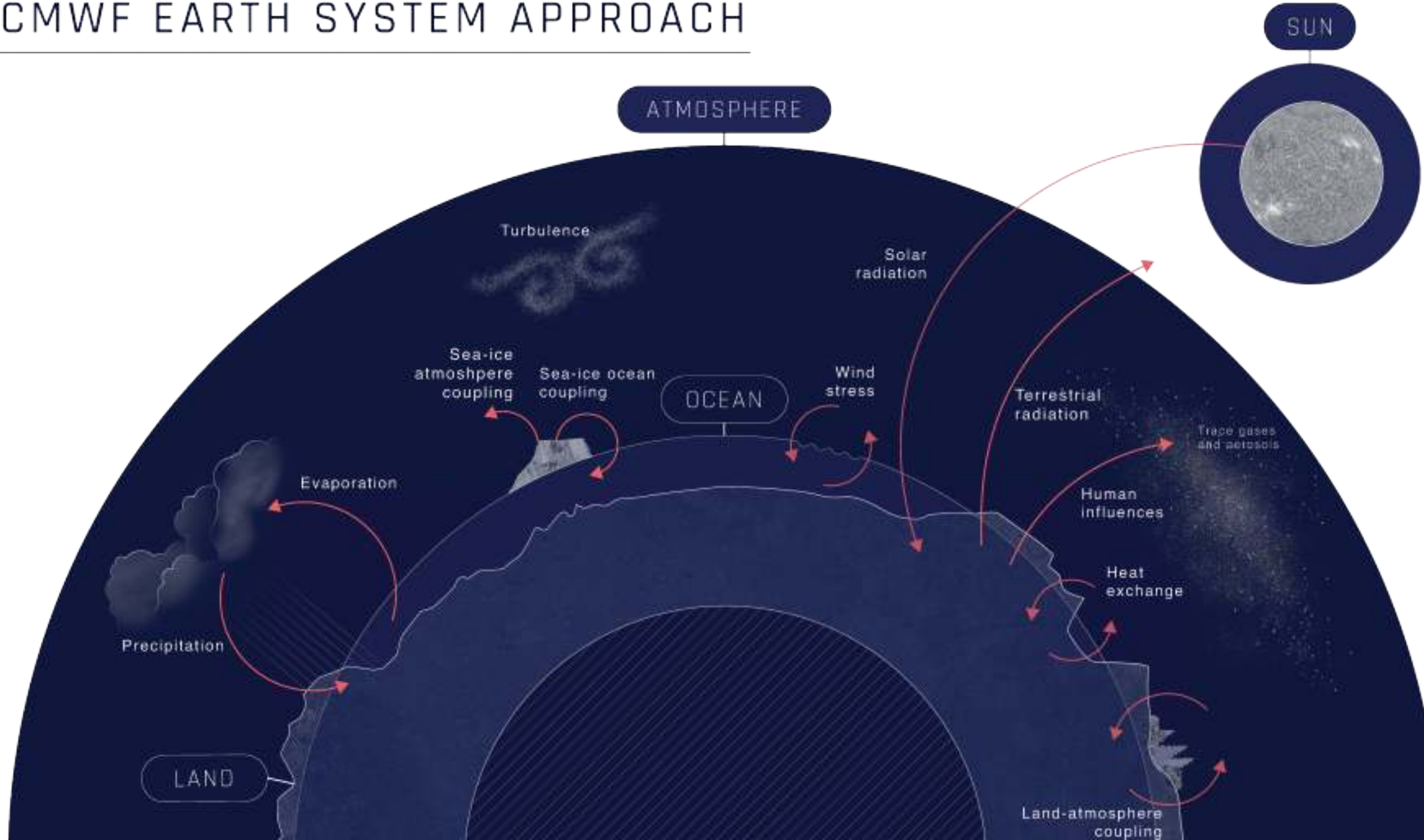


A: Late obs – 6h window

B: Late obs – 8h window

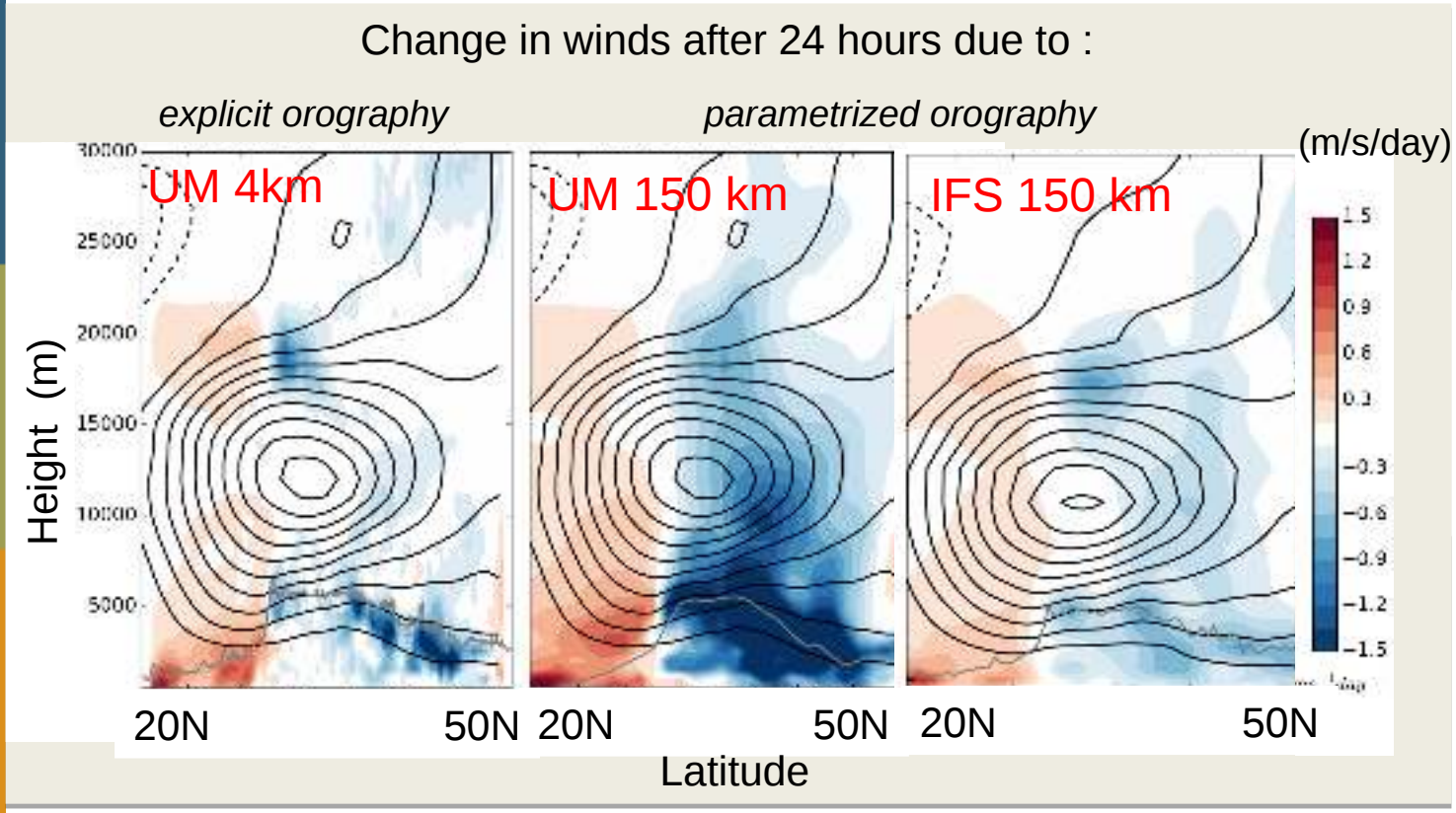
C: B + 4 outer loops

ECMWF EARTH SYSTEM APPROACH



Physics/dynamics as f(resolution)

Circulation response to resolved vs parametrized orographic drag



Errors in the circulation response induced by orographic drag at low/intermediate resolution are due to both the parametrizations and their coupling with the dynamics

van Niekerk, Sandu and Vosper, JAMES, 2018

New GASS/WGNE intercomparison
(DWD, Meteo-France, CMC, JMA, KIAPS, NOAA/NCEP)

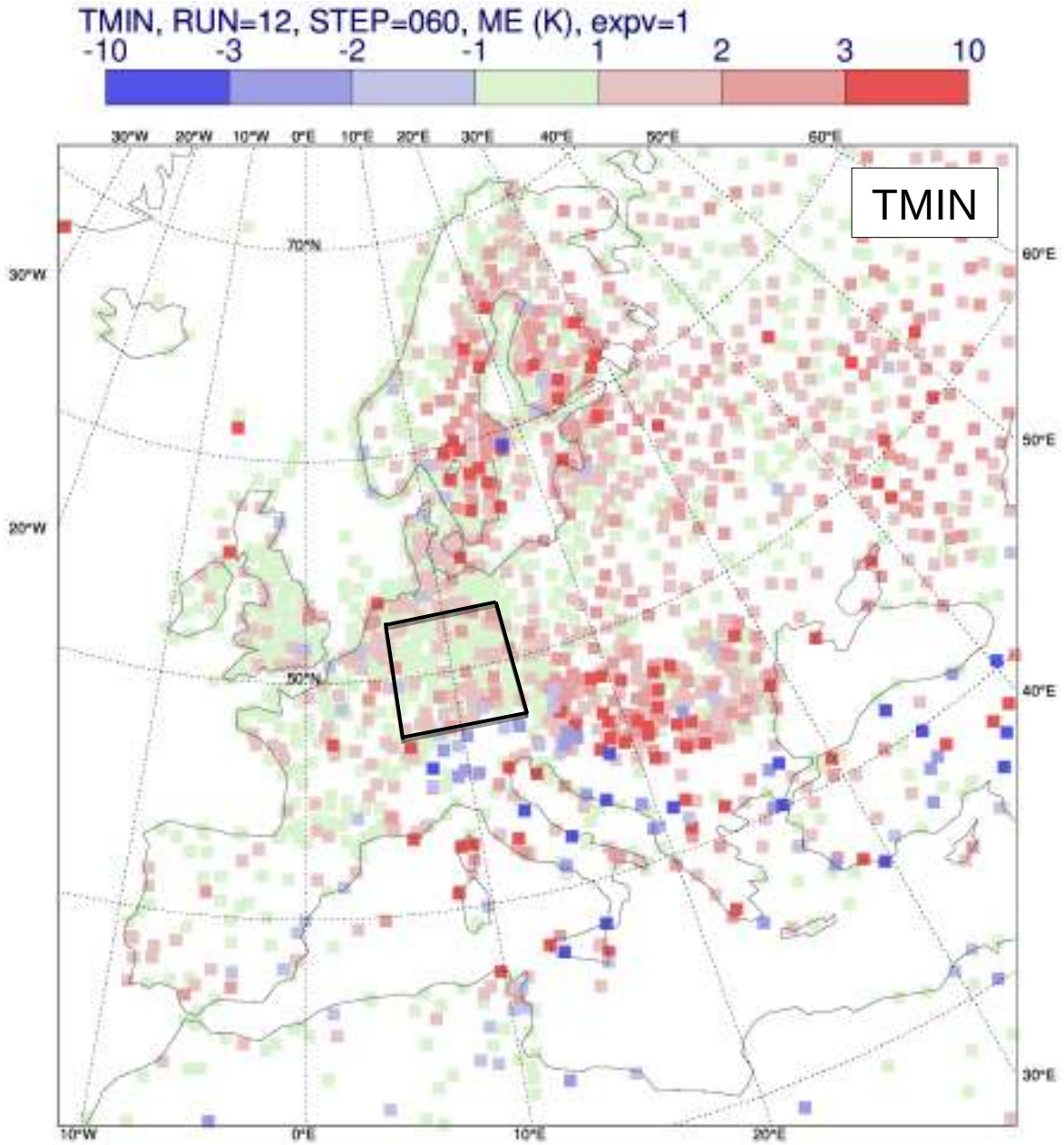
ECMWF

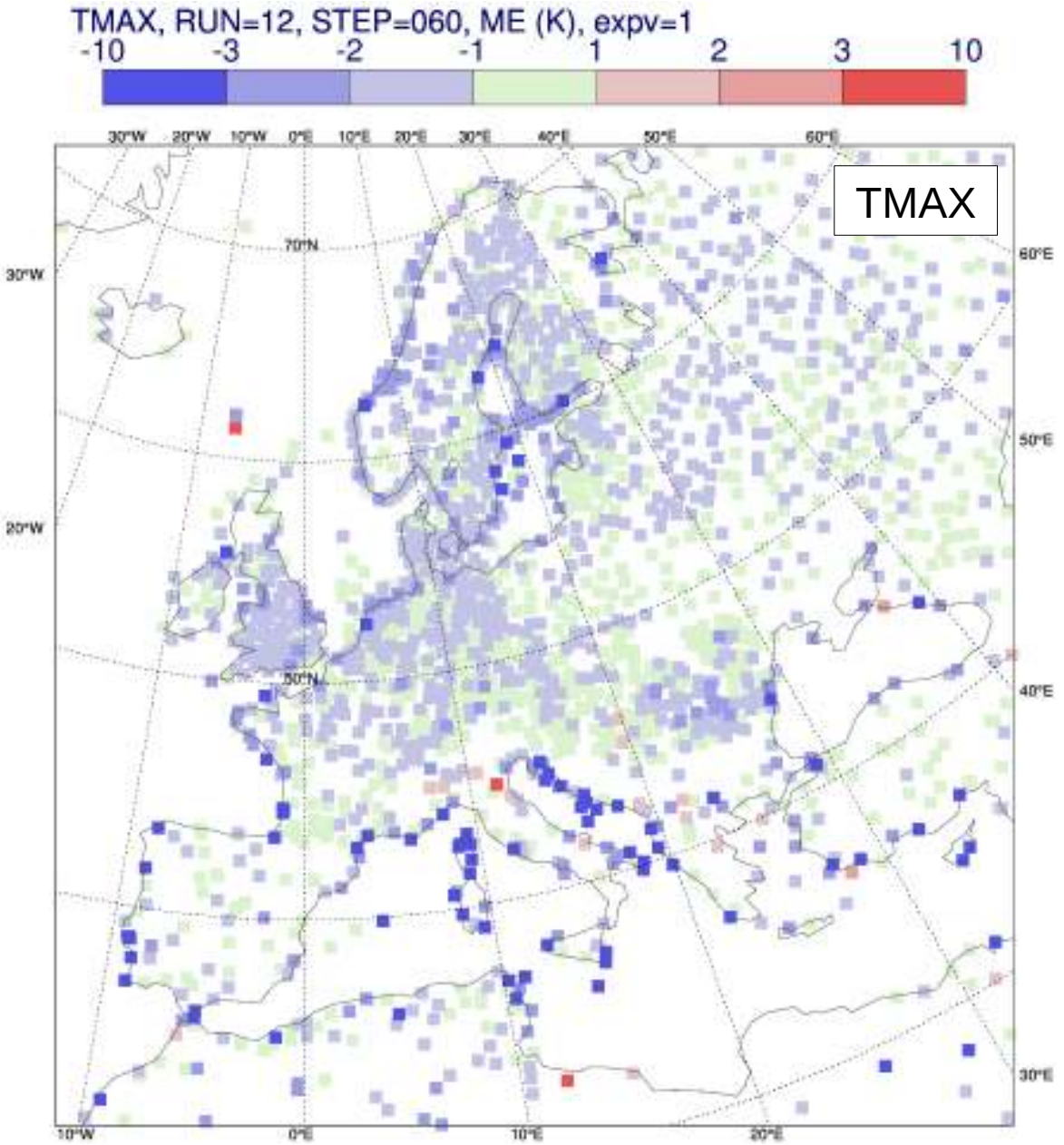
ECMWF

Met Office

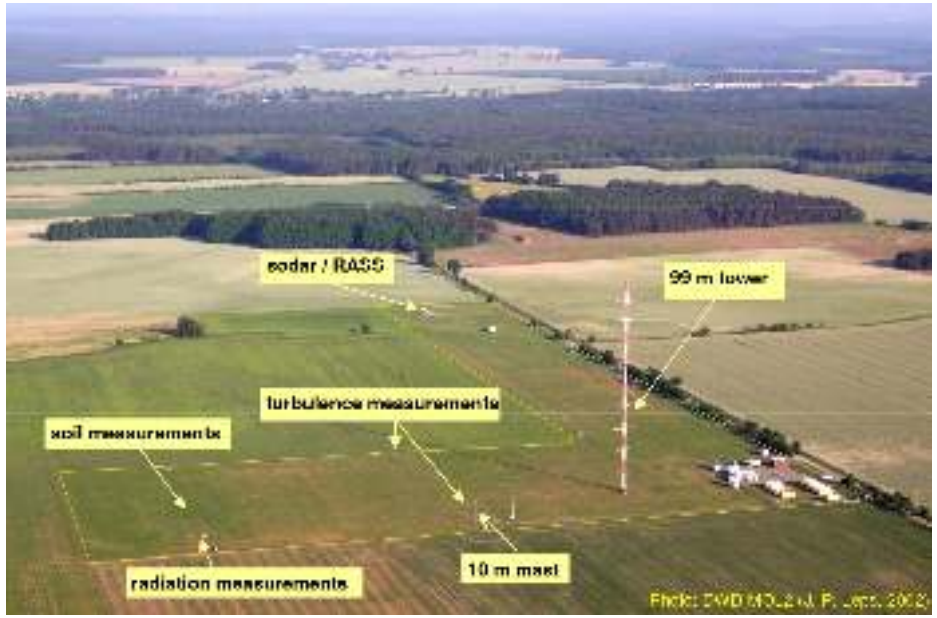
Focus on near-surface weather

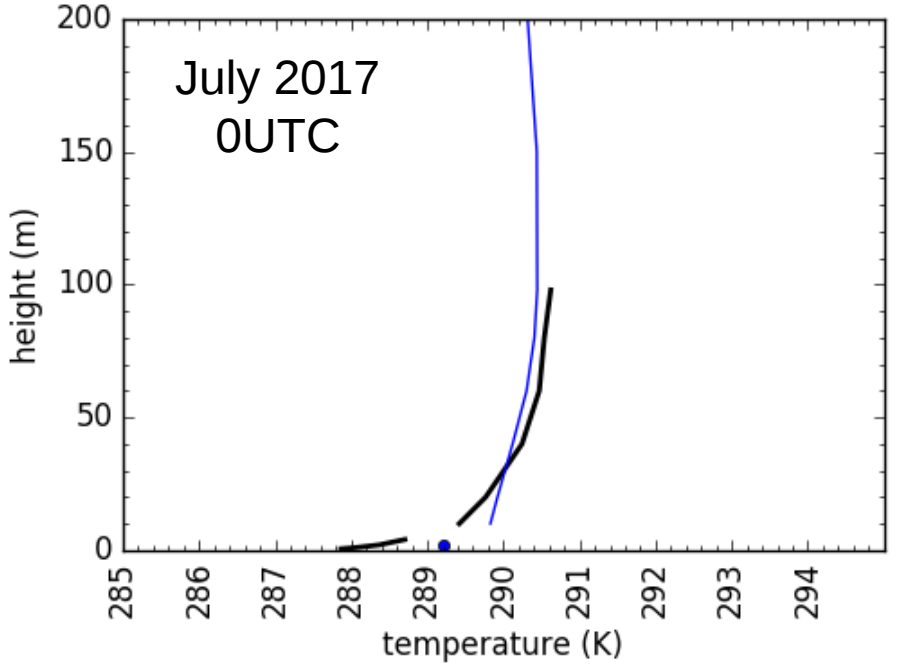
TMIN and TMAX bias – Europe June-July 2017



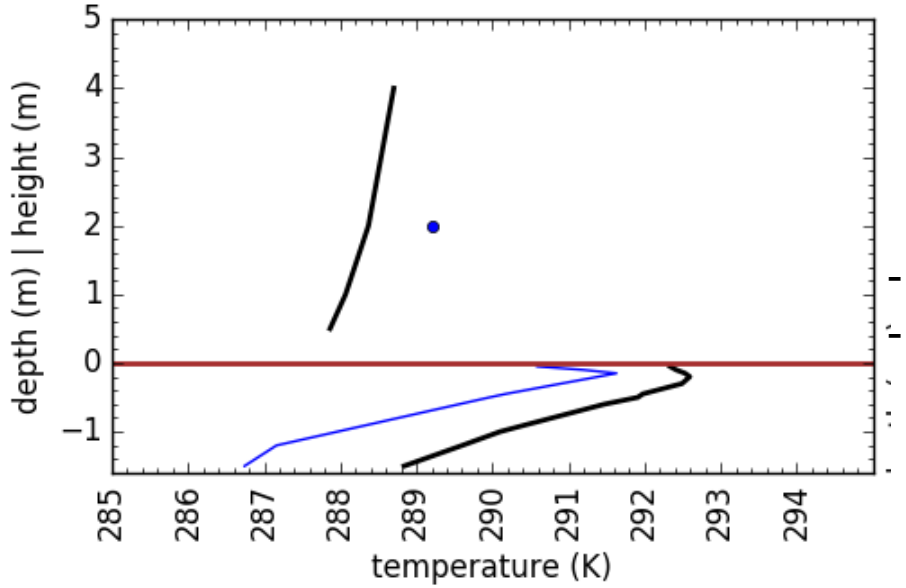


Using supersite data to understand biases





Obs
Oper

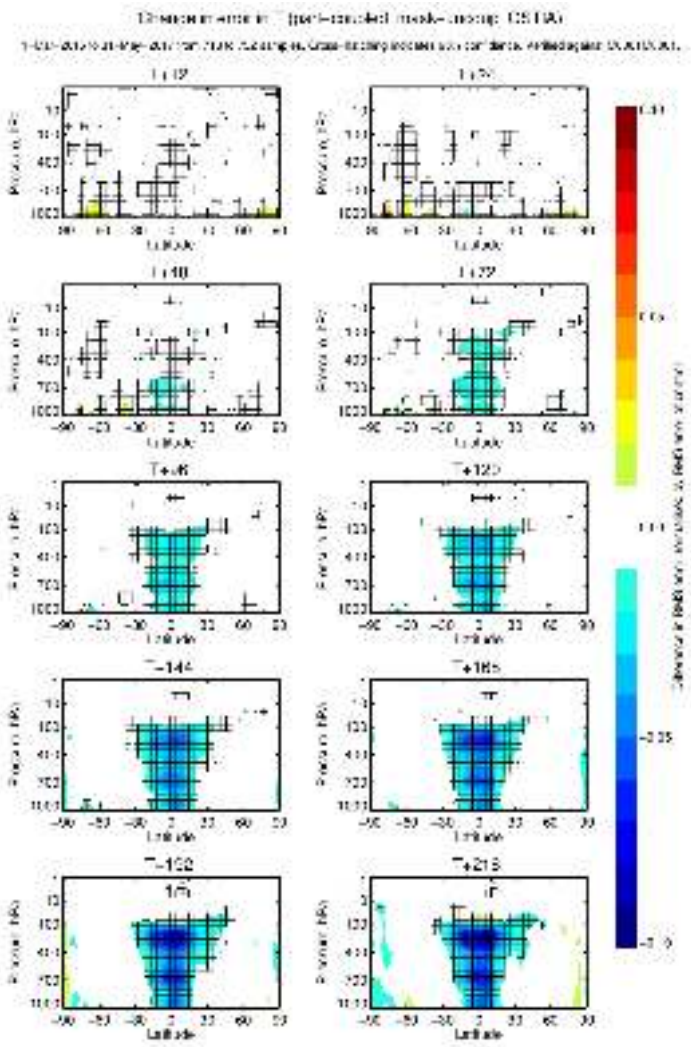


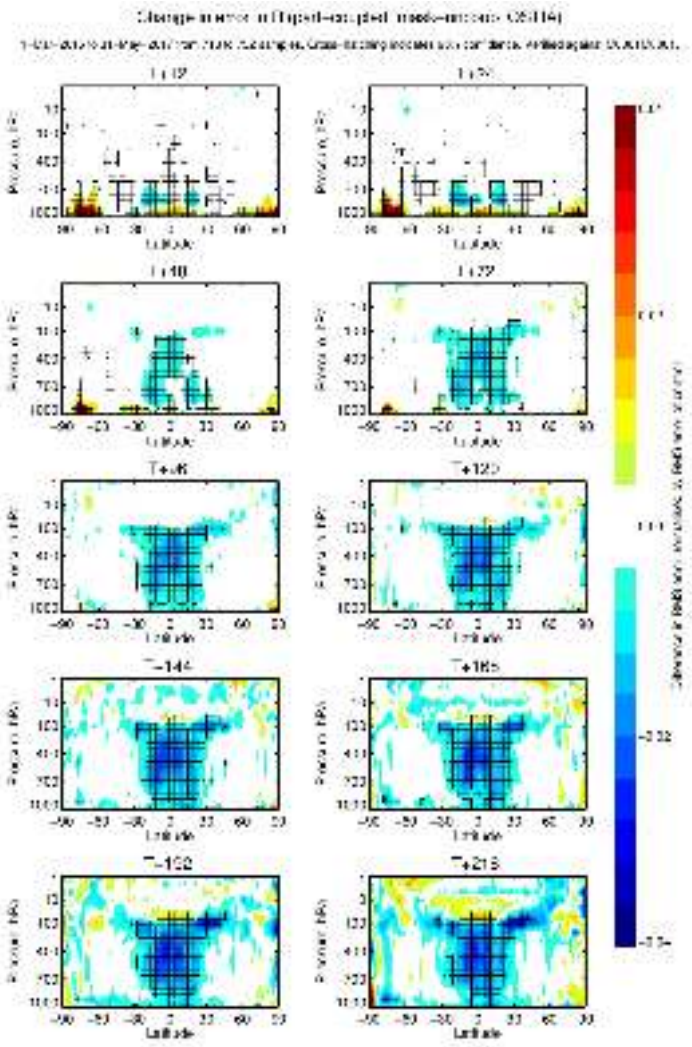
- 2T too warm
- soil too cold

P. Schmederer, I. Sandu, T. Haiden

Impact of coupling (2 years combined scores. TCo1279)

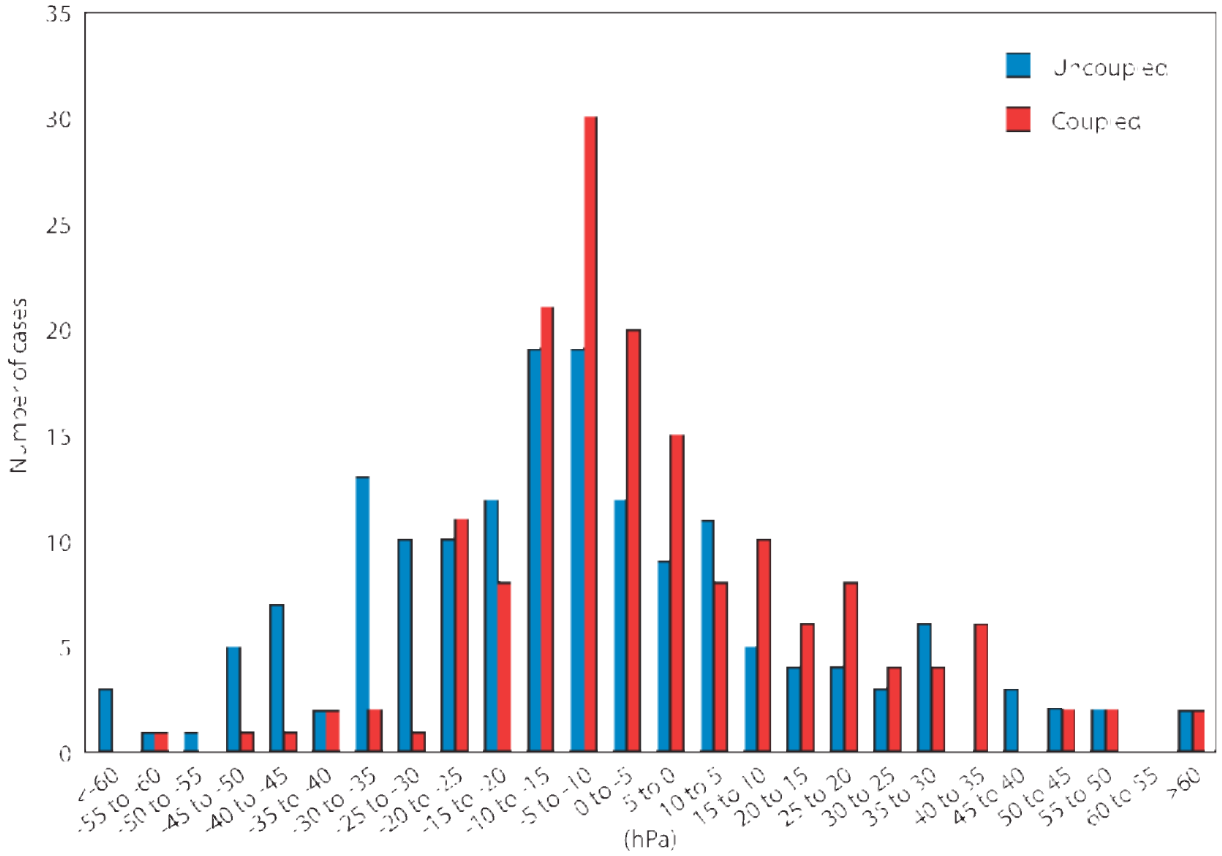
Temperature





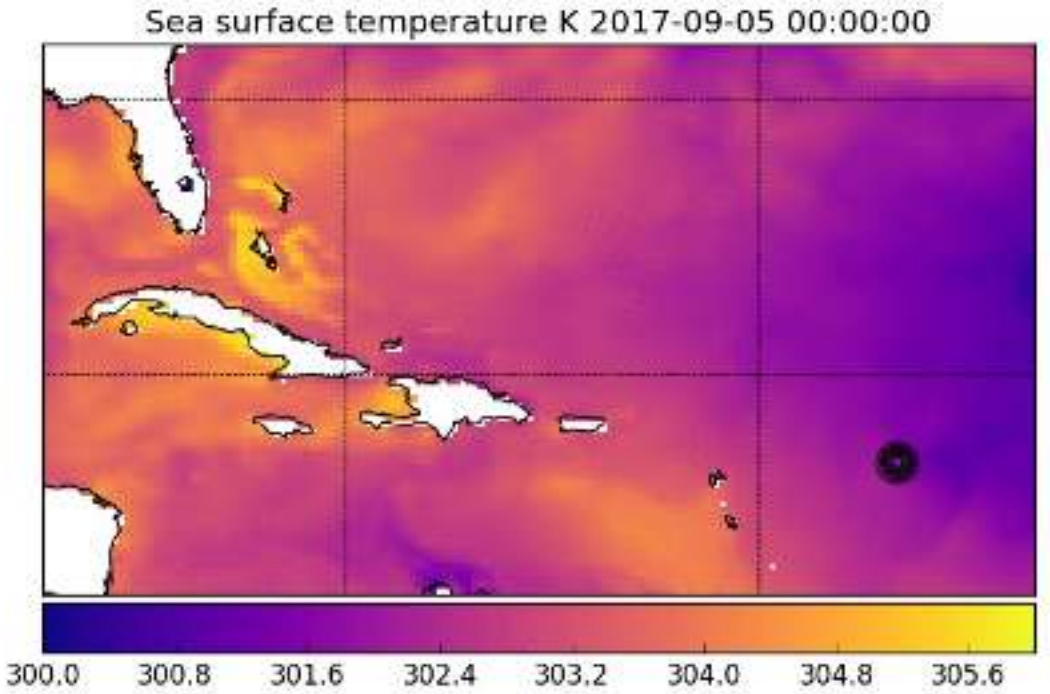
Humidity

Does the ocean coupling actually matter for a large sample of TC's?

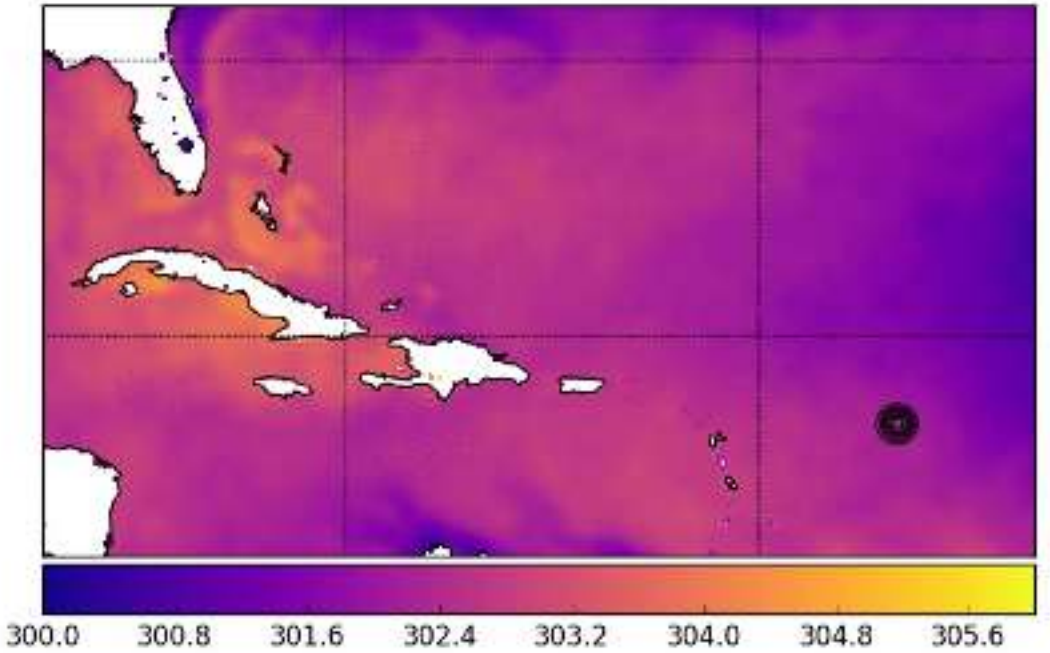


- Distribution of 7-day TC intensity forecast errors for coupled and uncoupled high-resolution forecast experiments.
- The experiments cover the period of March 2015 to June 2017 and were carried out over all basins for a total of 163 TCs.
- The number of over predictions is reduced in the coupled forecasts compared to the uncoupled forecasts.

Quasi-strong coupled data assimilation
(outer loop coupling)



Atmospheric data assimilation
(OSTIA SST)



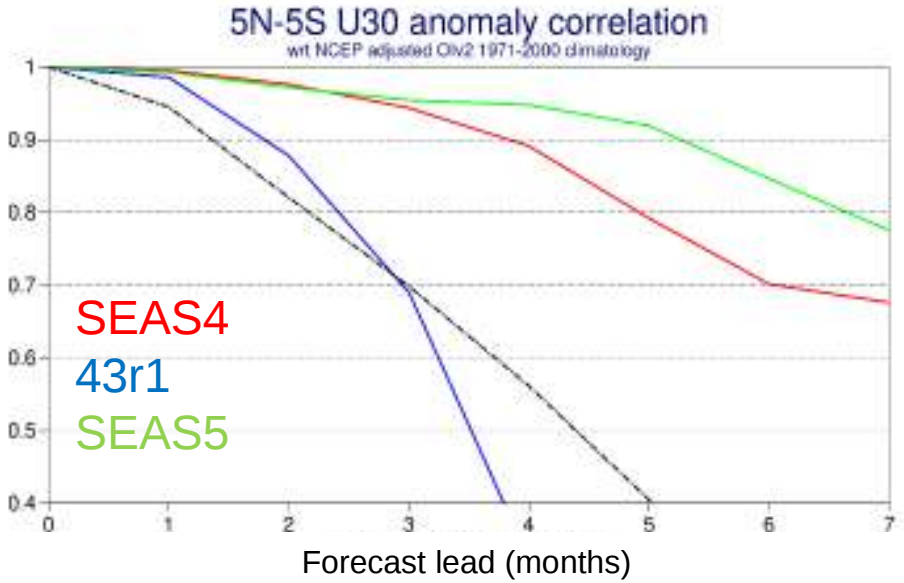
THE STRENGTH OF A COMMON GOAL

Seamless modelling systems

- Scientific and infrastructure advantages of convergence of approaches across timescales

- Seasonal SEAS5 only differs from the 43r1 ENS extended (monthly) system when testing demonstrated clear improvement in forecast skill or mean state
  - Horizontal (Tco319/ORCA25) and vertical resolution (L91/L75) identical

- Improvements found on one timescale applicable for others
  - Decreasing non-orographic gravity wave drag ameliorates the effect of stratospheric temperature and winds biases on the QBO
  - Preferred seasonal setting now found suitable for adoption for medium-range to monthly



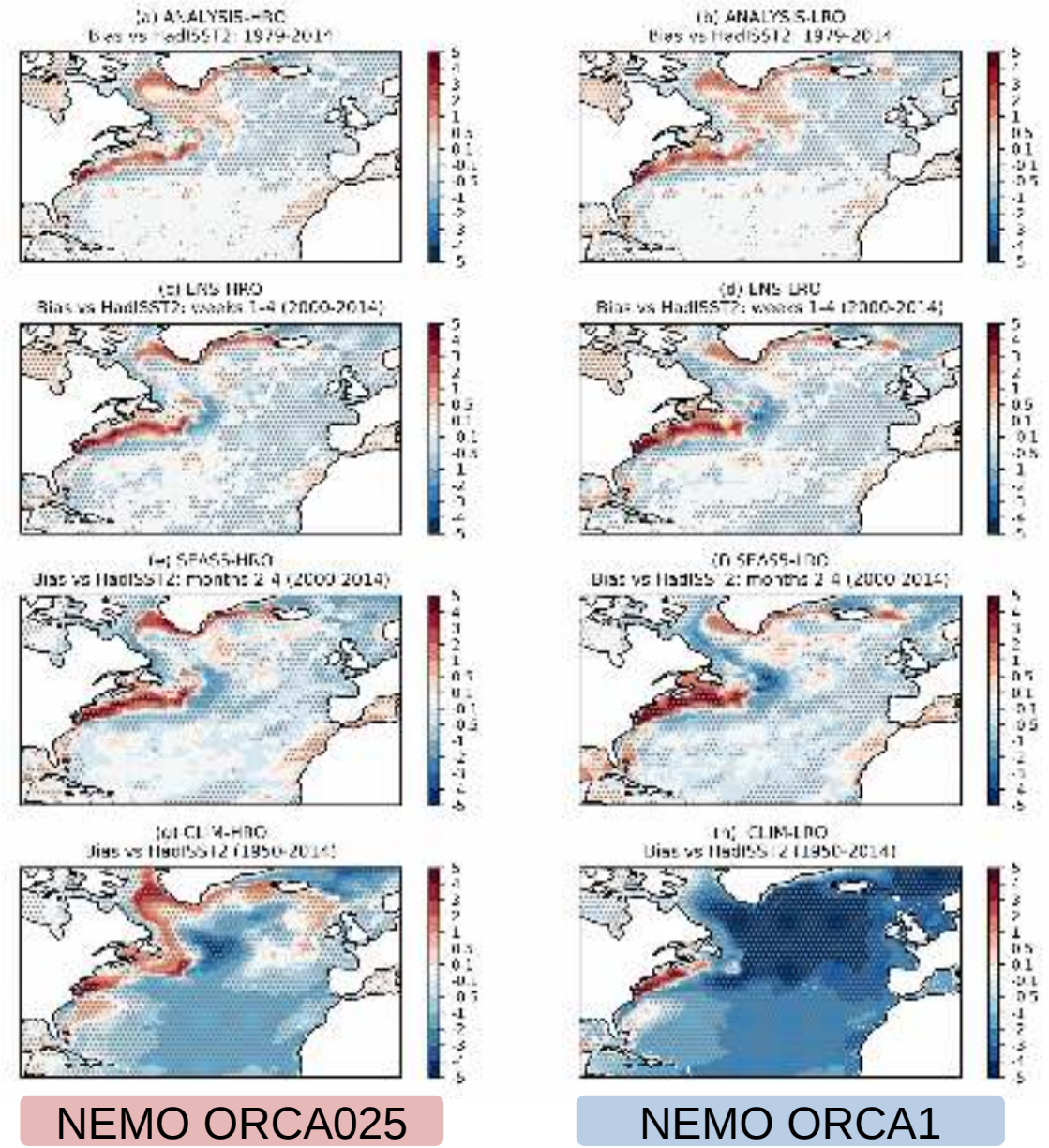
Impact of ocean resolution as a function of forecast lead time: North Atlantic DJF SST biases (K) vs HadISST2

Analysis

Weeks 1-4

Months 2-4

Model climate



NEMO ORCA025

NEMO ORCA1

Mean biases are similar at sub-seasonal time scales and to a large extent inherited from analysis.

Solutions begin to diverge at seasonal time scales

Model climate is very different – relevant for coupled reanalyses.

ECMWF Scalability Programme

Governance: ECMWF, Member states, Regional consortia

Projects:

Observation processing:
- Lean workflow in critical path
- Object based data store
- Screening/bias correction

Data assimilation:
- Flexible algorithms (C++)
- IFS integration
- Coupling with ocean and sea-ice
- Parallel minimization

Numerical methods:
- Numerical methods
- h/v/t-discretization, multiple grids
- Prognostic variables, coupling

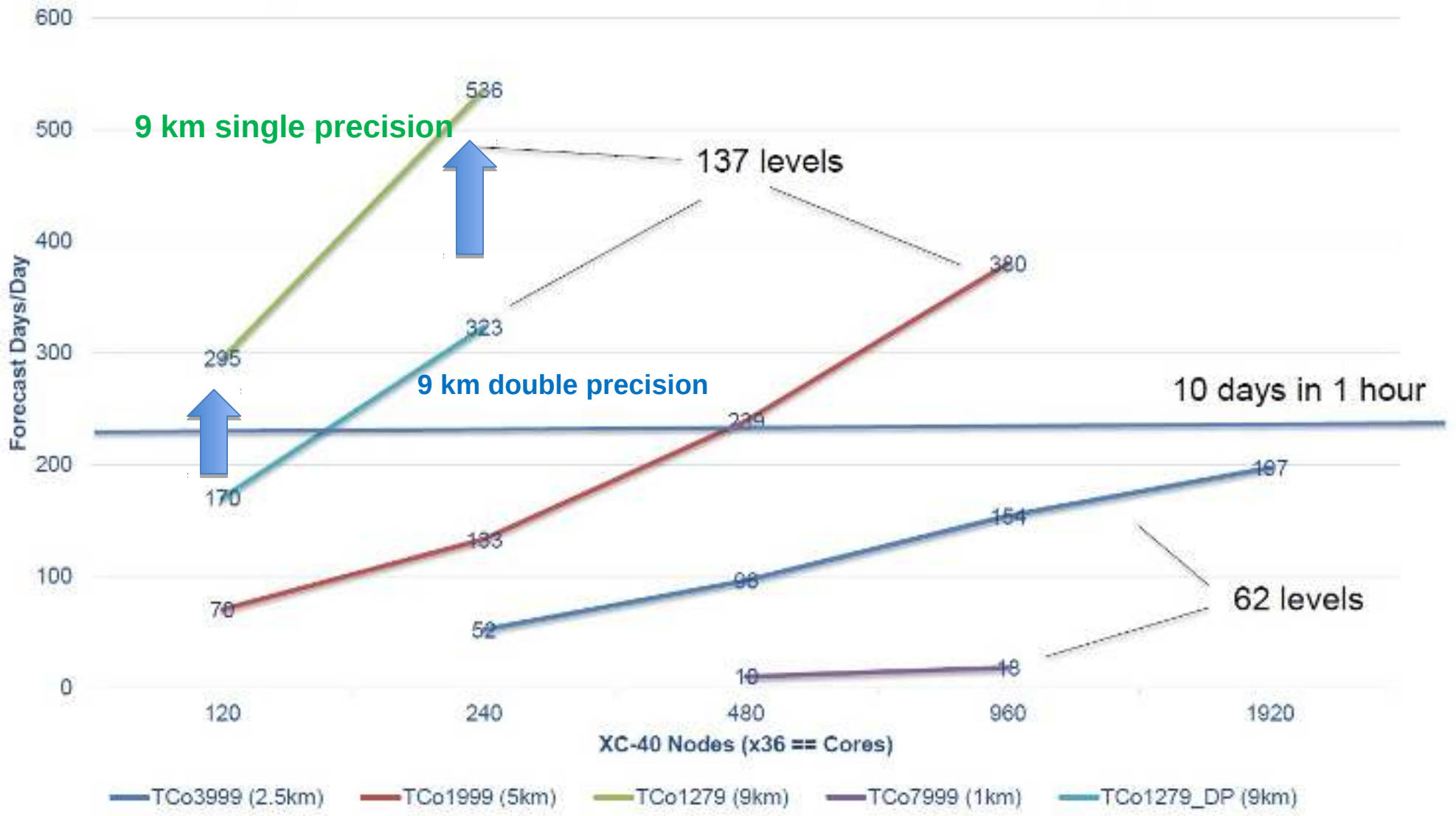
Model output processing:
- Broker-worker workflow
- Near-memory processing
- Data compression

Code adaptation:
· Benchmarking · Vectorization · Programming models · Precision · DSL/libraries · Transition to operations

Computer architecture support:
· Benchmarking · Novel architectures · Compilers · Vendor support · Transition to operations

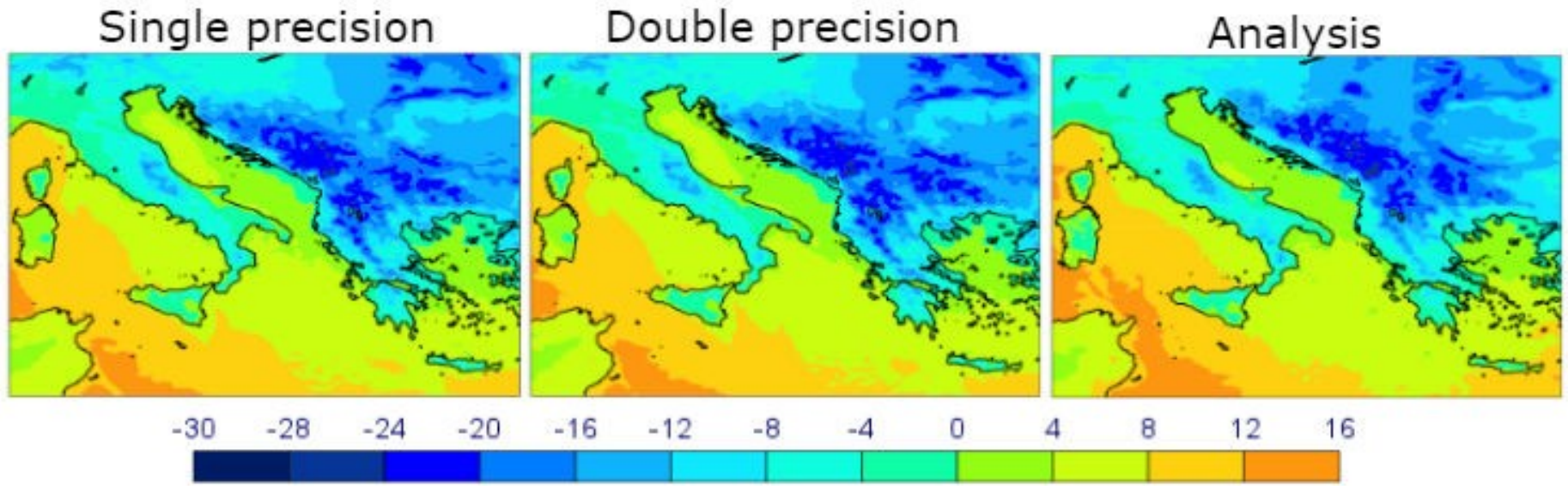
Funded by the
European Union

ESiWACE: Single precision IFS



Scalability across the NWP chain:

Single precision to deliver efficiency gains



Surface temperature in degree Celsius for five day forecasts for 8th January 2017 0:00 UTC. This date is during the European cold wave that caused very low temperature in Eastern and Central Europe. Results are shown for single precision and double precision simulations at 9km (TCo1279) resolution (left and middle) and the analysis as a reference (right). Differences between single and double precision are very small.

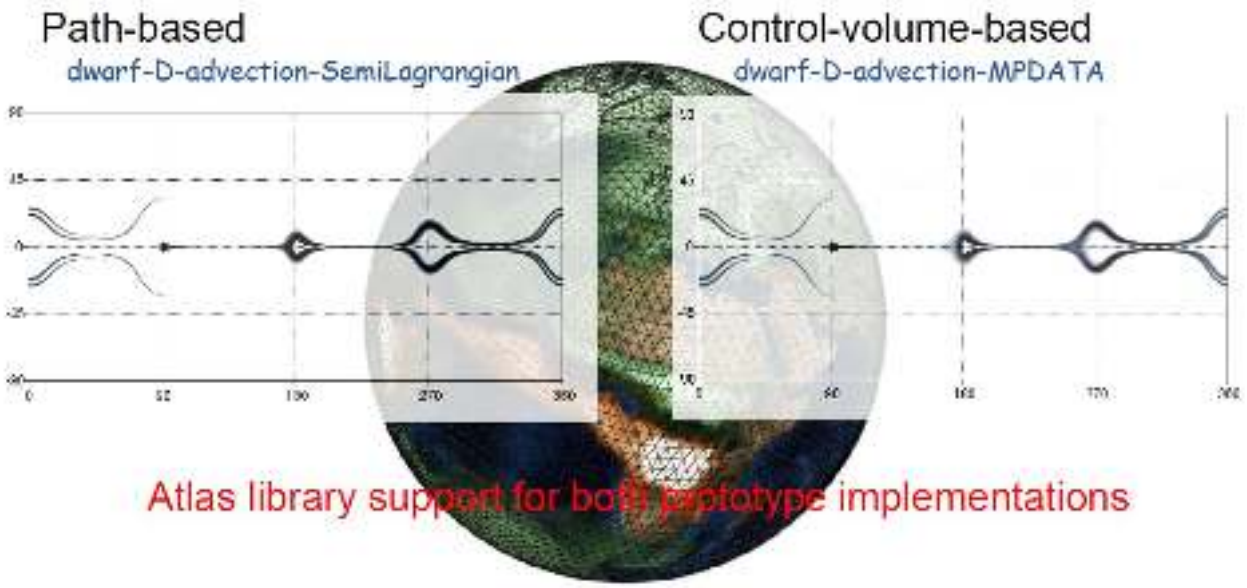
Funded by the
European Union

ESCAPE: Dwarfs

Concept:

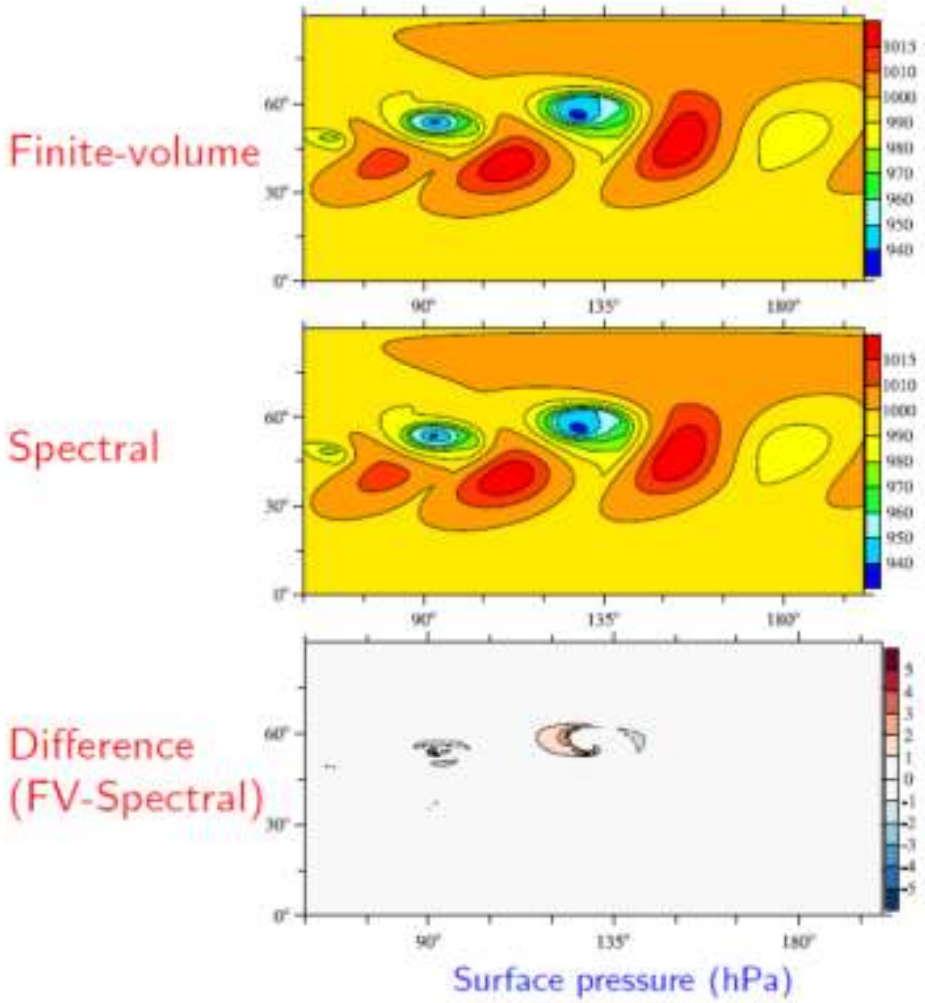
- Extract key functional components, adapt to new processors
- Build in algorithmic flexibility for future IFS

Rossby-Haurwitz test case after 7 days



Atlas library support for both prototype implementations

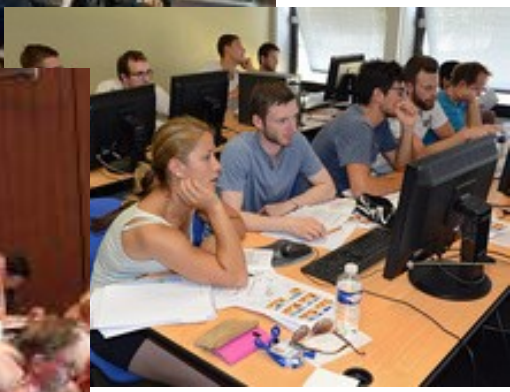
Dry baroclinic instability, FVM (O640) versus the spectral IFS ($T_{co}639$):



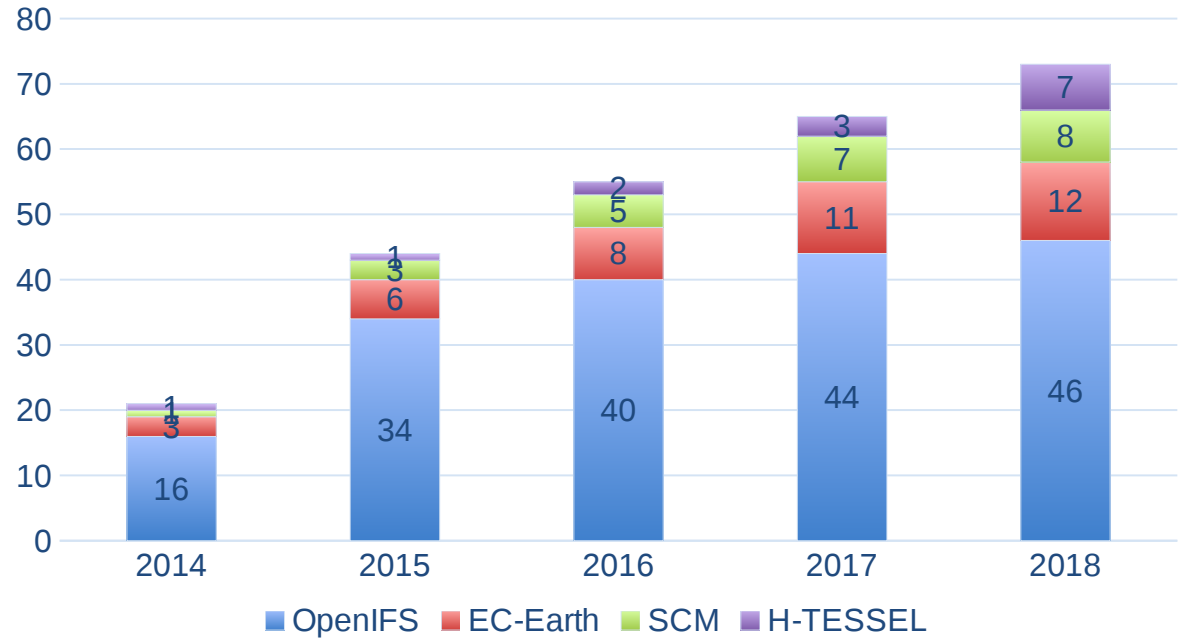
Deconinck et al, Computer Physics Communications, 2017

Collaborations and serving community: WORKSHOPS

- Workshop on shedding light on the greyzone
- Workshop on developing Python frameworks for earth system sciences
- ECMWF/ESA workshop on using low frequency passive microwave measurements in research and operational applications
- Workshop on observations and analysis of sea-surface temperature and sea ice for NWP and climate applications
- Workshop: Hydrological services for business
- Workshop: Radiation in the next generation of weather forecast models
- Workshop on Member and Co-operating State requirements for ECMWF outputs in support of multi-hazard Early Warning Systems
- Using ECMWF's forecasts (UEF2018)
- Hackathon: "Innovate with Open Climate Data"
- Workshop on physics-dynamics coupling 2018 (PDC18)
- Radio-Frequency Interference (RFI) workshop
- Annual Seminar: Earth system assimilation
- 18th Workshop on high performance computing in meteorology



Collaborations and serving community: OpenIFS licensed sites



- Total number of licensed sites with breakdown of main model used.
- Some sites use multiple models.
- Number of licensed sites does not match active users.

New licensees (09/2017 – 09/2018):

U. Bari, Italy : HTESSEL coupled to CaMa-Flood

Charles U., Prague : CHTESSEL (CAMS-81 project)

GEOMAR, Helmholtz Centre for Ocean Research : replacing ECHAM with OpenIFS in Kiel Climate Model.

UFZ, Helmholtz Centre for Environmental Research : HTESSEL cf Noah-MP.

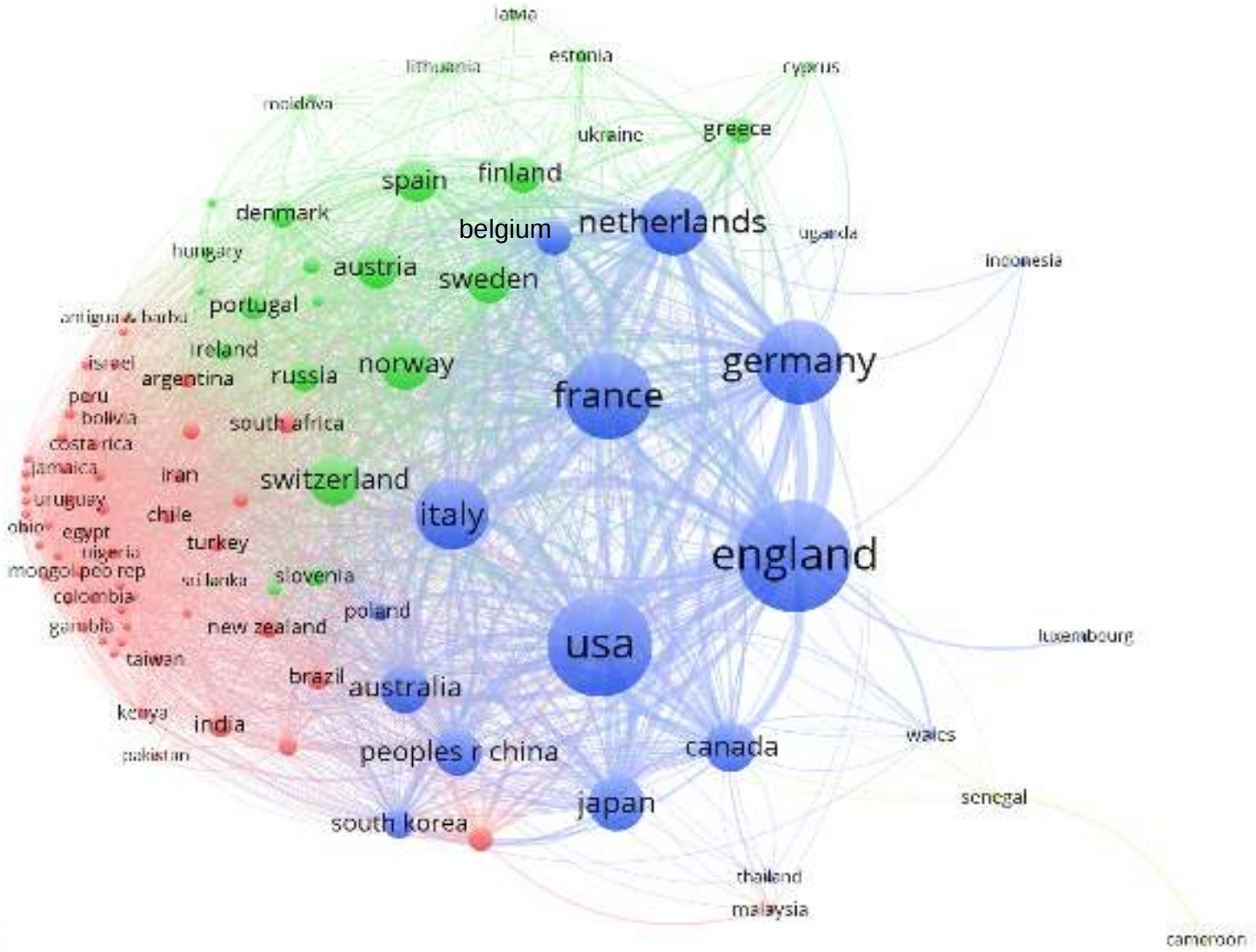
INPE, Brazil : Using SCM for tropical convection.

JRC-ISPRA : HTESSEL

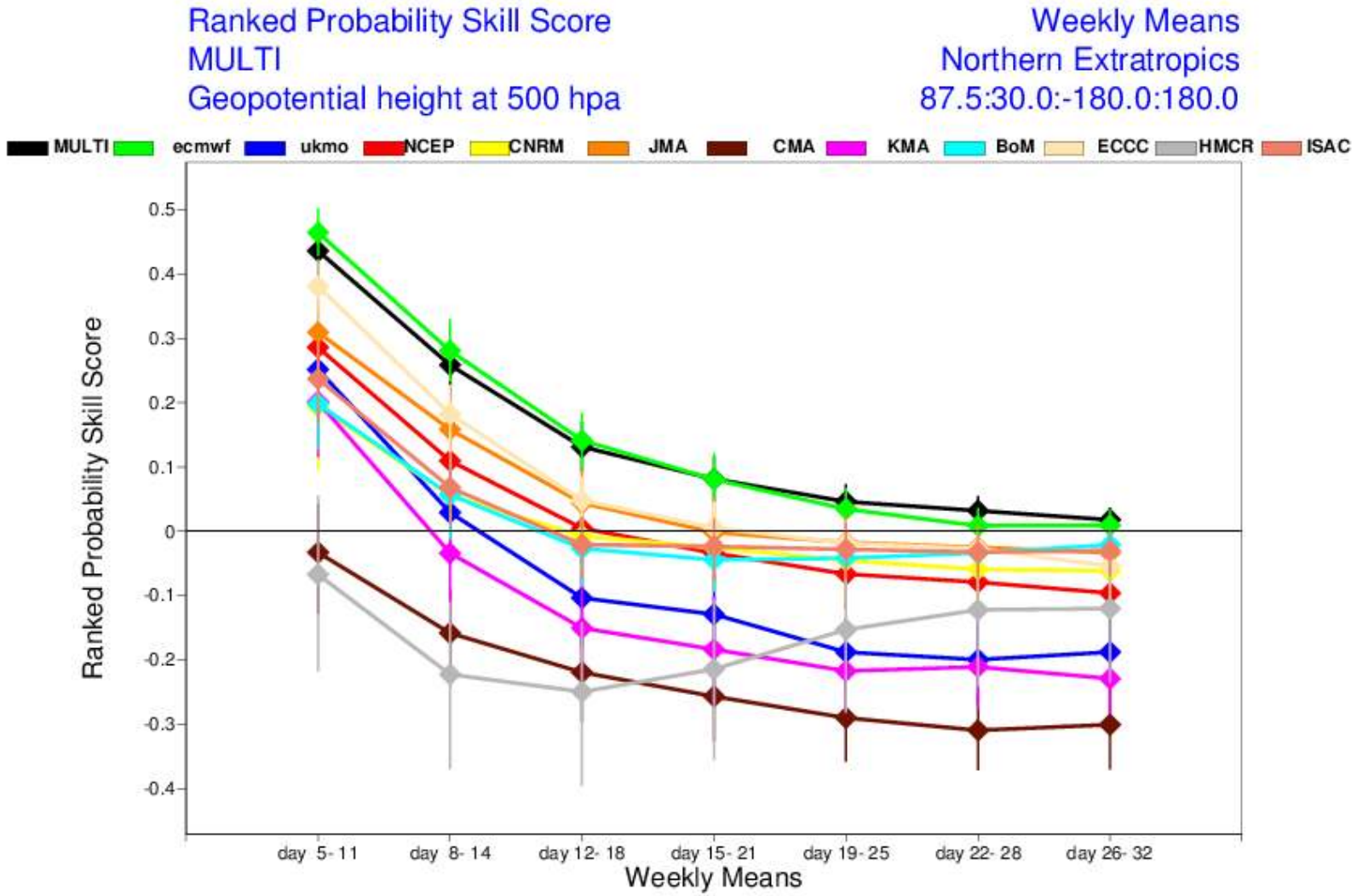
KTH Royal Institute of Technology, Stockholm : detection/visualization of flow features

U.Lisbon (E.Dutra) : HTESSEL & EC-Earth

Collaborations across the world



Collaborations and serving community: S2S project

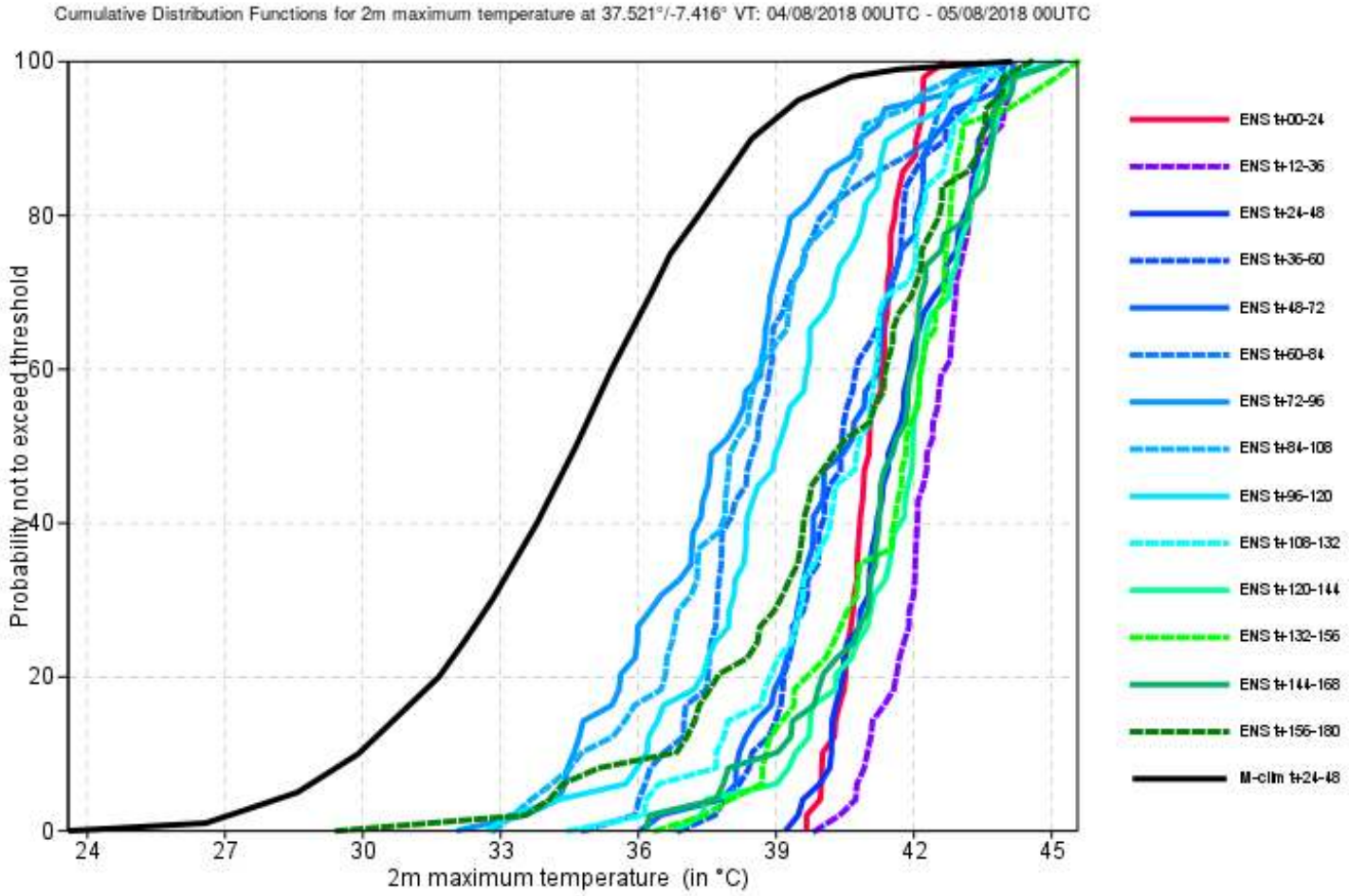


THE STRENGTH OF A COMMON GOAL

In summary

- Operational forecasts AND Research
- High-impact weather, regime transitions and global-scale anomalies
- Integrated ensemble at 5km resolution
- Earth-System model and analysis
- Scalable computation
- Collaboration

ECMWF


Cumulative Distribution Functions for 2m maximum temperature at 37.521°/-7.416° VT: 04/08/2018 00UTC - 05/08/2018 00UTC
Probability not to exceed threshold
100
80
60
40
20
0
24
27
30
33
36
39
42
45
2m maximum temperature (in °C)
ENS t+00-24
ENS t+12-36
ENS t+24-48
ENS t+36-60
ENS t+48-72
ENS t+60-84
ENS t+72-96
ENS t+84-108
ENS t+96-120
ENS t+108-132
ENS t+120-144
ENS t+132-156
ENS t+144-168
ENS t+156-180
M-clim t+24-48