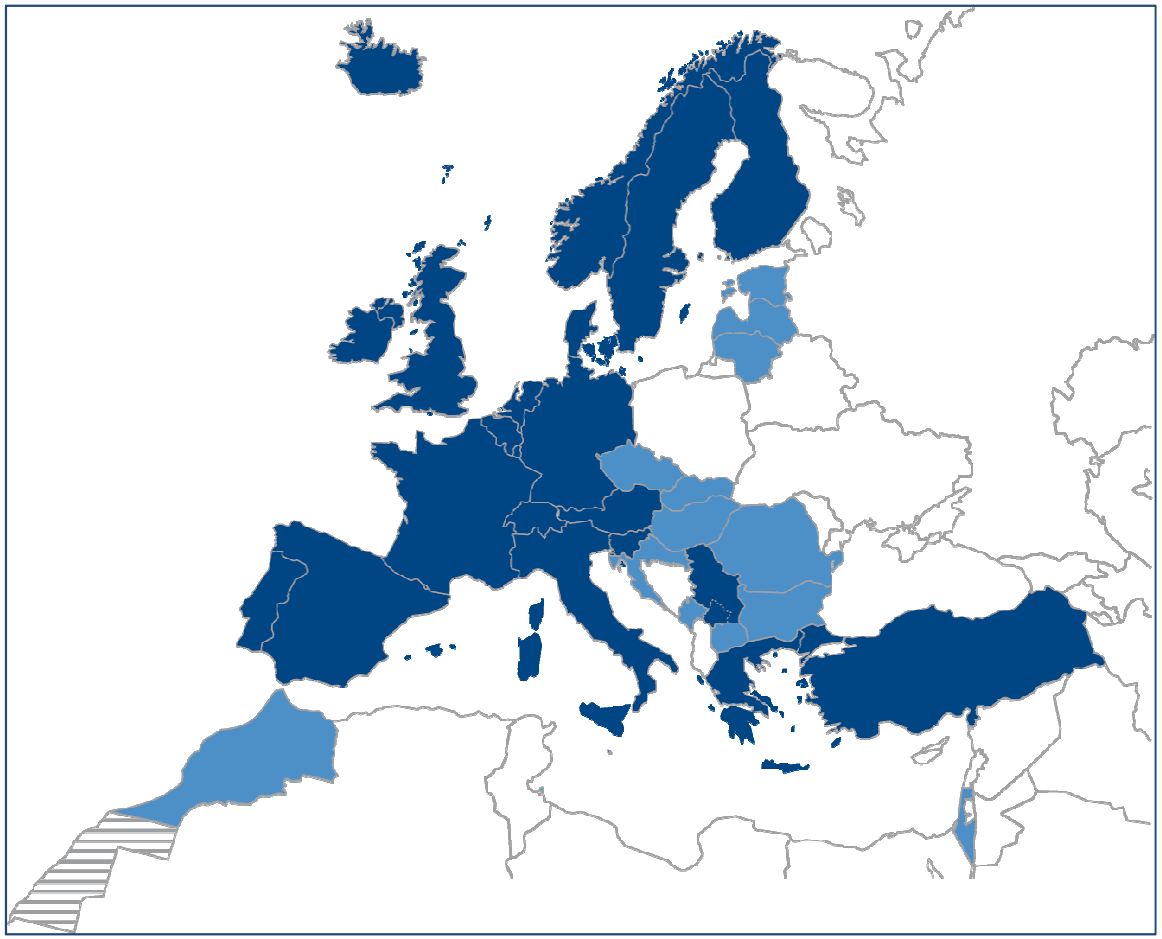
ECMWF Recent Developments and Plans

Richard Forbes

With thanks to many people at ECMWF!

EWGLAM/SRNWP Oct 2015

ECMWF – a collaboration



ECMWF

An independent intergovernmental organisation

established in 1975 (40 this year!)

with
21 Member States
13 Co-operating States

Outline

1. Overview
2. IFS upgrade Cy41r1 - 12 May 2015
3. Resolution upgrade Cy41r2 - Spring 2016
4. Future…

Recent key events at ECMWF

1. Recent IFS operational upgrades
   - 40r1 (19 Nov 2013)
   - 41r1 (12 May 2015)

2. New supercomputer Cray XC30
   - First operational forecast 17 Sep 2014

3. EC Copernicus Services initiated (11 Nov 2014)
   - CAMS (Copernicus Atmosphere Monitoring Service, oper Jul 2015)) global atmospheric composition monitoring and forecasting
   - C3S (Copernicus Climate Change Service) includes ECMWF reanalysis activity

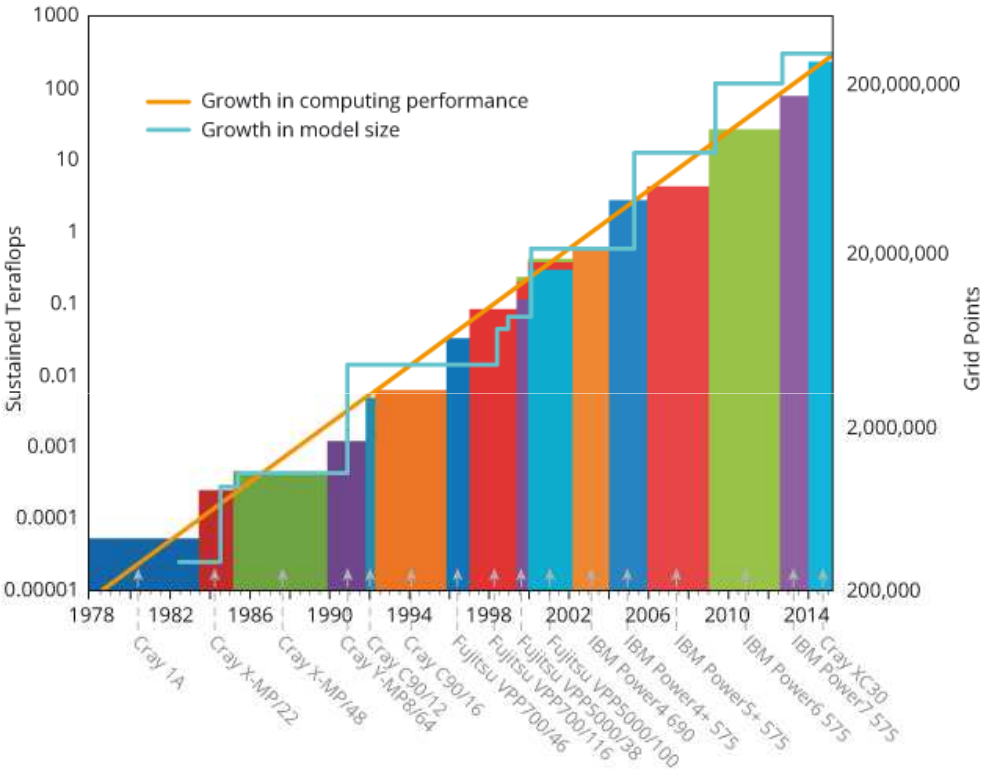
4. Scalability for future supercomputer architectures
   - Collaborative EU Horizon 2020 projects, e.g. ESCAPE

5. Defining the next ECMWF 10-year Strategy (2016-2025)

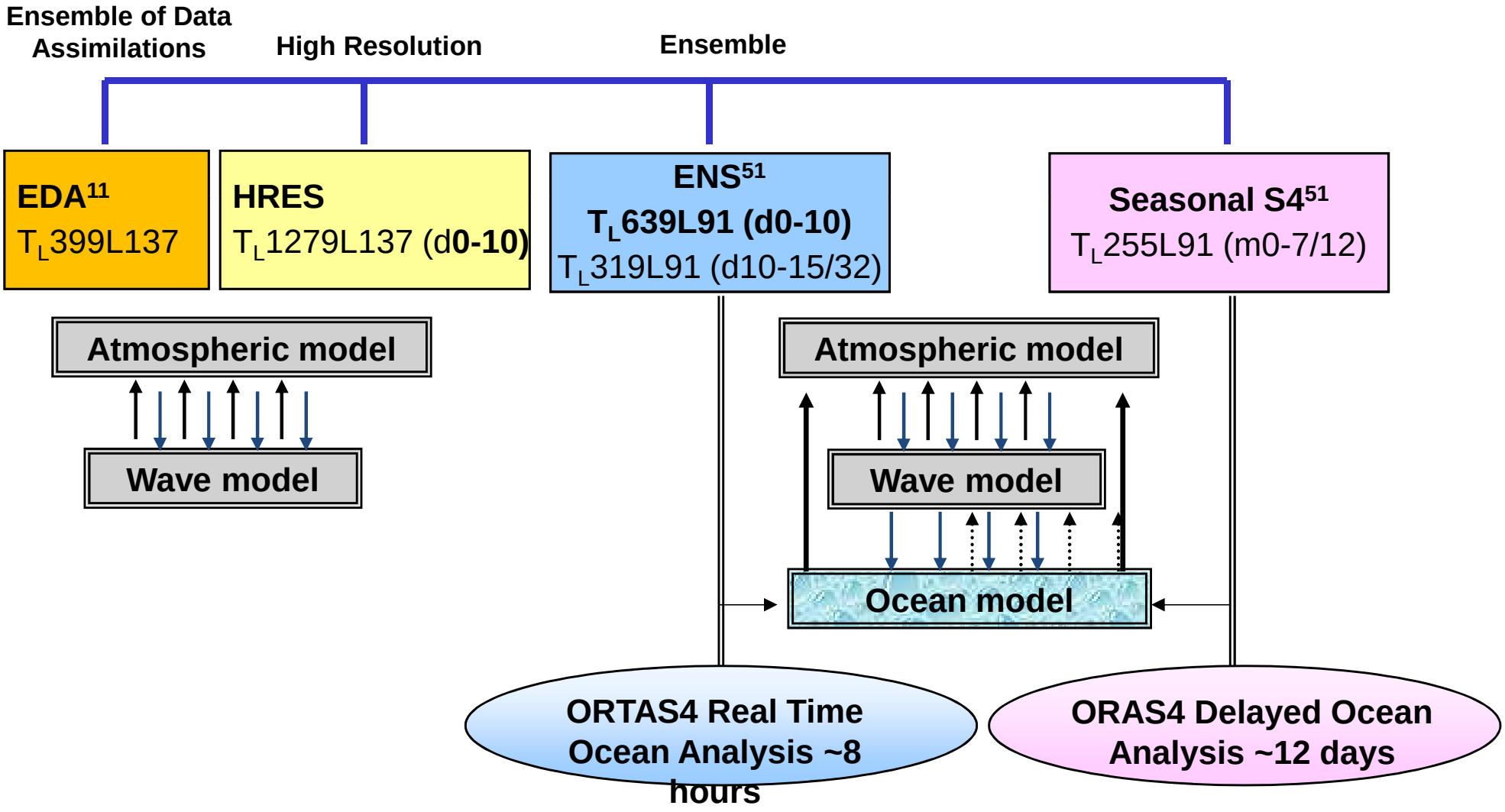
ECMWF – supercomputer

Cray XC30

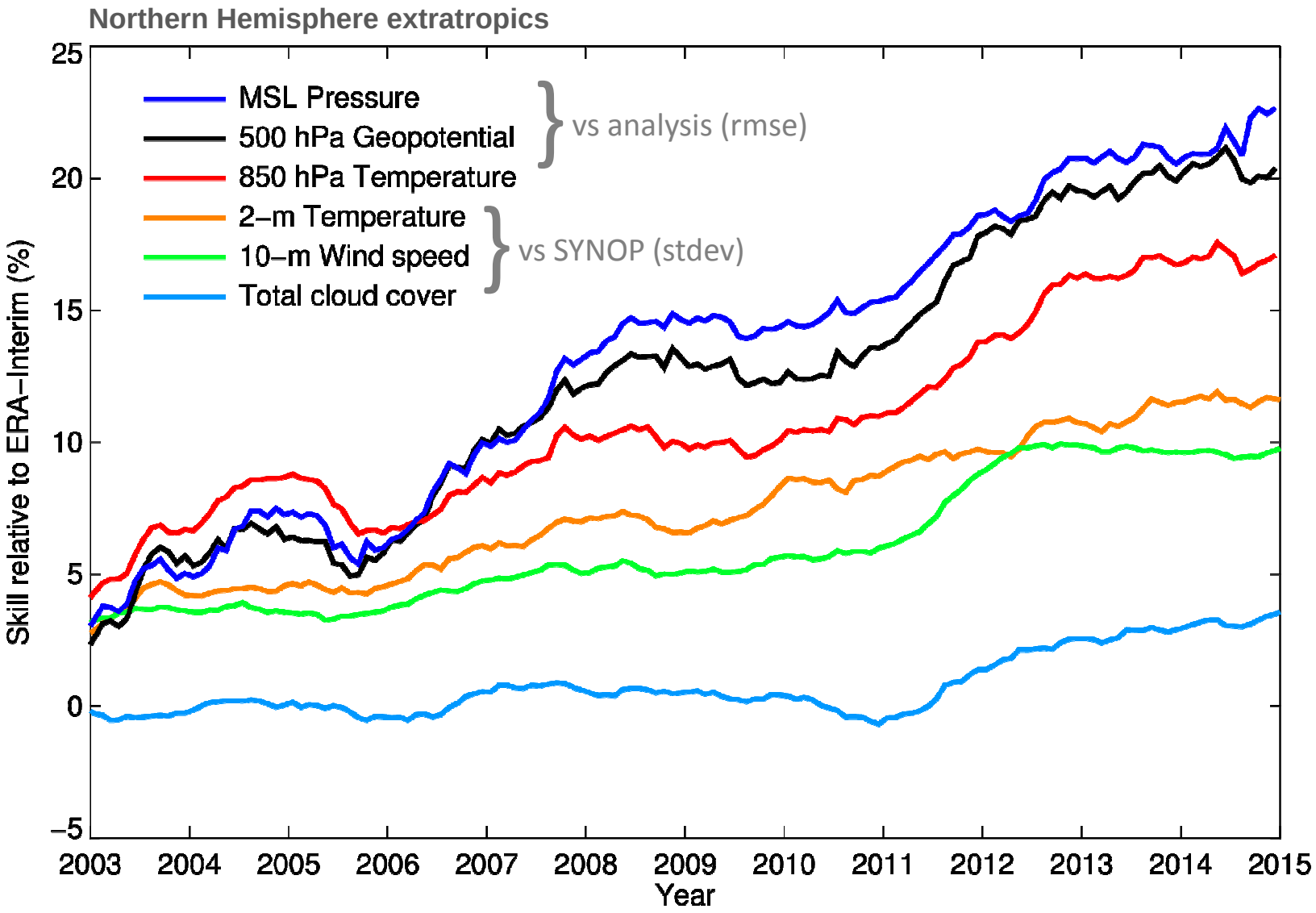
- Two phase service 2014-2018
- Sustained (peak) = 200 (3500) teraflops
- Increase in performance vs IBMP7 ~ x2.8



The ECMWF Integrated Forecasting System (IFS)



HRES Skill v ERA-Interim



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Cy41r1 (May 2015) Highlights

MOD

- New surface climate fields (land-sea mask, sub-grid orography)
- Improved SL-trajectory (stratospheric noise)
- Microphysics upgrade (drizzle, heavy rain, precipitation-type)
- Revised detrainment in convection scheme
- MACC-II CO_2/O_3/CH_4 climatologies; RRTM upgrade
- Lake model: Flake

SAT

- All-sky microwave humidity assimilation upgrade

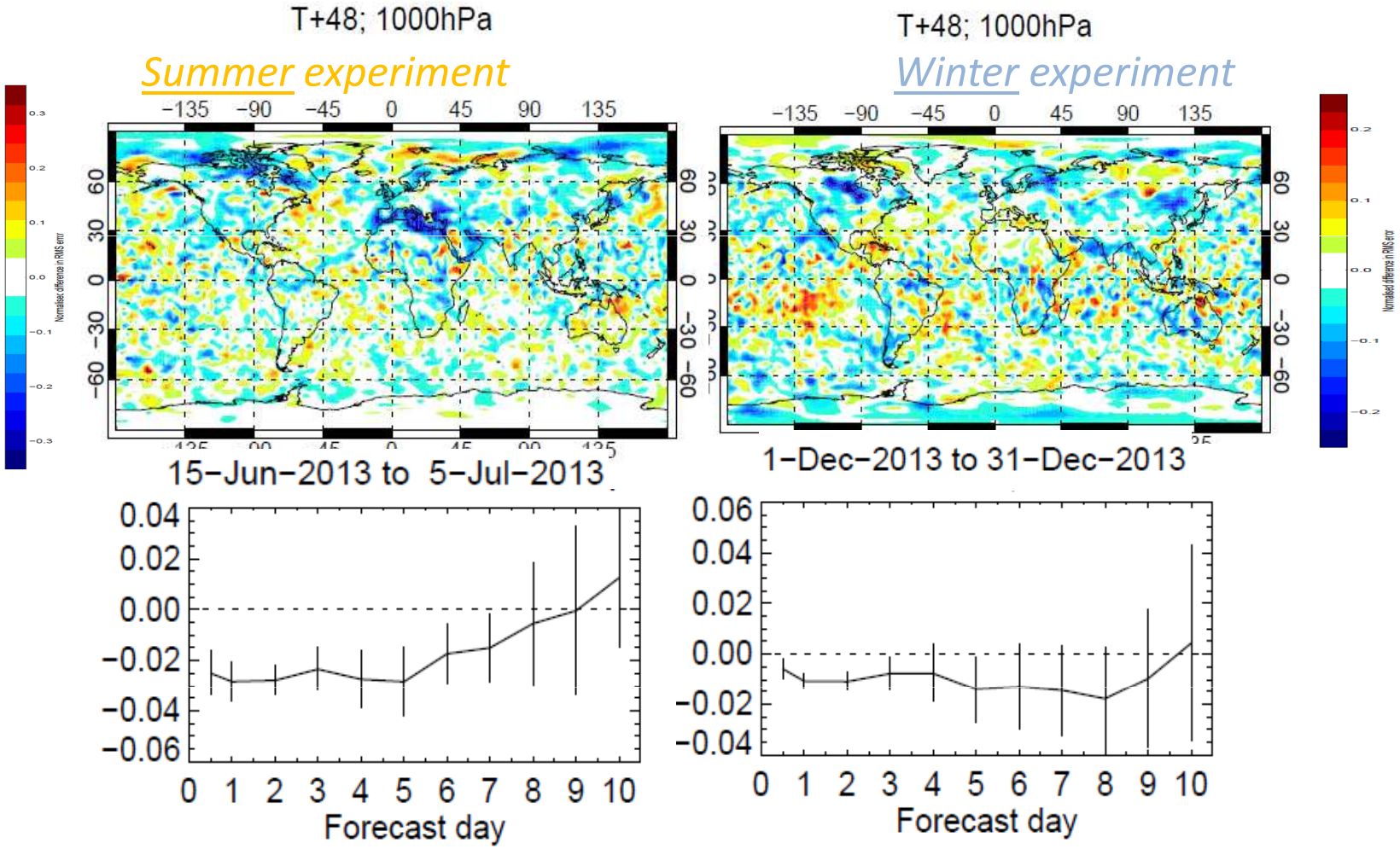
4DVAR

- 4DVAR upgrade of inner loop resolutions (255L-255L-255L grid)
- EDA improved noise filtering, reduced sampling window
- ASCAT assimilation

ENS

- ENS re-forecasts: from 5-member once to 11-member twice weekly
- Monthly forecast (leg B) extended to D+46 (from D+32)
- Active use of wave modified stress in coupled mode

Impact of water bodies (lake model)



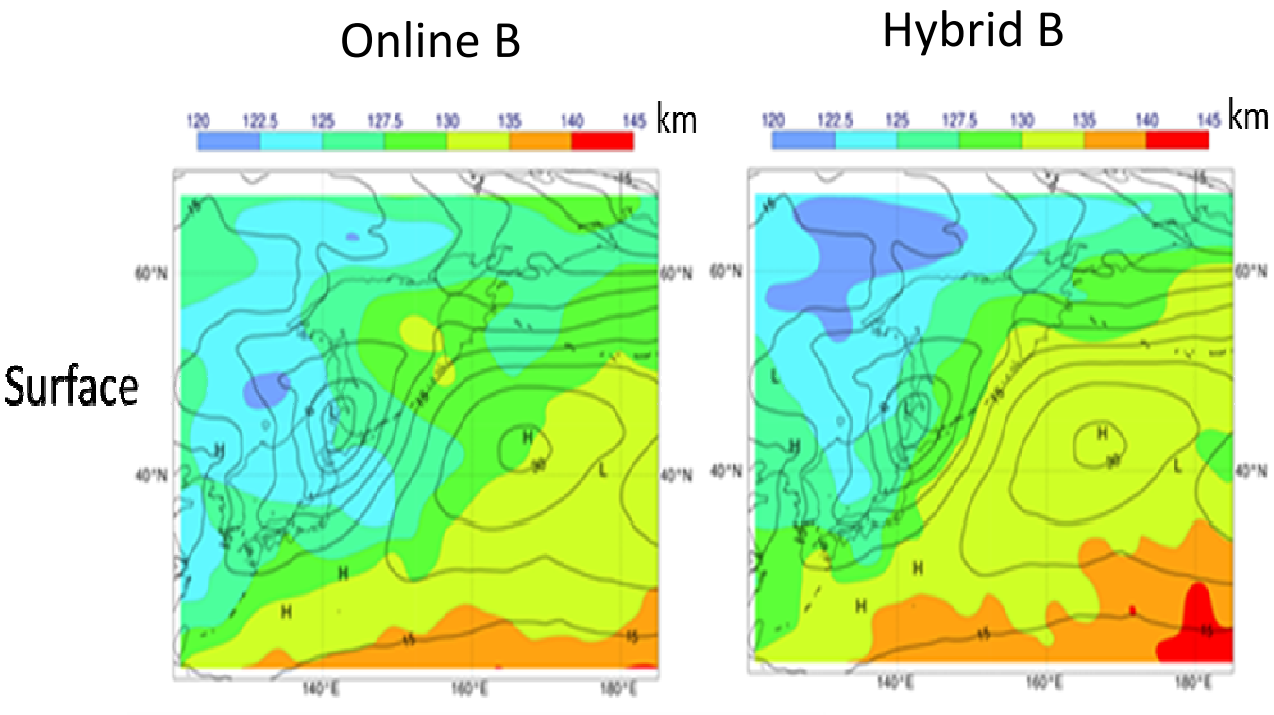
T 20N to 90N 1000hPa: Performance improved
(2-3% in summer; 1% in winter)

Balsamo et al, ECMWF Newsletter 137, Tellus-A, 2012

Flow-dependent EDA filtering

The new filtering method builds the training dataset of EDA perturbations as a combination of forecasts from the latest EDA (sampled every hour at t+0h, t+1h, …, t+7h) and a set of climatological EDA forecasts.

This hybrid wavelet B estimate produces a more realistic representation of the error correlation structures of the day.



Bonavita, ECMWF Newsletter 142

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Cy41r2 (Highlights)

MOD

- Radiation-surface LW/SW updating, radiation-surface LW tiling
- Improved physics for freezing rain
- TL/AD surface and VDF, non orographic drag
- Number of iterations in SL trajectory
- Higher resolution 8/16km, new cubic-octohedral grid

SAT

- GPSRO observation error adjustment
- Improved data coverage (screening and obs error changes)
- Observation operator improvements

4DVAR

- EDA resolution TCo639 fc/outer loop, TL191/T191 inner loops
- Same hybrid B both in EDA and HRES
- 4DVAR configuration TL255/TL319/TL399

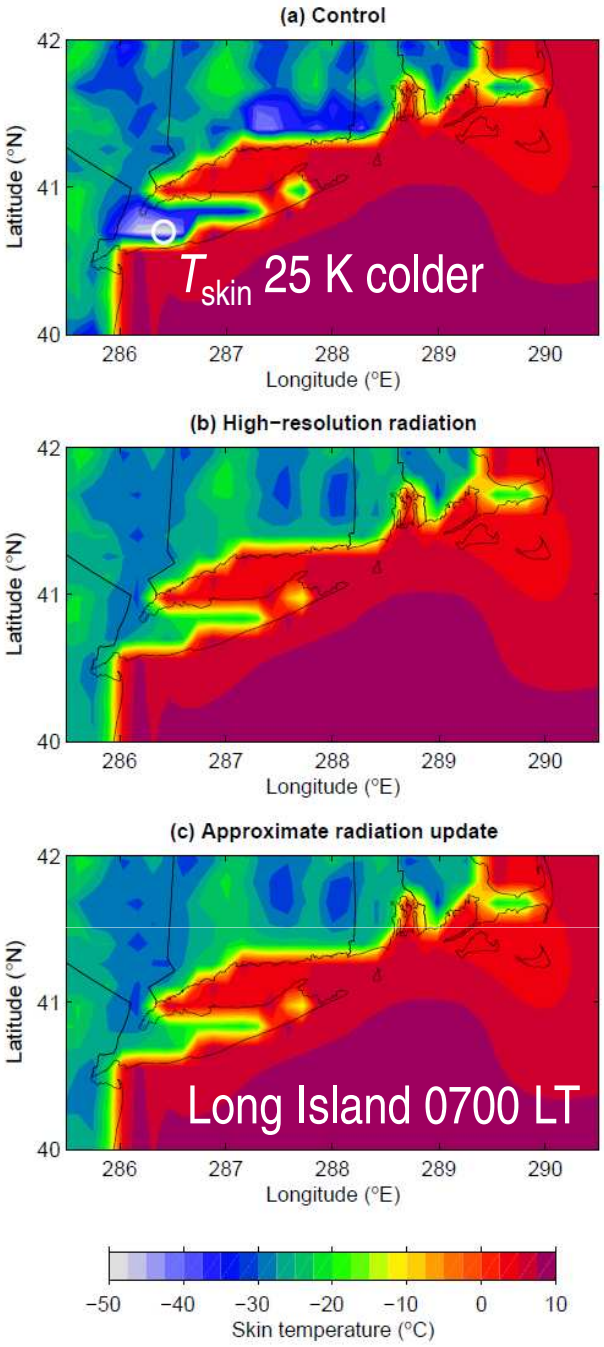
ENS/WAV

- Various technical changes preparing for the resolution upgrade

TECH

- Efficiency gains, HugePages, vectorisation, optimisation, IOSERV

Radiation approximate update: 41r2 T1279 (case 4 Jan 2014)



Control: radiation at T639/every 1h

Radiation 12.5% of model time

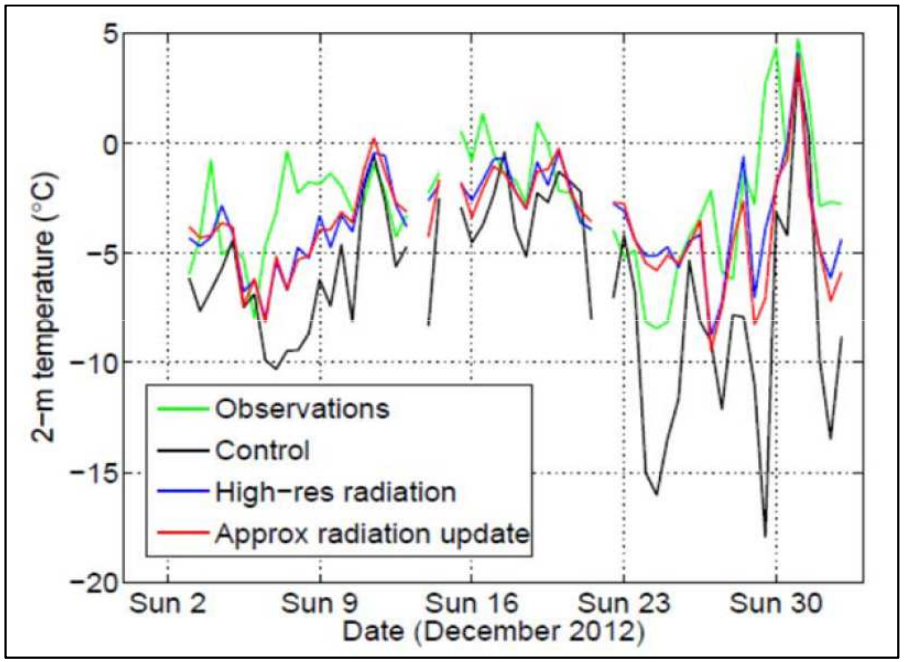
Radiation every timestep/gridpt

Radiation 12 times more expensive

New scheme

Radiation 2% more expensive

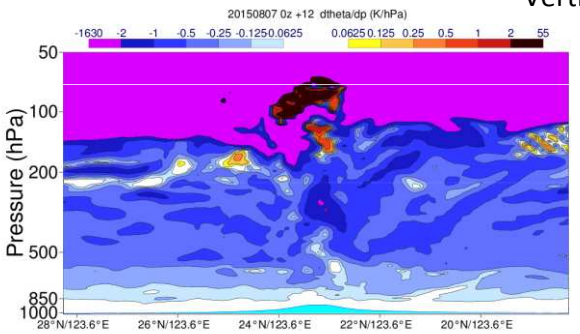
- Update surface LW&SW fluxes every timestep and gridpoint according to T_{skin} and albedo.
- Removes spurious cold/warm coastal T anomalies with minimal cost.

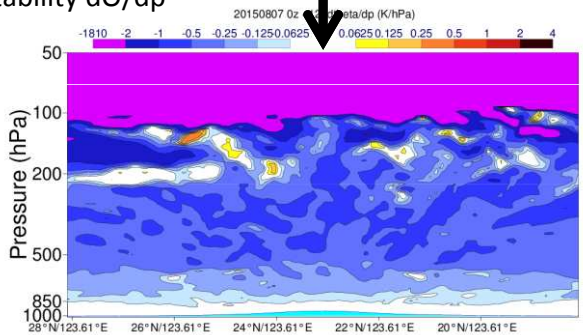


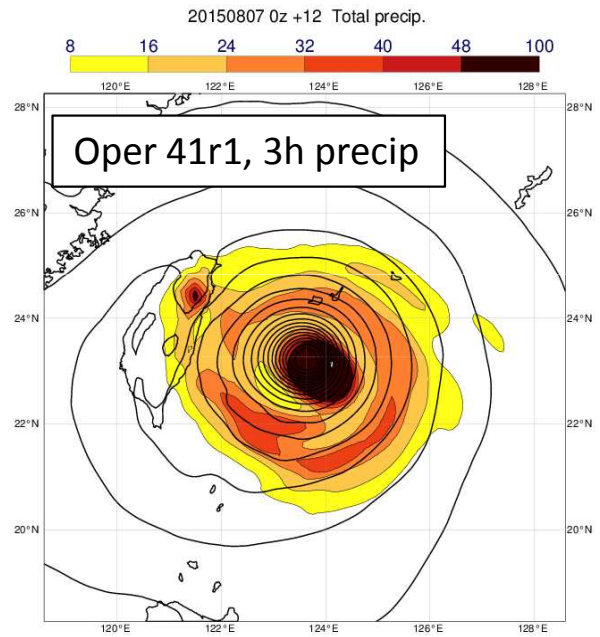
IFS Cycle 41r2 - Numerics

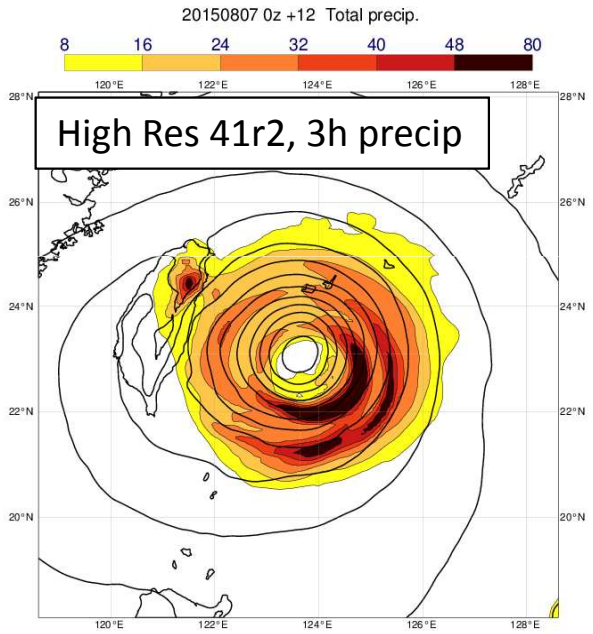
- Instability with 3 iterations for semi-Lagrangian departure point in extreme situations (gravity waves above Himalayas, tropical cyclones)
- Increase to 5 gives much improved results

Vertical stability dΘ/dp

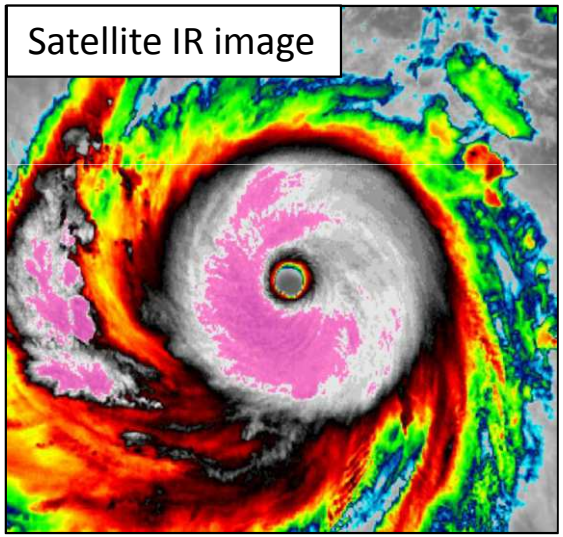






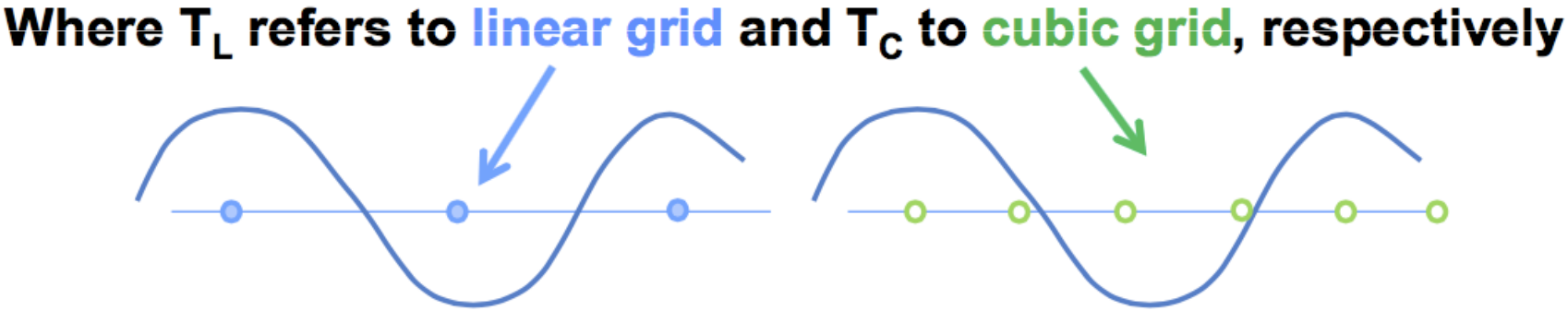


Tropical Cyclone Soudelor
Aug 2015



Resolution increase: cubic reduced Gaussian grids

2N+1 gridpoints to N waves : T_L linear grid
4N+1 gridpoints to N waves : T_c cubic grid



- Mathematically more correct in the presence of cubic non-linearities in the eqns
- Less numerical filtering – almost no numerical diffusion, no dealiasing
- Better mass conservation
- Less expensive than the equivalent linear grid (TC1023 cheaper than TL2047)

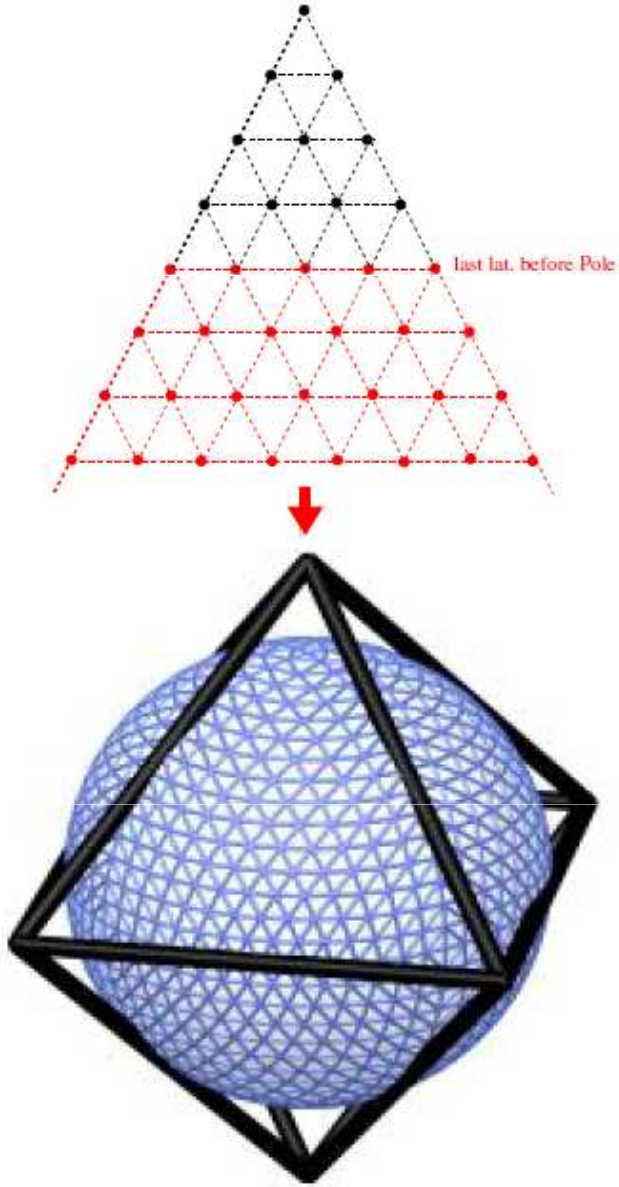
Octahedral grid

It is a reduced Gaussian grid with the same number of latitude circles ($NDGL$) than the standard Gaussian grid ($\leftrightarrow$ Gaussian weights) but with a new rule to compute the number of points per latitude circle.

Number of points per latitude

NLOEN(lat_N)=20 $\rightarrow$ Poles

NLOEN(lat_i)=NLOEN(lat_{i-1})+4

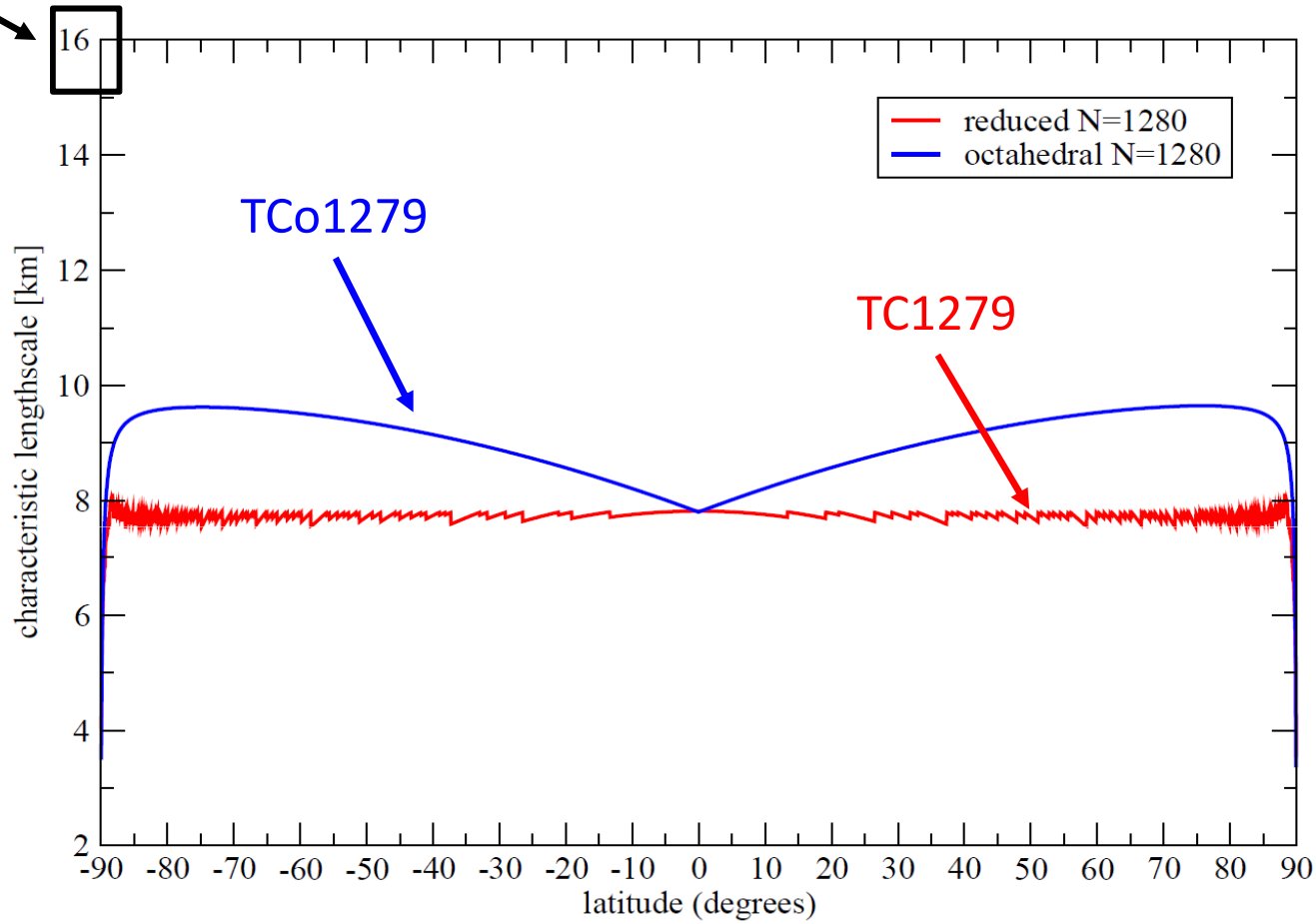


HRES resolution increase

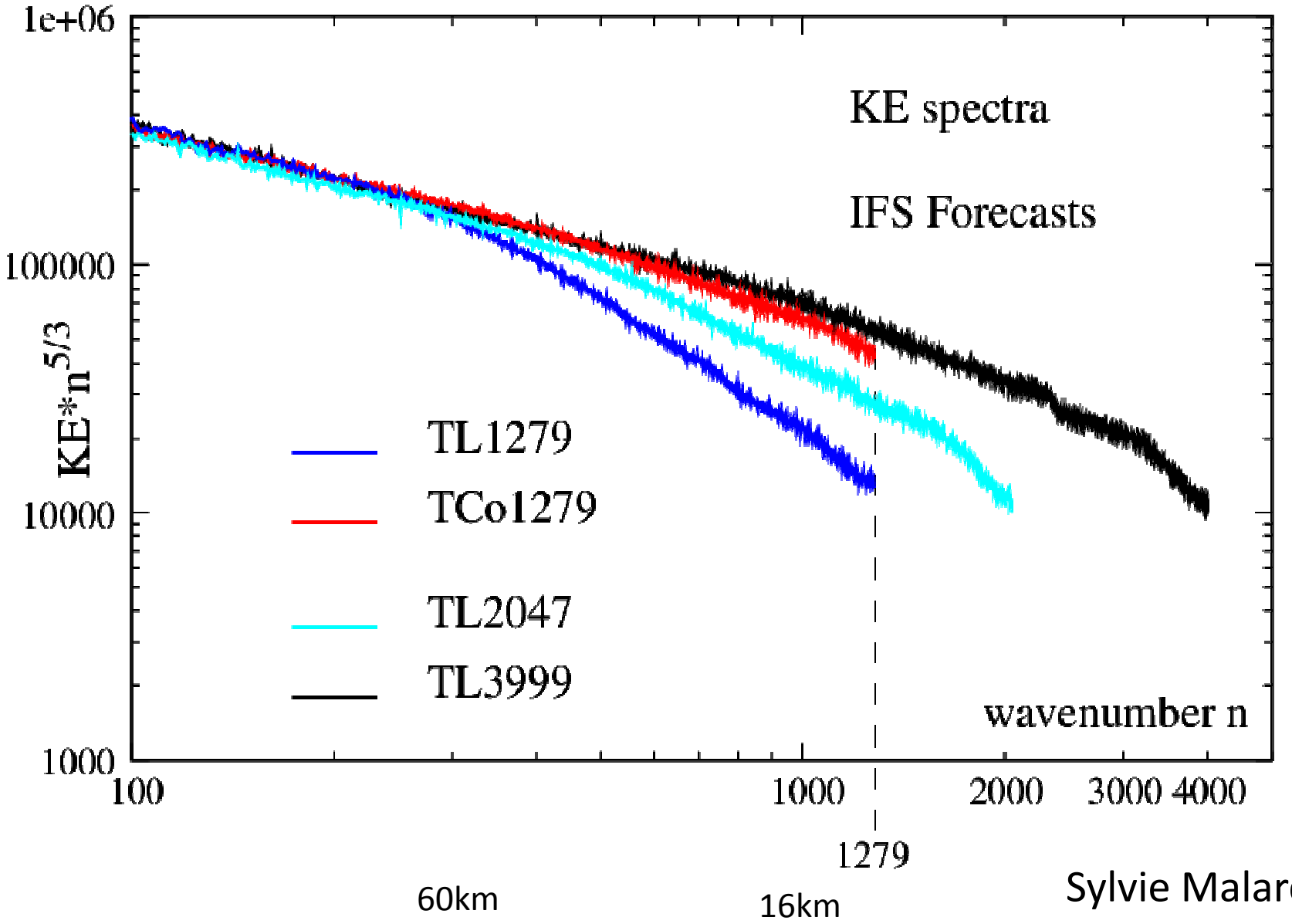
A) TC1279 (cubic, ~8km) ≈ 8.51 million grid points per level

B) TCo1279 (cubic, ~9km) ≈ 6.59 million grid points per level (octahedral cubic reduced Gauss. grid)

TL1279 (linear, ~16km) ≈ 2.14 million grid points per level

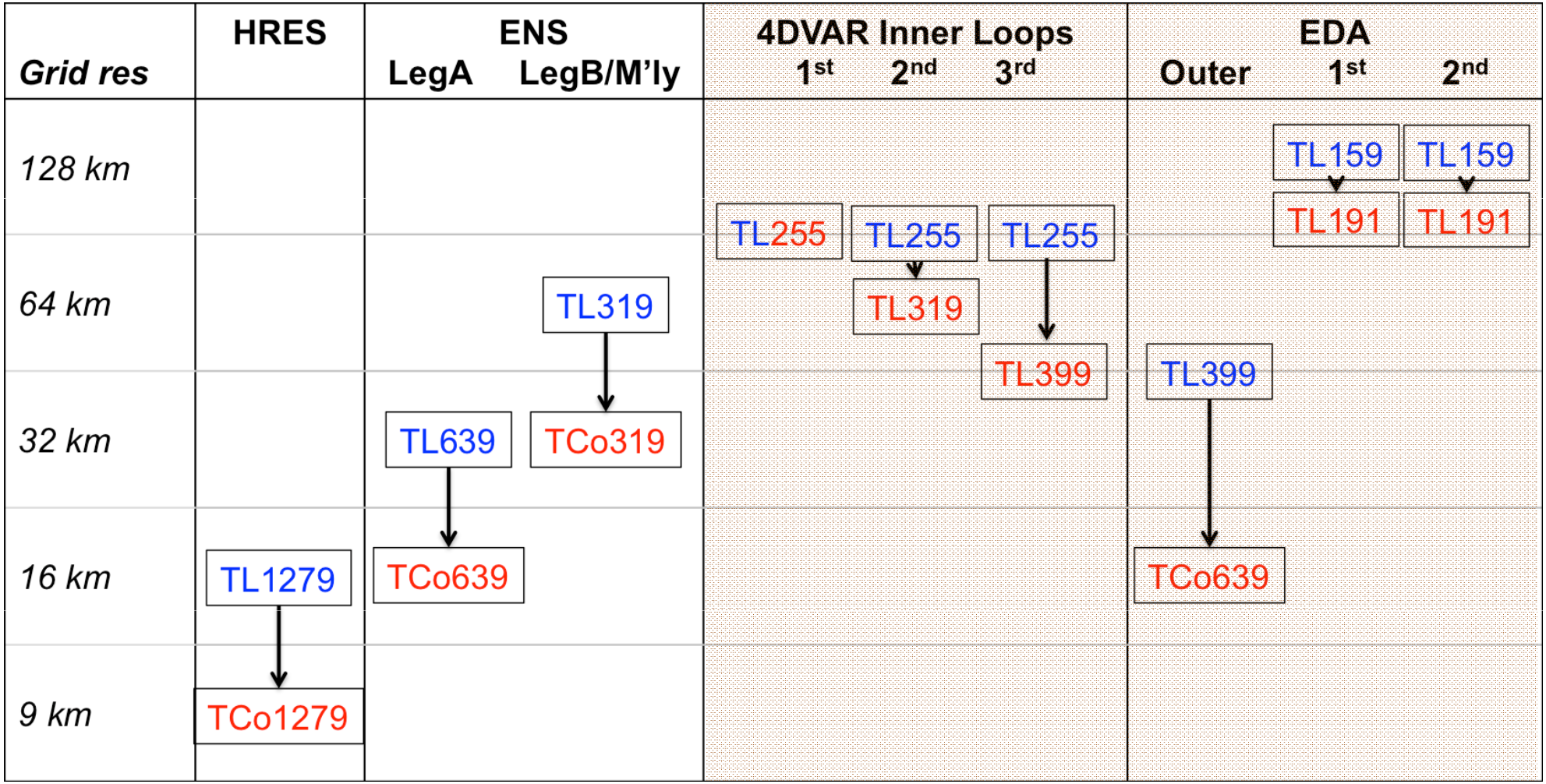


KE spectra



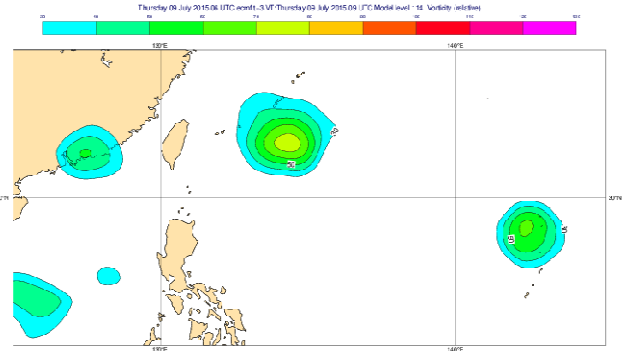
Sylvie Malardel

IFS resolution upgrade 41r1 ➔ ❽42r1❾

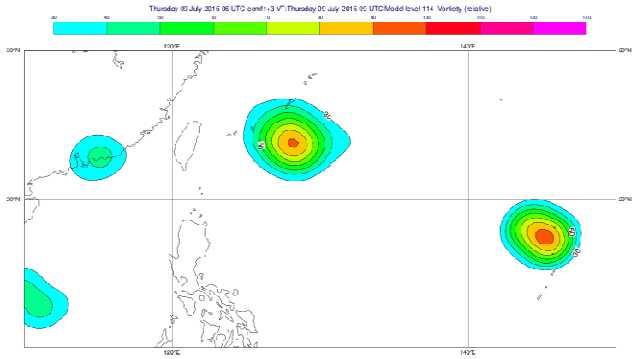


EDA improvements, TCo639 + B

Higher TCo639 resolution, smaller-scale variance and B heavily weighted towards the days errors at smaller scales gives more accurate analysis/forecasts—almost TL1279—and more spread where it matters.



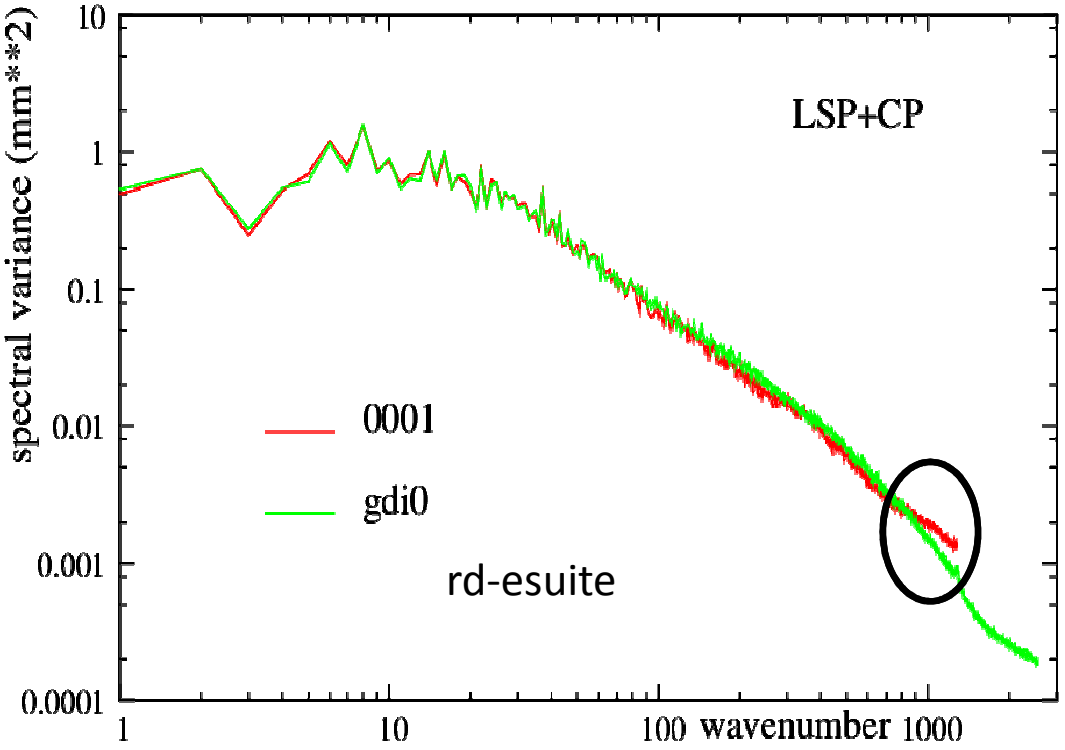
41r1 TL399
20150709
0900z



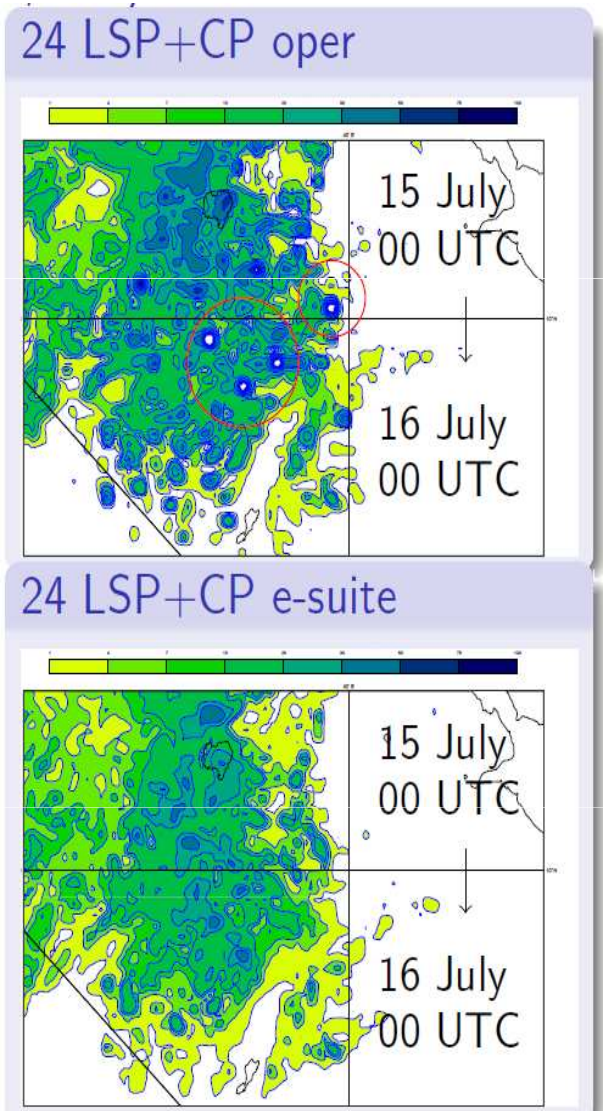
41r2 TCo639
20150709
0900z

“Linfa, Chan-hom, and Nangka”

Precipitation spectra: Oper TL1279 and TCo1279



"Grid point storms" seen in resolved precipitation (LSP) in certain regions have gone in TCo1279



East Africa

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Just some of the forthcoming challenges...

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

Thank you for your attention …