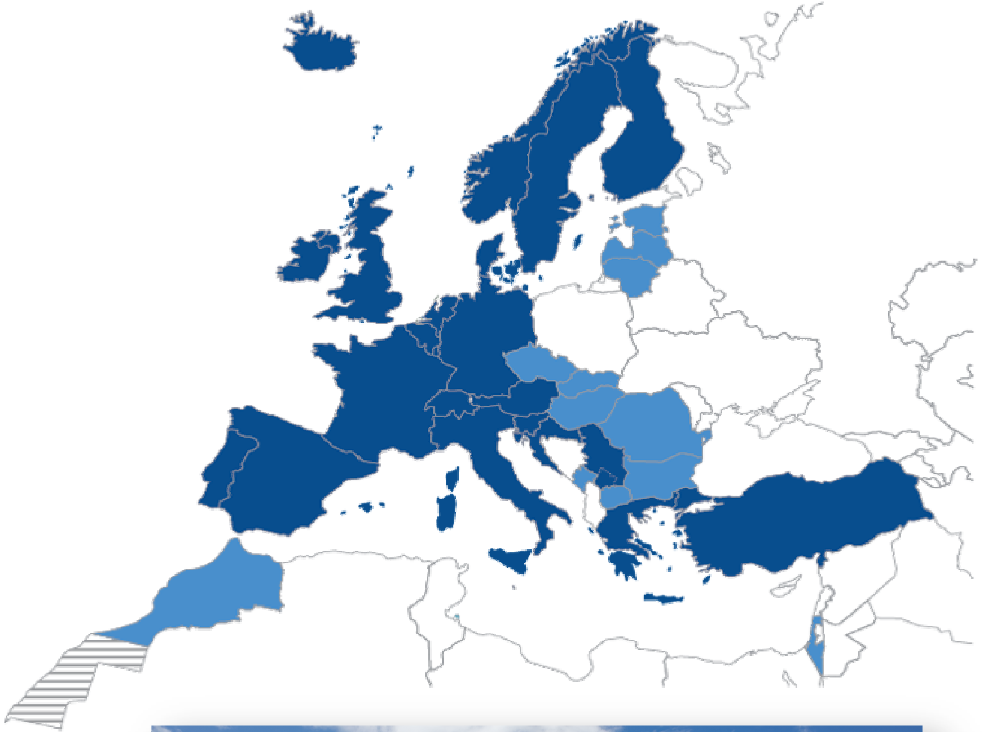
ECMWF Recent Developments and Plans

EWGLAM / SRNWP October 2016

Willem Deconinck

With thanks to many people at ECMWF!

willem.deconinck@ecmwf.int



ECMWF:

- An independent intergovernmental organisation
- Established in 1975
- 22 Member States
- 12 Co-operating States

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.

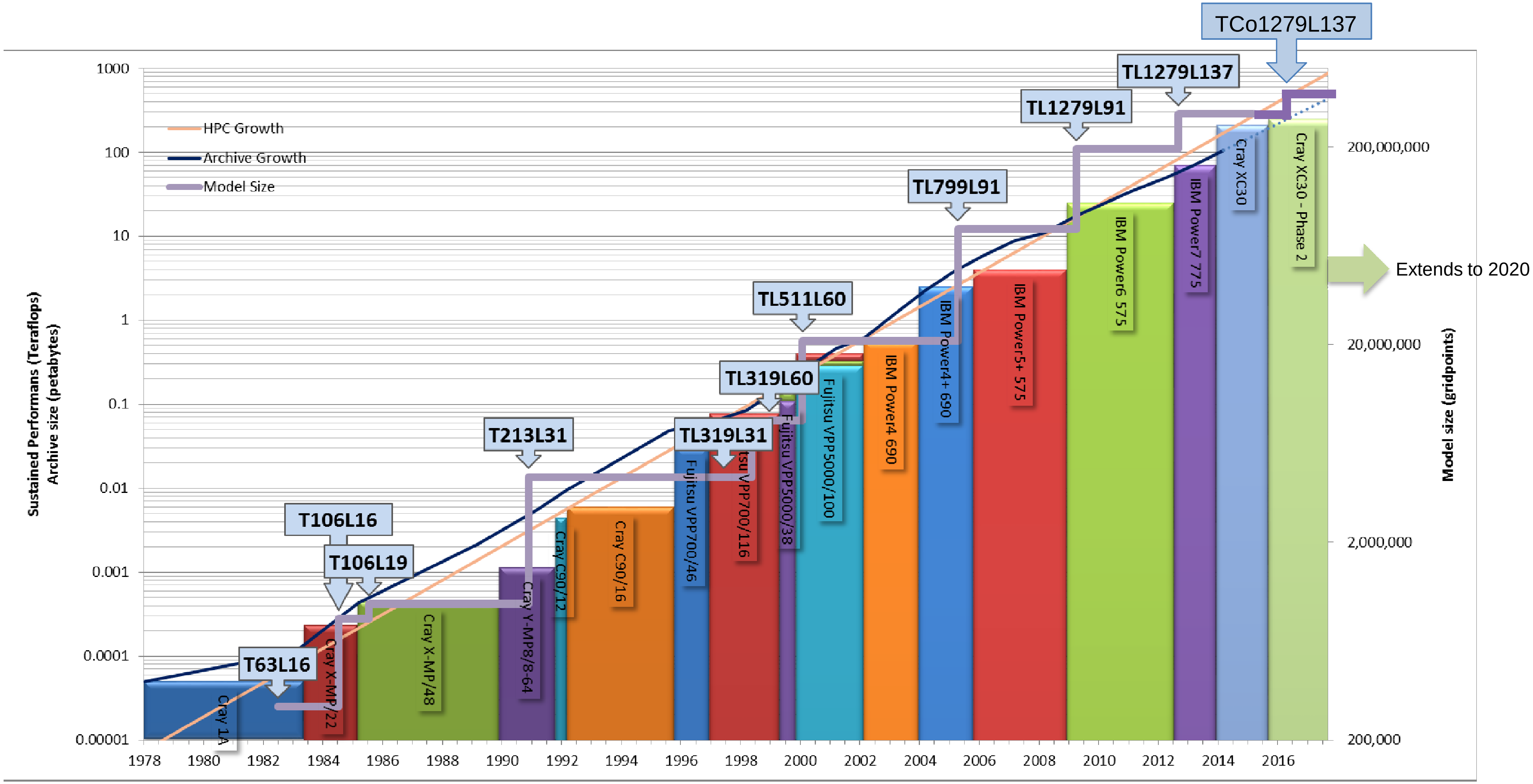
Outline

Overview

IFS upgrade Cy41r2 – 8 March 2016

What's next…

Growth of HPC sustained performance at ECMWF

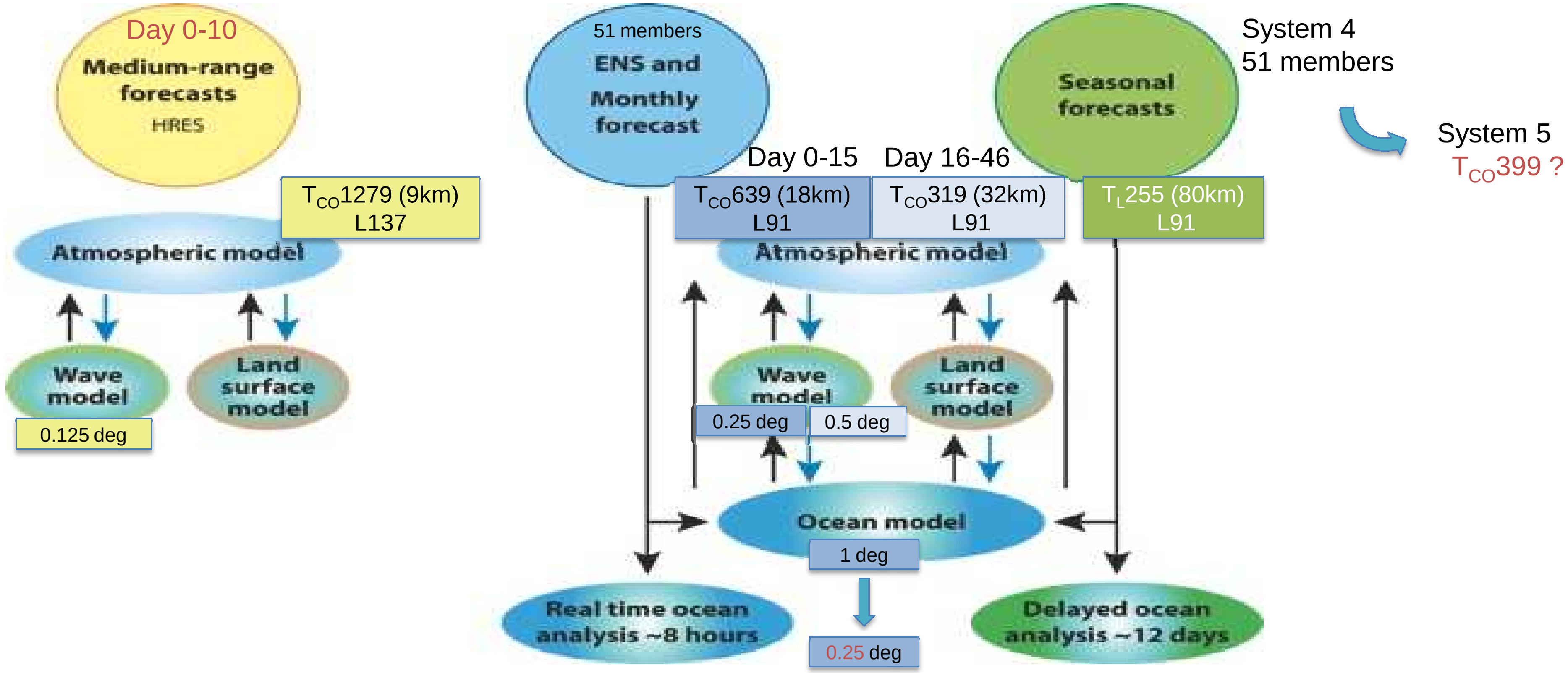


HPC upgrade: Cray XC30 → Cray XC40

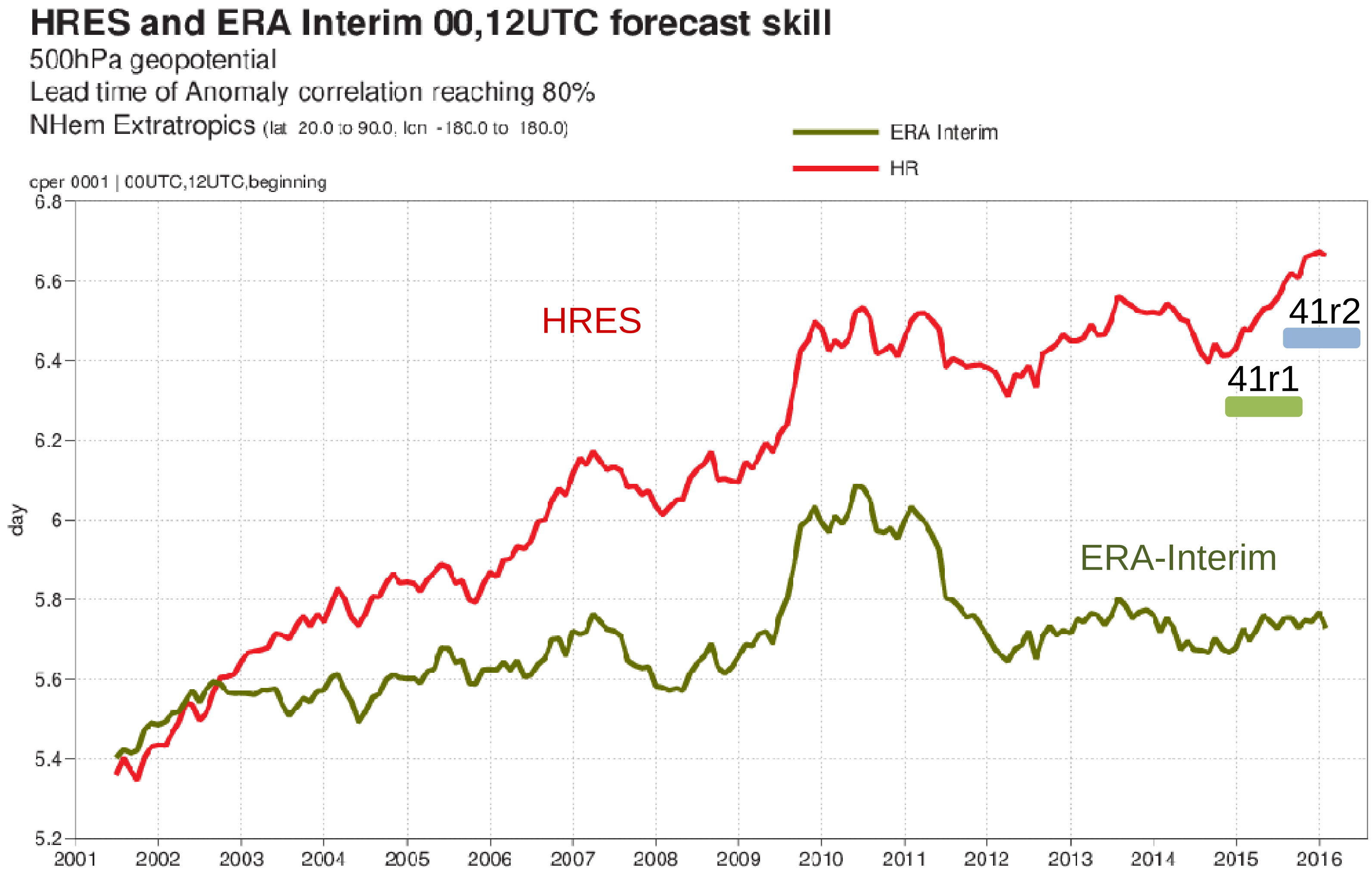
	Phase 1 (Ivybridge) – 2014-2016	Phase 2 (Broadwell) – 2016-2020
CPU	24 cores (2 x 12 core) @ 2.7GHz	36 cores (2 x 18 core) @ 2.1 GHz
Memory/Node	64 Gb (1866 MHz DDR3)	128Gb (2400 MHz DDR4)
Memory/Core	2.6 Gb	3.5Gb (+35% cf Phase 1)
Parallel Nodes (per cluster)	3,400	3,513 (+3% cf Phase 1)
Total Cores (per cluster)	84,096	130,212 (+55% cf Phase 1)
Tf sustained (both clusters)	200	320 (+60% cf Phase 1)

Overall increase ~ 1.5

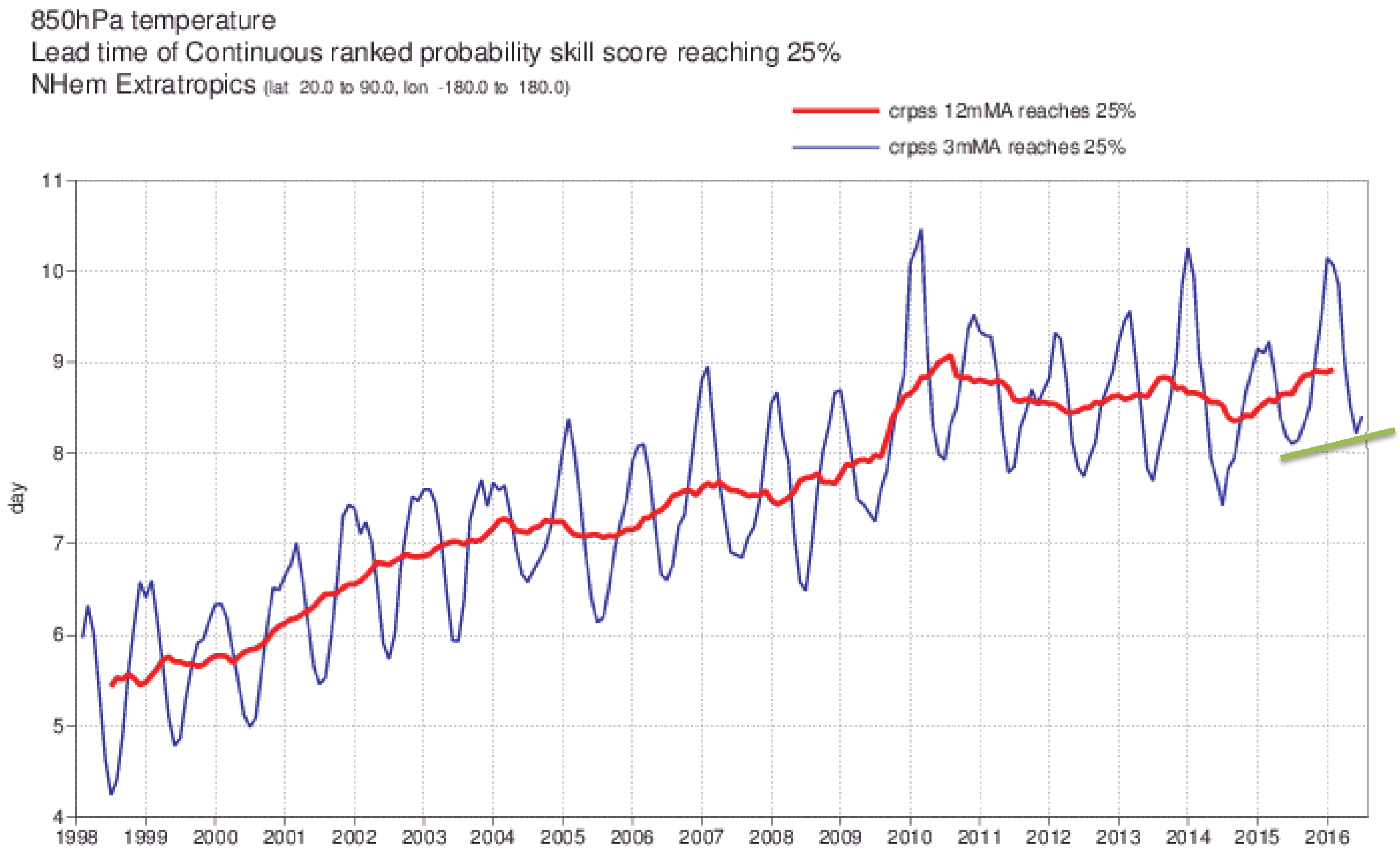
ECMWF forecasting systems



HRES headline score: 500 hPa height anomaly correlation

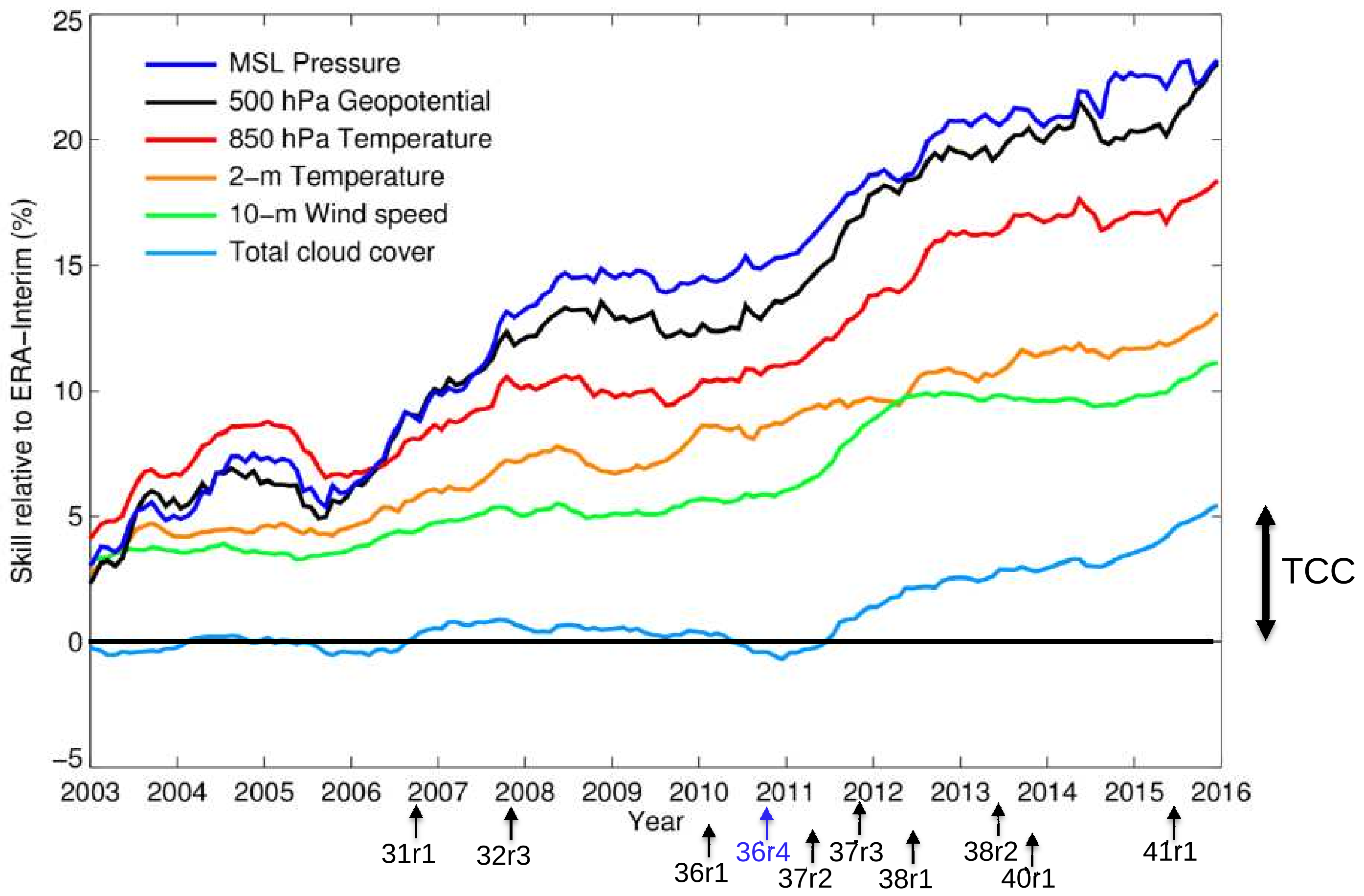


ENS headline score: 850 hPa temperature CRPSS



Improvement in cloud cover skill – the last decade

See also Haiden et al (2015) ECMWF Newsletter 143



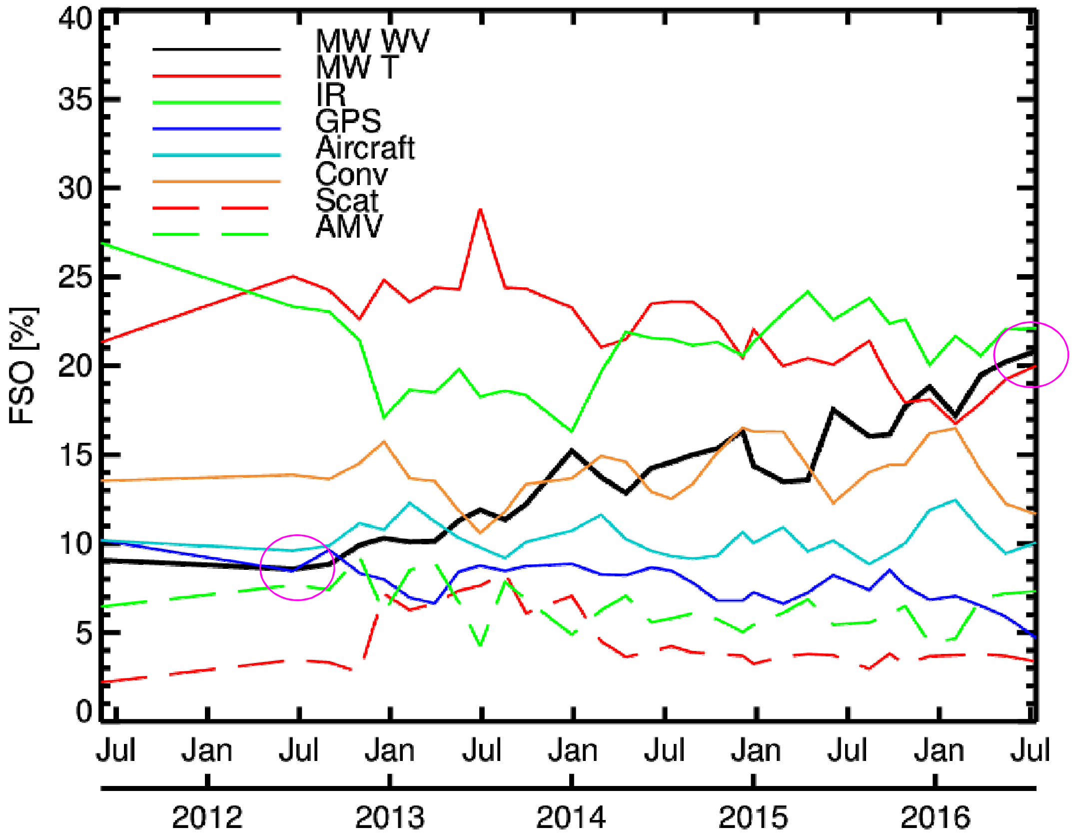
Evolution of skill of the HRES forecast at day 5, expressed as relative skill compared to ERA-Interim (12 month running mean)

ECMWF

Forecast sensitivity (FSO) of major observing systems in ECMWF operations

Summer 2006
(from Cardinali, 2009)

Microwave WV	6.2 %
Microwave T	35.5 %
Infrared	28.0 %



August 2016

Microwave WV	20.4%
Microwave T	20.1 %
Infrared	21.9 %

Outline

Overview

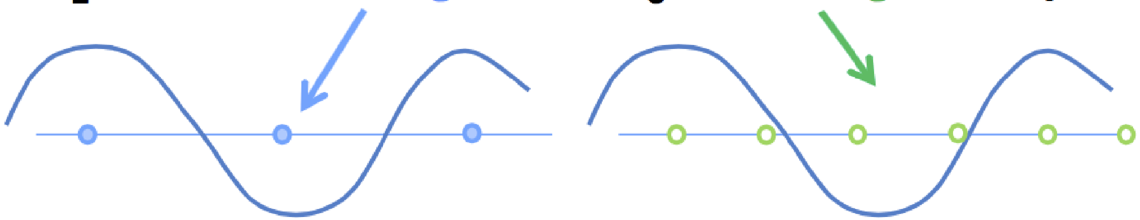
IFS upgrade Cy41r2 – 8 March 2016

What's next…

Resolution upgrade: cubic grids

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

Where T_L refers to linear grid and T_C to cubic grid, respectively



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

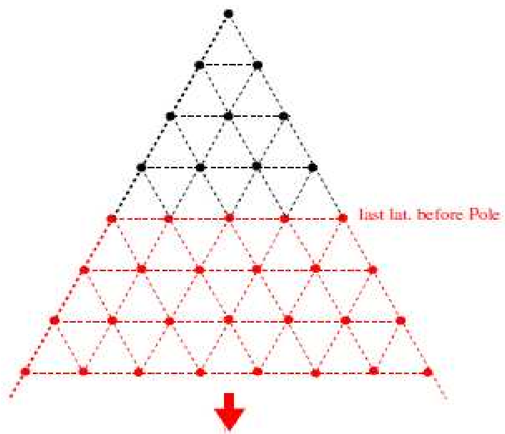
Resolution upgrade: octahedral reduced Gaussian grid

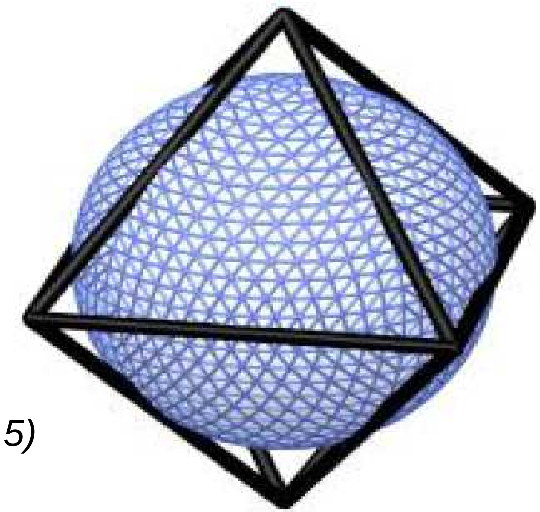
It is a reduced Gaussian grid with the same number of latitude circles (*NDGL*) than the standard Gaussian grid ($\leftrightarrow$ Gaussian weights) but with a new rule to compute the number of points per latitude circle.

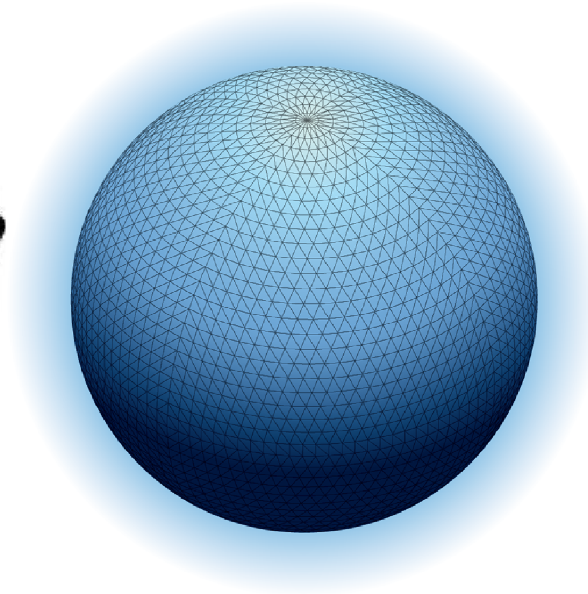
Number of points per latitude

$\mathrm{NLOEN}(lat_N)=20 \rightarrow \mathrm{Poles}$

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





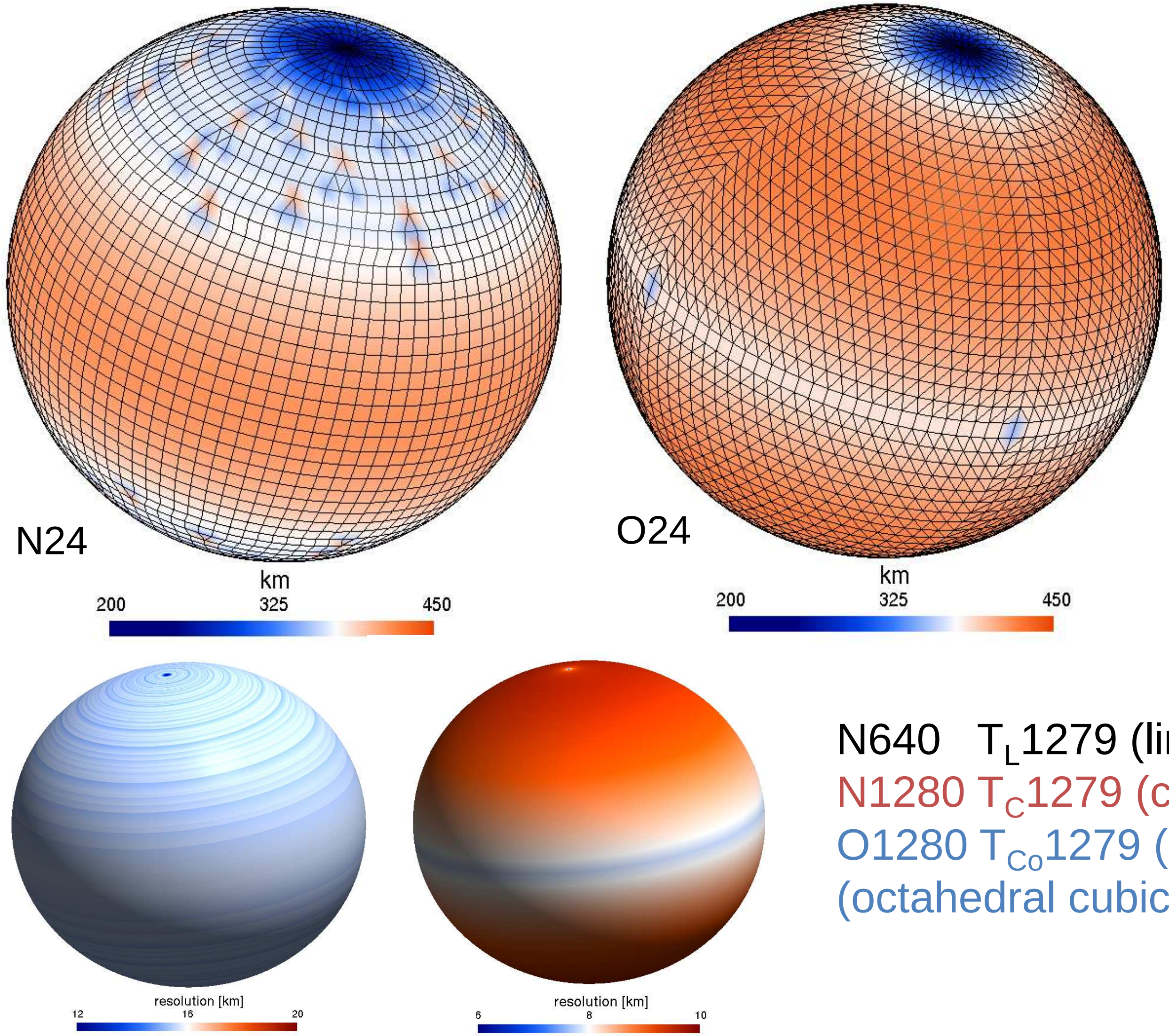


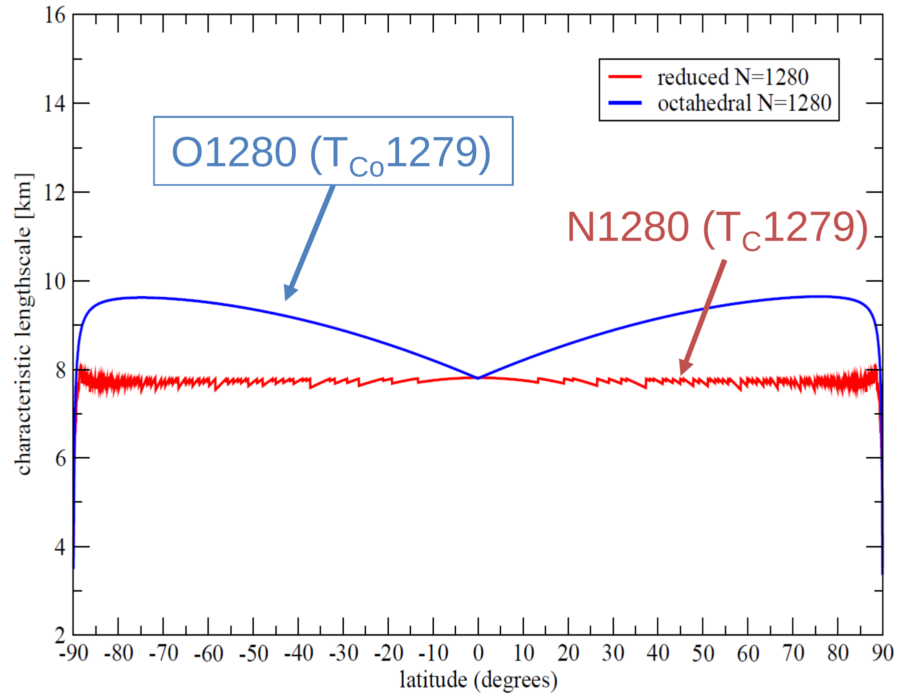
Re-think the spectral wave number truncation to gridpoint number ratio (Wedi 2014)

The cubic-octahedral grid (TCo1279) at ECMWF (Wedi et al 2015)

A new grid for the IFS (Malardel et al., ECMWF Newsletter 146)

Resolution upgrade: octahedral reduced Gaussian grid





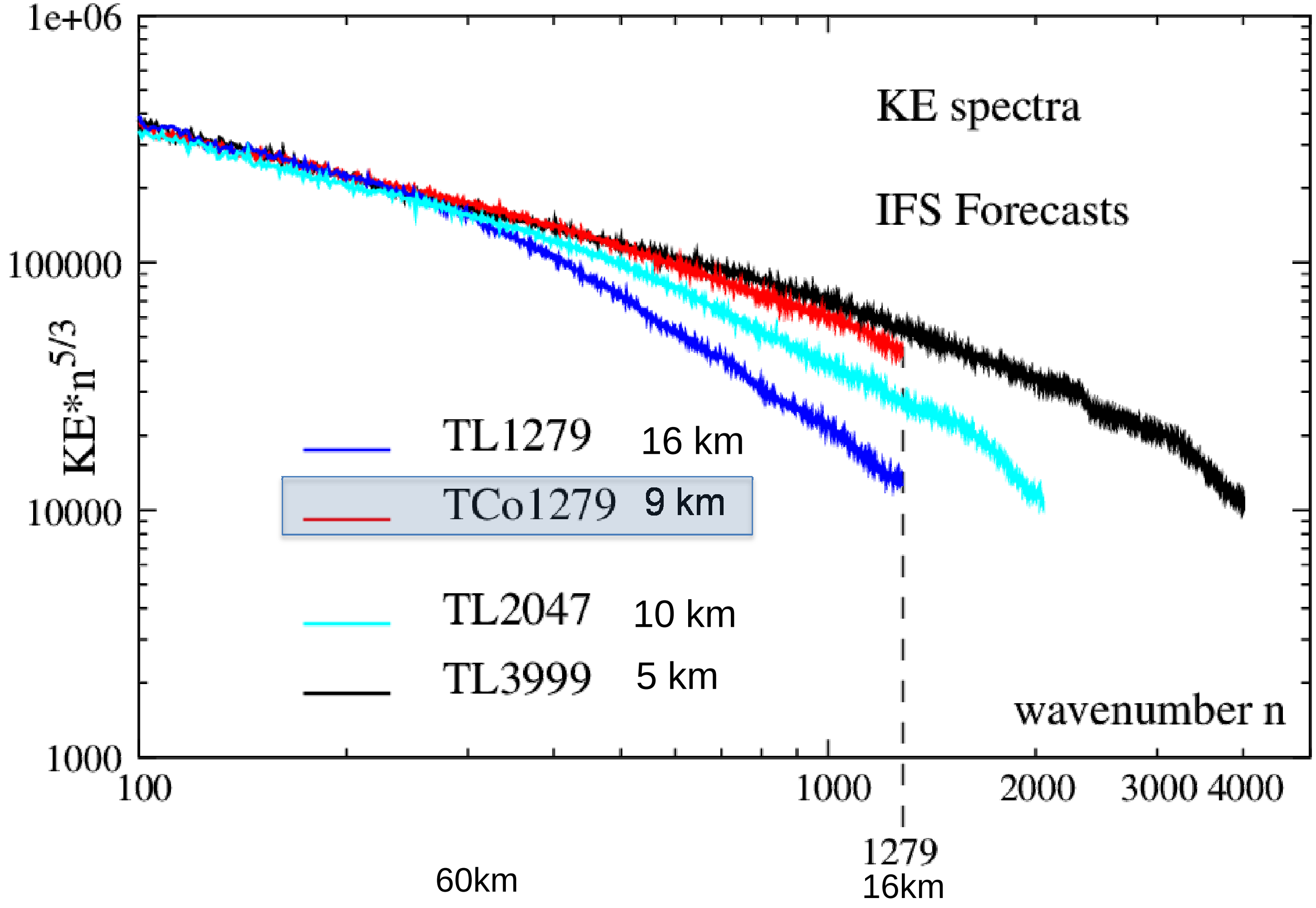
N640 T_L1279 (linear, ~16km) ≈ 2.1 million grid points per leve

N1280 T_C1279 (cubic, ~8km) ≈ 8.5 million grid points per leve

O1280 T_{Co}1279 (cubic, ~9km) ≈ 6.6 million grid points per leve

(octahedral cubic reduced Gauss. grid)

Resolution upgrade: cubic grid property on kinetic energy spectra

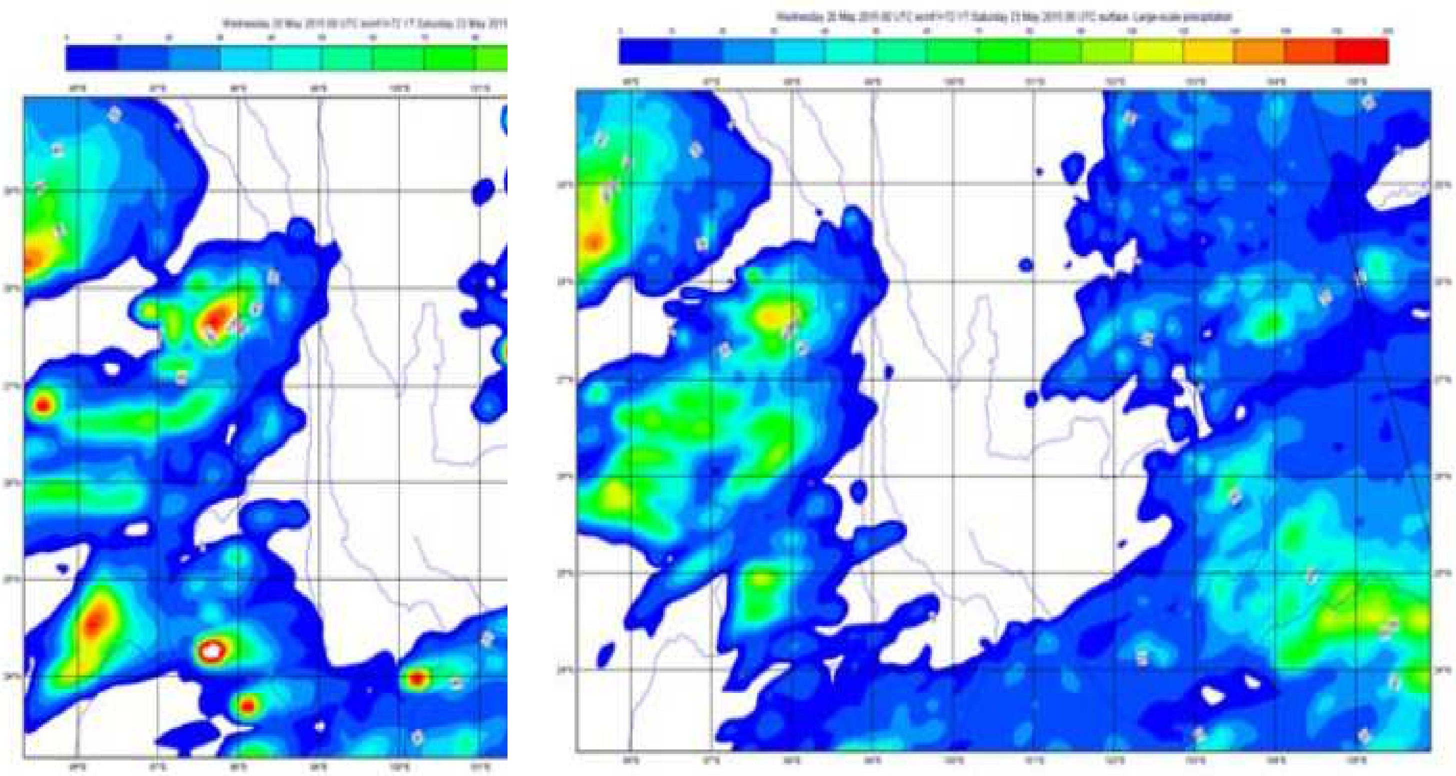


Resolution upgrade: cubic grid property on grid-point storm precipitation

T_{Co}1279 peak rainfall reductions

3 days accumulated large scale precip, south-east Asia

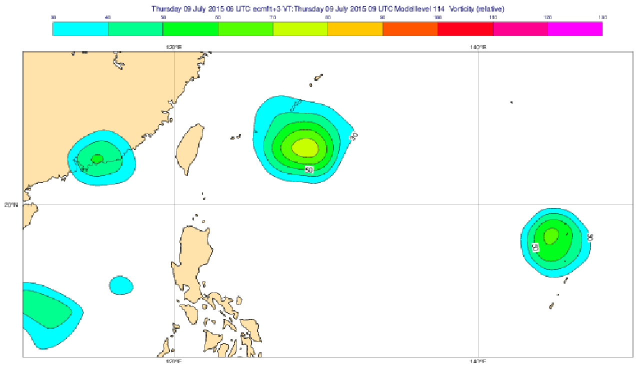
T_L1279



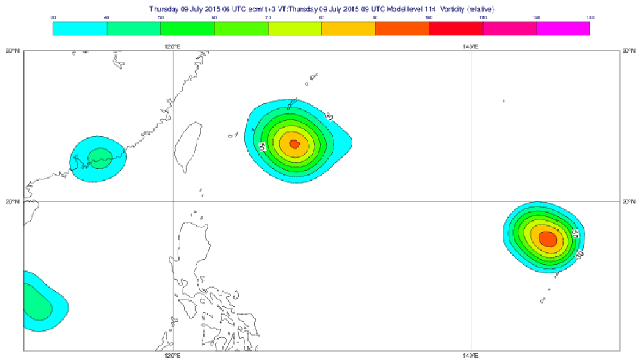
T_{Co}1279

Resolution upgrade: EDA improvements

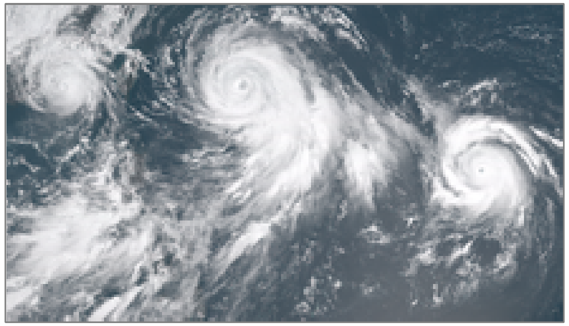
- Higher $T_{Co}639$ (16km) resolution
- More accurate analysis/forecasts
- More spread where it matters



41r1 T_L399
20150709
0900z

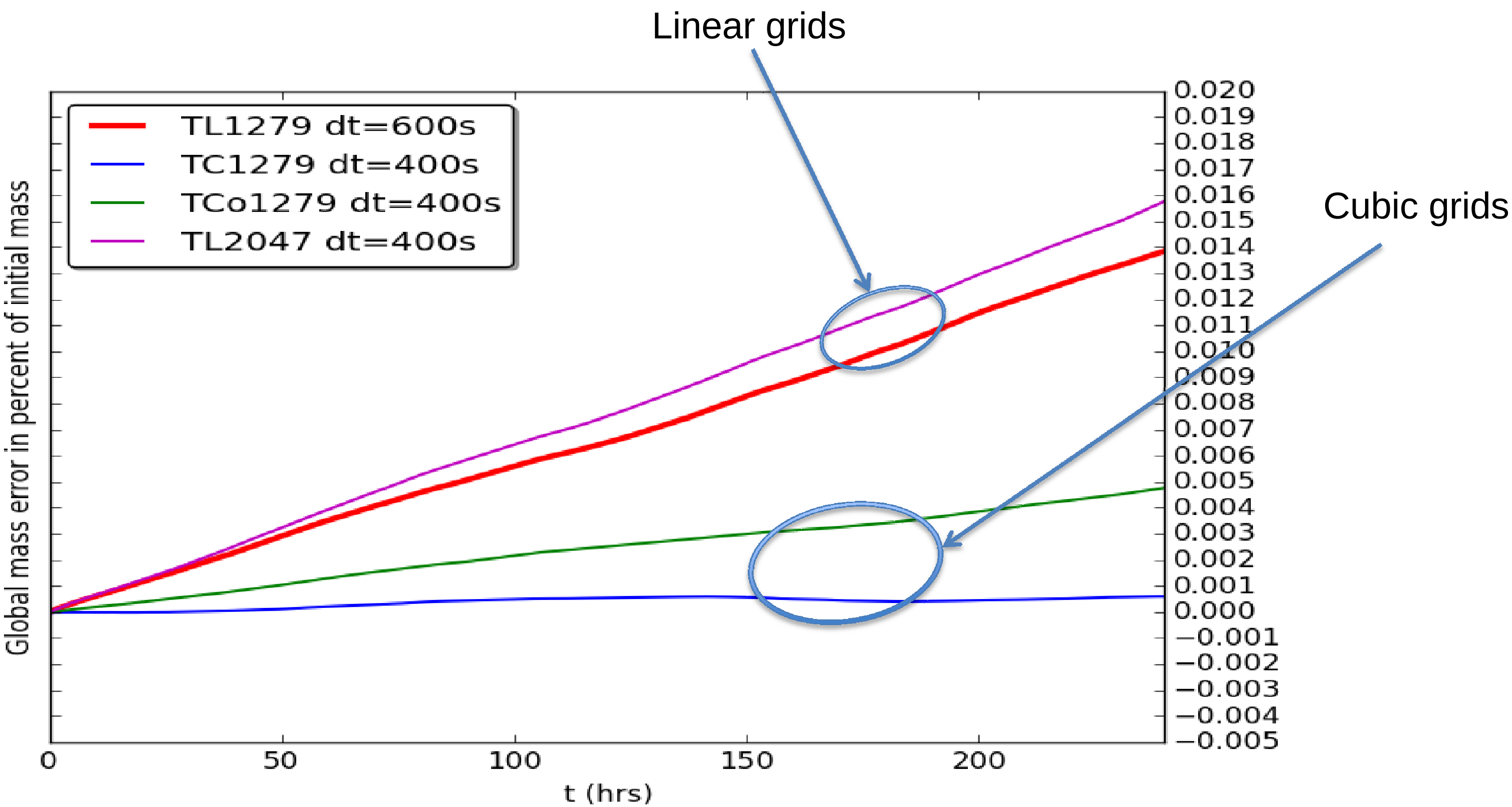


41r2 $T_{Co}639$
20150709
0900z



"Linfa, Chan-hom, and Nangka"

Resolution upgrade: cubic grid property on mass conservation

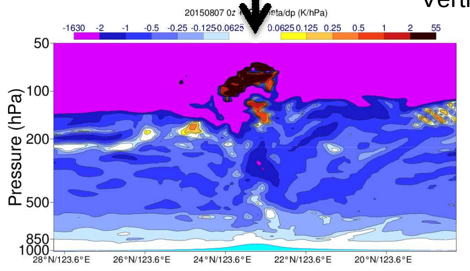


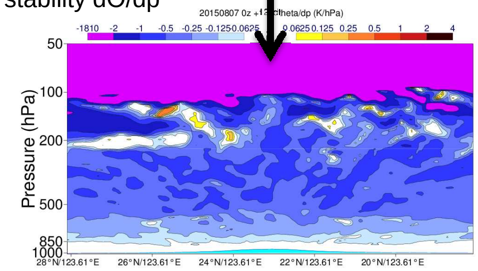
Improved semi-Lagrangian scheme

Instability with 3 iterations for semi-Lagrangian departure point in extreme situations (gravity waves above Himalayas, tropical cyclones);

increasing to 5 iteration considerably improves the results

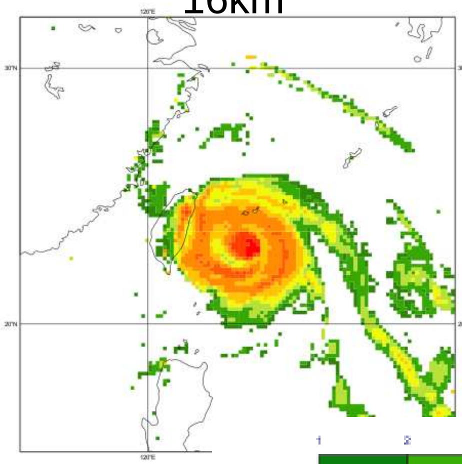
Vertical stability dΘ/dp



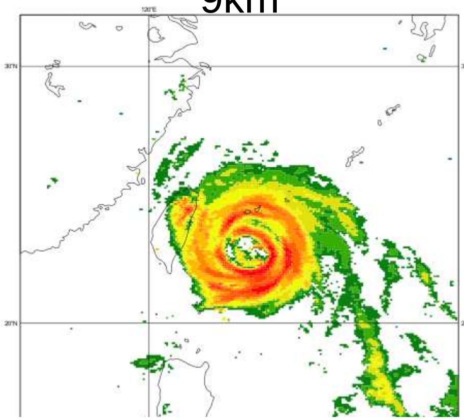


Tropical Cyclone Soudelor
Aug 2015

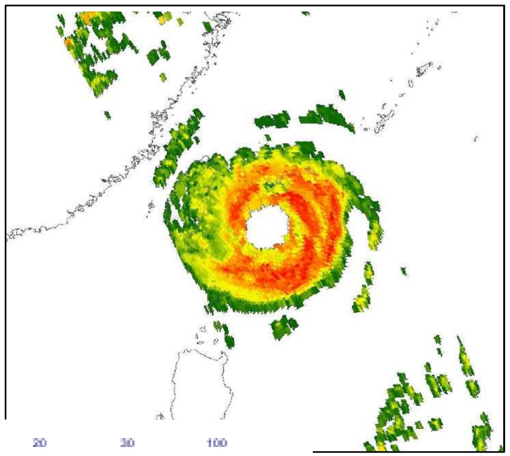
HRES T_L1279 Cy41r1
16km



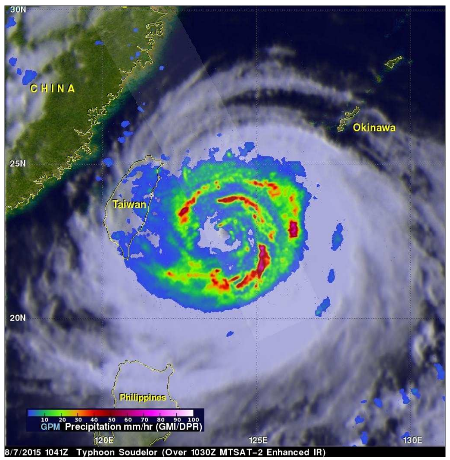
HRES T_{Co}1279 Cy41r2
9km

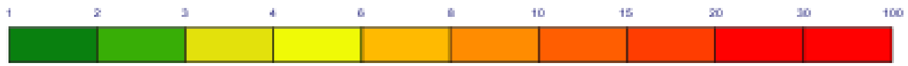


GPM observations



RADAR





Outline

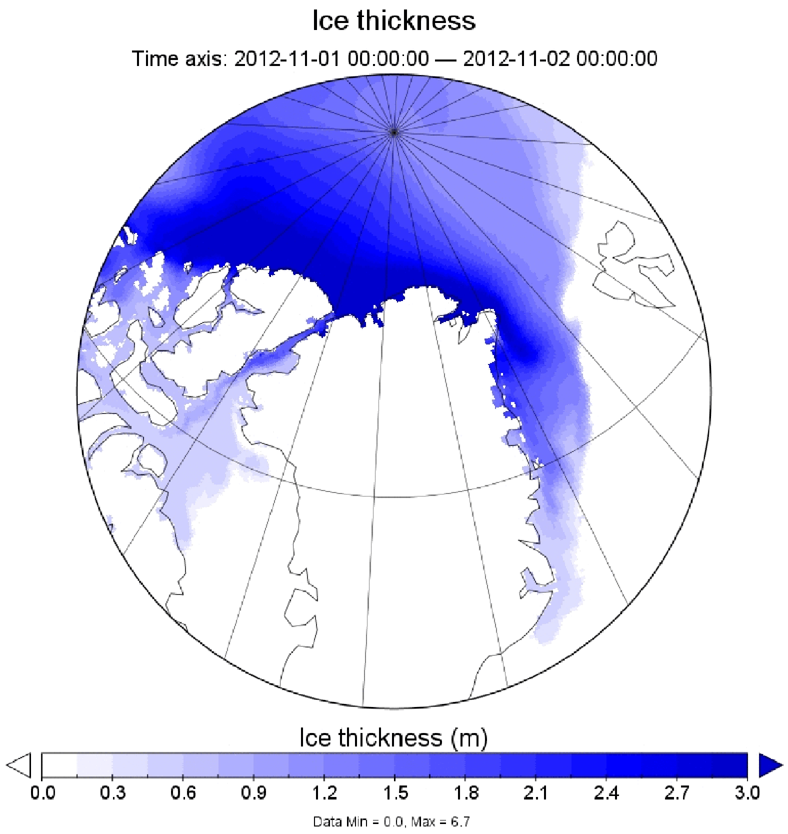
Overview

IFS upgrade Cy41r2 – 8 March 2016

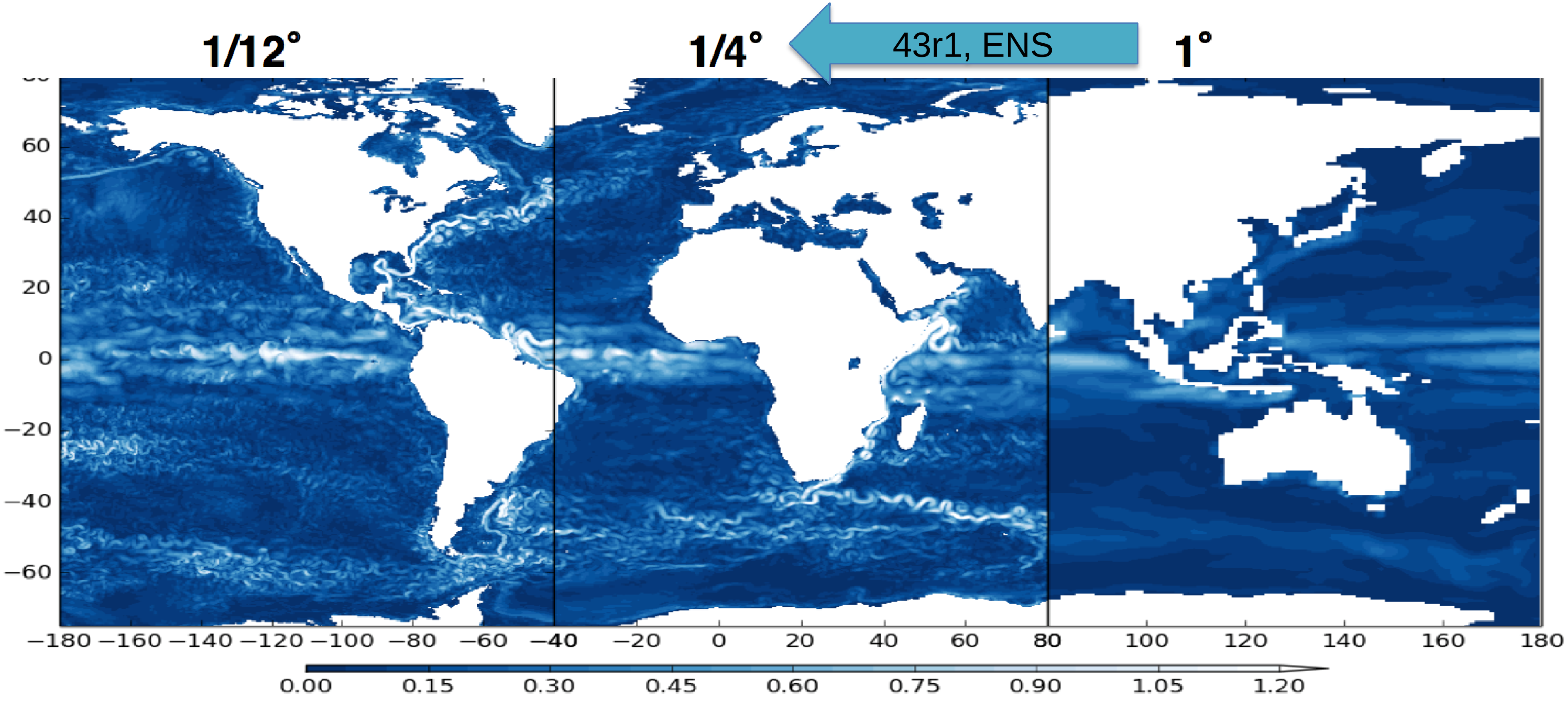
What's next…

Coupling of Sea-Ice model LIM2

- An interactive sea-ice model LIM2 for ENS
  (the Louvain-la-Neuve Sea Ice Model - LIM2)
- Sea-ice cover evolves dynamically, 1/4 deg ORCA
- Previously:
  - it was persisted for 15 days;
  - Over the next 30 days of the forecasts it was relaxed towards the climatology of the previous 5 years.

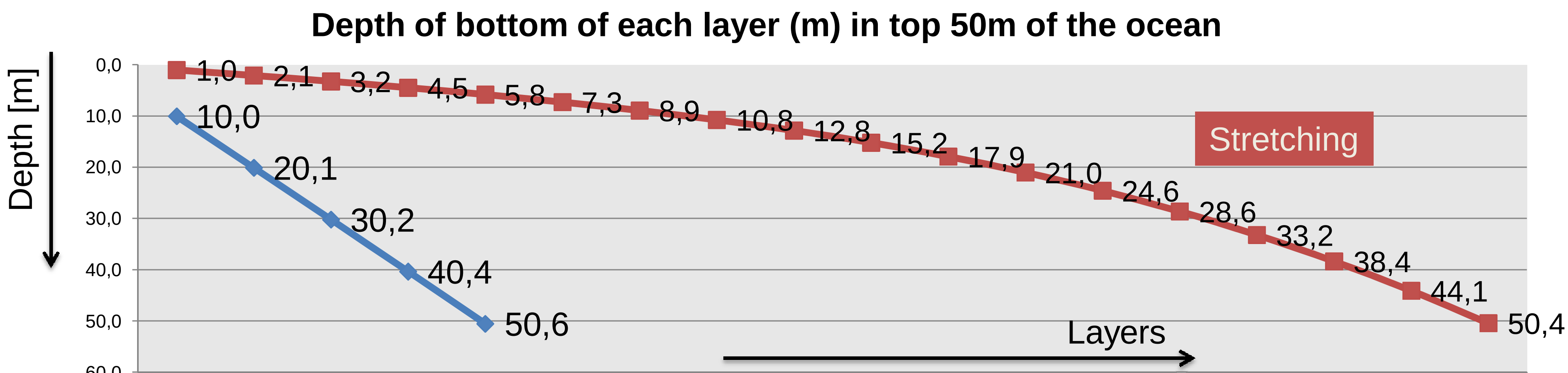


Ocean surface currents at various resolutions

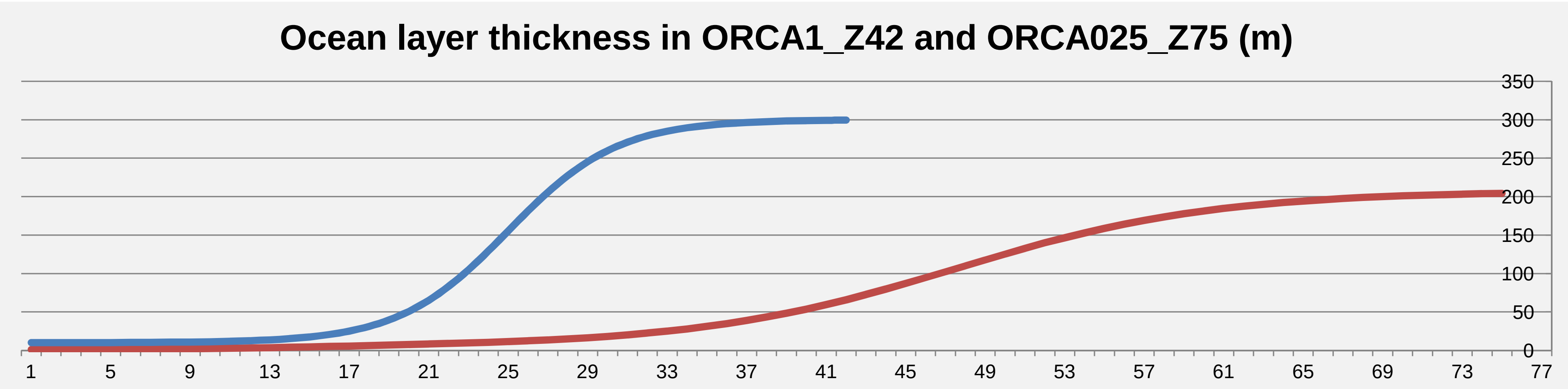


Eddy resolving | Eddy permitting | Eddy parameterising

Vertical layers in the ocean column for ORCA1_Z42 and ORCA025_Z75

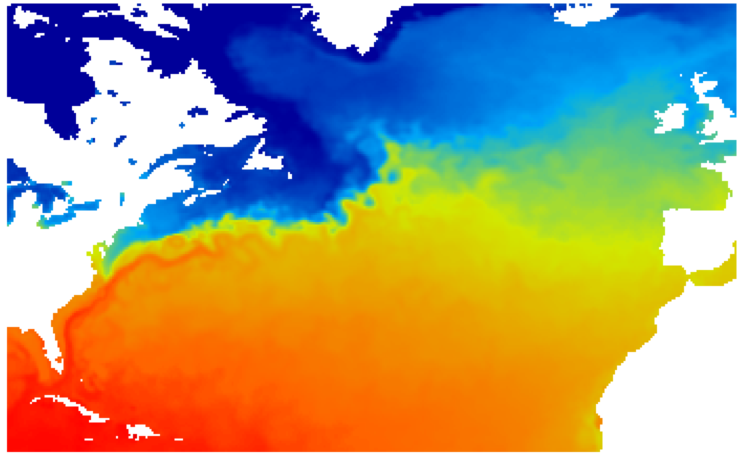


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ORCA1_Z42	10,0	20,1	30,2	40,4	50,6													
ORCA025_Z75	1,0	2,1	3,2	4,5	5,8	7,3	8,9	10,8	12,8	15,2	17,9	21,0	24,6	28,6	33,2	38,4	44,1	50,4



Thermal coupling of ocean

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.

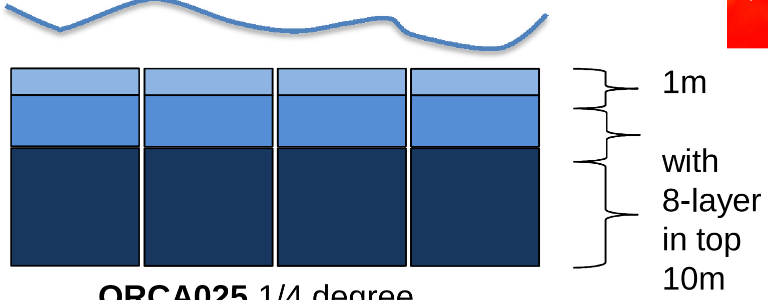


OSTIA 1/20 deg (5km) SST field has details of the eddies not resolved by ocean models

Data assimilation 4D-VAR uses

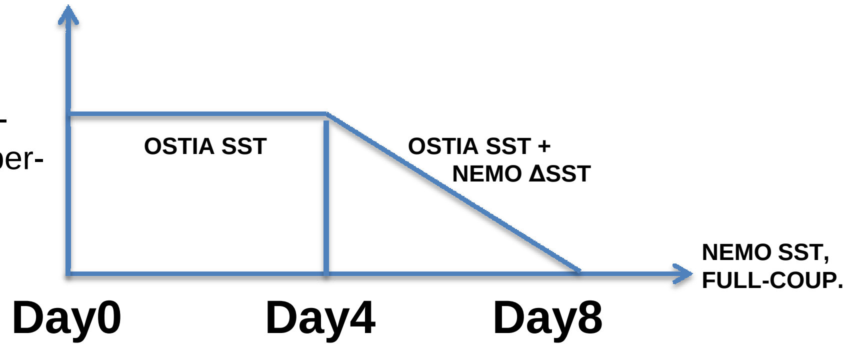
OSTIA SST

- 1/20 degree SST from OSTIA
- 1/4 degree SST from NEMO
  - dynamic, ocean tendencies
  - uncertainties



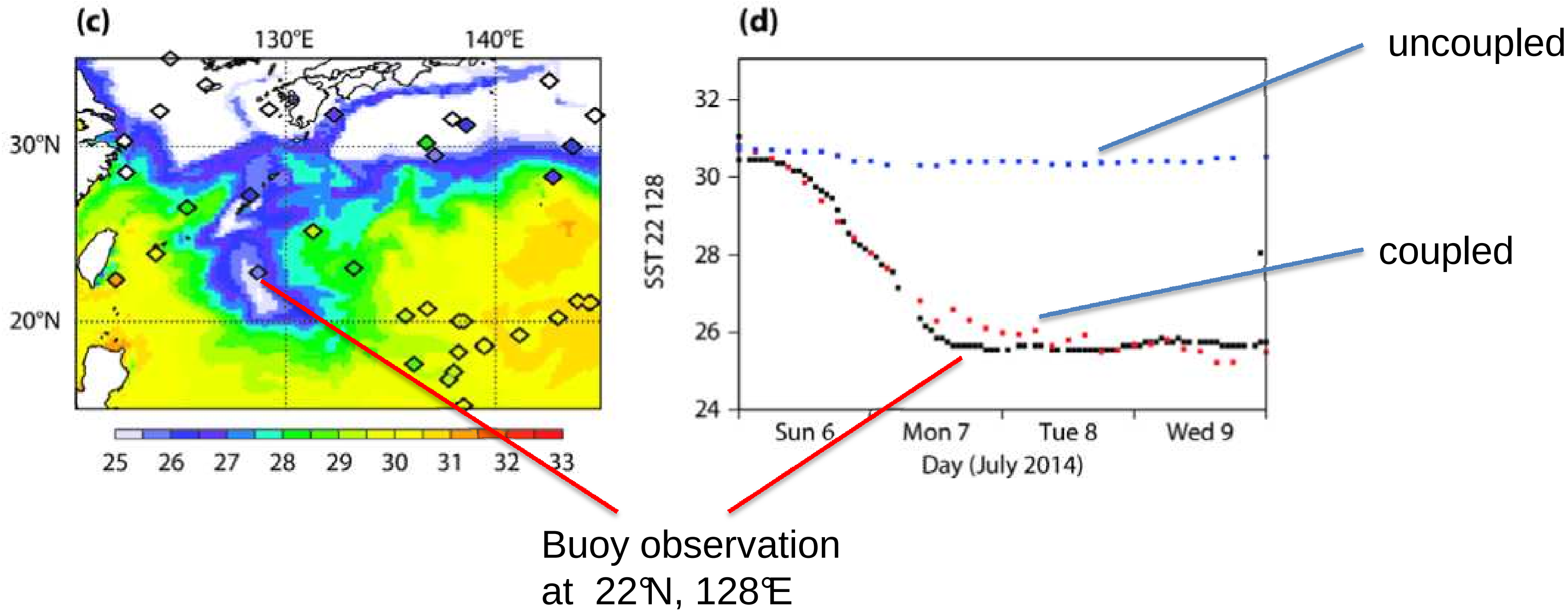
The **PARTIAL COUPLING** works well only in the short range as ocean eddies are assumed stationary
FULL COUPLING uses the dynamic ocean to advect eddies from day 0

OSTIA SST 1/20 degree is applied for 4-days and then relaxed to 0 gradually taper-down from day 4 to day 8
From day 8 onwards **FULL COUPLING**



Coupled ocean vs uncoupled simulation

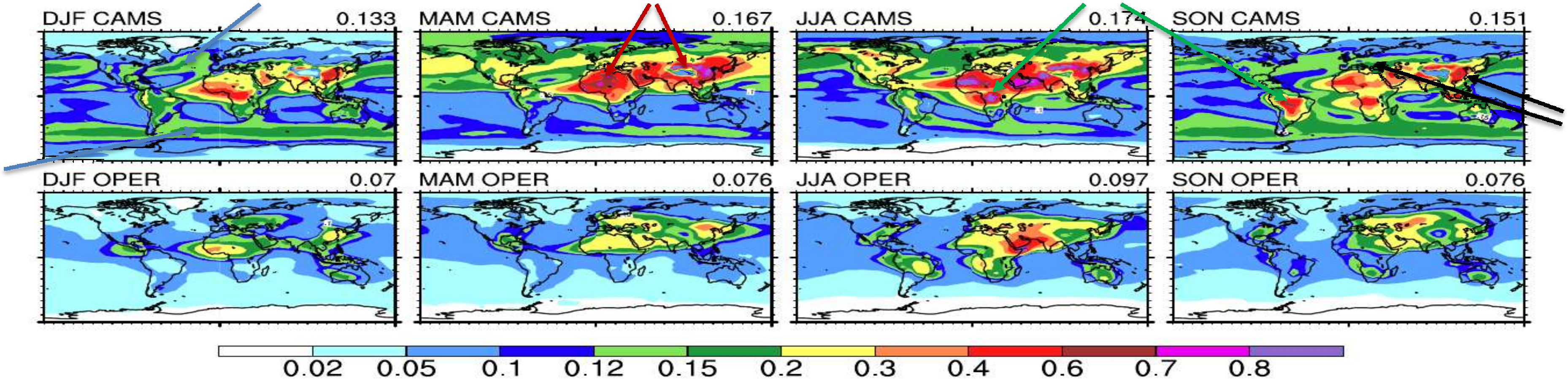
Tropical cyclone *Neoguri* with TCo1279 (HRES)



4-day forecast SSTs from the coupled forecast initialised at 0UTC on 6 July 2014 at the location of a buoy with approximate position 22°N, 128°E.

(Rodwell et al, ECMWF Technical Report 759, 2015)

Climatological AOD at 550 nm distribution
CAMS vs operational climatology (based on Tegen et al. 1997)

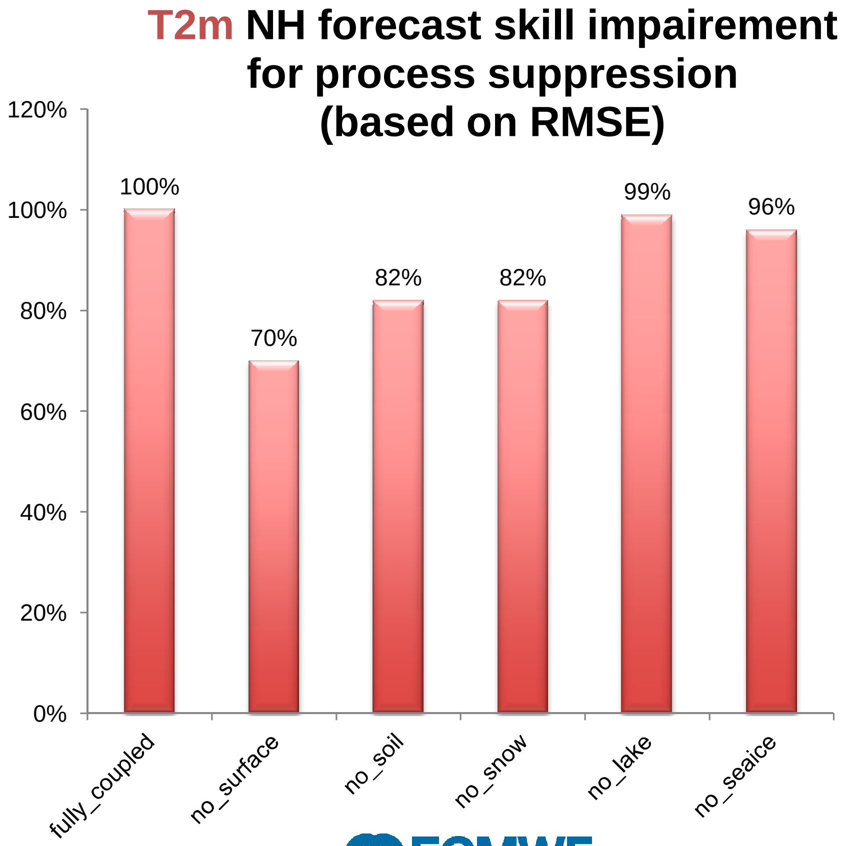


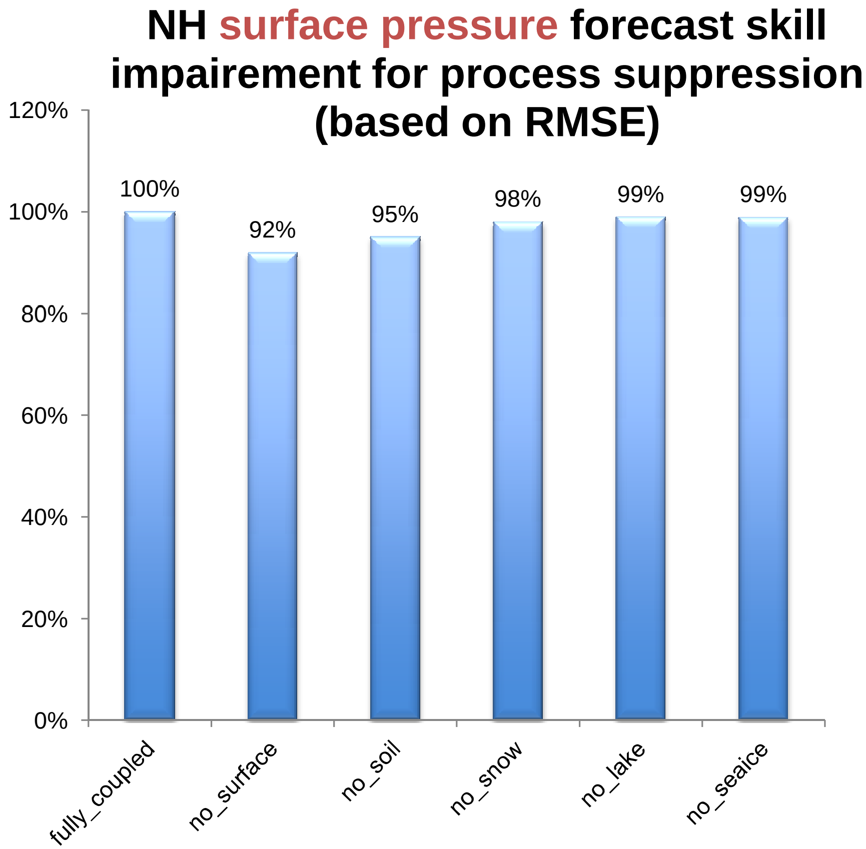
- Aerosol climatology computed using the CAMS-Interim reanalysis (Flemming et al. 2016)
- Updated spectral radiative properties, mass mixing ratio as input to radiation consistent with prognostic model, vertical distribution approximated by an exponential decay with scale height derived from the reanalysis for each aerosol type.
- 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

ECMWF

Weather impact of surface processes

- Evaluating the 3-day forecast-range skill deterioration induced by the surface process being deactivated (366 forecasts 1st June 2015 to 1st June 2016)





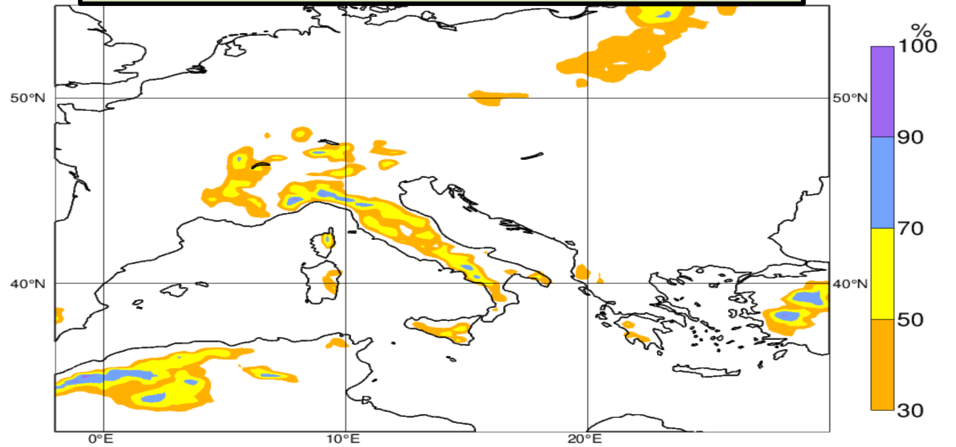
ECMWF

New diagnostic: Lightning in the Ensemble Prediction System

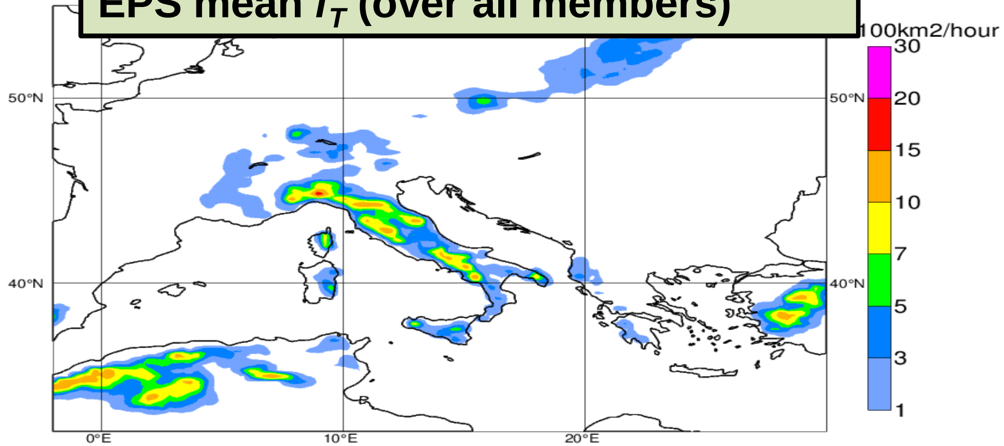
Example of 15h EPS global forecasts (31 members) from 9 Aug 2015 at 00Z.

3-hour mean lightning flash densities
31km resolution runs

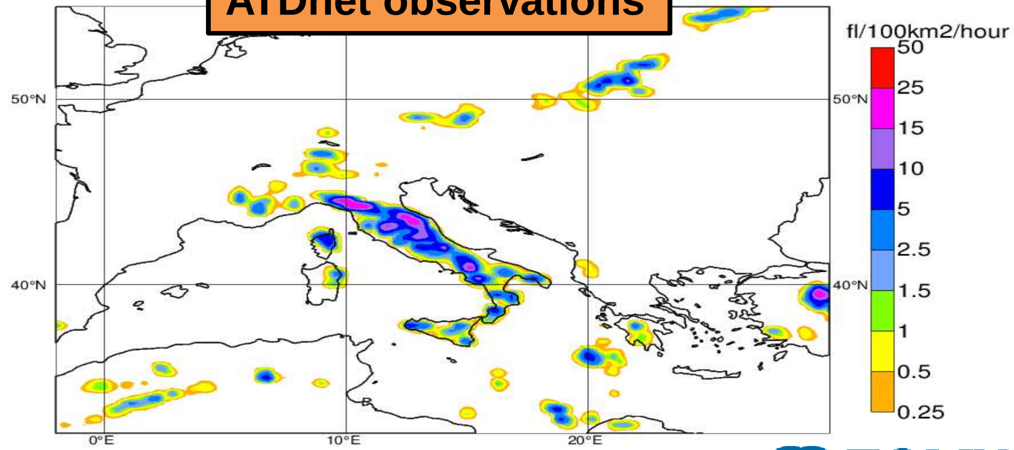
Prob (f_T > 1 flash/100 km^2/h)



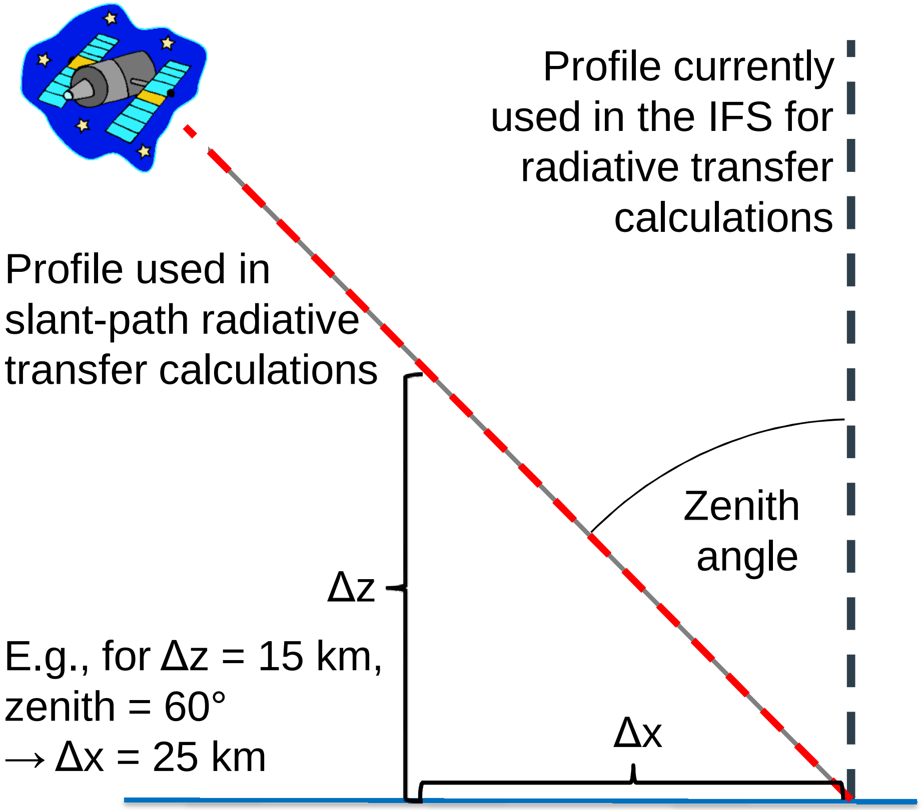
EPS mean f_T (over all members)



ATDnet observations

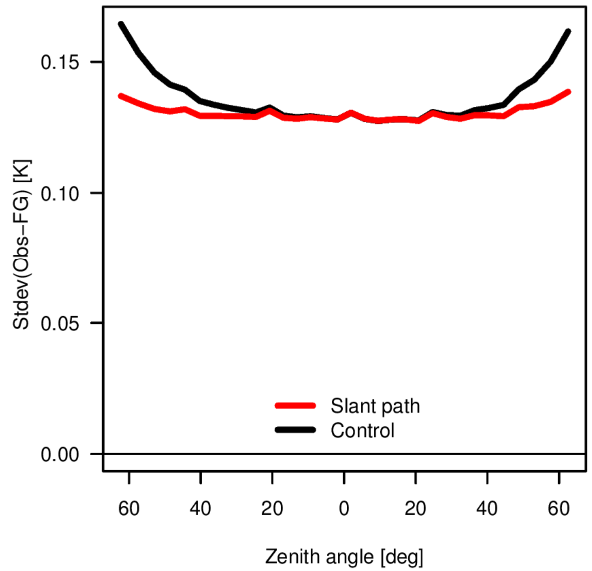


Satellite: Slant-path for radiative transfer calculations (→43r1)

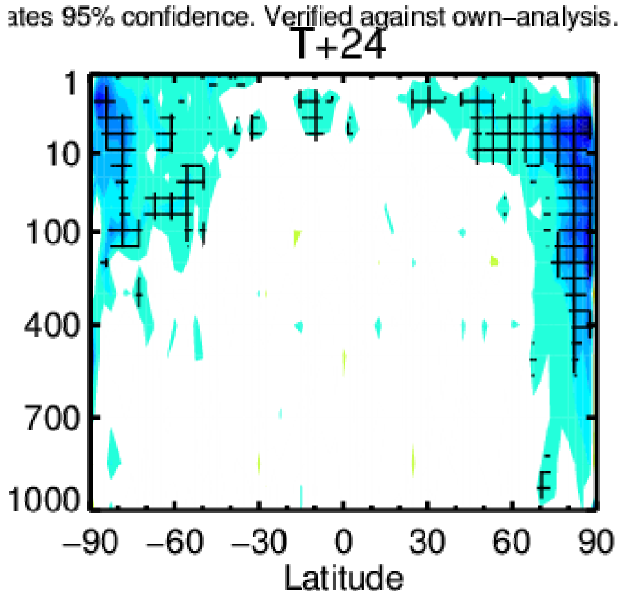


Effect on departure statistics:

E.g., stdev(Obs-FG), ATMS, channel 9, by scan-position



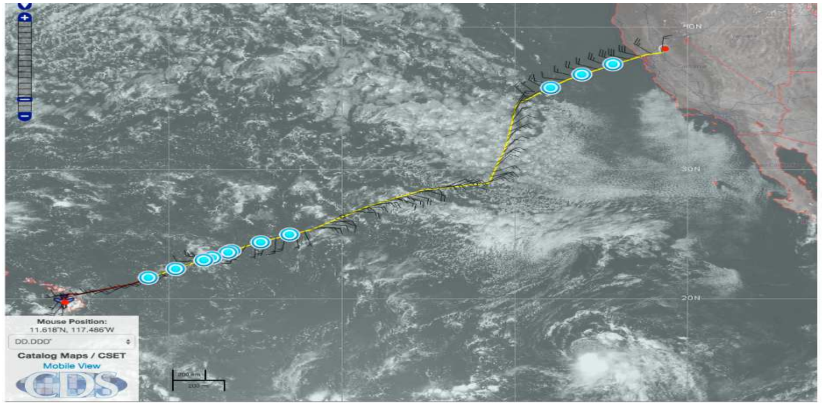
Stdev reduction in short range, e.g. T+24 fc wind



Slant-path RT leads to better agreement with observations

(see Tech Memo 782)

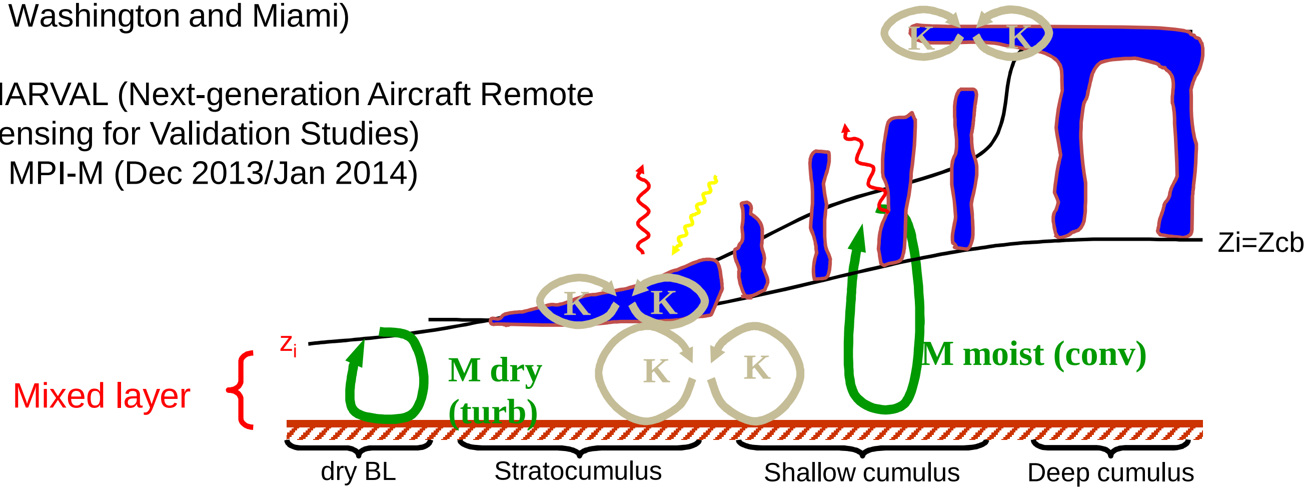
Evaluating forecasts against observations



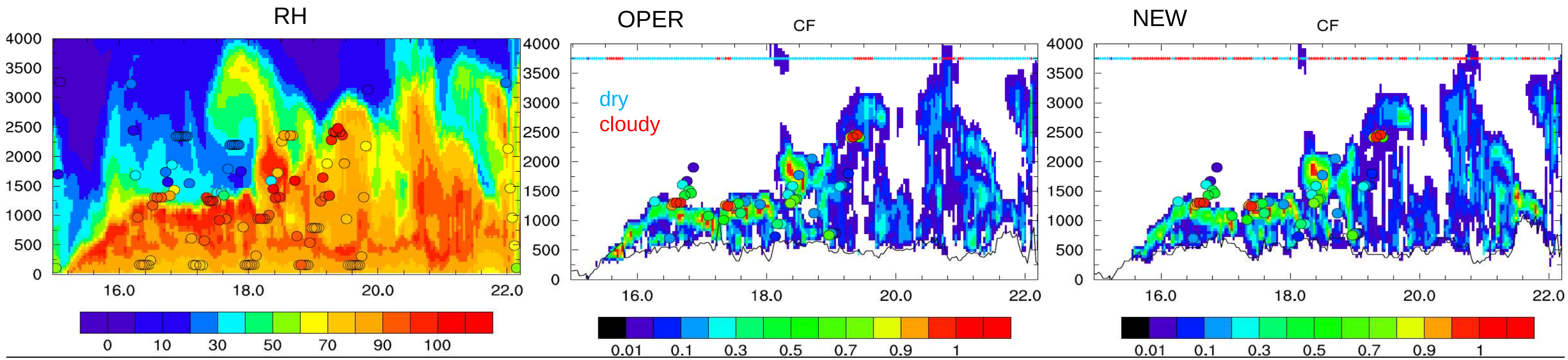
One of the flights during CSET

CSET, the Cloud System Evolution in the Trades
– July/August 2015 (University of Washington and Miami)

NARVAL (Next-generation Aircraft Remote sensing for Validation Studies)
– MPI-M (Dec 2013/Jan 2014)

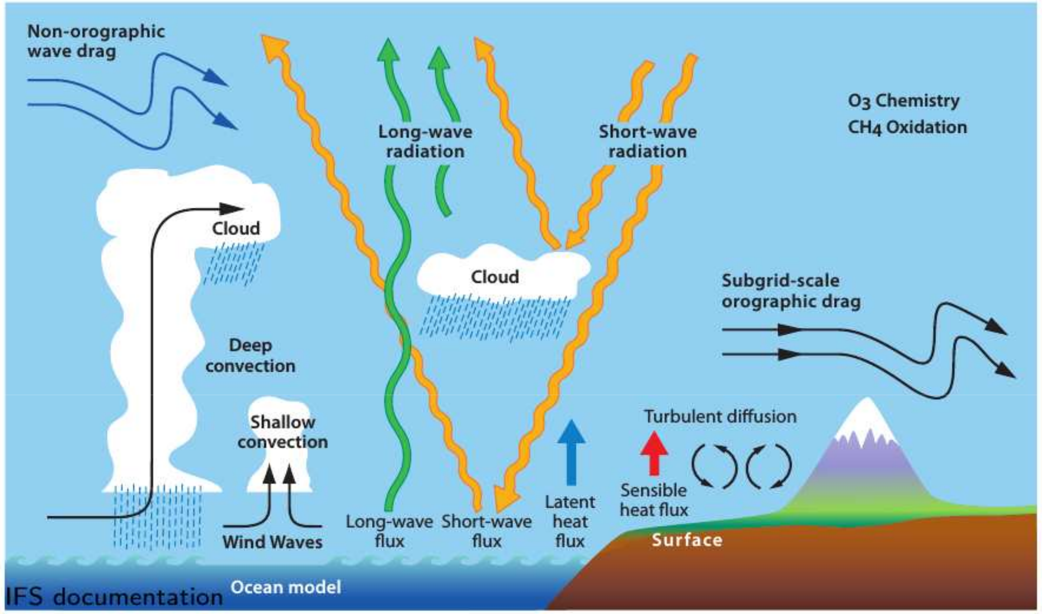


Towards a more unified turbulence, convection, cloud interaction



Towards process-level specification of uncertainties

Aim: Improve physical consistency of model uncertainty representation

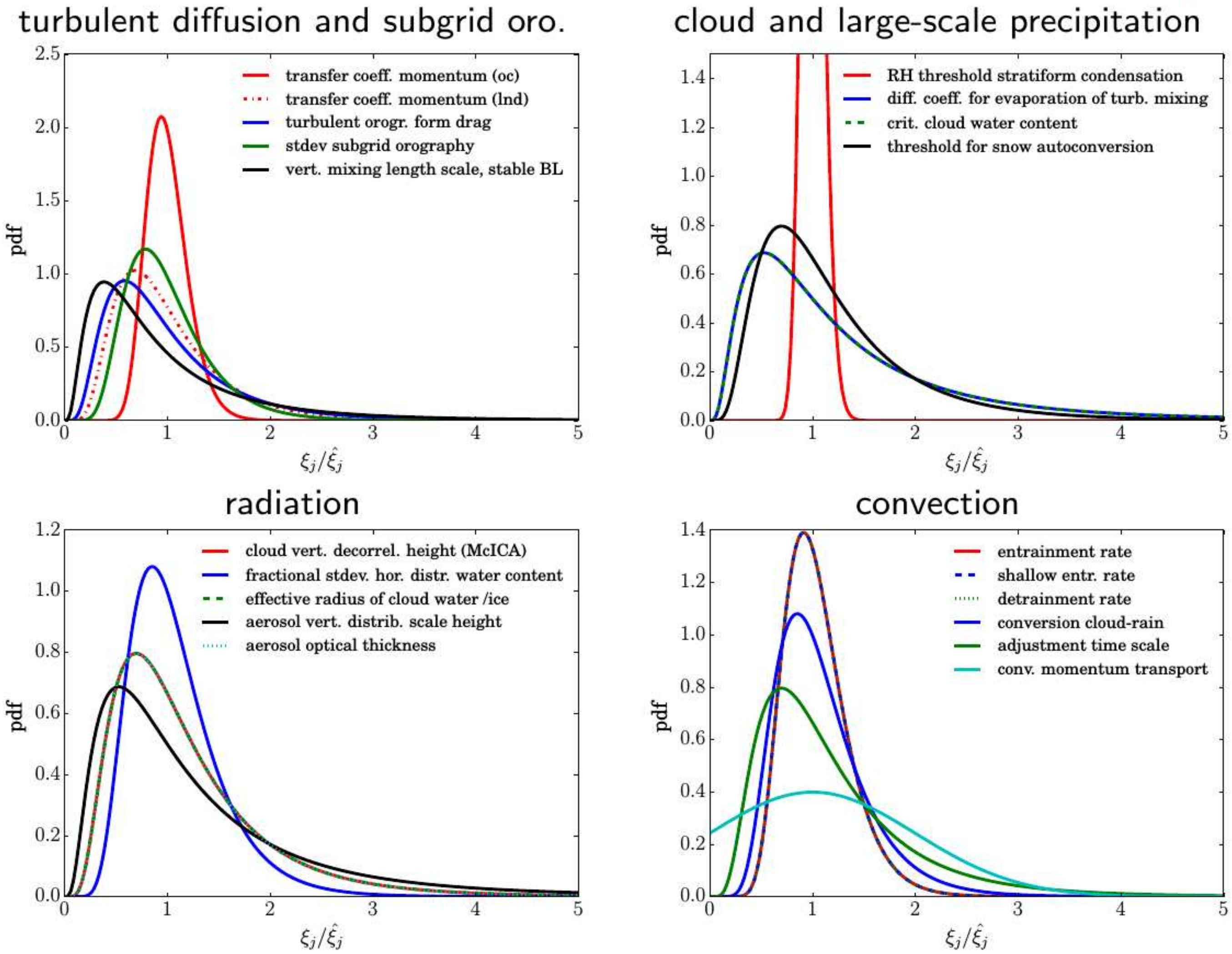


- Flux perturbations at TOA and sfc that are consistent with tendency perturbation in atmospheric column
- Conservation of water
- No ad hoc tapering in BL and stratosphere
- Include multi-variate aspects of uncertainties

- Embed stochasticity within IFS physics
- Local stochastic perturbations to parameters and variables with specified spatial and temporal correlations

- Target uncertainties that matter
- Stochastic parameterisation converges to deterministic IFS physics in limit of vanishing variance

The distributions sampled by SPP



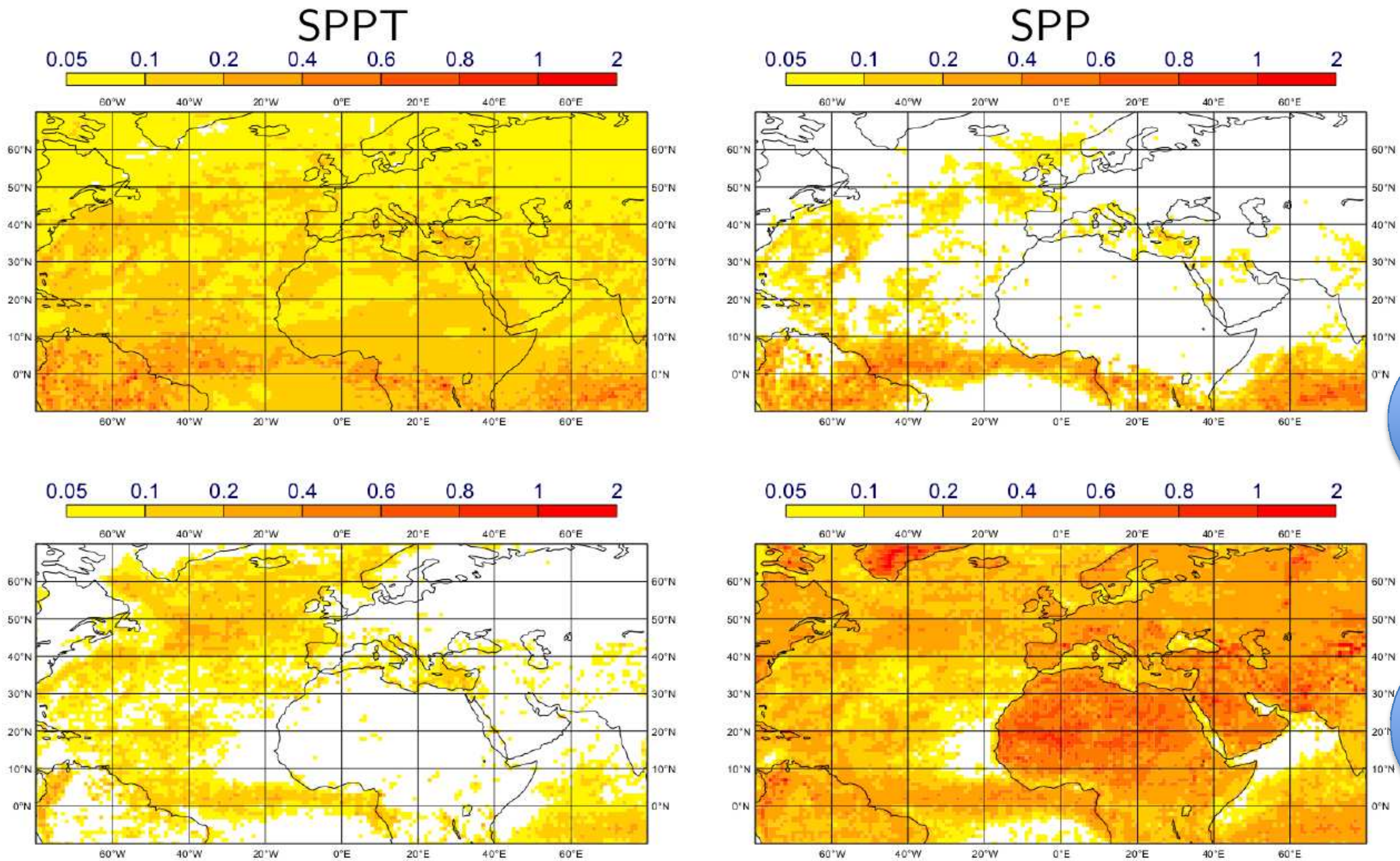
Ollinaho et al (2016, QJ in press): Stochastically Perturbed Parametrisations scheme (**SPP**)

ECMWF TM784

SAC special topic paper on model uncertainty, to be published as TM785

Intercomparison of SPP and SPPT

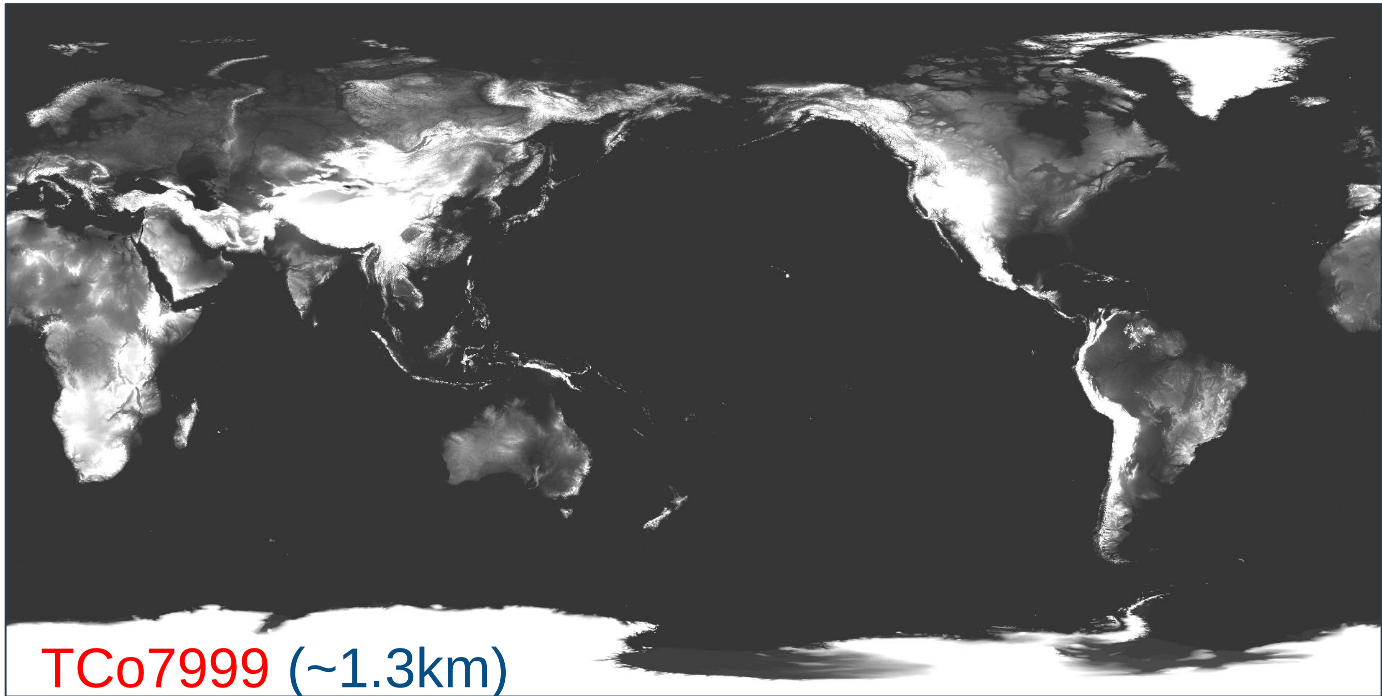
Ensemble stdev of 0–3 h temperature tendencies ($K[3\,h]^{-1}$)



no initial pertns. TL255, 20 member

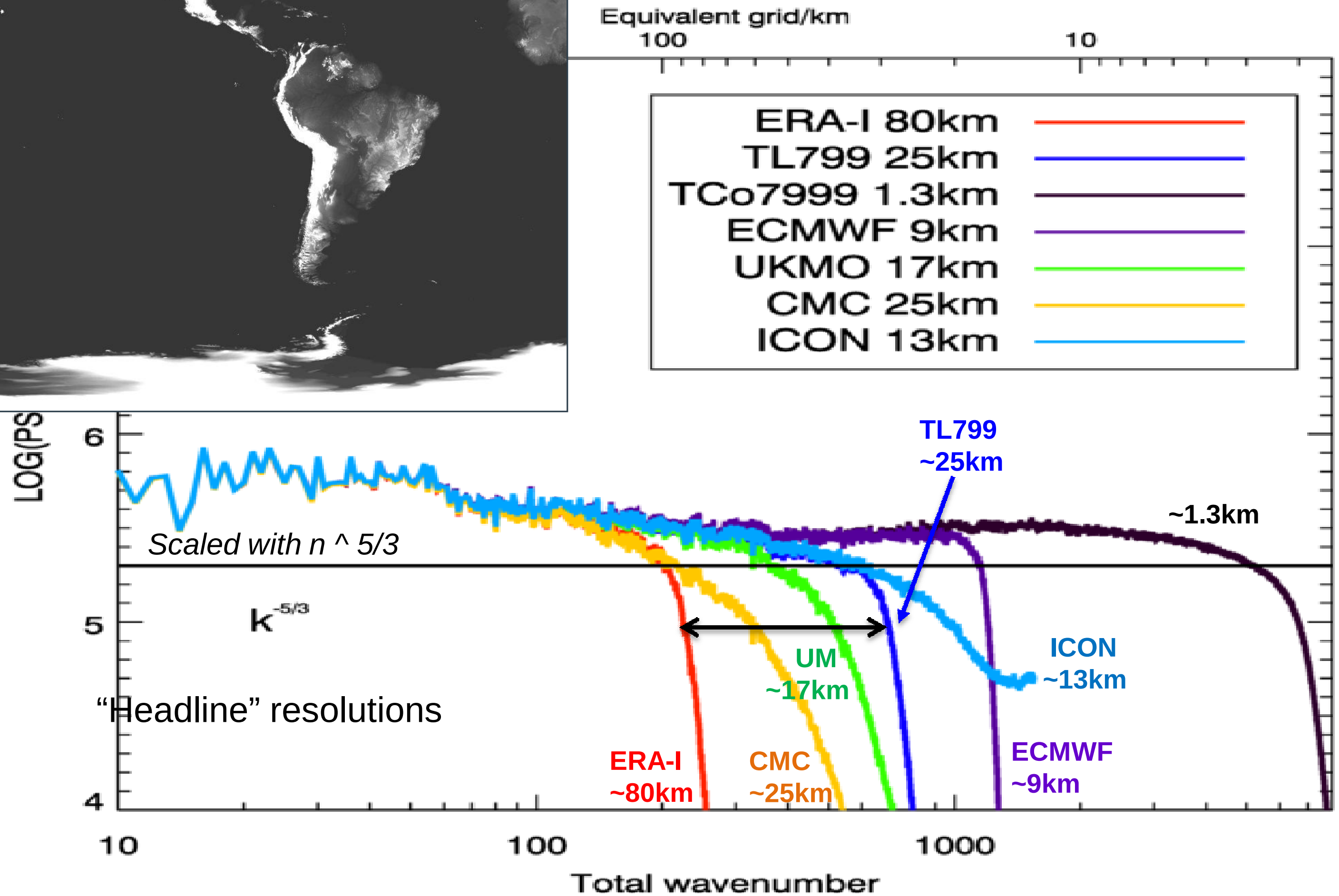
← level 64 ∼ 500 hPa

← level 91 10 m above surface

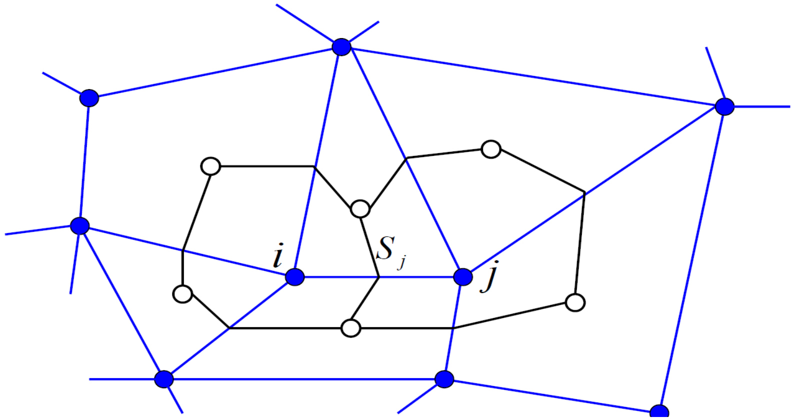


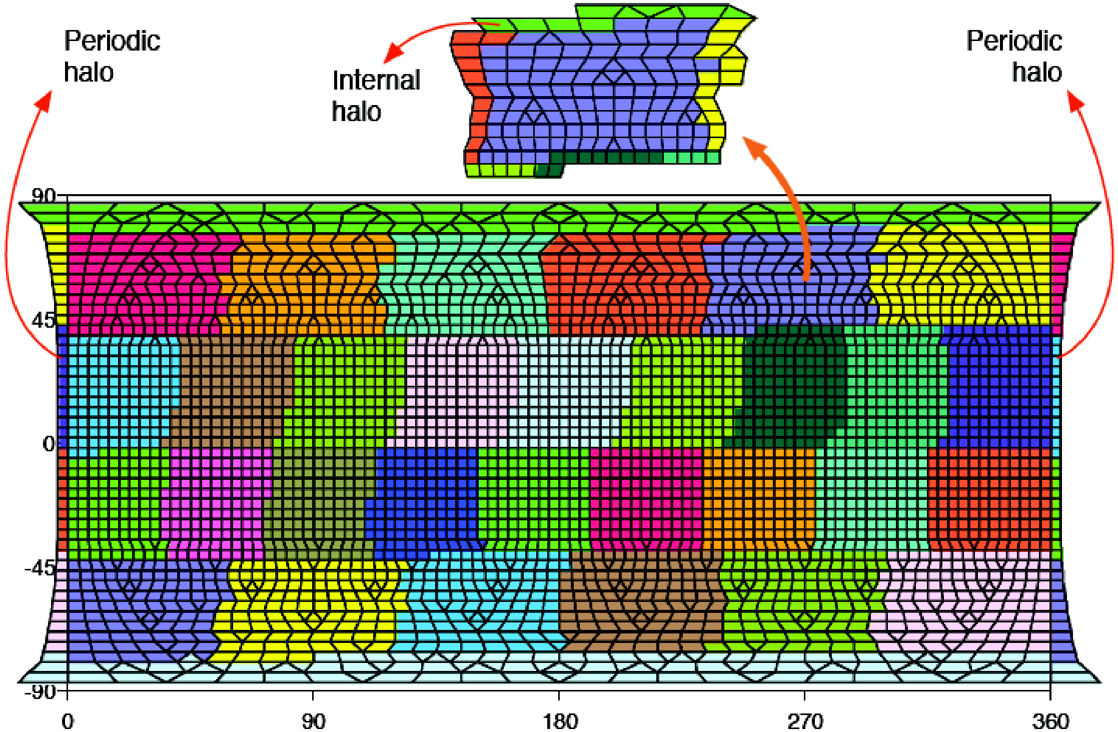
Mean Orography spectra at different NWP centres

Sylvie Malardel, Nils Wedi, Irina Sandu,
Ayrton Zadra, Simon Vosper,
Annelize van Niekerk, Daniel Klocke



More on dynamics tomorrow…





Local communication

Four-year plan: Projected HPC cost

EDA:

	2016		2017	2018	2019	2020
H resolution o/l	TCo639					TCo1279
H resolution i/l	TL191	TCo191				
V resolution	L137					
Coupling				orca025l75		
Ensemble size	M25		M50			
Window length	2x12h	4x6h				
Efficiency gains						
Nodes:	1600	2560	5120	5632	5632	28160
Factor:	1	1.6	2.0	1.1	1.0	5.0
Accum. factor:	1	1.6	3.2	3.5	**3.5**	**17.6**

ENS/legA:

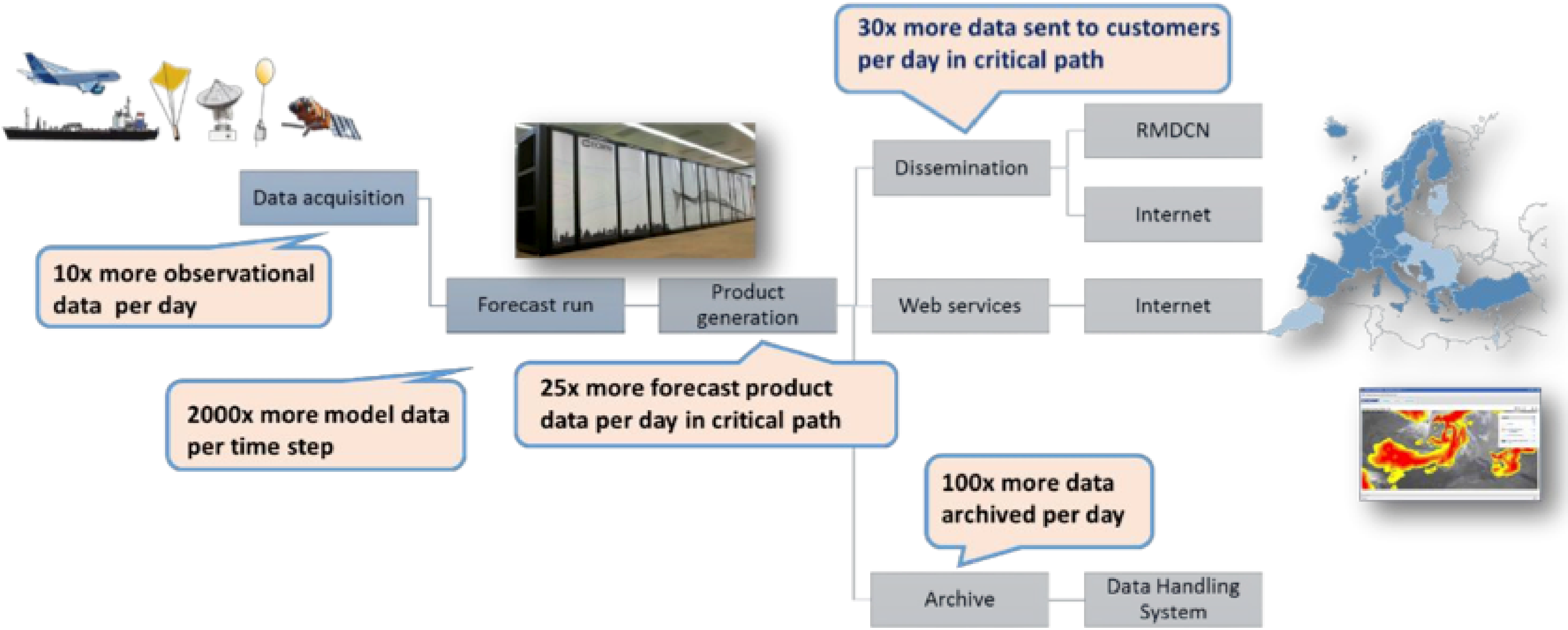
	2016		2017	2018	2019	2020
H resolution	TCo639					TCo1279
V resolution	L91			L137		
Coupling	orca100l42	orca025l75				
Forecast range	d10		d15			
Ensemble size	M51					
Reforecast ensemble size	M11				M15	
Efficiency gains						
Nodes:	1530	1683	2525	3787	4355	21774
Factor:	1	1.1	1.5	1.5	1.2	5.0
Accum. factor:	1	1.1	1.7	2.5	**2.8**	**14.2**

Strategic target:
Global 5km,
seamless analysis-
forecast ensemble
in 2025

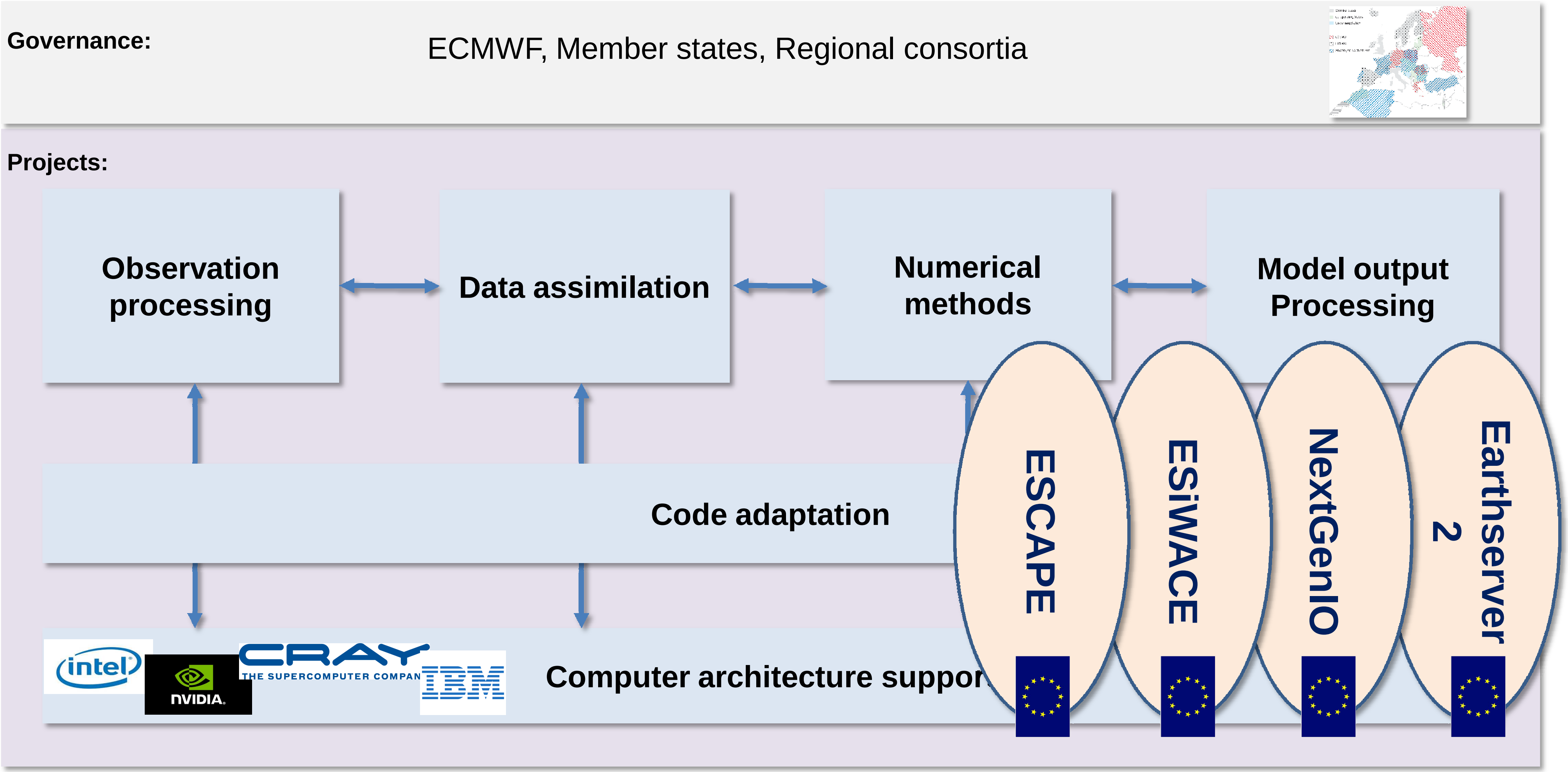
No
HRES

ECMWF

Challenges “tomorrow”…



ECMWF Scalability Programme



Thank you for your attention

ECMWF Recent Developments and Plans

EWGLAM / SRNWP October 2016

Willem Deconinck

With thanks to many people at ECMWF!

willem.deconinck@ecmwf.int