ECMWF Centre Report

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European Centre for Medium Range Weather Forecasts

Highlights

- Cycle upgrades (41r2, 43r1, 43r3, 45r1, SEAS5, ERA5)
- Earth system modelling
  - cloud microphysics and grey-zone physics
  - Stratosphere focus
  - CAMS aerosol climatology
  - TL/AD stability
  - Atlas library, FVM, ESCAPE weather & climate dwarfs
- Earth system data assimilation and predictability
  - OOPS
  - EDA and ensemble design
  - enhanced use of observations (satellite and conventional)
  - SEAS5: implementation

ERA5: the ERA-Interim replacement

What is new in ERA5?

	ERA-Interim	ERA5
Period	1979 - present	1979 – present, later back to 1950s
IFS	Cy31r2	Cy41r2
Model input (radiation and surface)	As in operations, *(inconsistent sea surface temperature)*	***Appropriate for climate***, e.g., evolution greenhouse gases, volcanic eruptions, sea surface temperature and sea ice
Spatial resolution	79 km globally 60 levels to 10 Pa	***31 km globally (TL639)*** 137 levels to 1 Pa
Uncertainty estimate		Based on a 10-member ***ensemble*** at 62 km (TL319)
Land Component	79km	9km (TCO1279), not started yet
Output frequency	6-hourly Analysis fields	***Hourly*** (three-hourly for the ensemble), ***Extended list of parameters ~ 5 Peta Byte***
Extra Observations	Mostly ERA-40, GTS	Various ***reprocessed CDRs***, ***latest instruments***
Variational Bias corrections	Satellite radiances Radiosondes: RASE	Also ozone, aircraft, surface pressure, Radiosondes: RICH + Solar-Elevation (RISE) operational bias control from 2015

ECMWF configuration since March 2016

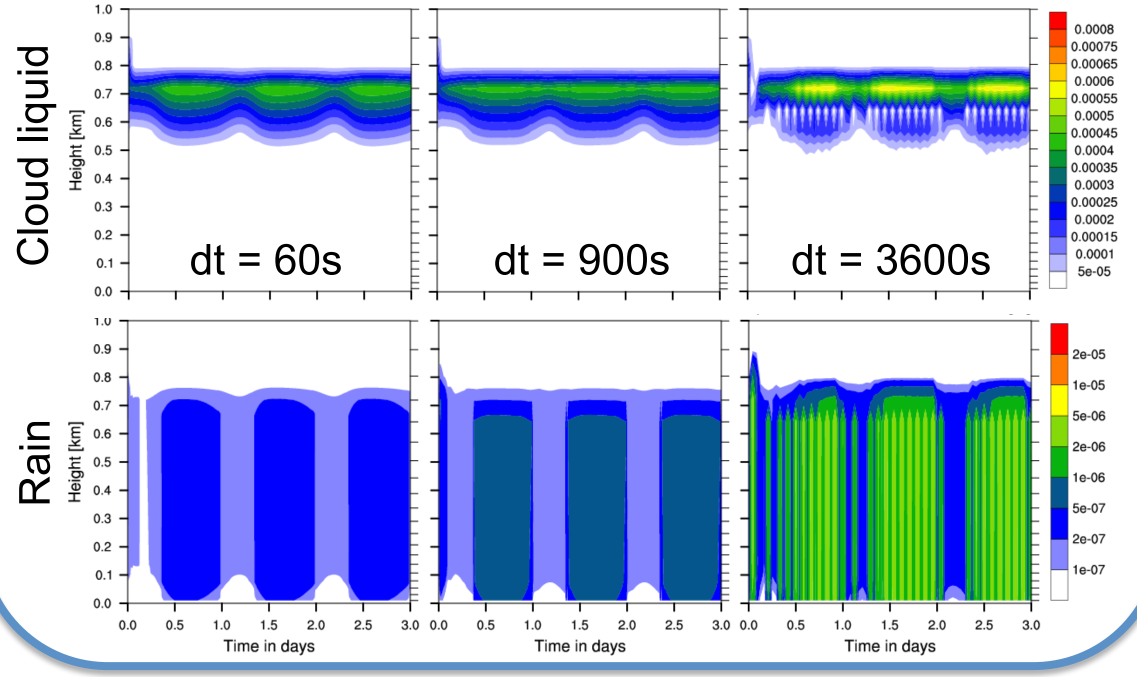
Grid res.	HRES	ENS LegA	ENS LegB/M'ly	4DV inner loops 1st	4DV inner loops 2nd	4DV inner loops 3rd	EDA Outer	EDA 1st	EDA 2nd
128 km								TL159 → TL191	TL159 → TL191
64 km	41r1 ↓		TL319 ↓	TL255	TL255 → TL319	TL255 → TL399	TL399 ↓		
32 km	41r2	TL639 ↓	TCo319						
16 km	TL1279 ↓	TCo639 (D10 → D15)					TCo639		
9 km	TCo1279								

Holm et al., ECMWF Newsletter 147

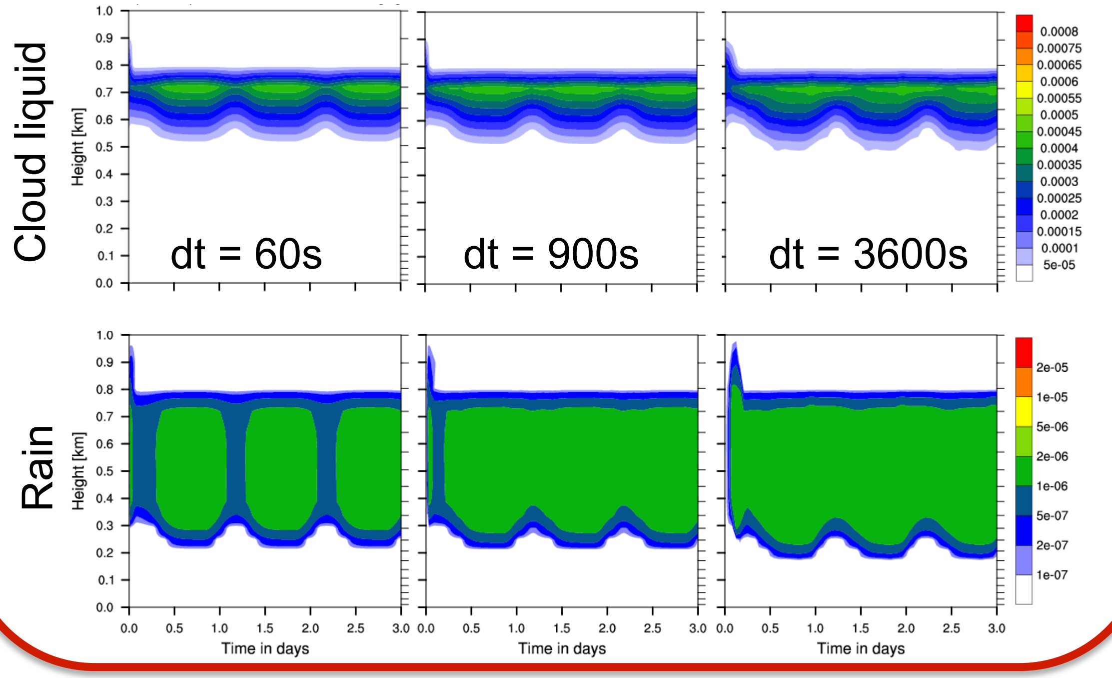
Warm-rain microphysics numerics package (45r1)

Single Column Model idealised stratocumulus diurnal cycle case study

IFS Cy43r3



Revised 45r1 microphysics



- Numerical artefacts
- Timestep dependency
- Overestimates surface “drizzle”

→

Improvements in 45r1

- Revised implicit numerics for **sedimentation**
- Variable **fall speed** for rain
- Relax thresholds for **rain evaporation**
- Remove thresholds for **autoconv&accretion**
- New **turbulent erosion** formulation

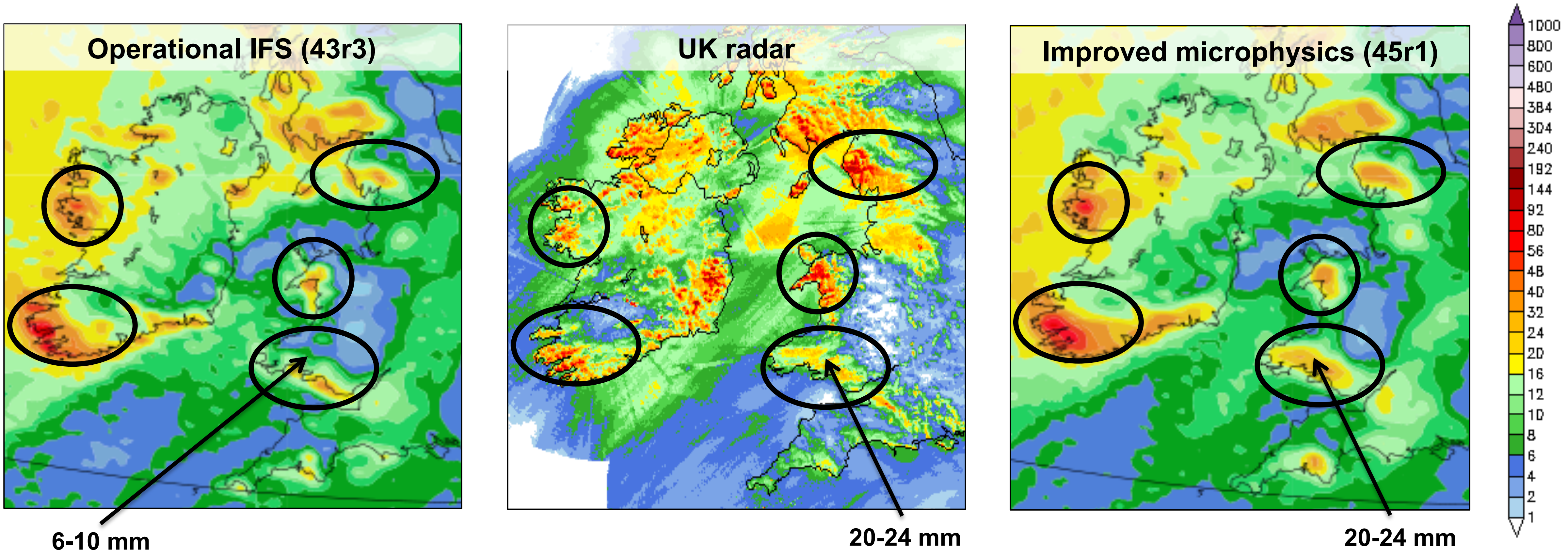
→

- No numerical artefacts
- Reduced timestep dependency
- Rain evaporates through sub-cloud layer → less “drizzle”

Warm-rain microphysics numerics package (45r1)

Improvements in precipitation along coast lines/lakes and over orography

Example case study 14 May 2017 00Z 48hr forecast accumulated precipitation (mm)

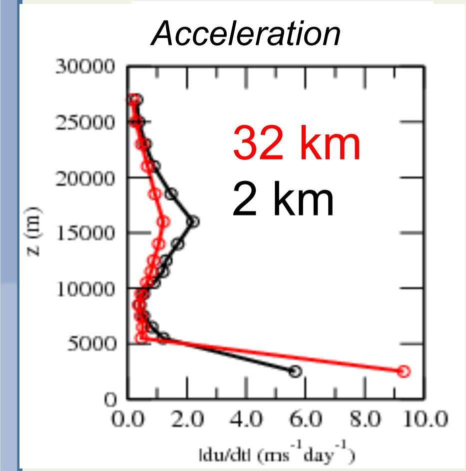


Advancing science in partnership (grey-zone)

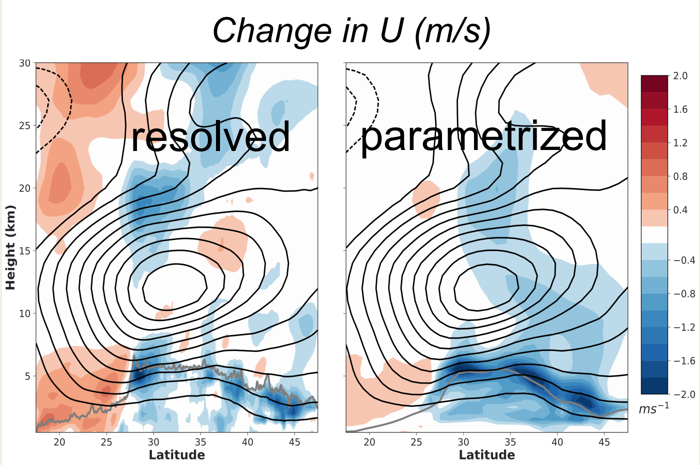
Orographic drag - Metoffice

2 - 5 km simulations of Rockies and Himalayas, used to evaluate parametrized drag in UM & IFS

Rockies (UM)



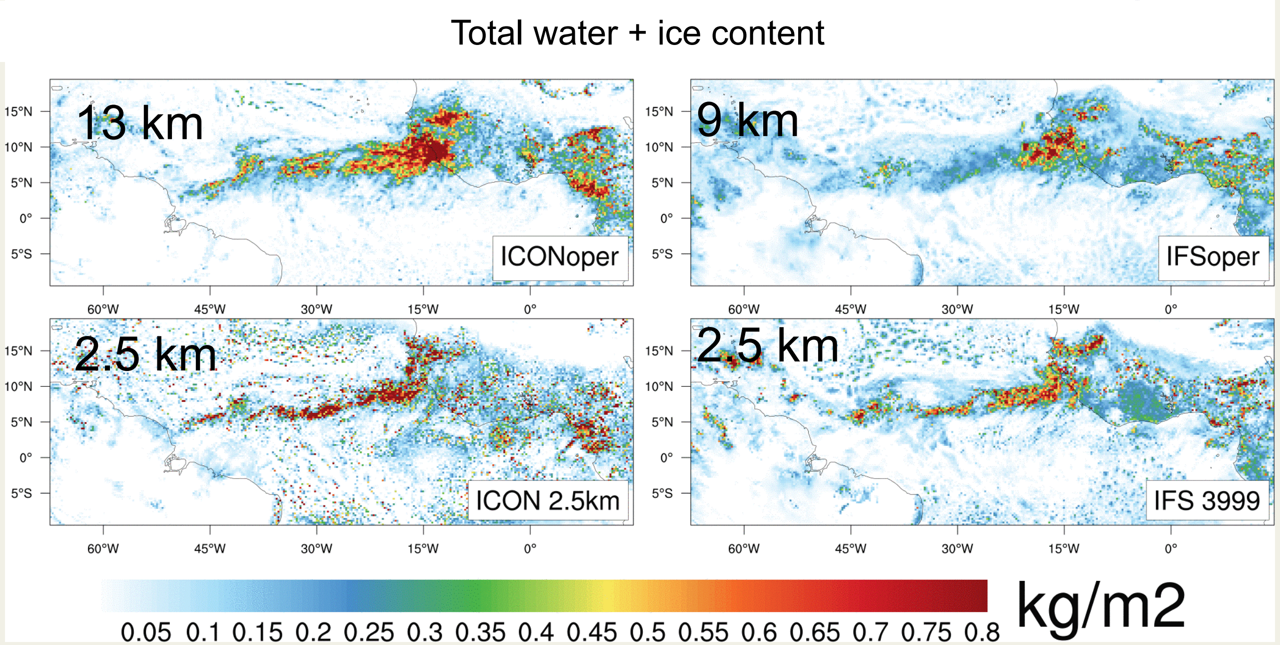
Himalayas (UM)



Vosper et al., Van Niekerk et al., in preparation

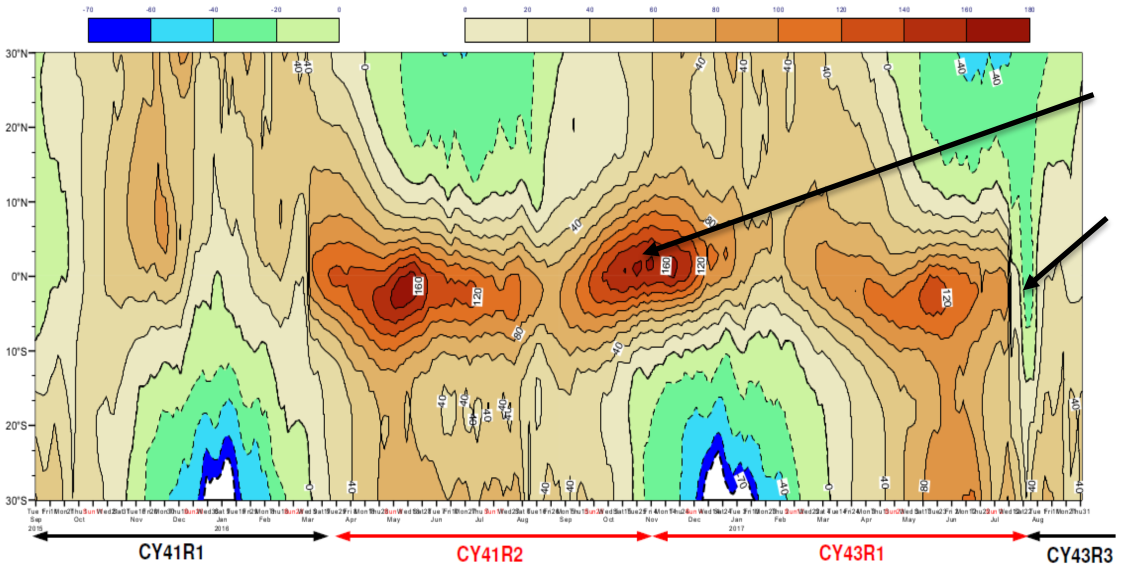
Convection - DWD

1, 2.5, 5, ~ 9 km of Tropical Atlantic with ICON & IFS



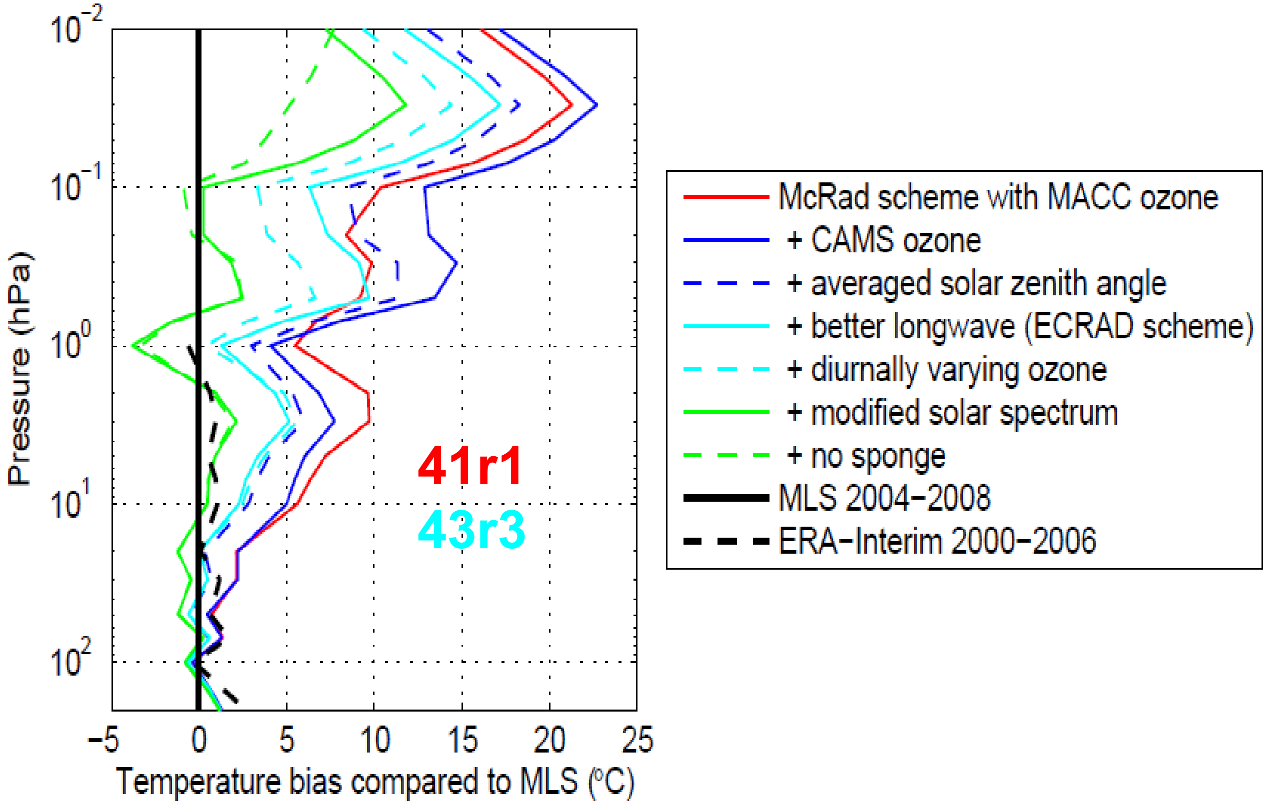
Courtesy Daniel Klocke and Nils Wedi

Improvements in the middle atmosphere

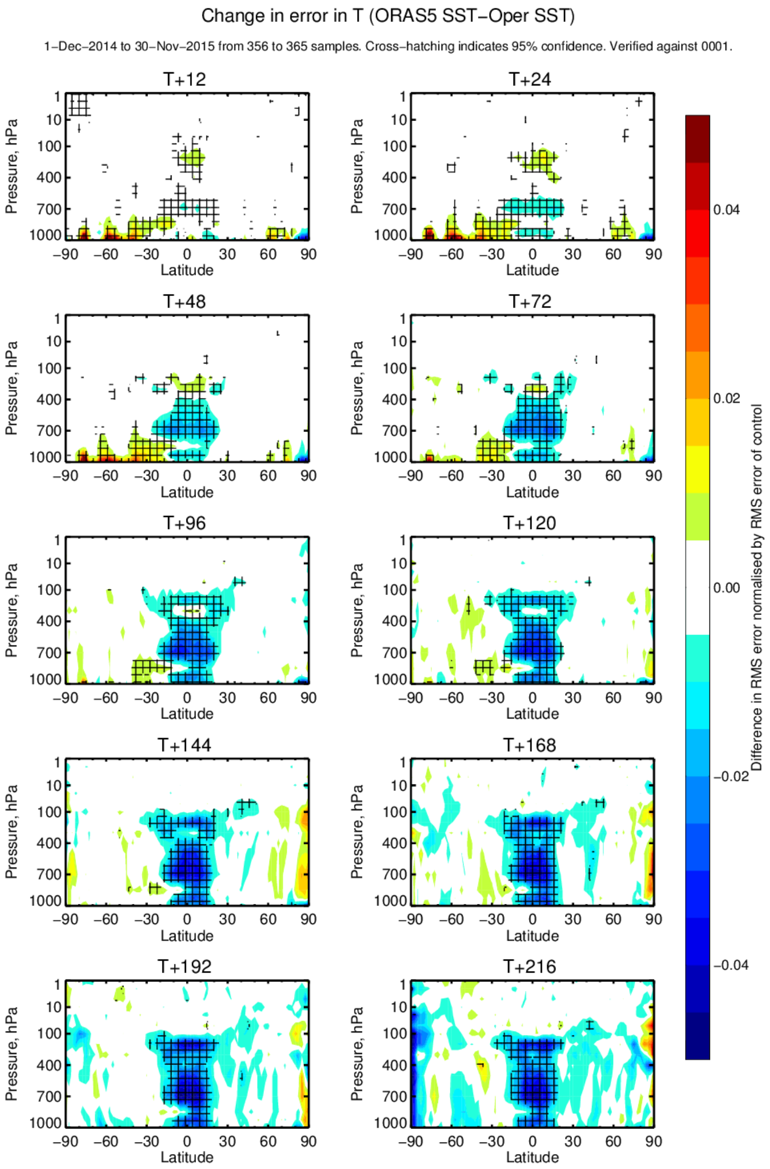


(1) Zonal winds in equatorial mesosphere too fast (180 m/s).
Improvement with new background error covariance model.

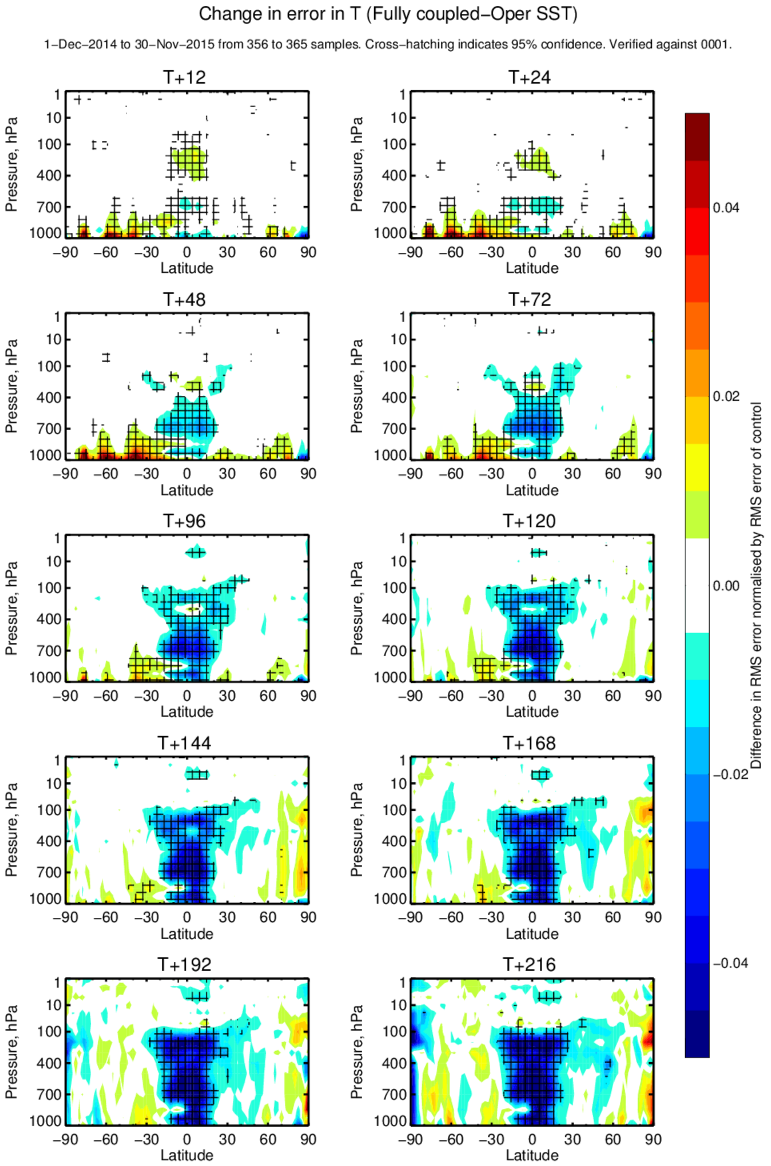
(2) Reduction in global warm bias in the mesosphere and upper stratosphere with a series of radiation updates. Further improvement possible with 8% reduction in solar UV, matching recent observations



Impact from ocean initial condition

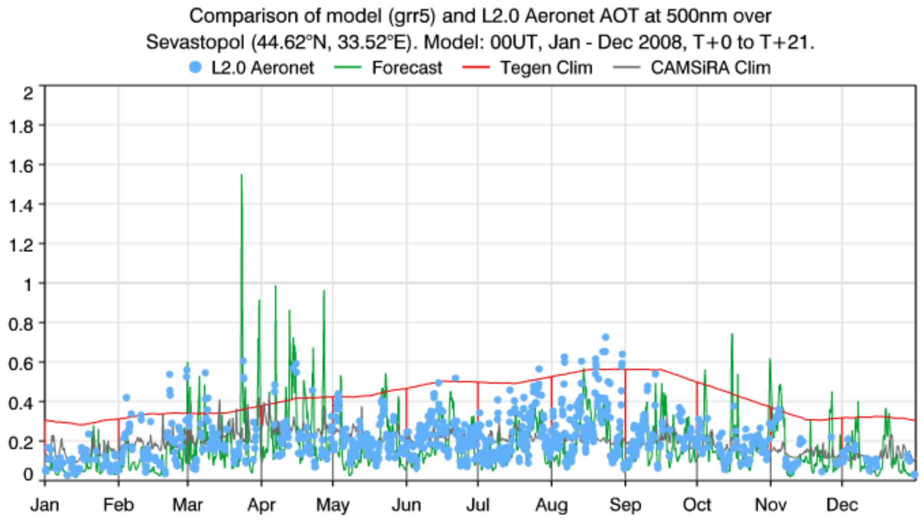


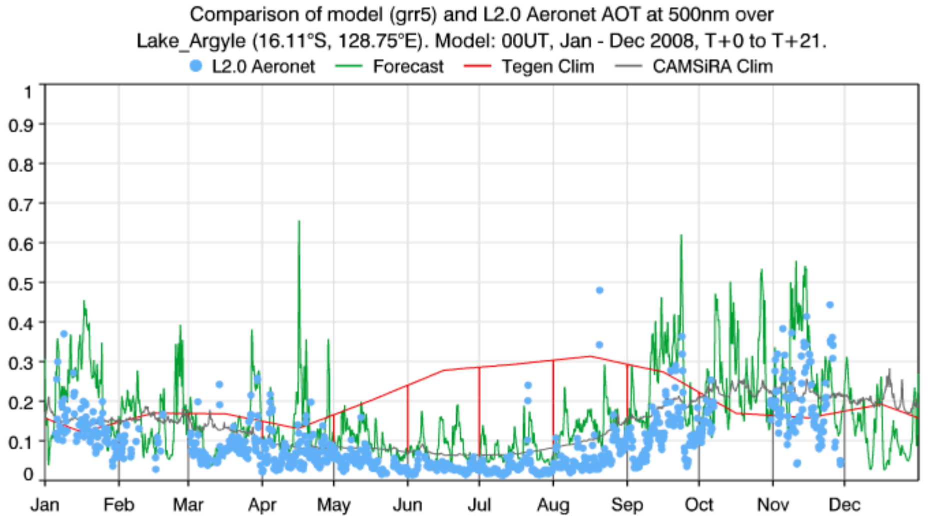
Additional impact from dynamical coupling to the ocean

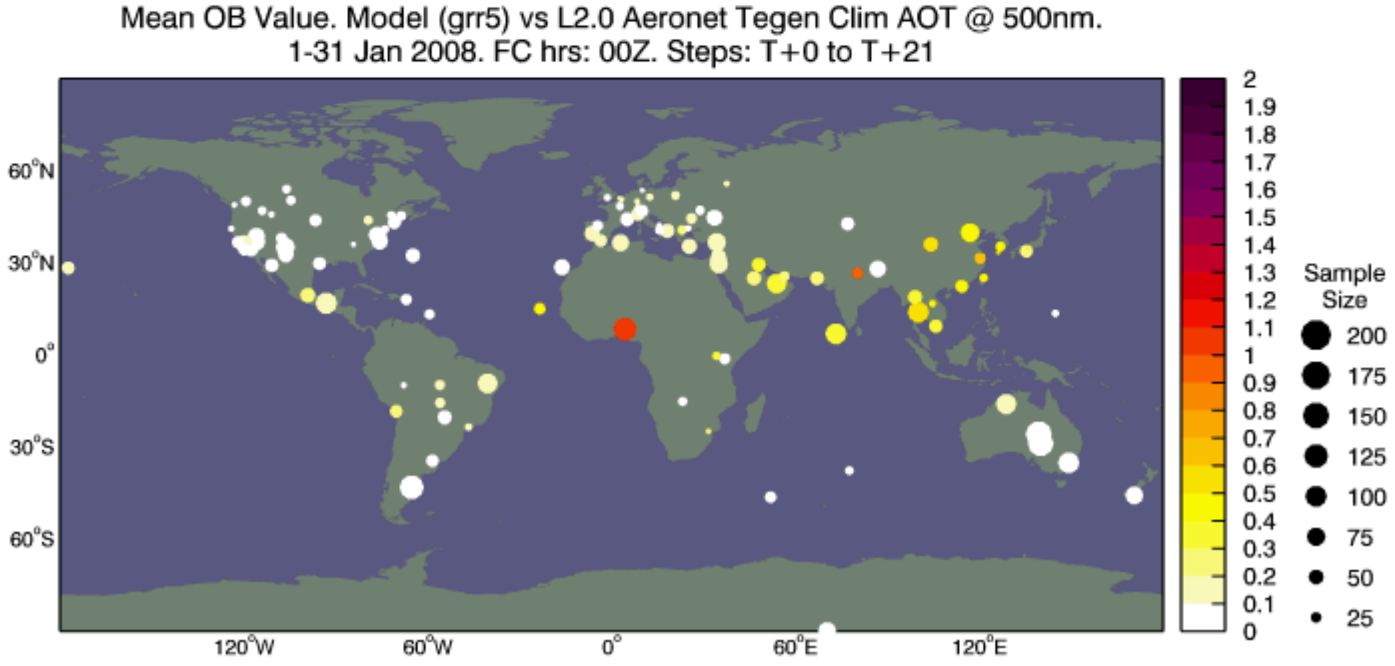


45r1 Coupled HRES

CAMS aerosols climatology implemented in IFS CY43R3







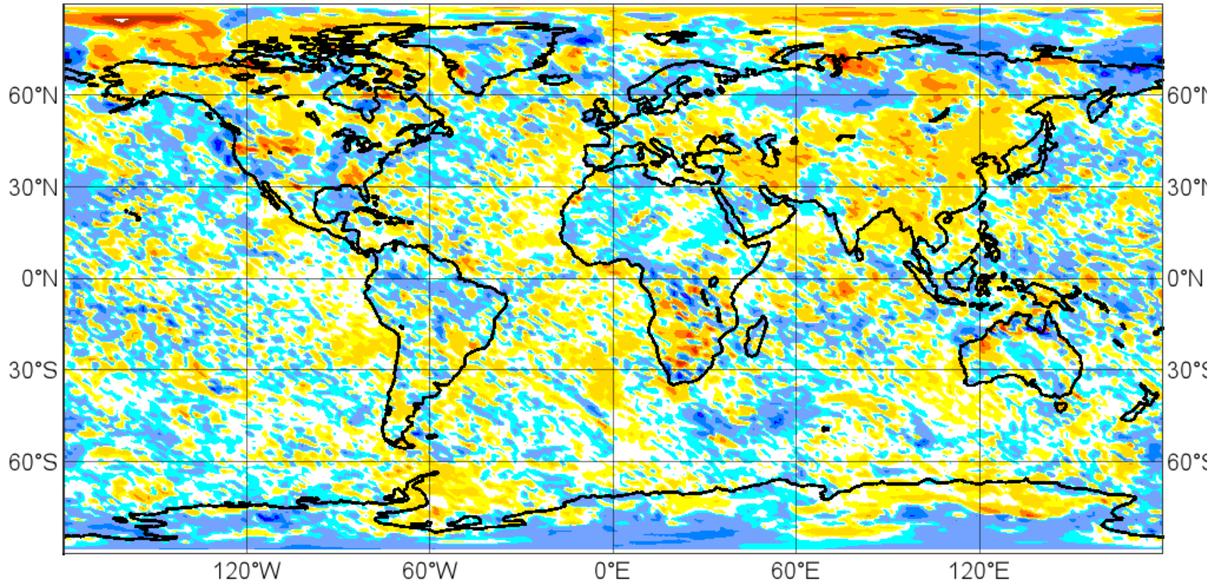
ECMWF

Assessment of TL approximation at very high resolution (TCo1279, ~9 km, 12h).

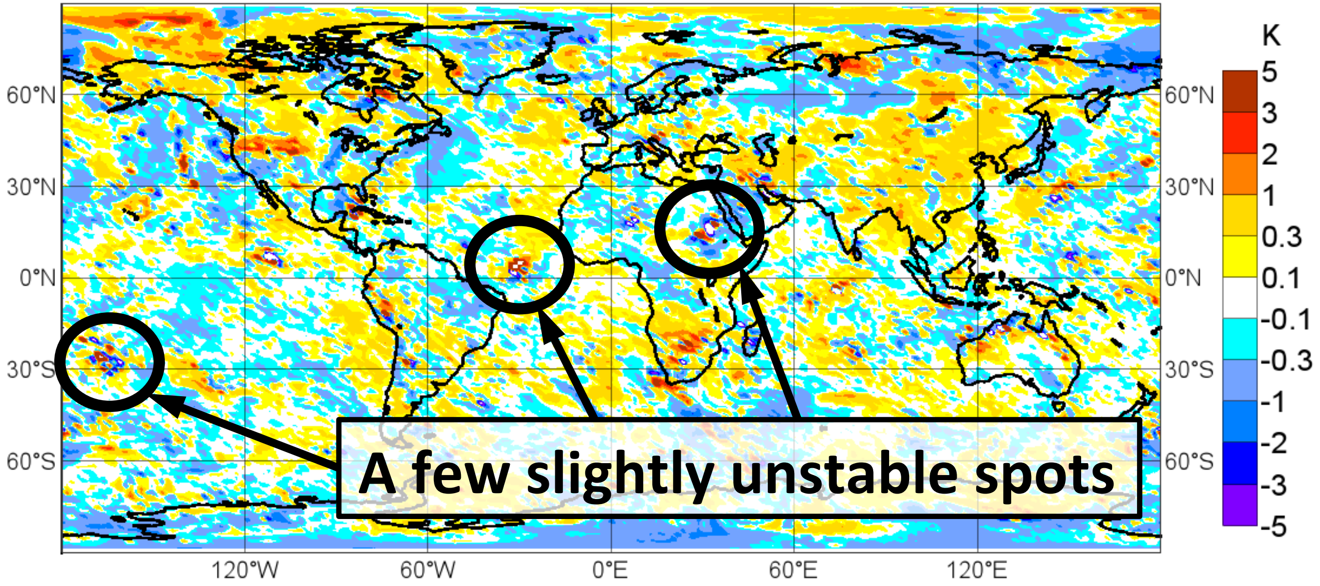
Comparison of non-linear difference $M(\mathbf{x}+\delta\mathbf{x})-M(\mathbf{x})$ with perturbation evolved using the tangent-linear model $\mathbf{M}'\delta\mathbf{x}$ after 12h of integration.

Example: Temperature at level 129 (~980 hPa) on 20140105 at 12Z.

$M(\mathbf{x}+\delta\mathbf{x})-M(\mathbf{x})$



$\mathbf{M}'\delta\mathbf{x}$



It is the first time that our TL model is tested at such high resolution and the results look surprisingly encouraging.

ESCAPE

Weather & Climate Dwarfs

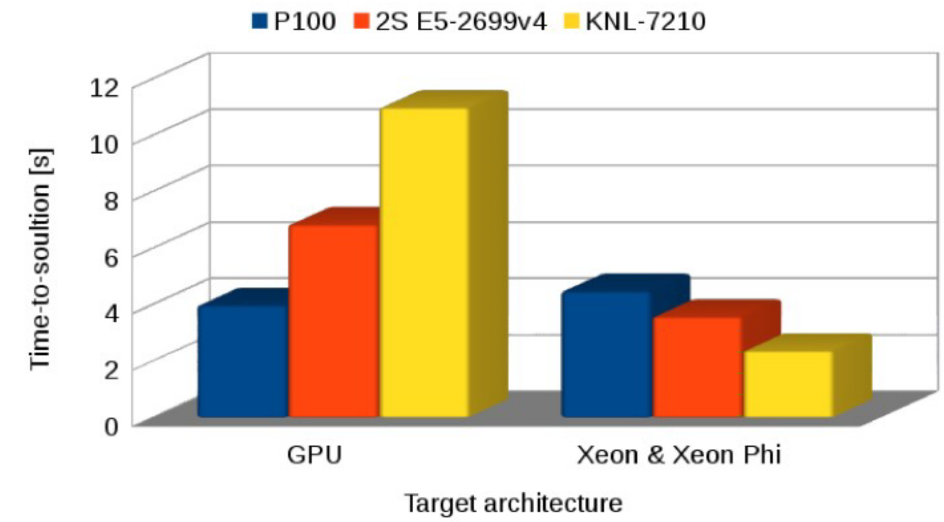
https://www.ecmwf.int/escape

Funded by the European Union

Dwarf	prototype implemented	docu-mented	based on Atlas	MPI	Open MP	Open ACC	DSL	Optalysys
D - spectral transform - SH	✓	✓	✓	✓	✓	✓		
D - spectral transform - biFFT	✓	✓		✓	✓	✓		✓
D - advection - MPDATA	✓	✓	✓	✓	✓	✓	✓	
D - advection - semi-Lagrangian	✓	✓	✓	✓	[illegible]	[illegible]	[illegible]	[illegible]
D - elliptic solver - GCR	✓	✓	✓	✓	[illegible]	[illegible]	[illegible]	[illegible]
P - cloud microphysics - CloudSC	✓	✓		✓	[illegible]	[illegible]	[illegible]	[illegible]
P - radiation scheme - ACRANEB2	✓	in progress	in progress	✓	[illegible]	[illegible]	[illegible]	[illegible]
I - LAITRI (3d interpol. algorithm)	✓	✓			[illegible]	[illegible]	[illegible]	[illegible]
planned next:								
D - advection - discontinousGalerkin	●	●	●	●	[illegible]	[illegible]	[illegible]	[illegible]
D - elliptic solver - multigridPrecon	●	●	●	●	[illegible]	[illegible]	[illegible]	[illegible]

✓: first version running
in progress: in progress
●: planned

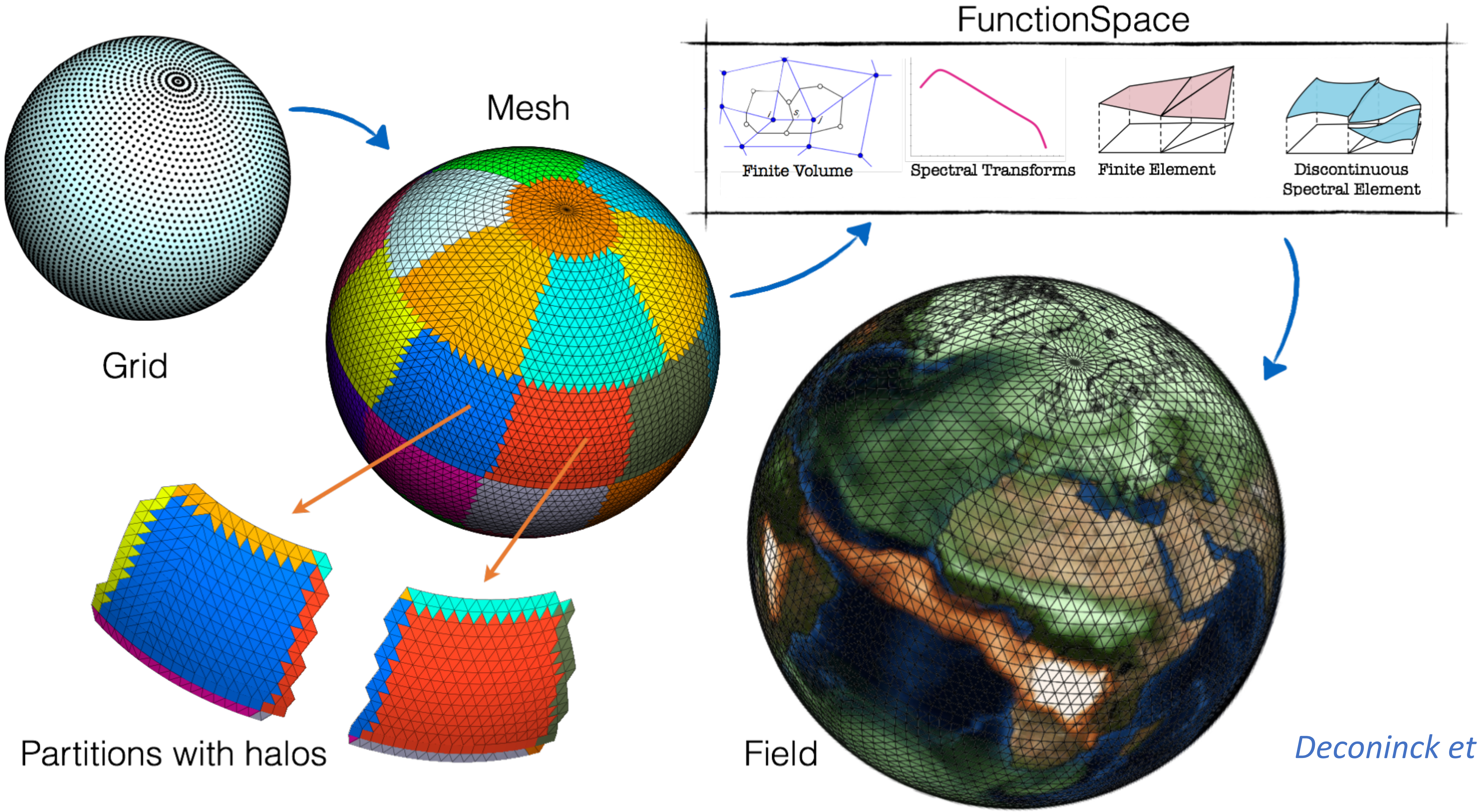
Comparison of software optimized for GPU and Xeon processors



Poulsen & Berg (2017)

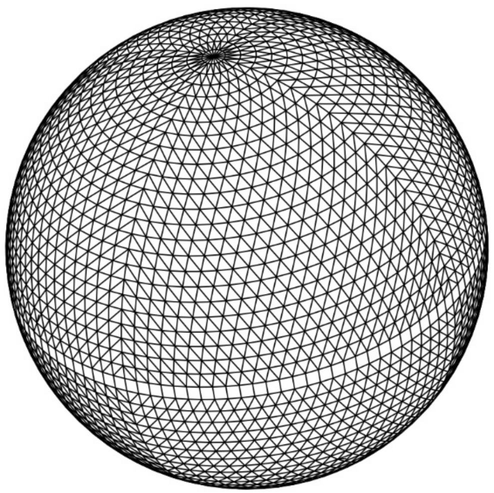
ECMWF · MeteoSwiss · DMI · RMI · NVIDIA · METEO FRANCE Toujours un temps d'avance · ICHEC · Deutscher Wetterdienst · Optalysys · Bull · PSNC · Loughborough University

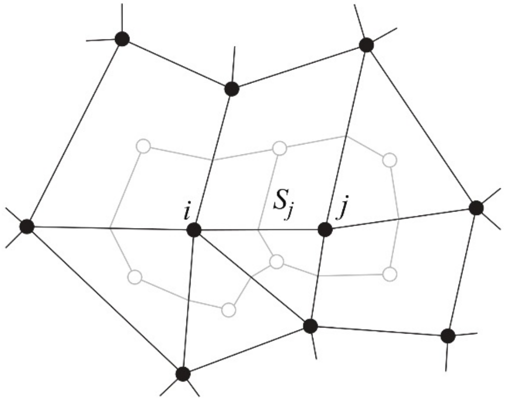
Atlas: a library for NWP and climate modelling



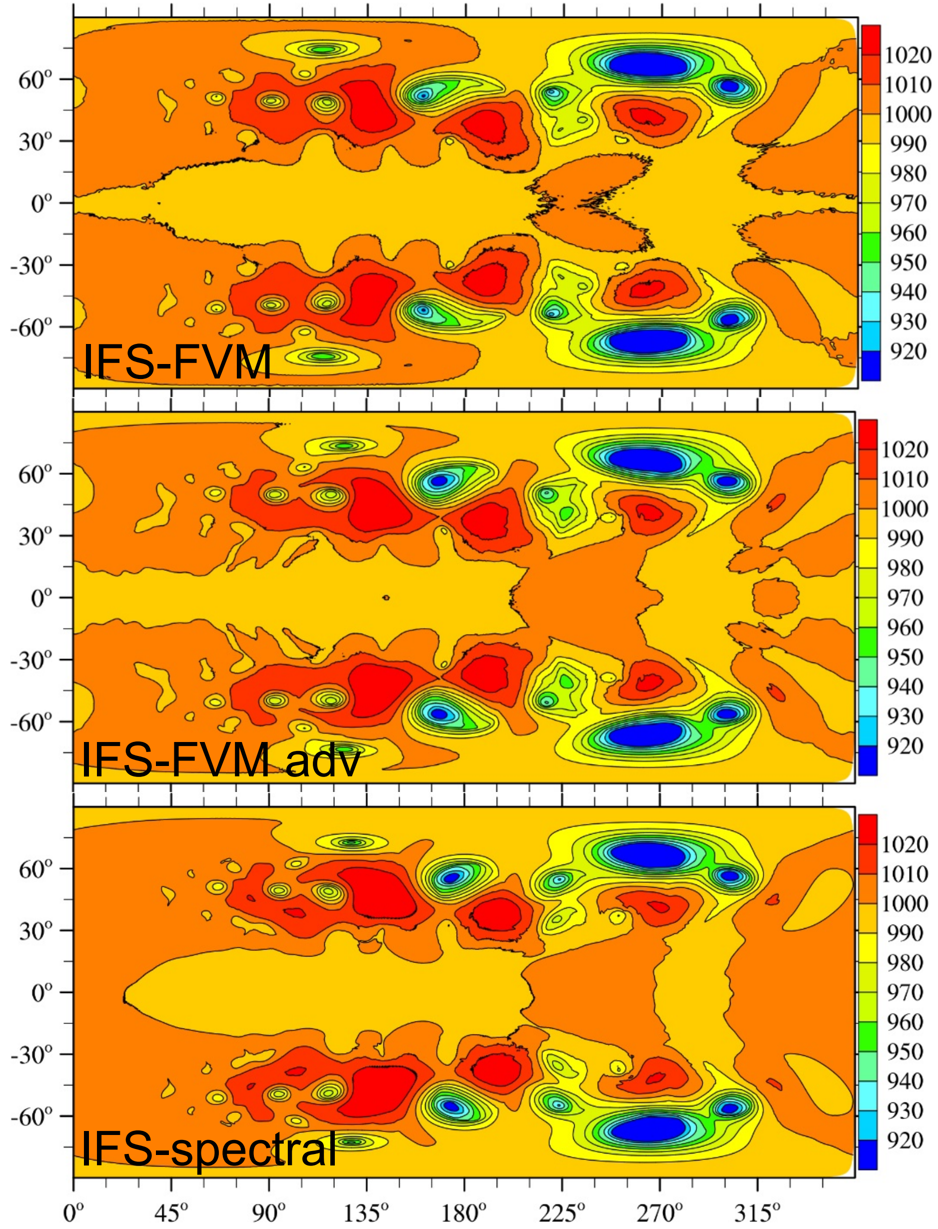
Deconinck et al. 2017

IFS Finite-Volume Module (FVM)

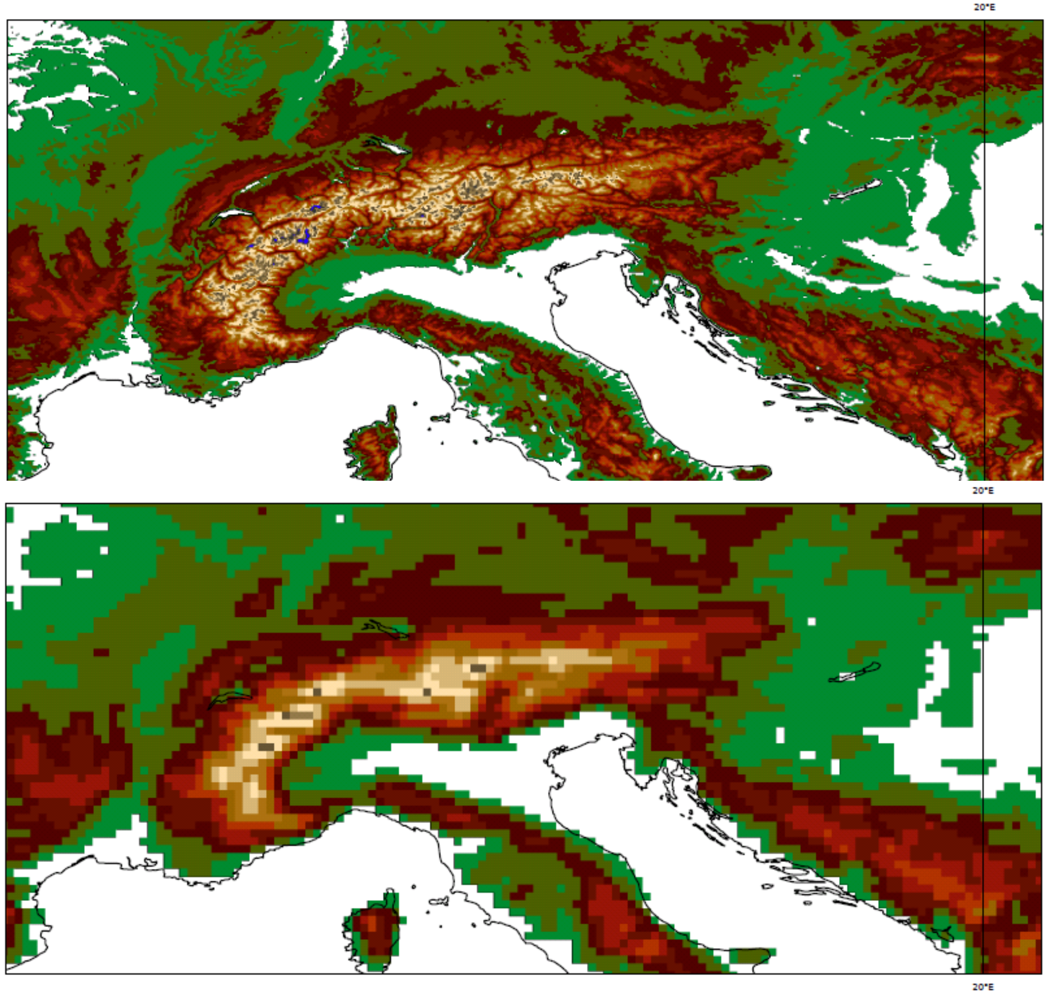


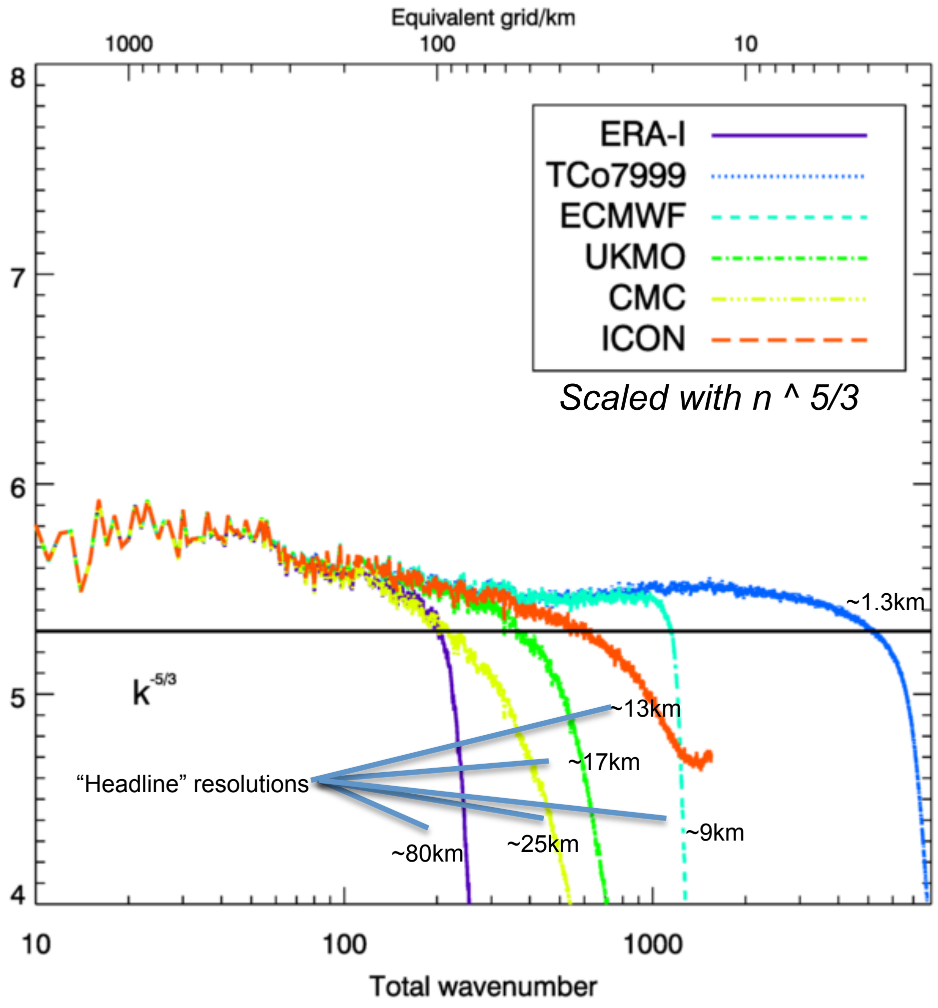


Moist baroclinic instability (surface pressure [hPa]; day 15)

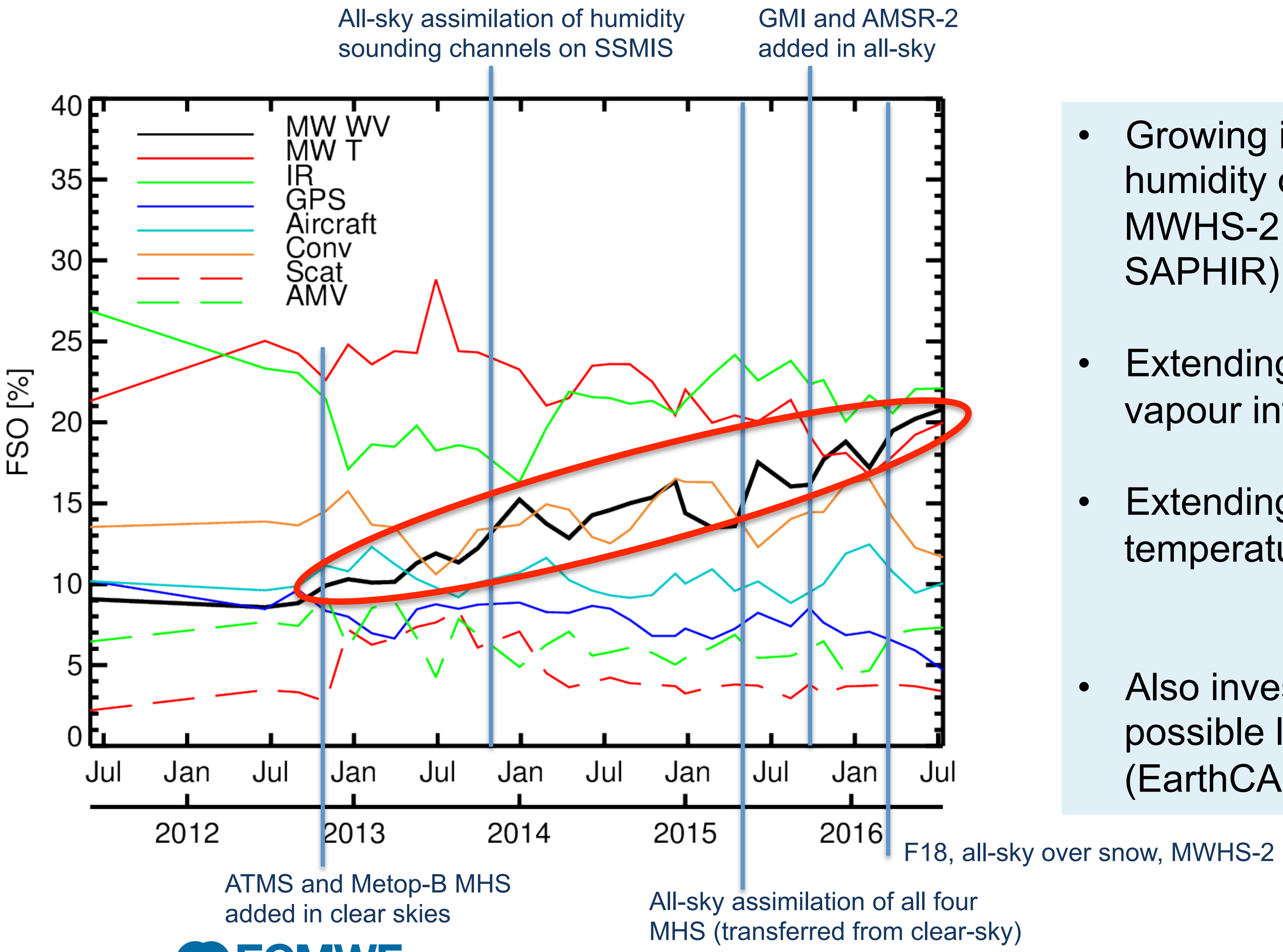


Mean Orography spectra at different NWP centres





Observation changes: the rise of all-sky!

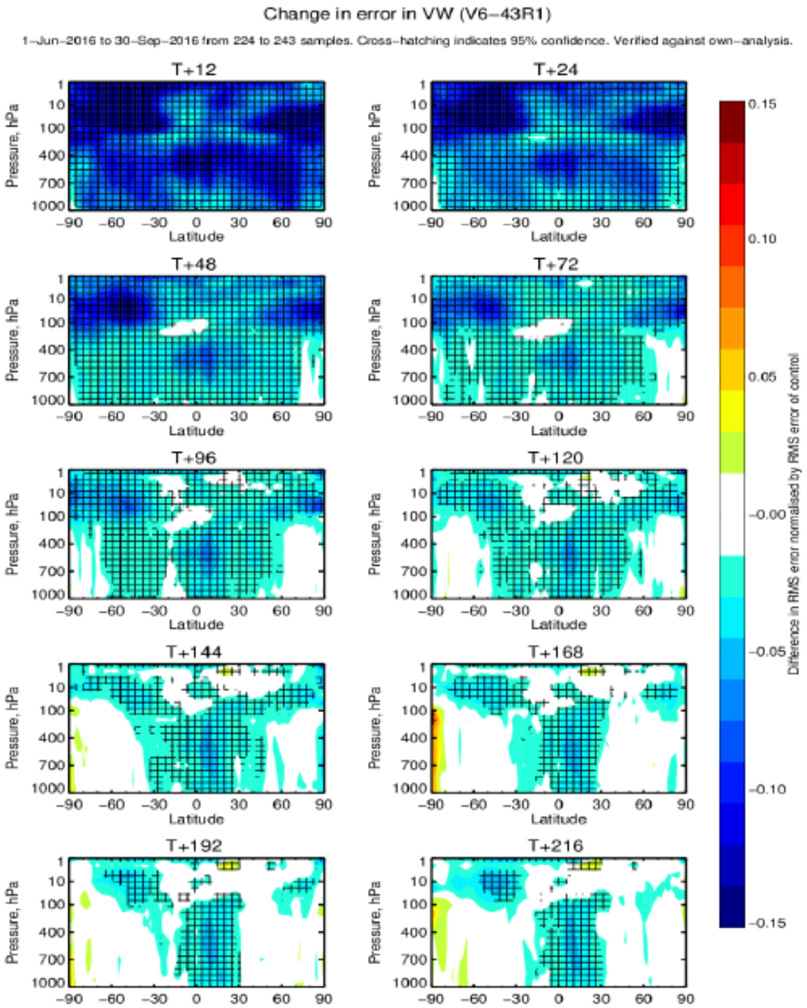


- Growing importance of microwave humidity observations (MHS, ATMS, MWHS-2, SSMIS, AMSR2, GMI, SAPHIR).
- Extending this to infrared water vapour information.
- Extending to all-sky microwave temperature observations.
- Also investigating radar, lidar, and possible lightning observations (EarthCARE,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

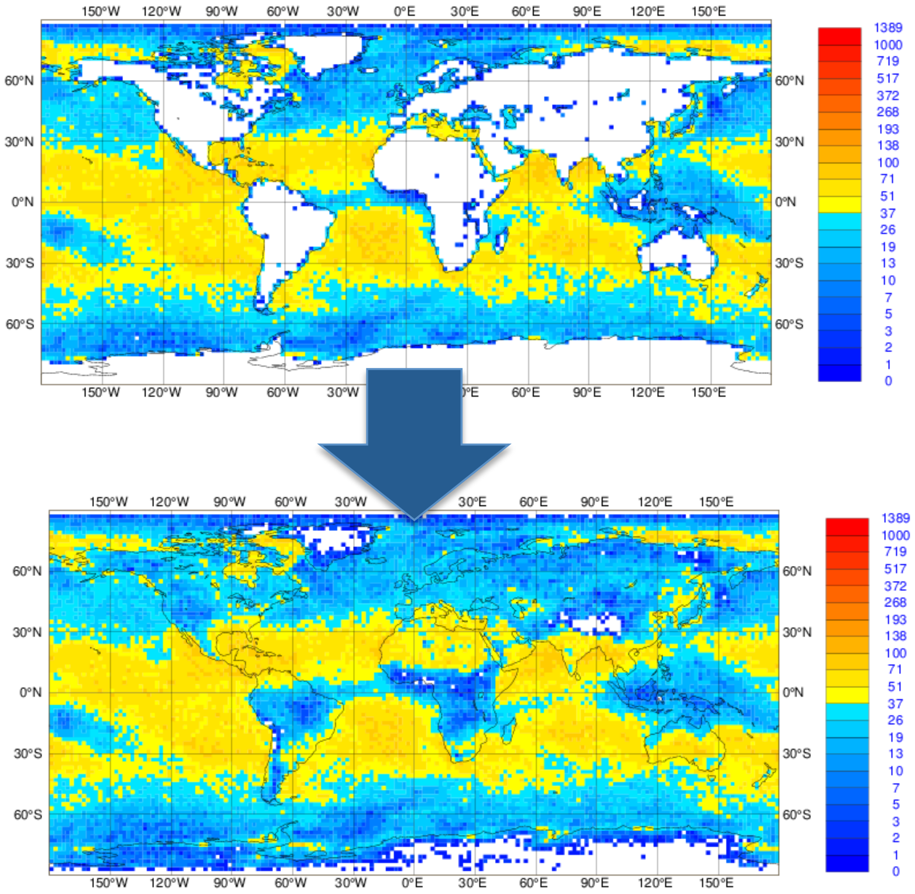
4DVar Development

- Hybrid **B** modelling: introduction of EDA estimated humidity errors (CY43R3; previously fixed statistical functions of background state)

  - Change in RMSE of wind vector forecast
  - Largest improvement in tropical winds since…
  - Confirmed against observations (SATOB winds)
  - Humidity tracer advection is believed to be the main driver
  - To be extended to cloud condensate (Q1/Q2 2018)



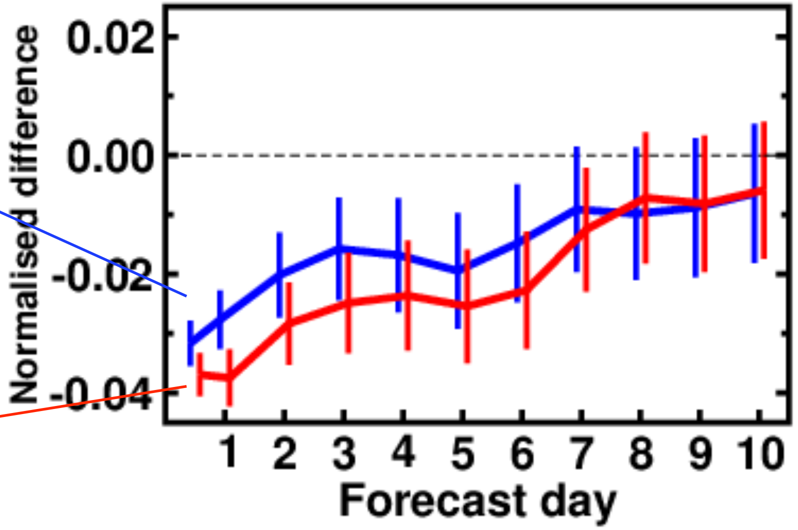
Increased use of hyperspectral infrared sounders over land



N.Hem. Z500
(RMSE)

*Current impact of IR radiances in **Cy43r3***

*Expected impact of IR radiances in **Cy45r1***

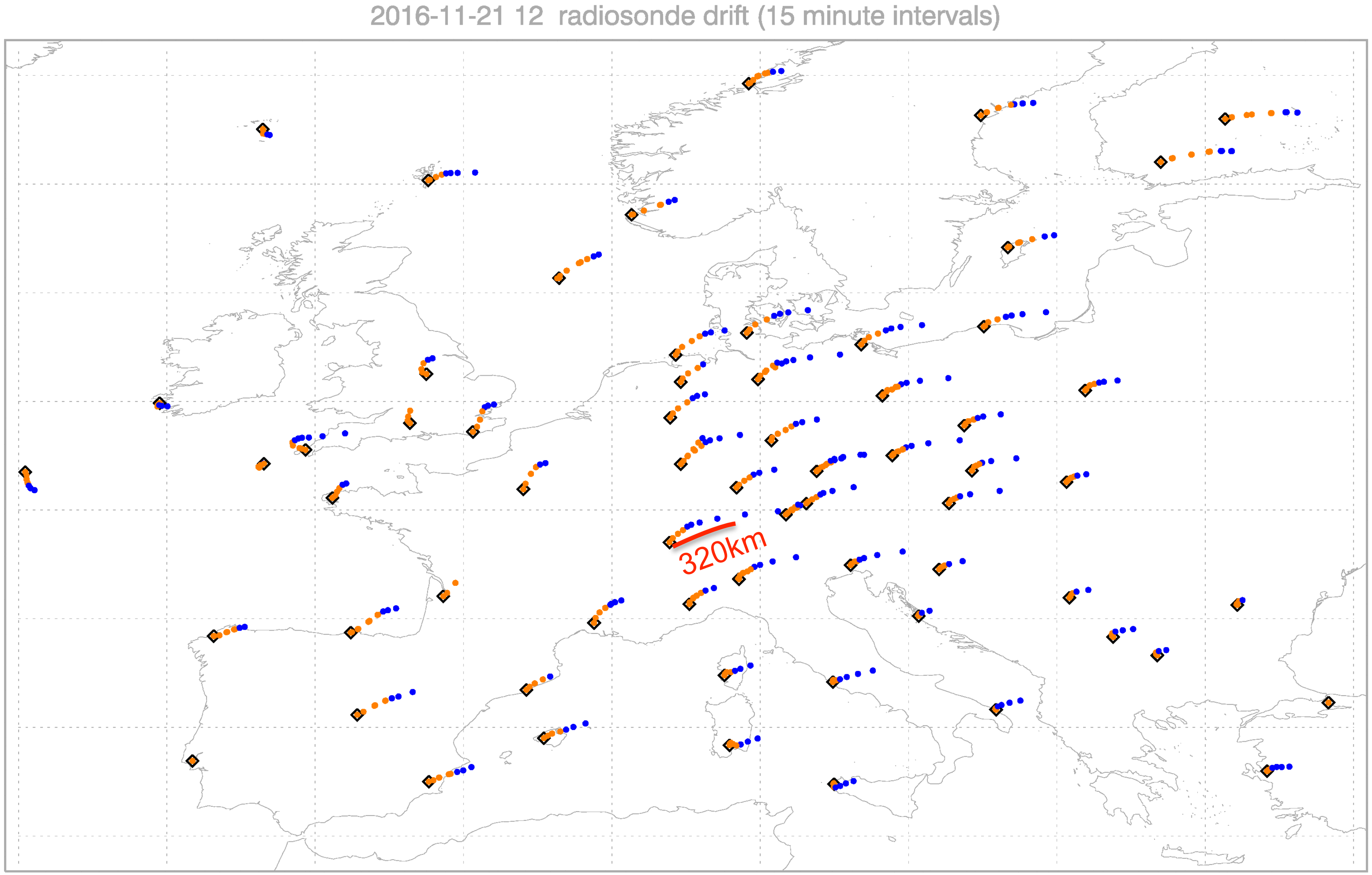


Activation of tropospheric IR data over land increased magnitude of forecast error reduction due to IR sounders by 50%

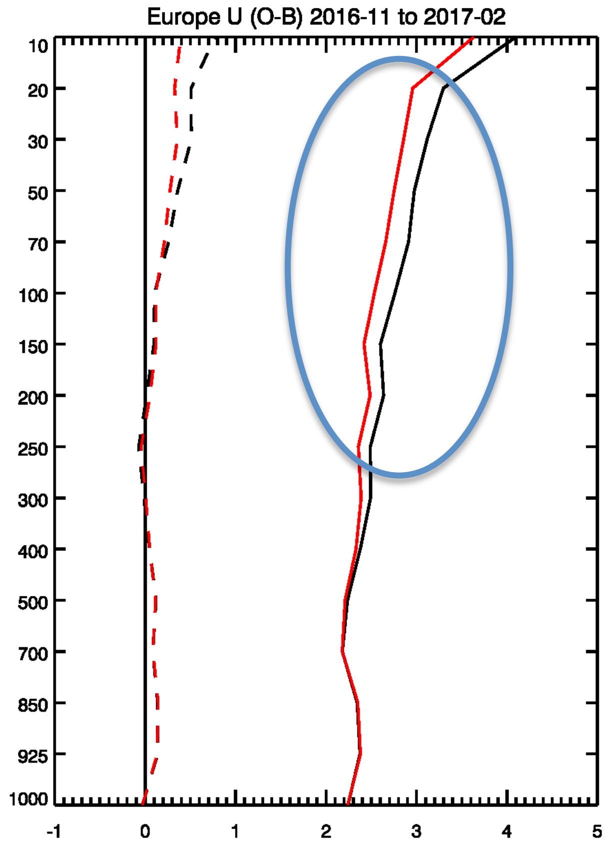
ECMWF

Radiosonde drift – 12 UTC 21 November 2016

- Black diamonds – launch, levels to 100 hPa, levels above 100 hPa



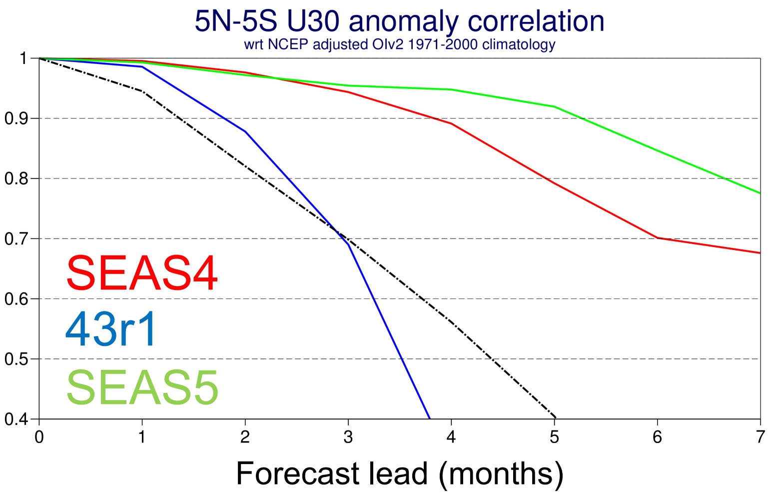
Example: Improved fit to wind above 400 hPa



15 Years of Progress on ENSO forecasting: From SEAS2 to SEAS5

SEAS5 development

2002 - SEAS2
2017 – SEAS5



RMS error of Nino3 SST anomalies