ECMWF research progress and plans

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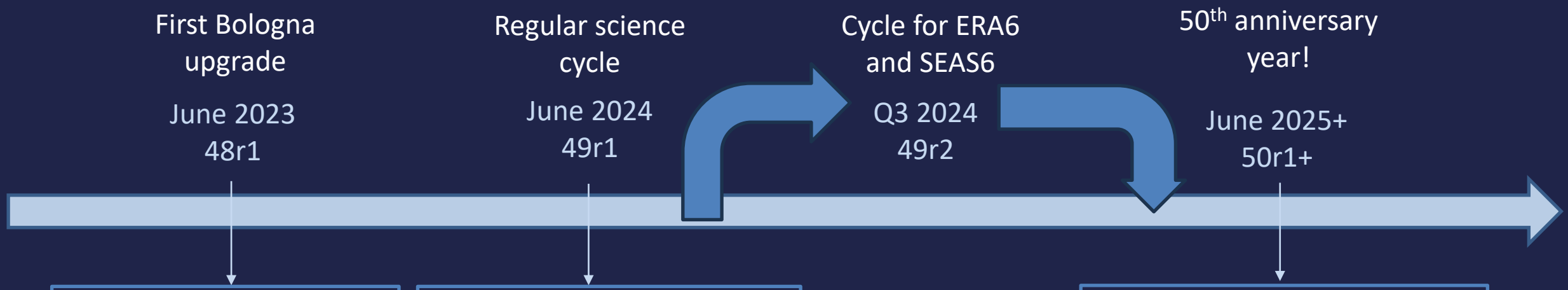
Deputy Director of Research

Thanks to many colleagues at ECMWF: Simon Lang, Massimo Bonavita, Gabriele Arduini, Sarah Keeley, Hao Zuo, Patricia de Rosnay, Gianpaolo Balsamo, Jean Bidlot, Robin Hogan, Alan Geer, Elias Holm, Tony McNally, Peter Dueben and certainly others I forgot to include and I hope will forgive me.

ECMWF

Beyond 48r1: Future evolution of IFS



ENS resolution increase to 9 km (HRES ~ ENS control)

Daily extended-range ensembles (100 members daily)

OOPS 4D-Var

Multi-layer snow scheme

Hybrid linear ozone scheme

Improved AC (COMPO) suite

SPP and soft-centred EDA

New land maps + synop T2m assimilation

Snow cover improvements

Improved ”all-surface” radiances, notably in polar regions

Wave model improvements

New Ocean – Sea ice (49r2)

Extended window and higher resolution 4D-Var

Use of MTG, EPS-SG, EarthCARE observations (could be outside cycle)

Preparing for next HPC

SPP extension to coupled processes

Outer-loop ocean-atmosphere DA

Unified Land DA

Likely 51r1 or later

48r1

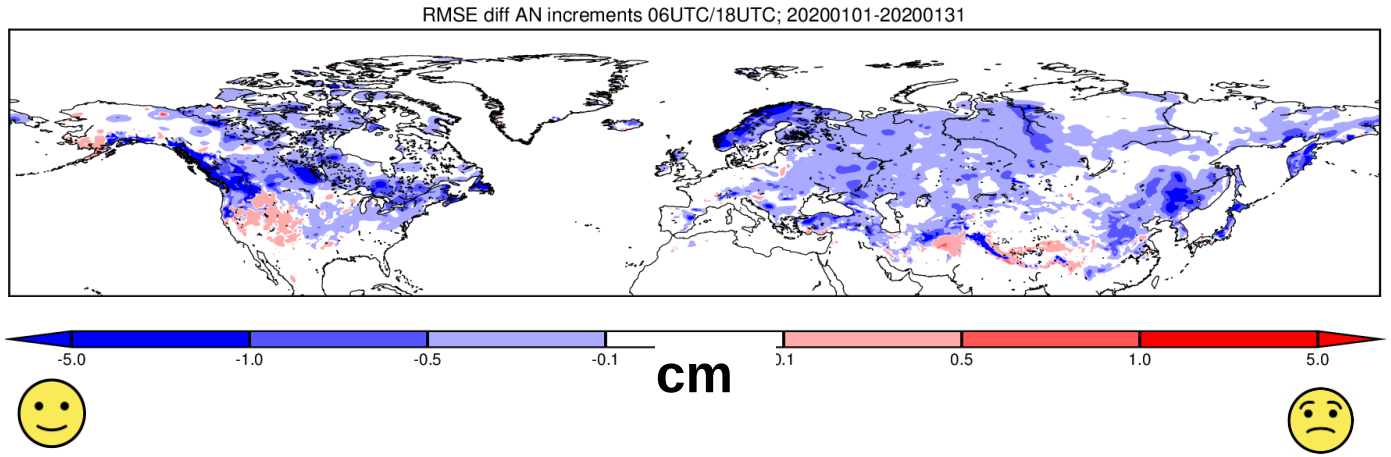
(in addition to points from Florian earlier and note Simon, up next, will give more on the ENS aspects)

48r1: Multi-layer snow scheme – improved snow and T2m forecast

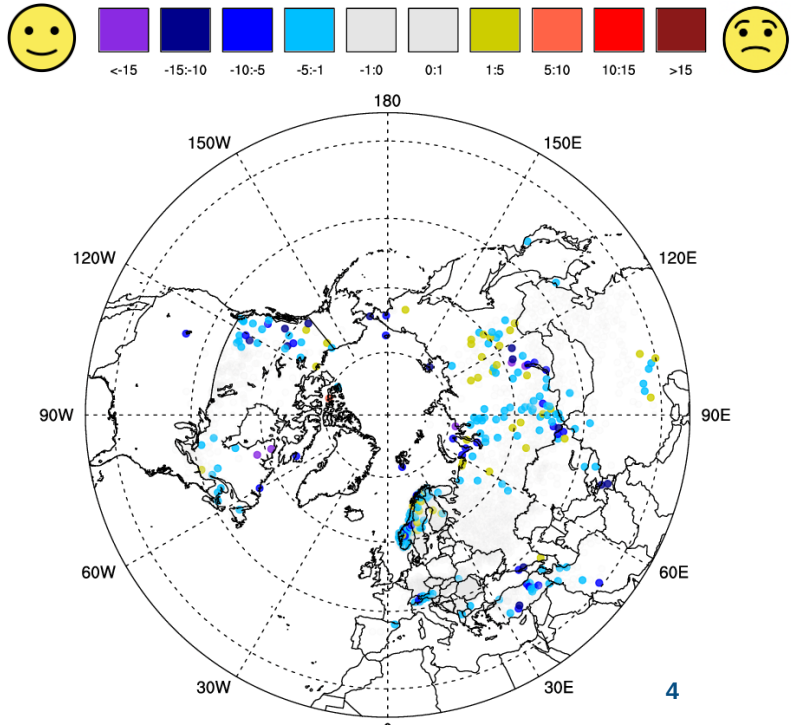
- **Improved snow depth in short-range forecasts**
- **Snow depth bias reduces for increased forecast range**
- **T2m improvement**

DAY 5	Rel.Difference RMSE (ML-SL)
ExTrop	-2.2%
Arctic	-3.9%
Europe	-0.7%

RMS difference between multi-layer and single-layer snow scheme in analysis increments (12h forecast – analysis), January 2020



T2m RMSE difference of forecasts at day 5 (compared with synop station), Winter 19/20



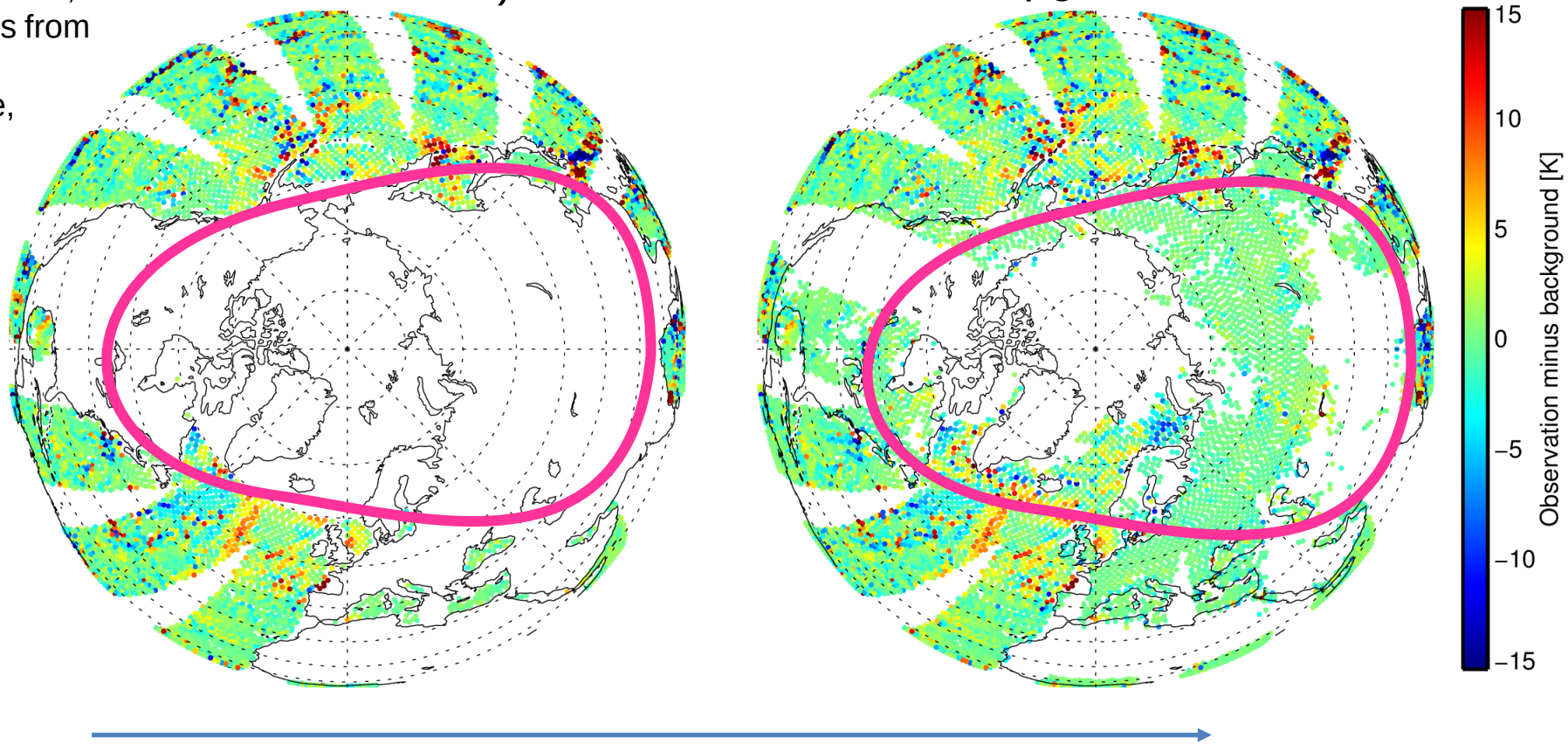
48r1: increased use of surface-sensitive microwave channels

37, 89, 150, 166 GHz from GMI, SSMIS, AMSR2

Active channel 10 (36.5 GHz, v-polarised) observations from AMSR2 during 00 UTC analysis cycle, 26th June, 2019

now (all-sky but not all-surface)

upgrade

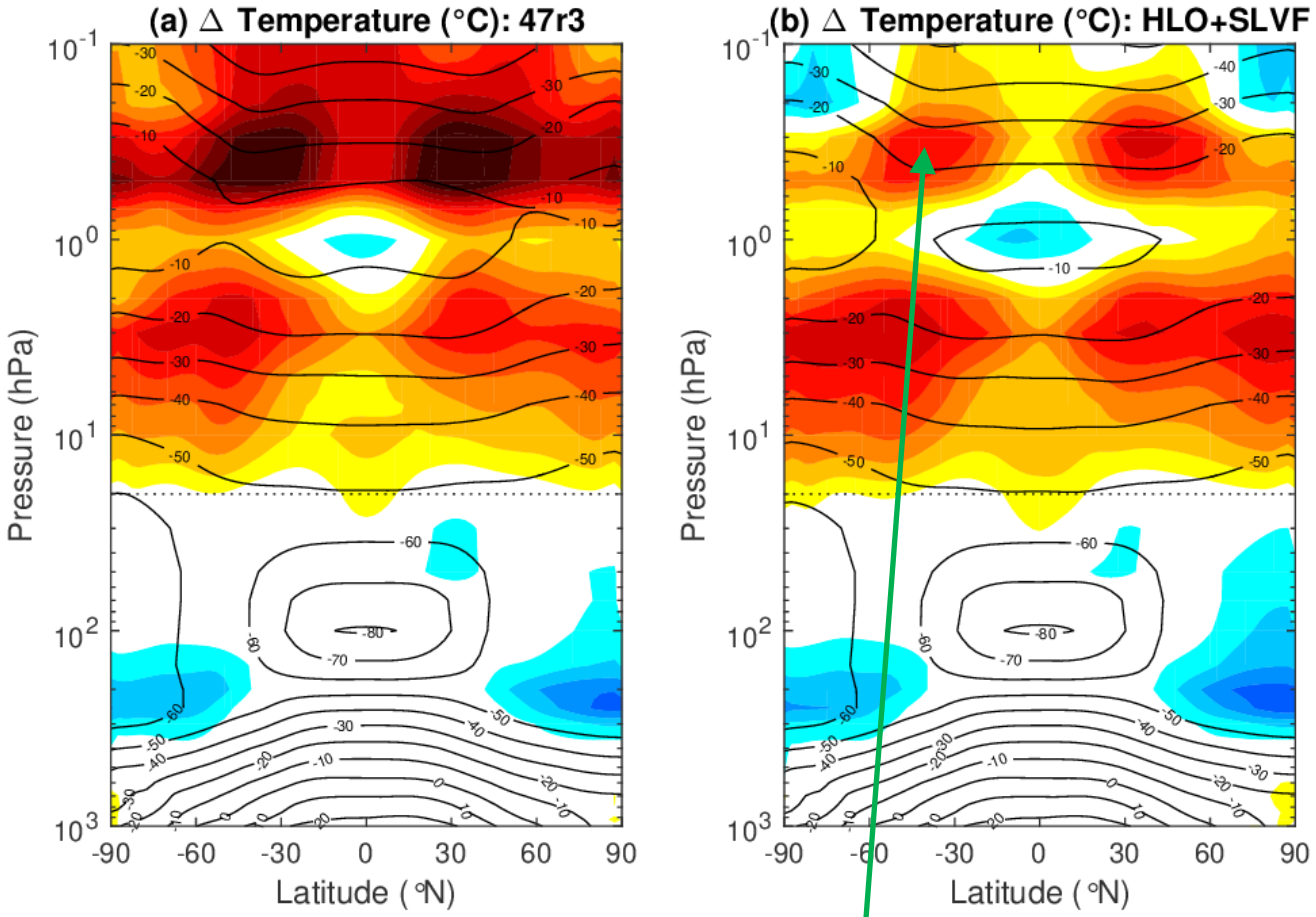


adding higher latitudes, land surfaces, mixed scenes (land – water)
(but excluding sea-ice, snow, high altitudes, desert soils)

48r1: Improving stratospheric temperatures in the IFS with HLO and SLVF

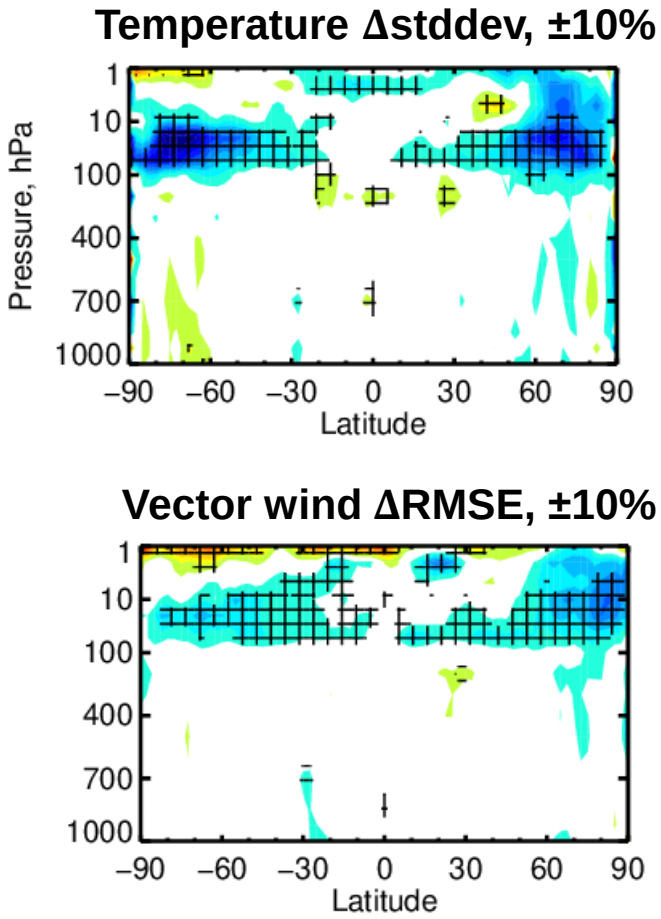
Temperature bias of free-running ECMWF model versus ERA5/MLS

troposphere | stratosphere | mesosphere



New “HLO” ozone treatment
reduces mesosphere warm bias

Scores v analysis



Other 48r1 highlights

Change	What does this mean for users?
T511 Inner loop in 4D-Var	Modest score improvements
OOPS	Modern, more flexible code
Higher density of scatterometer winds assimilated	Improved sharp features in analysis e.g. TCs
IR assimilation improvements (aerosol, trace gas)	Small impact
RTTOV V13	Small impact for clear sky but more significant in all-sky (RTTOVSCATT)
Improved assimilation of ATMS (Lambertian, slant path)	Making assimilation of all MW radiances consistent
Improved drag	Small impact
Consistent physics-dynamics interface across NL, TL and adjoint models	Small impact
New representation of freezing drizzle and more precipitation type parameters	More and better drizzle and precipitation information

49r1

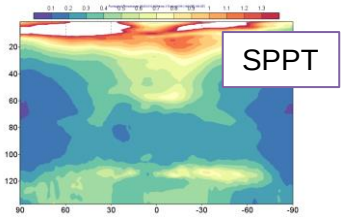
Representing model uncertainties with SPP (from 49r1)

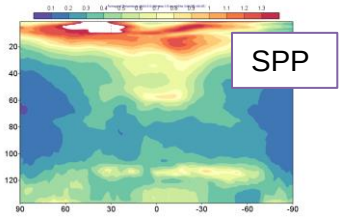
SPP replaces SPPT in all ensembles:

- Brings improved physical consistency
- Enhances spread near the surface
- Delivers competitive skill for medium-range fcs
- Improves MJO spread-error relationship
- Less overdispersive in seasonal fcs

EDA

- TCo399
- 10 members
- Every day, 1 month

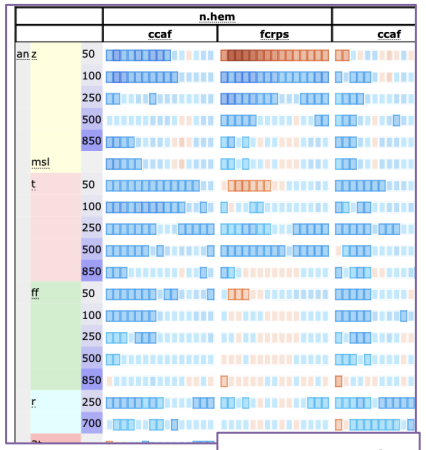




Ens stdev: T, t+3h

Medium-range

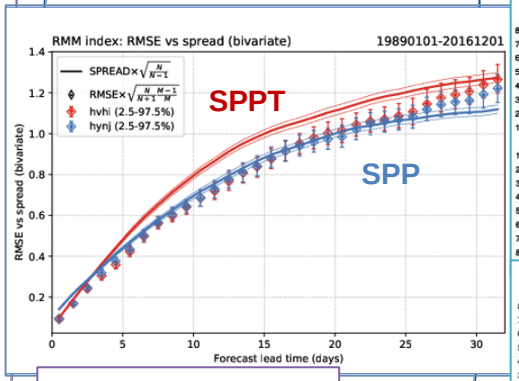
- TCo1279
- 8+1 members
- Every day 00/12 UTC, Jun,Jul, Dec 2020, Jan 2021
- fc period: 15 days



Δscorecard: SPP - SPPT

Extended-range

- TCo319, ORCA025
- 9+1 members
- 01/mm/2017
- refc: 1989..2016
- fc period: 32 days

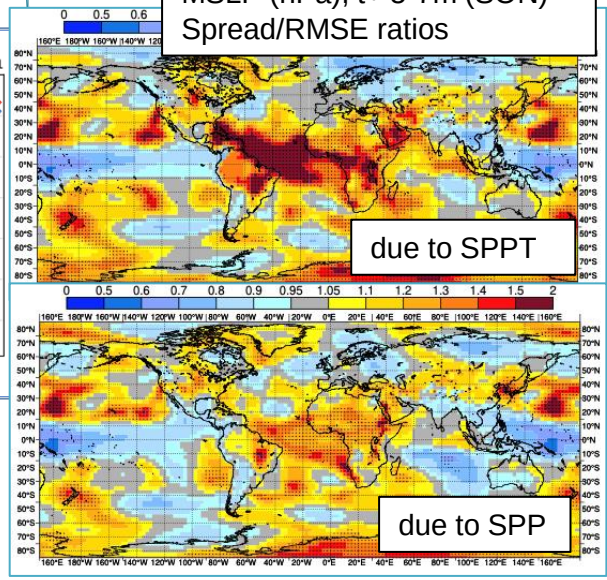


MJO RMM index: Spread and RMSE

Seasonal

- TCo319, ORCA025
- 15 members
- 01 May & 01 Nov, 1993..2020
- fc period: 7 months

MSLP (hPa), t+ 5-7m (SON)
Spread/RMSE ratios



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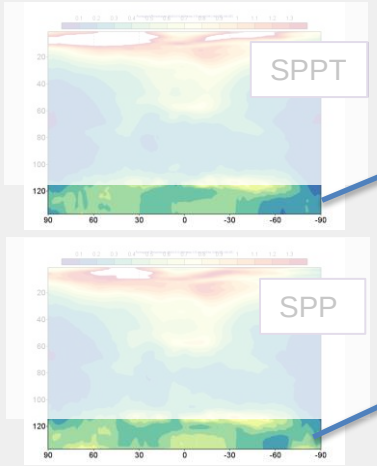

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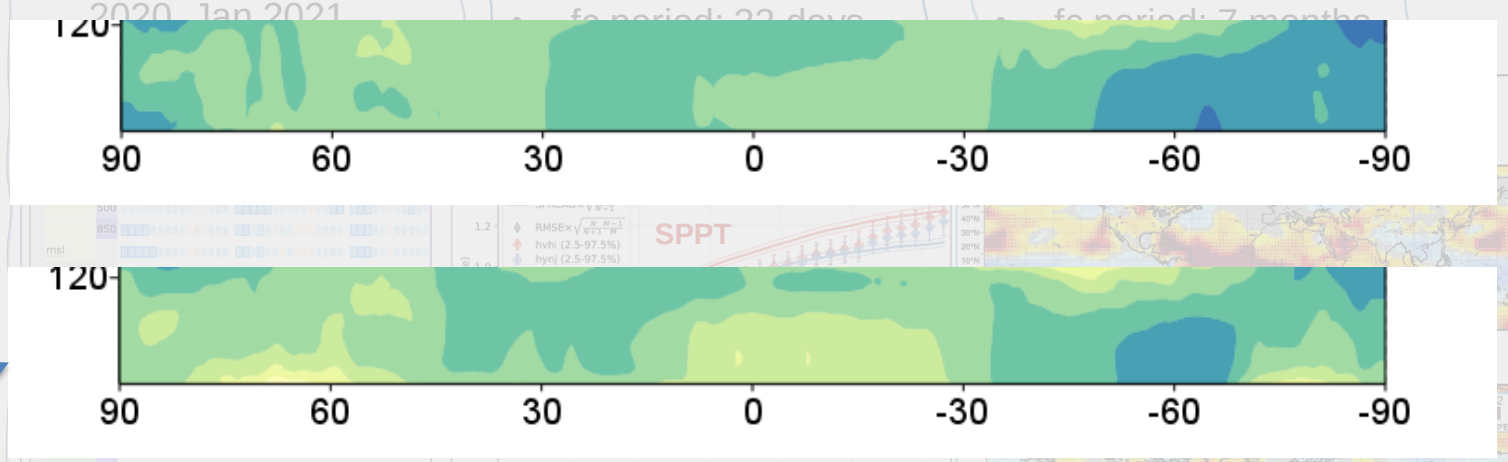

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Seasonal
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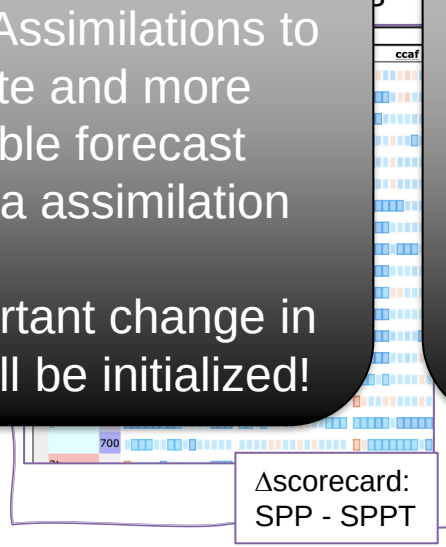
- 15 members
- 01 May & 01 Nov, 1993–2020

Also in 49r1 major change (called soft-centred EDA) in the Ensemble of Data Assimilations to make this both more accurate and more affordable, for better ensemble forecast initialization and improved data assimilation

Together these are a very important change in how the ensemble forecasts will be initialized!

See Simon Lang's talk up next for a lot more detail on the ENS changes!



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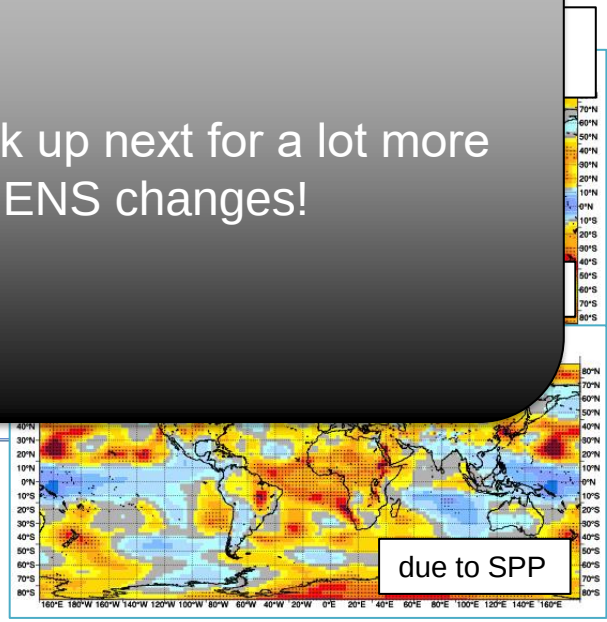
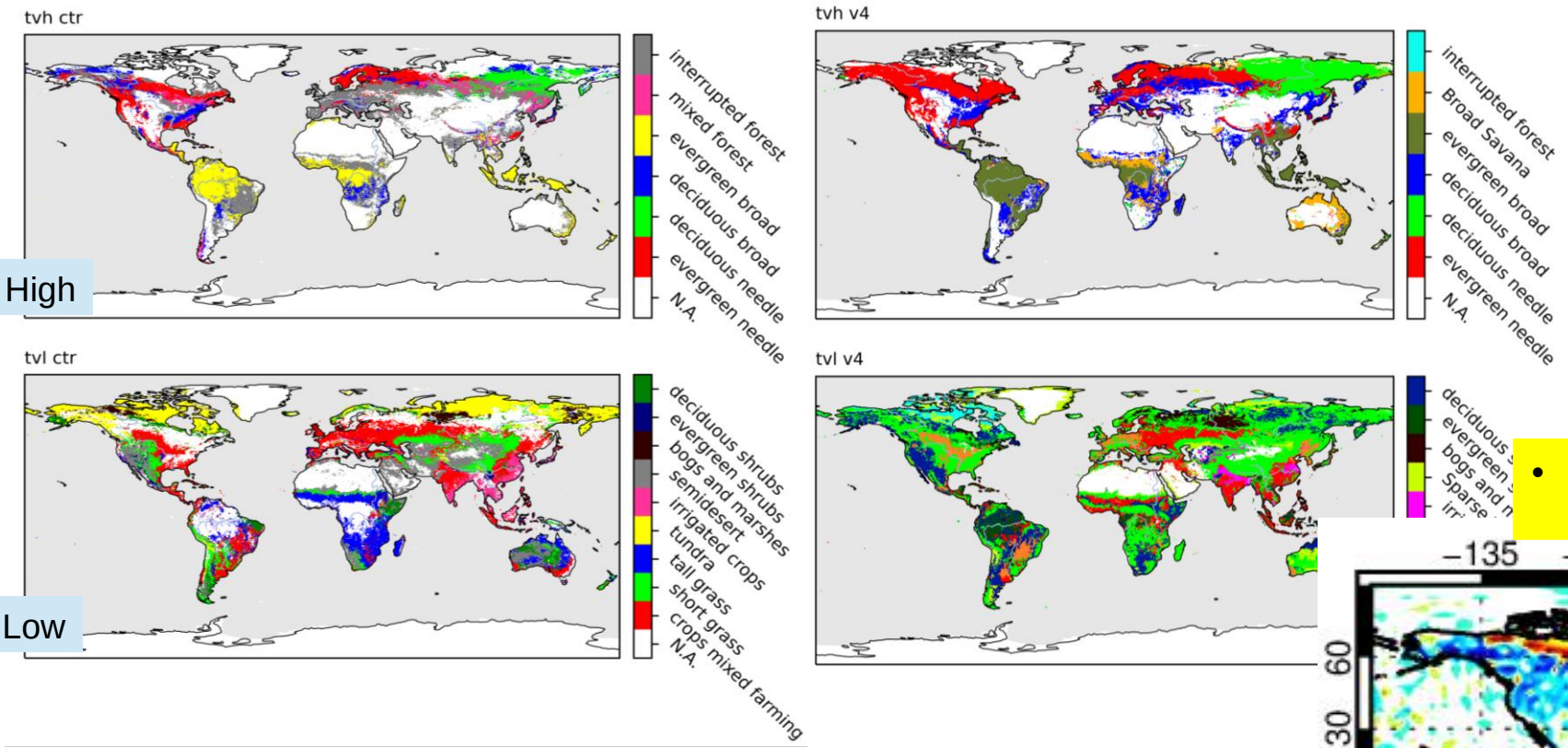


due to SPP

49r1 highlights: Improving T2m through land and assimilation changes

Operational GLCCv1.2 Vegetation Types

New ESACCI-V4 Vegetation Types



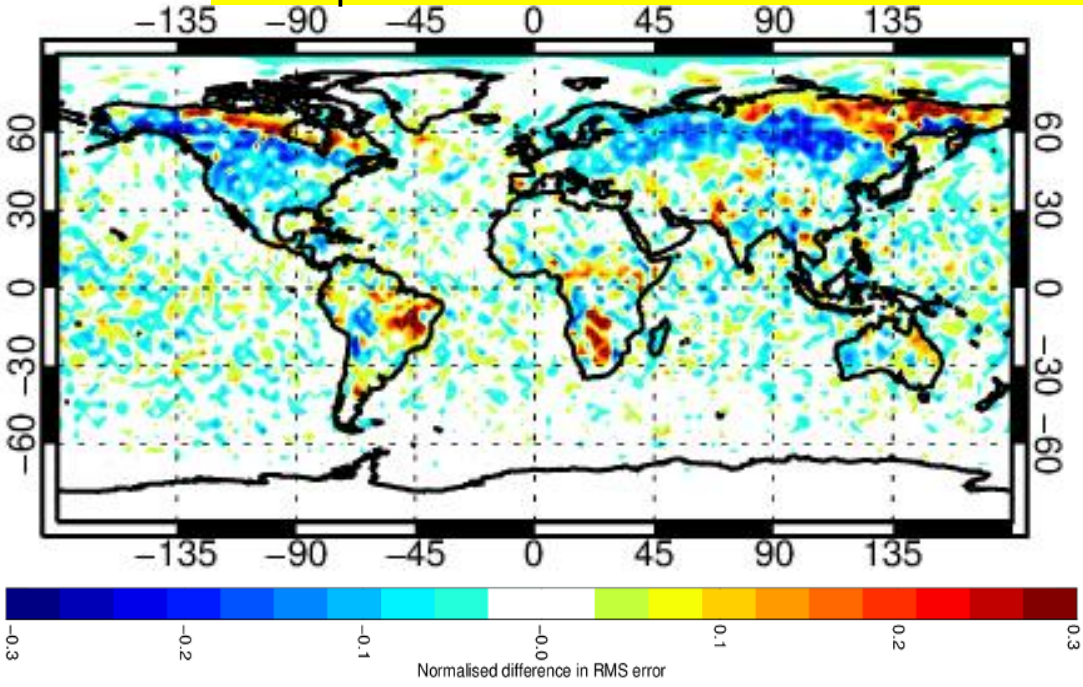
High

Low

Synop assimilation has lead to a lot of discussion. T2m better, notably in winter, but T850 degraded. With T2m benefit less obvious in summer, trade-off discussion is complicated

- ESACCI LU/LC–ECMWF land classification cross-walking table (CWT) evolution from v0 to v4 to improve screen-level scores.
- Compared to current operational (GLCCv1.2) maps, ESA-CCI decrease forest cover and increase low vegetation cover.

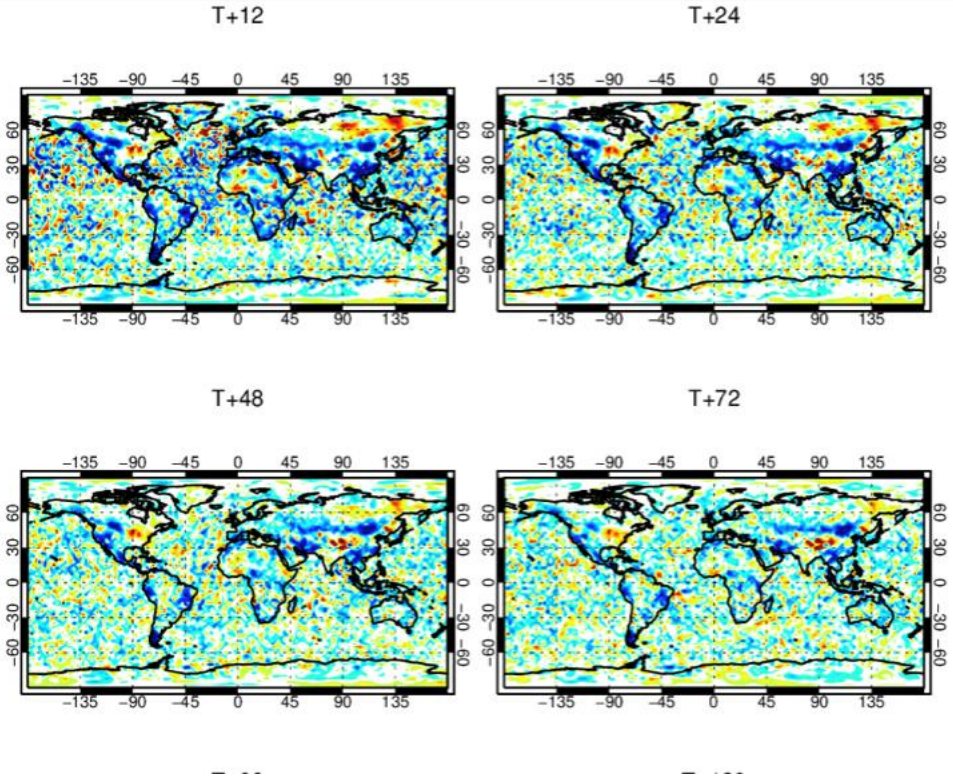
- Global evaluation through fc experiments



49r1 highlights: Improving T2m through land and snow DA changes

Impact of changes in land DA + snow cover fraction for 49r1

T2m verification versus own-analysis

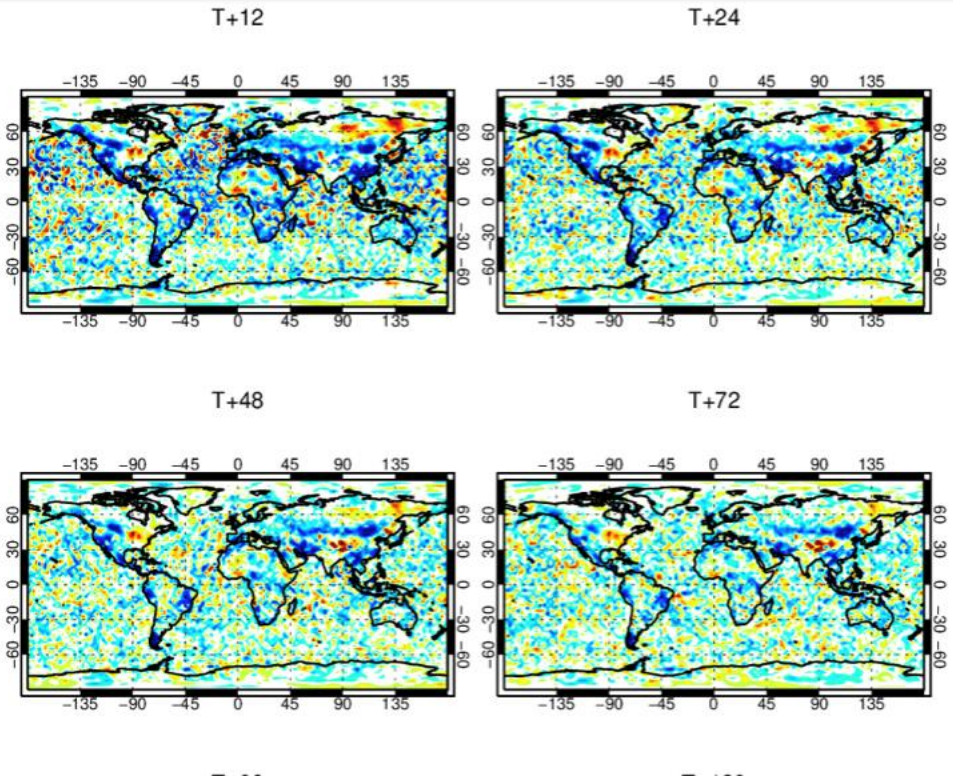


Scorecard for summer 2021/22

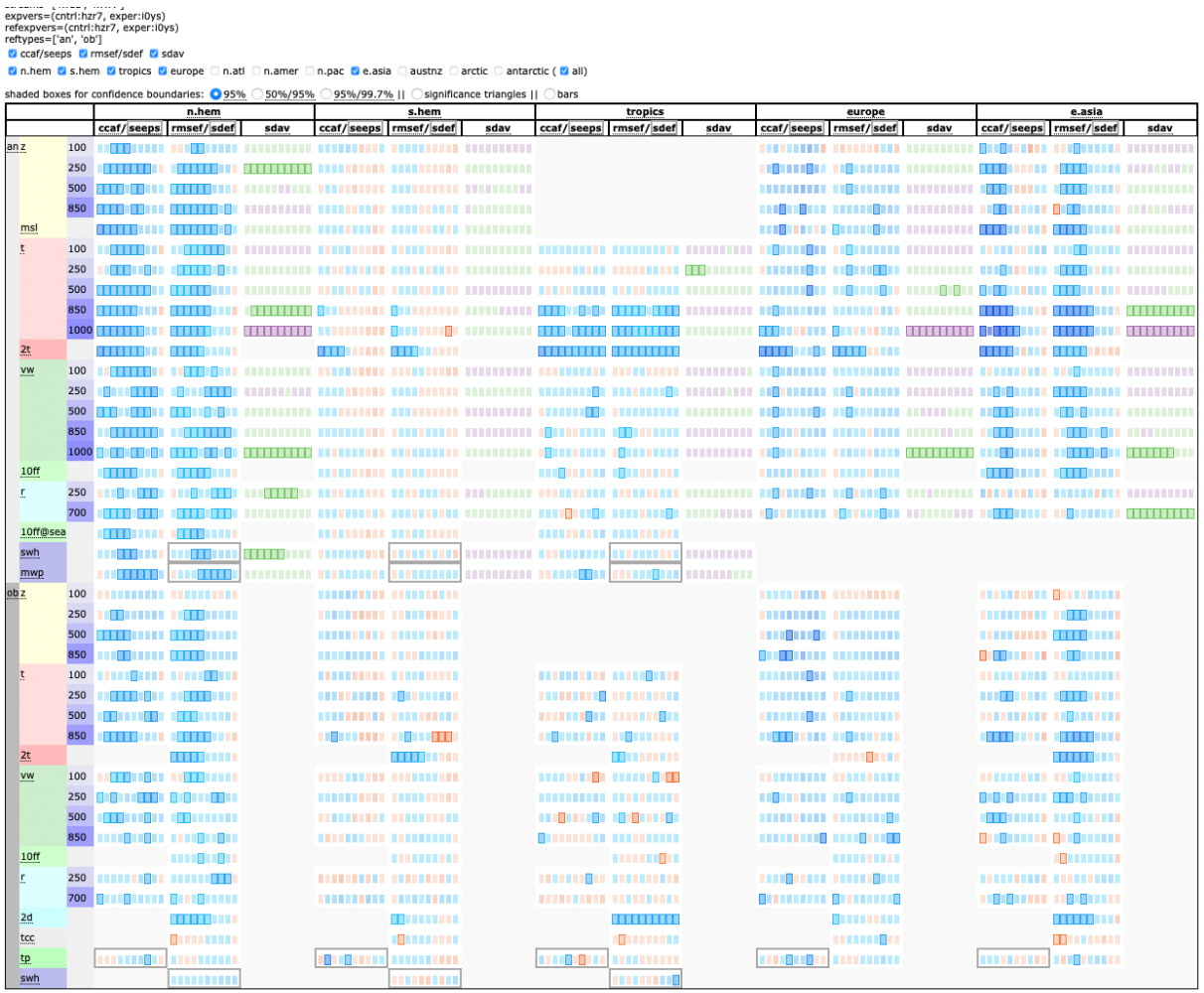
49r1 highlights: Improving T2m through land and snow DA changes

Impact of changes in land DA + snow cover fraction for 49r1

T2m verification versus own-analysis



Scorecard for winter 2021/22

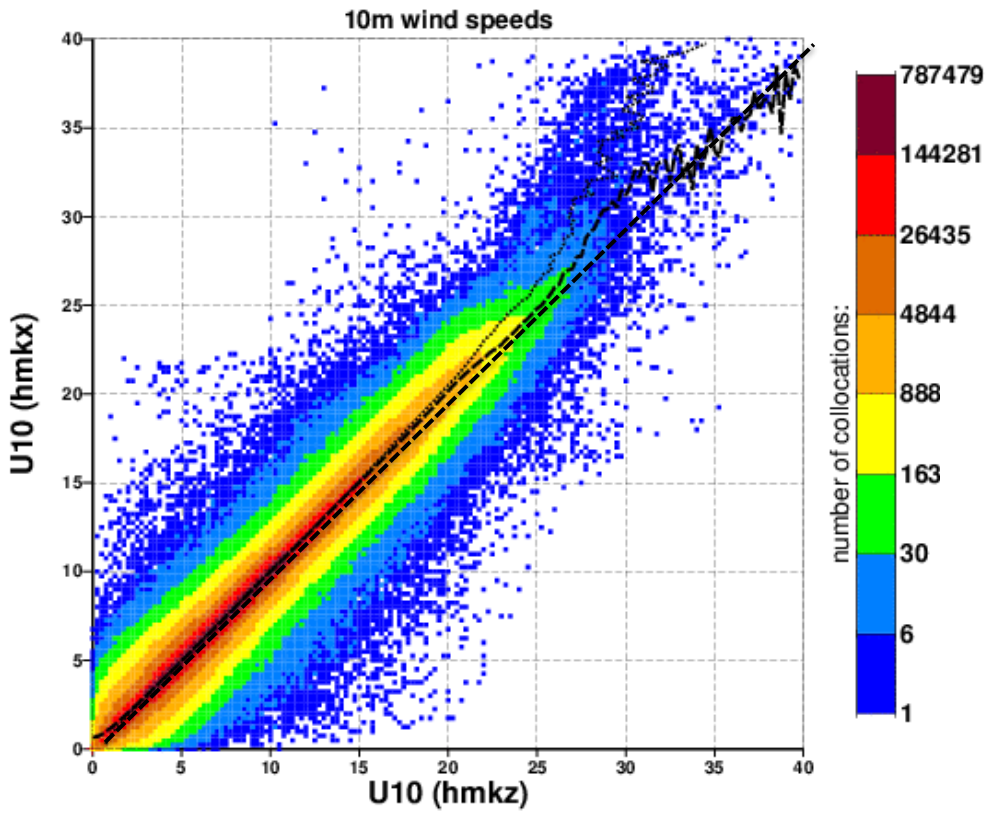


49r1: Wave changes: Impact on surface wind speeds

Wave improvements: model on TCO grid, new wave parameterization, hourly wave DA, surface stress passed to ocean model.

This will address the known underestimation of extreme ocean winds, will generate deeper tropical cyclones and a warmer tropical ocean.

new

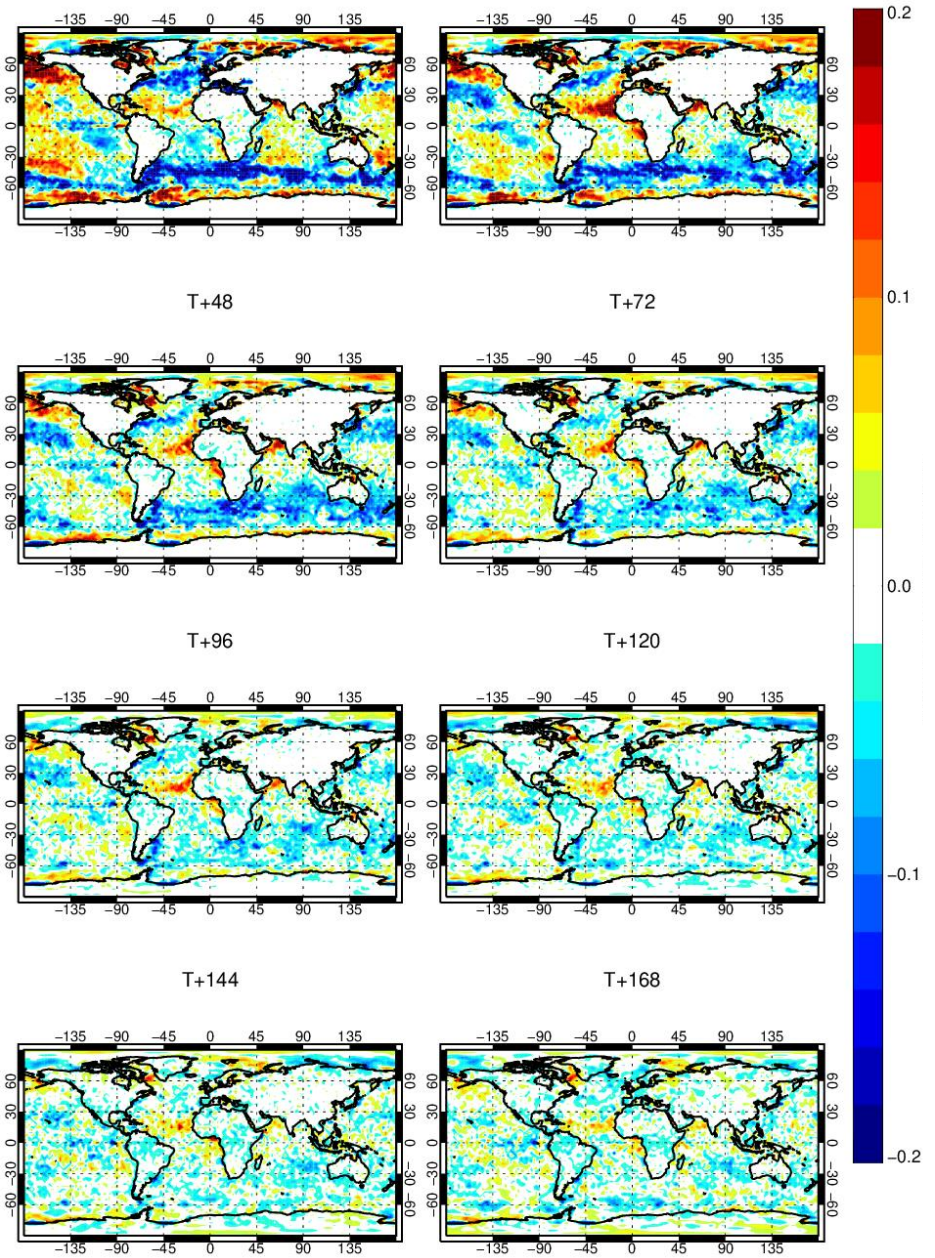


control

49r2: Ocean model: NEMO4 and SI^3

- 49r2=49r1+NEMO4+SI^3 for ERA6/SEAS6
- Development of the data assimilation system to support the reforecasts – OCEAN6/ORAS6
  - 11 member ensemble
- Prototype initial conditions have been used to test all coupled forecast systems
  - Results looking OK at all lead times
  - Multicategory sea ice model bringing new challenges which are being worked on
  - Single precision version of the model for forecasts

Change in RMS error T2m NEMO4 – NEMO34
Verified against the operational analysis



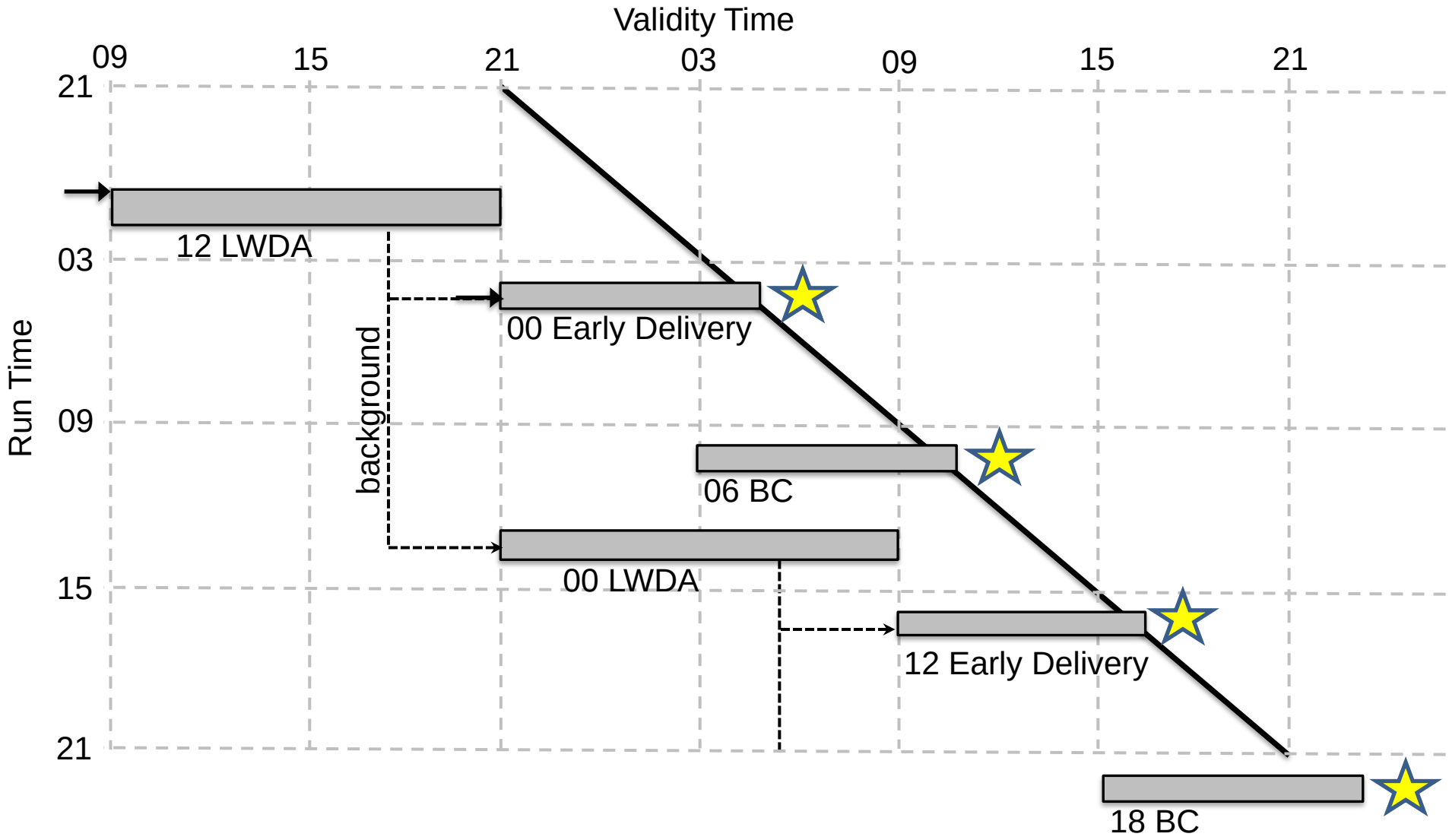
ECMWF

Other 49r1/2 highlights (*in addition to SPP, EDA, Land and Ocean changes*)

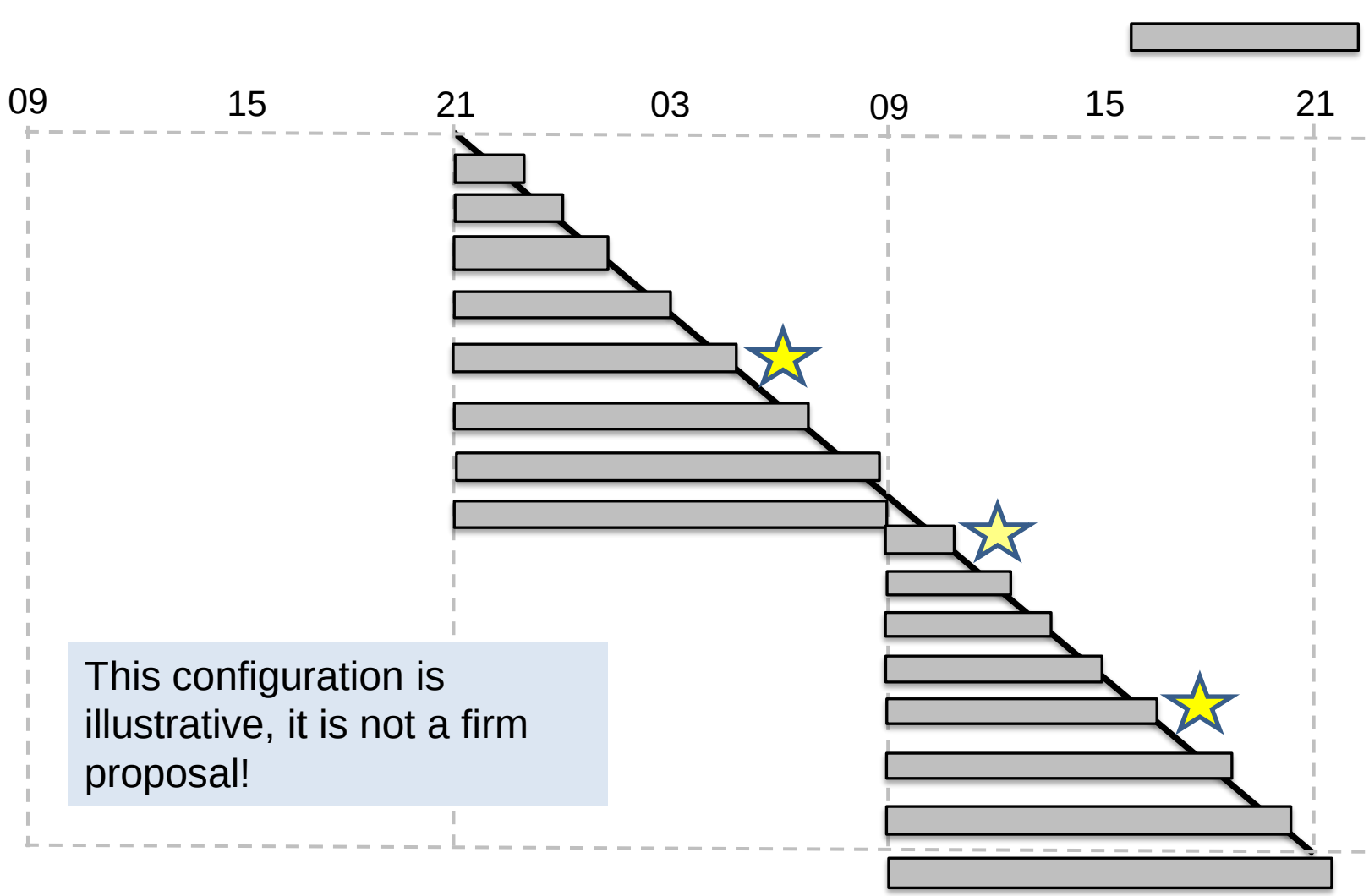
Change	What does this mean for users?
Satellite radiance assimilation package (All-sky microwave over sea ice + RTTOV version 13.2, reduced thinning); EPS-SG readiness.	Significant score improvements, plus analysis closer to observations
Continuous Observation Processing	A fresher analysis using all obs that reached ECMWF
Convection and gravity wave drag improvements	Significant improvement in scores in northern hemisphere
DA changes: VarQC in first trajectory	Improved screening of bad observations; less risk of minimization failures and possible delays.
Aerosol changes: New changing aerosol climatology	Impacts reforecasts only.
ERA6/SEAS6 readiness	In 49r2: new improved reanalysis and seasonal forecasts coming soon!

Looking beyond 49r1

Current Data Assimilation configuration



Schematic illustration of a possible Extending Window configuration



This configuration is illustrative, it is not a firm proposal!

In principle, an analysis can be taken at any point as required, for

- -Early Delivery
- -Boundary Conditions
- -LWDA
- -Forecast on-demand etc

Also higher resolution DA minimization to improve analysis

Other highlights of future cycles at 50r1 or 51r1 or beyond

Change	What does this mean for users?
New gas optics (ecCKD)	Improves some longstanding biases
SPP extension to coupled processes (51r1)	Better near surface ENS skill
Prognostic aerosol	CAMS already beats operations locally in areas with significant aerosol optical depth – we want these benefits in the weather configuration!
Unified Land DA	Improved surface and near surface analysis
Future HPC readiness	Flexibility in choices for next HPC could enable more “bang for buck”
Km-scale resolution	Building on Destine developments, ever higher resolution in the future!
Improved representation of sub-grid scale orography	Better representation of topography, e.g. for winds in the mountains
Learnt improvements from ML	e.g. new parameterisations, online model bias correction, but not clear where we will be at by 51r1

Take home messages

- Lots of T2m improvements on the way in 48r1 and 49r1 – will be good to get feedback on this.
- 3-hourly or even 1-hourly DA updates is a future possibility – bringing fresher initial conditions – what do you think? Would we run ENS more frequently?
- NEMO4+SI^3 in 49r2 but means it will not affect operational forecasts until 50r1
- Wave physics changes will generate deeper TCs and warmer tropical seas
- Major changes in ENS (SPP, soft-centred EDA)
- ECMWF is beginning to deliver on its Earth System strategy – many aspects
- **ENS RESOLUTION!!**

THE STRENGTH OF A COMMON GOAL