Introduction to Cycle 48r1

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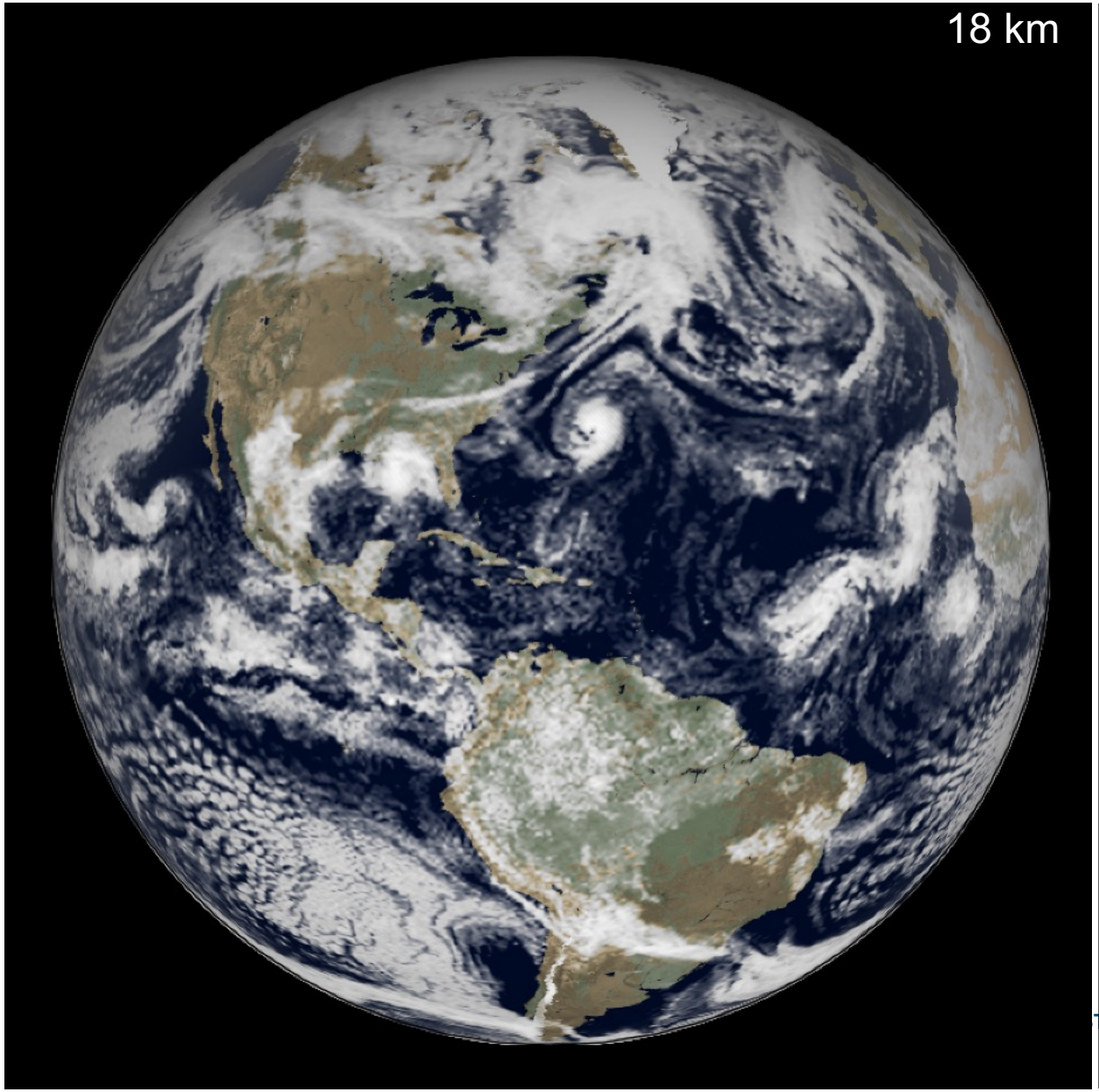
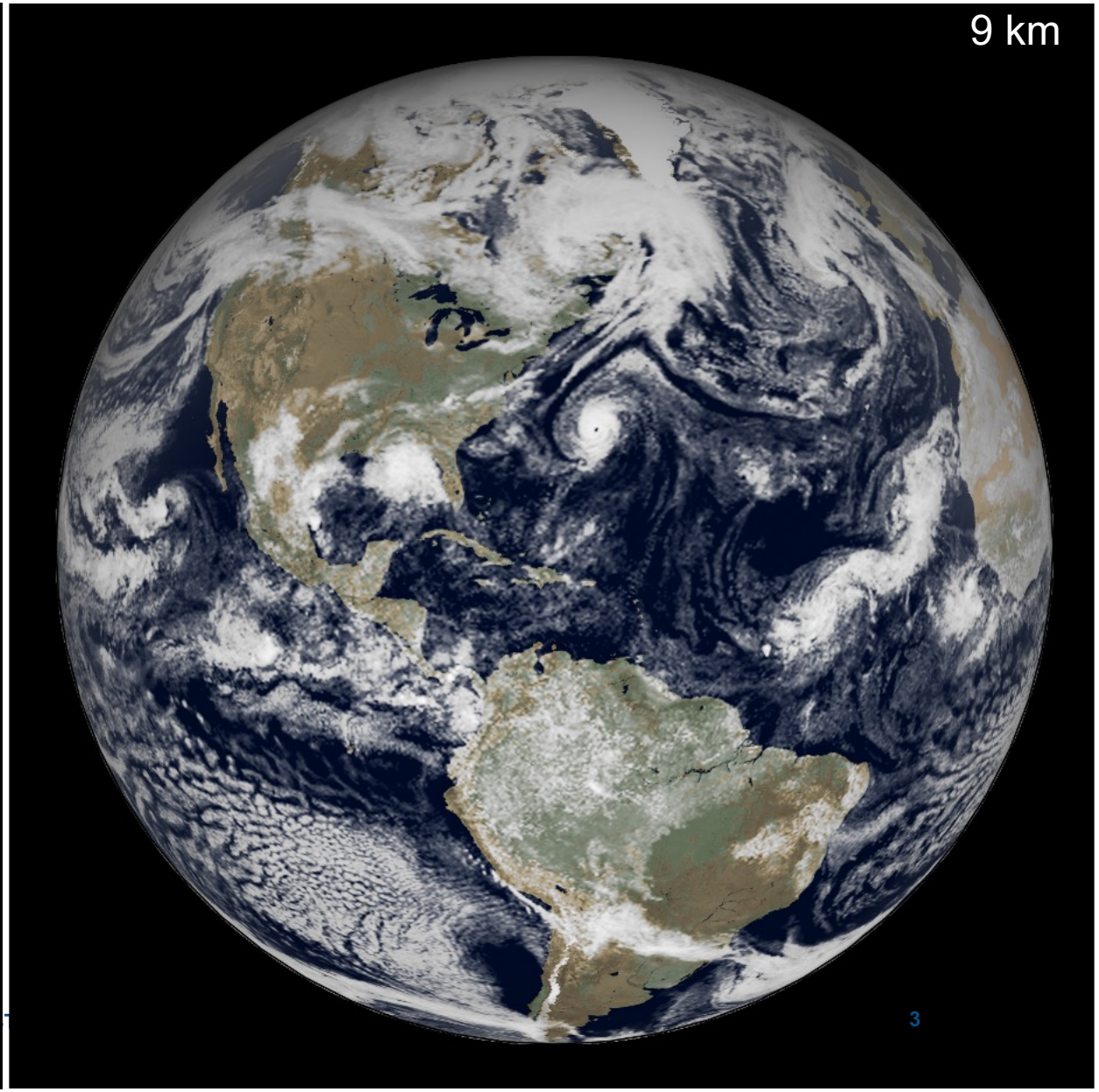
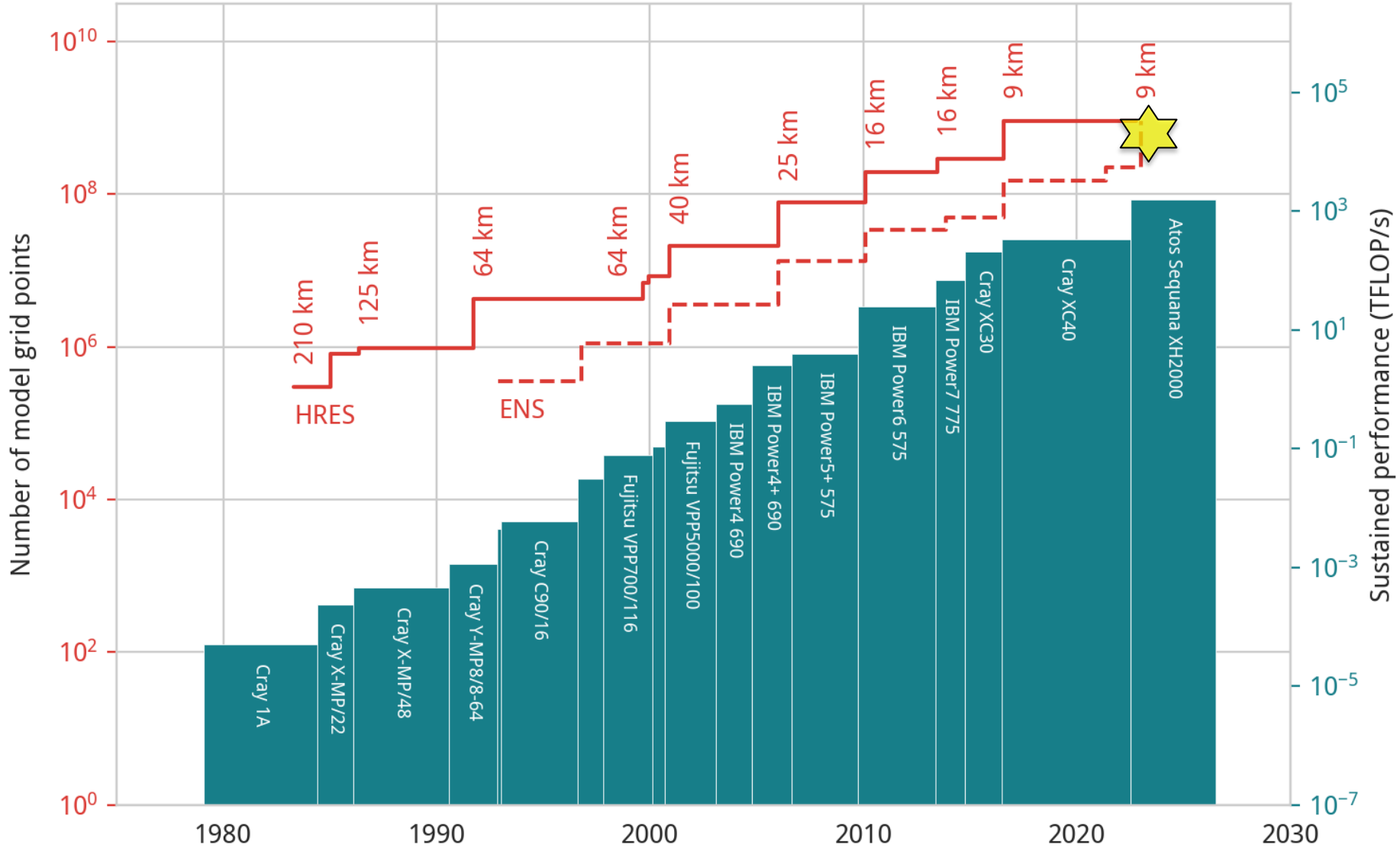
ECMWF

Medium range ensemble : 18 km to 9 km (same as HRES)
Extended range ensemble : 50+1 members twice weekly to 100+1 members every day



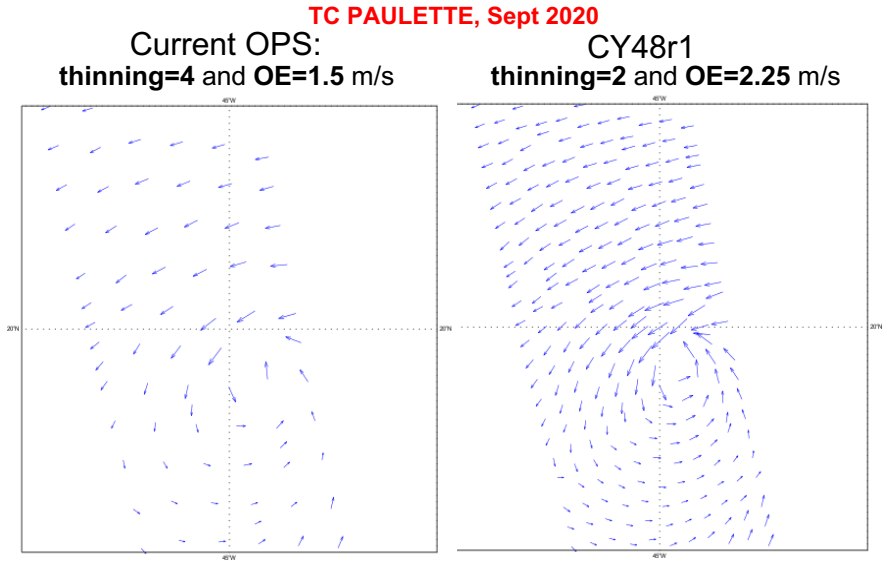


Evolution of HRES and ENS



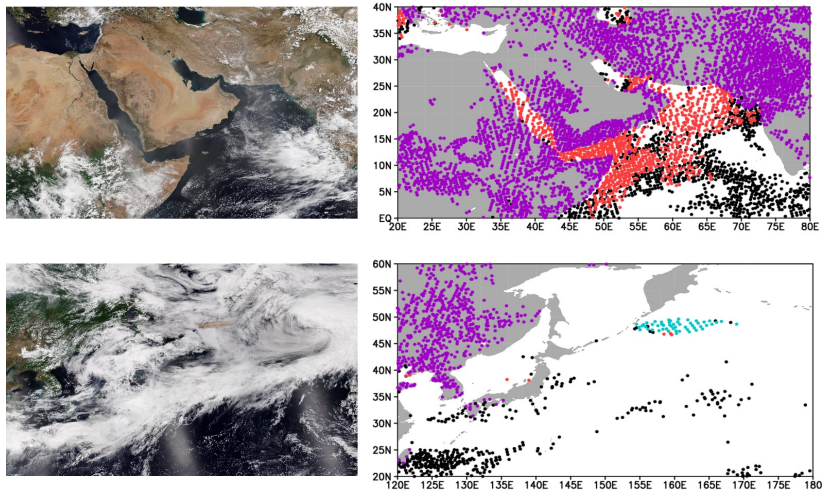
48r1: Improvements in data assimilation and observation use (I)

- TL511 inner loop resolution in HRES 4D-Var
- Operational activation of OOPS
- Higher-density assimilation of ASCAT L2 winds



Enhanced classification and rejection of aerosols for hyper-spectral IR (e.g. dust / volcanic ash)

- Improved assimilation of hyperspectral IR sounders
  - Unified VarBC setup for IR sounders
  - Allow usage of all pixels from IASI
  - Aerosol type classification in IR data
  - Update on the IR trace gas detection



48r1: Object-Oriented Prediction System (OOPS)

- **What is it?**
  - OOPS is a modular algorithmic control layer implementing variational data assimilation algorithms and forecasting applications. OOPS is the result of a joint effort by ECMWF, Météo-France and ACCORD partners, with development starting in 2010.
  - Adopted by the JEDI system of JCSDA

- **Why we have developed it?**
  - The idea is to separate the generic algorithmic level from the complex model-specific implementation code base and so enable fast prototyping of new algorithms.

- **What will it allow us to do?**
  - OOPS has already allowed us to explore new algorithms including:
    - Integration of machine learning into the incremental 4D-Var framework for model error estimation and correction,
    - Development of a Dual Configuration model for atmospheric composition applications.
    - Saddle point formulation of weak constraint 4D-Var,
    - 4D-EnVar (Météo-France),
    - Randomized preconditioners.

Increase of final 4D-Var inner-loop resolution from TL399 to TL511

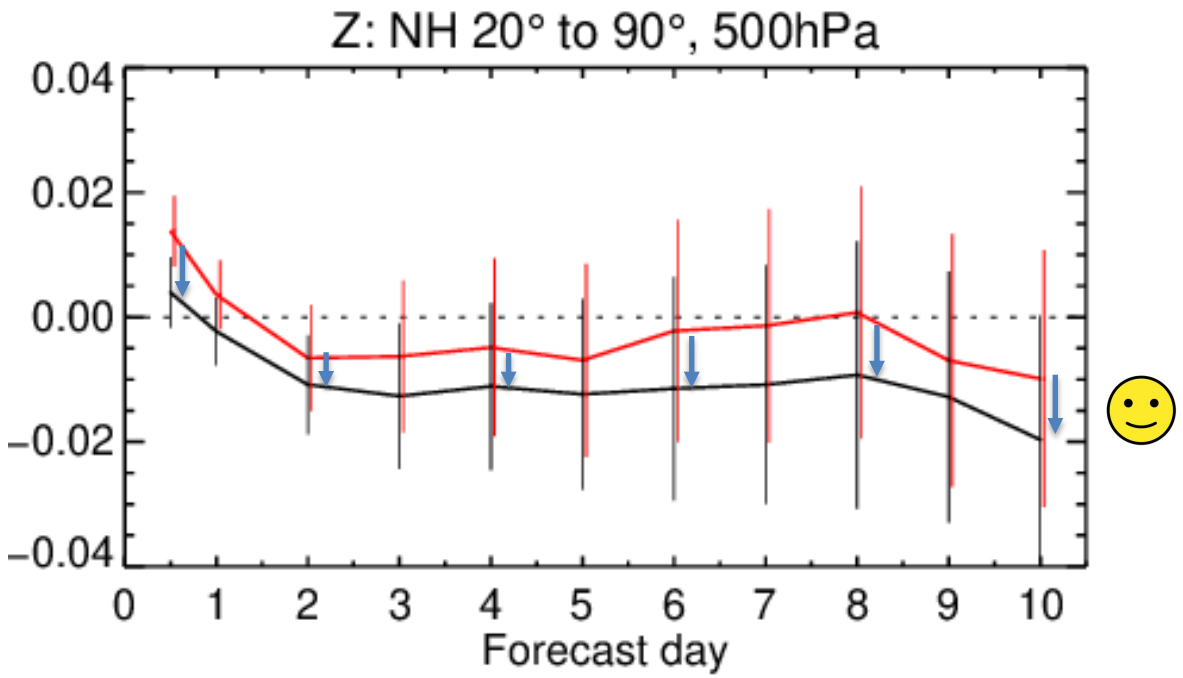
Increasing inner loop resolution to T511 improves the extraction of finer scale observation information in the 4D-Var analysis.

Forecast scores improvement moving from TL399 (50km) to TL511(40km) inner-loop resolution

TL399 inner loop

↓

TL511 inner loop



48r1: Improvements in data assimilation and observation use (II)

- Upgrade RTTOV to v13
  - Latest version of RTTOV: technical upgrade + additional capabilities to prepare for future
  - Microwave gas optical depth coefficient file upgrade, using new predictors (v13)
  - Major scientific upgrade of cloud and precipitation microphysics in RTTOV-SCATT

- ATMS snow, Lambertian, slant-path
  - Activate ATMS humidity channels over snow
  - ATMS Lambertian surface reflection over snow and sea-ice
  - Slant-path interpolation for selected MW sensors assimilated in the all-sky system

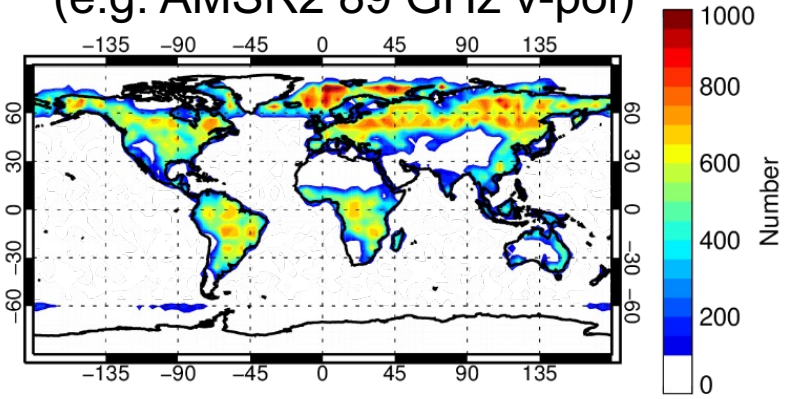
- Improved treatment of surface-sensitive channels in all-sky
  - Assimilate polewards of 60 degrees over land and ocean; relying on new sea-ice detection
  - Improved treatment of mixed land-water and water-sea-ice scenes

- Assimilation of microwave imagers over land surfaces
  - 89 GHz, 150/166 GHz channels of GMI, SSMIS + GMI 183 GHz over land
  - Add 37 GHz channels, Add AMSR2; improved bias correction, QC and error models

All-sky all-surface: more microwave observations over difficult surfaces

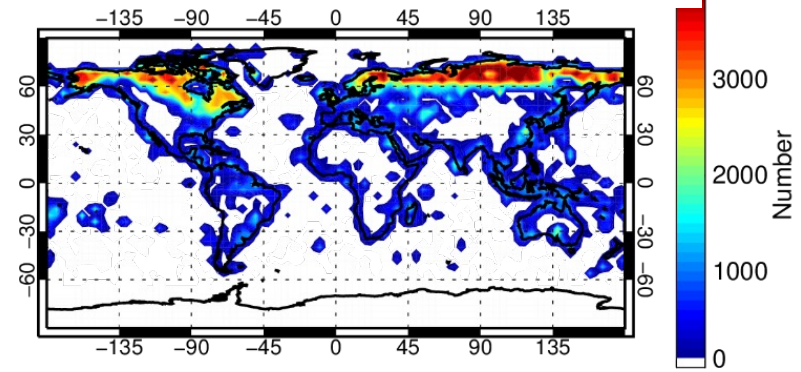
Increased use of MW imagers (e.g. AMSR2 89 GHz v-pol)

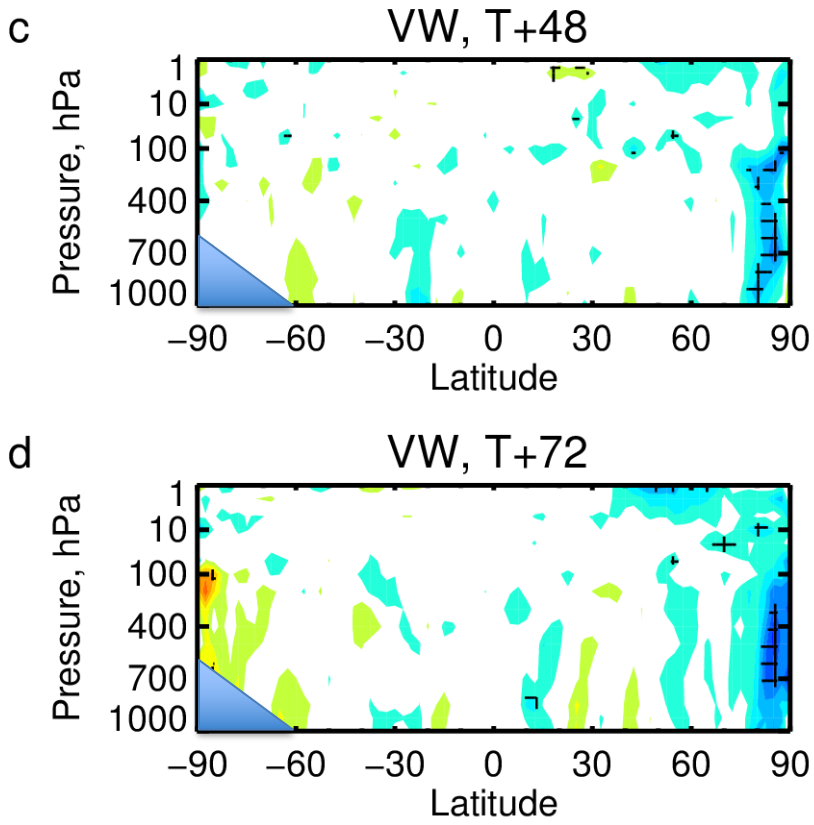
Observations used over land surfaces and polar oceans for the first time



Increased use of MW humidity sounders (e.g. MHS 183±7 GHz)

Observations used over polar land and mixed scenes (e.g. coasts, lakes) for the first time





Reduced rmse vector wind forecast errors to day 3 in northern polar regions

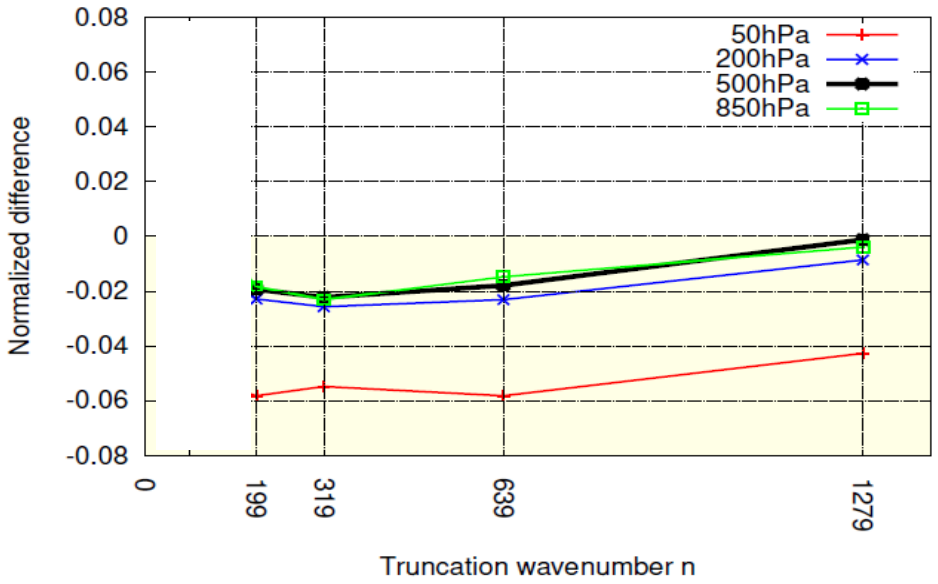
48r1: Selection of model contributions

- 9 km ensemble
  - Tracer mass fixer applied to moist species
  - Moist physics changes (saturation adjustment, ice fall speed)
  - Stochastic physics (saturation adjustment tendency excluded from SPPT)
- Improved drag representation
- Revised computation of Semi-Lagrangian advection departure points
- New model top sponge layer formulation
- Consistent physics-dynamics interface across non-linear/tangent-linear/adjoint model
- Radiatively interactive prognostic ozone using new HLO scheme + tuned Semi-Lagrangian vertical filter
- Multi level snow scheme
- Revised climate fields
- New representation of freezing drizzle and more precipitation type parameters

A new orographic drag package

- A new representation of the unresolved orographic effect: Taking into account the drag effect from scales between 5 km and **4** times the target resolution
- Revised formulation of the aspect ratio
- Low level blocking and TOFD calibration

Impact on geopotential height (day 5)



- *Improvements across all resolutions from TCo319 to TCo1279!*
- *Decrease in RMSEs getting smaller at higher resolutions due to decrease of SSO contributions (more resolved orography)*

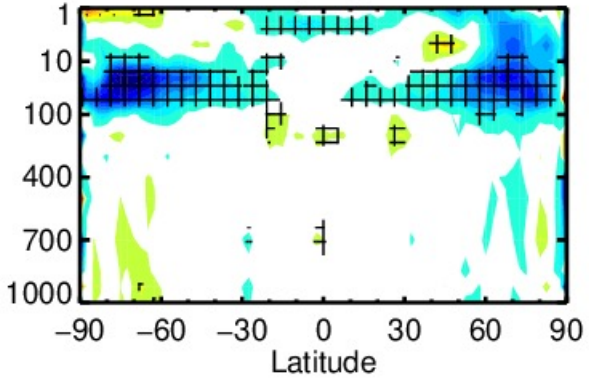
Kanehama et al. (2019), JAMES
Kanehama et al., TM, 2022

Radiatively interactive prognostic ozone “HLO”: medium-range impact

- A new *Hybrid Linear Ozone* (HLO) scheme has been developed, trained on the CAMS ozone reanalysis: a significant improvement over previous Cariolle linear ozone scheme, and already used operationally in CAMS forecasts
- Combined with *Semi-Lagrangian Vertical Filter* (SLVF) to suppress noise in temperature in the vertical

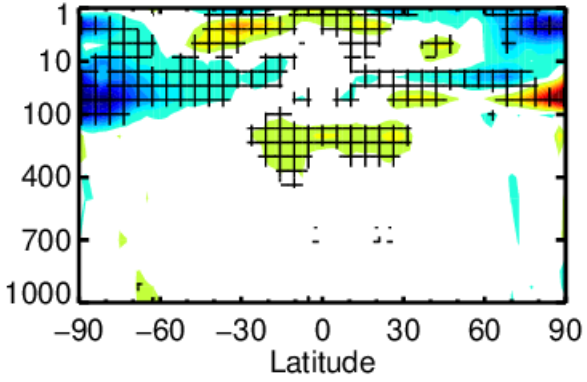
Percentage change to 5-day forecast skill, Tco399 (30 km), JJA 2020 + DJF 2020/21

Temperature Δstddev, ±10%



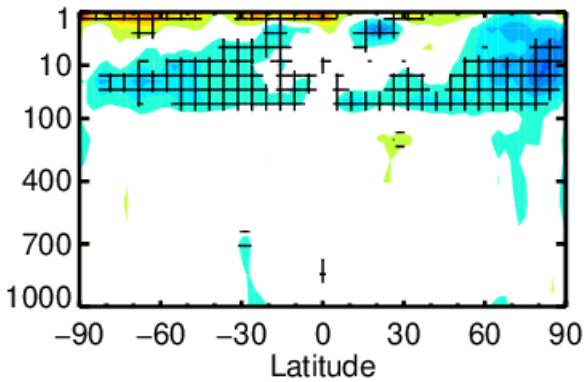
(Blue is good)
Standard deviation of error is improved

Temperature ΔRMSE, ±15%



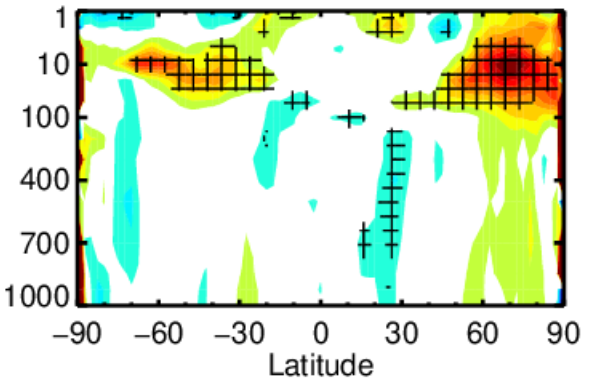
(Blue is good)
RMSE also affected by bias, which is changed slightly in both directions (~0.1 K up to the 5 hPa level after 5 days)

Vector wind ΔRMSE, ±10%



(Blue is good)
Clear improvement

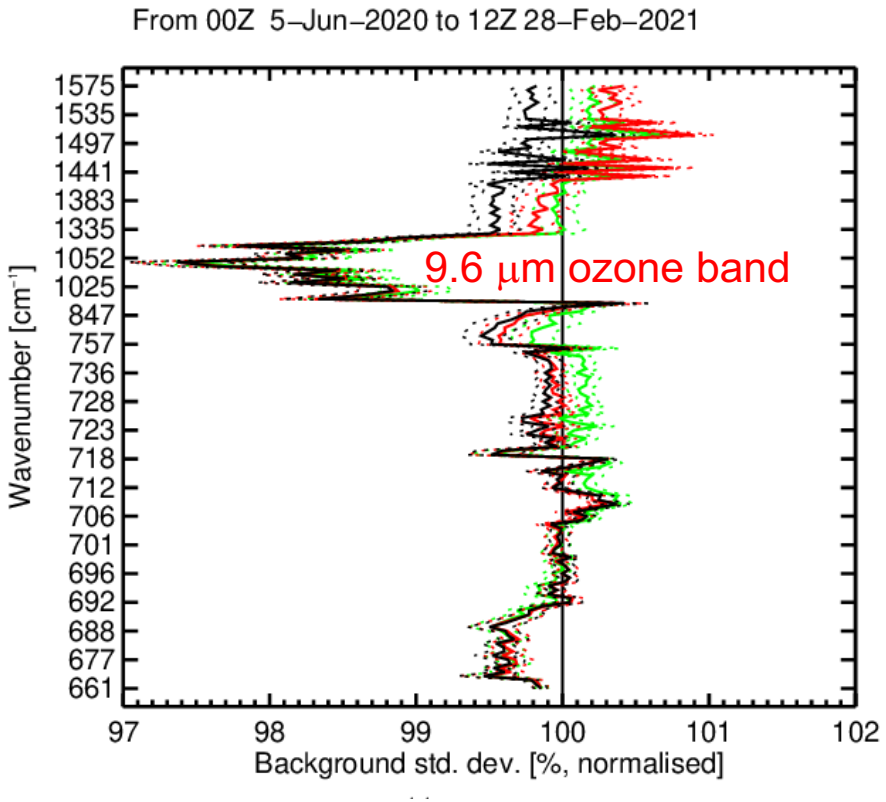
Geopot. height Δac, ±10%



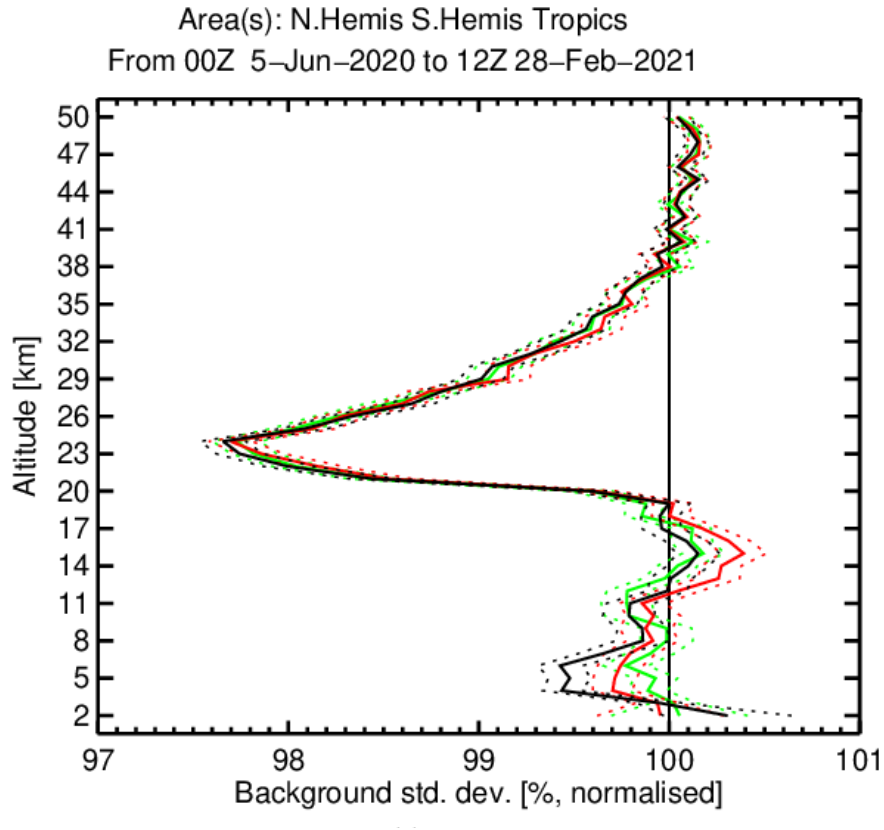
(Red is good)
Stratosphere better

HLO+SLVF: Improved fit to observations (JJA 2020 + DJF 2020/21)

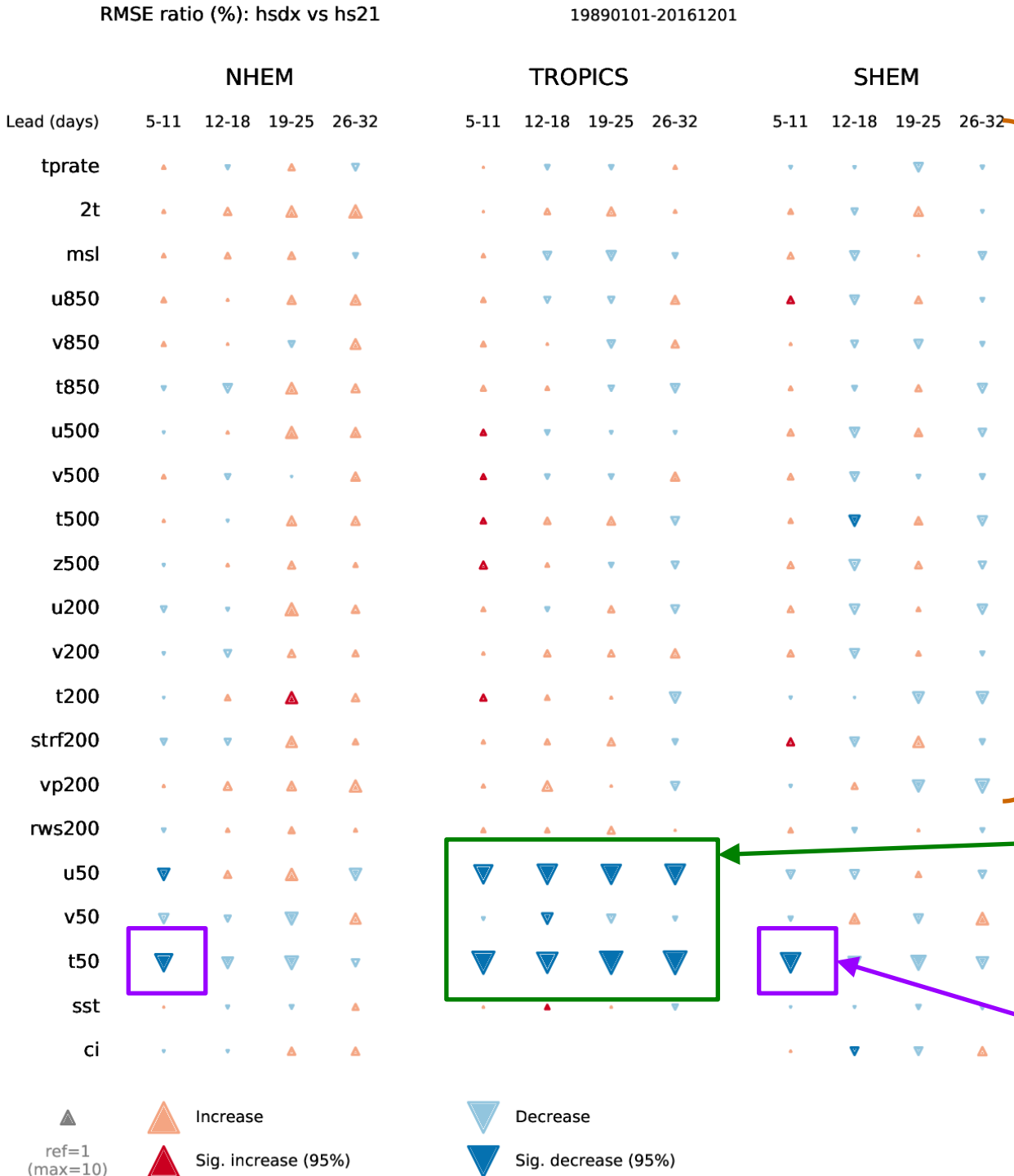
- **CRIS infrared sounder**: better ozone leads to better fit to ozone sensitive radiances



- **GPS radio occultation**: SLVF suppresses noise in temperature, improving fit



(Green line is impact of HLO+SLVF only, black and red lines include other model changes)



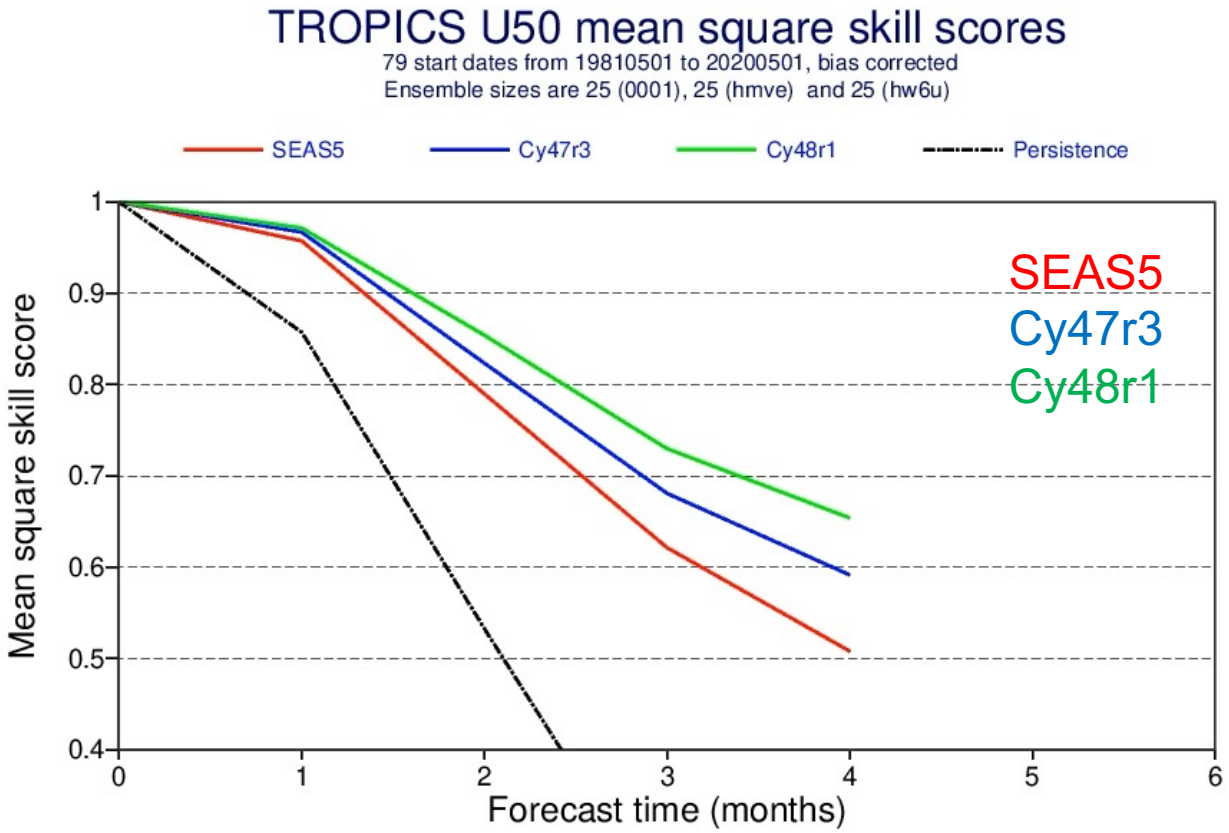
HLO+SLVF: Impact on monthly forecasts

- Tco319 hindcasts 1989-2016
- Score the change in bias-corrected RMS error
- No significant impact on tropospheric scores
- Statistically significant impact on tropical 50 hPa winds & temperatures to 1 month due to improved QBO
- Significant impact on extra-tropical 50 hPa temperatures up to 11 days ahead

Long-range forecasts

QBO scorecard 48r1 vs. 47r3
scoring zonal mean equatorial U wind

Months 2-4 of the long range forecast
Tco319 ORCA025 L137
51 members, 1981-2020

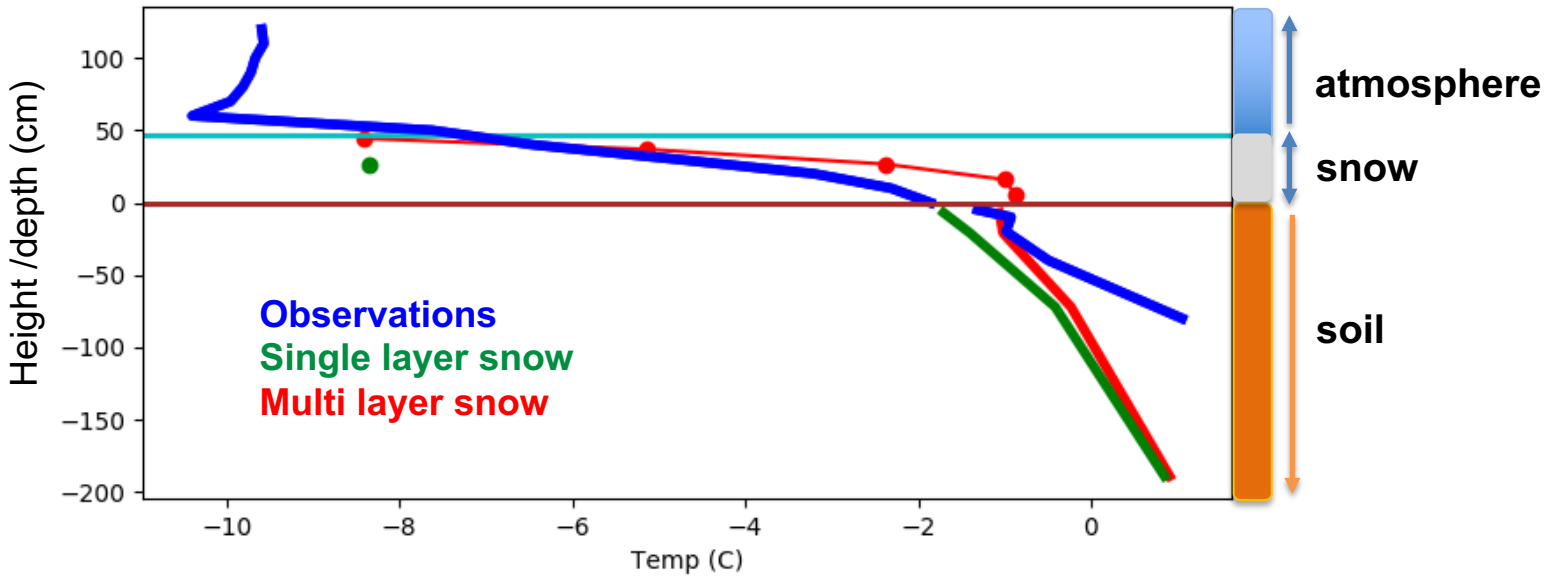


The gains in skill for stratospheric winds continue into the long-range forecast

Multi-layer snow scheme – improved coupling

- **New snow scheme with up to 5 layers, replacing single-layer snow scheme**
- **Improved the coupling** with the atmosphere and the soil underneath

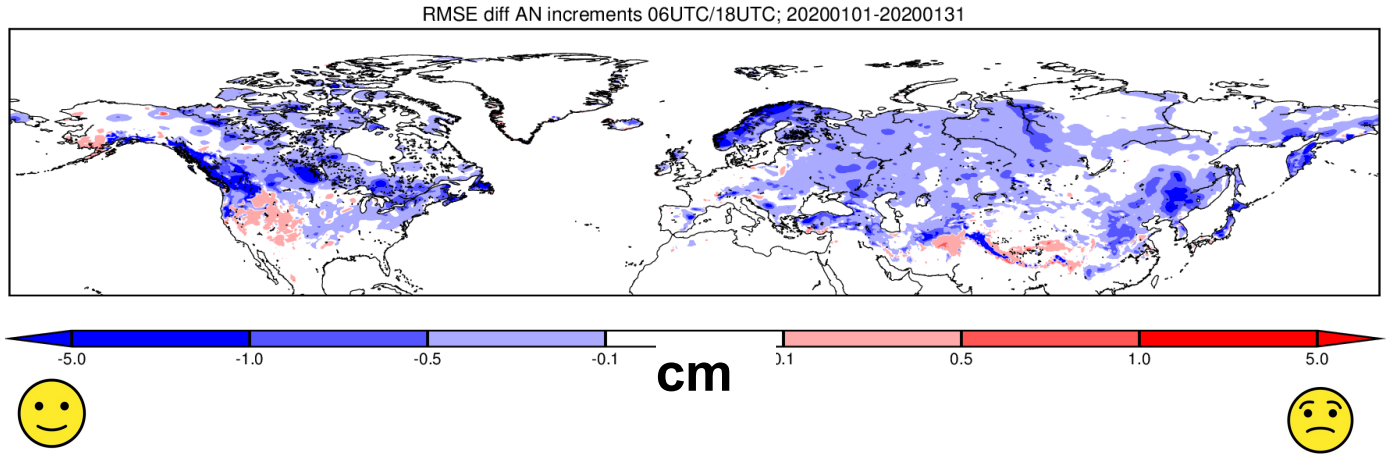
Temperature profile in the near-surface atmosphere, snow and soil layer at Sodankyla, Finland



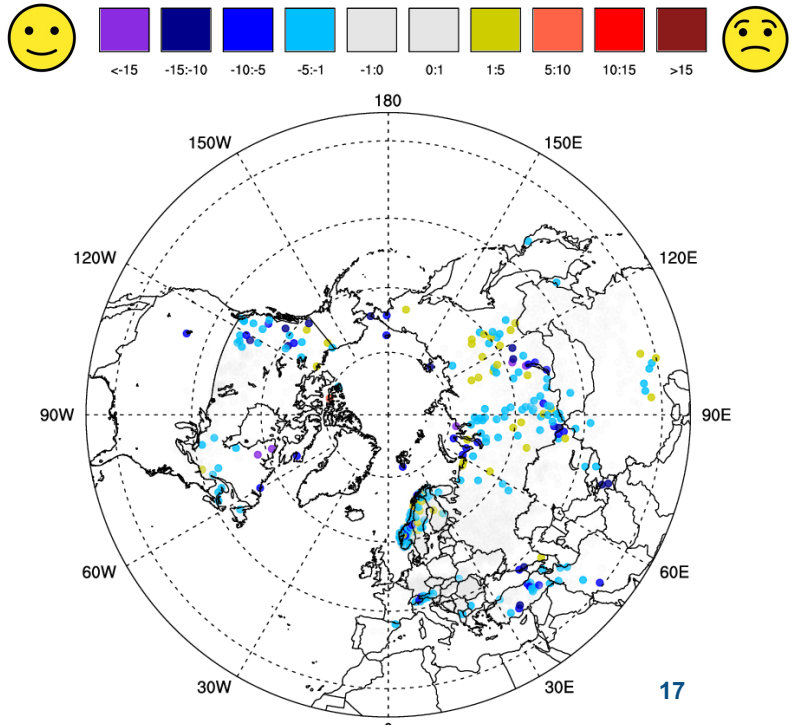
Multi-layer snow scheme – improved snow forecast

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

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



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

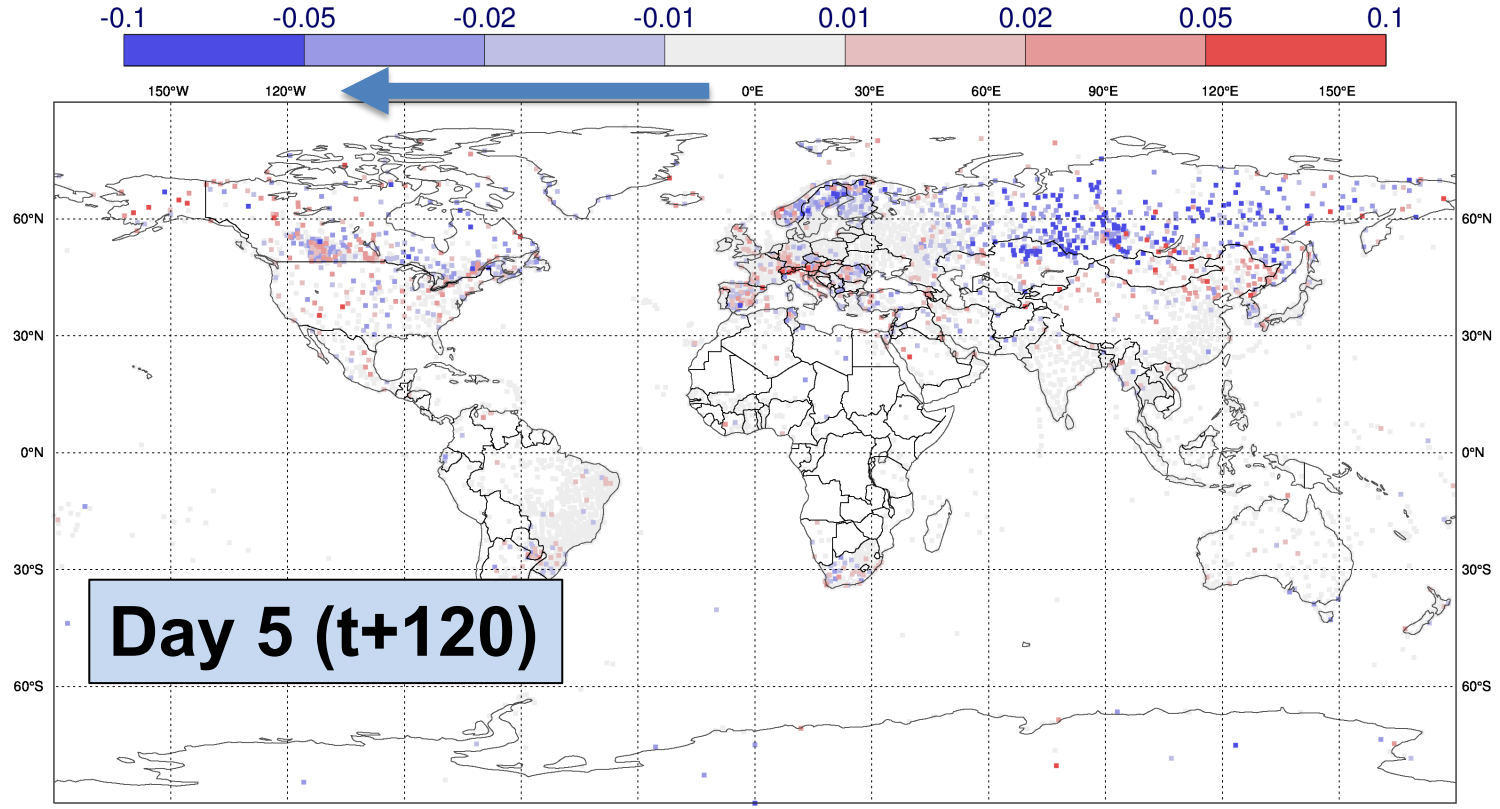


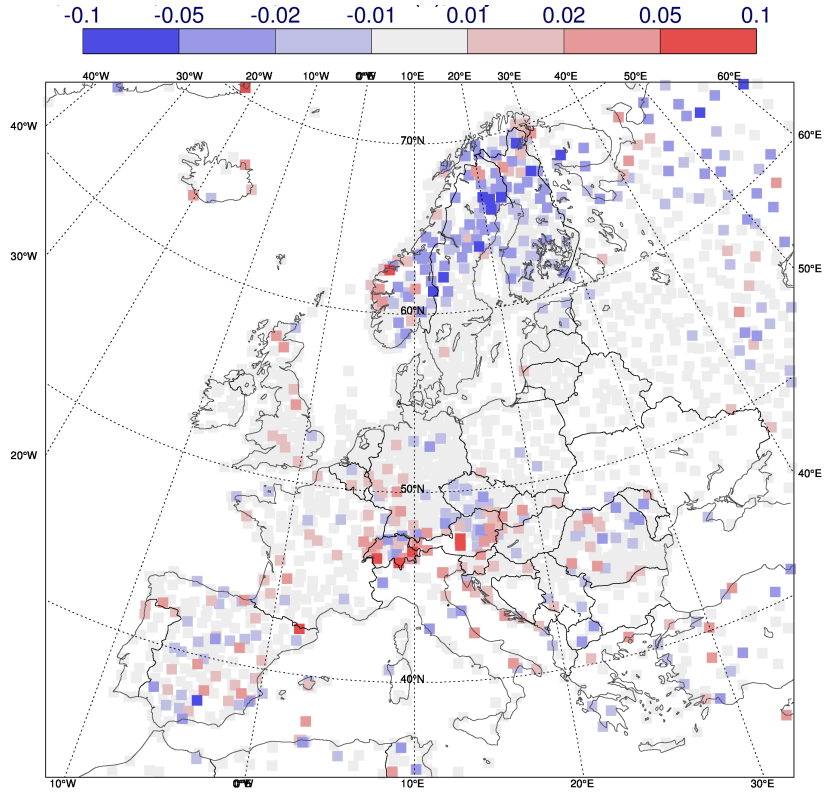
Multi-layer snow scheme – improved 2-metre temperature

Reduced fraction of large errors in ensemble

Fraction of CRPS errors in 2-metre Temperature > 5K in ensemble forecasts, Winter 2019/2020

Multi-layer snow reduces errors





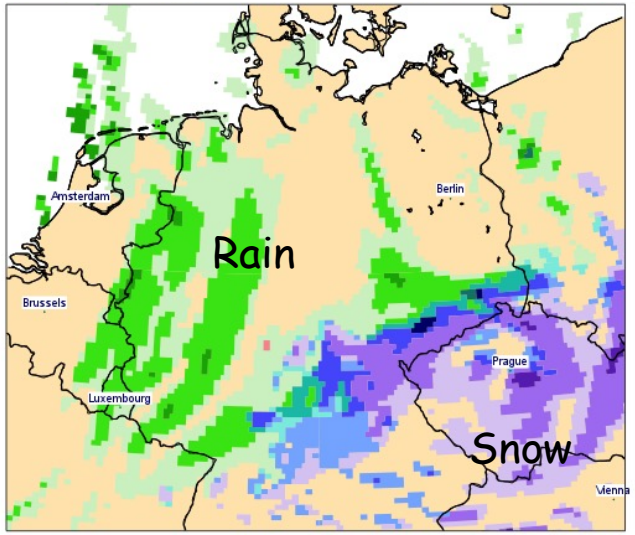
High impact weather – “Freezing drizzle” in 48r1

Freezing drizzle (= supercooled warm-rain process at sub-0°C temperatures)

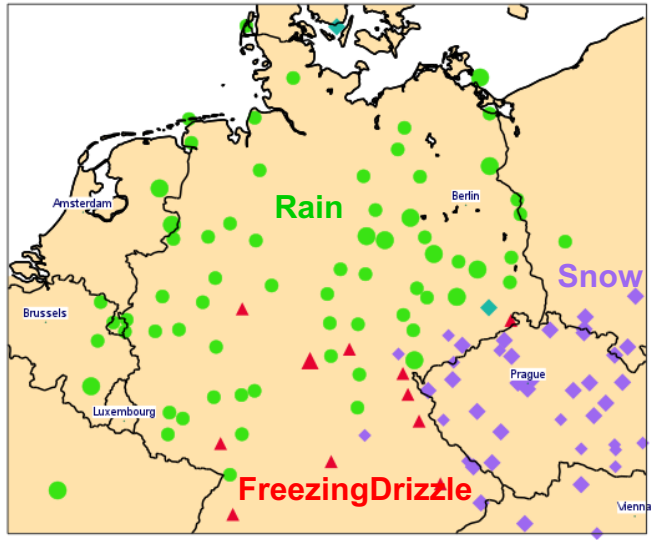
- Often light but prolonged precipitation can create icy surface, hazardous weather!
- Different formation process to freezing rain, **pre-48r1 freezing drizzle is not predicted in the IFS**
- New/revised microphysics in **48r1 allows freezing drizzle prediction**
- New **WMO code 12** in “Precipitation Type” parameter, will appear in ENS Precip-Type Meteograms

Example case study: Germany 19 Dec 2017

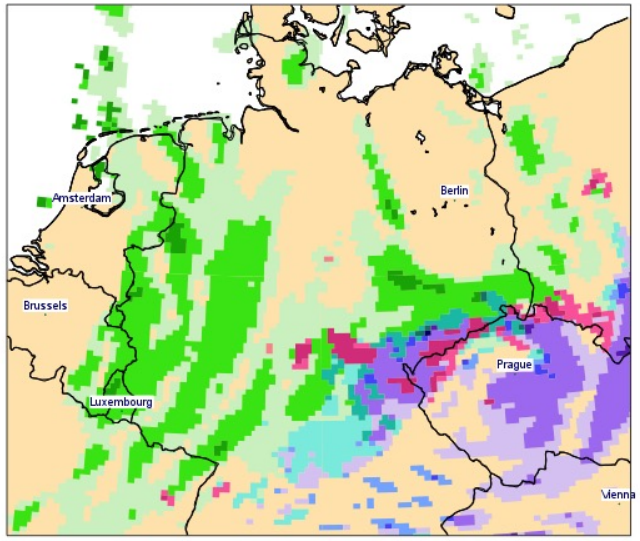
Operations at the time
No indication of freezing drizzle



Observed precipitation-type



New physics in 48R1
Freezing drizzle predicted in the area



rain / mix rain-snow / wet snow / snow / ice pellets / freezing rain / freezing drizzle

New parameters for precipitation type

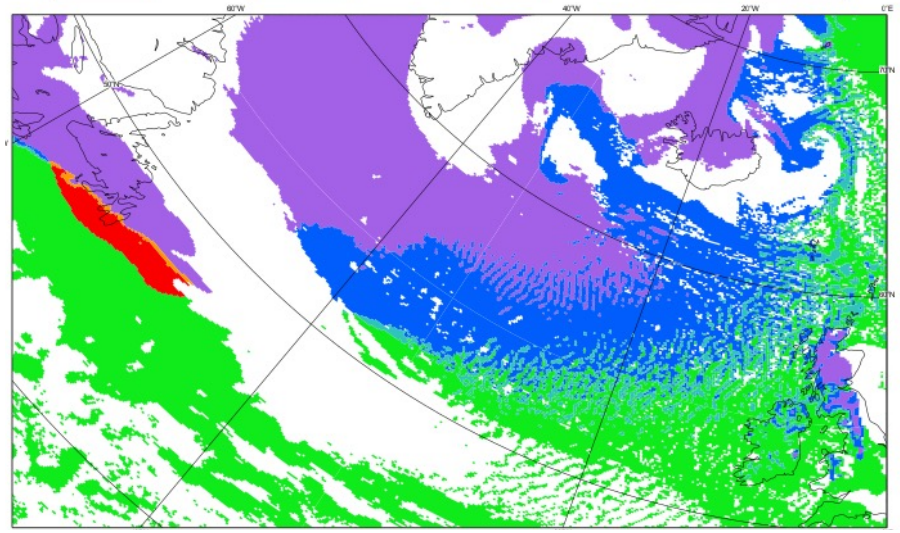
"Precipitation type" is only valid at the output time,

New parameters store the "**most frequent**" and "**most severe**" precipitation type occurrence in the last 1 hour, 3 hours or 6 hours depending on forecast lead time

6 new parameters:

Precipitation type (most severe) in the last 1/3/6 hours

Precipitation type (most frequent) in the last 1/3/6 hours



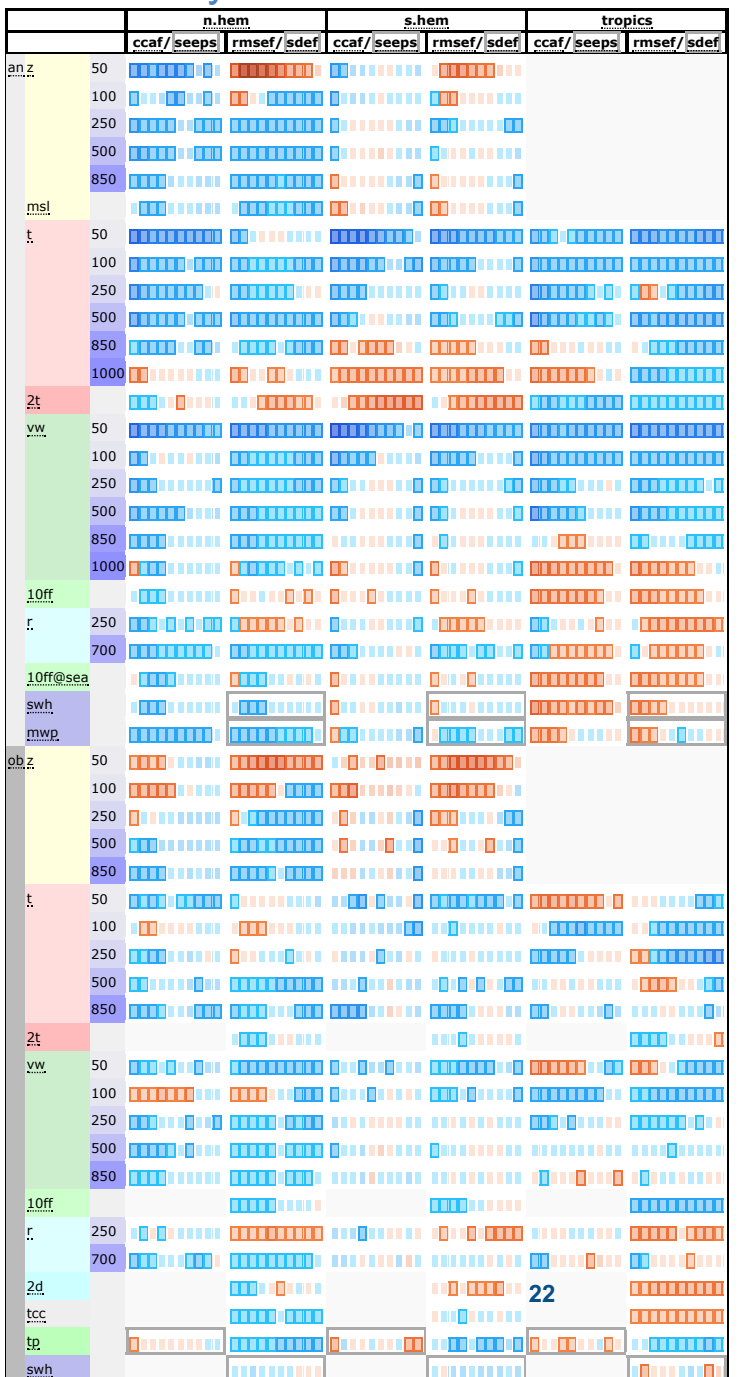
Precipitation types in the IFS and order of severity

Code	Precipitation Type	Severity
3	Freezing rain	*7*
12	Freezing drizzle	*6*
6	Wet snow	*5*
5	Snow	*4*
8	Ice pellets	*3*
7	Mixture of rain and snow	*2*
1	Rain	*1*
0	No precipitation	*0*

Scorecard, RD Esuite, 2020-06-03 – 2020-08-16 and 2020-12-03 – 2021-02-13, HR 00/12, ENS 00 only

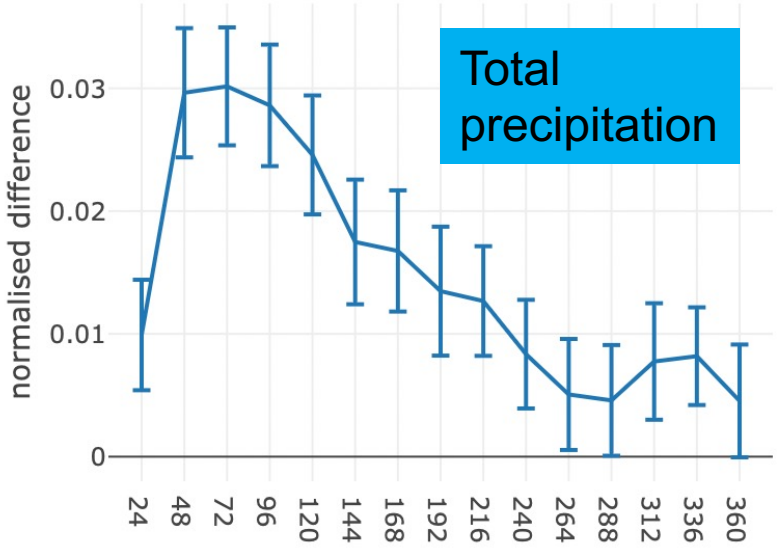
ENS

HR

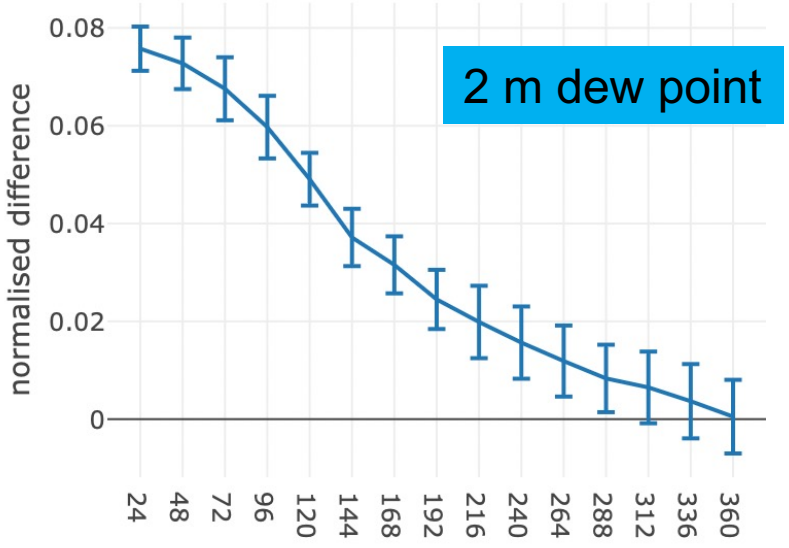


48r1, 2020-06-03 – 2020-08-16 and 2020-12-03 – 2021-02-13, ENS 00 – Improved SFC scores

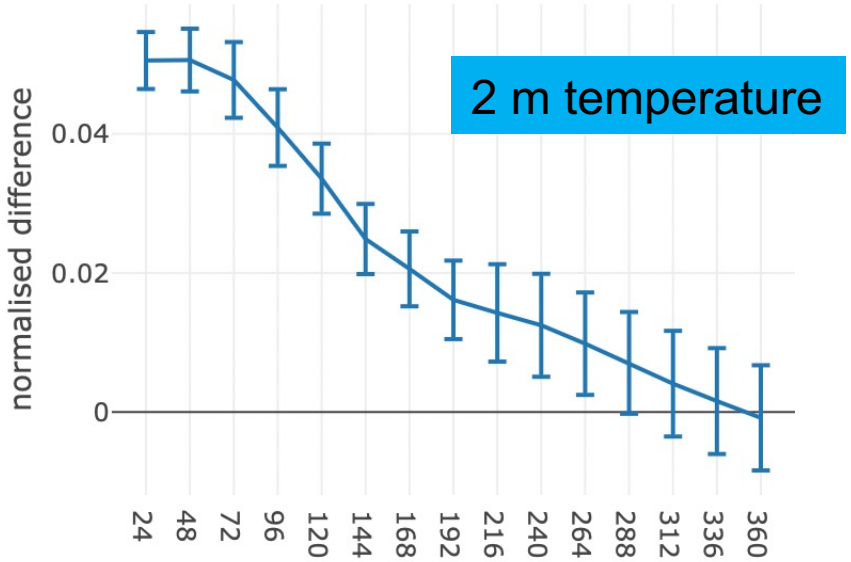
tp|0|europe|crps|ob



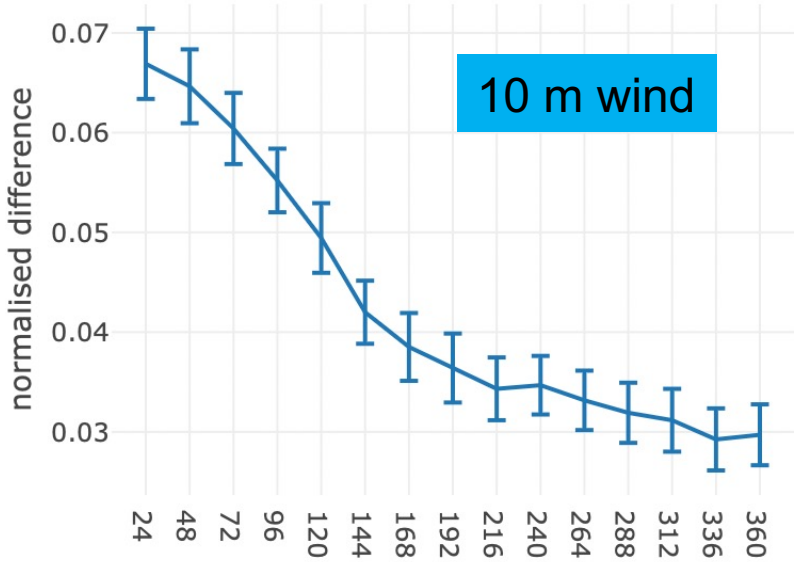
2d|0|europe|crps|ob



2t|0|europe|crps|ob

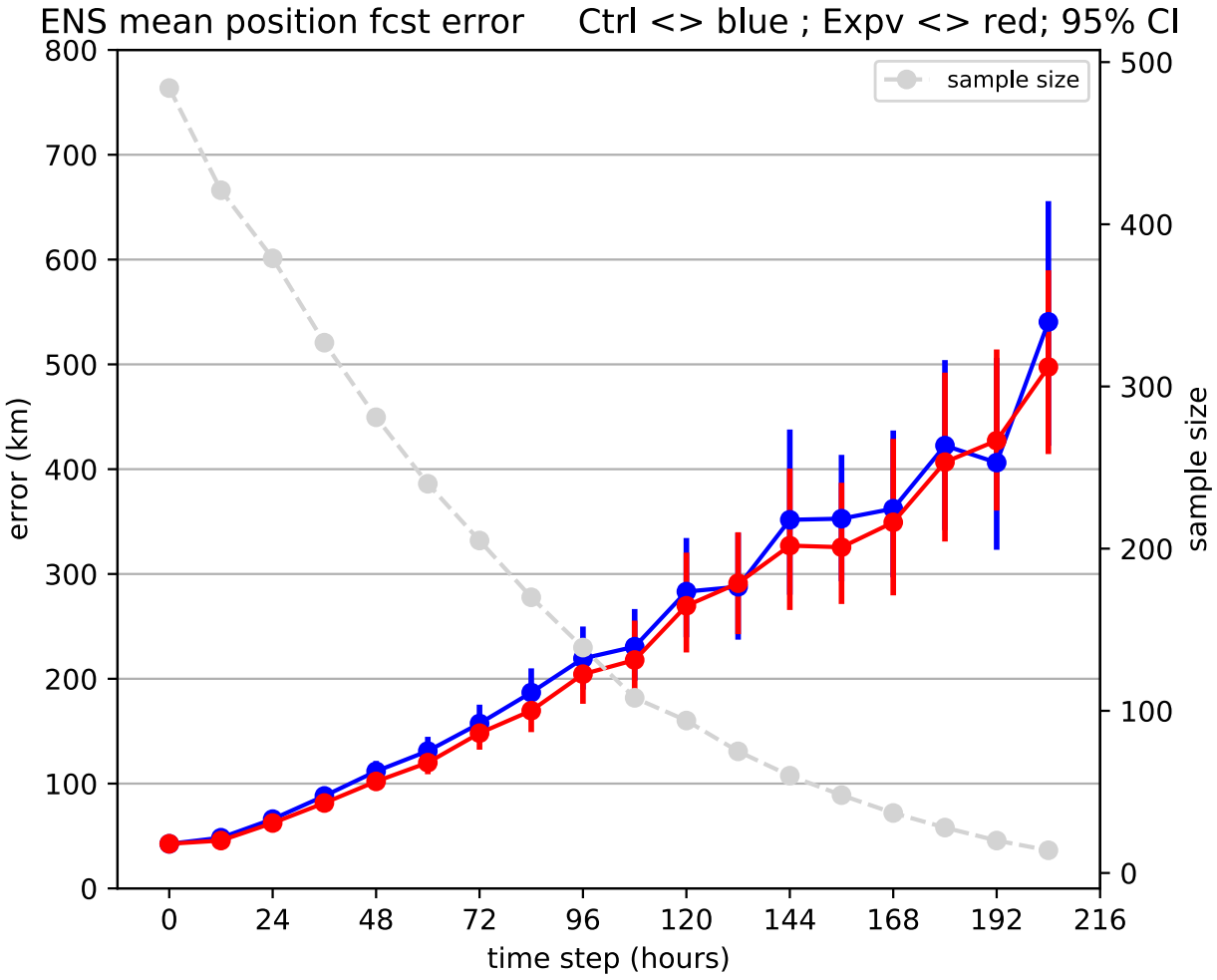


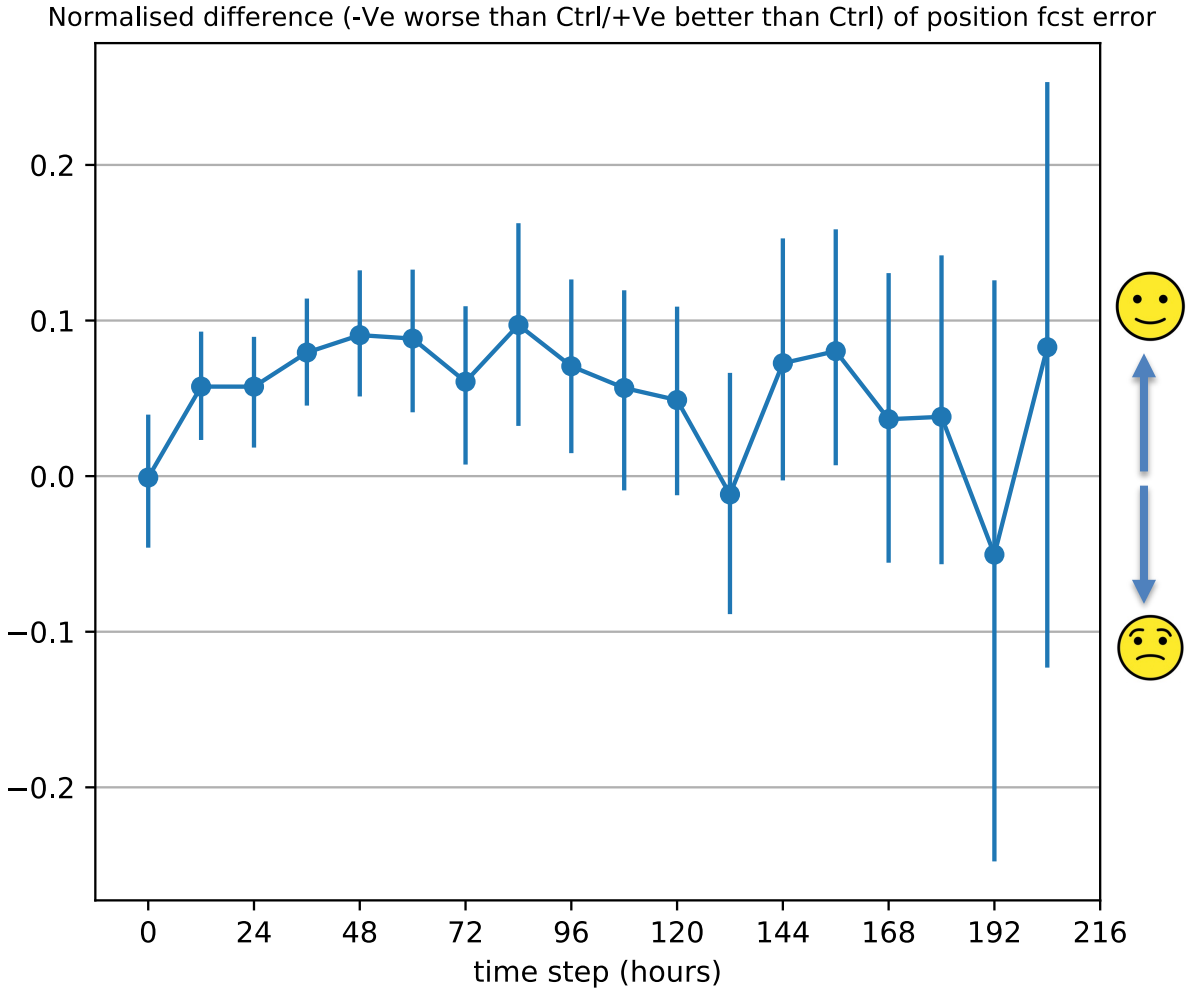
10ff|0|europe|crps|ob



48r1, ENS TC forecasts: Position

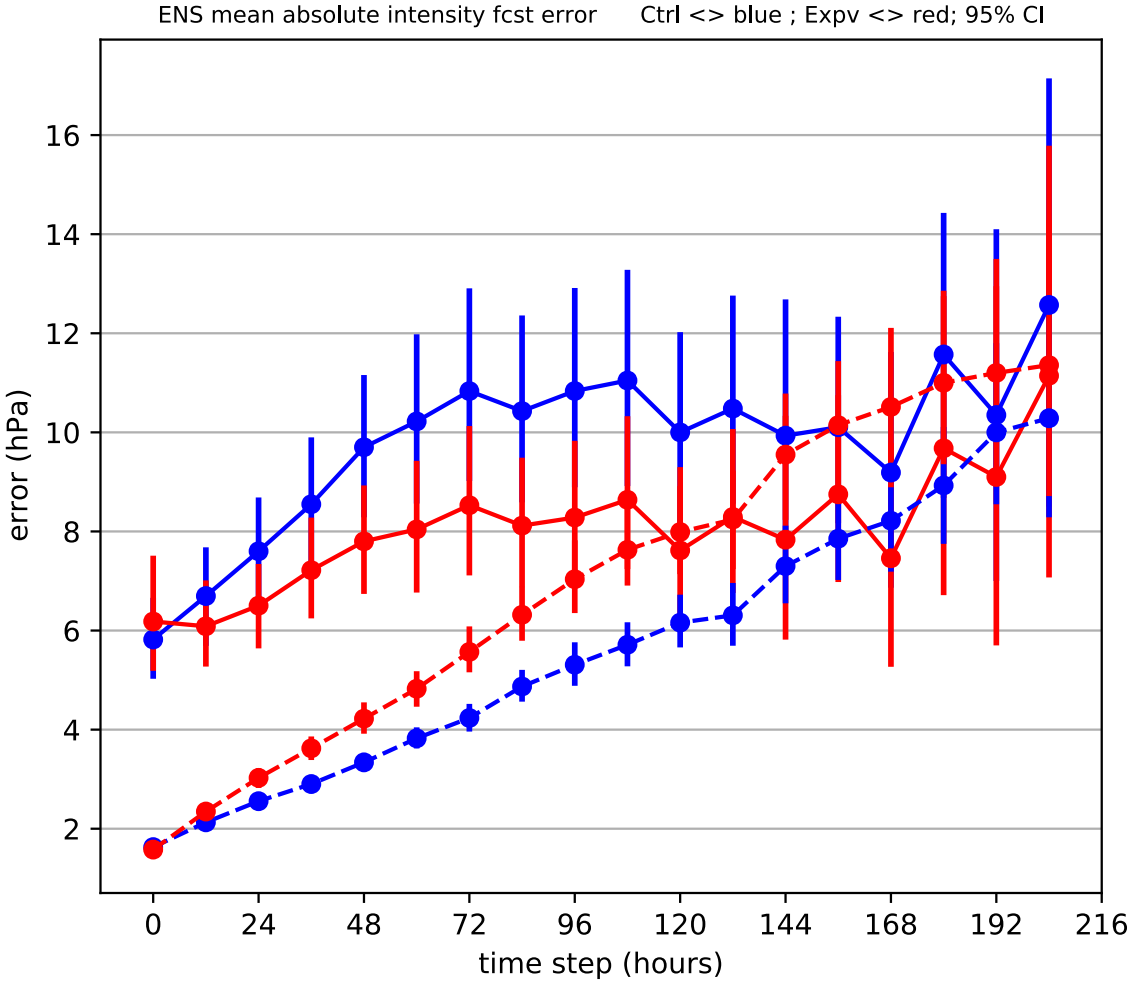
48r1, 47r3

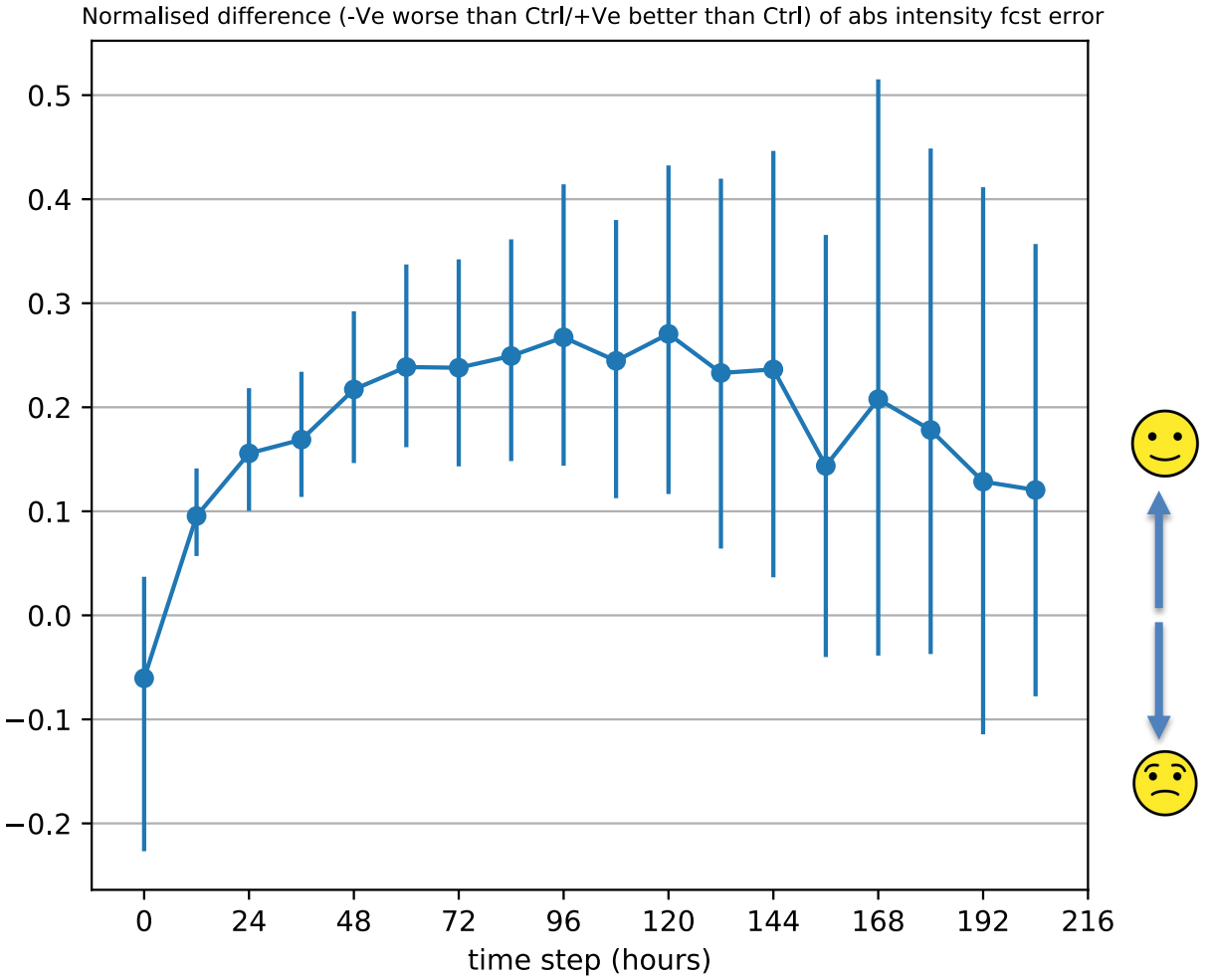




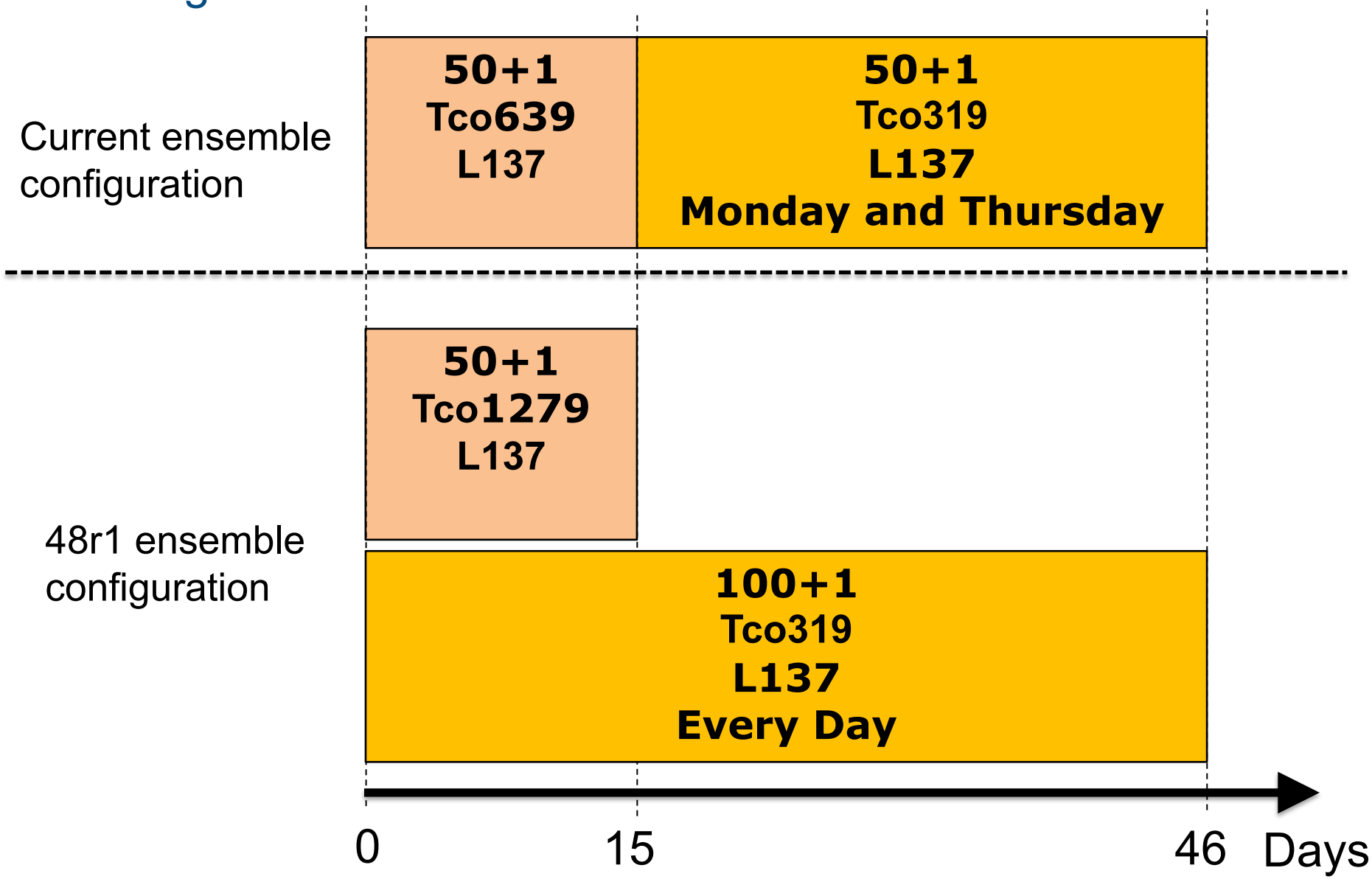
48r1, ENS TC forecasts: Intensity

48r1, 47r3



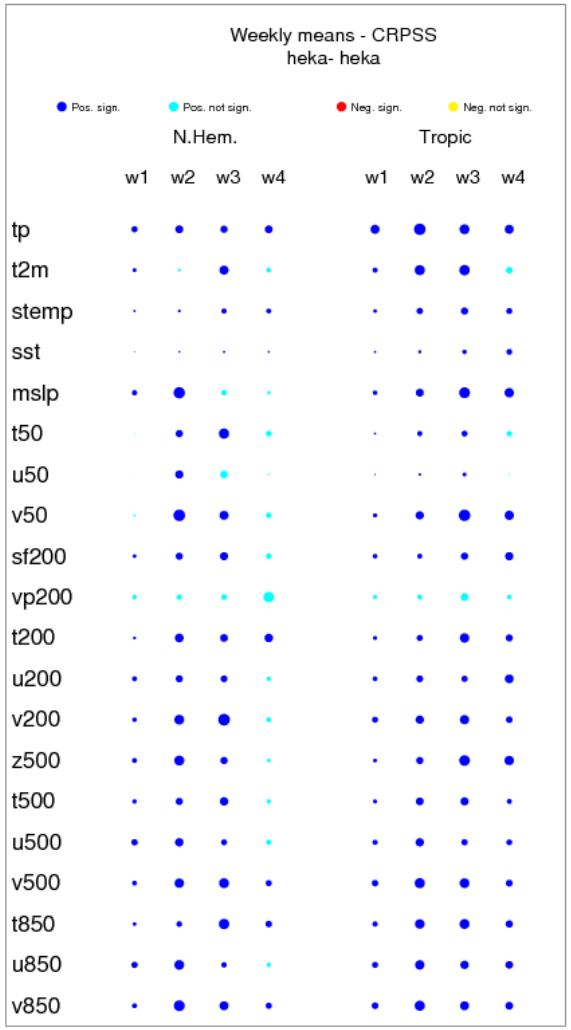


48r1: Extended range



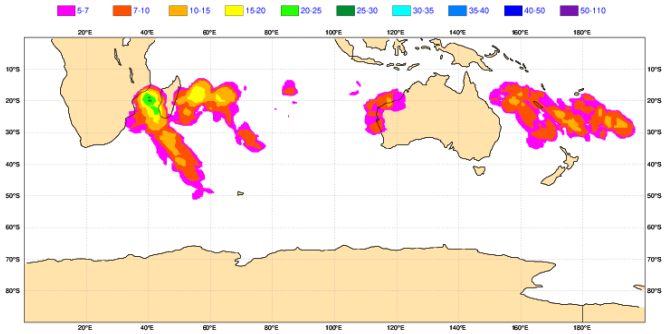
Change to extended-range forecast configuration in 48r1

Impact of increase of ensemble size

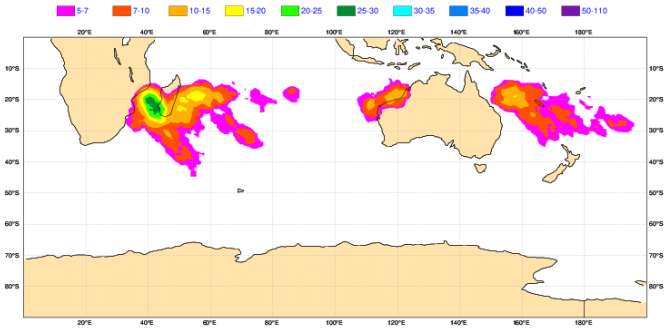


Tropical storm strike probability week 4 forecast
Start date:7/1/2021 – verification 1-7 Feb. 2021

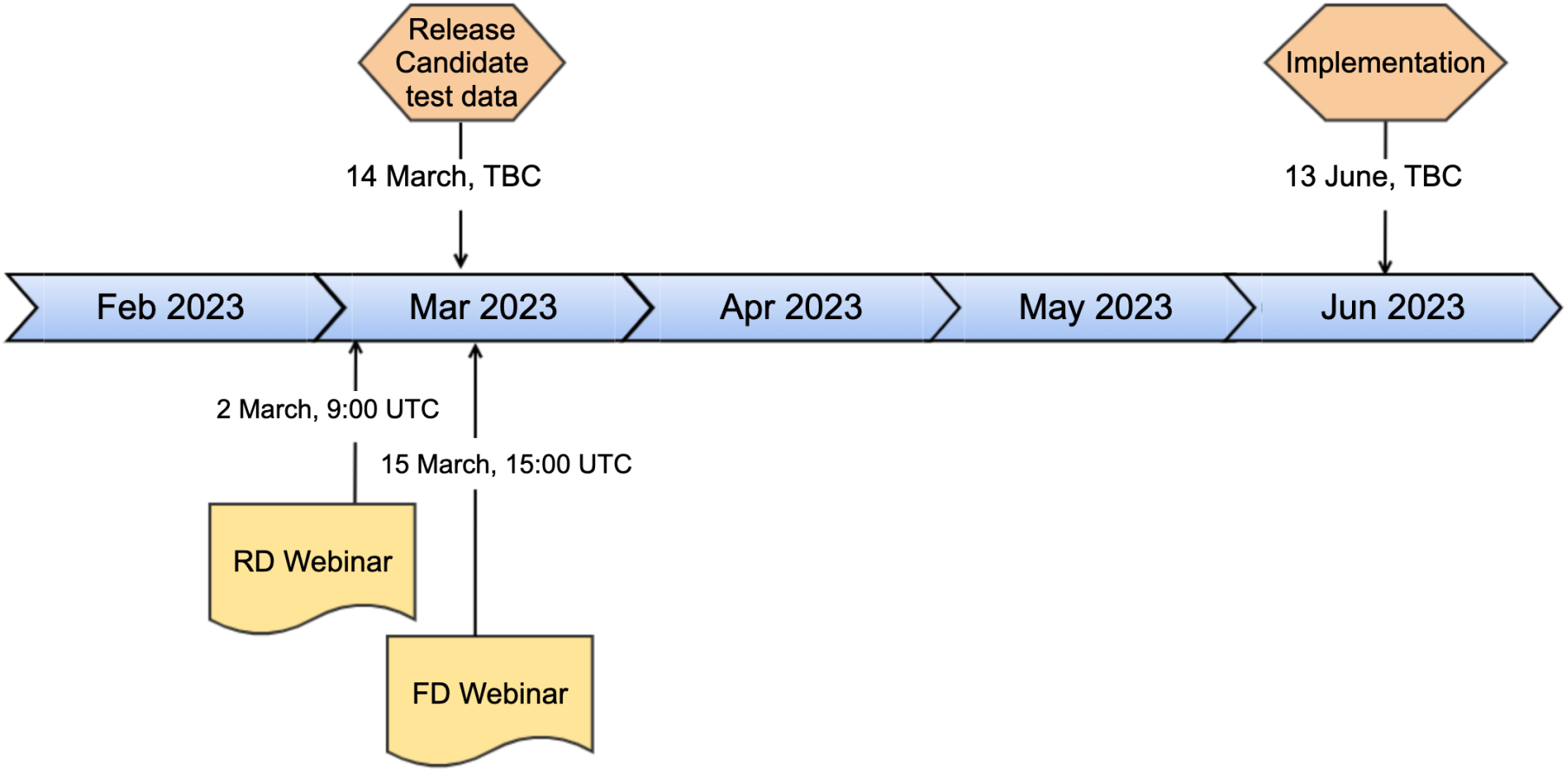
50+1 members



100+1 members

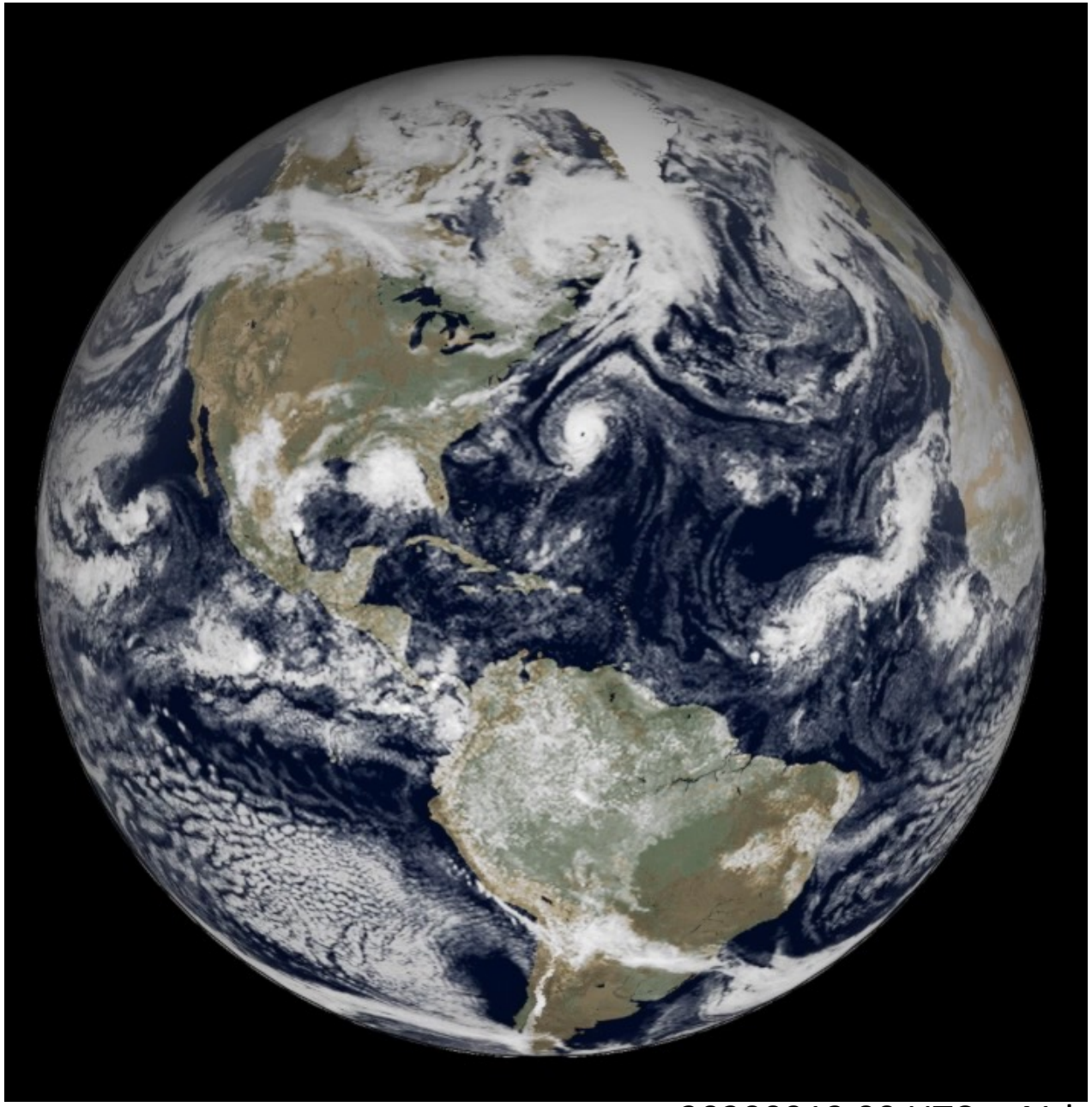


48r1 Implementation timeline

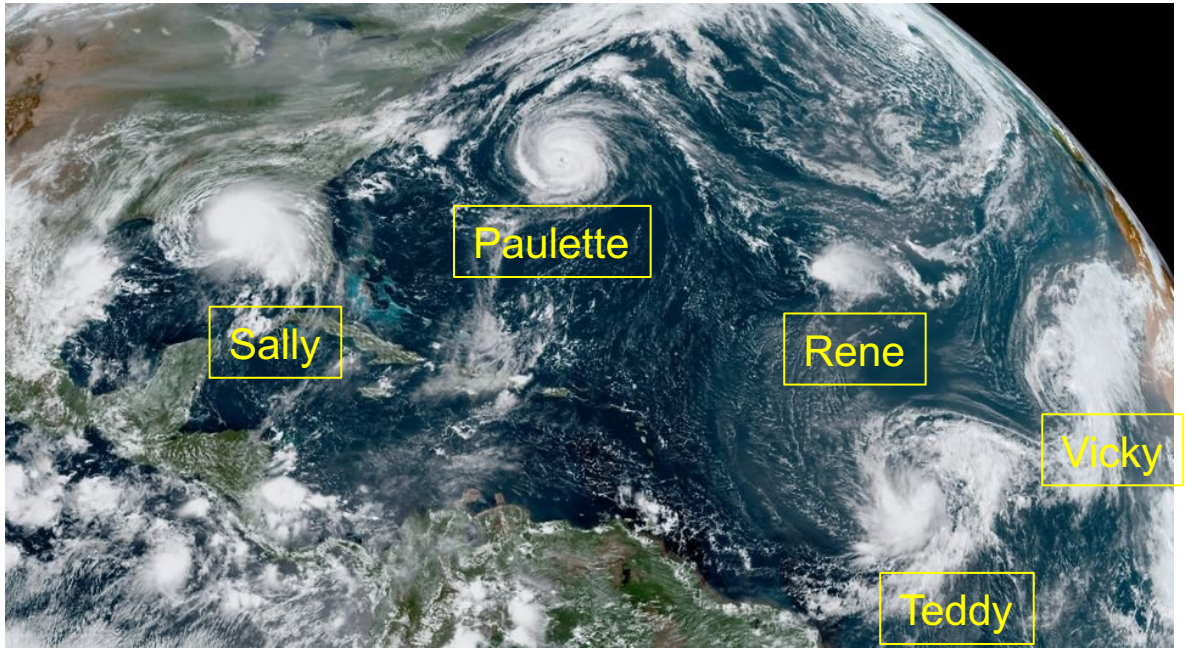


For more information and further updates ”watch”

https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+48r1



20200913 00 UTC + 41 h



NOAA

Cycle 48r1:
Delivering an operational 9 km medium-range global ensemble!