Cycle 47r3 overview

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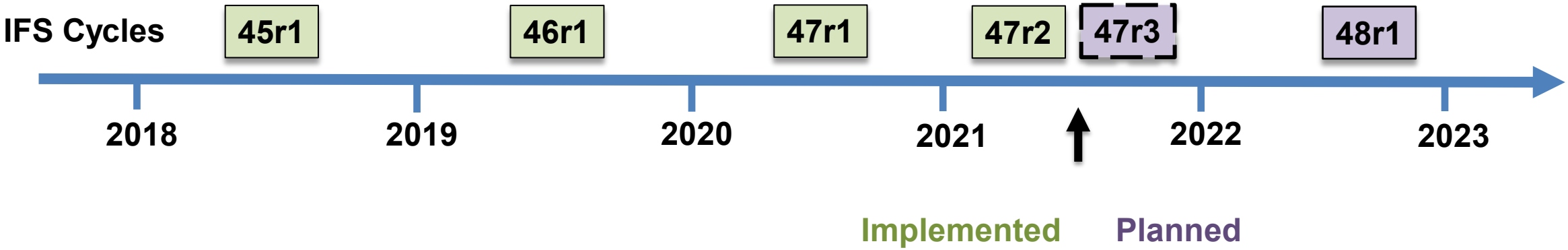
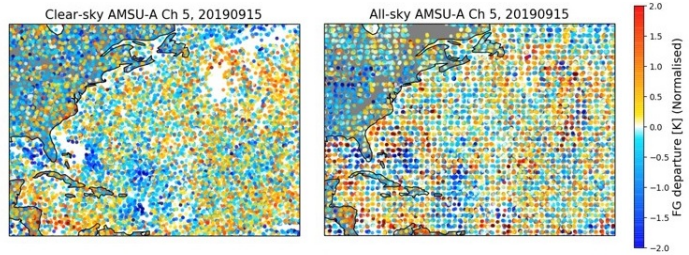
IFS Cycle 47r3

- IFS upgrades (“Cycles”) approximately one per year
- Originally planned for 48r1 to be the next Cycle after 47r1
- Single precision was brought forward to 47r2,
  enabled ENS vertical resolution to increase to L137 (operational implementation 11 May 2021)
- Now an opportunity to bring forward other planned changes for a second Cycle this year, 47r3

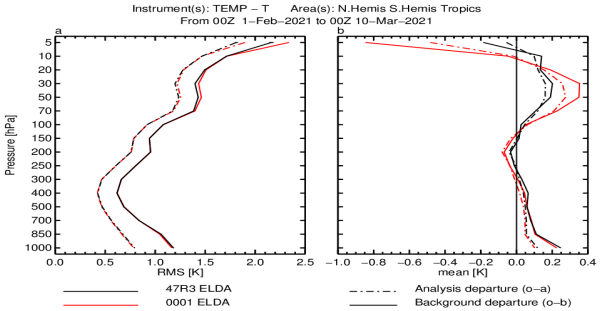


IFS Cycle 47r3

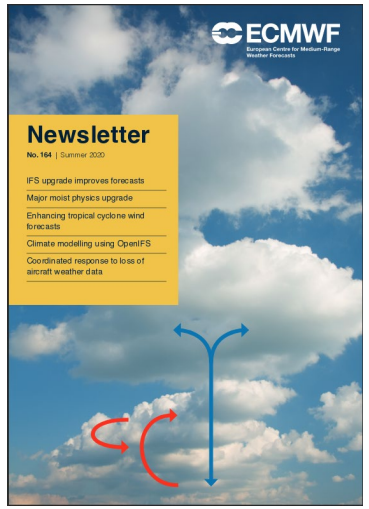
1. Changes to observation usage in the assimilation
   (infra-red, microwave, atmospheric motion vectors, Aeolus winds)



2. Weak constraint 4DVar for stratosphere in EnsembleDA



3. Major revision to improve the physical and numerical basis for moist processes in the IFS



SCIENCE DEVELOPMENTS IN 47R3

Observations: Assimilation of all-sky AMSU-A

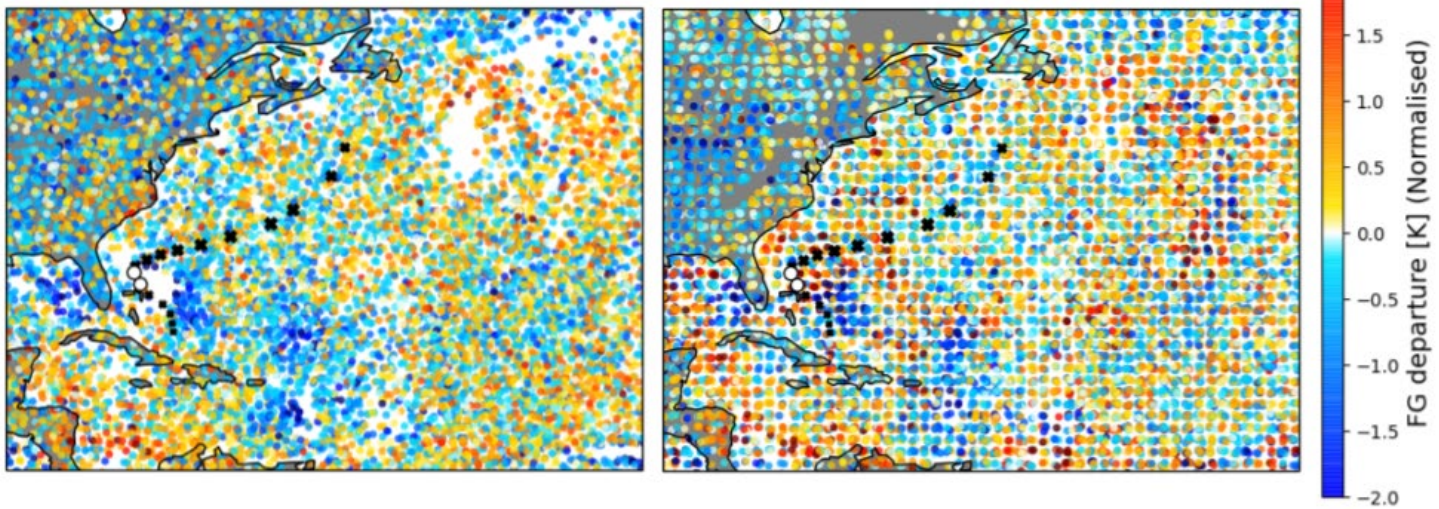
Satellite	Launch	EOL	Broken Channels
NOAA-15	1998	-	6, 11, 14
NOAA-16	2000	2014	8, 9
NOAA-17	2002	2003	N/A
Aqua	2002	-	1, 2, 5, 6, 7, 14
NOAA-18	2005	-	8, 9
Metop-A	2006	2021	7, 8
NOAA-19	2009	-	7, 8
Metop-B	2012	-	15
Metop-C	2018	-	-

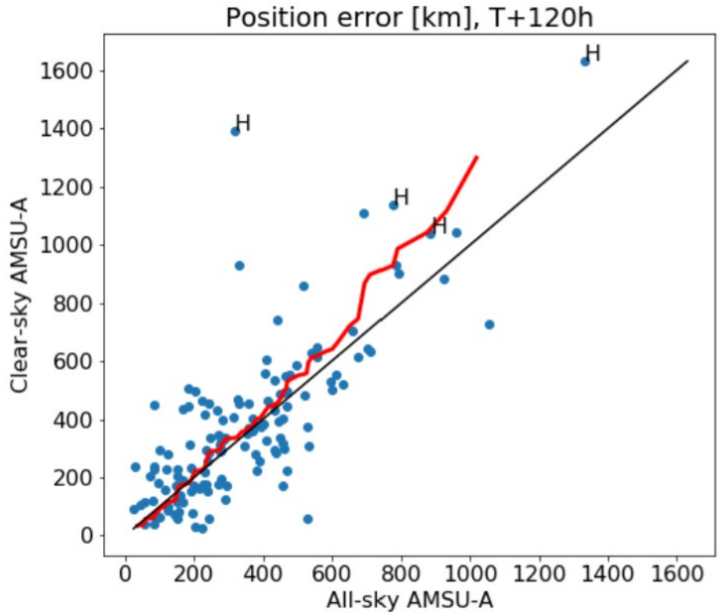
AMSU-A channels 5 to 14 are actively assimilated. These are channels with primary sensitivity to temperature from the mid-troposphere through upper stratosphere

In 47r3, **"clear-sky" assimilation is replaced by "all-sky"**, treating satellite radiances in all atmospheric conditions

Clear-sky

All-sky



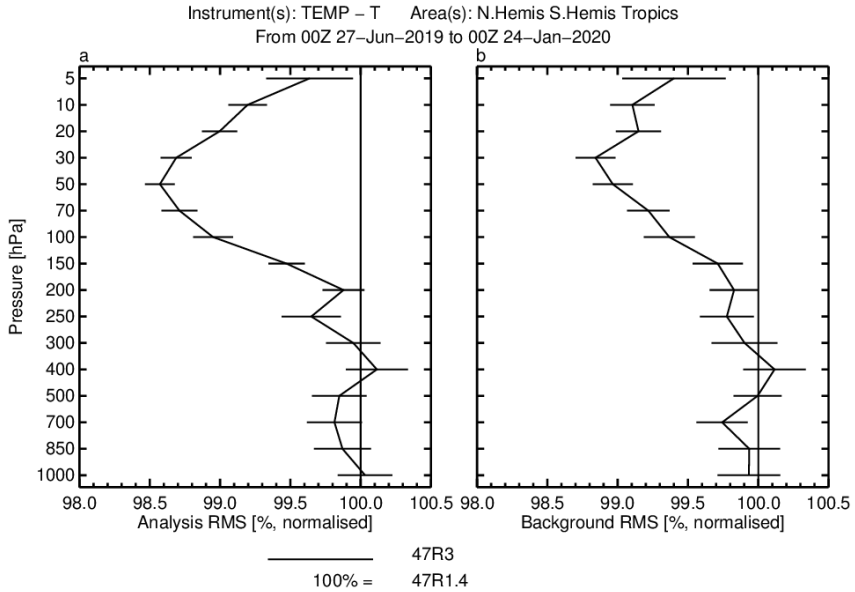


➔ Assimilation of all-sky AMSU-A: Increases use of microwave sounder data in areas of cloud and precipitation (+12% global increase for Channel 5)

➔ Provide critical observations near Tropical Cyclones (Hurricane Humberto shown on left)

Data assimilation: Improved upper atmosphere

1. New RTTOV coefficients for hyperspectral infrared (IR) sounders.
The new coefficients are based on a new CO2 transmittance scheme and more vertical layers



➔ Analysis better fits the temperature measurements from radiosondes

➔ Improvement translates in the forecast

2. Weak-constraint 4D-Var is implemented in EDA (stratosphere only) to reduce model biases in the stratosphere and make it consistent with HRES

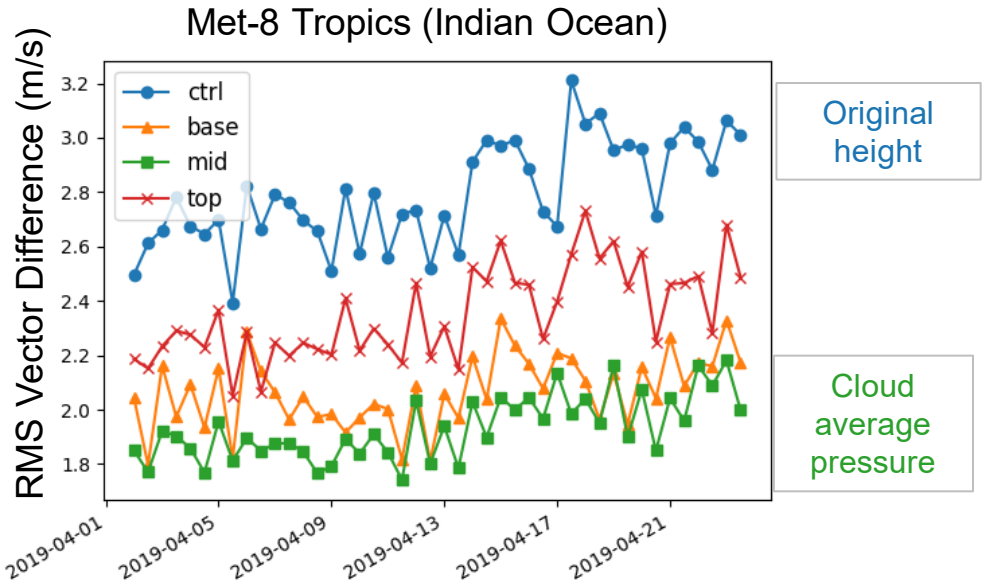
EDA Tco 399 (winter+summer) T RMSE

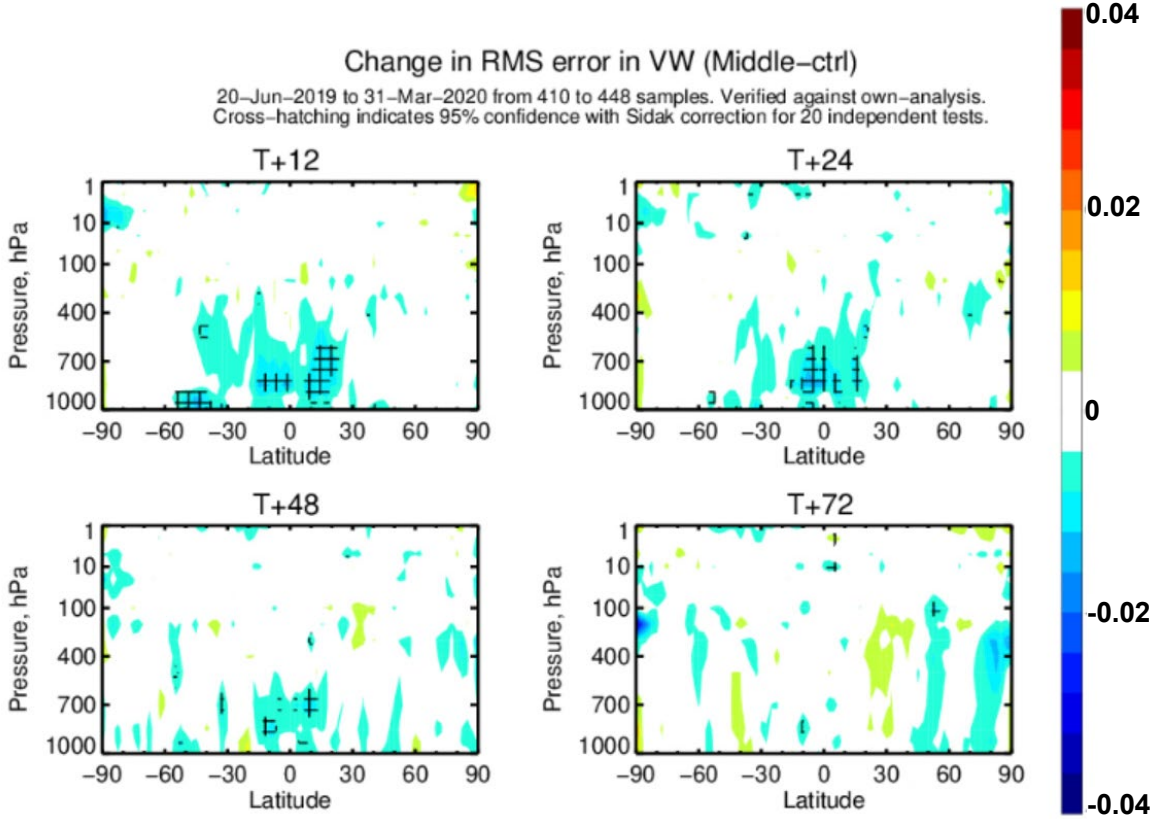
➔ RMSE is reduced by 5%

➔ The bias in the stratospheric temperature analysis is reduced by up to 50%.

Data assimilation: Improve wind analysis

1. Heights of low level AMVs diagnosed above the model cloud are reassigned to the cloud average pressure

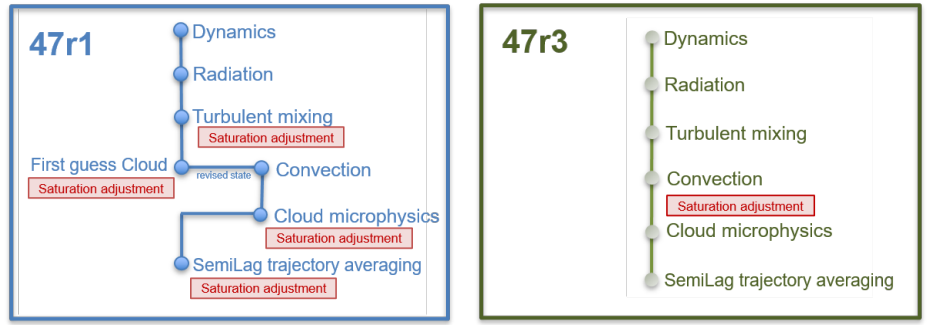




2. Add representativeness error in the total observation error for Aeolus

Moist physics upgrade – a significant package of developments

Timestep sequence with changes to saturation adjustment



Major revision to moist processes

A more consistent formulation of boundary layer turbulence, shallow convection, sub-grid cloud and microphysics

→ improved physics, numerics and interactions between parametrizations
→ simpler timestep sequence and approach to saturation adjustment
→ a stronger foundation for further improvements in the future
→ impacts all aspects of the forecast, across regions, across forecast time ranges

Parametrized convection

Total advective moisture convergence in convective instability closure (in addition to CAPE)

→ improved precipitation pdf, some MCS propagation improvement, increased rain in arid regions
→ improved scale-independence for convection-permitting resolutions

Parametrized cloud processes and radiation

Improved cloud/precip microphysical processes and cloud vertical overlap for radiation

Dynamics

Higher order departure point interpolation (cubic) for cloud liquid, ice, rain, snow

→ less smoothing of cloud/precipitation fields

More details in…

ECMWF Newsletter 164 (Summer 2020)

ECMWF

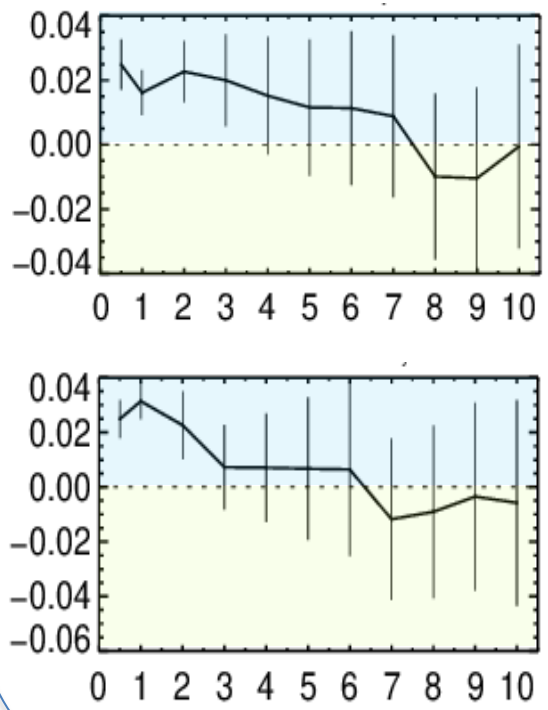
METEOROLOGICAL IMPACTS HIGHLIGHTS FOR 47R3

47r3 Highlight: Extratropical geopotential and wind

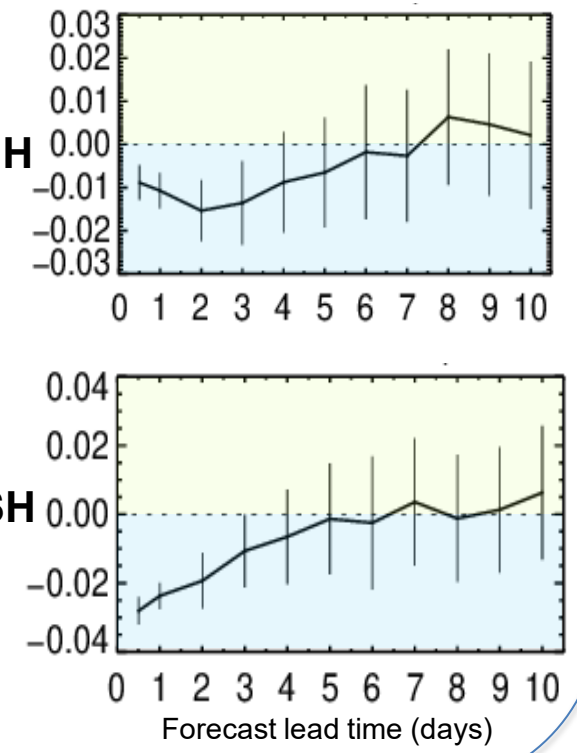
- Improved upper-air geopotential and winds (1-2%) in the first few days of the forecast
- Northern and Southern hemispheres, HRES and ENS

HRES

Geopotential 500hPa Anomaly Correlation
(normalised difference)

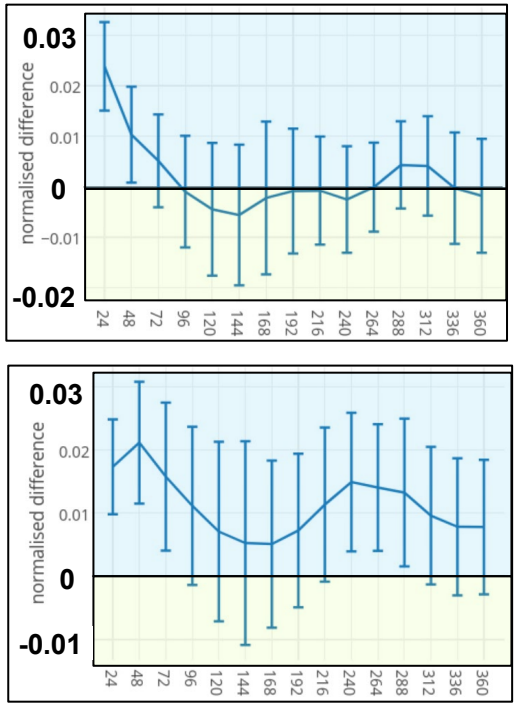


Vector Wind 500hPa RMSE
(normalised difference)

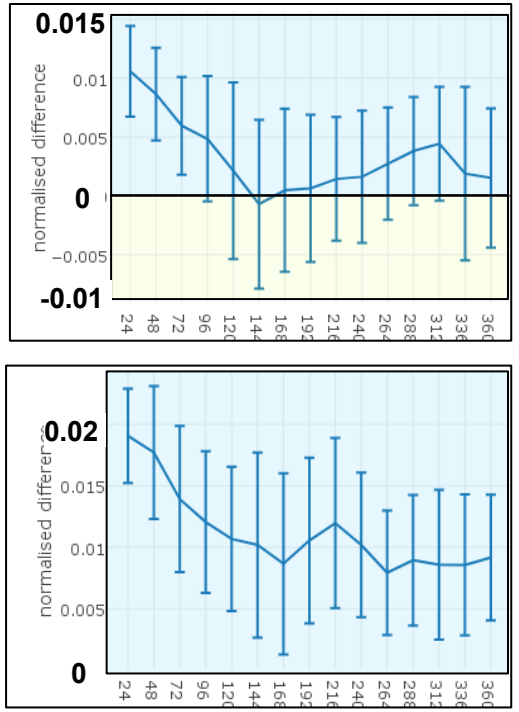


ENS

Geopotential 500hPa CRPS
(normalised difference)



Wind 500hPa CRPS
(normalised difference)

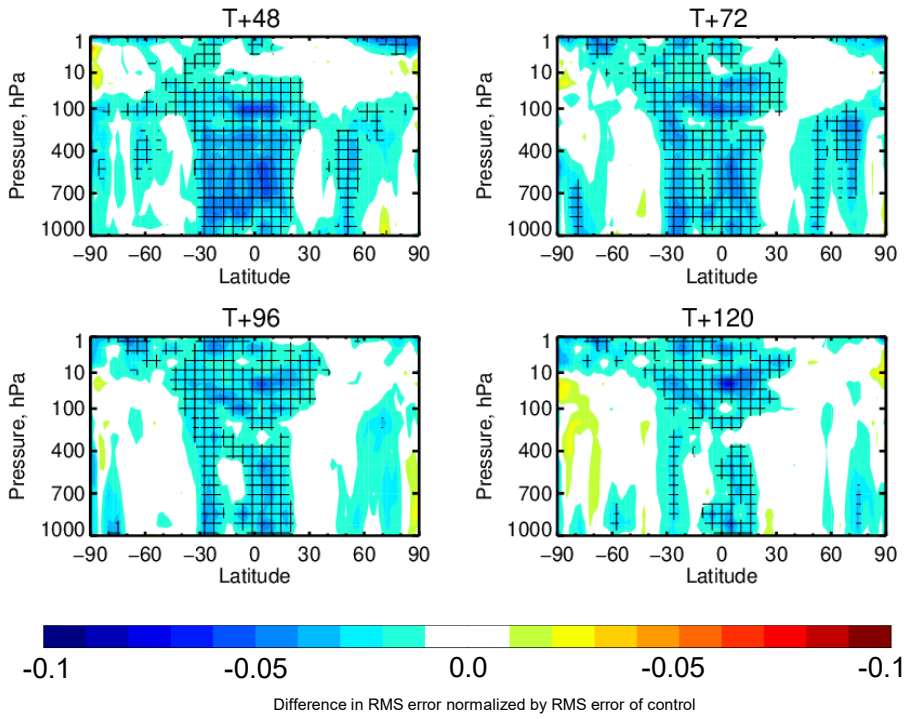


47r3 Highlight: Tropical winds

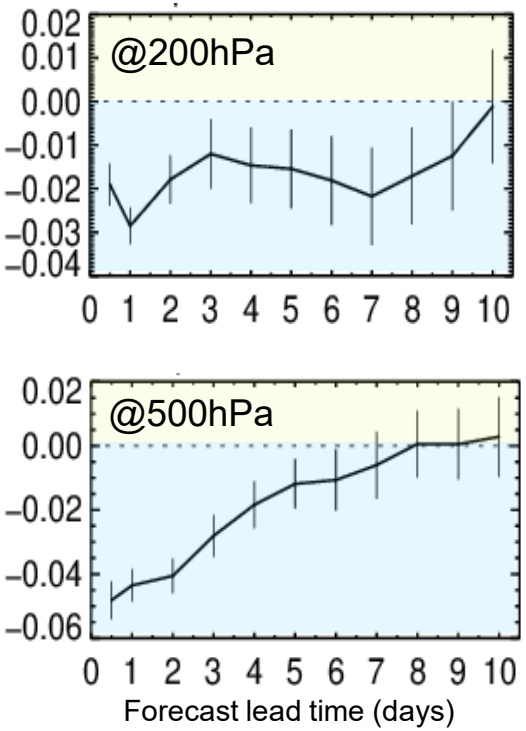
- Improved tropical upper-air winds (2-4%)
- HRES and ENS

HRES

Zonal cross section of Wind RMSE
(normalised difference)

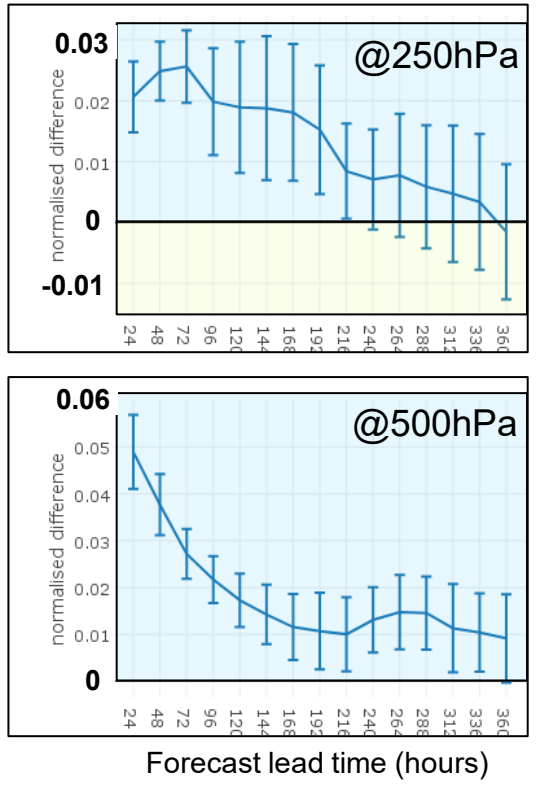


Tropics Wind RMSE
(normalised difference)



ENS

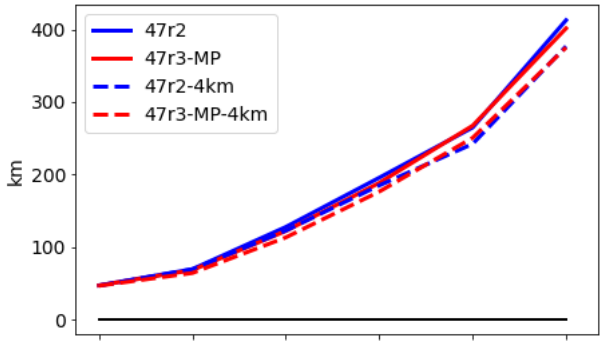
Tropics Wind CRPS
(normalised difference)



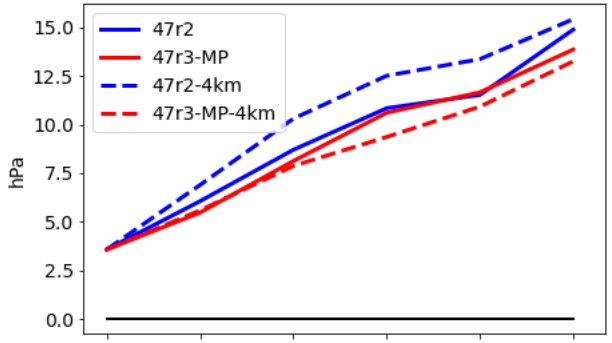
47r3 Highlight: Tropical Cyclones - HRES 9km and future 4km resolution

Absolute error (km/hPa)

TC position

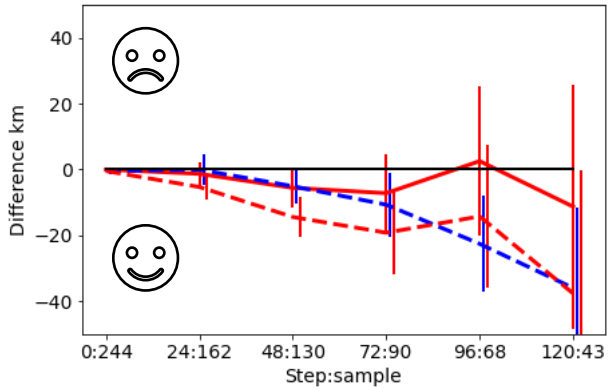


TC central pressure

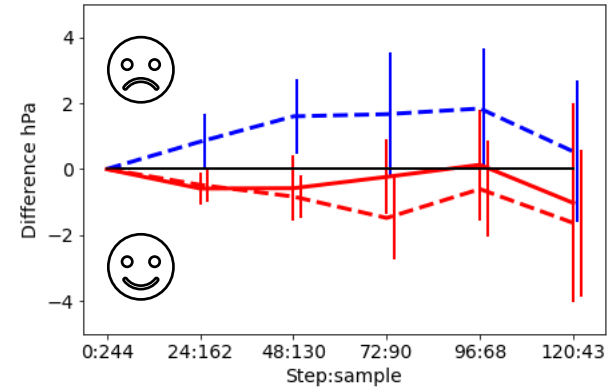


Absolute error (km/hPa) relative to 47r2 HRES

T+5 days



T+5 days



HRES (9km)
- 47r2
- 47r3 physics

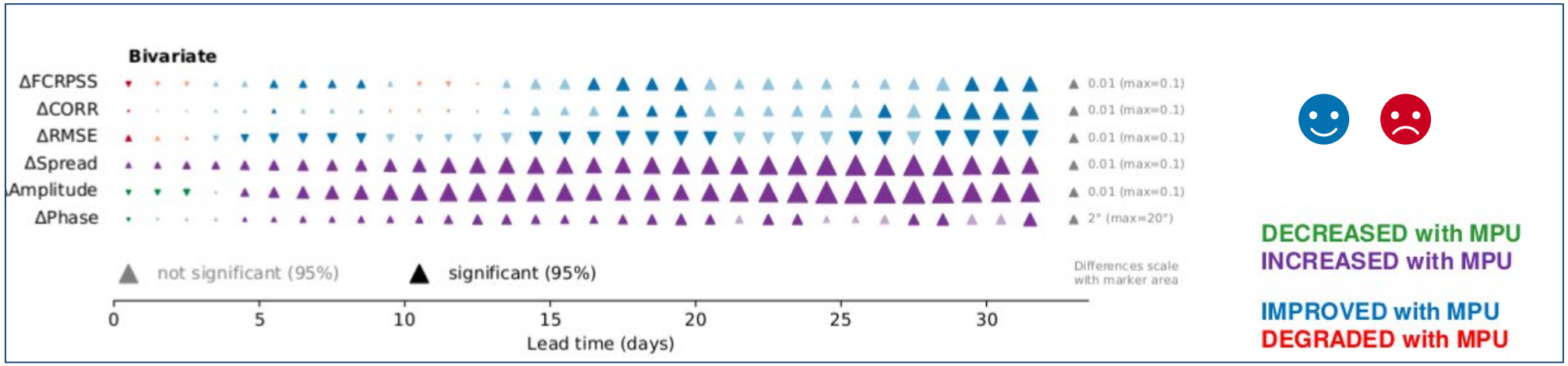
Future res (4km)
- 47r2
- 47r3 physics

- HRES position absolute error slightly improved (solid)
- HRES central pressure absolute error slightly improved (solid)
- Future 4km resolution significantly improved in 47r3 (dashed)

47r3 Highlight: Extended-range improvements to MJO

- TCo199 extended-range forecasts show improved MJO skill out to day 30
- Increase in amplitude/spread of RMM index and increase in eastward phase speed

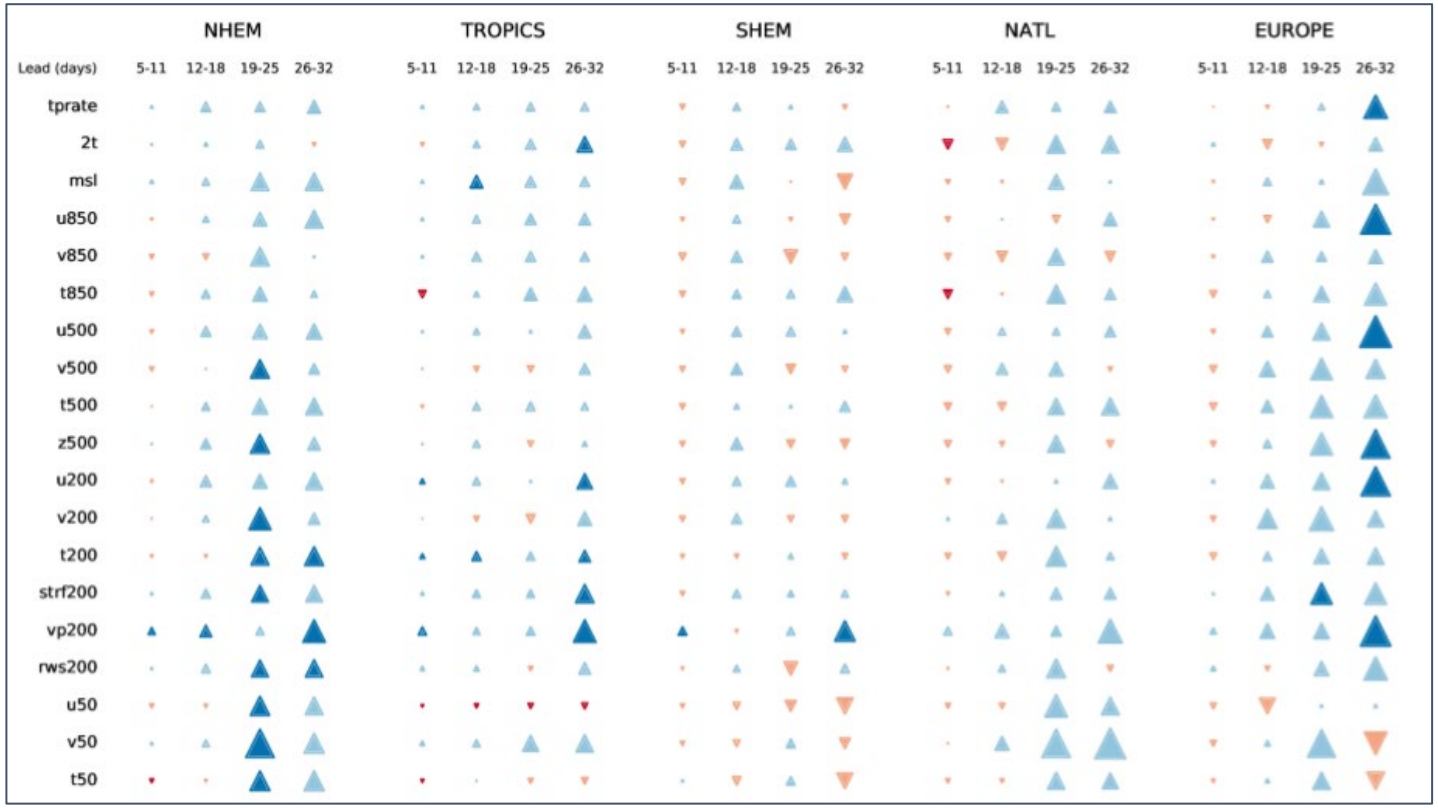
Madden-Julian Oscillation (MJO) RMM summary scorecard
47r3 versus 47r2, TCo199, 19890101-20161201

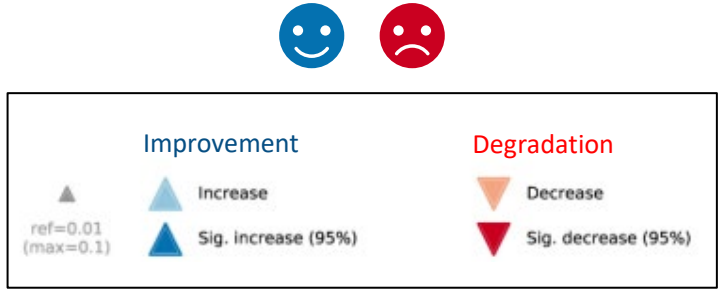


47r3 Highlight: Extended-range - small positive impact in weeks 3-4 Europe/NHem

- TCo199 extended-range forecasts suggest improvement in weeks 3 and 4 (NH, Europe)
- Due to improved representation of Madden-Julian Oscillation (MJO) and teleconnections from tropics

Impact on the weekly mean anomaly correlation for the extended-range forecasts

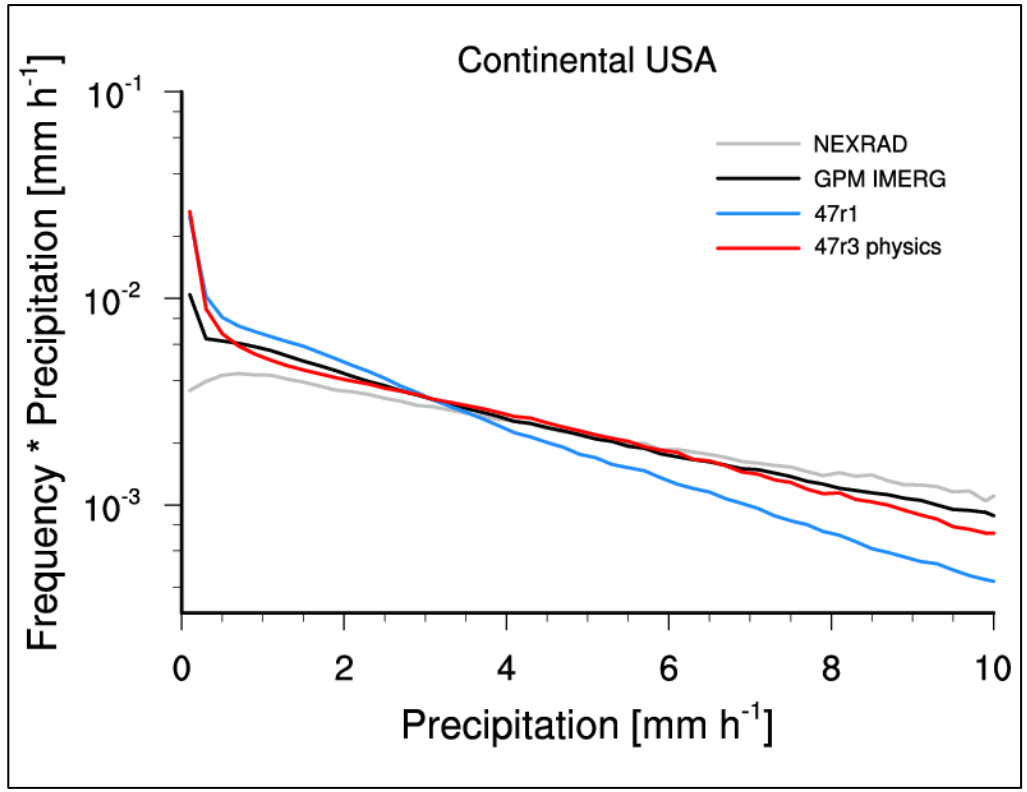


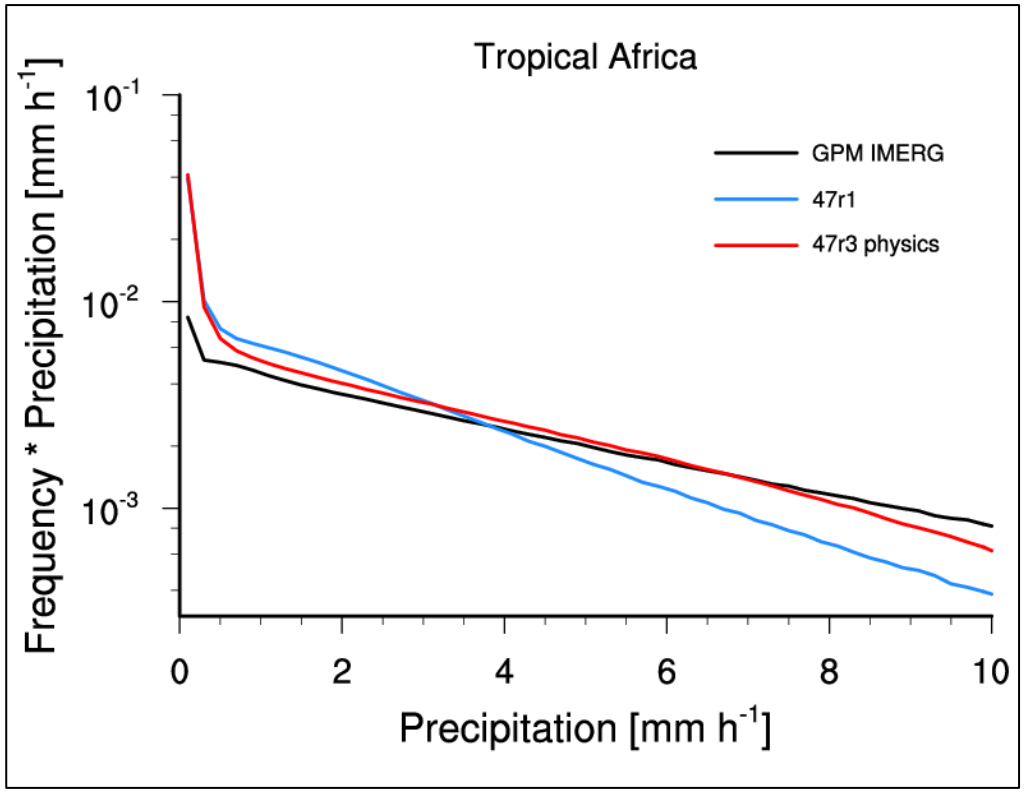


Change in the anomaly correlation due to the moist physics upgrade in Cycle 47r3 for different parameters and regions in the extended-range. The scores are weekly means from lower resolution (TCo199/ORCA1) extended-range forecasts for the period 1989 to 2016. Blue triangles represent an improvement, red represents a degradation.

47r3 Highlight: Improved precipitation PDF (convective regimes)

- With new convective closure, **47r3** IFS closer to **observed** PDF of precipitation rate than **47r1**

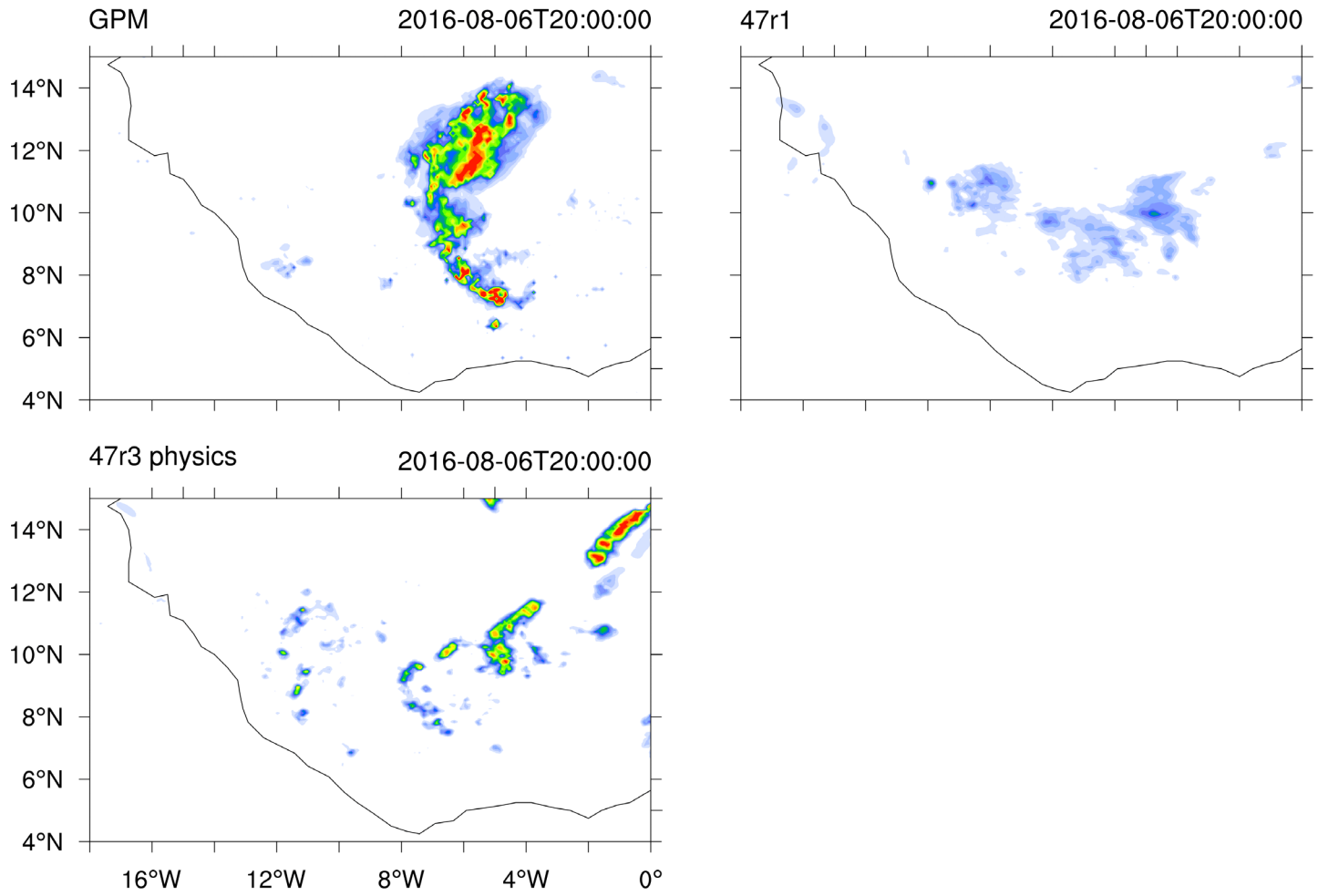




Frequency*precipitation distribution of the HRES 24-48 hour forecast hourly precipitation accumulations for the GPM-IMERG (black) and NEXRAD radar network (grey) observational products, 47r1 HRES (blue) and 47r3 physics (red). Data for August 2016 remapped to 0.1°. Note, the observational products tend to underestimate lighter rain rates.

47r3 Highlight: Improved organisation and propagation of squall lines (in some cases)

Animation of squall line propagation over Africa, 2016-08-06



47r3 scorecards for HRES and ENS (Jun & Dec 2020 + Feb/Mar 2021)

HRES (AC/RMSE)
(260 forecasts, 00&12Z)

ENS (CRPS)
(100 forecasts, 00Z)

NHem SHem Tropics

NHem SHem Tropics

Versus analysis

Upper-air Z HRES	**Upper-air Z** ENS	**ENS tropics T upper troposphere** CRPS very sensitive to 0.2K bias
Upper-air T HRES	**Upper-air T** ENS (excl tropics)	**T 850hPa vs analysis** over tropical/subtropical ocean
Upper-air Winds		**RH 700hPa vs analysis**
		T2m vs analysis over ocean

Versus obs

Upper-air Z	**ENS tropics T upper troposphere** CRPS very sensitive to 0.2K bias
Upper-air T (excl ENS tropics)	**T 850hPa** vs obs ~neutral
Upper-air Winds	**T2m** vs obs ~neutral
Upper-air Relative Humidity	**2m dew point / Wind 10m** (tropics)
Precipitation (CRPS tropics)	**Cloud Cover** increased variability

47r3 impact of small bias in ENS tropical upper tropospheric temperature

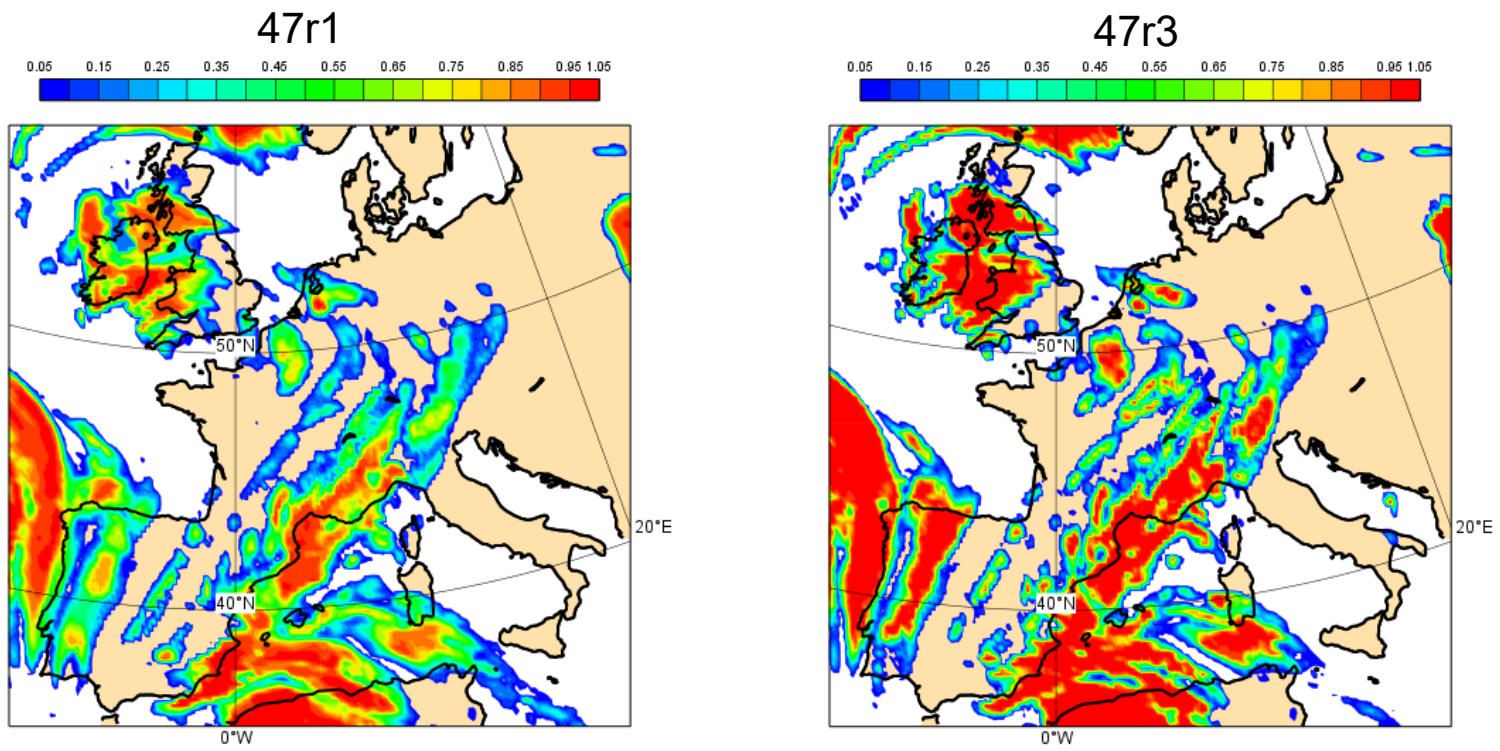
ENS RMSE
(very similar to CRPS)

ENS STDEV
(domain mean bias removed)

- In the tropical upper troposphere:
  - ensemble spread / STDEV is small ~1K
  - 47r1/47r2 ENS bias is close to 0
  - a small mean warming of ~0.2K gives a large relative change for bias-sensitive scores such as CRPS/RMSE
- Bias-independent scores (STDEV, bias-corrected CRPS) show positive / neutral change
- For example, tropics T500hPa versus analysis
  Full ΔCRPS gives 9% degradation,
  Bias-corrected ΔCRPS gives 3% improvement
- Helps to understand the large impact on the CRPS score, due to a small 0.2K increase in bias

47r3 increased variability in cloud-related fields

- In 47r3, cloud cover is increased by ~3%, is more binary (increased occurrence of cloud fraction=1) and has more smaller scale structure → less “smooth”, higher RMSE



Example: HRES High Cloud Cover 2021-03-03 00Z T+9

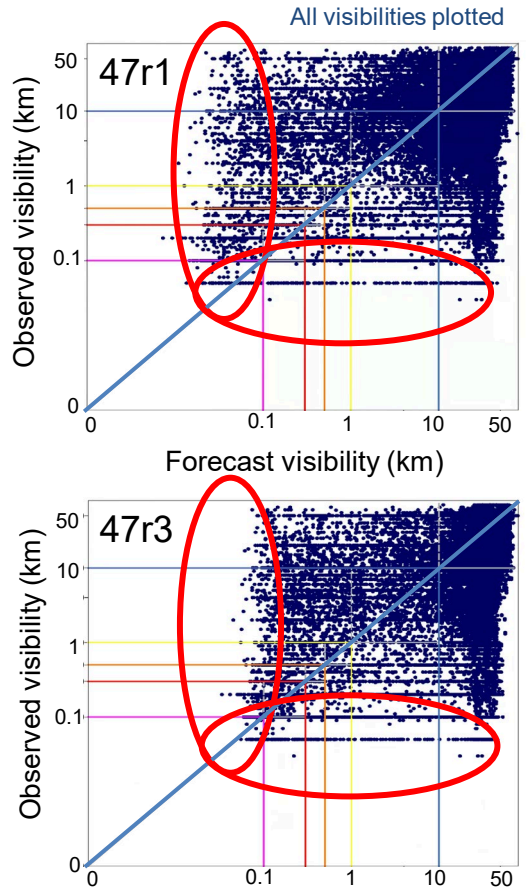
NEW AND REVISED PRODUCTS IN 47R3

47r3 Products – revised visibility in fog and precipitation

- Improved extinction coefficients for visibility calculations leads to reduced bias compared to observations

Fog

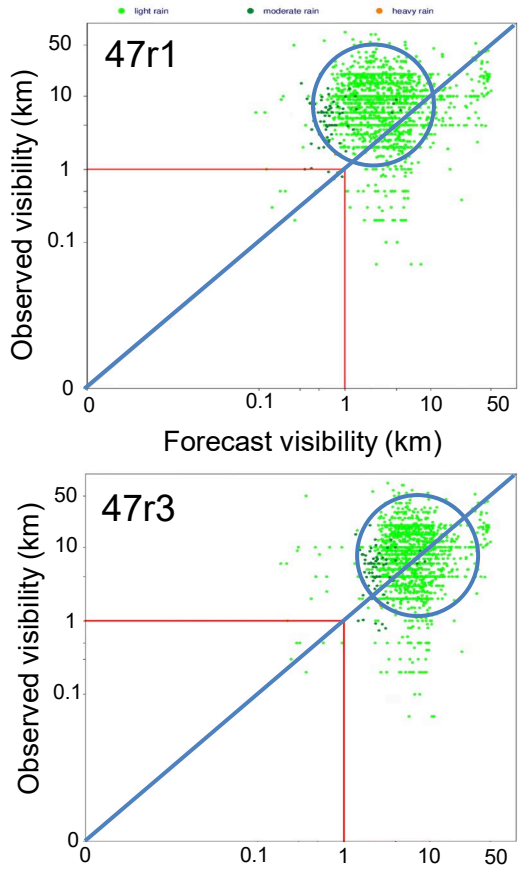
Visibility was too low in thick fog
Less occurrence of <100m visibility
Closer to obs



Rain

Visibility was too low
Now increased
Closer to obs

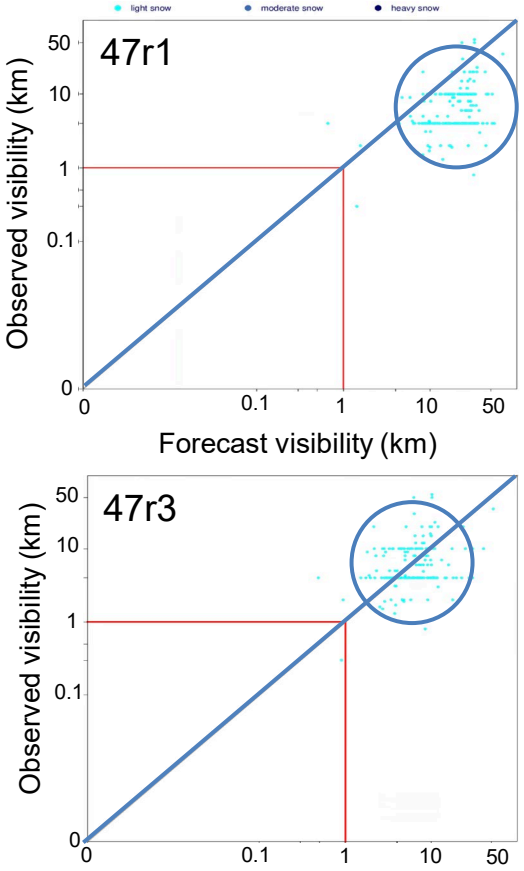
Light rain	Average visibility
Obs	9500 m
47r1	4500 m
47r3	7800 m



Snow

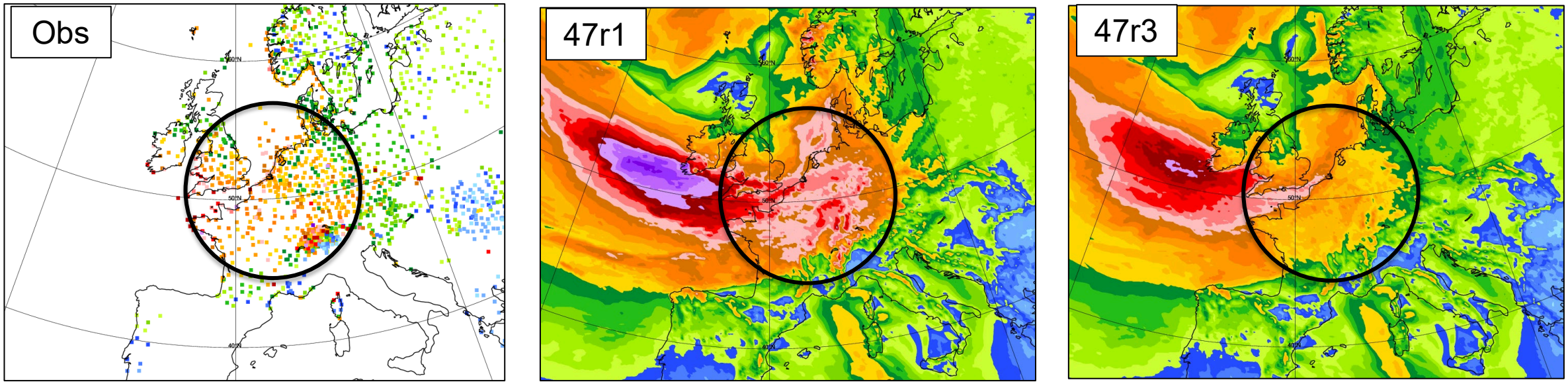
Visibility was too high
Now reduced
Closer to obs

Light snow	Average visibility
Obs	7300 m
47r1	22000 m
47r3	7700 m



47r3 Products – revised wind gusts

- Wind gusts too strong in unstable conditions in 47r1 HRES & ENS
- Revision of gust parametrization in 47r3 – half convective gust factor and 7% reduction in turbulent gust factor
- 47r3 closer agreement to observations



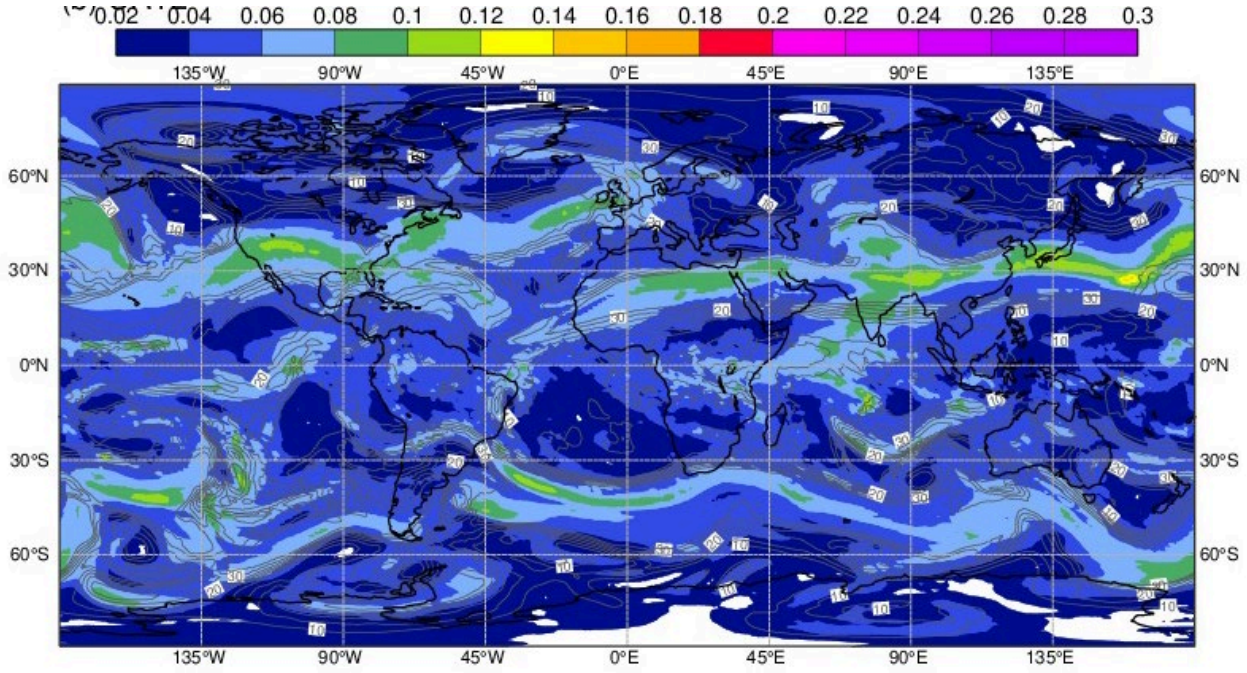
Case study: 8 Feb 2016 00z
HRES 24 hour forecast

47r3 New Products (Member State requests)

Short Name	Name	Units	Component
trpp	Tropopause pressure	Pa	HRES
degm10l	Altitude of -10 degrees C isothermal level	m	HRES/ENS
u10n	Neutral wind at 10 m u-component	$m\ s^{-1}$	ENS
v10n	Neutral wind at 10 m v-component	$m\ s^{-1}$	ENS
mlcape50	Mixed-layer CAPE in the lowest 50 hPa	$J\ kg^{-1}$	HRES/ENS
mlcin50	Mixed-layer CIN in the lowest 50 hPa	$J\ kg^{-1}$	HRES/ENS
mlcape100	Mixed-layer CAPE in the lowest 100 hPa	$J\ kg^{-1}$	HRES/ENS
mlcin100	Mixed-layer CIN in the lowest 100 hPa	$J\ kg^{-1}$	HRES/ENS
mucape	Most-unstable CAPE	$J\ kg^{-1}$	HRES/ENS
mudlp	Departure level (pressure) of the most unstable parcel	Pa	HRES/ENS
cat	Clear air turbulence (CAT)	$m^{-2/3}\ s^{-1}$	HRES (ml)

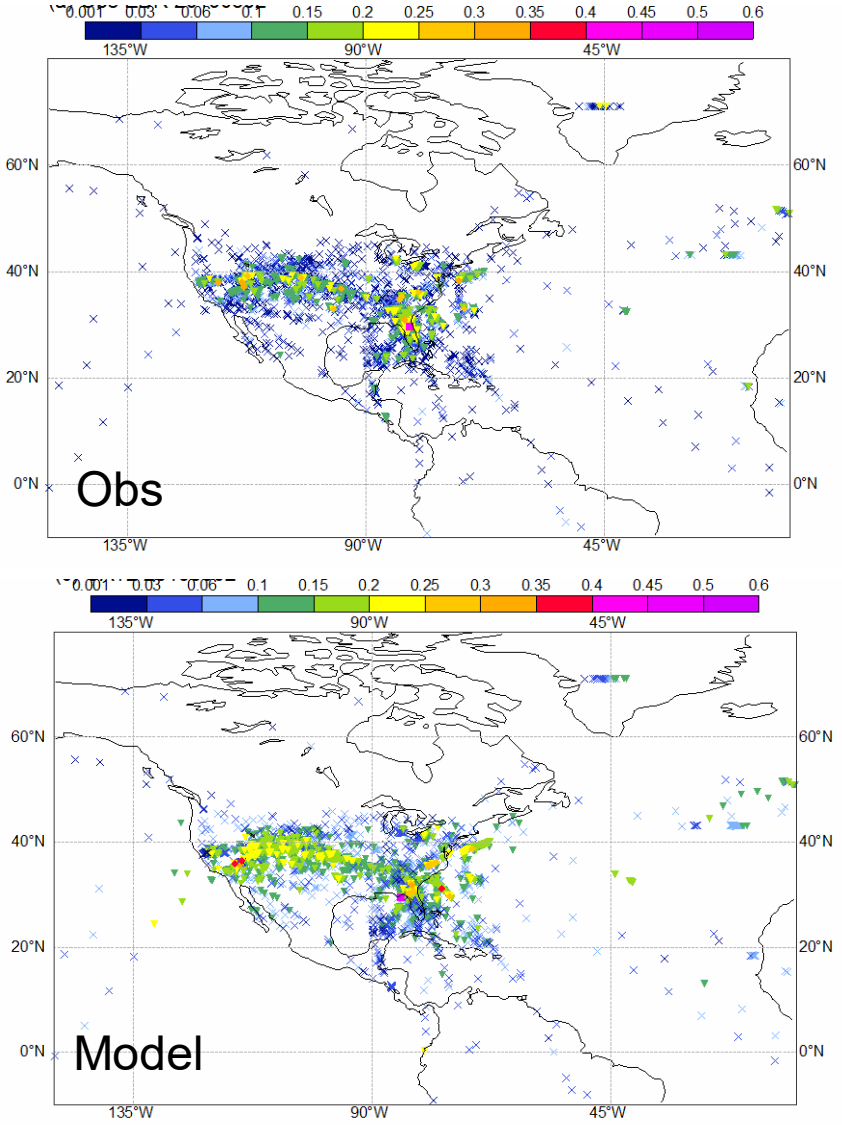
47r3 New Product: Clear Air Turbulence (CAT)

- Based on eddy dissipation rate (EDR)
- Details in
  - ECMWF Tech Memo 874
  - ECMWF Newsletter No 168, summer 2021



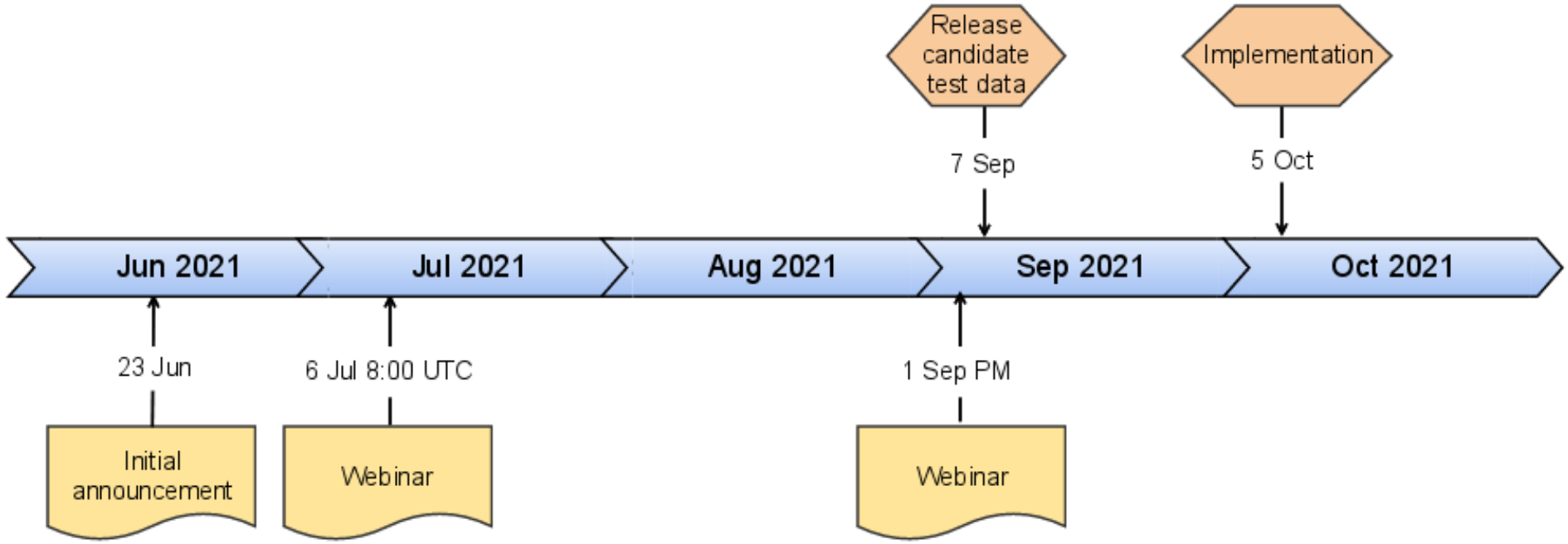
Eddy Dissipation Rate ($m^{2/3}$ s^{-1}) daily average for 20190302 level 10-12 km, wind isotachs at 250 hPa (grey contours)

Eddy Dissipation Rate ($m^{2/3}$ s^{-1}) at aircraft locations on 20190302



47r3 TIMELINE

47r3 Implementation timeline



See latest information at:
https://confluence.ecmwf.int/display/FCST/Implementation+of+IFS+Cycle+47r3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