Cycle 47r3 overview

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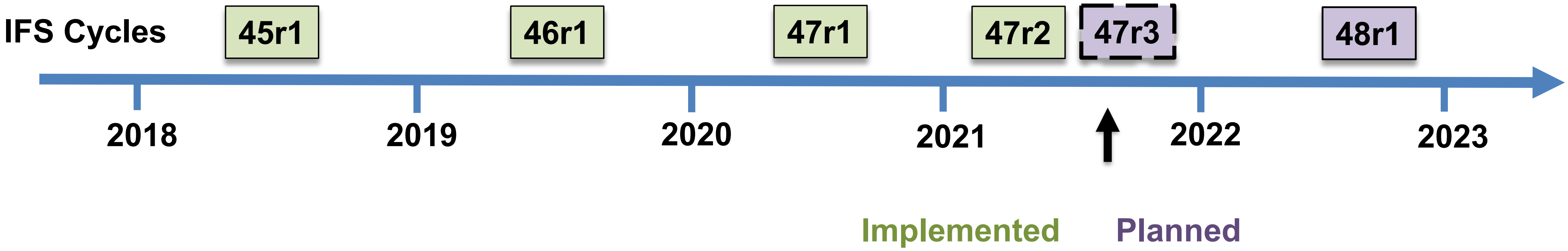
September 2021

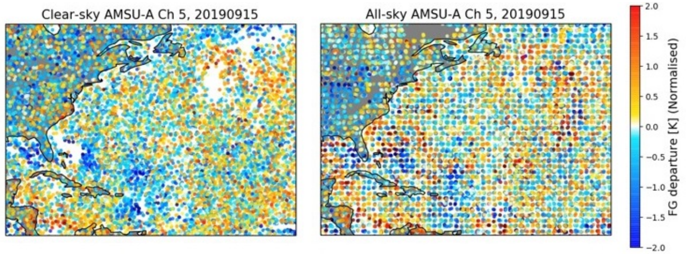
IFS Cycle 47r3

- 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

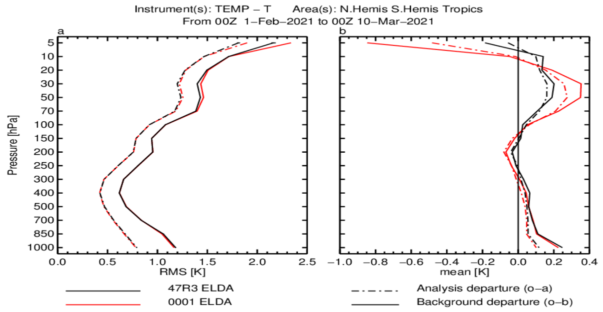


IFS Cycle 47r3

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

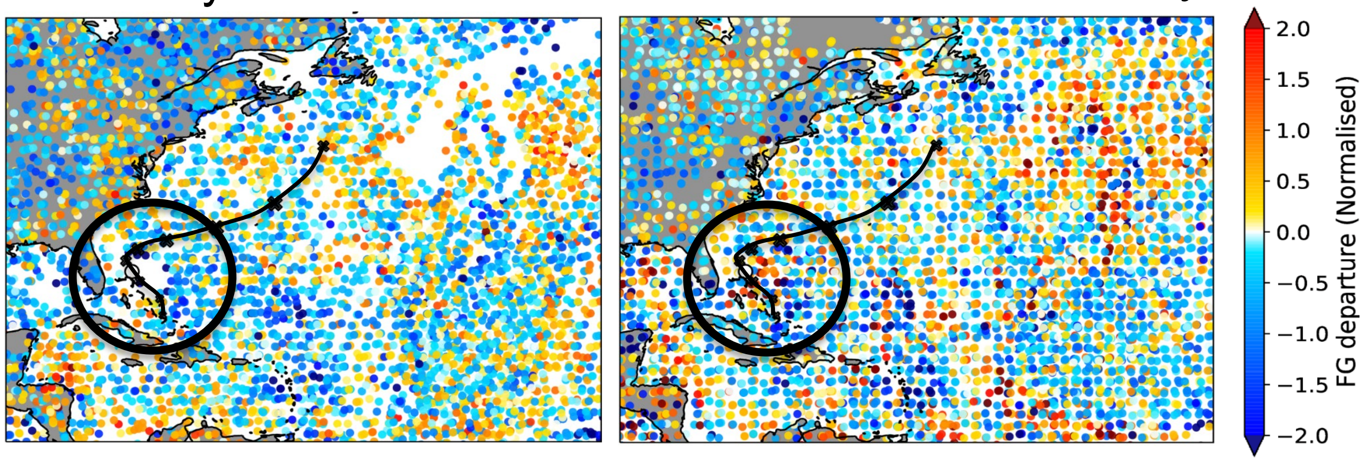
Observations: Assimilation of all-sky AMSU-A

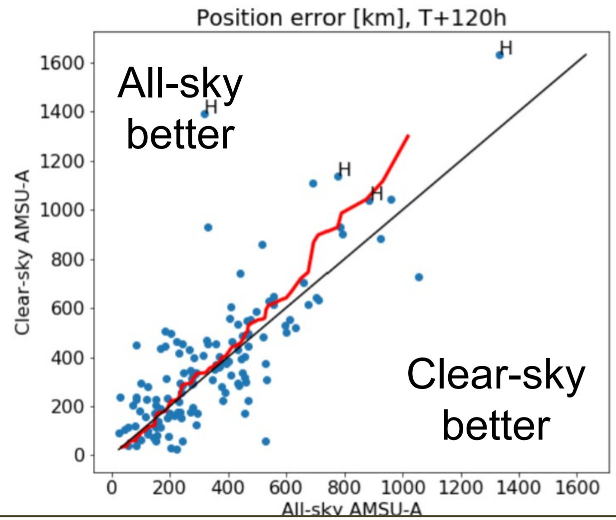
Satellite	Launch	EOL	Broken Channels
NOAA-15	1998	-	6, 11, 14
NOAA-16	2000	2014	8, 9
NOAA-17	2002	2003	N/A
Aqua	2002	-	1, 2, 5, 6, 7, 14
NOAA-18	2005	-	8, 9
Metop-A	2006	2021	7, 8
NOAA-19	2009	-	7, 8
Metop-B	2012	-	15
Metop-C	2018	-	-

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   Hurricane Humberto   All-sky

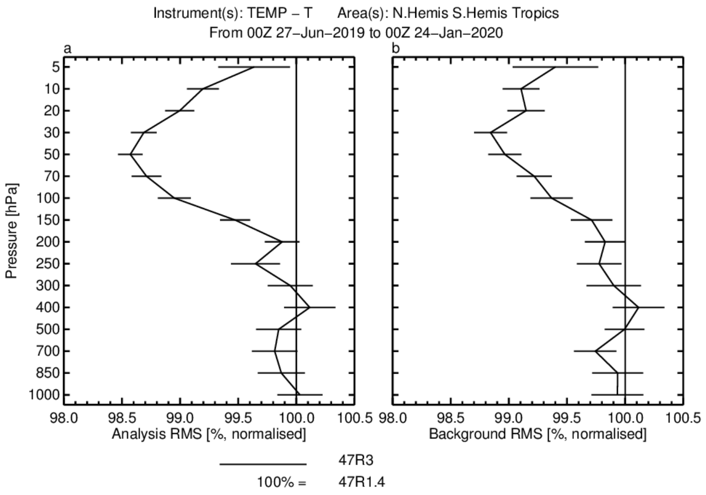




- ➔ Assimilation of all-sky AMSU-A: Increases use of microwave sounder data in areas of cloud and precipitation (+12% global increase for Channel 5)
- ➔ Provide critical observations near Tropical Cyclones (example: Hurricane Humberto)

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

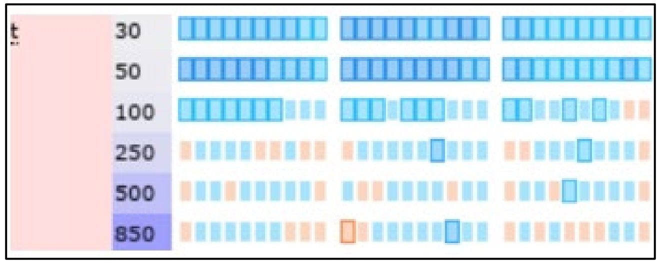


➔ Analysis better fits the temperature measurements from radiosondes

➔ 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

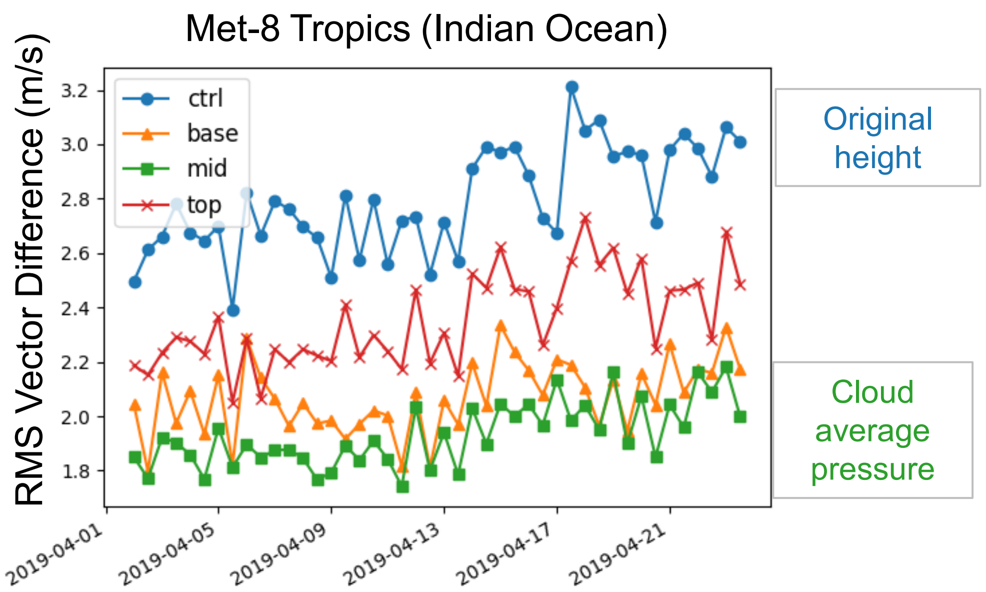


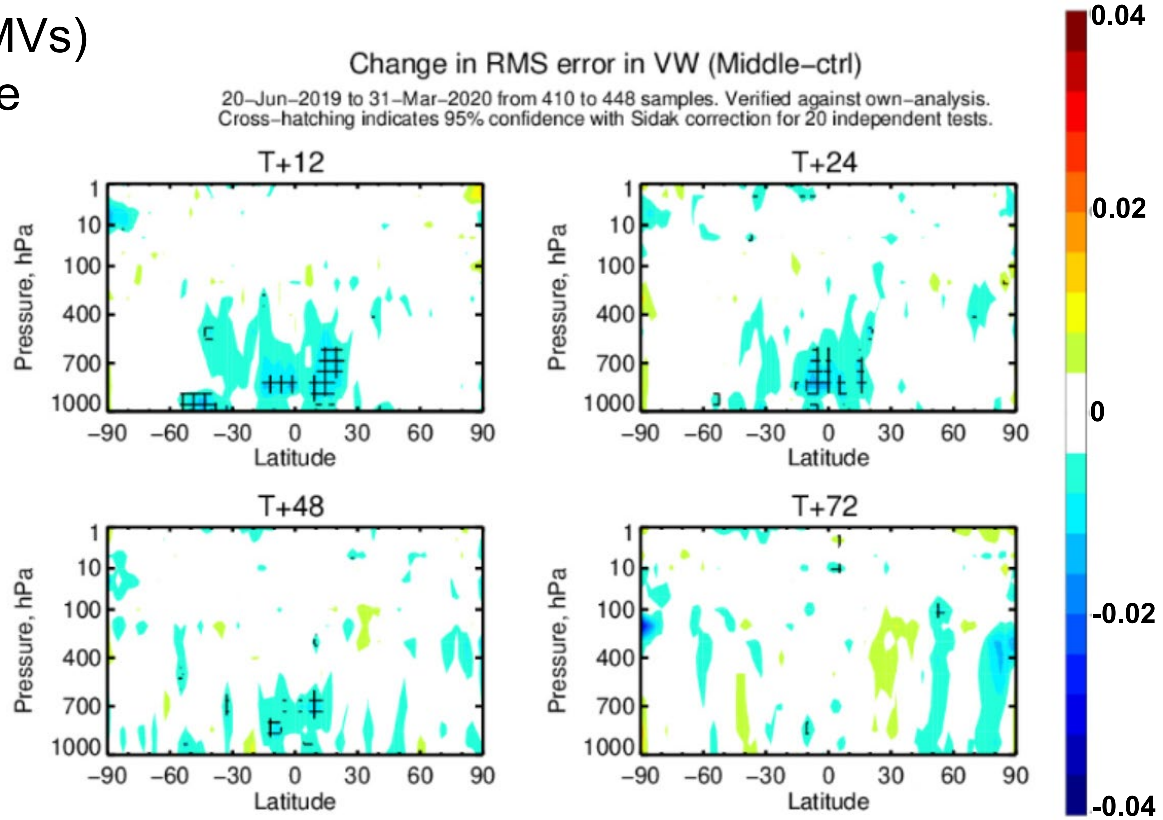
➔ RMSE is reduced by 5%

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

Data assimilation: Improved wind analysis

1. Heights of low level Atmospheric Motion Vectors (AMVs) diagnosed above the model cloud are reassigned to the cloud average pressure



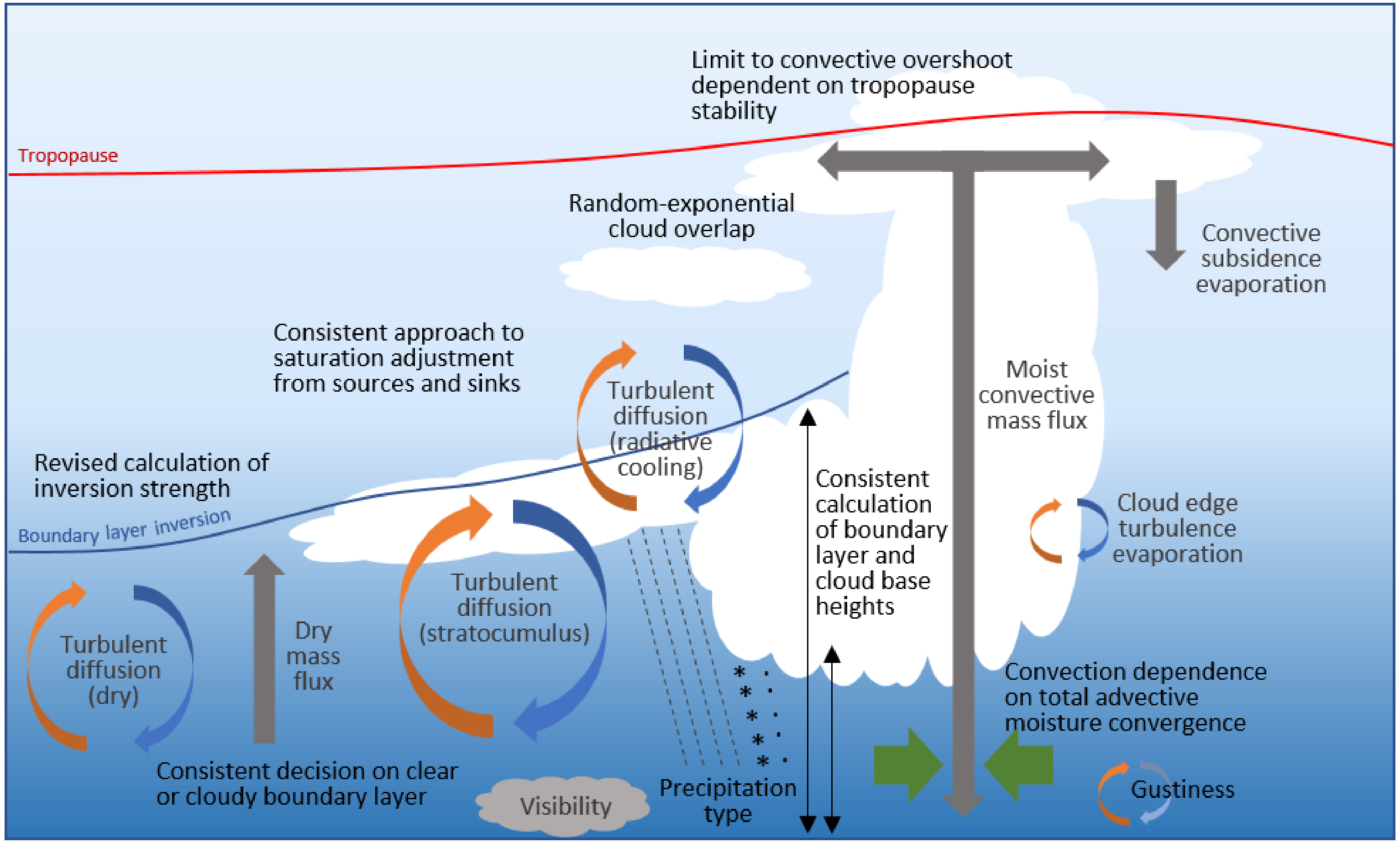


2. Representativeness error added into the total observation error for Aeolus (lidar winds)

Moist physics upgrade in IFS Cycle 47r3

- Major development to moist physics parametrizations (cloud, convection, turbulent mixing, microphysics)
- **Simpler interactions**, **more consistency**, **improved physical processes**, **better numerics**

Changes to many different aspects of the moist physics…



More details in…

ECMWF Newsletter 164 (Summer 2020)
(www.ecmwf.int/en/publications/newsletters)

Moist physics upgrade in IFS Cycle 47r3

- **Impacts all aspects of the forecast** across regions and across forecast timescales – many positives but also a few negatives

- **Changes the character of cloud and precipitation** (more small scale structure) and **improves storm organisation**
  (due to changes to the convective closure including total advective moisture, to saturation adjustment and higher order departure point interpolation)

- **More accurate tropical cyclone tracks** from improved tropical winds

- **Improved MJO** in the extended range

- **A stronger foundation for the IFS physics** for the move to higher resolutions (3-5km) and future developments

METEOROLOGICAL IMPACTS HIGHLIGHTS FOR 47R3

47r3 summary - scorecards

HRES
(AnomCorr/RMSE)

ENS
(CRPS)

NHem SHem Tropics | NHem SHem Tropics

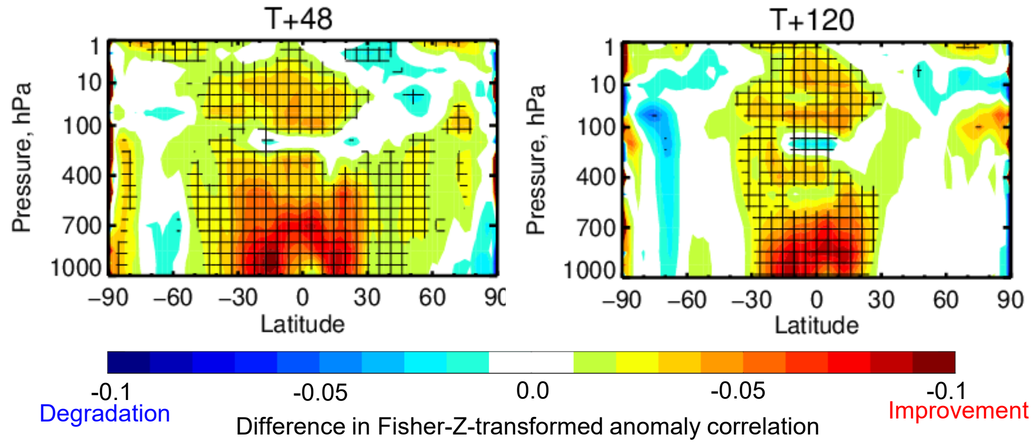
Versus analysis

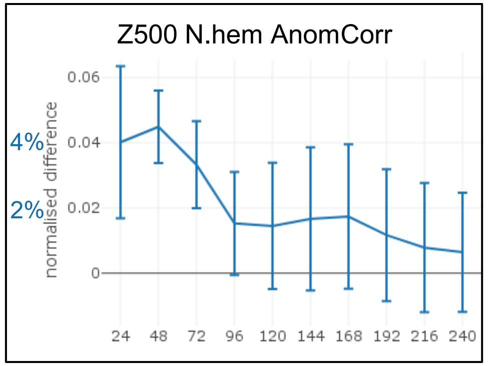
Versus obs

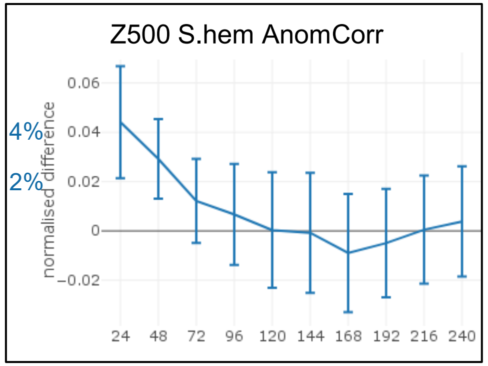
Based on 650 forecasts Jun 2020 - Aug 2021

(1) Improved upper air - GEOPOTENTIAL
AC Z500 geopotential NH/SH 1-4% improvement

HRES Geopotential Anomaly Correlation







47r3 summary - scorecards

HRES
(AnomCorr/RMSE)

ENS
(CRPS)

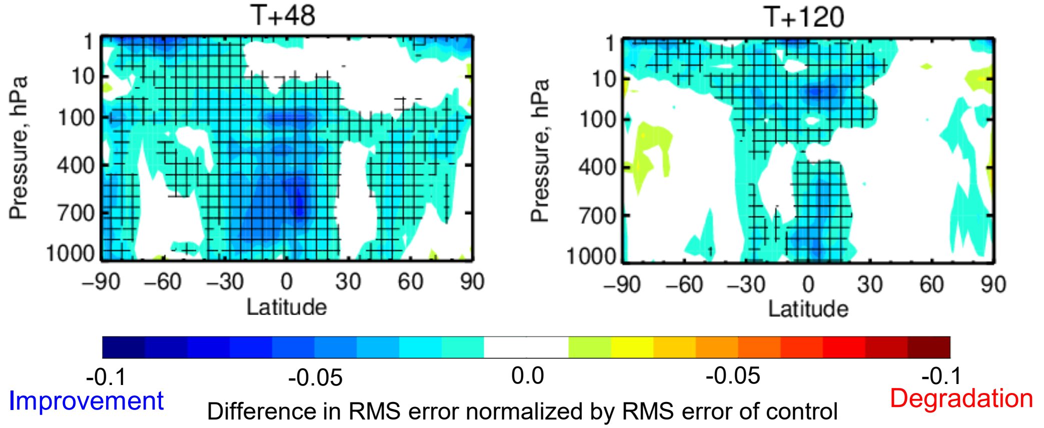
NHem SHem Tropics

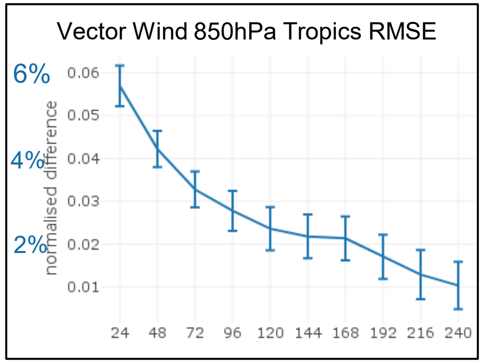
NHem SHem Tropics

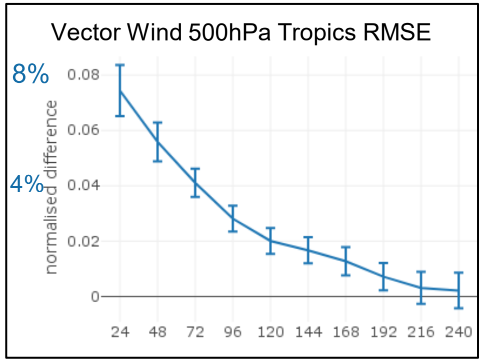
Versus analysis

Versus obs

(2) Improved upper air - WIND
RMSE extratropics 1-2%, tropics 1-7% improvement





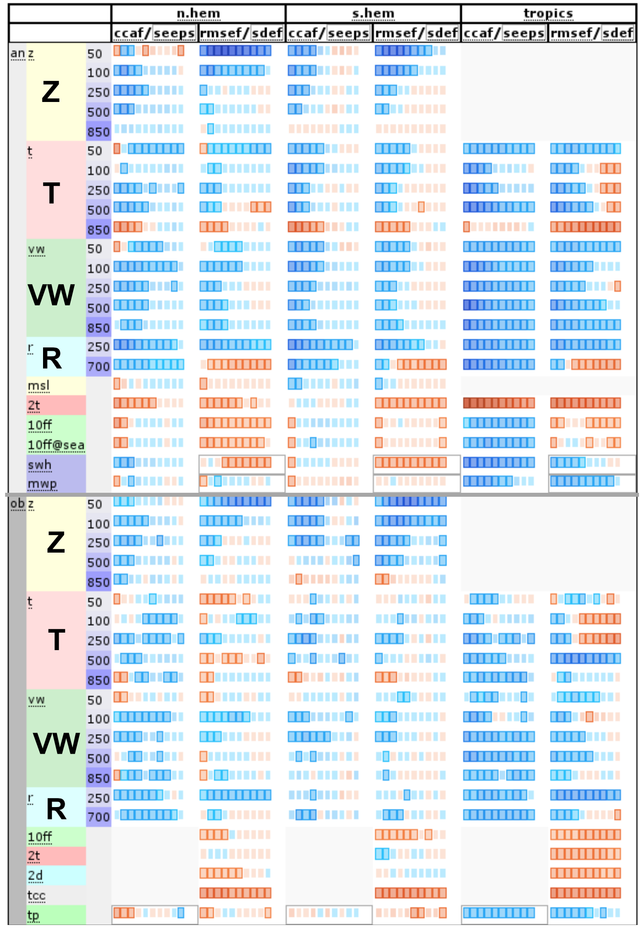


47r3 summary - scorecards

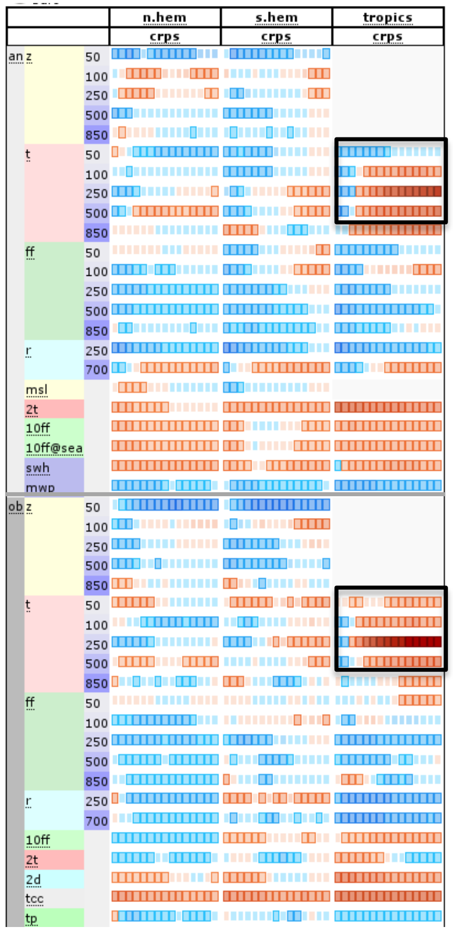
HRES
(AnomCorr/RMSE)
NHem SHem Tropics

Versus analysis

Versus obs



ENS
(CRPS)
NHem SHem Tropics

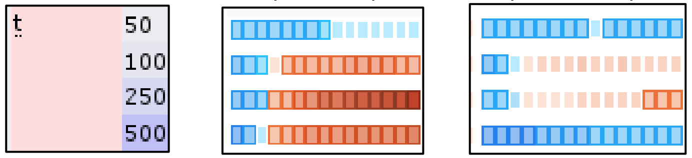


(3) Degraded tropical upper-tropospheric temperature

- In the tropical upper troposphere:
  - ensemble spread & STDEV small ~1K, bias close to 0
  - a small mean warming of ~0.2K gives a large relative change for bias-sensitive scores such as CRPS/RMSE

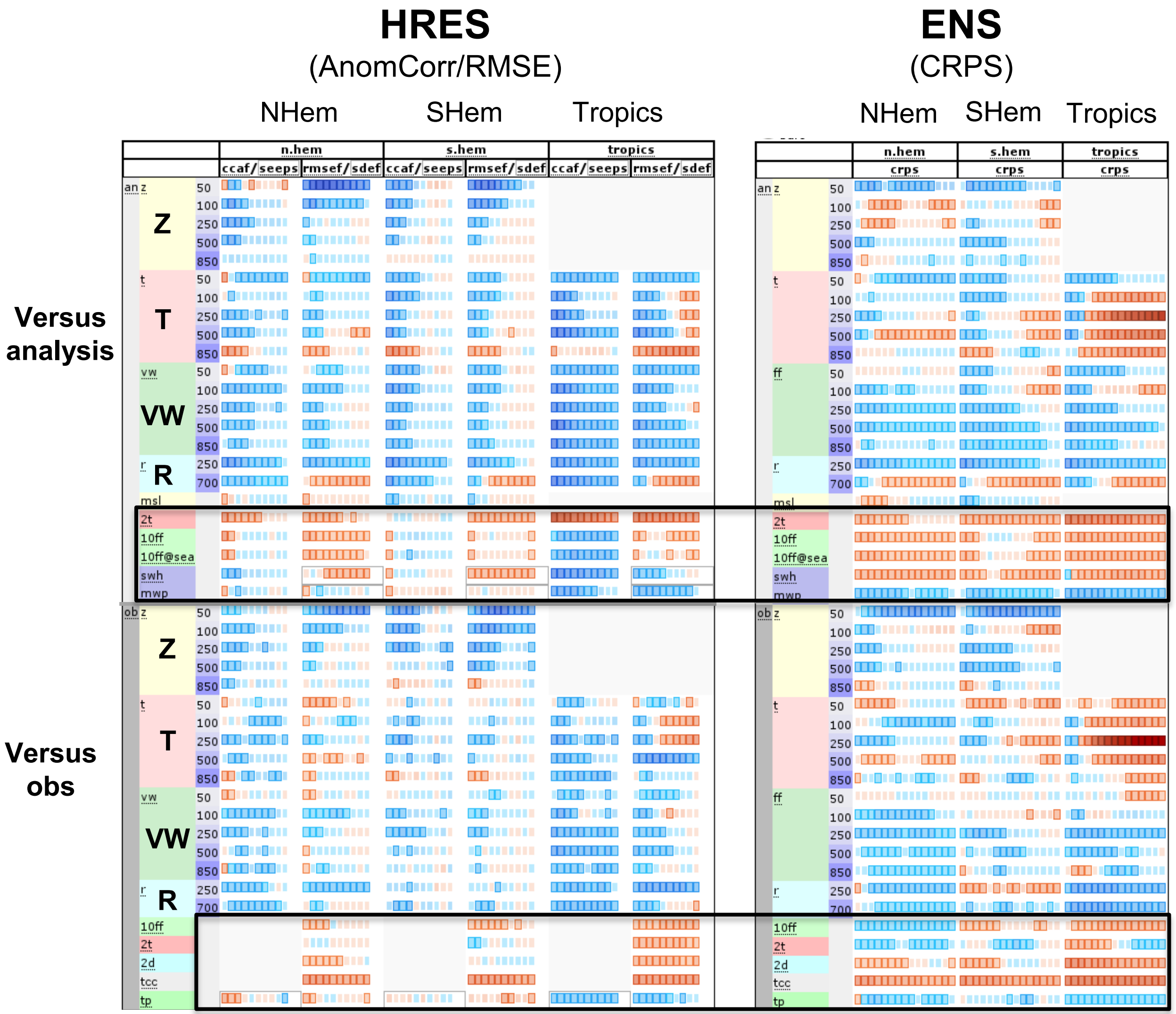
- Bias-independent scores (STDEV, bias-corrected CRPS) show positive / neutral change.
- For example, tropics T500hPa versus analysis ΔCRPS gives 9% degradation, bias-corrected ΔCRPS gives 3% improvement
- Helps to understand the large impact on the CRPS score, due to a small 0.2K increase in bias

ENS (RMSE) **ENS** (Std Dev)



Degradation present in RMSE of ensemble mean (+0.2K bias) but not std deviation

47r3 summary - scorecards



(4) Mixed signals in near-surface variables

Some degradations partly due to increased variability and/or small changes in biases

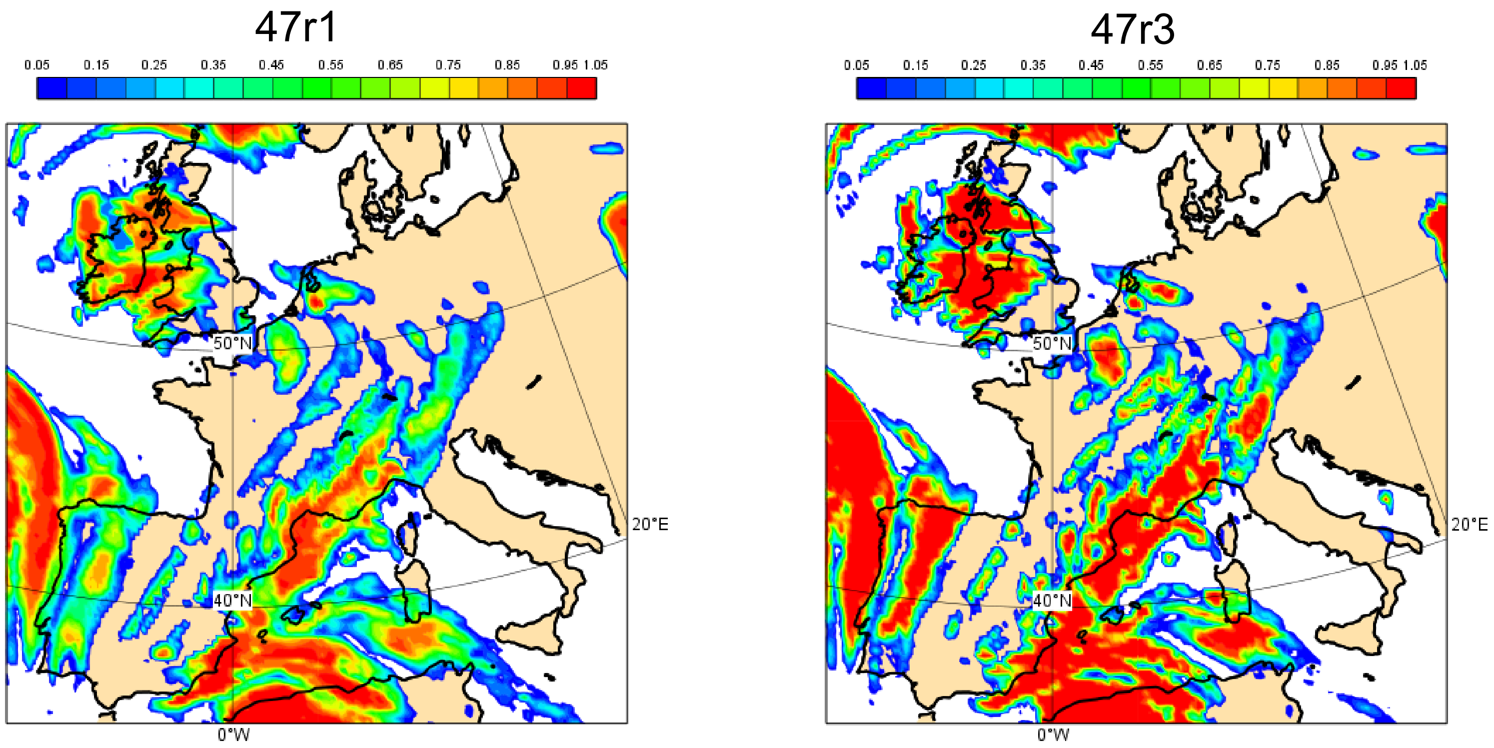
- **2m temperature**
  CRPS in ENS extratropics slightly improved against observations (0.5%)

- **Total precipitation**
  Neutral to slightly improved (0.5%)

- **Total cloud cover**
  3% increase in cloud cover results in degradation versus SYNOP
  Will look at further developments in upcoming Cycles

47r3 changes to cloud cover: example snapshot

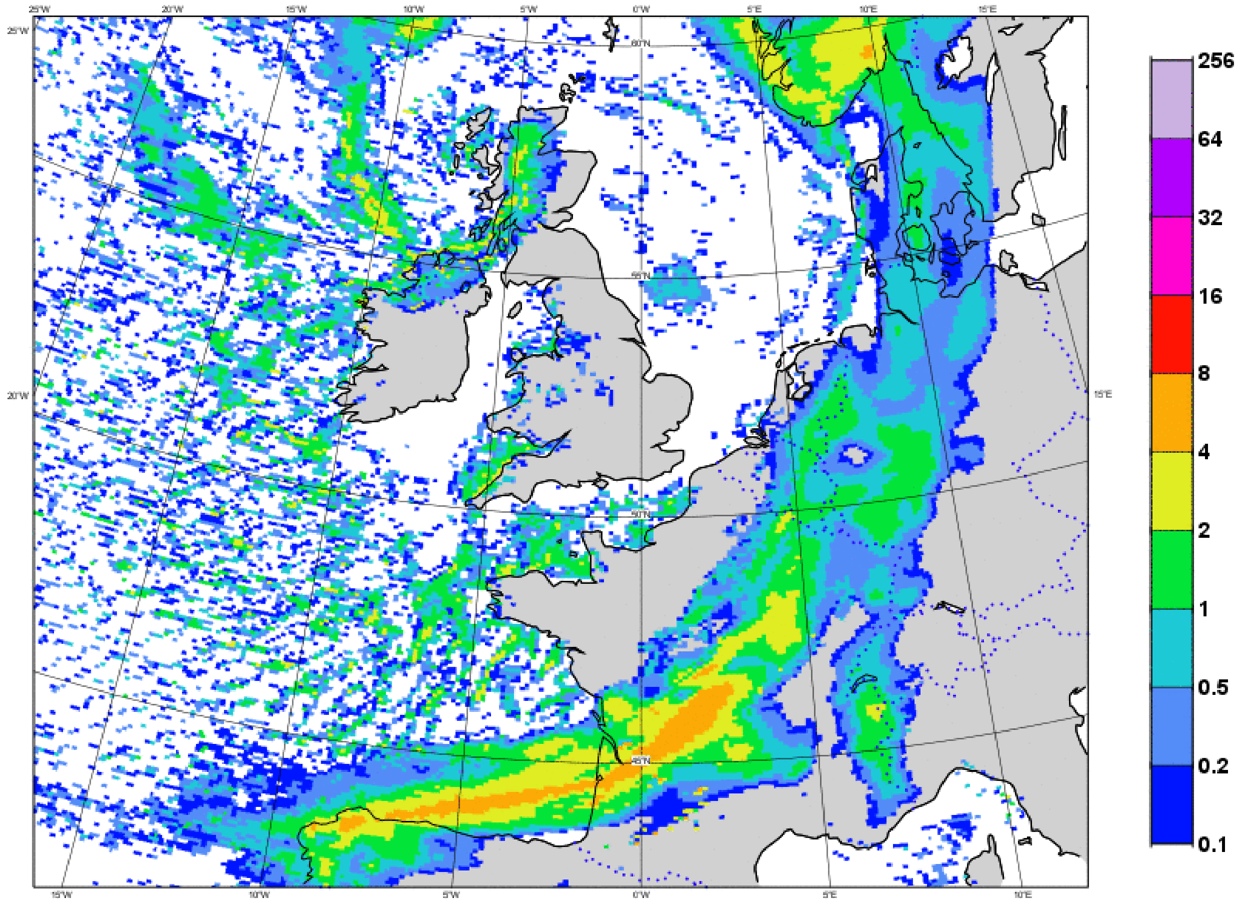
- In 47r3, cloud cover is increased by ~3%, is more binary (increased occurrence of cloud fraction=1) and has more smaller scale structure → less “smooth”, higher RMSE



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

Precipitation rates – change in character of precipitation

Animation of 47r2 and 47r3 (new cycle) instantaneous precipitation rate
for 26 Dec 2020 30 hour forecast



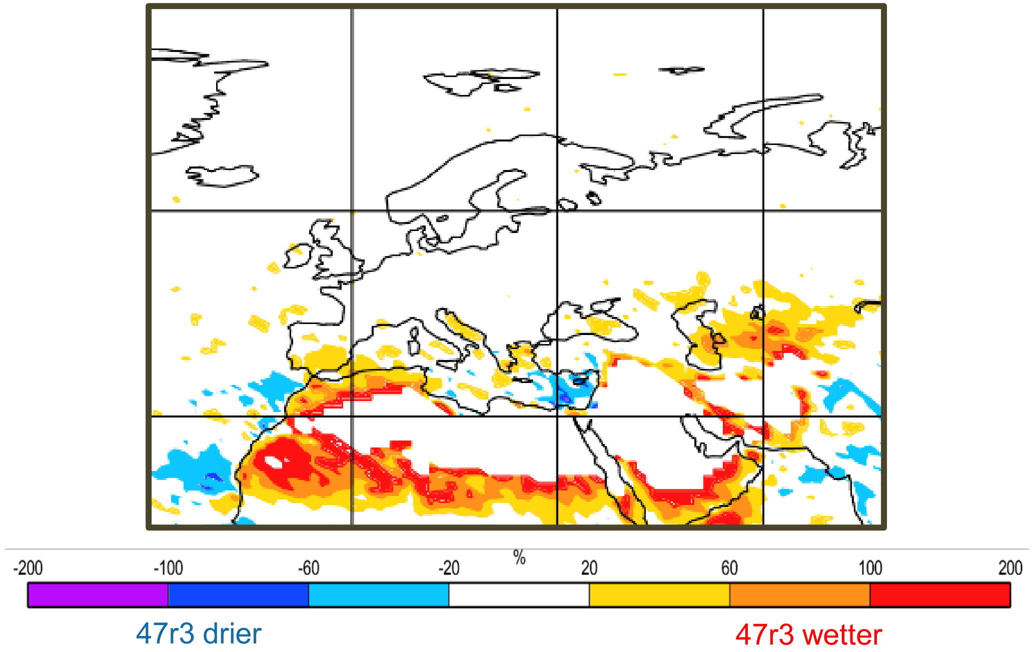
Precipitation accumulations similar but with increased smaller scale structure in 47r3

Precipitation rates, 47r3 has:

- Smaller and more realistic rain area
- Increased small scale structures
  (e.g. in convective regime over the sea)
- Higher peak rain rates with more variability
  (e.g. stronger cold front line convection)

Precipitation: Changes in model precipitation climate (tails of the pdf)

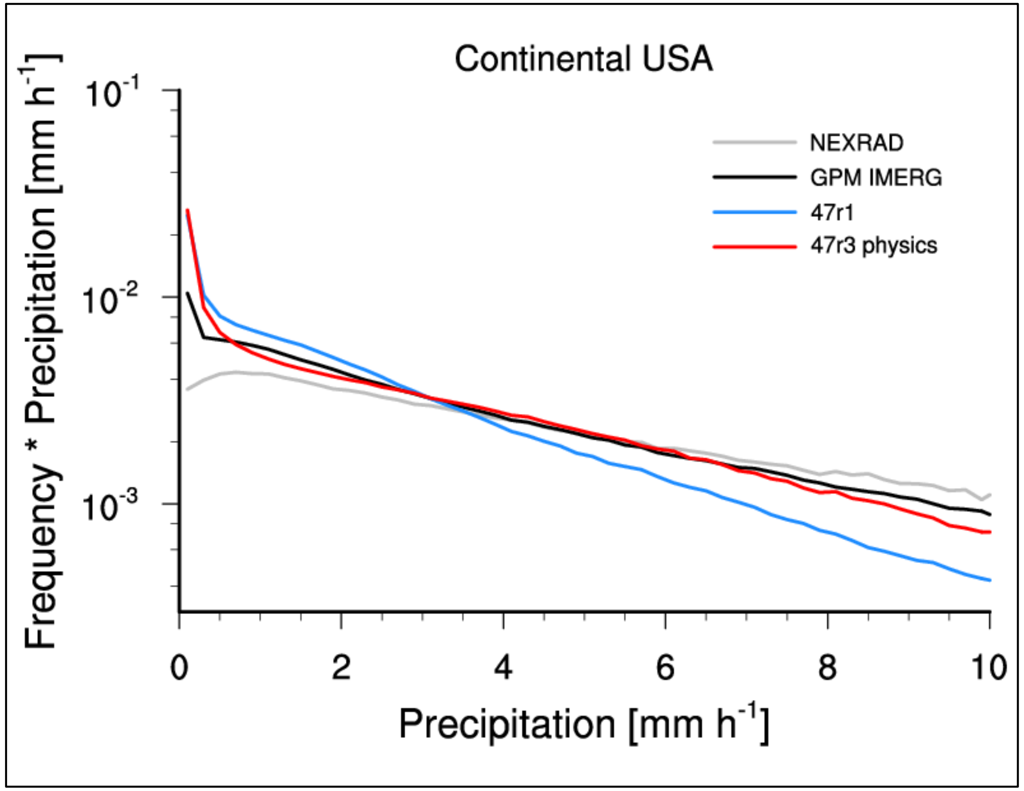
- 47r2 and 47r3 similar over central and northern Europe
- Increased convective precipitation (reduced dry bias) in semi-arid regions further south

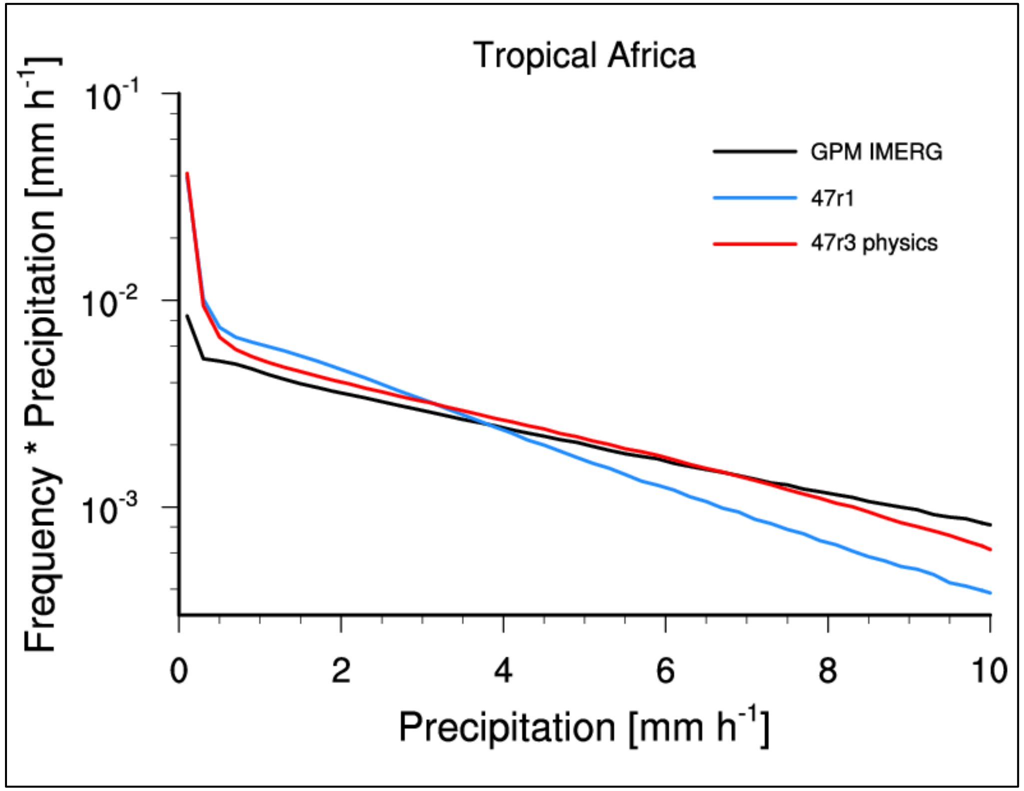


Relative percentage difference in the 99th percentile of 24-48h precipitation between the 47r3 and 47r2 model climates from reforecasts for the extended range ENS on 29 July 2021. The formula is 200*(E-suite - O-suite)/(E-suite + O-suite)

Precipitation: Improved precipitation PDF (convective regimes)

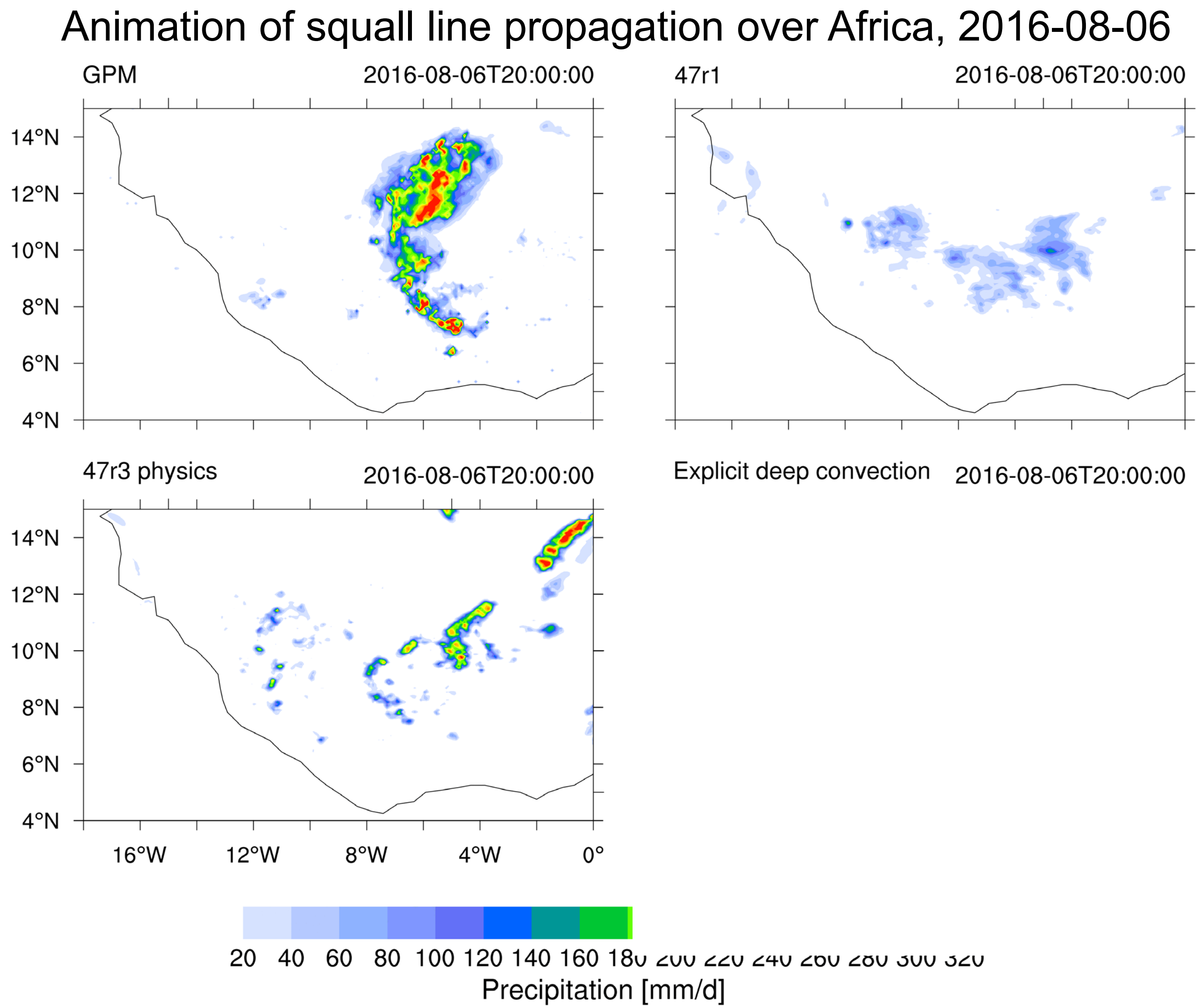
With new convective closure, **47r3** IFS closer to **observed** PDF of precipitation rate than **47r1**





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.

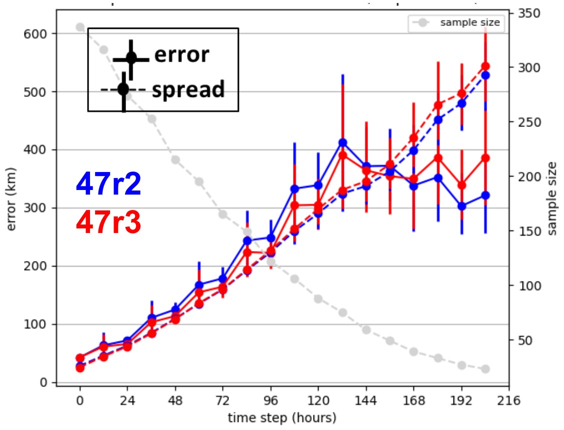
Precipitation: Improved organisation and propagation of squall lines (in some cases)



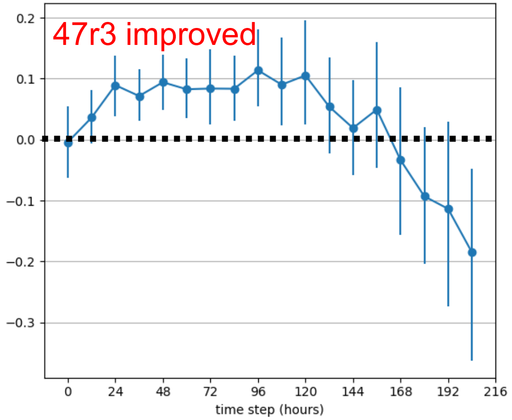
Tropical cyclone performance: track and intensity

ENS TC mean position error
(HRES results similar)

Mean error



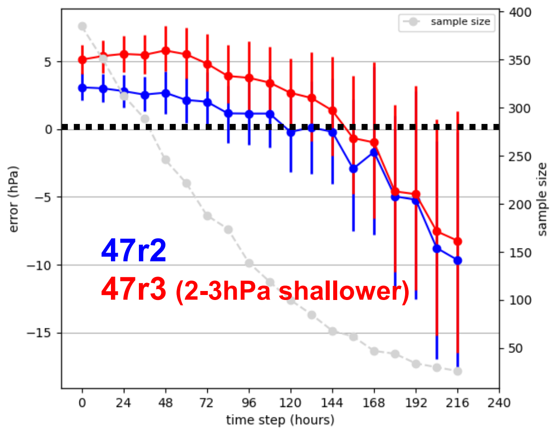
Mean error normalised difference



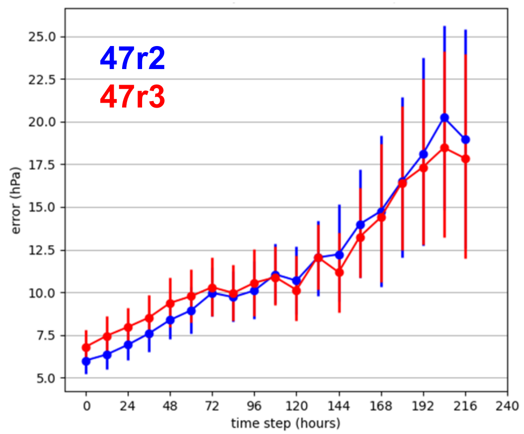
47r3 is 10% more accurate
(due to better winds assimilation + physics)

HRES TC mean intensity (central pressure) error
(ENS results similar)

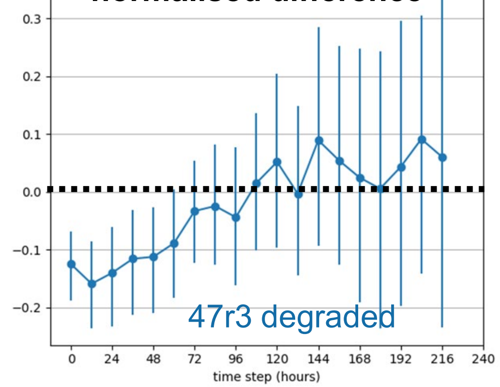
Mean error



Mean absolute error



Mean absolute error normalised difference

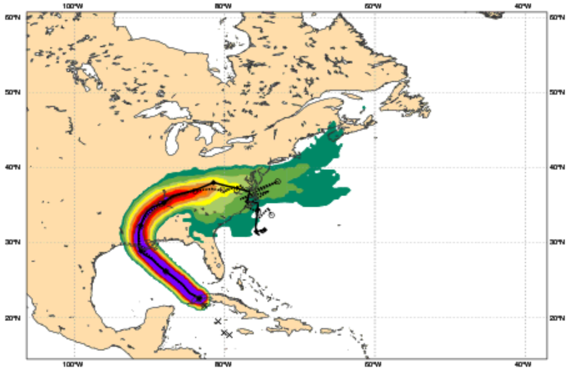


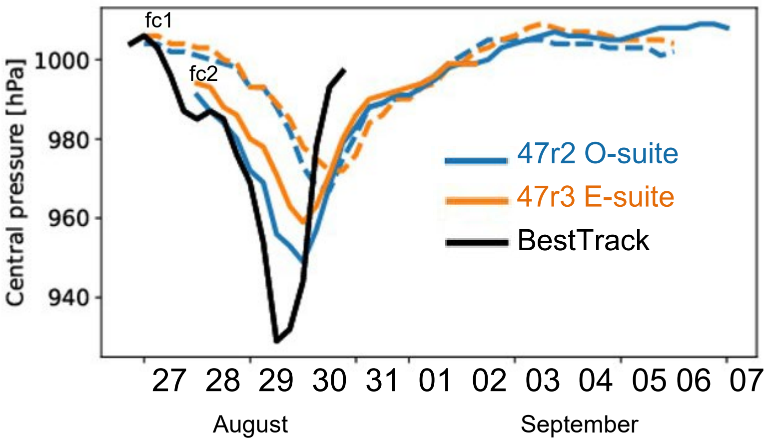
47r3 is 2-3 hPa shallower, mean absolute error 1hPa (10%) increased = small degradation **at current HRES/ENS resolutions**

Data: Dec 2020 – Aug 2021, All basins, Homogeneous samples

Tropical cyclone performance: Central pressure – two examples

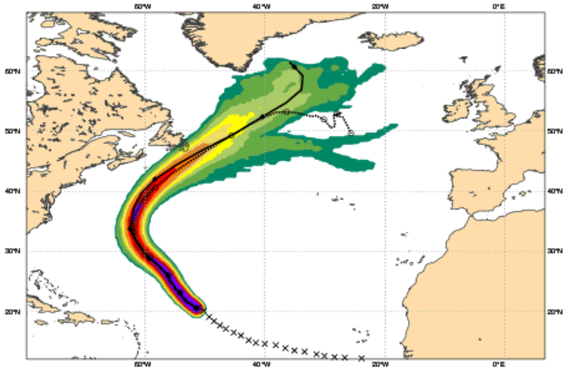
TC Ida - Aug 2021

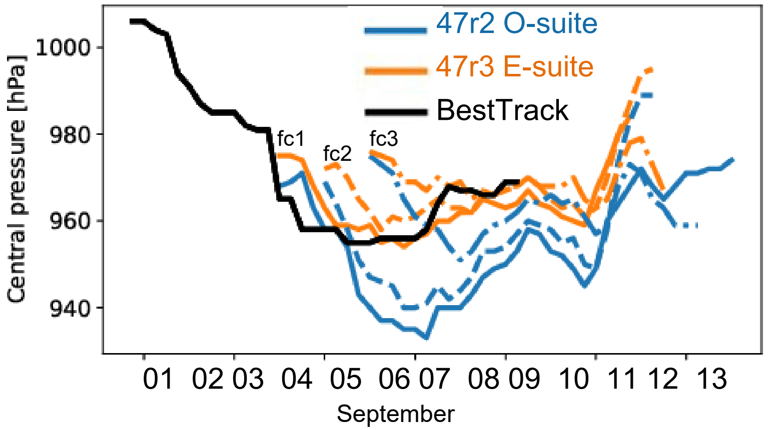




- In rapidly deepening tropical cyclones, at TCo1279 (9km) resolution, 47r3 is less deep than 47r2, and too shallow versus obs estimate
- But at future higher resolutions (4km), 47r3 is closer to obs than 47r2 (not shown here)

TC Larry – Sep 2021



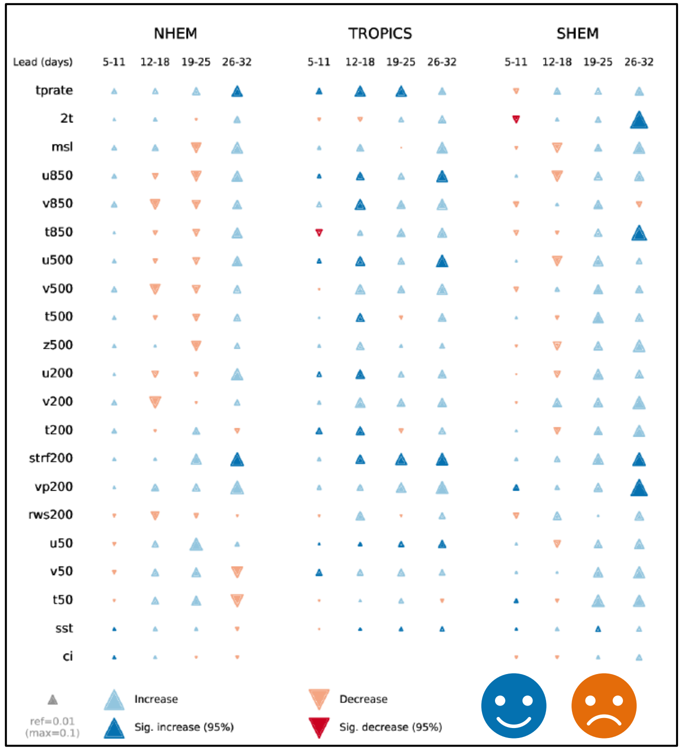


- And 47r3 mitigates over-deepening of HRES often seen in current operations in late stages of cyclone evolution

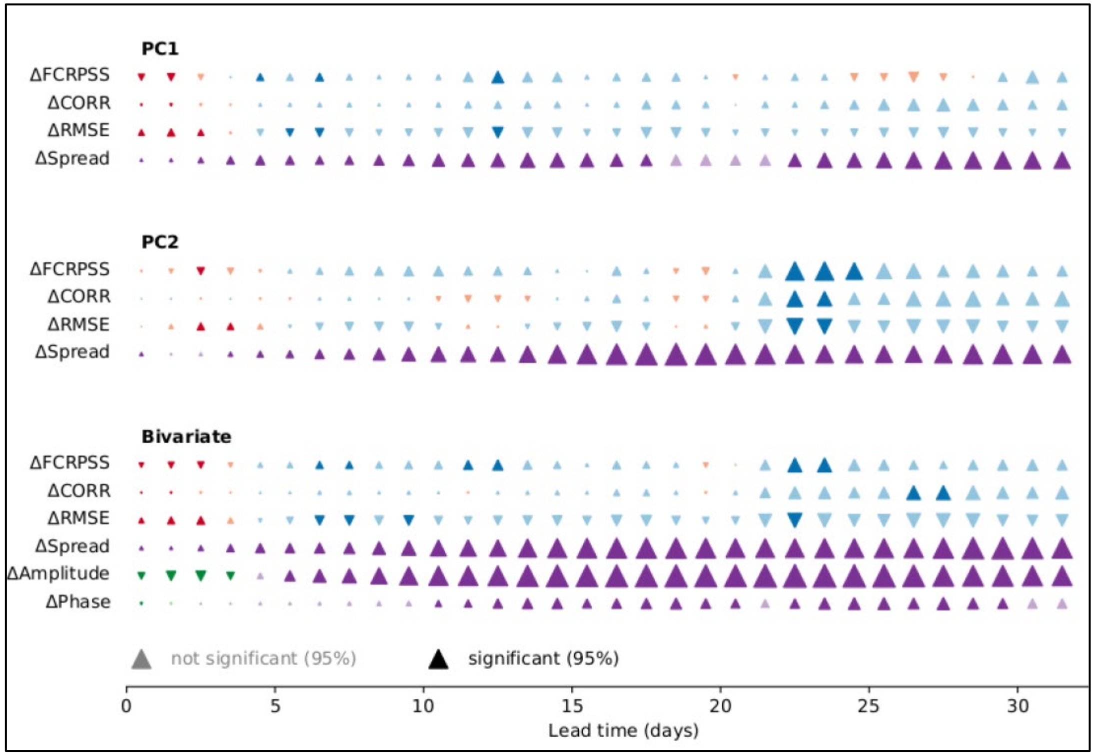
Extended-range: Improvements to MJO

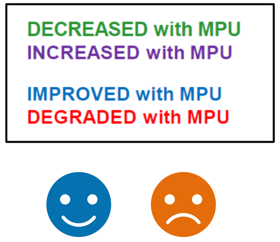
- Extended-range forecasts overall skill similar at full resolution (lower resolution had shown improvements)
- MJO skill shows some small improvements out to day 30
- Increase in spread leads to beneficial increase in MJO amplitude and eastward phase speed

Anomaly correlation weeks 1-4 summary scorecard
47r3 versus 47r2, TCo319L137, 19890101-20161201



Madden-Julian Oscillation (MJO) RMM summary scorecard
47r3 versus 47r2, TCo319L137, 19890101-20161201





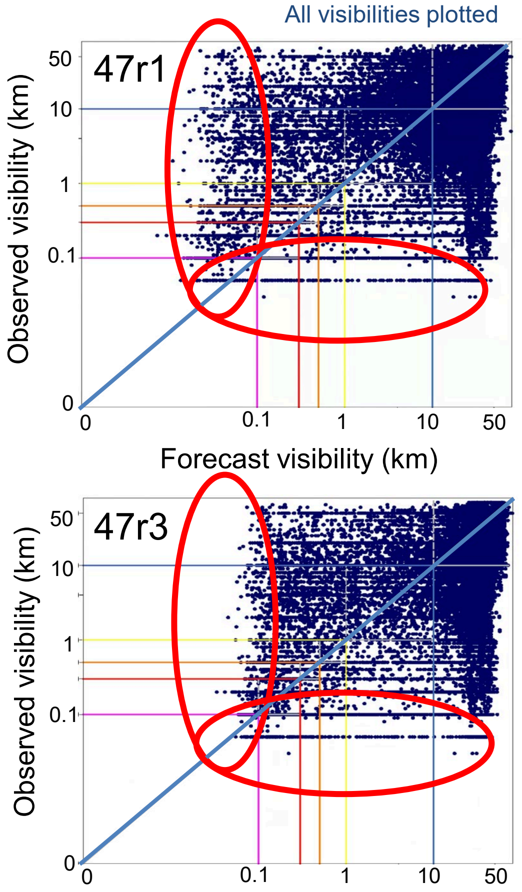
NEW AND REVISED PRODUCTS IN 47R3

47r3 Products – revised visibility in fog and precipitation

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

Fog

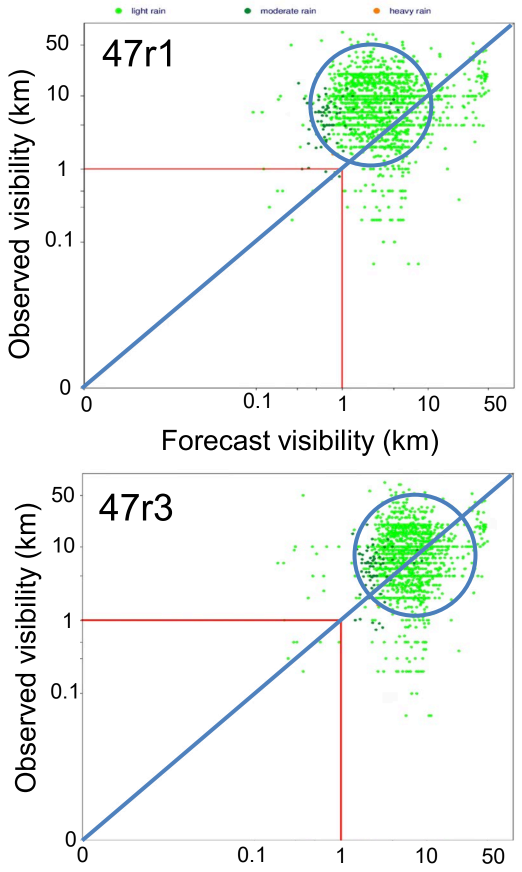
Visibility was too low in thick fog
Less occurrence of <100m visibility
Closer to obs



Rain

Visibility was too low
Now increased
Closer to obs

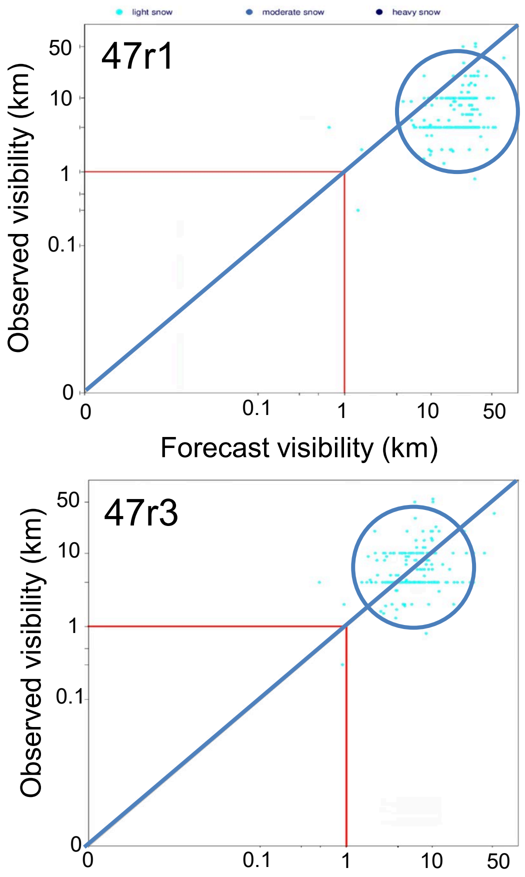
Light rain	Average visibility
Obs	9500 m
47r1	4500 m
47r3	7800 m



Snow

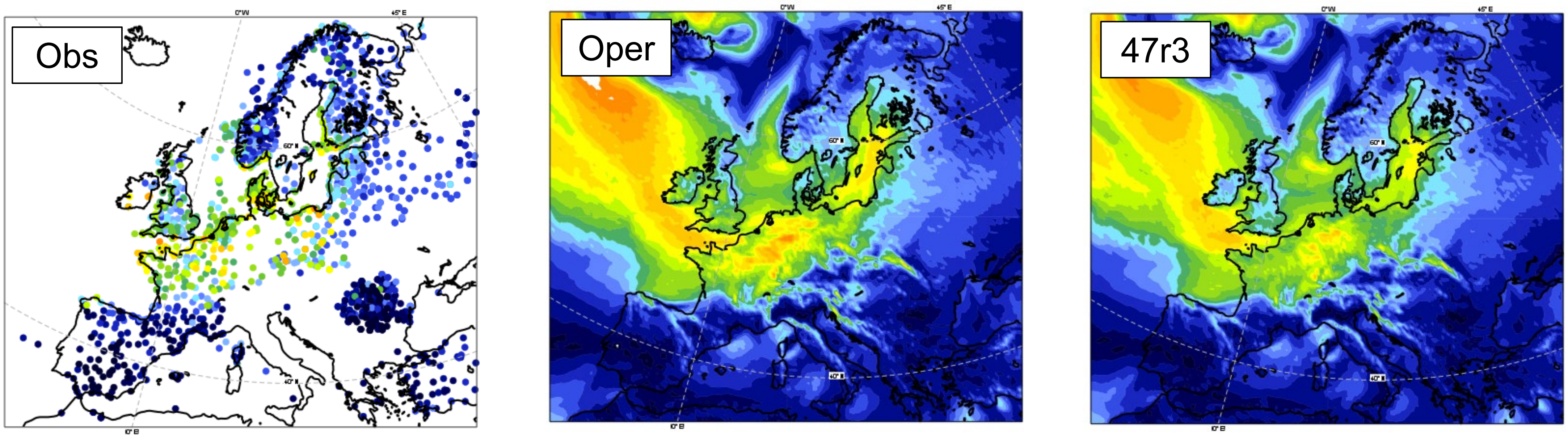
Visibility was too high
Now reduced
Closer to obs

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

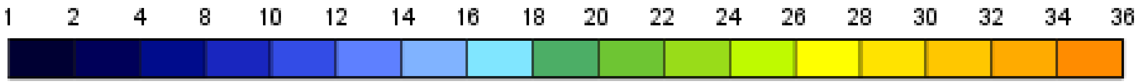


47r3 Products – revised wind gusts

- 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: 10 Feb 2020 00z
HRES 24 hour forecast



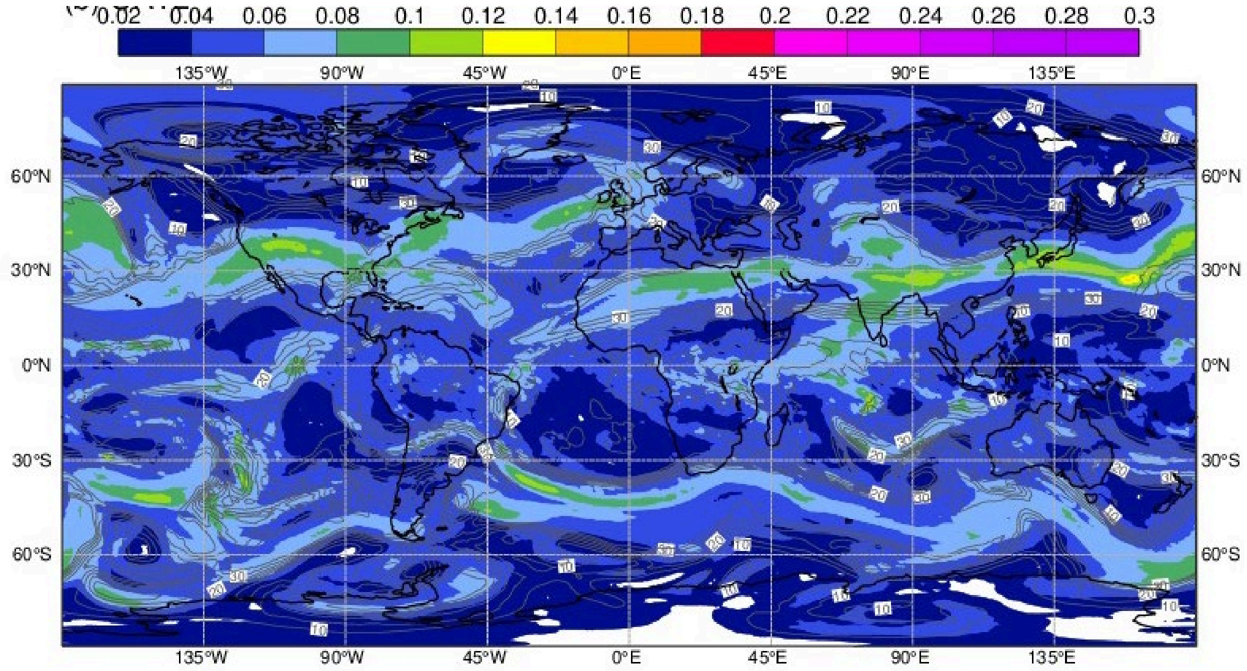
Maximum 10m wind gust in 24 hours (m/s)

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)

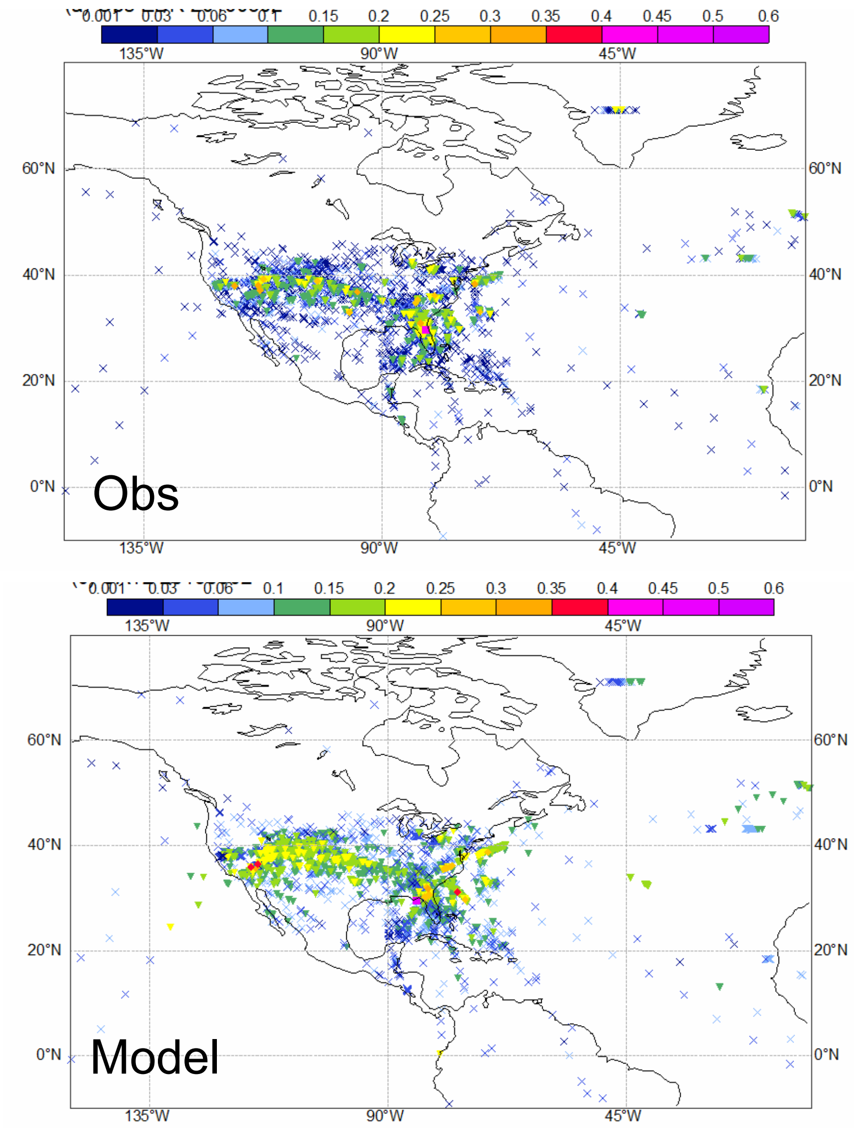
47r3 New Product: Clear Air Turbulence (CAT)

- 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)

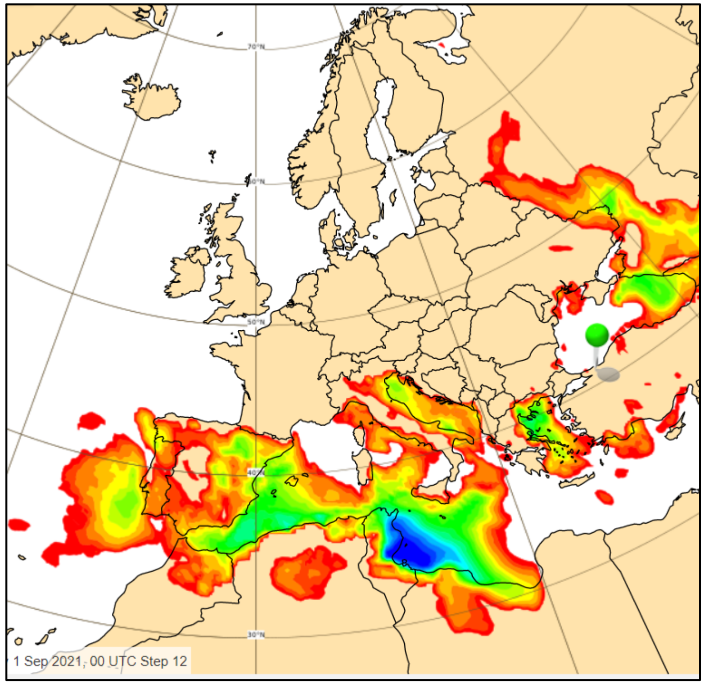
Eddy Dissipation Rate ($m^{2/3}$ s^{-1})
at aircraft locations on 20190302



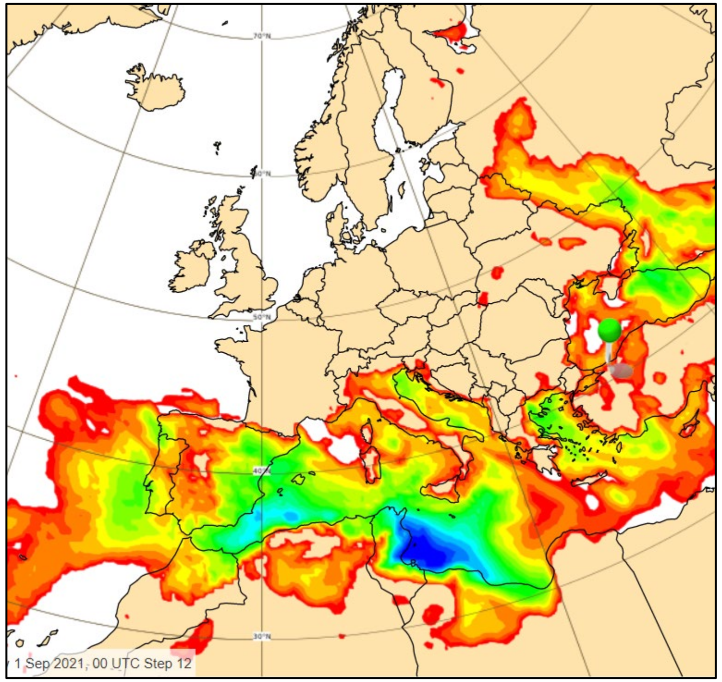
47r3 New Product: Most Unstable CAPE (Convective Available Potential Energy)

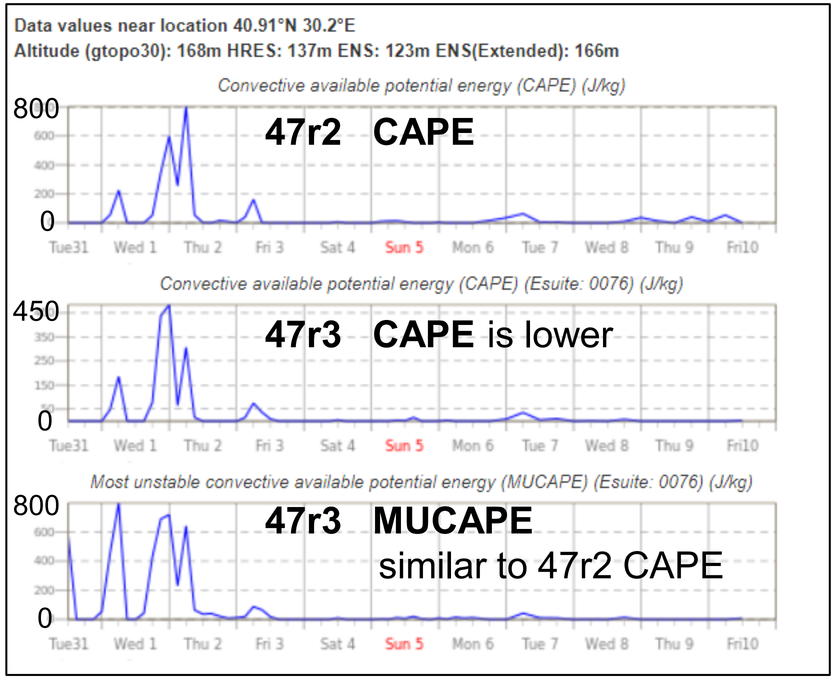
- Current CAPE uses Theta-E in the calculation for computational efficiency
- New most-unstable CAPE (MUCAPE) parameter correctly uses Theta-V
- MUCAPE > CAPE, but both are reduced by 47r3 physics, so 47r3 MUCAPE is only sligthly higher than 47r2 CAPE
- Encourage use of MUCAPE

47r2 CAPE



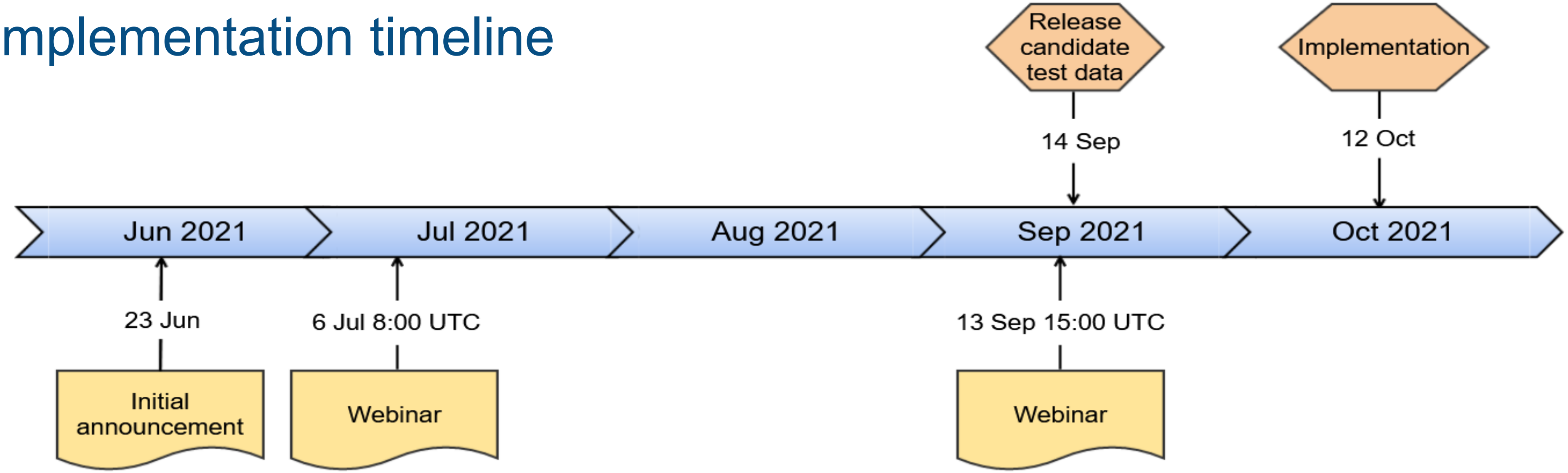
47r3 MUCAPE





Implementation timeline and next steps

47r3 Implementation timeline



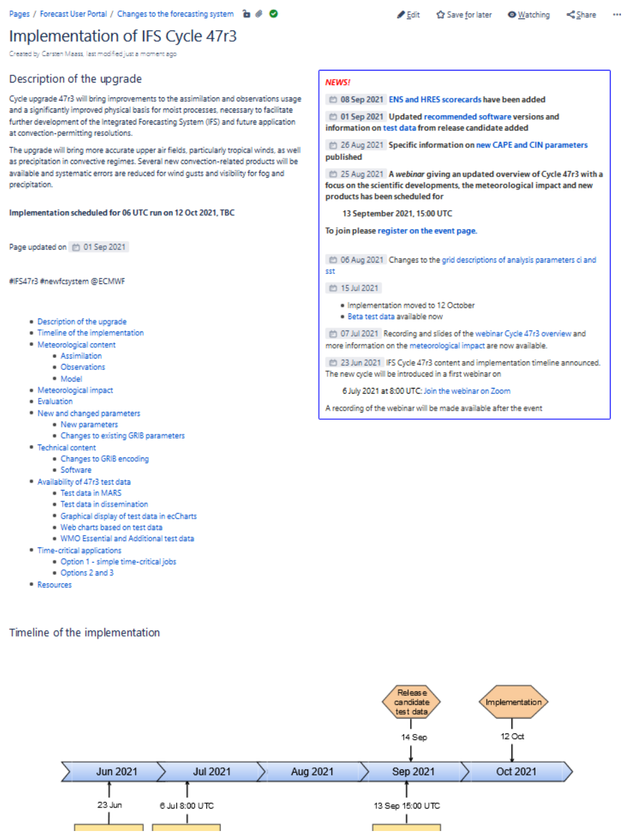
On 14 September, the start of the *release candidate phase*

- A full set of 47r3 test product services will be offered until the operational implementation, e.g.
  - Dissemination: products based on operational requirements
  - ecCharts: layers labelled “0076”
  - Meteograms and vertical profiles as web charts
- Test products will be generated daily shortly behind operational HRES and ENS
- Availability of the test data does not follow any strict schedule

Next steps

- Keep testing data *and* software
  - Release Candidate test data available from 14 Sep
  - For longer time series available beta test data from 15 April can be used
  - New software versions required to handle all 47r3 data will become the default on ECMWF systems on 6 October

    Users are strongly encouraged to test their applications and data processing chains with the software versions before that change



- Please Watch the implementation page for more details and to keep up to date with latest news

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

- Implementation planned for 6 UTC run on 12th October

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