Upcoming science changes in the IFS

UEF 2021

European Centre for Medium-range Weather Forecasts

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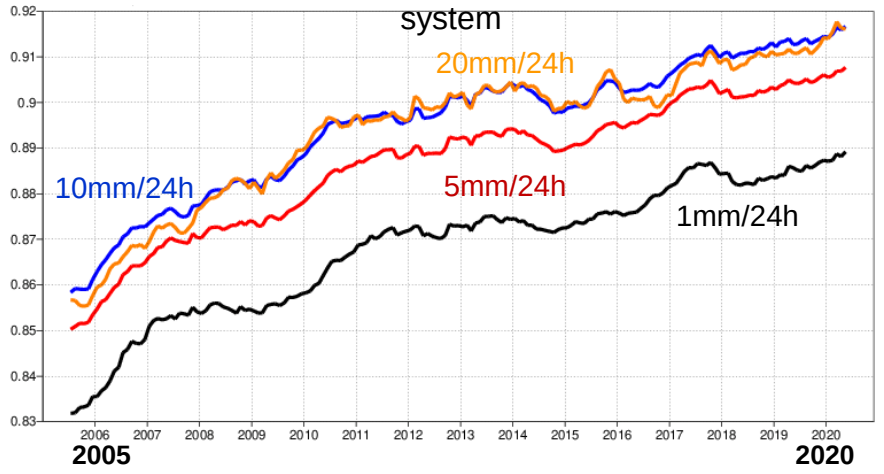
Thanks to ECMWF Research Department

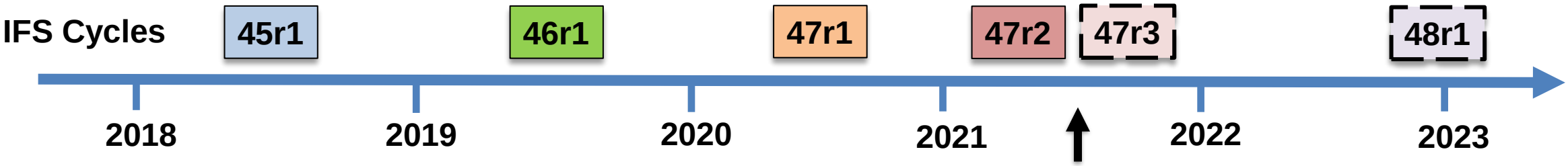
Recent and upcoming IFS upgrades

- Regular updates (approx. 1 Cycle per year in recent years)
- Many contributions in each Cycle from across different areas of research (physics, numerics, assimilation, observations)
- Mix of longer-term and shorter-term developments
- For an individual Cycle upgrade, rarely is everything improved, often some degradations, but different aspects addressed with different Cycles, and over time overall improved NWP ("*1 day per decade*")
- Upcoming plans for Cycles 47r3 and 48r1

Example: Increasing forecast skill over the last 15 years for precipitation from the operational ECMWF IFS global ensemble system



Timeseries of Discrimination score (ROC area) for extratropics oper IFS forecast day 5. Measures the ability of the forecast to discriminate between events and non-events for different precipitation thresholds.



47r3 Main contributions

Improving model physics

Major revision to moist processes

- A more consistent formulation of boundary layer turbulence, shallow convection, sub-grid cloud and microphysics
  → improved physics and numerics impacts all aspects of the forecast across forecast time ranges

Parametrized Convection

- Total advective moisture convergence in convective instability closure
  → improved precipitation pdf, MCS propagation, rain in arid regions, improved scale-independence for convection-permitting resolutions

Radiation

- Improved cloud vertical overlap for radiation

Dynamics

- Higher order departure point interpolation (cubic) for cloud liquid, ice, rain, snow → less smoothing of cloud/precipitation fields

Improving products

- Revision of visibility, gustiness
- New Clear Air Turbulence, MUCAPE, MLCAPE/CIN
  → responding to requests from Member States

Improving deterministic 4D-Var (HRES)

Infrared sounders

- new RTTOV coefficients for hyperspectral sounders
- new observation error covariance matrix for AIRS

Microwave sounders

- Assimilation of all-sky AMSU-A (rather than clear-sky only)

Atmospheric Motion Vectors

- new height reassignment for low level AMVs

Aeolus

- new observation representativeness error

Sea surface temperature analysis

- Robust implementation avoiding operational failures

Improving ensemble of 4D-Var (EDA)

Stratospheric analysis

- Implementation of weak-constraint 4D-Var

→ improved stratosphere

47r3 Moist Physics Upgrade - Motivations

ECMWF 2020 Summer Newsletter 164

1. Towards convection-permitting resolutions

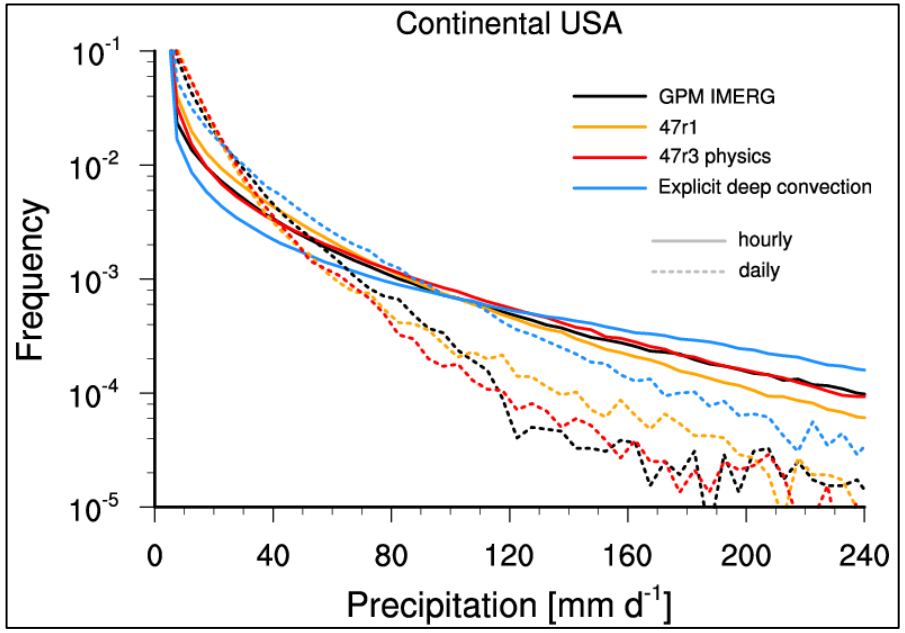
2. An improved physical and numerical basis

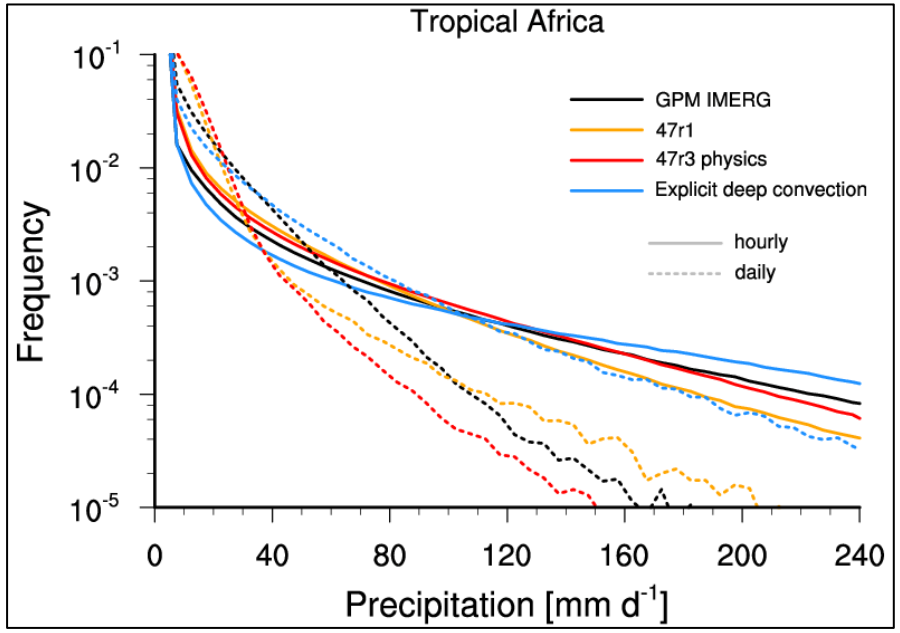
3. Improved forecasts

The aim is to ensure that the complicated interactions between turbulence in the lowest part of the atmosphere, convective motions and cloud physics are described more simply, more efficiently, more accurately and more scale-independently.

47r3 Example: Total advective moisture convergence in convective instability closure

- With new closure, 47r3 IFS closer to **observed PDF** of precipitation for the higher rain rates (vs 47r1)
- Improved propagation of squall lines/MCS
- 9km and 4km resolutions similar, without parametrized deep convection (explicit), extreme precip is overdone



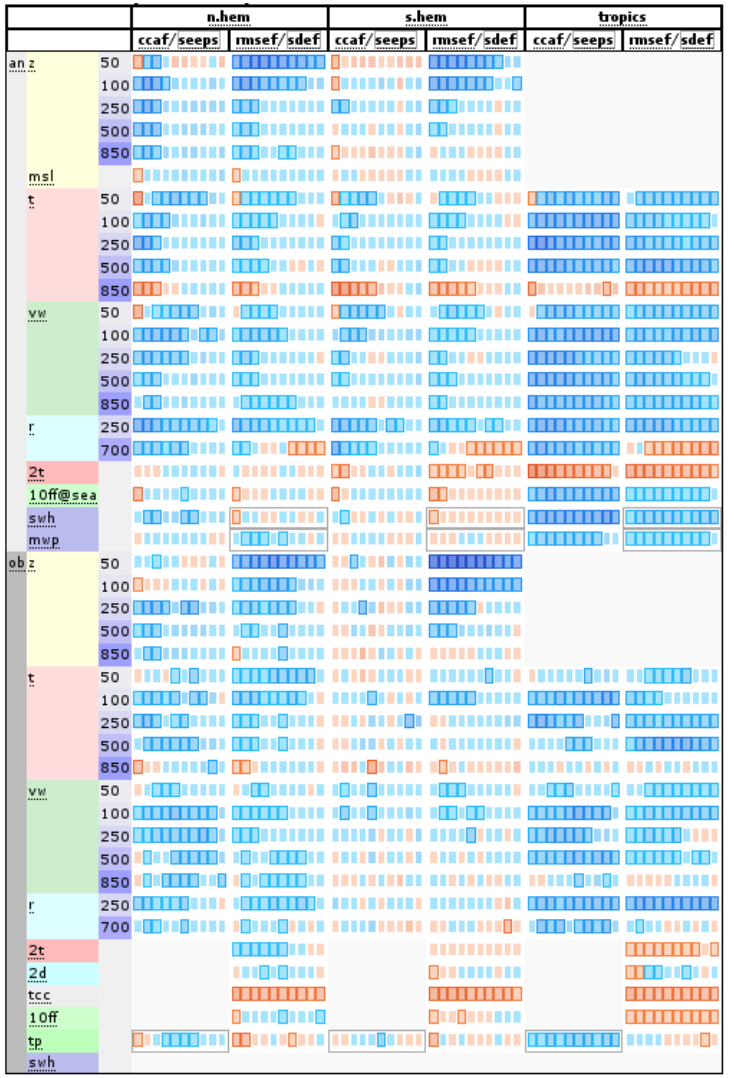


Frequency distribution of the summertime 24-48 hour forecast precipitation intensities (hourly – solid lines; daily - dashed lines) over the continental USA for the GPM-IMERG observational product (black), 47r1 HRES (orange), 47r3 physics upgrade (red) and a simulation with explicit deep convection (blue). Data for August 2016 remapped to 0.1°. The overestimation of light and underestimation of heavy precipitation events is corrected for with 47r3. The forecast with explicit (not parametrized) deep convection shows too intense precipitation events.

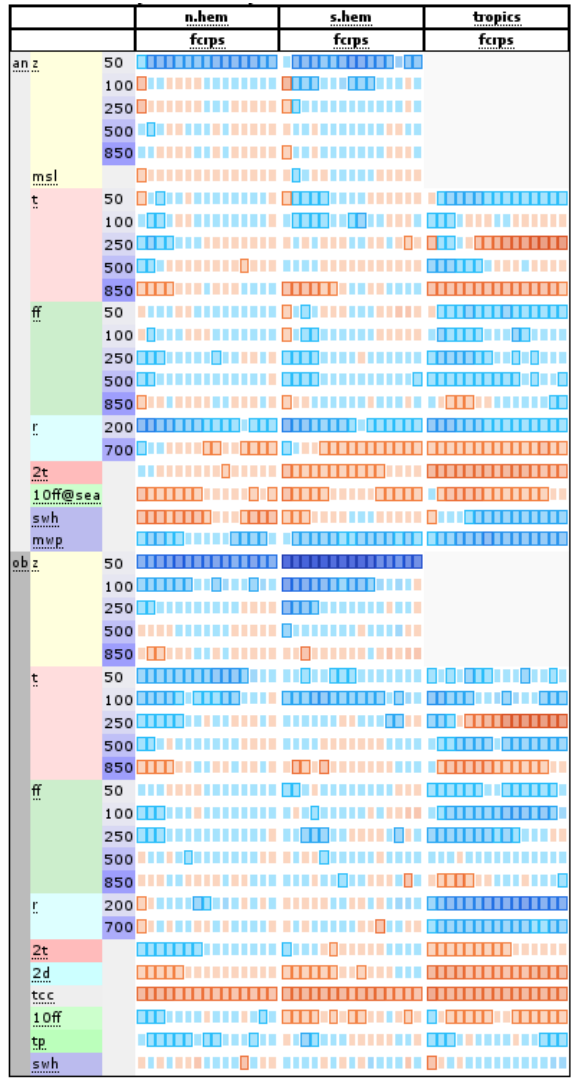
47r3 Preliminary scorecards (summer + winter from lower resolution testing)

- Overall positive for upper air fields
- Particularly tropical winds, stratosphere
- Not everything is positive. Ensemble CRPS sensitive to small increase in biases for some variables/heights
- Verification of full system (EDA, HRES 4DVAR, ENS) ongoing…

Deterministic (= ensemble control)



Ensemble



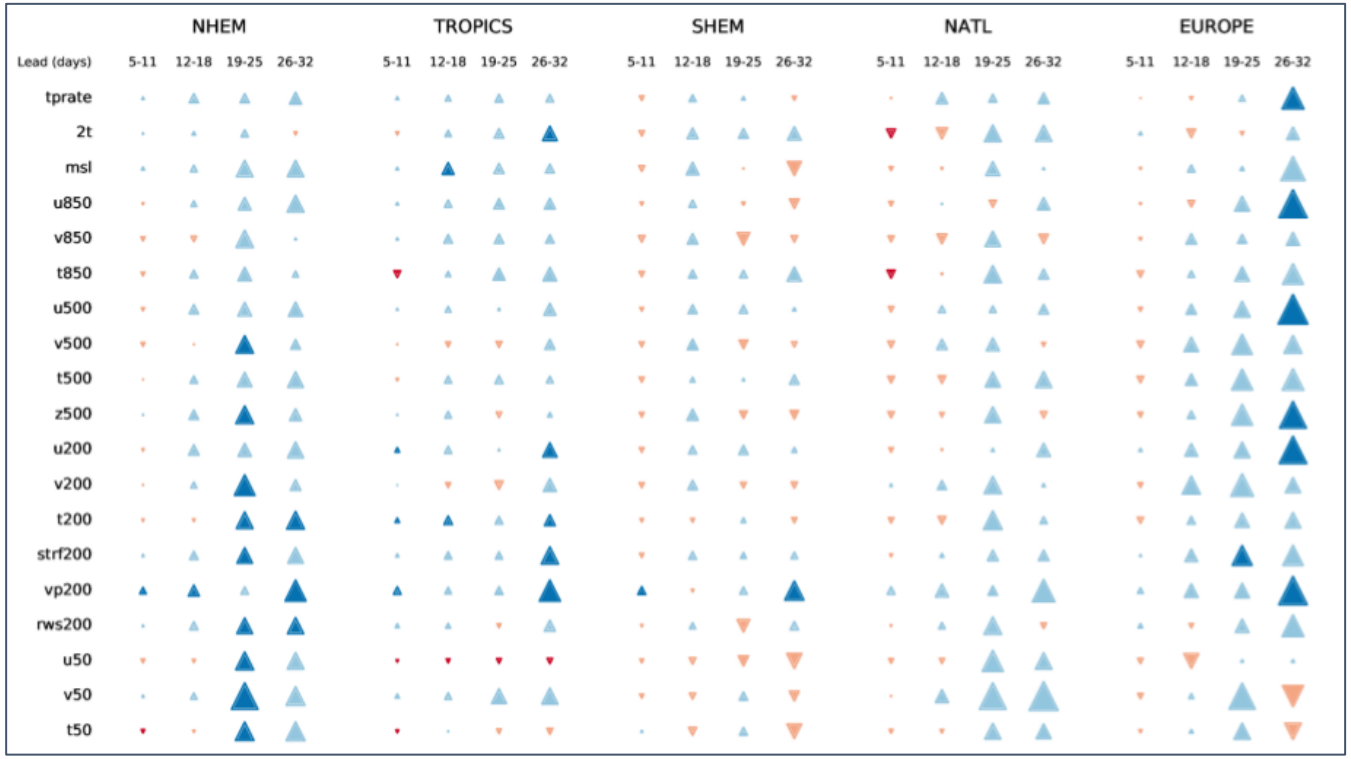
Left: Anomaly correlation and RMSE (NH, SH, Tropics) for 47r3 low resolution TCo399 10-day unperturbed forecasts for 6 months (summer/winter 2019-2020)

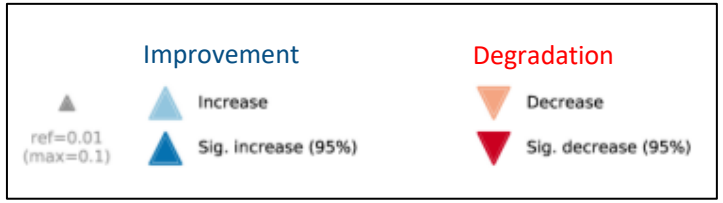
Right: Fair CRPS (NH, SH, Tropics) for 47r3 low resolution TCo399 15-day ensemble forecasts (8-perturbed members) forecasts for 6 months (summer/winter 2019-2020)

47r3 Moist physics upgrade: Small positive impact in weeks 3-4 for Europe/NHem

- Extended-range forecasts show improvement in weeks 3 and 4
- Possibly 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



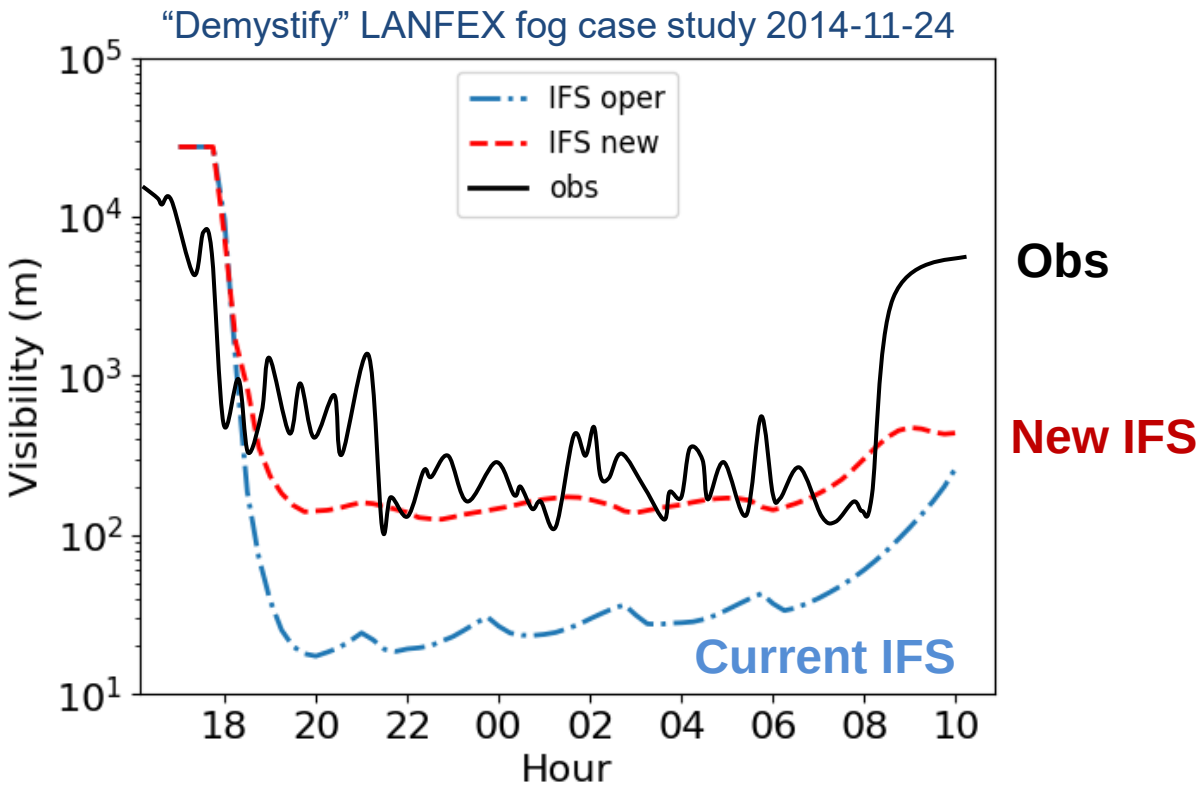


Change in the anomaly correlation due to the moist physics upgrade in Cycle 47r3 for different parameters and regions in the extended-range. The scores are weekly means from lower resolution (TCo199/ORCA1) extended-range forecasts for the period 1989 to 2016. Blue triangles represent an improvement,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

47r3 Addressing systematic errors in visibility

- IFS forecast visibility too low in fog, too low when raining, too high when snowing (verification, user feedback)
- Improved visibility formula reduces systematic errors for fog/rain/snow (see talk by Ivan Tvonevsky)
- Fog remains difficult to predict (highly variable, sensitive to conditions) but ENS gives useful probabilities

Case study showing current IFS fog too thick. New version closer to observations



Obs from Boutle et al. (2018)

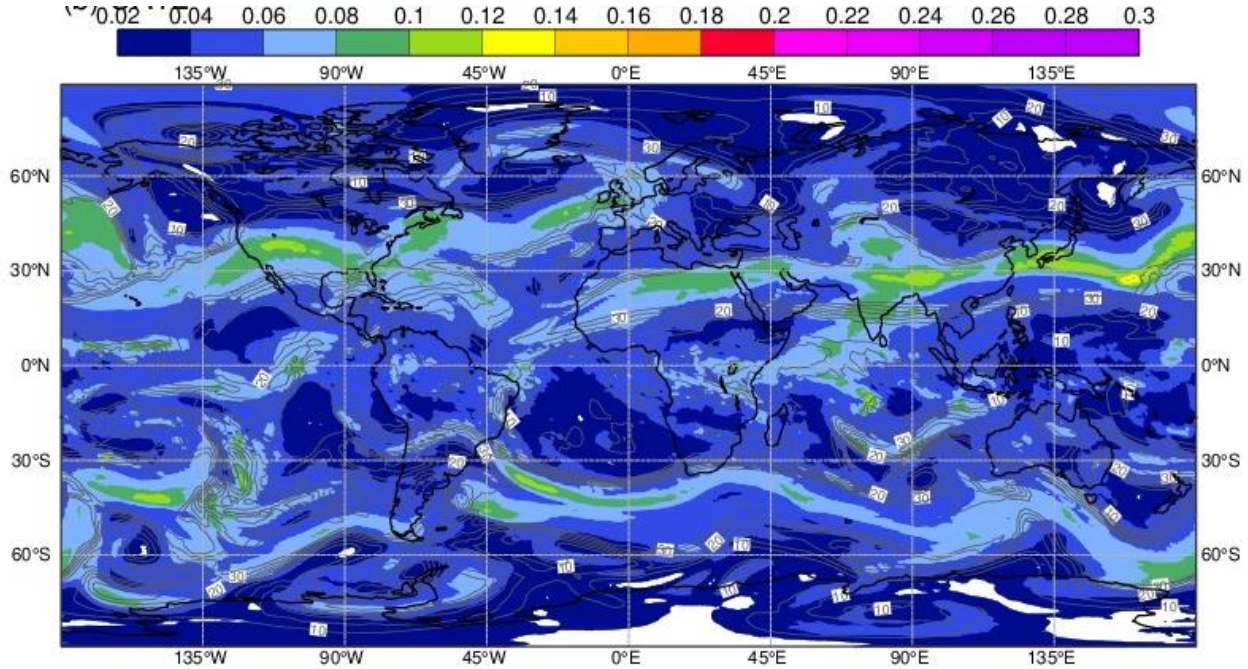
Obs

New IFS

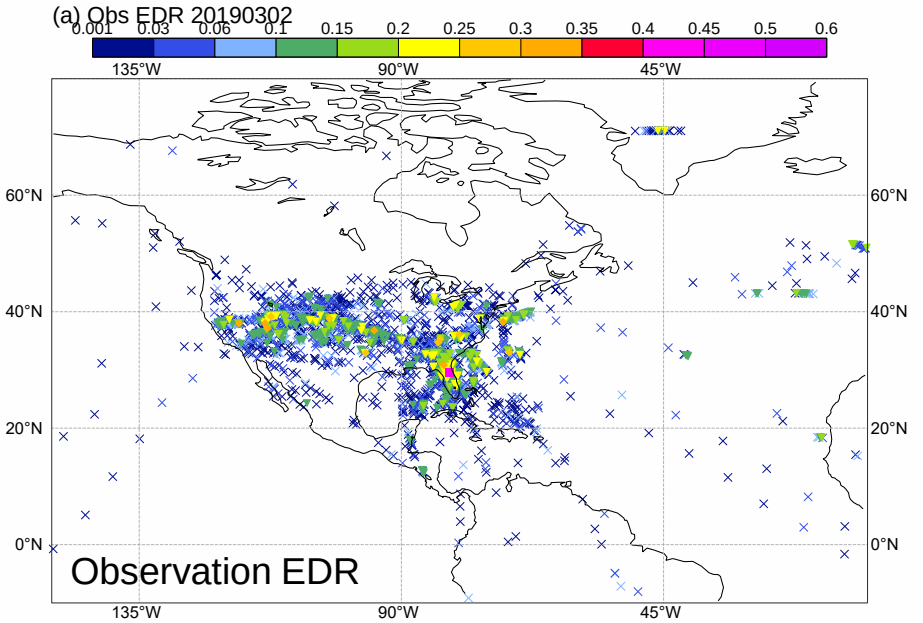
47r3 Clear Air Turbulence (CAT) parameter based on eddy dissipation rate

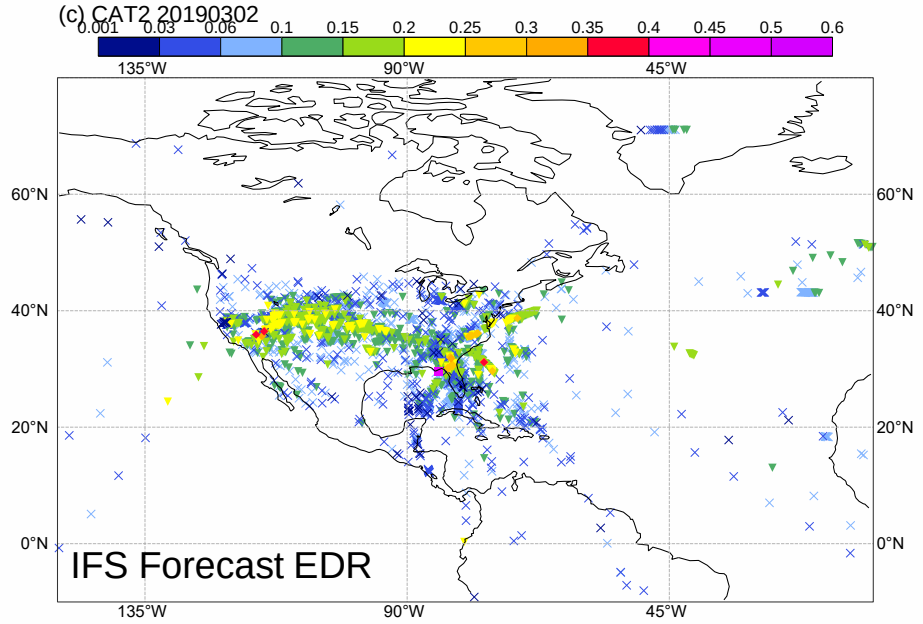
ECMWF Tech Memo 874
ECWMF Summer 2021 Newsletter No 168

Eddy Dissipation Rate (EDR) forecast



Daily average eddy dissipation rate ($m^{2/3}$ s^{-1}) for 20190302
level 10-12 km + wind isotachs at 250 hPa (grey contours)



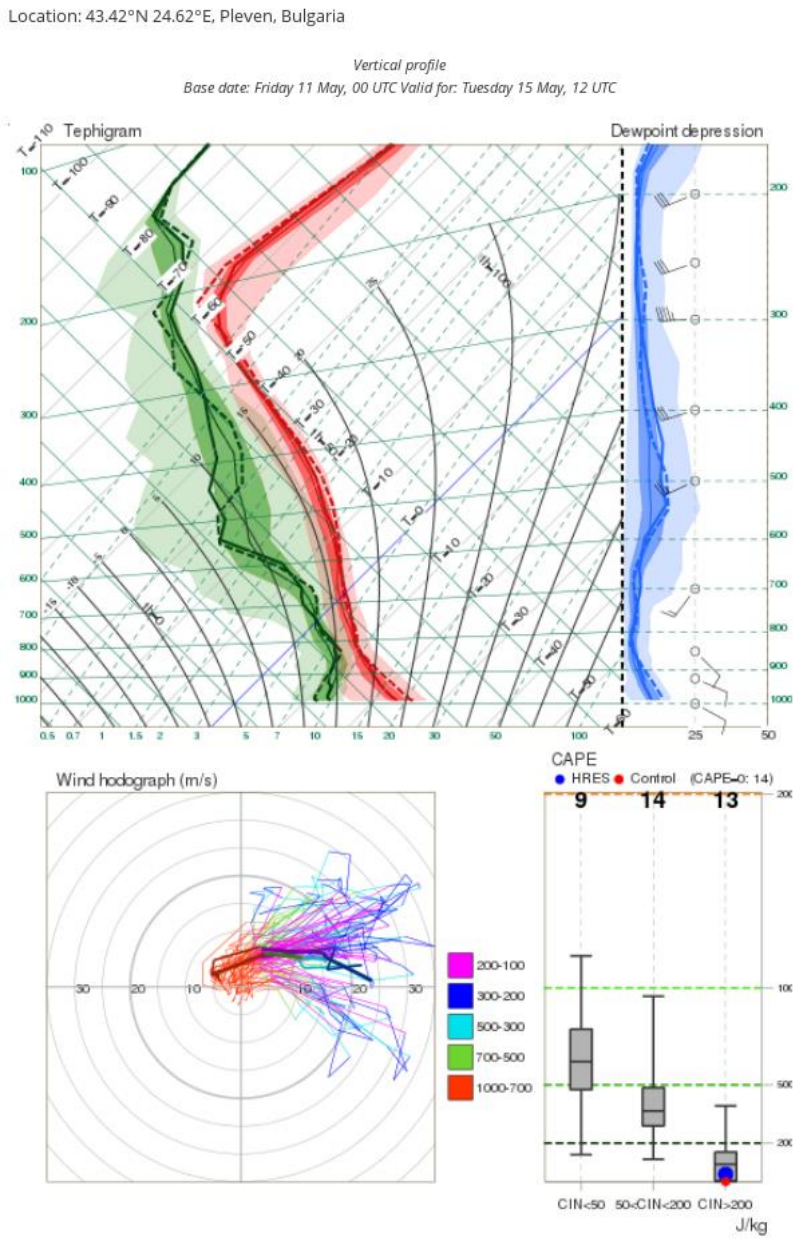


47r3 New products for CAPE and CIN

Most Unstable CAPE (using virtual potential temperature)
MUCAPE

Mixed layer CAPE and CIN (100hPa)/50hPa)
MLCAPE50, MLCAPE100
MLCIN50, MLCIN100

PDEPL, PTRP, MDEG10L
PDEPL is the departure level (Pa) of convection, i.e. most unstable parcel
PTRP=pressure of stability tropopause
MDEG10L = -10C isotherm



Summary

- Short and longer term research and development feeding into IFS Cycles
- Cycle 47r3 (planned for later in 2021)
  - A major revision to improve the physical and numerical basis for moist processes in the IFS
  - Changes to observation usage (IR, microwave, AMV, Aeolus)
  - Weak constraint 4DVar for stratosphere in EDA
  - Revised/new products (visibility, CAT, MUCAPE, MLCAPE/CIN)
- Cycle 48r1 (Bologna), planned contributions:
  - increase ENS horizontal resolution (9-11km)
  - daily extended-range ensembles (increased members)
  - new multi-layer snow scheme
  - interactive prognostic ozone, updated solar spectrum, SL vertical filter
  - improved representation of orographic drag
  - update of surface water (lake cover/depth, glacier mask)
  - EDA, observations + many more