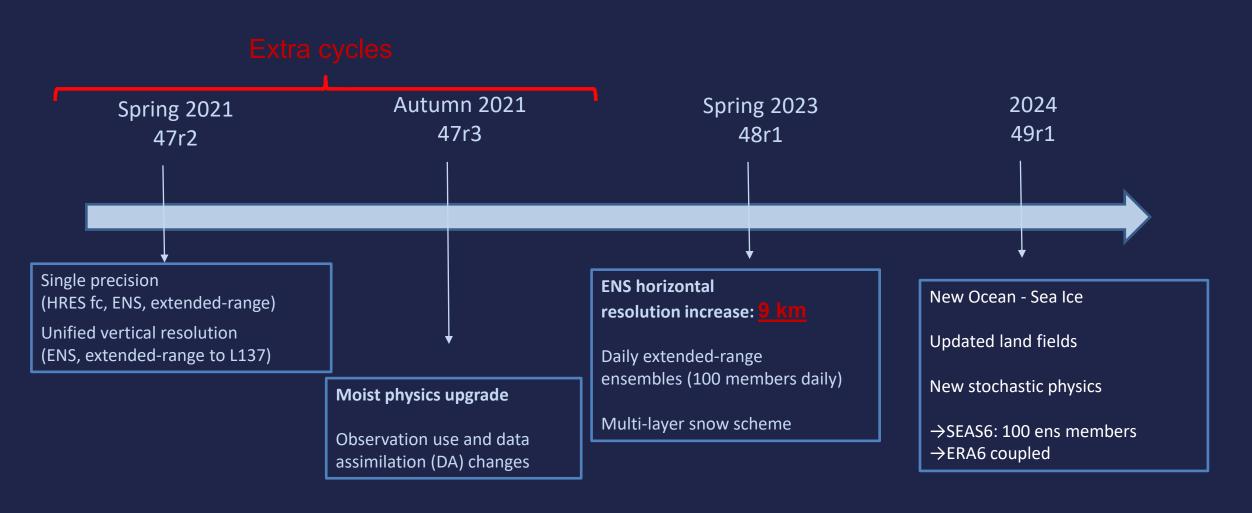
ECMWF research progress and plans

Andy Brown
Director of Research



ECMWF

Integrated Forecasting System (IFS) cycle upgrades



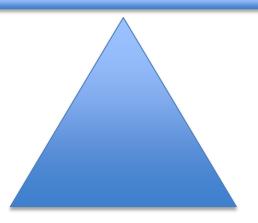
Cycle 47r2

Neutral impact

Saving of computational cost through implementation of single precision

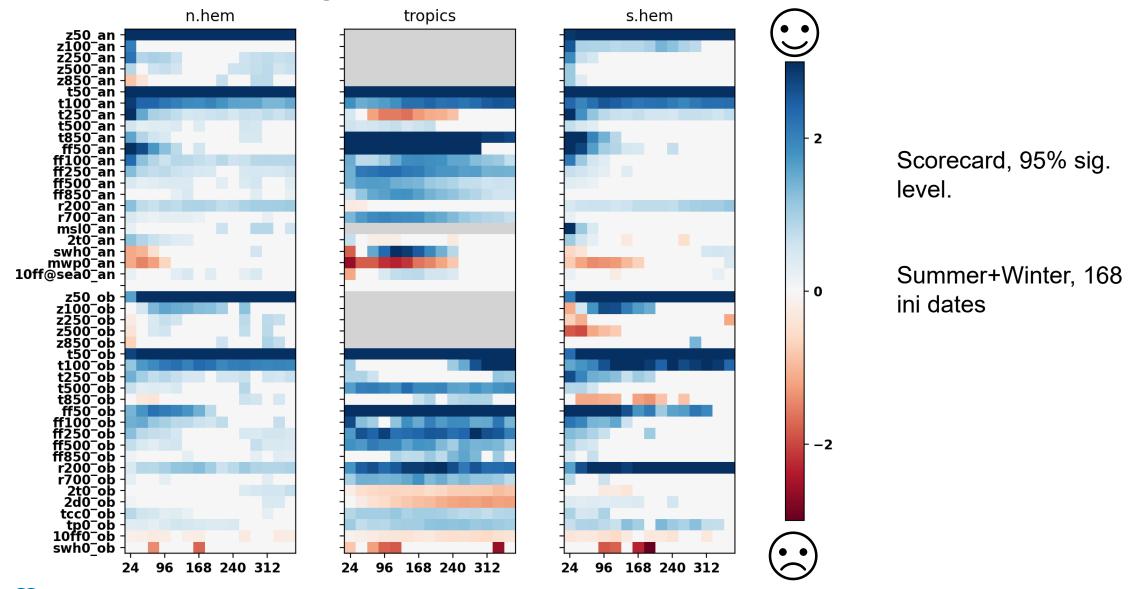
Positive impact

Investment to take ENS (medium and extended-range) from L91 to L137





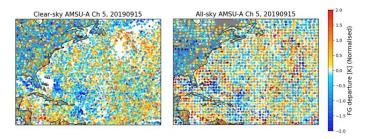
47r2: Impact of single precsion and vertical levels increase



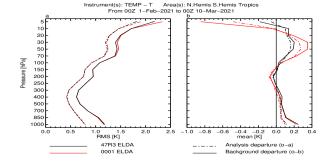


IFS Cycle 47r3

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



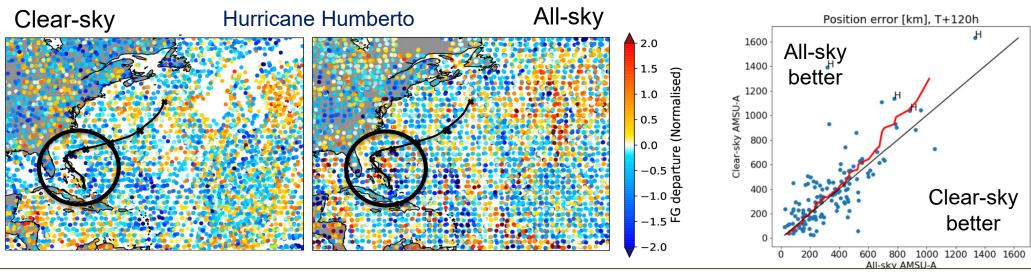


Observations: Assimilation of all-sky AMSU-A

| 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

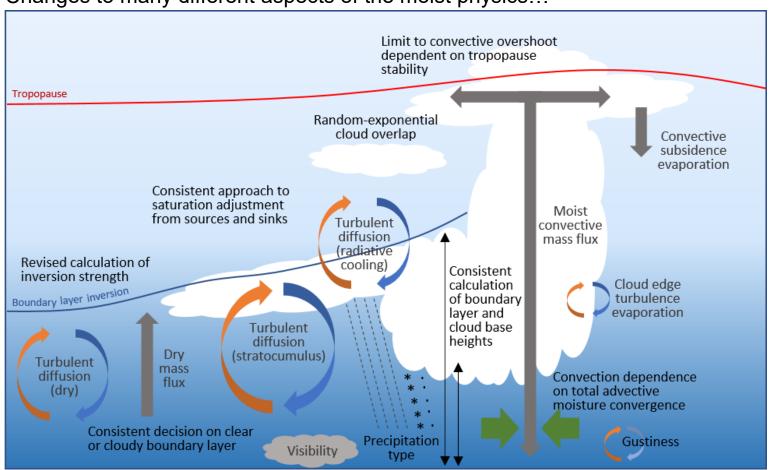


- → Assimilation of all-sky AMSU-A: Increases use of microwave sounder data in areas of cloud and precipitation (+12% global increase for Channel 5)
- → Provide critical observations near Tropical Cyclones (example: Hurricane Humberto)

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)



ECMWF Overview of IFS Cycle 47r3, Webinar, Sep 2021

HRES

ENS

(AnomCorr/RMSE)

(CRPS)

NHem SHem

NHem SHem Tropics

s.hem tropics s.hem n.hem tropics ccaf/seeps rmsef/sdef ccaf/seeps rmsef/sdef ccaf/seeps rmsef/sdef 10ff@sea 100

Tropics

Based on 650 forecasts Jun 2020 - Aug 2021



Versus analysis

Versus obs

(1) Improved upper air - GEOPOTENTIAL

AC Z500 geopotential NH/SH 1-4% improvement

HRES

ENS

(AnomCorr/RMSE)

(CRPS)

NHem SHem Tropics NHem SHem **Tropics** n.hem s.hem tropics ccaf/seeps rmsef/sdef ccaf/seeps rmsef/sdef ccaf/seeps rmsef/sdef Versus analysis 10ff@sea

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

(2) Improved upper air - WIND

RMSE extratropics 1-2%, tropics 1-7% improvement

Versus obs

HRES

(AnomCorr/RMSE)

NHem

SHem

Tropics

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- (1) Improved upper air GEOPOTENTIAL
 - AC Z500 geopotential NH/SH 1-4% improvement
- (2) Improved upper air WIND RMSE extratropics 1-2%, tropics 1-7% improvement
- (3) Degraded tropical upper-tropospheric temperature

HRES ENS (AnomCorr/RMSE) (CRPS)

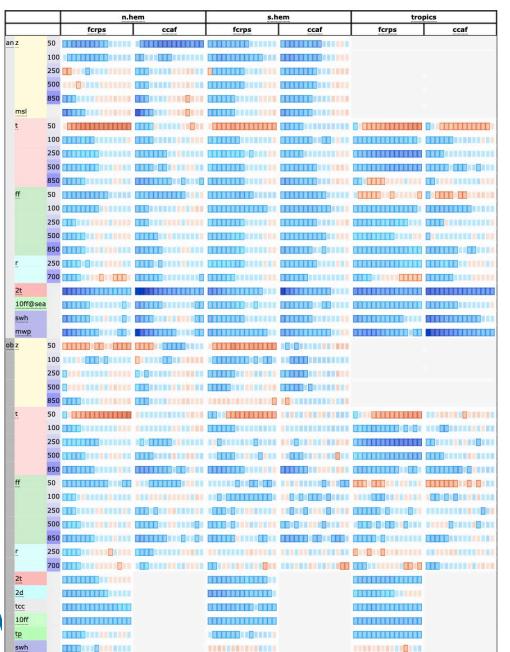
NHem SHem Tropics SHem NHem Tropics n.hem s.hem tropics ccaf/seeps rmsef/sdef ccaf/seeps rmsef/sdef ccaf/seeps rmsef/sdef analysis

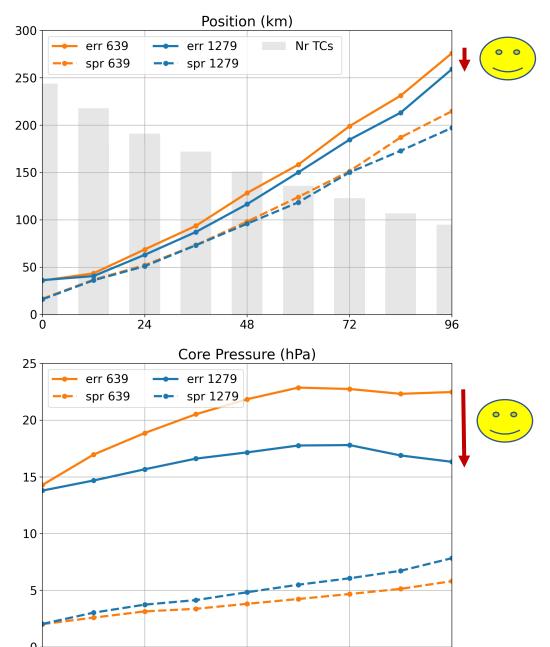
- (1) Improved upper air GEOPOTENTIAL AC Z500 geopotential NH/SH 1-4% improvement
- (2) Improved upper air WIND RMSE extratropics 1-2%, tropics 1-7% improvement
- (3) Degraded tropical upper-tropospheric temperature
- (4) Mixed signal in near surface variables

Versus

Versus obs

48r1 High resolution ensemble: scorecard and tropical cyclone improvements





48

72

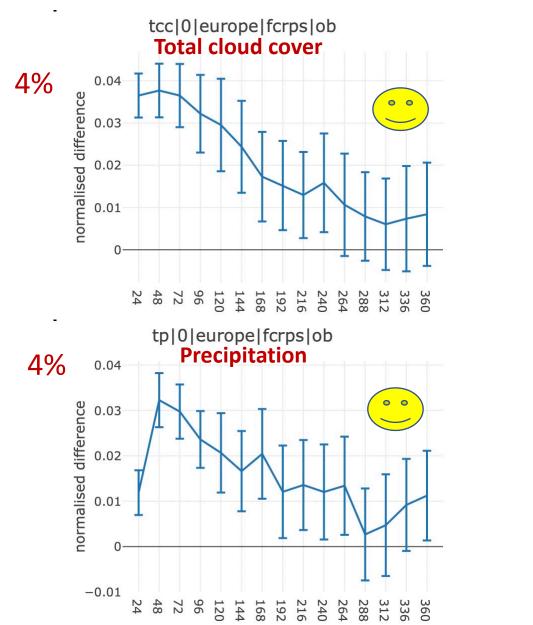
96

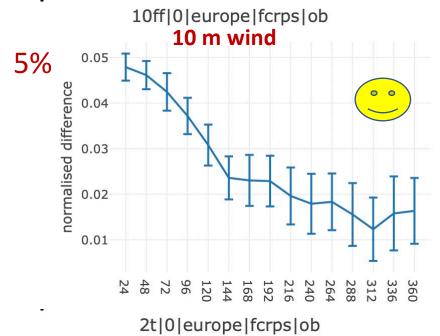
8 pert members, 00, 12 UTC 20200602 - 20200724, 20210901 - 20211019, 20201202 - 20210211

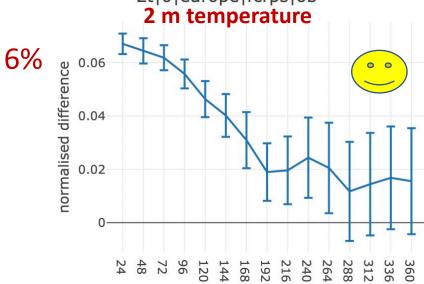
9 km (TCo1279) vs 18 km (TCo639)



48r1 High resolution ensemble: near-surface weather improvements

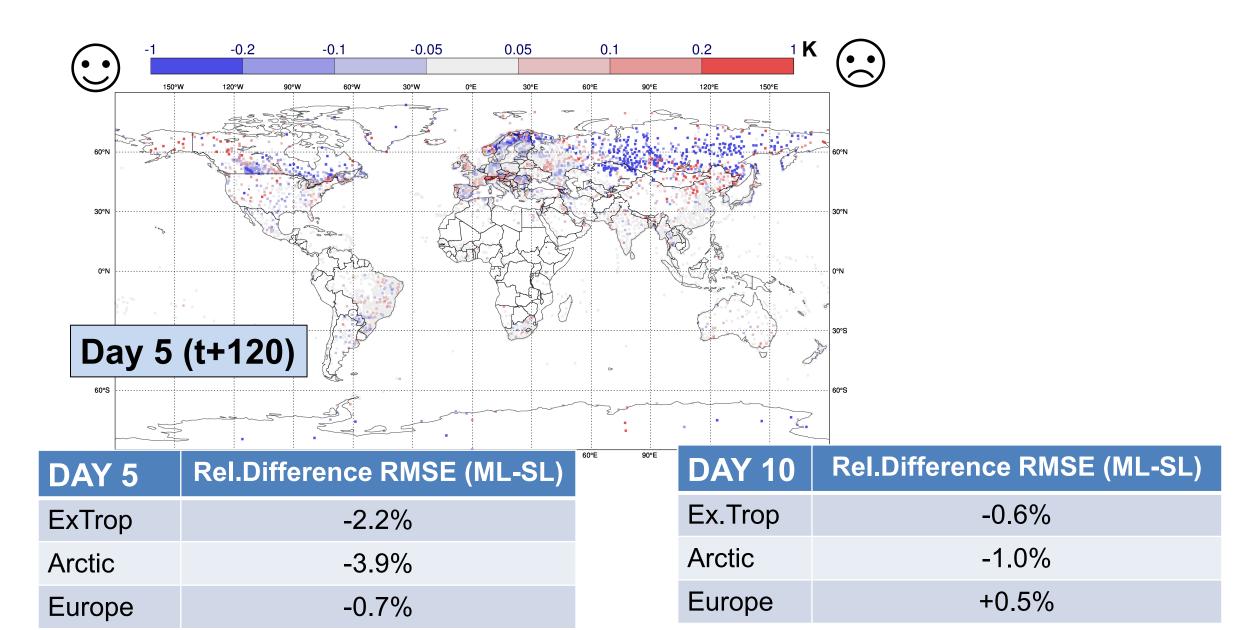




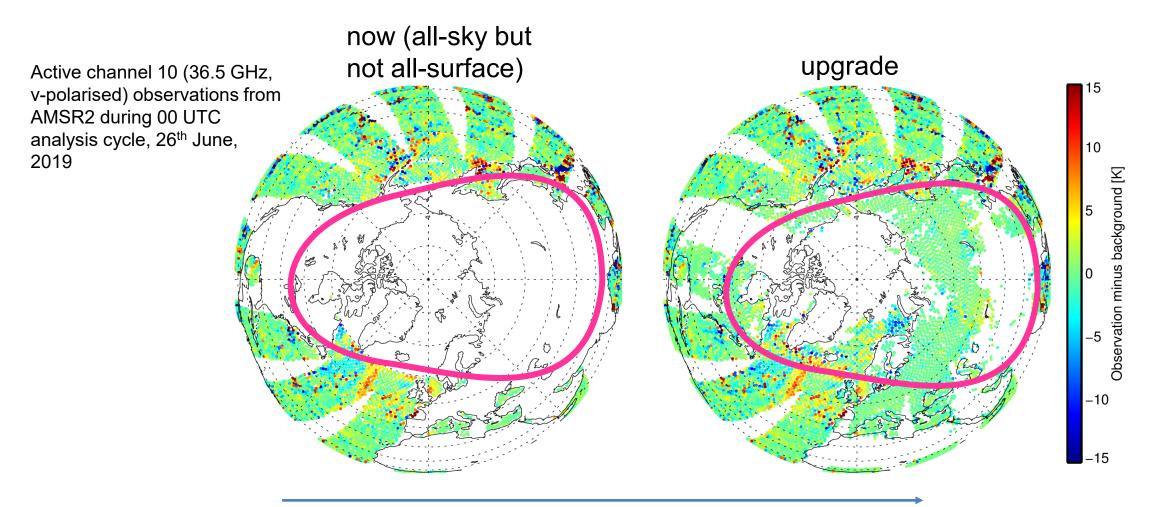


48r1: Impact of multi-layer snow

Winter, 47r1.3, DJF 2019/2020 Impact on 2-metre temperature ensemble CRPS (TCo399; L137)

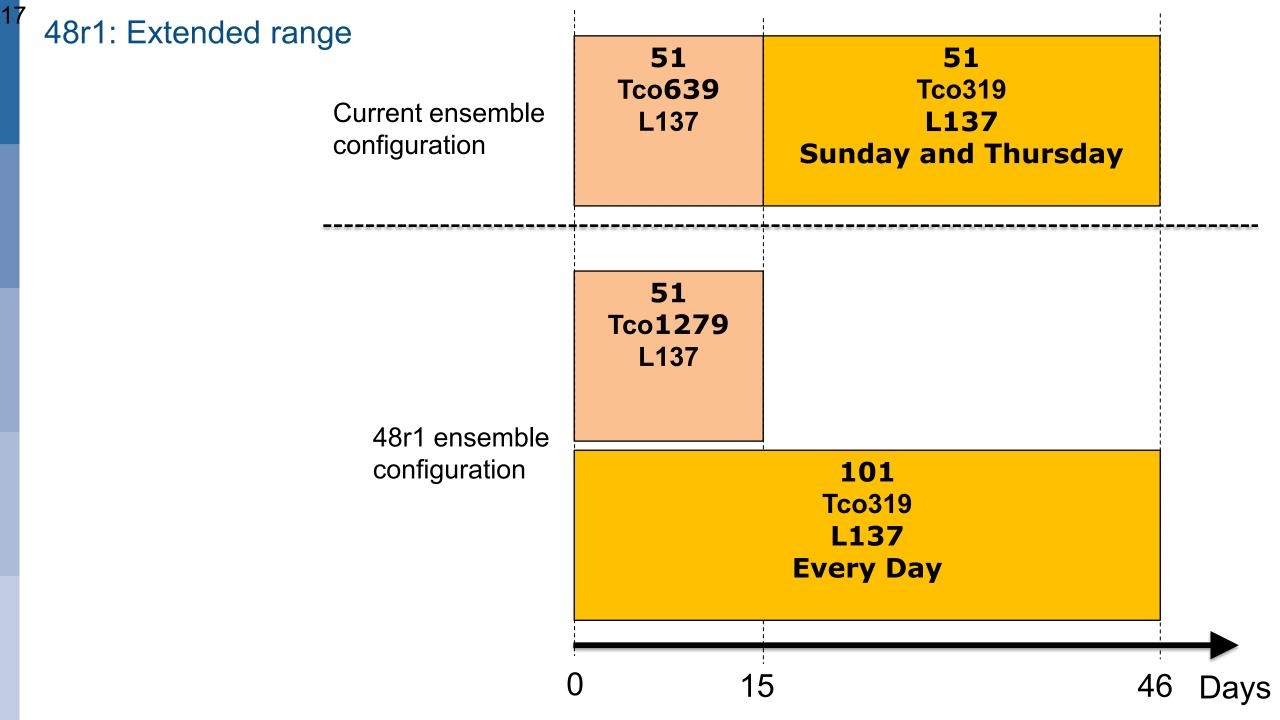


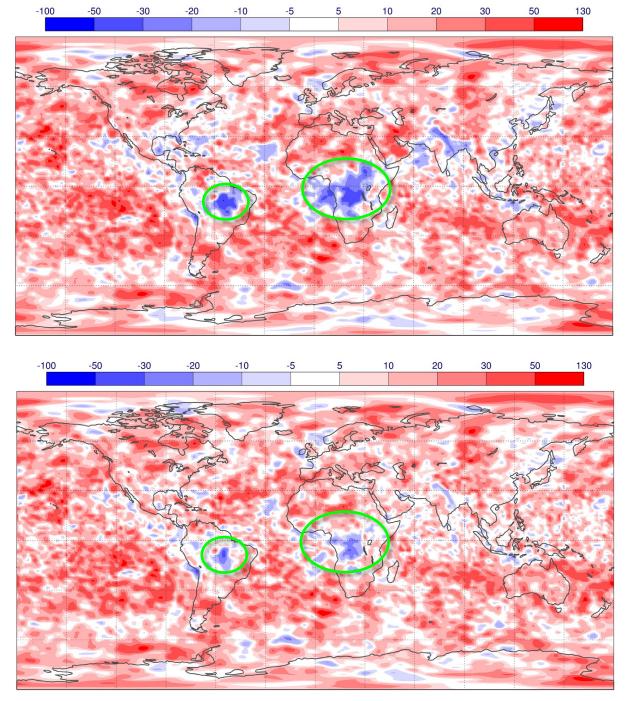
48r1: increased use of surface-sensitive microwave channels



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







Looking further ahead: Impact of prognostic aerosols

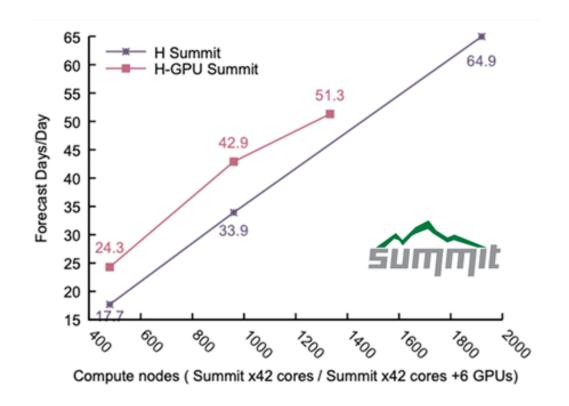
CAMS (prognostic) vs HRES (climatology)

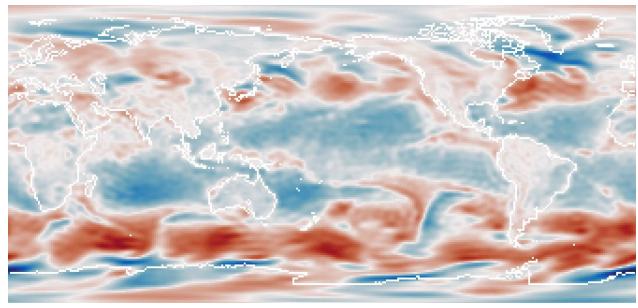
JJA 2021, T850 at 5 days

- RMS error: CAMS HRES (%)
 - CAMS appears better in southern Africa and Amazonia

- Error standard deviation: CAMS HRES (%)
 - Some improvement still remains in both locations!
 - Also T2m Siberia stddev reduced (not shown)

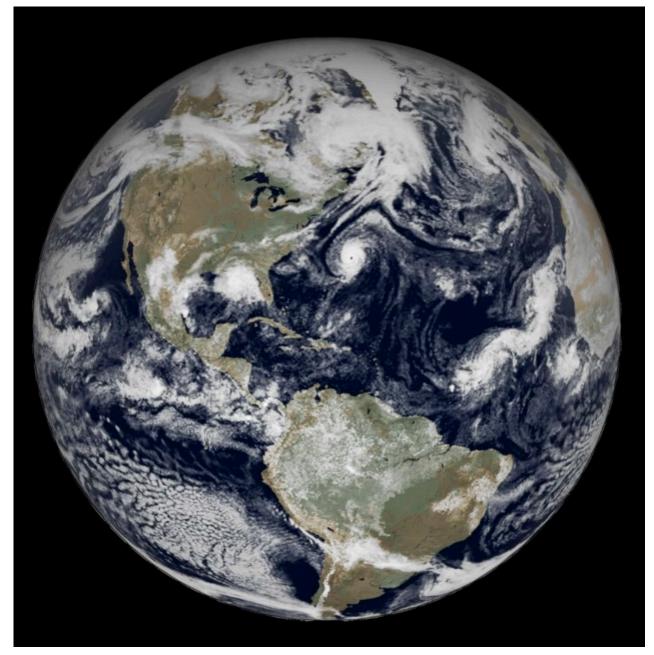
Performance of IFS at 1 km on Summit and first tests on Fugaku





Fugaku, RIKEN Center for Computational Science

Status of machine learning at ECMWF NOGWD emulation Low dimensional S2S Challenge Unstructured ecPoint Soil moisture Bias correction ocean models grids in 4D-Var assimilation **CAMS** emulator Assimilate TL/AD of M4Land scatterometer emulator for **Tropical** backscatter 4D-Var Cyclone Wildfire prediction Bias correction Estimates of the detection, ecRad emulation in 4D-Var in 3D first guess of S2S Observation Observation model error in prediction quality control operators **OOPS** AI4Emissions Lookdown induced NO2 Study tropical cyclone correction changes genesis Numerical weather Observations Data assimilation Post-processing forecasts and dissemination High-performance and (big) data processing infrastructure Sea ice Learn machine **MAELSTROM** CliMetLab Wave model Learn and understand Precipitation **Tropical Cyclone Tracking** surface learning model in 4Dco-design cycle emulation model error from downscaling emissivity Var observations Anomaly Infero detection Ensemble post-Fastem-7 for RTTOV ocean **SPARTACUS** emulation **Neural Network** Precipitation processing emissivity preconditioner downscaling **Ongoing Planned Published**





NOAA

TCo1279L137 ENS, 51 members, 20200913 00 UTC + 41 h





THE STRENGTH OF A COMMON GOAL