ICON news – higher resolution?

Günther Zängl, Martin Köhler

Deutscher Wetterdienst DWD

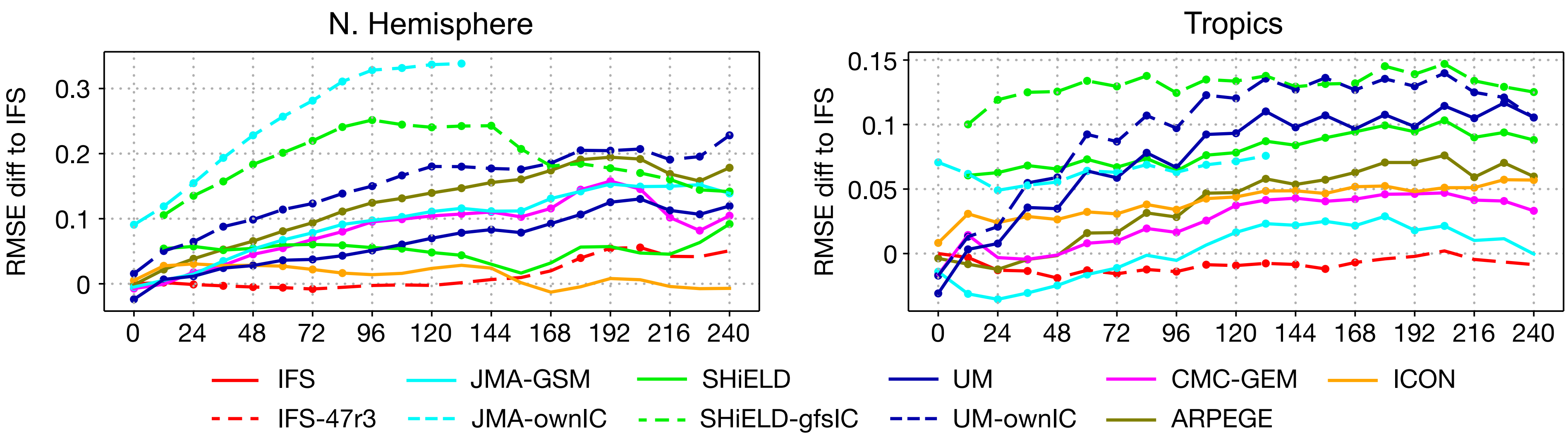
- 40, 20, 13, 10, 6.5, 3.25km

- 120 levels
- 26km ensemble
- MERIT orography

- surface parameter data assimilation
- sub-grid condensational heating

Linus Magnusson et al, DIMOSIC, 2022, BAMS subm.

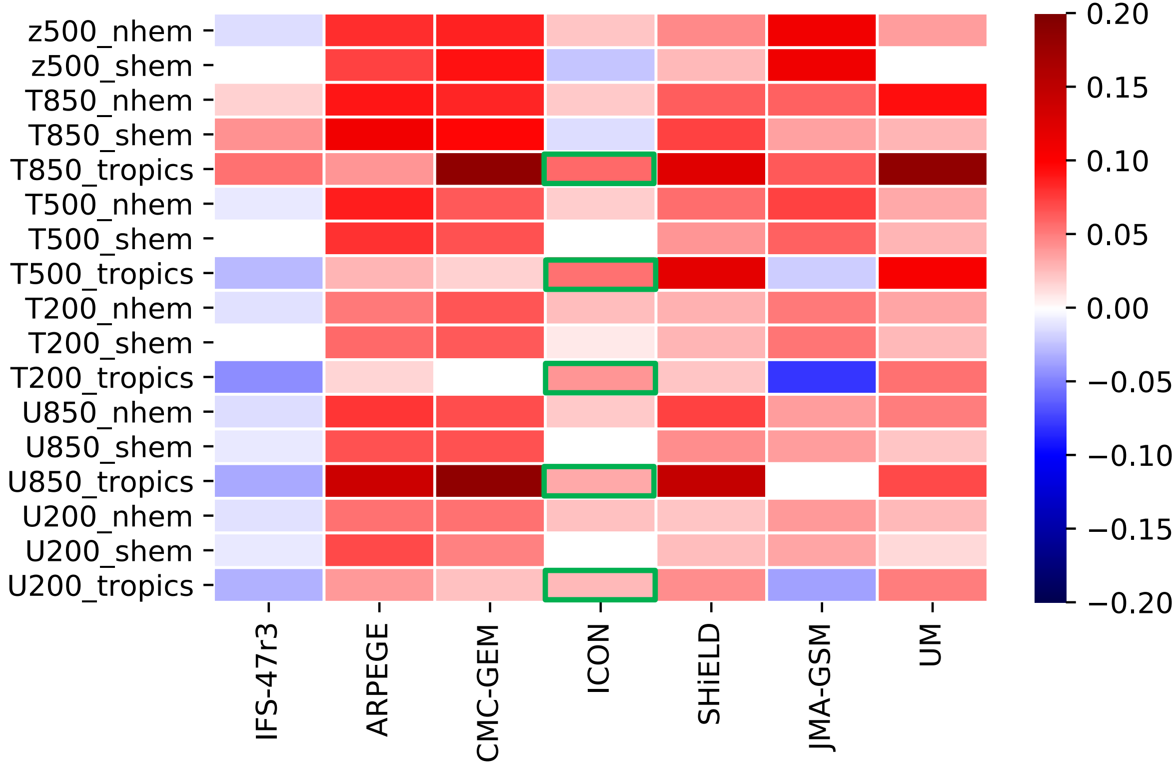
Different Models, Same Initial Conditions



T500 bias-corrected RMSE difference to IFS.

Linus Magnusson et al, DIMOSIC, 2022, BAMS subm.

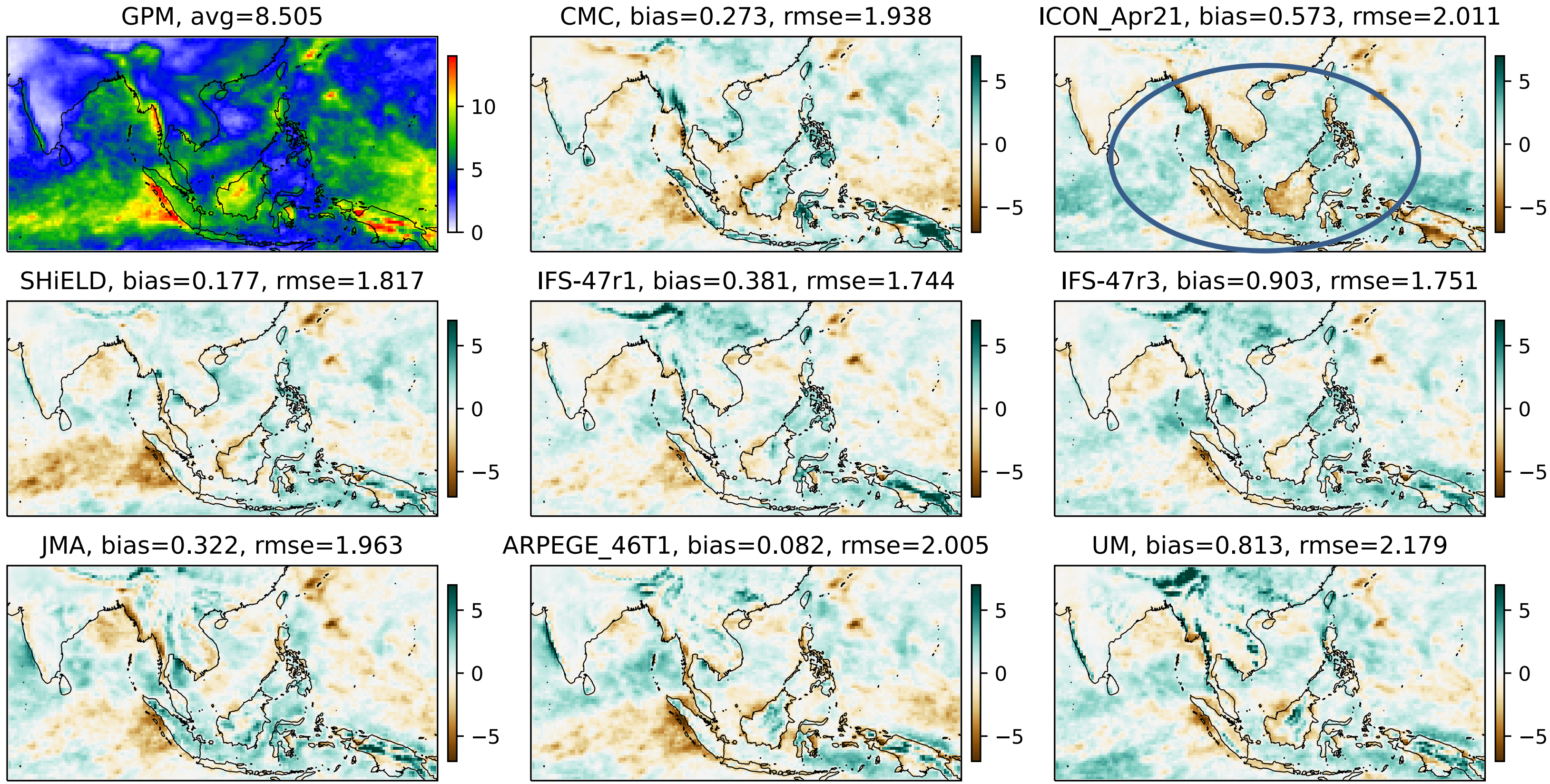
Different Models, Same Initial Conditions



Scorecard of normalized, bias-corrected RMSE difference to IFS, 72 hours

Linus Magnusson et al, DIMOSIC, 2022, BAMS subm.

Different Models, Same Initial Conditions



Mean precipitation from GPM observations and model bias averaged over 10 days.

Gray zone issues

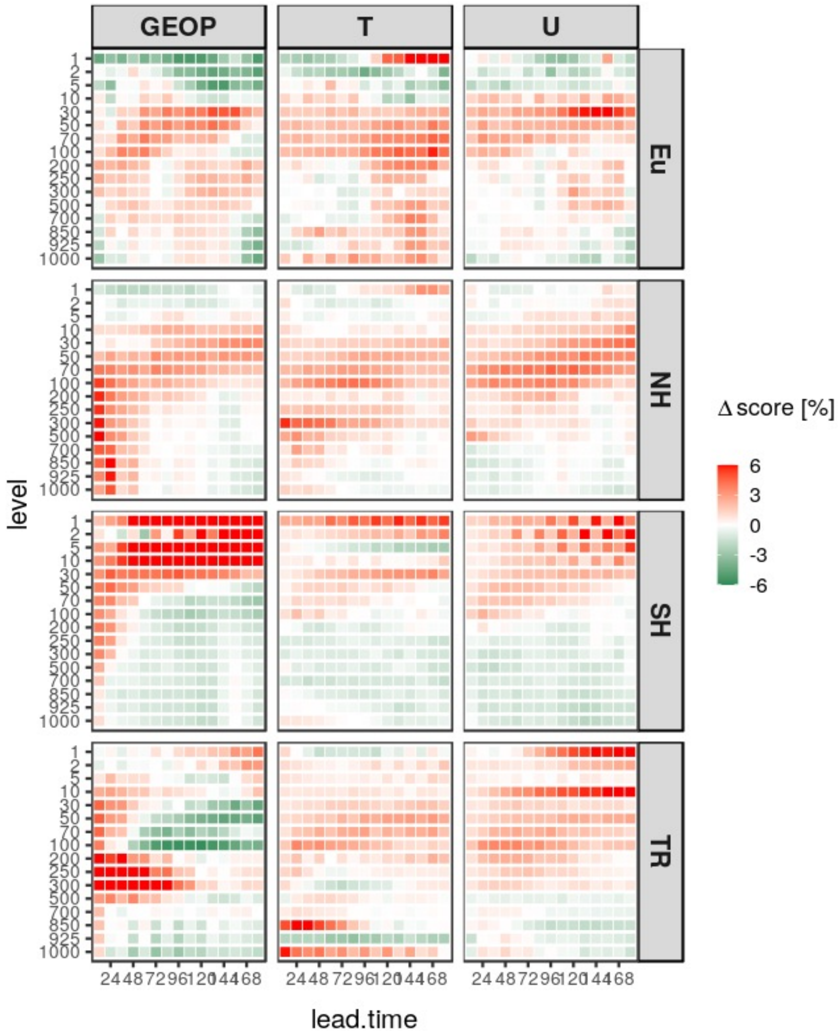
- Turning off the deep convection scheme at convection-permitting resolution improves some aspects of tropical convection that are notoriously misrepresented by the existing parameterizations.
- However, this comes at the price of other systematic errors.

- Most importantly, triggering convection explicitly at convection-permitting resolution requires a too high amount of instability, which is generated by a cold bias in the middle/upper troposphere over the tropical oceans.
- Subgrid-scale condensational heating (ongoing work) helps a bit, but still, convection-permitting is not convection-resolving!

Configuration / Tuning for the gray zone

- High-resolution raw data for **orography**
- **Subgrid-scale condensation**
- **Tuning turbulen**ce scheme (TKE source terms) to avoid excessive turbulence in breaking orographic gravity waves
- **cloud ice sedimentation** speed halved for the experiments without deep convection scheme in order to counteract the cold bias in the upper tropical troposphere

Verification against IFS analyses, 13 km vs. 6.5 km



green:
6.5km is better
change in RMSE [%]

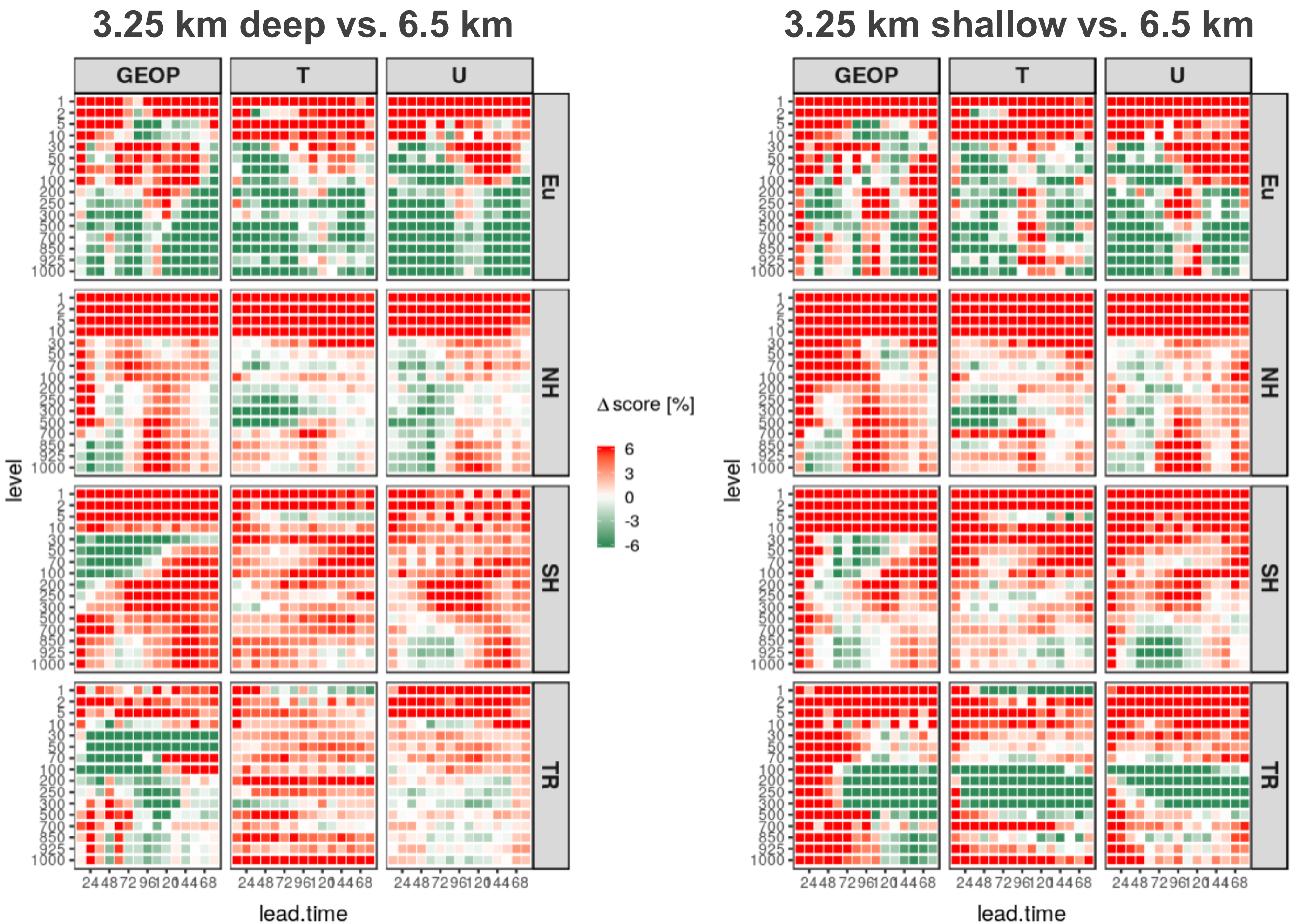
Improvements in surface-based quantities benefitting from the higher (orography) resolution.

At higher levels, results are mixed.

configuration:
120 levels to 75km
IFS initial conditions

time:
20210101 - 20210207

Verification against IFS analyses, 6.5 km vs. 3.25 km



green:
3.25km is better
change in RMSE [%]

configuration:
120 levels to 75km
IFS initial conditions

time:
20210101 - 20210112

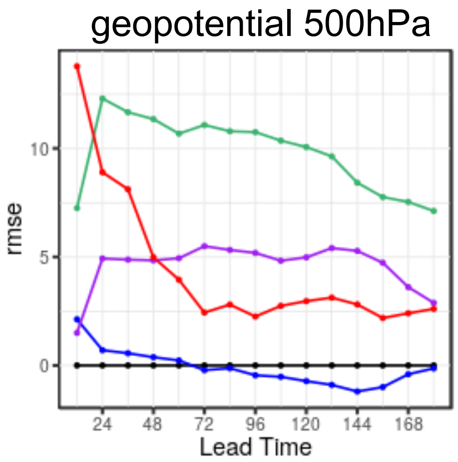
Global applications in the convective gray zone

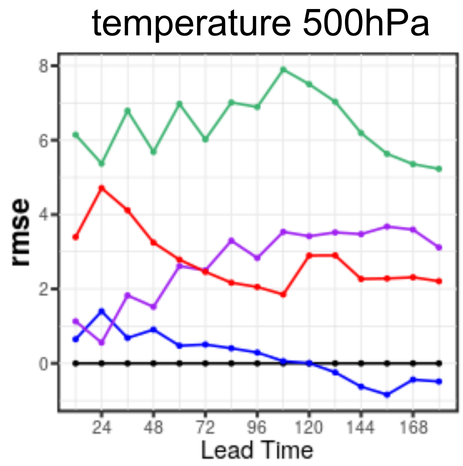
- Dynamics of tropical convection is better represented without deep convection scheme (at <3km resolution).
- Improvements for precipitation and dynamical fields in the middle/upper troposphere.

- Global forecast quality is not “ready for NWP”.
- When approaching the convective gray zone, the simple relationship “higher resolution = better scores” ceases to be valid, indicating that substantial development work on parameterisation packages is needed.

Regarding current activities on global convection-permitting modelling, it is by no means sufficient to focus on technical aspects like the GPU port of model codes and I/O optimization

Sensitivity to horizontal resolution





(Europe nest)
40km (20km) ← oper EPS
26km (13km) ← new EPS
13km (6.5km) ← oper deterministic
10km (5km)
6.5km

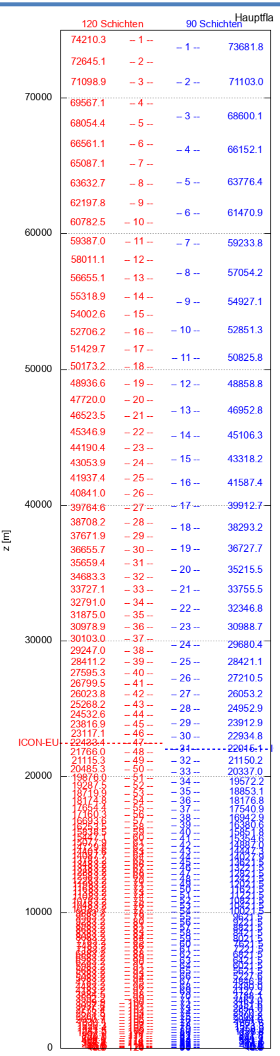
relative differences [%] to operational configuration (13/6.5 km)
verification against IFS analyses (January 2021)

Resolution upgrade in global ICON

Enhance EPS resolution from 40/20 km to 26/13 km while keeping the deterministic configuration at 13/6.5 km; increase number of vertical levels from 90 to 120 (60 to 74 in EU-nest) in DET and EPS, placing the majority of the additional levels in the stratosphere

Planned to become operational end of November 2022.

120 versus 90 levels



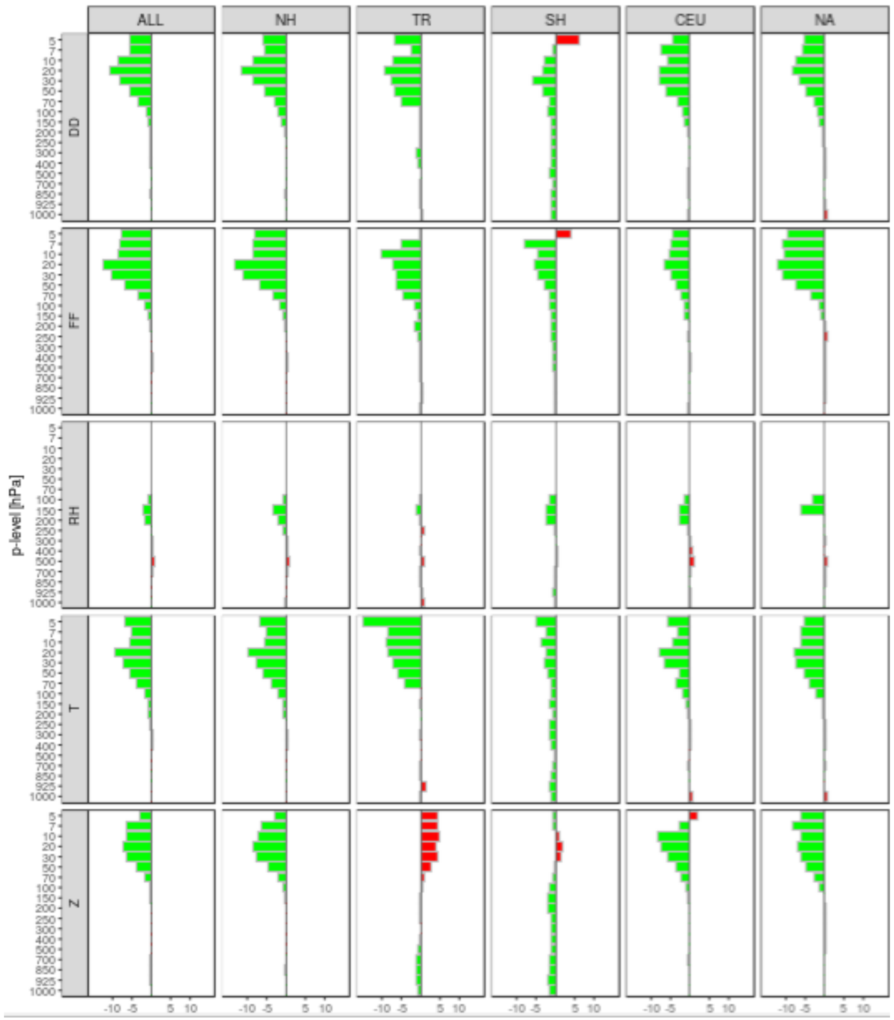
wind direction

wind speed

rel. humidity

temperature

geopotential



green:
120 is better
change in CRPSF [%]
radiosondes

important for
assimilation
of satellite data

EPS January 2021

EPS resolution increase 26km vs 40km and L120 vs L90

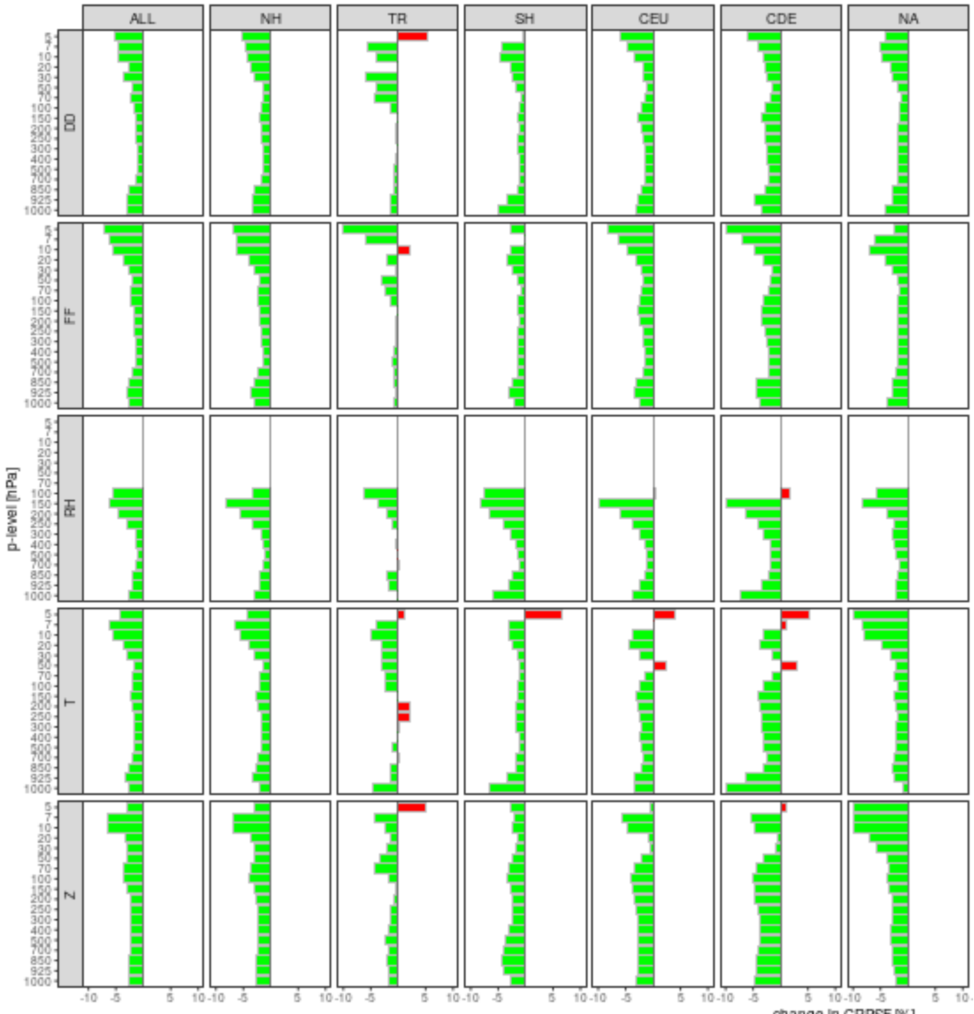
wind direction

wind speed

rel. humidity

temperature

geopotential



green:
26km is better
change in CRPSF [%]

Winter 2020/21
80 days

New orography data: motivation

- The **GLOBE** data set currently used for the global system has a rather coarse resolution (30´´, ~ 1km) and known errors
- The high-resolution **ASTER** data set (1´, ~30m) used for ICON-D2 is limited to 60°N-60°S
- Finding a global high-res data set without obvious quality issues turns out to be difficult; we thus decided to use a merge of **MERIT** (90°N-60°S) and **REMA** (62°S-90°S) data (~90m).

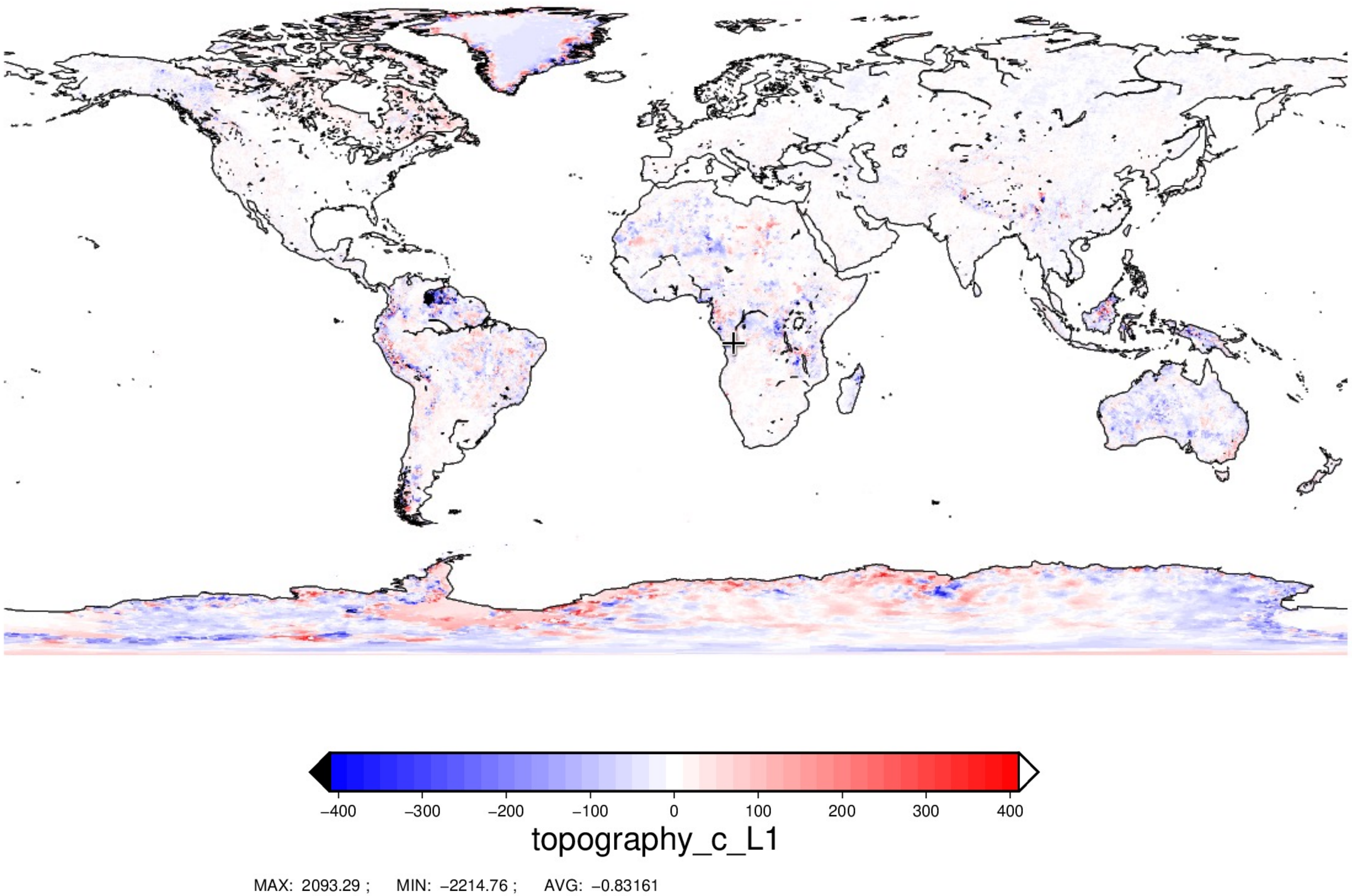
- Most importantly, the higher raw data resolution allows a more accurate calculation of SSO parameters, which are highly relevant for the forecast quality in NH winter

- Will become operational together with the resolution upgrade.

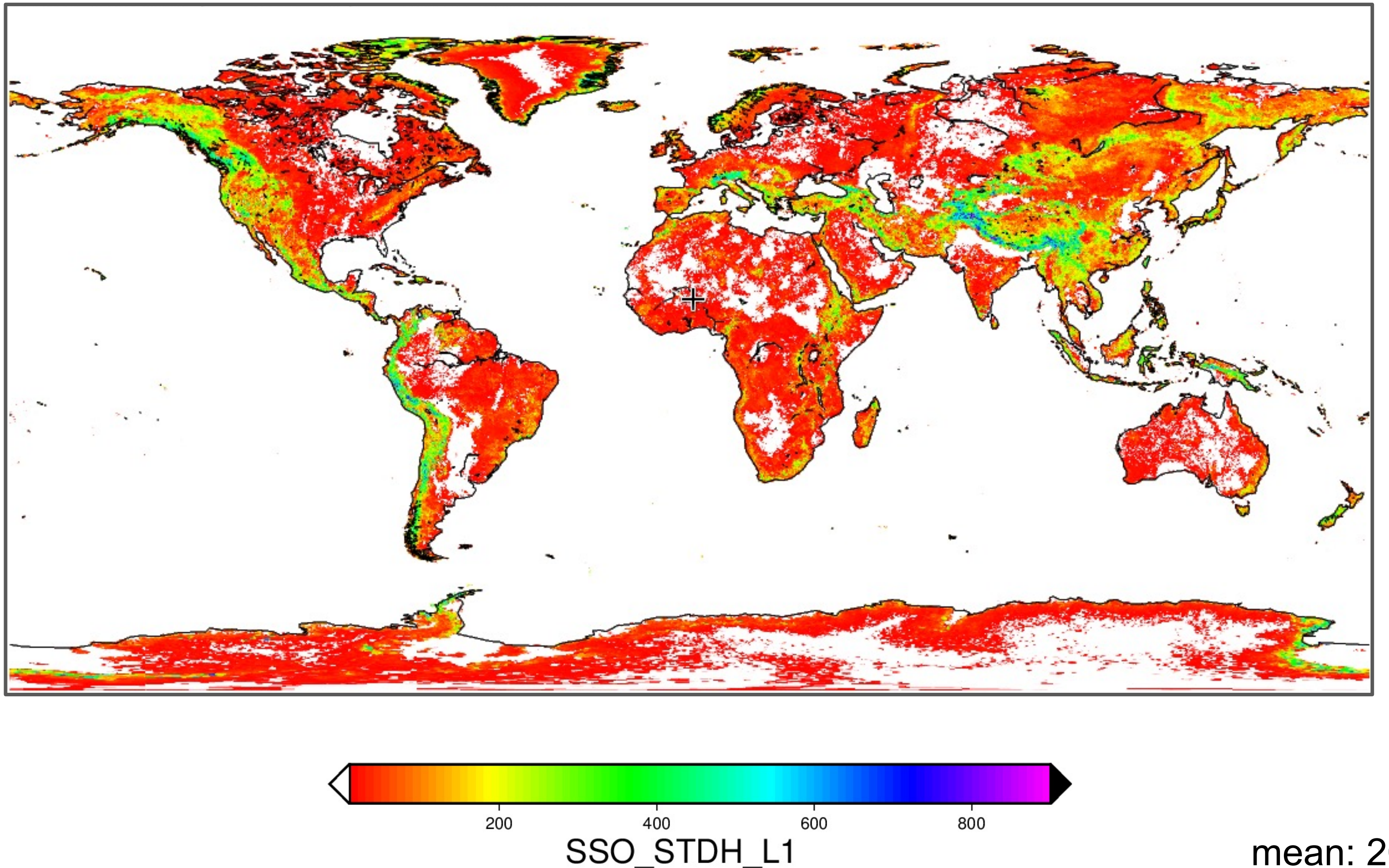
Many thanks to Jürgen Helmert, Astrid Schöne, René Redler

Orographies for ICON at 13km: MERIT/REMA – GLOBE

90m 1000m

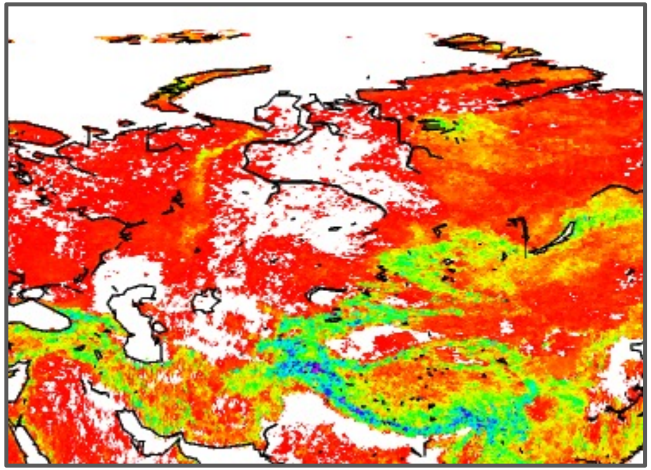


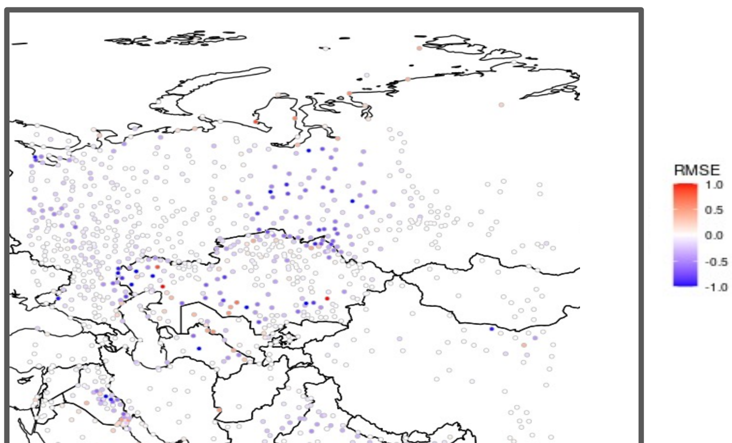
SSO-STDH for ICON-R3B7 (white for < 10m)



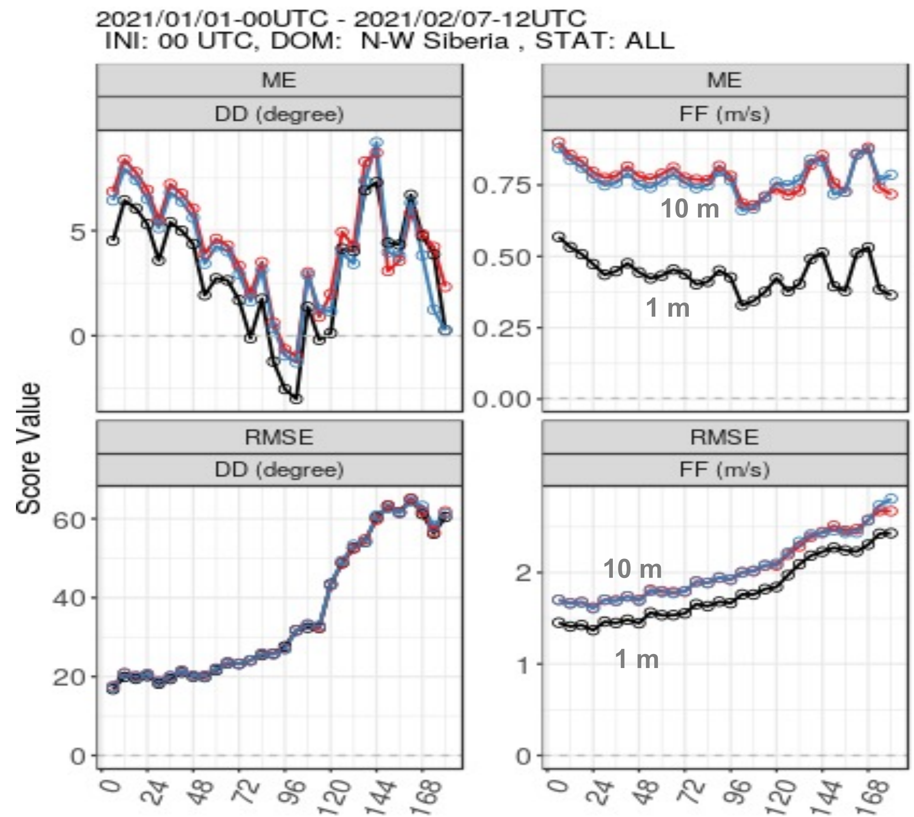
mean: 20.4m

NW-Siberia: reducing “SSO cutoff” from 10m to 1m

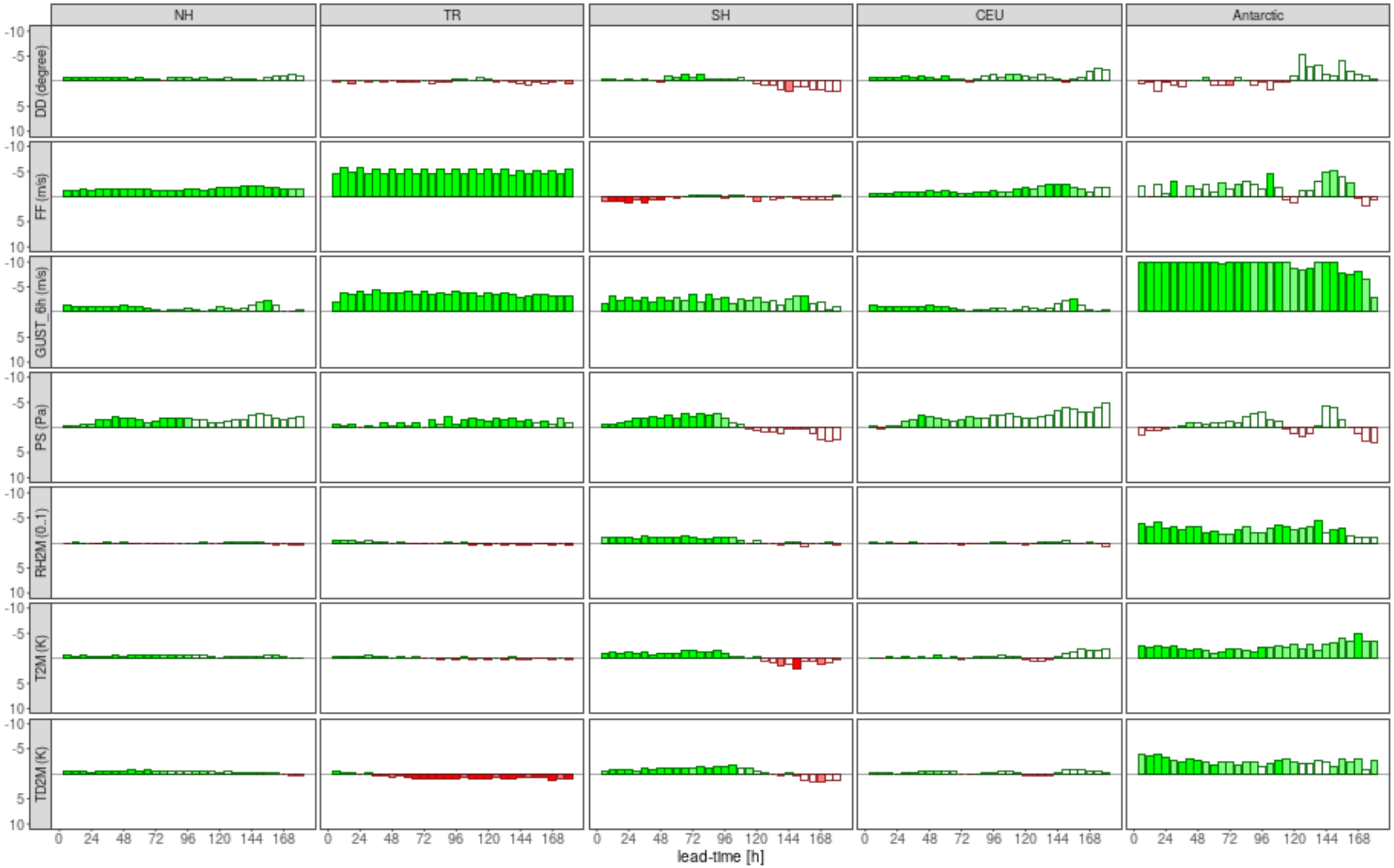




RMSE difference FF10M



MERIT/REMA orography vs GLOBE: SYNOP verification



green:
MERIT is better
change in RMSE [%]

Winter 2020/21
80 days
full data assim.

T2M assimilation and model-DA coupling

T2M assimilation provides input that can be used for an adaptive adjustment of uncertain model parameters in order to minimize systematic errors. On the other hand, successful T2M assimilation relies upon this error minimization.

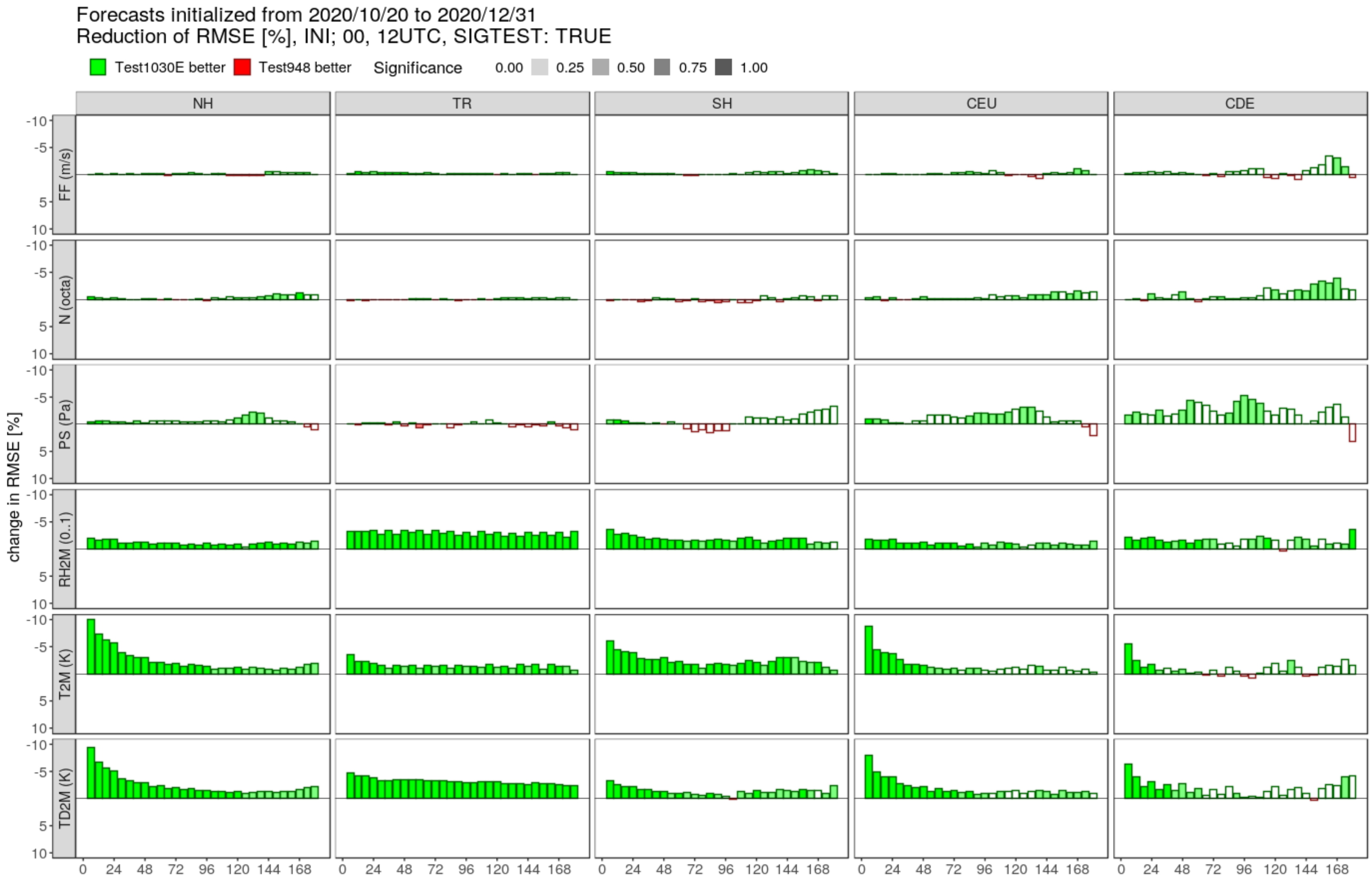
Methodology:

- Compute time-filtered DA increments of T and RH at the lowest model level as a proxy for the T2M and RH2M model bias (this obviously implies that T2M and RH2M need to be assimilated)
- In addition, a filtered T increment weighted by COS(local time) is computed as a proxy for the T2M amplitude bias
- Based upon this information, uncertain model parameters like stomata resistance, bare soil evaporation (c_soil), snow albedo, skin conductivity, soil heat capacity and conductivity are varied around their base value derived from external parameter data and parameterization assumptions

Became operational on May 11, 2022.

Thanks to Harald Anlauf.

Scorecard SYNOP verification

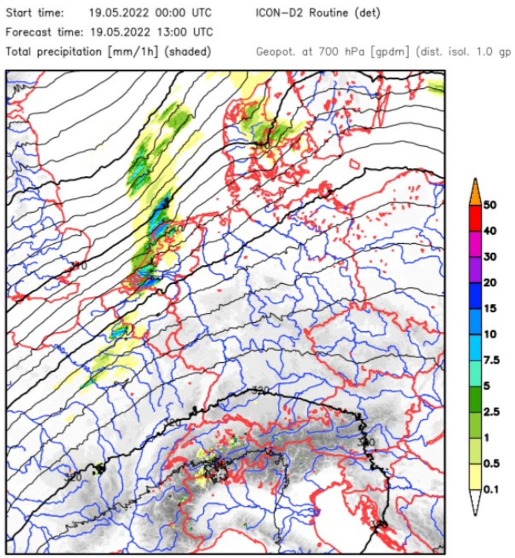


Subgrid-scale condensational heating

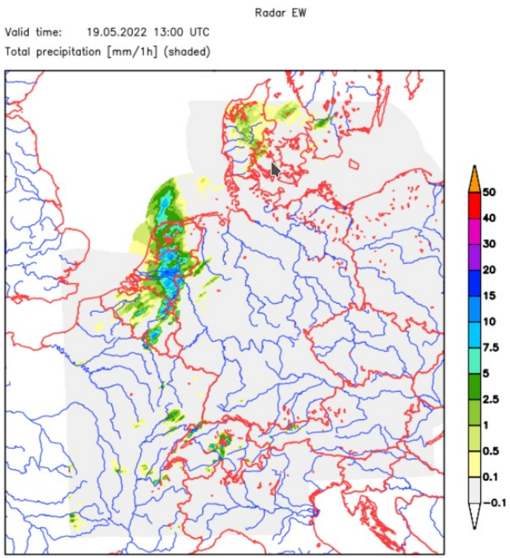
- Forecasters complain that ICON-D2 triggers convection too late / too sparsely in some situations, primarily under weak large-scale forcing
- Grid-scale saturation adjustment obviously delays the onset of latent heating at convection-permitting (but not resolving) scales
- A consistent treatment of subgrid-scale variability in saturation adjustment and cloud microphysics would be a major new development with uncertain time-to-success
- This led to the idea of a simplified approach that focuses on the leading-order process, i.e. to account for the latent heating related to changes in diagnosed subgrid-scale cloud water
- Forecast scores tend to show light to moderate improvements on average over longer periods; however, a large impact was found in a few cases of (original) forecast failures

Showcase 19.05.2022

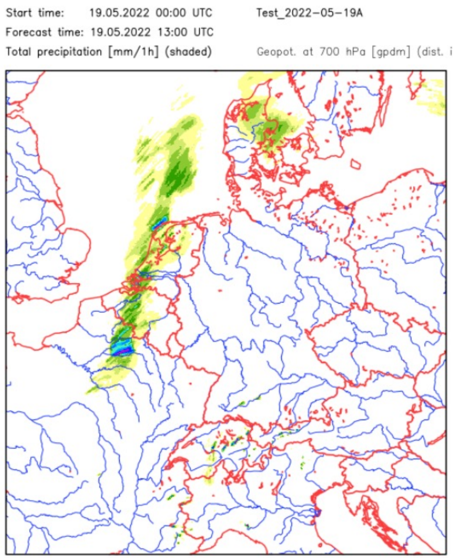
00-UTC forecast run, 1h-precipitation 12-13 UTC



Operational forecast



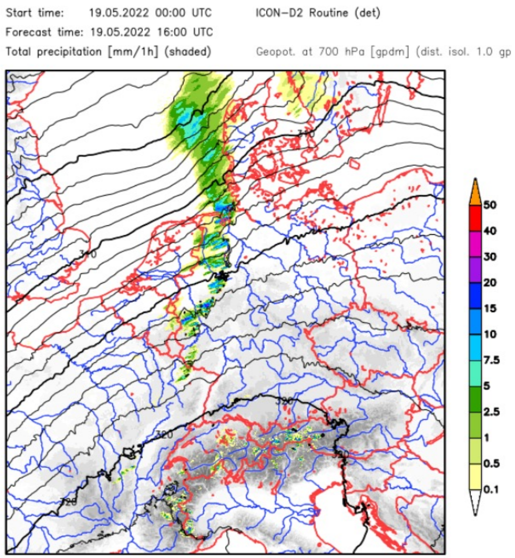
Radar



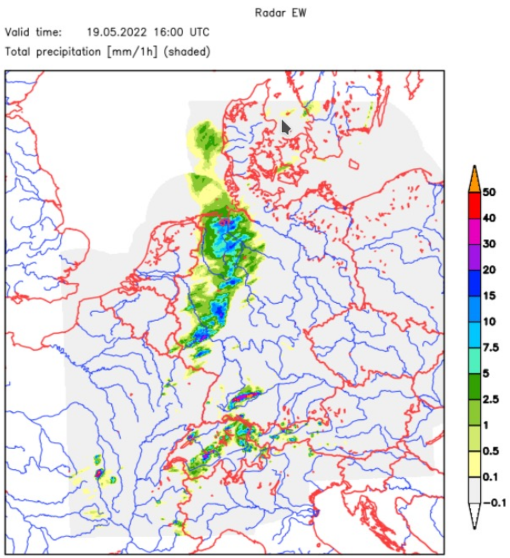
Experiment with subgrid-scale condensation

Showcase 19.05.2022

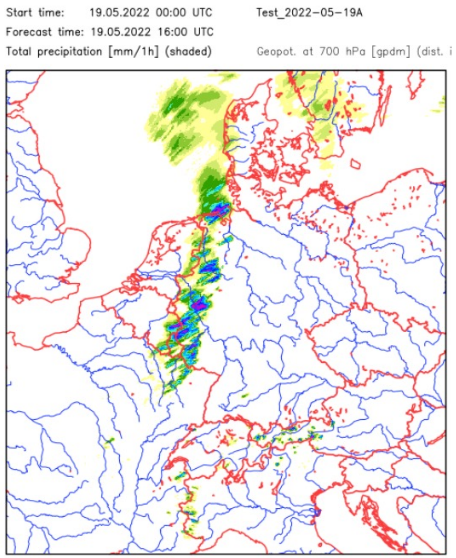
00-UTC forecast run, 1h-precipitation 15-16 UTC



Operational forecast



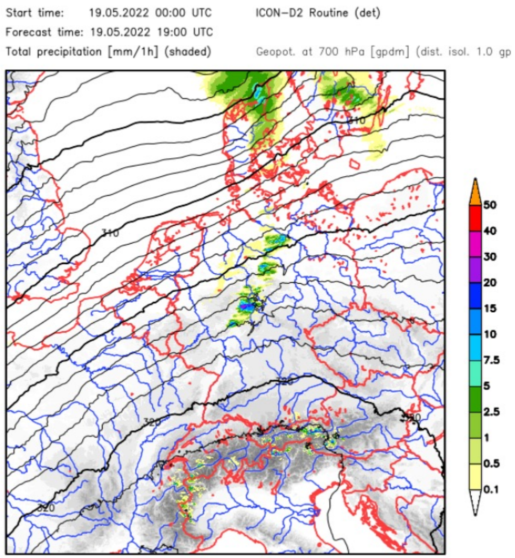
Radar



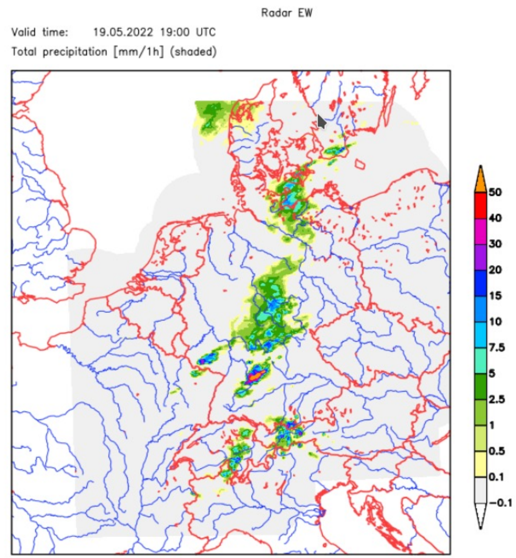
Experiment with subgrid-scale condensation

Showcase 19.05.2022

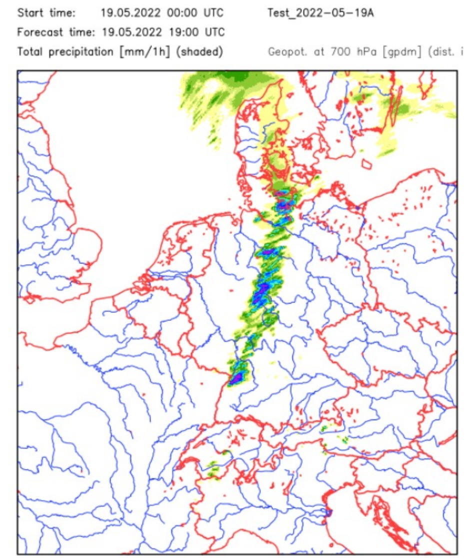
00-UTC forecast run, 1h-precipitation 18-19 UTC



Operational forecast



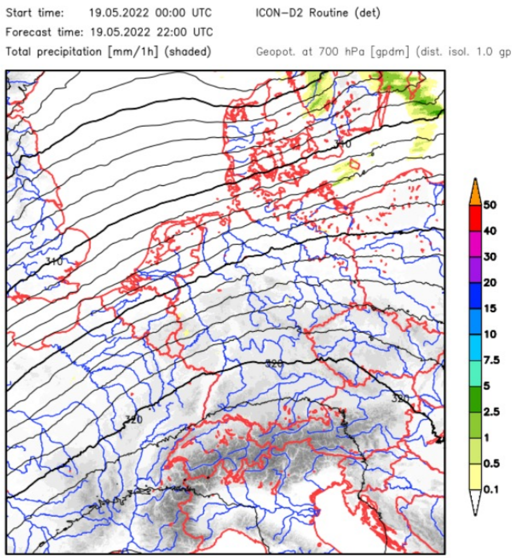
Radar



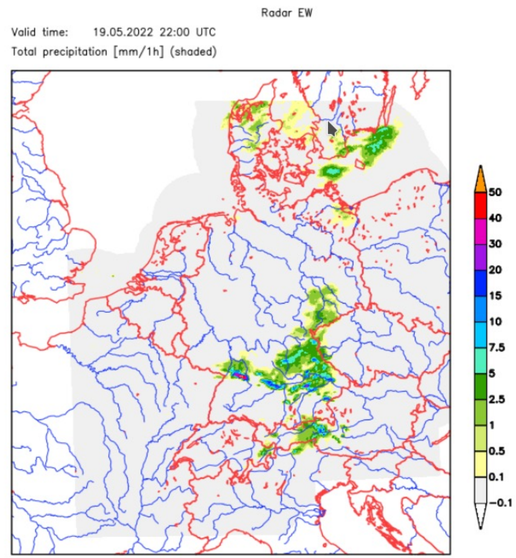
Experiment with subgrid-scale condensation

Showcase 19.05.2022

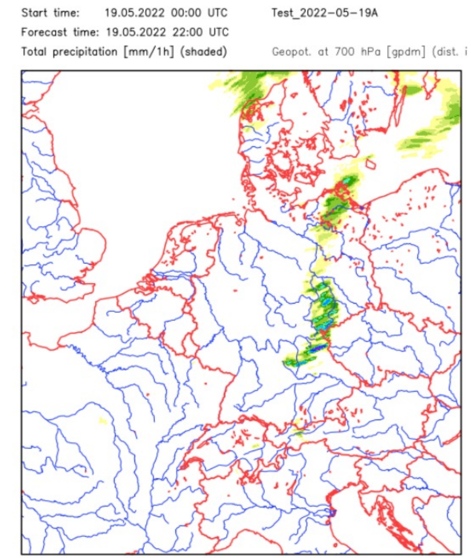
00-UTC forecast run, 1h-precipitation 21-22 UTC



Operational forecast



Radar



Experiment with subgrid-scale condensation

summary

- **Resolution sensitivity** of ICON (40, 20, 13, 10, 6.5, 3.25km)

  best performance at ~10km

- **Resolution package** for end 2022
  - 120 levels
  - 26/13km ensemble
  - MERIT / REMO orography (90m)

- T_{2M} assimilation and automatic surface model parameter tuning
- sub-grid condensational heating