Parameterization approaches in ICON for the convective gray zone

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on behalf of the ICON development group at DWD

ECMWF Annual Seminar 2022

13.09.2022

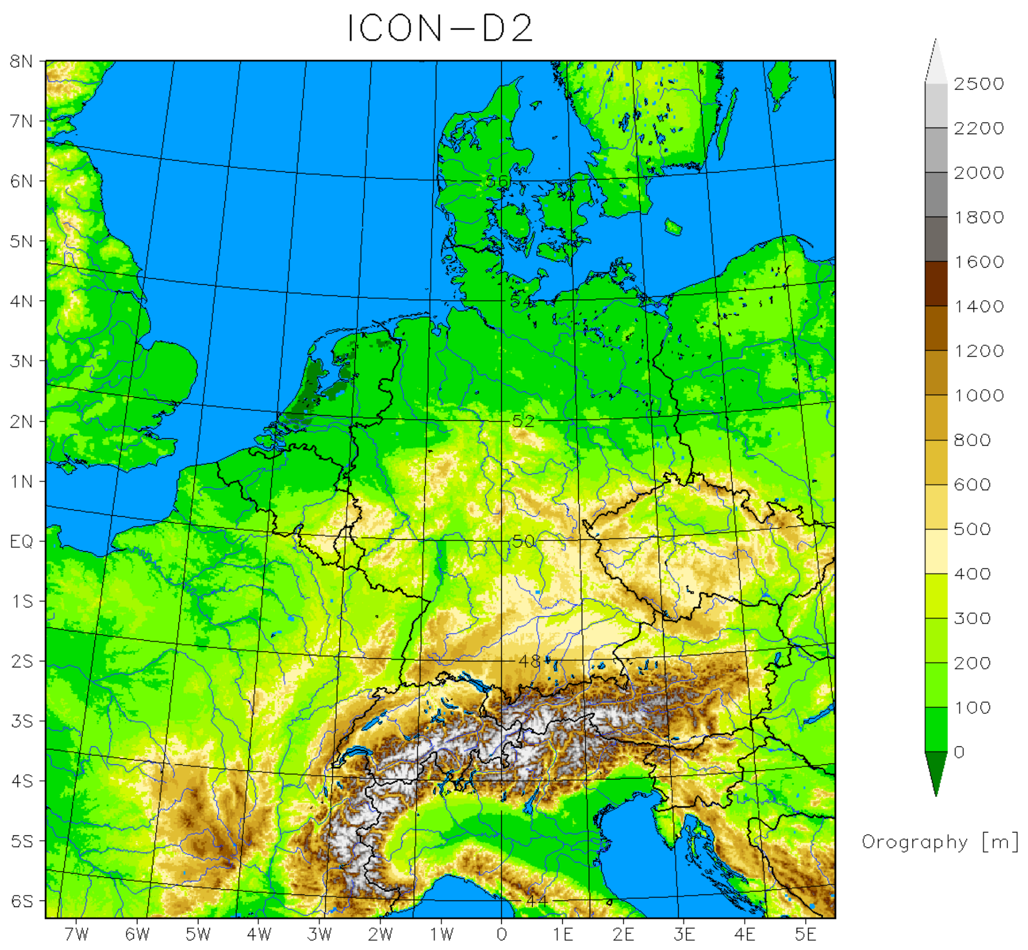
Overview

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- Operational convection-permitting LAM configuration: ICON-D2
  - Basic configuration
  - Parameterization approach w.r.t. precipitation/convection
  - Recent development: subgrid-scale condensational heating
- First results from global convection-permitting experiments
- Summary and need for future work

ICON-D2: Basic configuration

Model domain / orography



- Domain is defined as rectangle in rotated lat-lon coordinates in order to match coverage of previous COSMO-D2
- Horizontal mesh size 2.1 km
- 65 levels with top at 22 km
- lead time 48 h, 8 forecasts per day for deterministic run plus 20 EPS members
- LETKF-based data assimilation scheme with 40 members

ICON-D2: Parameterization approach

- **Grid-scale single-moment cloud microphysics scheme coupled with grid-scale saturation adjustment**
- **Tiedtke-Bechtold convection scheme in 'grayzone deep convection' mode**
  - components for shallow and deep convection are active, but not mid-level convection
  - convective adjustment time scale, entrainment profile, and CAPE closure are strongly tuned in order to reduce activity of the scheme
  - additionally, the shallow convection depth and the cloud-base entrainment rate are resolution-dependent for dx < 5 km
- **Diagnostic cloud cover scheme, RH-based with additional coupling to turbulence and convection scheme**
- **Recent development: temporal changes in diagnosed subgrid-scale excess cloud water are associated with latent heat release, passed as 'slow physics forcing term' to the dynamical core**

Motivation for 'grayzone deep convection'

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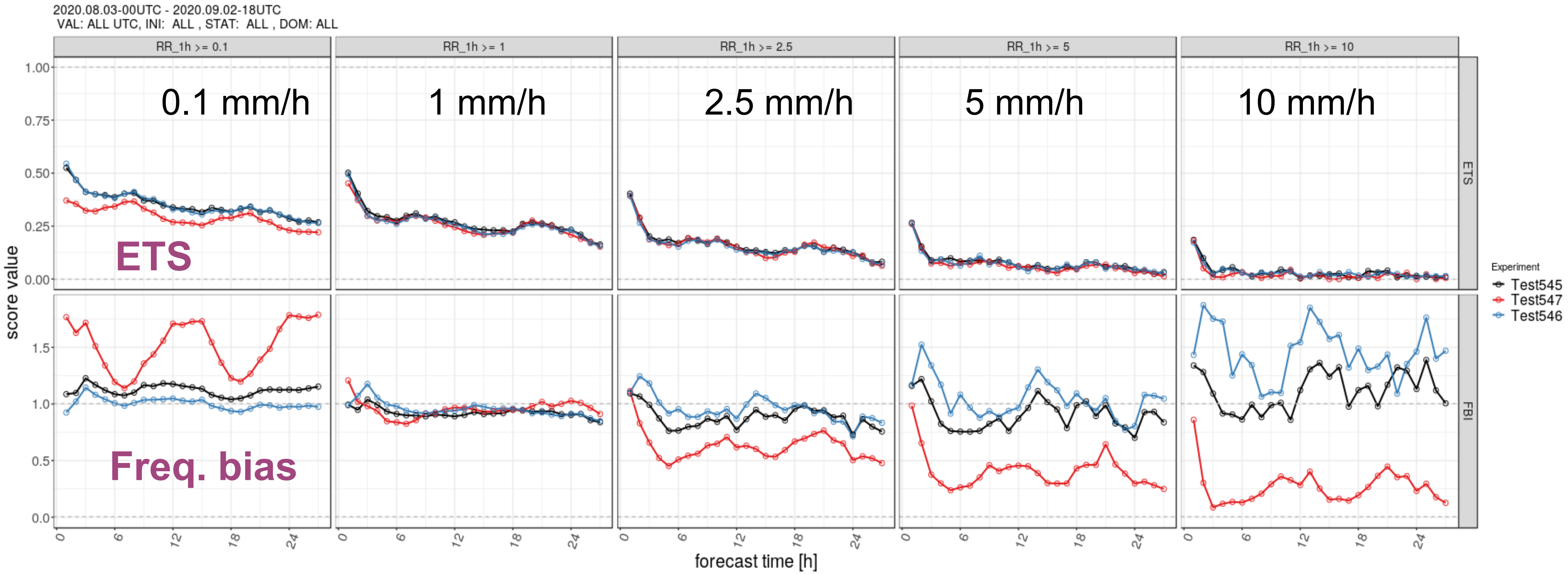
Verification scores for 1-month experiments (August 2020) with grayzone deep convection, standard deep convection, shallow convection only



Grayzone deep convection generates the best precipitation intensity spectrum

Caveat: it does not provide satisfactory scores in global applications

Subgrid-scale condensation

- ➔ Our forecasters complained 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 us 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
- ➔ Example: squall-line front of May 19, 2022

Showcase 19.05.2022

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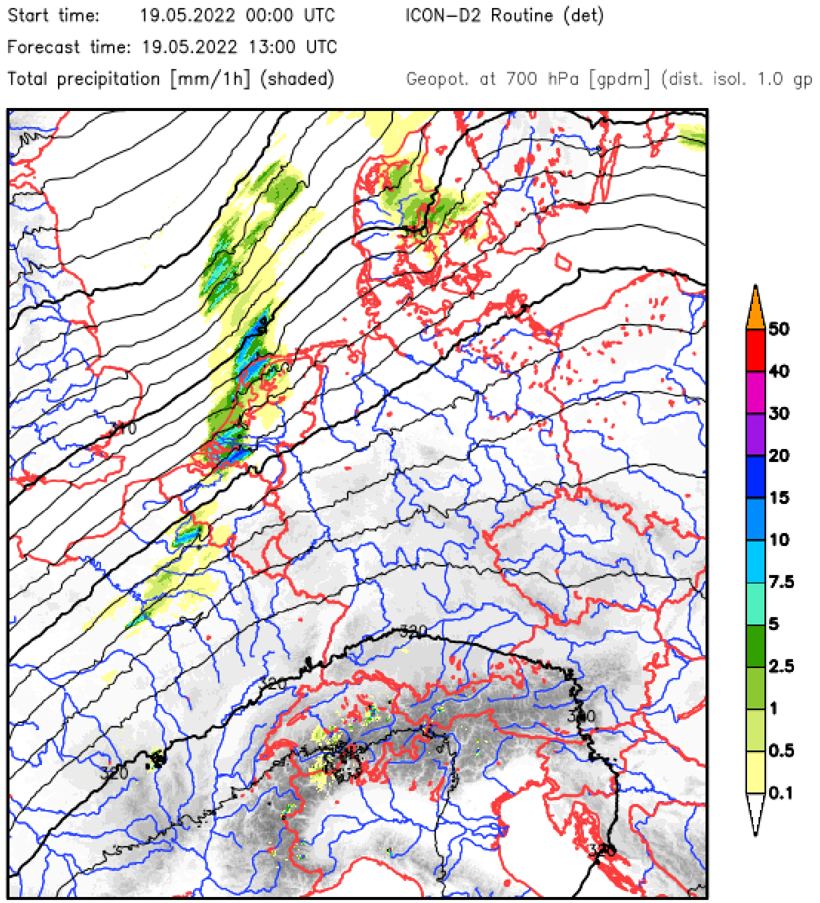
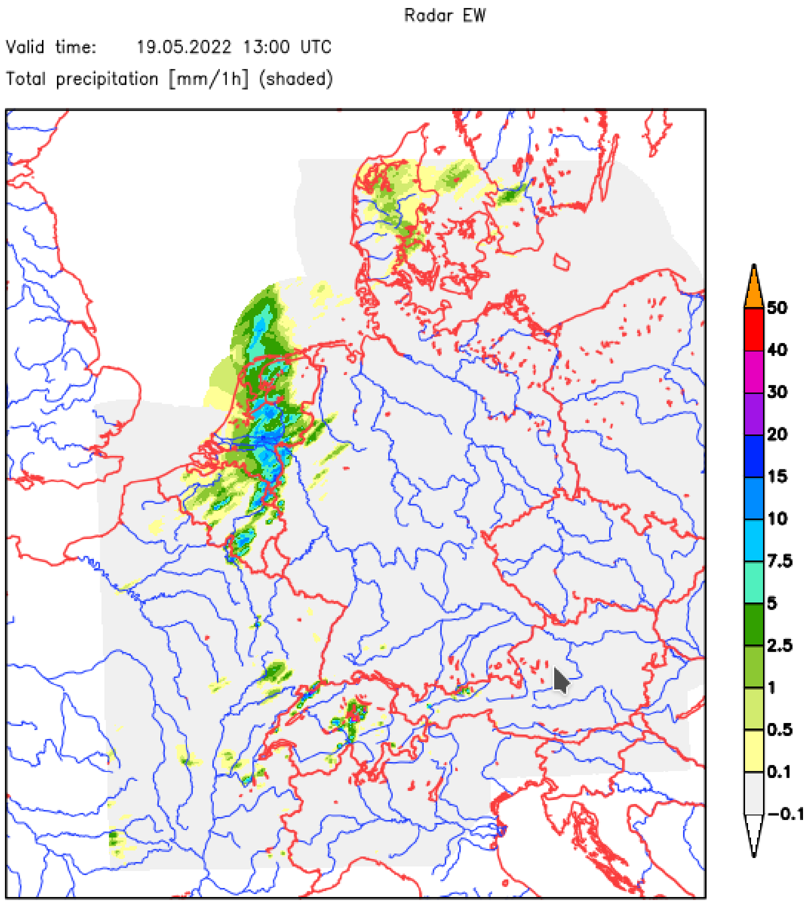
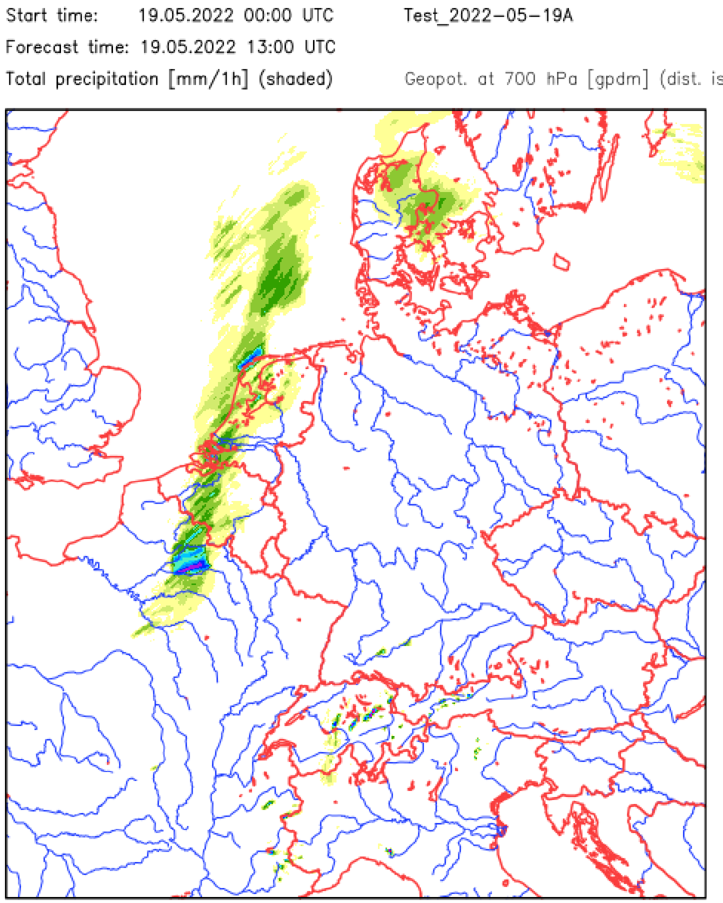
00-UTC forecast run, 1h-precipitation 12-13 UTC



Operational forecast



Radar



Exp. with subgrid-scale cond.

Showcase 19.05.2022

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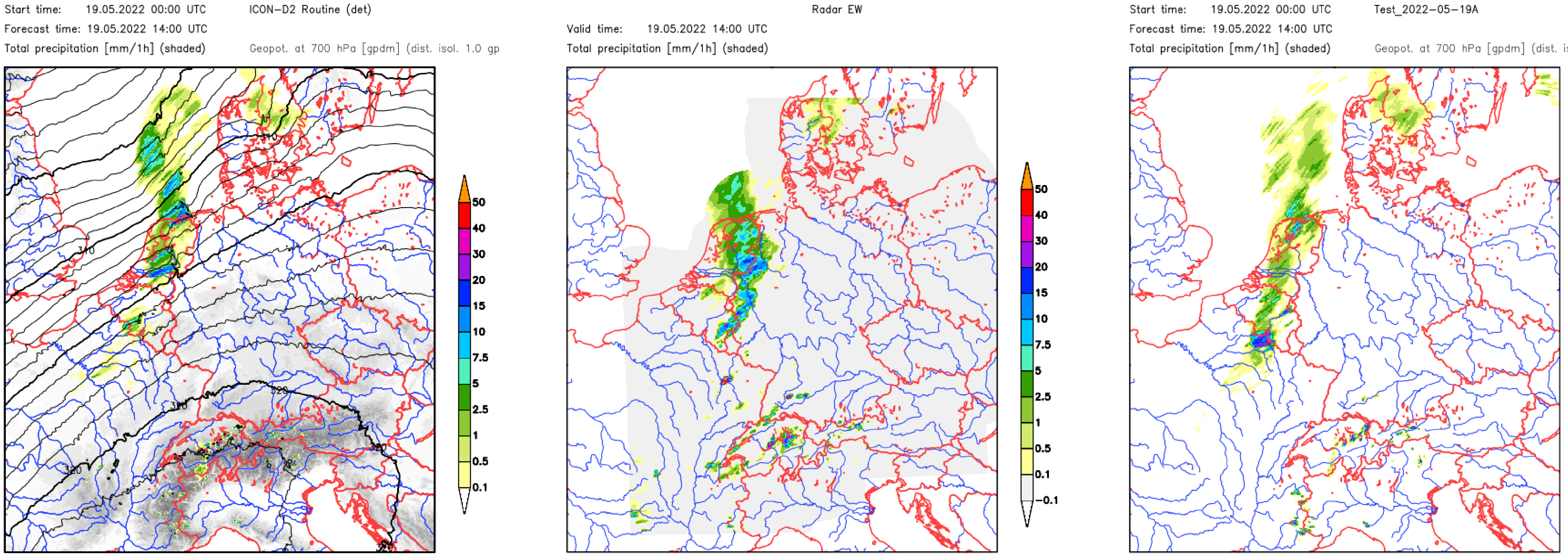
00-UTC forecast run, 1h-precipitation 13-14 UTC



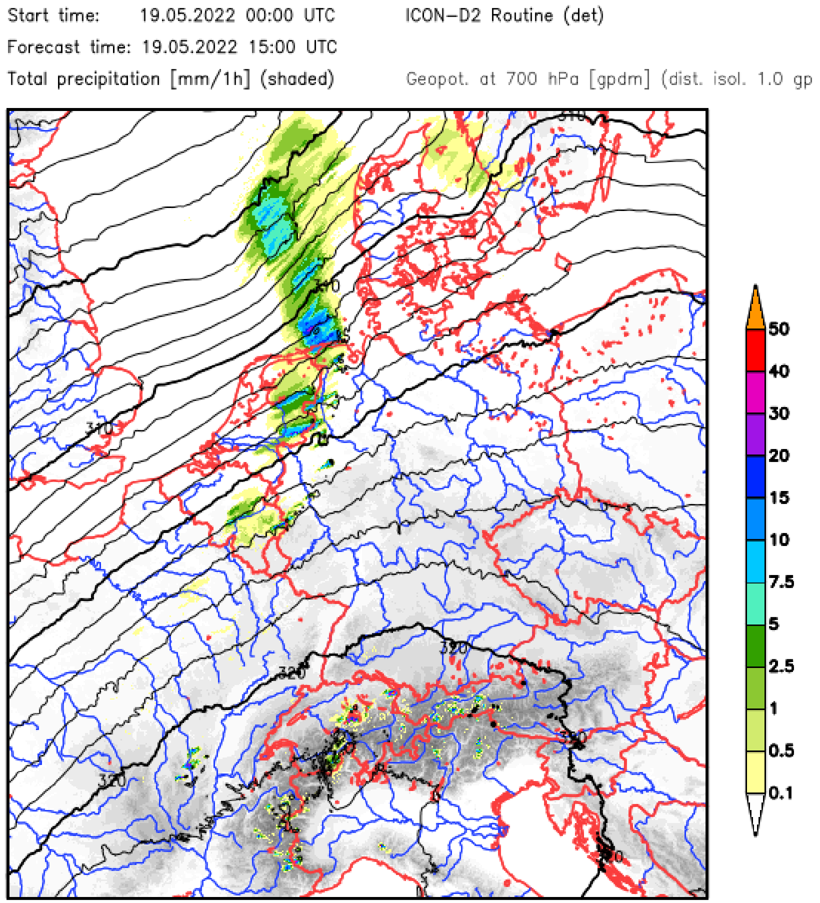
Operational forecast

Radar

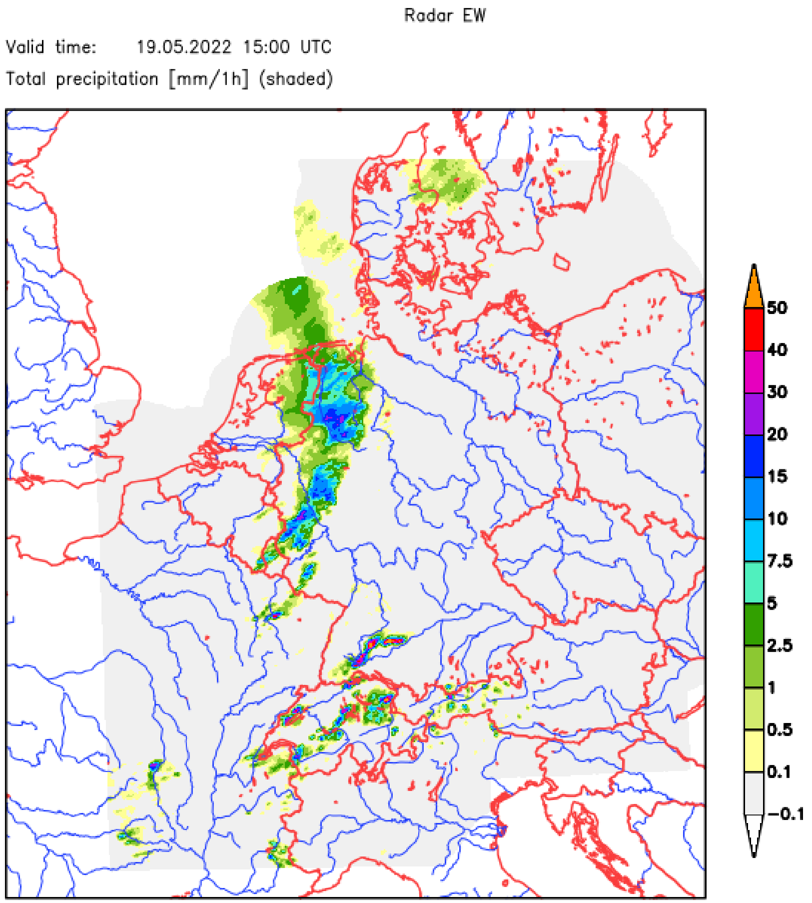
Exp. with subgrid-scale cond.

Showcase 19.05.2022

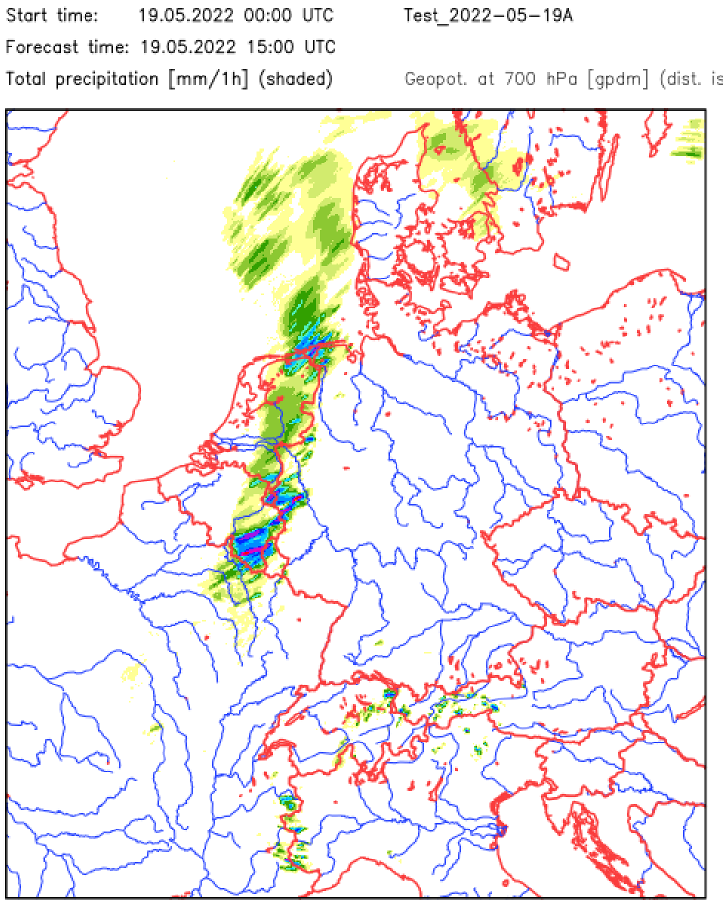
00-UTC forecast run, 1h-precipitation 14-15 UTC



Operational forecast



Radar



Exp. with subgrid-scale cond.

Showcase 19.05.2022

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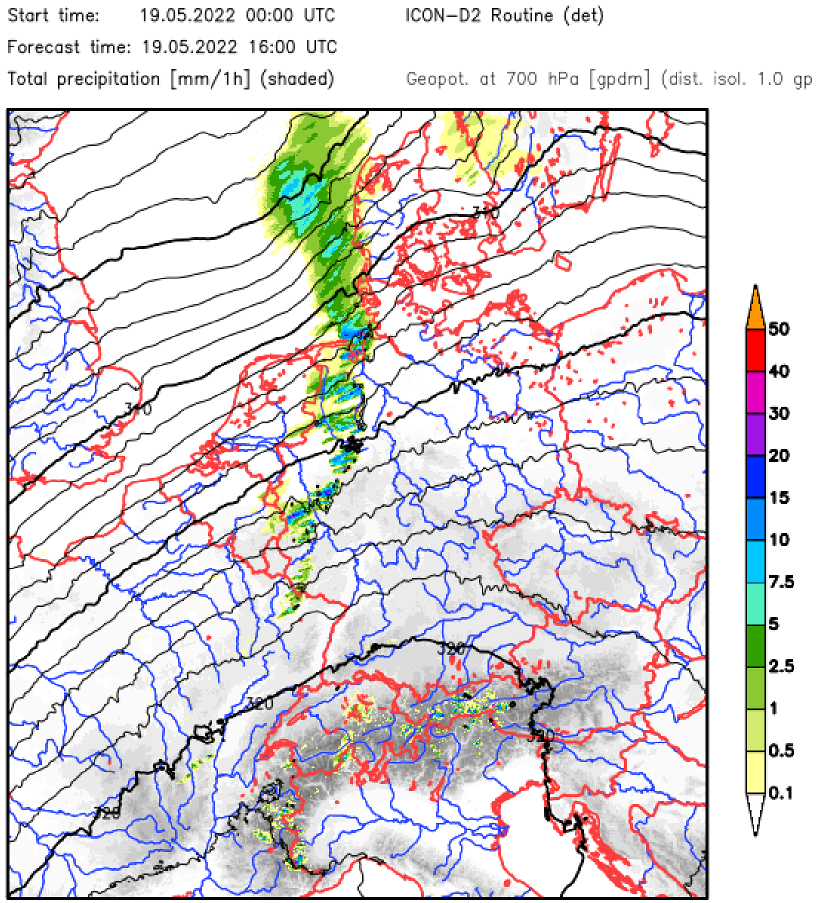
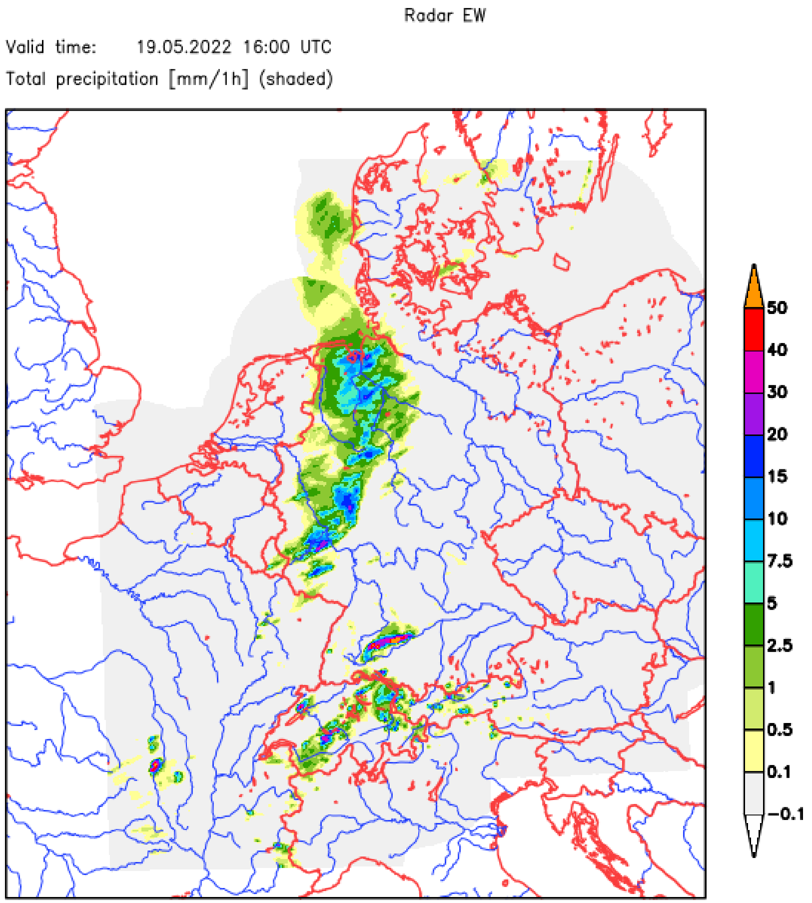
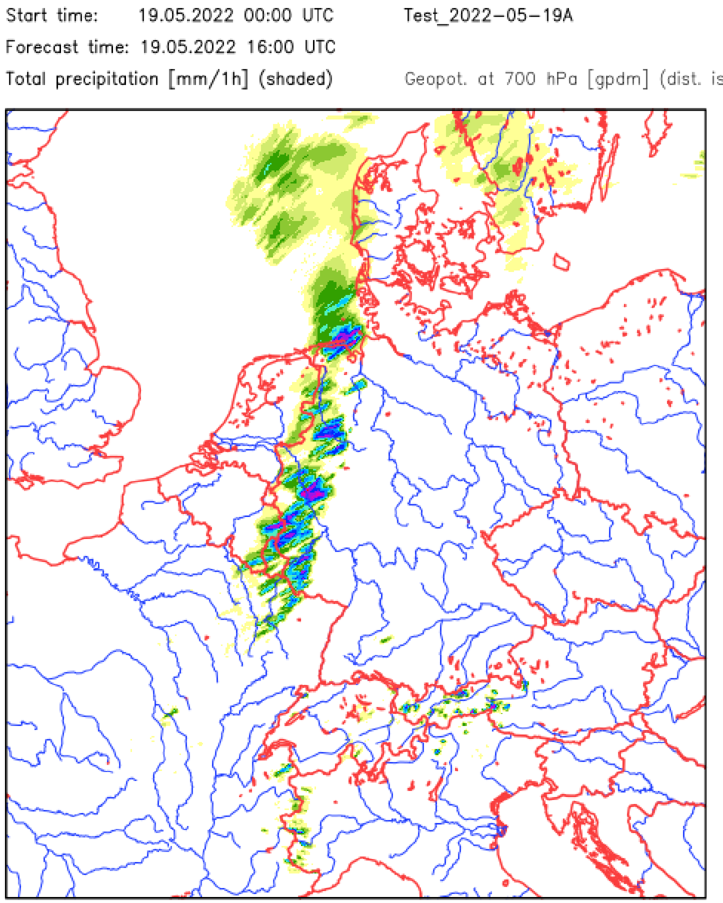
00-UTC forecast run, 1h-precipitation 15-16 UTC



Operational forecast



Radar

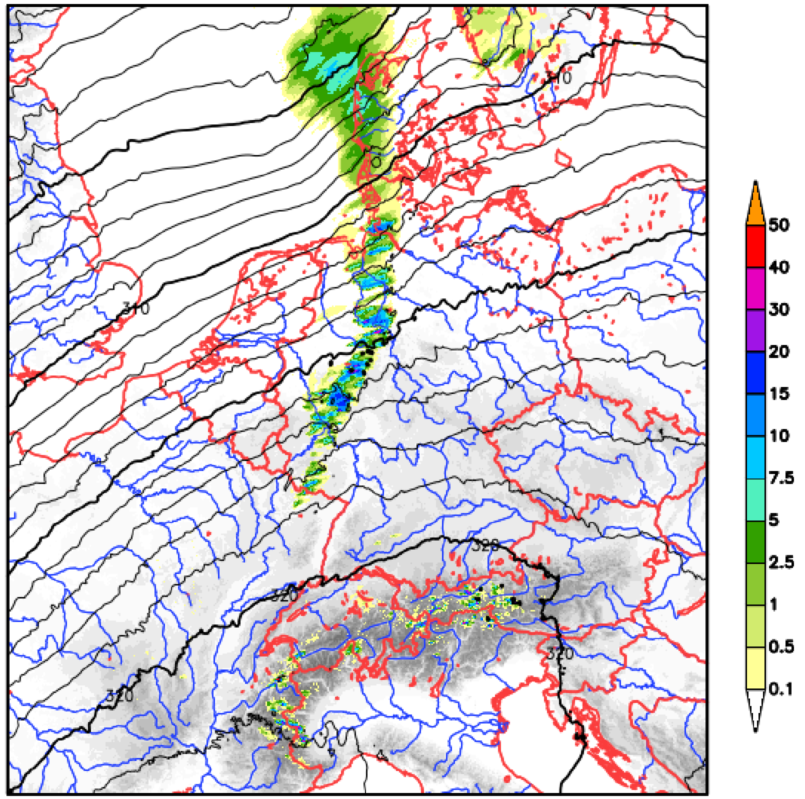


Exp. with subgrid-scale cond.

Showcase 19.05.2022

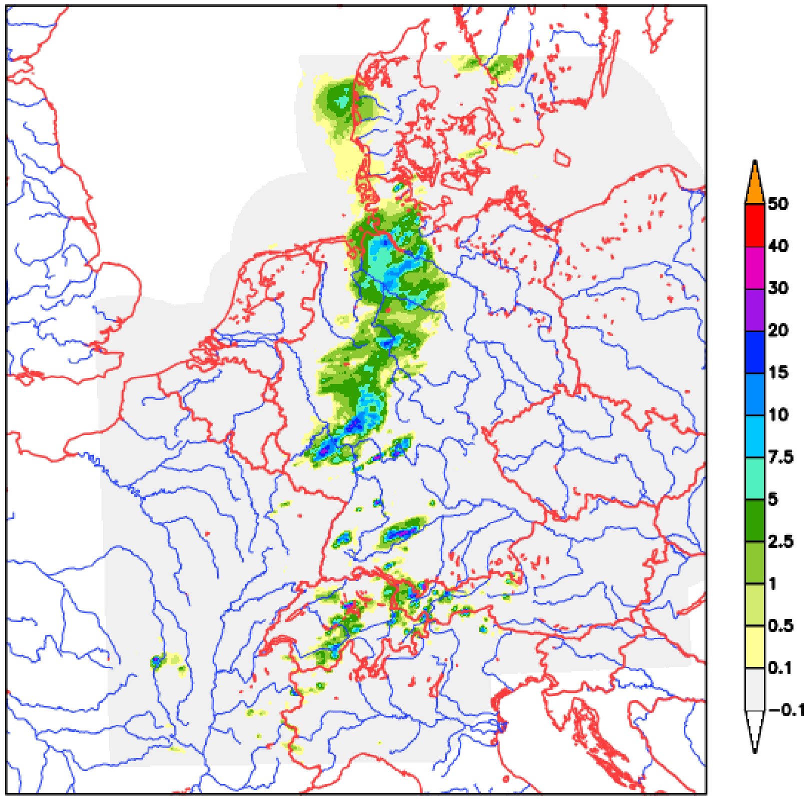
00-UTC forecast run, 1h-precipitation 16-17 UTC

Start time: 19.05.2022 00:00 UTC ICON–D2 Routine (det)
Forecast time: 19.05.2022 17:00 UTC
Total precipitation [mm/1h] (shaded) Geopot. at 700 hPa [gpdm] (dist. isol. 1.0 gp



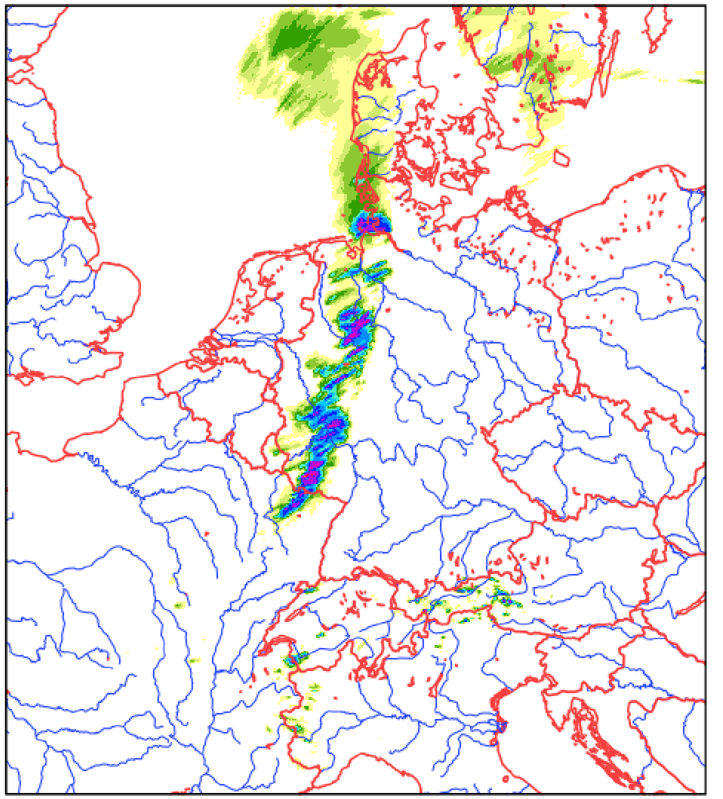
Operational forecast

Radar EW
Valid time: 19.05.2022 17:00 UTC
Total precipitation [mm/1h] (shaded)



Radar

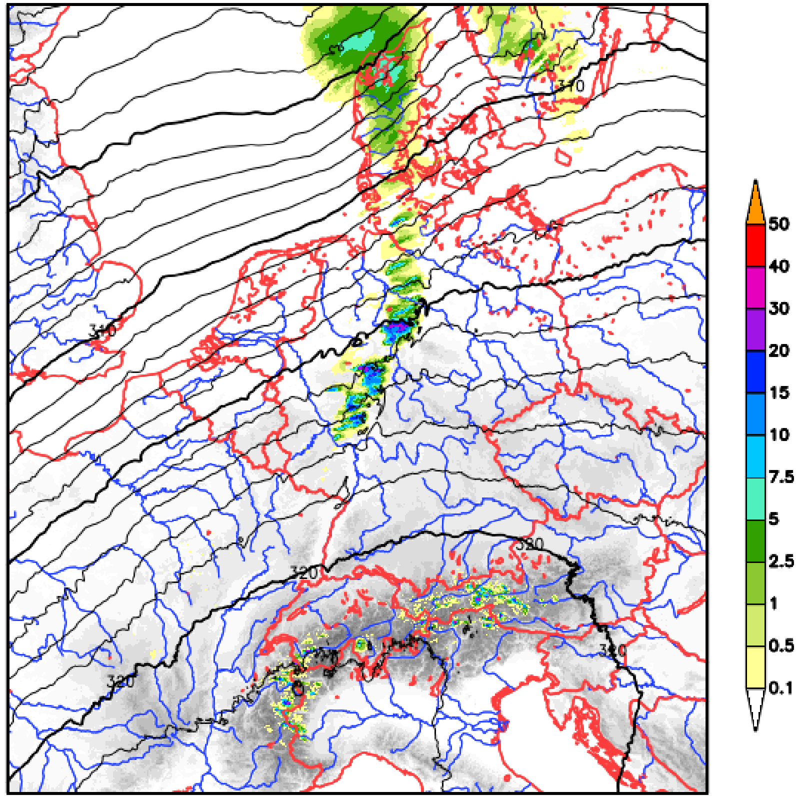
Start time: 19.05.2022 00:00 UTC Test_2022–05–19A
Forecast time: 19.05.2022 17:00 UTC
Total precipitation [mm/1h] (shaded) Geopot. at 700 hPa [gpdm] (dist. is



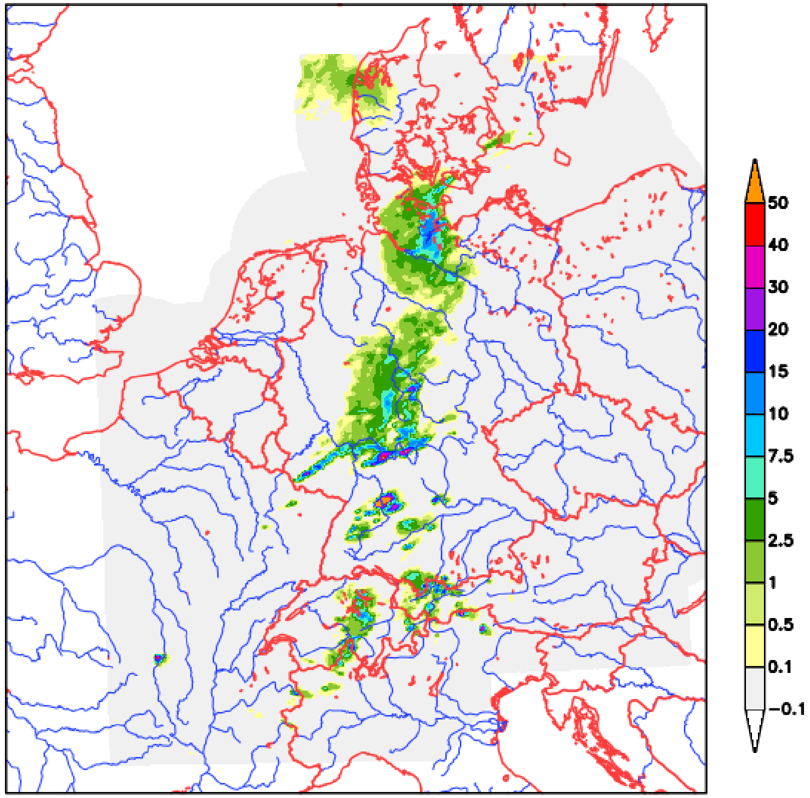
Exp. with subgrid-scale cond.

Showcase 19.05.2022

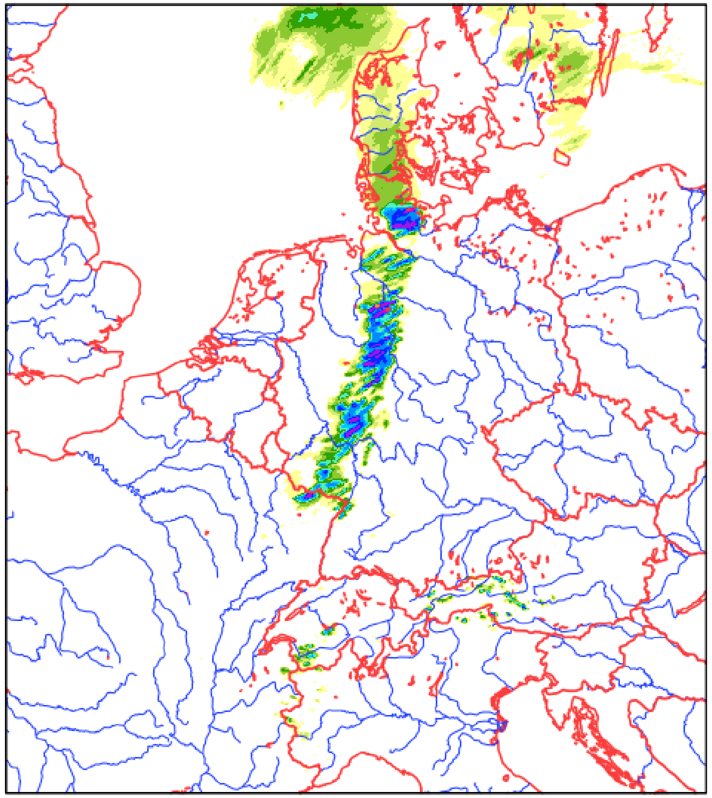
00-UTC forecast run, 1h-precipitation 17-18 UTC



Operational forecast



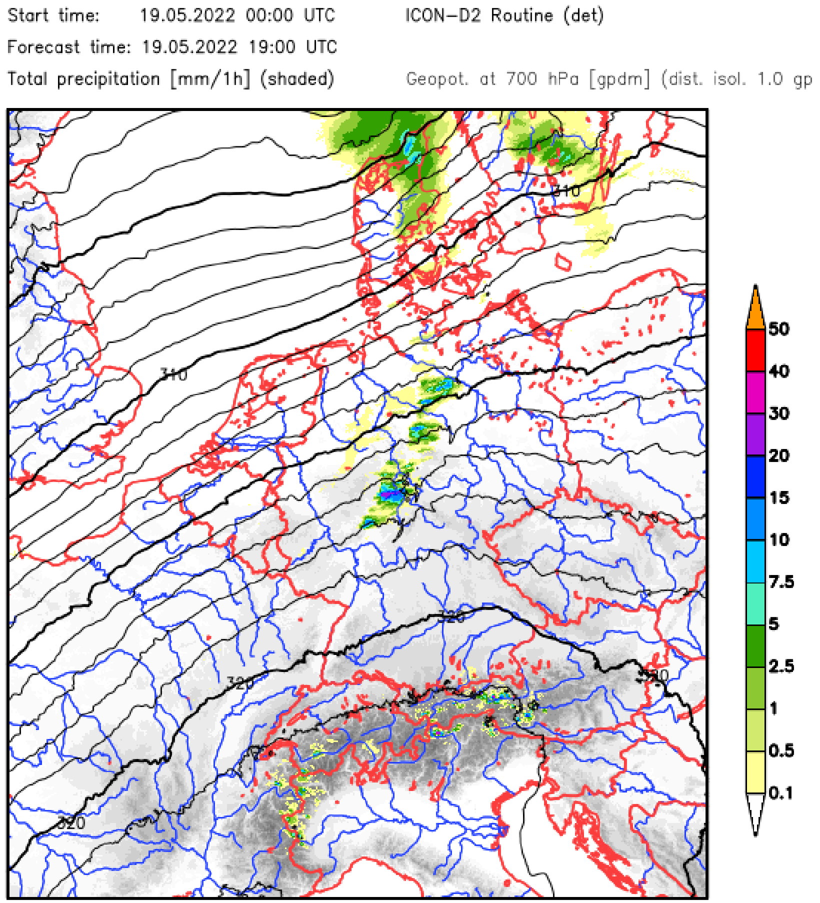
Radar



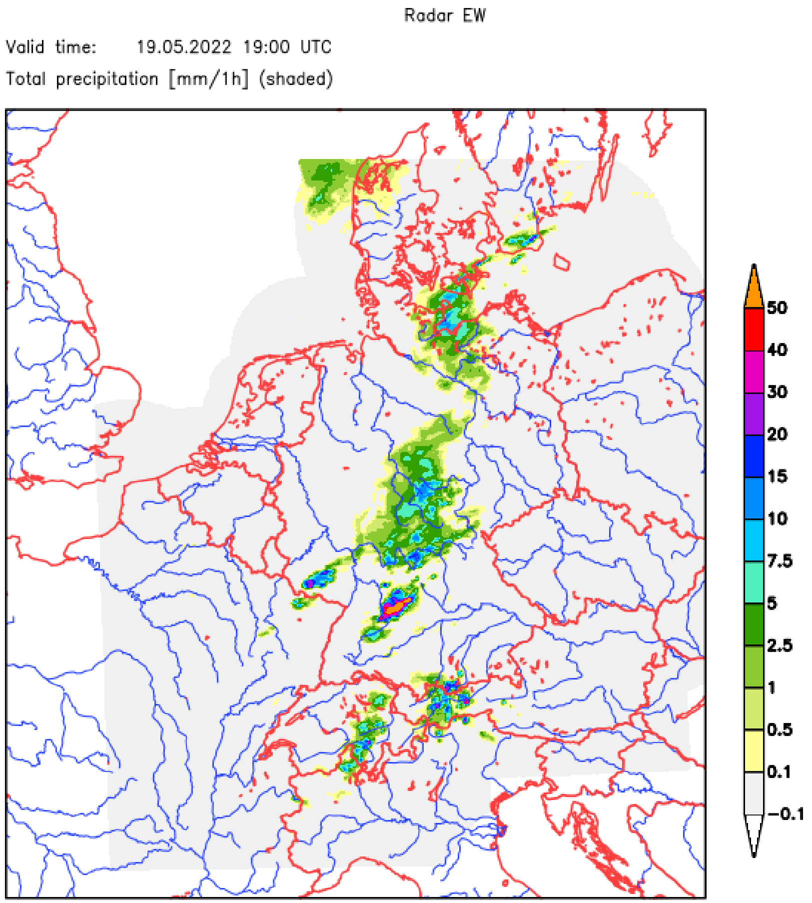
Exp. with subgrid-scale cond.

Showcase 19.05.2022

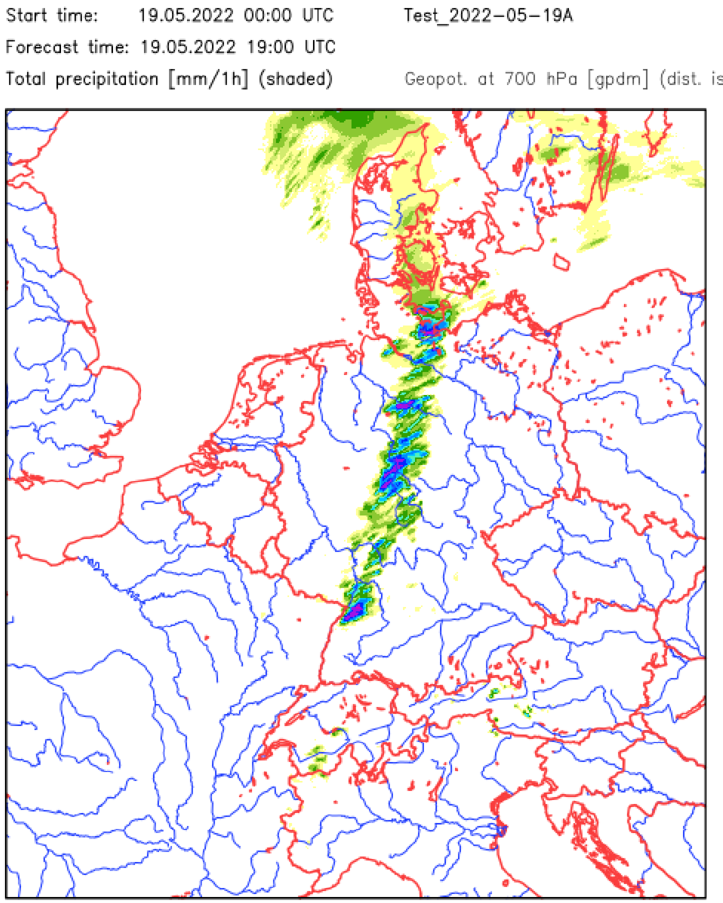
00-UTC forecast run, 1h-precipitation 18-19 UTC



Operational forecast



Radar



Exp. with subgrid-scale cond.

Showcase 19.05.2022

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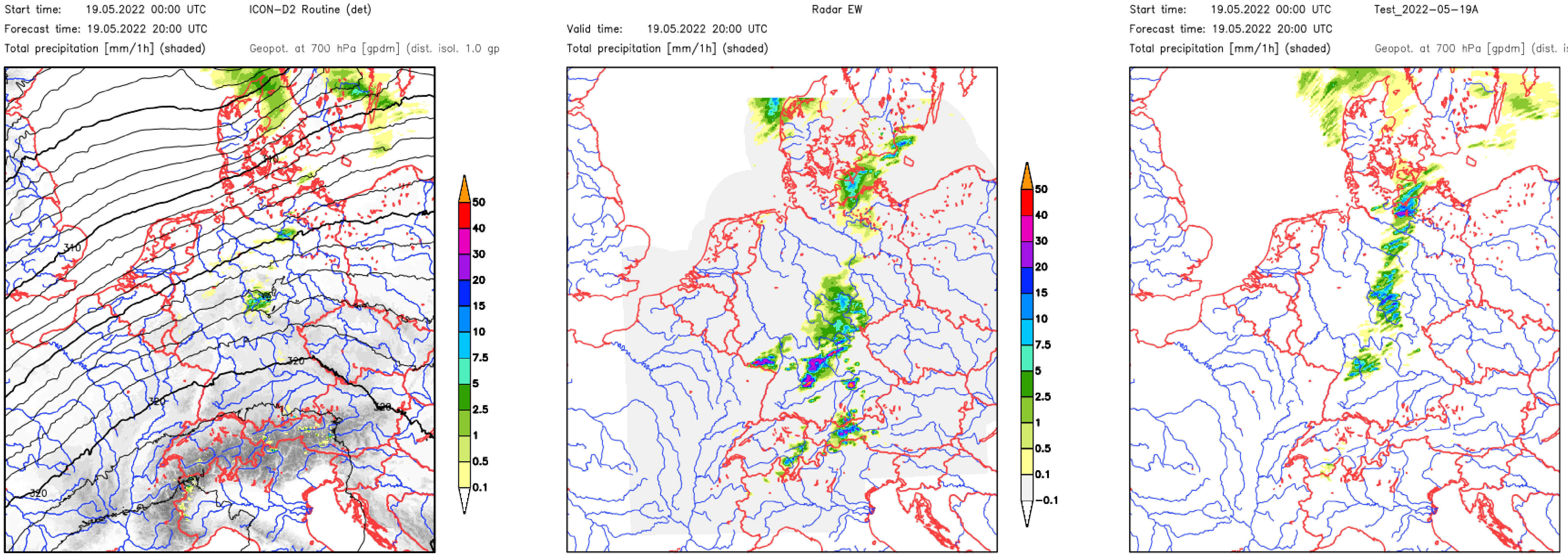
00-UTC forecast run, 1h-precipitation 19-20 UTC



Operational forecast | Radar | Exp. with subgrid-scale cond.

Showcase 19.05.2022

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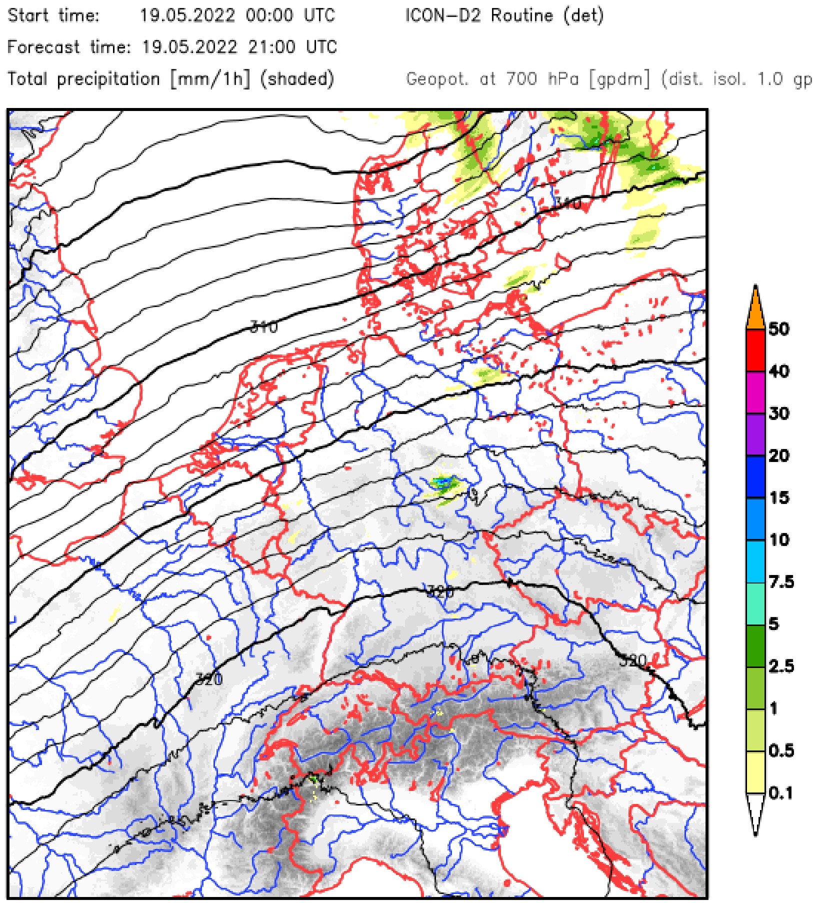
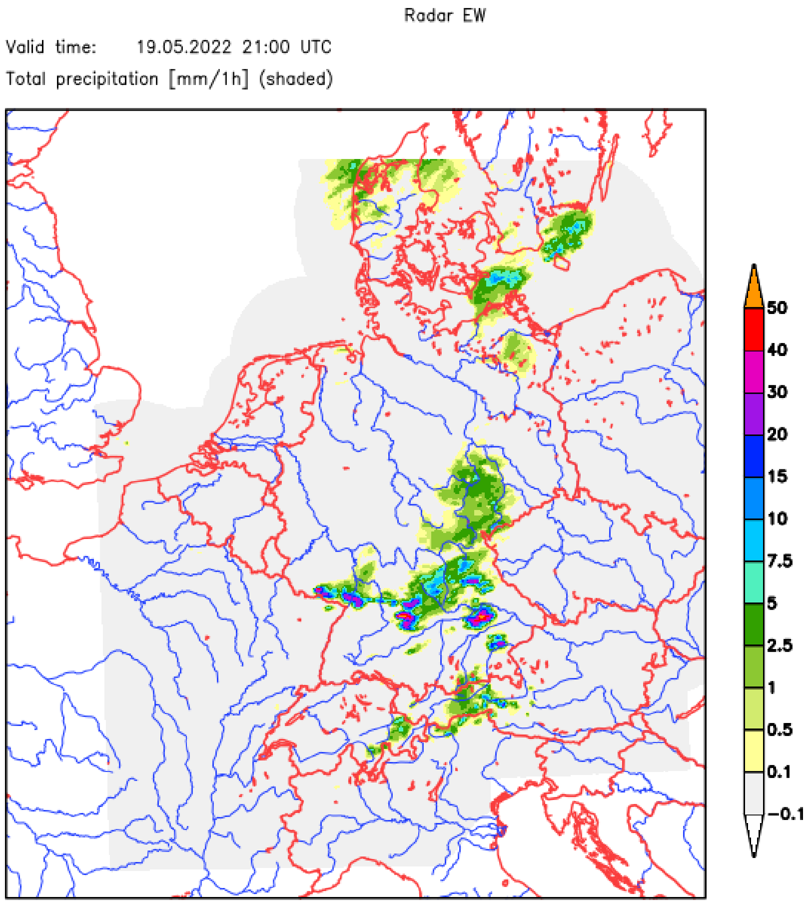
Wetter und Klima aus einer Hand

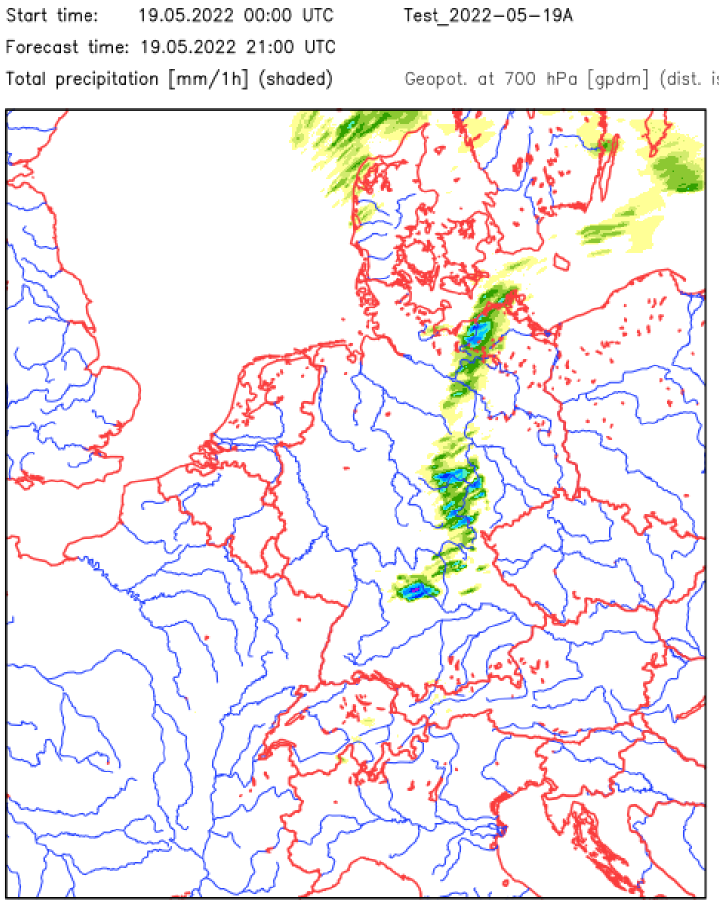
00-UTC forecast run, 1h-precipitation 20-21 UTC



Operational forecast



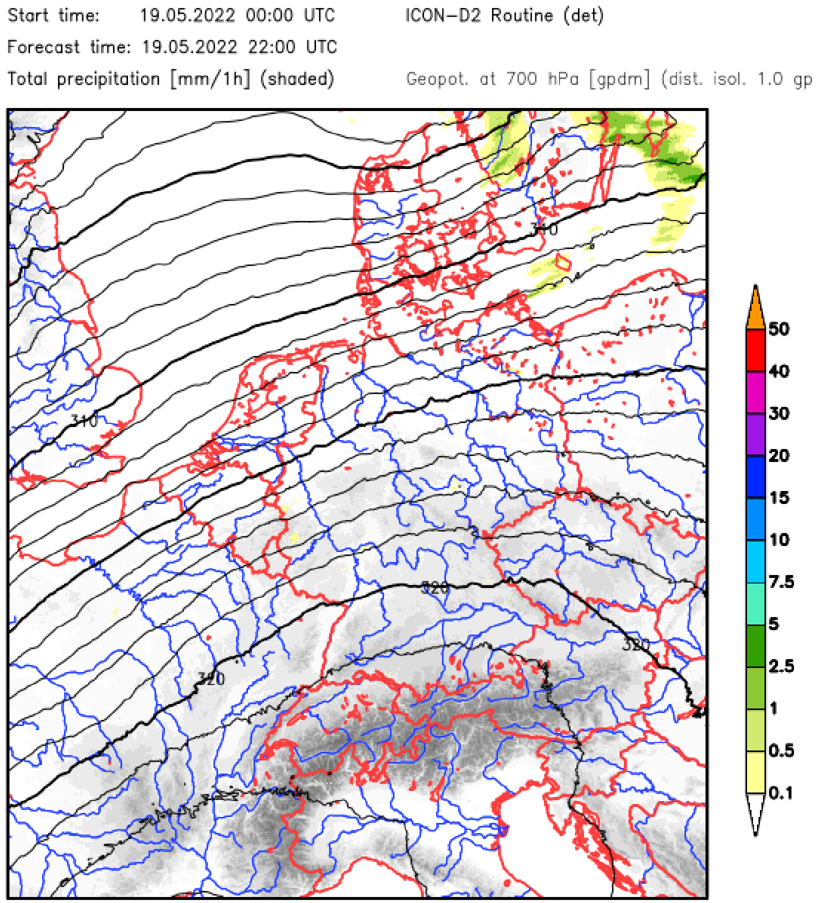
Radar



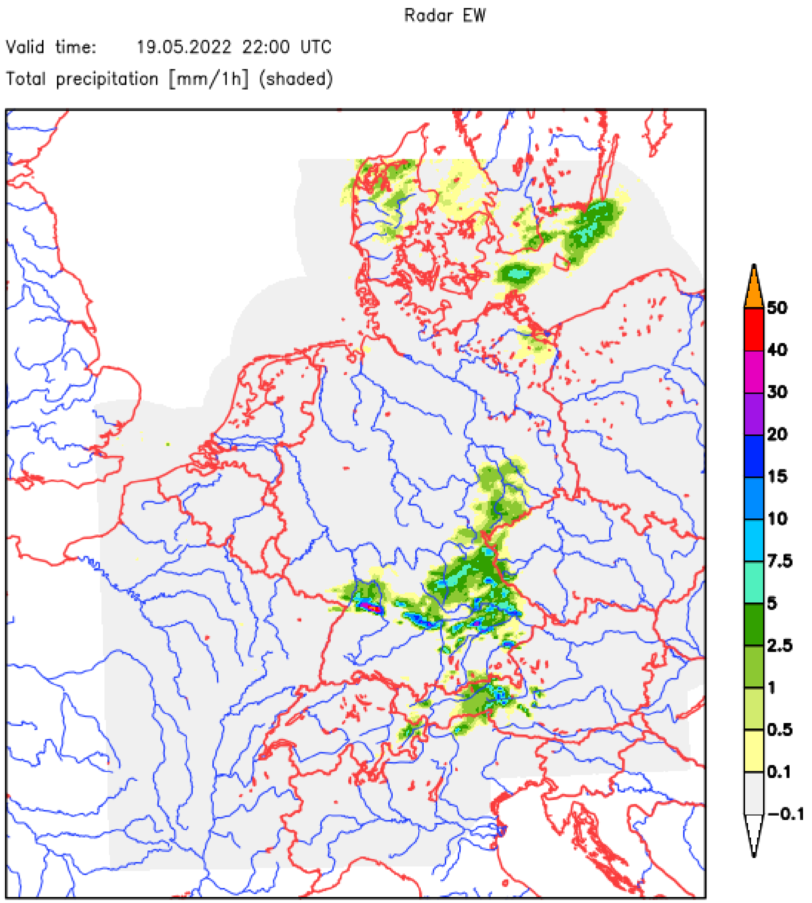
Exp. with subgrid-scale cond.

Showcase 19.05.2022

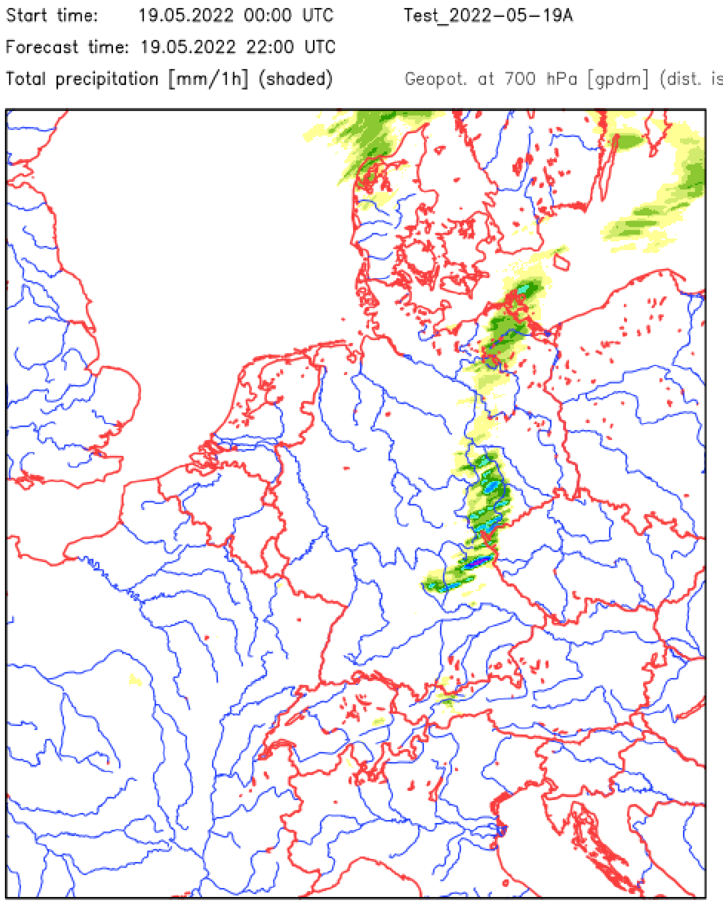
00-UTC forecast run, 1h-precipitation 21-22 UTC



Operational forecast



Radar

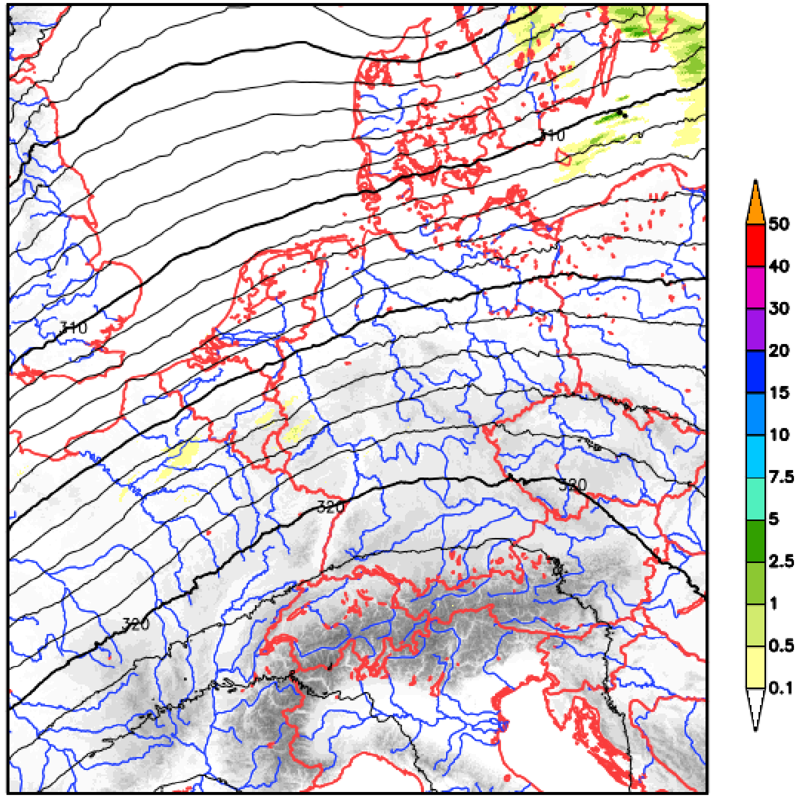


Exp. with subgrid-scale cond.

Showcase 19.05.2022

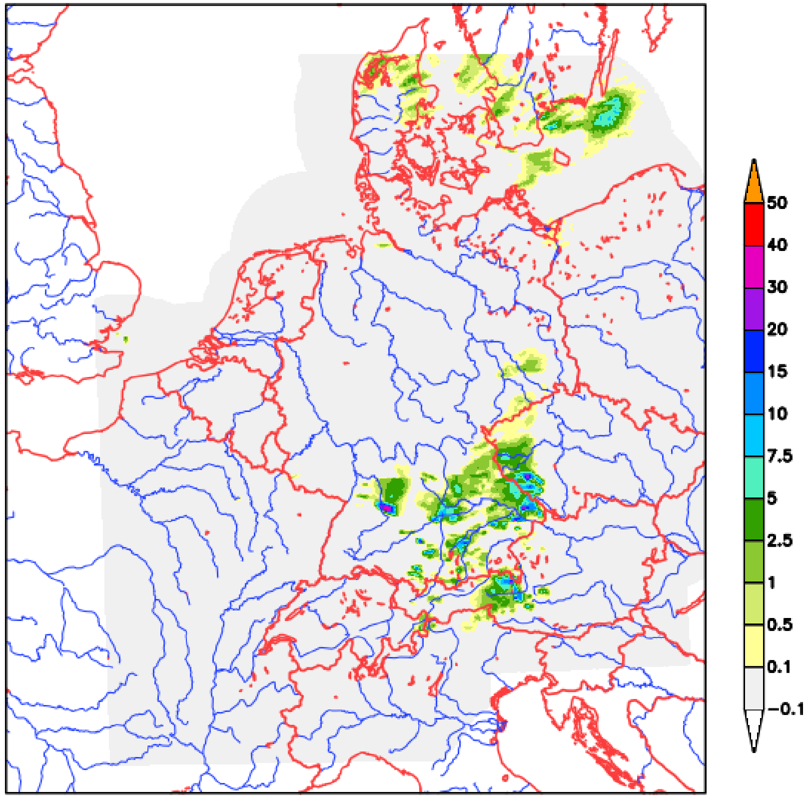
00-UTC forecast run, 1h-precipitation 22-23 UTC

Start time: 19.05.2022 00:00 UTC ICON-D2 Routine (det)
Forecast time: 19.05.2022 23:00 UTC
Total precipitation [mm/1h] (shaded) Geopot. at 700 hPa [gpdm] (dist. isol. 1.0 gp



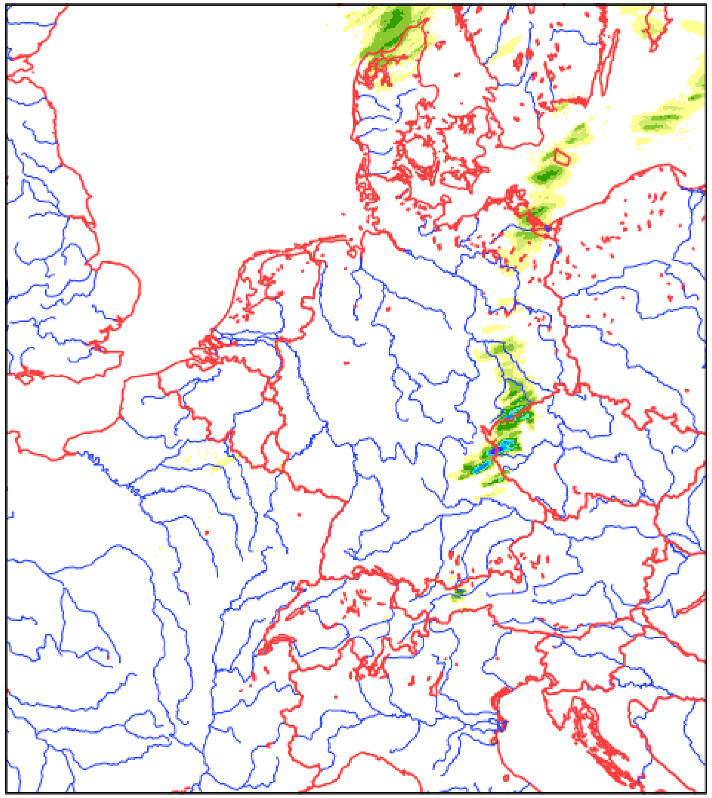
Operational forecast

Radar EW
Valid time: 19.05.2022 23:00 UTC
Total precipitation [mm/1h] (shaded)



Radar

Start time: 19.05.2022 00:00 UTC Test_2022-05-19A
Forecast time: 19.05.2022 23:00 UTC
Total precipitation [mm/1h] (shaded) Geopot. at 700 hPa [gpdm] (dist. is



Exp. with subgrid-scale cond.

Global convection-permitting tests

- ICON forecast runs for January 2021 (only the first 5 days for the time being) at R3B9 (3.25 km), with references for the full month at R3B8 (6.5 km) and R3B7N8 (operational configuration with 13 km globally and 6.5 km over Europe)
- 120 vertical layers extending up to 75 km
- Initial conditions interpolated from IFS analyses for atmospheric fields, combined with interpolated surface fields from ICON analyses
- This is to avoid a possible advantage for the currently operational configuration, which otherwise would start from its ‘own’ analysis

Evaluation metrics:

- Standard verification against SYNOP and TEMP observations
- Analysis verification against IFS data

Remarks

- Compared to the first set of experiments conducted last year, several improvements have become available:

- High-resolution raw data for orography
- Subgrid-scale condensation
- Tuning change in turbulence scheme (TKE source terms) to avoid excessive turbulence in breaking orographic gravity waves

- In addition, the cloud ice sedimentation speed has been halved for the experiments without deep convection scheme in order to counteract the cold bias in the upper tropical troposphere

Preface

- Comparison of R3B8 (6.5 km) with operational configuration R3B7N8 (13 km with 6.5 km nest over Europe)
- Standard deep convection is used in both cases
- We start with looking at general NWP scores because medium-range forecasts need to perform well at the planetary-to-synoptic scale

Score card for verification against surface stations, 13 km vs. 6.5 km (green: 6.5 km better)

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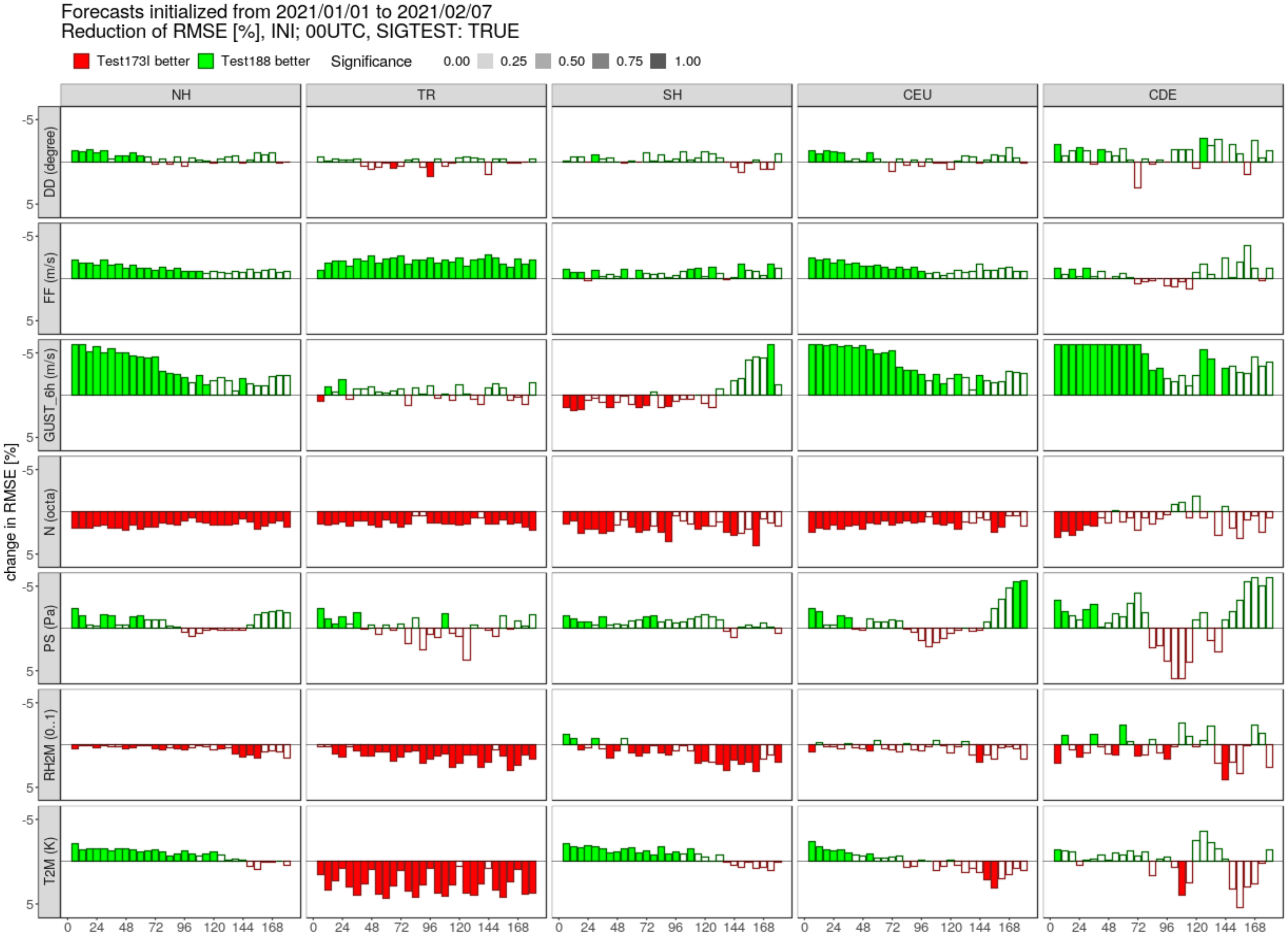

wind dir.

wind speed

gusts

total cloud cover

sfc pres

RH2M

T2M

Score card for verification against radiosondes, 13 km vs. 6.5 km (green: 6.5 km better)

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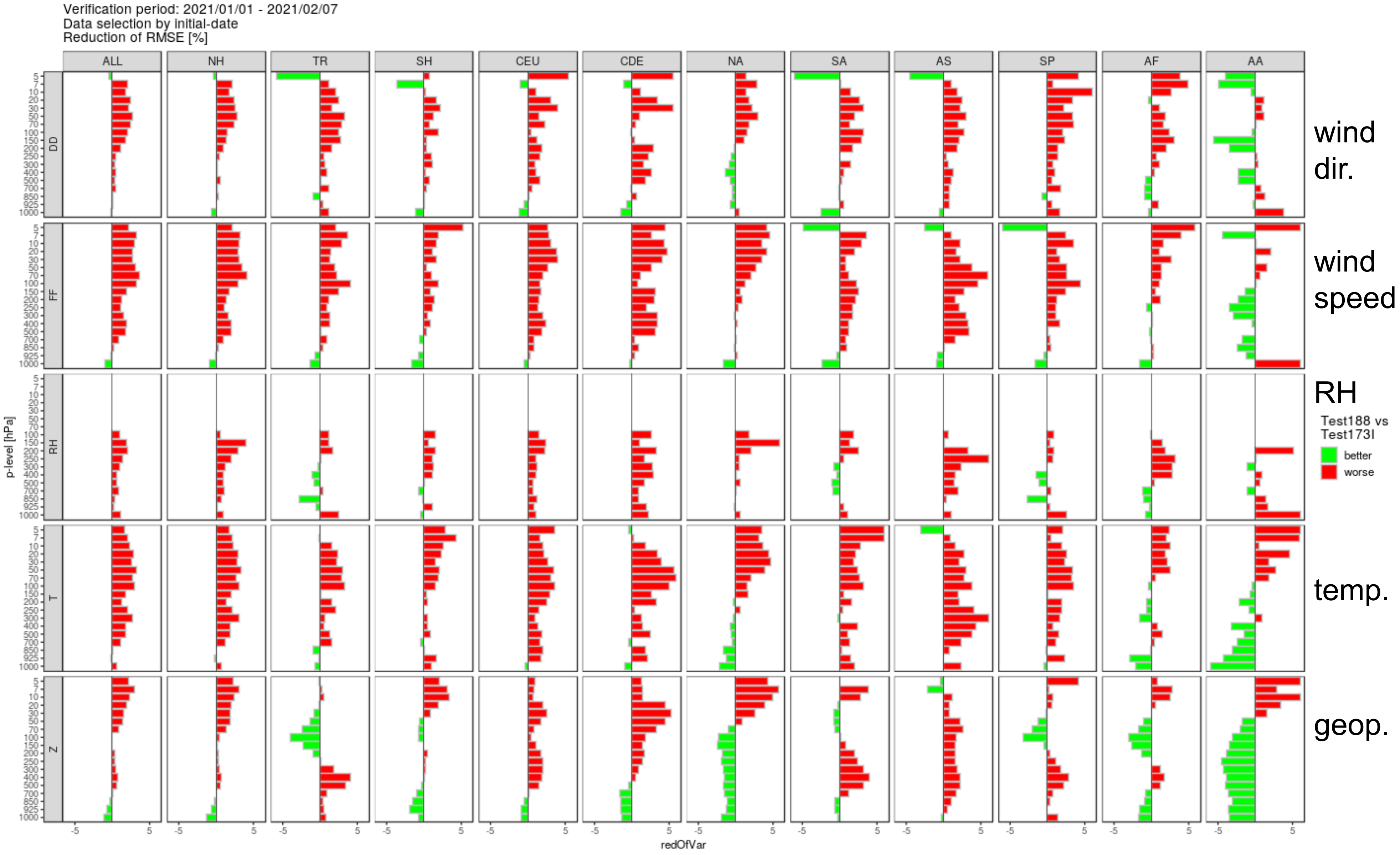
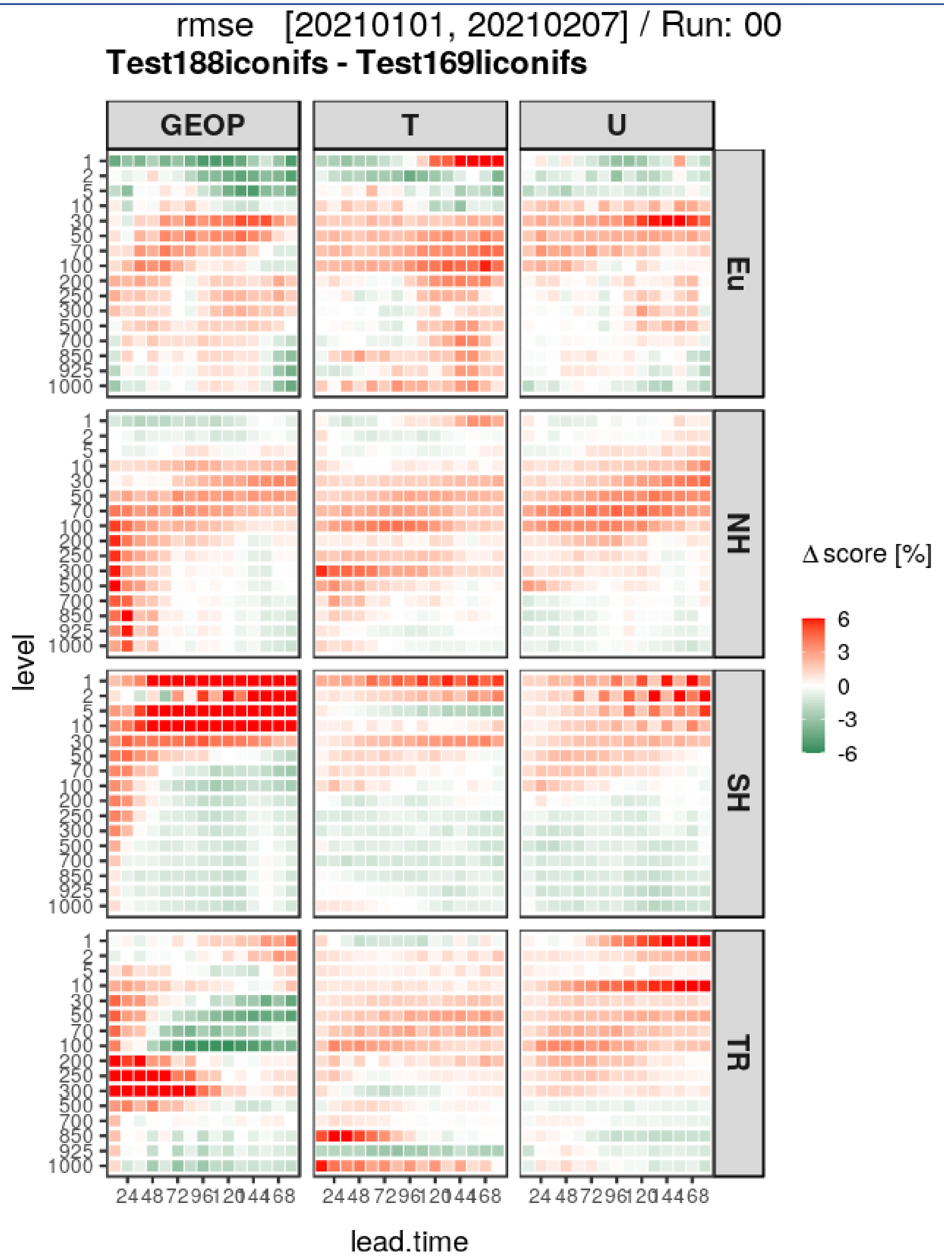


Verification against IFS analyses, 13 km vs. 6.5 km (green: 6.5 km better)



13 km vs. 6.5 km:

Improvements are primarily found for surface-based quantities benefitting from the higher (orography) resolution

At higher levels, results are mixed

Score card for verification against radiosondes, 6.5 km vs. 3.25 km (green: 3.25 km better)

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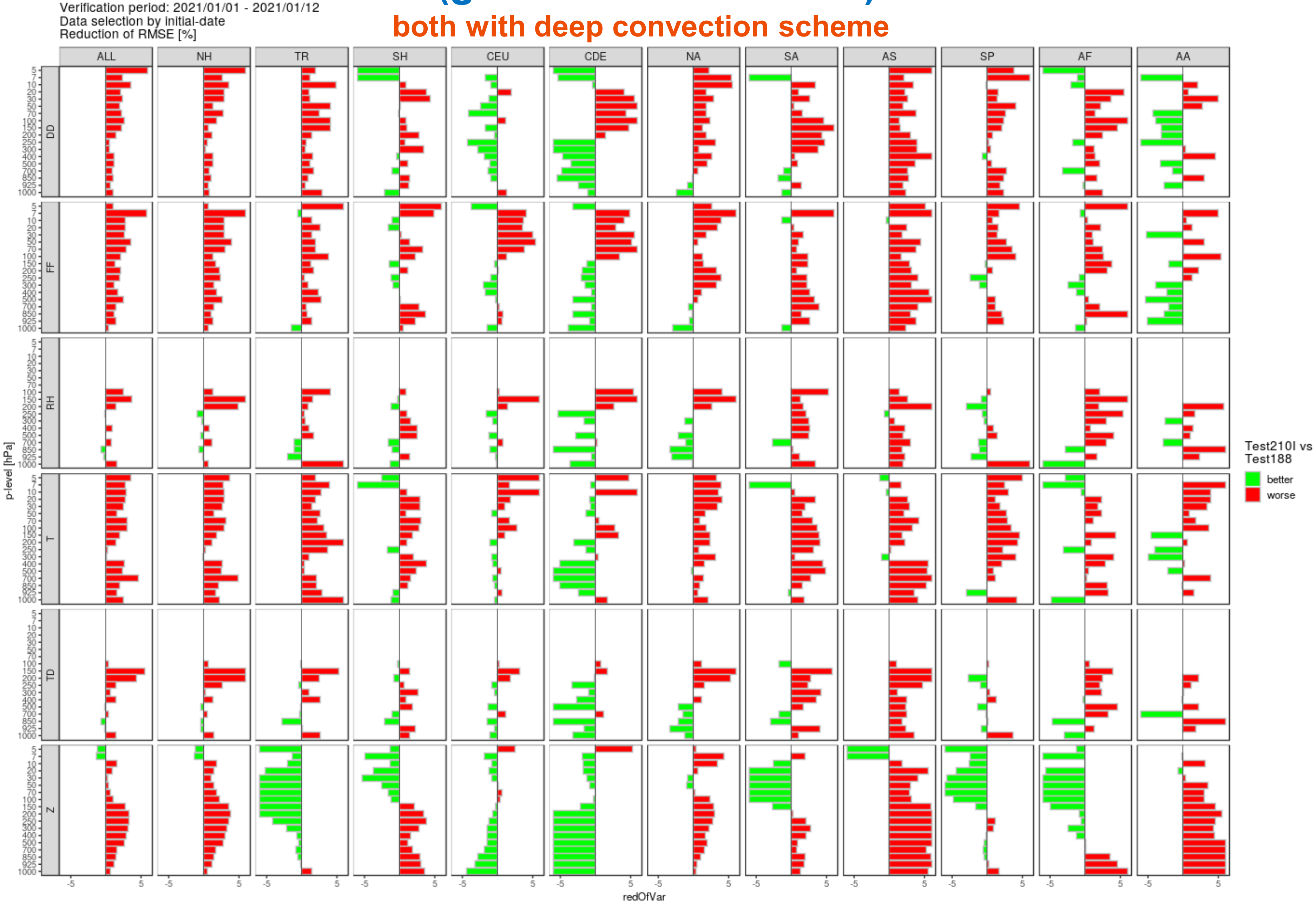
both with deep convection scheme



Score card for verification against radiosondes, 3.25 km shallow vs. deep (green: shallow better)

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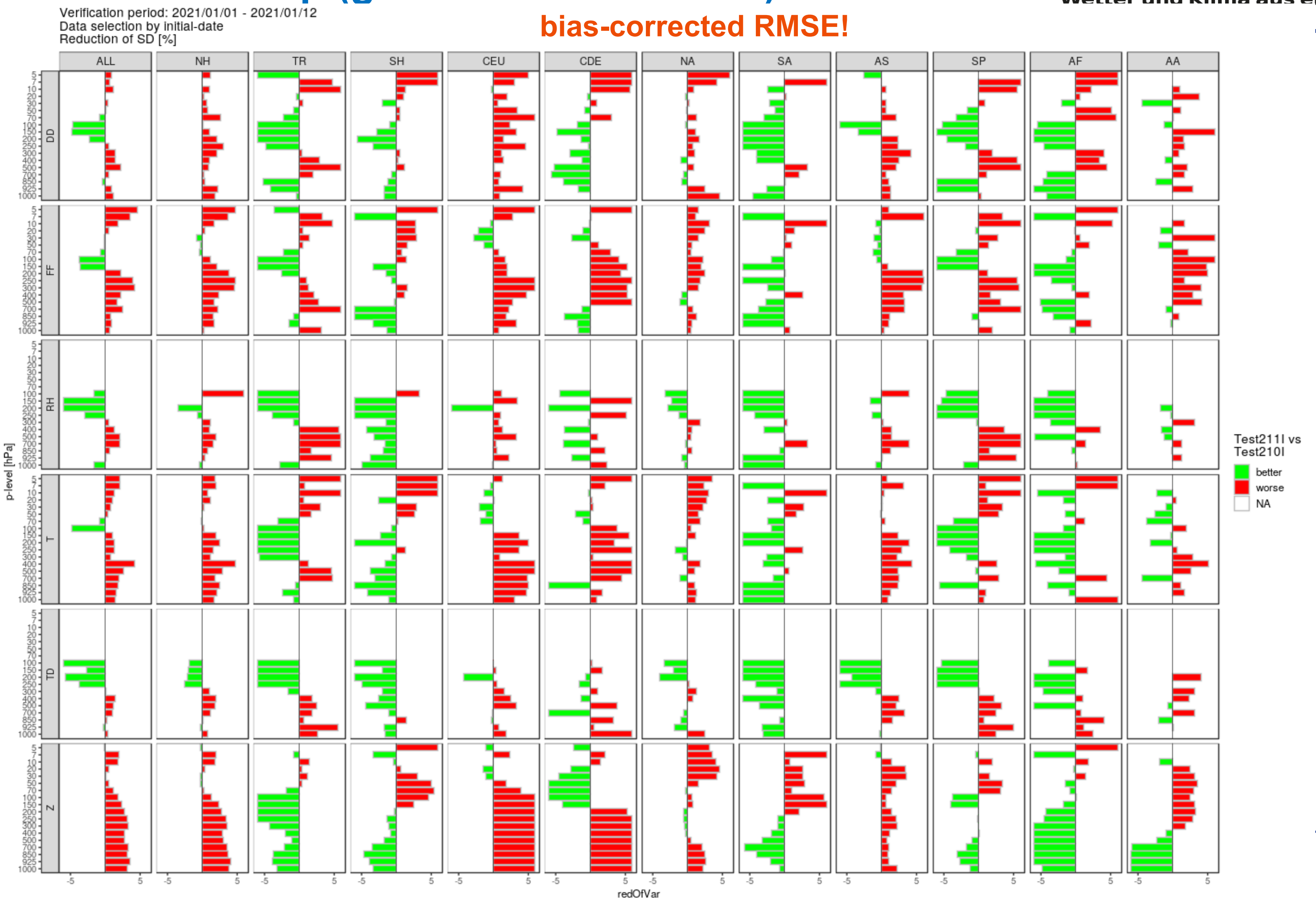
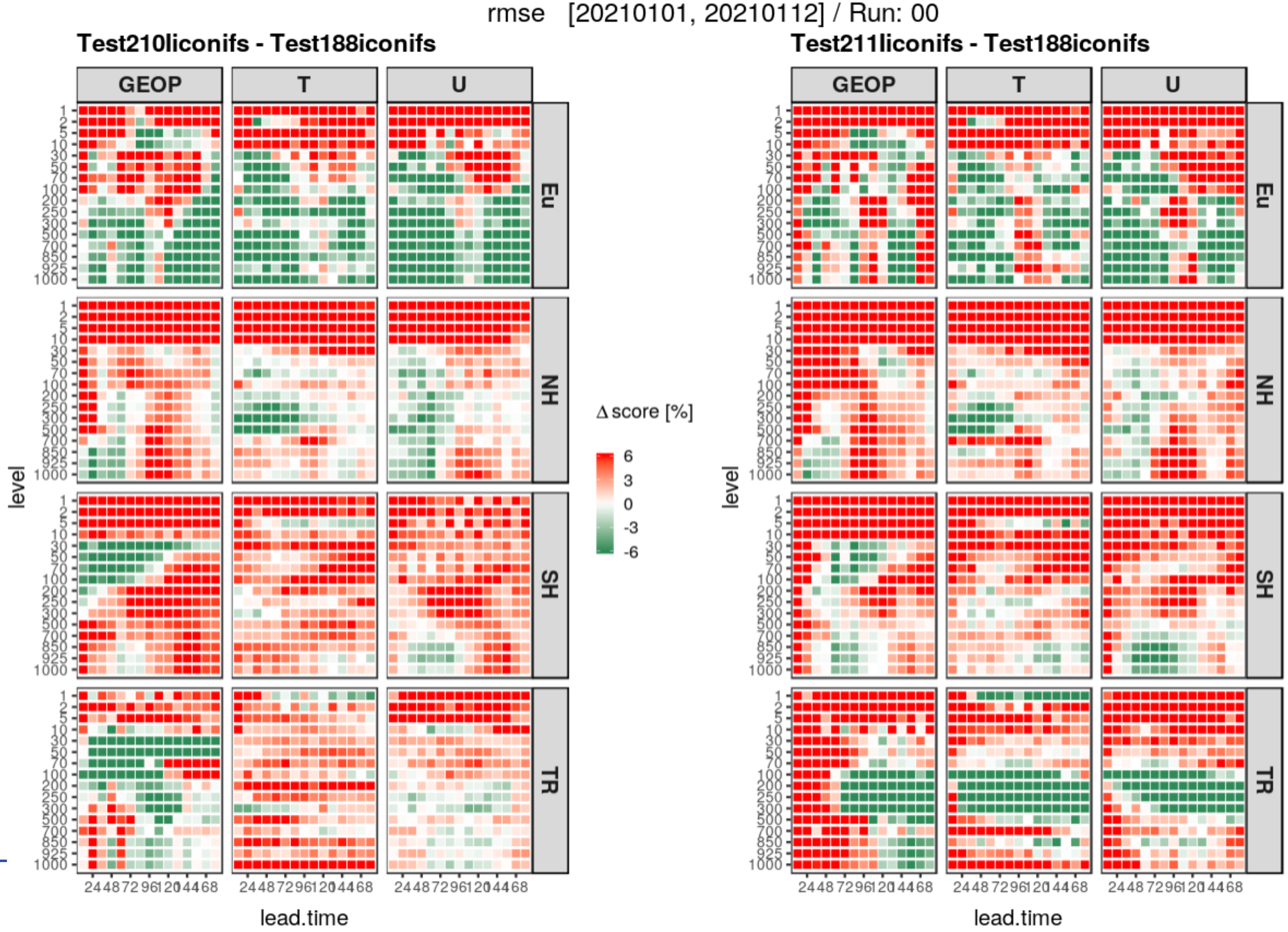
bias-corrected RMSE!



Score card for analysis verification against IFS

3.25 km deep vs. 6.5 km

3.25 km shallow vs. 6.5 km



Analysis verification, tropics, 200 hPa

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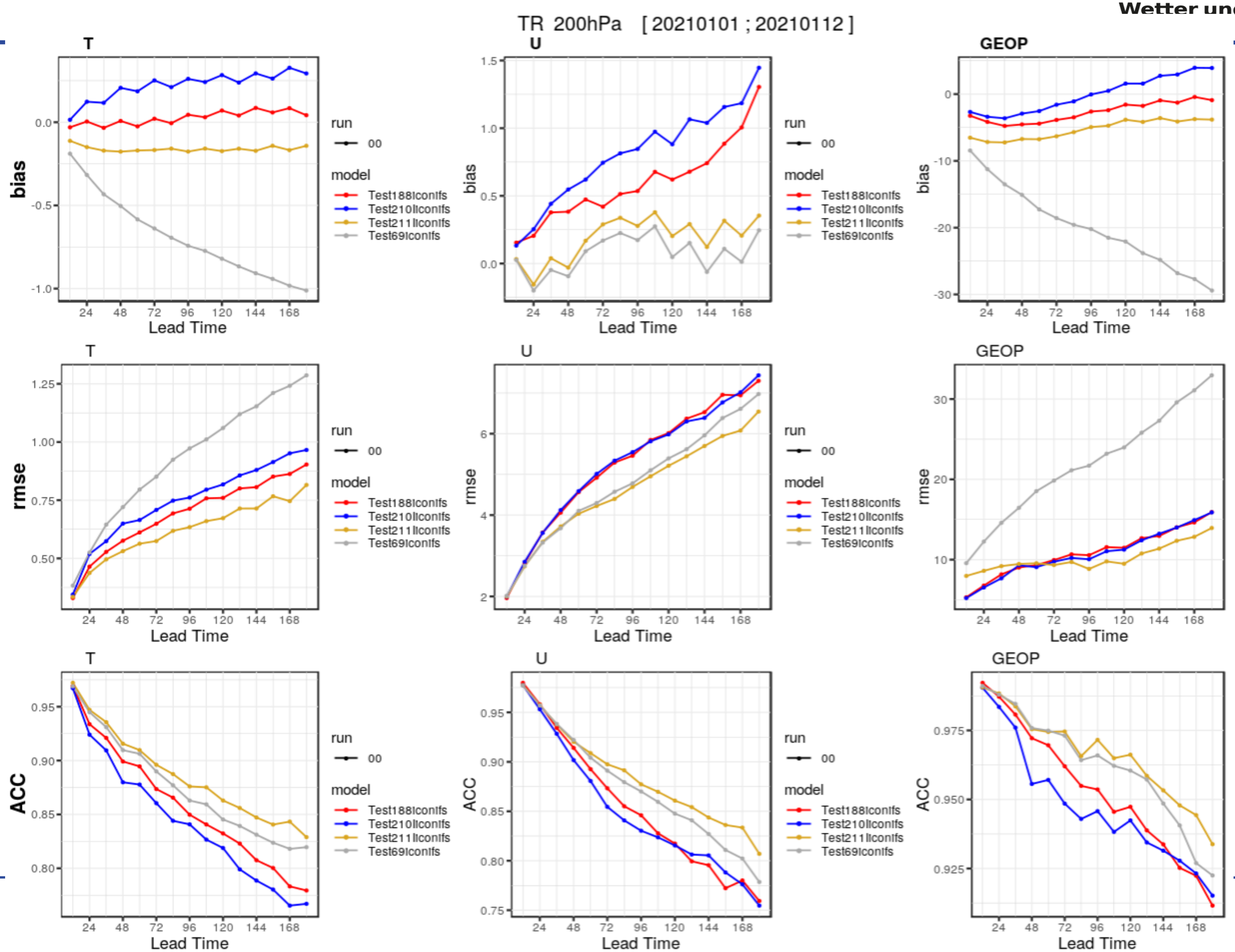

6.5 km

3.25 km
deepconv

3.25 km
shallow conv.

3.25 km
shallow conv.
first try

Precipitation verification, tropics, 6.5 km / 3.25 km deepconv / 3.25 km shallow conv.

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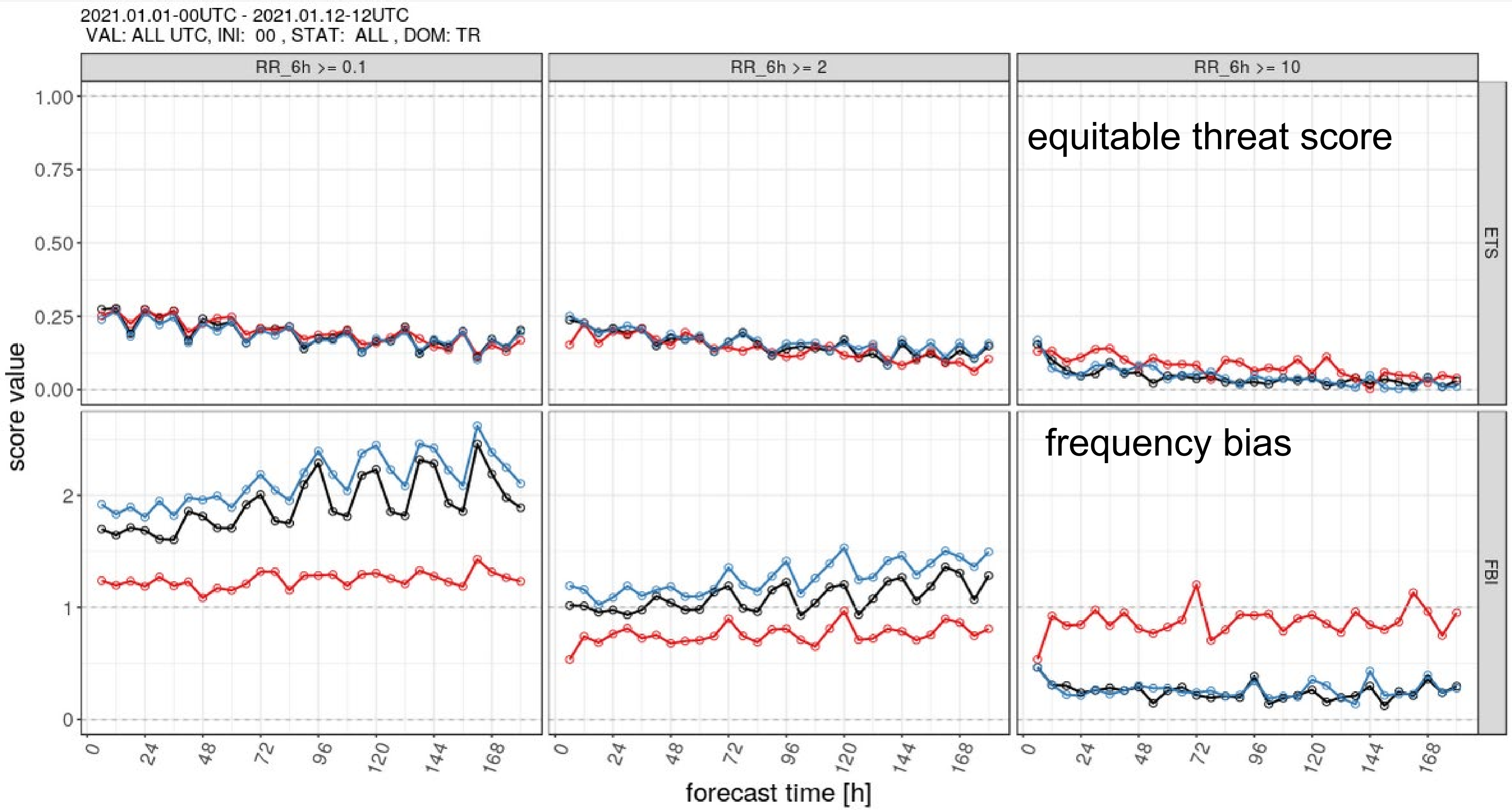

Much better representation of intensity spectrum without parameterization for deep convection

Summary

Global applications in the convective gray zone

- Our experimental results are consistent with the notion that the dynamics of tropical convection is better represented without a deep convection scheme
- The most evident improvements are obtained for precipitation and the dynamical fields in the middle/upper troposphere

- However, the 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 our parameteri-zation packages is needed

Overall conclusion

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