Microphysics developments in ALARO

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Outline

- developments of prognostic graupel
- changed evaporation parameterization

Brief history of graupel in ALARO

- diagnostic graupel
  - temporary subcategory of snow
  - produced by $\Delta_{aco}^{l \to g}$ if q_i present (representing the WBF process)
  - fall speed and collection as rain
  - evaporation and melting as snow
- first implementation of prognostic graupel inherited these properties

Graupel treatment

- prognostic equation for microphysical processes:

$$\frac{dq_g}{dt} = +\Delta_{aco}^{l\to g} + \Delta_{col}^{l\to g} + \Delta_{col}^{i\to g} - \Delta_{melt}^{g\to r} - \Delta_{subl}^{g\to v} + \Delta_{fre}^{r\to g}$$

- shape parameters:
  - size distribution
  - fall-speed relation
  - mass-size relation and density

Proposed treatment of graupel

- size distribution: $N_g = N_0 e^{-\lambda D},\ N_0 = 4 \cdot 10^6\,\mathrm{m}^{-4}$
- fall-speed relation: $w_g = 124 D^{0.66}$
- mass-size relation: $m_g = \frac{\pi D^3}{6}\rho_g,\ \rho_g = 400\,\mathrm{kg}\cdot\mathrm{m}^{-3}$
- collection efficiency set to $E_{ff}^{g} = 0.15$ (between rain and snow)
- prognostic equation unchanged

Basic characteristics of the new set of parameters

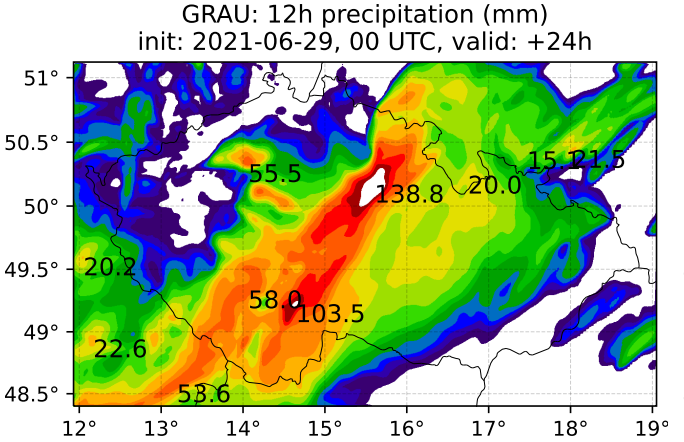
- model: 1080x864 points, $\Delta x = 2.325\,\mathrm{km}$, 87 vertical levels, 3MT active
- lower fall speed $\Rightarrow$ enhanced evaporation leads to:
  - more moisture between 700-500 hPa
  - cooling below around 700 hPa in summer and 850 hPa in winter
  - geopotential raised below 700 (850) hPa and lowered above
- around three times higher graupel specific content in Cumulonimbi

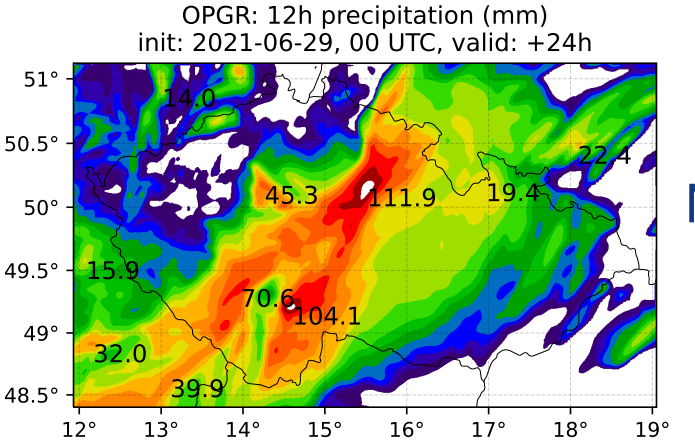
Influence on forecasts

- reduced precipitation maxima in convective storms (+)
- precipitation less influenced by the orographic effect (+)
- cold bias at the surface (-)
- scores not much changed but delivers more physical realism

Mesoscale convective system 2021-06-29

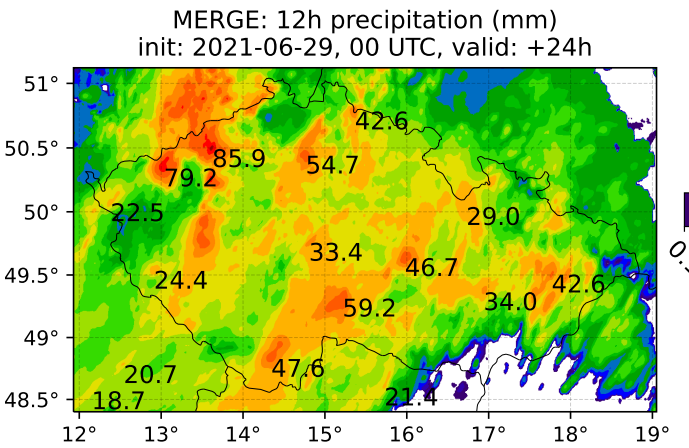
Original

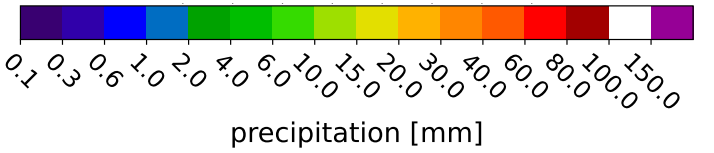




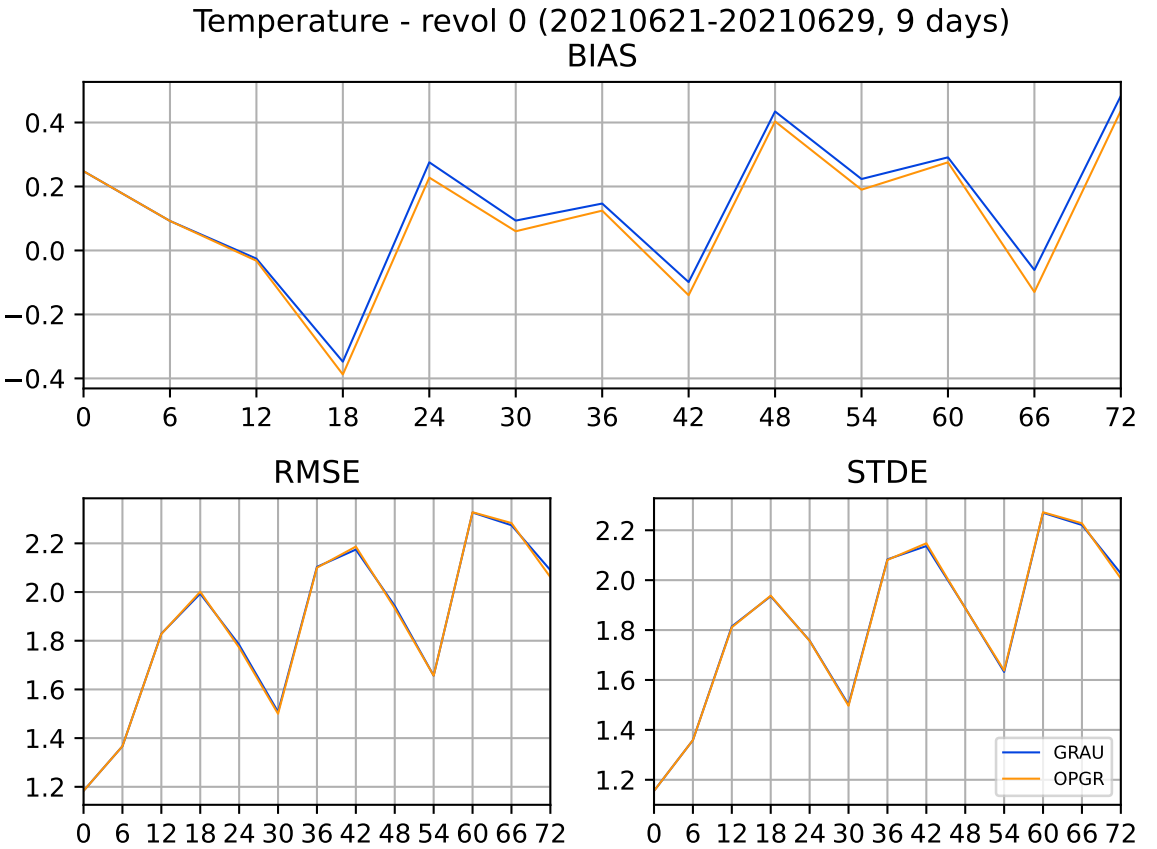
New

Observations





Cold bias: around -0.05 K



Modified evaporation parameterization

- ALARO originally Kessler-type
  - based on tabulated data
  - underestimates evaporation rates

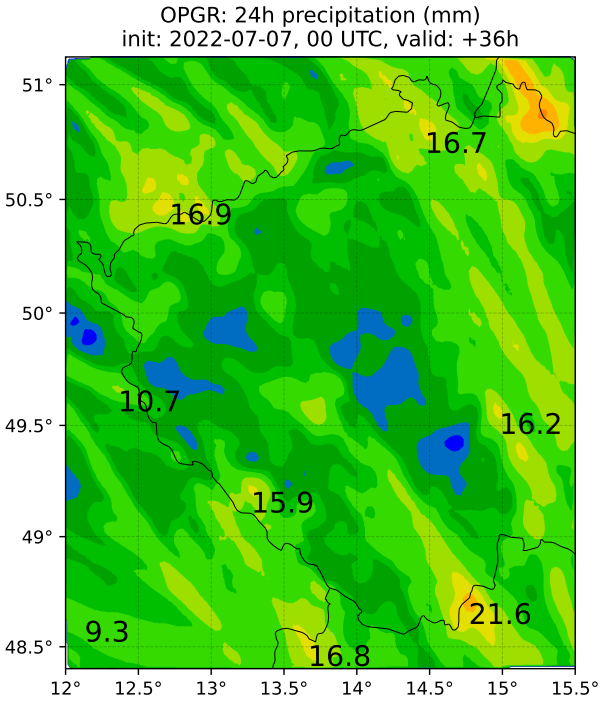
- new approach: extended Lopez evaporation
  - based on the “standard” evaporation equation (e.g., used in AROME):

$$\frac{dm}{dt} = \frac{2\pi D(1 - RH)}{\mathcal{K} + \mathcal{D}} F$$

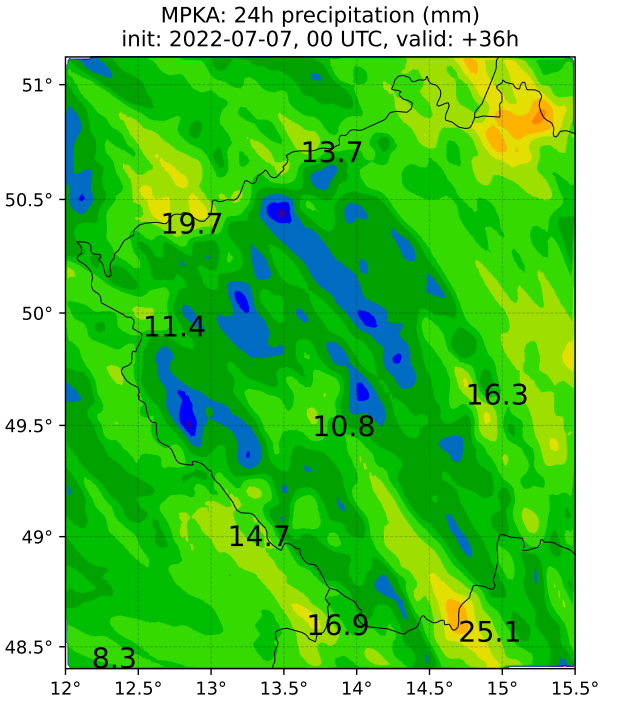
Precipitation changes

- reduction of precipitation maxima in convection (+)
- improved rain shadow behind mountains (+)
- summer convection: FSS improved for 18 and 24 UTC (storms), worsened for 06 and 12 UTC (weak precipitation)
- feedback: more graupel in cumulonimbi as snow sublimates

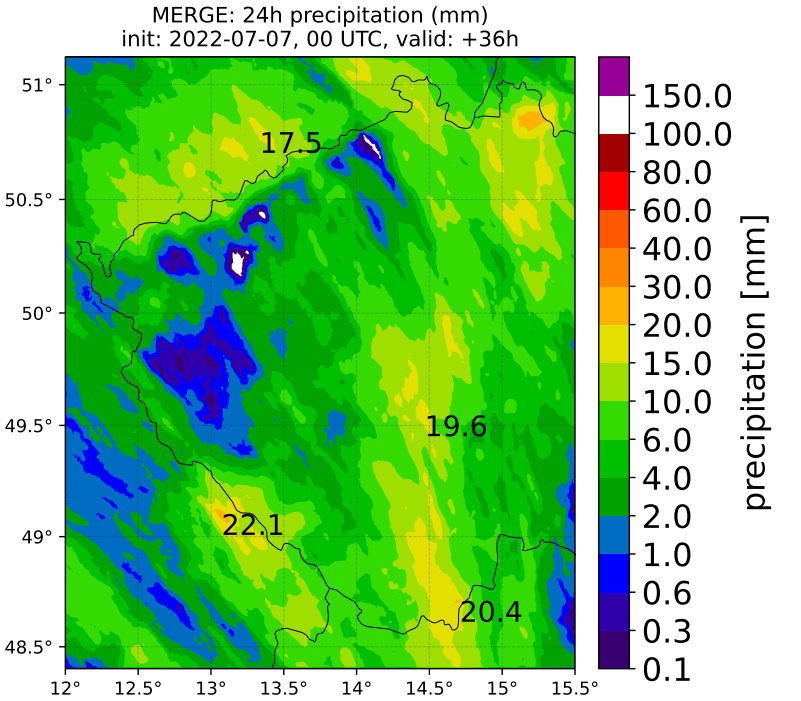
Rain shadow on cold front in summer



Operative



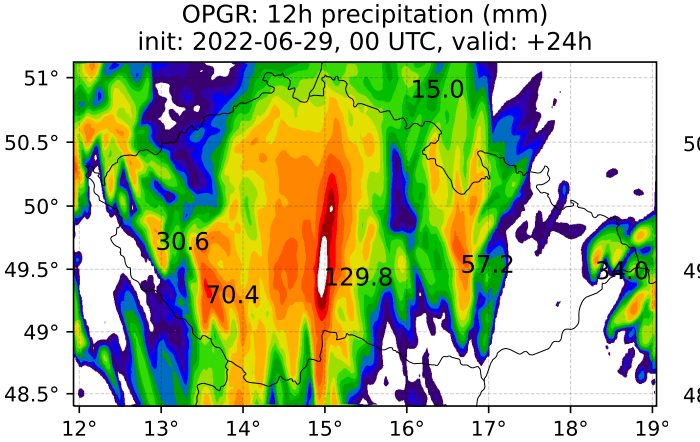
Lopez evaporation

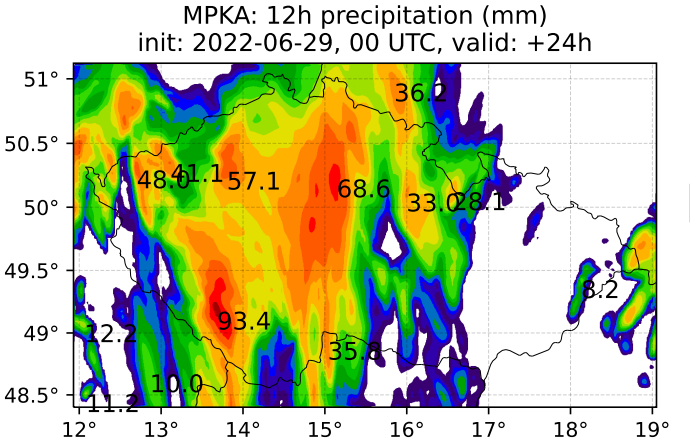


Observations

Mesoscale convective system 2022-06-29

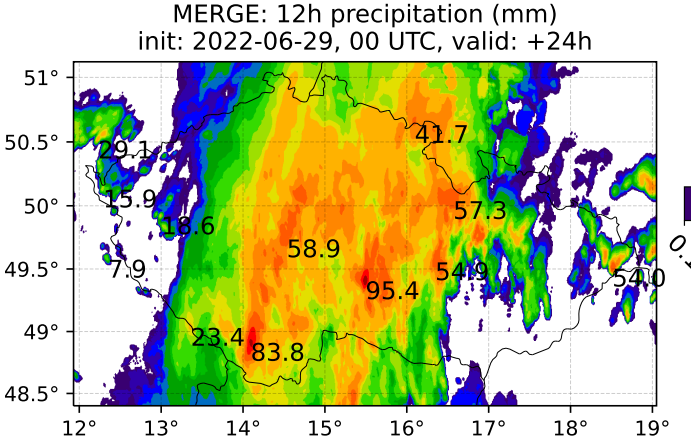
Operative

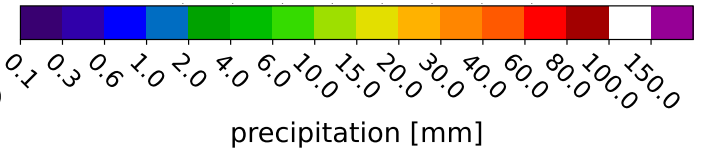




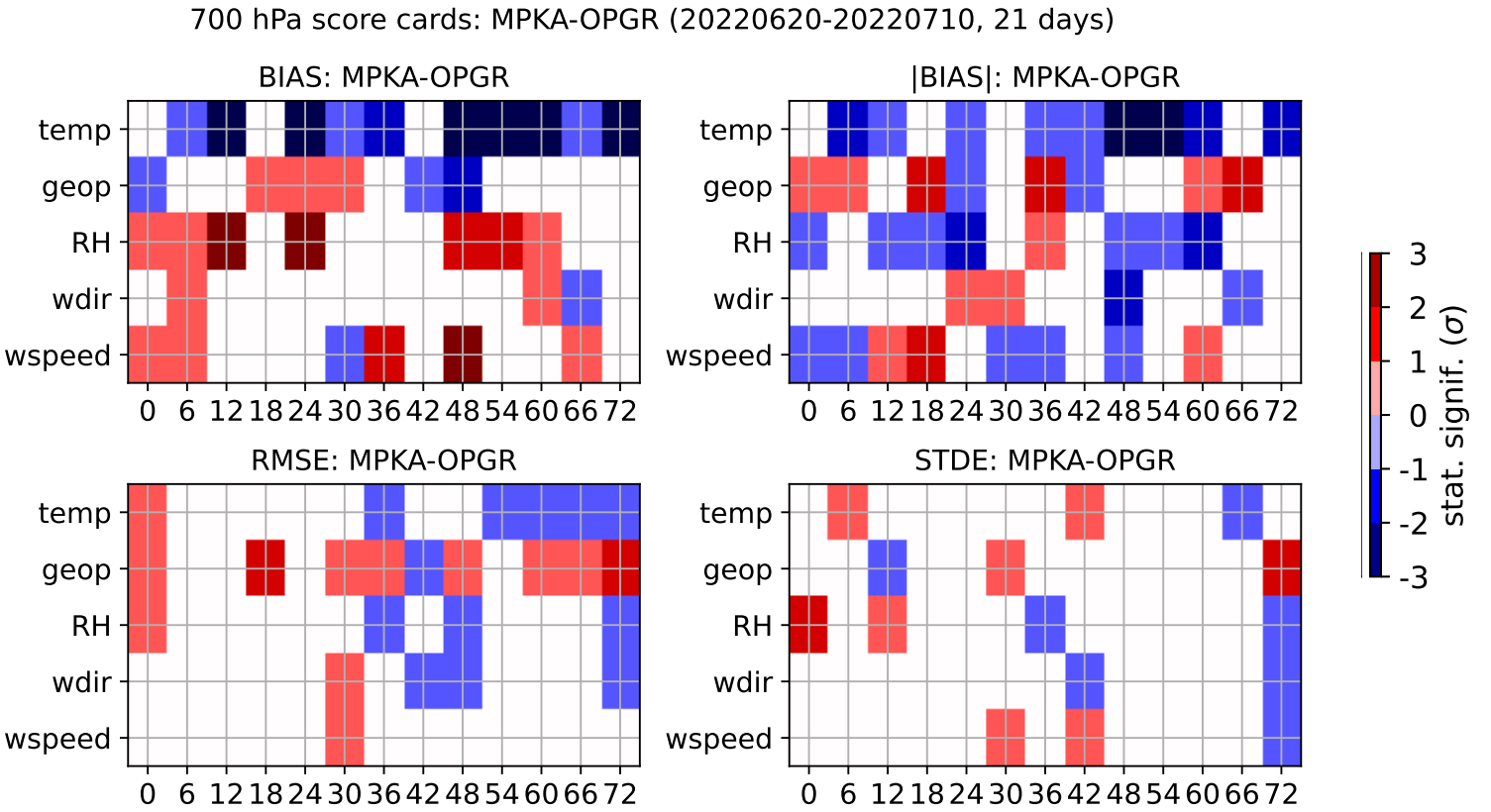
Lopez

Observations

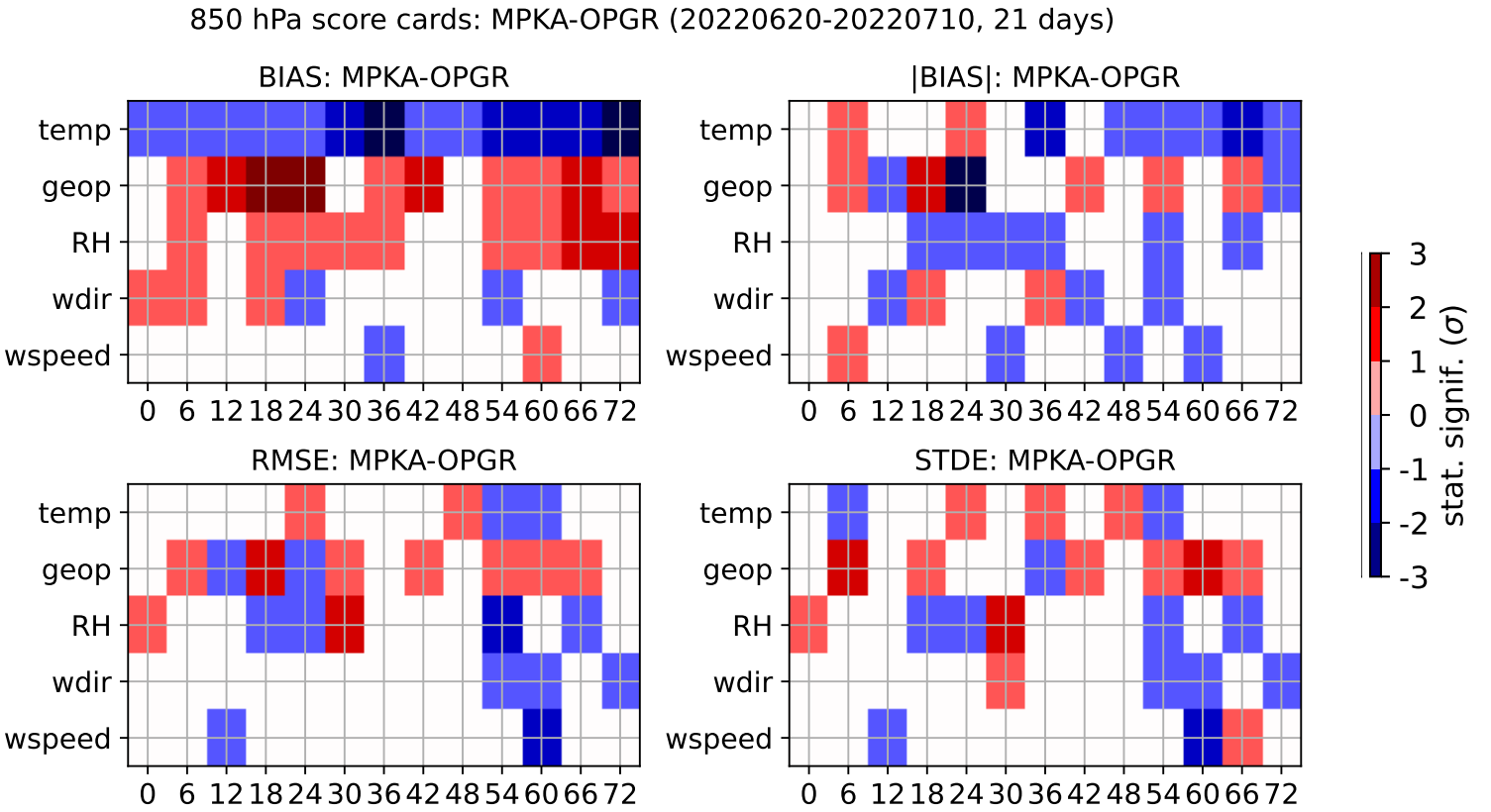




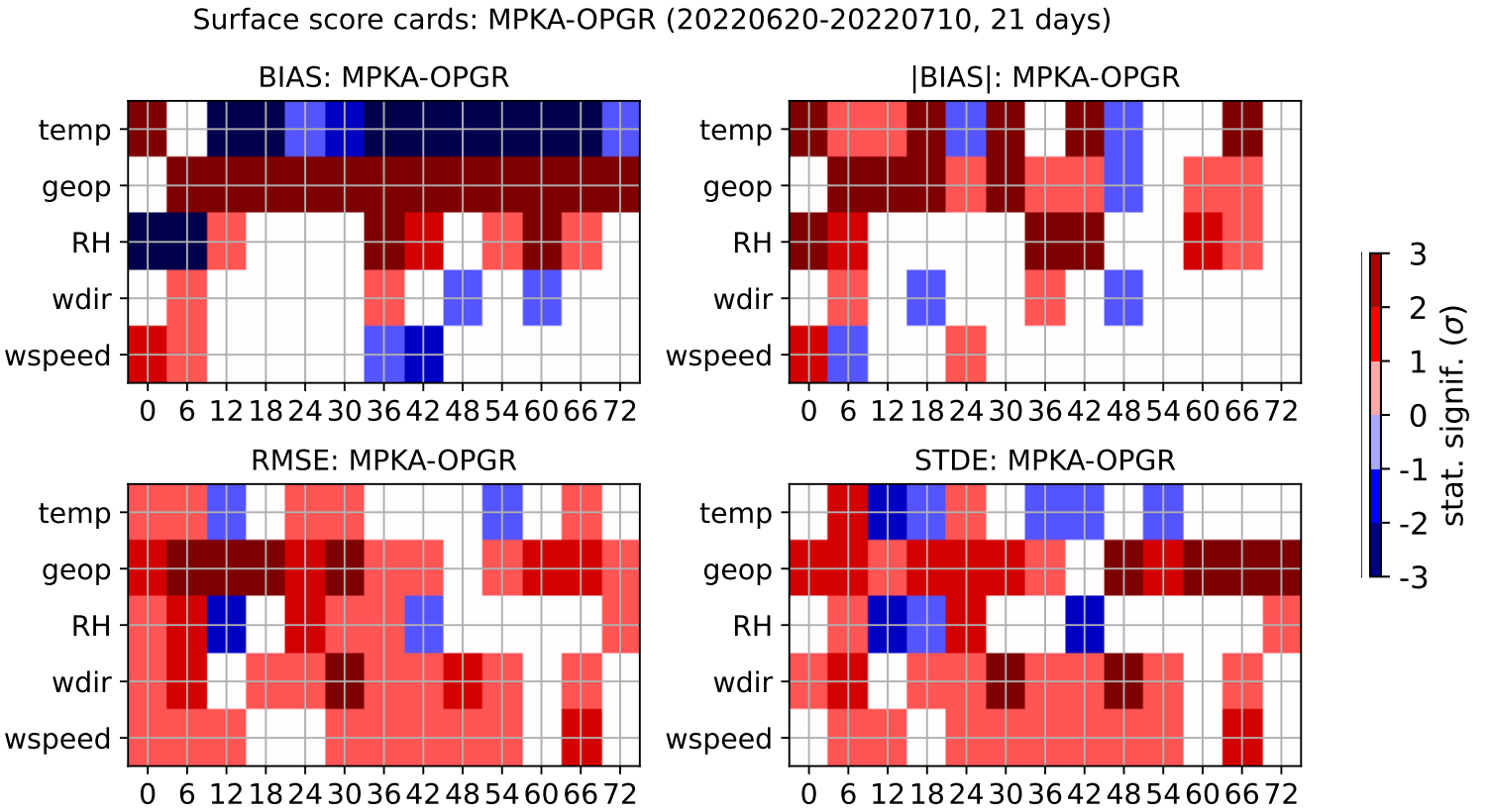
Scores at 700 hPa



Scores at 850 hPa



Scores at the surface



Conclusion

- graupel parameterization:
  - delivers more physical realism
  - only minor changes of scores
  - subtle reduction of precipitation maxima
- evaporation parameterization:
  - more significant change
  - improves precipitation field
  - improves upper air scores, significantly worsens surface scores

Thank you for your attention

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