A COMPREHENSIVE UPDATE TO THE BOUNDARY LAYER SCHEMES IN HARMONIE-AROME (FOCUSING ON LOW CLOUDS)

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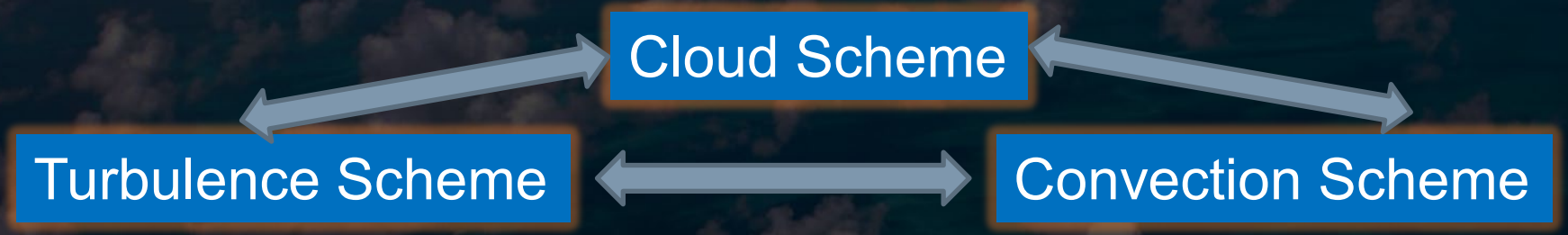


Integral approach

Develop and optimize tightly coupled parametrizations together!

Substantial modifications to all three schemes based on

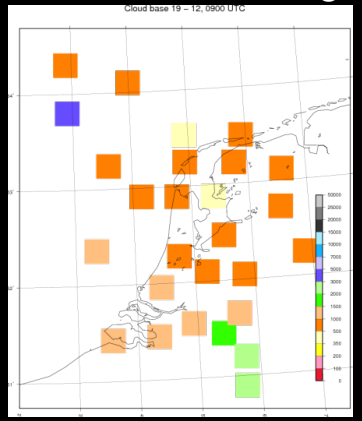
- process studies: LES, 1D idealized cases
- theoretical: cloud scheme (thermodynamics), turbulence (similarity)
- 3D optimization (uncertain parameters)

Impact of the new configuration

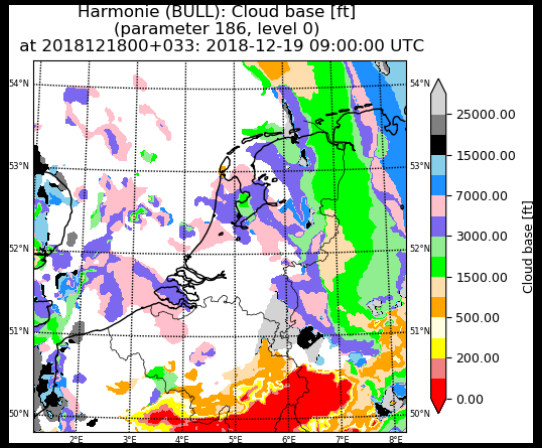
Most important deficiency Harmonie-Arome: Underestimation low cloud cover and overestimation cloud base height (aviation)

Example:
19th of December 2018.
Cloud base height in ft

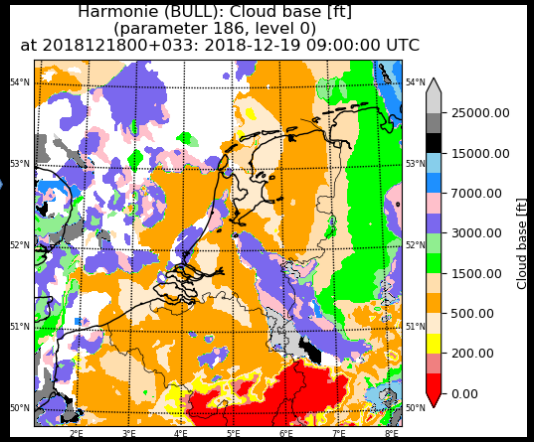
Observed cloud base height



Harmonie-Arome cy40 Ref.



Harmonie-Arome cy40 New



- Impact confirmed by several idealized cases and long-term verification of low cloud climatology:
  From large underestimations to well balanced.
- Preservation of atmospheric inversion strengths is key. Impact on clouds and (heavy) precipitation!

Summary

- Strong feedback between boundary layer schemes demands an integral approach
- Considerable changes to turbulence/convection/cloud scheme based on process studies (LES), theory, and 3D runs.
- Substantial improvement especially on clouds and precipitation. Can be seen for more than a year and almost every day at KNMI (e.g. by forecasters) in a KNMI parallel run.
- Preserving good performance of previous configuration (in particular wind speed).
- With increased insight in underlying physical processes → most sensitive SPP EPS parameters.
- All modifications are included in new (default) Harmonie-Arome cy43 and the new Harmonie-Arome Climate model.
- Paper: Model development in practice: A comprehensive update to the boundary layer schemes in *HARMONIE-AROME. de Rooy et al. (*submitted to GMD)