Recent developments in HARMONIE-AROME physics

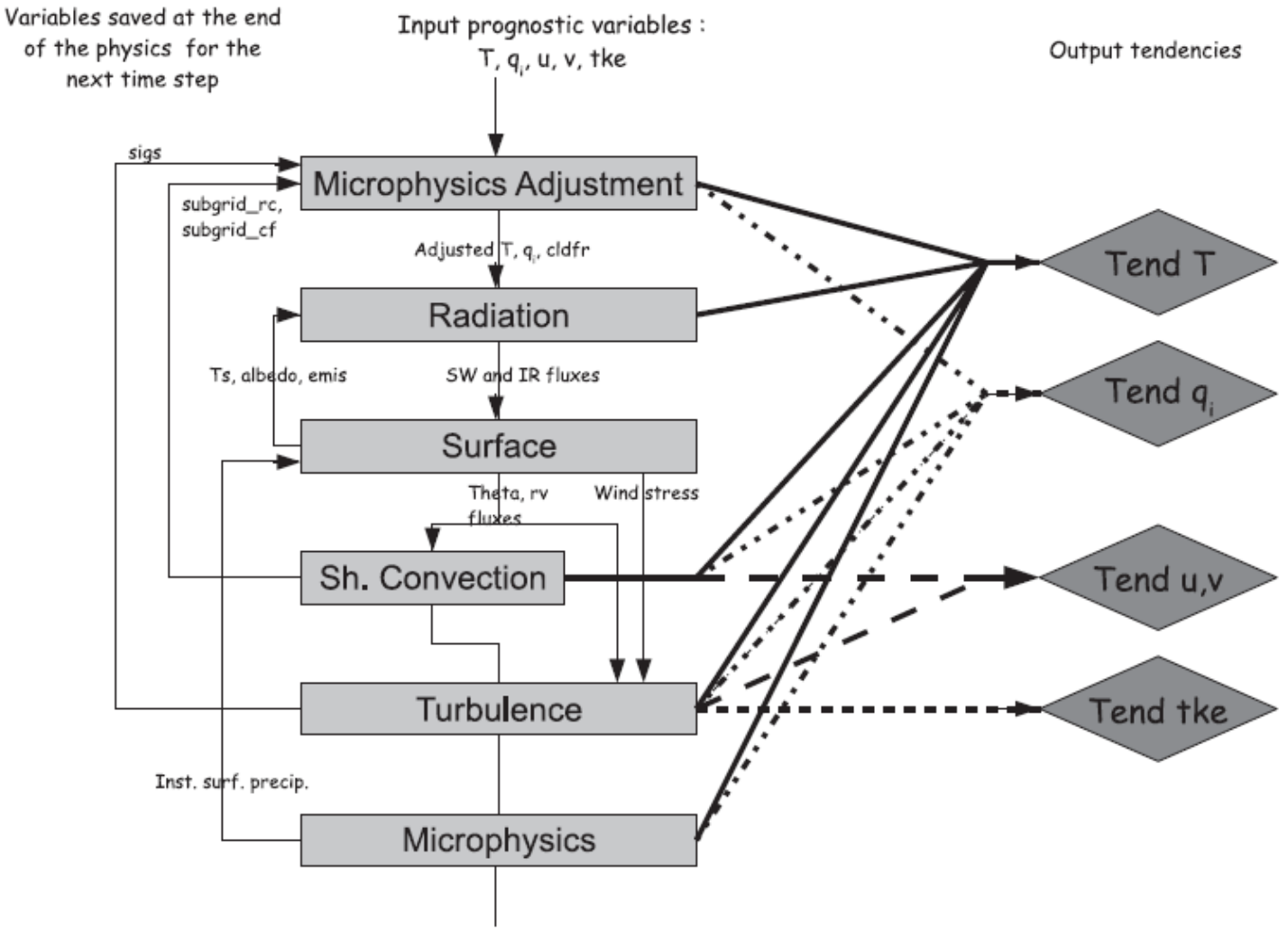
Lisa Bengtsson, SMHI
PL for forecast model development in HIRLAM-C

With input from many HIRLAM colleagues!

Outline of the presentation

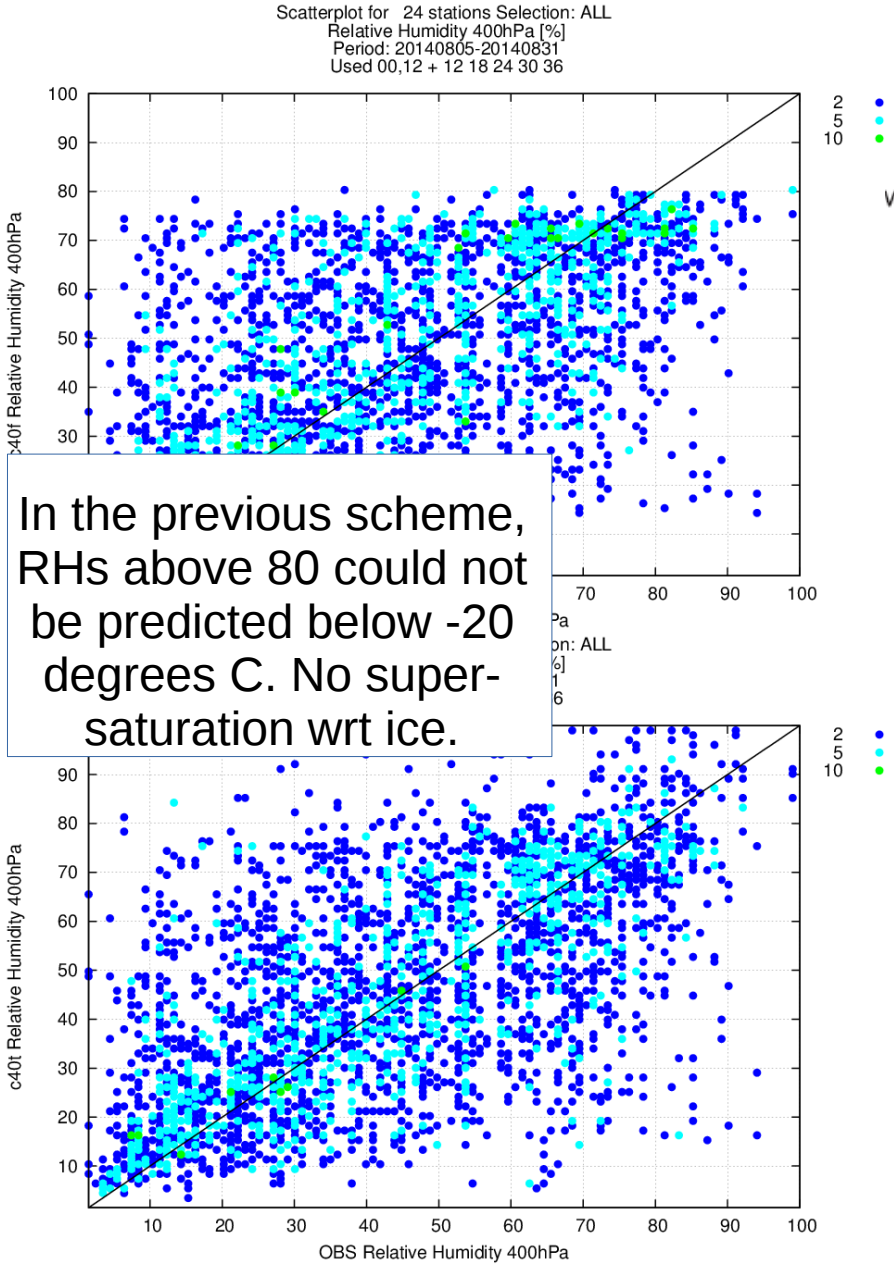
- Recent validation and developments in:
  - Cloud microphysics
  - Shallow and deep convection
  - Turbulence
  - Radiation
- Future developments

Physics time-step organization, AROME.



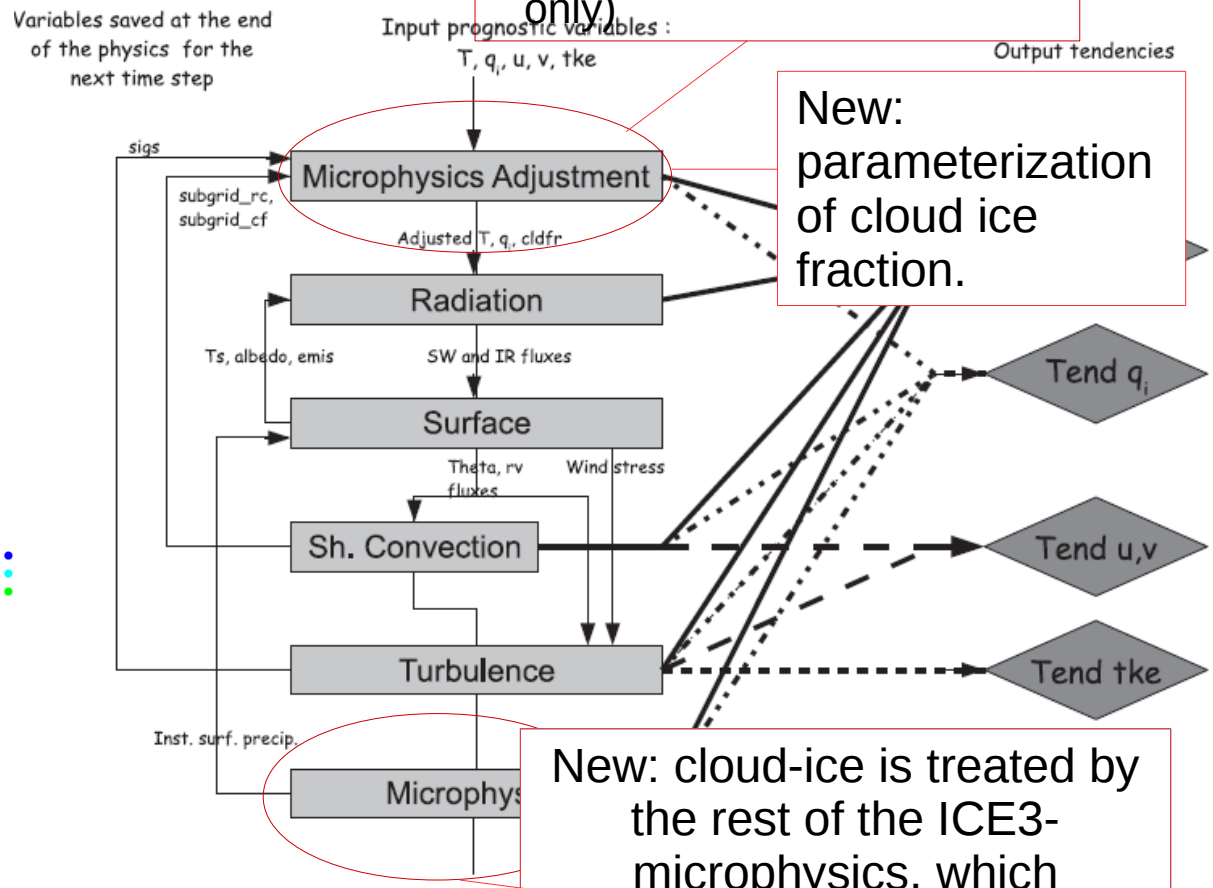
Physics time-step flow chart from : Seity et al. 2011

Improved representation of mixed-phase and ice clouds - OCND2



In the previous scheme, RHs above 80 could not be predicted below -20 degrees C. No super-saturation wrt ice.

Previously: Cloud fraction, cloud-water and cloud-ice (function of temperature only)

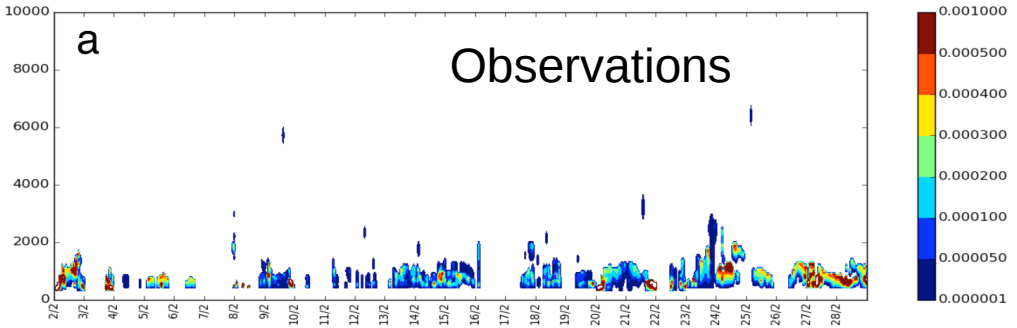


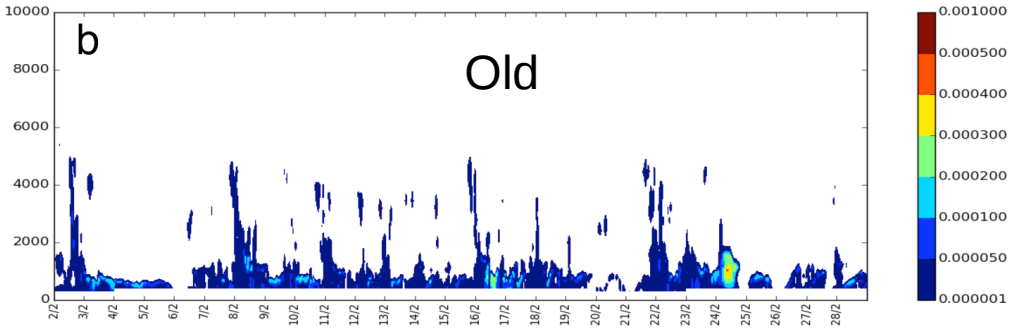
New: parameterization of cloud ice fraction.

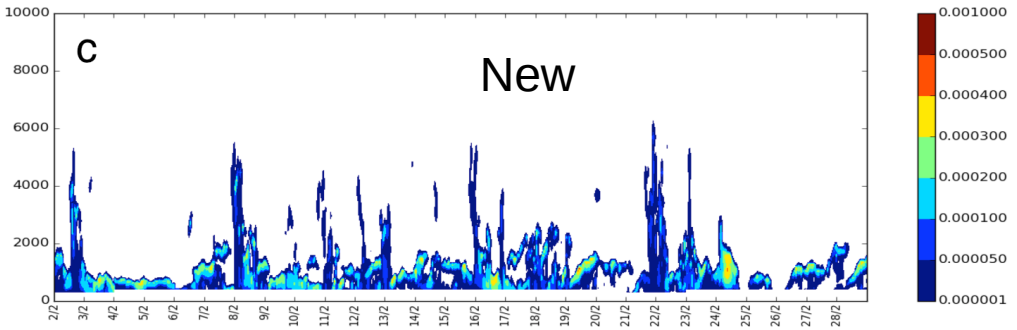
New: cloud-ice is treated by the rest of the ICE3-microphysics, which includes sublimation, evaporation and interactions with other water species

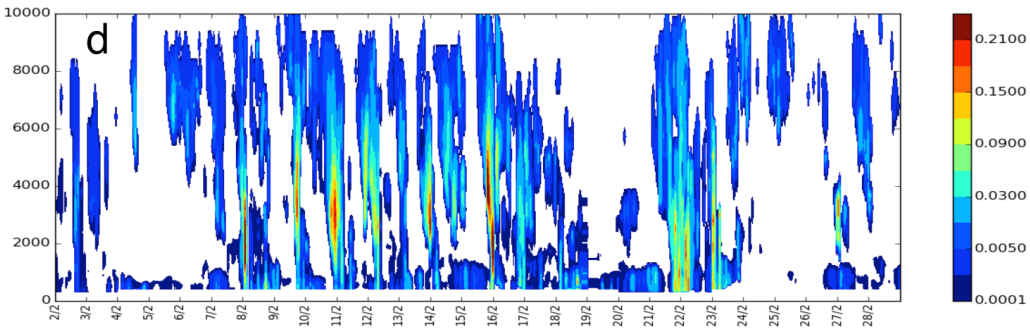
The AROME-France Convective-S
Y. SEITY, P. BROUSSEAU, S.MAL
BOUTTIER, C. LAC, AND V. MASS

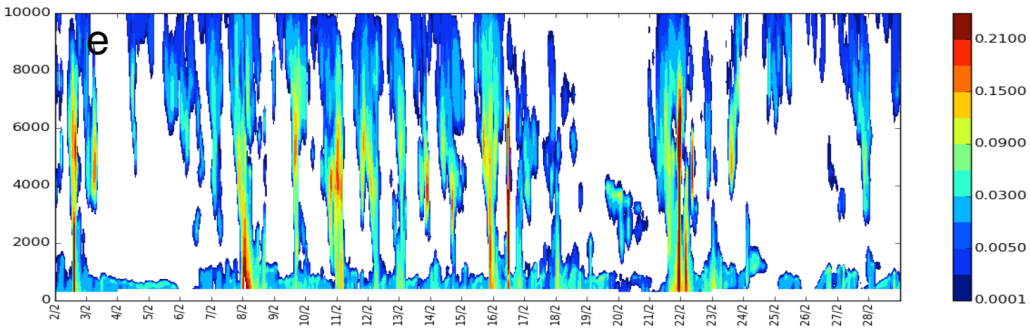
Improved representation of mixed-phase and ice clouds - OCND2

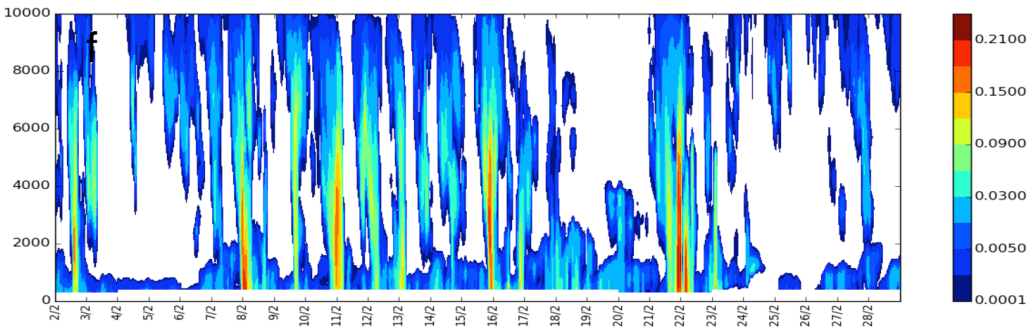










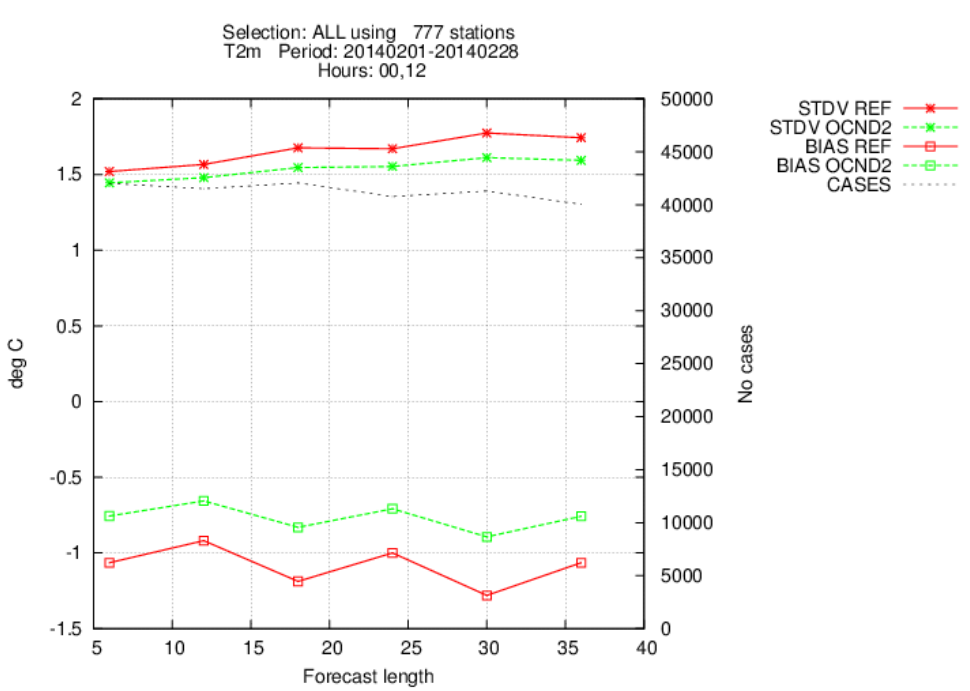


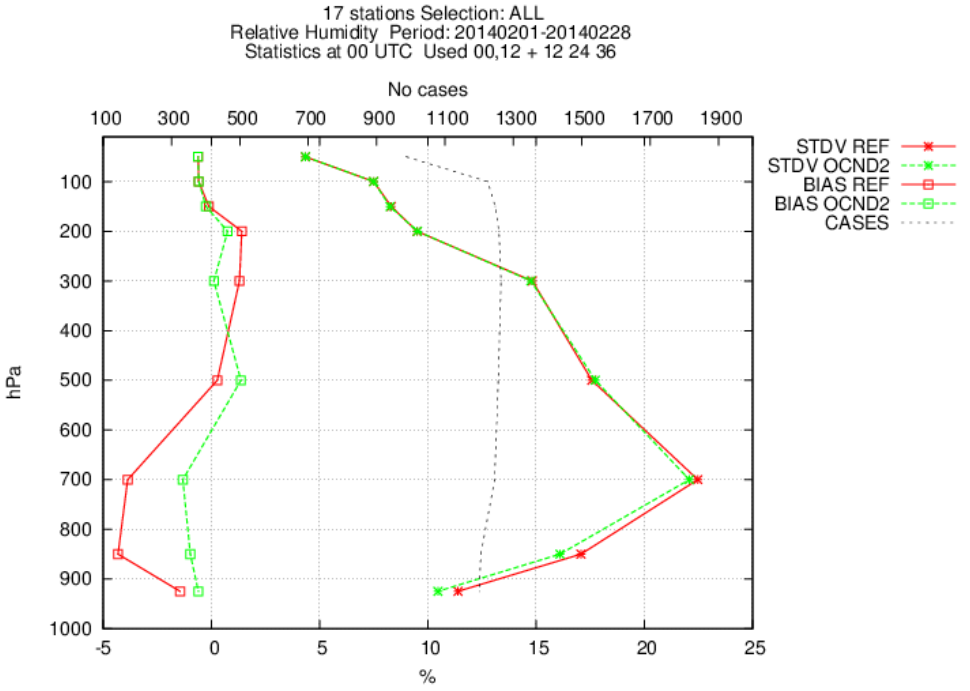
Liquid water content

Ice water content

Hytiälä, 2014 02

Improved representation of mixed-phase and ice clouds - OCND2



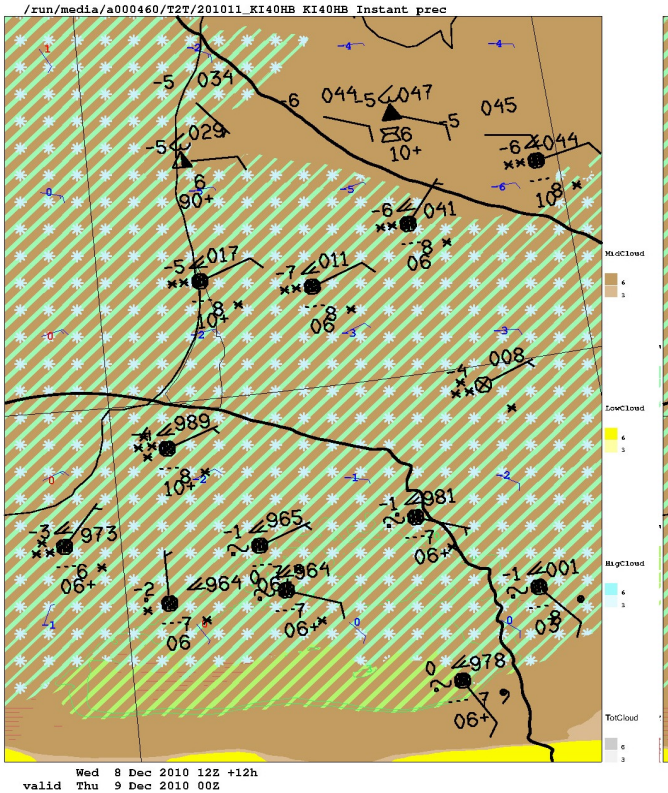


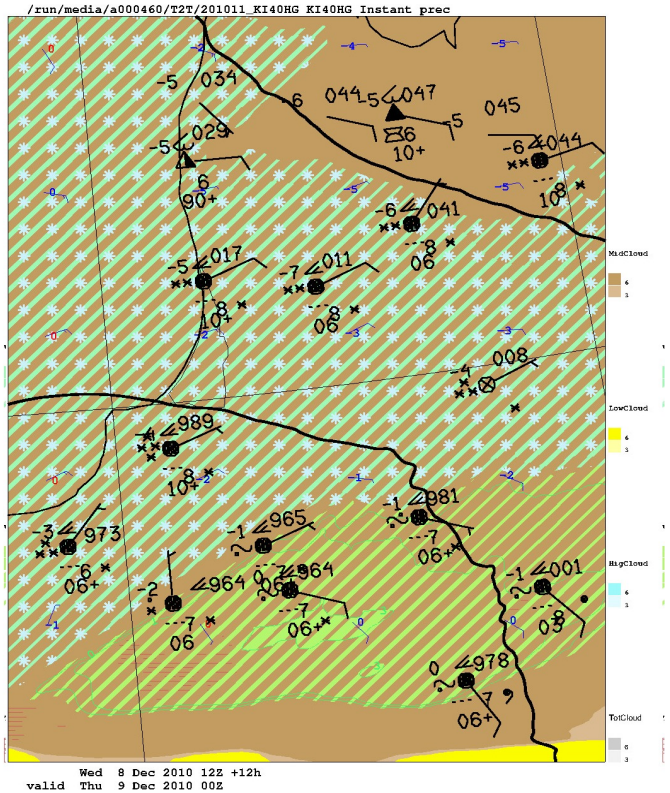
Impact on 2m temperature (left), and relative humidity profile (right). February 2014. Green is with OCND2 scheme, and Red is the old scheme.

Other updates in cloud microphysics

- Replaced Kessler (1969) autoconversion scheme with “Kogan autoconversion” (Khairoutdinov and Kogan 2000) in the reference cycle (cycle 40h1.1)
- Conversion of graupel to snow at high supersaturation and small (close to 0) mixing-ratio values of graupel. (aim cycle 40h1.2)
- Modifications to better describe freezing rain (currently supercooled rain is modelled as snow). (aim cycle 40h1.2)

OLD





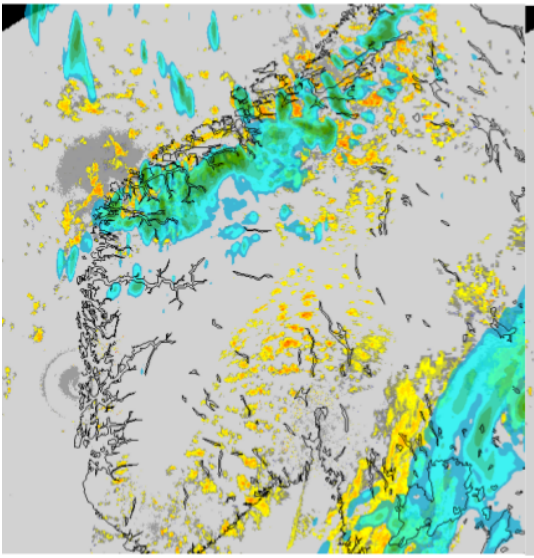
NEW

From Karl-Ivar Ivarsson, SMHI

Convection – problem with small scale showers

From Morten Költzow, Met-Norway

HARMONIE-AROME



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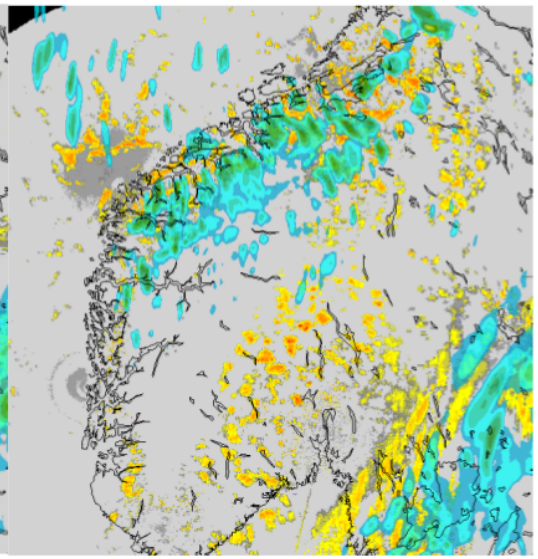

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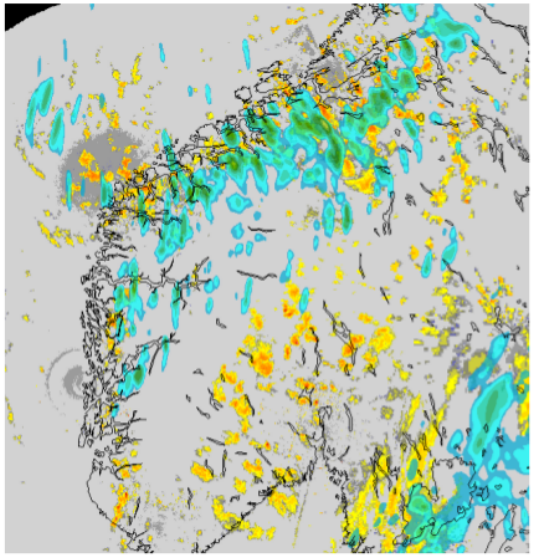

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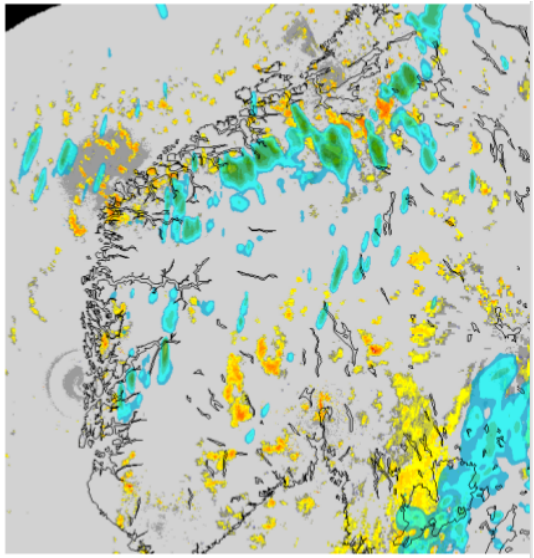

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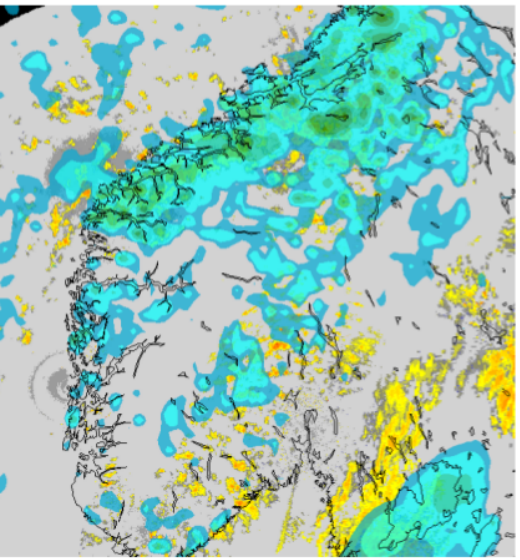
ECMWF



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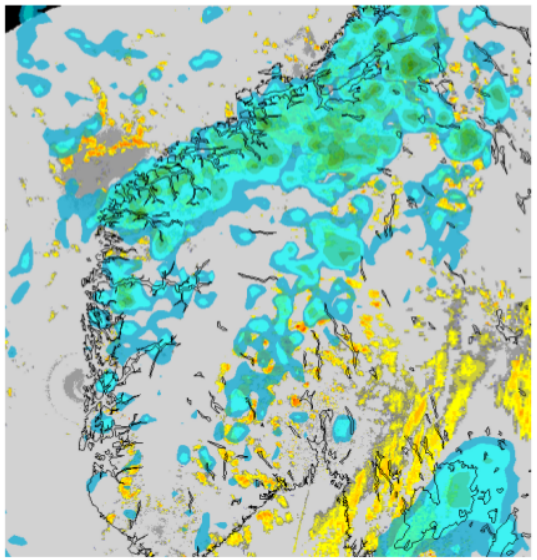

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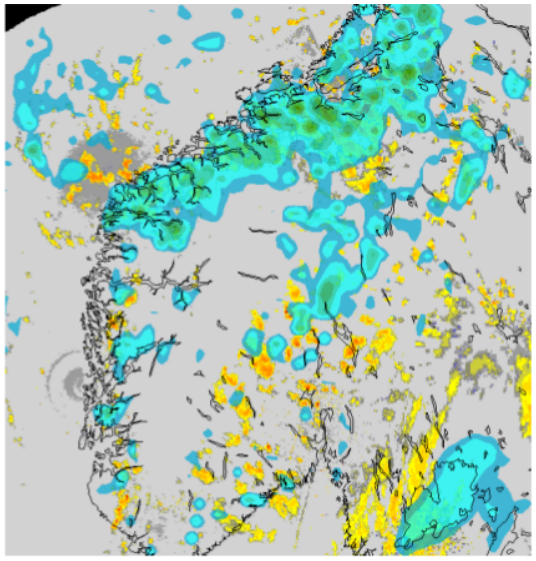

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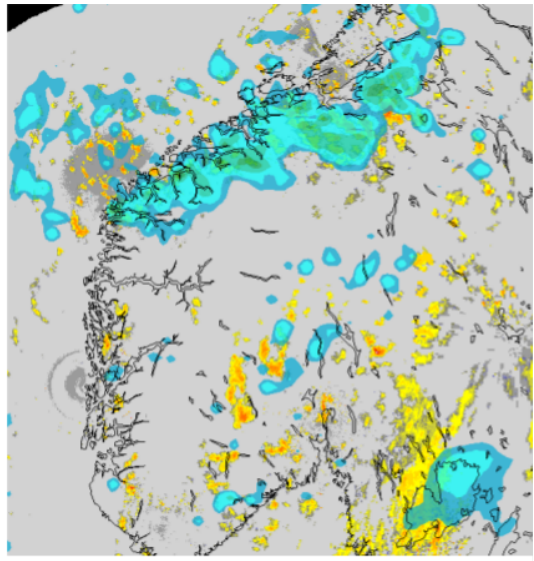

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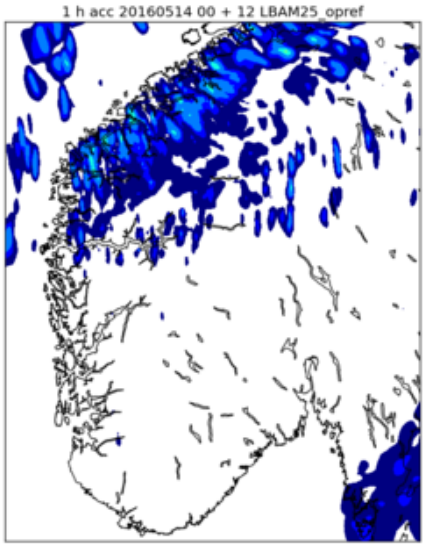
MetCoop operational, 38h12.



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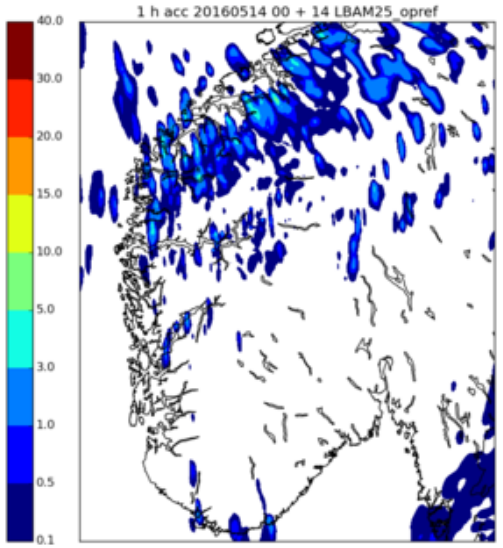

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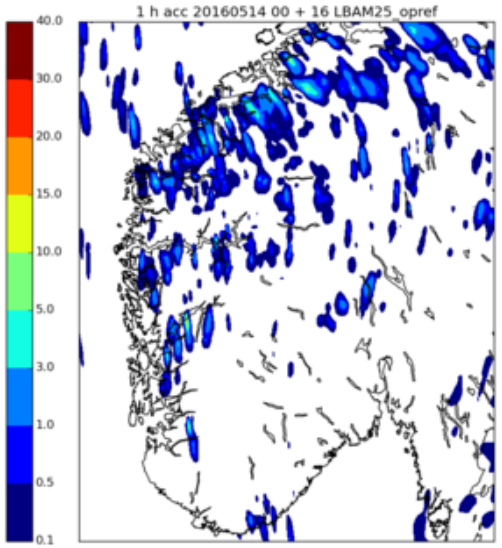

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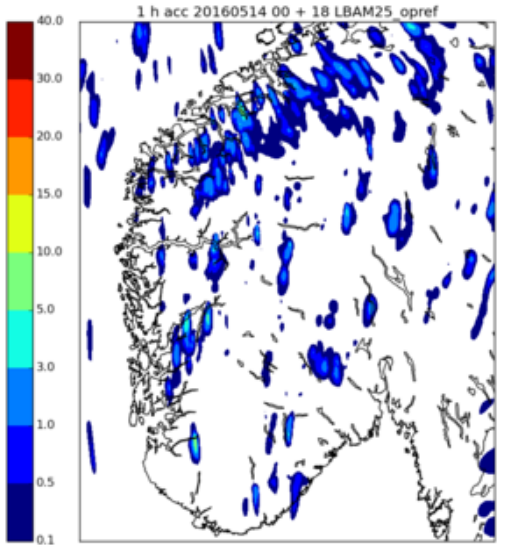

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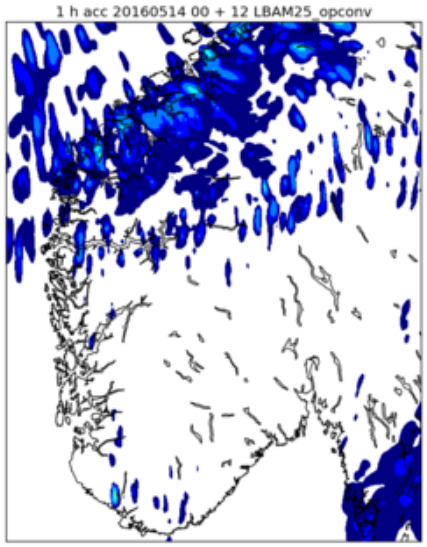
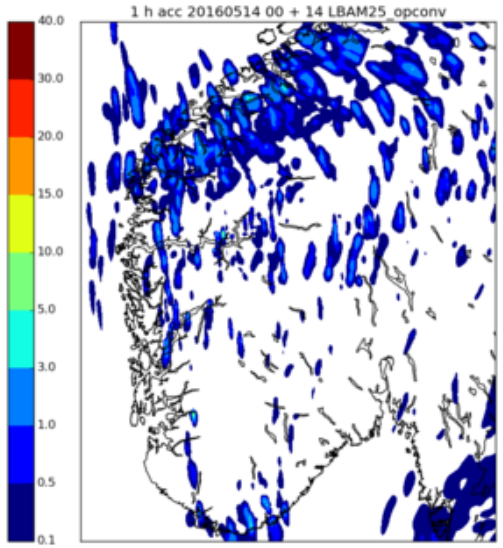
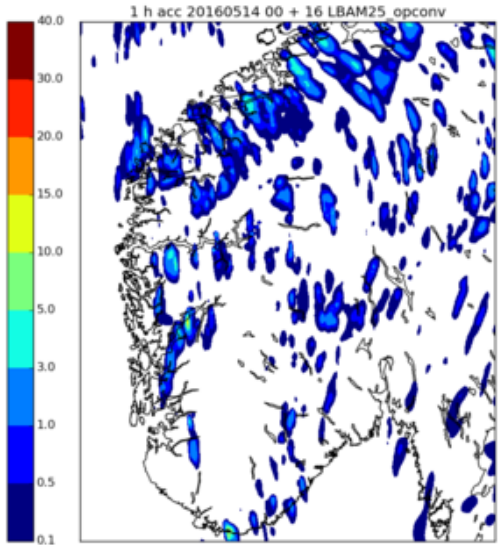
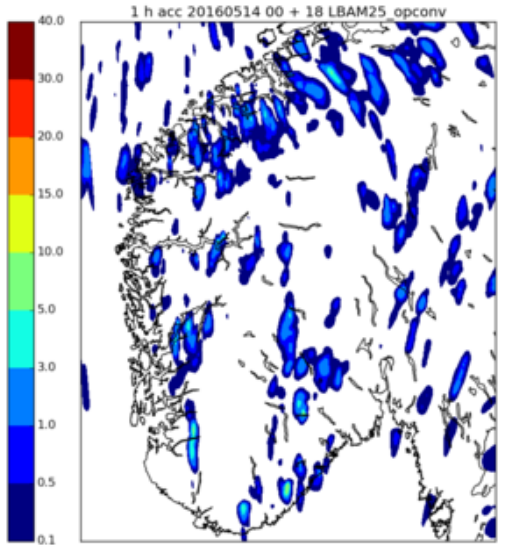








Experiment where shallow conv. scheme is switched off.

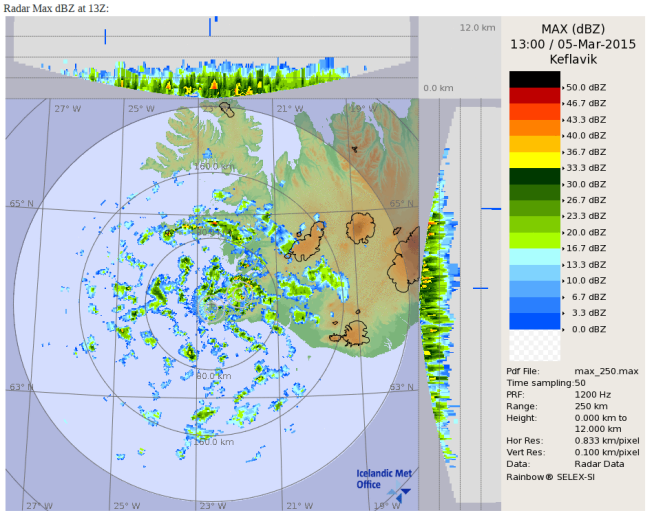
Convection – problem with small scale showers

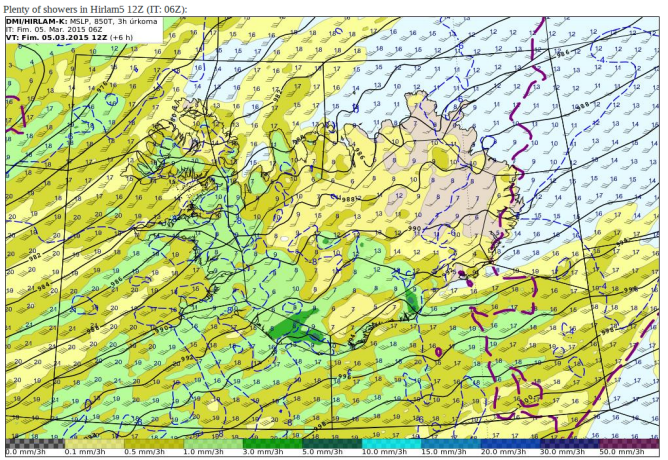
- Letting the model resolve all the convection yields more precipitation in the region of interest.
- The mass-flux scheme stabilizes the atmosphere – could delay/diminish resolved convection.
- However, the mass-flux scheme also moistens the atmosphere – could enable strong intense resolved convection and precipitation.
- Problem that we are in the gray-zone of convection. Can not capture the growth from shallow to deep precipitating convection using a mass-flux scheme for shallow, and explicitly resolve deep convection.

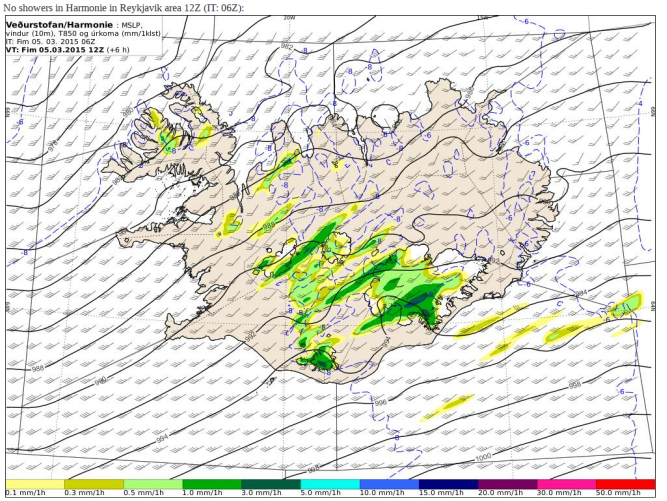
Plans

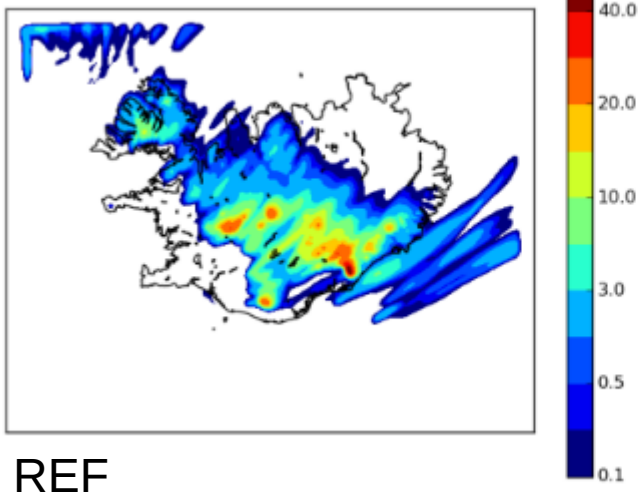
- Currently, all precipitation in the shallow convection scheme falls out without being advected. Experiment with reformulation of method so it becomes advected as the large-scale and deep convective precipitation.
- The “microphsyics” of the mass-flux scheme is rather simple, work to improve the precipitation generation in the shallow convection scheme.
- Experiment with use of cellular automata in the shallow convection scheme in order to enhance lateral communication (advection in from sea to land), and stochastisity (triggering).

Convection – example shallow precipitation in cold conditions









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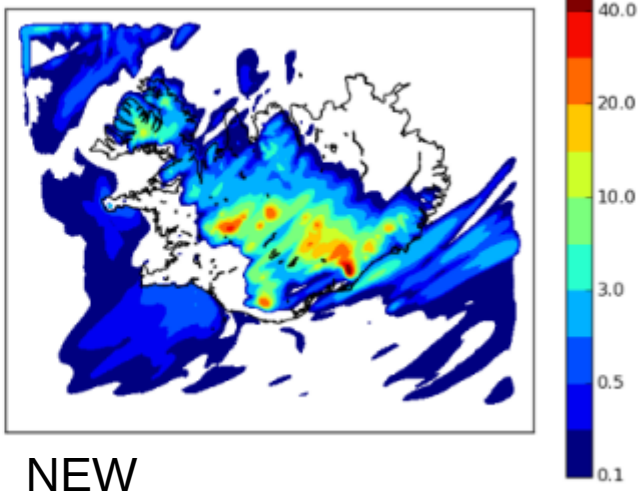


NEW

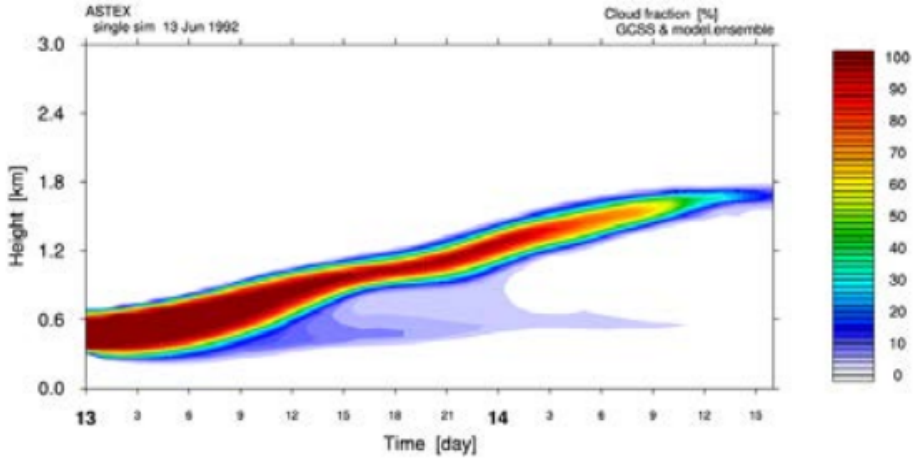
12 h accumulated precipitation

Assume that precipitation production is likely to be favoured by active ice-phase processes, so that when cloud-base temperature is close to 0C, precipitation is possible with relatively shallow convective clouds.

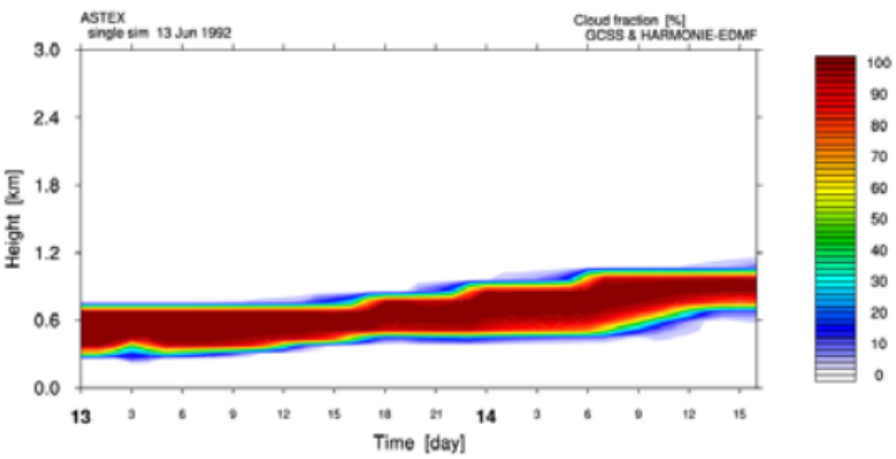
Still problem of precipitation generated by sub-grid scheme over sea is not advected in over land.

Turbulence

- Since cycle 40h1.1 there is a new default turbulence formulation in HARMONIE-AROME called HARATU.



LES



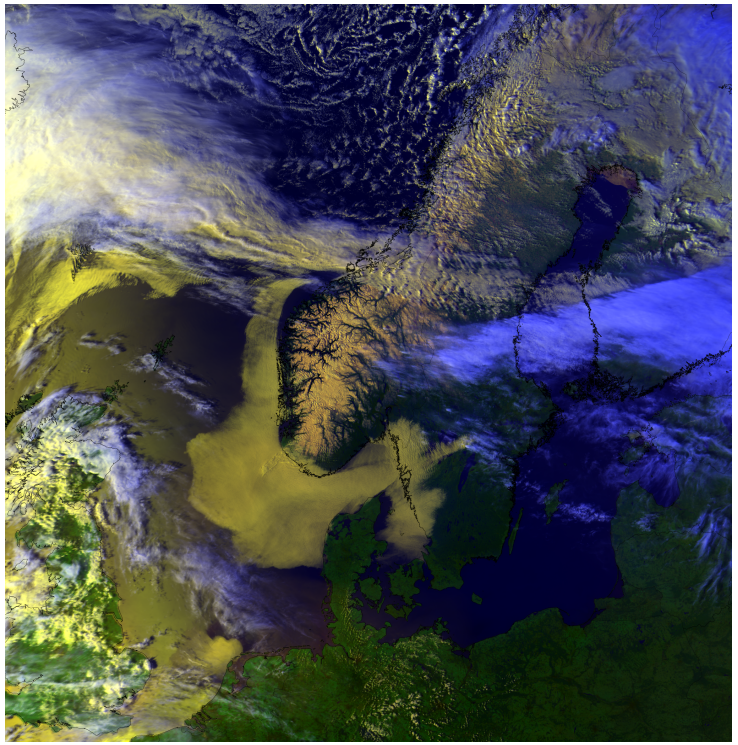
1D HARMONIE-AROME – cycle 36h1.1

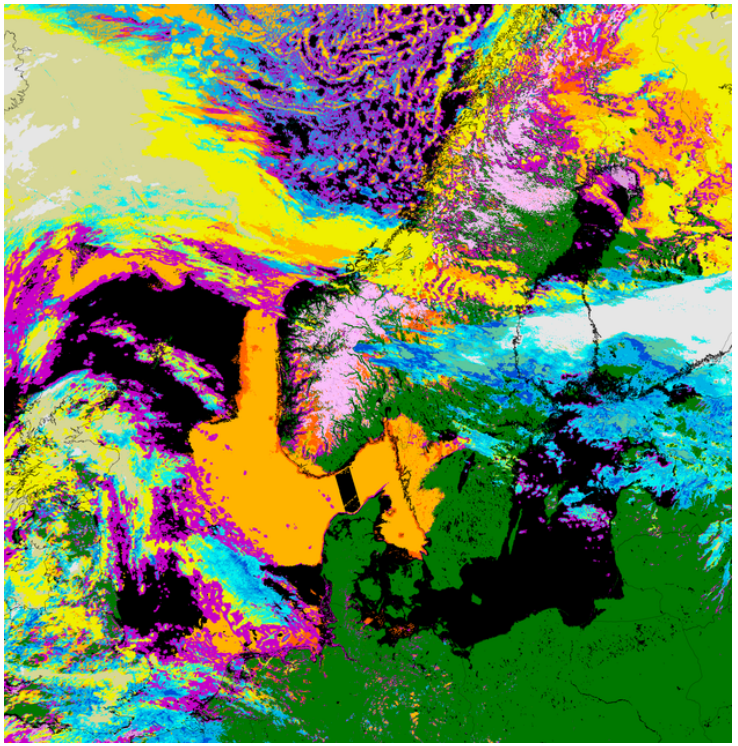
The motivation for this was that 1D simulations within the ASTEX (stratocumulus) campaign revealed that there was not enough cloud top entrainment in the previous model, and the model over-estimated low level clouds and fog both over land and over sea.

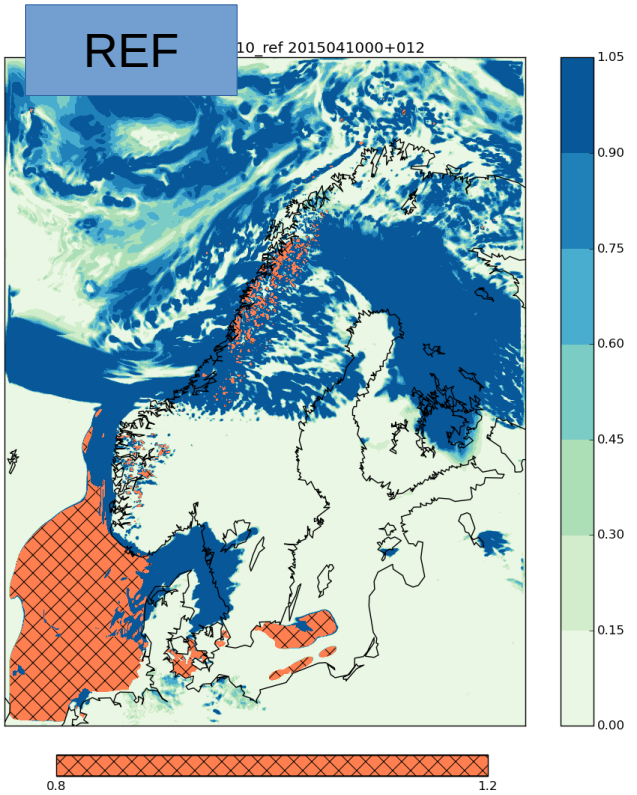
Main difference with the previous (CBR, Cuxart et al. 2000; Seity et al. 2011) scheme is in the length scale formulation, and changed TKE computations from full to half levels.

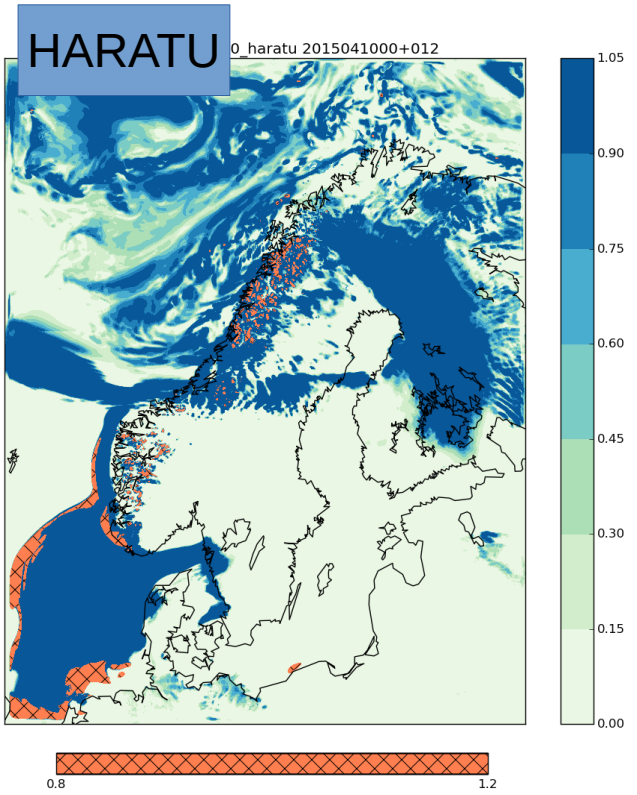
Wim de Rooy, KNMI

Impact of HARATU turbulence scheme - fog

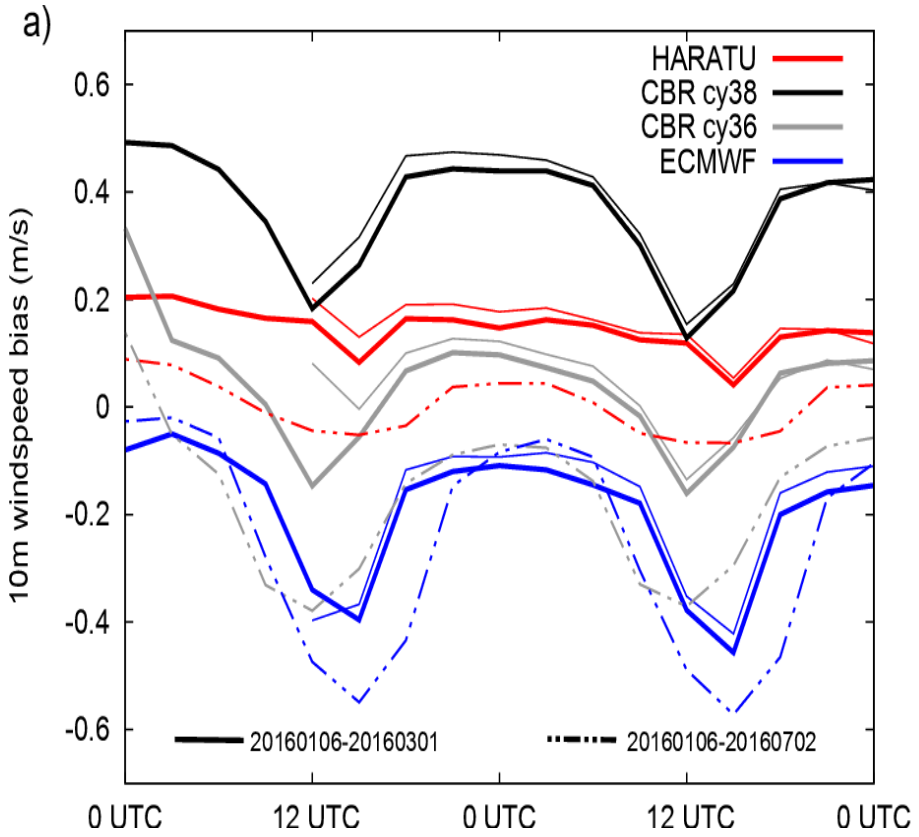


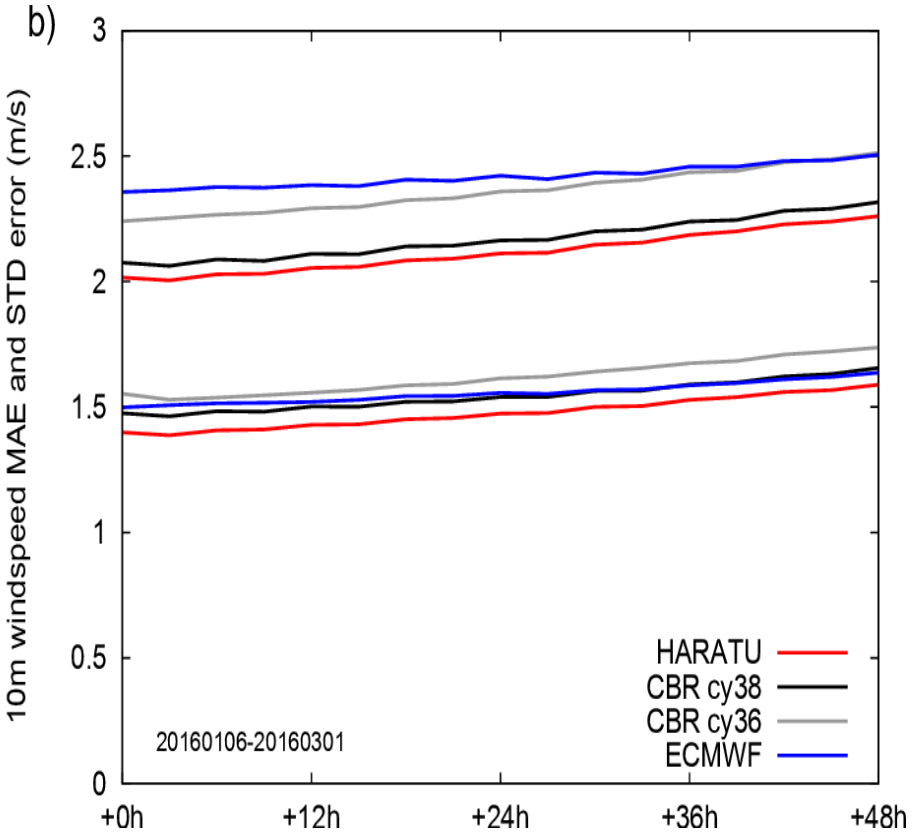






Impact of new turbulence scheme – wind



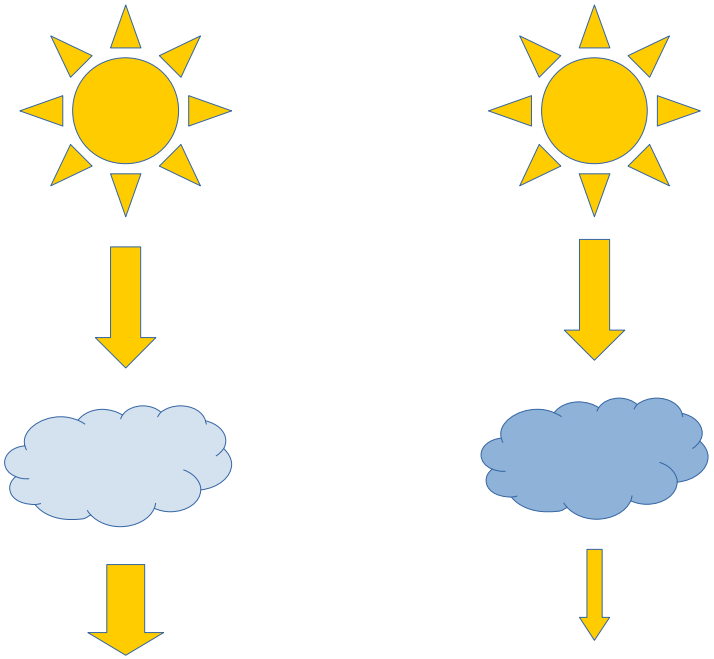


Wim de Rooy, KNMI

Radiation

In cycle 40h1.1 the updates in radiation are in how the radiation sees clouds.

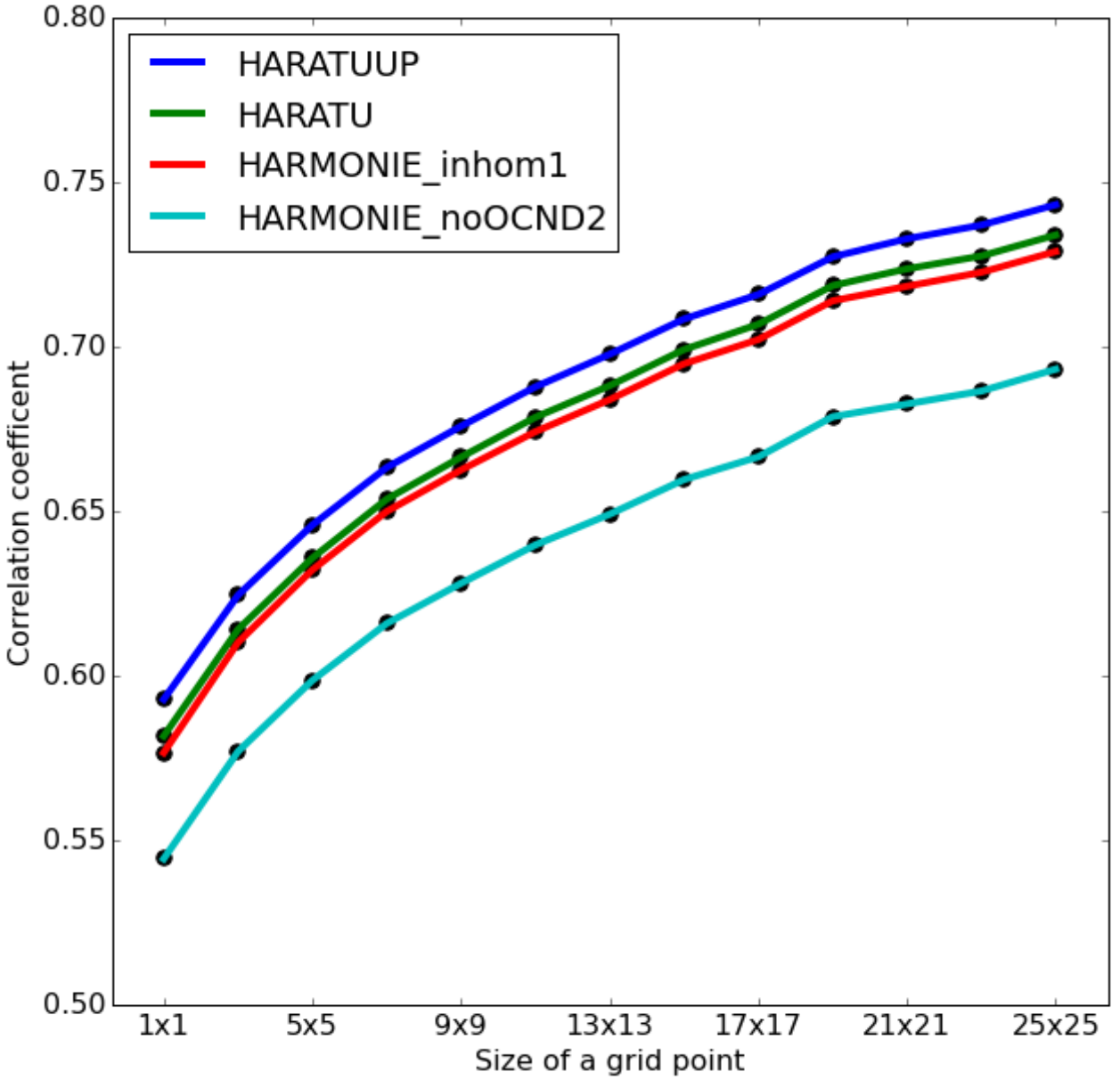
- Updated inhomogeneity factor (from 0.7 to 1.0)
- New cloud liquid optical property scheme. (Nielsen et al. 2014).



Both of the updates yields a reduction in downwelling short wave radiation, as the clouds seen by radiation becomes less transparent.

Please see Emily Gleeson's poster for more radiation activities in ALADIN-HIRLAM.

Cloud cover verification against MSG



Christiaan van Dalum and Wim de Rooy, KNMI

Some plans for the future (1/2)

- **Microphysics:**
- Assess the behaviour of the 2-moment microphysics scheme LIMA developed at Meteo-France (Vié et al. 2016).
- Prepare and test introduction of near-real-time aerosol information from MACC/SILAM in close collaboration with ALADIN partners.
- **Clouds and Convection:**
- Study if a better assessment of the variance term used in the statistical cloud scheme can be found from observations/LES, in order to improve the forecasted cloud cover.
- Study the behaviour of the mass-flux scheme in “common single column framework” (HARMONIE and Meteo-France), based on “KNMI testbed MUSC cycle 38h1.2”. Compare with cloudnet stations and super-sites (fluxes, meteorology), Large Eddy Simulations.
- Study if triggering and organization of sub-grid convection can be modelled better with help of cellular automata.
- Revisit the cloud microphysics used in the sub-grid scheme (see previous slides on convection).
- Study the coupling between land soil properties and initiation/strength of deep convection, and the sensitivity of deep convection and its organisation to improvements in surface data assimilation or surface-atmosphere coupling.

Some plans for the future (2/2)

- **Turbulence:**
- Assess further the sub-km resolution, how the model behaves when shallow plumes are resolved, and turbulent mixing in the horizontal direction is no longer assumed to be neglected.
- Assess the behaviour of the HARATU scheme in the stable boundary layer, and if the model can be improved further in this regime.
- **Radiation:**
- The ACRANEB2 radiation scheme from the ALARO NWP model (Masek et al. 2016) and the HLRADIA radiation scheme from the HIRLAM model (Savijärvi, 1990) have been tested in HARMONIE-AROME. These schemes only have 1 SW spectral band and 1 LW spectral band. They have the advantage that they are fast enough to run at each model time step, unlike the current default ECMWF IFS radiation scheme, which is only run at every 15th time-step, based on a model time-step of 60 seconds. The fast interactions between clouds and radiation and the surface and radiation could be of greater importance than accounting for the spectral details of clear-sky radiation.
- Tests will be carried out to verify whether it is correct to assume that graupel has the same IOPs as snow and whether snowflakes can be treated like cloud ice crystals. If not, new parametrizations will be developed.
- An update of the aerosol climatology to the Monitoring Atmospheric Composition and Climate (MACC) reanalysis dataset, which includes assimilated AOD measurements, is planned for representing the direct effect of aerosol.

Thank you for your attention!

Questions?