HARMONIE atmospheric and surface physics developments.

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With input from HIRLAM colleagues.

Main scientific objectives foreseen for 2016-2020

- (Continue) to identify and address systematic model error.
- Where needed, develop/introduce parametrizations with increased physical realism (surface, microphysics-clouds-radiation-aerosol interactions, stable, BL)
- Research on model behaviour at sub-km grid-spacing.
- Coupling the model with aerosol and later hydrological/ocean wave models.
- Stay involved in ECMWF activities on dynamics/numerics developments; scalability, pantarhei, ECSCAPE activities on more flexible grids in relation to the physics, in which DMI is involved.

Identify and address systematic model error

Example of systematic errors that have been detected within the joint cloud/radiation WG, and addressed are:

- Over-prediction of clouds in winter and spring, (in particular low clouds and fog) (Improved with new turbulence scheme, HARATU).
- Positive bias in 10m wind (Improved with new turbulence scheme, HARATU).
- Significant bias in the downward radiative flux (Improved with new optical properties scheme, and changed inhomogeneity factor)
- Too little mixed-phase clouds in cold situations (Improved with updated microphysics processes under OCND2)
- Too low cloud base associated with weak top entrainment in stratocumulus. (Improved with HARATU)
- Over-prediction of extreme precipitation. (Improved significantly with updated microphysics processes under OCND2).
- No precipitation from convection in cold conditions (shallow) (Improved with update of EDMF-m).

Identify and address systematic model error

Other known weaknesses which still need to be tackled more rigorously 2016-2020 are:

- Over-prediction of strong winds over sea
- Too much liquid water in the thickest clouds
- Problems with too great soil evaporation under summer conditions
- Too strong latent heat fluxes from surface in spring/summer – problem with LAI?
- Freezing rain – model converts to ice/snow too quickly.
- Too much graupel in frontal snow bands.
- Positive drift in mean-sea level pressure.
- Poor surface temperatures under very stable conditions
- Poor surface temperatures in snow/forest conditions

To do jointly: Do we see the same problems in the three different CMC's? Use common MUSC to evaluate various physical schemes against observations of surface fluxes, radiation and cloud water/ice. As well as campaign studies; ASTEX, ARM, GABLS4. Identify if any of these systematic errors can be solved by a better process description. Organize consortia-wide "working groups" depending on topic?

Where needed, develop parameterizations with increased physical realism.

- 2016-2020:
  - Utilize SURFEX physics better for NWP so that it is “up-to-speed” with the physical realism of surface descriptions in the HIRLAM model. Work on Ensemble Kalman Filter methods in parallel to reach this goal.
  - We will continue to identify lack of processes in SURFEX which are important for NWP/(climate) and add/improve such processes in collaboration with experts. Currently that concerns e.g. sea ice and glaciers.

    Joint action: As all model configurations aim to use SURFEX, there is already active collaboration between the HIRLAM/ALADIN consortia and the SURFEX community.
  - Introduction of aerosol parametrizations in the new physics-dynamics interface, parametrization and assessment of indirect aerosol effects, the initialization of aerosols and surface emissions, a review of the cloud microphysics parameters, and studying the evolution of aerosols with the LIMA 2-moment microphysics scheme developed by meso-NH/Meteo-France.
    - **Joint action: Continue with the common radiation branch, explore various radiation aerosol interactions in the same framework (hl_radia, ACRANEB2, ECMWF radiation)**
    - **Joint action: Use of the 2-moment microphysics interesting for all configurations, test in various domains (e.g. northern latitude with mixed phase clouds, and formulate a clear common plan for interaction with aerosols).**
  - Stable boundary layer. Explore behavior of HARATU. Explore stochastic parameterization.
    - **Joint action: participate in field campaigns, GABLS4. Collaboration with universities. Consortia-wide workshop on stable boundary layer?**

Research on model behaviour at sub-km grid-spacing.

- Higher vertical resolution – impact on stable boundary layer. More realistic interaction between atmosphere and surface.
- Explicit shallow convection and a 3D description of turbulence (and possibly radiation). How? Consequences for code? Related to scalability programme.
- In-cloud turbulence parameterization?
- Adaptations in the dynamics to address stability issues arising from increasingly steep slopes in model orography. (Long term in agreement with the ECMWF scalability programme.)
- Settings/behaviour of Semi-Lagrangian Horizontal Diffusion (SLHD)
- More detailed orographic and physiographic datasets (such as ASTER) should be introduced and inspected for gross errors.
- Sub-km model runs can be compared with the downscaling of ~1km AROME/HARMONIE/ALARO with an LES.
- Engage in field experiments with dense and non-standard local observations.
- What are other consortia doing? COSMO/UK-met office/WRF community?
- **Meteo-France has most experience with AROME at ~1km and ~90 levels resolution, as well as in-depth studies on turbulence/shallow convection at increased resolution. Perhaps a workshop on sub-km scale modelling could be organized to share knowledge between the members of our joint consortia?**

Where/how to do joint work, with which partners

- Externalized test-bed, and common MUSC code, ALARO/AROME-MF/HARMONIE
- A single technical call tree to physical parameterizations developed by the “emerging” groups: AROME-MF, ALARO, and HARMONIE, extremely vital for successful collaboration.
- IF we would like to fully collaborate, the aim must be to develop physics which is available to everyone (not necessarily compatible with other physics options), within the common call tree.
- Could we formulate a strategy to have constellations (e.g. common working teams) based on scientific topics in the “new joint consortia”? e.g “Radiation”, “Turbulence”, “Scalability”, “Numerics”, “Surface”...