Potential MSc thesis topics

Martin Weissmann, 28 October 2015

MSc thesis topic “Ensemble sensitivity analysis“

Main objective: Quantification of the potential impact of observations related to clouds and precipitation on convective-scale precipitation forecasts through the use of ensemble sensitivity analysis

Motivation: Several studies showed that the impact of assimilating radar observations is often limited to the lifetime of the observed individual systems (i.e. up to 1-2 h). It is, however, unclear if this limitation is due deficiencies in the procedures for assimilating radar observations, or if it is an inherent limitation. A recent study Lien et al. (2015) for example indicates that precipitation observations can have a longer lasting impact on dynamic variables when the observations are treated differently in data assimilation. The HErZ group in Munich has a strong focus on the assimilation of remote sensing observations related to clouds and precipitation. Investigating the potential impact of different observation types is therefore essential for the strategy of the group, but also for future convective-scale data assimilation systems in a broader context.

Approach: The project shall investigate the sensitivity of precipitation forecasts to initial condition changes in different variables using the ensemble sensitivity analysis (ESA). This shall provide information on the potential impact of observations related to clouds and precipitation, i.e. the impact that these observations would have if we exploit them optimally. The core tool shall be the ESA code from Greg Hakim, applied first to KENDA/COSMO ensemble simulations for two events of convective precipitation over Germany (one case with locally driven precipitation and another one dominated by large-scale forcing). The second part of the thesis shall investigate the ESA methodology using a 1000-member ensemble performed at the RIKEN institute in Japan. While the ESA method has been evaluated extensively for global-scale applications, the strong non-linearity encountered in convection-permitting simulations poses significant challenges for the approximation. The main limitation in this context is the ensemble size (currently 40 members for KENDA/COSMO). For the evaluation of the methodology the planned 1000-member ensemble provides a unique opportunity to evaluate the methodology through comparison of the results using the full ensemble to results for using limited subsets of the ensemble. A few previous studies applied ESA on convective-scale model forecasts (e.g. Hanley et al. 2013, Barrett et al. 2014) and claim that the results “appear” realistic. The 1000-member ensemble, however, would for the first time allow evaluating the methodology, its applicability for convective-scale forecasts and its limitations. As a by-product, the 1000-member ensemble itself could be interesting for a number of different applications as such a simulation is currently completely new territory that has just become feasible with the latest generation of supercomputers (where few meteorological institutions worldwide have as much computing time as the RIKEN institute).

Applied tools:

- KENDA/COSMO: Simulations with the KENDA/COSMO ensemble will provide the basis for the ensemble sensitivity analysis. KENDA/COSMO is used by a number of people in the HErZ group and a suitable setup is available.
- Ensemble sensitivity analysis (ESA): The method (Ancell and Hakim 2007, Torn and Hakim 2008) calculates the sensitivity of a chosen forecast metric (e.g. error of the precipitation forecast) to changes in the initial conditions. ESA shall be used to compare the sensitivity of precipitation forecasts over Germany to initial condition changes in different variables (humidity, clouds, precipitation, winds). This shall provide insights on the potential impact of assimilating observations related to convection. Greg Hakim has a Matlab code for ESA that has already been used by Julia Keller at DWD who is willing to support the implementation if necessary. Minor adaptations of the will be required for changing e.g. the verification metric and handling extensive ensemble data sets, in particular for its application to the 1000-member ensemble.

Remarks to extended visit at the RIKEN institute in Kobe, Japan

- An extended visit at RIKEN is not compulsory, but highly recommended
- The visit shall inter alia include support of the RIKEN data assimilation group to conduct the runs of the 1000-member ensemble simulation
- The local contact person is Takemasa Miyoshi
- Takemasa just wrote that he can apply for full travel support for visitors, but the funding is first come first serve, so it would be good to inform him soon …

MSc thesis topic “Atmospheric motion vectors“

Main objective: Evaluating the benefit of lidar-based height correction functions for global NWP forecasts

Motivation: Atmospheric motion vectors derived from the propagation of cloud structure in consecutive satellite images are an essential part of global data assimilation systems as these observations provide unique wind information in otherwise unobserved areas (oceans, large parts of the southern hemisphere). Their height assignment, however, remains a difficult issue as current height assignment procedures introduce both correlated errors and biases that are difficult to deal with in data assimilation systems. In the framework of HErZ, Kathrin Folger at LMU developed a methodology to significantly reduce the wind errors of AMVs through the use of CALIPSO cloud top observations, either through a direct correction of collocated observations or on a statistical (climatological) basis (Weissmann et al. 2013, Folger and Weissmann 2014, Folger and Weissmann 2015). The latter approach has the advantage that all global AMVs from a respective satellite can be corrected and that CALIPSO observations are not required in real-time. Therefore, the second (statistical) approach is seen as a promising approach for future data assimilation systems. In cooperation with DWD, Kathrin conducted first data assimilation experiments with the global ICON model that incorporate the statistical height correction. First results look promising, but given the end of her PhD project in December 2015, the simulations and their evaluation will only provide a preliminary assessment of the potential of the height correction method.

Approach: The project shall first systematically evaluate the benefit of the statistical AMV height correction in the global modelling system ICON based on existing simulations. Based on the results, further ICON experiments shall be conducted using different settings, longer lead times and longer evaluation periods to further improve the height assignment of AMVs and demonstrate the potential of a lidar-based height correction for global NWP systems.

Applied tools:

- AMV height bias correction: See Folger and Weissmann 2015.
- ICON model of DWD: ICON is the new global NWP model of DWD. Simulations with ICON will be supported by Harald Anlauf and Alexander Cress at DWD. The modelling setup will follow the operational system of DWD except a reduced horizontal resolution and the incorporation of the AMV height correction.

MSc thesis topic “Assimilation of cloud observations“

Main objective: Investigate the potential of assimilating structure and displacement information of satellite cloud observations instead of the direct assimilation of satellite images

Motivation: Clouds exhibit the earliest signal of convective systems that can be observed area-wide and cloud observations are therefore heavily used for observation-based nowcasting. Current data assimilation systems however, hardly used cloud information as these observations are difficult to assimilate for a number of reasons. The observations are nevertheless a potentially important data source, particularly for convection-permitting regional NWP models and therefore a hot topic of current research both within HErZ and at other institutes. One major issue for the assimilation of cloud observations is the double-penalty problem, where a small displacement of a convective system can lead to worse results than a completely wrong forecast. This has long been recognized for the validation of forecasts and several feature based scores have been developed in the past (e.g. DAS: Displacement and amplitude, SAL: Structure, amplitude and location). While these score are quite often used for forecast validation, they have not been tested in the context of data assimilation yet.

Approach: The project shall use an idealized setup of the KENDA/COSMO data assimilation system following Lange and Craig (2014) to evaluate the potential of feature-based scores (e.g. DAS, SAL) in convective-scale data assimilation. The idealized model setup will be used to conduct a virtual “truth” simulation, simulate observations from the truth simulations and then assimilate them in KENDA/COSMO. This approach has the advantage that the “truth” is known at all stages in contrast to real simulations. The DAS and SAL scores shall be used for the assimilation instead of the direct differences between observations and model equivalents. For the evaluation of the simulations, particular emphasis will be given to the resolvable scale as feature-based scores are inevitable of lower resolution than the observations. A potential extension of the project would the application of novel evaluation techniques from the visualization/informatics community that is involved in the recently funded project Waves2Weather.

Applied tools:

- Idealized KENDA/COSMO setup: See Lange and Craig 2014.

- SAL: See Wernli et al. 2008
- DAS: See Keil and Craig 2007 and 2009