Summary of working group meeting on transversal DA-EPS-Phys aspects, Thursday 18/4

As introduction, Nils gives a presentation prepared by Jose-Antonio Garcia-Moya on the basis of a paper by Fabry and Sun. This paper addresses the questions: for how long should which data be assimilated for mesoscale forecasting, and why? And what are the consequences of IC errors for data assimilation? What observations are worth to be assimilated? Predictability as a function of scale is a key issue for data assimilation. It makes no sense to fit observations beyond their range of predictability. Also the timescales of propagation of IC errors from one variable to the next should be considered. Fabry and Sun studied these issues with an experimental setup over the Great Plains under summertime conditions; a control run with no perturbations, and perturbations of IC one field at a time. Forecast errors are computed in energy terms. The WRF model was used at 4km grid and with a domain with a size of 1600x1600 km^2. They compared the run with unperturbed fields against runs with perturbed fields (one field at a time). The mid-level humidity and wind and mid- and low-level temperature turned out to be of higher priority to assimilate than e.g. cloud or hydrometeor information. How fast do error signals in one variable propagate to another? After 15m this propagation is still quite small, but after ~3h an even spread over all parameters is seen. The memory of the IC for some variables and for small scales is actually lost before +3h (for the conditions studied by Fabry and Sun). By means of a non-linearity index, they show that e.g. cloud condensates and rain very quickly become unpredictable, using 100km horizontal averaged perturbation. It helps to assimilate observations on larger scales because these are inherently more predictable. For less predictable quantities, care should be taken to assimilate them at the end of the assimilation window, because otherwise their influence is lost too quickly. In similar experiments using the observations, Fabry estimated the strength of the observed parameters' signal.
Jose-Antonio proposes to redo a Fabry&Sun-type experiment for Mediterranean conditions.

After this introduction, Jelena lists a number of aspects to consider in the context of the relations between predictability and DA, ensemble forecasting and physics:

- What processes do we want to resolve?
- How predictable are these processes?
- What is the timescale of developments that we focus on?
- What is the frequency of data assimilation cycling?
- What observations are meaningful to assimilate?
- Model dynamics for evolution, physics for interactions?
- Grid resolution?
- Uncertainty in model description; use DA to assess this?
- Tools to extract information on uncertainty?

She then formulates some questions which she believes we should study and try to find answers to:
Is a lower-resolution ensemble able to provide information relevant to the interpretation of a high-resolution model? Or should an ensemble be run on deterministic scales? Should deterministic thinking be abandoned or do we need a high-resolution deterministic model?

This is followed by a general discussion:
Teresa: When running EPS, do we intend to produce a forecast of high reliability (e.g. perfect ensemble mean) or to get the definition of uncertainty right? Of course, both are important! But for our experiments we will have to decide which criterion will be the

leading on to define a successful experiment or to rank a number of experiment results. Therefore this is a question of validation.

Jan: The basic aim of an EPS is to provide an estimate of the inherent predictability of the atmosphere. In our deterministic models we can describe smaller and smaller features, but these are not predictable. An EPS can be used to filter out these features.

Åke: The ensemble is the future system, and this future system combines EPS with DA in a synergetic system, that is the marriage of DA and EPS.

Jelena: Predictability limits depends on phenomena.

Jan: We need to focus on those phenomena we would like to forecast well, this should give us guidance on what we wish to assimilate and how often.
In this context he recalls radar data assimilation experiments, which suggest that also the way **how** data is being assimilated requires attention.

Nils: Hesitating in what Jan is saying. As the available observations are limited in spatial resolution, the initial model state can also only describe the relatively larger scales.

Jeanette: Wonders whether the more observations we use the better we may be able to drive the model. Do observations themselves impose balance if you have enough of them? Or can one get out of balance by frequent assimilation of certain variables? Some observations have more "dynamical" constraints "built into them" than others. This is reflected in Fabry and Sun's arguments to prioritize assimilation of humidity, temperature and wind over e.g. cloud and hydrometeor information.

Gergely: The above priority of variables for assimilation implies that we do not still necessarily need to incorporate balances of hydrometeors and cloud particles with other variables to the background error constraint. With a flow dependent update (e.g the hybrid method) of the presently used balances (between humidity, temperature and wind, which are the more predictable variables) we might do well.

Jean-Francois: radar have a high temporal frequency, and the joint assimilation of Doppler winds and reflectivity in precipitating areas allows to provide a consistent dynamical environmnent in areas where the analysis add or remove moisture. Hydrometeors have a fast adjusment time scale (less than an hour). Therefore, in terms of priority for the prediction skill of meteorological phenomena (such as severe precipitation events few hours in advance) it is more useful to initialize accurately the dynamics and the humidity than the hydrometeors.

About the question on having low-resolution EPS and high-resolution deterministic model.

Jean-Francois: The density of the observation network does not require to go for higher-resolution model.

Nils: The B matrix will kill every signal below 10 km.

About the phenomena we would like to study, and the models we would like to use.

Nils, Lisa, Radmila:One needs to use models
with "converging" behavior of the physics across the range of scales. This way an ensemble with coarser horizontal resolution than the deterministic model grid could be explored as an option for representation of the model uncertainty associated with model physics.

It was further stressed to use an ensemble with the same (2.5 km) horizontal resolution as the deterministic model as a reference, in order to conclude, in the cleanest way possible, whether a coarser resolution ensemble can yield a satisfactory representation of the model error (uncertainty)

Theresa: Another issue is the availability of references for the intended experiments. Can the observations/analyses/reference forecasts resolve the predicted phenomena? We should probably keep that in mind when choosing a test case.

Phenomena of interest: polar lows and severe summertime convection;
Experiment design:

Ensemble system: 10, 5, and 2.5 km horizontal resolutions;
Mesoscale deterministic model: 2.5km resolution;
DA: 3D-, or 4D-VAR and later (for the ultimate test) in the hybrid configurations;
Physics: ALARO;

Gergely:Beside the above ensemble data assimilation experiments also predictability and sensitivity runs are necessary using the model we want to focus on (AROME or ALARO). This is because the findings of Fabry and Sun on predictability of different variables do not necessarily stand for our models (or the real atmosphere) but are specific to WRF at 4 km resolution

Jan:At the moment we have no clear picture of how predictability properties will change when moving to the km scale.

Jeanette: After this meeting we will need to discuss more details about these experiments like for example surface DA, etc …. And also how the validation and verification of the experiments will be done.

Åke: The size of the domain is an issue that has to be addressed in a mor explicit way and has to be a part of the whole endeavour.

Nils: Do we support Jose-Antonio's proposal to perform Fabry&Sun-type experiment for Mediterranean conditions?

The idea is supported by most of the participants.
Roger: We can use the moist total energy norm (MTEN) tool in this study.

Agreed actions:

The group agrees to try to obtain answers to Jelena's questions by means of a sensitivity study. To study whether a high-resolution ensemble is able to add more reliable forecast information to a deterministic model than coarser ones, it is decided to run the deterministic model at 2.5km resolution and an ensemble over 2.5, 5 and 10km resolution (the 5 and 10km ensembles on correspondingly larger domains than the 2.5km runs). This will be done for a small number of phenomena which we aim to be able to forecast well: e.g. summertime severe organized convection (super-cells?) in the Mediterranean, and wintertime polar lows for high latitudes. It is stressed that it is important to use the same physics on all scales. If explicit deep convection is used at 5 and 10km scales, then there is a risk of missing convective transport in the model. Therefore it is proposed to use ALARO as model. For data assimilation, an ensemble setup with 3D-VAR and/or 4D-VAR should be used. It is important to select test periods in which the phenomena to be described occur clearly and for which many and good observations are available. The experiments should address also the issue of which variables should be used in the initialization process or not and which should be given the greatest weight.

There is no time to discuss the experimental setup more deeply, but clearly there are still many details to be settled concerning e.g. the specification of the surface and surface analysis in the model and ensemble, the observations to be used in assimilation and verification, the test periods, and resource constraints. It will also be relevant to discuss beforehand which diagnostics to use: how to analyse the answers which can be derived from the experiments? It is agreed that after the notes of the meeting have been sent around by Roger and Jeanette, a group (relevant HIRLAM/LACE project leaders and ALADIN CSSI members for ensemble forecasting, data assimilation and physics) works out a draft experimental setup asap, to be distributed for wider discussion and comments.