Case-study based evaluation of stochastic physics effects in the high-resolution ensemble COSMO-E

Christina KLASA[1,2], Heini WERNLI[1], André WALSER[2], and Marco ARPAGAUS[2]
[1] Institute for Atmospheric and Climate Science, ETH Zurich, [2] MeteoSwiss, Zurich

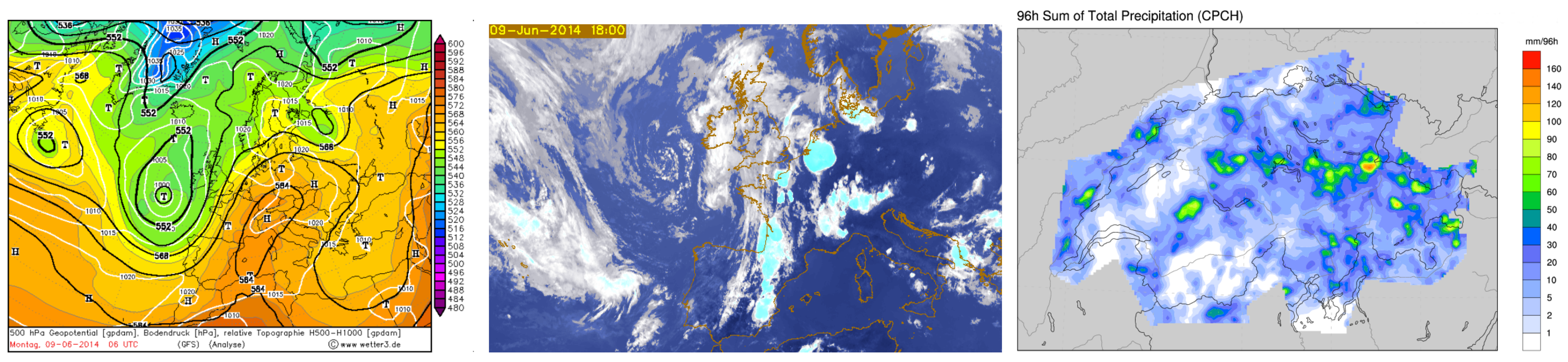
Background

MeteoSwiss (MCH) will soon be operating an ensemble version of the COSMO model, COSMO-E. COSMO-E is a 21-member limited-area ensemble prediction system with a convection-permitting mesh-size of 2.2 km and covers the Alpine area. The ensemble mode accounts for uncertainty in the initial conditions, lateral boundary conditions are perturbed, as well, and the Stochastically Perturbed Parameterization Tendencies (SPPT) scheme accounts for uncertainties related to the model physics. Assessment of the model performance showed underdispersiveness mostly at lower levels, which is worse for humidity than for temperature and especially strong during wintertime. We work on a case-study basis to find approaches improving the spread-skill relation of our model.

Model

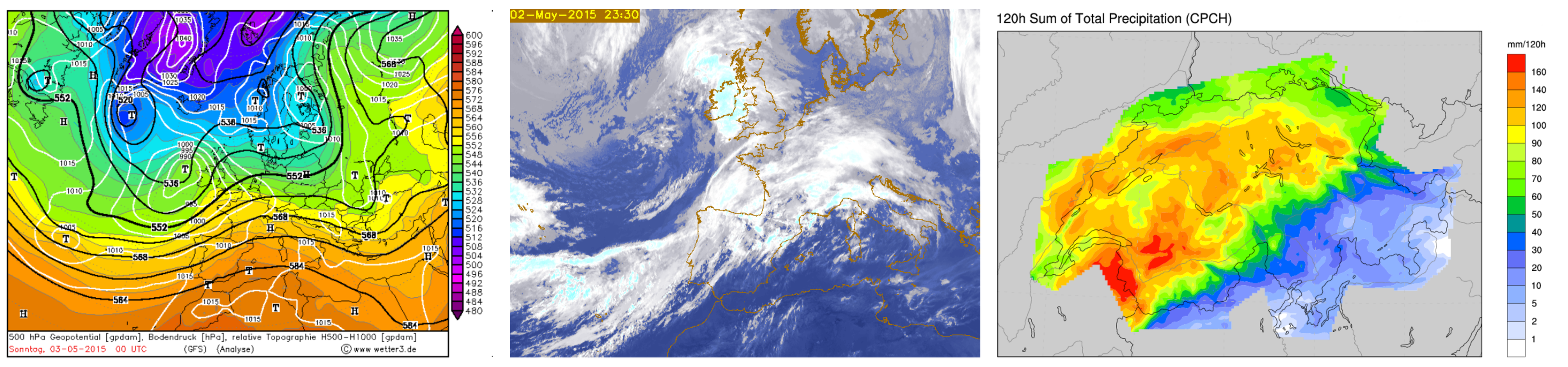
Initial condition and lateral boundary condition perturbations are used from the first 21 members of the IFS ensemble. The SPPT experiments use a spatial correlation of 5° and a temporal correlation of 6 h for the random number patterns. The random numbers stem from a Gaussian distribution with a mean of zero and a standard deviation of unity. The range is 0.9. In addition, a *test setup* of initial soil moisture perturbations is used with the same random number characteristics, but a spatial correlation of 2°. Perturbations are applied to the soil moisture index. Since sensitivity is to be tested, the perturbations are quite strong.

Case 2014-06-09: Synoptic situation



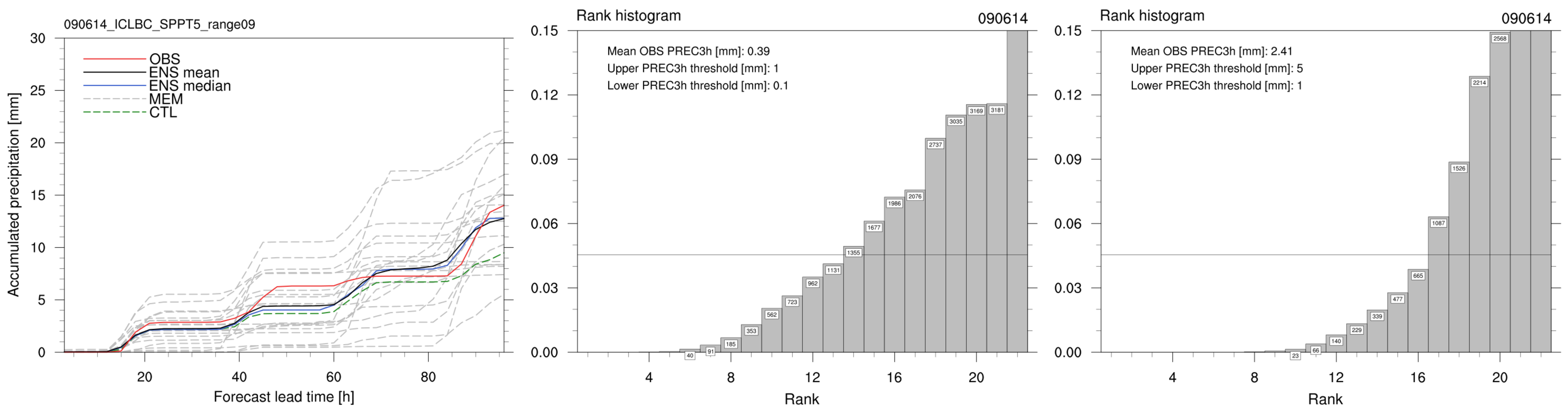
An upper-level ridge is extended over central Europe. The weak large-scale forcing leads to convective precipitation. GFS analysis (wetter3; 06 UTC 09 June 2014), satellite (MCH; 18 UTC 09 June 2014), observations (MCH; 00 UTC 09 June 2014 + 4 days).

Case 2015-05-01: Synoptic situation

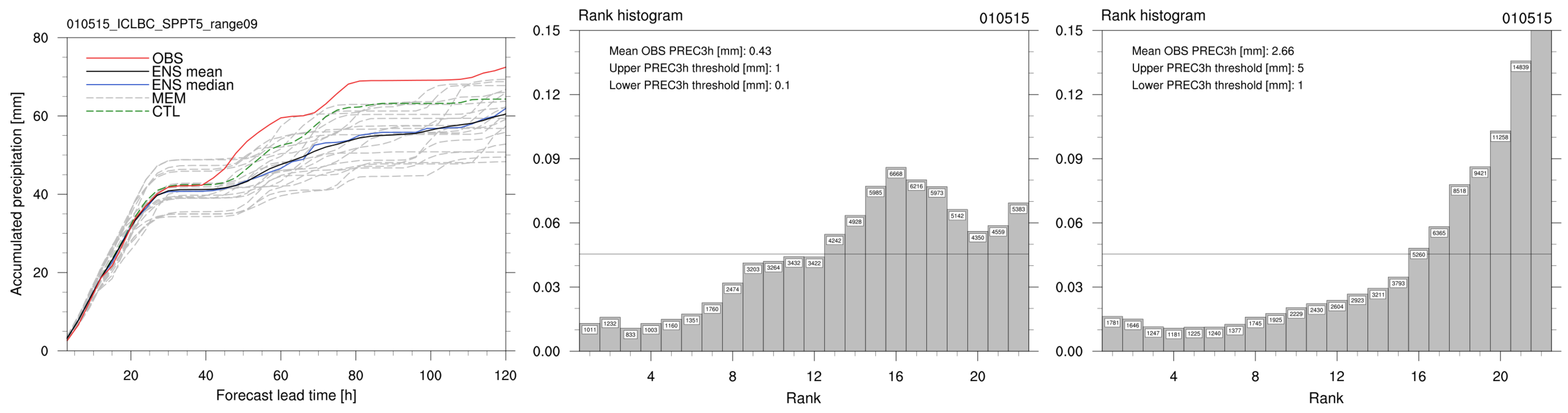


The large-scale advection of moisture by the westerly to south-westerly flow induced by the broadly extended upper-level trough causes heavy precipitation in Switzerland. GFS analysis (wetter3; 00 UTC 03 May 2015), satellite (MCH; 00 UTC 03 May 2015), observations (MCH; 00 UTC 01 May 2015 + 5 days).

Case 2014-06-09: Precipitation

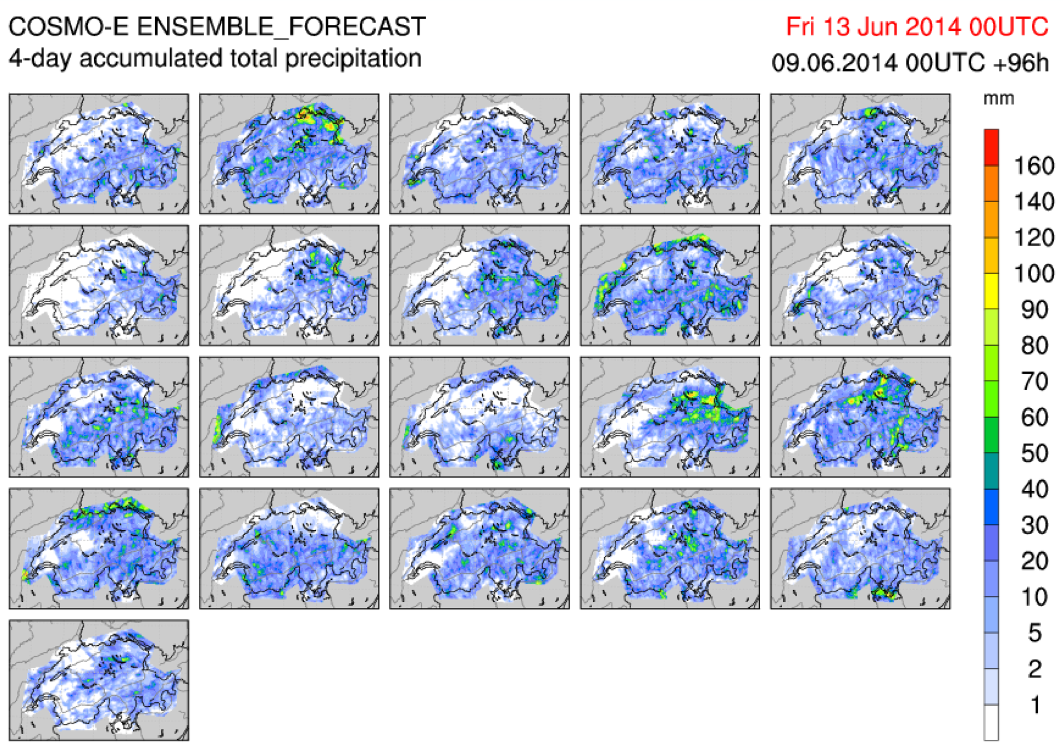


Case 2015-05-01: Precipitation

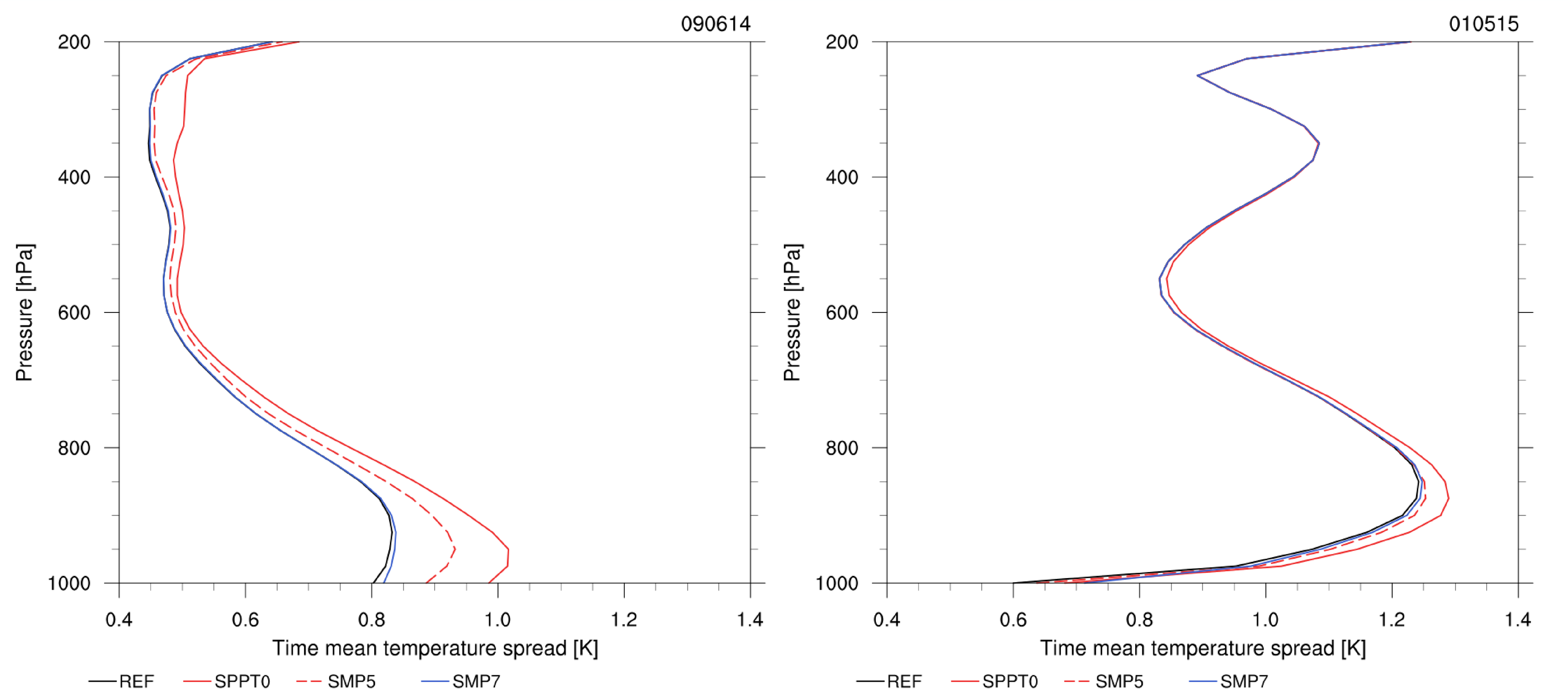


The leftmost plot shows (in both cases) the accumulated precipitation as a function of forecast lead time, averaged over Switzerland. The observations are in red, the ensemble mean (median) in black (blue), and the ensemble members are grey, dashed lines. Both remaining plots show rank histograms of 3 h accumulated precipitation, evaluated on a grid-point basis. The rank histograms are set up for two different ranges of precipitation. The plot in the middle is for values between 0.1 and 1.0 mm/(3 h), the rightmost plot for values between 1.0 and 5.0 mm/(3 h). The horizontal line corresponds to a uniform distribution.

Case 2014-06-09: Stamp map precip



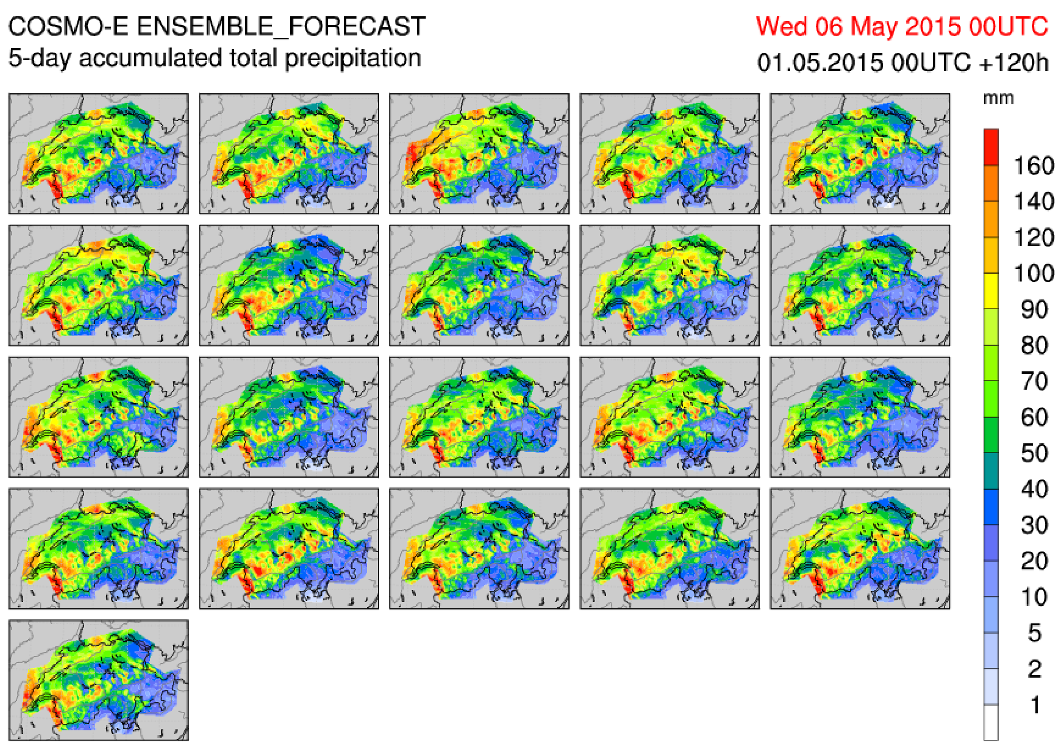
Sensitivity to stochastic perturbations: Temperature T



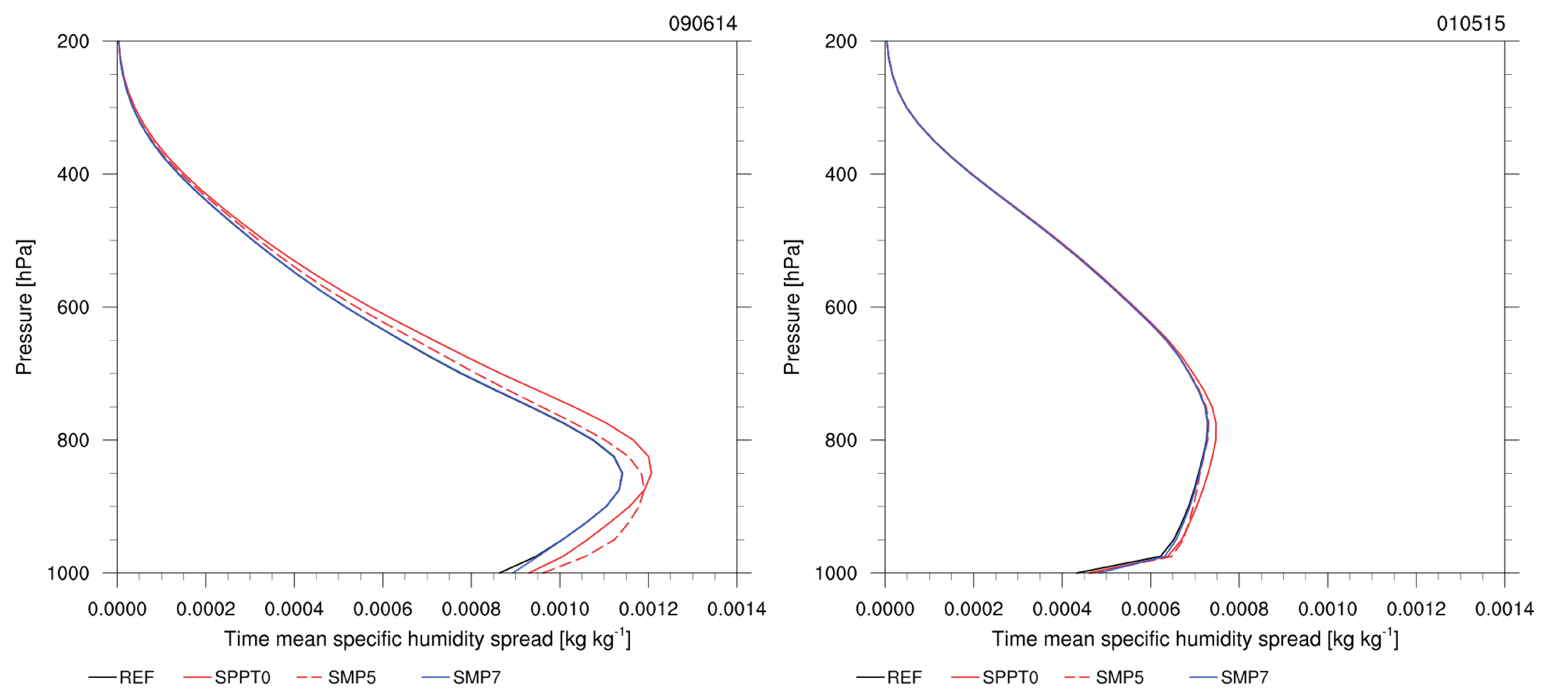
Vertical profiles

- Vertical profiles of ensemble spread
- Temporal mean: average over entire forecast lead time
- Spatial mean: average over entire model domain
- Temperature (T) spread (to the left)
- Specific humidity (QV) spread (below)
- Case 2014-06-09 (left-hand side)
- Case 2015-05-01 (right-hand side)

Case 2015-05-01: Stamp map precip



Sensitivity to stochastic perturbations: Specific humidity QV



Sensitivity experiments (T, QV)

- **REF** In the experiment initial and lateral boundary conditions are perturbed. All following experiments use these types of perturbations.
- **SPPT0** (solid) In the SPPT experiment the model physics are perturbed.
- **SMP5** (dashed) The experiment perturbs the initial fields of soil moisture. It is a test setup and perturbations are quite strong.
- **SMP7** The experiment perturbs the initial fields of soil temperature.

Conclusions

Precipitation

- In the convective case (2014-06-09), the ensemble forecasts the precipitation amount well on an area average. On the grid-point scale, high precipitation amounts are underestimated by the model (see rank histograms).
- The forecast of the large-scale advection case (2015-05-01) underestimates the precipitation amount on area average and on the grid-point scale. The observations are outside of the range of the ensemble.

Sensitivity experiments

- Temperature (T) spread: Spread is largest in SPPT0. The effects of SMP7 are always very tiny.
- Specific humidity (QV) spread: The effects on QV are similar to the effects on T, except for the convective case, where in the lowest levels spread in SMP5 is larger than in SPPT0.
- In the convective case (2014-06-09), the effects of the stochastic perturbations are much stronger than in the large-scale advection case (2015-05-01).

Open questions

- The weak effect of the stochastic perturbations in the 2015-05-01 case is in agreement with the lack of spread in our model especially during wintertime when events forced on the large scale dominate midlatitudinal weather.
- Spread in our ensemble still needs to be increased in the large-scale advection case. We are looking for methods to improve the spread-skill relation of our model especially in such cases.
- How can the error be represented better in limited-area models? Is it possible to improve large-scale advection cases by stochastic physics approaches? Does this improve quantitative precipitation forecasts?

References

Buizza, R., Miller, M. and Palmer, T.N. 1999. Stochastic representation of model uncertainties in the ECMWF Ensemble Prediction System. *Quart. J. Roy. Meteor. Soc.*, **125**, 2887-2908.
Maurer, D., Walser, A. and Arpagaus, M. 2014. First COSMO-E experiments with the Stochastically Perturbed Parametrization Tendencies (SPPT) scheme. *COSMO Newsletter*, **14**, 19-27.

Correspondence: Christina KLASA, Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland. christina.klasa@env.ethz.ch