# SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

| | |
|---|---|
| **Reporting year** | 2013 |
| **Project Title:** | Upscale transport of uncertainty |
| **Computer Project Account:** | SP DEADEN |
| **Principal Investigator(s):** | Prof. George Craig |
| **Affiliation:** | Meteorologisches Institut<br>Ludwig-Maximilians-Universität<br>Theresienstraße 37<br>80333 München |
| **Name of ECMWF scientist(s) collaborating to the project** (if applicable) | |
| **Start date of the project:** | 2011 |
| **Expected end date:** | 2016 |

## Computer resources allocated/used for the current year and the previous one

Please answer for all project resources

| | | Previous year | | Current year | |
|---|---|---|---|---|---|
| | | Allocated | Used | Allocated | Used |
| **High Performance Computing Facility** | (units) | 300K | 290K | 400K | 0K |
| **Data storage capacity** | (Gbytes) | 500G | 500G | 2T | 500G |

## Summary of project objectives

Although several studies have identified latent heat release as a main source of rapid small-scale error growth, it is still less clear how fast these errors move upscale and under which conditions they make a significant contribution to the inherent meso- and large-scale uncertainty from imperfect initial conditions. In addition, latent heat release itself can occur on very different time- and spatial scales and by very different physical processes, ranging from a bunch of isolated convective cells over mesoscale convective systems up to large-scale regions of synoptically forced ascent. To investigate their roles and mechanisms in limiting predictability is the basic objective of our Special Project “Upscale transport of uncertainty”.

## Summary of problems encountered

The COSMO model appeared to have a memory leakage when running on the ECMWF computer which seems to be related to output writing. The problem was also discussed with DWD staff but could not be fixed yet. This caused a few “MEMKILL” events and the need to prepare restart files to continue the simulation as a new job afterward.

## Summary of results of the current year

After having performed and analyzed error growth experiments of a highly convective summertime weather event during the last years a simulation of a more stable weather event was carried out. The latent heat release in that case is not mainly caused by convective instability but initiated by synoptically forced large-scale upward motion. Such weather systems are also known as Warm conveyor belts (WCBs, see e.g. Browning, 1986). Originating from the boundary layer of the warm sector they undergo slant-wise, cross-isentropic ascent ahead of the surface cold front. This motion is driven by the latent heat released by microphysical processes, especially condensation and ice phase processes (Joos and Wernli 2012). WCBs have a significant direct impact being responsible for most of the precipitation associated with extra-tropical cyclones (Wernli and Davies 1997). Furthermore, they are also able to impact downstream development and cyclogenesis by modifying the upper-level potential vorticity (Pomroy and Thorpe 2000).

We chose the IOP2-case of the last T-NAWDEX field campaign (13 October 2012) which showed a WCB with strong vertical ascent and latent heat release over central Europe originating from the Mediterranean Sea. The associated cyclone was of medium strength with minimum surface pressure of about 1000hPa located over the British Isles. It developed a distinct cold front over central Europe together with a band of precipitation. Independent from this low-pressure system several local convective cells developed during the day over Italy and the Adriatic See. The COSMO model was used in a 2.8km grid-resolution without parametrization of deep convection and a domain size of about 8,000 times 5,000 km to simulate these events.

As conveyor belts are Lagrangian features, trajectories have been the favored analyzing tool: The position of air parcels is followed as it is advected, and certain tracers are observed along the trajectory path. So far, however, studies of WCBs have mainly been performed based on coarse-grid simulations or reanalysis data that use a parametrization scheme for convection and the trajectory information was interpolated based on model output. Data from such simulations is not able to resolve potentially embedded convective processes. For this reason a new online trajectory module was implemented into the COSMO model by Miltenberger et al. (2013), which is able to follow the trajectory positions and tracer values at each time step during the model run. This allows for reasonably using the Lagrangian concept in a convection permitting resolution. With permission of ETH we included the online trajectory tool in our simulation.

So far, we performed some basic statistics on the ascent characteristics of the parcels. Out of the 149,000 computed trajectories 17,550 fulfilled the WCB criterion (ascended more than 600hPa in a 48h time period). Figure 1 (Histogram) shows the distribution of the time needed for the 600hPa ascent of preselected trajectories. Noticeable are the two peaks, one at <1h ascent time and the second one at roughly 1d ascent time. The later is in agreement with typical ascent times for WCBs, while the large number of very quickly ascending trajectories is likely to be a consequence of local convective cells.

According to this frequency distribution the trajectories where separated into two groups around the minimum between the two peaks (~12h ascent time). The fast group is classified as "convective", the slow group as "non-convective". Figures 2 and 3 (XY-Plots) show the trajectory paths for each of the two cases. Interestingly, two branches can be identified in the diagrams. One slowly ascending branch over Germany, where the ascent spans a distance of >1000km (see figure 2), and one branch, where ascent happens almost instantaneously in the convective cells over the Mediterranean Sea (see figure 3). The first shows a typical path for a WCB, rising slantwise along a developing cyclone. These trajectories split into two separate coherent packs in the outflow region over Scandinavia. One is turning anticyclonically towards the East with the background flow, the other is turning cyclonically around the cyclone center.

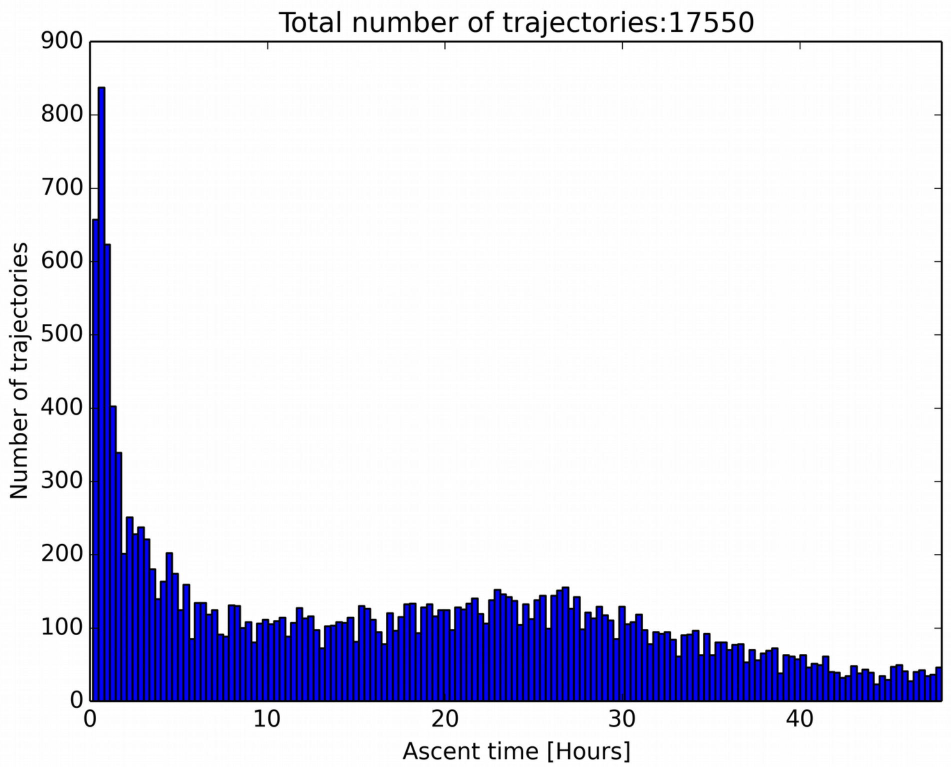


Figure 1:
Histogram of trajectory ascent time to climb 600 hPa.

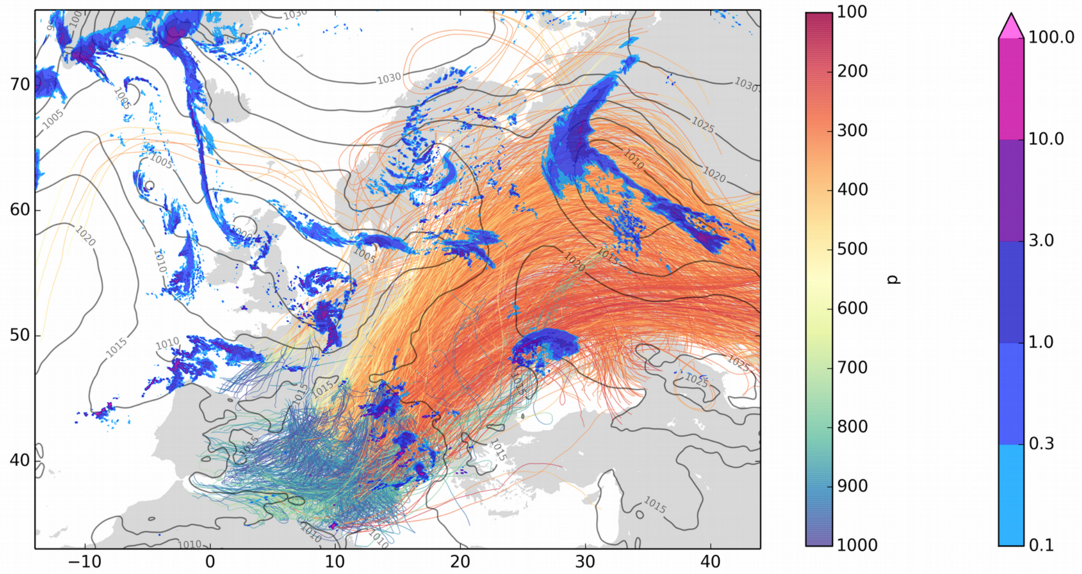


Figure 2:
Paths of all “convective trajectories”. The height of the trajectories in hPa is indicated by color. Blueish shaded areas indicate the precipitation rate in mm/h.

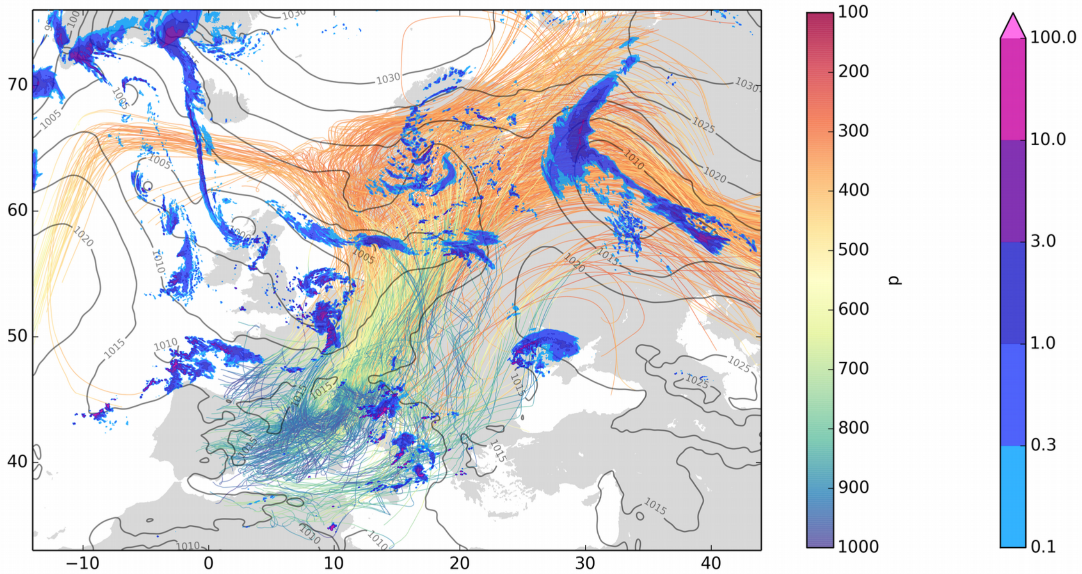


Figure 3:
Als Figure 2, but for all “non-convective trajectories”.

## References

Browning, K.A., 1986. Conceptual models of precipitation systems. Weather Forecasting 1: 23–41.

Joos H. and Wernli H., 2012: Influence of microphysical processes on the potential vorticity development in a warm conveyor belt: a case-study with the limited-area model COSMO. Q. J. R. Meteorol. Soc. 138: 407–418. DOI:10.1002/qj.934

Miltenberger, A., Pfahl, S and Wernli, H, 2013: An online trajectory module (version 1.0) for the nonhydrostatic numerical weather prediction model COSMO. Geoscientific Model Development 6, 1989-2004.

Pomroy, H. R., and A. J. Thorpe, 2000: The evolution and dynamical role of reduced upper-tropospheric potential vorticity in intensive observing period one of FASTEX. Mon. Wea. Rev., 128, 1817–1834.

Wernli, H., and H. C. Davies, 1997: A Lagrangian-based analysis of extratropical cyclones. I: The method and some applications

## List of publications/reports from the project with complete references

Groenemeijer, P.; Craig, G. C., 2011: Ensemble forecasting with a stochastic convective parametrization based on equilibrium statistics, Atmos. Chem. Phys., 12, 4555-4565, 2012

Selz and Craig, 2014: Upscale error growth in a high-resolution simulation of a summertime weather event over Europe. Monthly Weather Review, submitted.

## Summary of plans for the continuation of the project

It is planned to simulate further WCB events with the online trajectory module and compare their ascent statistics. These diagnostics will then be used to assess how convective or stable stratified a certain WCB is. After that the most different cases will be selected to perform further error growth experiments to address the question how important spatial and temporal properties of latent heat release are for predictability and error propagation.

In addition it is planned to carry out some COSMO-simulations of upscale error growth from convection in a highly idealized setup as extension to Selz and Craig, 2014. The main goal here is to confirm the proposed relation on f by varying the earth rotation rate in the simulation.