SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2020
Project Title:	Upscale impact of diabatic processes from convective to near-hemispheric scale
Computer Project Account:	spdecrai
Principal Investigator(s):	George Craig
Affiliation:	Meteorologisches Institut Ludwig-Maximilians-Universität München Theresienstr. 37 80333 München Germany
Name of ECMWF scientist(s) collaborating to the project (if applicable)	None
Start date of the project:	2019
Expected end date:	2021

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

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	5M	3.5M	5M	3.7k
Data storage capacity	(Gbytes)	0	0	0	0

Summary of project objectives (10 lines max)

The main goal of this project is to investigate the role convection and its (deficient) representation in numerical models play in reducing and limiting predictability of the atmospheric flow. Although these errors usually originate at the smallest scales resolved by the model, they grow upscale and eventually contaminate even planetary modes. There are two types of error sources on small scales related to convection: Fast decorrelation of clouds due to physical processes and unphysical errors due to the models incomplete representation of the convection. While the former intrinsically limits the predictability, the latter type provides room for improvement. In the course of this and past special projects we aim to consider both error sources and try to assess their impact and relevance.

Summary of problems encountered (10 lines max)

None

Summary of plans for the continuation of the project (10 lines max)

We intend to use this years computing resources mainly for a series of global simulations with ICON of varying resolution, up to convection-permittng (ca. 2.5km). These simulations will be analysed in a special way using global space-time spectra to diagnose the models representation of atmospheric processes on a variety of spacial and temporal scales (see below). Our focus will be on those scales that are close to the resolution of the simulation, since they are most prone to errors. In addition to comparing different resolutions of the same model (ICON) a comparison to the IFS model is also planned in collaboration with Dr. Christian Kühnlein from ECMWF. Furthermore, these diagnostics may be useful in our theoretical understanding of the atmosphere and its scale interactions

List of publications/reports from the project with complete references

None yet.

Summary of results

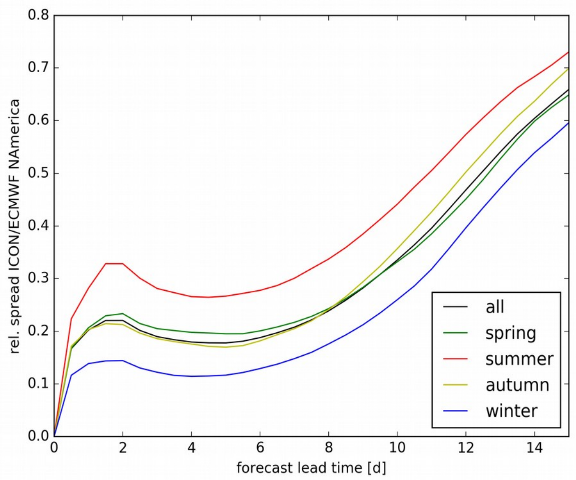
a) Latent heat perturbations over North America

The computing resources of 2019 have mainly been used to further explore the role of convection and the associated latent heat release in numerical weather prediction. Past studies (e.g. Rodwell et al., 2013) suggested a degrading influence of convection over the North American continent on forecast quality over Europe. This hypothesis has been explored using the ICON global model together with perturbations of latent heat over North America.

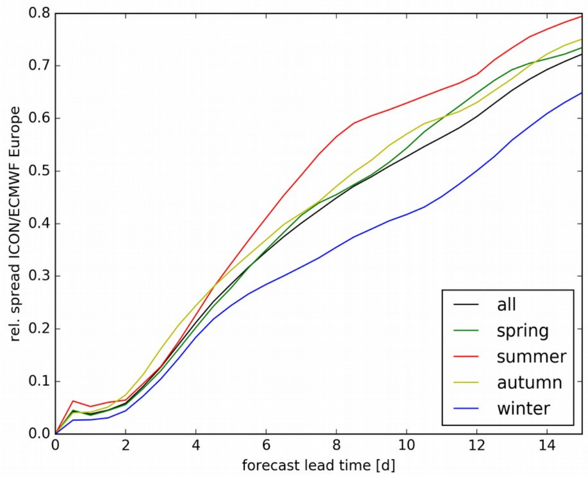
To do so, the ICON model has been used to simulate one year (2016) of 15 day forecasts, starting from 0 UT at every day of the year. In addition to an unperturbed run, latent heat perturbations over the North American continent have been applied early on in the forecast (the first 48h of simulation time). One run with 75% of the normal latent heat and one run with 125% of the normal latent heat has been computed. Thus there is for each day in 2016 a small, three member ICON ensemble that accounts for potential uncertainties in the latent heating over North America.

We first measured the impact of the latent heat perturbation over North America on the forecast in terms of the spread, that they generated. Therefore we computed the standard deviation of Z500 of the 3-member ICON ensemble over North America and Europe as a function of forecast lead time. To better assess the magnitude of this spread we divided it by the standard deviation of the ECMWF ensemble forecasts at equal location and forecast lead time. The figures below show the results, which are also separated by season.

a) North America



b) Europe

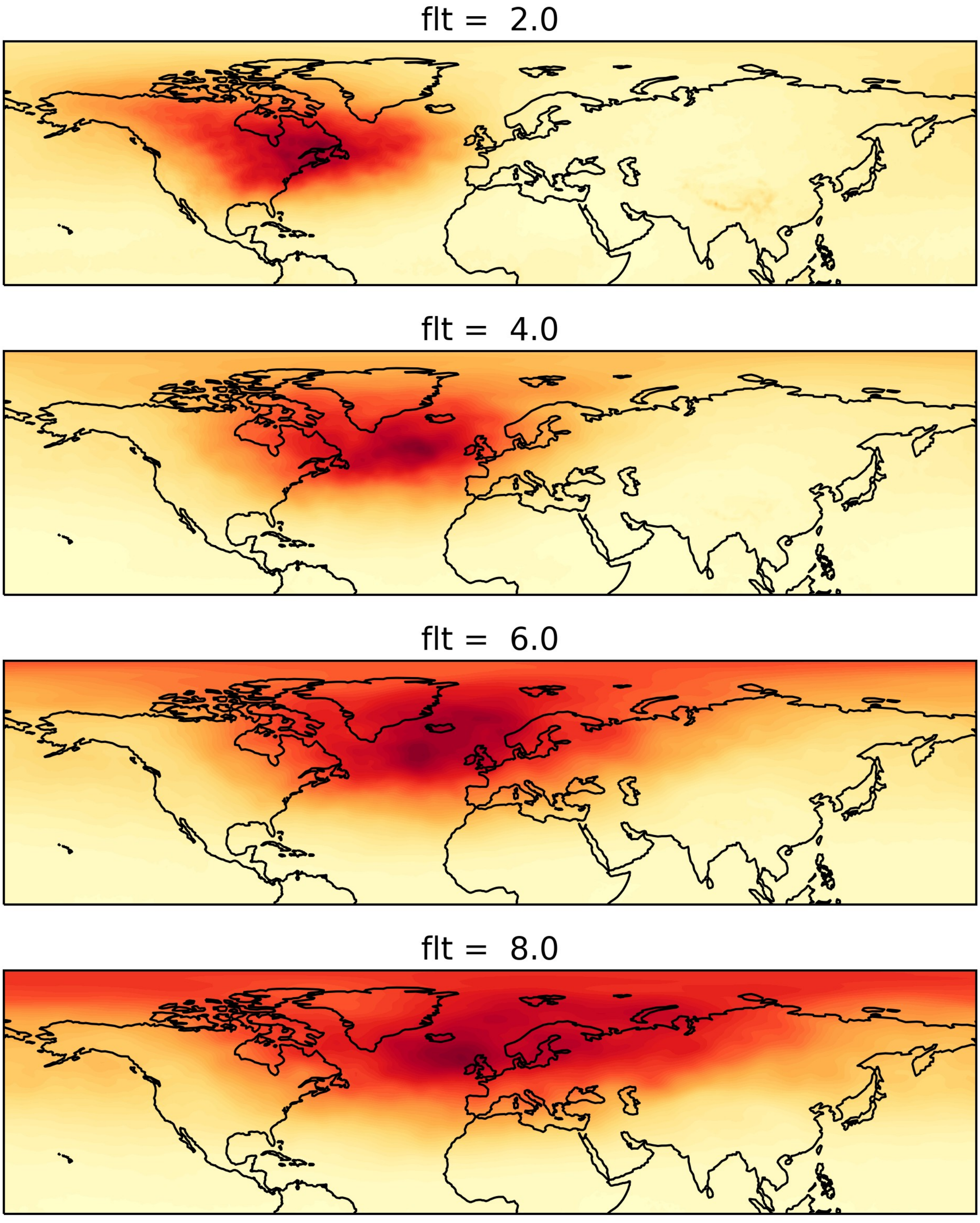


In the North America plot the impact of the perturbations is directly visible. They are active for 48 hours and till then the spread is continuously increasing relative to the spread of the ECMWF ensemble from zero initially to about 30% in summer and only about 10% in winter. This seasonal dependence is expected and reflects the much more intense convection over land at summertime. After the first 48 hours the spread decreases for about 4 days (relative to ECMWF) until it increases again and reaches values close to 70% at 15 days forecast lead time.

Over Europe, the spread starts to significantly increase after 2-3 days of forecast lead time. It is initially quite insensitive to the magnitude of the initial perturbation over North America and shows little seasonal dependence. After 5 days into the forecast this seasonal dependence starts to show and further increases untill 8-10 days of forecast lead time. About 5 days is also the expected time for a perturbation to cross the Northern Atlantic. At 8 days into the forecast the spread over Europe reaches about 60% of the spread of the ECMWF ensemble in summer, compared to only about 30%

in winter. These results suggest a significant impact of latent heat release and convection over the Northern American continent for the forecast over Europe.

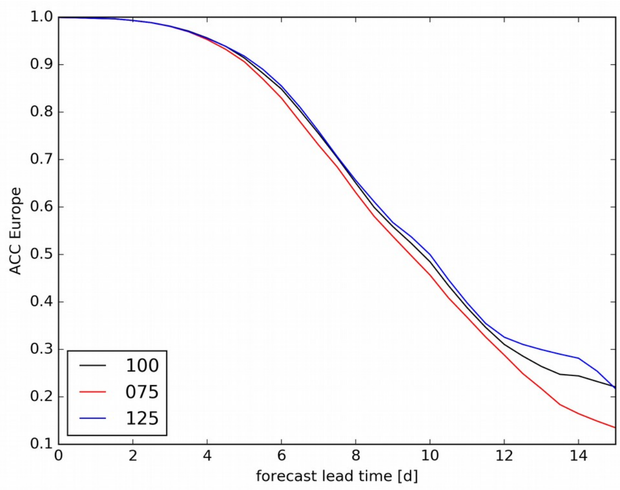
To spatially track the evolution of the perturbations we plotted the spread of the 3-member ICON ensemble for each gridpoint and averaged it over the year. The result is shown below for several forecast lead times, the magnitude is normalized within each picture.



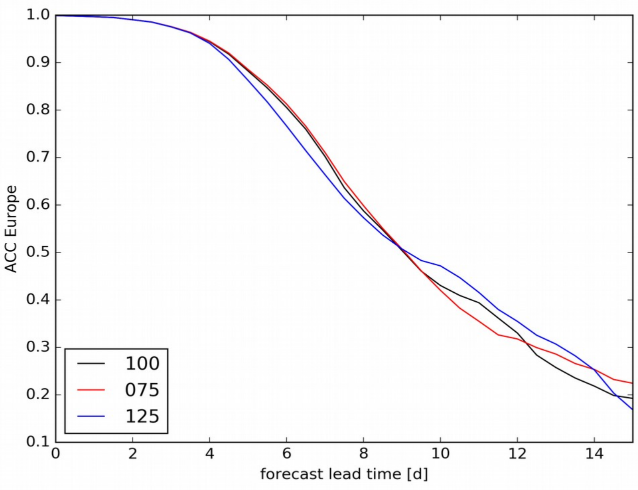
The average eastward propagation of the disturbances is clearly visible and reaches a velocity of about 10 m/s. Interestingly, the peak of the influence of the latent heat perturbation seems to lock into place after about 4 days over the Central to Eastern North Atlantic. Thus this region appears to be more affected on average by the North American convection than Europe. Even further to the east, the signal fades away and at 8 days there is still no significant impact over East Asia or the Pacific Ocean.

After looking into the development of the magnitude of the perturbations we were interested in the question of how the forecast quality over Europe is influenced. To this end we computed the anomaly correlation coefficient (ACC) over Europe for each of the three ICON ensemble members for each forecast lead time and each day of the year. The figures below show the results averaged over the four seasons.

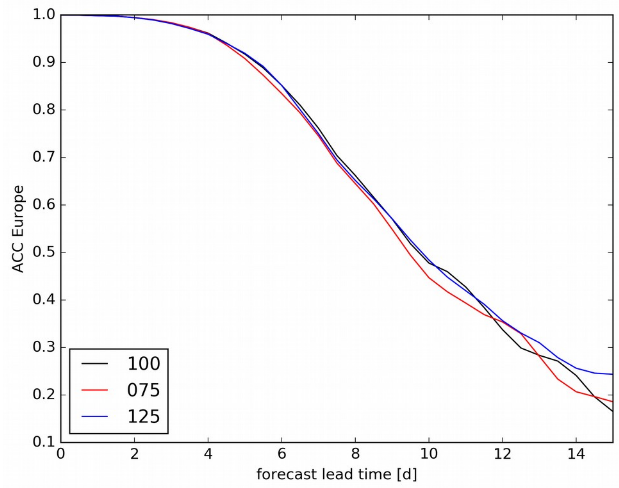
a) spring



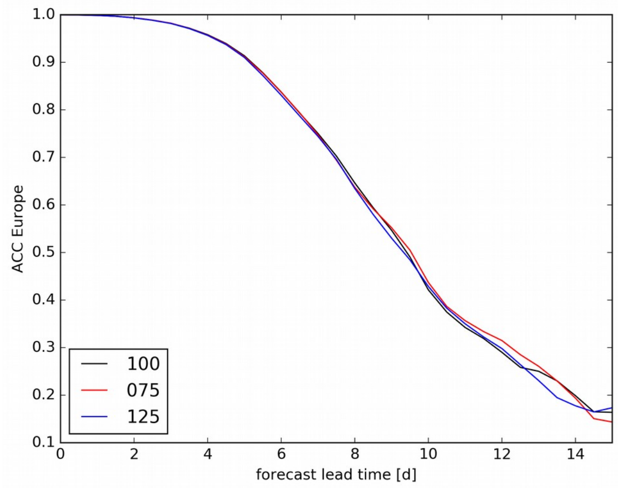
b) summer



c) autumn

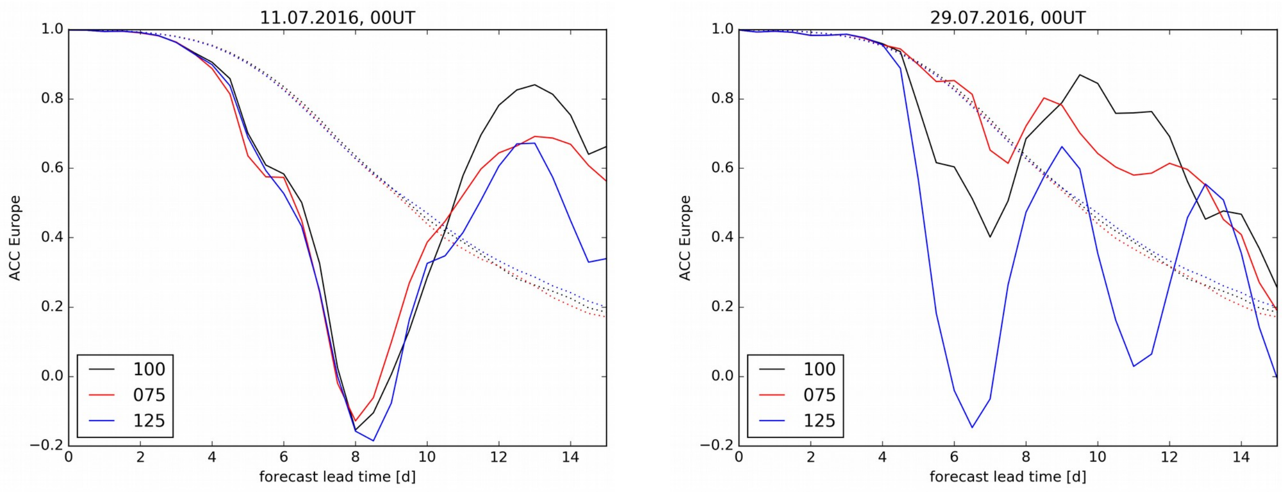


d) winter



The figures again show the already observed seasonal dependence, but the impact of the latent heat modification on forecast quality over Europe on average seems small for all seasons. Neither the reduction nor the increase of the latent heating consistently leads to a better or worse forecast. For a well calibrated model, one would expect that both, reduction and increase, on average worsen the forecast, but this also does not seem to be the case. These impact of the perturbations thus seems random on average.

Individually, the impact of the latent heat perturbations can be much larger. As suggested by the Rodwell, 2013-study, convection over the US and its deficient representation in the model could lead to particularly bad forecasts over Europe about 6 days later. In our yearlong times eries we see examples in favour as well as in contrast to this hypothesis, as illustrated by the following two example figures.



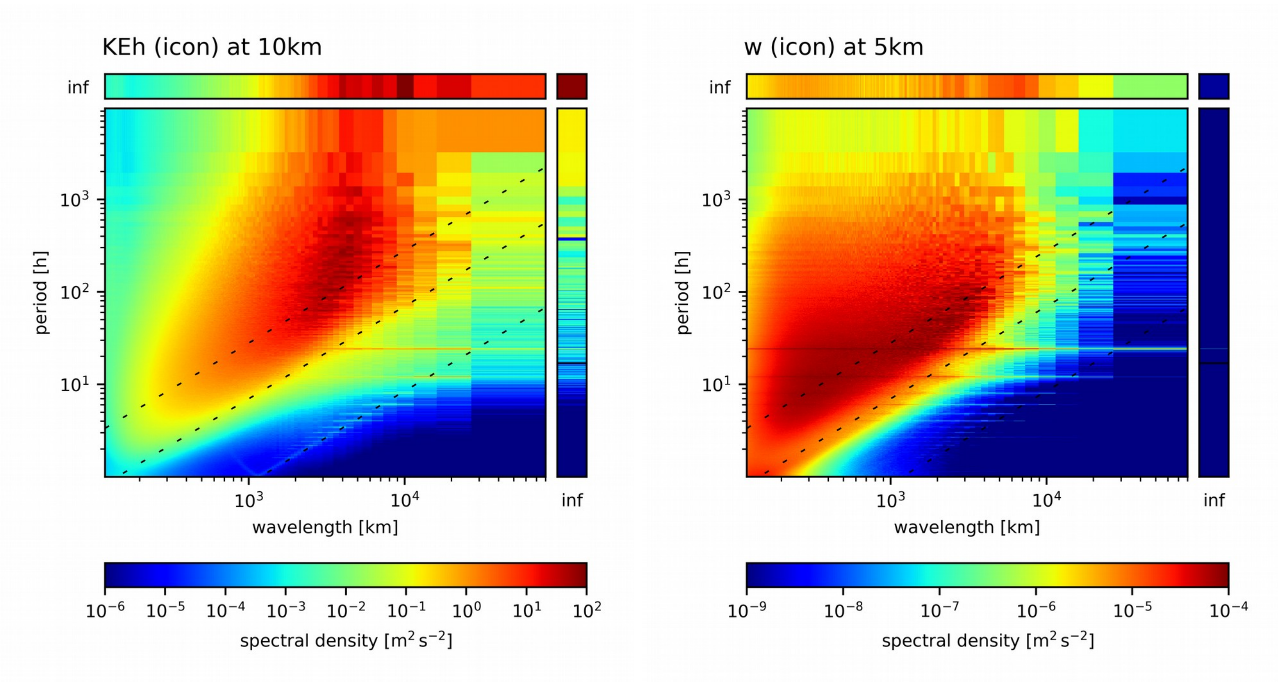
The figure on the left-hand side shows the ACC of the forecasts started on 11th of July 2016 and shows a clear dropout in forecast quality at 8 days forecast lead time. This forecast “bust” however does not seem to be connected to the latent heat perturbation and thus to convection over North America at all since the perturbation show only a very little impact. On the other hand for the forecast started on 29th July 2016, the latent heat perturbation show a huge impact on forecast quality, especially at 7 days forecast lead time. While the reduced latent heat run performs more or less like an average forecast, the increased latent heat run generates a very significant forecast bust with an ACC drop into the negative range.

We are still working on a more systematic way to assess the impact of latent heat release and convection over the North American continent for the weather forecast in Europe. As the results so far have shown, the impact is highly dependent on the weather situation. Furthermore, not every forecast bust is the result of sensitivity to North American convection, and not every sensitive situation leads to a bust.

b) Space-time spectra of model simulations

Besides the latent-heat perturbation experiments we performed a couple of ICON simulations at about 40km resolution to develop and test global space-time diagrams as a new diagnostic tool for model evaluation as well as for theoretical research on atmospheric processes and their interactions. The simulations were standard, except for their long simulation time (up to 100 days) and the high frequency output (half an hour). This is however necessary to provide a certain range of temporal scales in addition to the range of spatial scales that are given by the model resolution and the size of the earth.

A spatial spectral analysis globally requires the use of spherical harmonics to quantify structures of a certain wavelength on a spherical geometry. While calculating the spherical harmonics expansion is a routine task in spectral models like the IFS, it is a challenge for models like ICON because of its unstructured Icosahedral grid. For resolutions around 40km the Climate Data Operators (CDO) have provided the transform functionality and space-time spectra of the ICON runs could be computed. The figures below show the horizontal kinetic energy spectrum at 10km height and the vertical wind energy at 5km height.



This analysis will be extended in the future to higher resolutions, possibly down to convection-permitting resolution. A comparison between ICON and IFS is also planned with the help of Christian Kühnlein from ECMWF.