SPECIAL PROJECT PROGRESS REPORT

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

Reporting year	2021
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	1.8M
Data storage capacity	(Gbytes)	0	0	0	0

Summary of project objectives (10 lines max)

The main goal of this project is to study upscale error growth and its role in limiting predictability, especially with respect to convection and its (deficient) representation in numerical models. By applying a stochastic convection scheme we seek to reduce the model error close to the gridscale. This improved model setup enables a more accurate investigation of the transition from current practical to intrinsic predictability and the impact of the convection scheme to those limits, even at a relatively low resolution of 40km. Furthermore, we explore the significance of global space-time spectra as a diagnostic tool for understanding the dynamics of the atmosphere and differences and error in model simulations.

Summary of problems encountered (10 lines max)

None

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

Our work on the transition from practical to intrinsic predictability is currently being written up for publication, but we plan to revisit it with a focus on local forecast bust cases in a new special project. The remaining resources are intended for research on global space-time spectra from different model simulations and configurations.

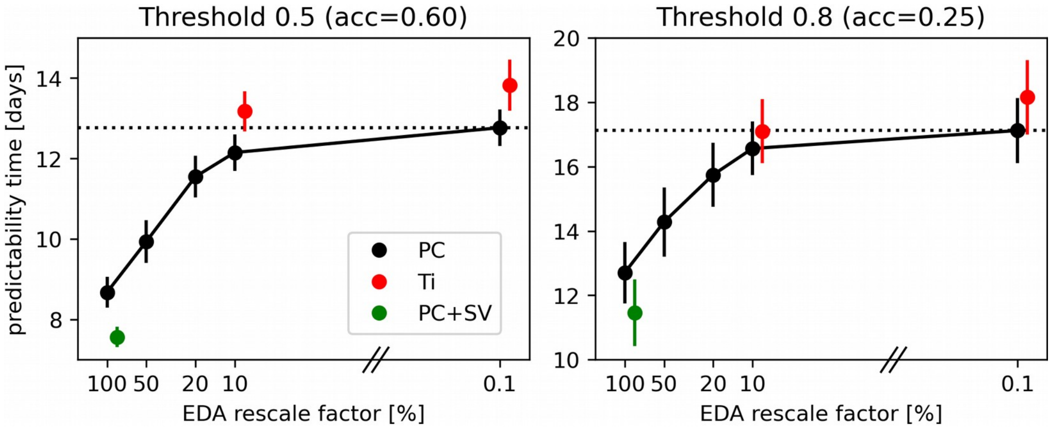
List of publications/reports from the project with complete references

Talk at the DWD ICCARUS meeting, March 2021.

Summary of results

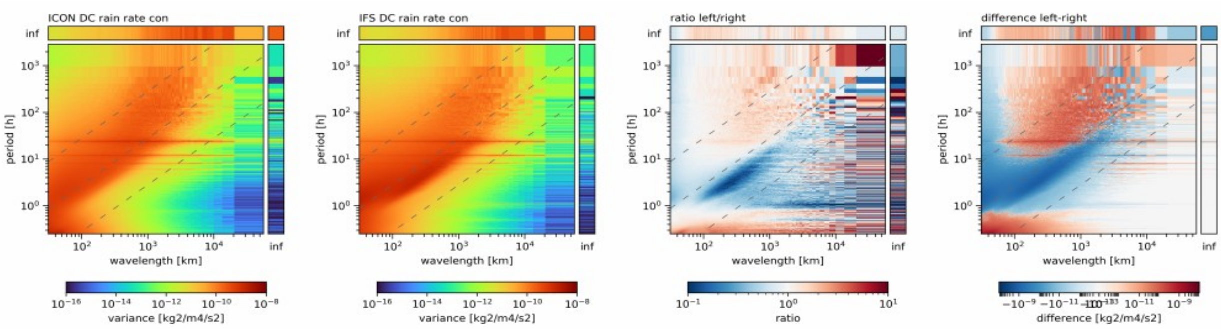
The largest part of our computational resources was spent on experiments investigating predictability limits with ICON model simulations. Therefore, we computed five member ensembles for 12 cases, starting from an initial condition uncertainty sample which was taken from ECMWF's EDA system. In different experiments, the EDA perturbations were multiplied by several factors (100%, 50%, 20%, 10%, 0.1%) to represent potential further improvements in the observation and assimilation system and to demonstrate and quantify the transition to the intrinsic predictability limit. The simulations use the stochastic convection scheme of Plant and Craig (PC) to correct the weak error growth in convective regions typically found in coarse resolution simulations where convection is parameterized.

The figure below shows the change in predictability time with the amplitude of the initial condition error (scaling factor in percent), defined using two different thresholds (0.5 and 0.8 times climatological variance). The 0.1% experiments represent our estimation of the intrinsic limit. From the figure it can be seen that at a 10% value, most of the possible benefits are already achieved and that further reductions in initial condition error would lead to diminished returns. The potential improvement relative to current initial condition errors is 4-5 days of forecast time. The figure also shows control experiments with a standard deterministic convection scheme (Ti), which further documents the slower error growth and the potential overconfidence of such models when the initial condition error is small. In one additional control experiment singular vectors were included in the initial conditions (PC+SV).



These results are based on the difference kinetic energy at tropopause level and are averaged over 12 cases, distributed over one year and over both hemispheres. So far, we have not considered seasonal, temporal or local variations in predictability, which we plan to investigate further in the next special project.

In a second line of work we explore global space-time spectra and their potential as a diagnostic for comparing different models and model configurations. The spectral distribution, especially of energy, has been shown to have a large impact on scale interactions and error growth and thus potentially impacts predictability. ICON runs at 10km resolution with high frequency output have been performed to compute global space-time spectra for several variables. Christian Kühnlein (ECMWF) has provided similar simulations, computed with the IFS model. The figure shows an example of the space-time spectral diagnostic applied to the convection scheme precipitation rate, comparing an ICON and an IFS simulation for January 2020.



The space-time spectra provide a detailed analysis of the temporal and spatial characteristics and difference between the models. In both models the precipitation rate is concentrated in a diagonal band, which indicates advection with a speed of 5-20m/s as the dominant process. However, within this advective band the IFS model shows a higher activity at the lower boundary of the band, i.e. at advection speeds of about 20m/s. Besides the diurnal cycle being clearly visible in the convective precipitation rate, it can be seen that the convection scheme produces increased high frequency variability up to scales up to about 1000km, which is more pronounced in ICON than in IFS. This is likely related to the trigger function of the convection scheme, which may turn convective cells on and off again at consecutive calls. These artificially short-lived cells may contribute to the fact that we saw slower error growth in simulations with parameterized convection, since they may remove instability without a corresponding dynamical impact.

Space-time spectra of several other variables have been investigated, including kinetic energy, available potential energy, vertical wind and divergence. We also performed runs without a deep convection scheme (but still at 10km resolution) for comparison. Investigation of the interpretation and significance of these spectra is ongoing, and we are considering extending the study to include era5 reanalysis data.