TransRegio
Waves to Weather

Project Catalog

Erding, 15.07.13

Concept

Scientific Goal

Elucidate the dynamical and physical interactions that connect the relatively predictable continent-scale weather systems with the local scales where weather impacts society.

The success of weather prediction is built on medium-range (1-10 day) forecasts of synoptic-scale (ca. 1000 km) weather systems. But human impacts happen on smaller scales of kilometres or less. The key challenge for improving predictions of high impact weather is to understand the processes and limits of predictability that arise as small-scale disturbances grow to affect the synoptic-scale waves, and these wave evolve and break, leading local high impact weather events. This is not only a complex nonlinear fluid dynamical process, but involves additional physical processes, most importantly moist physics and interactions with the earth's surface.

Approach

Advancing theoretical understanding through carefully designed numerical experiments – using the new generation of high resolution atmospheric models as a flexible laboratory.

It is now possible to simulate tha atmosphere over the full range of scales from planetary to kilometre scale or finer, and the numerical modeling tools are increasingly widely available. We will take advantage of this infrastructure to design numerical experiments to test theoretical ideas, selecting tools appropriate to the task. This ranges from idealised models that represent particular physical and dynamical processes to ensemble prediction systems that attempt to quantify the full range of behaviours possible in the atmosphere. The approach is complementary to projects that aim to push technological boundaries to produce the best possible simulation with the cost that the experiments are strongly constrained by expense and data management issues.

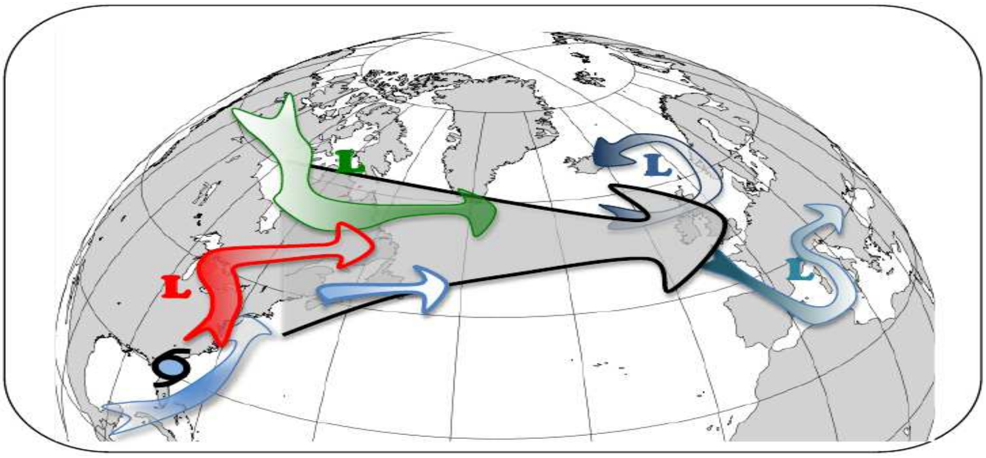
Consortium

Core is atmospheric dynamics community assembled in the DFG Forschergruppe PANDOWAE, with partners from key related fields.

These are likely to include atmospheric physical processes (e.g. clouds, aerosol, orography), information technology (e.g. HPC, visualisation), and theory of similarly complex physical systems (e.g. mathematics, statistical physics, data assimilation, geophysics).

Strategic Partners

- model development: HDCP2, DWD, ECMWF
- field experiment: T-NAWDEX
- international: High Impact Weather initiative of the World Weather Research Programme



Research Areas

The project will be organised around clusters or *Research Areas*. The structure is inspired by the view of mid-latitude weather that has emerged from the international THORPEX programme. A high impact weather event is the result of a chain of events that starts with the excitation of a disturbance on the jet-stream waveguide which evolves and propagates downstream, eventually breaking and producing the local structure that produces human impacts (see schematic above). The three research areas correspond to the key scientific challenges of the origin and development of forecast uncertainty throughout this chain.

A) Error Growth
Errors in weather prediction often originate at small scales, but grow rapidly in space and time through a complex process of nonlinear scale interactions.
Key challenge: How do the effects of rapidly growing small scale processes project coherently onto the large-scale waves?

B) Clouds and Uncertainty
Error growth is not purely a dynamical problem, but is strongly influenced by uncertain physical processes. The most important of these are clouds and moist physics, which are not well known in themselves and strongly influence the dynamics.
Key challenge: How much do cloud processes contribute to forecast uncertainty, both directly and by modifying the evolution of forecast errors?

C) High Impact Weather
High impact weather events result from a range of factors from local conditions or instabilities that occur under the influence of the large-scale atmospheric state to structures such as fronts that are a direct result of downscale interactions.
Key challenge: How much predictability does the large scale provide for weather events in the presence of uncertain small scale processes?

Research Area A:

Error Growth

Diabatic production of low PV in cyclones

Classification

Munich, Research Area A

Principal Investigator(s)

George Craig

Summary and central question

The generation of Potential Vorticity in the upper troposphere is a major process that is able to significantly modify the development of Rossby wave trains and hence the weather development downstream. Upper level PV generation is mainly caused by the release of significant amounts of latent heat in moist and intense cyclones. Its exact amount and distribution however depends on properties and processes of the atmospheric flow that show low predictability or that are not yet completely understood:

- Variability and uncertainty of boundary layer moisture content when transported to the upper troposphere in a warm conveyor belt
- Mesoscale convective systems or embedded convection in large-scale ascent
- Concentration of condensation and freezing nuclei and cloud microphysical processes

Central questions of the project are:

- What do small-scale moist processes in a mid-latitude cyclone contribute to uncertainty in synoptic wave development?
- What properties characterize a high sensitivity to uncertainties in moisture and latent heat release?
- How realistic is the models representation of the interesting features?
- How well do stochastic model components work representing the uncertainty?

State of the art and preliminary work

Recently, a stochastic convection scheme has been developed and implemented into the COSMO and the ICON model. A stochastic boundary layer scheme is currently being developed. Several model experiments have been performed that show the importance of moist processes on error growth.

Research programme

- Identification of synoptic situations that show a high sensitivity to variations in upper level PV production.
- Identification of a series of forecast busts related to upper level PV generation, especially such cases where the actual weather development was not covered in the ensemble.
- Evaluation of field campaign data (T-NAWDEX Falcon and T-NAWDEX Halo) and their comparison to model fields. Identification of relevant strengths and weaknesses of different models.
- Performing (very) high resolution simulations on large domains to directly resolve some of the related processes (Connection to HDCP2). Again comparison to observational data.
- Implementation and development of a suitable combination of stochastic parametrization schemes (convection, boundary layer, microphysics) to represent the relevant uncertainties on coarser model grids, that are used for global or large-scale operational weather forecast.
- Evaluation, how well reforecasts of the forecast bust-cases with the implemented stochastic model components improve the forecasts.
- If successful, the stochastic physic components could be integrated into DWDs or ECMWFs forecast system in the framework of a transfer project. A systematic long-term evaluation could also be performed.

Links to other projects

- T-NAWDEX (LMU)
- Transfer Project - integrate parameterisation in DWD or ECMWF system

Funding

1 Postdoc, 4 years
total: 248 k€

Bearbeiten

Warm conveyor belt dynamics (T-NAWDEX)

Classification

Munich, Research Area A

Principal Investigator(s)

Schäfler, Dörnbrack

Summary and central question

The THORPEX North Atlantic Waveguide and Downstream Impact Experiment (T-NAWDEX) is a field experiment that is planned for 2016 with the new research aircraft HALO. The project was initially proposed by DLR, LMU and ETH Zurich and is planned in cooperation with national partners from the University of Mainz and the KIT Karlsruhe. T-NAWDEX is trying to measure the same nonlinear dynamical and physical processes that are the topic in w2W, i.e. the predictability and dynamics of mid-latitude weather. The new data can be a strong enhancement to the theoretical and modeling work in w2w.

The central hypothesis is that there are systematic errors in model representation of waveguide perturbations in modern NWP models. These systematic errors are attributable to diabatic processes manifested as errors in PV distribution that correspond to errors in the jet stream, which in turn lead to errors in forecasts of high-impact weather downstream. It will be the first field experiment to examine the development of forecast errors on a transatlantic scale over many days to study the physical processes responsible for modification, propagation and downstream impact of Rossby waves.
Key Questions are:

- what are factors modifying wave-guide disturbances?
- how well is the waveguide and the downstream evolution of PV anomalies represented?
- what is the downstream impact of diabatically modified PV anomalies, e.g. on wave breaking and synoptic features

To get an answer to these questions a state of the art instrumentation including a wind lidar and a microwave temperature profiler to observe wind and temperature profiles is implemented. Additionally, in-situ observations of water vapor, cloud microphysical properties and trace gas concentrations of CO and Ozone will be studied with respect to stratospheric to tropospheric exchange processes (see Project Reutter/Spichtinger).

State of the art and preliminary work

Recent preparatory campaigns showed the impact of diabatic processes associated with Warm Conveyor Belts on the waveguide. Within the preparation of the campaign an analysis of existing observational wind data will help to identify shortcomings in NWP and associate the errors to physical processes that are insufficiently represented. A further envisaged model data based analysis is planned to identify regions with increased forecast errors to find strategies for the envisaged flights.

Research programme

- Data analysis of wind and temperature fields to analyse FC errors
- Analysis of Lagrangian flights to study the propagation of wave guide disturbances
- Analysis of combined temperature and wind observations to get an approximate PV estimation

Links to other projects

- Cirrus clouds and Stratosphere-Troposphere-Exchange (Reutter, Spichtinger)
- Diabatic production of low PV in cyclones (Craig/Selz)
- Impact of small- and mesoscale diabatic processes on Rossby wave trains (Riemer/Wirth:)
- Impact of stochastic parameterisations and representation of uncertainty (Kober)

Funding

1 Postdoc, 4 years total: 248 k€

Bearbeiten

Impact of stochastic parameterisations and representation of uncertainty

Classification

Munich, Research Area A

Principal Investigator(s)

Kober, Craig

Summary and central question

Due to limitations in the resolution of numerical models, several physical processes in the atmosphere are subgrid scale and hence their effects on resolved variables have to be parameterised. Stochastic approaches allow to consider not only their mean effects but also their variability. Of particular interest in this project are physical processes contributing to variability in precipitation such as moisture, turbulence, clouds and the precipitation formation itself. The representation of the inherent uncertainty of these processes, their properties, the dependence and the interaction with large scale properties and the interaction of their variability is not known and will be investigated in this project. Central questions of the project will be:

- How can the variability of specific processes contributing to convective uncertainty be formulated?
- How can the respective variability be measured?
- How do several stochastically formulated processes interact?
- How does the introduction of stochasticity influence the forecast? In which weather situations?
- How well does an ensemble based on stochastic physics represent uncertainty?
- When should which sources of uncertainty be considered in the ensemble's design?

State of the art and preliminary work

A fully stochastic convection scheme has been developed and implemented into the COSMO and the ICON model. Additionally, a stochastic boundary layer scheme is under development.

Research programme

- Identification of synoptic situations where forecasts show a high sensitivity to physical formulation of the physics in the model
- Identify physical sources of variability
- Quantify these sources (measurements – TNAWDEX?, LES)
- Implementation of higher order moments in parameterisation
- Investigation of interaction of stochastic formulation of several processes
- Regime-dependent evaluation of resulting ensemble

Links to other projects

- B1 (Craig/Selz, WCB)
- C1 (Dörnbrack/Schäfler, TNAWDEX)
- E3a (Gneiting, Postprocessing)
- E3b (Kober/Keil, Stochastic parameterisations & Postprocessing)
- ?C5 LES, Clouds?
- ?E2?

Funding

1 Postdoc, 4 years total: 248 k€

Bearbeiten

5D Visualisation of ensemble forecast data

Classification

Munich, Research Area A

Principal Investigator(s)

Rüdiger Westermann, Marc Rautenhaus

Summary and central question

Given scalar and vector valued time-varying 3D ensemble data sets, how can we a) measure the stability or robustness of relevant features in such ensembles, and b) how can we effectively and efficiently visualize these features and the associated uncertainty.

State of the art and preliminary work

Ensembles consist of many fields, where every single field, or instance, represents a possible occurrence of the phenomenon represented by the data values. Ensembles are often generated numerically via multiple simulation runs using slightly perturbed input parameter settings. The rationale underlying such a procedure stems from the observation that the result of every single run is affected by a certain degree of uncertainty, for instance, due to model approximations or approximations inherent to the employed numerical schemes. By generating multiple instances one hopes to predict and quantify the range of outcomes that follow from the collection and, thus, to separate those features which remain stable across instances and are not affected strongly by the uncertainty.

One important class of features in scalar fields are level-sets, ie., the set of all points in the underlying domain where the scalar field takes on a prescribed value. In previous work, we have studied the effect of uncertainty on level-sets, by deriving a stochastic model including correlations to predict the probability of intersection events between rays of sight and level-sets in uncertain scalar field. In our previous work, it has been mainly analyzed the positional variations of level-sets due to uncertainty, making it possible to estimate spatial probabilities of occurrence of such structures. Such an analysis, on the other hand, does not allow making reliable estimates of the possible geometric or topological variations of level-sets.

In a different project we have analyzed ways to infer on the effect of uncertainty on differential quantities such as the gradient, which depend on the variability of the rate of change of the data. Analyzing the variability of gradients is more complicated than analyzing the data uncertainty, since, unlike scalars, gradients vary in both strength and direction. This requires initially the mathematical derivation of their respective value ranges, and then the development of effective analysis techniques for these ranges. In our work we have taken a first step into this direction: Based on the stochastic modeling of uncertainty via multivariate random variables, we have first derived uncertainty parameters, such as the mean and the covariance matrix, for gradients in uncertain discrete scalar fields. Here we did not make any assumption about the distribution of the random variables. Then, we have developed a mathematical framework for computing confidence intervals for both the gradient orientation and the strength of the derivative in any prescribed direction, for instance, the mean gradient direction.

In both projects we have developed specific visualization approaches to encode the uncertainty into color, for instance, a color diffusion model to simultaneously visualize the absolute variability of the derivative strength and its magnitude relative to the mean values, a special family of circular glyphs to convey the uncertainty in gradient orientation, a distance-based coloring scheme for SDF surfaces to encode the distance from a mean surface in units of standard deviation. For a number of synthetic and real-world data sets, we have demonstrated the use of our approaches for analyzing the stability of features in uncertain scalar fields.

Lastly, we have developed an interactive GPU-based visualization system for 3D ensemble data sets. This system provides functionality to directly read ECMWF ensemble data sets as model-Level-data, to interactively select horizontal and vertical clipping planes, to visualize contour lines, to directly ray-cast isosurfaces, and to load, filter and visualize trajectories from the LAGRANTO model. From these trajectories, WCB probabilities can be computed and visualized interactively. One can loop through the individual ensemble members or visualize statistical parameters like mean and standard deviation.

Research programme

Building upon our previous work we would like to pursue the following research in the scope of the envisioned SFB:

Interactive visualization techniques for 3D+1 scalar- and vector-valued ensemble data sets

1. Integration of uncertainty-aware Spaghetti plots to reveal distributions characteristics (positional variability) for uncertain trajectories
2. Streaming of large time-varying ensemble data sets
3. Development of methods to control uncertainty propagation in the visualization pipeline (including sensitivity analysis, dimension reduction, visual mapping)
4. Augmentation by labels and annotations
5. Graph-based visualization techniques to provide statistical overviews of the data at different levels of detail, linked to 3D visualization to enable spatial localization

Analysis of the effect of uncertainty on specific atmospheric features

1. Minima/maxima, critical points
2. Techniques for revealing topological variations of flow fields due to uncertainty
3. Application specific features (vortex cores, low pressure regions, jet streams etc.)
4. Uncertain particle trajectories, ie. numerical integration of uncertainties
5. Visual representations for features + uncertainty in 3D+time
6. On-the-fly computation and visualization of local and global correlation structures

Links to other projects

Wherever 3D visualization and uncertainty quantification is required, we may find collaborations.

Funding

1 FTE

Bearbeiten

Impact of small- and mesoscale diabatic processes on Rossby wave trains

Classification

Mainz, Research Area A

Principal Investigator(s)

Riemer, Wirth

Summary and central question

We have developed two complementary diagnostics for upscale growth and error propagation in Rossby wave trains. The developed PV tendency diagnostic, however, cannot be applied in a simple, automated manner due to limitations of the employed (standard) PV inversion code. The wave activity flux diagnostic on the other hand can be applied easily but is subject to conceptual restrictions for highly non-linear waves.
Both approaches stem from different communities and are usually considered in isolation. Very recent developments in the wave activity flux community give reasons to believe that the two frameworks could now be unified.
Central questions:

- Characterization of error growth and propagation in Rossby wave trains?
- To what extent can finite-amplitude wave activity fluxes be cast in terms of PV tendencies from piecewise PV inversion?

State of the art and preliminary work

During PANDOWAE we developed significant relevant expertise. On the one hand we studied upper level Rossby waves trains from several points of view (kinematic, wave activity fluxes, statistical), on the other hand we developed the piecewise PV inversion diagnostic to be applied in the current project. There are a number of publications from this previous work.

Research programme

- improvement of piecewise PV inversion code and quasi-operational application to EC forecast and analysis; useful to gain intuition
- develop conceptual picture unifying the PV-perspective and the wave activity flux perspective
- setup one or two key cases, improve understanding of diabatic processes on RWT (with an eye to collaboration with Craig/Selz)
- study upscale error propagation

Bearbeiten

Vision

1st phase:

2nd phase:

Links to other projects

- good link to Craig/Selz "Diabatic production of low PV in cyclones" and T-NAWDEX (Schäfler/ Dörnbrack): They deal with meso- and smallscale aspects, we then make the transfer up to the synoptic scale
- possibly D5

Funding

1 PostDoc

Bearbeiten

Adjustment to balance of an idealised convective cluster

Classification

Mainz, Research Area A

Principal Investigator(s)

Riemer, ?

Summary and central question

The upscale growth of uncertainty from the convective to the synoptic scale is thought to occur as a three-stage process: saturation on the convective scale, organisation of the convective-scale perturbation into a balanced perturbation, and finally growth of this balanced perturbation by tapping into baroclinic instability. The second stage leaves open several fundamental questions. This work aims to address the complex processes during the adjustment of convective perturbations to a balanced circulation in highly idealized, numerical experiments.

The idealized experiments comprise a localised, convectively-unstable region in which a small number (~5) of convective bursts are initiated. Based on very recent work by Roger Smith, it is expected that these bursts spin up vorticity locally. This resulting (horizontal) circulation will then modify the entrainment of “environmental” air into the convective cluster. Associated increased inertial stability will help to “trap” the released latent heat to convert to kinetic energy of balanced flow. The experiments shall be run for a few inertial periods after which the “balanced” state of the flow is analyzed.

The central question then is: Is the balanced state governed by “environmental” parameters, i.e. the convectively available potential energy and the environmental moisture profile? Or does the balanced state depend also on the organisation of convection, as mimicked here by the initial distribution of convective cells and subsequent entrainment and vortex-vortex interaction?

State of the art and preliminary work

Expertise in George Craig's group on the stochastic nature of convection. This work is rather explorative but potentially very fruitful. Roger Smith has studied vorticity spin up of individual convective updrafts. Other authors have studied entrainment into individual updrafts. The idea here is to extend such studies to a convective cluster.

Research programme

- perform (deep-)convection-resolving experiments with conserved initial energy (no radiation, no surface fluxes)
- develop characterization of balanced state (total energy, vertical profile, degree of symmetry)
- use PV inversion to address the question: How well is this state represented by the diabatic term in the PV equation?
- diagnose (energy of) outward propagating inertia-gravity waves as characterization of adjustment process
- diagnose entrainment into convective cluster (isentropic analysis, trajectory analysis a la Yeo and Romp 2012)
- having gained insight into the benchmark experiment, perform additional experiments to examine sensitivity of evolution to background rotation, initial CAPE, distribution of initial convective cells, ...
- what aspects of the balanced state are most robust?

outlook:

- extend/ complete sensitivity analysis
- add surface fluxes to experiments
- extend examination of entrainment (vortex tracking and mixing barriers associated with vortex-vortex interaction)

Links to other projects

- B1, C1 (diabatic PV redistribution)
- D1 (impact of "stochastic" convection on "final" balanced state)
- D4 (diagnostic of entrainment/ mixing barriers)
- A4 (surface fluxes in experiments in 2nd phase)

Funding

1 PostDoc

Bearbeiten

Structure formation on cloud scale and propagating impact on larger scales

Classification

Mainz, Research Area A

Principal Investigator(s)

Spichtinger, Lukacova, Hildebrandt

Summary and central question

In atmospheric physics we tend to think along Kolmogorow's energy cascade, i.e. large eddies dissipate and transport their energy to smaller eddies until final dissipation on molecular scales appears. Thus, we usually think in terms of a downscale energy cascade. However, it is a common feature in many atmospheric situations that small-scale processes trigger structure formation on larger scales (emergence) or processes on the same scale tend to organize themselves to larger structures (self organization). These features might further influence processes on the same scales or on larger scales, leading to an upscale cascade. An important but still not well-known example is the formation of structures in clouds and cloud systems, triggered by cloud processes on the microscale but influencing atmospheric flows on much larger scales. Structure formation is often triggered by instable modes or dominant perturbations leading to dominant patterns. For clouds it is not really understood how this works, although an interaction with dynamics is important. Finally, the transition from quasi-homogeneous states to structures is often guided by order parameters determined by differential equations. For clouds and other atmospheric phenomena (e.g. PV structures from small to large scales) it is not known how to determine such parameters. Thus, we want to focus on the following central questions:

- How do typical cloud structures form, i.e. which types of organisation are necessary (emergence, self-organization etc.), which types are preferred?
- How do structures on the cloud (system) scale influence atmospheric flows on larger scales?
- Are there order parameters determining cloud structures and how can they be described in terms of differential equations?
- How do perturbations in the initial states influence structure formation?

State of the art and preliminary work

Structure formation on cloud scales was investigated in simple dynamical system approaches, but only for single cloud parcels (Wacker, 1992; 1995; 2006) In recent work, we extended this approach for ice clouds and could make qualitative and quantitative studies on cirrus cloud formation. In Spichtinger's group, some effort is going on in coupling this simple cloud models to Navier-Stokes equations for asymptotic analysis; additionally, there is long-term expertise in LES modelling of clouds. Lukacova has strong expertise on the field of geophysical fluid dynamics, analysis of singular limit problems and asymptotic analysis. Hildebrandt is an expert on structure formation as described by Landau-Ginzburg-equations.

Research programme

The project has two parts, i.e. (1) high-resolution simulations and data investigations and (2) mathematical analysis

Part 1: LES/DNS modelling of idealized cloud systems for structure formation

- Joint development of a simplified but analytical cloud model for coupling with Navier-Stokes-Equation (or better compressible/anelastic equations) – together with Part 2
- Identification of idealized situations with structure formation on cloud scale (e.g. shallow convection in warm/mixed-phase/ice clouds, warm frontal clouds)
- Simulation of idealized situations using the coupled cloud-flow-model
- Identification of structure formation via data analysis and comparison with mathematical analysis from Part 2
- Perturbation of initial conditions and/or model equations in order to investigate perturbed structure formation or even robustness

Part 2: Mathematical analysis of structure formation

- Joint development of a simplified but analytical cloud model for coupling with Navier-Stokes-Equation (or better compressible/anelastic equations) – together with Part 1
- Perturbation analysis of equations (e.g. methods from analysis of Landau-Ginzburg-equations) in order to identify dominant modes, leading to structure formation
- Determination of order parameters and their differential equations
- Comparison of analytical results with (perturbed) simulations

Links to other projects

Spichtinger/Hanke-Bourgeois, Hoose et al. (severe convection), Craig/Selz, Wirth/Schoemer and to be determined

Funding

two PhD positions (75% TV-L E13) + travel

Bearbeiten

Influence of land-atmosphere couplings on predictability

Classification

Karlsruhe, Research Area A

Principal Investigator(s)

Harald Kunstmann

Summary and central question

Regional atmospheric models still are characterized by a limited representation of terrestrial hydrologic processes, particularly with respect to lateral water fluxes. As land-atmosphere-coupling processes play a significant role in the generation of precipitation at different spatial and temporal scales, it is crucial to investigate 1) the influence of these coupling processes on the precipitation predictability and 2) the potential of more complex process descriptions for improved predictions. We aim at more comprehensive process descriptions accounting for the interdependencies between water- and energy fluxes at the compartmental interfaces between atmosphere, land surface and subsurface.
The central questions are

- Which improvements in regional precipitation predictability can be achieved by a more sophisticated treatment of terrestrial hydrologic processes in regional atmospheric models?
- What is the role of lateral water fluxes at the surface and subsurface for precipitation processes?
- What is the role of possible interactions between the saturated zone (i.e. groundwater) and the boundary layer for precipitation processes on long time scales?
- How do hydrologically enhanced process descriptions alter the energy flux partitioning at the land surface?

The above mentioned questions will be addressed on different spatial and temporal scales and in different climate zones. In addition to Central Europe a focus can be set on tropical West Africa.

State of the art and preliminary work

We are currently developing fully coupled model systems aiming at closing the regional water cycle. Based on the regional atmospheric model WRF, hydrological enhanced modules are developed and applied, allowing e.g. to cover the interaction of the unsaturated zone with aquifers (2-dim) and also re-infiltration of saturation excess water.

Research programme

- Hydrologically enhancement of fully coupled model systems: further coupling schemes for saturated/unsaturated zone interaction, allowing interaction of several aquifers (e.g. via leakage), dynamic vegetation descriptions
- Setup of coupled model system for different target regions
- Performance analysis: standard vs. fully coupled (hydrologically enhanced) version in reproducing hydrometeorological variables under different drivings (reanalysis, forecast, decadal prediction, climate control run/scenario)
- Development and of measures for land surface atmosphere interactions on different spatial and temporal scales (e.g. memory effect)
- Analysis of predictability increase/decrease under different hydrological (sub-)model complexities

Links to other projects

- REKLIM (HGF, Regionale Klimainitiative)
- WASCAL (BMBF, West African Science Service Centre for Climate Change and Adapted Land Use)
- PREFEED (DFG, Long Term Land Use - Precipitation Feedbacks in the Hai River and Poyang Lake Region in China)

Funding

1 Postdoc (TV-L E13)

Bearbeiten

Research Area B:

Clouds and Uncertainty

Data Assimilation I: Impact of model errors associated with cloud microphysics on initial condition errors

Classification

Munich, Research Area B

Principal Investigator(s)

Martin Weissmann, Tijana Janjic-Pfander
(Possible coauthors: Florian Harnisch and Prof. Bernhard Mayer)

Summary and central question

Systematic errors of NWP models pose a severe problem for data assimilation (DA) systems. Current DA methods usually assume that the model is unbiased and systematic differences of model and observations therefore lead to a suboptimal analysis. In ensemble DA for example, the space spanned by the ensemble constrains the analysis and observations far away from the short-term model forecast are likely to either have a very low impact or lead to an inconsistent analysis.

In the framework of the HErZ Data Assimilation Branch at LMU, a forward operator has been developed for the assimilation of visible and near-infrared satellite observations in the future regional ensemble DA system KENDA-COSMO of DWD. Such observations provide a wealth of information on atmospheric clouds and are therefore seen as valuable addition to improve the representation of clouds in NWP models. Based on this development, observations in these channels were recently be directly assimilated in an NWP model for the first time, but their impact in the first sensitivity experiment was comparably small. This is assumed to be related to an imperfect representation of clouds in COSMO that lead to large systematic differences of model clouds and observed clouds. As a consequence, the observed satellite observations are often far away from the possible scenarios spanned by the short-term ensemble forecasts.

The proposal intends to reduce model errors associated with cloud microphysics to fully eploit the information provided by visible and near-infrared MSG satellite observations in DA. This shall be accomplished through sensitivity studies with different COSMO microphysics schemes and settings.

Research questions:

- What is causing systematic differences between observations and simulated clouds?
- Which settings in COSMO microphysics need to be modified for a more realistic representation of clouds in COSMO and smaller systematic differences between the model and satellite observations?
- What is the impact of improved microphysics on the assimilation of visible and near-infrared satellite observations?

State of the art and preliminary work

Preliminary work: Implemetation and testing of the experimental DWD ensemble DA and forecasting system KENDA-COSMO at LMU (completed)
Development of visible and near-infrared satellite operator (completed)
Quantification of systematic differences between MSG observations and synthetic satellite images using COSMO output (ongoing)

Research programme

Sensititivity studies will be performed to test different COSMO microphysics schemes and the sensitivity of COSMO microphysics to different parameters for a reduction of systematic models errors concerning the representation of clouds and a better exploitation of the information provided by visible and near-infrared satellite observations in DA. In addition, different settings for the operator (e.g. assumed effective radii) will be tested to quantify the uncertainty that is due to the forward operator. The sensitivity studies shall provide input for the LETKF parameter estimation of the project Janjic/Weissmann and vice versa the estimated parameters from Janjic/Weissmann will be used to reduce systematic errors in model clouds. Optimized microphysics settings will then be applied in KENDA-COSMO and their impact on the assimilation of visible and near-infrared satellite observations will be evaluated.

The work shall be performed in cooperation with DWD (Carmen Köhler and Axel Seifert) and benefit from ongoing efforts to improve COSMO microphysics in the framework of the DWD EWELINE project.

A joint transfer project with Janjic/Weissmann is planned for transfer of the findings to DWD.

Links to other projects

Cooperation with Janjic/Weissmann (see above)
HErZ Data Assimilation Branch (LMU)
EWELINE (DWD)
Transfer project with Janjic/Weissmann

Funding

1 PhD student
Hiwi
travel, publications

Bearbeiten

Data Assimilation II: Constrained Parameter estimation in EnKF with application to cloud physics

Classification

Munich, Research Area B

Principal Investigator(s)

Tijana Janjic-Pfander, Martin Weissmann

Summary and central question

Data assimilation produces initial conditions for NWP models by combining observations and background (forecast) using the estimates of their uncertainties. A major contributor to the forecast uncertainty is model error. Inaccuracies of numerical schemes, unrepresented sub-grid scale processes, inaccurate boundary conditions, inadequate representation of orography as well as parameterization uncertainties all contribute to the model error. Nevertheless, many current implementations of data assimilation algorithms assume that numerical models are perfect.

Parameterizations in numerical models in turn depend on tuning parameters that are generally hard to estimate precisely with data alone, and their specific values often depend on the numerical model used. These parameters should not be constant in time and space, and often depend on a season and atmospheric conditions taking on values in a certain range.

As a part of this project, a methodology for constrained parameter estimation with ensemble Kalman filter will be developed. Important microphysical parameters identified in the subproject Impact of model errors associated with cloud microphysics on initial condition errors will be estimated using the Ensemble Kalman filter algorithm in order to obtain optimized values. Possible extensions to the boundary layer surface fluxes will be considered as well.

- Whether and how much the model representation of the microphysical processes (and possibly the surface fluxes) are improved with optimized parameter values?
- How well the variations of the parameters work in representing the uncertainties?

State of the art and preliminary work

German Weather Service (DWD) has recently developed a data assimilation system KENDA based on the Ensemble Transform Kalman filter (ETKF) algorithm for the convective scale data assimilation. In the framework of the Hans Ertel Center for Weather Research, Data Assimilation Branch at LMU, a forward operator has been developed for assimilation of visible and near-infrared satellite observations. In addition, a methodology for obtaining physically constrained estimates has been recently developed for the ensemble Kalman filter algorithms.

Research programme

- In order to estimate the parameters the current state vector that contains prognostic model variables on COSMO-DE grid will be augmented with them. Constrained data assimilation methodology will be developed for parameter estimation in EnKF.
- First parameters that will be estimated are the once used by the VIS observation operator itself.
- Further, parameters associated with cloud microphysics scheme identified within subproject “Impact of model errors associated with cloud microphysics on initial condition errors” will be estimated.

Links to other projects

If successful, parameter estimation could be integrated into DWDs KENDA data assimilation system in the framework of a transfer project. The transfer project will be done jointly with subproject Impact of model errors associated with cloud microphysics on initial condition errors.

Funding

1 PhD, 3 years
Travel and publication costs
Total: 150 k€

Bearbeiten

Robustness of cloud patterns - Identification via inverse methods

Classification

Mainz, Research Area B

Principal Investigator(s)

Spichtinger, Hanke-Bourgeois

Summary and central question

The formation of structures and patterns in clouds depends on the cloud processes themselves. These are highly non-linear and a priori one would think that changes in the initial conditions should lead to a wide spread in the final cloud. However, the variations in cloud states are very different, ranging from only slight variations to huge changes in microscopic and macroscopic. On the other hand, it is not clear for almost identical final clouds if the formation states are also quite close. In general it might be that “the same cloud” originates from very different initial states. There is also a discussion about the so-called buffering of clouds. It seems to be possible that a macroscopic feature like precipitation could originate from different process pathways (e.g. “warm” rain formation vs. “cold” rain formation). Form an observational point of view this can be seen as an inverse problem, because we usually can observe a cloud, a cloud system or just precipitation at a state, when the phenomenon is present, but usually we cannot measure the actual origin or initialisation and development of the pattern. Thus, we would like to address the following questions using inverse techniques.

- How robust is a cloud or cloud system in terms of its initialisation and development with respect to variations in the cloud structure?
- Are there different process chains to the same final cloud state (buffering)? Is it possible to identify transitions in the cloud formation and development in the sense of buffering?
- How important are environmental parameter settings for the development of a cloud or a cloud system? How plausible are simple models including only few key processes?

State of the art and preliminary work

There are some investigations on the spread of clouds in terms of sensitivity studies, starting with perturbed initial conditions and then using forward integrations. A rigorous treatment starting from a final state was not carried out, at least to our knowledge. There are some adjoint cloud models available from literature since about 10 years. However, the basic questions as stated above were not addressed using these models. Spichtinger has a long-term experience with cloud models and atmospheric flow simulations. Recently, some very simple cloud models were developed and used for mathematical analysis – this type of research is going on (link to HD(CP)2 project). Hanke-Bourgeois is an expert on inverse problems fro ma mathematical point of view.

Research programme

- Start with a very simple cloud model, which then will be coupled to a kind of dynamics (e.g. linear/non-linear advection, kinematic framework, full anelastic/compressible equations, Navier-Stokes equations).
- First approach should be a simple reverse time approach, which might break down because of the singular nature of cloud formation. Identification of the breakdown of such a simple method.
- Development of an adjoint model for this very simple set of equations
- Use of the adjoint model in order to investigate the robustness of cloud formation. For comparison, reference simulations using a simple flow solver will be carried out (e.g. in collaboration with the project Spichtinger/Lukacova/Hilderbrandt or using existing codes).
- Extension of the adjoint model or different processes in order to address the problem of different pathways to the “same” final cloud state. Also in this case, high resolution reference simulations might be helpful.

Links to other projects

Spichtinger/Lukacova/Hilderbrandt, other projects in research area A, to be determined at the workshop

Funding

2 PhD positions (75% TV-L E13) + travel

Bearbeiten

Cirrus clouds and Stratosphere-Troposphere-Exchange

Classification

Mainz, Research Area B

Principal Investigator(s)

Reutter, Spichtinger

Summary and central question

The exchange of air masses across the tropopause plays an important role for the chemical composition of the stratosphere and troposphere. For instance, the injection of stratospheric air through the tropopause can enhance the ozone concentration and reduce significantly the amount of water in the troposphere.

The mass flux of air through the tropopause is enhanced in the vicinity of extra-tropical cyclones (actual work of Philipp Reutter together with group of Prof. Heini Wernli, ETH Zurich). Cirrus clouds, induced by the ascending air in warm conveyer belts (WCB), are the first signs of an approaching extra-tropical cyclone. First idealized 2D simulations with EULAG, initialized with a potentially unstable layer close to the tropopause and mimicking the updraft of a WCB, showed that cirrus clouds are able to mix air up to higher regions and vice versa. They also change the potential stability close to the tropopause.

Central questions are:

- How and to what extent do cirrus clouds change the structure of the tropopause?
- If mixing occurs, how does this influence the further development of a cyclone?

State of the art and preliminary work

First idealized 2D EULAG model simulations focussing on development of cirrus convection close to the tropopause by Philipp Reutter.

A recently finished diploma thesis in the group of Prof. Peter Spichtinger is dealing with the formation of cirrus clouds at an idealized warm front with high-resolution EULAG simulations.

Philipp Reutter and the group of Prof. Heini Wernli are working on the quantification of stratosphere-troposphere exchange (STE) in the vicinity of extra-tropical cyclones, using ERA-Interim data.

Research programme

- 2D/3D simulations of idealized warm front cirrus clouds using realistic tracers using EULAG.
- Building up and performing EULAG model simulations for realistic 3D simulations of extra-tropical cyclone, with special focus on cirrus clouds.
- Evaluation of field campaign data (T-NAWDEX Falcon and T-NAWDEX Halo).

Links to other projects

- T-NAWDEX (LMU)

Funding

1 PostDoc (4 years)

total: 248 k€

Bearbeiten

Impact of convection parameterisations on the dynamics of the atmosphere

Classification

Mainz, Research Area B

Principal Investigator(s)

Tost, Wirth, Spichtinger

Summary and central question

The project aims at investigating uncertainties in large scale models due to convection parameterisations. The anticipated project targets three major questions and associated action items:

- Can we gain climate model skill by using an online ensemble of convection parameterisations ?
- What is the impact of the chosen convection parameterisation on the development and fate of midlatitude waves (including the ensemble approach) ?
- How do detailed process description in convection modify the wave structure by comparison of parameterised and super-parameterised convection ?

State of the art and preliminary work

The PI Tost has implemented and evaluated several convection parameterisations in a global chemistry climate model. So far the focus has been mainly on analysis of temperature, precipitation and tracer transport, including influences of climate change and nudging.
The PIs Wirth and Spichtinger have year long expertise in analysing tropospheric waves and cloud processes.

Research programme

According to the research questions also the research programme is separated into action items, all investigated with the chemistry climate model EMAC:

- Development of the capability of an online calculated ensemble of convection parameterisations within the EMAC model.
- Development of a suitable weighting matrix to determine the individual impact of the convection schemes with the aim to obtain maximum skill in reproducing precipitation and radiation observations.
- Analysis of the development and fate of midlatitude waves and their interactions with parameterised convection by a series of simulations with individual and the ensemble convection parameterisations applying the analysis algorithms developed and applied by PI Wirth.

- Comparison of midlatitude waves in case of a superparameterisation approach for convection.

Links to other projects

The application of the superparameterisation depends on an ongoing PhD project developing this tool, for which a separate proposal for funding is currently under review at the DFG.

Funding

1 PhD student + travel and publication costs

Bearbeiten

Impact of mineral dust on short-term predictability

Classification

Karlsruhe, Research Areas B

Principal Investigator(s)

Bernhard Vogel, Peter Knippertz

Summary and central question

As the most important aerosol species by mass, mineral dust plays a central role in feedback processes involving the land surface and the atmosphere. Dust affects radiation through scattering and absorption in the short and longwave range, and is one of the most prominent ice nuclei, thereby modifying cloud formation and precipitation. Dust atmosphere feedbacks are particularly important for forecasting near source regions as for example in West Africa. During the summertime, this region is dominated by mesoscale convective systems (MCSs). Evaporation of precipitation from MSCs causes cold pools that spread at the surface emitting large amounts of dust. During the following day the stably stratified, humid, dusty air is heated by solar radiation and new convection can develop, creating an ideal testbed to quantify the relative importance of the feedback between mineral dust, cloud formation and precipitation.
The central research questions to be addressed in this project are:

- Are we able to simulate the complex feedback loop convection – wind – dust emissions – radiative impact – new cloud formation sufficiently well?
- How important is the effect of dust radiative forcing on the development of convection relative to dynamical (convergence) and thermodynamical (stability, moisture) factors?
- How important are dust microphysical effects to modify cloud characteristics once convection has been initiated in aged cold pools?
- To what extent enhances the inclusion of dust processes the predictability of convection over summertime West Africa?
- What can we learn from this for the predictability in more remote regions (e.g. dust transport to Europe)?

State of the art and preliminary work

KIT has developed the comprehensive model system COSMO-ART, one of only few such systems worldwide that allows addressing the research questions mentioned above. For example, Bangert et al. (2012) used COSMO-ART to show that during dust transport events to Europe temperature forecasts could be considerably improved if relevant feedback processes are included. Work as part of Desert Storms at Leeds has investigated the dynamics of dusty cold pools and their representation in models in great detail.

Research programme

- Selection of relevant cases (e.g. June 2010, June 2012)
- Convection-permitting simulations with COSMO-ART
- Comparisons with observations (SEVIRI dust product and AOT, Fennec AWSs)
- Sensitivity studies to quantify and to assess the relevant feedback processes
- Idealised 2-fluid experiments to systematically probe the relevant parameter space
- Improvement of current parameterizations in COSMO-ART and operational COSMO
- Including the most relevant processes into ICON-ART

Links to other projects

- Development of ICON-ART
- DACCIWA

Funding

4 years of salary for 1 Postdoc (TV-L E13; model development, technical realization) and 1 PhD student (75% TV-L E13; case studies, idealized experiments) + travel expenses

Bearbeiten

Research Area C:

High Impact Weather

Postprocessing of complex EPS II: Stochastic parameterisation vs advanced postprocessing

Classification

Munich, Research Area C

Principal Investigator(s)

K. Kober, C. Keil and T. Gneiting

Summary and central question

Motivations for the use of stochastic parameterisations and postprocessing methods to address the challenge of representing or accounting for model errors can be found in the Teilprojekte D1 and E3a. This project will try to quantify the impact and benefit of stochastic parameterisations in comparison to postprocessing methods. In particular this includes the quantification of the upscale effects of stochastic parameterisations that cannot be considered in postprocessing methods.

Central questions of the project will be:

- How well does an ensemble based on stochastic physics represent uncertainty?
- How well does an postprocessed ensemble represent uncertainty?
- How do error statistics change with the use of stochastic parameterisations?
- How is the spatial and regime-dependent variability in skill?

State of the art and preliminary work

A fully stochastic convection scheme has been developed and implemented into the COSMO and the ICON model and a stochastic boundary layer scheme is under development. Additionally, a recent study proofed the value of regime-dependent postprocessing method. This was conducted in collaboration with the group of Tilmann Gneiting. This collaboration will be continued in this TR with the Teilprojekt E3a where an advanced regime-dependent postprocessing method will be developed.

Research programme

- Identification of synoptic situations where forecasts show a high sensitivity to physical formulation of the physics in the model
- Bring together methods to create EPS with stochastic physics and statistical postprocessing
- Systematic comparison of EPS-STOCH, EPS-POSTPROC, EPS-STOCH-POSTPROC and EPS-REF
- Regime-dependent evaluation of ensembles: quantification of differences and impact

Links to other projects

- E3a (KA Postprocessing)
- D1 (MU Stochastic parameterisations)

Funding

1 Phd (75%), 3 years, total: ?K€

Bearbeiten

Rossby wave trains and summer heat waves

Classification

Mainz, Research Area C

Principal Investigator(s)

Wirth

Summary and central question

The last decade has seen a number of severe summer drought conditions over parts of the Northern Hemisphere. A recent paper by Petoukhov suggests that this may be due to quasi-resonant Rossby waves. However, this paper is rather sketchy, and Brian Hoskins e.g. doubts whether the summer jet stream is strong enought for this quasi-resonant mechanism to work.

The idea here is to base the analysis on Rossby wave trains (localized in longitude) rather than Rossby waves (spanning the entire globe). The question is how the RWT gets quasi-stationary.

So this would really connect synoptic scales (waves) with weather, although admittedly „weather“ here is severe drought which is rather large scale (i.e. almost synoptic).

State of the art and preliminary work

- PI's PhD work is on linear theory of planetary Rossby waves (publications)
- more recently PI has done quite some work on upper tropospheric Rossby waves trains (including publications)

Research programme

- Use Rossby wave linear theory as background and check quasi-resonant hypothesis for various cases

Links to other projects

[to be determined during workshop]

Funding

- 1 PhD student
- Funding for HiWi

Bearbeiten

Banner clouds. Visualization of complex microscale structures over obstacles

Classification

Mainz, Research Area C

Principal Investigator(s)

Wirth, Schoemer

Summary and central question

Weather is often locally modified by obstacles like mountains. An examle are banner clouds sometimes observed at steep and high mountains. The challenge is to find local flow features for given environmental conditions (wind, stratification, moisture) given very complex flow geometry in case of steep obstacles: there are both waves and vortices, which may be stationary or transient.

The main idea here is to develop advanced visualization as a heuristic tool to diagnose flow features in neighborhood of mountains

State of the art and preliminary work

- Prof. Schoemer has done previous work together with Prof. H. Wernli (one/two publications)
- Prof. Wirth has demonstrated expertise in flow over complex orography (Banner clouds, several papers)
- currently the two co-PIs habe a HiWi working on some preliminary aspects, hope to get funding from Mainz computational sciences in order to prepare a sound proposal

Research programme

- Data provided by LES
- Vortex identification: Further develop and adjust existing algorithms to the current problem
- Flow visualzation: Schlieren technique, trajectories, …
- all that with an eye to develop fast algorithms in order to deal with large (time-dependent 4D) data sets later (phase 2)

Vision

1st phase: develop basic algorithms using time averaged stationary flow fields

2nd phase: also consider fully turbulent time-varying flow (need to deal with large data sets and to develop efficient algorithms)

Links to other projects

[I believe there is some work on visualization elswhere in the TR?!]

Funding

1 PostDoc

Bearbeiten

Banner clouds. Moist simulations of banner clouds

Classification

Mainz, Research Area C

Principal Investigator(s)

Wirth, Schoemer

Summary and central question

Banner clouds have been simulated in the past mostly using dry dynamics. It turns out that the occurrence of banner clouds requires a rather narrow „window“ of conditions on the inflowing moisture profile. The current project wants to explore this „window“ in some detail in order to be able to predict banner cloud occurrence for given environmental conditions.

State of the art and preliminary work

The PI has demonstrated expertise in banner clouds (including a number of publications), plus some experience with ensembles from PANDOWAE; there is a running model setup using the EULAG numerical model for both idealized and (in 2014) realistic orography.

Research programme

- implement interactive moisture into existing EULAG model code
- carry through simulations of moist flow
- study sensitivity of banner cloud occurrence with respect to inflow moisture profile
- apply some ensemble technique (needs to be learned from some other partner) in order to estimate the likelihood of banner cloud formation

Vision

1st phase: do analysis in idealized model setup

2nd phase: generalize investigation to realistic orography, actually predict banner cloud at Matterhorn

Links to other projects

[to be identified at workshop]

Funding

1 PhD position

Funding for HiWi

Bearbeiten

Dynamics, Lagrangian mixing, and predictability of tropical cyclones in vertical shear

Classification

Mainz, Research Area C

Principal Investigator(s)

Riemer, Schoemer

Summary and central question

Vertical shear of the environmental winds is a major contribution to intensity and structure change of tropical cyclone (TC). While distinct patterns of structural changes are frequently observed in association with vertical wind shear, it has recently been shown that vertical shear decreases predictability of TC intensity.
Intrusion (“mixing”) of environmental low-entropy air into the TC’s inner-core convection is central for the intensity evolution of TCs in vertical wind shear. Shear-induced vortex Rossby waves (VRWs) may play an important role in this mixing process that is not yet well understood. This project will investigate the casual link between the seemingly predictable dynamic response of the TC vortex to shear forcing, the mixing of low-entropy air into the TC circulation, and the TC intensity evolution exhibiting low predictability.

Central questions are:

- Through which pathways does environmental low-entropy air intrude the inner-core convection?
- To what extent are mixing barriers modified by VRWs?
- Are there different mixing regimes (dominant mixing at low, mid-, or upper levels)?
- If so, what governs these regimes (ratio TC intensity/ shear strength, radial profile of TC winds, vertical profile of environmental entropy)?
- What is the degree of predictability of different aspects of the TC evolution (vortex tilt, shear excited wave activity, convective asymmetries, different metrics for TC intensity (integrated kinetic energy, wind maxima, ...), ...)?

State of the art and preliminary work

Expertise in TC-vertical shear interaction. Mixing barriers in a simplified framework have been identified. A trajectory analysis of mixing properties is being performed. MR is co-PI for this year’s field program of NOAA’s Hurricane Research Division dedicated to shear interaction of TCs. A set of ensemble experiments of idealized TCs in shear for preliminary studies is available through collaboration with Fuqing Zhang at Penn State.
Prof. Schoemer has done previous work together with Prof. H. Wernli (one/two publications) for objective identification of meteorological features and a clustering algorithm has been developed in his group.

Research programme

- perform a series of idealised numerical, convection-permitting experiments of TCs in vertical shear with different ratio of TC intensity and shear strength
- examine intrusion of low-entropy air in the TC circulation using trajectory analysis
- implement and extend trajectory clustering to identify coherent pathways air low-entropy intrusion
- identify mixing barriers using finite-time Lyapunov exponents and its relatives suitable for strong vortices
- develop objective identification and classification of mixing barriers
- characterize vortex dynamics
- relate mixing properties to vortex dynamics

outlook phase 2:

- use results of benchmark experiments to design ensemble experiments
- determine predictability of different aspects of TC evolution
- apply diagnostics of vortex dynamics and mixing to ensemble experiments and determine their relationship in ensemble sense
- extend an improve objective identification of mixing barriers

Links to other projects

- D2 (identification of flow features in complex flows)
- D1/ A4 (potentially: design of ensemble with respect to uncertainty in representation of surface fluxes)

Funding

1 Postdoc (IPA), 1 PhD (Informatik), 1 HiWi

Bearbeiten

Prediction of peak surface gusts in cyclones

Classification

Karlsruhe, Research Area C

Principal Investigator(s)

Peter Knippertz, Ulrich Corsmeier, Andreas H. Fink

Summary and central question

Predictions of the track and intensity of severe cyclonic storms have substantially improved over recent decades with often-satisfactory skill up to several days. Prediction of the location, timing and intensity of peak surface gusts, one key parameter besides heavy precipitation events for warnings and socio-economic impacts, is a much greater challenge and depends on processes that are less understood and potentially of lower predictability such as:

- mesoscale dynamics within the cyclonic storm such as sting jet formation and the development of multiple cyclone cores;
- deep and slab moist convection, particularly along the cold front and in the dry slot;
- turbulent mixing of high momentum from the top of the boundary layer to the surface.

The central research questions to be addressed in this project are:

- Which physical processes on the cyclone scale determine the location (relative to the cyclone centre) and timing of the area affected most by maximum surface gusts?
- What is the role of deep or midlevel convection and cold pools for the downward mixing of high momentum to the surface (PI, CSI, MAUL)?
- What is the role of shear-driven turbulence for injecting high momentum into the boundary layer?
- How different are the situations over sea and land (inhomogeneities, roughness, fluxes, orography)?
- How realistic are representations of these processes in current models?
- To what extent do these processes limit our ability to predict peak gusts?

State of the art and preliminary work

Recent projects such as DIAMET, SEAMSEW and PANDOWAE have concentrated on synoptic to mesoscale aspect of cyclonic storms setting the scene for more detailed studies of predictability aspects of surface gusts.

Research programme

- convection resolving modelling with COSMO/ICON, convection parameterising ensemble simulations using Plant-Craig scheme in COSMO,
- sensitivity studies (ensembles) with respect to grid size, boundary conditions, representation of convection, boundary layer and surface characteristics (e.g. sea/land/orographic influence)
- case studies of well observed storms over land (e.g. Kyrill, Klaus) and ocean
- comparison with available observations (gusts from surface stations, scatterometer over ocean (QuikSCAT, ASCAT) since 2003, tower data from Karlsruhe, Cabauw and Lindenberg, research aircraft, wind turbine observations)
- comparison with state-of-the art operational products (deterministic and ensemble) and gust parameterisations for coarser-resolution models
- development of forecast tools, visualisation of gust forecasts, gust probabilities.

Links to other projects

- T-NAWDEX
- Follow-up proposals to DIAMET (e.g. WIMC, Schultz et al.)

Funding

1 Postdoc (TV-L E13) 4 years + travel expenses Total 260 k€
KIT could contribute KITcube / DO128 measurements in kind to the project to fill in for possible delays with T-NAWDEX.

Bearbeiten

Asian winter monsoon, cold surges and Borneo Vortices

Classification

Karlsruhe, Research Area C

Principal Investigator(s)

Peter Braesicke (PB)

Summary and central question

Extreme weather, by its very nature, affects communities strongly. Our abilities to forecast extreme events days ahead and to project how certain types of events will behave under climate change are intrinsically linked. This project focuses on a challenging example that involves two-way scale interactions: The formation and life-cycle of Borneo Vortices (BVs) in the South China Sea (SCS) during the Asian winter monsoon.

Many aspects of the two-way scale interactions are neither fully understood nor quantified. BVs occur during the winter monsoon season in the SCS, triggered by cold surges (CSs) from the Siberian high pressure system (the large scale). If CSs occur often enough in close succession or their duration is long enough a BV is triggered. BV interactions with orography lead to strong coastal precipitation events (the small scale). In turn, the BV decelerates regionally the subtropical jet and a dry ozone rich layer develops (the large scale). It is important to note that one important factor for the occurrence of BVs is the state of the Pacific Ocean: BVs are more common during La Niña and are suppressed during El Niño events, therefore a global approach is required.

Central questions of the project are:

- How are the ‘initial’ CSs triggered?
- When is a BV formed by a CS?
- - What is the role of the Pacific state?
- What is the lifecycle of a typical BV?
- - Where and when does the strongest precipitation occur?
- How does the CS/BV influence the large-scale circulation?
- Do the Upper Tropospheric/Lower Stratospheric (UT/LS) composition changes (water vapour and ozone) matter?
- - Would a forecast be better if they could be considered?

State of the art and preliminary work

A case study of a BV in January 2010, using reanalysis and radiosonde data demonstrated the two-way scale interaction described above. Further work using ERA-Interim data demonstrated the ability of the reanalysis system to produce a reliable representation of the (larger scale) BV (and accompanying CS) features and discussed the composition changes. Current work on the ENSO modulation of BVs and coastal impacts is on-going.

The availability of ECMWF’s OpenIFS model for research opens up a new avenue for improving the earlier work with high resolution global modelling/downscaling.

Research programme

- Identification of all BV episodes from ERA-Interim for 1979 – present. The earlier work started screening in 1989, because the 1979 – 1988 analysis was released later. Different metrics for the screening will be used.
- Selection of candidate episodes for global downscaling, e.g. under consideration of the Pacific Ocean state and where the detected BVs interacted with orography.
- Collection and evaluation of available sonde/surface/remote sensing data from the SCS area, including Borneo/Malaysia in conjunction with the previous task.
- High resolution global hindcasts (downscaling) will be performed with the standard set-up of OpenIFS.
- - How well is the CS/BV forecasted up to ten days ahead?
- - How does the forecast quality depend on the Pacific Ocean state?
- - How well are the strong precipitation events captured?
- - What are the factors that determine the longevity of the BV and its impact on the UT/LS composition (water vapour only in the base model)?
- Does a simple parameterisation for the CS/BV induced UT/LS ozone (composition) change improve the forecast performance (modified version of OpenIFS)?

Links to other projects

- European Climate Research Alliance (ECRA) High Impact Events (HIE) Collaborative Programme (CP)
- Transfer Project – feedback to the ECMWF for forecast model improvements

Funding

1 Postdoc, 4 years

Total: 248 k€

Bearbeiten

Prediction of wet and dry periods of the West African monsoon mediated by extratropical disturbances

Classification

Karlsruhe, Research Areas C

Principal Investigator(s)

Andreas H. Fink, Peter Knippertz, Tilmann Gneiting

Summary and central question

This project seeks to exploit the extended predictive skill of convective rainfall events and dry spells over tropical North Africa related to extratropical wave activity during the April–October season. At this time, intruding upper-tropospheric troughs are weak and shallow, or absent for weeks. However, recent research suggests remote impacts of extratropical wave activity in modulating West African monsoon (WAM) convection by: (A) mid-to-upper level dry air intrusions originating from the extratropical polar jet, (B) heat low ventilation from the Atlantic Ocean, and (C) cold air surges from the eastern Mediterranean. The main research questions are:

- What are the mechanisms of the north–south meandering of the heat low and Intertropical Discontinuity associated with weak transition-season troughs and how do they differ from winter cases?
- Can weak upper-level troughs open “outflow channels” through inertial instability that organise afternoon convection?
- How can we disentangle the dynamical link “extratropical troughs off the NW African coast/in the Mediterranean - heat low ventilation – WAM onset and breaks”
- Mid-to-upper level dry air intrusion in summer can be detrimental or favourable to convection. What determines their effect?
- What are the processes that – depending on the region - suppress or enhance WAM convection after cold surges in the Etesian/Harmattan winds?
- What is the effect of the processes listed above on rainfall and dry spell predictability?
- How does their importance compare to tropically dominated mechanisms (e.g. MJO)?

State of the art and preliminary work

Recent projects such as AMMA have concentrated on tropical synoptic to mesoscale dynamic aspects at the peak of the monsoon season (June–September). EN group led by PK has investigated tropical-extratropical interactions but not focused on predictability.

Research programme

- case studies of weak trough incursion, dry air intrusion and cold surges
- comparison with available observations (IMPETUS campaign 2002; AMMA SOP 2006, DACCIWA SOP 2015; CATCH/AMMA and WASCAL mesosites)
- comparison with state-of-the art deterministic/ensemble operational products
- convection resolving modelling with COSMO/ICON
- sensitivity studies with respect to boundary conditions and representation of convection
- regime-dependent postprocessing for ensemble forecasts for precipitation (ECMWF, TIGGE)

Links to other projects

- DACCIWA
- AMMA II

Funding

1 Ph.D (0.75 TV-L E13) 3 years + travel expenses Total 145 k€

Bearbeiten

Prediction of ice/liquid phase partitioning and hail formation in convective clouds

Classification

Karlsruhe, Research Area C

Principal Investigator(s)

C. Hoose, M. Kunz, B. Vogel

Summary and central question

The liquid/ice phase partitioning and the generation of precipitation via the ice phase are currently poorly predicted in operational weather forecast models. Especially, supercooled cloud droplets and hail are poorly represented although being important for aviation forecast and the prediction of severe hailstorms with a high damage potential. Within our research project we want to identify which processes have to be included to improve the current situation by addressing the following questions:

- Which physical, in particular microphysical, processes contribute significantly to the predictability of convective clouds and hail formation?
- How sensitive are these processes and their interaction on various scales to small changes in ambient conditions (e.g., external forcing, temperature/moisture profile, aerosol spectra)?
- How important is it to resolve updrafts and supersaturated patches inside the clouds?
- Can we simulate the amount of supercooled liquid water accurate enough for aviation forecast?
- How important is the coupling of heterogeneous ice nucleation to natural and anthropogenic aerosols?

State of the art and preliminary work

KIT has developed the comprehensive model system COSMO-ART and runs the unique cloud chamber AIDA. The combination of both was already used for developing and testing of new ice formation parameterizations (Niemand et al., 2012). While it is known from numerous laboratory experiments that heterogeneous ice nucleation is strongly dependent on aerosol properties (Hoose and Möhler, 2012), it is less clear in how far this translates into the sensitivity of clouds and precipitation to aerosol conditions. In numerical simulations, these sensitivities have been investigated, e.g. by Noppel et al. (2010) who have demonstrated that hail formation is aerosol sensitive. Hail probability, assessed by a combination of radar and insurance loss data, show a large spatial variability that can be partly related to orographic influences (Kunz and Puskeiler, 2010; Puskeiler, 2013).

Research programme

- cloud resolving modeling with COSMO/COSMO-ART/ICON-ART
- sensitivity studies (ensembles) with respect to boundary conditions, aerosols, land surface
- simulations of cold cloud phase partitioning and supercooled liquid water content with dynamic aerosol and comparison with observations
- case studies based on selected episodes for which observational data (in particular hail on the ground) are available
- evaluation of the simulated vertical and temporal evolution of cloud phase and precipitation make using remote sensing observations (satellite, radar and ground-based instruments; KIT-cube)
- development of a 2-way coupling between aerosols and a 2-moment cloud scheme for ICON-ART

Links to other projects

- HD(CP)2
- DFG research group INUIT

Funding

4 years of salary for 1 Postdoc (TV-L E13; model development, technical realization) and 1 PhD student (75% TV-L E13; case studies, idealized experiments) + travel expenses

Bearbeiten

Postprocessing of complex ensemble predictions

Classification

Karlsruhe, Research Area C

Principal Investigator(s)

Tilmann Gneiting

Summary and central question

In weather forecasting, the use of ensemble prediction systems and statistical postprocessing techniques has become routine over the past two decades.

In this context, there is an increasing recognition that statistical postprocessing techniques may benefit from regime-dependent training and forecasting, given that biases and dispersion errors in NWP ensembles are likely to be flow dependent. However, despite the theoretical appeal of the concept, there have been very few practical attempts of regime-dependent postprocessing. We will adress this problem from both theoretical and applied perspectives.

Furthermore, we will seek to address the critical question of the relative benefits of stochastic physics parametrization schemes vs. statistical postprocesing in ensemble systems.

State of the art and preliminary work

In ongoing joint work between the groups of George Craig (Munich) and Tilmann Gneiting (Heidelberg), we have been looking at statistical postprocessing techniques for precipitation forecasts with the COSMO-DE ensemble prediction system (EPS) run by the German Weather Service (DWD), depending on four distinct weather regimes, which are discriminated on the basis of precipitation accumulations, convective available potential energy (CAPE), and the convective timescale. This is a preliminary pilot study within Reza Owji's Diploma Thesis project (Mathematics, Heidelberg) under the supervision of Michael Scheuerer.

Research programme

(1) Theoretical study of quantitative measures of unconditional and conditional predictability, with generalized entropy functions that derive from proper scoring rules being key candidates.

(2) Empirical studies:

(a) Precipitation forecasts over Germany with the COSMO-DE EPS: Identification of suitable indicators of atmospheric regimes, quantification of conditional predictability, and development of regime-dependent statistical postprocessing techniques in close collaboration with project D1 (Craig/Kober) and the DWD (support to be confirmed).

(b) Regional scale precipitation forecasts over West Africa with the ECMWF EPS: Identification of suitable indicators of atmospheric regimes, quantification of conditional predictability, and development of regime-dependent statistical postprocessing techniques in close collaboration with project C5 (Fink/Knippertz) and possibly the ECMWF (support to be confirmed).

(3) Comparison of the relative benefits of stochastic physics parametrization schemes vs. statistical postprocesing in ensemble systems, in close collaboration with project D1 (Craig/Kober).

Links to other projects

The project links to ongoing joint work with DWD and ECMWF, and to ongoing work within the ERC Advanced Grant *ScienceFore*.

Funding

1 postdoc (100%) for 4 years each: 420kEUR

Bearbeiten