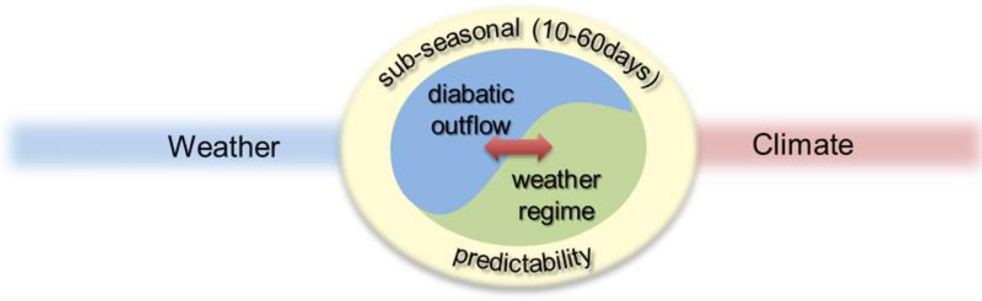
Helmholtz Young Investigator Group VH-NG-1243: "**S**ub-seasonal **PRE**dict**A**bility: understanding the role of **D**iabatic **OUT**flow" (SPREADOUT)

Karlsruhe Institute of Technology



HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

Sensitivity of Diabatic Outflow of Warm Conveyor Belts on Ensemble Configuration

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Background and Motivation

Forecast uncertainty related to WCBs

- WCBs introduce forecast uncertainty …
  - … by translating small-scale errors to the large scale, where they grow along the wave guide and propagate downstream (Grams, 2018)
  - … because their representation and their influence on large-scale flow depends on the parametrizations of diabatic processes (Joos and Forbes, 2016)

Representation of forecast uncertainty in the IFS

- Initial condition uncertainty: Combination of Ensemble Data Assimilation (EDA) and Singular Vectors (SV) to generate perturbations of the initial state
- Model uncertainty: Stochastic physics pertubation tendencies (SPPT) scheme adds random factors to the net parametrization tendencies to generate model perturbations (Leutbecher and Palmer, 2008)

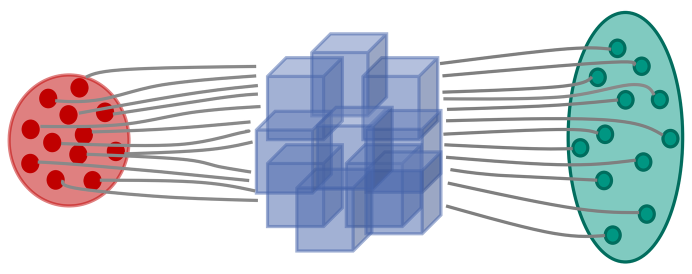


Fig. 1: Schematic of ensemble prediction systems, consisting of initial condition perturbations, perturbed model physics and the ensemble forecast

Stochastic physics perturbation tendencies (SPPT)

- Net tendencies of physical parametrizations are multiplied with a 2D random number $r \in [-1,1]$
- **r** varies on 3 spatio-temporal correlation scales (500km and 6h, 1000km and 3d, 2000km and 30d)
- Stochastic perturbation scales with the magnitude of parametrization tendencies

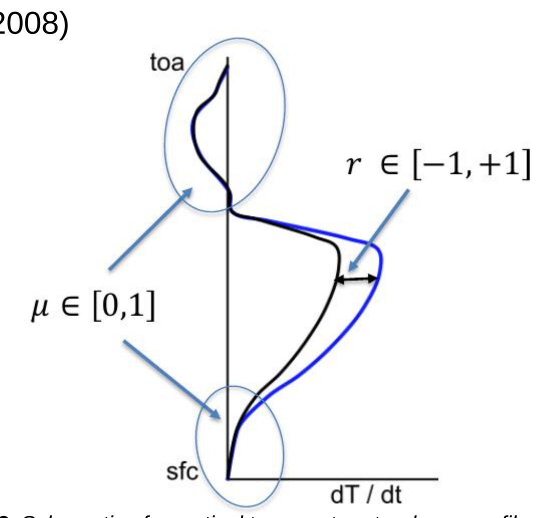


Fig. 2: Schematic of a vertical temperature tendency profile obtained by parametrizations (black line) and its perturbation with a random number r (blue line). Source: www.ecmwf.int

Research questions and Approach

Research questions

- Large parametrization tendencies in vicinity of WCBs due to cloud-condensational processes lead to introduction of strong perturbations by the SPPT-scheme

→ **Are WCBs and their diabatic outflow sensitive to the SPPT-scheme?**

→ **Do these sensitivities depend on model resolution and the setup for trajectory calulation?**

Experimental design

- NWP-simulations of a weather regime transition case with the ensemble prediction system (EPS) of the Integrated Forecasting System (IFS) with 51 members at TCO 639 (18 km) and TCO 399 (36 km)
- 3 experiment setups:
  - Operational setup (**CTRL**)
  - Experiment with disabled model uncertainties (**no-SPPT**)
  - Experiment with disabled initial condition perturbations (**no-INI**)

Post-processing

- Lagrangian detection of WCB-air streams in all members of the ensemble forecast using LAGRANTO (Sprenger and Wernli, 2015)
- Calculation of 48-h forward trajectories starting at an equidistant grid (every 100km) below 800 hPa for different spatial (1.0°, 0.5°, 0.25°) and temporal (6h, 3h, 1h) model output resolutions
- Filtering trajectories which ascend at least 550 hPa during 48h, tracing of Θ, Θ_e, PV and Q along their path and gridding trajectories onto 2D-fields to calculate WCB-probabilities in the ensemble

WCB-sensitivities on SPPT in a case study

Case overview (Grams et al., 2018)

- Forecast bust initialized on 2016-03-07 00 UTC with very low ACC-values in Europe
- Wrongly represented WCB over the North Atlantic at early lead time (48-96 h) led to a wrong depiction of the large-scale flow pattern
- Figs. 3-5 show a later situation (WCB starting at lead time 108 h)

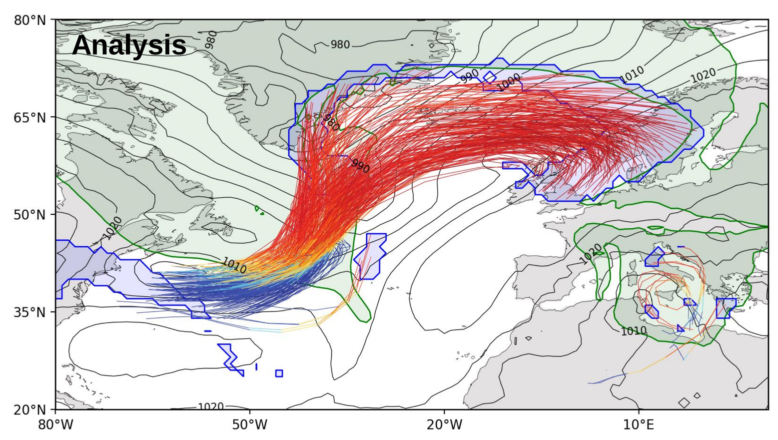


Fig. 3: Analyzed 48h WCB-trajectories and SLP contours on March 11th 12 UTC and WCB-outflow and 2 PVU at 315K on March 13th 12 UTC, 2016

Spatial structure of SPPT-influence (Fig. 5)

- The differences between WCB-outflow of **CTRL** and **no-SPPT** are mostly positive, indicating that more diabatic outflow is present when SPPT is active
- The largest differences of WCB outflow between **CTRL** and **no-SPPT** are mostly located close to the wave guide. The different positions of the ensemble-mean 2-PVU contours show an effect of SPPT on the Rossby-wave pattern

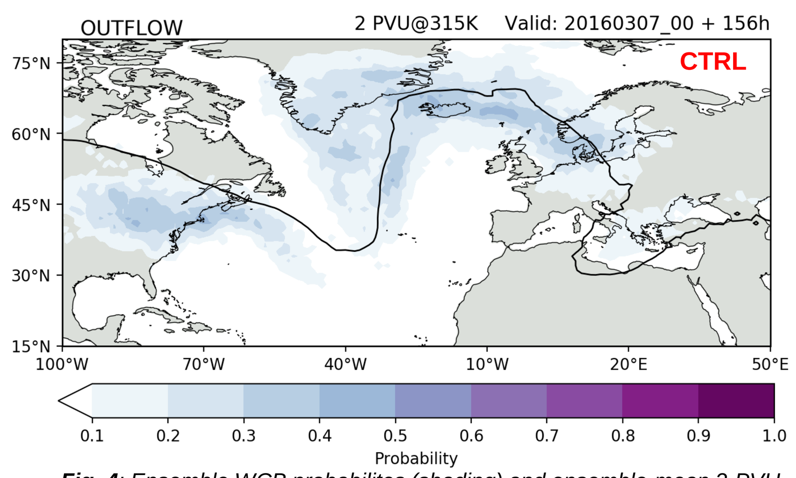


Fig. 4: Ensemble WCB probabilites (shading) and ensemble-mean 2-PVU contour at 315K of CTRL on March 13th 12 UTC, 2016 (leadtime +156 h)

Systematic effects (Figs. 6)

- Calculation of net diabatic heating, minimum outflow pressure and ascent speed of all trajectories over the North Atlantic in the forecast for all ensemble members for the three experiments (1.0° spatial and 6h temporal resolution)
- Trajectories are heated stronger and ascent higher and faster when SPPT is active

→ **stochastic zero-mean perturbations lead to a non-zero-mean response**

- Due to the very low spread in **no-INI**, the probability densitiy functions reflect only one scenario and are therefore not representative

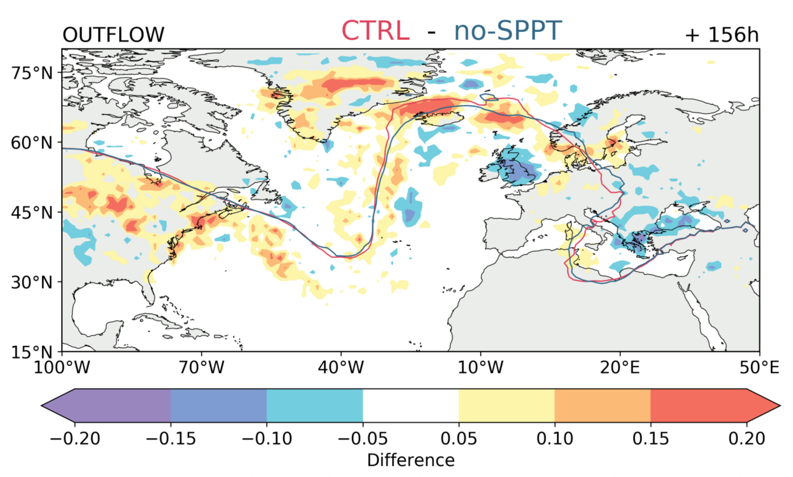


Fig. 5: WCB probability difference of CTRL – no-SPPT (shading) and ensemble-mean 2-PVU contours at 315K on March 13th 12 UTC, 2016 (leadtime +156 h)

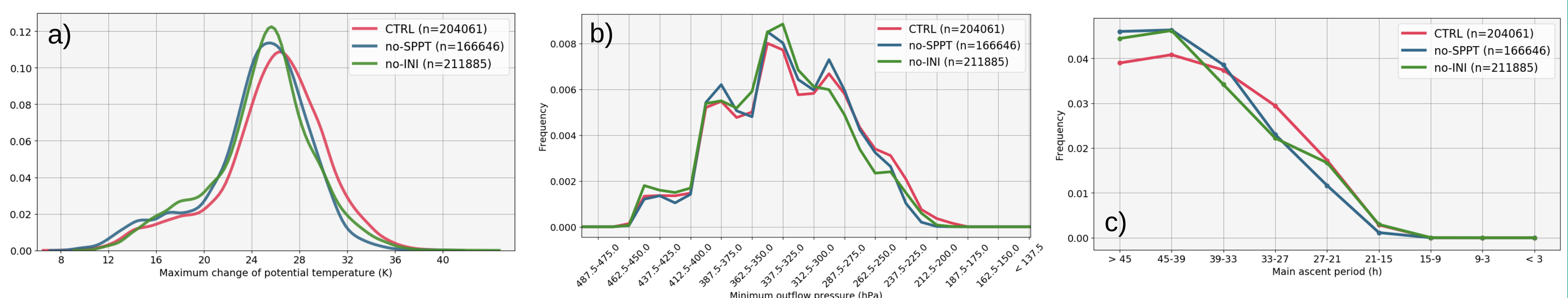
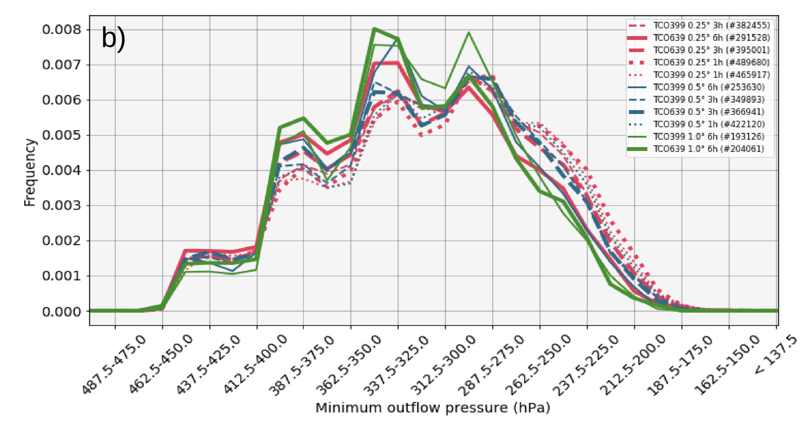


Fig. 6: Probability density functions of the quantities latent heating rate (a), minimum outflow pressure (b) and main ascent period (c) of all WCB-trajectories over the North Atlantic in the forecast for all ensemble members for the three experiments CTRL, no-SPPT and no-INI.

Role of model resolution and LAGRANTO setup

- WCB-quantities are calculated for different model resolutions and spatial and temporal model output in the **CTRL** experiment
- Stronger latent heating, lower outflow pressure and faster ascent rates for higher temporal and spatial resolutions
- Trajectory time stepping has largest effect, followed by grid spacing of model output. Smallest effects can be seen for native model resolution



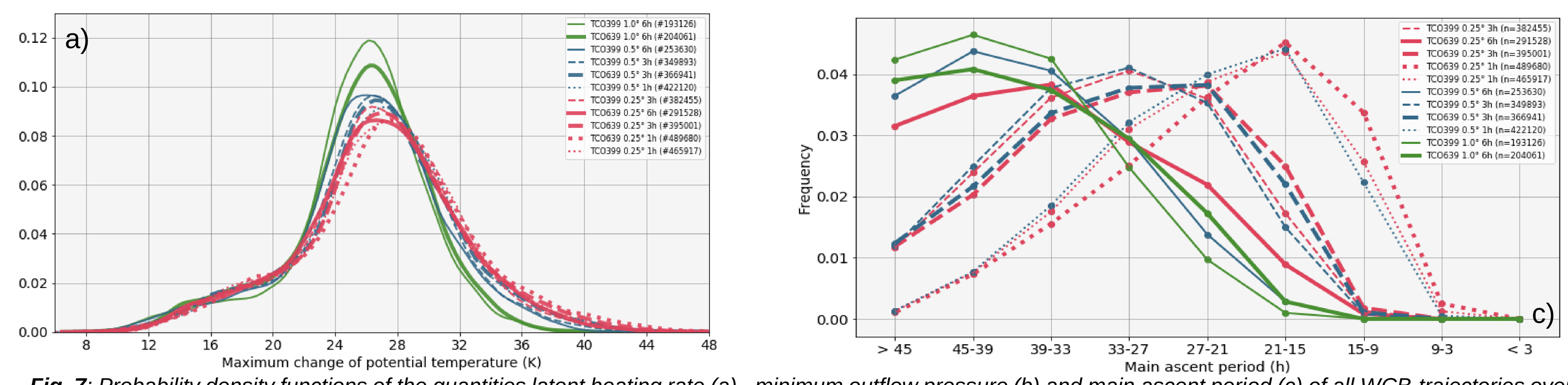


Fig. 7: Probability density functions of the quantities latent heating rate (a), minimum outflow pressure (b) and main ascent period (c) of all WCB-trajectories over the North Atlantic in the forecast for all ensemble members for different model resolutions (TCO639, TCO 399) and spatial (1.0°, 0.5° and 0.25°) and temporal (6h, 3h, 1h) data output

Conclusions and Outlook

- The SPPT-scheme tends to increase the number of trajectories fulfilling the WCB-criterion and increases the latent heating, the ascent speed and the outflow height of WCBs

  → **stochastic perturbations produce a non-zero-mean response, probably due to non-linearities in WCB-dynamics** (e.g. Tompkins and Berner, 2008)

- WCB-related quantities are strongly sensitive to the setup of trajectory calculation, especially the time stepping and the grid spacing of the model output

  → **Compromise between computational cost and representation of processes is necessary**

- Systematic investigation of sensitivity of WCB-outflow on SPPT with experiments globally over a longer time period (~2 months)

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