Analysis of Uncertainty in Large Scale Climate Change Projections over Europe

1 Introduction
Quantifying and reducing the uncertainties in climate change projections is currently one of the biggest issues in climate research. The major sources of uncertainty in global climate change projections are:

- external variability of the climate system
- model uncertainty
- data reconstruction method

Previous studies dealing with uncertainties in climate change signals (CCSs) mainly focus on 2 m temperature and precipitation. Here not only surface but also upper air parameters are analyzed to address the following topics:

- deriving a detailed overview of the magnitude and uncertainty of CCSs over Europe
- analyzing the vertical distribution of CCSs
- quantifying the sources of uncertainty in CCSs

The results of this study aim to aid the application of global climate scenarios as boundary conditions for regional climate change impact studies in Europe.

2 Data and Methods
2a) Domains and Data
The focus area of this study is central Europe (see Fig.1). Nine parameters (described in Tab.1) from 84 runs (23 different GCMs) of the Climate Model Intercomparison Project 3 (CMIP3) are considered. Only one CMIP3-GCM (ECH-G) was disregarded because of missing data.

For the CCSs calculation data of the B1, A1B, and A2 emission scenario runs and the reference period 20C3M data are used.

2b) Climate Change Signals (CCSs)
For the CCSs calculation all perturbed initial condition runs of one GCM are averaged (but not for the uncertainty analysis) and shown in box-whisker plots. The CCSs are calculated for two different time periods:


2c) Uncertainty Estimation
The uncertainty estimation was done with a method described in DEQUE et al. (2007). The basic idea is to use the analysis of variance (ANOVA) method to split the total variance into sums according to the uncertainty components.

However, to use the ANOVA all GCMs must have simulations in all three emission scenarios and overall nine perturbed initial condition runs. Therefore, a missing data reconstruction method is used to estimate the CCSs of the not missing GCM simulations.

3 Results & Discussion
3a) CCS Analysis
Positive CCSs are projected by all simulations in all seasons for air temperature (Fig.2a, and 3 Ia & Ib), geopotential height, and specific humidity. The CCSs of those three parameters are increasing with altitude in the Troposphere (Fig 2b, 2c). The increase in specific humidity is in good agreement with temperature increase following the Clausius Copeyron equation.

3b) Uncertainty Analysis
Temperature (Fig.4 & c & d), precipitation (Fig.5 & c & d), and specific humidity are most uncertain in summer (weak synoptic scale forcing, smaller scale processes). Parameters which are stronger related to larger scale processes, like wind speed, sea level pressure and geopotential height, have their uncertainty maximum in winter.

Model uncertainty contributes the major fraction to total uncertainty (between 50 % and 85 %) particularly in the first half of the 21st century (Fig. 4-7). Emission scenario uncertainty is small (below 10 %) in the first half and higher only for temperature, specific humidity, and geopotential height in the second half of the century (Fig. 4 & 6). Internal uncertainty is normally below 20 %. The uncertainty components of geopotential height and eastward wind speed show a height dependency (Fig. 6 and 7).

The absolute uncertainty is higher in the small domain D2 for all parameters, seasons, and periods. However, the relative contributions of the uncertainty components or the seasonal variation of absolute variance stays similar.

4 Conclusions
- 2m temperature (T2M), geopotential height (ZG), and specific humidity (HUS) are projected to increase by all GCMs.
- For all other parameters, GCMs show different signs of climate change signals (CCSs) and partly different directions for different seasons.
- GCM formulation contributes the largest part to total uncertainty (50-80 %) especially in the first half of the 21st century.
- Emission scenario uncertainty is negligible until 2050 and gets only important for T2M, ZG, and HUS until 2100.
- Internal uncertainty is small (9 %) for 30 year mean CCSs. However, internal variability is expected to be more dominant when looking at shorter time periods.
- Studies focusing on downscaling, regional climate change, and regional climate change impacts in Europe should be based on a carefully selected set of GCMs in order to avoid undersampling uncertainty. It is by far more relevant to reasonably capture model uncertainty than emission scenario uncertainty. This is particularly true for the first half of the 21st century and particularly important for more uncertain parameters like precipitation.

References: