The computing time proposal is for three sub-projects at University of Leipzig that contribute to the Collaborative Research Center (Sonderforschungsbereich/Transregio TR172) "ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms, $(AC)^3$" (http://www.ac3-tr.de/).

Project "D01: Large–scale dynamical impacts on regional Arctic climate change"
http://www.ac3-tr.de/projects/cluster-d/d01/
Wwe shall investigate the interaction between the variable large–scale circulation and Arctic regional climate patterns. We will diagnose the degree of Arctic Amplification on regional scales in response to large–scale dynamics and its past and projected changes. The central question is to what degree regional Arctic climate change and Arctic Amplification is modulated by changes in large scale horizontal heat fluxes, planetary wave–mean flow interactions, in particular during sudden stratospheric warming events, and generally tropospheric and stratospheric circulation patterns, expressed in terms of the variability of Northern hemisphere circulation variability, e.g., of the NAO (North Atlantic Oscillation) and the NAM (Northern Annual Mode). This includes potential linkages to stratospheric ozone, and the question which part of Arctic Amplification is generated by stratosphere–troposphere exchange. Meteorological reanalyses as well as climate model simulation results, such as available in the Coupled Model Intercomparison Project Phase 5 (CMIP5) (Taylor et al., 2012) multi–model ensemble, together with additional climate model runs with the ICON model, conducted in the project, will be used. The variability of large scale heat fluxes, planetary waves, and dynamical patterns like NAO and NAM will be analysed statistically in connection with regional Arctic tropospheric and surface parameters focusing on temperatures and sea ice extent. The final result will be a quantitative analysis of the:
– Role of horizontally and vertically coupled large–scale circulation changes on regional patterns of Arctic climate change and Arctic Amplification,
– Relative importance of changes in the large–scale circulation and of local feedback processes on Arctic Amplification, regionally resolved in the Arctic, and
– Role of troposphere/stratosphere coupling for Arctic Amplification, including the role of stratospheric ozone variability.

This will provide a tool to interpret observed regional climate change and to distinguish between the effects of changes in the large–scale circulation and those of regional physical processes responsible for Arctic Amplification.

Regionally dependent large–scale and local feedback effects are expected to be of different strength, and the question is, where local feedback effects are observed most strongly.

Project D02: Modelling aerosols and aerosol-cloud interactions in the Arctic
http://www.ac3-tr.de/Projects/Cluster-D/D02/

The quantification of the aerosol and cloud processes and their effects is important to understand the current rapid climate change and to improve predictions of future climate in the Arctic. The quantification of the aerosol direct and indirect climate forcing is particularly challenging in the Arcticdue to specific characteristics of polar regions, such as the dramatic seasonal changes in insolation and surface albedo. Large variations in the distribution and chemical, microphysical, and

optical properties of Arctic aerosol further complicate the assessment of the aerosol effects. Current climate model predictions for the Arctic region largely suffer from uncertainties related to the model representation of mixed–phase Arctic clouds, aerosol–cloud interactions, the vertical layering and deposition of aerosol, and the impact of aerosol processing on radiative properties. All these processes also impact the highly uncertain aerosol transport to the Arctic. This study will, therefore, focus on the three main factors of the direct and indirect aerosol radiative effects: (i) the particle mixing/ageing, (ii) the deposition on snow and ice, and(iii) the interaction with clouds.
Using a new–generation general circulation model, the aerosol transport and impact on radiation and clouds will be investigated. Based on the model simulations, the direct radiative forcing and related dynamical feedback mechanisms will be quantified for the Arctic region. This will include considering the impact of ageing and mixing processes on microphysical and optical properties as well as the snow/ice–albedo forcing. A particular focus will be on black carbon (soot) from increasing ship and wildfire emissions. Aerosol–cloud interactions and the aerosol indirect radiative forcing will be studied by applying a comprehensive double–moment cloud microphysical scheme and by evaluating and improving existing cloud parameterizations in the climate model, with particular emphasis on mixed–phase clouds, to explore their role in the Arctic Amplification.

Project E01: Assessment of Arctic feedback processes in climate models
http://www.ac3-tr.de/Projects/Cluster-E/E01/

Arctic Amplification is driven by changes in the large scale circulation on the one hand, and by local forcing and feedback mechanisms on the other hand. This project investigates quantitatively the physical feedback mechanisms enhancing or dampening climate change following a radiative forcing, and evaluates and improves their representation in general circulation models. These are the Planck, water vapour, lapse rate, surface albedo and cloud feedback mechanisms. We aim at a quantitative characterization of the physical climate feedback processes, their relative importance, their distribution, and their uncertainty, in the Arctic region based on climate simulations with General Circulation Models (GCMs). GCMs are known to have difficulties in realistically simulating relevant processes, especially in the Arctic, and particularly for the representation of clouds. Consequently, the approach is two–fold. On the one hand, the models are used to quantify the feedback given the current state–of–the–art, and to characterize to the extent possible the uncertainty. On the other hand, the models are thoroughly evaluated and the representation of the processes in the models by parameterizations is improved.

For the feedback quantification, we will leverage tools as the partial–radiative–perturbation method we developed in the past to compute the feedback strengths from simulation results of available multi–climate–model ensembles (CMIP5 and, as they become available, CMIP6). The geographical distribution of the feedback strengths in the Arctic is assessed, and the uncertainty is quantified from the inter–model spread and the methodological uncertainty. A particular focus is on the cloud feedback. We will thoroughly assess the cloud parameterizations in the ICON climate model applying different cloud parameterizations, and making use of the ground–based supersite observations. Cloud processes and distributions in the GCM will be evaluated in a process–oriented manner with active satellite measurements (cloud radar and lidar) as a reference. Statistical relationships will be used to assess the representation of the temperature–, water vapour– and surface albedo feedback mechanisms in the models of the multi–model ensamble, in comparison to observations. In a climate–oriented evaluation, trends and their uncertainty in transient, historical simulations, will be evaluated against observed trends in the Arctic. The results of the process–oriented evaluation will be used to define and perform dedicated simulations with the most reliable model versions. From these simulations we will analyse which means (observations network, length of records) might allow a detection and attribution of the feedback processes with statistical significance.