Project: **688**

Project title: **Zirren in der Tropopausenregion**

Project lead: **Peter Spichtinger**

Report period: **1.1.2014 - 31.12.2015**

Progress report:

(1) *subproject CIRRUS-INH*

In this project, inhomogeneities inside cirrus clouds are investigated (DFG-Project) using the EULAG model including the ice microphysics. We further investigated the case of Kelvin-Helmholtz instabilities with a dominant wave length, depending on the environmental conditions (vertical extension of the shear layer, shear and stability). Using the high resolution output of the simulations, we investigated the frequency spectrum for thermodynamic/dynamic variables (e.g. temperature, vertical wind and humidity) and for microphysical variables. In fact, in the first case most variables represent the dominant wave numbers in a sufficient way. However, the wave number could hardly be detected in microphysical variables. It depends crucially on the ratio of time scales for microphysical processes and driving dynamic forcings, if the wave structure could be seen in cloud variables or even not. In fig. 1 an example of the vertical wind field and the resulting FFT analysis is shown.

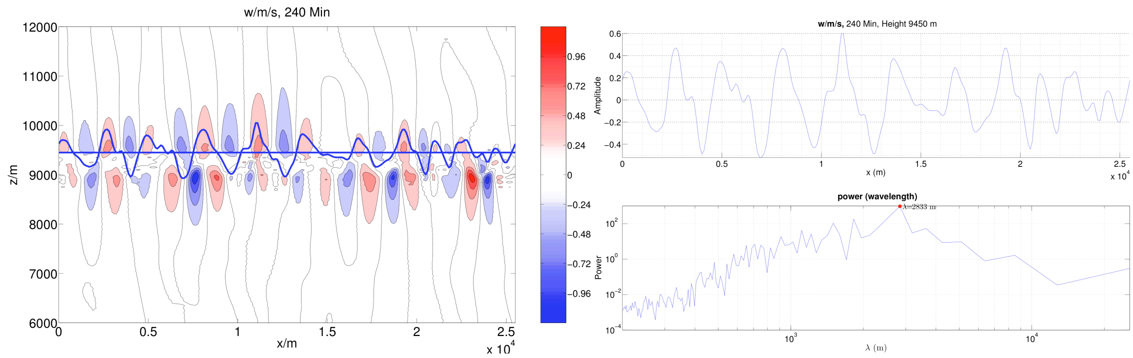

Figure 1: left: vertical wind field and cross section at 9km. Right: FFT analysis of cross section

Additionally, realistic simulations of cirrus clouds as measured in the field campaigns for the underlying DFG project were carried out. For several situations, 2D and 3D simulations of cirrus clouds at the tropopause were carried out. Here, we investigated different synoptic cases. From about 5 cases, we can highlight 2 interesting cases.

In the first case, a nucleation event of a cirrus cloud embedded into a very slow upward motion could be measured. Such measurements are quite seldom. In this case, very few ice crystals could be found. The simulations suggest that we cannot decide about the nucleation pathway (homogeneous or heterogeneous), because both extreme cases (switching off one of these competing effects) leads to the same number concentrations. Thus, for slow updrafts the exact nucleation pathway is not important anymore, since all lead to the same state.

In the second case, a potentially unstable situation including shallow cirrus convection (Spichtinger, 2014) could be measured. We could represent qualitatively the effect, however the exact values of cirrus properties depend crucially on the initial states of the simulations. In fig.2 an example of the 2D simulations is shown.

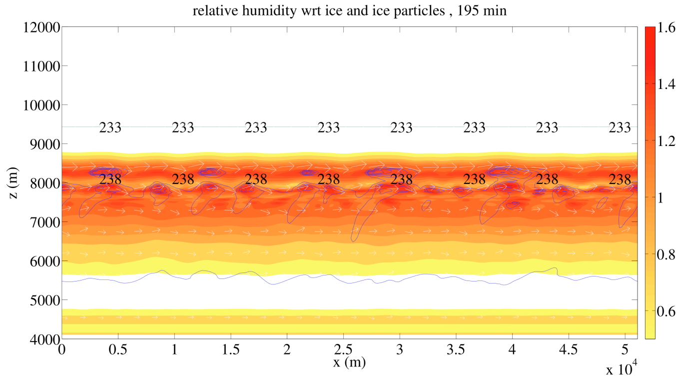

Figure 2: contour plot of relative humidity (color bar) and ice water content (blue isolines) for a potentially unstable scenario.

The results of the investigations will be submitted in a peer-reviewed journal (ACP). The work was carried out within the DFG project “Spatially Inhomogeneous Cirrus: Influence on Atmospheric Radiation” (SP 1163/3-1).

(2) *subproject CIRRUS-FRONT*

In this project, cirrus clouds along an idealized warm front are simulated. In addition to the simulations as shown in the previous reports, we investigated the possibility of detecting the impact of heterogeneous nucleation in a planned field experiment. A research aircraft should release high concentrations of heterogeneous IN in a developing warm front situation and the effect of disturbed vs. undisturbed cirrus clouds should be measured. Unfortunately, we could show in the simulations that the difference between these two situations would be hardly detectably, even under the highly controlled scenario in the simulations (as shown in fig. 3)

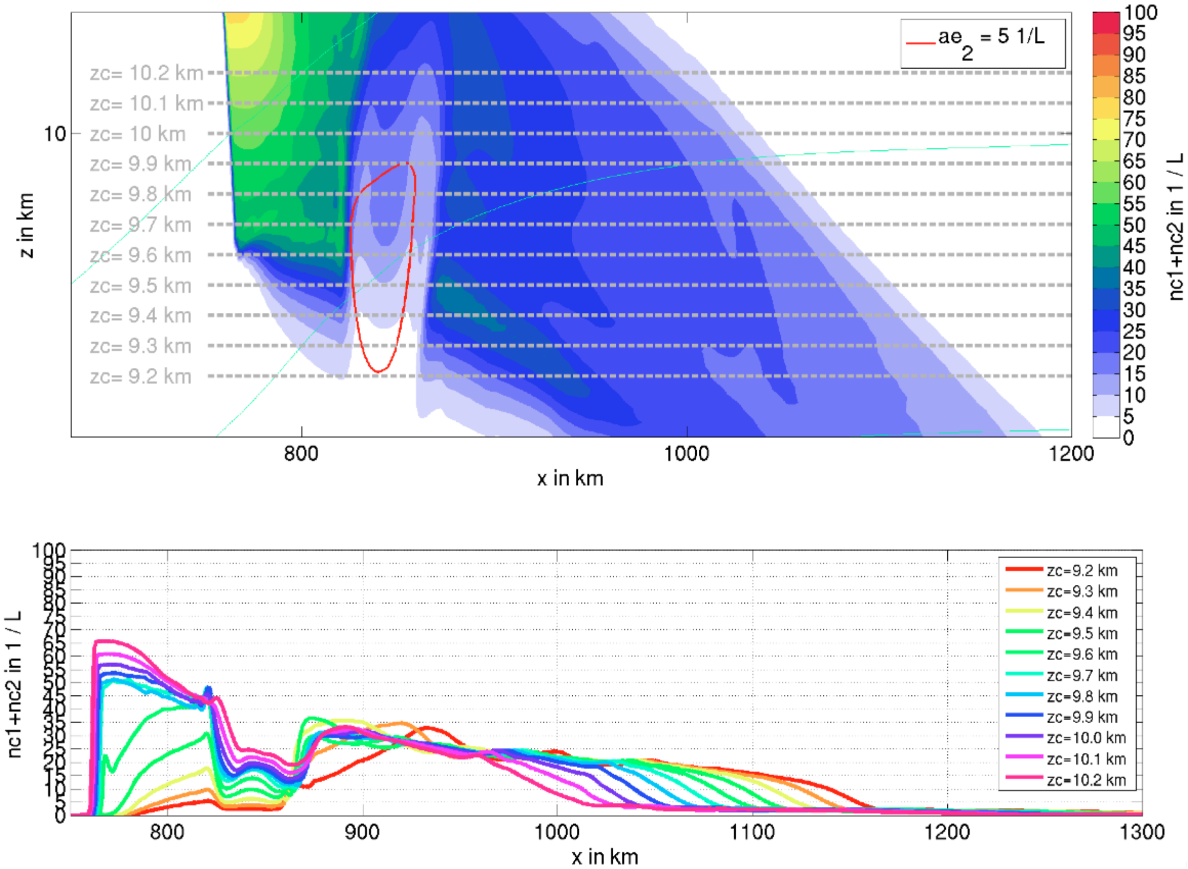

Figure 3: Top panel: ice crystal number concentration in a frontal cirrus, disturbed by additional INs. Bottom panel: Number concentrations at horizontal sections.

(3) subproject CIRRUS-ETP

In this project we investigated the impact of convective cells on the exchange of tracers close to the tropopause. For this purpose we simulated cirrus clouds in a potentially unstable layer, which was moved upwards and downwards. In figure 4 the distribution of the tracers (marked by their vertical start position) are showed at the beginning and the end of the simulation. Shallow cirrus convection leads to mixing of the tracers and to destabilisation of the whole layer. We will extend this kind of simulations in order to investigate the impact of cirrus clouds on mixing in a more comprehensive way and extend our setups to 3D simulations.

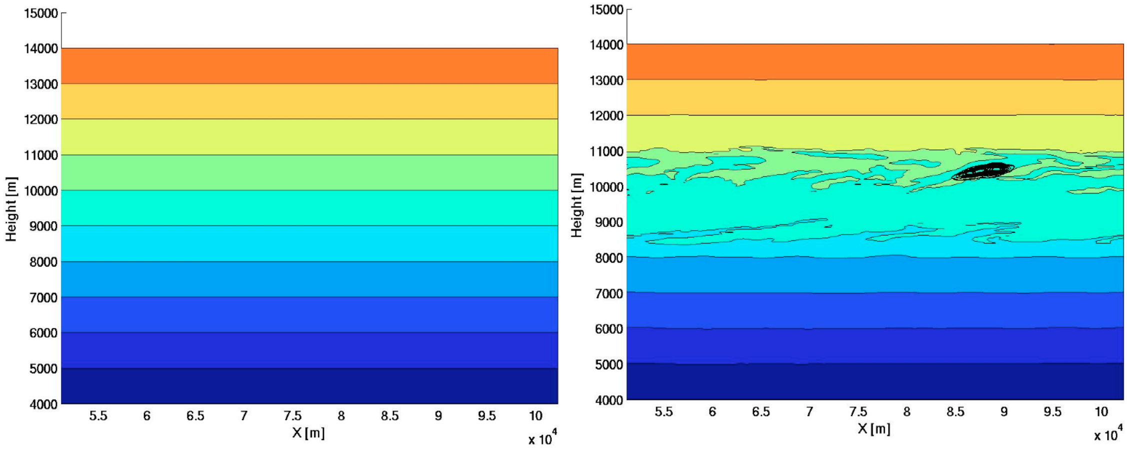

Figure 4: Start and end situation of a tracer marked by vertical position at the beginning after experiencing shallow cirrus convection.

(4) subproject CIRRUS-GW (new)

We already started with a new subproject (see also request for 2016) on feedbacks between the tropopause dynamics and gravity waves and their impact on cirrus clouds. For this purpose we conducted 2D simulations of gravity waves propagating vertically up to and through the tropopause. We investigated different scenarios, where we changed the environmental conditions as background horizontal wind, wind shear, stratification and excited wave lengths. In figure 5 one example of the simulations is shown.

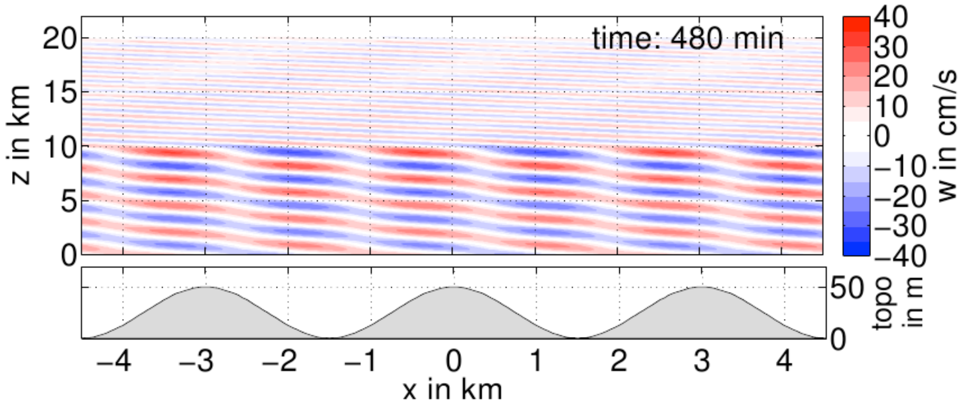

Figure 5: Propagating gravity waves for typical stratifications in the troposphere and the stratosphere as simulated with the EULAG model.

The results of the simulations are investigated using wavelet analysis in order to determine the dominant wavelengths and characteristics of the waves after transmission through the tropopause. In addition to the idealized simulations as shown in figure 5 and 6, realistic simulations were carried out, based on measurements of gravity waves during field campaigns in Sweden and New Zealand.

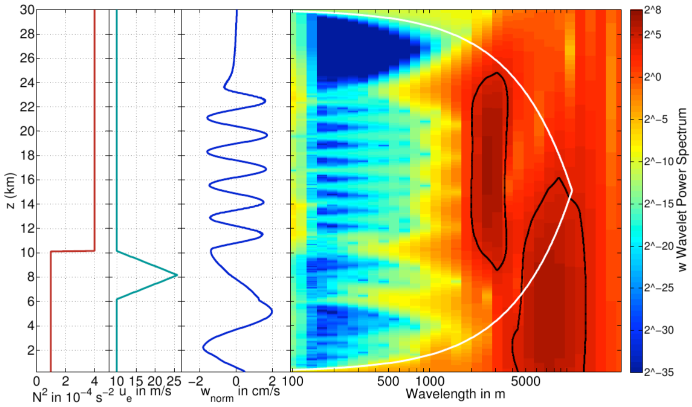

Figure 6: Wavelet analysis of a gravity wave propagating through a tropopause jet.

These investigations are part of an already funded DFG-project ("Modification of gravity waves propagating across the tropopause", SP 1163/5-1) within the framework of the research group MS-GWaves . We will continue this work within the next project period (i.e. 2016).