Validation of explicitly resolved orographic gravity waves in ICON simulations

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Motivation

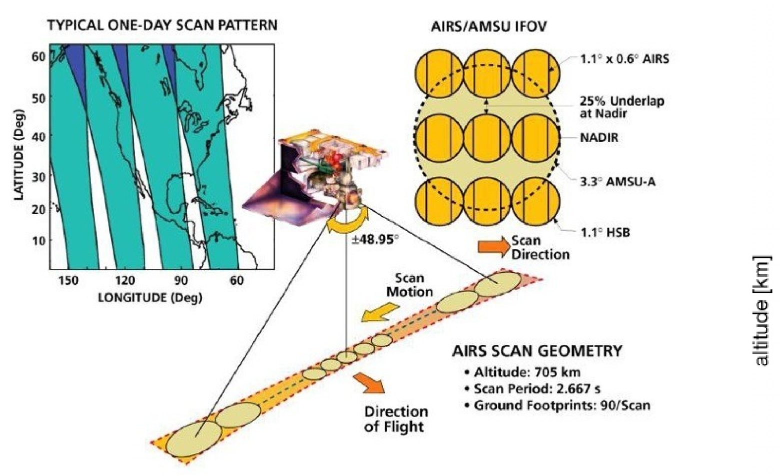
- Orographic waves are part of the complex dynamical interaction of winds with topography, and one piece in the puzzle that is topography's effect on global circulation.
- Parameterized OGW drag provides an important control on model wind biases at levels from the surface through the middle atmosphere, and these alterations in winds in turn affect stationary and synoptic Rossby wave propagation and dissipation
- Properly tuned OGW drag parameterizations can improve weather model prediction skill from synoptic to seasonal timescales
- Research activities directly linked to the International Space Science Institute's project 'New Quantitative Constraints on Orographic Gravity Wave Stress and Drag: Satisfying Emerging Needs in Seasonal-to-Subseasonal and Climate Prediction' [1]
- The ISSI project will utilize recent advances in the analysis of high-resolution satellite data for studies of the full 3D properties of orographic gravity wave (OGW) events, and will evaluate of existing and new parameterizations of OGW drag in global models
- The study focuses on simulations and observations for OGW hotspots in the southern hemisphere, in particular for the Southern Andes and Antarctic Peninsula and the time period of the Concordiasi field campaign from September 2010 to January 2011

ICON simulations

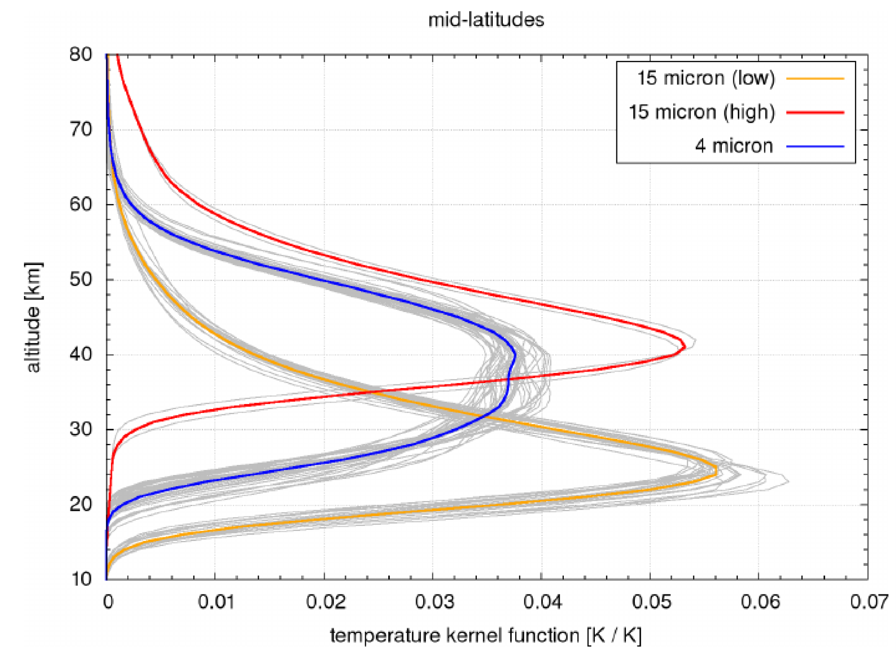
- Simulations are based on ICON V2.5.0
- Simulation of actual events over Southern Andes and Antarctic Peninsula
- Coverage:
  - Latitude: 82.0″S to 34.0°S
  - Longitude: 275.0° - 360.0°
- 12 Overpass Times of AIRS between 9 to 17 October 2010
- Simulations initialized at 12 UTC each day, running for 3 days
- Initial and boundary conditions: operational IFS analysis
- Resolution of horizontal grid: 13 km
- 242 vertical level

The AIRS satellite instrument

Source: http://airs.jpl.nasa.gov



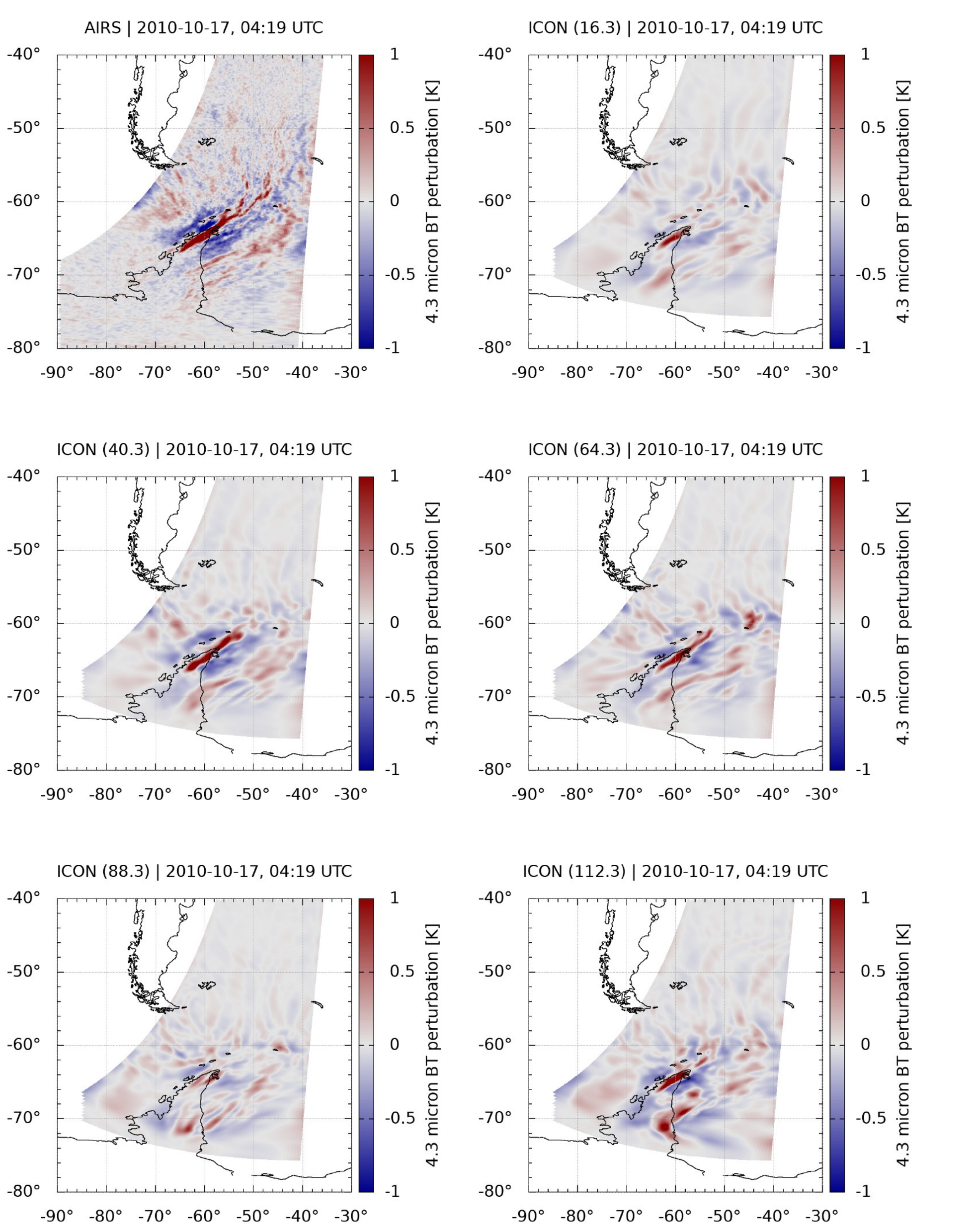
- The Atmospheric Infrared Sounder (AIRS) is one of six instruments aboard NASA's Aqua satellite
- Aqua operates in a sun-synchronous polar orbit with 98° inclination at 705 km altitude
- AIRS measures 14.5 orbits per day with equatorial crossing at 1:30 am and 1:30 pm LT
- AIRS measures about 2.9 million footprints/infrared spectra per day
- Nearly continuous measurements since September 2002
- Can provide information on the 3D structure of OGWs (e.g. Hoffmann and Alexander, 2009; Hoffmann et al., 2013; Ern et al., 2017; Wright et al., 2017; Meyer et al., 2018)



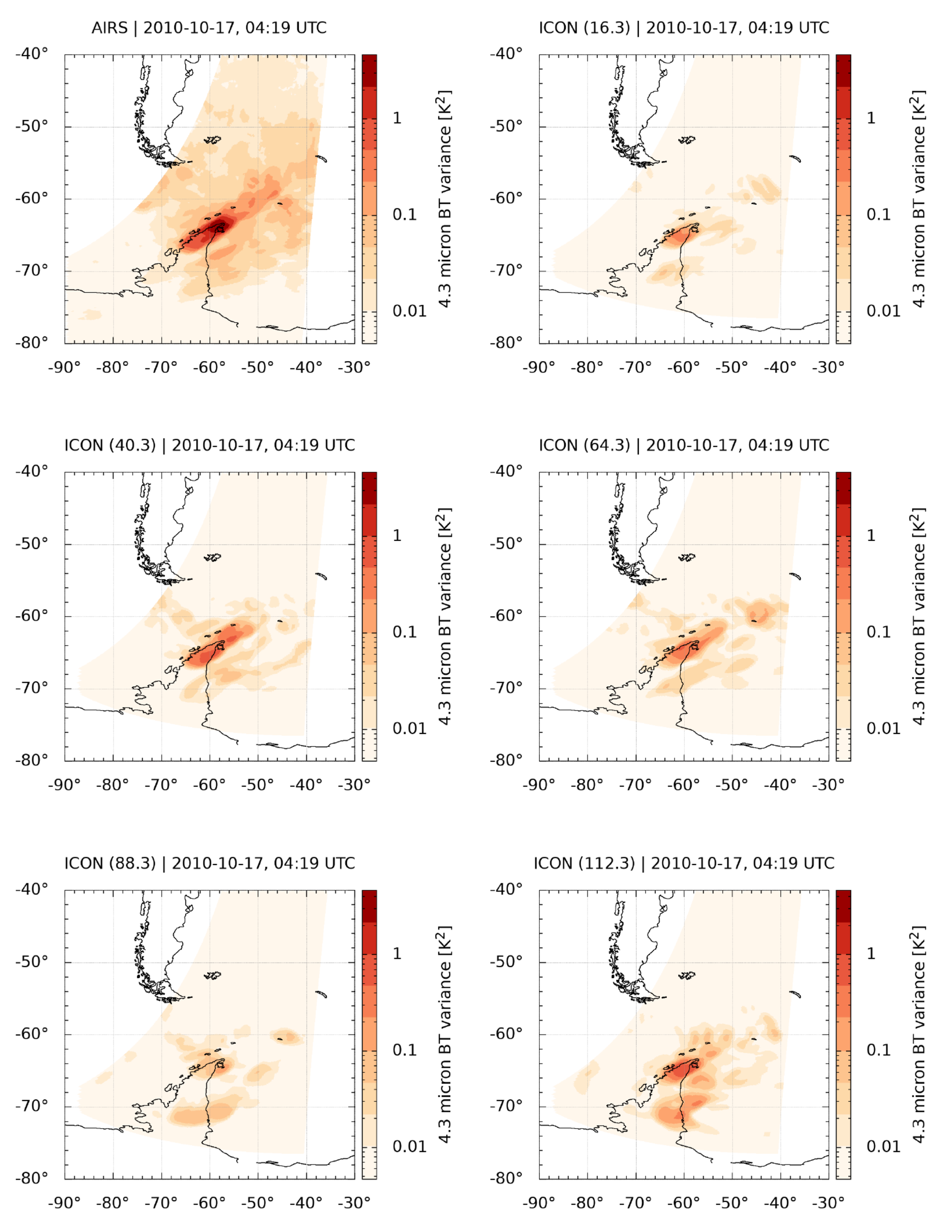
- Model validation based on real and simulated 4.3 and 15 micron AIRS brightness temperature measurements
- Three sets of AIRS channels provide information on stratospheric temperatures at about 20-25, 30-40, and 40-45 km of altitude (see kernel functions)

Influence of spin-up time of the simulation

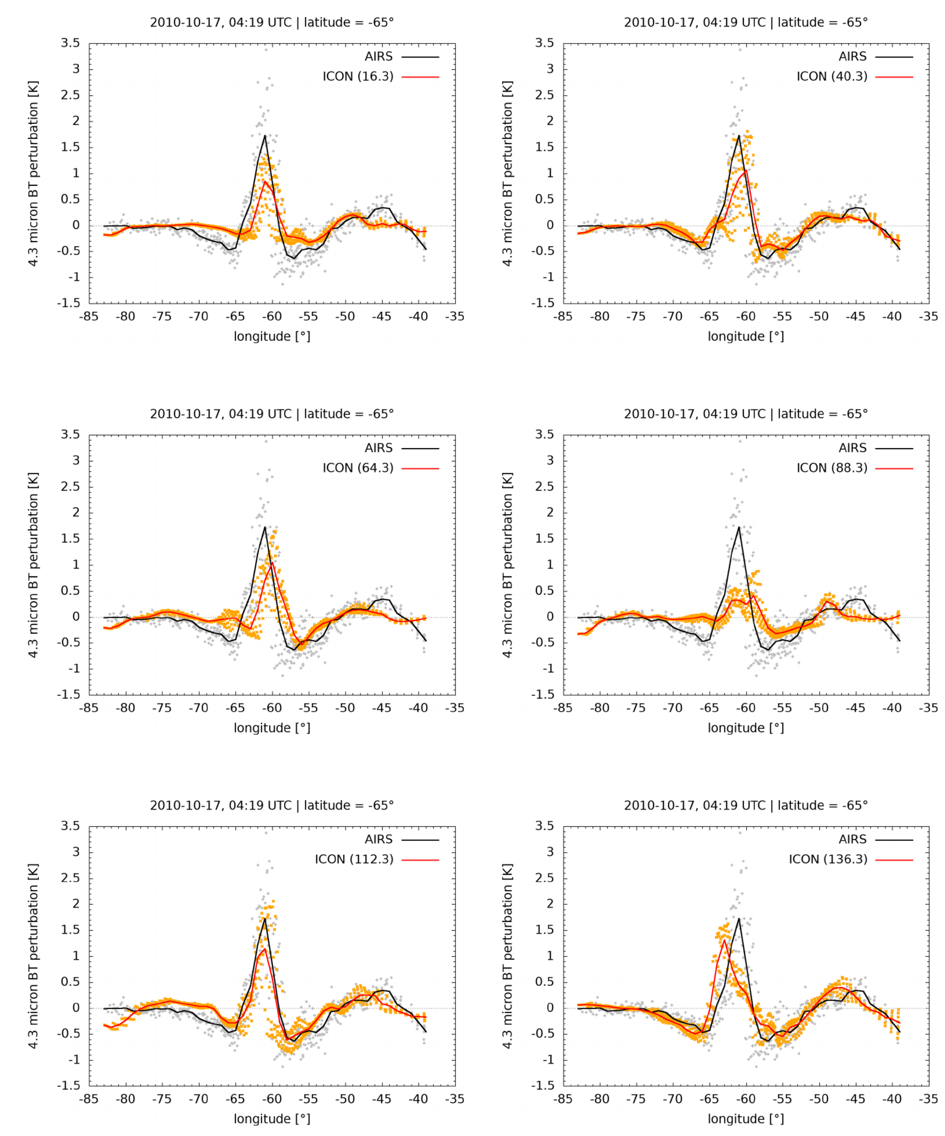
4.3 µm brightness temperature perturbations



4.3 µm brightness temperature variance



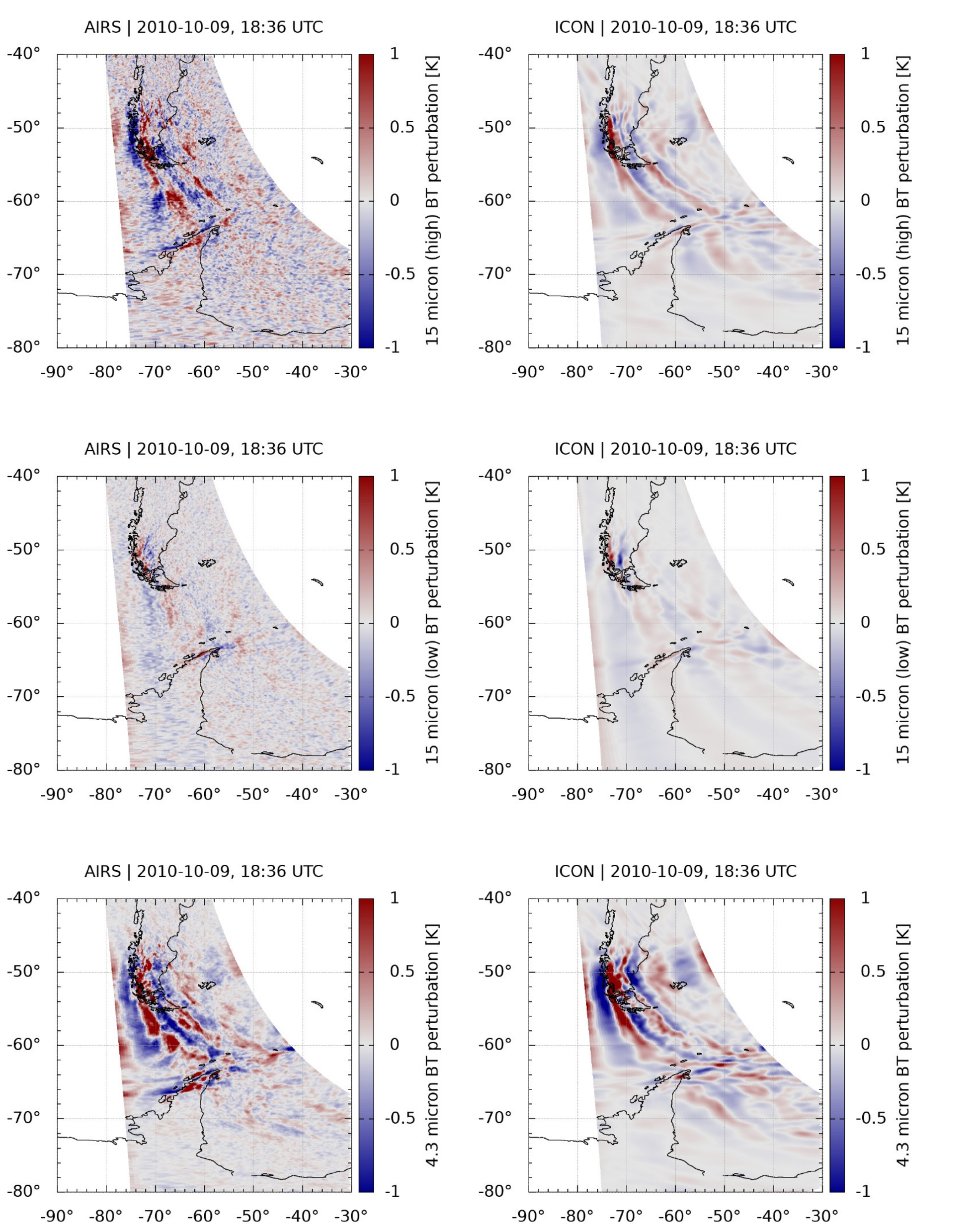
4.3 µm brightness temperature perturbations at -65° latitude



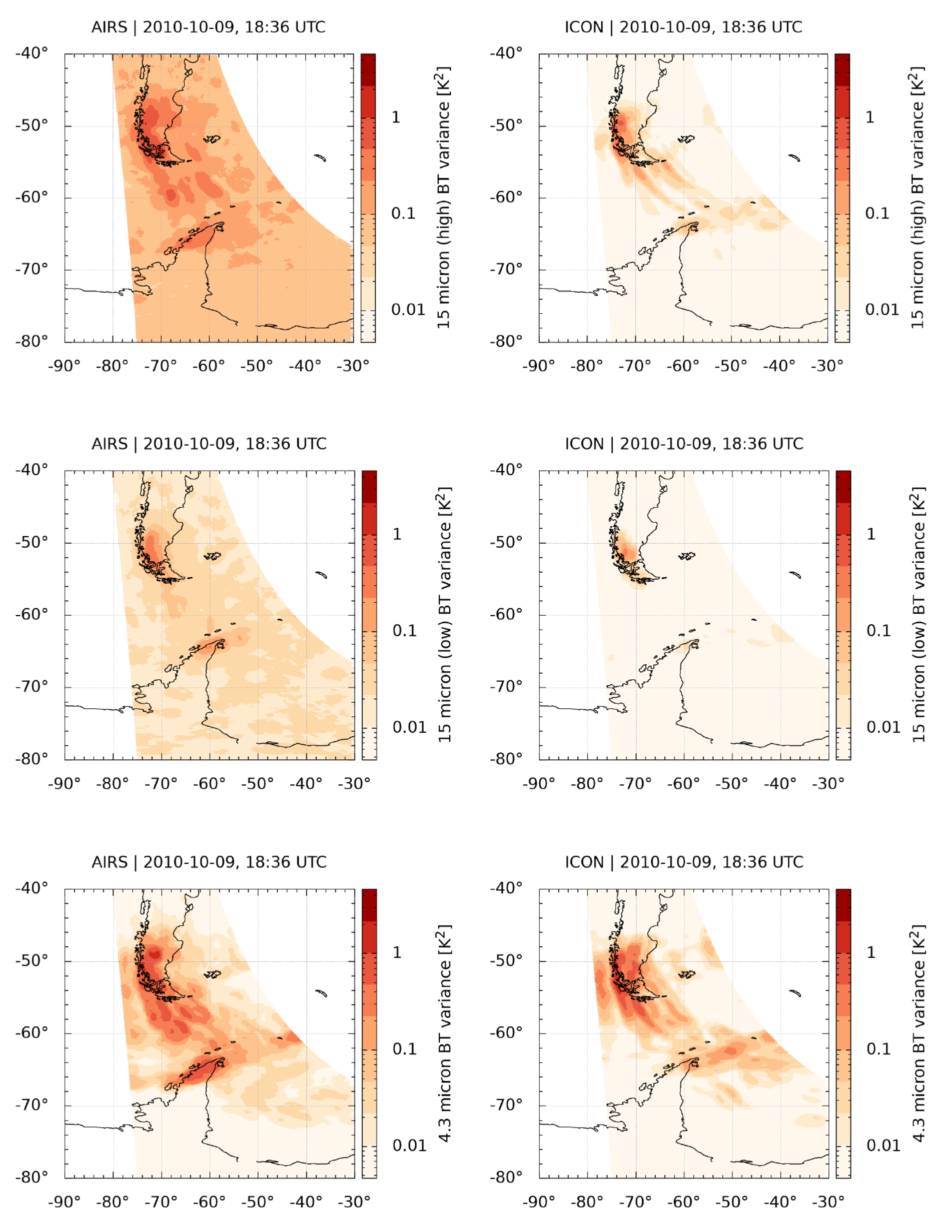
- Influence of spin-up time of the simulation is investigated
- Comparison between AIRS overpass and ICON simulations started 16.3 h, 40.3 h, 64.3 h, 88.3 h, 112.3 h and 136.3 h ahead of the overpass
- Best agreement between measurement and model could be found for starting times inside of 24 and 48 h
- Agreement with previous studies of using the WRF and UM model (Plougonven et al., 2008; Orr et al., 2015)

Comparison between AIRS and ICON

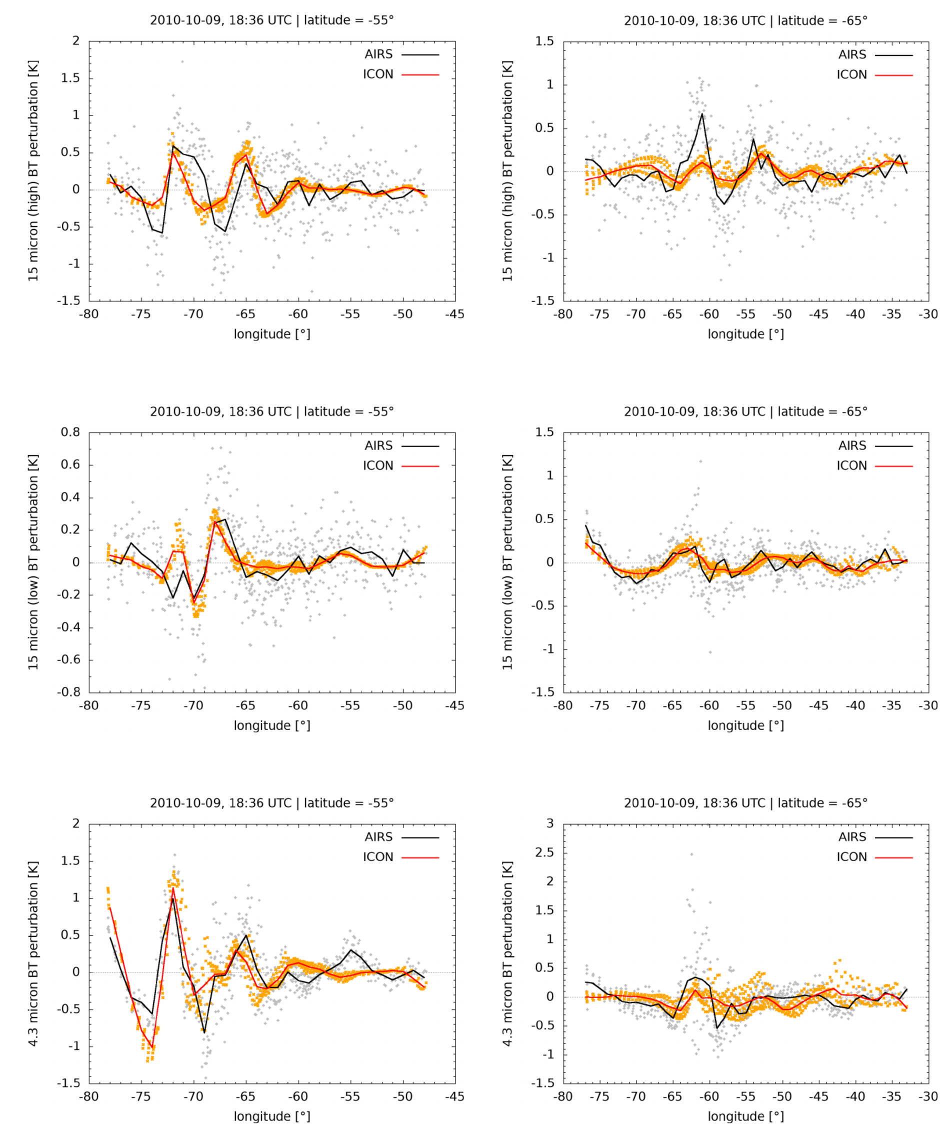
Brightness temperature perturbations for 15 µm high (top), 15 µm low (middle) and 4.3 µm (bottom)



Brightness temperature variance for 15 µm high (top), 15 µm low (middle) and 4.3 µm (bottom)



Brightness temperature perturbations for 15 µm high (top), 15 µm low (middle) and 4.3 µm (bottom) in each case at - 55° latitude (left) and - 65° latitude (right)



- The example of the satellite overpass of the Southern Andes on 9 October 2010 shows particularly good agreement between real AIRS measurements and simulated AIRS data based on ICON output
- ICON model is capable of reproducing realistic horizontal wavelengths, amplitudes, and propagation direction of observed mountain waves
- Remaining differences in observed and simulated wave fields may be attributed to interference with other wave sources (convection, storm system, jets) or differences background wind and stability affecting the propagation of the waves
- Future work will focus on sensitivity test with respect to model resolution and choices of model physics
- Future work will also focus on spectral wave analysis to estimate gravity wave momentum flux and drag from the observations and the ICON simulations

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1) http://www.issibern.ch/teams/consonorogravity/