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Detection of Snow Surface Thawing and Refreezing Using Satellite Data: Implications for Reindeer Herding

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Ice crusts on snow

- Caused by snow surface thawing and refreezing due to
  - Rain on snow – ROS
  - General warming and subsequent cooling

- ROS are related to larger scale weather patterns, such as variations in the North Atlantic Oscillation (NAO) and the Pacific-North America pressure patterns (Rennert et al. 2009)
- Occurrence on regional to circumpolar scale is estimated by use of field data, re-analyses data and global climate models

- Decrease of duration of ice crust on top of snow cover in the Russian Arctic since 1980s (from snow course data)
  - Buligyna, O. & Groisman, P. 2009 (AGU)
- Mid winter ROS events may increase in
  - north western North America and European Russia (Rennert et al. 2009)
  - European Russia (Ye et al. 2008)

Impacts on wildlife

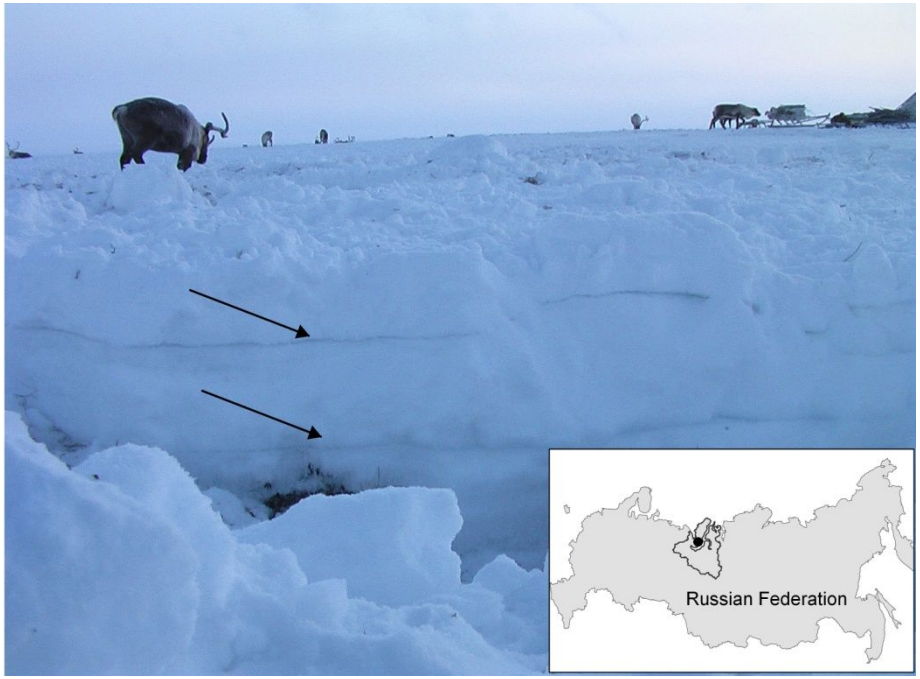
- ROS events are linked with large-scale ungulate deaths
  - reindeer, caribou, elk, musk-ox

- Example: Reindeer
  - Reindeer lichens are a main source of fodder during the winter and are dug up from beneath the snow when it is present.
  - The accessibility of terricolous lichens is therefore in large parts determined by snow properties.
  - Important parameters are the establishment of snow cover in autumn, snow depth, melting of snow in spring and the structure within the snowpack.
  - The refreezing of snow cover is used for modelling the vulnerability of reindeer husbandry to global change (Rees et al. 2008)

- Bartsch, A., Kumpula, T., Forbes, B., Stammler, F. (2010): Detection of snow surface thawing and refreezing in the Eurasian Arctic using QuikSCAT: implications for reindeer herding. Ecological Applications e-View. doi: 10.1890/09-1927

Implications for reindeer herding

- Southern Yamal peninsula has been affected by a rain-on-snow (ROS) event in November 2006.
- The ROS event and subsequent refreezing with formation of ice crusts **forced a major change in migration**.
- Some of the brigades were additionally affected by an event to the west in January and as they migrated back northwards across the snowpack, which still consisted of the previous ice layers. **The loss amounted to 25% of the animals including deaths and still-births resulting from exhaustion and poor nutrition of pregnant females.**



Snow profile taken on the 19th of November 2006. (Photo: Florian Stammler)

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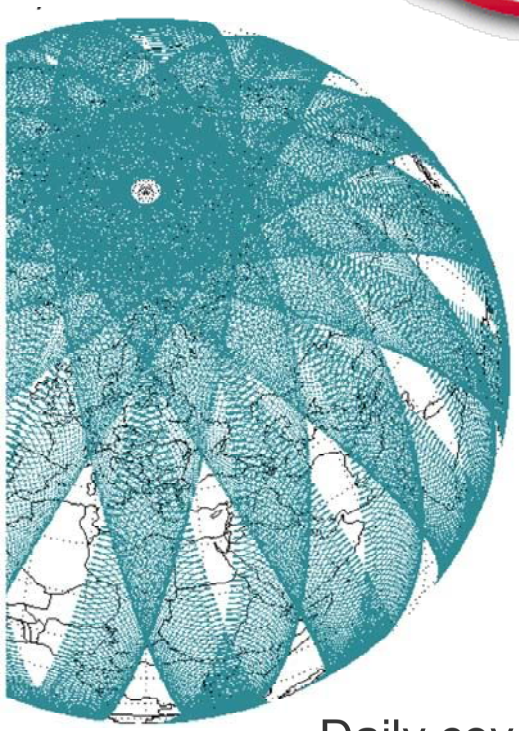
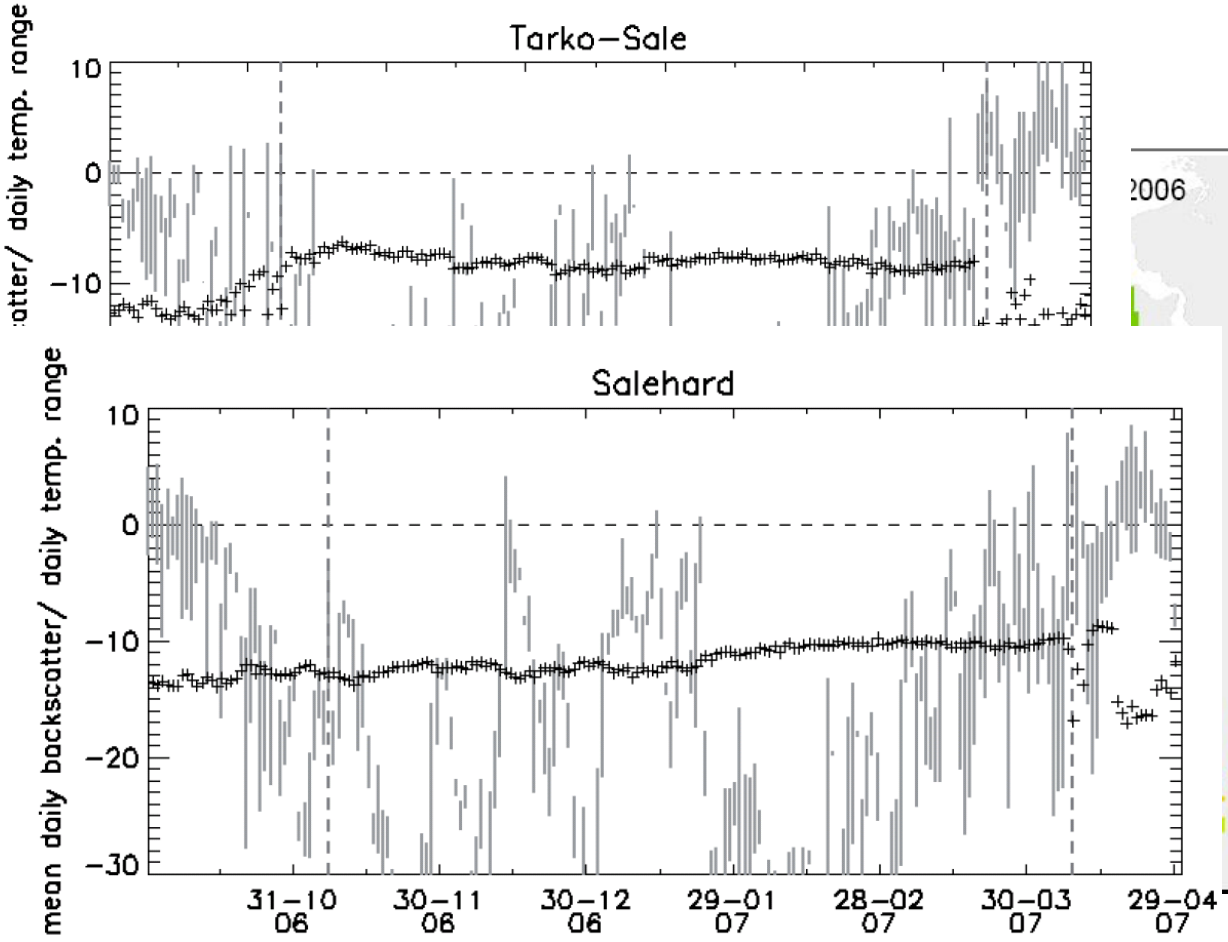
Possibilities of remote sensing

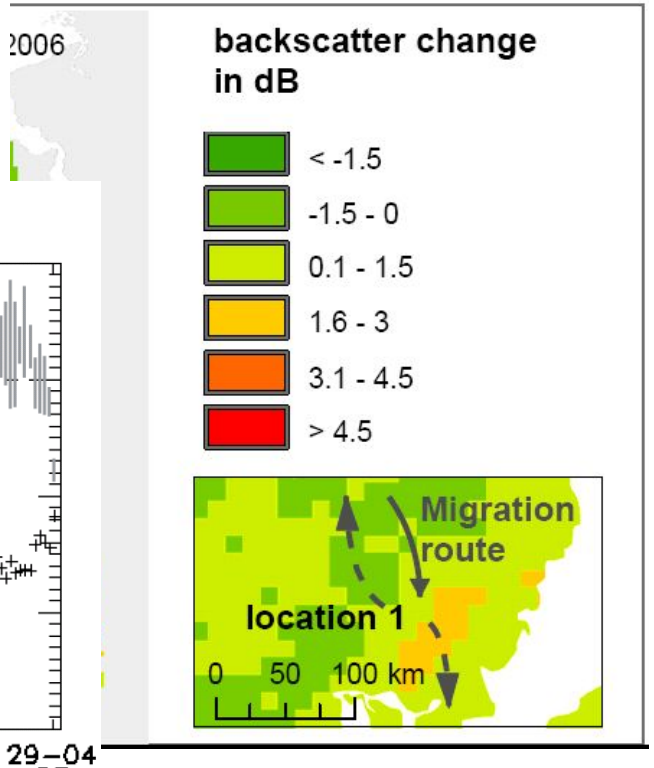
- Sensors working with short microwaves (wavelength in the order of a few cm) are sensitive to changes in the snow pack
- Backscatter behaviour
  - Depends on snow structure and depth
  - Increases due to
    - Snow depth increases
    - Metamorphoses of snow crystals – thaw and refreeze
- Suitable band width is Ku-band (~13.4 GHz)
  - Available from Seawinds QuikScat 2000 – 2009



Daily coverage

The Yamal event





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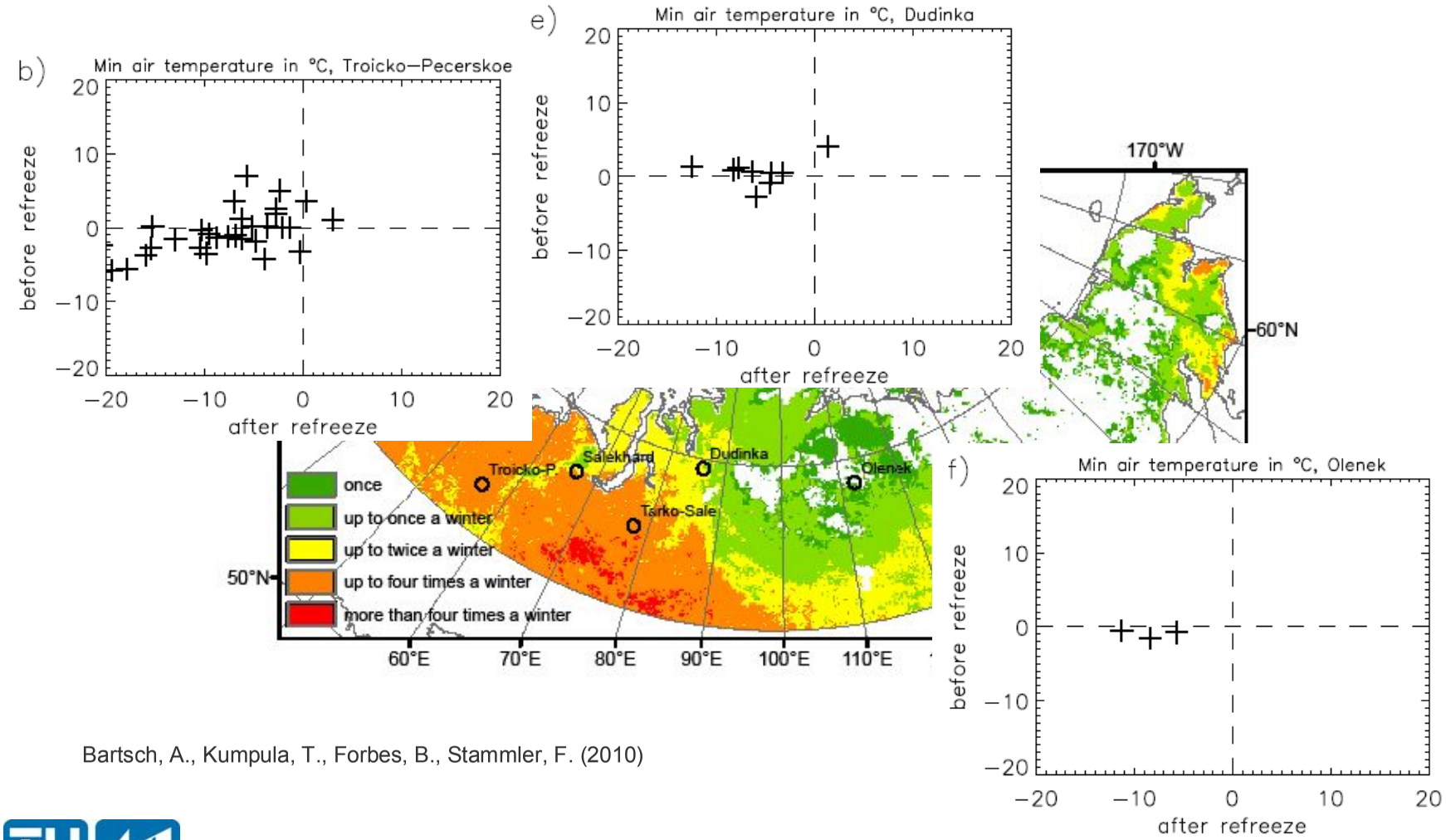
Results – Northern Eurasia

- Comparison with WMO station data



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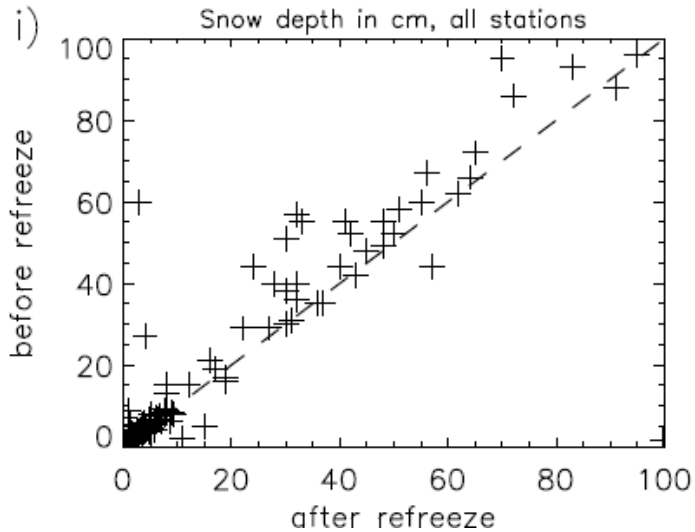
Discussion Northern Eurasia I

- Captured events do relate to cooling events
- Backscatter increase also does not relate to heavy snowfall

- But
  - it needs to be determined whether all events are captured
  - It cannot be distinguished if the snow structure change is due to rain –on-snow
  - Does not reveal severity of events

- Results agree with other data sources



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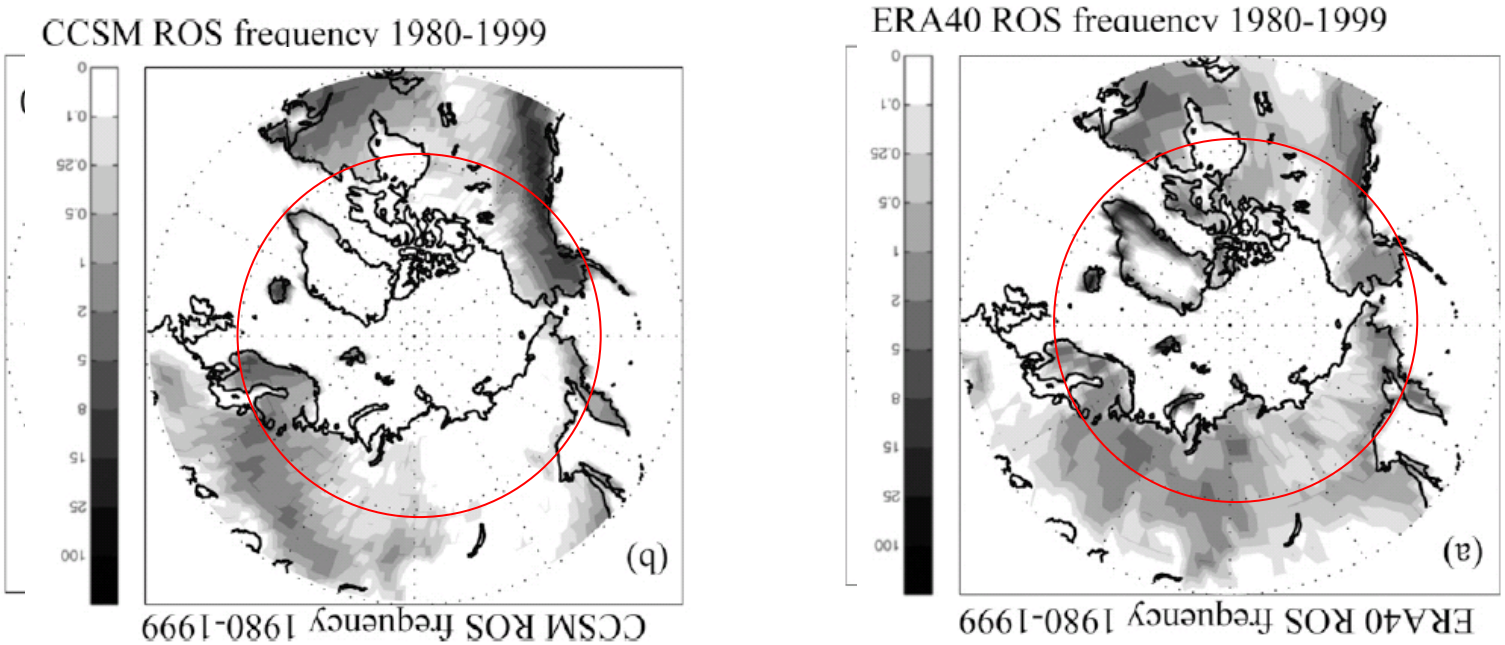
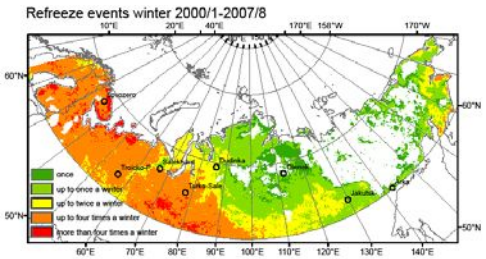
Comparison with other data sources

Renne et al. 2009





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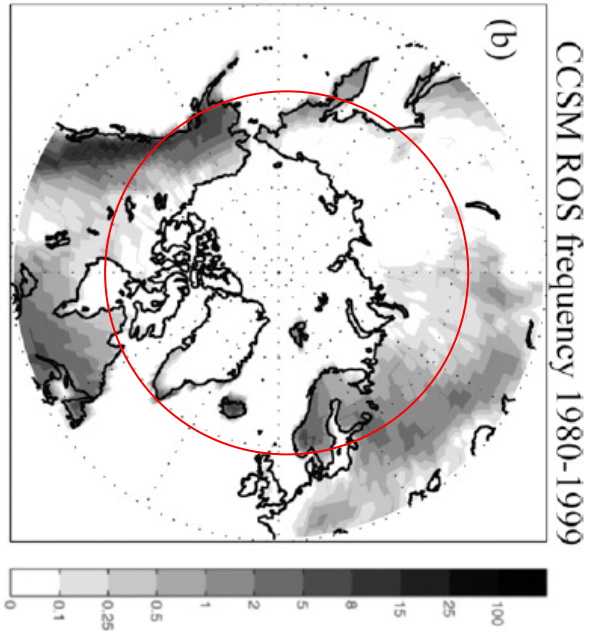
Discussion Northern Eurasia II

- Severity for reindeer herding
  - Thresholds used have been determined based on in the field determined sever events
  - Any ice crust, independent whether its from ROS or not is problematic
  - Timing of events is crucial
    - early winter
    - spring

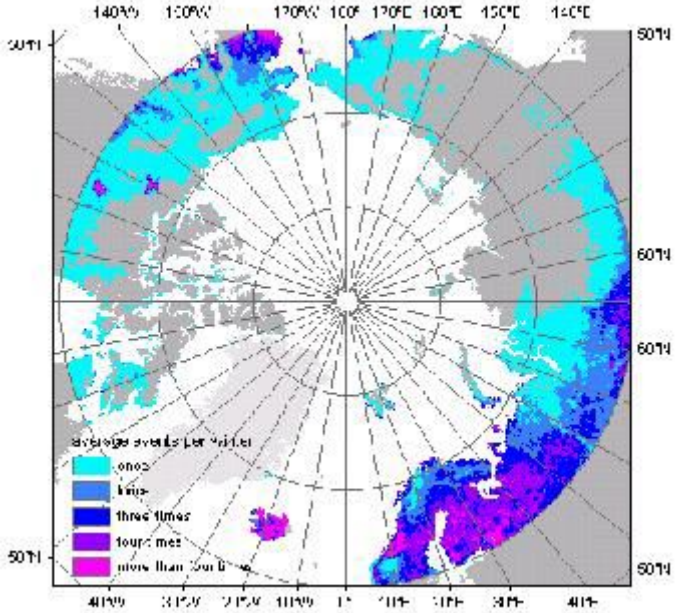
- Footprint size roughly 24 km×31 km! - Heterogeneity

Circumpolar

- Midwinter
- November to February
- 2000 - 2009



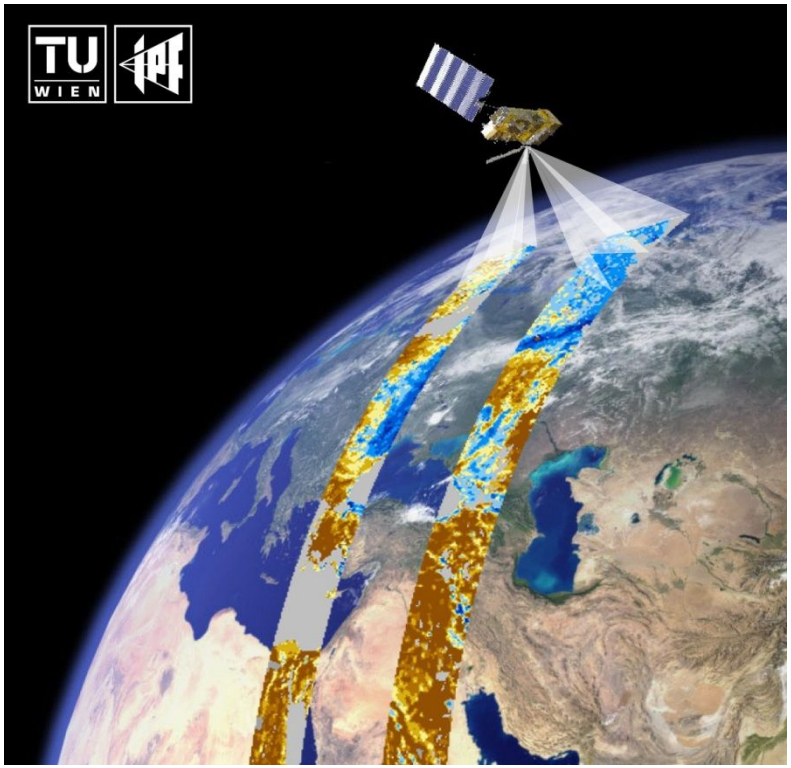
Renne et al. 2009



Bartsch (in review)

Outlook

- Comparison with field (snow course) data of ice crusts
- Transfer to other sensors for continuation of records – **trend analyses!**
  - Currently operational scatterometer with daily measurements is Metop ASCAT
  - Its continuity is ensures since it is part of a series of satellites used for weather forecasting by EUMETSAT
  - But it operates at a longer wavelength (C-band) and is less sensitive to changes of snow properties



THANK YOU!