Using QuikSCAT to monitor terrestrial surface water cover over the arctic and boreal regions

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Background:

- **Carbon reservoir in frozen soil, mainly in Siberia and central Alaska:** ~1000 GtC, > global vegetation (650 GtC), ~140 times of global annual fossil fuel burning.
- ~30% of carbon in permafrost is decomposed by microbes and converted to methane;
- **Beginning of the Holocene:** ~500 GtC released from permafrost (~70 years of fossil fuel burning the current rate).
• **Average arctic temperatures increased at almost twice the global average rate in the past 100 years (IPCC 2007).**

• **The Positive feedback could release massive amount of CO$_2$ and CH$_4$ into atmosphere even after the society were able to control the anthropogenic emission.**

A positive feedback:

- **Warming**
  - **Permafrost melting**
  - **Release CO$_2$, CH$_4$**

**This process is not included in the Global climate models, it may surprise us in future with a much stronger warming than that projected by the IPCC.**
Lakes and permafrost:

- **Indicator of changing permafrost conditions**
  - Thermokarst - lake creation as permafrost degrades
  - Draining of lakes when deep permafrost disappears
  - So, appearance or disappearance of lakes in arctic can give clues to changing permafrost conditions

**1 - Frozen ice rich permafrost**

- Ice Wedge

**2 - Initial stages of thaw**

- Perched water table where water cannot drain due to ice below it - see Lakes at the surface

**3 - Final stages of thaw**

- As subsurface ice disappears, water drains away leading to decreasing surface water cover

Walter et al. 2007
Emissions of CO₂ and CH₄ in Arctic and Boreal regions are largely controlled by temperature AND distribution of water

- Redox conditions
- Volume available for aerobic respiration (much more efficient than anaerobic)

Fig. 4 Total daily $R_{\text{day}}$ as a function of mean daily soil temperature at 5-cm depth ($T_{s5}$) for 2004. Averaged data including standard errors around each point are presented. Bin size = 2 °C ($n > 5$).
Objective:

- Map changes in lake and wetland area using QuikSCAT (4-days average QuikScat slice inner beam (h-pol) or 'qush' product).

- Next: Relate to changes in water table height.

- Eventually: use this to drive a model of CO₂ and CH₄ fluxes - estimate interannual variability and trends in emissions
QuikSCAT

- *Microwave is highly sensitive to surface water*
- *Near-daily coverage since 1999*
- *Fewer problems with cloud contamination than AVHRR or other IR sensors*

Initial area of focus
Vegetation Map derived from AVHRR

Hansen et al. 1998

- Evergreen needleleaf forest
- Deciduous broadleaf forest
- Mixed forest
- Woodland
- Grassland
- Cropland
- Tundra
Splitting out pixels by vegetation type first yields even better curves, with smaller standard deviation (this is average August H-pol slice backscatter signal for North America 1999-2008)

Lines are quadratic fit to data
Use these curves to generate monthly average fractional water cover maps
Fractional Water Cover Derived from QuikSCAT - Aug 2003
Seasonal Changes in Lake Area

May be complicated by seasonal changes in vegetation and ice, which we haven’t investigated yet.
Appearance/Disappearance of Lakes

2008

Fractional water cover
Slope in $f_{\text{water}}$ 1999-2008
Slope in $f_{water}$ 1999-2008
Summary

- **Initial analysis suggests QuikSCAT will be useful in generating a time series of water cover in arctic and boreal regions.**

- **Some issues have not been examined yet, such as effects of snow cover, lake freeze/thaw, and changes in vegetation.**
Near-term Work Plan:

• Compare the seasonal and interannual changes in lake area with observations from the Canadian lakes database, investigate the effect of snow and lake freeze-thaw on the backscatter signal.

• Generate monthly water cover map globally north of 45°N.

• Combine with near surface satellite methane observations to determine the relationship between methane release and increase of lake area.

• Provide input of water coverage for modeling methane emission change in climate model, e.g., NCAR CLM.
Variability in H-pol slice backscatter as a function of surface water cover
Tipping Elements of the Earth System:

(Lenton et al. 2008 PNAS)