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

Nicole Smith-Downey

Rong Fu

Jackson School of Geosciences,

The University of Texas at Austin

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David Long

For providing QuikScat slice inner beam (h-pol) product and helpful advices on application of the data.

Background:

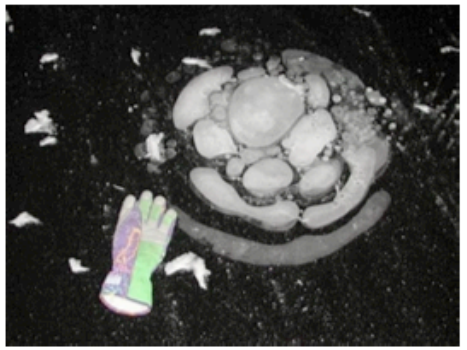
- ***Carbon reservoir in frozen soil, mainly in Siberia and central Alaska: ~1000 GtC, > global vegetation (650 GtC), ~140 times of global annual fossil fuel burning.***
- ***~30% of carbon in permafrost is decomposed by microbes and converted to methane;***
- ***Beginning of the Holocene: ~500 GtC released 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.***

Scientists Find New Global Warming 'Time Bomb'

by Seth Borenstein

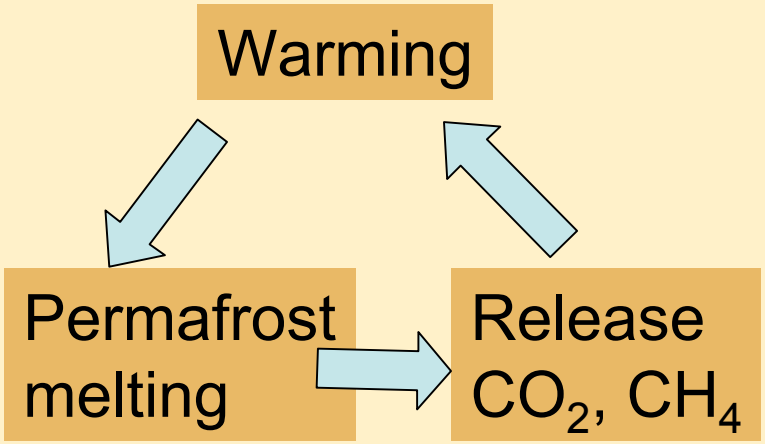
WASHINGTON — Global warming gases trapped in the soil are bubbling out of the thawing permafrost in amounts far higher than previously thought and may trigger what researchers warn is a climate time bomb.



Methane bubbles trapped in lake ice in Siberia in early autumn.

Methane trapped in a special type of permafrost is bubbling up at rate five times faster than originally measured, according to a study in the

A positive feedback:

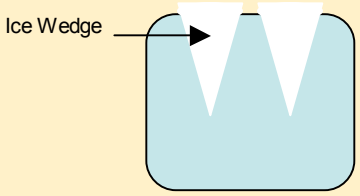


- ***This process is not included in the Global climate models, it may surprise us in future with a much stronger warming than that projected by the IPCC.***

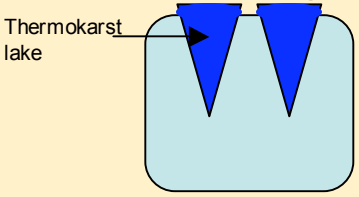
Lakes and permafrost:

- *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

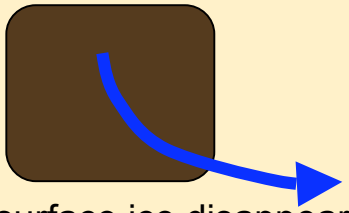


2 - Initial stages of thaw

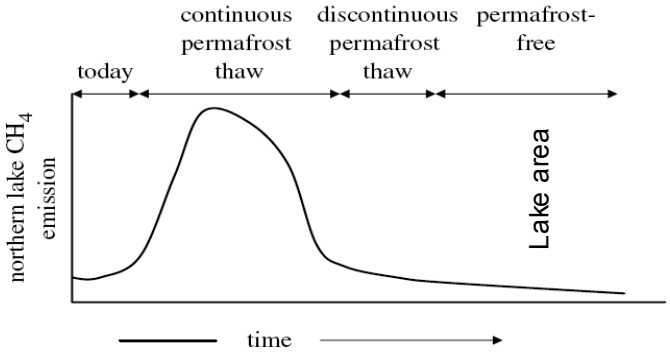


Perched water table where water cannot drain due to ice below it - see Lakes at the surface

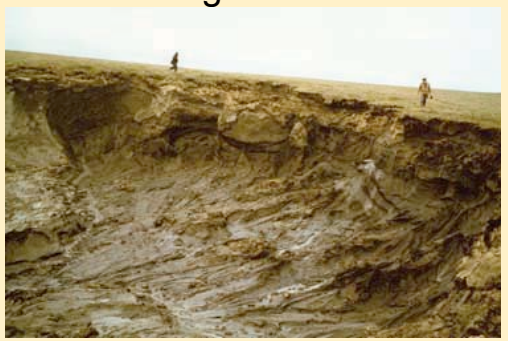
3 - Final stages of thaw



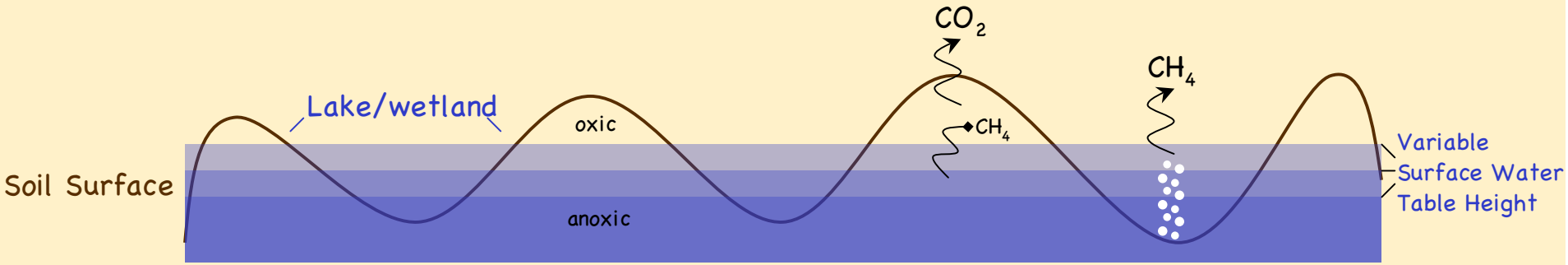
As subsurface ice disappears, water drains away leading to decreasing surface water cover



Walter et al. 2007

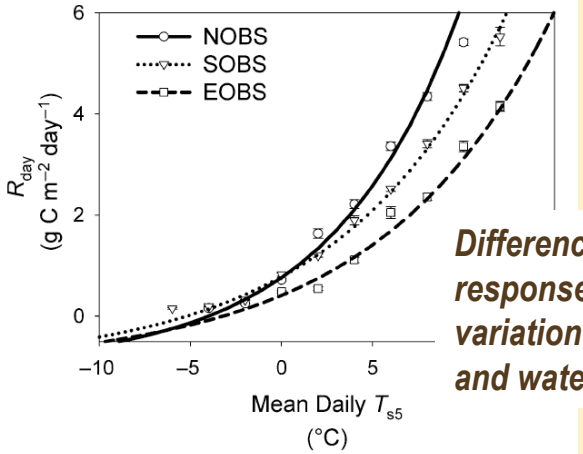


Water cover and CO_2 & CH_4 emissions



Emissions of CO_2 and CH_4 in Arctic and Boreal regions are largely controlled by temperature AND distribution of water

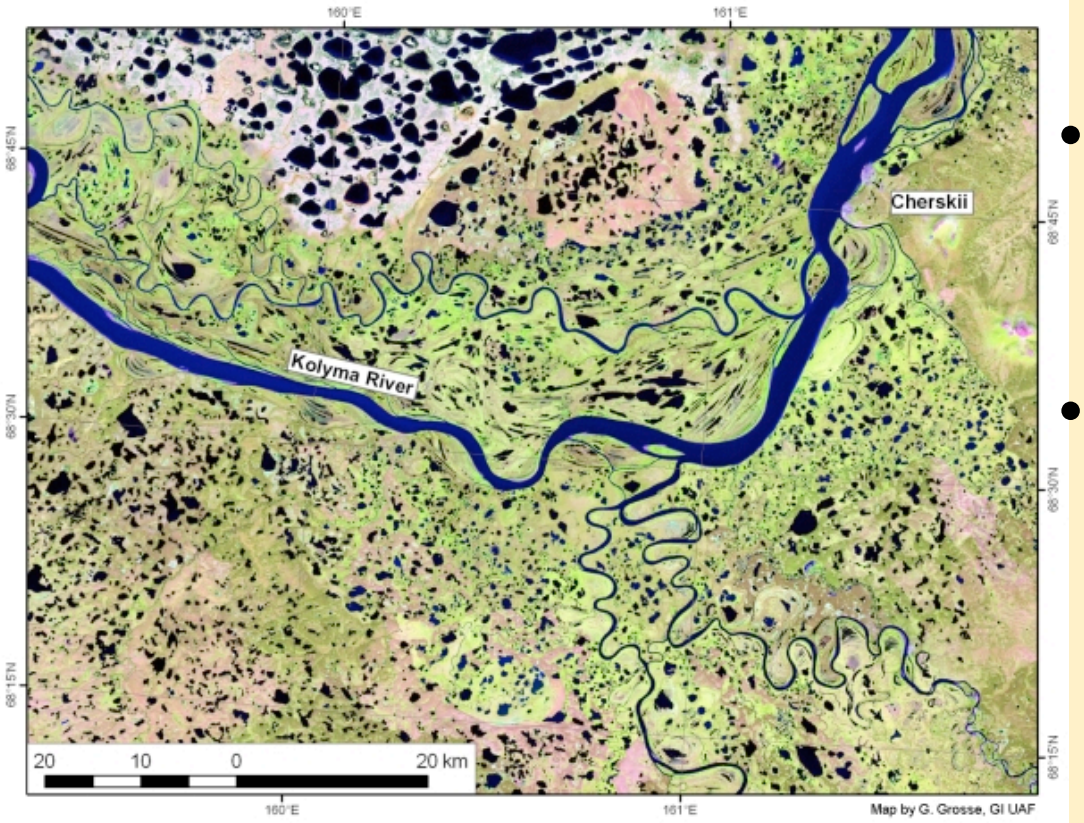
- ***Redox conditions***
- ***Volume available for aerobic respiration (much more efficient than anaerobic)***



Differences in site level responses to T is attributed to variation in Soil water content and water table depth

Fig. 4 Total daily R (R_{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 ($n > 5$).

Methane emissions from Lakes

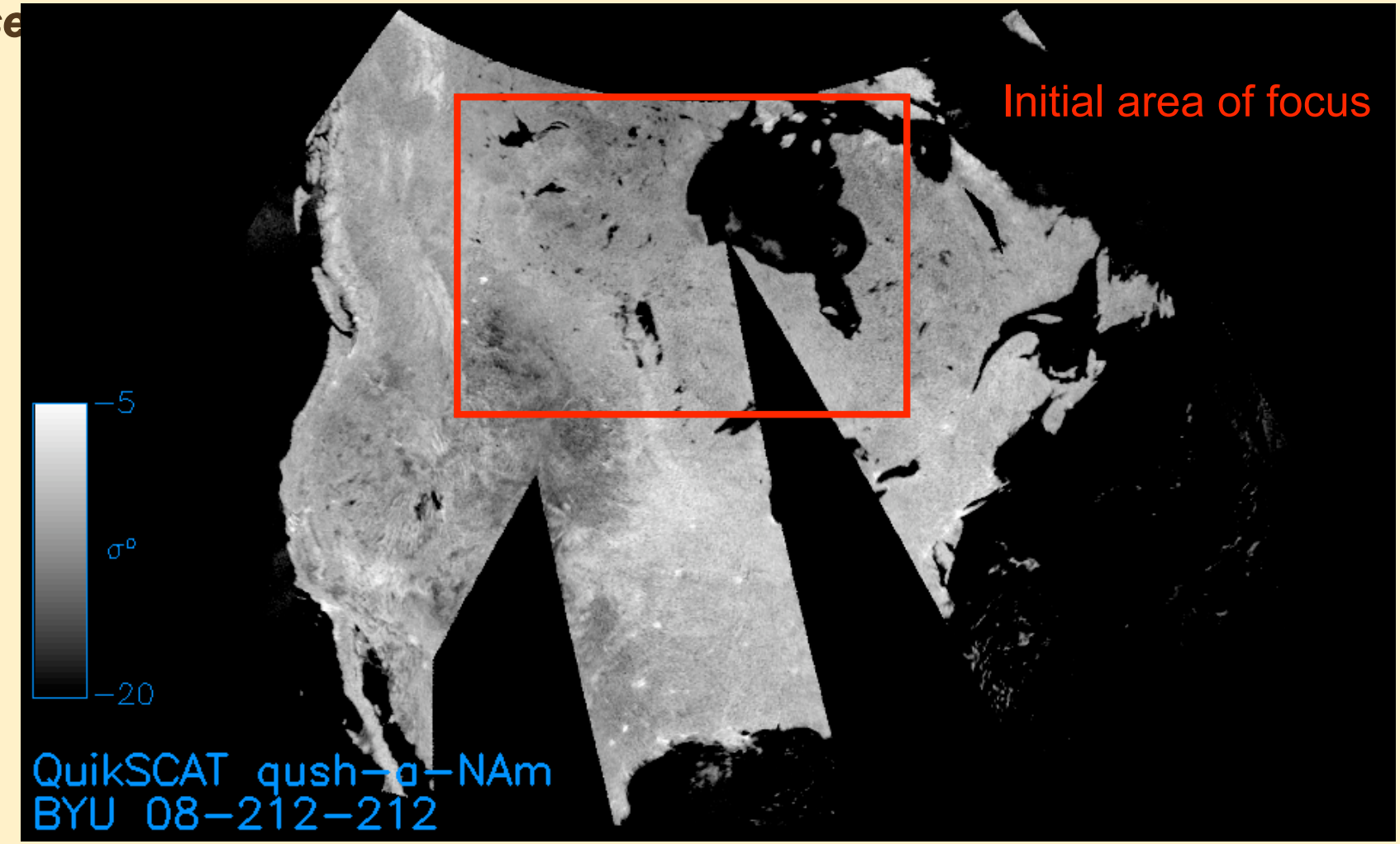


Objective:

- ***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 CO_2 and CH_4 fluxes - estimate interannual variablility and trends in emissions***

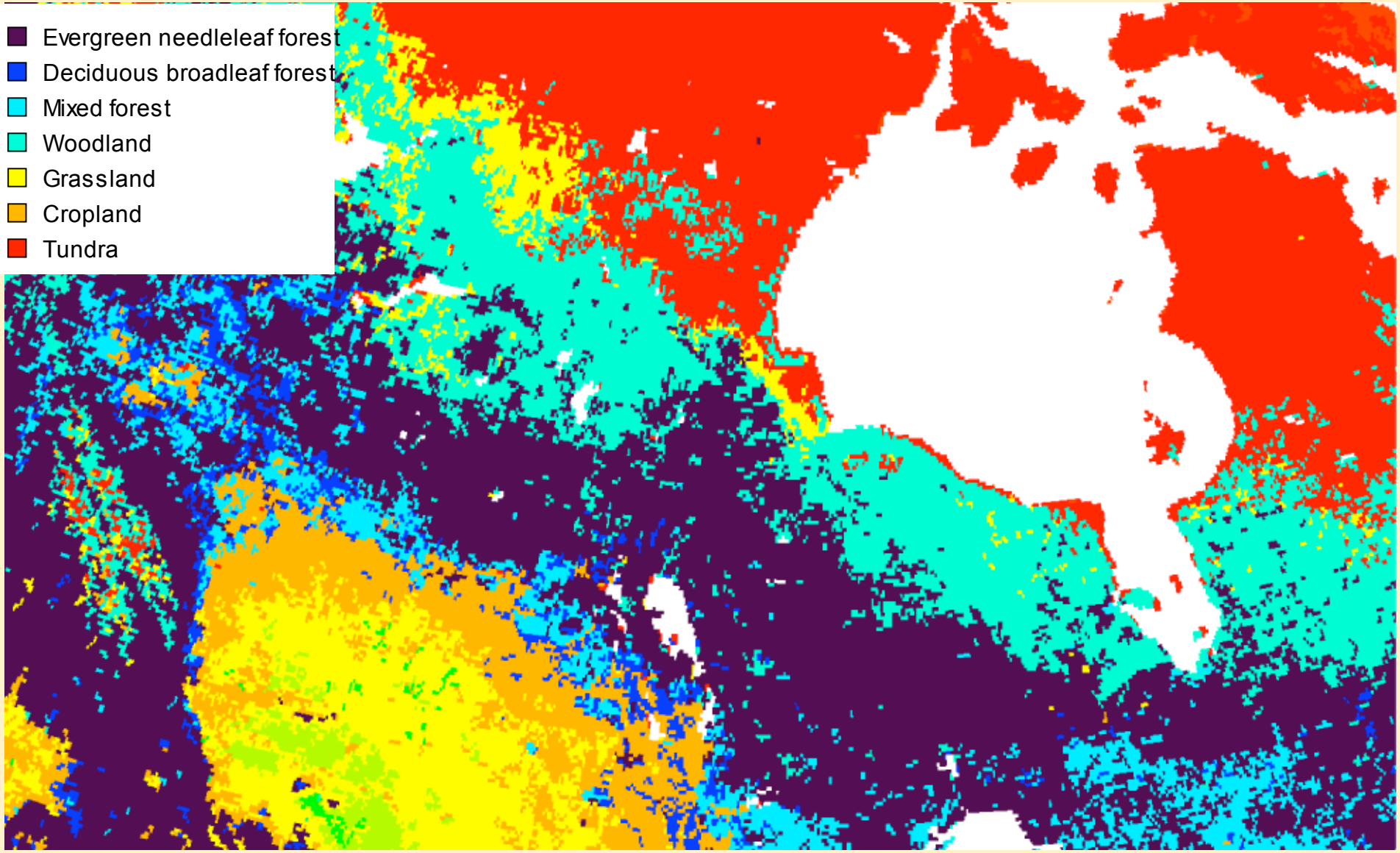
QuikSCAT

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

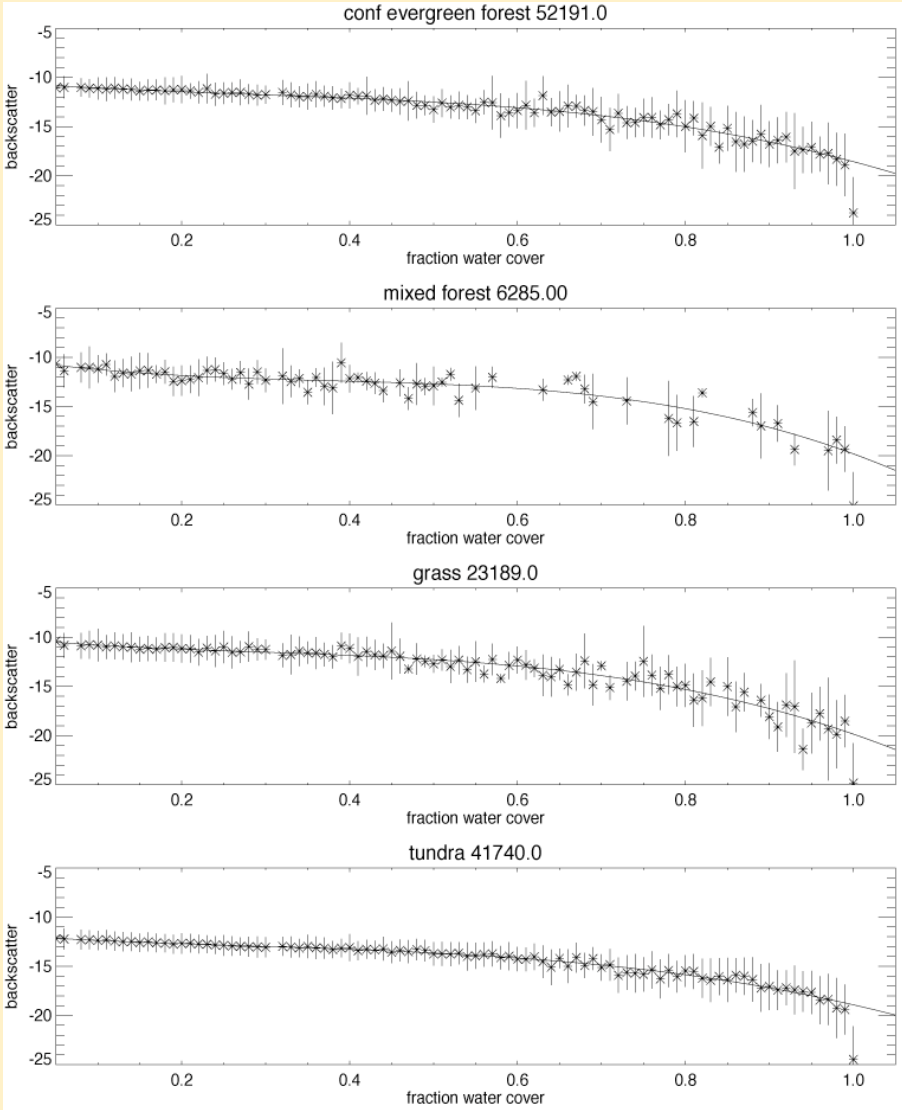


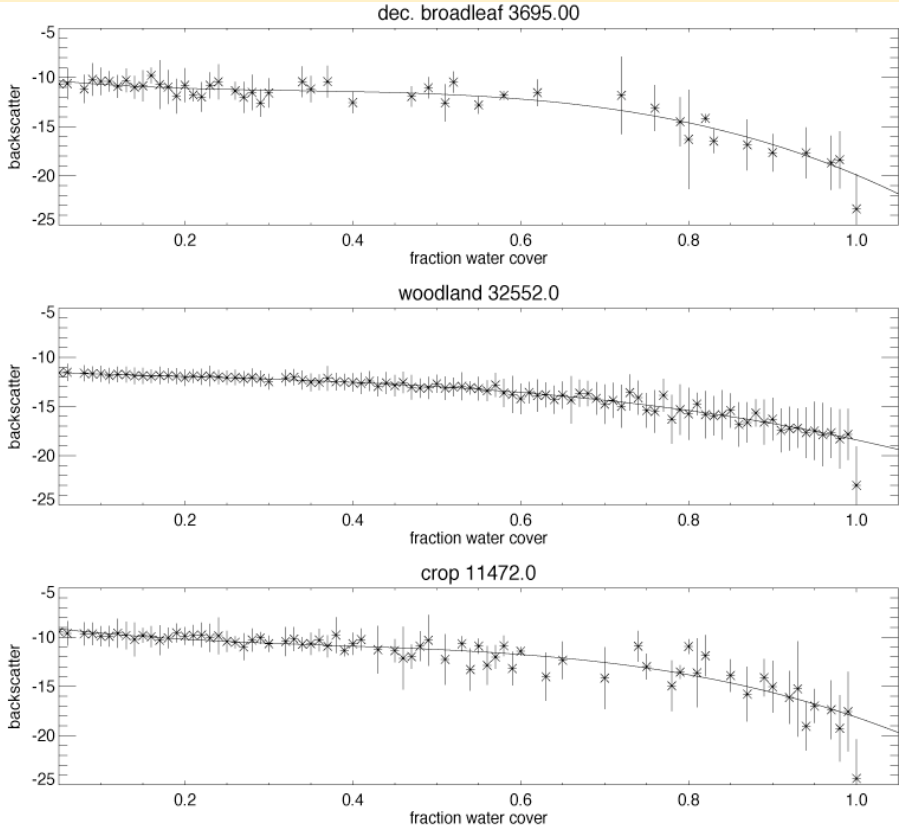
Vegetation Map derived from AVHRR

Hansen et al. 1998



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)

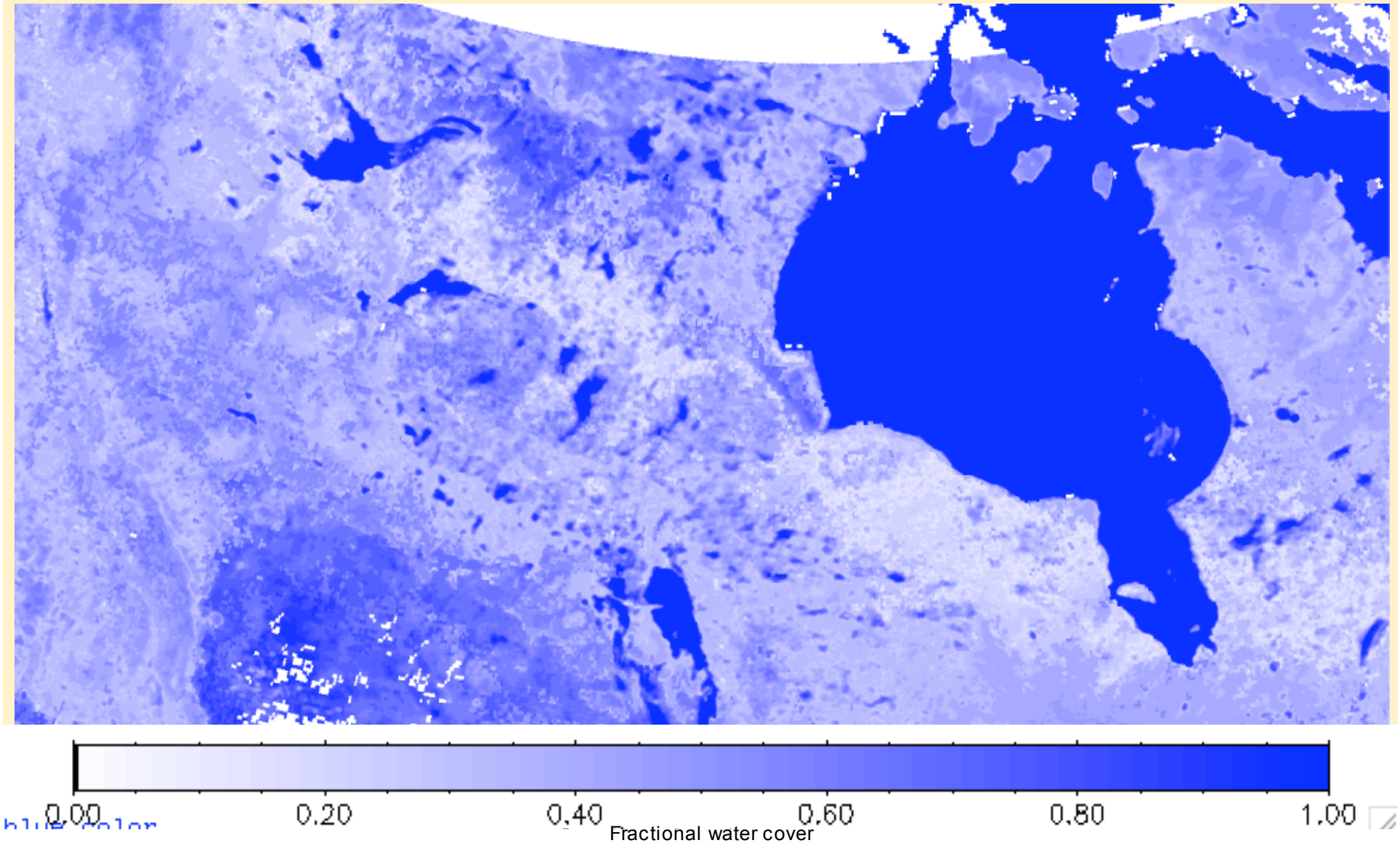




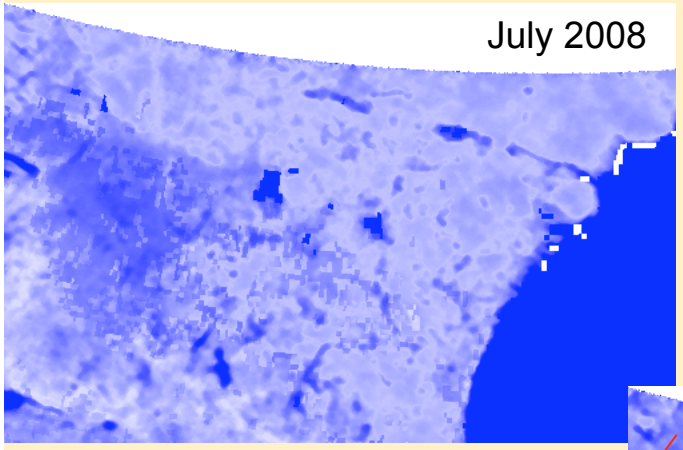
Lines are quadratic fit to data

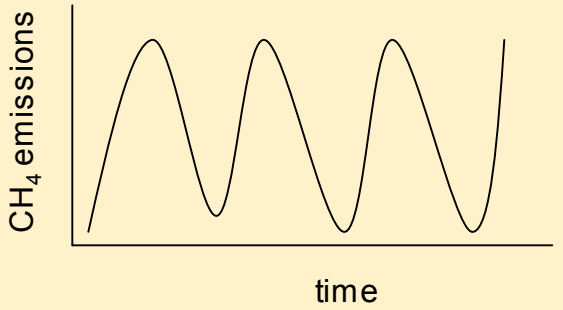
Use these curves to generate monthly average fractional water cover maps

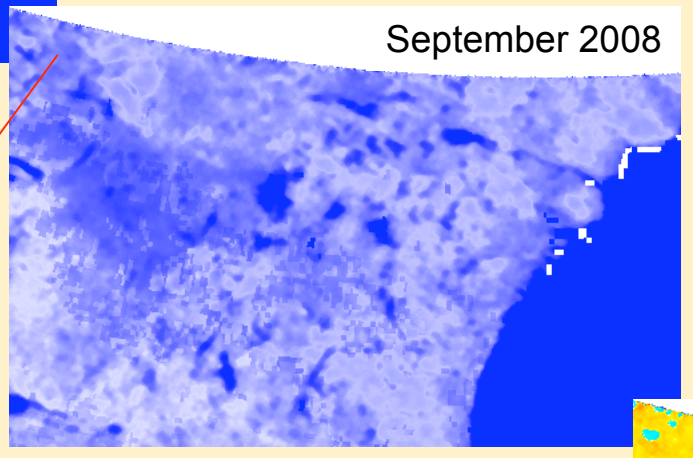
Fractional Water Cover Derived from QuikSCAT - Aug 2003



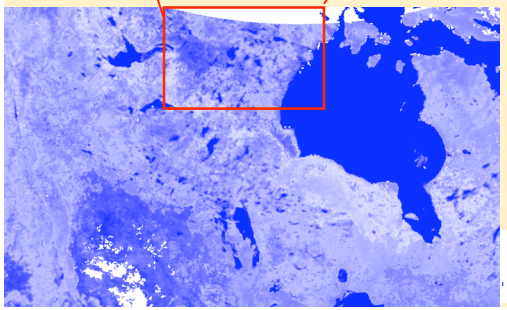
Seasonal Changes in Lake Area

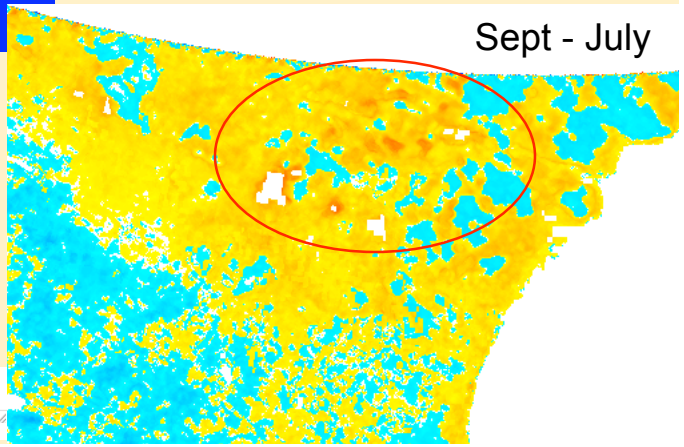


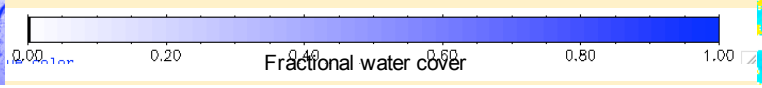




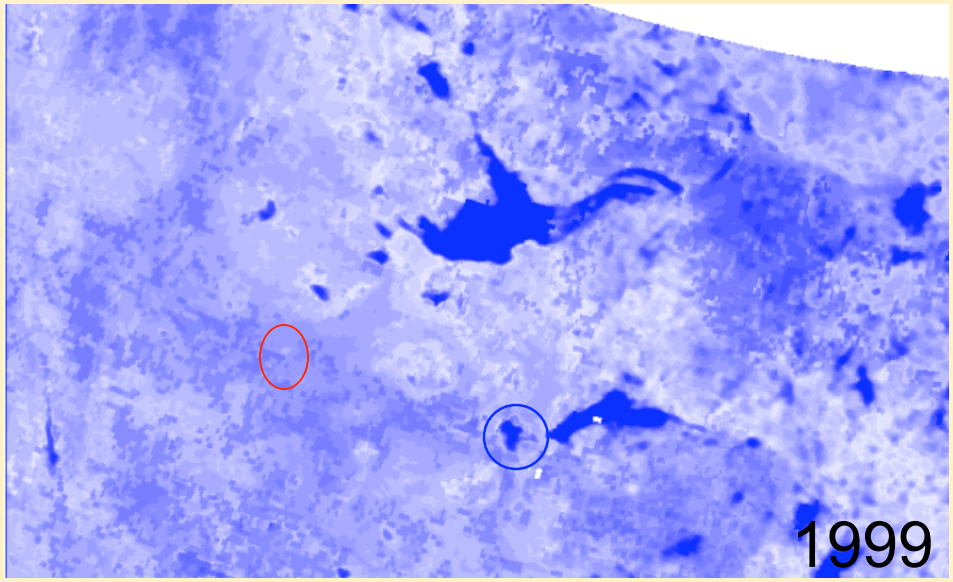
May be complicated by seasonal changes in vegetation and ice, which we haven't investigated yet

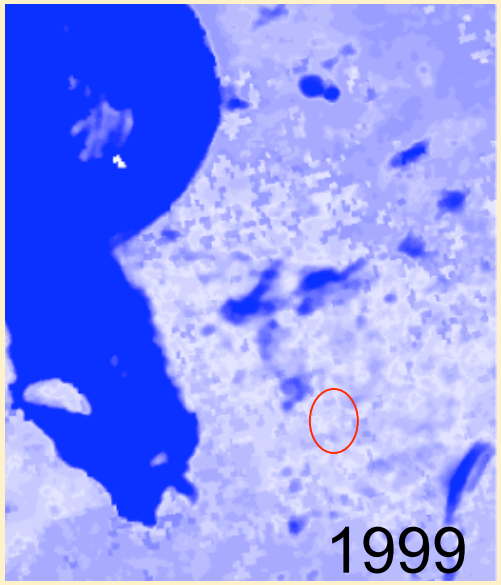


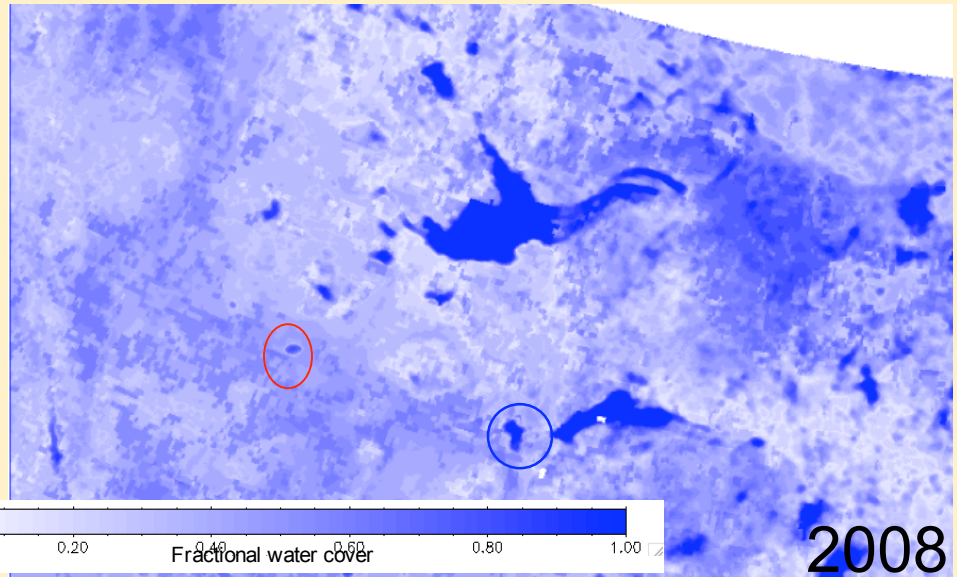




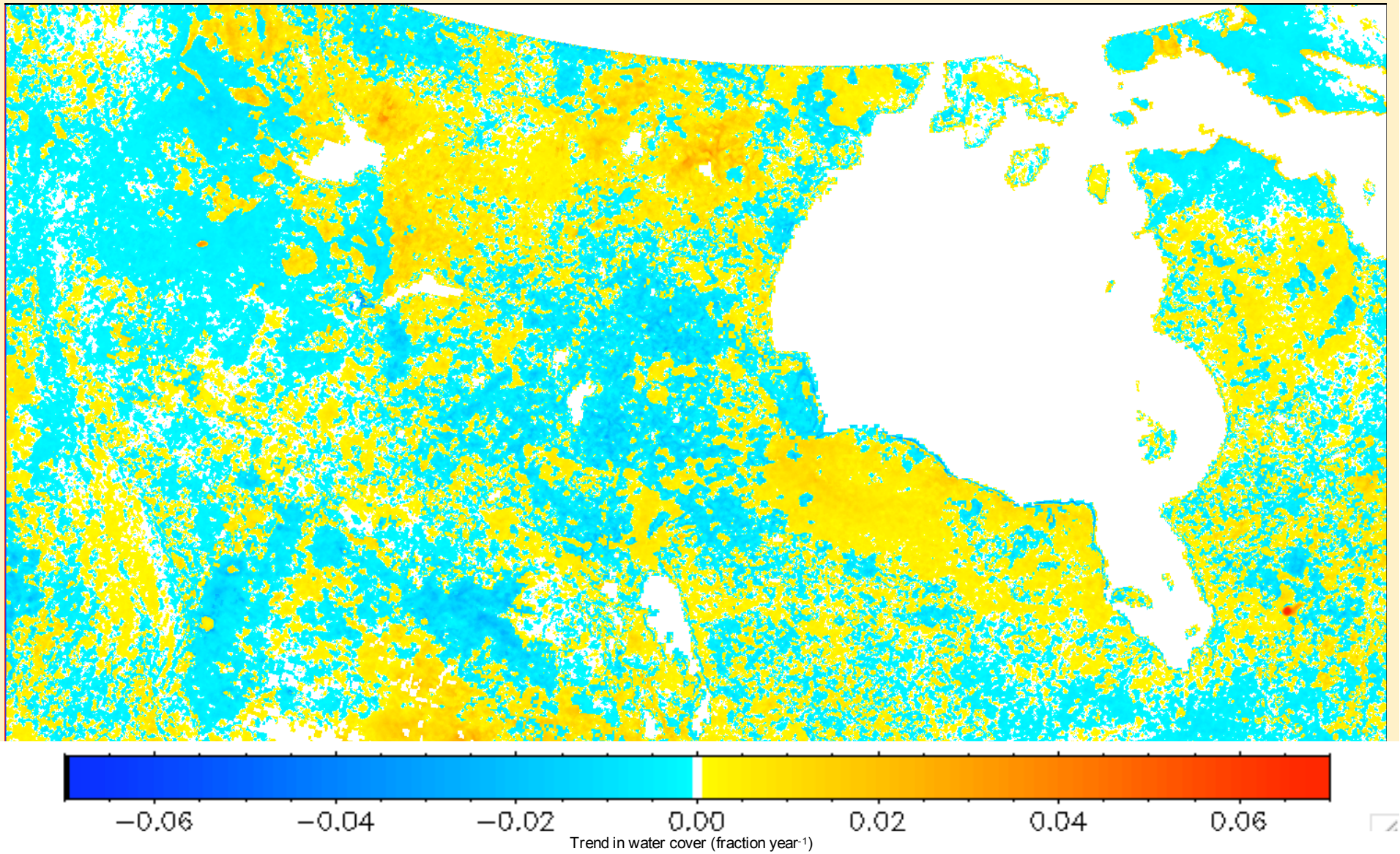
Appearance/Disappearance of Lakes



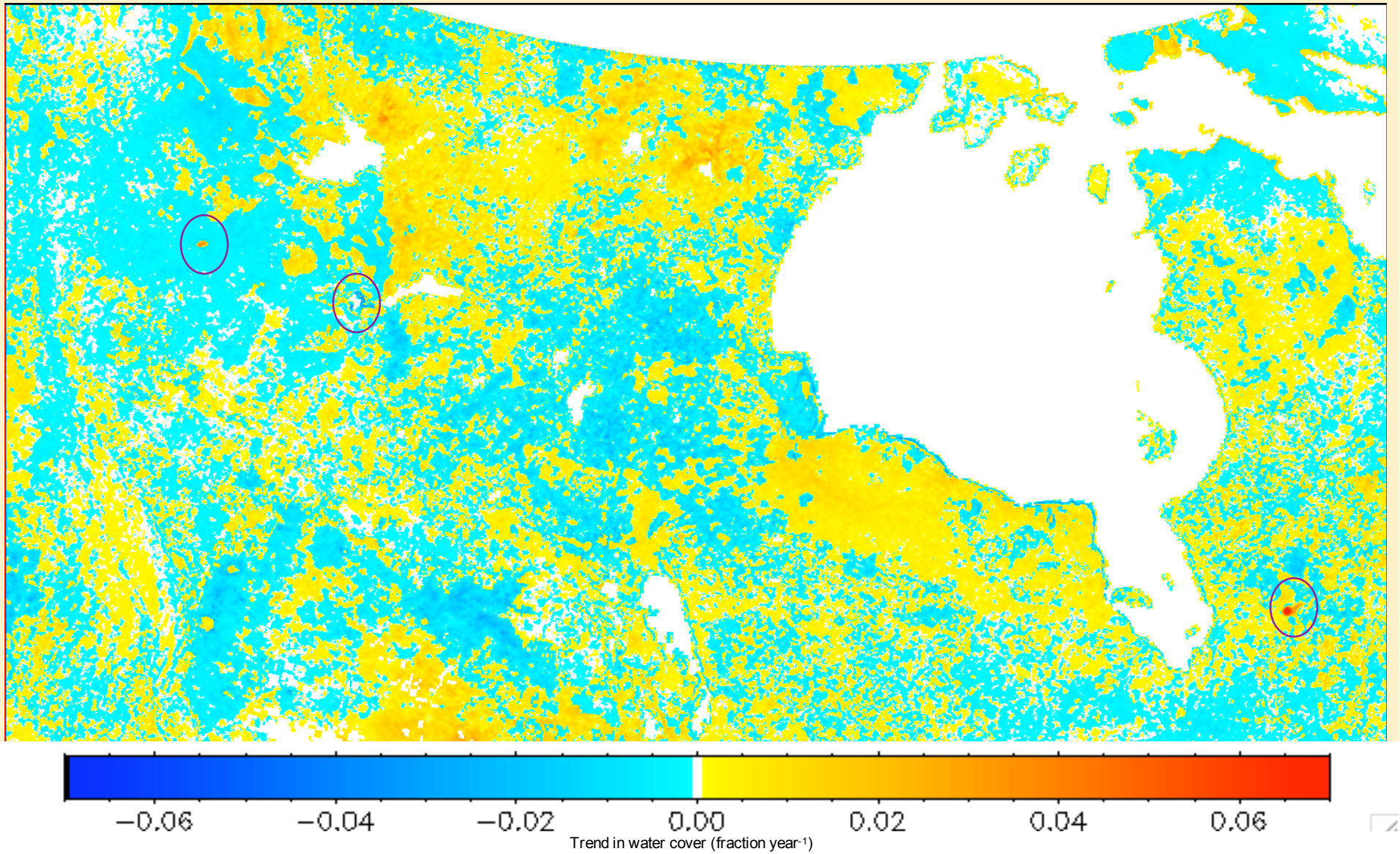




Slope in f_{water} 1999-2008



Slope in f_{water} 1999-2008



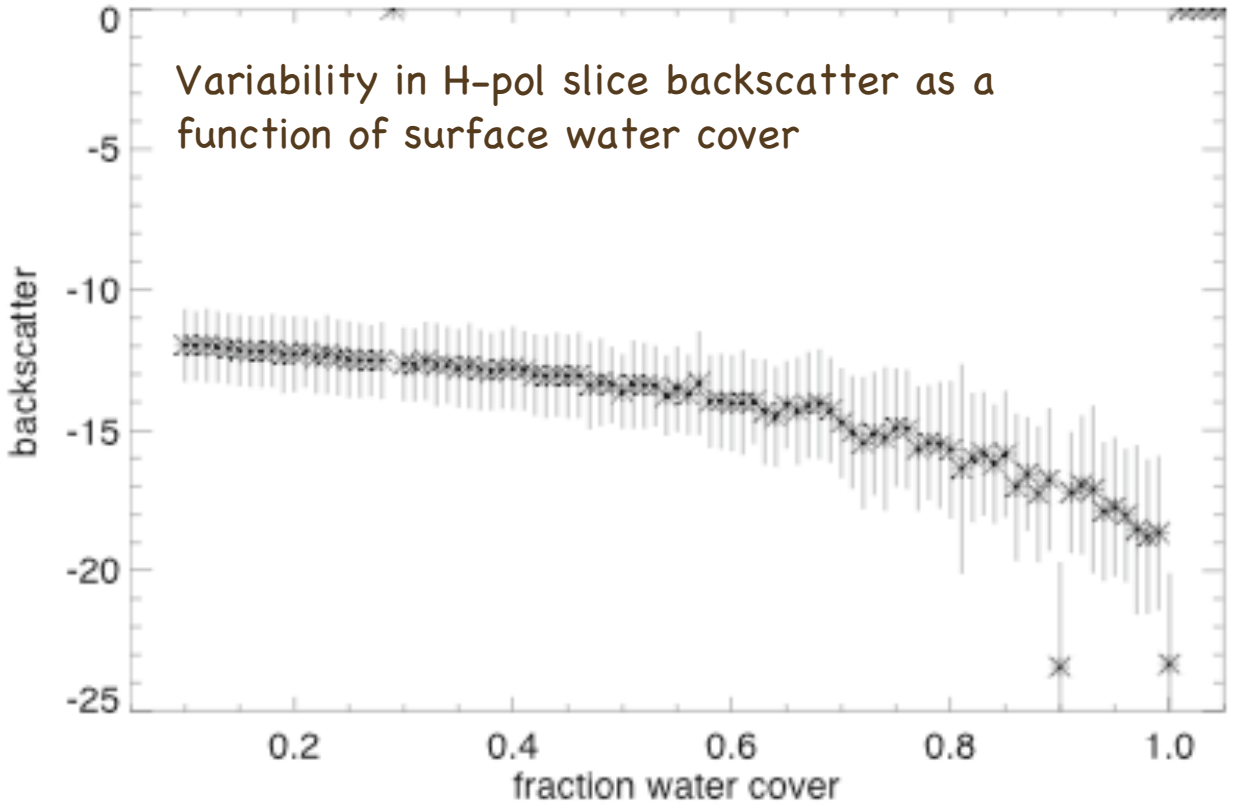
Summary

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

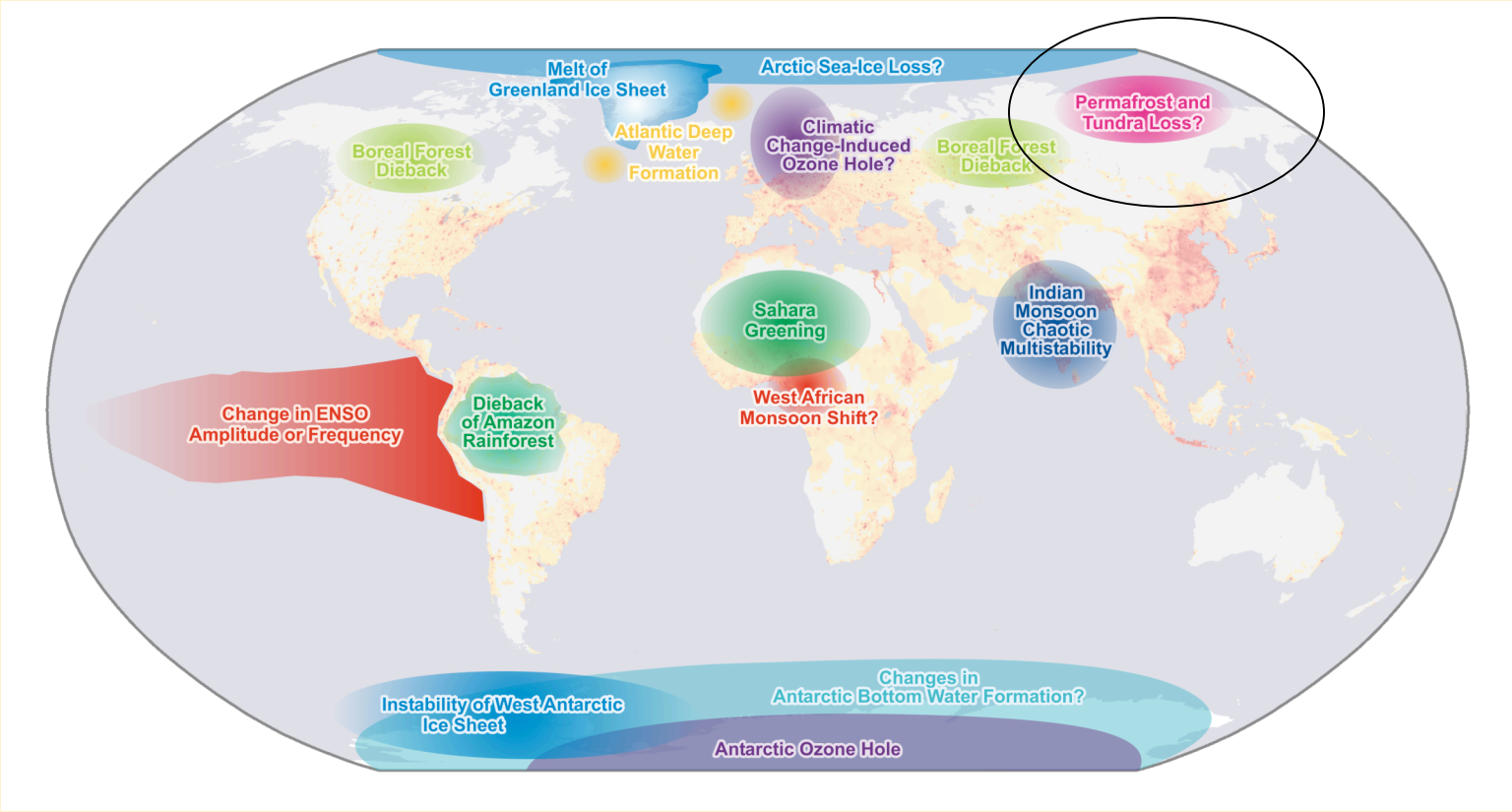
- *Some issues have not been examined yet, such as effects of snow cover, lake freeze/thaw, and changes in vegetation*

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
backscatter
0
-5
-10
-15
-20
-25
0.2
0.4
0.6
0.8
1.0
fraction water cover

Tipping Elements of the Earth System:



(Lenton et al. 2008 PNAS)