Assimilation of tower and satellite-based methane observations for improved estimation of methane fluxes over northern Eurasia

Year 2 Progress Report

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Background: This is a project of the University of Washington with (unfunded) collaboration with the Jet Propulsion Laboratory (JPL), the National Institute for Environmental Studies, Tsukuba, Japan (NIES). The goal of the project is to investigate the response of wetland methane emissions in Northern Eurasia to environmental conditions on daily, seasonal, and interannual time scales, and over a range of spatial scales from flux tower footprints of roughly 1 km^2 to the scale of the major Eurasian Arctic river basins. Our approach is to develop a modeling framework that assimilates observations from flux towers and satellites of surface water and methane concentrations into biogeochemical models. Flux tower observations will be supplied by NIES. Satellite observations of surface water, derived from a combination of high resolution, slow-repeat-cycle SAR data (primarily from ALOS/PALSAR) and low-resolution, fast-repeat-cycle passive microwave data (primarily from AMSR-E) will be provided by JPL. Satellite observations of methane concentrations over all of Northern Eurasia (derived from GOSAT) are being provided by NIES. The biogeochemical modeling framework consists of the Variable Infiltration Capacity (VIC) macroscale hydrology model (Liang et al., 1994; Bowling and Lettenmaier, 2003), linked, through collaborations with ongoing work at MPI-Hamburg with a terrestrial carbon model (BETHY; Knorr, 2000; Knorr and Heimann 2001a; Knorr and Heimann 2001b), and with a lake and wetland methane model developed at MPI-Jena (WHM; Walter and Heimann, 2000; Walter et al., 2001a; Walter et al., 2001b). Subsidiary goals include assessing improvements in performance garnered by the use of SAR surface water data; constraining errors in model estimates of surface water and methane emissions; and improving our understanding of how wetland methane emissions respond to climate change.

Tasks: The tasks as outlined in the proposal are:

Task 1: Incorporation of NIES high-resolution land cover classifications
Task 2: Develop sub-grid parameterization of wetland microtopography
Task 3: Calibrate UW hydrologic and methane emissions modeling framework
Task 4: Test assimilation of AMSR-based inundation time series into methane emissions prediction framework
Task 5: Link UW methane emissions prediction framework to NIES atmospheric transport model
Task 6: Evaluate methane concentration predictions
Task 7: Assimilation of methane observations

Summary of progress to date:

Task 1: We are working in close collaboration with Dr. Kyle McDonald at JPL on this task. The high-resolution land cover data supplied by NIES is being used to validate classifications of PALSAR images, which, in turn, are being used to validate and bias-correct AMSR-based inundation estimates.

Task 2: In progress. The relationship of wetland methane emissions to microtopography is being investigated relative to the effects of spatial variation in water table depth. Bogs and fens (the dominant wetland types in Northern Eurasia) have substantial microtopography such as hummocks and depressions, which lead to variations in the bog surface elevation on the order of tens of cm. Given the porous nature of near-surface peat soils, this can lead to similarly large variations in water table depth within a bog or fen (see for example Eppinga et al., 2008; Saarnio et al. 1997). To date, previous studies of wetland methane emissions have ignored variation in water table depth within wetlands, assuming either a uniform depth across the wetland (a "uniform" scheme), or considering emissions only from the saturated area (a "wet-dry" scheme). Because methane emissions depend strongly and non-linearly on local water table depth, such approximations will tend to be biased, compared to a scheme that takes emissions from the distribution of water table depths into account (a “distributed” scheme). We have shown (Bohn and Lettenmaier, 2010) that this effect can result in biases of up to +/- 30% in estimates of end-of-century methane emissions from the world's boreal wetlands.

Our colleagues at NIES have provided us with in situ observations of the spatial distribution of a) soil temperatures b) water table depths and c) methane emissions at various sites along a north-south transect spanning West Siberia. These observations have been extremely helpful in helping us calibrate our modeling framework across West Siberia. An example is shown in figures 1 and 2, for the Bakchar Bog (approx. 56.82 N, 82.82 E) near Tomsk in West Siberia. Figure 1 shows observed (dots) and observed (lines) soil temperatures and Figure 2 shows simulated and observed water table depths for this area. In both figures, panel a) depicts detailed behavior over the summer of 1999 at site “B3”; panel b) shows the observations from a transect across a portion of the bog in the summer of 2006; and panel c) shows a timeseries of observations spanning the period 1993-2006 at site “B3”. In figure 1, the simulated results consists of a single average soil temperature of the wetland at the same depth as the observations. Panel 1b. shows temperatures at 0 (black), 5 (red), 15 (green), and 45 (blue) cm depths at each location along the transect. The simulated soil temperatures are close to observations, capturing the observed seasonal and interannual variations (panels a. and c.) and falling near the mean of the observations along the transect (panel b.). In figure 2, the simulated results consist of three traces: the minimum, average, and maximum simulated water table depths in the area. Most observations fall between the minimum and maximum of the distribution.

<u>Task 3</u>: In progress. Calibrations of the modeling framework are under way, using the time series of inundation derived from AMSR-E and QuickScat developed by our collaborators at JPL (Schroeder et al., 2010). An example of this work is shown in figure 3, where the fractional areas of AMSR/QSCAT product (dots) are compared to those of canonical permanent open water, simulated permanent open water plus seasonal inundation, and simulated permanent and seasonal surface water plus saturated soil, for four test basins in West Siberia. Permanent plus seasonal surface water extents agree fairly well in three of the four basins, but problems with the AMSR/QSCAT product in the Konda basin (in which the AMSR/QSCAT areas severely underrepresent the known permanent open water extent) prevent a good match there. Simulated saturated soil extents are poorly constrained since they remain poorly observed.

<u>Task 4</u>: In progress. We have started testing assimilation of the AMSR/QuickScat-derived inundation dataset. The first step has been to characterize the errors of the observations. We have been able to do this by comparing the AMSR/QuickScat values of open water area to those estimated from ALOS/PALSAR (taken to be the “truth”). Scatter about the 1:1 line between these two products increases in proportion to the area, with a spread of approximately 25%. This spread becomes our time-varying estimate of the observation error. For simulations, the errors will be estimated by forming ensemble runs starting from perturbations about the initial surface water extent, whose scatter will depend on the residual errors and parameter ranges exhibited by the calibrations in step 3.

Tasks 5-7: In progress. NIES has sent us the code for their atmospheric transport model, and we have successfully compiled it here at UW. We are currently setting up the model parameters and inputs, and awaiting delivery of the NIES tower network observations.

Future work: Our plans for the next year include:

1. Finishing calibration and validation of VIC estimates of open water and inundated vegetation across the Northern Eurasia, using the AMSR-derived inundation product supplied by JPL. This task is nearly complete.

2. Calibration and validation of simulated methane emissions, taking microtopography into account. This task is nearly complete.

3. Testing of the assimilation of AMSR-derived inundation data set into the modeling framework. This task is underway.

4. Testing of the assimilation of methane concentrations observed at the NIES tower network into the combined land biogeochemistry-atmospheric transport modeling framework.

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Figures:

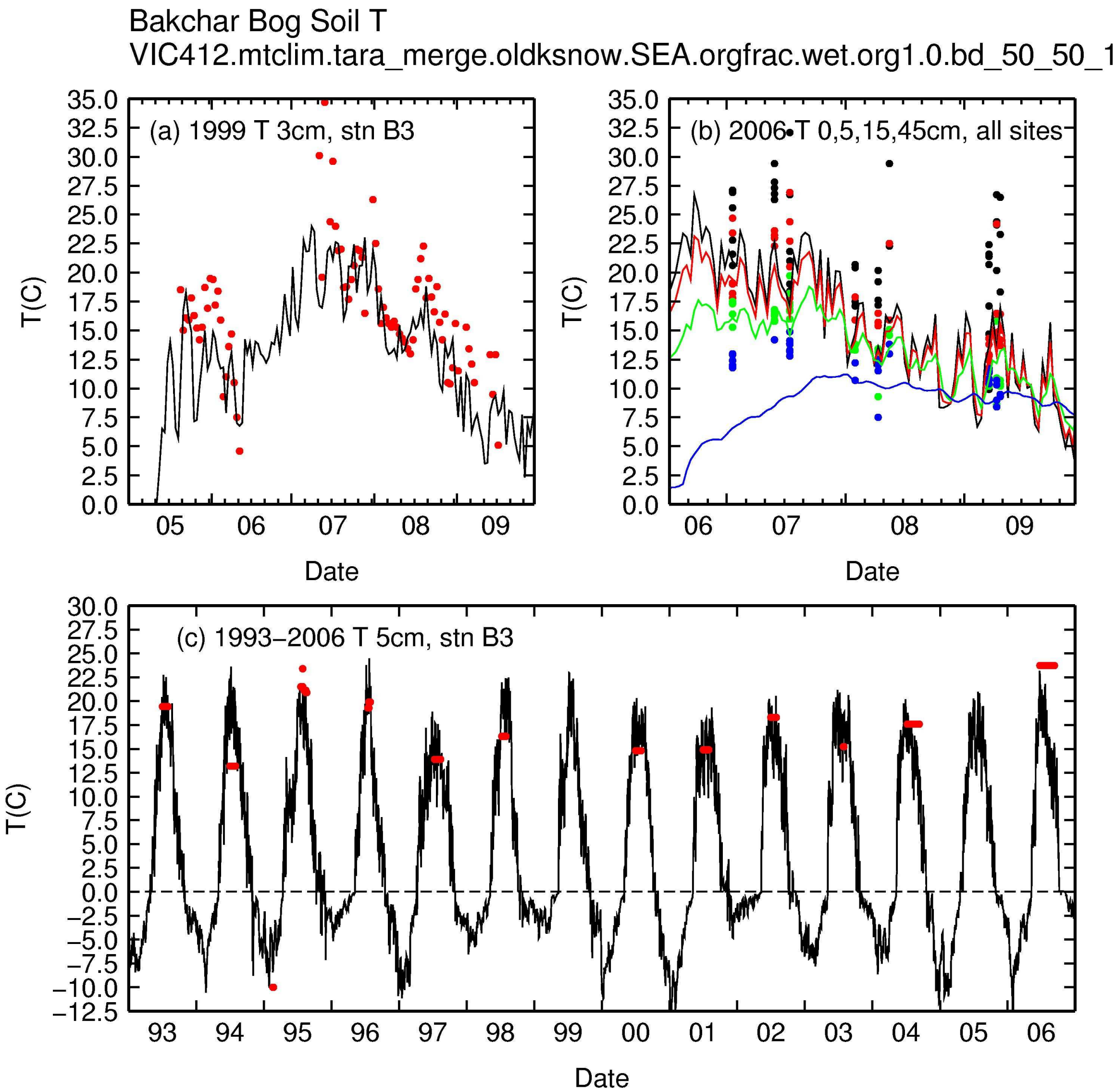

Figure 1. Observed (dots) and simulated (lines) soil temperatures for the Bakchar Bog, 1993-2006. Panels a) and c) correspond to site B3 within the bog, while panel b) corresponds to multiple locations along a transect across a portion of the bog. Panels a) and c) show temperatures for just one depth (3cm, panel a. and 5cm, panel c.). Panel b) shows, for each site, temperatures at 0cm (black dots/lines), 5cm (blue dots/lines), 15cm (red dots/lines), and 45 cm (blue dots/lines).

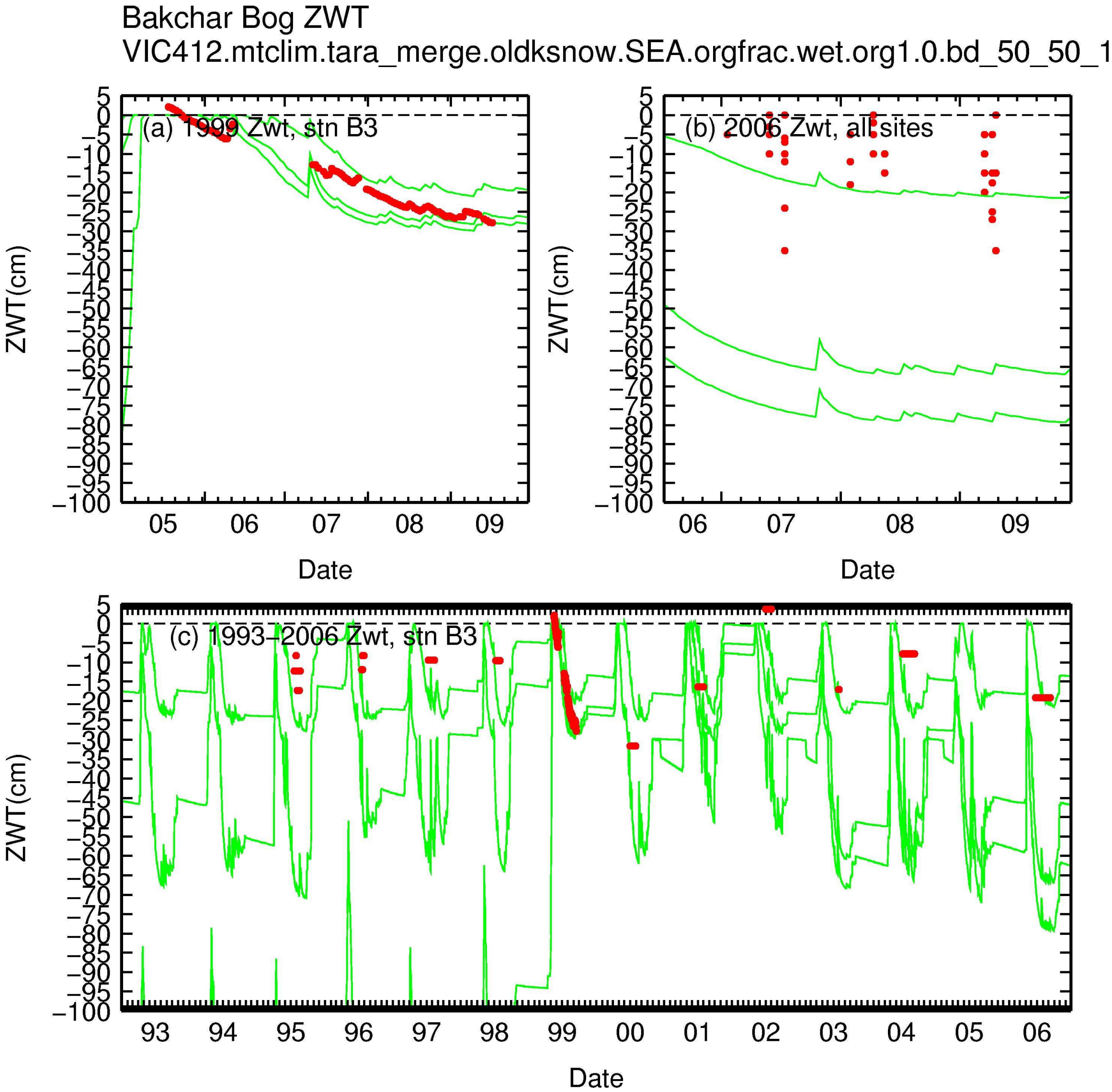

Figure 2. Observed (red dots) and simulated (green lines) water table positions for the Bakchar Bog, 1993-2006. Panels a) and c) correspond to site B3 within the Bakchar Bog. Panel b) corresponds to several locations along a transect spanning a portion of the bog. In all panels, the three green lines show minimum, mean, and maximum water table depths for the pixels in the region surrounding site B3.

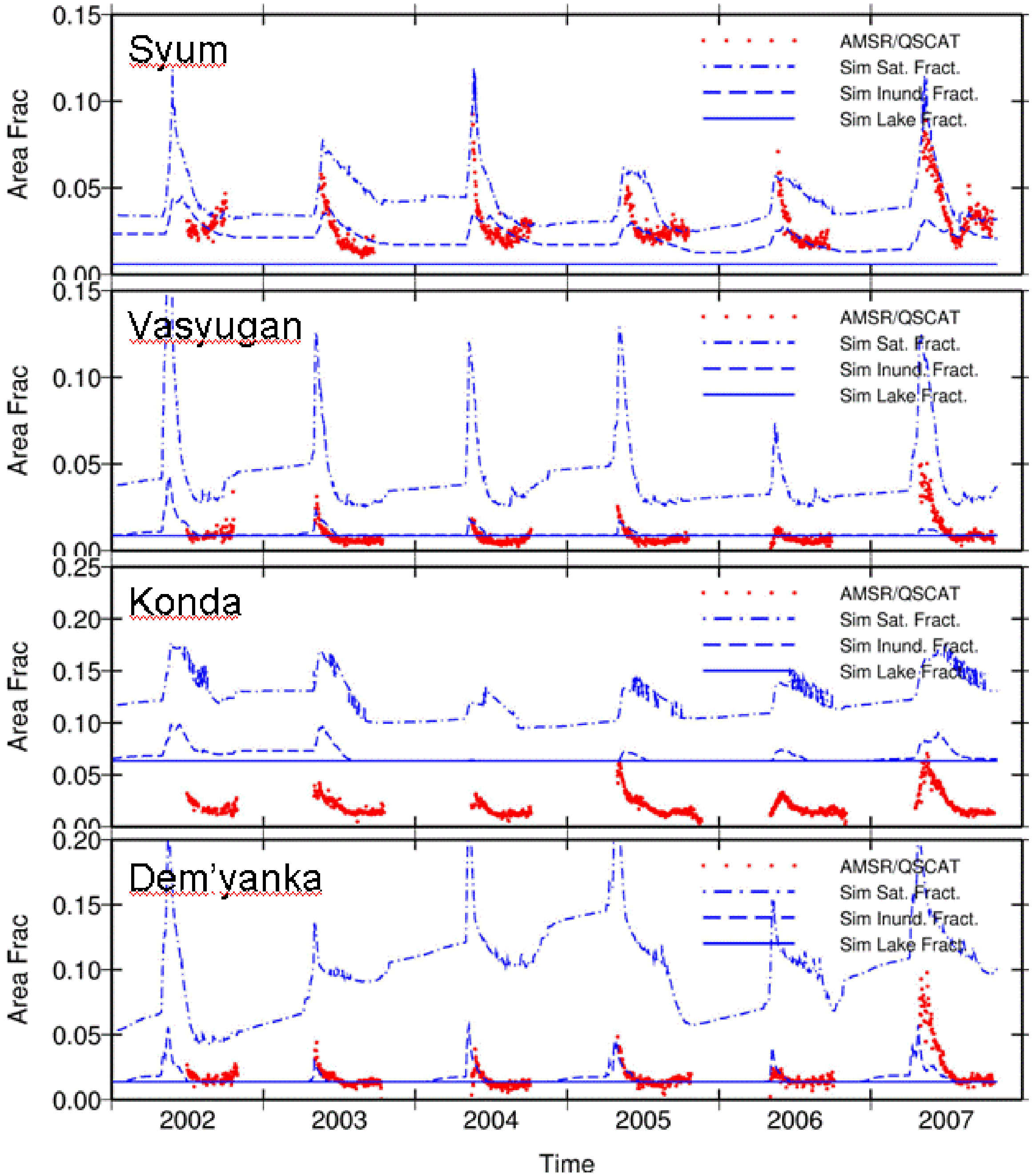

Figure 3. Comparison of fractional areal extents of AMSR/QSCAT surface water observations (red dots) with canonical permanent open water bodies (solid blue line) and various simulated surface water quantities: simulated permanent open water bodies plus seasonal inundation (dashed blue line); simulated permanent and seasonal surface water plus saturated soil (dot-dashed blue line); for four test basins in W. Siberia.