Use of SMAP Seasonal Inundation and Soil Moisture Estimates in the Quantification of Biogenic Gas Fluxes

John F. Galantowicz[1], Janusz Eluszkiewicz[1], Hanqin Tian[2]

[1]Atmospheric and Environmental Research (AER), Inc., Lexington, Massachusetts – johng@aer.com

[2]Auburn University, Auburn, Alabama

1. Objectives

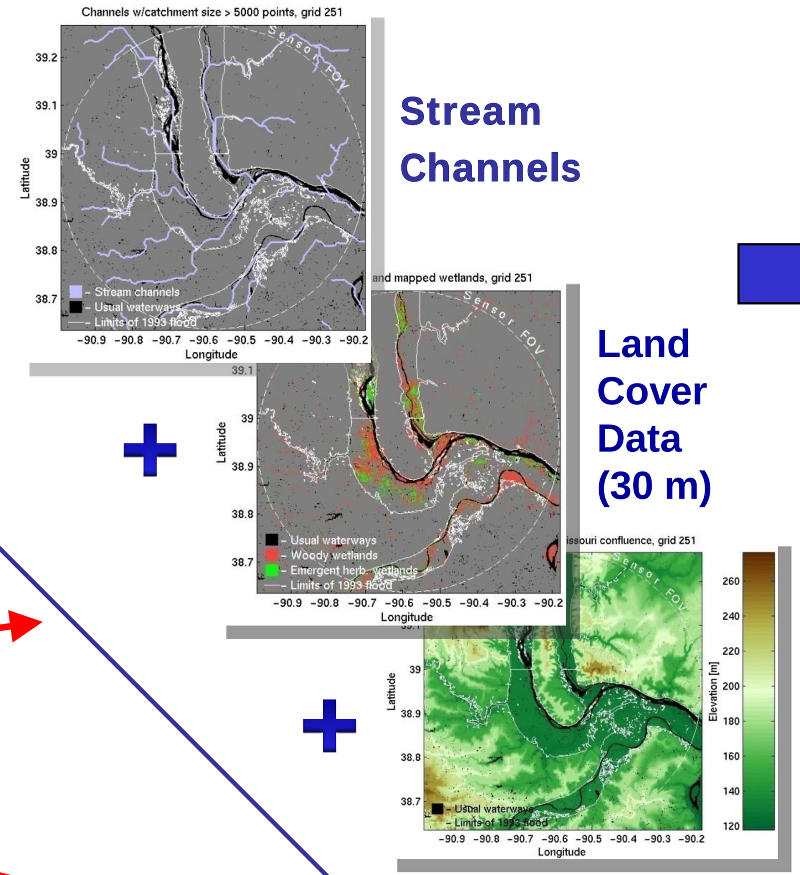
- Characterize land ecosystem model greenhouse gas (GHG, e.g., CH_4+CO_2+N_2O) flux sensitivity to seasonal inundation area and duration in diverse ecological zones
- Characterize future SMAP (Soil Moisture Active Passive Mission) inundation extent and duration measurement abilities
- Assess potential SMAP mission impact in daily GHG flux modeling when used in place of static wetland databases and modeled soil moisture status
- Develop and test an SMAP-ecosystem model fusion system

2. Key Elements

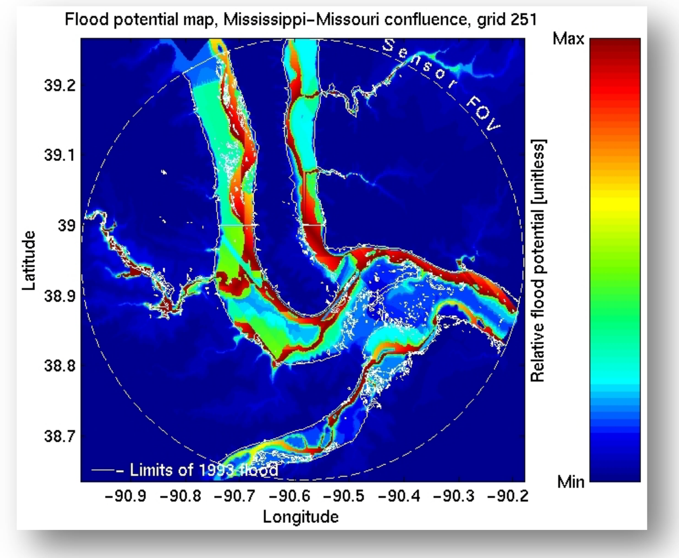
- Inundation mapping framework with SMAP data downscaling
- Sensor scene simulation with high-resolution data sources
- Dynamic Land Ecosystem Model (DLEM)
- Data-model fusion using observed CH_4 and WRF/STILT (Weather Research and Forecasting/Stochastic Time-Inverted Lagrangian Transport) model

Water fraction (f_w) downscaling

Localized relative flood potential derived from static, high-resolution sources



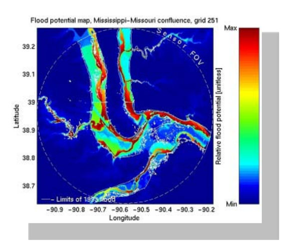
Localized flood potential database



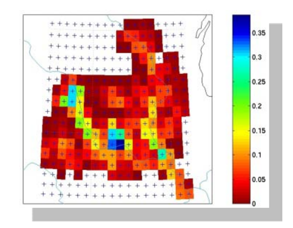
High-resolution inundation mapping from daily, low-resolution f_w

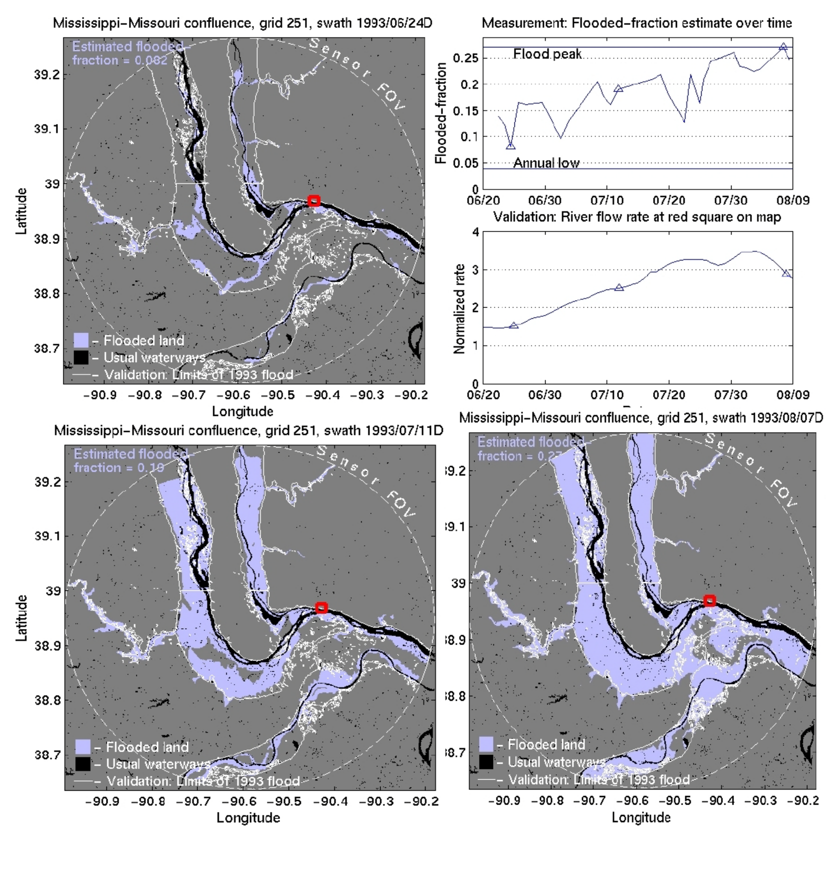
Inputs:

- Flood potential database



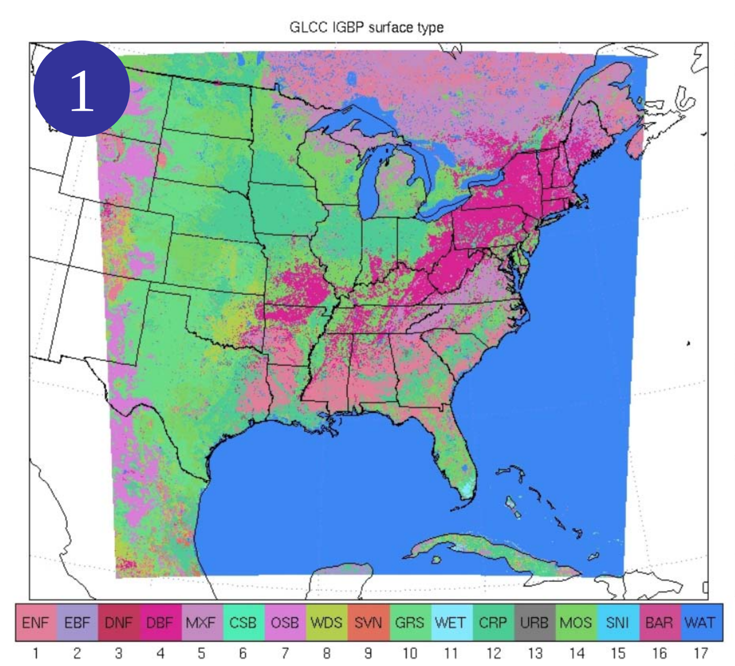
- f_w retrieval

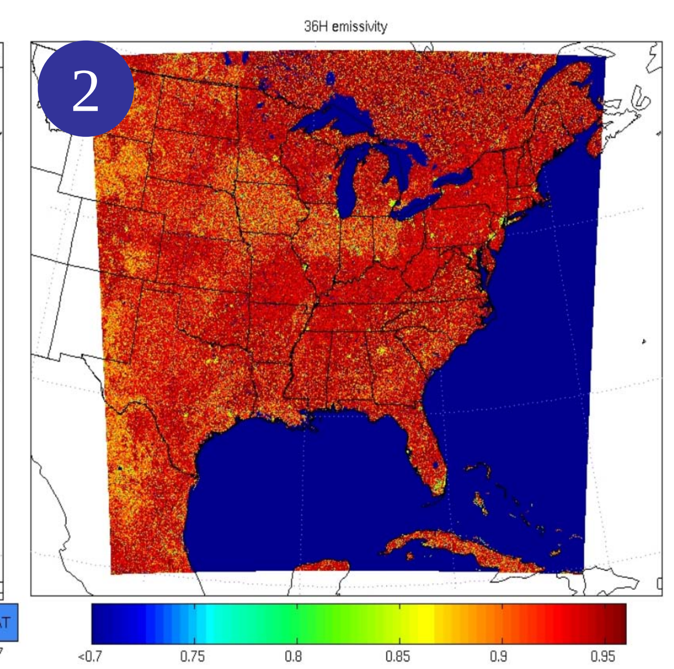




Sensor scene simulation example: Spatial sampling test (emissivity retrieval)

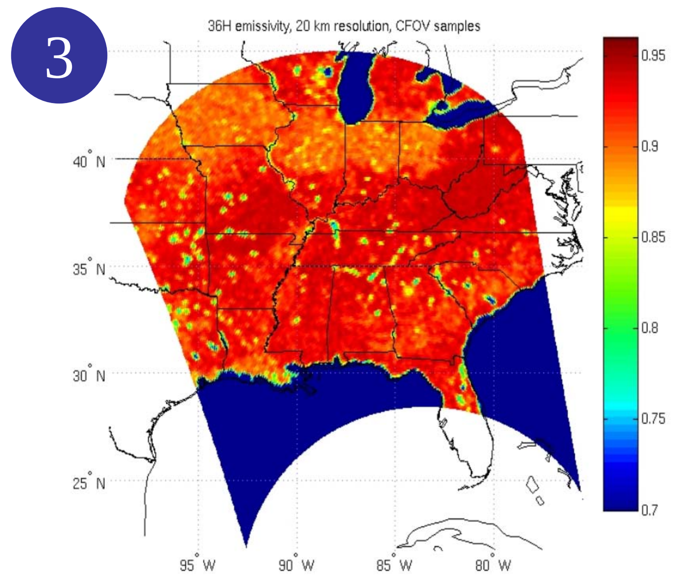
IGBP surface type (1 km)

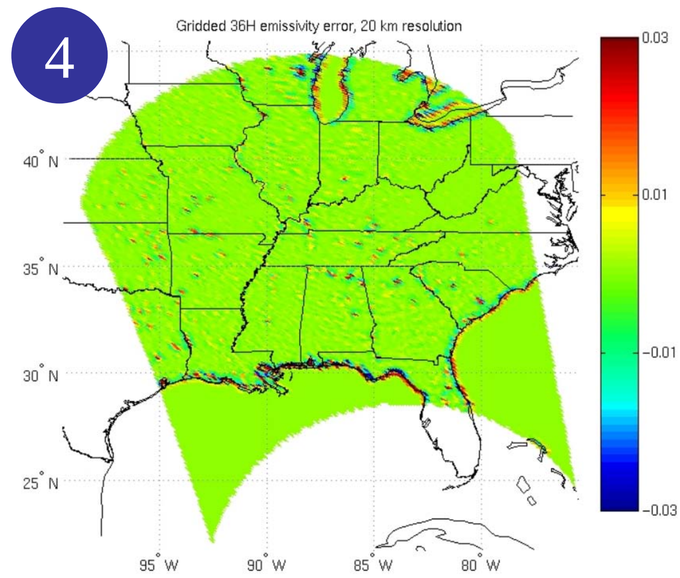




Emissivity modeled from surface type (1 km)

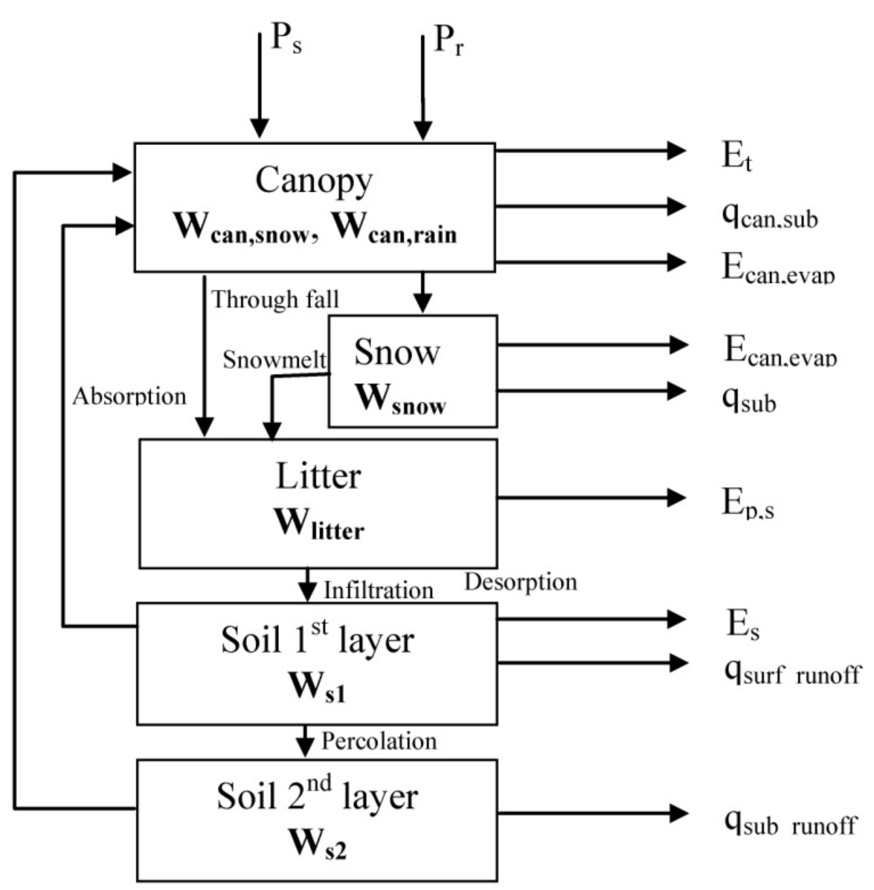
Simulated emissivity retrieval in sensor sampling geometry (20 km)



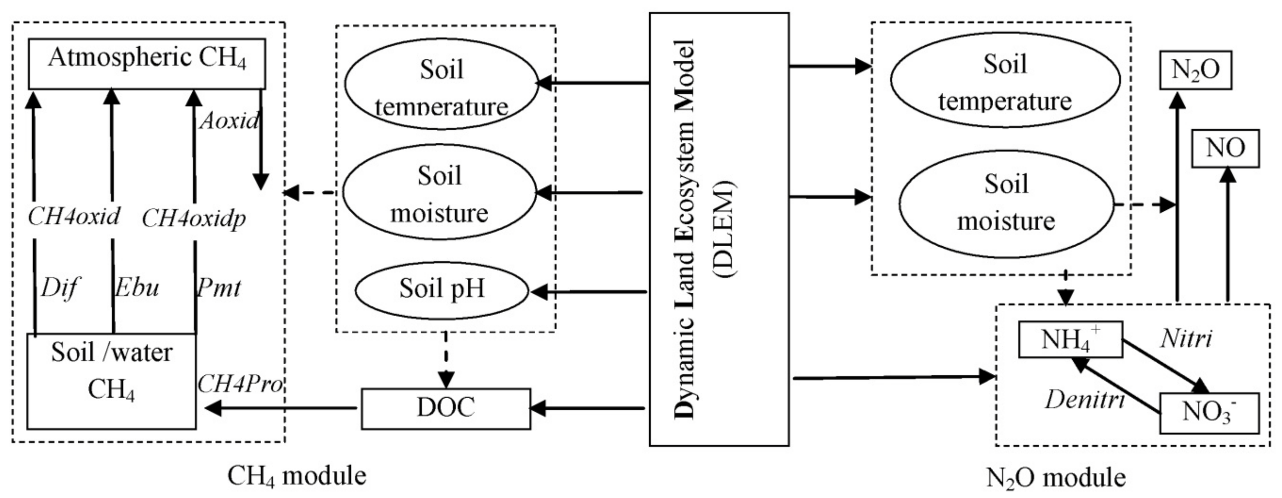


Error analysis for earth-gridded emissivity product: *Water bodies dominate errors*

Dynamic Land Ecosystem Model (DLEM)



Major water processes



Major processes: *Aoxid*: Atmospheric CH_4 oxidation; *CH4pro*: CH_4 production; *CH4oxid*: CH_4 Oxidation during diffusion and ebullition transport; *CH4oxidp*: CH4 oxidation during plant-mediated transport (Occur in herbaceous wetland only); *Dif*: CH_4 diffusion transport; *Ebu*: CH_4 ebullition transport; *Pmt*: Plant-mediated transport of CH_4; (Occur in herbaceous wetland only); *Nitri*: Nitrification; *Denitri*: Denitrification; DLEM provides the environment factors and substrate for CH_4 and N_2O modules; the environmental controls were shown as dash lines.

Conceptual model of the CH_4 and N_2O module, showing production, consumption and transport. Both CH_4 and N_2O are closely linked to moisture, which could be input to or simulated in DLEM.

3. SMAP Overview

- Launch expected Nov. 2014 – May 2015
- Mission concept
  - 40 km L-band (~1.4 GHz) microwave radiometer
  - 1-3 km L-band synthetic aperture radar (SAR)
    - Unique features: wide swath, high resolution, frequent revisit (2-3 days)
  - L-band measurements enable vegetation and clouds penetration and deeper soil moisture sensitivity
- Primary mission products (9-40 km resolution)
  - Soil moisture
  - Freeze/thaw detection
  - Net ecosystem exchange (NEE)
- Inundation mapping characteristics (ancillary product)
  - Water detection or water fraction (f_w) at 1-9 km resolution
  - 2-3 day revisit interval
  - Able to detect water beneath vegetation

4. Managing f_w uncertainty

- Expect SMAP f_w uncertainties to decrease with scale
  - Radar signal-to-noise ratio decreases at smaller scales
- f_w error model must also account for regional factors
  - Heterogeneity of surface types (including water bodies)
  - Vegetation types in dry and wet parts of scene
  - Soil moisture and freeze/thaw status
  - Topography
- Choice of scale for the SMAP-DLEM interface depends on DLEM robustness to f_w errors
  - Highly robust:
    - Interface at smaller SMAP scale
    - Higher f_w errors managed by DLEM
  - Less robust:
    - Interface at larger effective scale (i.e., spatial noise filter)
    - Apply time-series smoothing (i.e., temporal noise filter)

5. Plan

Phase 1 – Baseline simulation

- SMAP scene simulation
  - Low-resolution: N. America (primary) & S. America (secondary)
  - High-resolution: Selected intensive study regions at high-latitude, mid-latitude & tropics
- Develop and test baseline and alternative SMAP inundation algorithms
  - Predict retrieval performance stratified by ecosystem type etc.
- Run North America DLEM simulations to test sensitivity to a range of prescribed conditions (inundation and soil moisture)
- Combine SMAP+DLEM sensitivity analyses for preliminary assessment of potential SMAP data impacts on GHG model fluxes

Phase 2 – Data-model fusion

- Develop and test SMAP-DLEM interface
- Simulate SMAP f_w retrievals from analogous sensor data
- Compare 1-year DLEM runs with and without f_w inputs

Phase 3 – Synthesis and validation

- Run WRF/STILT model to create emission footprint maps for a representative sample of CH_4 atmospheric measurements
- Convolve footprints with SMAP-DLEM modeled CH_4 fluxes
  - Yields incremental CH_4 concentration at the measurement point due to land surface processes in the emission footprint
- Adjust for background CH_4 field and compare to measurements

3-way trial concept

Three-way trials combine simulations and real-world analogous sensor data to more accurately quantify future sensor retrieval performance:

1. DLEM+SMAP simulation: Predicts future system performance
2. DLEM+AMSR-E simulation: Predicts performance of a system analogous to SMAP
3. DLEM+AMSR-E data: Analyzes real-world analog system performance
   - Directly validates the DLEM+AMSR-E simulation (2)
   - Validates many aspects of the DLEM+SMAP simulation (1) e.g., temporal sampling impact, downscaling impact, SMAP-DLEM interface

6. Status

- Expected project start June 1
- SMAP status
  - Preliminary Design Review: January, 2011
  - Water fraction/detection algorithm being developed
- Other developments
  - ESA SMOS (Soil Moisture and Ocean Salinity) launch in January
    - Provides another SMAP sensor analog (L-band radiometer) in addition to AMSR-E (6 – 89 GHz radiometers)
    - Current static water bodies databases are unsatisfactory
    - RFI is apparently not an issue in Americas

Acknowledgment

This work is sponsored by the NASA Terrestrial Ecology Program.