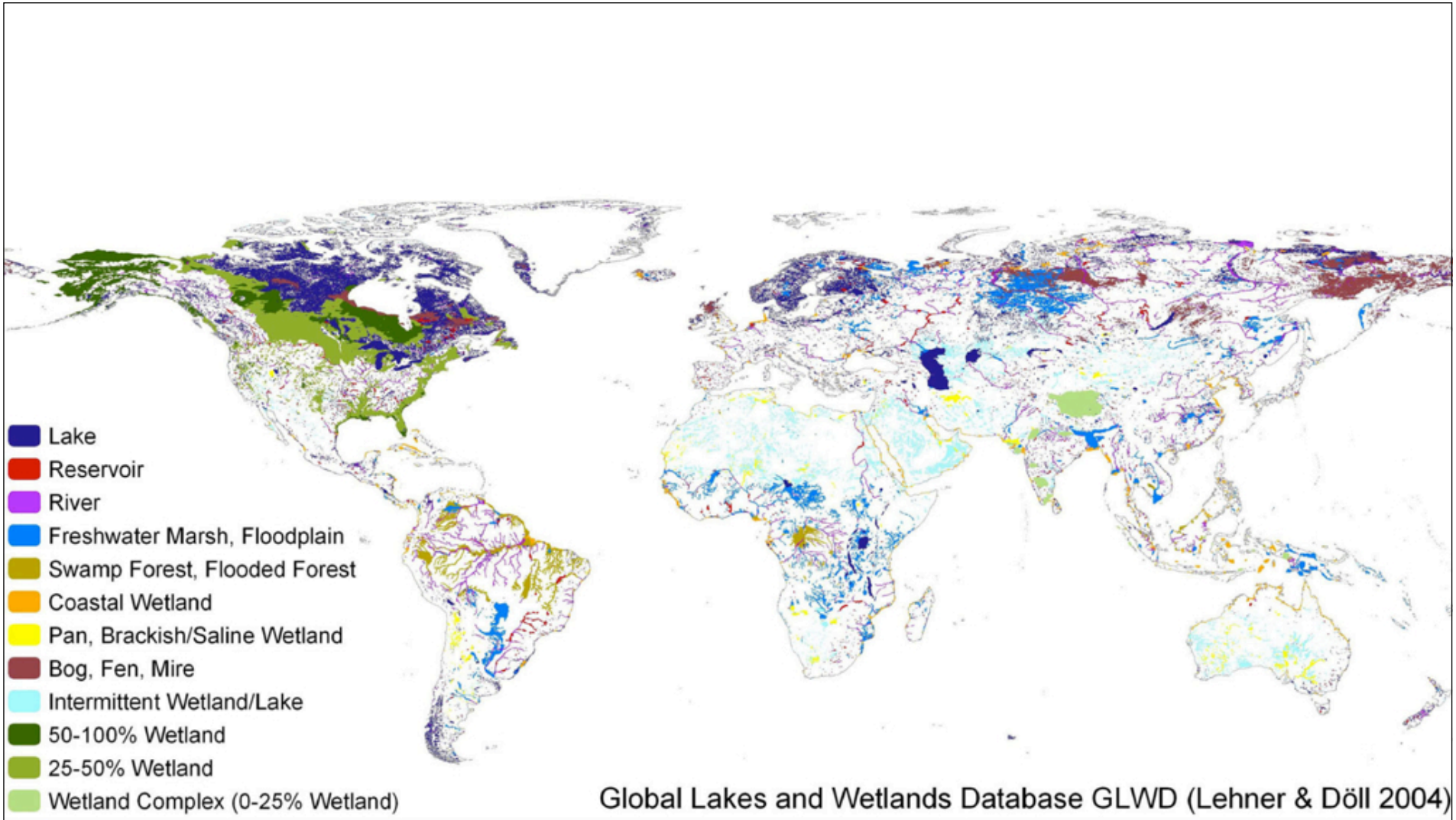
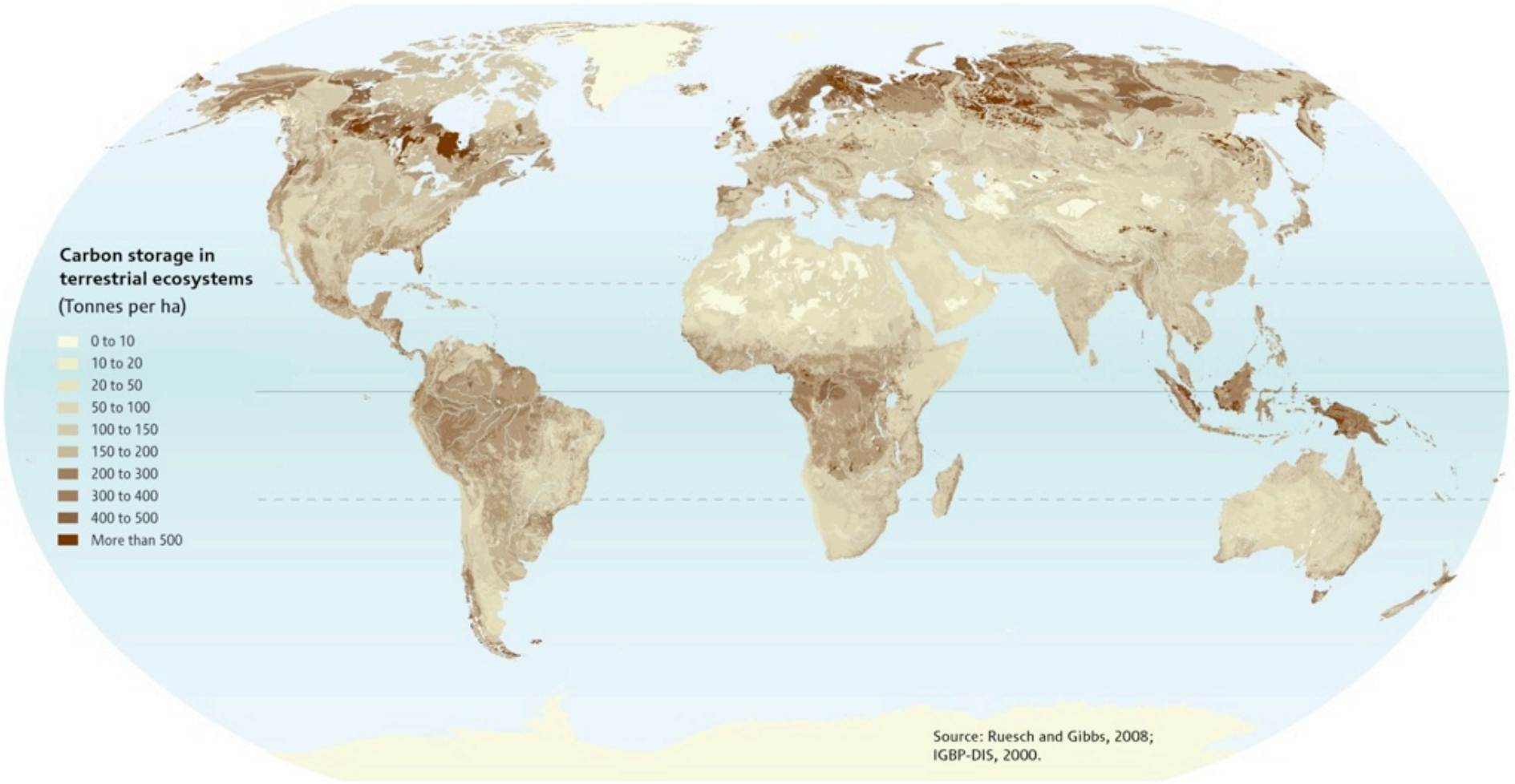
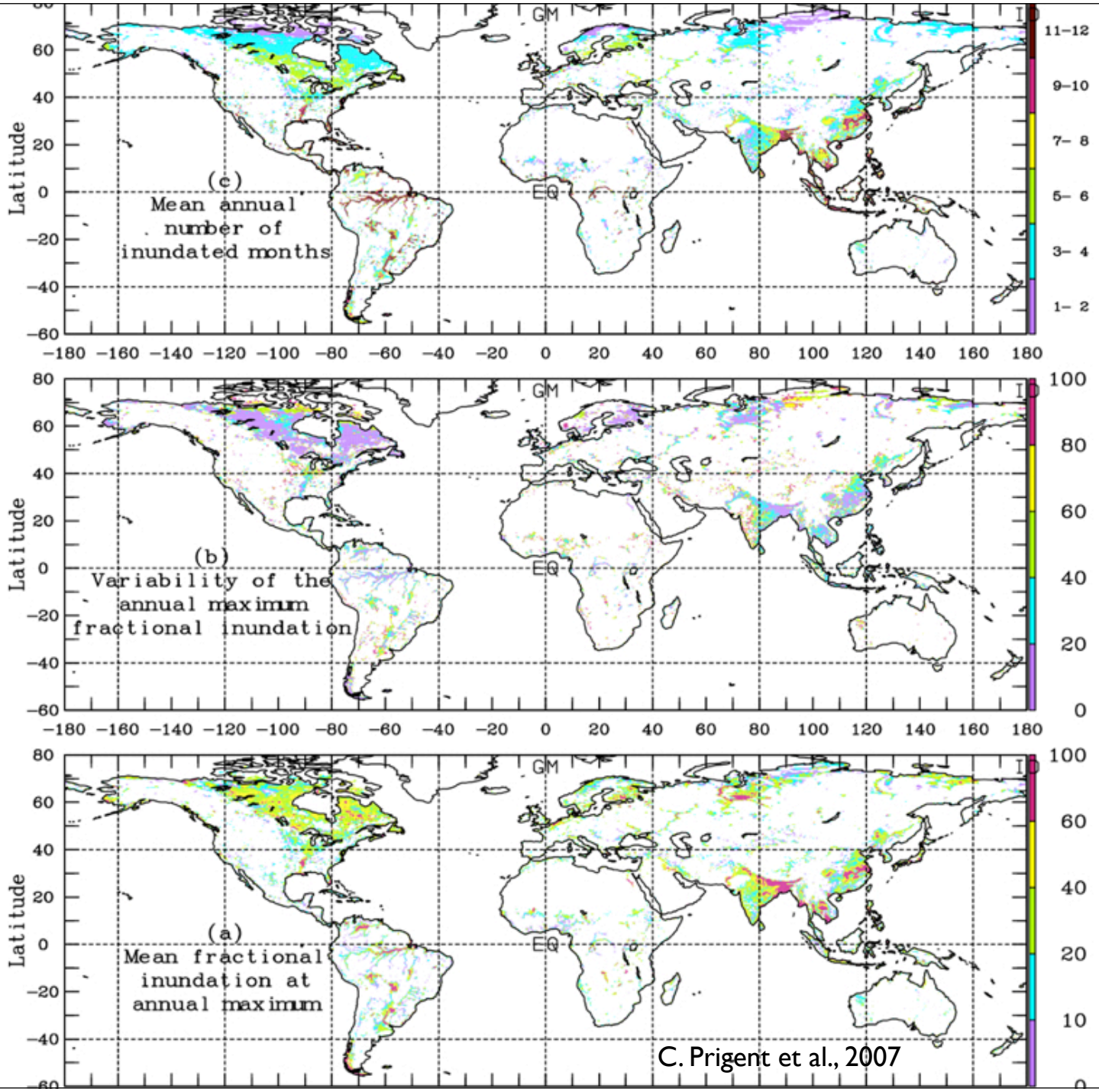

Wetlands
Modeling their extent, heat flux and trace gas exchange
Parker Kraus



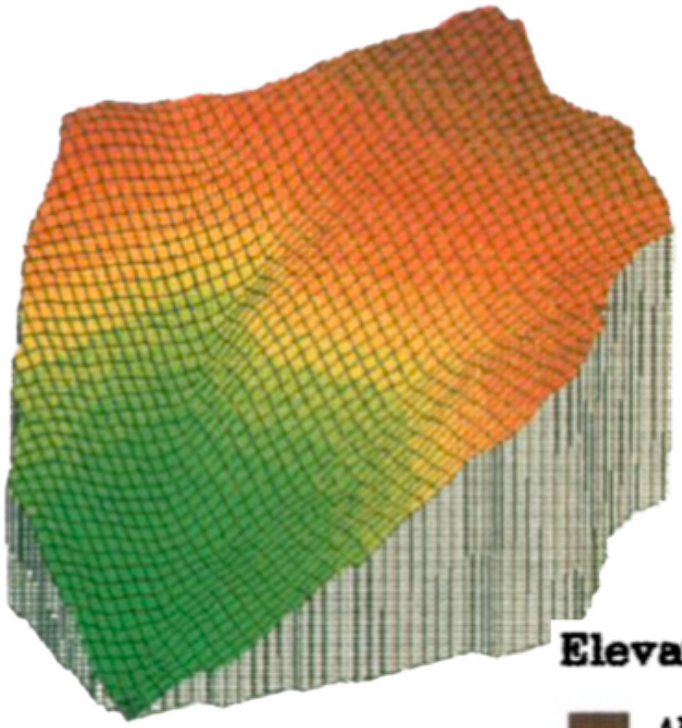
Global Lakes and Wetlands Database GLWD (Lehner & Döll 2004)

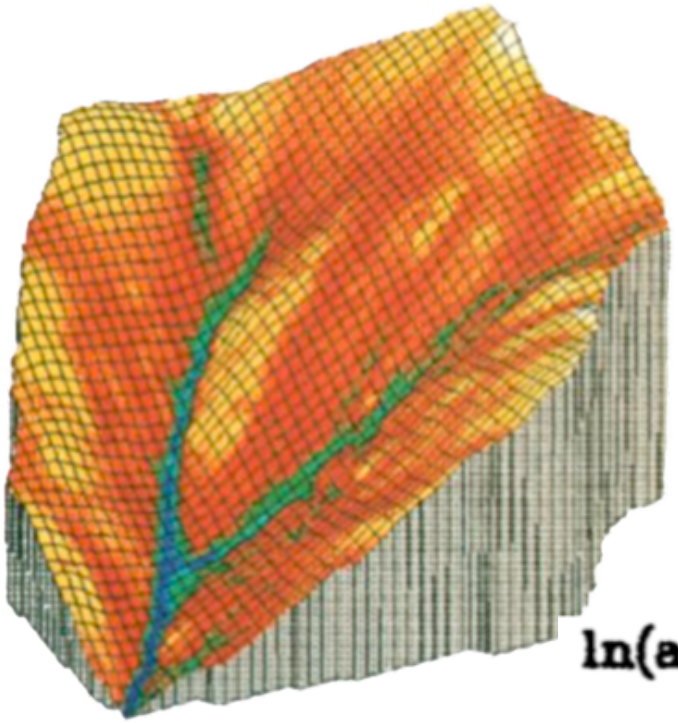

Carbon storage in terrestrial ecosystems
(Tonnes per ha)
0 to 10
10 to 20
20 to 50
50 to 100
100 to 150
150 to 200
200 to 300
300 to 400
400 to 500
More than 500
Source: Ruesch and Gibbs, 2008;
IGBP-DIS, 2000.



C. Prigent et al., 2007

TOPMODEL





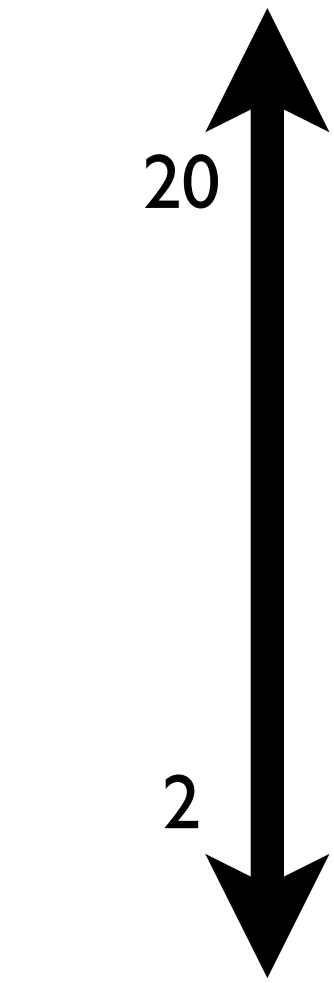
Ambroise et al., 1996

Elevation (m)

ABOVE	1000
975 –	1000
950 –	975
925 –	950
900 –	925
875 –	900
850 –	875
825 –	850
800 –	825
775 –	800
750 –	775
BELOW	750

ln(a/tanβ)

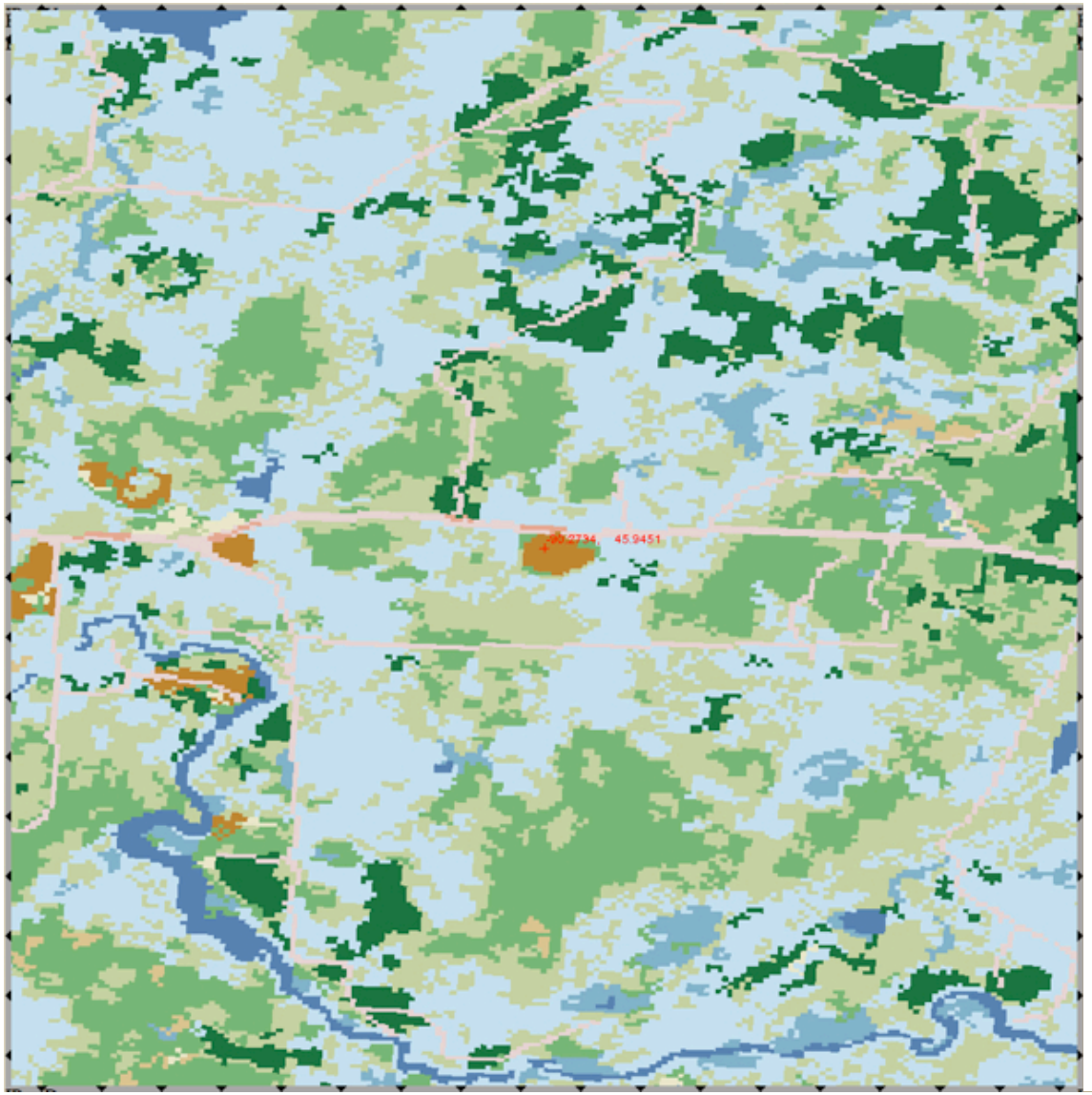
ABOVE	11.5
10.5 –	11.5
9.5 –	10.5
8.5 –	9.5
7.5 –	8.5
6.5 –	7.5
5.5 –	6.5
4.5 –	5.5
3.5 –	4.5
BELOW	3.5



$$TI = \ln(a/\tan\beta)$$

Estimating Wetland Extent

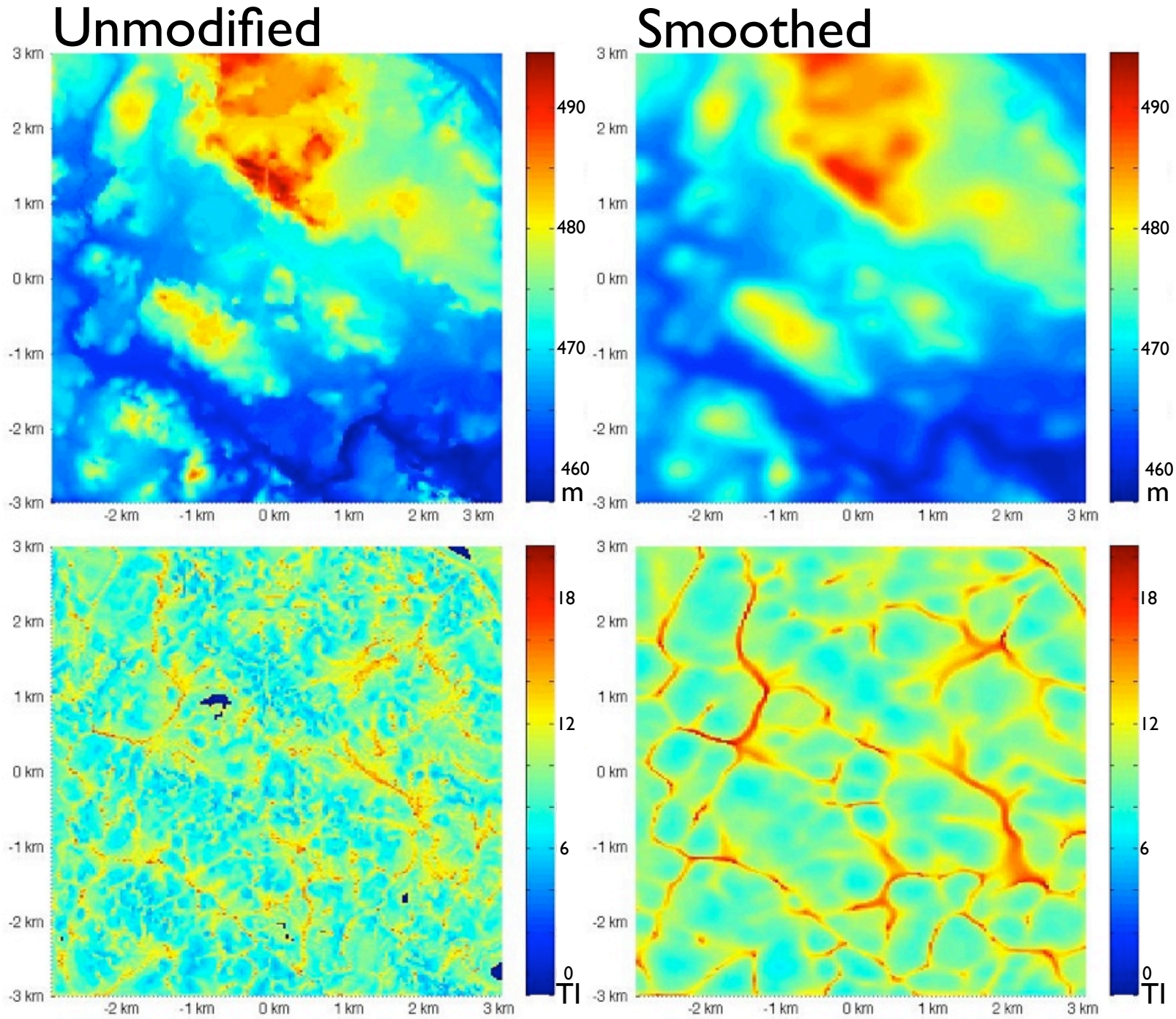
The WLEF tall tower

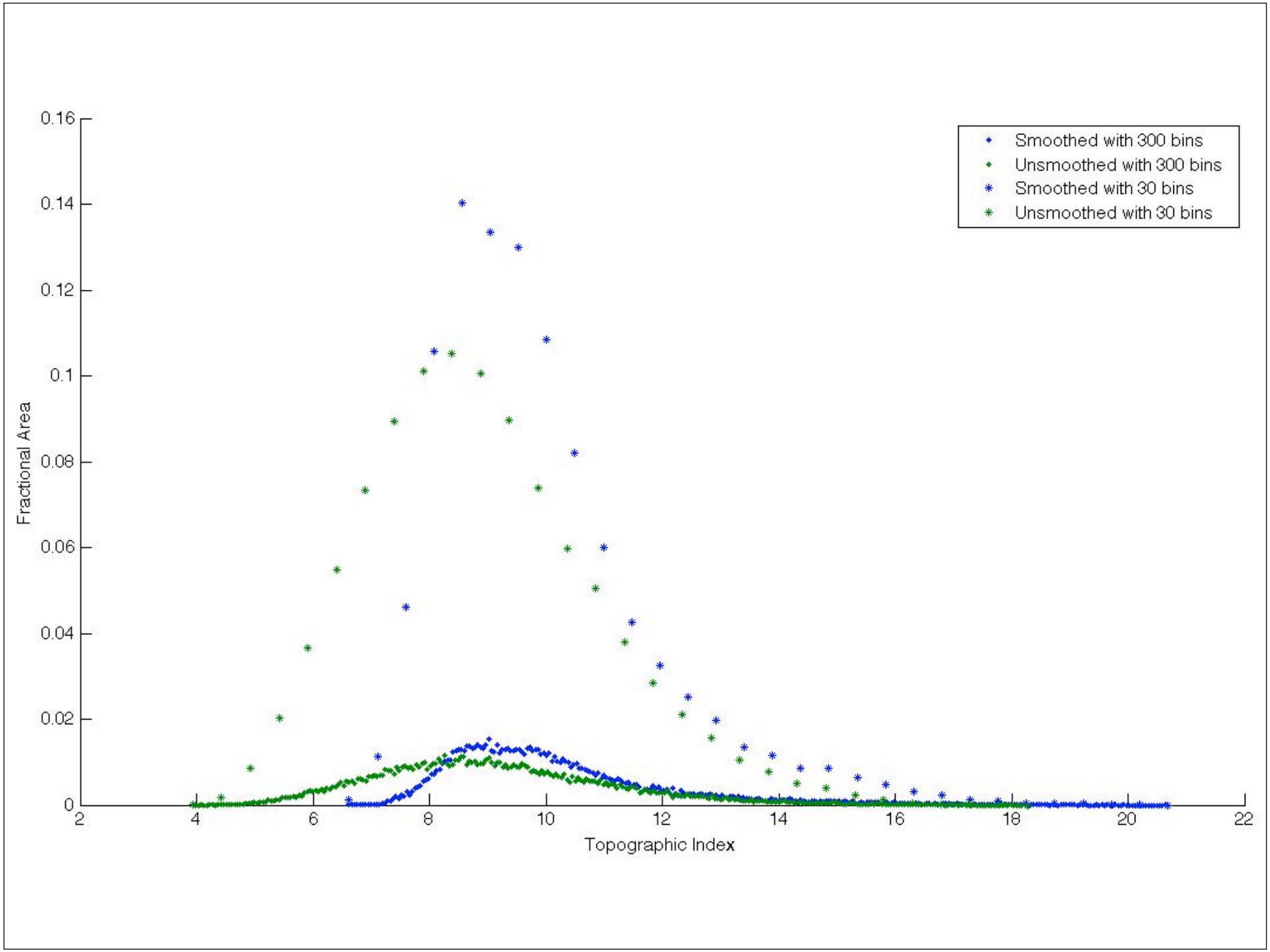


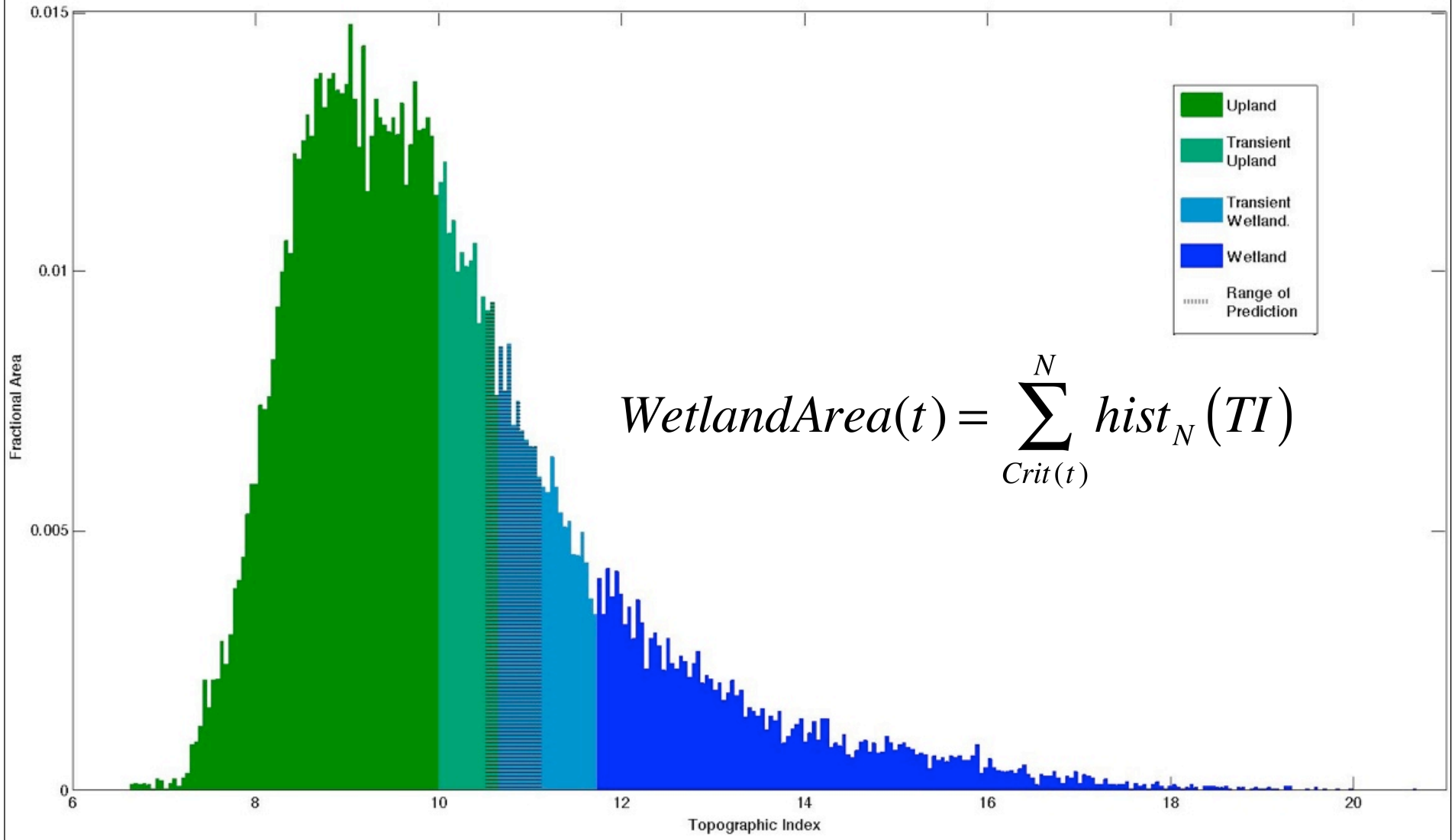
North-central Wisconsin
(45°55'N, 90°10'W)

447 m tall

Instruments
measuring CO_2, CH_4 and
heat fluxes at 30 & 76 m

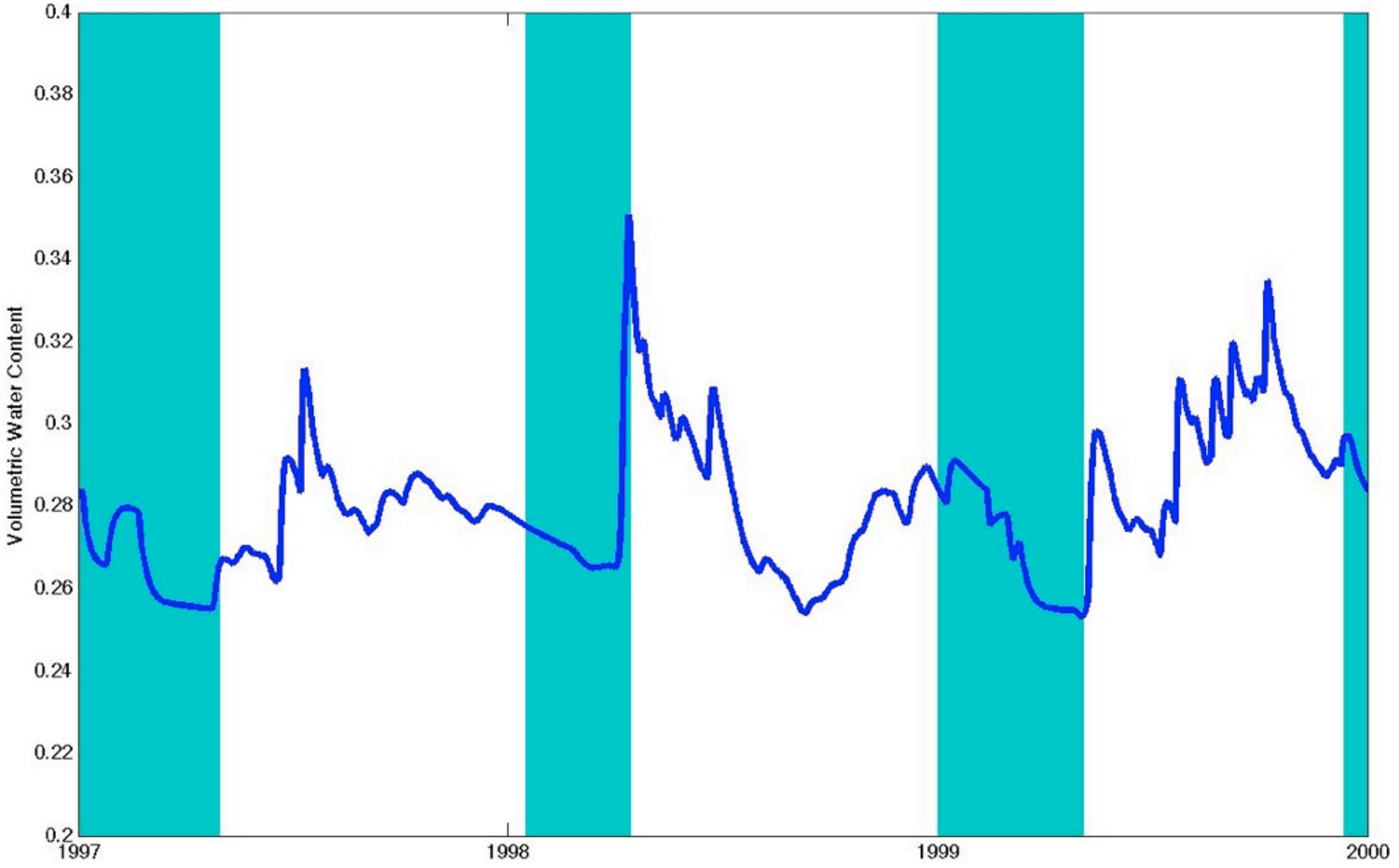

Unmodified
Smoothed
3 km
2 km
1 km
0 km
-1 km
-2 km
-3 km
-2 km
-1 km
0 km
1 km
2 km
3 km
490
480
470
460
m
18
12
6
0
TI


Smoothed with 300 bins
Unsmoothed with 300 bins
Smoothed with 30 bins
Unsmoothed with 30 bins
Fractional Area
Topographic Index
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2
4
6
8
10
12
14
16
18
20
22

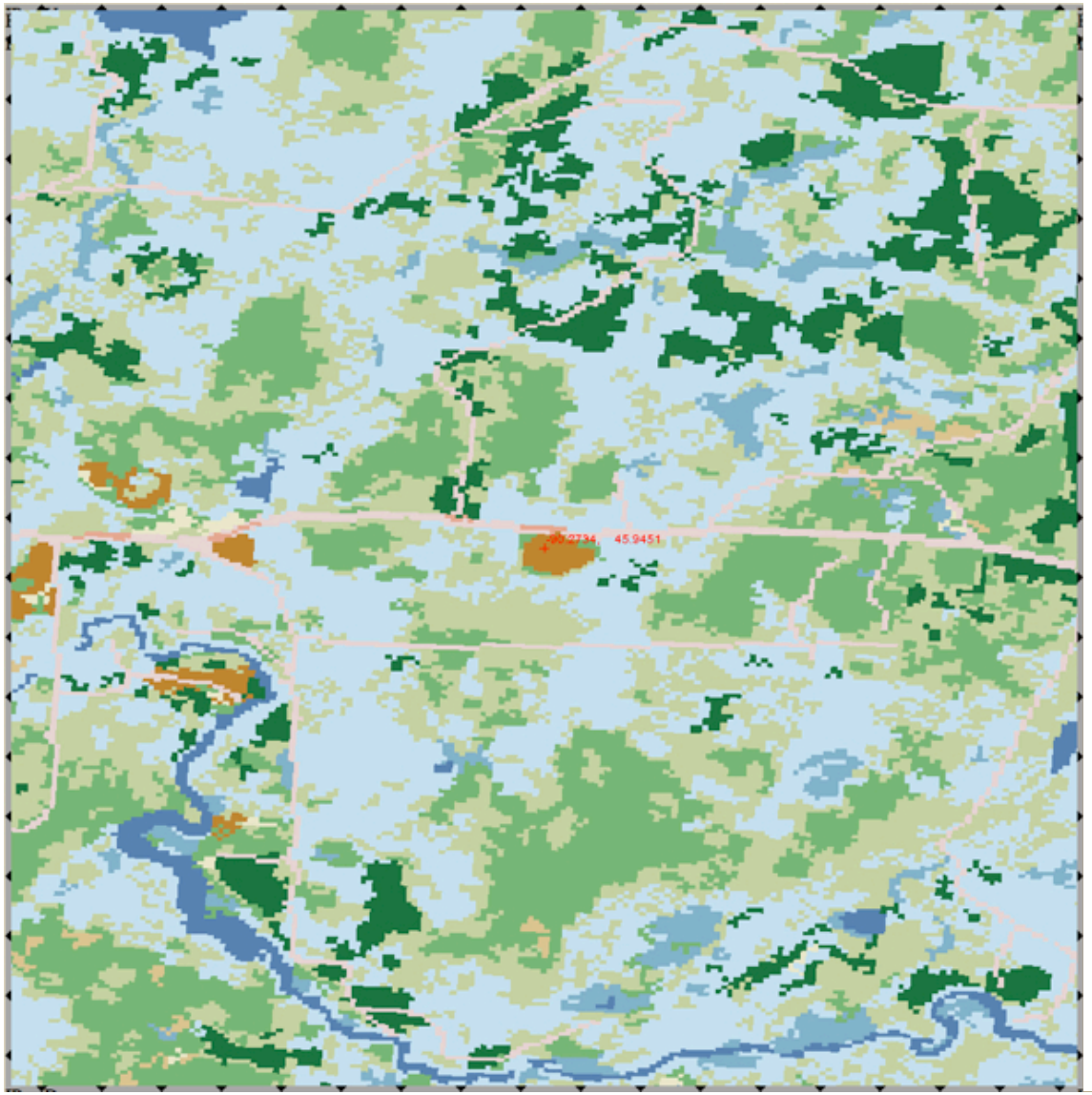


$$WetlandArea(t) = \sum_{Crit(t)}^{N} hist_N(TI)$$

$$Crit(t) = \left(1 - WaterContent(t)\right) \cdot m$$



The WLEF tall tower



To calibrate the model:

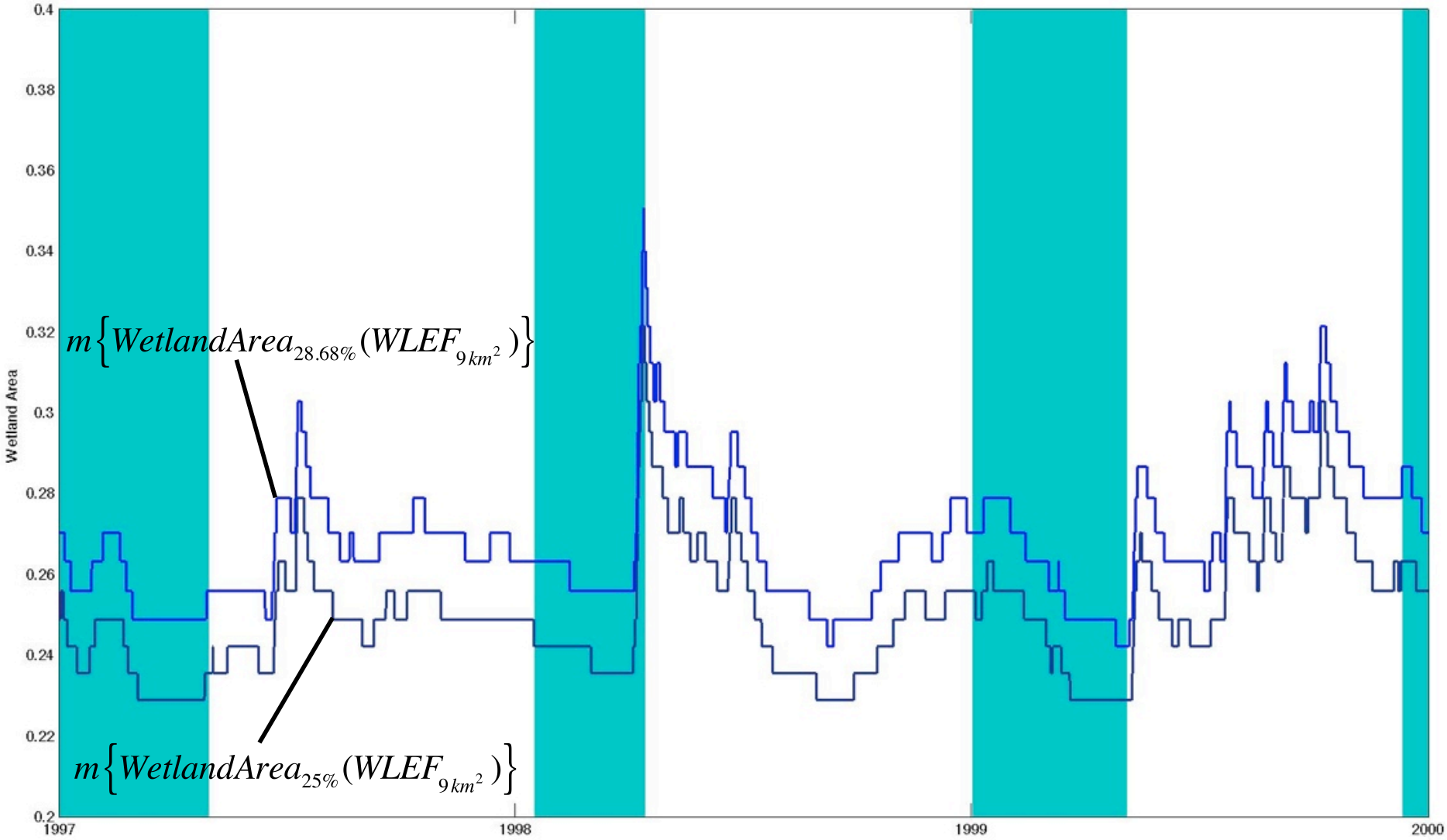
$$Crit_O = \left(1 - \overline{WaterContent}\right) \cdot m_0$$

$$WetlandArea_O = \sum_{Crit_O}^{N} hist_N(TI)$$

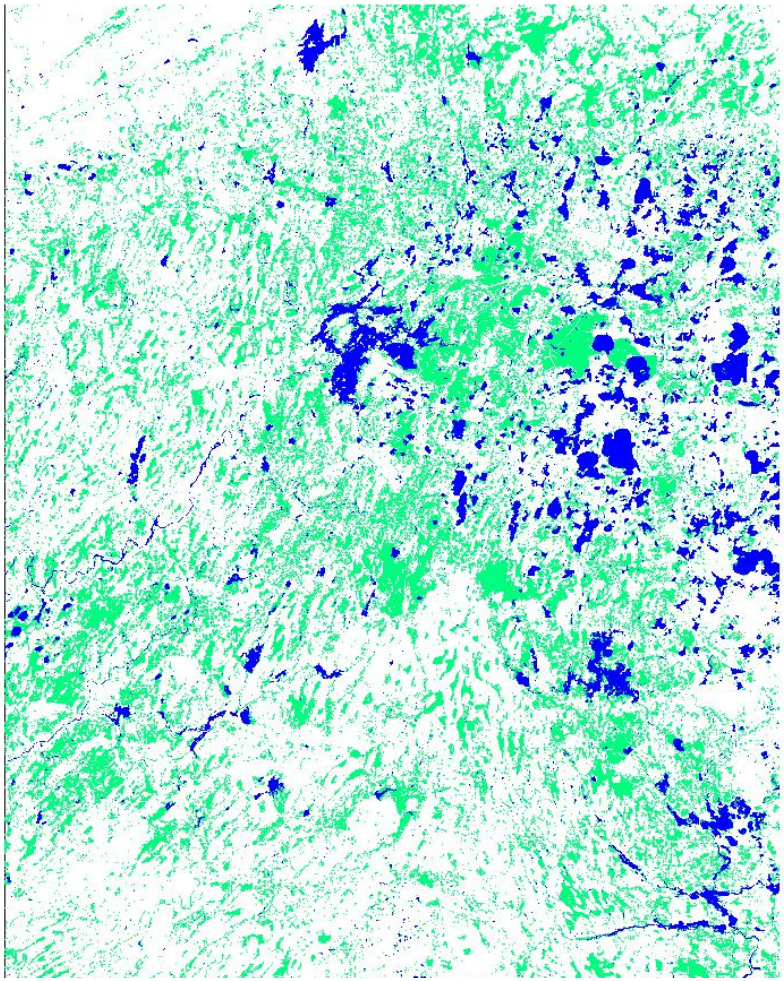
$$WetlandArea_O(WLEF_{9km^2}) = 28.68\%$$

$$m_0(WLEF_{9km^2}) = 122.35$$

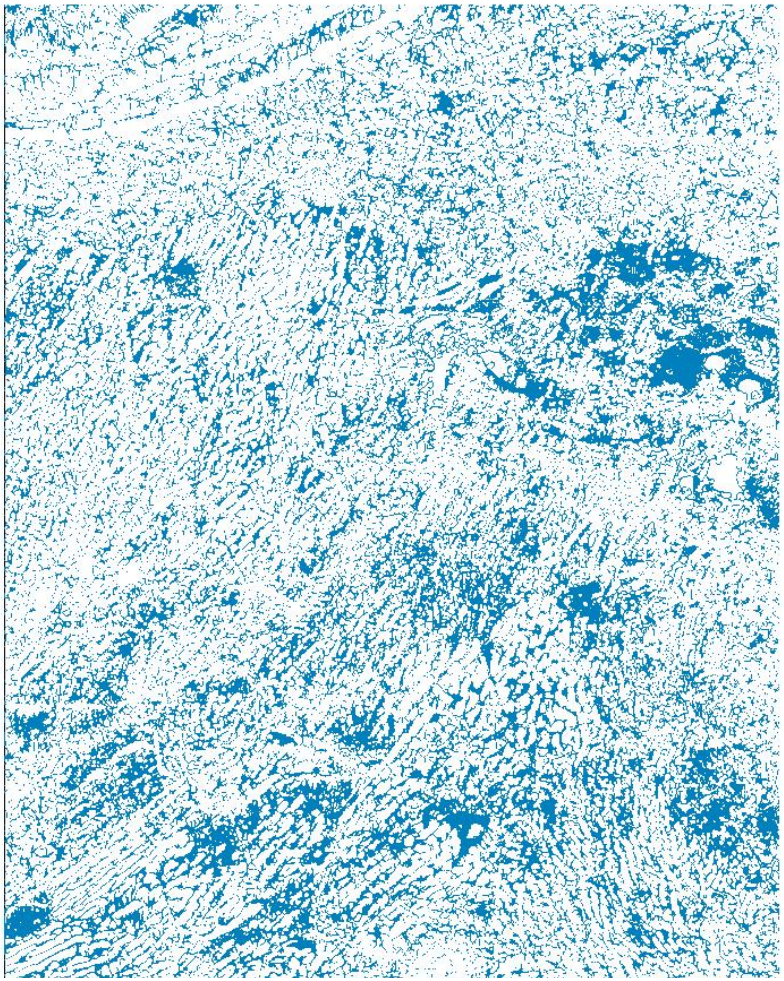
Modeled Wetland Area at the WLEF 9 km^2 site



WLEF 1° x 1°

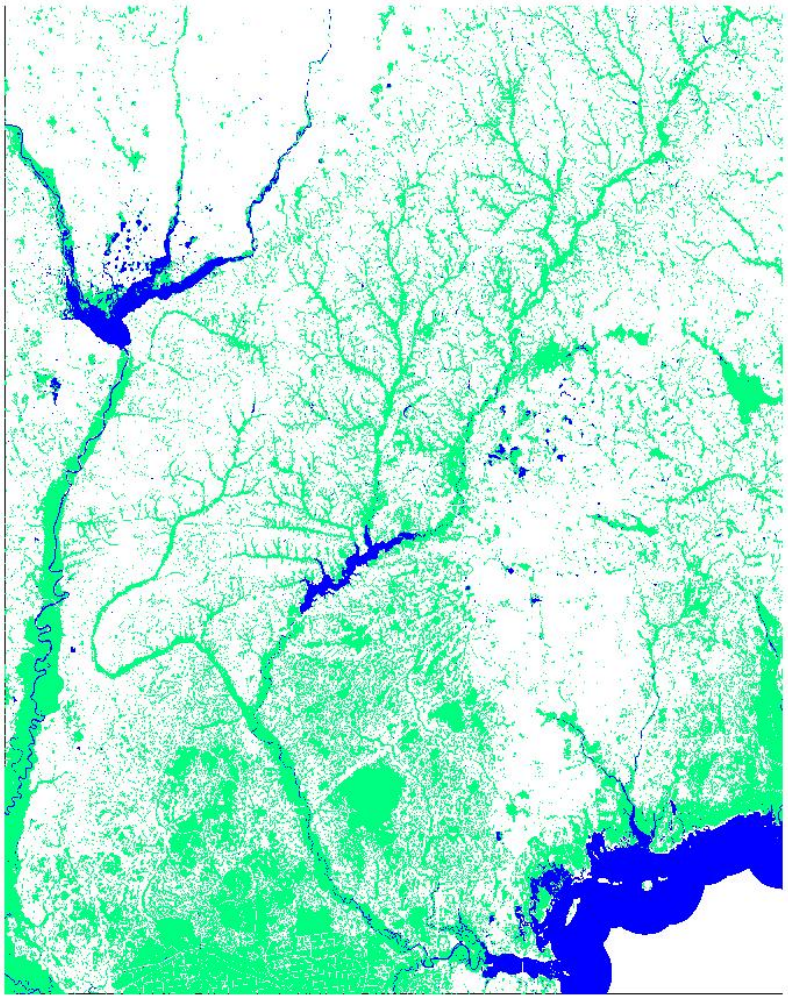


NLDC Land Cover

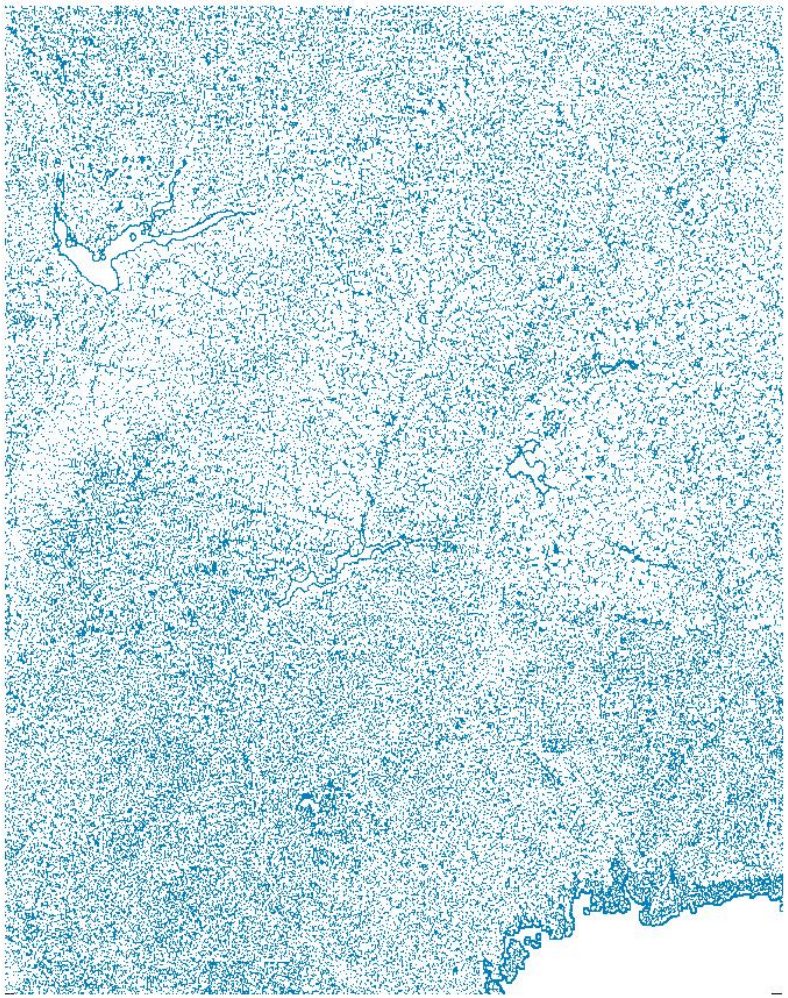


TI-predicted wetland

Tallahassee, FL 1°x1°

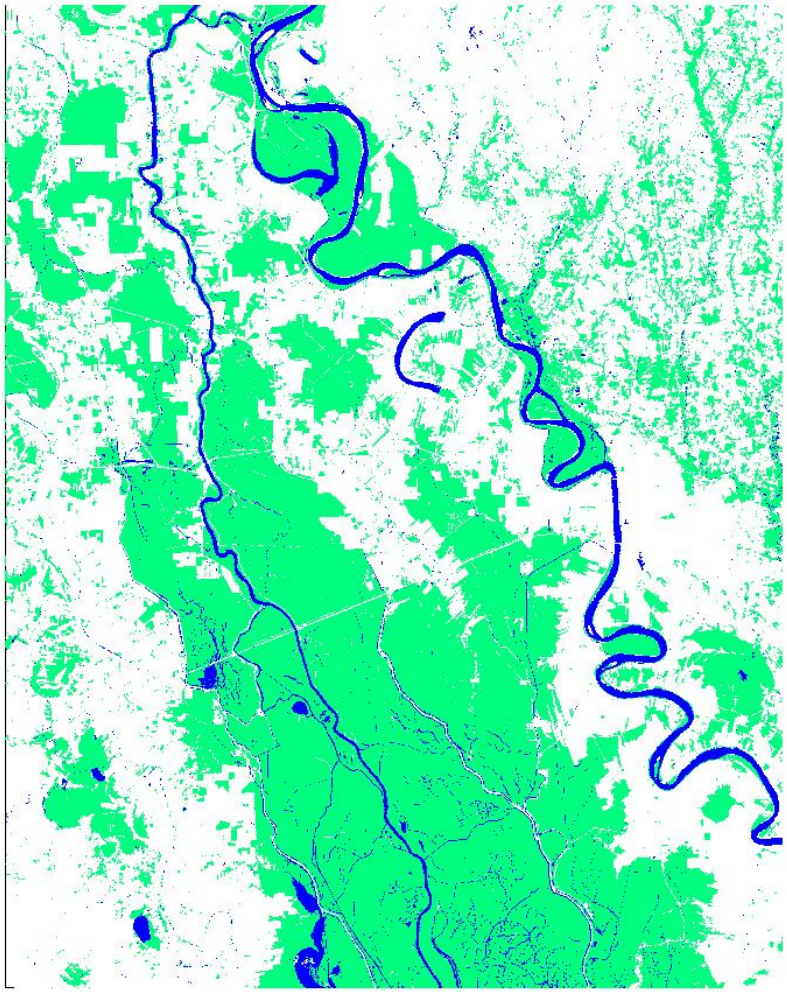


NLDC Land Cover

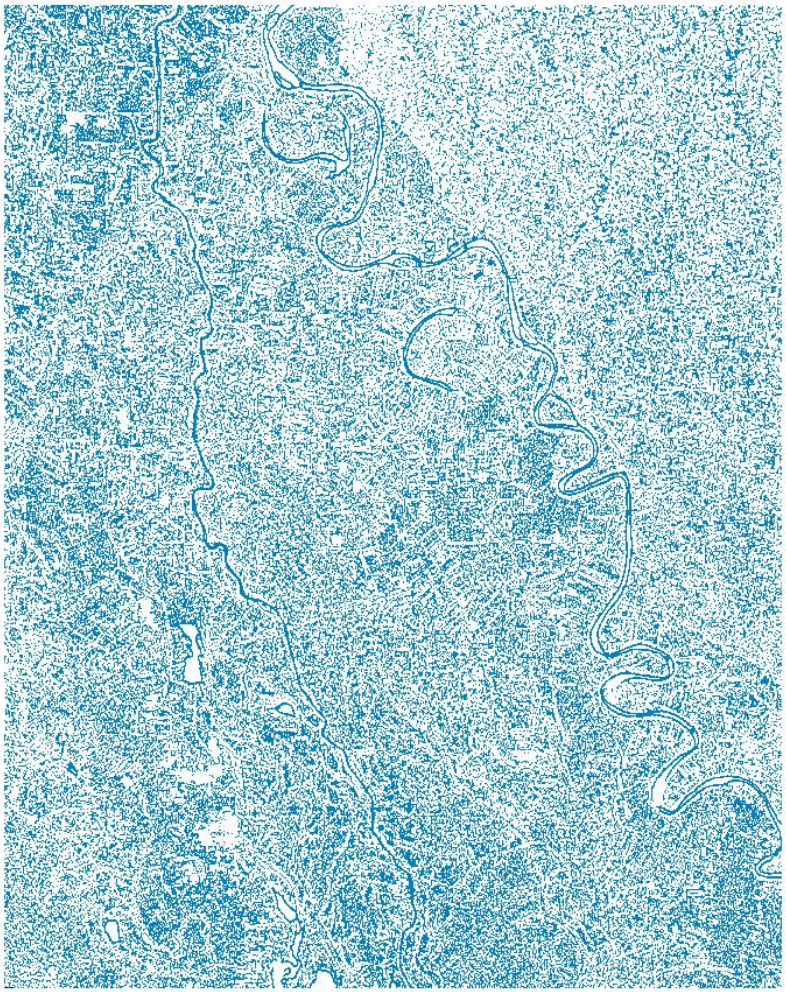


TI-predicted wetland

Baton Rouge, LA 1°x1°

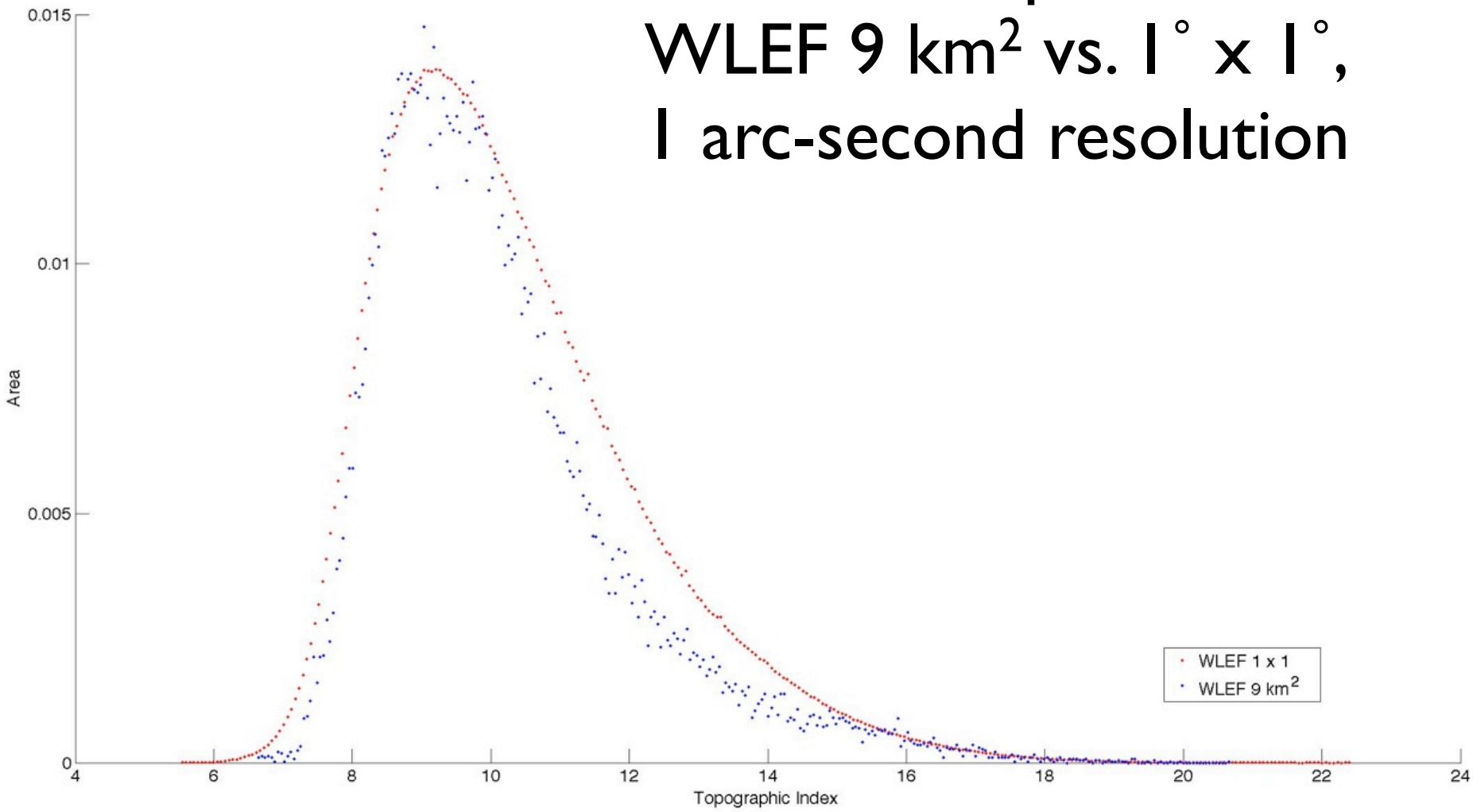


NLDC Land Cover

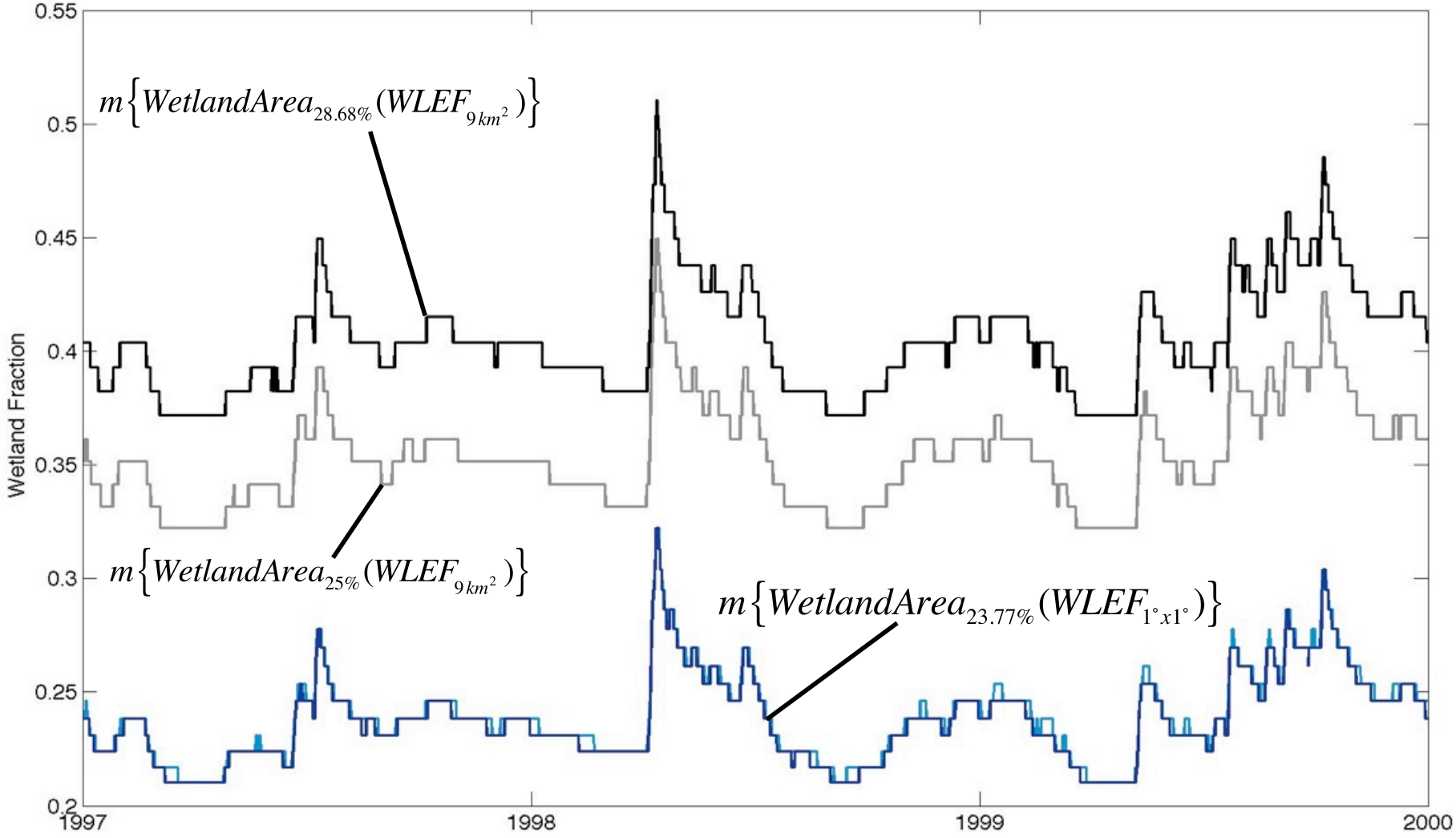


TI-predicted wetland

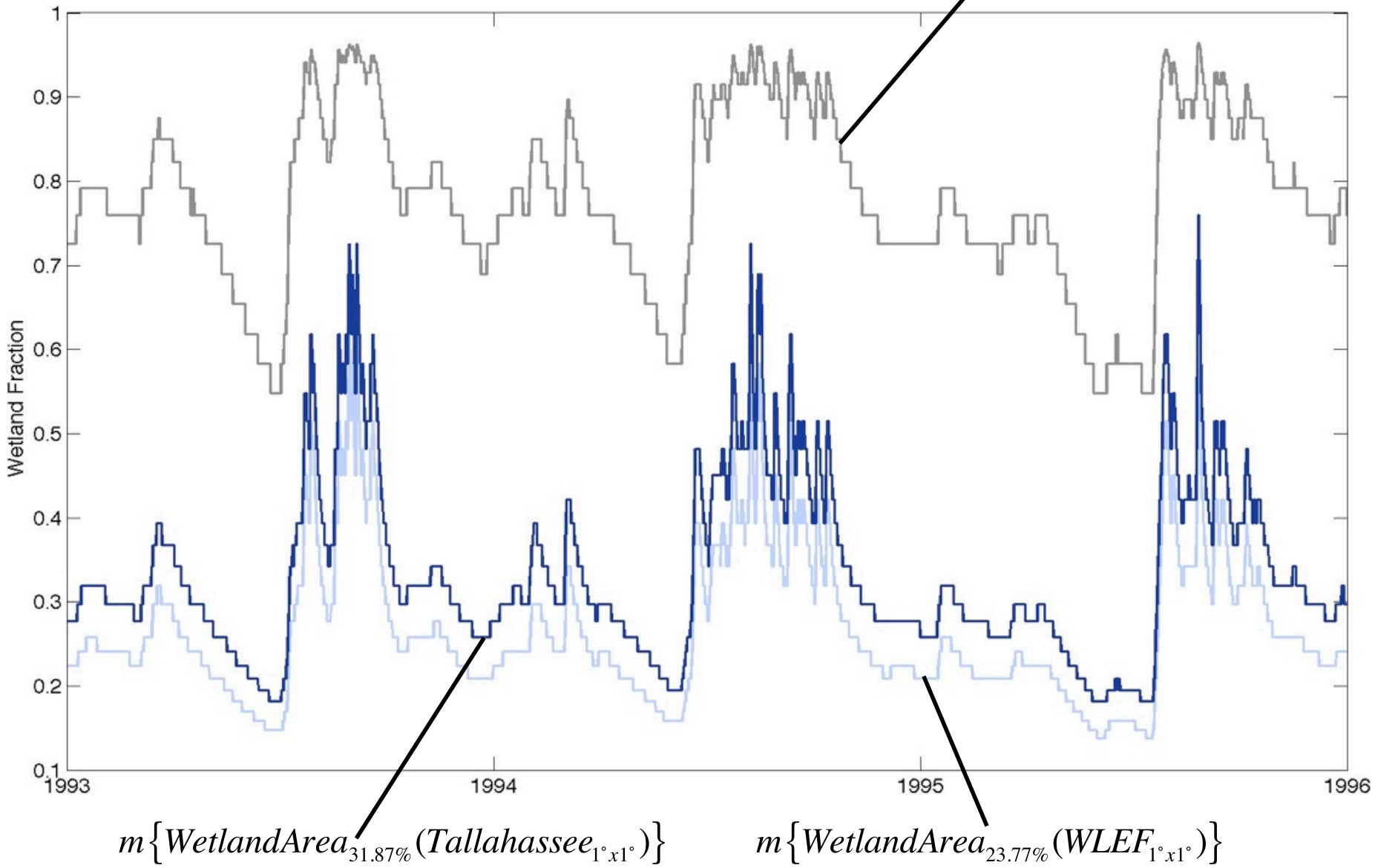
Domain Dependence: WLEF 9 km^2 vs. 1° x 1°, 1 arc-second resolution



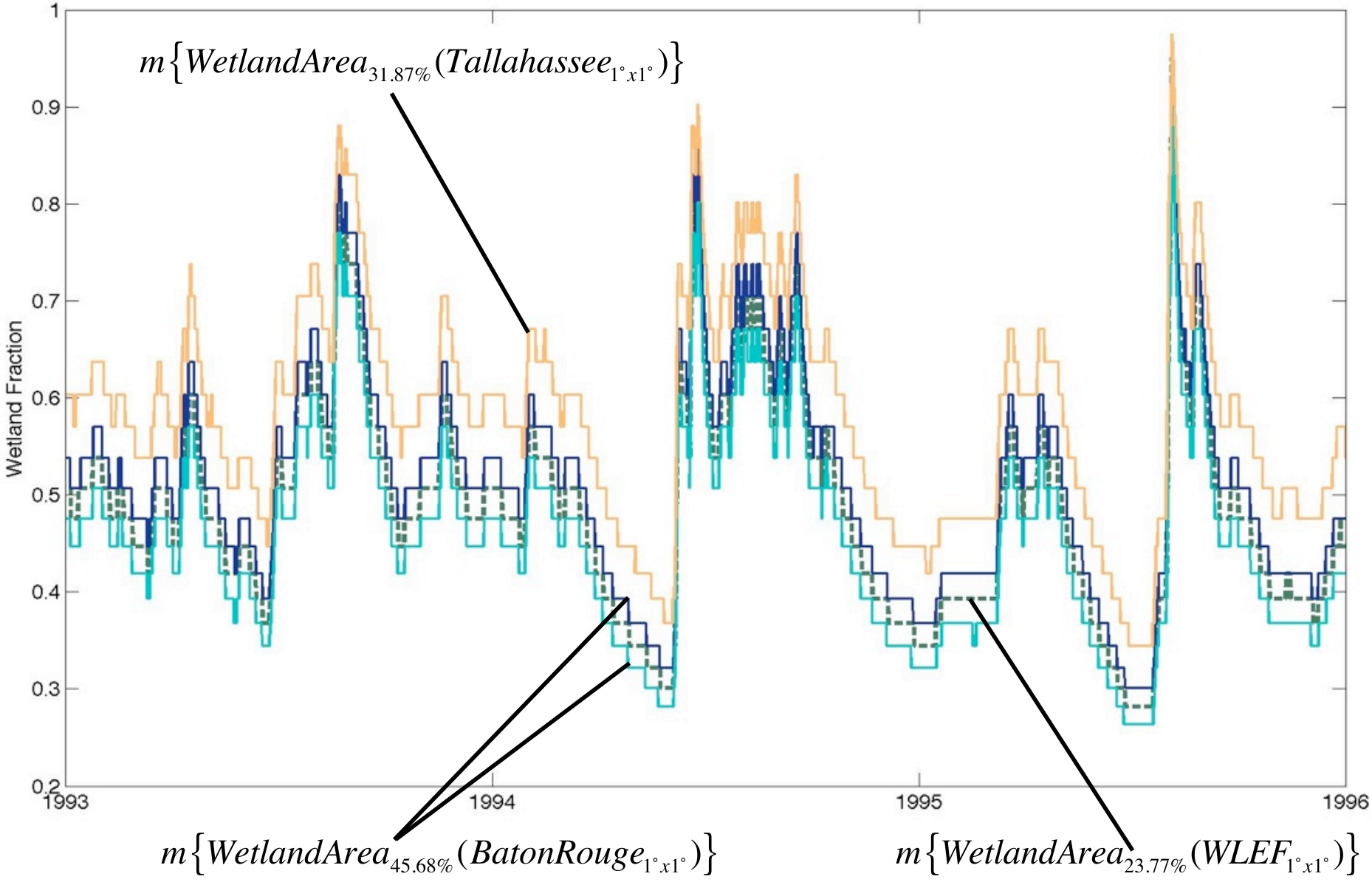
WLEF 9 km^2 vs. 1° x 1°



Tallahassee, FL 1°x1°

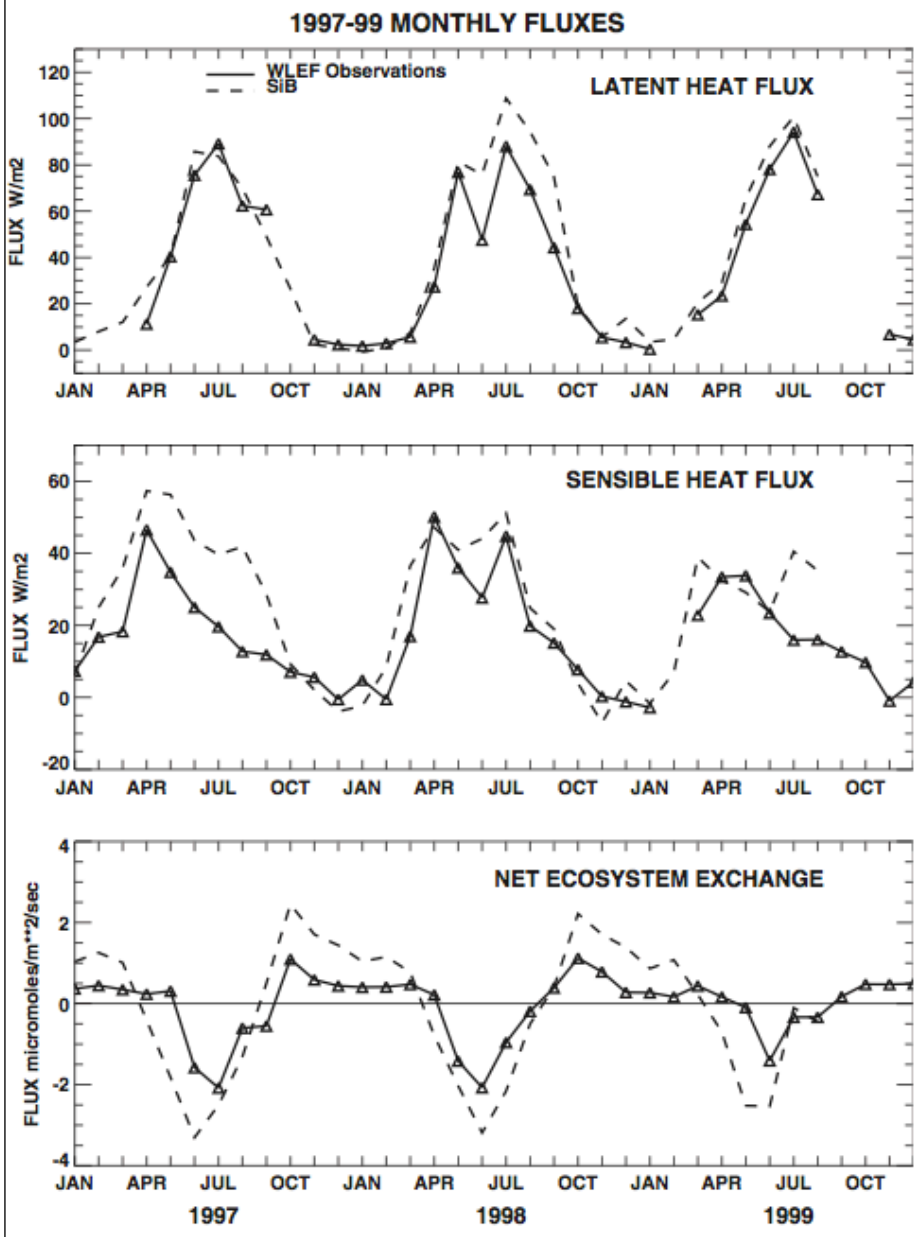


Baton Rouge, LA 1°x1°

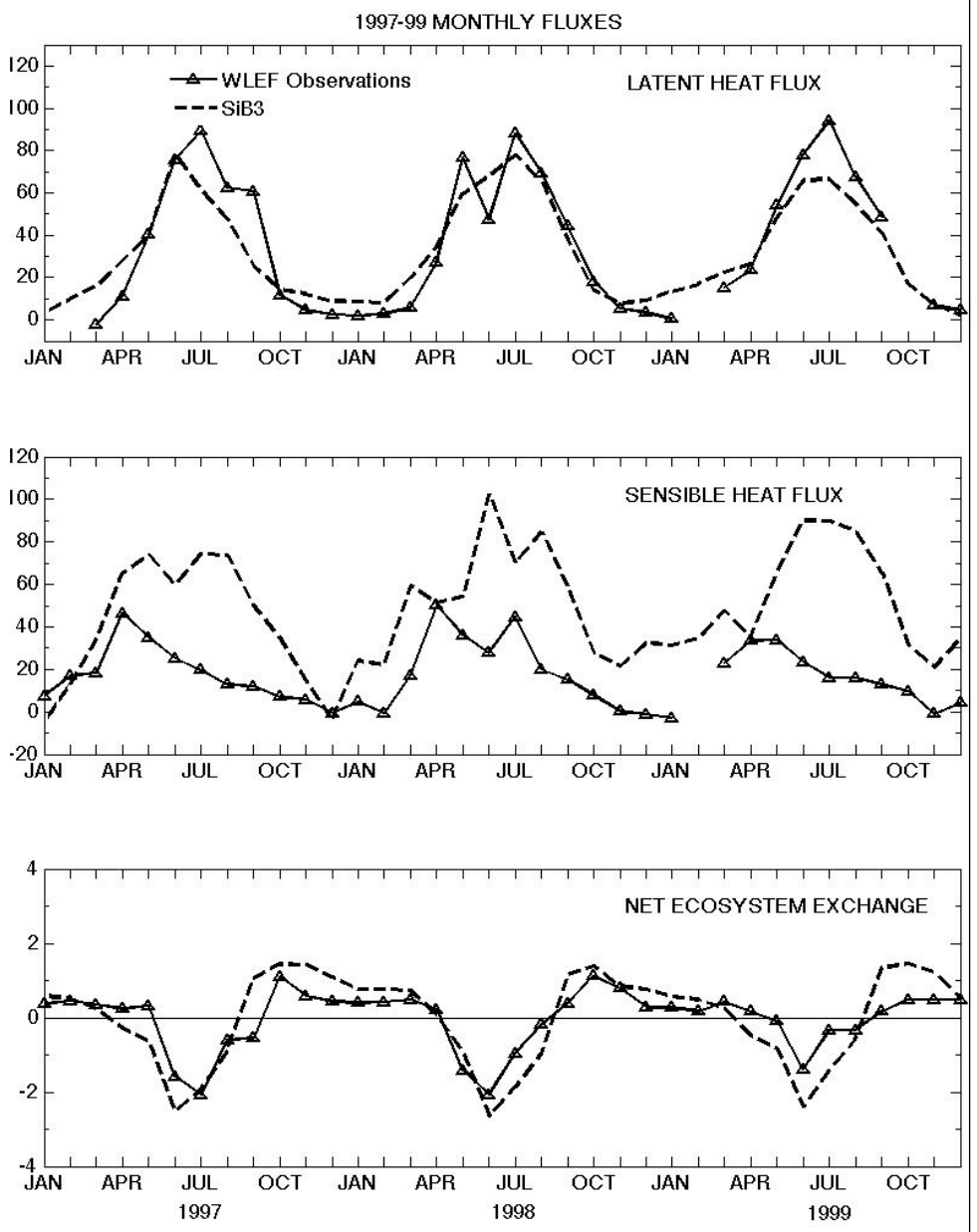


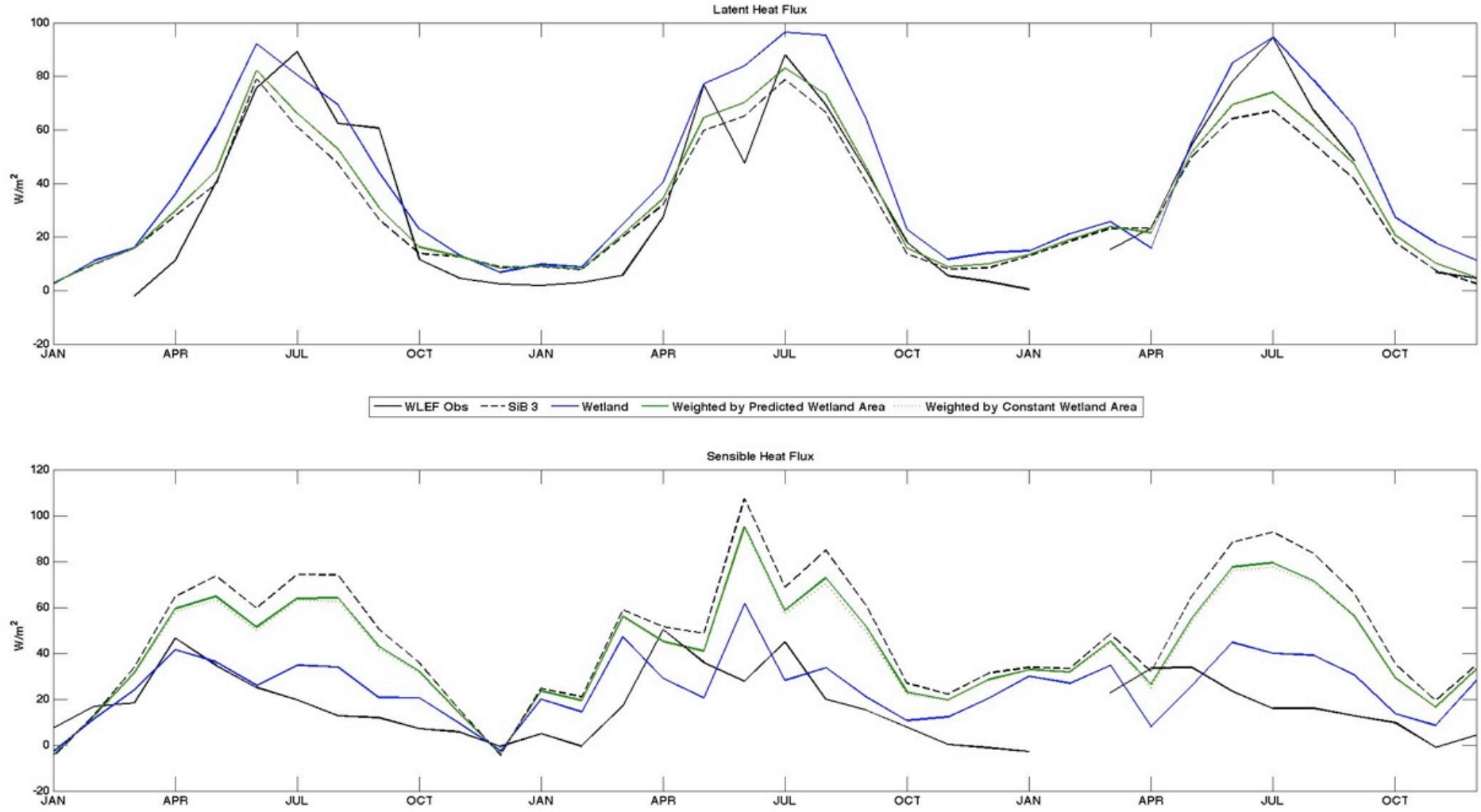
Heat fluxes and CO_2 exchange at the WLEF

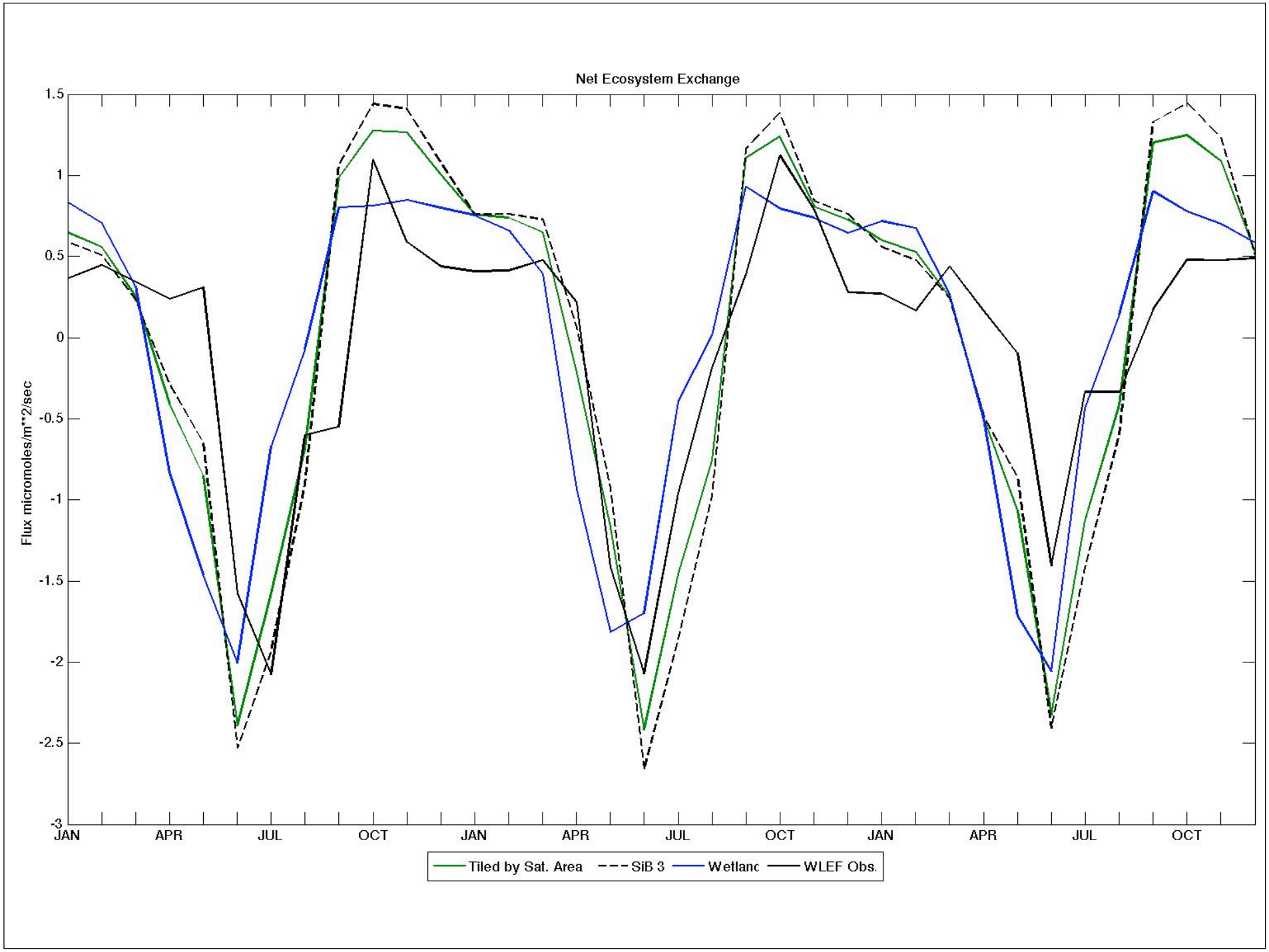
SiB 2.5 Baker et al., 2003



SiB 3



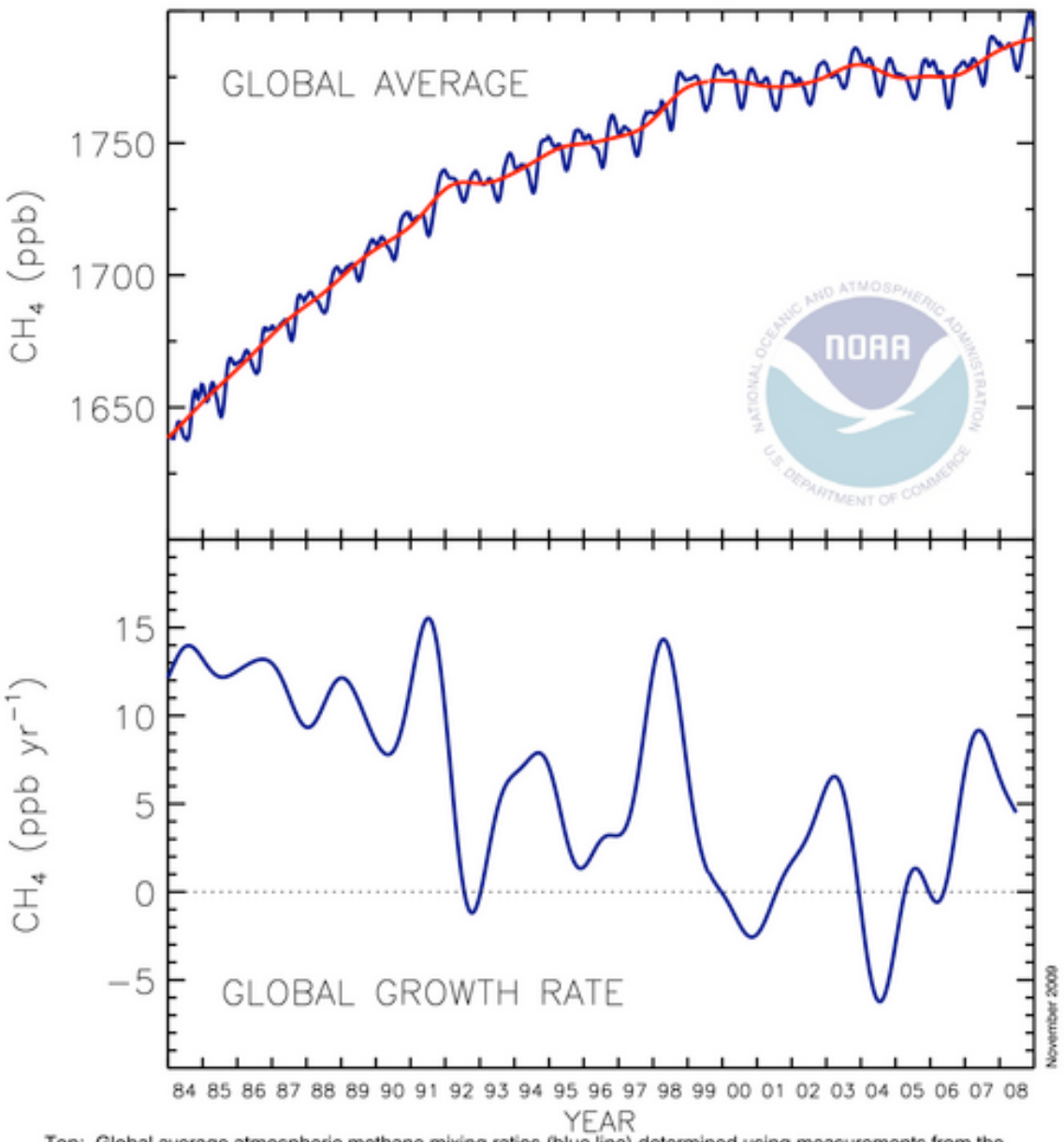

Latent Heat Flux
W/m²
100
80
60
40
20
0
-20
JAN
APR
JUL
OCT
JAN
APR
JUL
OCT
JAN
APR
JUL
OCT
WLEF Obs
SiB 3
Wetland
Weighted by Predicted Wetland Area
Weighted by Constant Wetland Area
Sensible Heat Flux
W/m²
120
100
80
60
40
20
0
-20
JAN
APR
JUL
OCT
JAN
APR
JUL
OCT
JAN
APR
JUL
OCT


Net Ecosystem Exchange
Flux micromoles/m**2/sec
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
JAN
APR
JUL
OCT
JAN
APR
JUL
OCT
JAN
APR
JUL
OCT
Tiled by Sat. Area
SiB 3
Wetlanc
WLEF Obs.

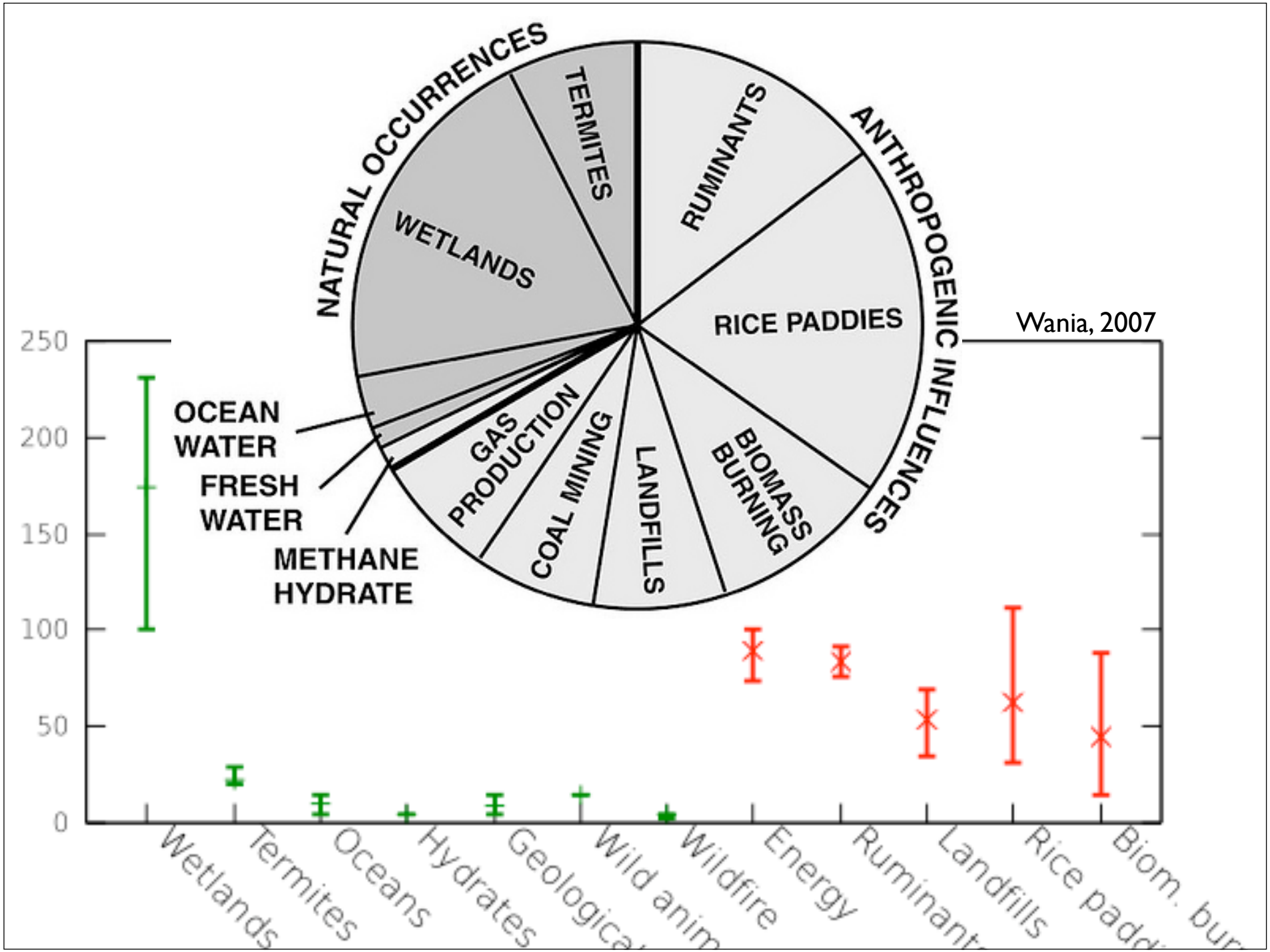
Methane

Methane Measurements

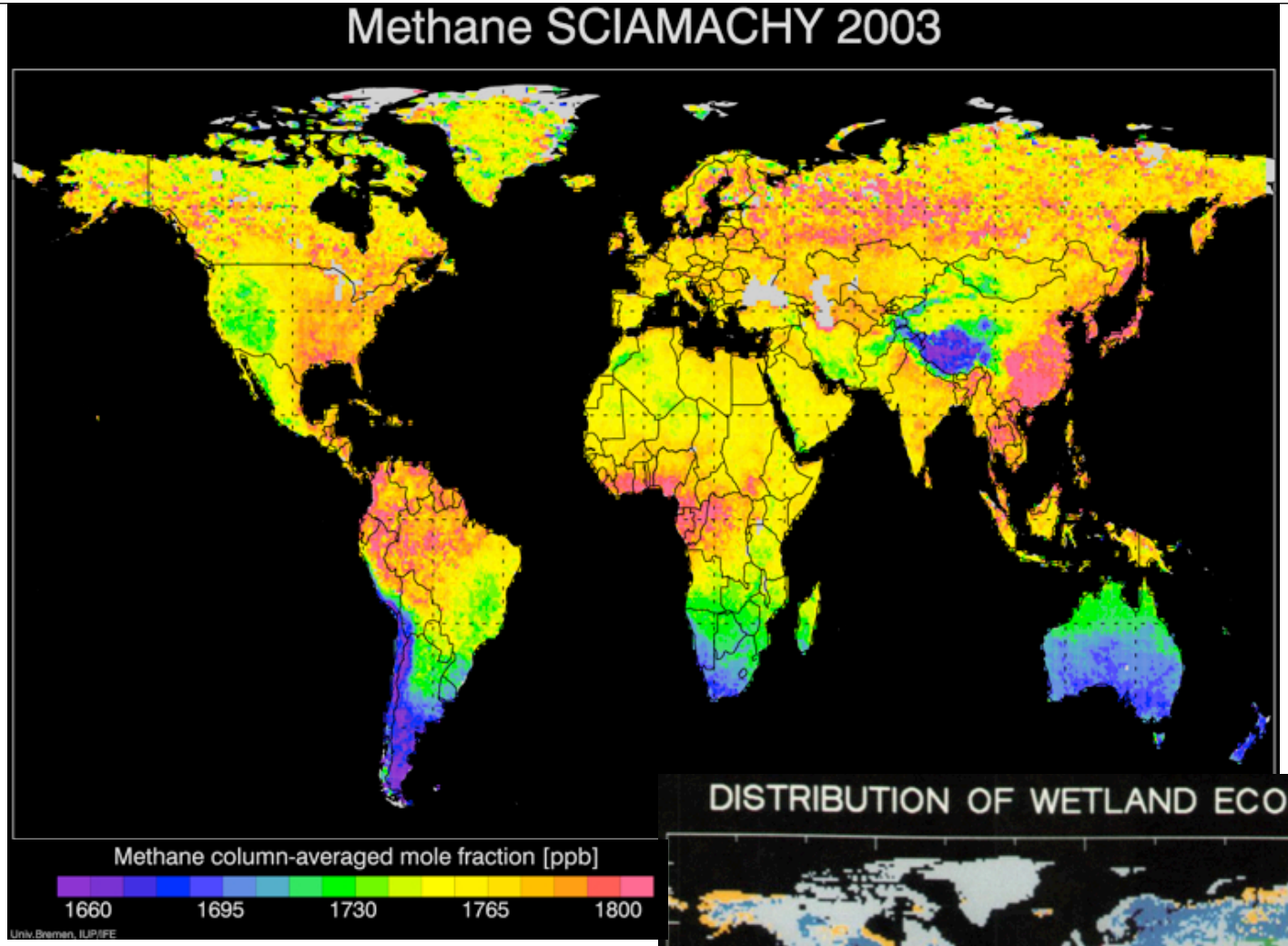
NOAA ESRL Carbon Cycle



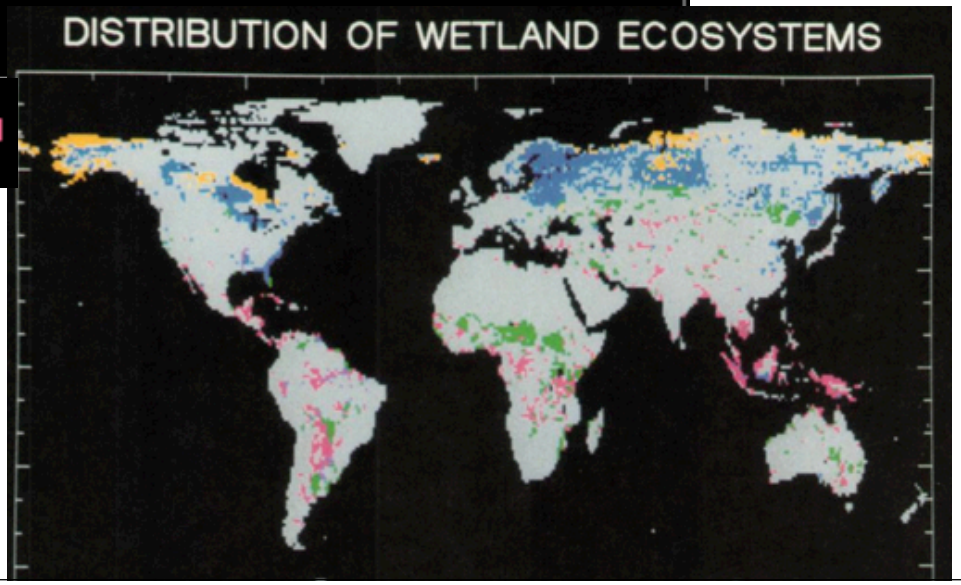
Top: Global average atmospheric methane mixing ratios (blue line) determined using measurements from the Carbon Cycle cooperative air sampling network. The red line represents the long-term trend. Bottom: Global average growth rate for methane. Contact: Dr. Ed Dlugokencky, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6228, ed.dlugokencky@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.


NATURAL OCCURRENCES
WETLANDS
TERMITES
ANTHROPOGENIC INFLUENCES
RUMINANTS
RICE PADDIES
BIOMASS BURNING
LANDFILLS
COAL MINING
GAS PRODUCTION
OCEAN WATER
FRESH WATER
METHANE HYDRATE
250
200
150
100
50
0
Wetlands
Termites
Oceans
Hydrates
Energy
Ruminants
Landfills
Rice paddies
Biom. burning

Wania, 2007



Buchwitz et al., 2005



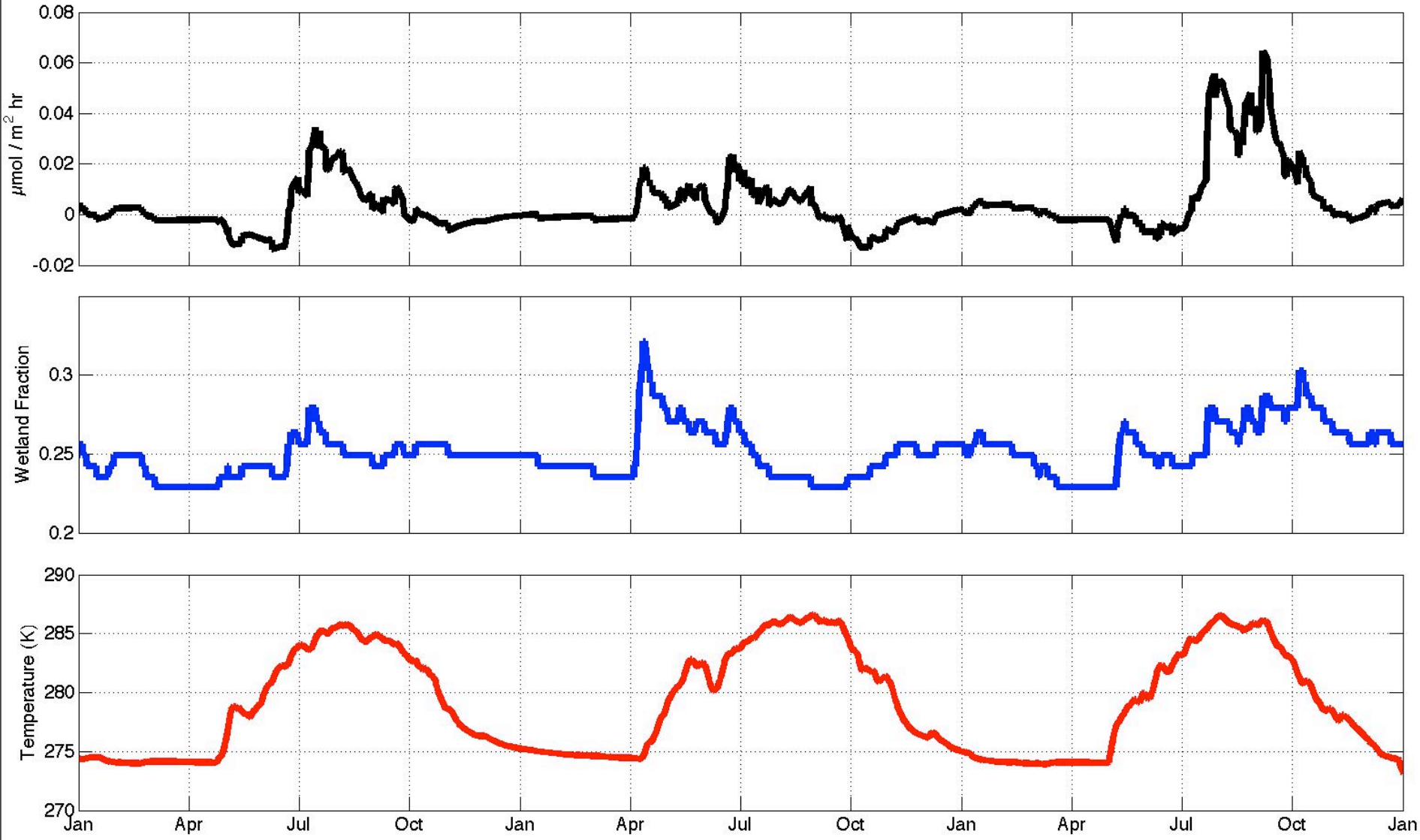
Matthews & Fung, 1987

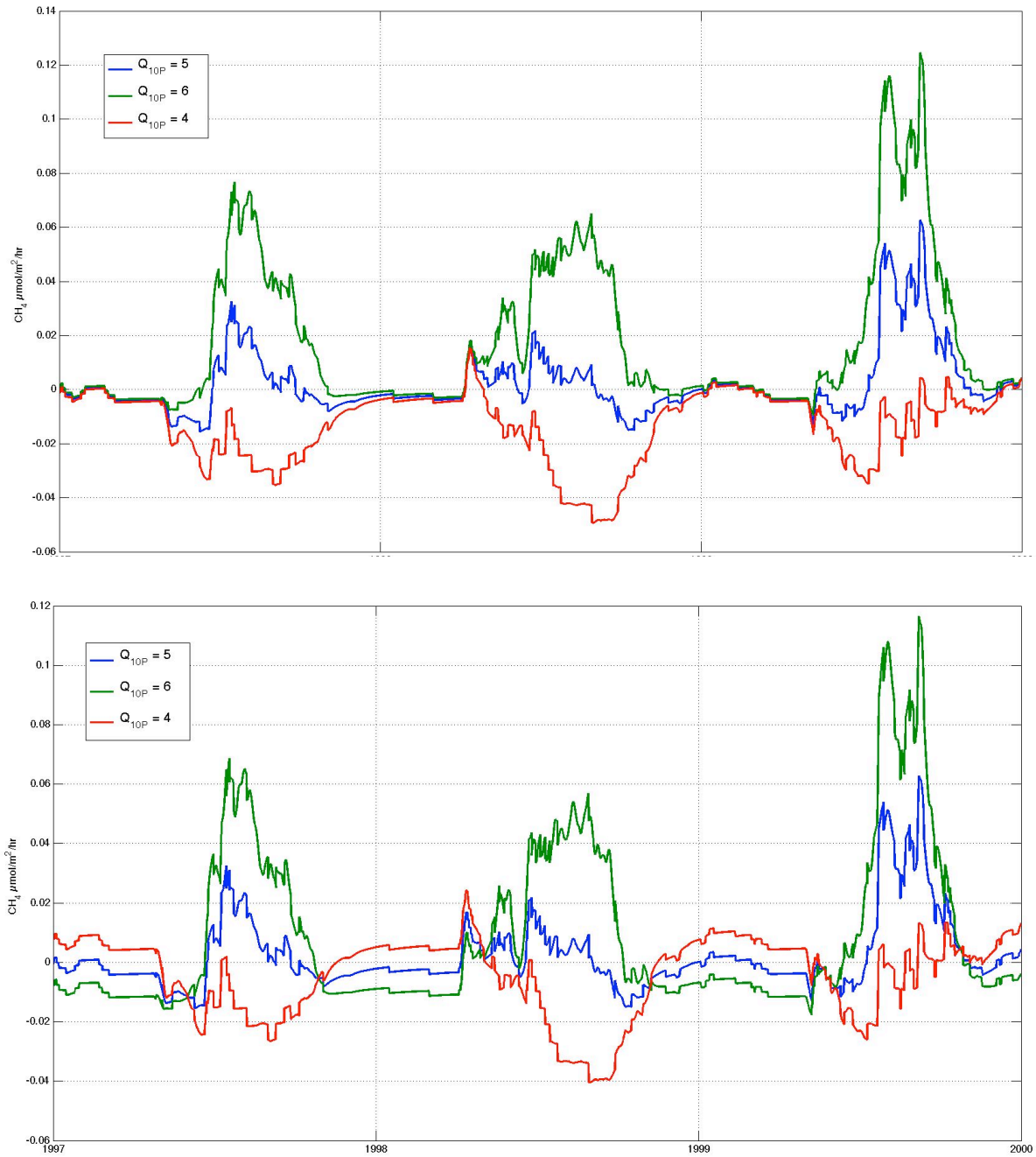
$$CH_4 production = S_P \cdot WF \cdot Q_{10P}^{\left(\frac{td_6 - 273.15}{10}\right)}$$

$$CH_4 consumption = S_C \cdot \left(1 - WF\right) \cdot Q_{10C}^{\left(\frac{td_6 - 273.15}{10}\right)}$$

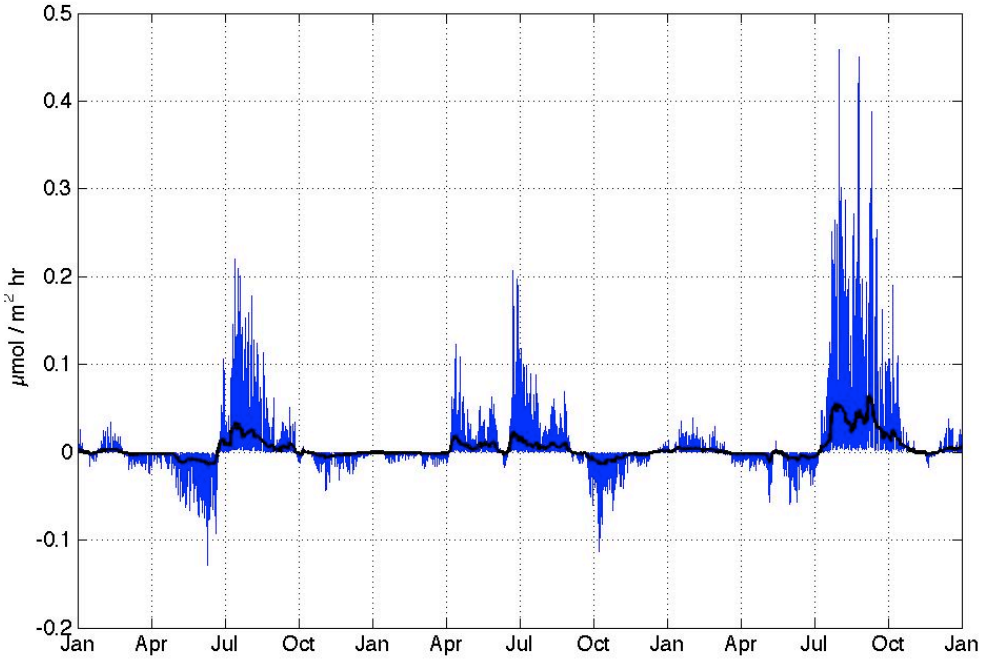
$$CH_4 flux = CH_4 production - CH_4 consumption + k$$

Model Results



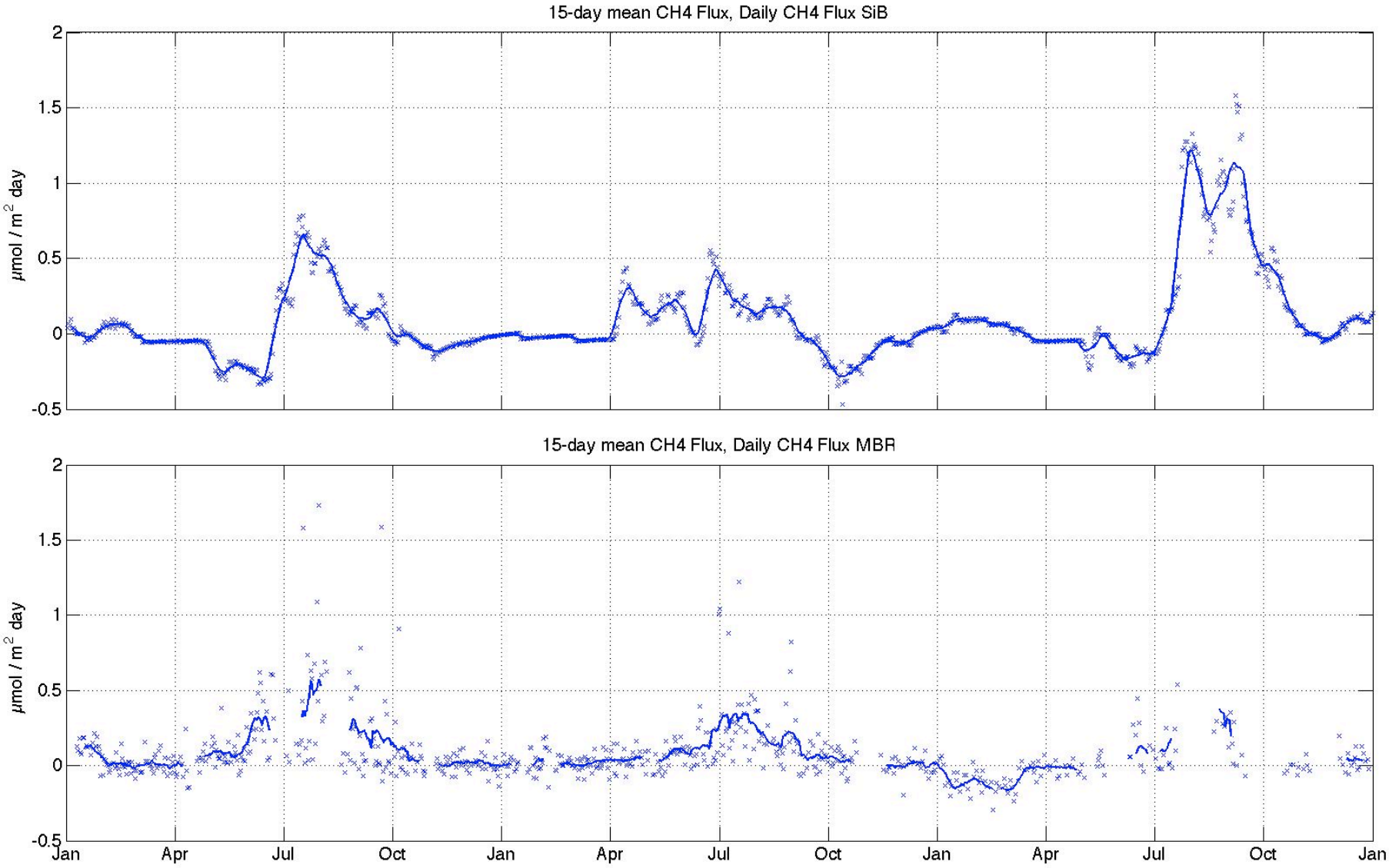

Q_{10P} = 5
Q_{10P} = 6
Q_{10P} = 4
CH_4 $\mu mol/m^2/hr$
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
1997
1998
1999
2000

In SiB


0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
μmol / m2 hr
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan

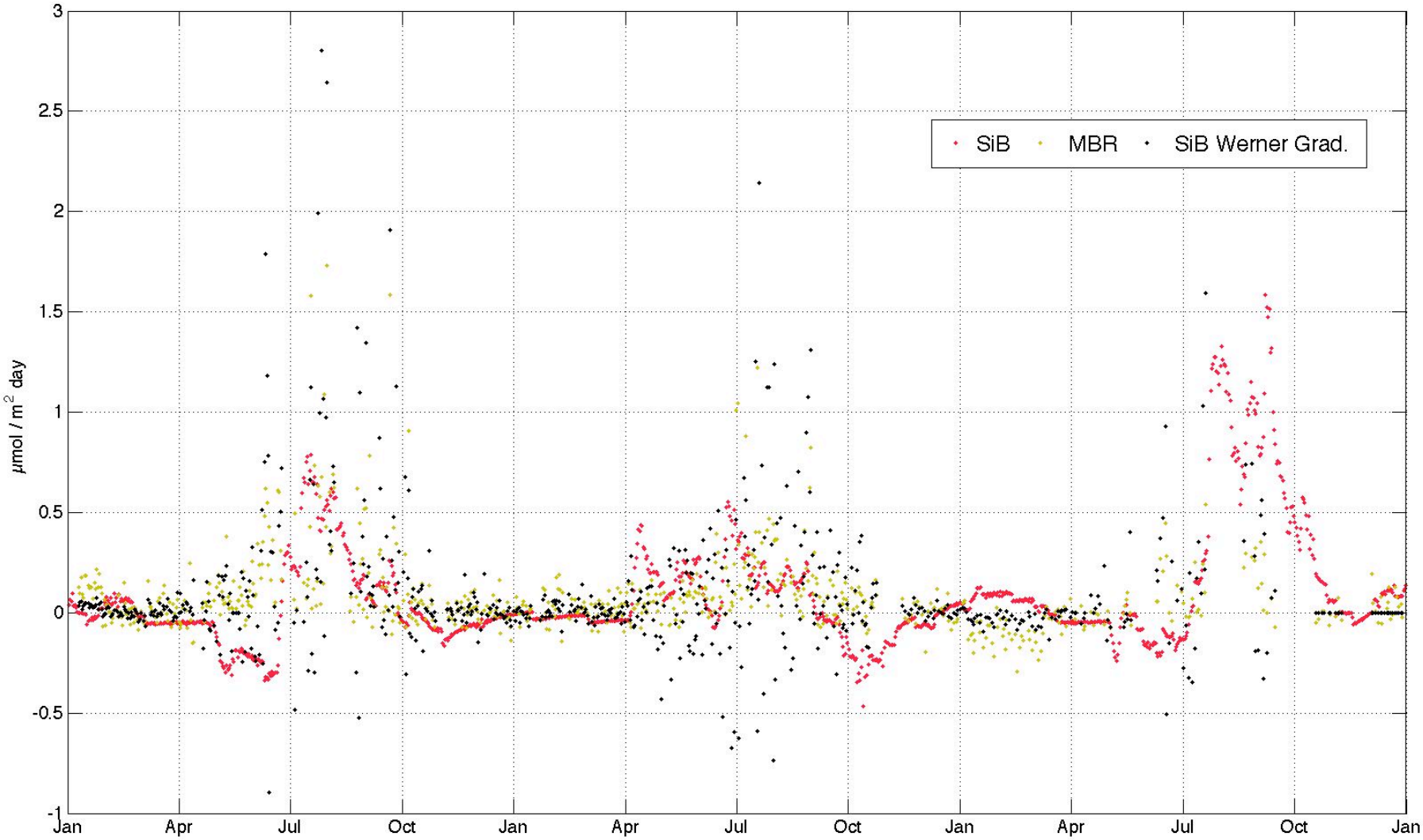

2
1.5
1
0.5
0
-0.5
μmol / m2 day
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan

Comparison to observations



$$Flux_{CH_4-30m} = Flux_{CO_2-30m}\left(\frac{\delta CH_4/\delta z}{\delta CO_2/\delta z}\right)$$

C. Werener et al., 2003


SiB
MBR
SiB Werner Grad.
µmol / m2 day
3
2.5
2
1.5
1
0.5
0
-0.5
-1
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan

Conclusions

- Temporally varying estimates of wetland area at sub-gridscale are necessary.
- To this end, the topographic index is useful, but should not be calculated from unmodified or depression-less elevation maps.
- Scaling heat and CO_2 fluxes by estimated wetland area improves model predictions.
- Estimating wetland area permits model representation of wetland biogeochemistry

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Wania, R. (2007), Modelling northern hemisphere peatland land surface processes, vegetation dynamics and methane emissions, 116 pp, University of Bristol, Bristol, UK.

Werner, C., K. Davis, P. Bakwin, C. X. Yi, D. Hurst and L. Lock (2003), Regional-scale measurements of CH4 exchange from a tall tower over a mixed temperate/boreal lowland and wetland forest, *Global Change Biol*, *9(9)*, 1251-1261.