

# The Gulf of Mexico Basin in the North American Carbon Cycle

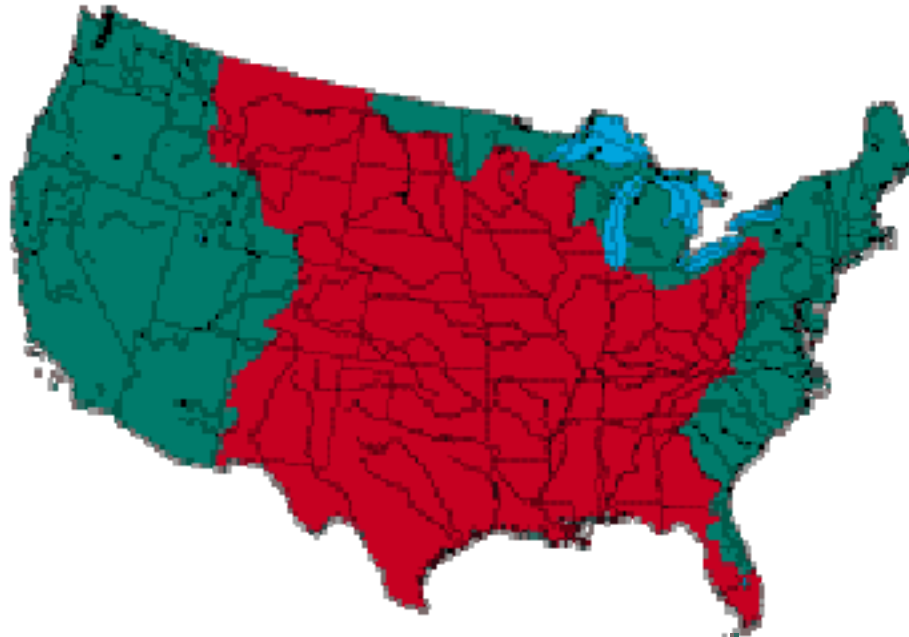
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Colorado State University



*Acknowledgements:  
Support by NOAA, NASA, DoE*



# Gulf of Mexico Basin (US Only)



- Over 60% of land area of USA
- 33 major river systems and 207 estuaries

## Gulf Region (US Only)

- 44.2 million people in 5 Gulf States in 1995
- Increasing to an estimated 61.4 million in 2025 (40% increase)
- Fisheries: 1.3 billion pounds valued at \$689 million (2006)
- Produces  $\frac{1}{4}$  of the U.S. domestic natural gas and  $\frac{1}{8}$  of its oil
- Offshore petroleum industry employs over 55,000 U.S. workers

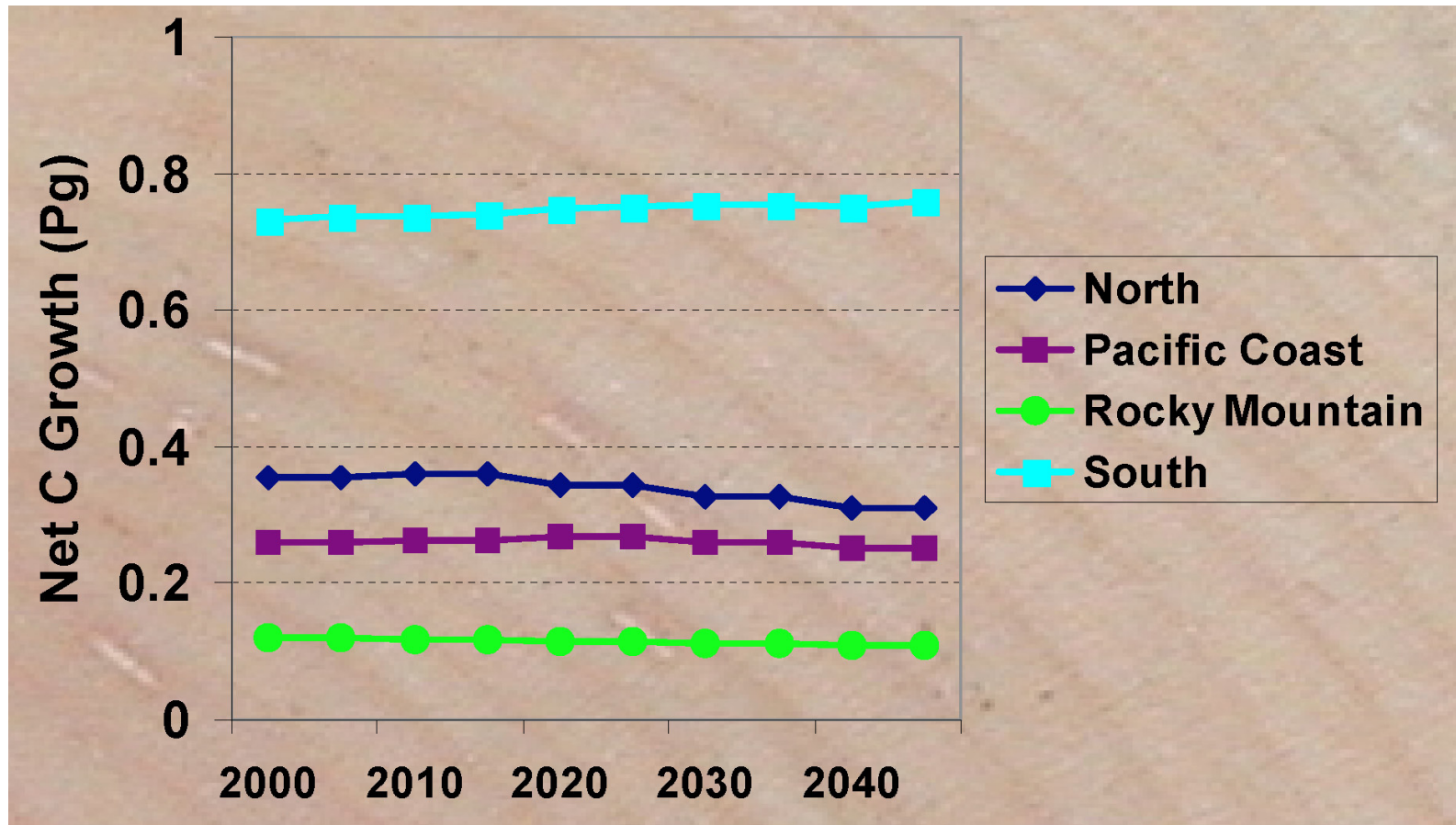
# Plantation Forestry



- Timber, Pulp, and Paper
- Fastest turnover of forest biomass



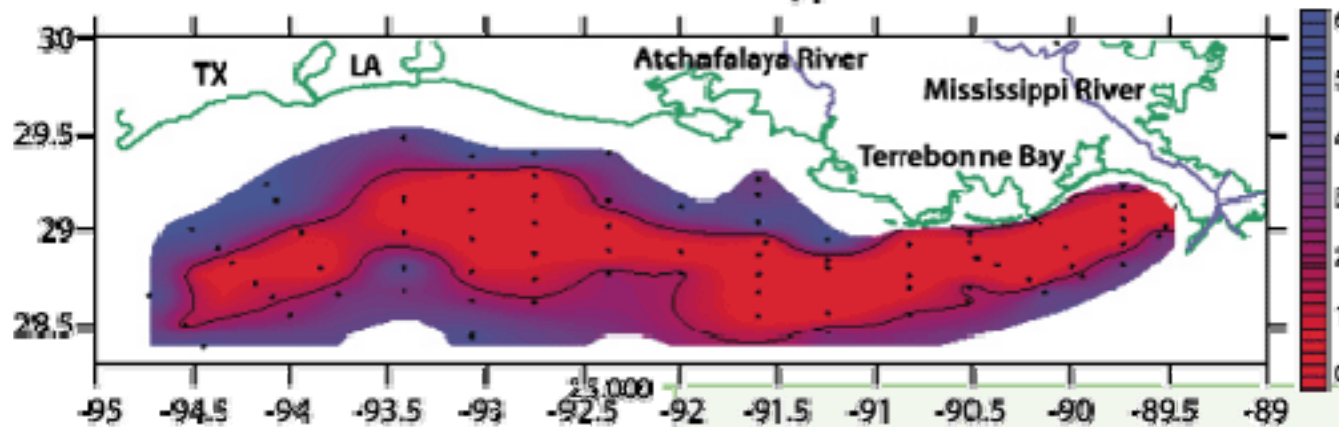
# Commercial Forest Sink!



- Forests in Southern USA sequester almost 0.8 Pg C / yr !

# Mississippi "Dead Zone"

Areal Extent of 2008 Hypoxic Zone



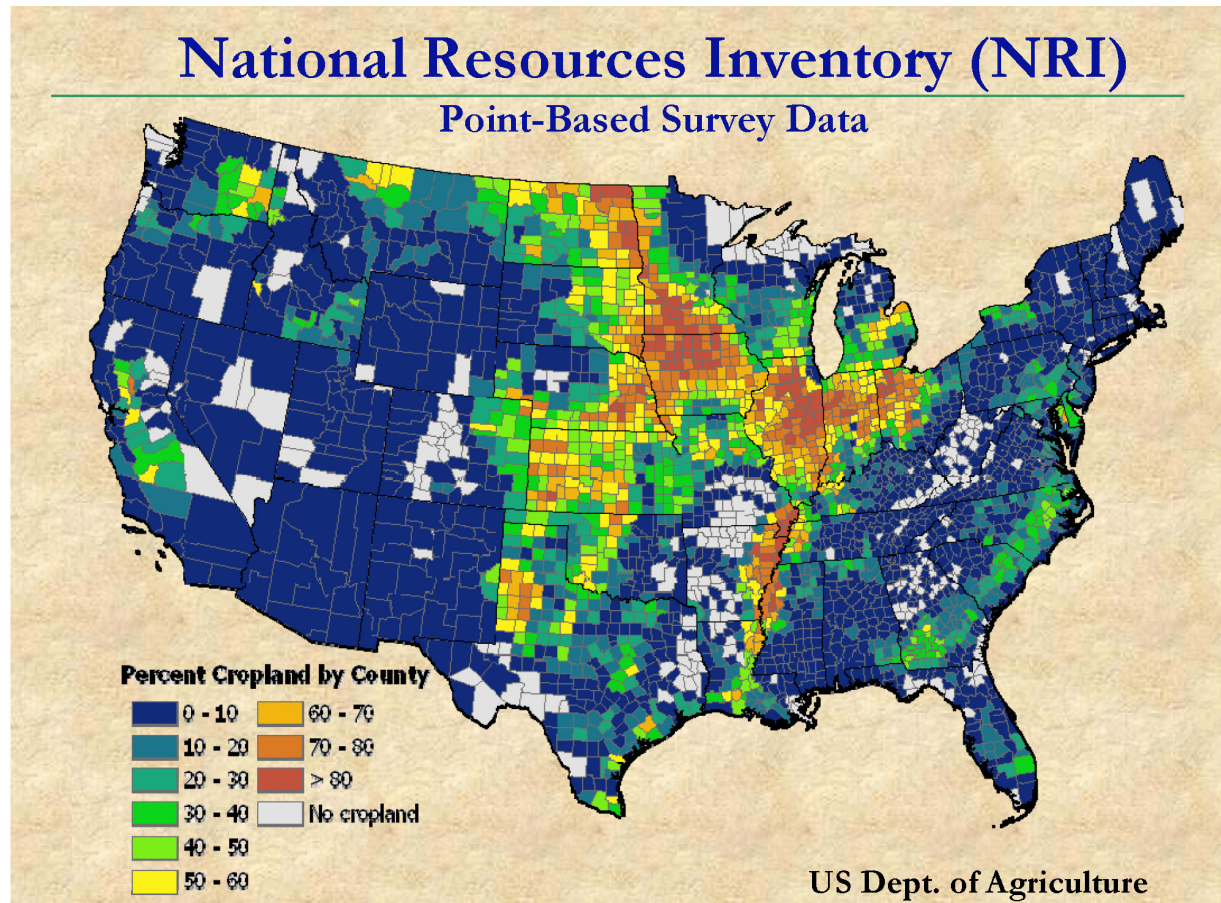
5-Year Average (2004-2008)

Annual Hypoxic Zone Size (1985-2008)

Action Plan Goal

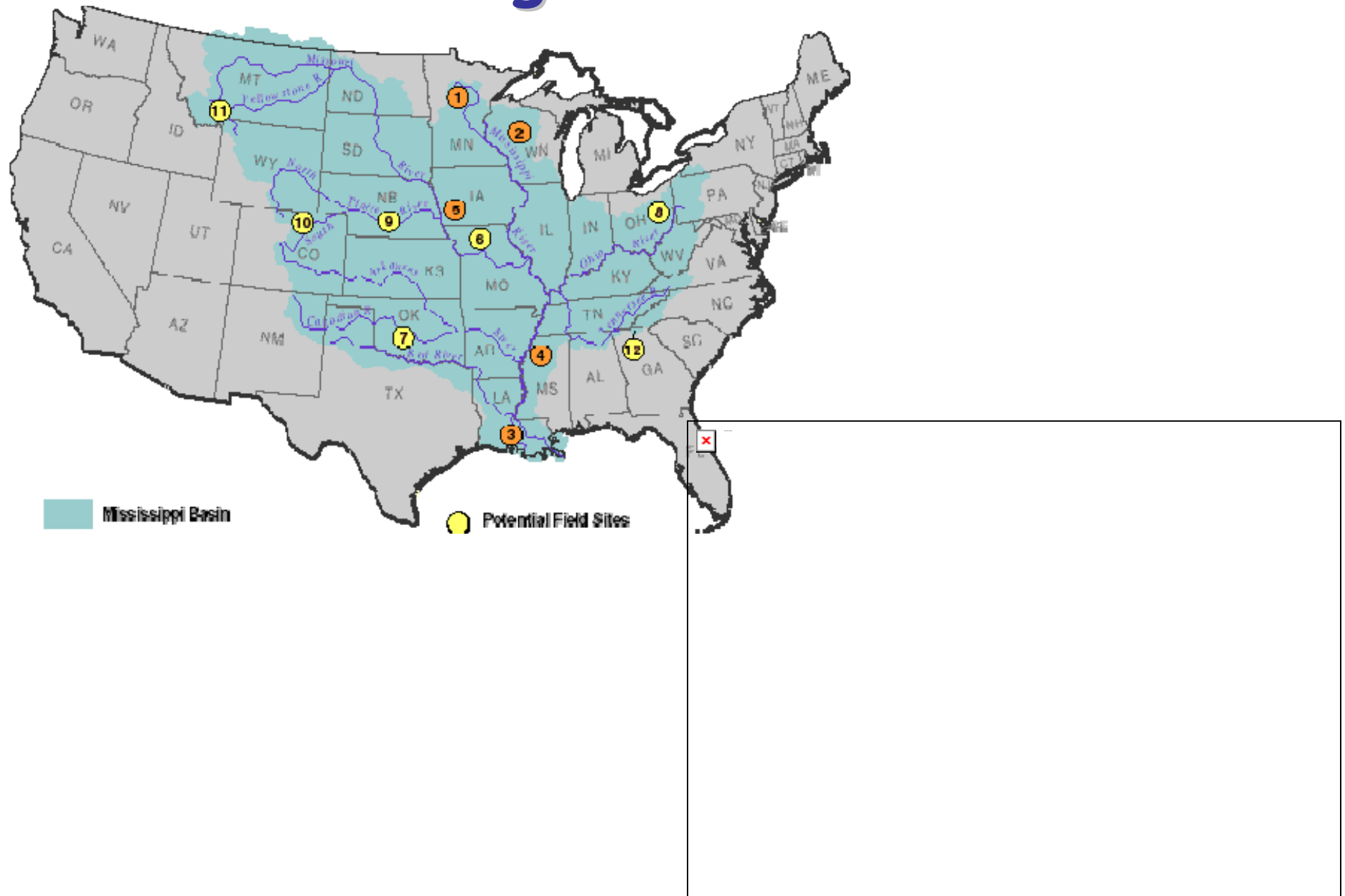
Figure adapted from data provided by N. Rabalais

# Crop Coverage



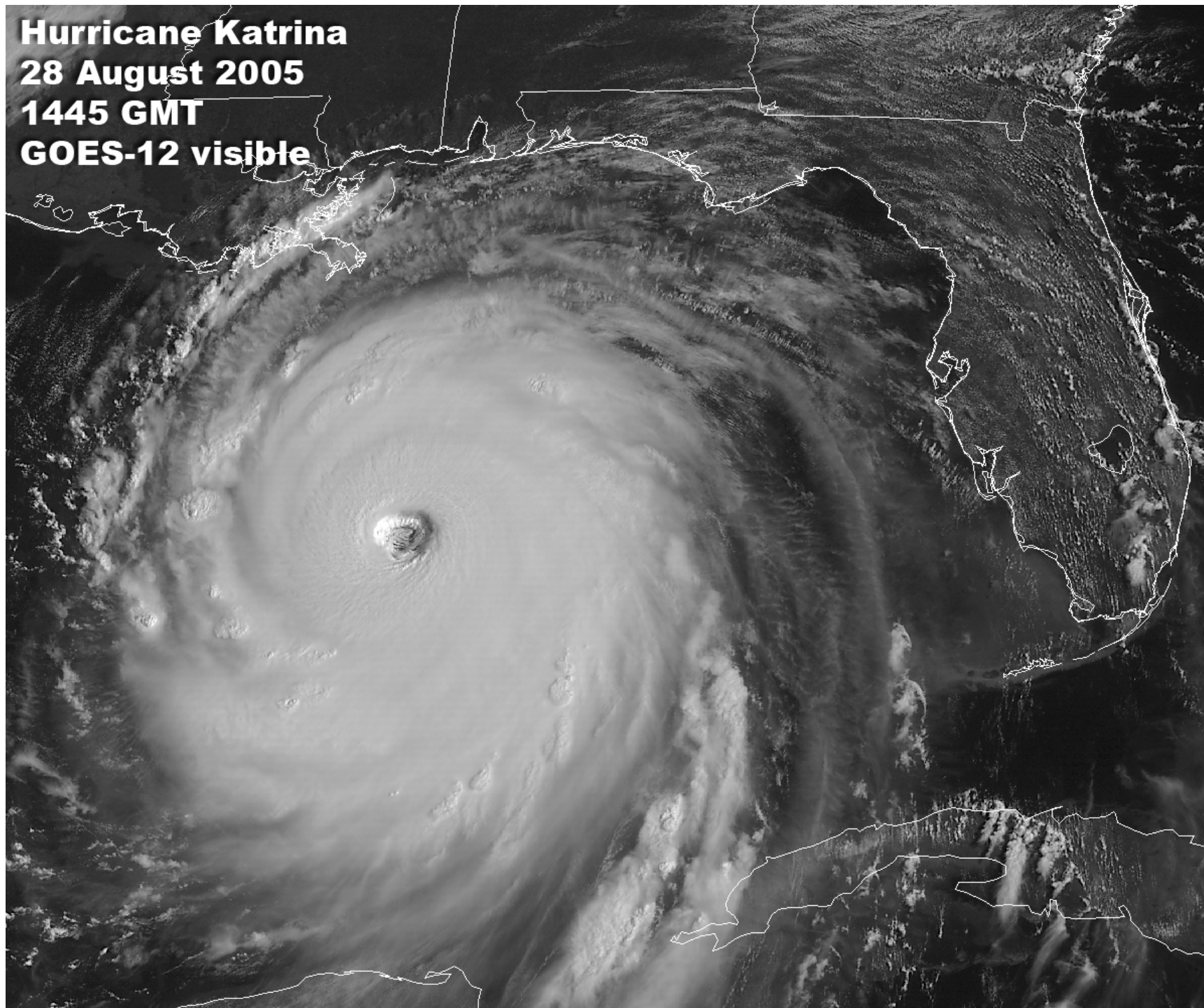
- Intensive agriculture in GOM Basin!
- Fertilizer, nutrient runoff, topsoil erosion

# Monitoring Nutrients & Chl





**Hurricane Katrina**  
**28 August 2005**  
**1445 GMT**  
**GOES-12 visible**









# Vulnerability to Hurricanes

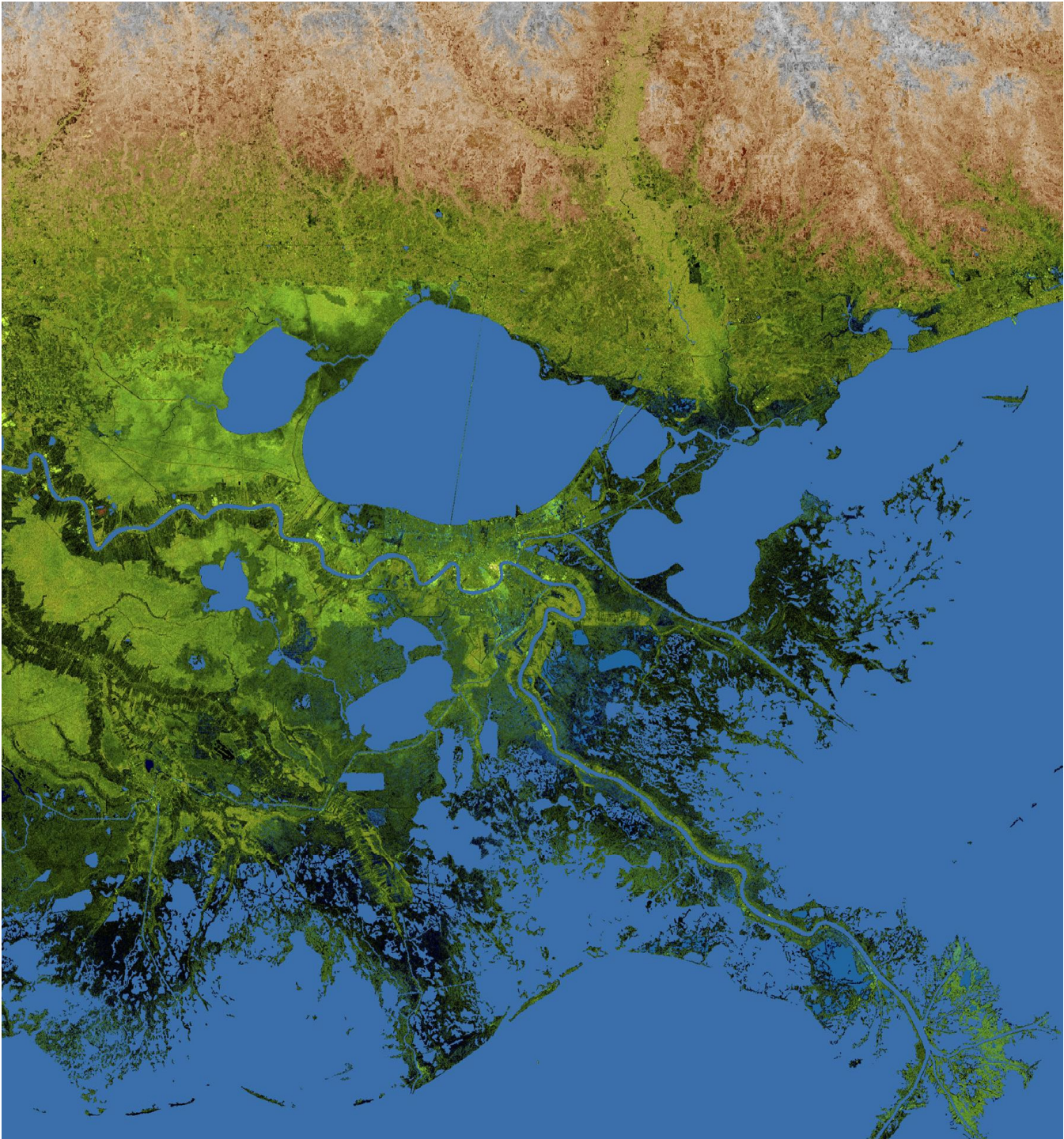


september 26, 2005



september 21, 2005

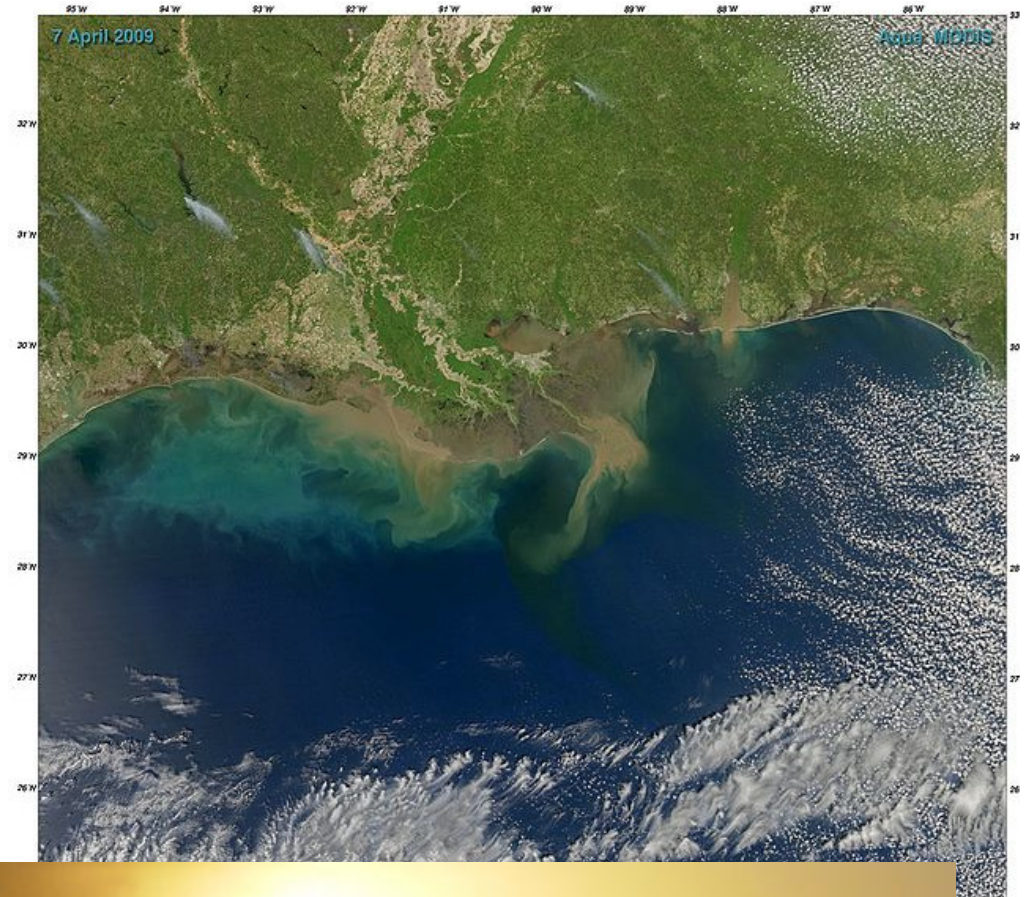






# CarboNA: Gulf of Mexico Basin Experiment

- Atmospheric inflow to North America
- Mid-continent agriculture & runoff
- River transport of C and nutrients
- Delta discharge, sedimentation, BGC
- Coastal-zone eutrophication & fisheries
- Coastal flooding & climate change
- Sustainable development in Mexico



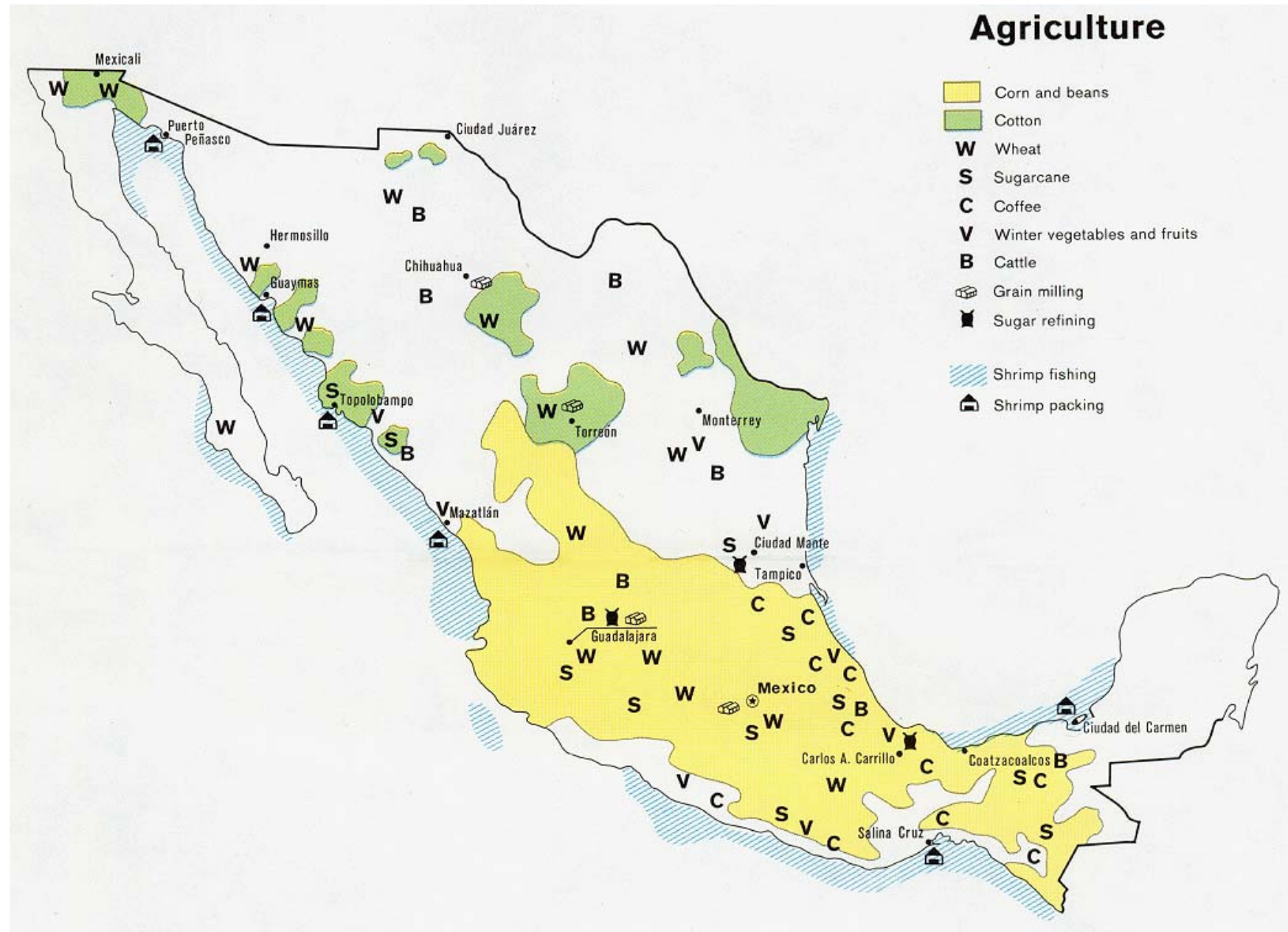
# Gulf Watershed in Mexico

- Coral reefs
- Development
- Agriculture
- Tourism
- Fisheries



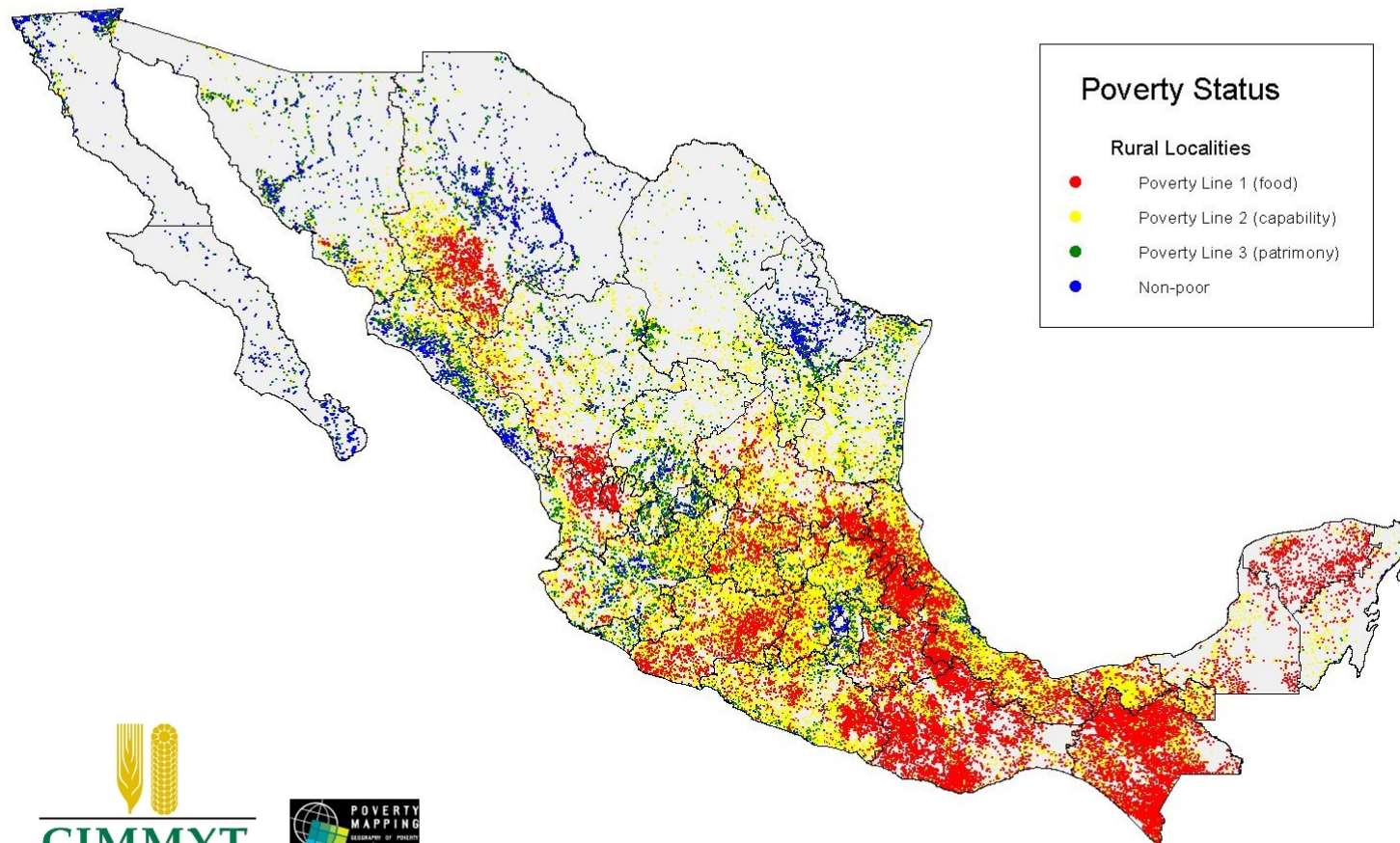


# Mexican Agriculture

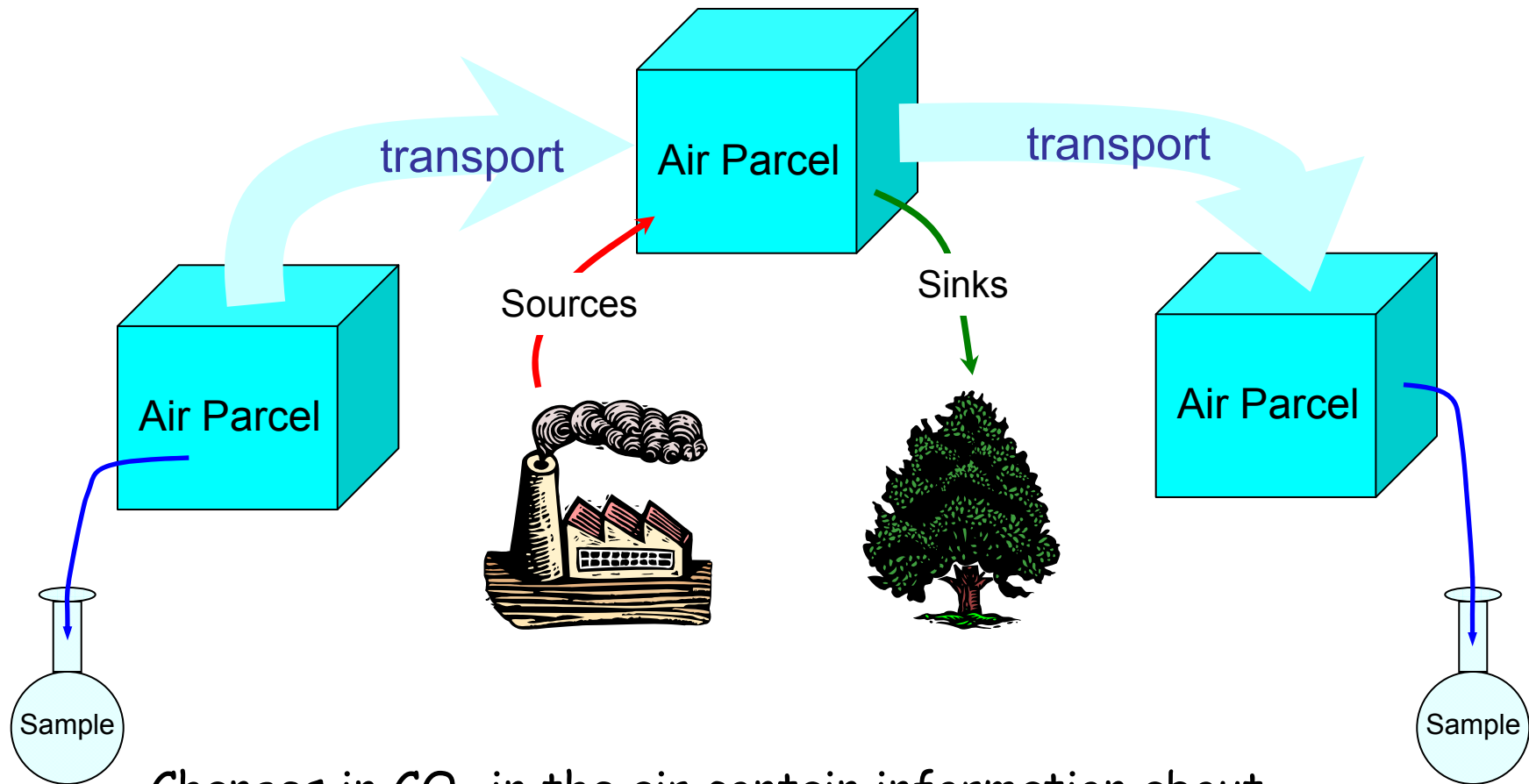


# Poverty in Mexico

Fig. 5. Poverty status based on predicted total expenditure for rural localities



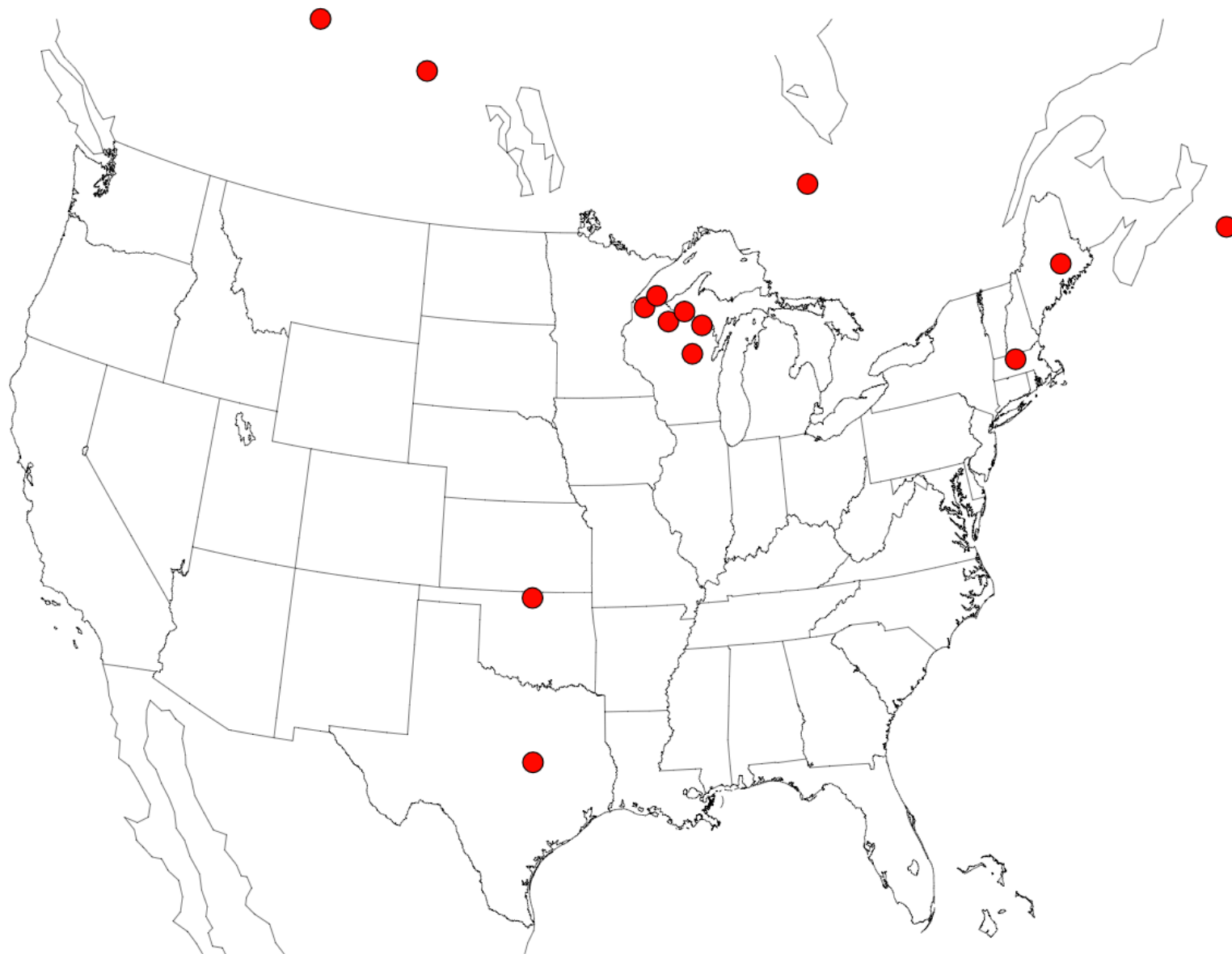
# Regional Carbon Budgeting from Atmospheric CO<sub>2</sub>



Changes in CO<sub>2</sub> in the air contain information about all sources and sinks encountered along the way

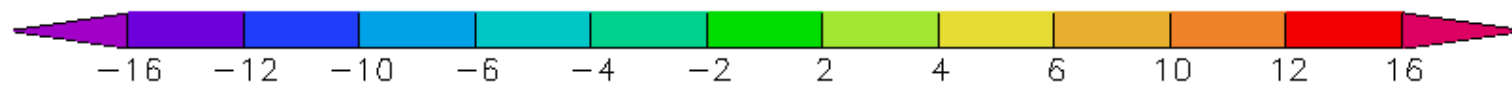
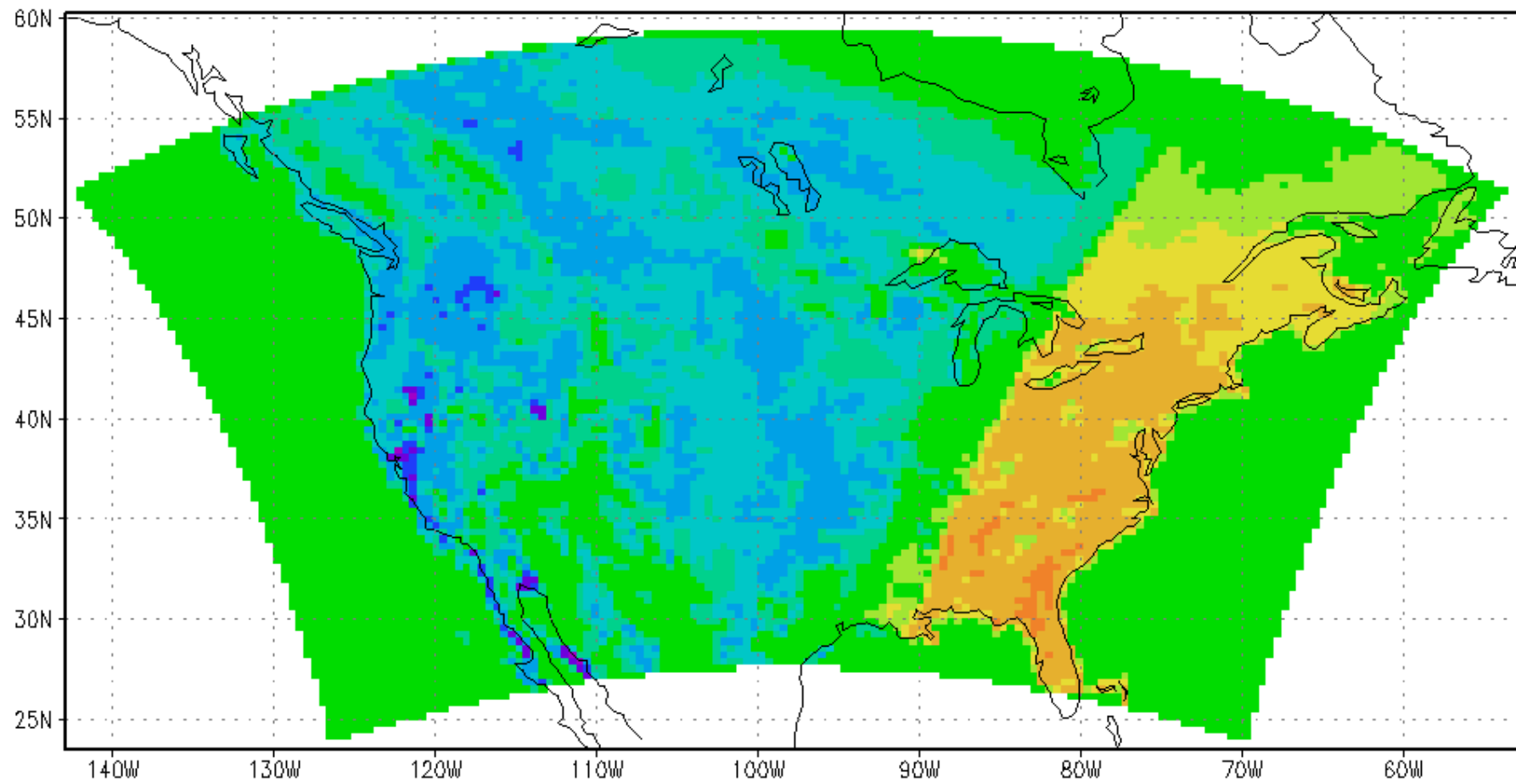
Requires: **observations**, accurate accounting for **transport**!

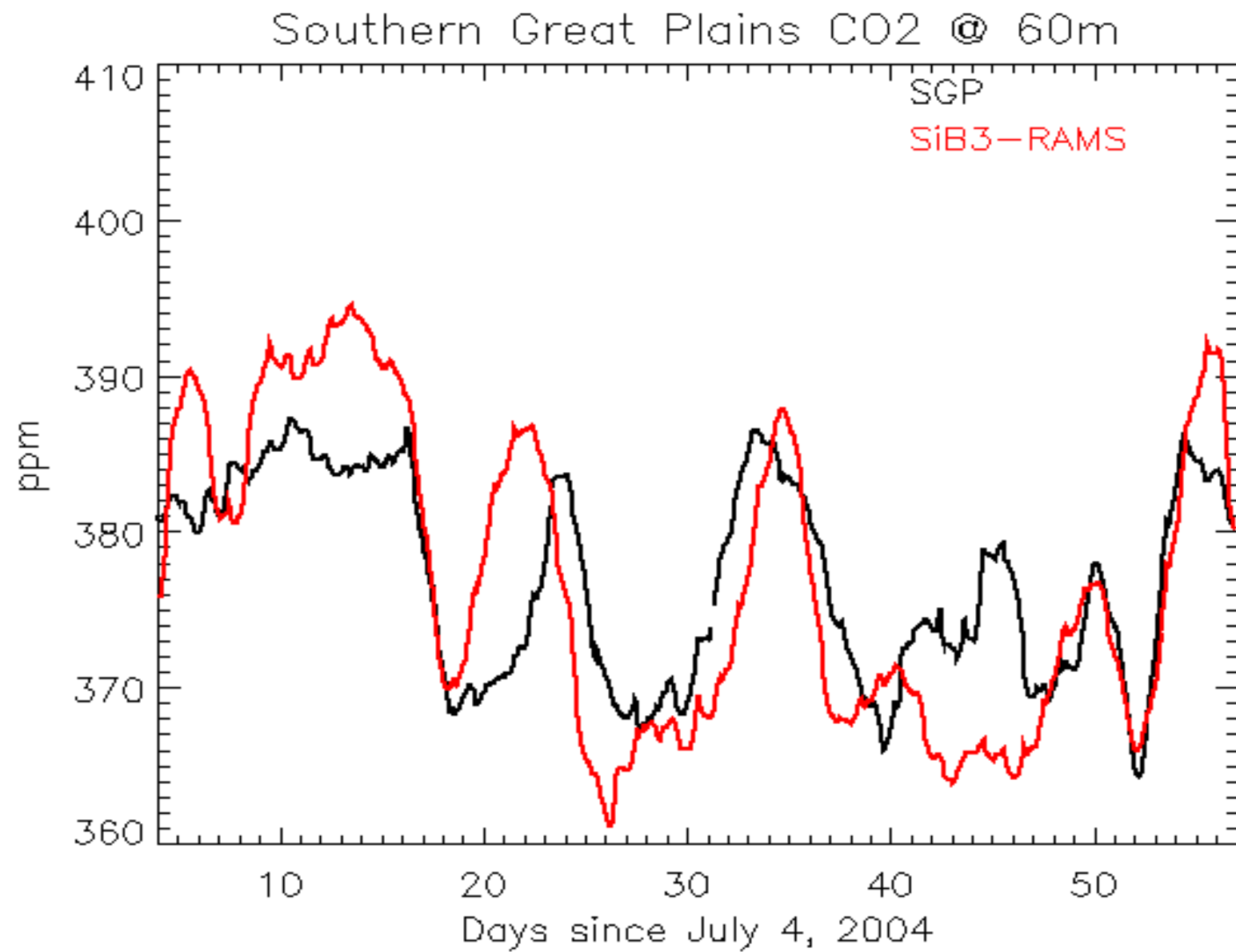
# Continuous CO<sub>2</sub> Network, 2004



Hourly [CO<sub>2</sub>], calibrated to absolute standards (WMO/NOAA)

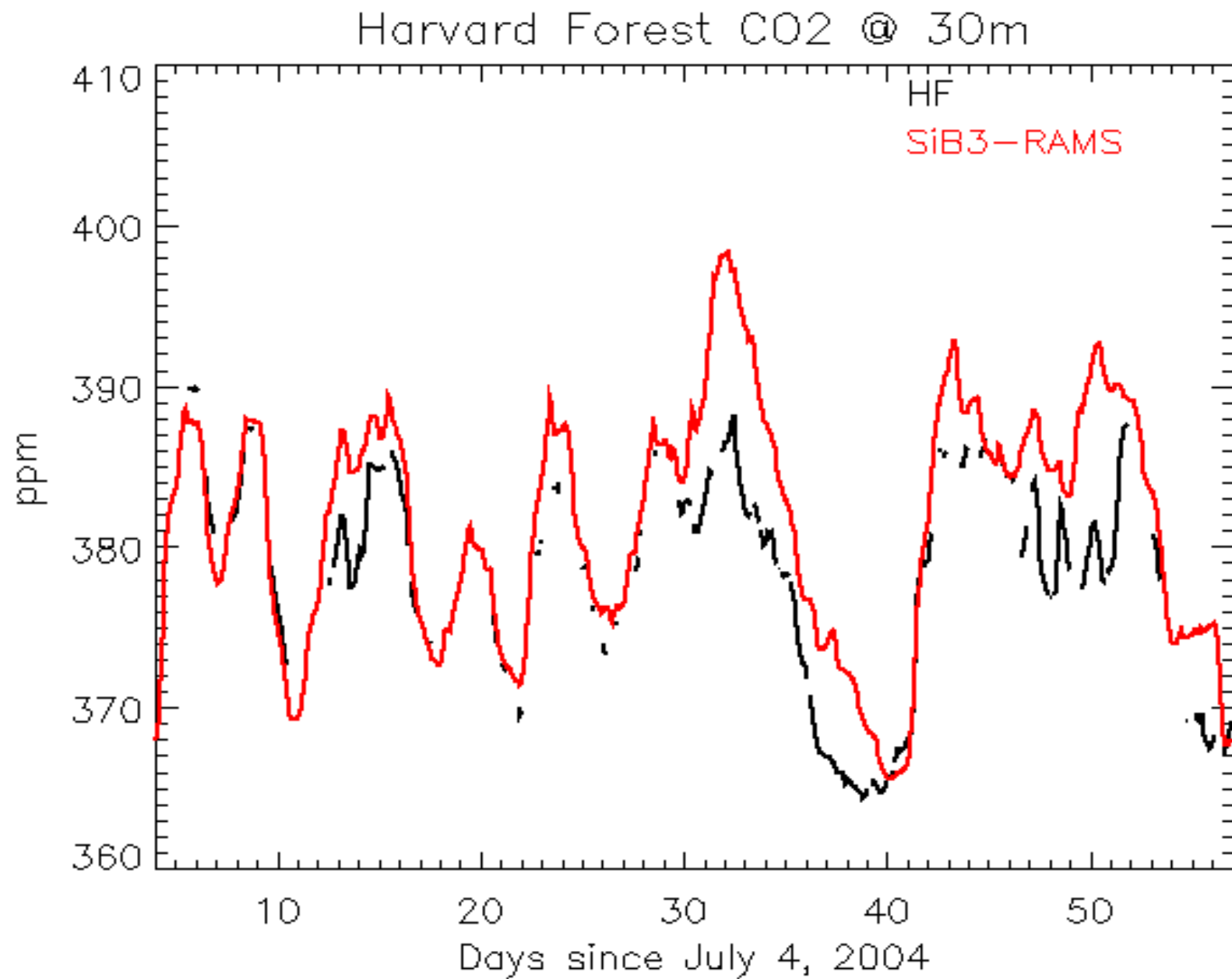
01Z01JUN





Filtered: diurnal cycle removed





Filtered: diurnal cycle removed

# Treatment of Variations for Inversion

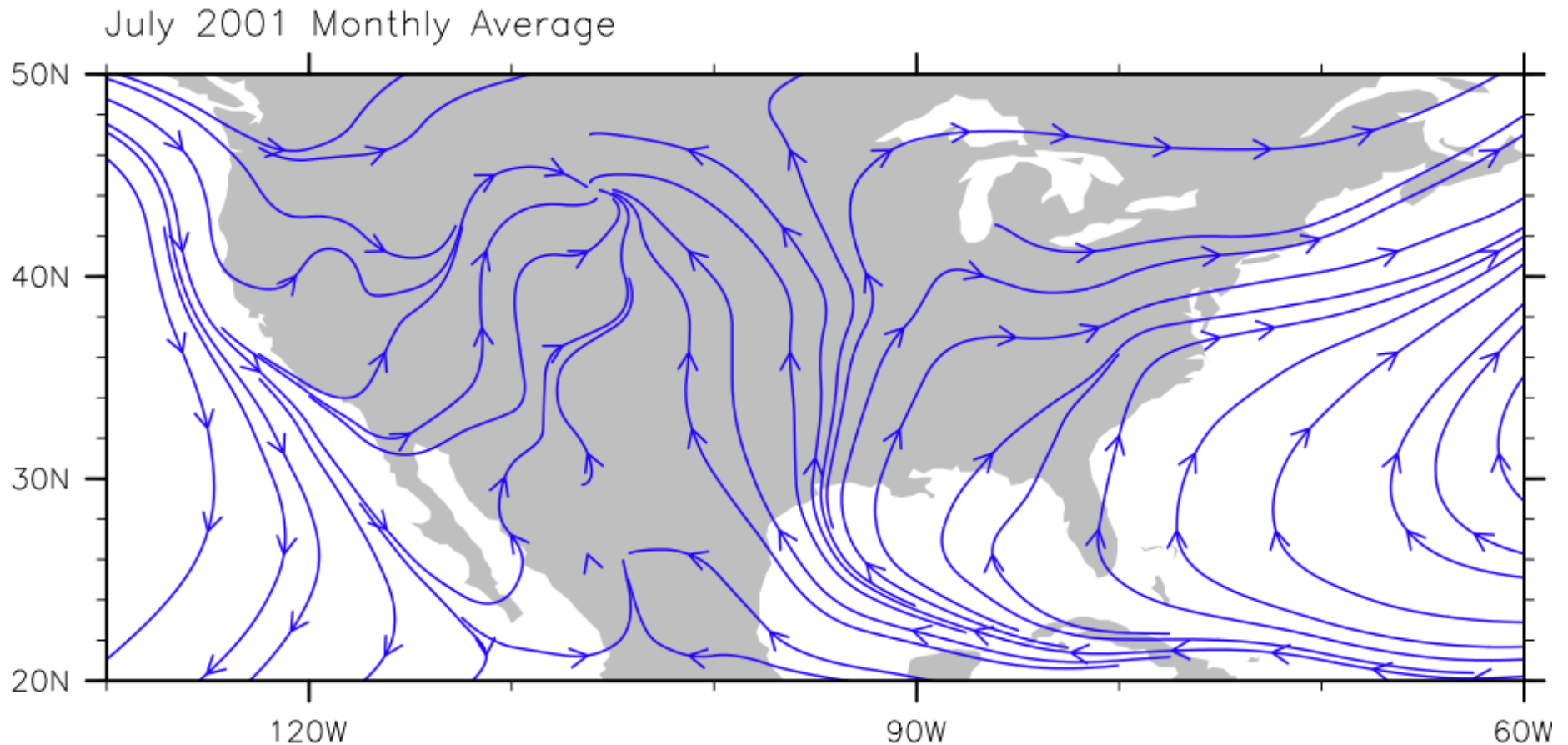
$$F_{CO_2}(x, y, t) = \underbrace{\beta_R(x, y)}_{\text{unknown!}} \overbrace{R(x, y, t)}^{\text{SiB}} - \underbrace{\beta_{GPP}(x, y)}_{\text{unknown!}} \overbrace{GPP(x, y, t)}^{\text{SiB}}$$

- Fine-scale variations (hourly, pixel-scale) from weather forcing, MODIS, as processed by forward model logic (SiB-RAMS)
- **Multiplicative biases** (caused by "slow" BGC that's not in the model) derived by from observed hourly [CO<sub>2</sub>]

$$C_{k,m} = \sum_{i,j,n} \left( \beta_{R,i,j} R_{i,j,n} C_{Rk,m,i,j,n}^* + \beta_{A,i,j} A_{i,j,n} C_{Ak,m,i,j,n}^* \right) \Delta t_f \Delta x \Delta y + C_{IN}$$

*Flux-convolved influence functions derived from SiB-RAMS*

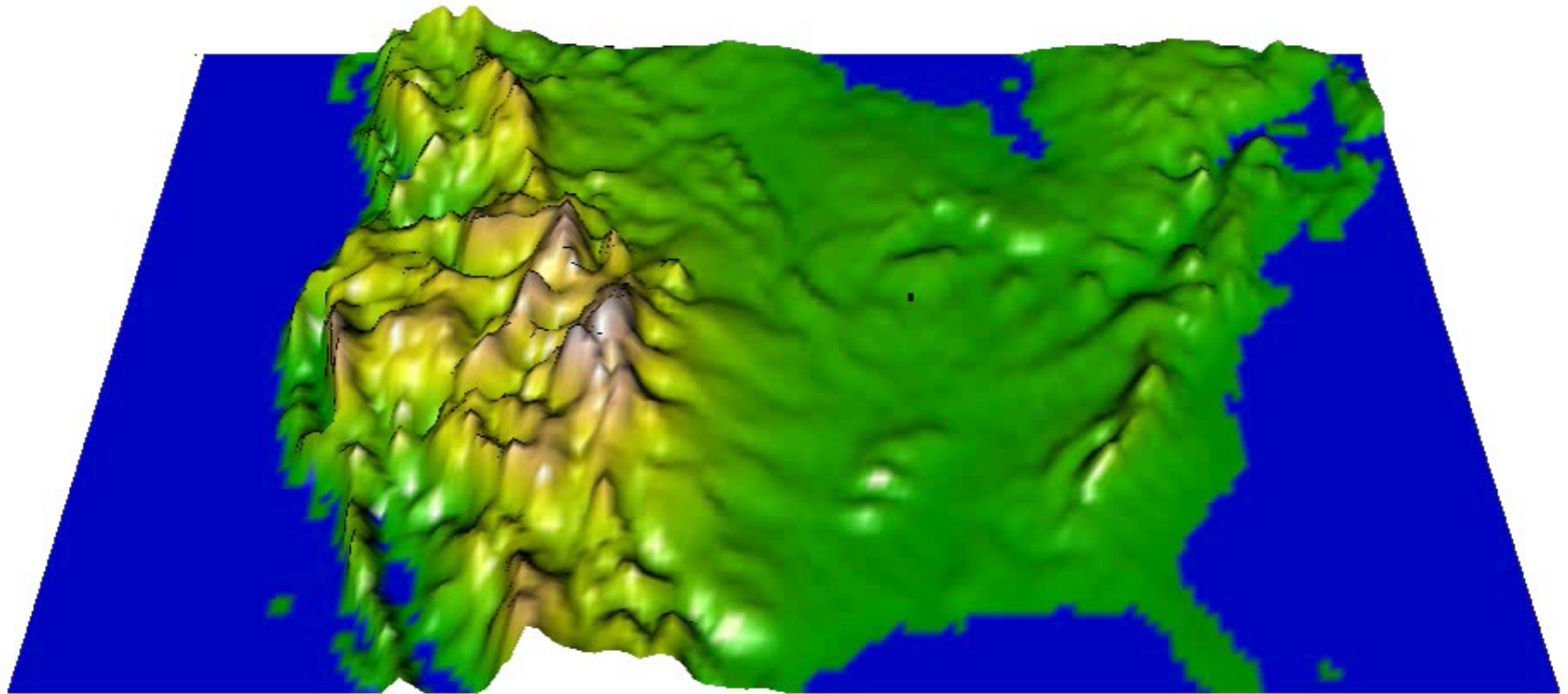
# July Surface Wind Streamlines



- Much of summer inflow is from Gulf of Mexico
- Very few  $\text{CO}_2$  measurements in this region!

# Back-Trajectories from WLEF Tower

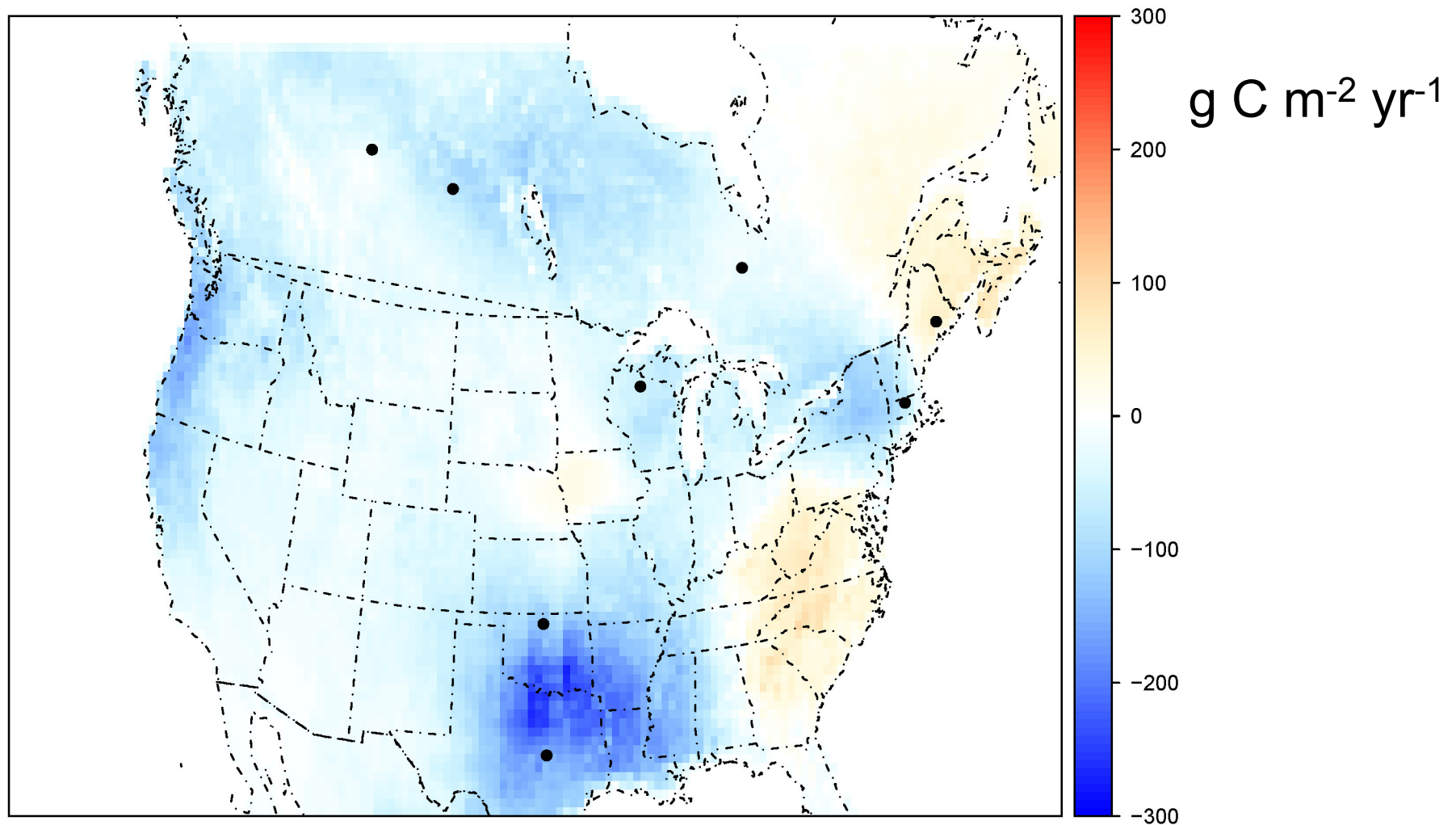
(400 m TV tower near Park Falls, WI)



20 days of “upstream” transport in 50 seconds

Black: air parcels in contact with surface  
Red: air parcels reach lateral boundaries

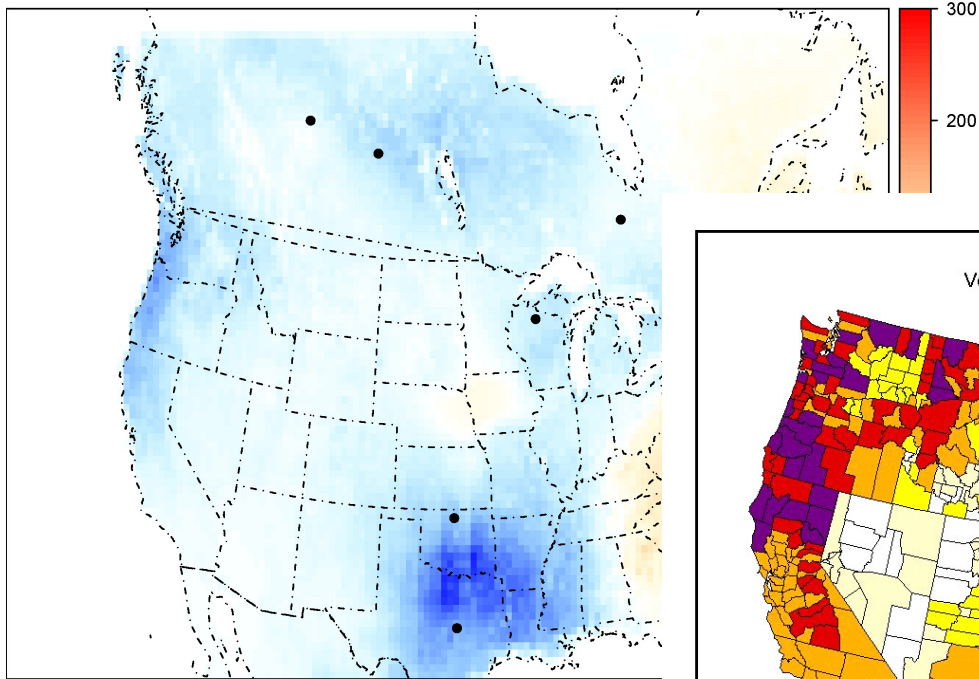
# Result: Estimated 2004 Net Ecosystem $\text{CO}_2$ Exchange



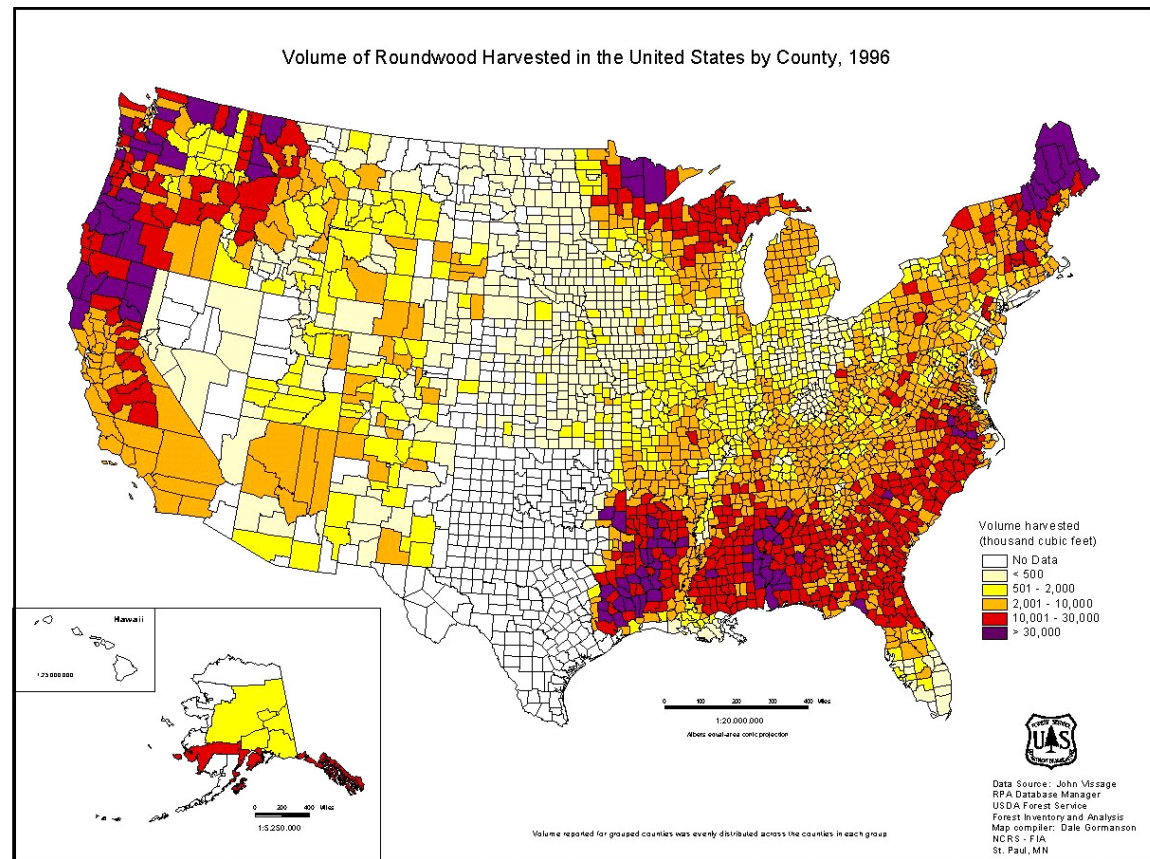
Please see posters by Schuh & Uliasz on Wednesday afternoon!



# Result: Estimated 2004 Net Ecosystem CO<sub>2</sub> Exchange



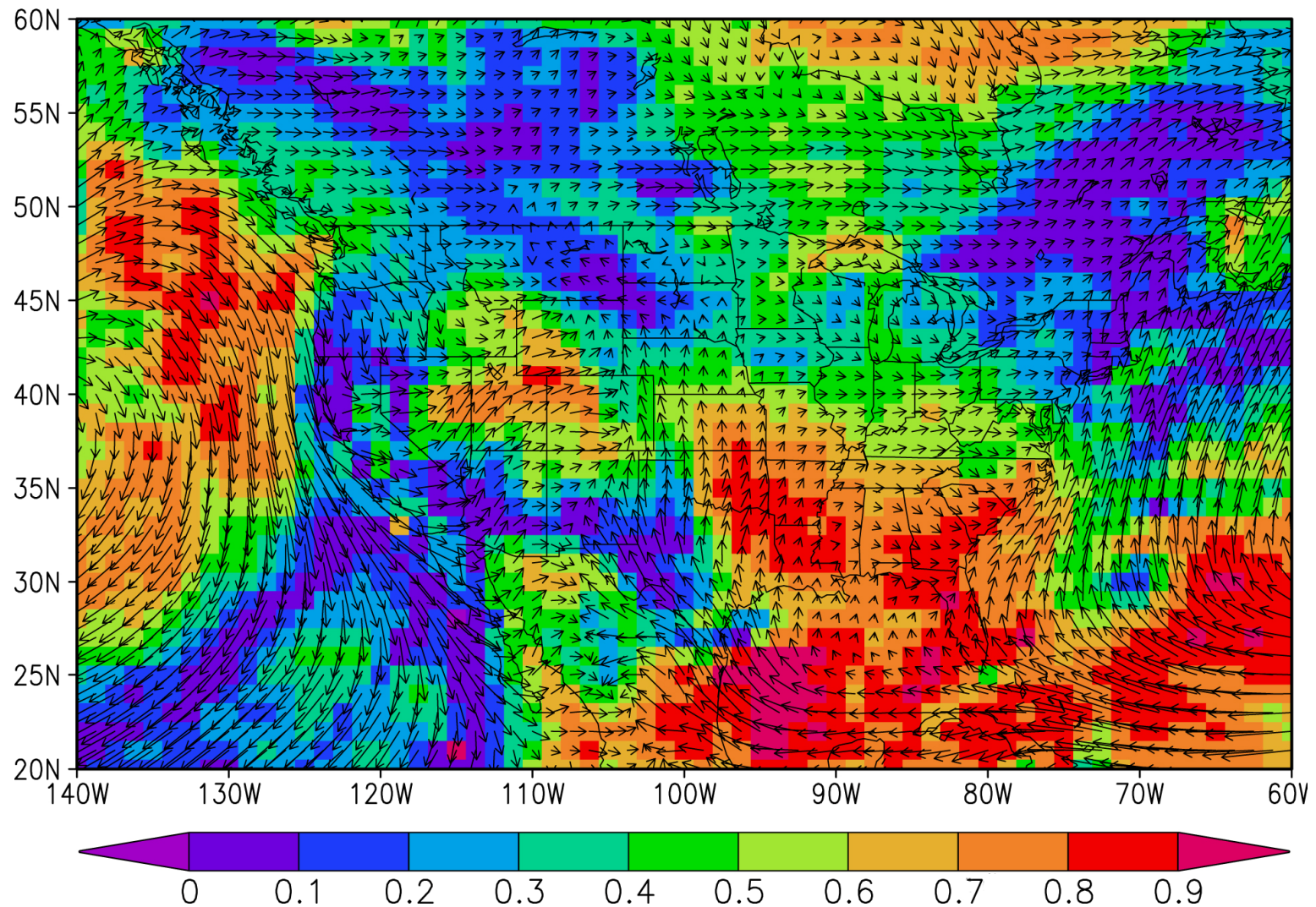
## Forest Harvest



# Lateral Boundary Forcing

- Regional inversions must specify correct **time-varying lateral boundary conditions**
- Prescribed from global transport model (PCTM) with land BGC (SiB), fossil fuel emissions, air-sea gas exchange (Takahashi)
- **Sensitivity exp: turn off all NEE in Western Hemisphere, analyze  $CO_2(x,y,t)$**
- Compare daytime  $CO_2$  over North America between sensitivity and control experiments

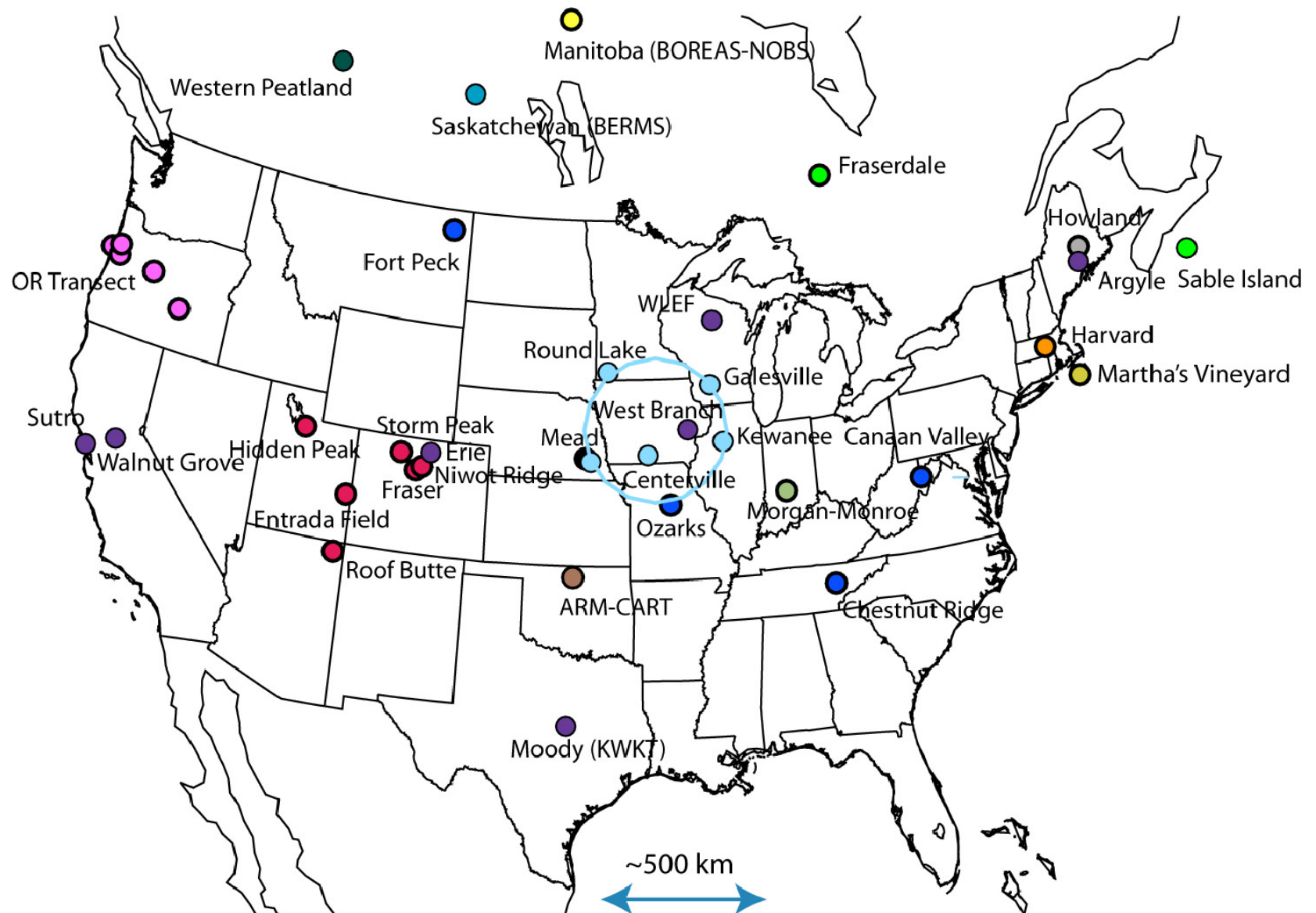
# Distant Influences on CO<sub>2</sub>



Correlation of Eastern Hemisphere CO<sub>2</sub> with all CO<sub>2</sub>  
(also shows surface wind vectors, July 2004)



# Continuous CO<sub>2</sub> Network, 2008



Hourly [CO<sub>2</sub>], calibrated to absolute standards (WMO/NOAA)

# Conclusions

- Gulf of Mexico Basin (GOMB) is a huge part of NA Carbon budget (land, rivers, sea, air, fossil fuel, humans)
- Uptake of about  $200 \text{ g C m}^{-2} \text{ yr}^{-1}$  in Gulf Coast region in 2004 may be related to forest harvest & regrowth
- Lateral boundary inflow in Gulf Coast region explains 80% to 90% of summer  $\text{CO}_2$  variance, reaches most of SE USA
- Opportunity for groundbreaking interdisciplinary (& international) research!