

# Missing the "sink"

What observations and models tell us about the future of land carbon dioxide uptake and why it matters for future climate change

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Wisconsin Ecology Sampler Seminar

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# About Me

- UW Dept of Atmospheric & Oceanic Sciences, 2007-
  - Assistant Professor
  - Faculty affiliate, CCR, SAGE, LMS, WE
  - B.A. Computer Sci/Envi; Studies, Oberlin College 93-97
  - M.S. Geography, U. Minnesota 98-00
  - Ph.D. Meteorology, Penn State 02-06
  - Post-doc (ASP Fellow) NCAR, Boulder, CO 06-07
  - Stints: USFS; EPA; Dept of Forest Resources, UMN
  - Married, 3 girls: 1, 3, 7, “South Jersey” native



## How does ecosystem ecology progress?

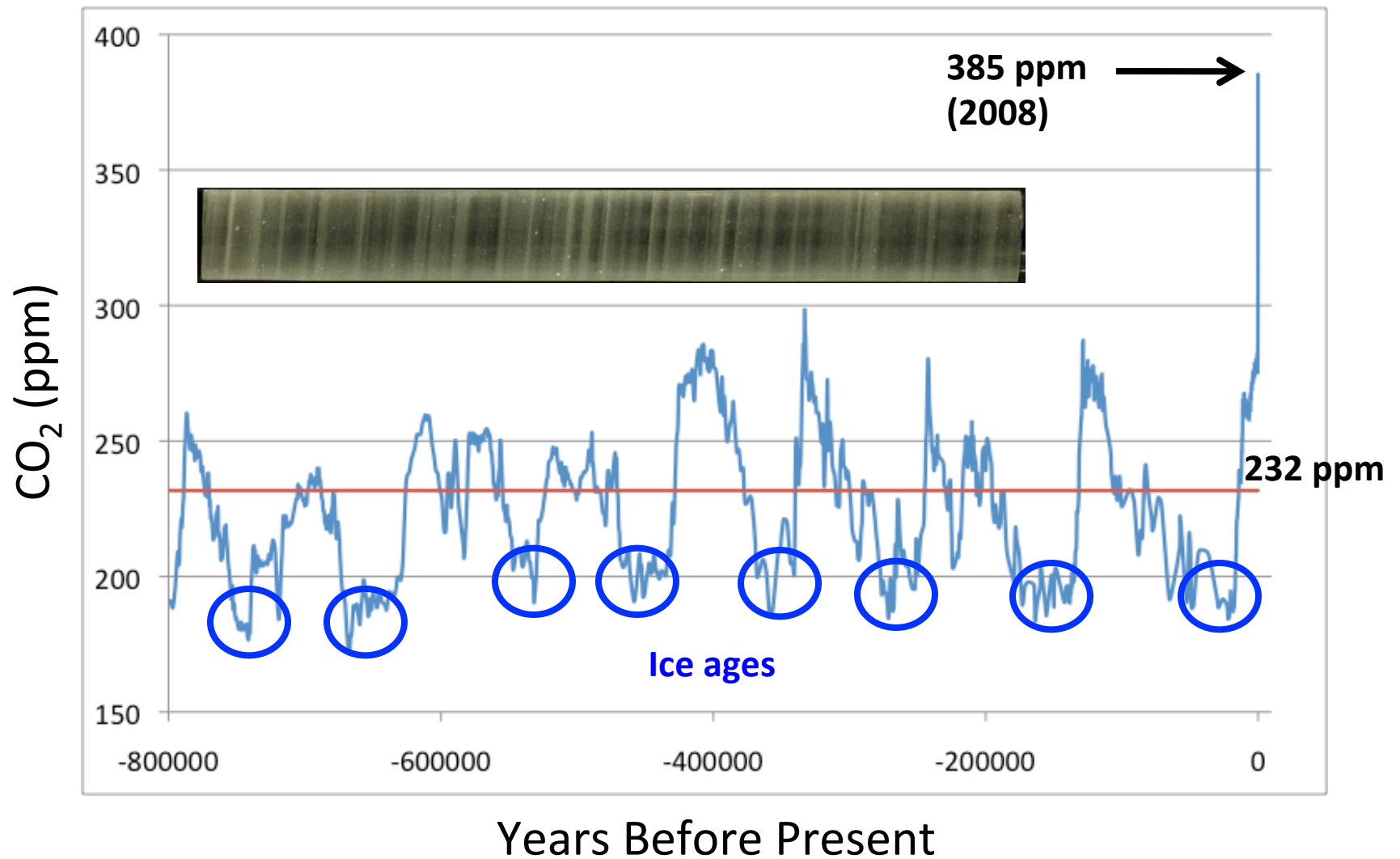
- **Ecosystems** are generally evolutionarily adapted to regional climate and its short-term variability
- **Expectations** of how these ecosystems respond to climate variation form the basis of ecosystem ecology and biogeochemistry
- **But: Surprises** are likely given the complex interplay between ecosystems and climate

# SURPRISE!

- Surprises are no fun for ecosystem **management**
- But: It' s also how science **progresses**
- And: We are likely entering an era where surprises will be more **common**.

**Why?**

# Why? CO<sub>2</sub>!

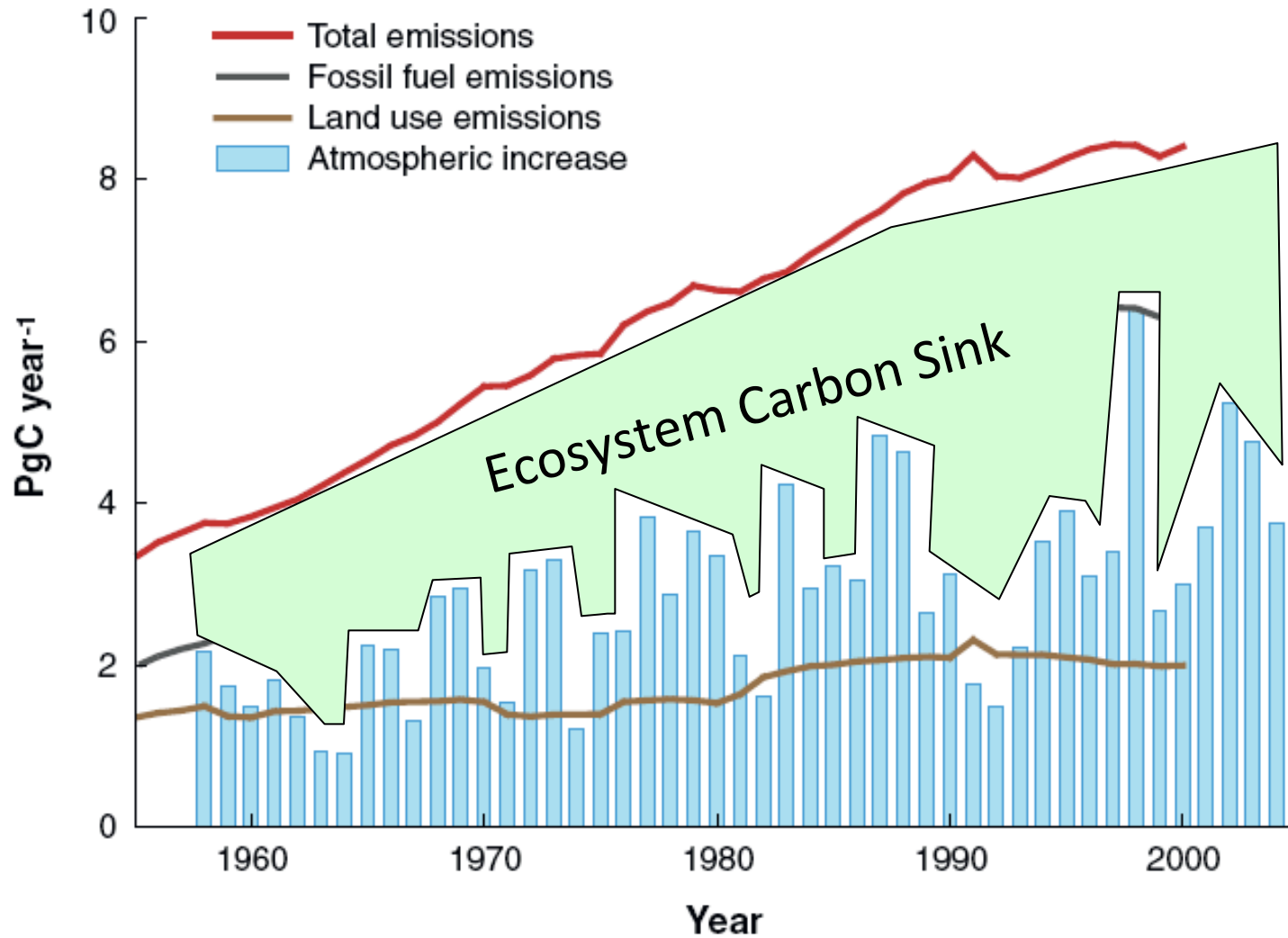


Source: Lüthi et al (2008), CDIAC, & Wikimedia Commons

## Since 1990

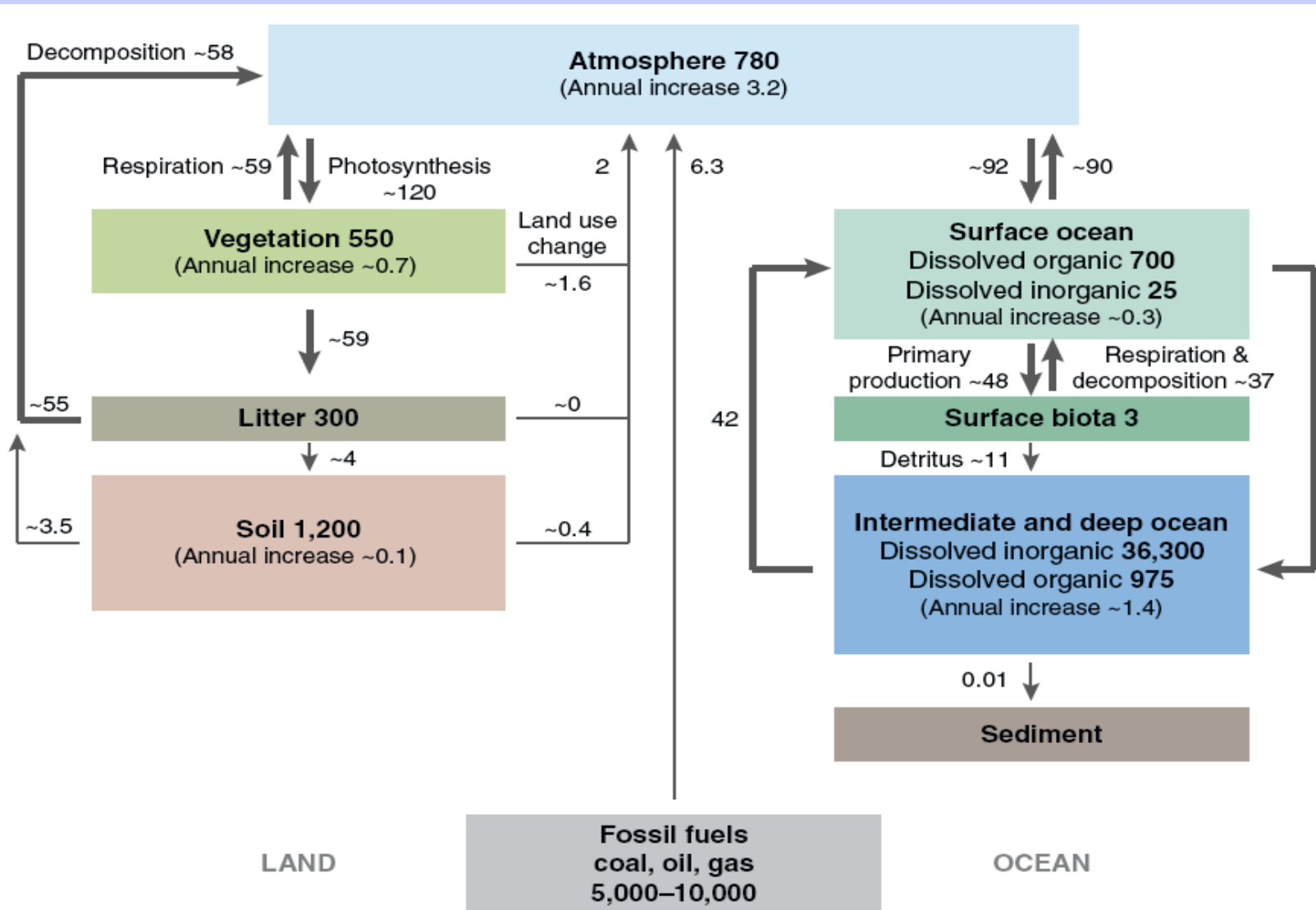
- Global annual CO<sub>2</sub> emissions grew 25% to 27,000,000,000 tons of CO<sub>2</sub>
- CO<sub>2</sub> in the atmosphere grew 10% to 385 ppm
- At current rates, CO<sub>2</sub> is likely to exceed 500-950 ppm sometime this century
- But: Rate of atmospheric CO<sub>2</sub> increase is about half the rate of emissions increase. **Why?**

# Where Is The Carbon Going?



Houghton et al. (2007)

# Carbon Cycle

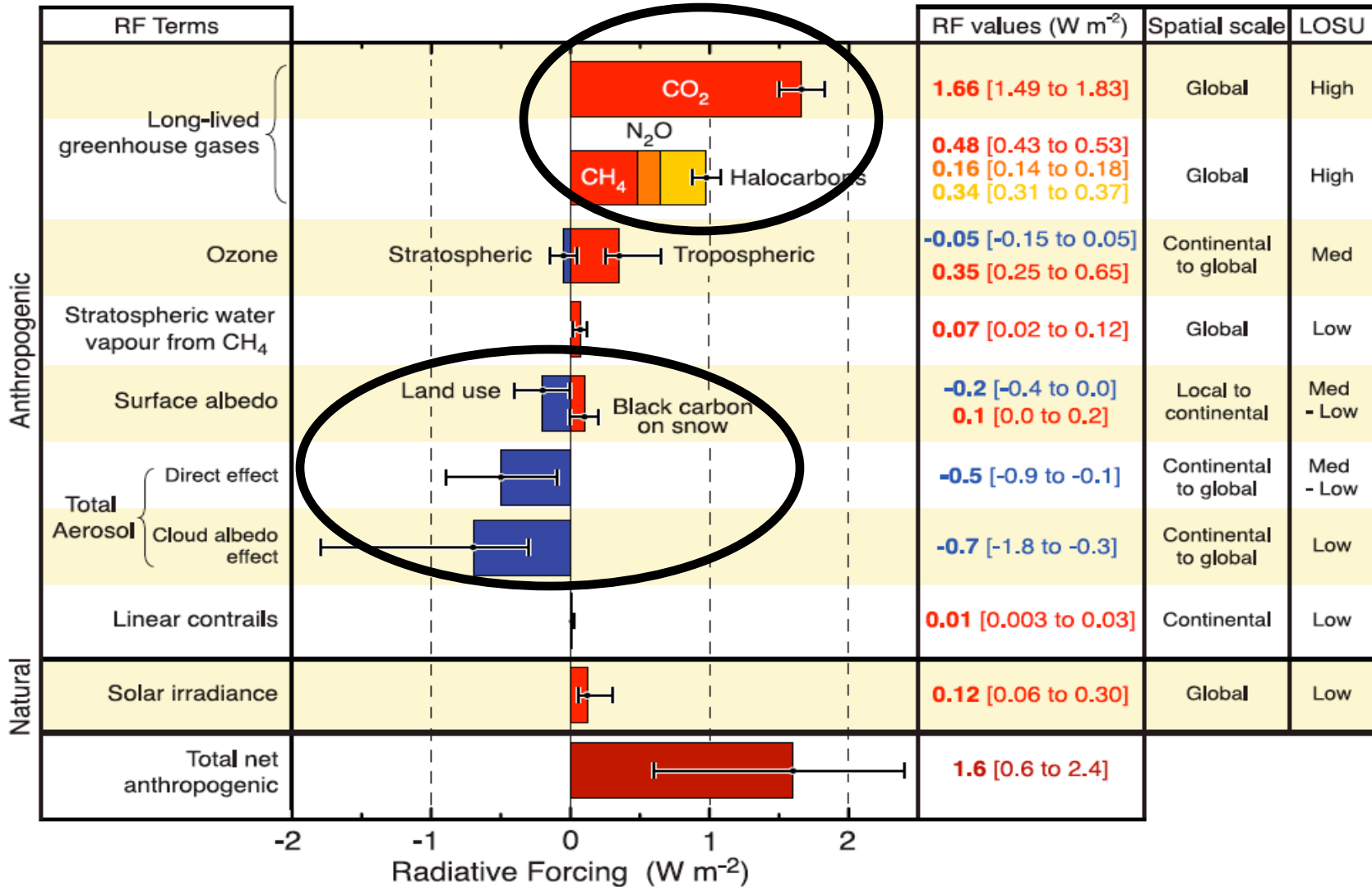


Houghton et al. (2007)



# What's The Big Deal?

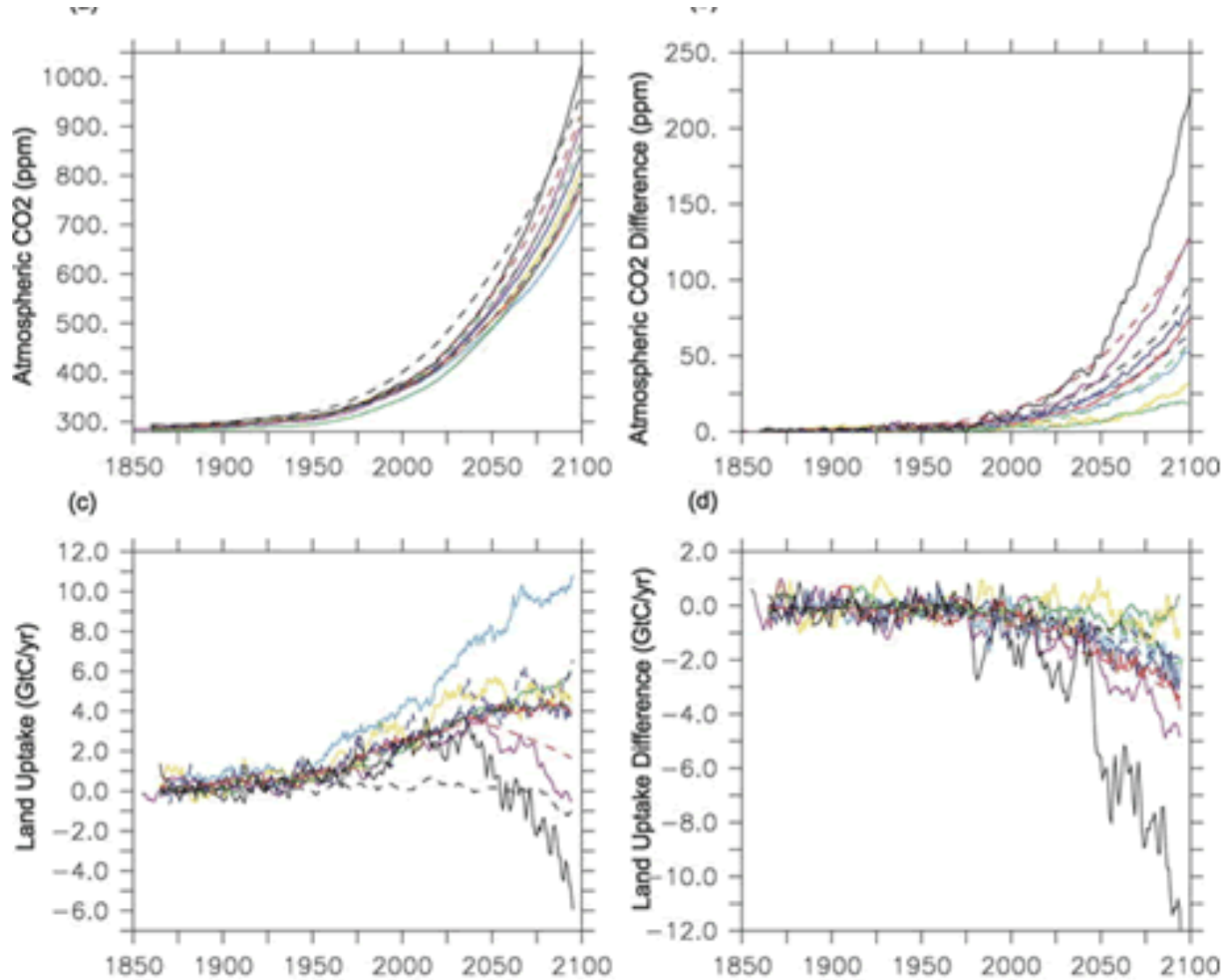
## RADIATIVE FORCING COMPONENTS



IPCC, 4<sup>th</sup> AR, (2007)

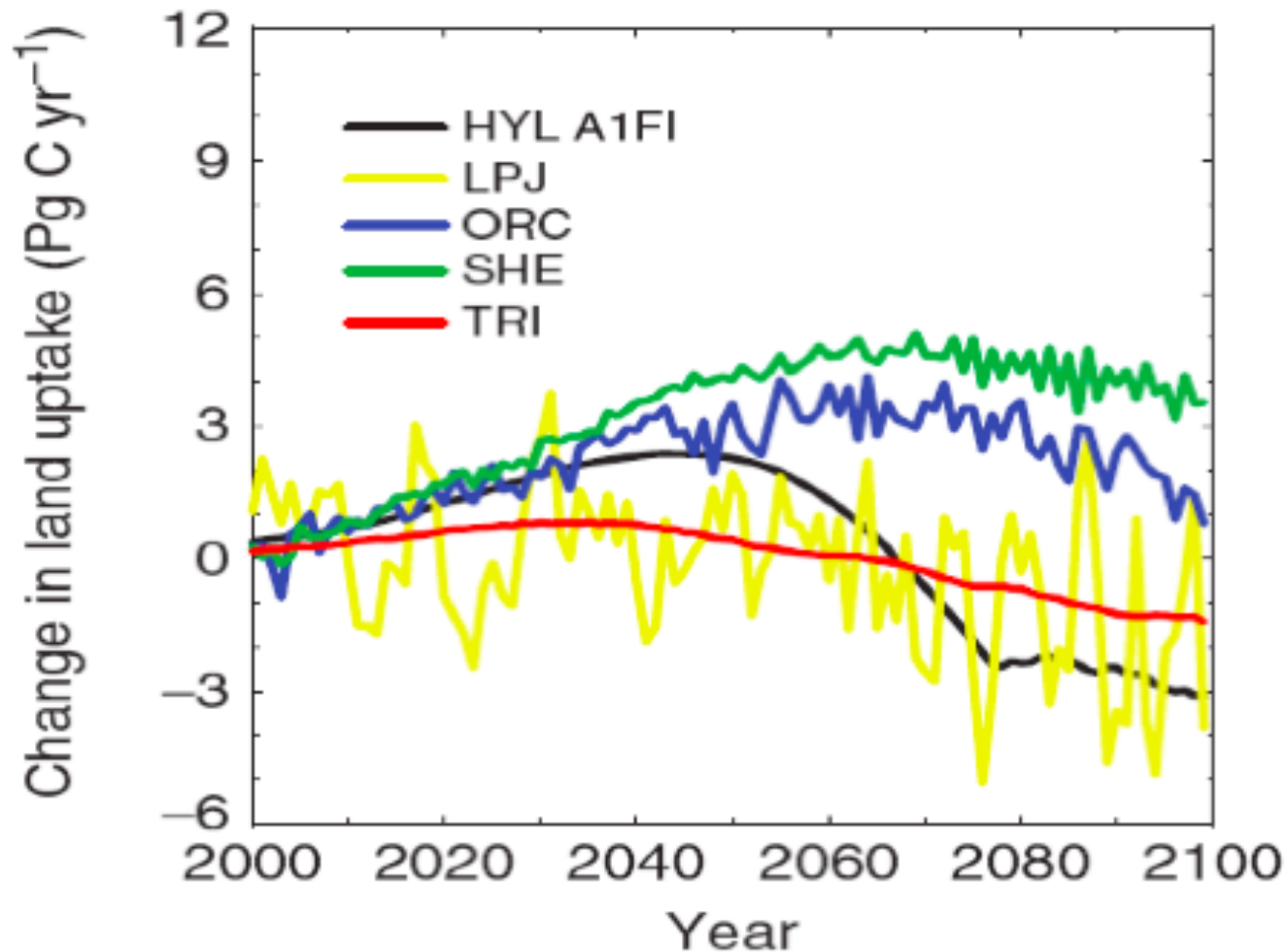
# Common Theme: Uncertainty

- Friedlingstein et al., 2006

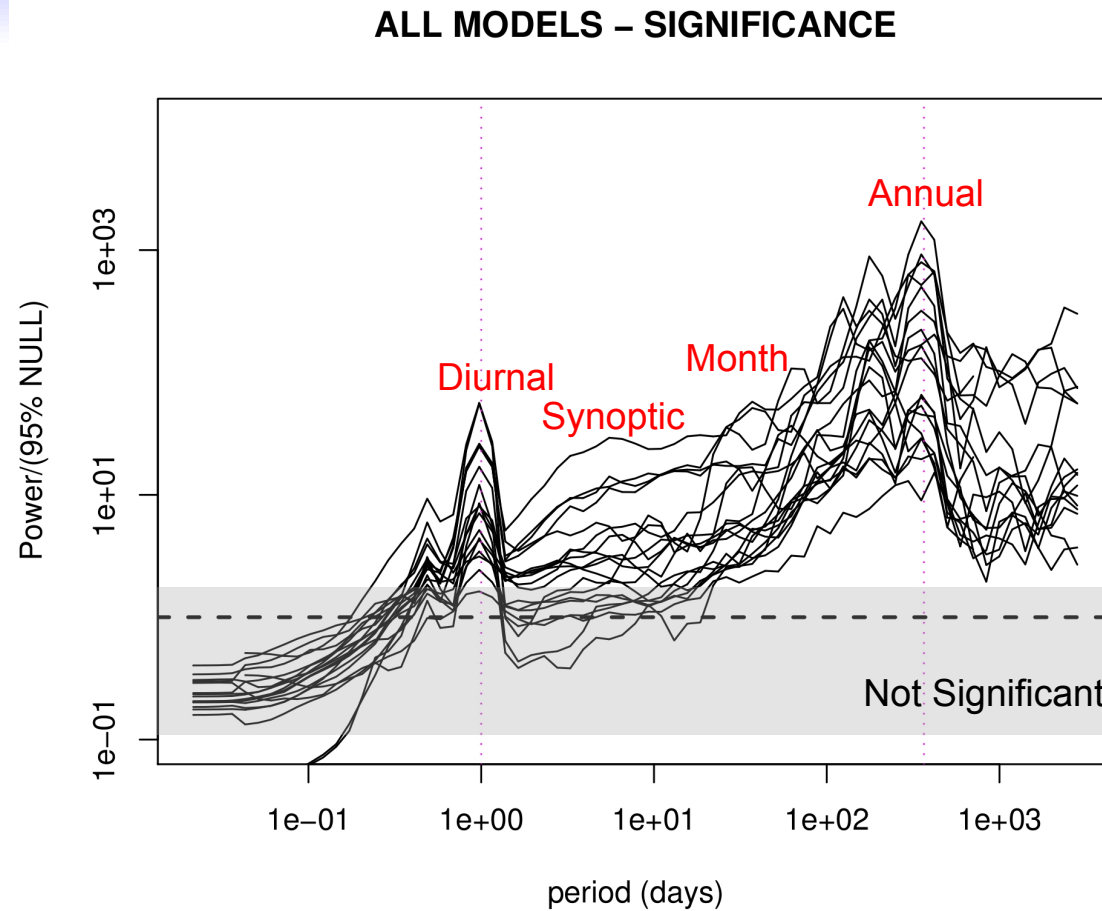


# Common Theme: Uncertainty

- Sitch et al., 2008



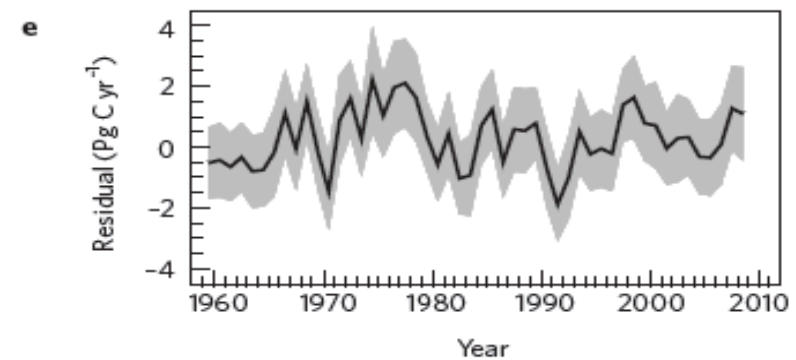
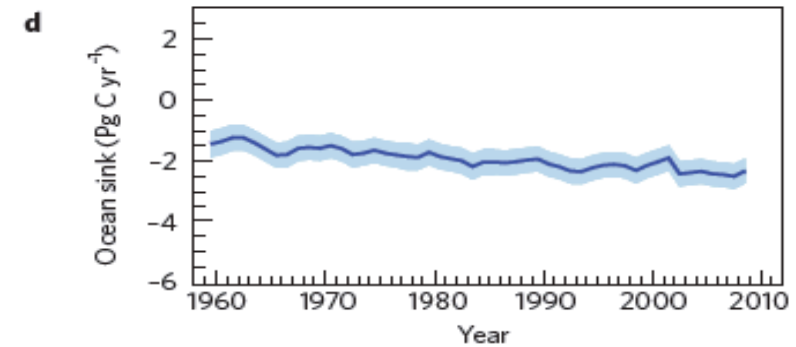
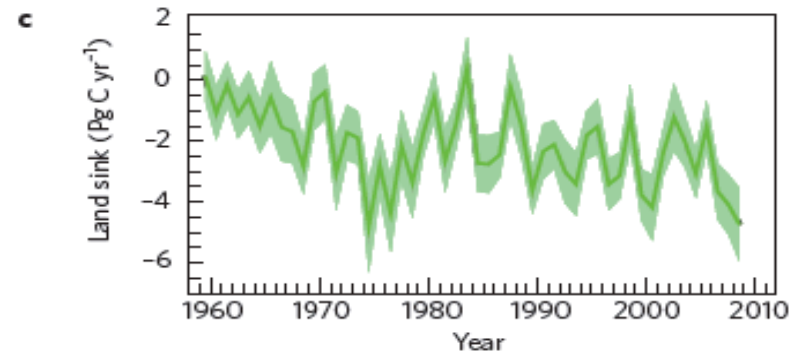
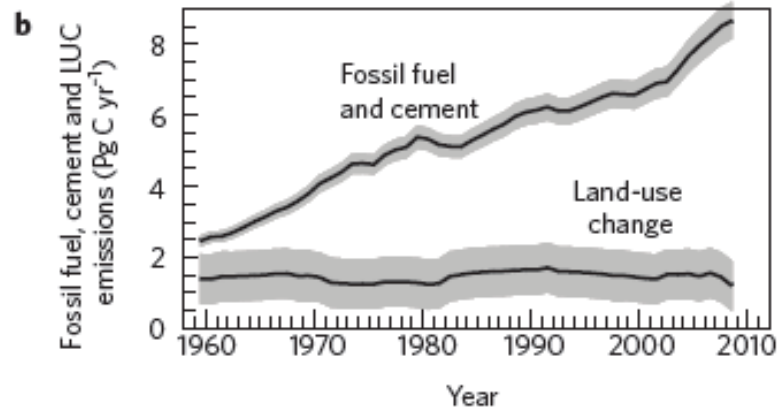
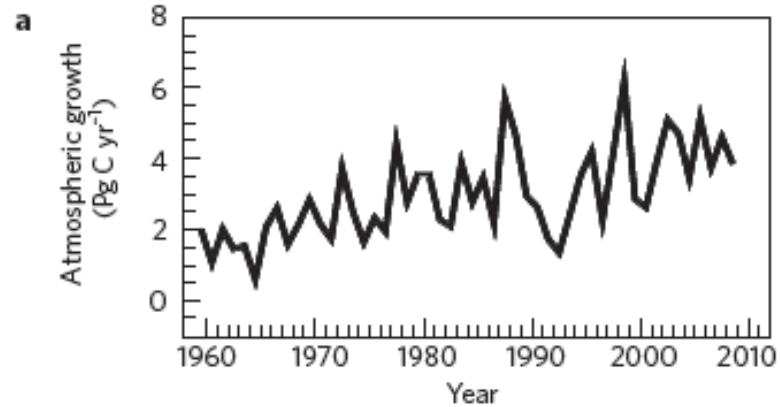
# Common Theme: Uncertainty



- Error peak at diurnal & annual time scales
- Errors at synoptic & monthly time scales

Dietze et al., submitted

# Why Do I Study Terrestrial Carbon?

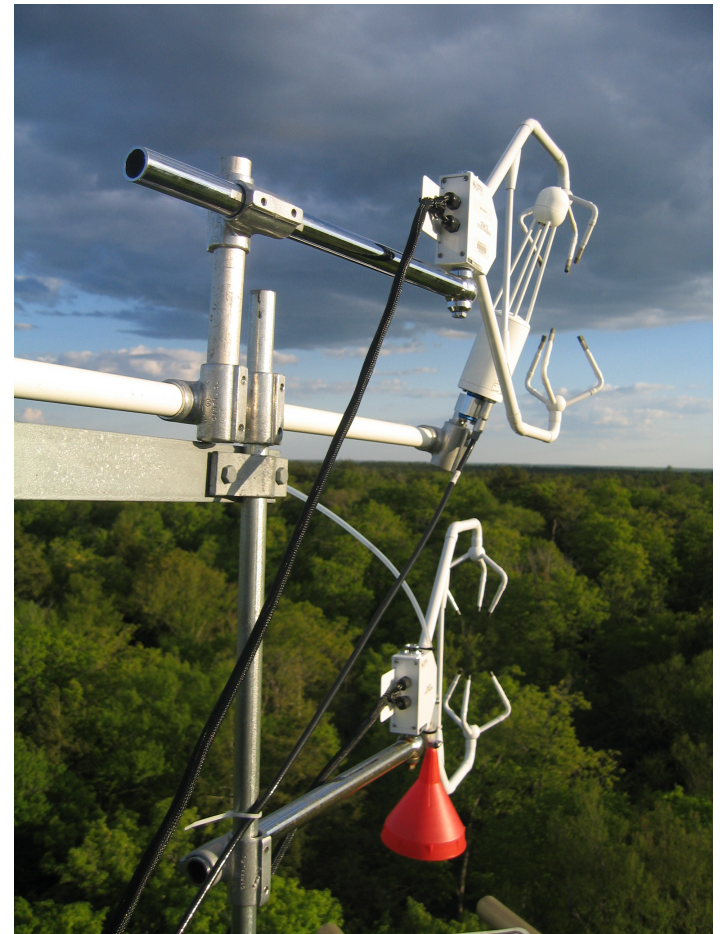
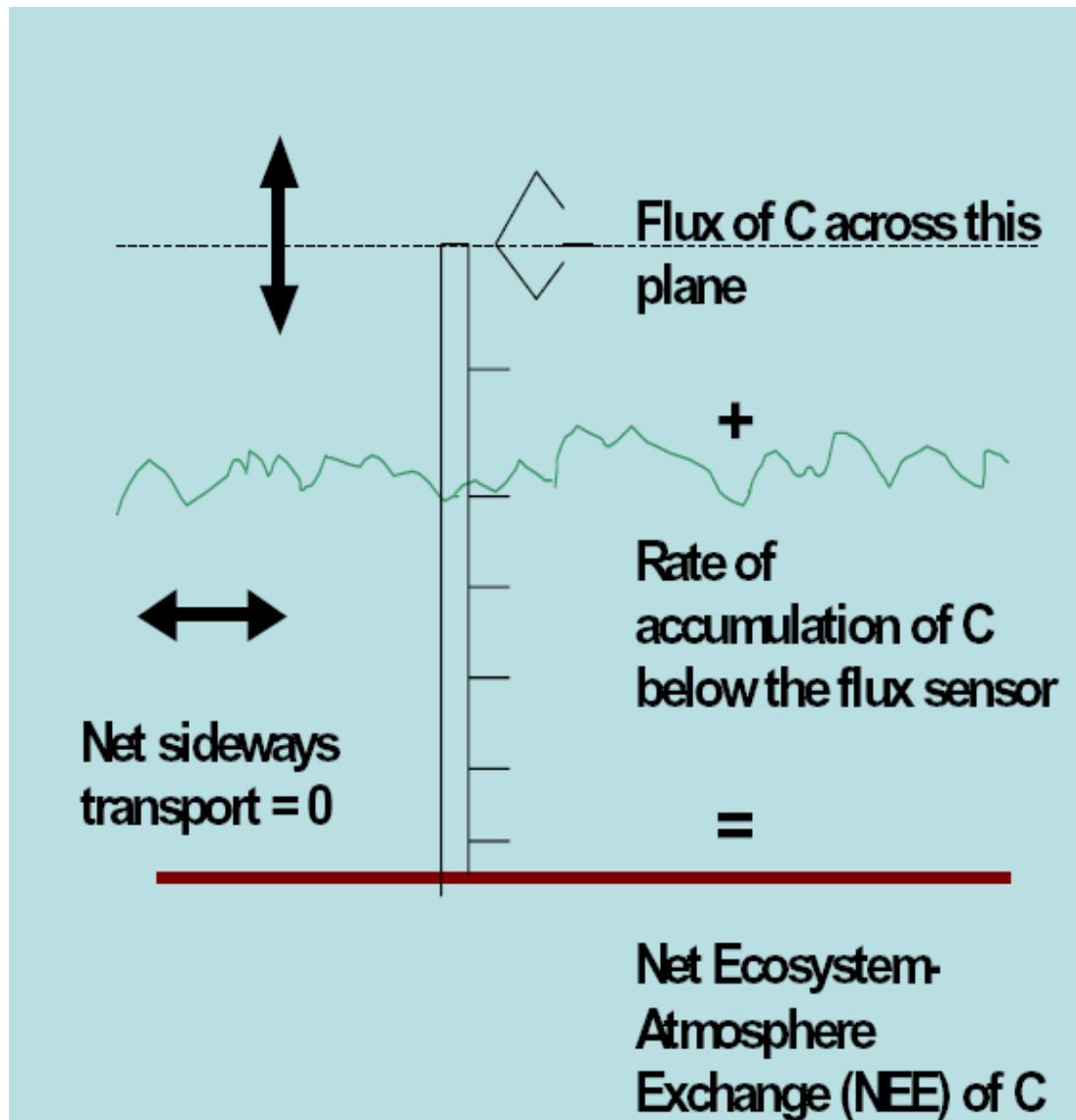


Le Quéré et al., 2009

# A Tower



# A Useful Tower

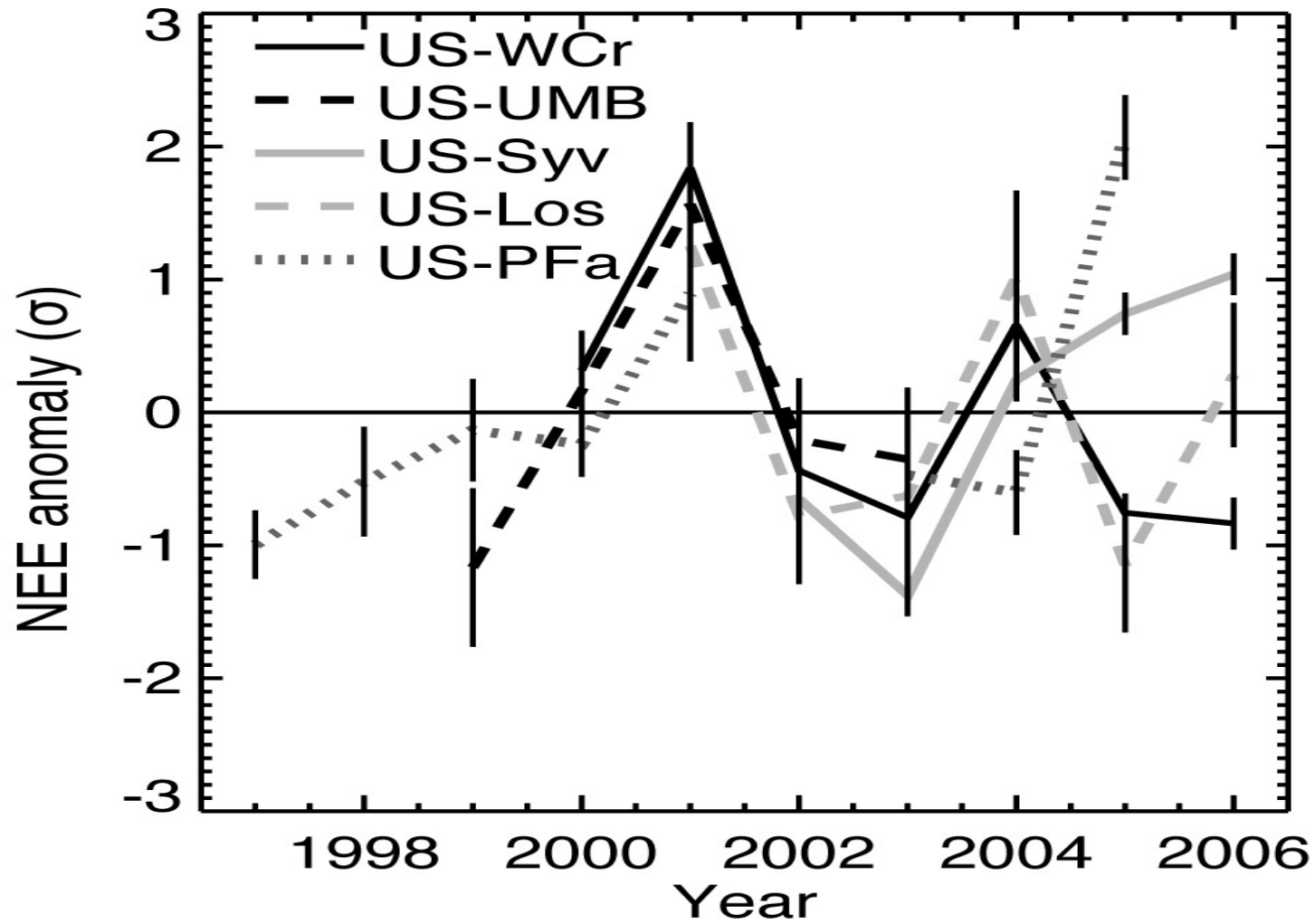


# A Region

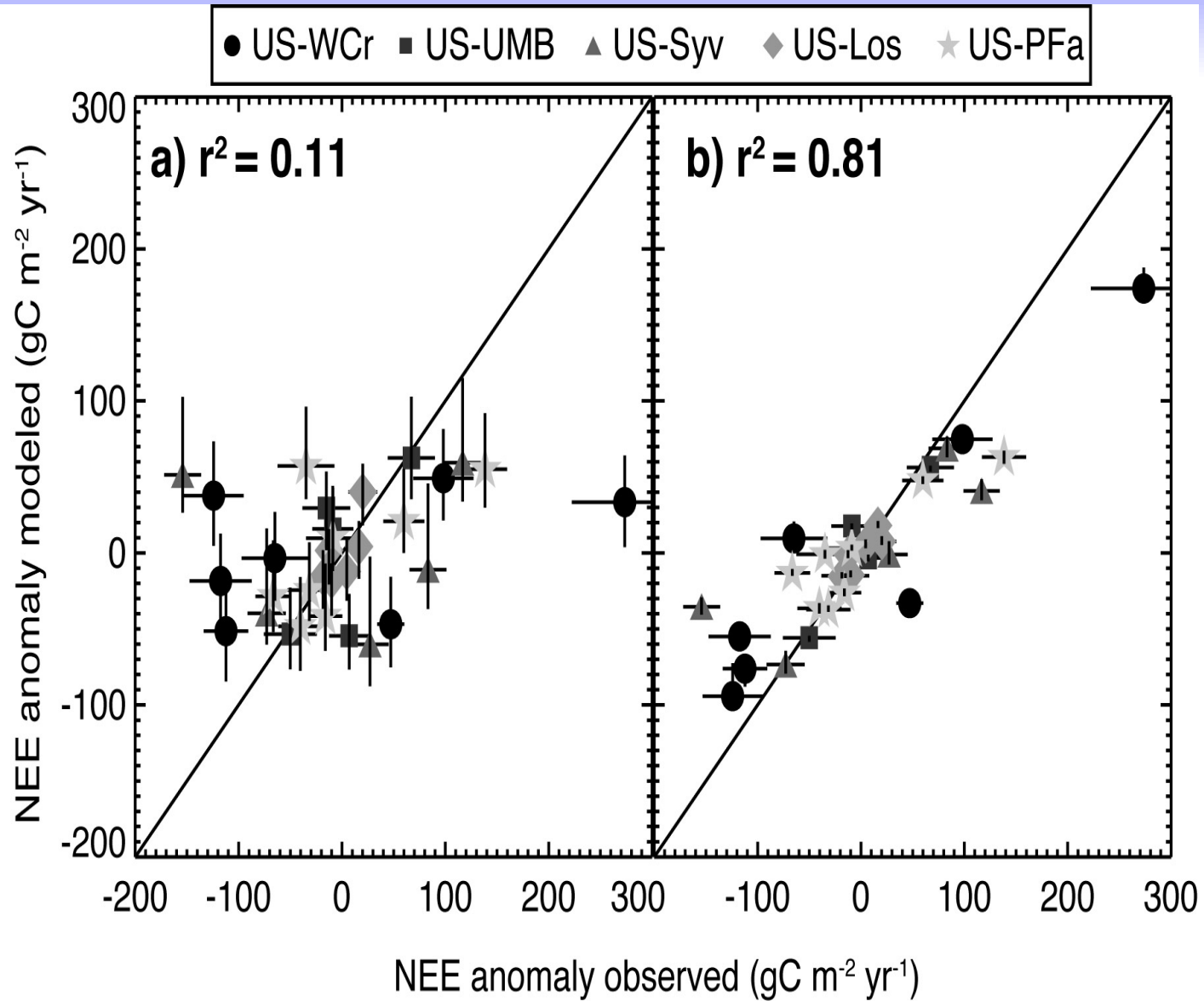




# Regional Coherence

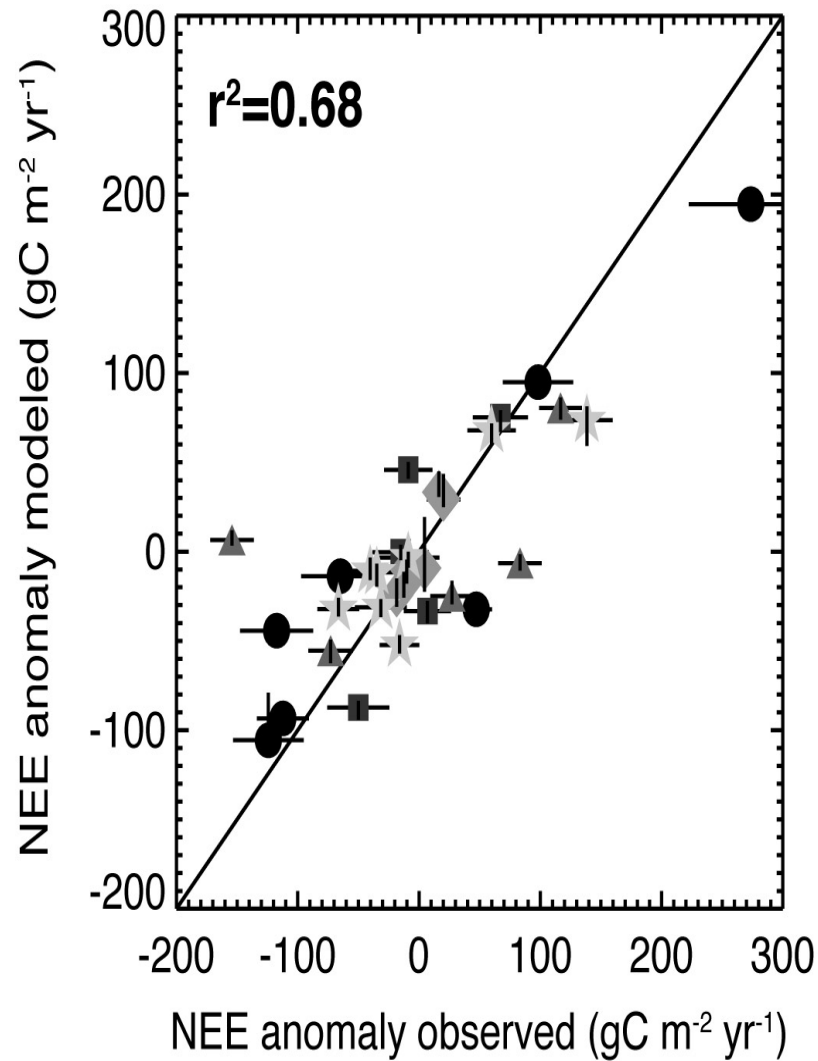


# Model-Data Assimilation



# Explaining Coherence

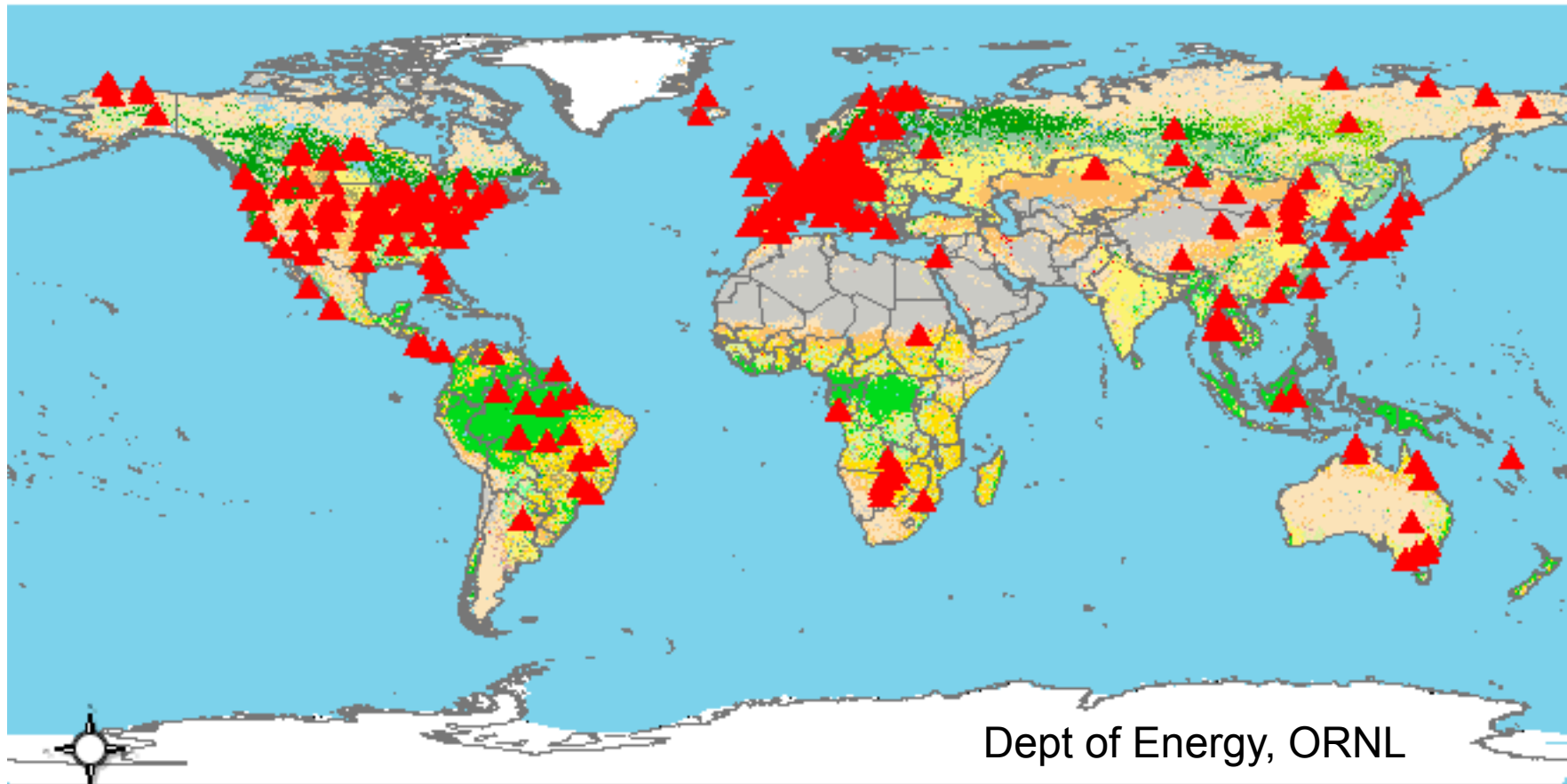
● US-WCr ■ US-UMB ▲ US-Syv ◆ US-Los ★ US-PFa



# The Value of Network Science

- Ecology is a “synthesis” science

Carpenter et al., 2009

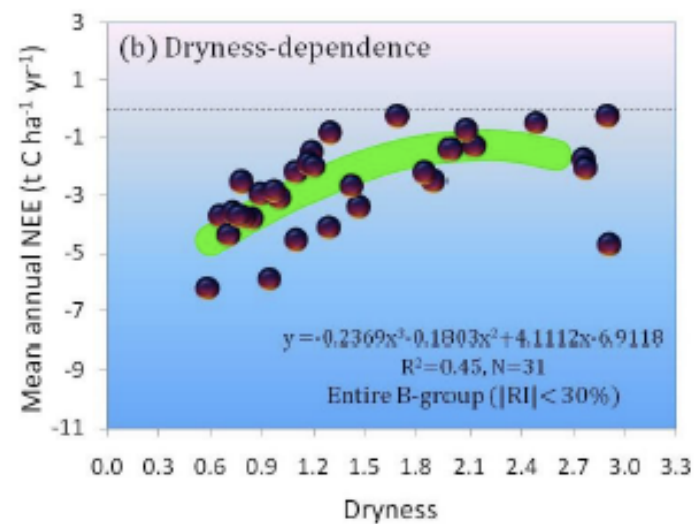
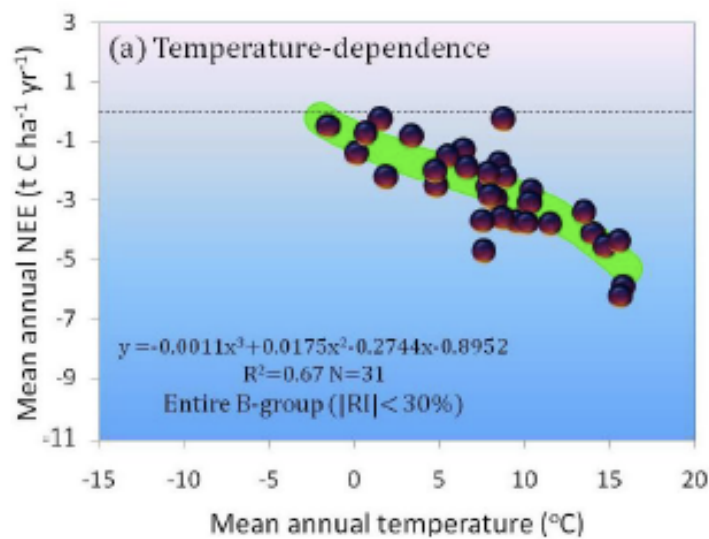
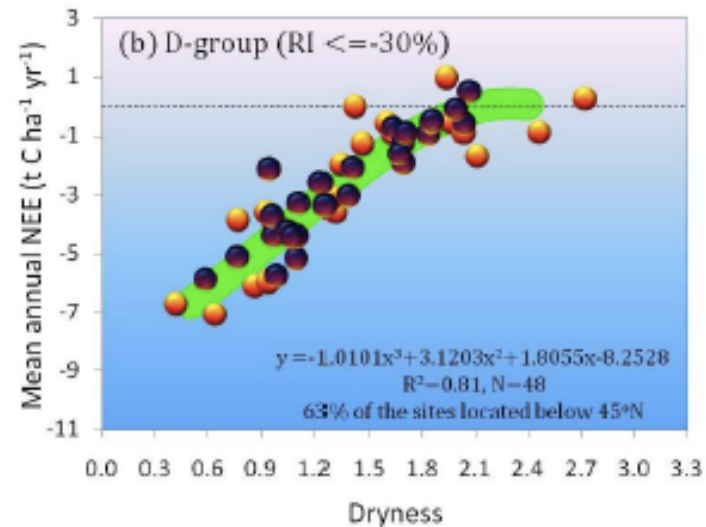
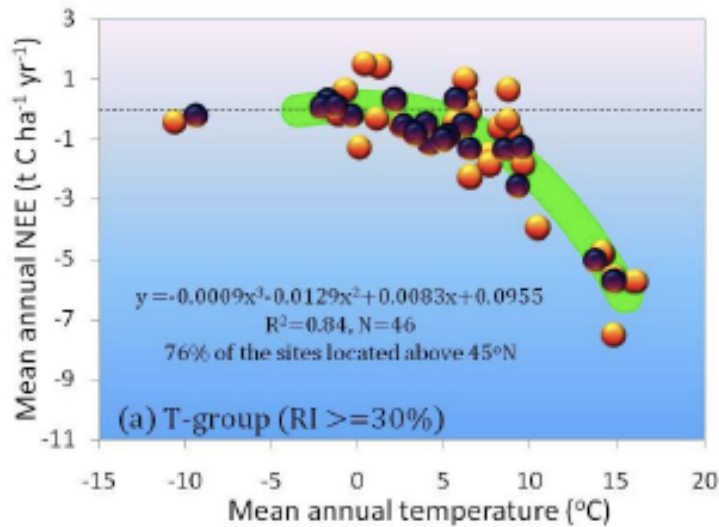


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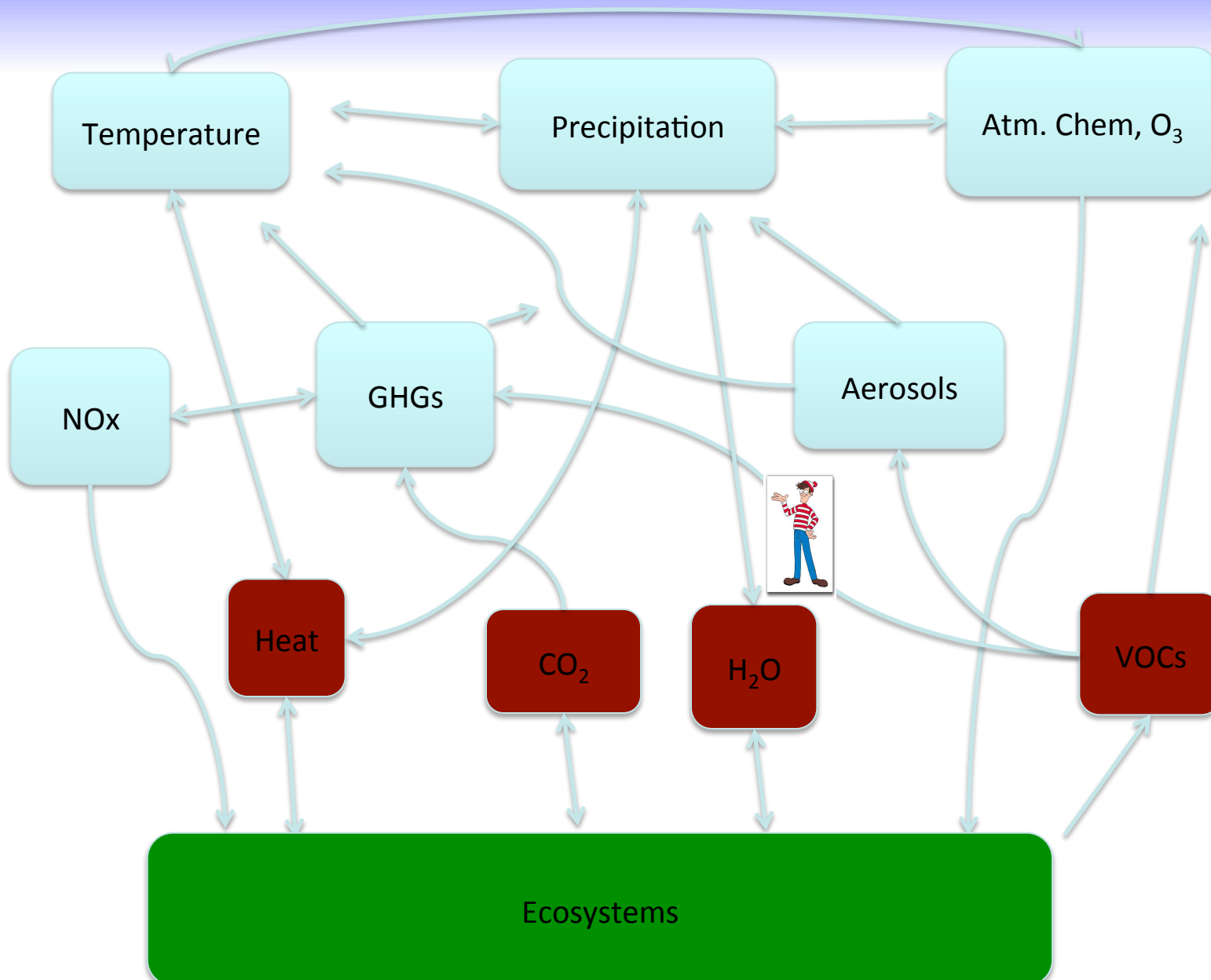
# Climate control of terrestrial carbon exchange across biomes and continents

Chulxiang Yi<sup>1</sup>, Daniel Ricciuto<sup>2</sup>, Runze Li<sup>3</sup>, John Wolbeck<sup>1</sup>, Xiyan Xu<sup>1</sup>, Mats Nilsson<sup>4</sup>, Luis Aires<sup>5,117</sup>, John D Albertson<sup>6,117</sup>, Christof Ammann<sup>7,117</sup>, M Altaf Arain<sup>8,117</sup>, Alessandro C de Araujo<sup>9,117</sup>, Marc Aubinet<sup>10,117</sup>, Mika Aurela<sup>11,117</sup>, Zoltán Barcza<sup>12,117</sup>, Alan Barr<sup>13,117</sup>, Paul Berbigier<sup>14,117</sup>, Jason Beringer<sup>15,117</sup>, Christian Bernhofer<sup>16,117</sup>, Andrew T Black<sup>17,117</sup>, Paul V Bolstad<sup>18,117</sup>, Fred C Bosveld<sup>19,117</sup>, Mark S J Broadmeadow<sup>20,117</sup>, Nina Buchmann<sup>21,117</sup>, Sean P Burns<sup>22,117</sup>, Pierre Cellier<sup>23,117</sup>, Jingming Chen<sup>24,117</sup>, Jiquan Chen<sup>25,117</sup>, Philippe Ciais<sup>26,117</sup>, Robert Clement<sup>27,117</sup>, Bruce D Cook<sup>28,117</sup>, Peter S Curtis<sup>29,117</sup>, D Bryan Dall<sup>30,117</sup>, Ebba Dellwik<sup>31,117</sup>, Nicolas Delplerre<sup>32,117</sup>, Ankur R Desai<sup>33,117</sup>, Sabina Dore<sup>34,117</sup>, Danilo Dragoni<sup>35,117</sup>, Bert G Drake<sup>36,117</sup>, Eric Dufrene<sup>32,117</sup>, Allison Dunn<sup>37,117</sup>, Jan Elbers<sup>38,117</sup>, Werner Eugster<sup>21,117</sup>, Matthias Falk<sup>39,117</sup>, Christian Felgenwinter<sup>40,117</sup>, Lawrence B Flanagan<sup>41,117</sup>, Thomas Foken<sup>42,117</sup>, John Frank<sup>43,117</sup>, Juerg Fuhrer<sup>7,117</sup>, Damiano Gianelle<sup>44,117</sup>, Allen Goldstein<sup>45,117</sup>, Mike Goulden<sup>46,117</sup>, Andre Granier<sup>47,117</sup>, Thomas Grünwald<sup>48,117</sup>, Lianhong Gu<sup>2,117</sup>, Haiqiang Guo<sup>49,117</sup>, Albin Hammerle<sup>50,117</sup>, Shijie Han<sup>51,117</sup>, Niall P Hanan<sup>52,117</sup>, László Haszpra<sup>53,117</sup>, Bernard Helnesch<sup>10,117</sup>, Carole Helfter<sup>54,117</sup>, Dimmie Hendriks<sup>55,117</sup>, Lindsay B Hutley<sup>56,117</sup>, Andreas Ibrom<sup>57,117</sup>, Cor Jacobs<sup>38,117</sup>, Torbjörn Johansson<sup>58,117</sup>, Marjan Jongen<sup>59,117</sup>, Gabriel Katul<sup>60,117</sup>, Gerard Klely<sup>61,117</sup>, Katja Klumpp<sup>62,117</sup>, Alexander Knohl<sup>21,117</sup>, Thomas Kolb<sup>34,117</sup>, Werner L Kutsch<sup>63,117</sup>, Peter Lafleur<sup>64,117</sup>, Tuomas Laurila<sup>11,117</sup>, Ray Leuning<sup>65,117</sup>, Anders Lindroth<sup>58,117</sup>, Heping Liu<sup>66,117</sup>, Benjamin Loubet<sup>23,117</sup>, Giovanni Manca<sup>67,117</sup>, Michal Marek<sup>68,117</sup>, Hank A Margolis<sup>69,117</sup>, Timothy A Martin<sup>70,117</sup>, William J Massman<sup>43,117</sup>, Roser Matamala<sup>71,117</sup>, Giorgio Matteucci<sup>72,117</sup>, Harry McCaughey<sup>73,117</sup>, Lutz Merbold<sup>74,117</sup>, Tilden Meyers<sup>75,117</sup>, Mirco Migliavacca<sup>76,117</sup>, Franco Migletta<sup>77,117</sup>, Laurent Misson<sup>78,117,118</sup>, Meelis Mölder<sup>58,117</sup>, John Moncrieff<sup>27,117</sup>, Russell K Monson<sup>79,117</sup>, Leonardo Montagnani<sup>80,81,117</sup>, Marlo Montes-Helu<sup>34,117</sup>, Eddy Moors<sup>82,117</sup>, Christine Moureaux<sup>10,83,117</sup>, Mukufute M Mukelabal<sup>84,117</sup>, J William Munger<sup>85,117</sup>, May Myklebust<sup>65,117</sup>, Zoltán Nagy<sup>86,117</sup>, Asko Noormets<sup>87,117</sup>, Walter Oechel<sup>88,117</sup>, Ram Oren<sup>89,117</sup>, Stephen G Pallardy<sup>90,117</sup>, Kyaw Tha Paw U<sup>39,117</sup>, João S Pereira<sup>59,117</sup>, Kim Pilegaard<sup>57,117</sup>, Krisztina Pintér<sup>86,117</sup>, Casimiro Plo<sup>91,117</sup>, Gabriel Pita<sup>92,117</sup>, Thomas L Powell<sup>93,117</sup>, Serge Rambal<sup>94,117</sup>, James T Randerson<sup>46,117</sup>, Celso von Randow<sup>95,117</sup>, Corinna Rebmann<sup>64,117</sup>, Janne Rinne<sup>96,117</sup>, Federica Rossi<sup>77,117</sup>, Nigel Roulet<sup>97,117</sup>, Ronald J Ryel<sup>98,117</sup>, Jorgen Sagerfors<sup>4,117</sup>, Nobuko Salgusa<sup>99,117</sup>, María José Sanz<sup>100,117</sup>, Giuseppe-Scarascia Mugnozza<sup>101,117</sup>, Hans Peter Schmid<sup>102,117</sup>, Guenther Seufert<sup>103,117</sup>, Mario Siqueira<sup>89,117</sup>, Jean-François Soussana<sup>62,117</sup>, Gregory Starr<sup>104,117</sup>, Mark A Sutton<sup>105,117</sup>, John Tenhunen<sup>106,117</sup>, Zoltán Tuba<sup>86,117,118</sup>, Juha-Pekka Tuovinen<sup>11,117</sup>, Riccardo Valentini<sup>107,117</sup>, Christoph S Vogel<sup>108,117</sup>, Jingxin Wang<sup>109,117</sup>, Shaoqiang Wang<sup>110,117</sup>, Welguo Wang<sup>111,117</sup>, Lisa R Welp<sup>112,117</sup>, Xuefa Wen<sup>110,117</sup>, Sonia Wharton<sup>113,117</sup>, Matthew Wilkinson<sup>20,117</sup>, Christopher A Williams<sup>114,117</sup>

# Climate and Carbon



# Find the Surprise!



# The Future?

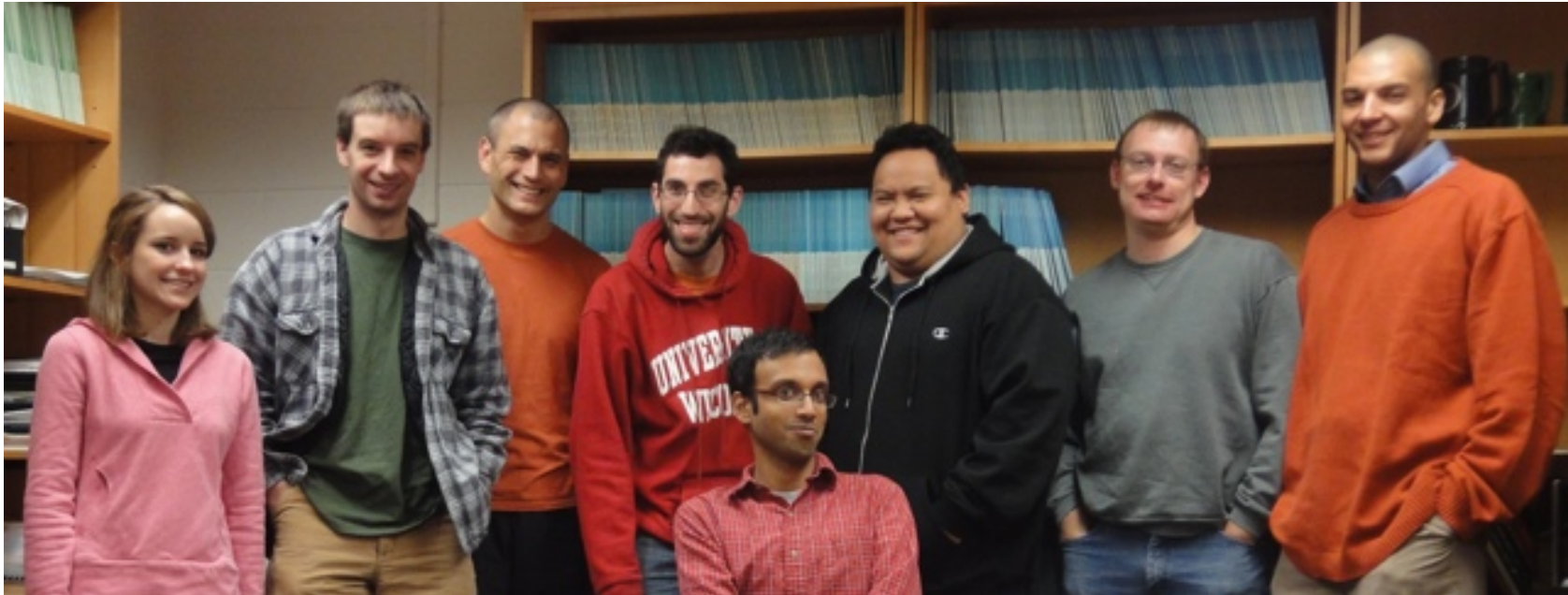
## **A primer for data assimilation with ecological models**

J.M. Zobitz\*



# Thanks!

- Desai Ecometeorology Lab ([flux.aos.wisc.edu](http://flux.aos.wisc.edu)):



- Funding partners: UW Graduate school, NSF, UCAR, NOAA, USDA NRS, NASA, DOE, DOE NICCR, WI Focus on Energy

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Proposing Ideas  
Designing Experiments  
Interpreting Results

Creativity



Teaching

Research

Presenting  
Writing  
Mentoring

Communication

Service/Outreach

Management

Time  
Money  
People