In Situ CO_2 Monitoring Network Evaluation and Design: A Criterion Based on Atmospheric CO2 Variability

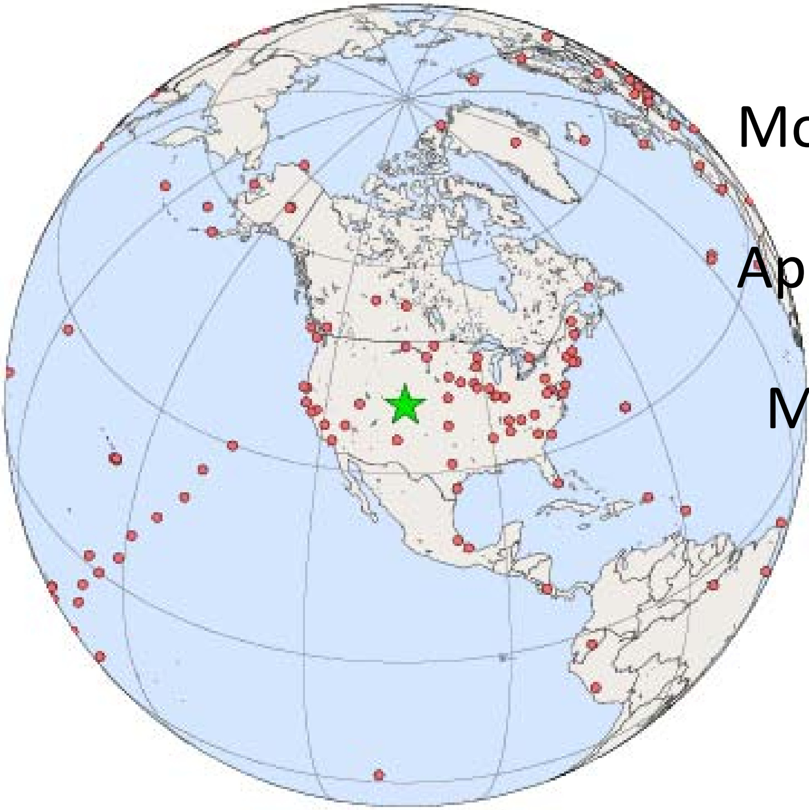
Y. Shiga[1], A.M. Michalak[2], A. Chatterjee[3], D. Hammerling[3], K.L. Mueller[4], S.M. Gourdji[5], V. Yadav[2], S.R. Kawa[6] and R.J. Engelen[7]

1. Department of Civil and Environmental Engineering, Stanford University, Stanford, CA
2. Carnegie Institution for Science, Department of Global Ecology, Stanford, CA
3. Civil and Environmental Engineering, University Of Michigan, Ann Arbor , MI
4. American Meteorological Society University Corporation for Atmospheric Research Congressional Fellow, Washington DC
5. Environmental Earth System Sciences, Stanford University, Stanford, CA
6. NASA Goddard Space Flight Center, Greenbelt, MD
7. European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom

CARNEGIE INSTITUTION FOR SCIENCE | GLOBAL ECOLOGY

STANFORD UNIVERSITY

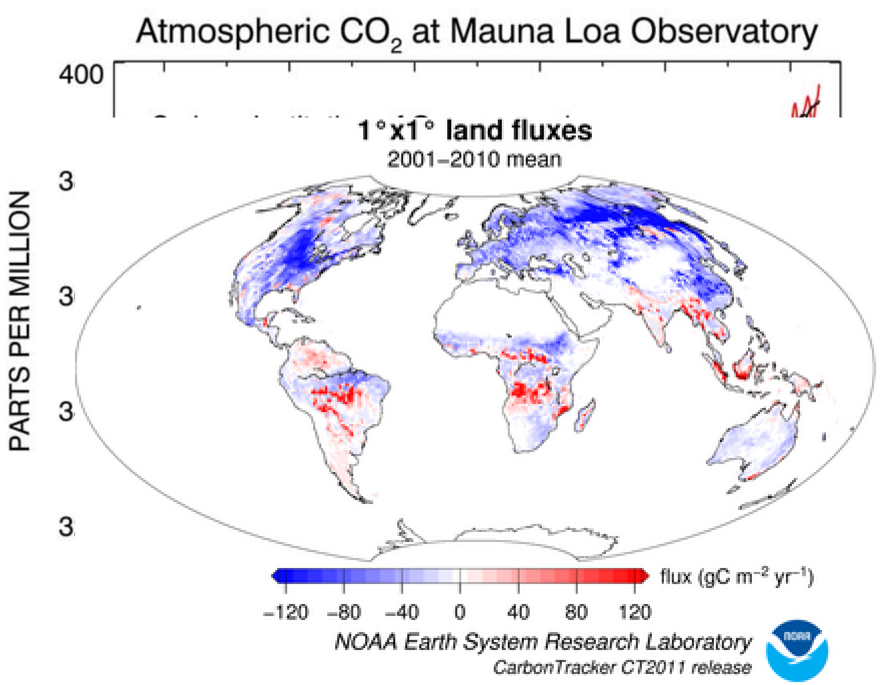
Outline



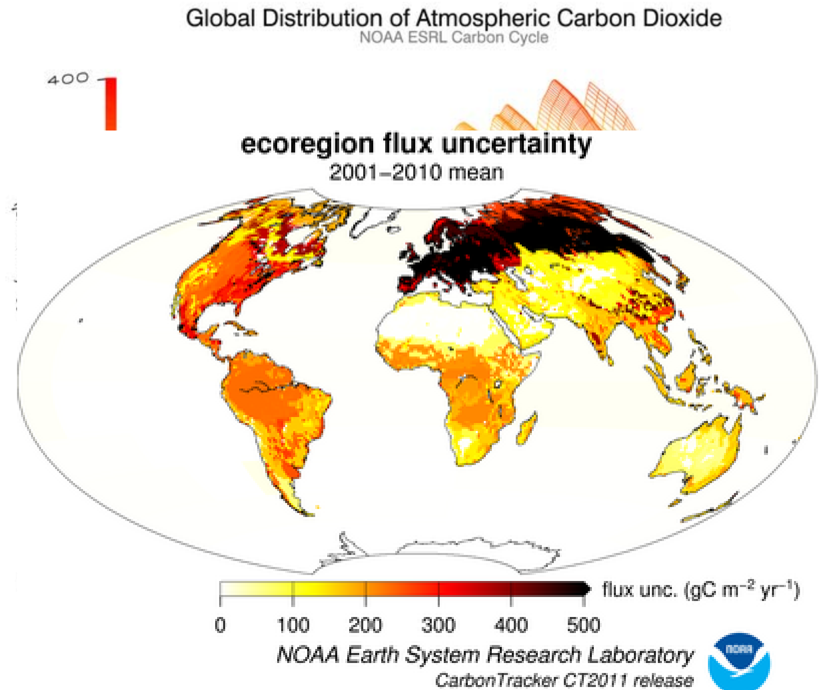
- Motivation
- Approach
- Methods
- Results/Validation
- Conclusions

http://www.esrl.noaa.gov/gmd/dv/iadv/

Goals of CO_2 Monitoring Network



Grid Scale



3 Hourly

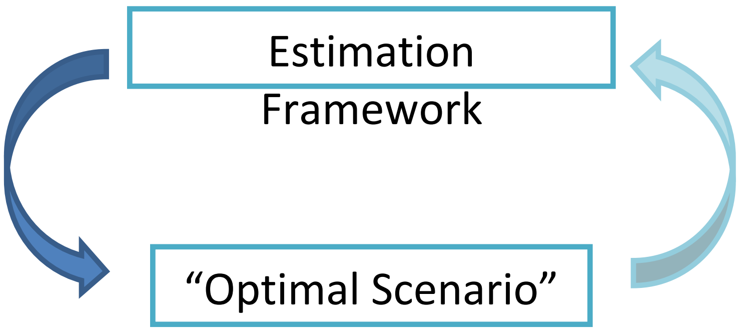
Also depends on the *method* used to recover fluxes…

Motivation for CO_2 Monitoring Network Design Tool

- Robust methods to augment the existing network within selected framework (Inverse modeling/ Data Assimilation) ~ Optimization problem ex. Simulated Annealing
  - Computationally intensive (especially for network expansion)

- Optimal network is intrinsically tied to specific model assumptions

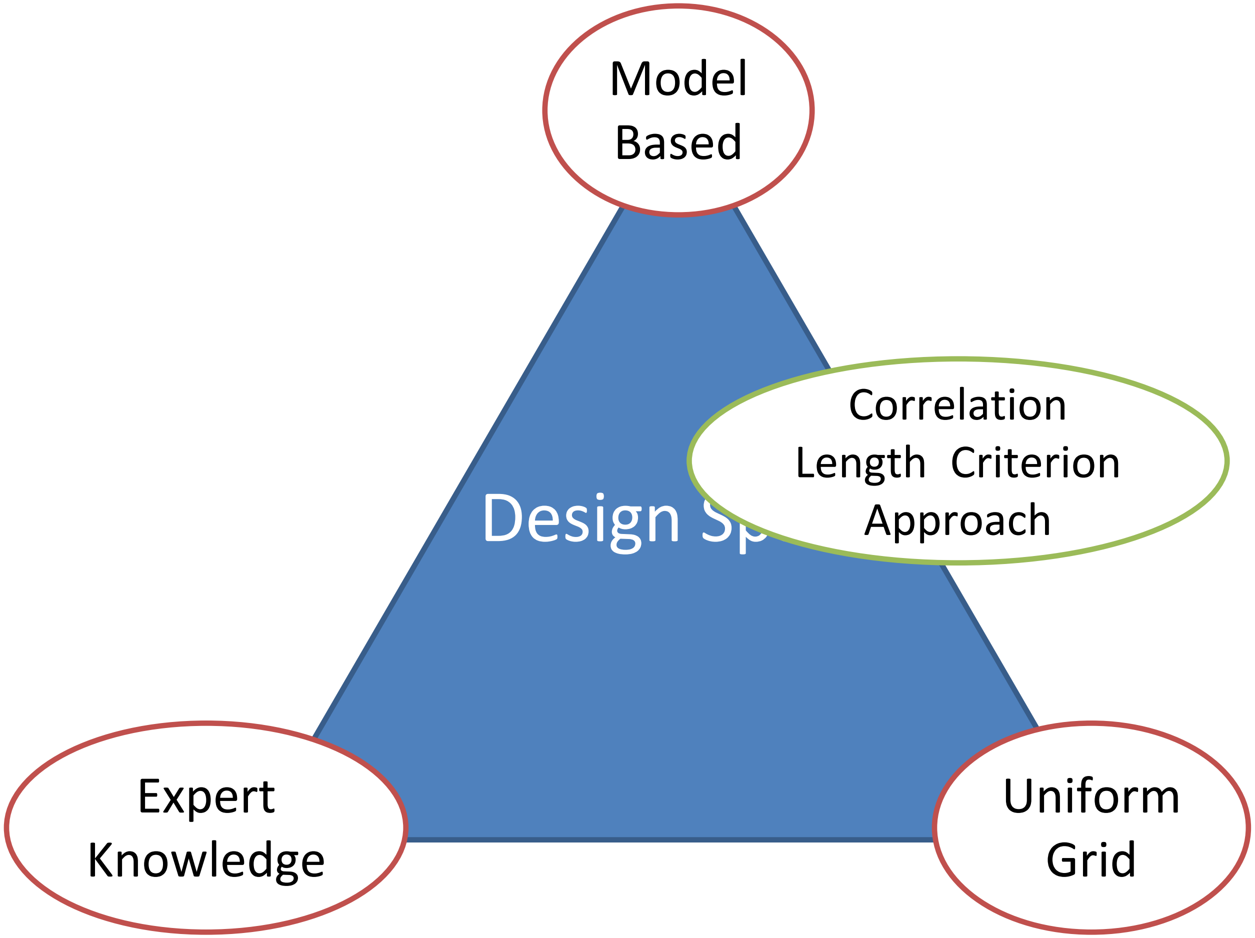
- To name a few…
  - Resolution of estimates
  - Atmospheric transport model
  - Choice of *a priori* flux information
  - Choice of *a priori* error structure



STANFORD UNIVERSITY

CARNEGIE INSTITUTION FOR SCIENCE | GLOBAL ECOLOGY

How should this network be designed?



CARNEGIE INSTITUTION FOR SCIENCE | GLOBAL ECOLOGY

STANFORD UNIVERSITY

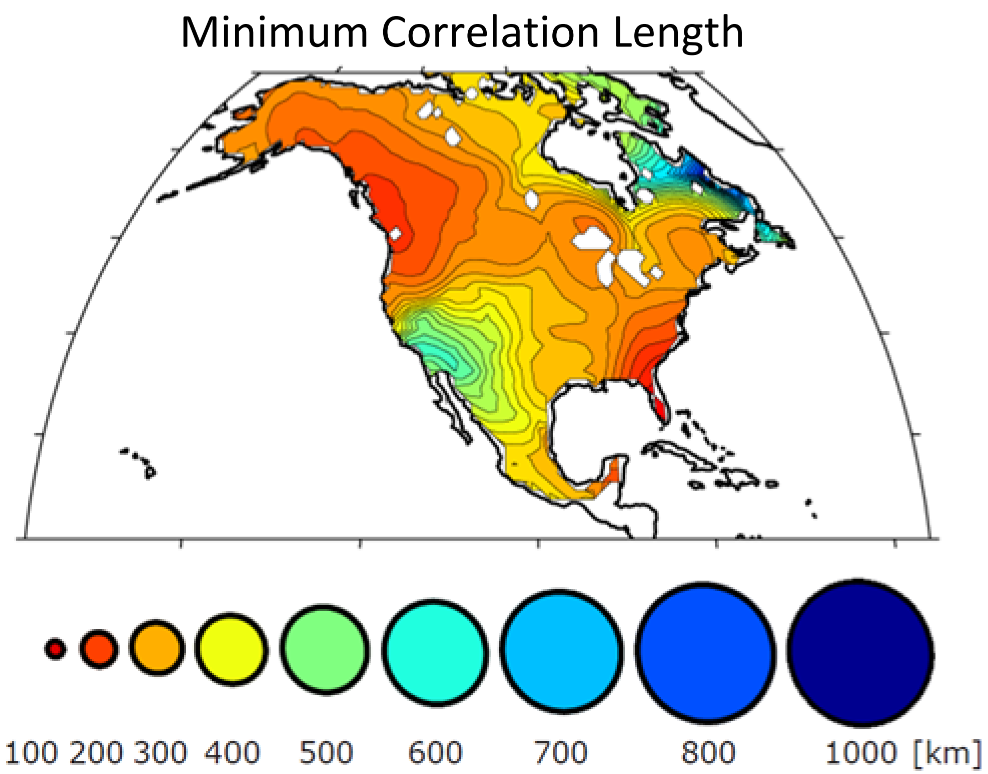
Can variability in atmospheric CO_2 be used to inform a network design tool?

- Use modeled CO_2 concentrations to represent true variability of atmospheric CO_2, Alkhaled et al. 2008
- Develop information criterion, based on variability of atmospheric CO_2, to define network coverage
- Evaluate 2004-2008 network expansion in North America
- Create two hypothetical network expansions
- Validation study – Synthetic data inversion
- Caveat
  - Many external factors go into actual tower placement
  - Not a stand alone tool

Identifying Spatial Variability in CO_2

Local Variogram Analysis

- Spatial variability of surface level CO_2 is location dependent
- Shorter correlation lengths ≈ higher variability
- Network should be able to capture most variable signal throughout year



How to define network coverage?

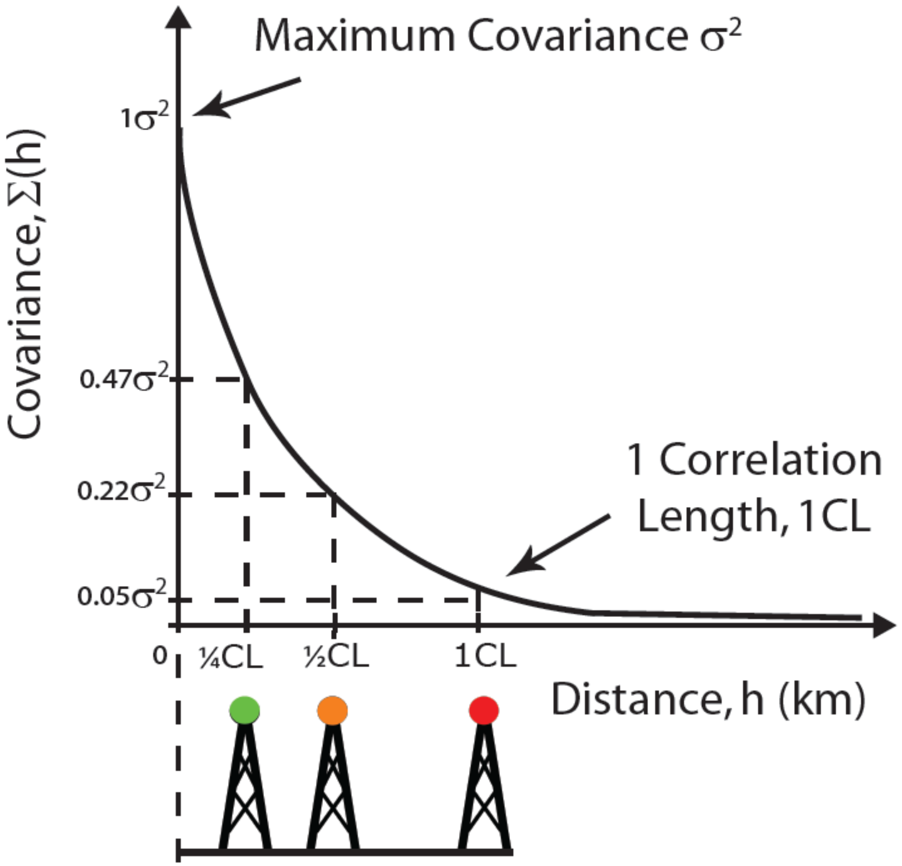
Correlation Length

- The separation distance at which two points become nearly independent (uninformative)

Fractional Correlation Length Scale

- Distance to nearest tower, h_i, divided by CL_i
- Defined per grid cell - h_i/Cl_i

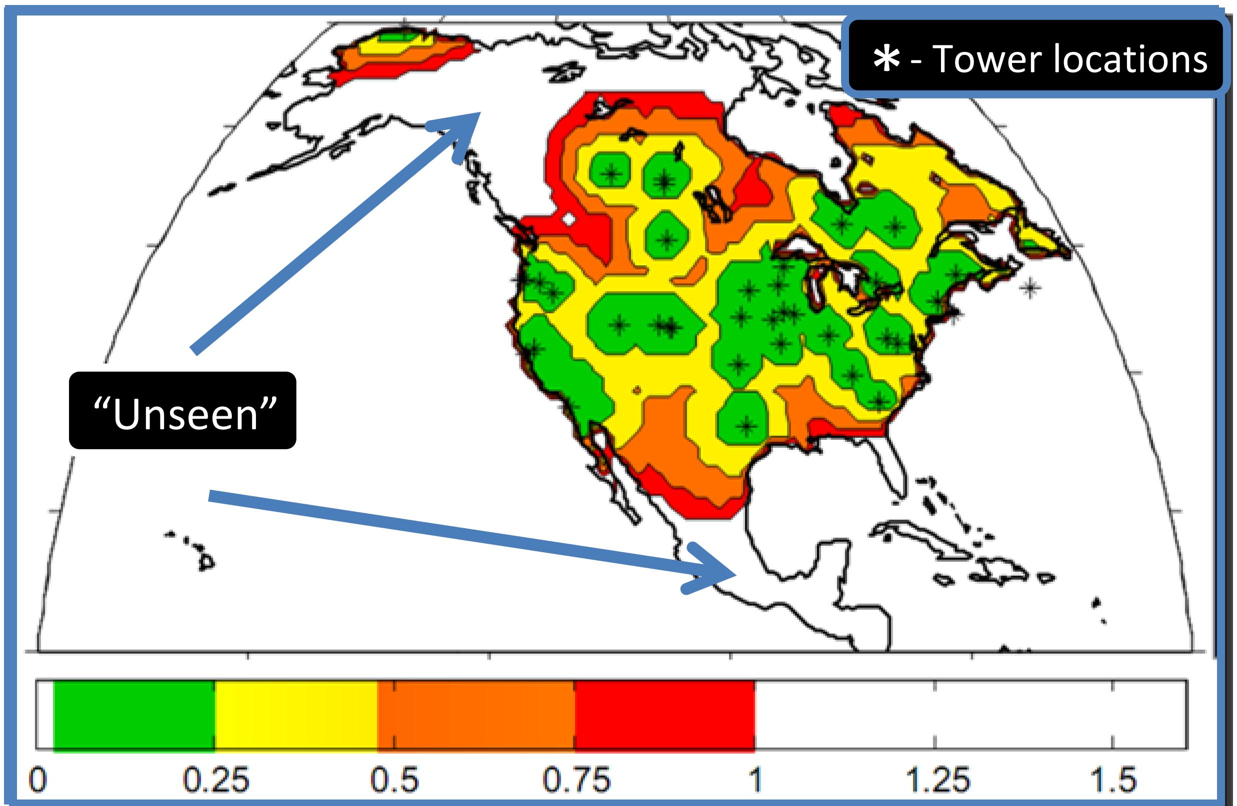
Ensures that a tower captures some fraction of atmospheric variability of each grid cell



CARNEGIE INSTITUTION FOR SCIENCE | GLOBAL ECOLOGY

STANFORD UNIVERSITY

Network Expansion 2004 – 2008



“Correlation Limit”

h/CL

2008 – 439 Towers

2004 – 139 Towers

CARNEGIE INSTITUTION FOR SCIENCE

GLOBAL ECOLOGY

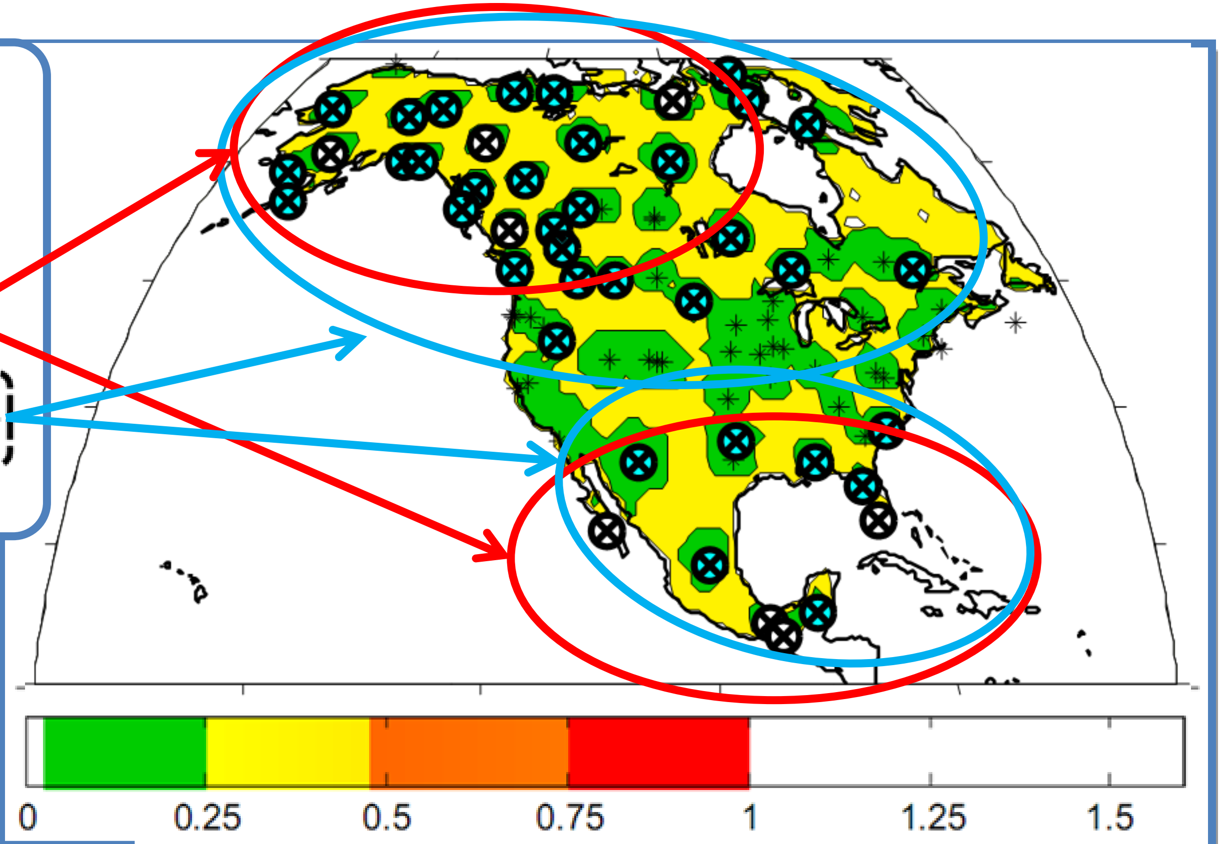
STANFORD UNIVERSITY

Hypothetical Network Expansion

Networks

1. 39 Towers [*]
2. 1CL = 39 + 8
3. ½ CL = 39 + 43

* - Real locations
- 1 CL Towers
- ½ CL Towers



h/CL

STANFORD UNIVERSITY

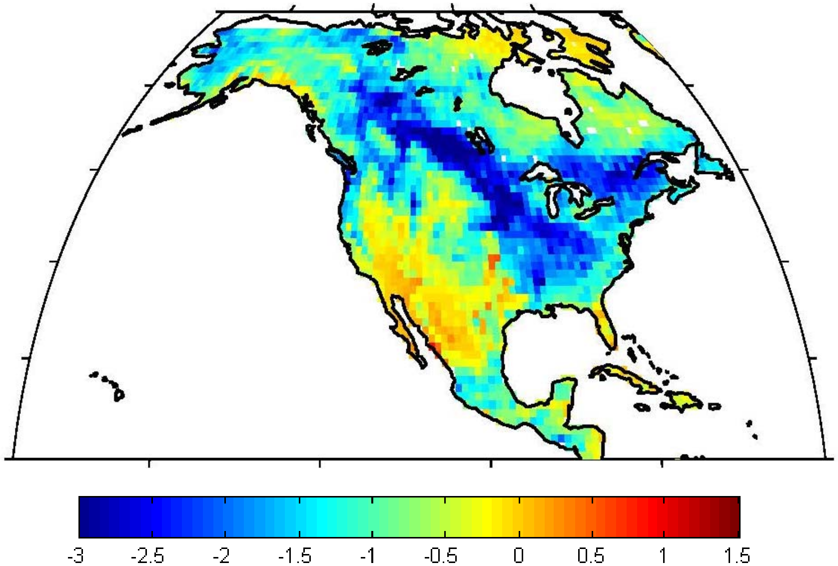
CARNEGIE INSTITUTION FOR SCIENCE

GLOBAL ECOLOGY

Validate Hypothetical Networks Using Pseudo Data Inversion

- Synthetic Data
  - Transported CASA fluxes forward to towers using STILT/WRF
- Domains:
  - Spatial: North America at 1°x1°
  - Temporal: 1 month, July at 3hrly
- Tested 3 Networks
  - Current 2008 network
  - 1CL Network (+ 8 towers)
  - ½ CL Network (+ 43 towers)

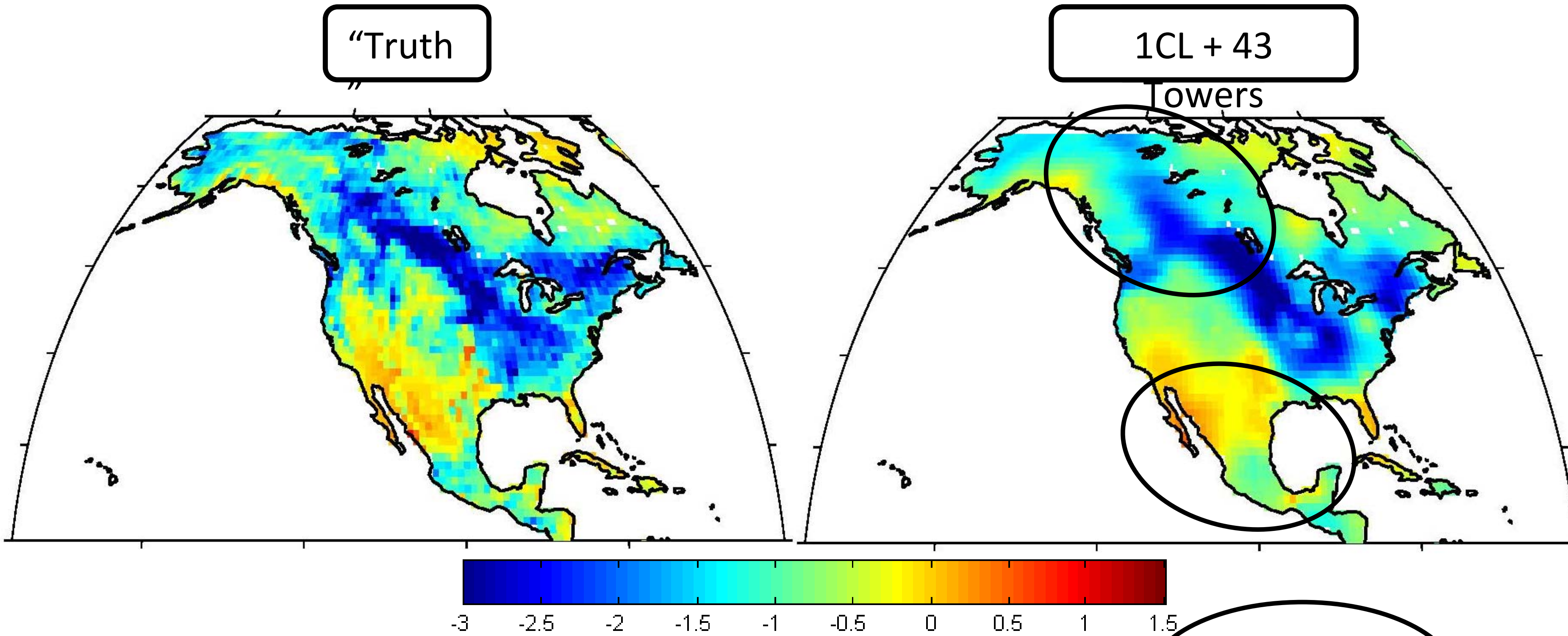
July 2004 CASA "truth" fluxes



STANFORD UNIVERSITY

CARNEGIE INSTITUTION FOR SCIENCE | GLOBAL ECOLOGY

Average Monthly Fluxes July 2008



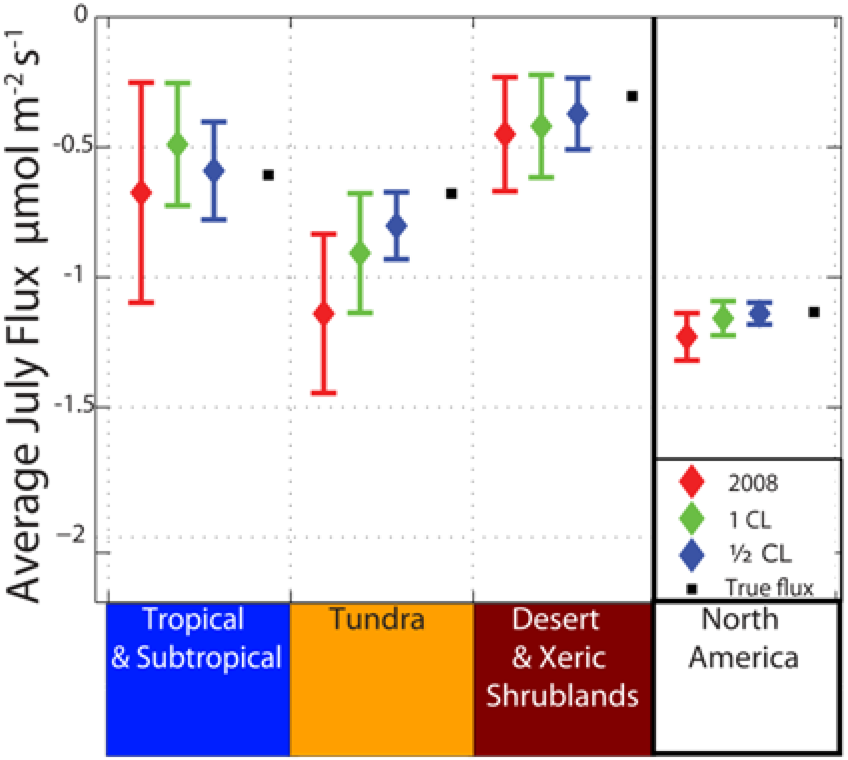
NA Average = -1.14 µmol/m²s
= -671 TgC

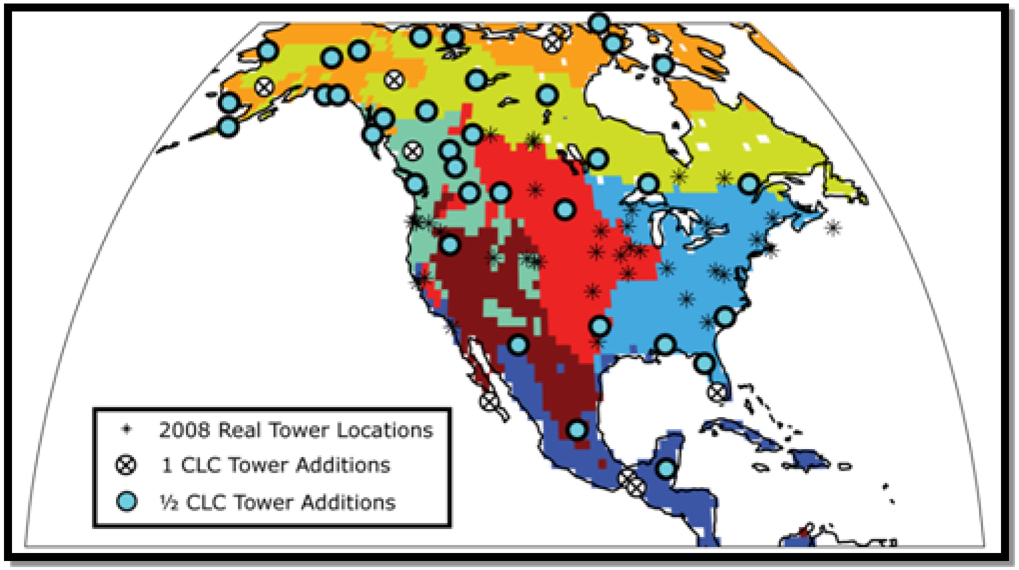
NA Average = -1.28 µmol/m²s
= -685 +/- 29 TgC

STANFORD UNIVERSITY

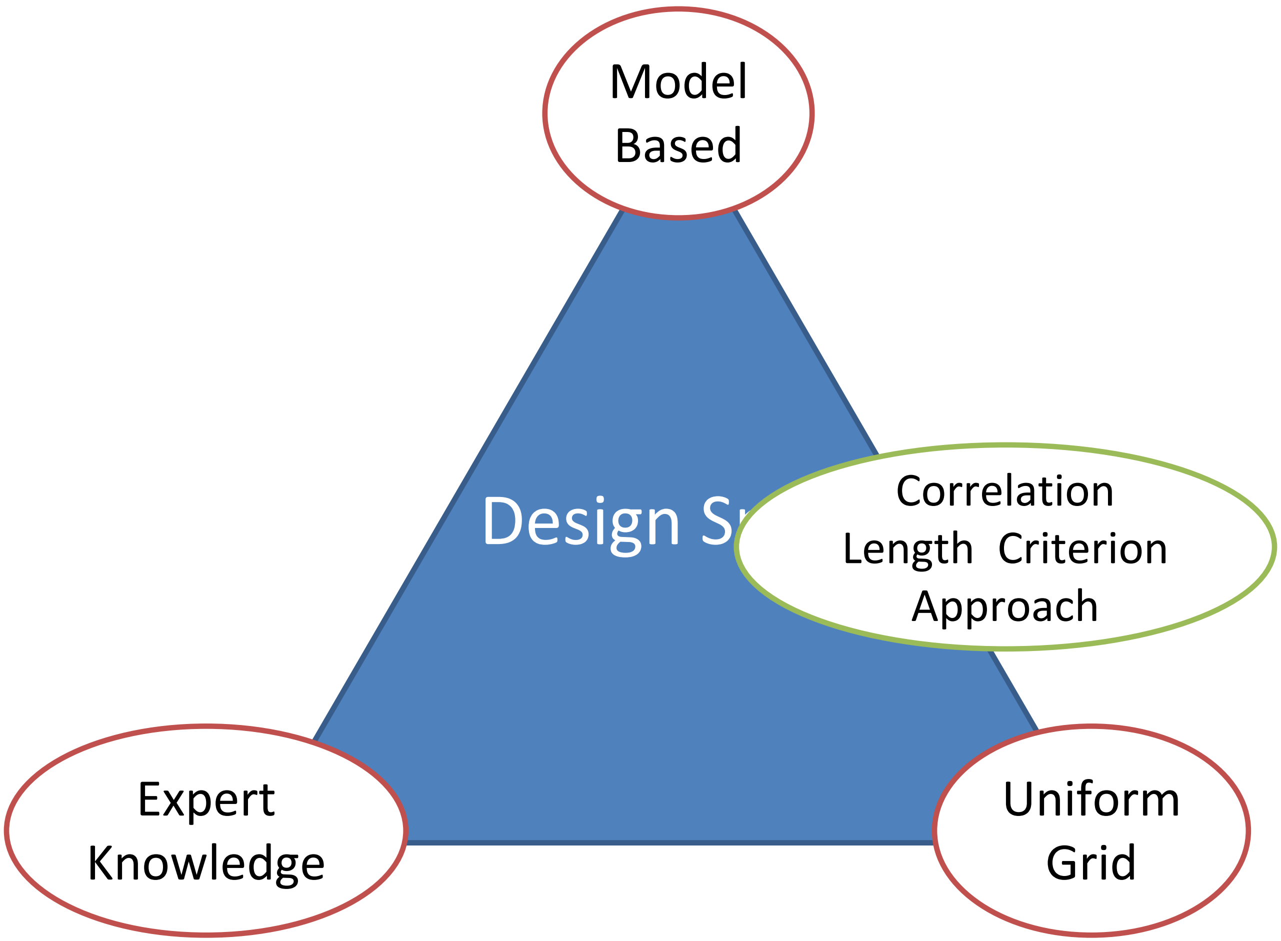
CARNEGIE INSTITUTION FOR SCIENCE | GLOBAL ECOLOGY

Pseudo Data Results Biome





Need to leverage all three…



CARNEGIE INSTITUTION FOR SCIENCE | GLOBAL ECOLOGY

STANFORD UNIVERSITY

Conclusions

- Correlation Length Criteria
  - Uses variability in atmospheric signal to inform network design
  - Provides an exploratory tool for CO_2 monitoring network design
  - Method to locate areas in need of monitoring stations – find gaps in current network