Network design for regional CO2 flux inversions

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CO2 atmospheric inversions from the MCI

Are the actual inverse systems able to give reasonable estimates, i.e. do we converge to similar numbers with different methods?

Are regional observational networks sufficient to constrain regional/local GHG balances?

What is the sensitivity of the retrieved flux distributions to atmospheric observations?

Are the assumptions made in the inverse system reasonable?

The Mid Continent Intensive Experiment

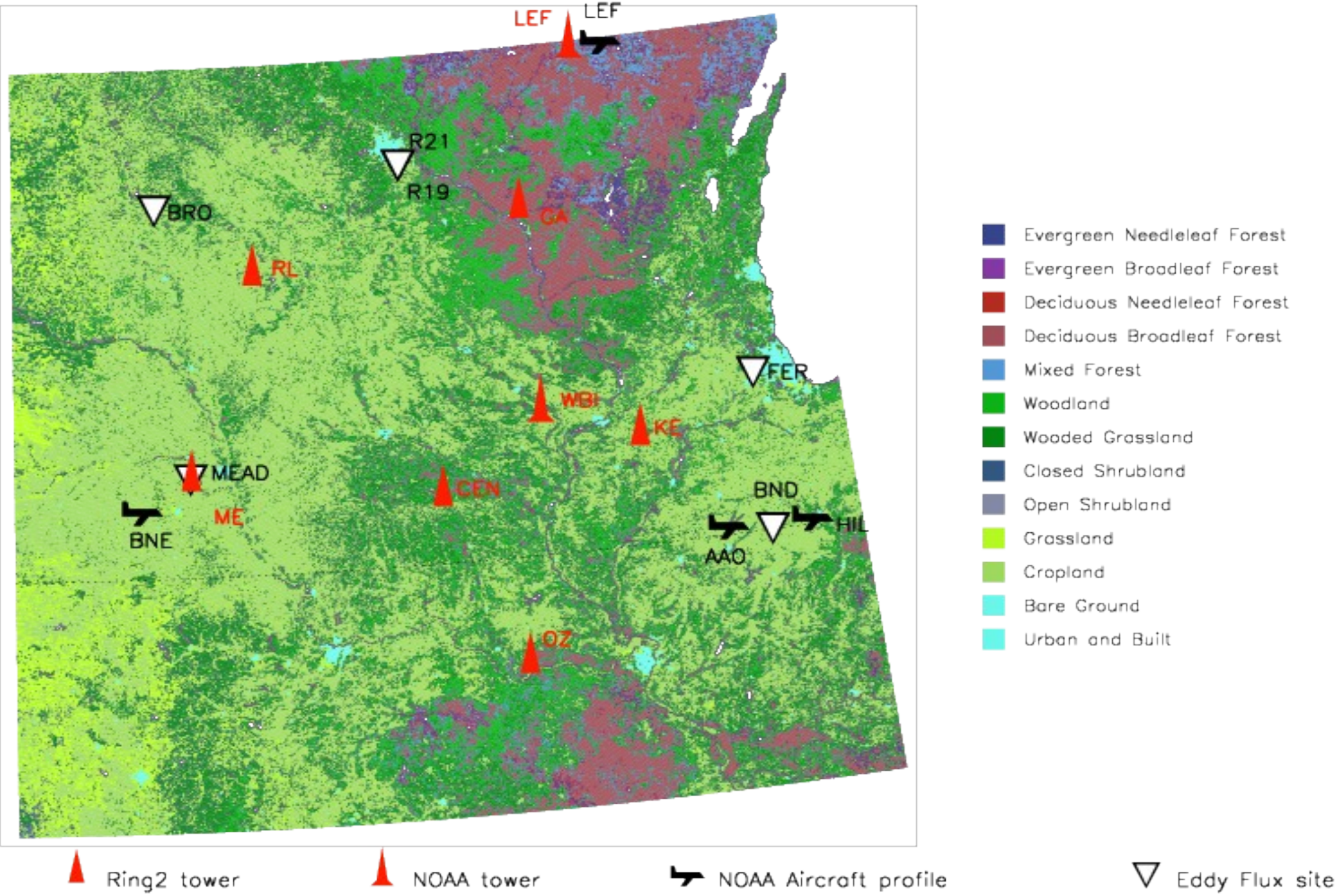
Agricultural area: well-documented bottom-up estimates (inventories using reported yield statistics, till practices, crop cover,...)

- Deployment of 5 additional in situ concentration measurements
- 2 Tall towers in the region from the NOAA surface network
- 1 calibrated flux tower (forested area) in Missouri

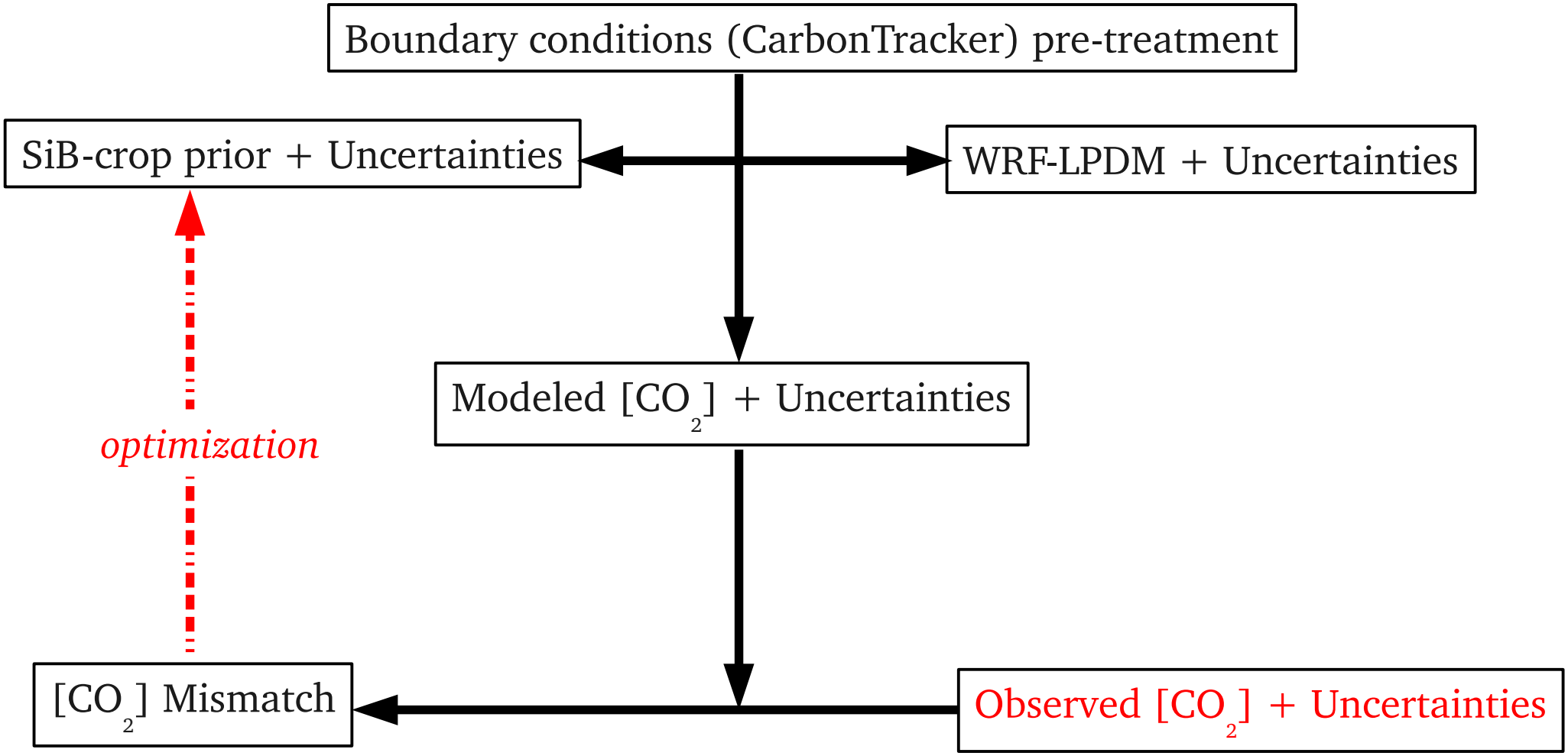
Can we reconcile agricultural inventories with atmospheric inversions?

Comparison of 3 inversion systems: CSU, NOAA-CT, PSU

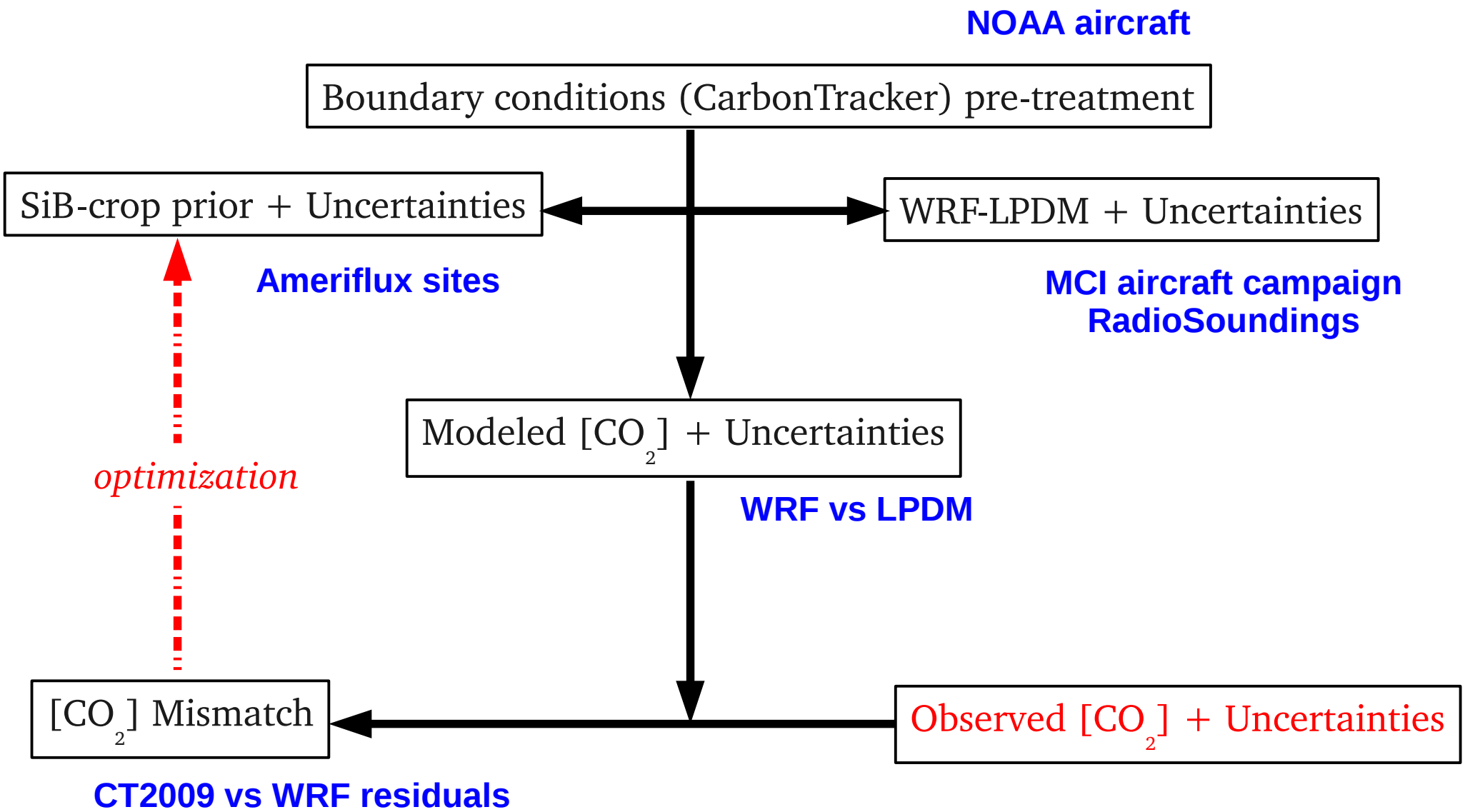
The Mid Continent Intensive Experiment



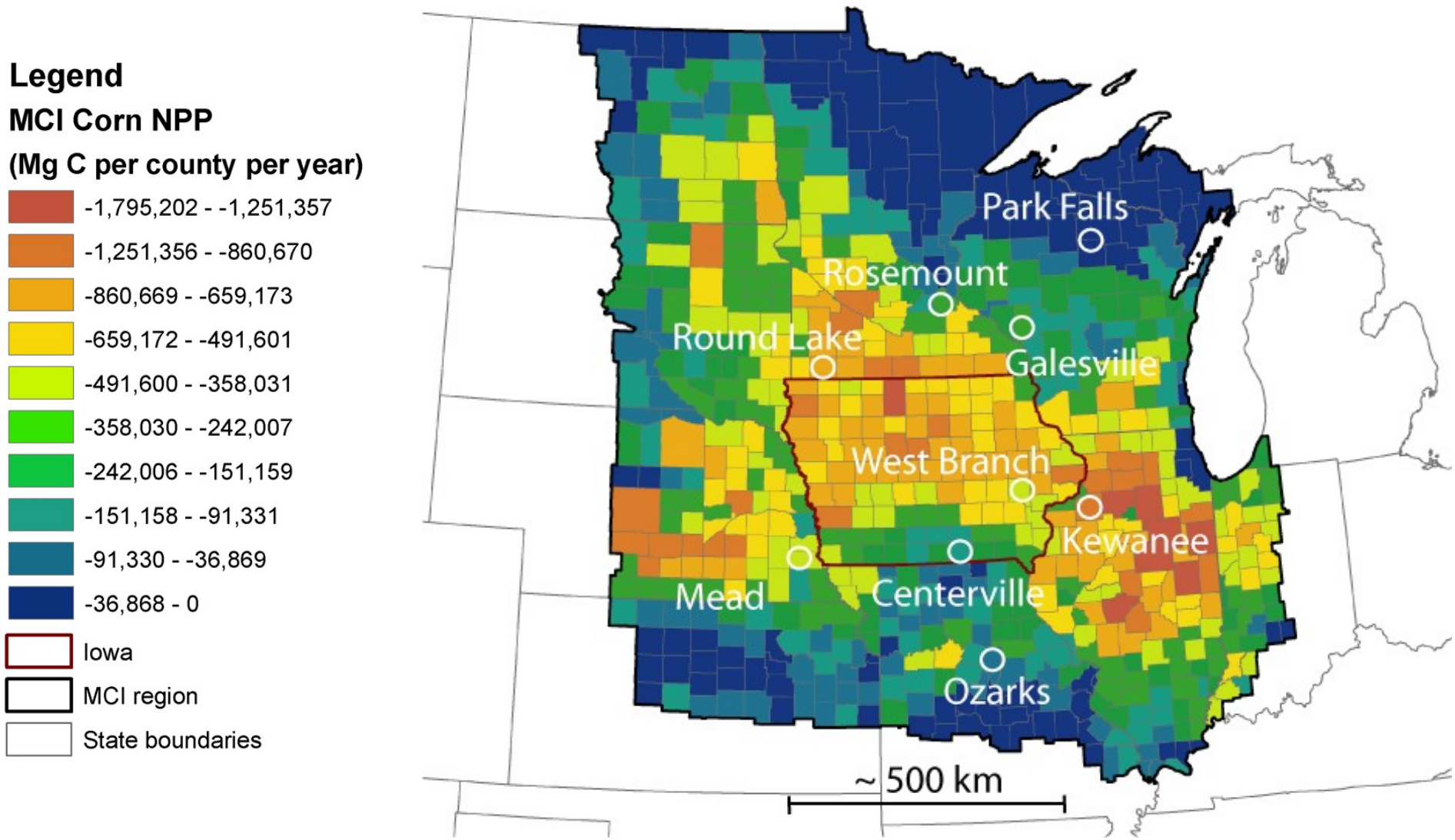
The inverse system framework



The inverse system framework



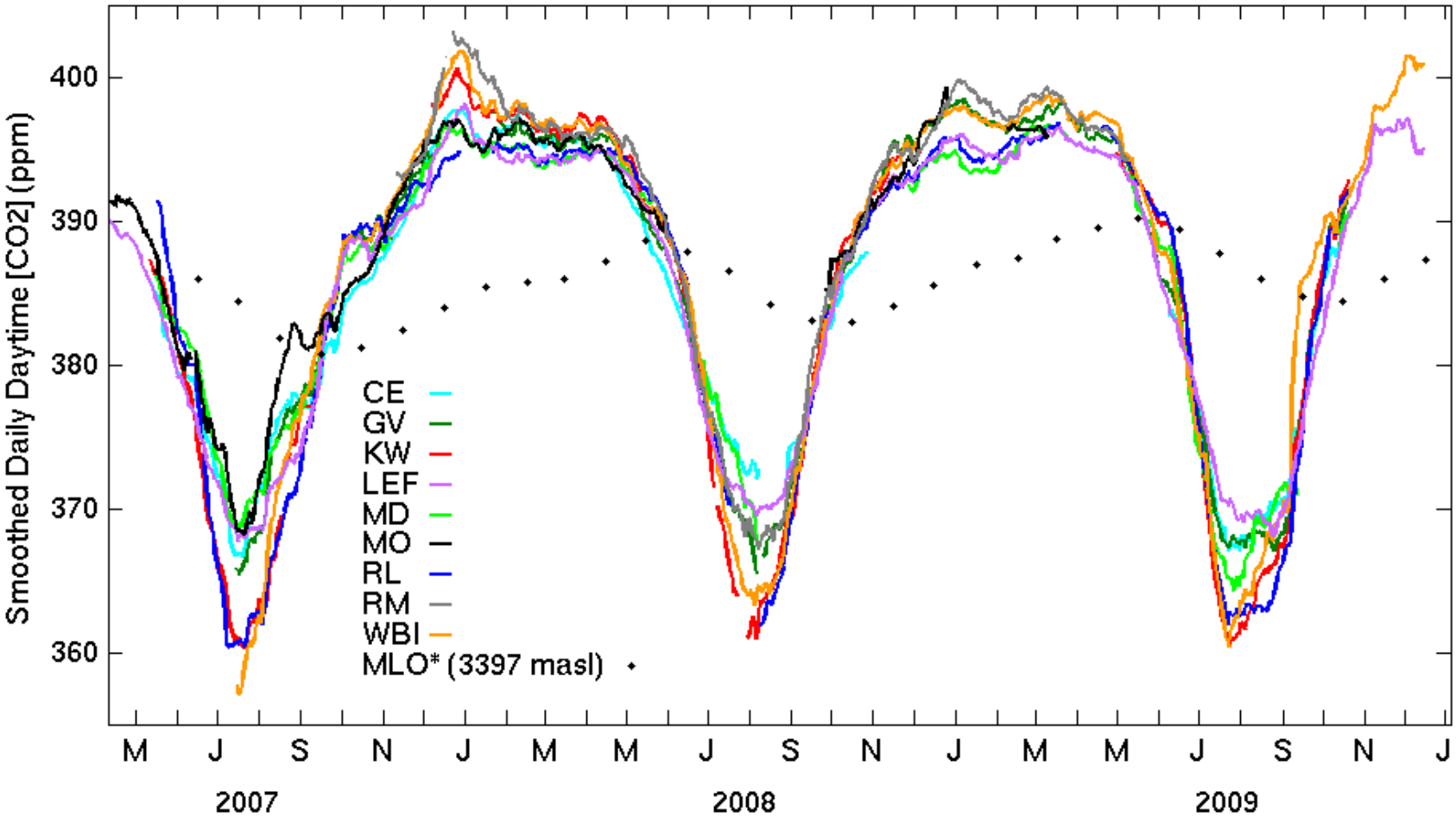
Corn productivity from agricultural inventories



CO_2 concentration towers over the corn NPP per county (in MgC/year) in the corn belt area

Courtesy of T. West

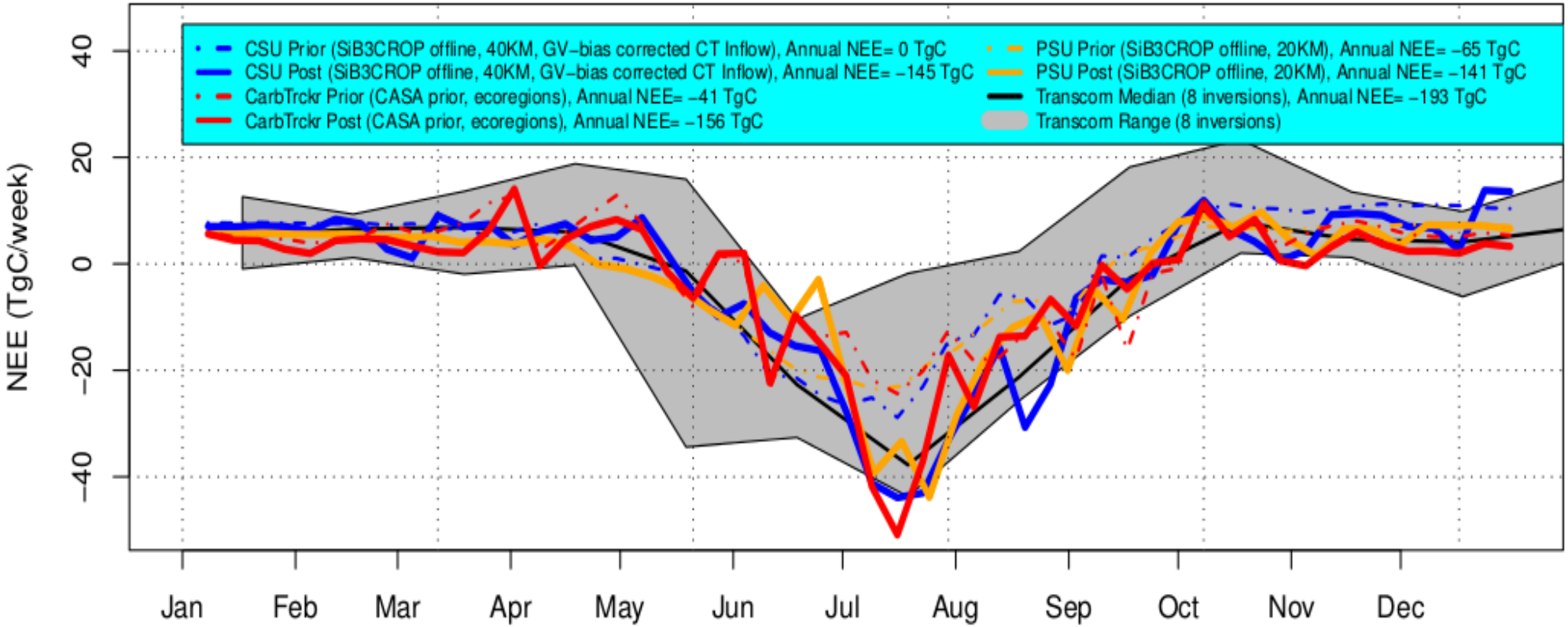
Atmospheric mixing ratios over the US upper Midwest



Atmospheric CO2 mixing ratios from the MCI tower network (31-day running mean) and from Mauna Loa (oceanic site) between June 2007 to December 2009

From Miles et al., 2012, JGR-B

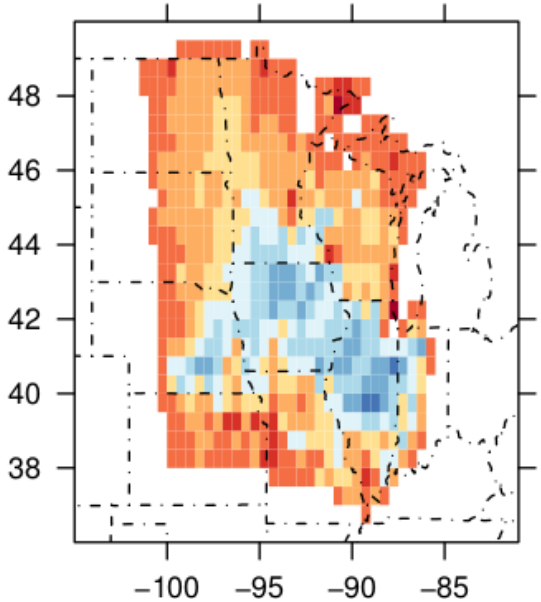
Regional carbon balance: weekly estimates

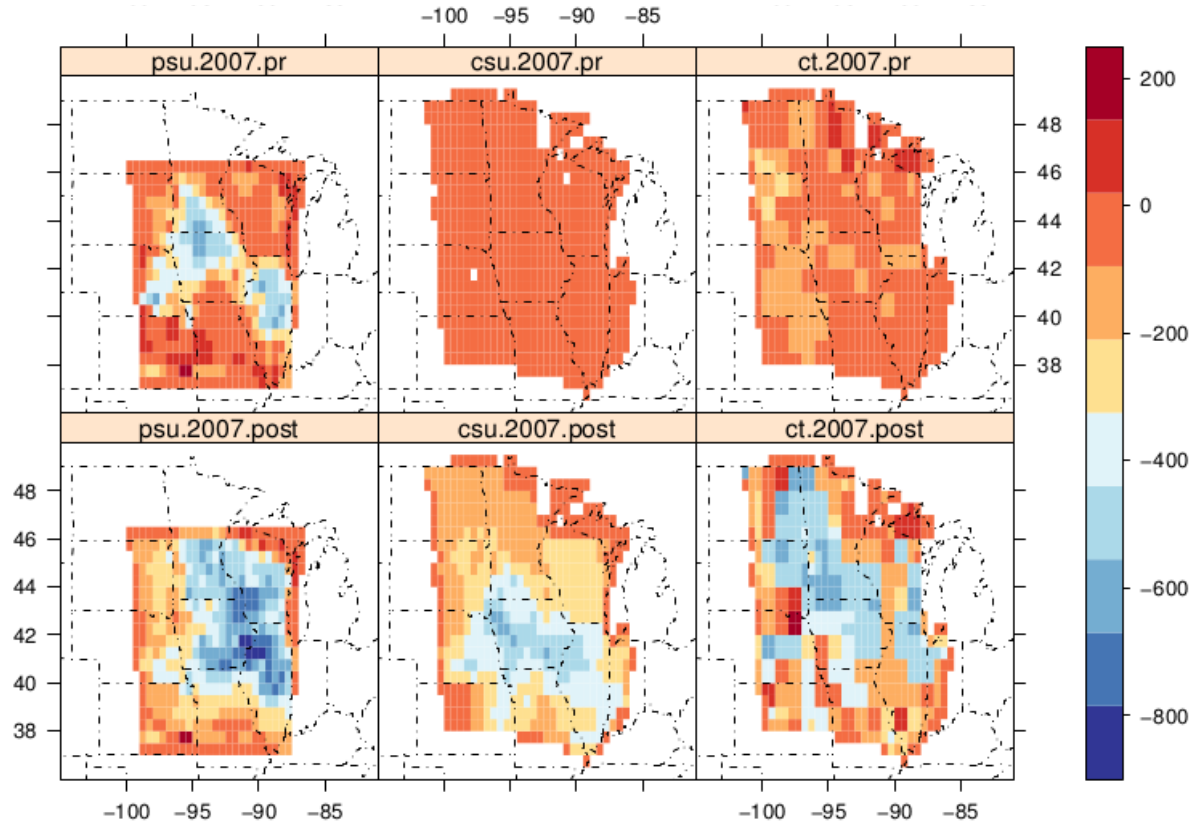


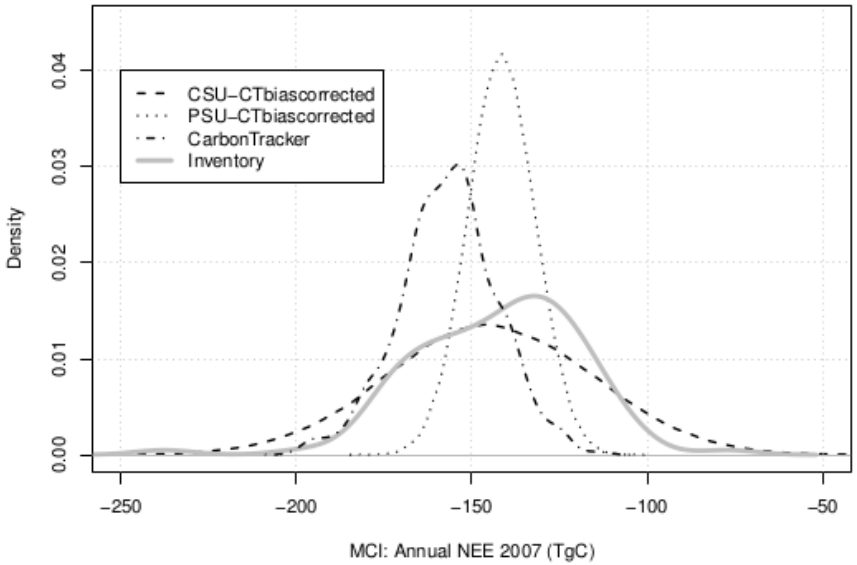
Net CO2 inverse flux comparison for 2007 (CSU, PSU, NOAA-CT) and Transcom models in gray, in TgC/week

From Schuh et al., submitted to GCB

Regional carbon balance: evaluation







Regional CO2 fluxes from agricultural inventories (left), PSU, CSU and NOAA-CT interpolated at 0.5° resolution (2007)

From Schuh et al., submitted to GCB

Network design: 4 sub-sampled networks

	prior	posterior (TR0)	NON-CORN (5 sites)	CORN (3 sites)	SPARSE (5 sites)	MIN (2 sites)
Regional carbon balance (TgC)	-110	-194	-179	-159	-185	-177
Total flux error (TgC)	35.5	32.1	32.7	33.1	32.5	33.6
Corn area averaged flux ($gC.m^{-2}$)	-335.7 ±98.6	-343.84 ±88.16	-280.62 ±92.39	-372.38 ±88.92	-328.9 ±89.56	-336.85 ±92.03
Out-of-corn averaged flux ($gC.m^{-2}$)	-27.3 ±36.13	-110.71 ±32.86	-114.49 ±32.87	-69.56 ±34.75	-108.23 ±33.26	-97.75 ±34.55

Carbon balance for the MCI domain using four different observation networks

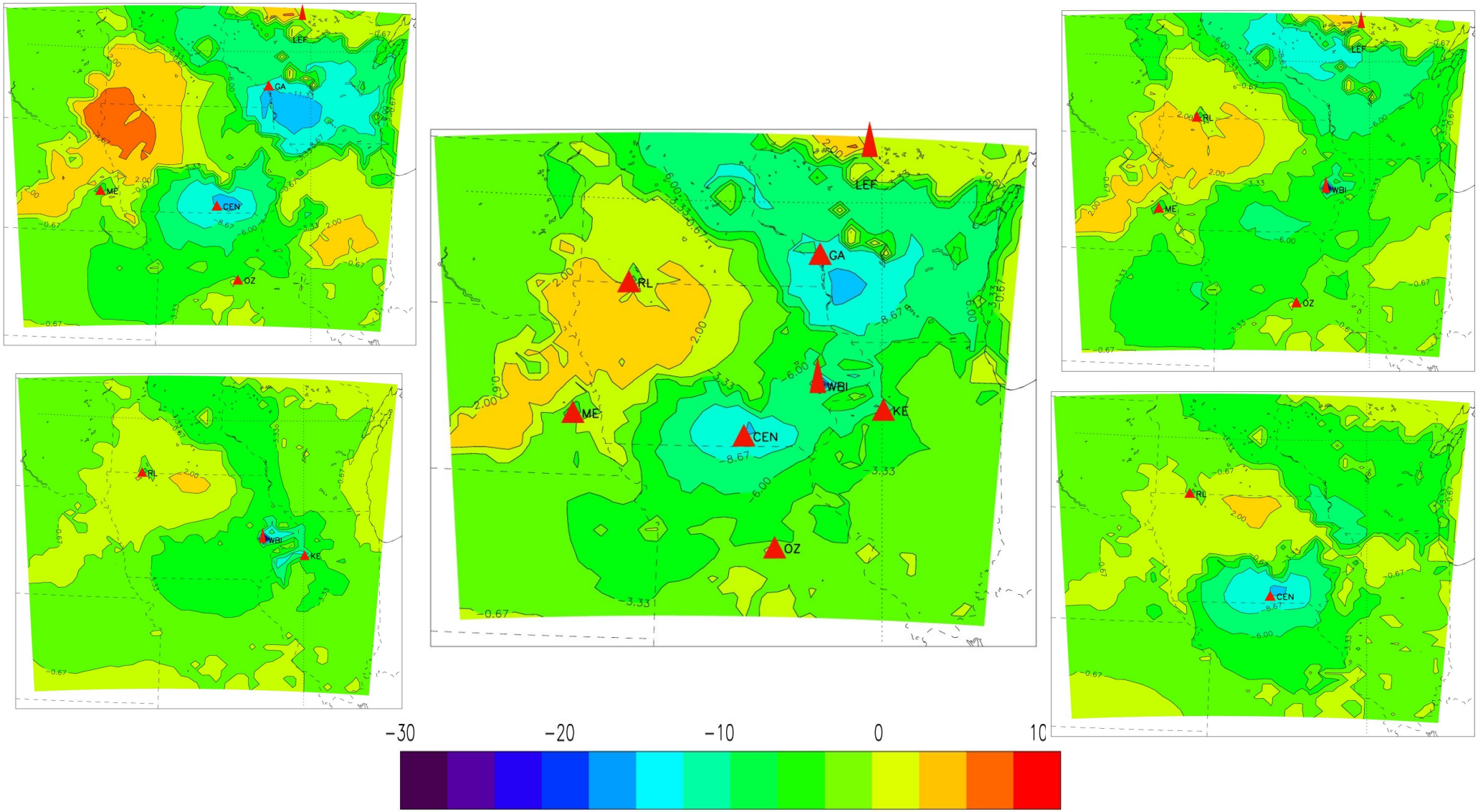
- Regional balance well-constrained in all cases

- Sites located in each major ecosystem are necessary

- Error reduction limited in all cases

From Lauvaux et al., accepted, Tellus B

Network design: 4 sub-sampled networks

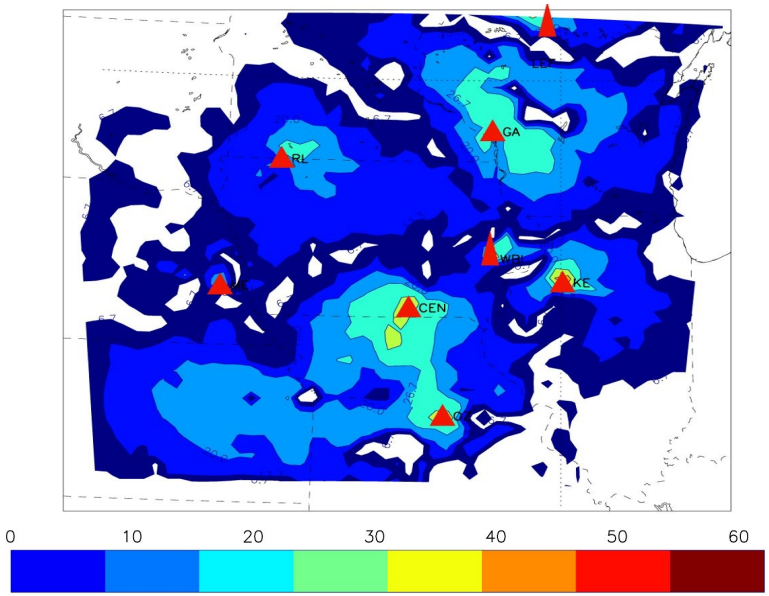


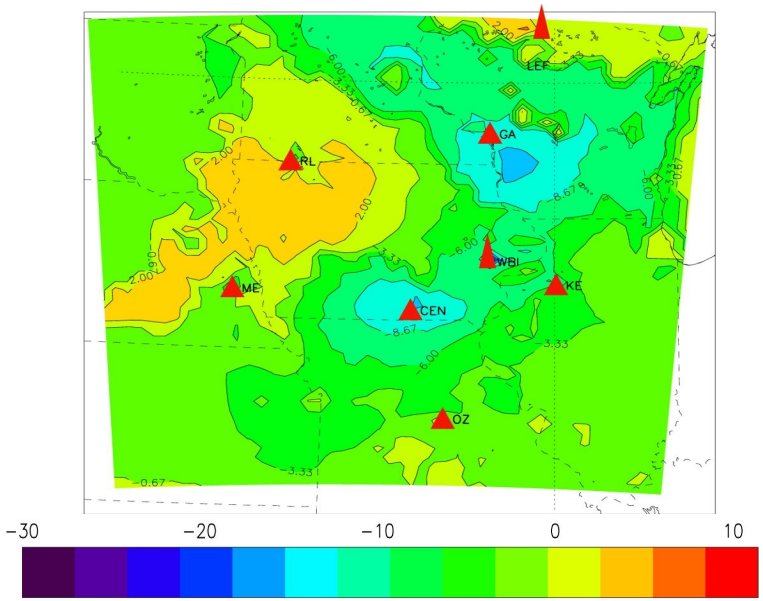
Flux correction using the entire tower network (in TgC.deg^{-2})

From Lauvaux et al., accepted, Tellus B

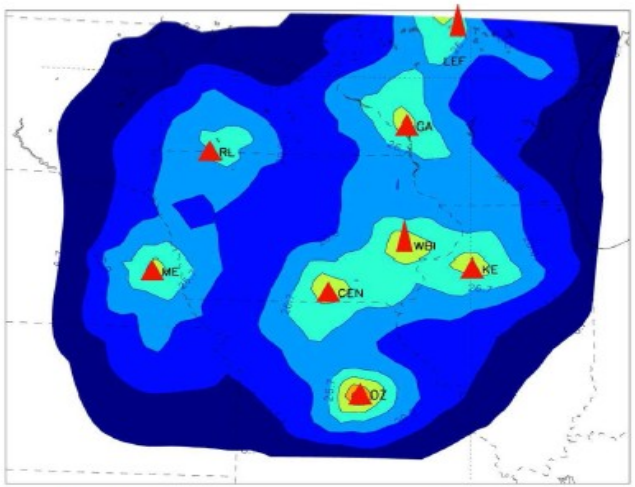
Sensitivity to prior flux error structures

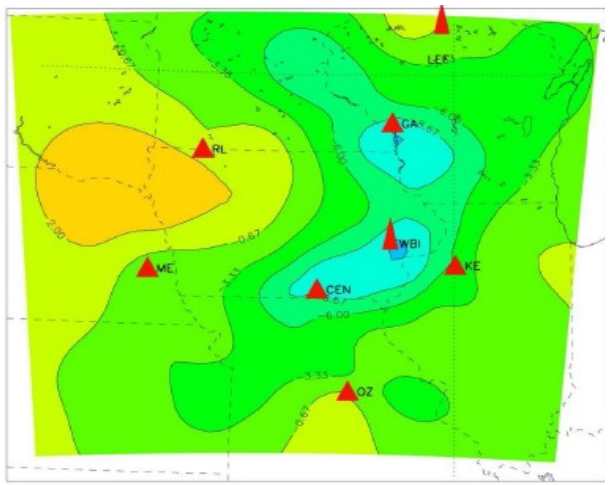
Correlation length
L=300km
And
Ecosystem-based





Correlation length
L=300km



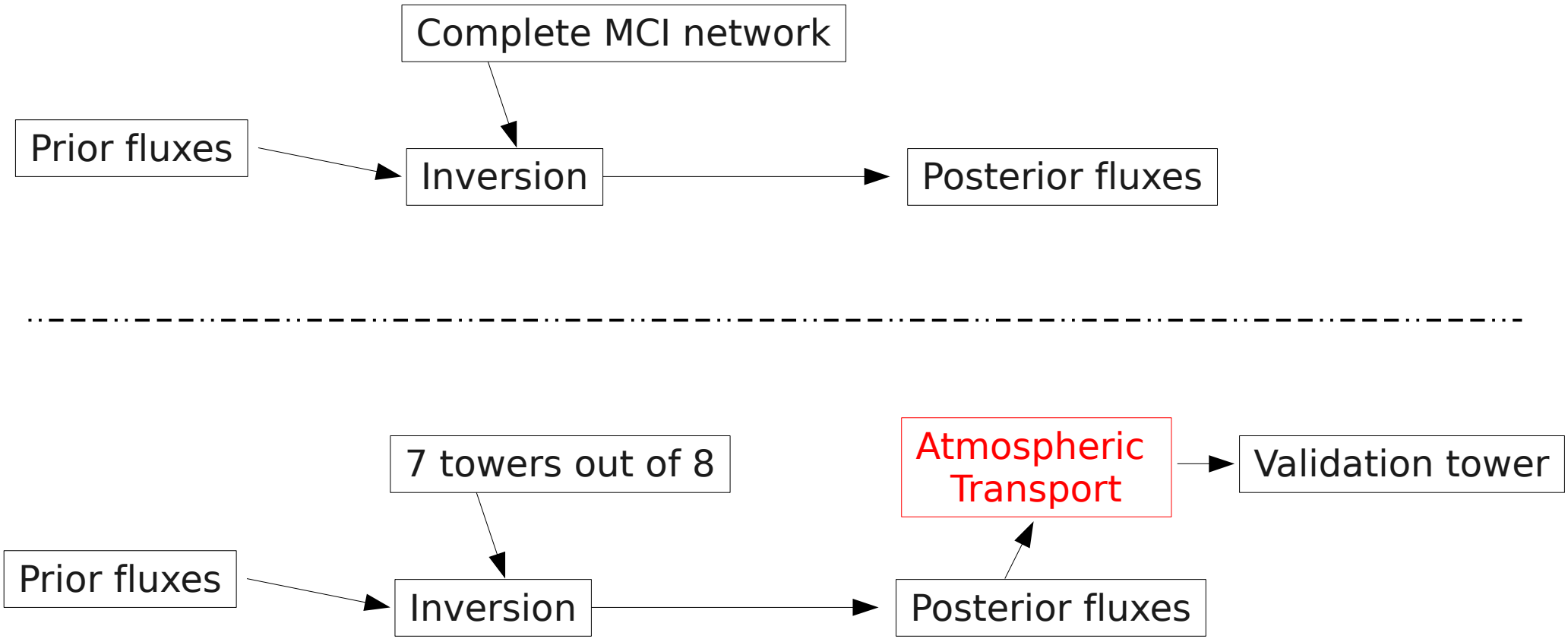


Error reduction (%)

Flux correction ($TgC.deg^{-2}$)

NB: Observational constraint with ecosystem-based correlation is 2 times smaller

Leave-One-Out Cross-Validation experiments



Objective: Verify the assumptions and the corrections after inversion

Leave-One-Out Cross-Validation experiments

		Centerville	Kewanee	Round Lake	Mead	Galesville	Missouri	WBI	LEF
A priori	Mean	-1.708	-1.248	-0.583	-1.025	-1.912	-0.578	-1.203	-0.167
	RMSE	7.641	7.169	7.284	6.858	7.970	7.884	8.341	6.786
A posteriori	Mean	-0.103	-0.028	-0.104	-0.074	-0.162	0.102	0.467	0.171
	RMSE	3.711	3.757	3.638	3.511	4.244	4.067	4.269	3.837
LOOCV	Mean	-1.045	-0.283	-0.613	-0.883	-1.371	-0.119	0.235	0.865
	RMSE	7.003	7.564	7.479	6.794	7.602	7.727	7.656	7.848

Model-data residuals at the validation towers in ppm using the entire MCI network
And for the different LOOCV experiments

- Both RMS and mean residuals decrease after inversion

- Mean residuals decrease in LOOCV experiments: correction of the regional bias

- RMS unchanged (or degraded) in LOOCV: small scale structures not corrected for

Spatial structures in the prior flux errors are incorrect

Regional inversions: conclusions

Inversions produce reasonable estimates over the region using 8 concentration towers

Uncertainties remain large from both methods (about 35TgC compared to the net flux of about -125TgC)

Each tower really helps constraining the local fluxes only (about 100-200km)

Regional balance is reasonable with only few towers over the domain

Assumptions in the prior flux errors are not correct:

- over-estimation of the correlation length?
- Temporal component in the structures?