The Influence of North American Carbon Flux Spatial Distribution on the Temporal Variability of Atmospheric Carbon Dioxide

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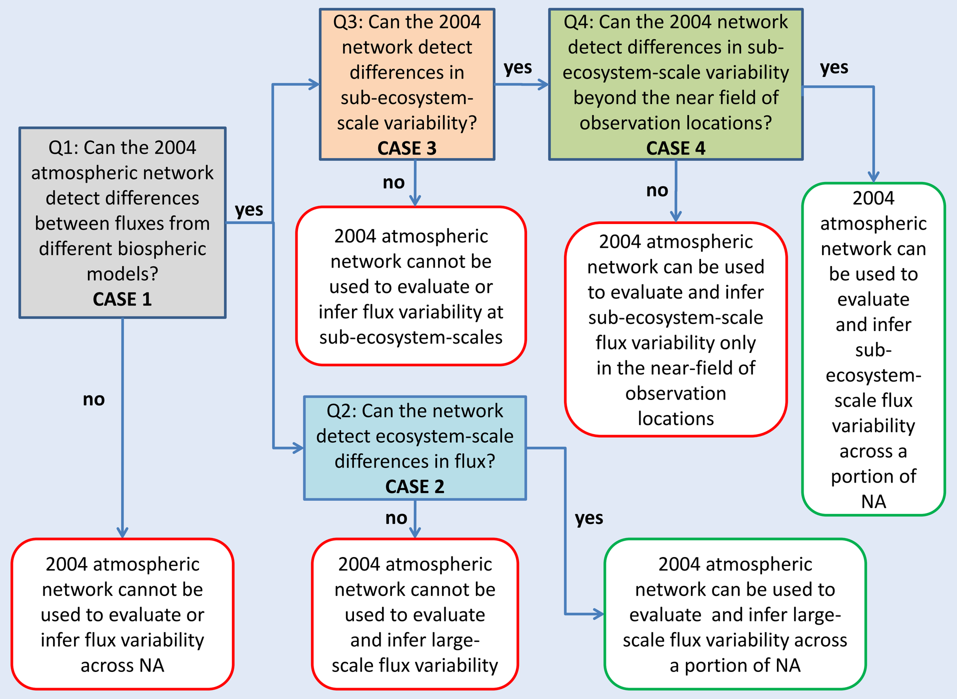
Introduction

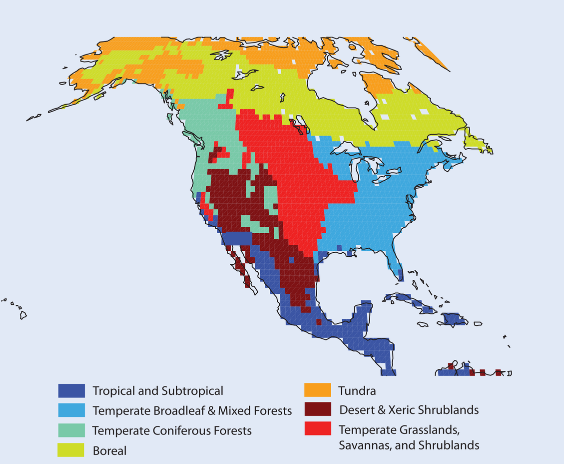
Inverse models predict fluxes that are quantitatively consistent with atmospheric measurements, but atmospheric mixing coupled with the sparseness of observations leave the problem ill-posed and frequently under-constrained. Depending on the scale of estimation, multiple sets of surface flux estimates may be consistent with a single record of observed CO_2 concentrations. To address this, the surface flux distributions of net ecosystem exchange (NEE) from four different biospheric models are used to evaluate the ability of the North American (NA) atmospheric CO_2 sampling network to detect grid-scale (i.e., 1° x 1°) and regional spatial variability in land-atmospheric carbon flux.

Approach

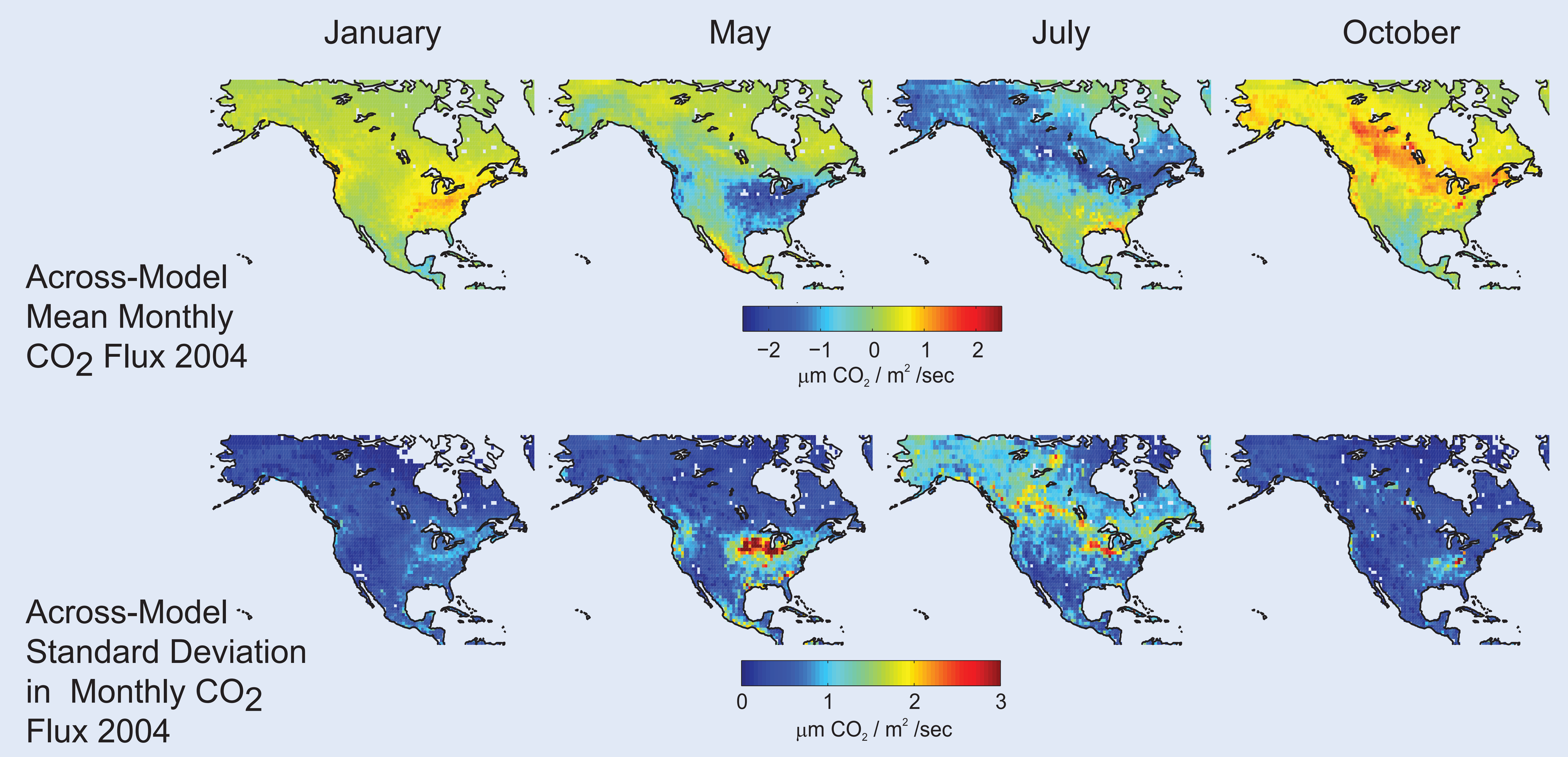


The questions to the left are addressed using four (4) case studies. These case studies involve manipulating the surface flux distribution from the models in such a way as to isolate the influence of sub-ecosystem-scale variability, ecosystem-scale variability, and the near-field of observation locations on CO_2 concentration.

Case	Description	Information Gained
1	Transport unique surface flux distributions from forward models to tower locations	Influence of surface flux magnitude and distribution on CO_2 concentration.
2	Apply a model-specific mean to all cells within a given ecosystem. Thus, there is a different flux magnitude by biome among models, however no sub-ecosystem-scale variability	Influence of ecosystem-scale differences in surface flux on CO_2 concentration.
3	Normalize surface flux distribution by biome. Thus, across models, there is the same net monthly flux by ecosystem. However, the distribution of fluxes within each biome is still unique to each model.	Influence of sub-ecosystem-scale, surface flux variability on CO_2 concentration.
4	If sub-ecosystem scale variability is detected in the atmospheric CO_2: apply an across-model mean to the near field of observation locations and preserve far field sub-ecosystem-scale variability	Influence of sub-ecosystem-scale variability beyond the near field of observation locations.



Biomes / ecoregions used for scaling fluxes. Based on work of Olson 2001

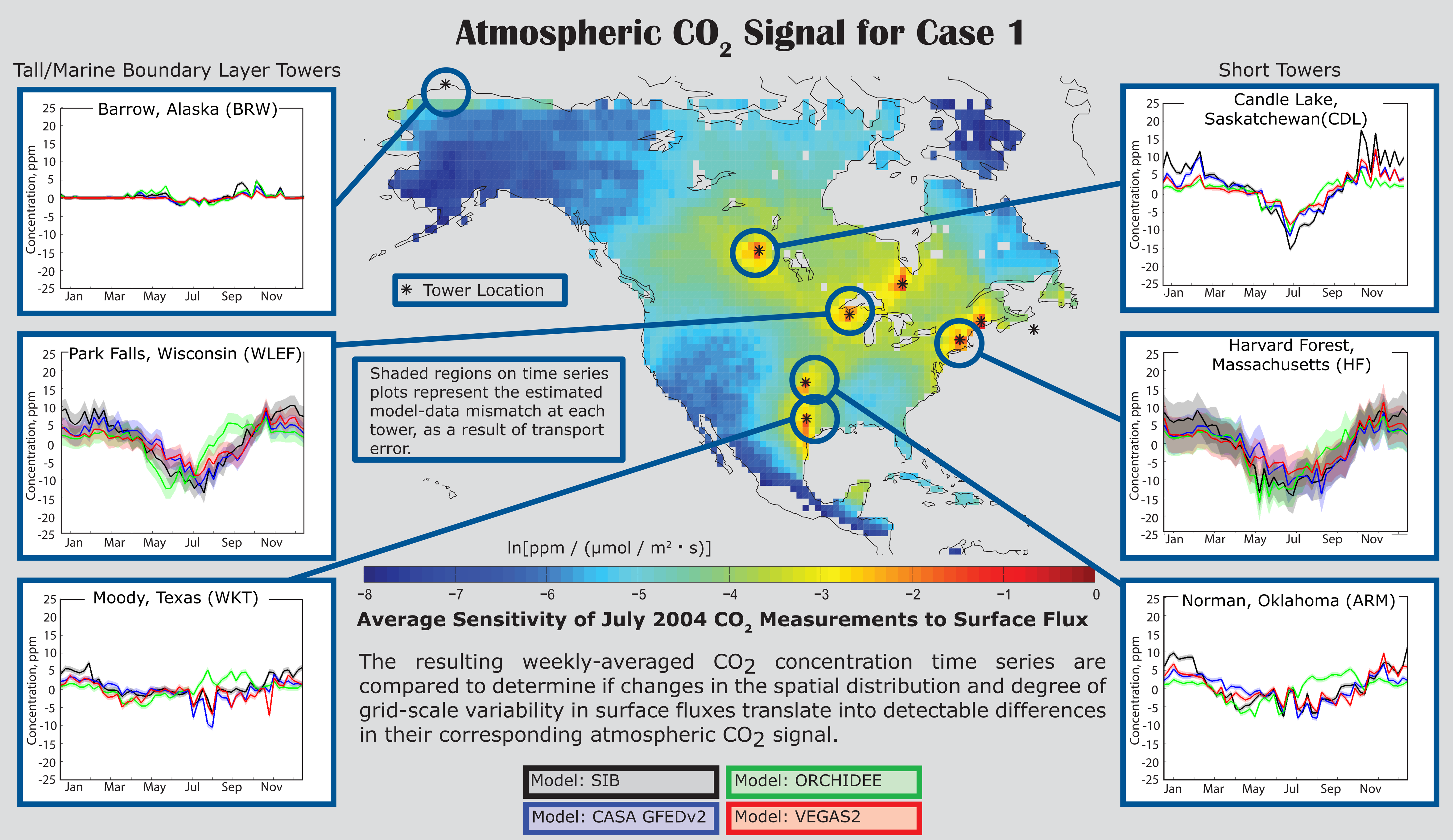


Variability in Surface Flux Distribution

The 3-hourly, 1° x 1° surface flux distribution predicted from SiB3.0 (Sellers et al. 1986; Baker et al. 2008), CASA GFEDv2 (Potter et al. 1993; Randerson et al. 1997; van der Werf et al. 2006), ORCHIDEE (Krinner et al. 2005), and VEGAS2 (Zeng et al. 2008) are used in conjunction with the WRF-STILT atmospheric transport model (Skamarock et al., 2005; Lin et al. 2003) to generate an atmospheric signal at continuous observation locations operating in 2004. Monthly VEGAS2 and CASA GFEDv2 fluxes were down-scaled to 3-hourly using the methods of Olsen and Randerson (2004). Pseudo-atmospheric concentrations were generated for all 24 hours at tall (>= ~ 400 m) and marine boundary layer towers, and for the afternoon only at shorter towers (<= ~100m).

Much of the variability in surface flux across models is located in the agricultural regions of the Great Plains and Midwest.

Atmospheric CO_2 Signal for Case 1



Average Sensitivity of July 2004 CO_2 Measurements to Surface Flux

The resulting weekly-averaged CO_2 concentration time series are compared to determine if changes in the spatial distribution and degree of grid-scale variability in surface fluxes translate into detectable differences in their corresponding atmospheric CO_2 signal.

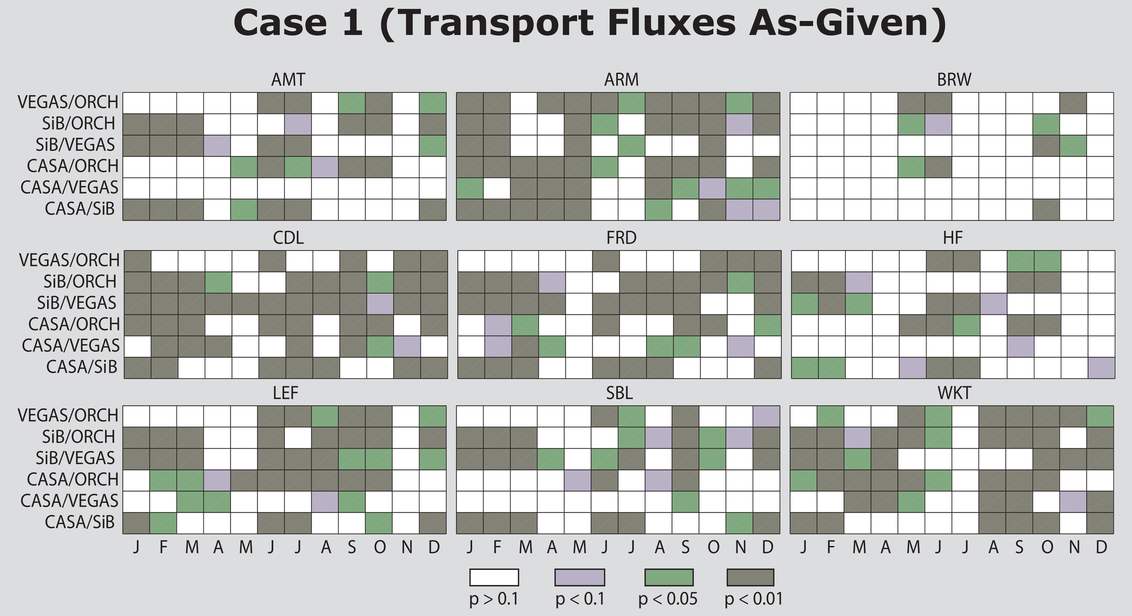
Model: SIB | Model: ORCHIDEE | Model: CASA GFEDv2 | Model: VEGAS2

Significance Testing

Two-sample, two-tailed z-tests using tower-specific model-data mismatch error derived from real data and estimated using Restricted Maximum Likelihood (RML) (Gourdji et al. In Review), is used to assess the significance of observed differences among CO_2 time series. The p-value for cases 1 through 3 and each model combination are shown below. The lower the p-value, the greater the significance of the difference between resultant CO_2 signals. If no significant differences are observed, then inverse modeling approaches may be unable to infer a unique surface flux distribution at the grid-scale (i.e., 1° x 1°) or even at coarser resolutions, given the current sampling network.

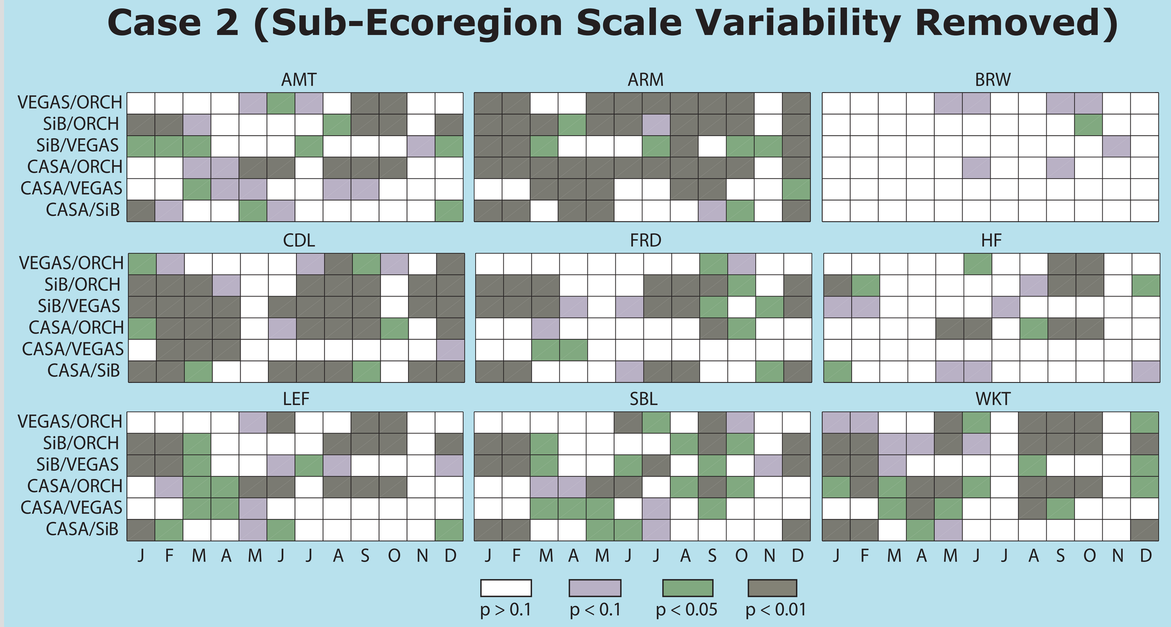
Tower Name	Location	Height (m)
AMT	Argyle, Maine	107
ARM	Norman, Oklahoma	60
BRW	Barrow, Alaska	10
CDL	Candle Lake, Saskatchewan	30
FRD	Fraserdale, Ontario	40
HF	Petersham, Massachusetts	30
LEF	Park Falls, Wisconsin	396
SBL	Sable Island, Nova Scotia	25
WKT	Moody, Texas	457

Case 1 (Transport Fluxes As-Given)



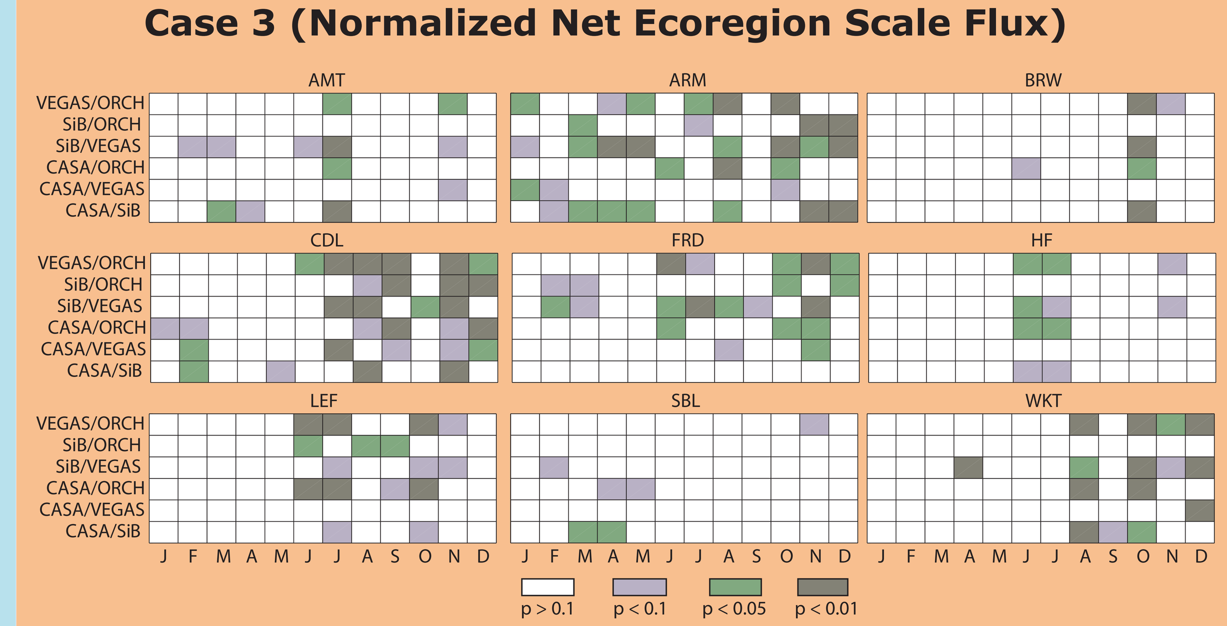
At most towers, and during most times of the year, there is a significant difference in transported CO_2 signal among the originating surface flux distributions. These differences could be due to either the individual or combined effect of surface flux magnitude and distribution.

Case 2 (Sub-Ecoregion Scale Variability Removed)



Much of the differences observed in Case 1 appear to be a result of large, ecosystem scale variability in flux magnitude. Or rather, the impact of differences in the net magnitude of flux from each model rather than the distribution of surface fluxes within ecoregions.

Case 3 (Normalized Net Ecoregion Scale Flux)



The difference between resultant CO_2 signals among models becomes much less significant when the influence of sub-ecosystem scale variability in surface flux is isolated.

Conclusions

In general, distinct atmospheric CO_2 signals resulting from the different biospheric models appear to be attributable to large scale variability in flux magnitude, rather than differences in sub-ecosystem flux distributions. Towers with larger measurement footprints, and those located in more dynamic flux regions, however, do appear to be sensitive to sub-ecosystem-scale variability both in the near and far field. Highlighting those regions where variation in flux distribution do not translate into significant differences in atmospheric CO_2 signals provides information about the uniqueness of flux estimations from inversions. Such information will help inform inverse modeling, and improve our understanding of land-atmosphere carbon exchange.

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