Frontal Passage Effects on PCTM CO_2 Concentration in Continental North America

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Introduction

- CO_2 emissions, primarily from fossil fuel burning, are the largest anthropogenic climate driver and will be for the coming decades to centuries (IPCC, 2001)
- If climate models are to accurately project future CO_2 levels, there is a need to more fully understand what controls the highly variable atmospheric CO_2 concentrations (Kawa, 2004)
- As more high frequency CO_2 observations become available, there are more opportunities to analyze, verify, and improve our current understanding of the sources and sinks of CO_2

Ring 2: Observations

Figure 1. Map of ring 2 sites in the Upper Mississippi Valley

- Five towers located across the Midwest taking CO_2 measurements from Spring 2007 to Summer 2008
- Part of the Mid-Continental Intensive study (MCI)
- Goal is to seek convergence between top-down (tower-based) and bottom-up (direct modeling-based) ecological estimates of regional flux

Site	Date installed	Latitude	Longitude	Sampling Heights
Kewanee, IL	26-Apr-07	41.27 N	89.97 W	30/140 m AGL
Centerville, IA	27-Apr-07	40.79 N	92.87 W	30/110 m AGL
Mead, NE	30-Apr-07	41.13 N	96.45 W	30/120 m AGL
Round Lake, MN	1-May-07	43.52 N	95.41 W	30/110 m AGL
Galesville, WI	29-Jun-07	44.09 N	91.33 W	30/140 m AGL

Table 1. List of tower locations with data collection levels. On the right is the Mead, NE tower.

PCTM: Model

- Parameterized Chemistry Transport Model
- CO_2 fluxes input from:
  - Simple Biosphere Model (SiB)
  - Ocean models
  - Known fossil fuel (FF) emissions
- Goddard Earth Observation System 5.1.0 reanalysis data set used to drive transport in PCTM

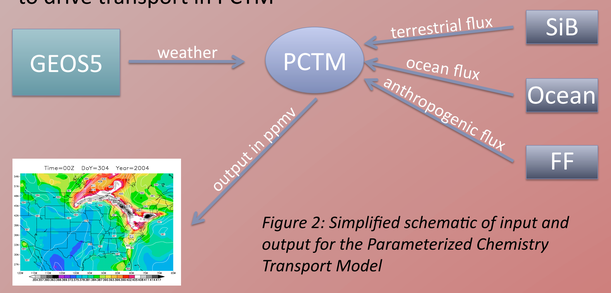


Figure 2: Simplified schematic of input and output for the Parameterized Chemistry Transport Model

Conclusions

- Diurnal cycle well-represented temporally, while maxima and minima need improvement
- Source of ambient air affects agreement between PCTM and observations
  - When air travels over agriculturally dominated land, CO_2 drawdown from crops is underestimated
- PCTM may overestimate nocturnal vertical mixing leading to lower than observed CO_2 readings near ground level
- Close spatial, high frequency CO_2 measurements are extremely informative and allow for verification of model processes that would otherwise be impossible
  - Call for more studies similar to the MCI in other locations across the continent and across the world

Case Study: July 15th – 25th 2007

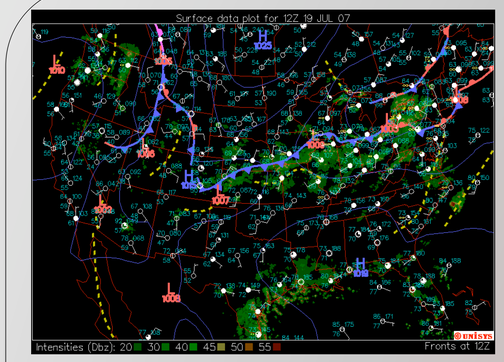


Figure 3. Unisys weather surface map from 12Z (7 AM CST) on July 19th 2007. Features of interest include: the cold front moving through the Ring 2 region, and the station wind barbs before and after the front, which show a distinct wind shift.

- On July 19th, a relatively well-defined cold front passed through the Ring 2 region
- PCTM modeled CO_2 levels were close to Ring 2 observation daytime minima prior to frontal passage, however, after the cold front passed, PCTM overestimated CO_2 minima at multiple sites by as much as 20-25 ppmv
- Nocturnal maxima were often underestimated by PCTM, especially prior to frontal passage
- Onset of increased drawdown can be seen to move in time and space by looking at multiple tower time series due to the towers' close proximity and availability of high frequency measurements

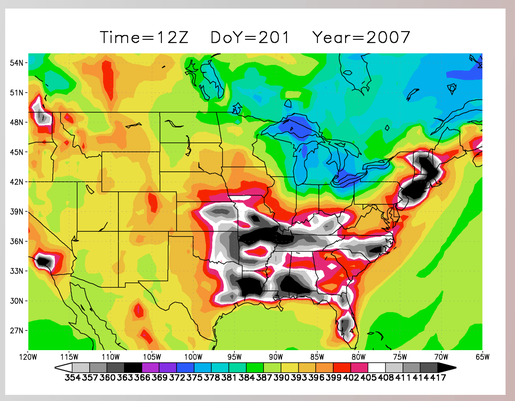
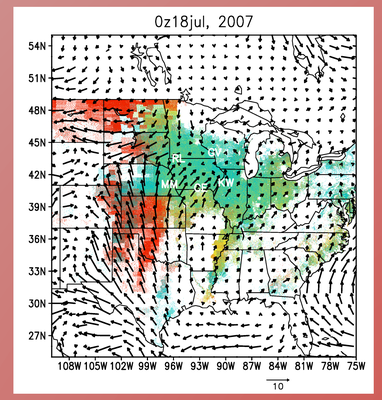
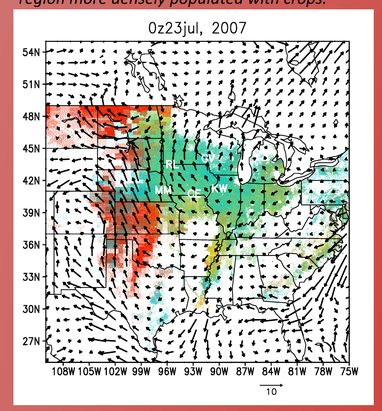


Figure 4. Map of 100m PCTM CO_2 concentrations in ppmv for 12Z (7AM CST) on July 19th 2007. Summer agriculture obscures well-defined CO_2 front, however, many anthropogenic sources of CO_2 are easily distinguishable.

Figure 5. Time series of Ring 2 sites' measured CO_2 concentrations compared to PCTM output from July 15th – July 25th 2007. Ring 2 observations are taken from the higher of the two sampling heights for each tower. PCTM values are for the 100m level. Wind directions in degrees with 0° (360°) corresponding to northerly flow.



Figures 6 & 7. Midwest region agriculture map with GEOS5 winds superimposed prior to and following frontal passage. Colors correspond to crop type: Corn=blue, Soy=yellow, Wheat=red. Notice the difference in source region for the air flowing past the Ring 2 sites. After the front has passed on July 23rd, ambient air comes from a region more densely populated with crops.



Future Research

- Statistically represent findings to get a more quantitative understanding of where PCTM needs improvements
- Increase PCTM grid resolution and investigate how output changes
- Study the effects of adding a crop representation to SiB input and compare findings to this study

Figure 8. Accounting for agricultural crops is likely to improve future modeling of CO_2

References

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Kawa, S. R., D. J. Erickson III, S. Pawson, and Z. Zhu (2004), Global CO_2 transport simulations using meteorological data from the NASA data assimilation system, J. *Geophys. Res.*, **109**. D18312.

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