REGIONAL TRANSPORT ANALYSIS FOR CARBON CYCLE INVERSIONS

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NOAA Project Goal: Climate

Key Words: Carbon cycle, greenhouse gases, terrestrial CO_2 sinks

1. Long-term Research Objectives and Specific Plans to Achieve Them:

We expect to achieve the following objectives:

1) Produce a library of influence functions based on mesoscale high-frequency RUC analyses
2) Evaluate the RUC-based influence functions
3) Store and disseminate the output to other researchers for use in carbon cycle inversions.

We will achieve objective 1 by adapting the CSU Lagrangian Particle Dispersion Model (LPDM) to read meteorological fields from the RUC analyses. We will run the model backward in time from each continuous CO_2 observing tower site in the US for 5 days prior to each observing time. Then we will integrate surface and lateral-boundary particle locations at each previous hour to quantify the influence of surface fluxes in each upstream grid cell at each previous hour on measured CO_2 concentrations at the towers. This step is a lot of work, involving use of the Jet supercomputer for simulations and many terabytes of model output.

We plan to achieve objective 2 by propagating estimated surface fluxes forward in time using the influence functions to reconstruct timeseries of measured concentrations at each tower, and comparing to the observations.

Objective 3 involves making choices about data formatting and compression, and about what products are likely to be most useful to the community of inverse modelers. We have opted for a strategy of saving particle positions rather than influence functions, and generating influence functions “on the fly” in response to user requests through a web interface. This will save enormous amounts of disk space and be flexible enough to allow different users to combine influence functions with their own models of fluxes or space/time covariance.

2. Research Accomplishments/Highlights:

Working closely with colleagues at NOAA, we have obtained test data sets of hourly meteorological analyses generated by the Rapid Update Cycle (RUC) assimilation system on the 13-km grid over North America. We developed and tested subsetting software to extract only the transport fields from these analyses, and adapted the CSU Lagrangian Particle Dispersion Model (LPDM) to read the 13-km RUC fields. We have now verified that we can calculate adjoint, or backward-in-time, transport influence functions for specified sampling stations to quantify the sensitivity of each observation at NOAA sampling towers to unit surface fluxes of CO_2 or other trace gases at all points upstream in the RUC domain.

For each data point, i.e., tower location and sampling time (1 hour or longer), a separate influence function is derived which depends on spatial coordinates of source areas as well as release time of fluxes from the surface. Therefore, the RUC-LPDM system is generating a huge amount of data, which would be impractical to store and disseminate at full resolution for a year.

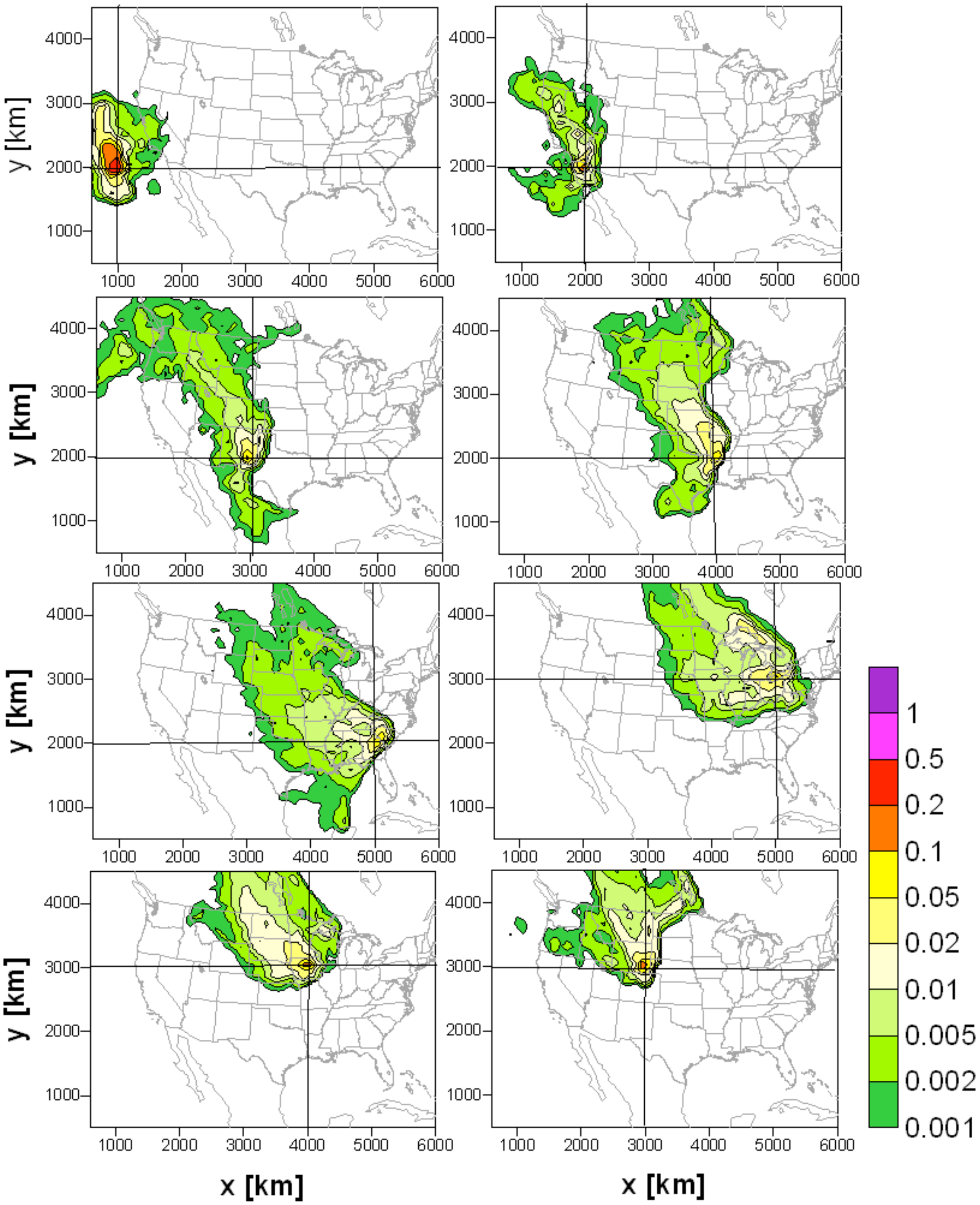

Figure 1 presents a series of influence functions [ppm/umol] calculated during testing the prototype RUC/LPDM system. They are derived for the 10-day period of March 6-16, 2006 and hypothetical 400 m towers spaced every 1000 km across the RUC domain. The influence functions are integrated with unit CO_2 flux from the surface (1 umol/m^2/s). In a similar manner the influence functions can be derived for all active NOAA towers (or any other locations of interest) and can be integrated with the user provided CO_2 fluxes instead of the unit flux.

We have investigated several methods of aggressive data compression to solve this problem. It would be possible and perhaps advisable to convolve the transport influence functions with a surface flux model (such as SiB, which we use at CSU), and integrate over longer periods of time. We have shown that compression of the order of a factor of 100 is possible by this method, which assumes that high-frequency (hourly to daily) variations in surface fluxes are well-captured by the model and that the influence functions would be used to correct the model on time scales of several days. We will apply this approach at CSU/CIRA, but recognize that other users of the influence functions may prefer to use the product at full temporal resolution or apply their own models to the compression and flux inversion problem.

To compromise between the need for data compression and flexibility in applying flux models to the influence functions, we have designed the storage and dissemination system to store Lagrangian particle positions rather than integrated influence functions. The advantage with respect to storage is the, unlike for the case of gridded integrated influence functions, only locations that influence a particular measurement are stored. The system will therefore need to integrate influence functions "on the fly," at the time that the product is disseminated. The system will offer influence functions convolved with hourly SiB fluxes and deliver vastly compressed data, or to send the gridded functions at full resolution for shorter periods. This approach involves a necessary trade off in increased computational cost in the data system to achieve disk storage savings.

We are currently investigating different approaches for mass-adjustment of the RUC wind fields before they are used in the LPDM. We have also begun work on a new scheme in the LPDM model for subgrid-scale vertical transport associated with parameterized cloud mass fluxes due to cumulus clouds. This work will continue in year 2 of the project during which we will complete the system, and build and deploy a web interface for delivery of the product to other researchers.

3. Comparison of Objectives vs. Actual Accomplishments for the Reporting Period:

State the status of the objectives as: (can be more than one): "yet to be started," "complete," "in progress," "unsuccessful," "determined to be inappropriate," "tech transferred**." Include a description of the work done on each objective. If slippage occurred between what was proposed vs. what was achieved, please explain.

1) Produce a library of influence functions based on mesoscale high-frequency RUC analyses

In progress. We have successfully adapted the LPDM model and "particle analysis" (PANAL) influence function generation algorithm to the RUC output, and have generated test output (see Fig 1 above). We have tested various options for representing the effects of cumulus convection and enforcing mass conservation.

We have encountered a possibly serious problem with regard to frequent gaps in the RUC analysis. We had been assured that a “second source” of the analysis fields was available for filling gaps, and that gaps would likely be much less than 1% of the hourly data. In reality, the second source has not been archived, and the analysis contains over 3% gaps. We will work with our colleagues at ESRL in the coming weeks to find a way to deal with missing analyses.

2) Evaluate the RUC-based influence functions

In progress. We are evaluating both meteorological variables (wind roses, precipitation, depth of mixing) against direct observations, and also comparing RUC-derived influence functions with those derived from high-resolution transport products derived from RAMS simulations.

3) Store and disseminate the output to other researchers for use in carbon cycle inversions.
Yet to be started.

4. Leveraging/Payoff:

The fate of anthropogenic CO_2 introduced into the atmosphere by the combustion of fossil fuels is one of the leading sources of uncertainty in projections of future climate. Coupled carbon-climate models simulate positive feedback (warming promotes additional CO_2 release to the atmosphere), but a recent comparison of 11 such models found a range of nearly 200 ppm in CO_2 and 1.5 K of warming in 2100 (Friedlingstein et al, 2006). Research leading to improved quantification and understanding of carbon sources and sinks has therefore been identified as a major priority for the US Carbon Cycle Science Program, with special focus on North America in the near term. The North American Carbon Program (NACP, Wofsy and Harris, 2002; Denning et al, 2005) involves process studies, an expanded flux measurement network, remote sensing and modeling, and inversions using new atmospheric mixing ratio observations. Cross-evaluation of models and data sources and hypothesis testing at a variety of spatial and temporal scales is envisioned within a new framework of model-data fusion.

5. Research Linkages/Partnerships/Collaborators, Communication and Networking:

The North American Carbon Program (NACP): an interagency collaboration on carbon cycle research sponsored by 9 federal agencies.

Denning chairs NACP Science Steering Group, and serves on the NACP Mid-Continent Intensive Task Force, Data Systems Task Force, and Synthesis Task Force

6. Awards/Honors:

7. Outreach:

8. Publications: