An Eulerian vs. Lagrangian Comparison of Modeled Carbon Monoxide in Texas during Biomass Burning Events

Atmospheric and Environmental Research

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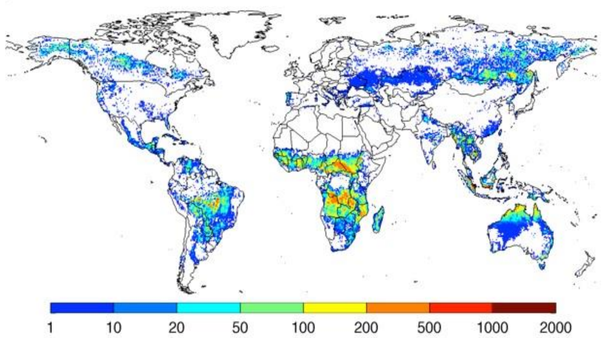
Motivation

Biomass Burning Impacts Air Quality and Climate

- Large global source of trace gases and particles
- Emissions highly variable between fires
- We want to examine potential errors in biomass burning transport and the impacts of fires on air quality.

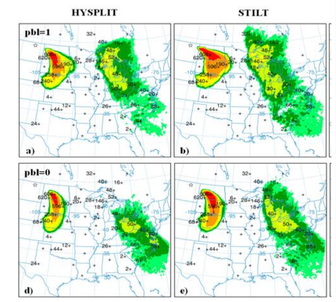


Annual carbon emissions (as g C m^{-2} $year^{-1}$), averaged over 1997-2009, derived using MODIS fire counts and burned area (van der Werf et al., ACP, 2010).

Approach

Stochastic Time-Inverted Lagrangian Transport (STILT) Model

STILT (Lin et. al, 2003; stilt-model.org) is a Lagrangian particle dispersion model derived from HYSPLIT but contains modifications that improve mass conservation and allow the use of customized meteorological fields. STILT allows for multiple air parcels to be released from a single location and for those parcels to be dispersed according to turbulence.

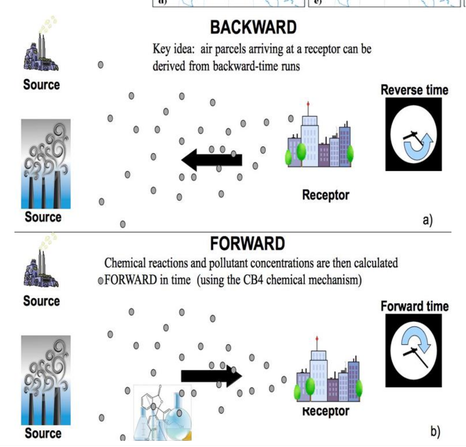


Lagrangian Model Analysis of Biomass Burning Events

Derive upstream influence on receptor by propagating air parcels **backward** in time.

Determine resulting species concentrations by calculating emissions, deposition and chemistry along each parcel's path **forward** in time.

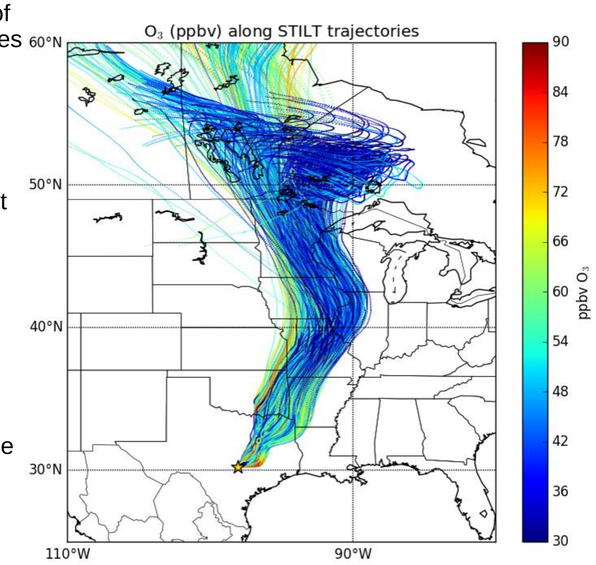
D. Wen et al. (2012, 2013, 2014)



Aerosol Simulation Program (ASP v2.1, Alvarado et al., 2015)

ASP models the formation of O_3 and SOA in smoke plumes

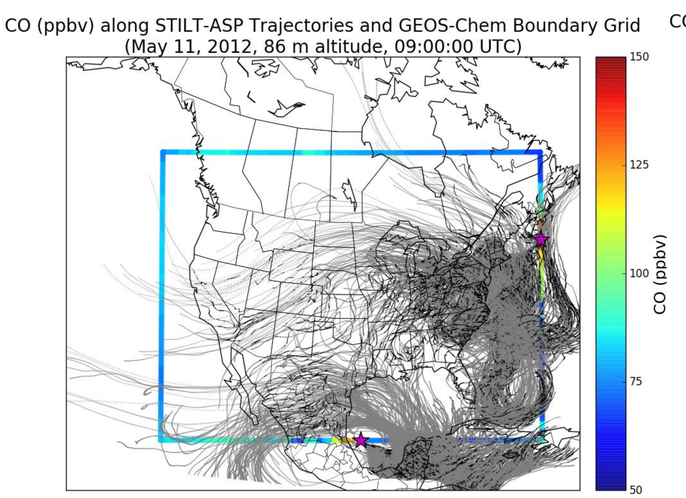
- Gas-phase chemistry
  - $\leq C_4$ gases follow MCM v3.2 (Saunders et al., 2003).
  - Other organic gases follow RACM2 (Goliff et al., 2013)
- Inorganic aerosol thermodynamics
- OA thermodynamics using the Volatility Basis Set (Robinson et al., 2007)
- S/IVOC oxidation following Ahmadov et al. (2012)
- Evolution of the aerosol size distribution and optical properties
- ASP can be run as a box model, or as a subroutine within 3D Eulerian models (Alvarado et al., 2009) and Lagrangian transport models



A STILT-ASP run for Austin, TX at 2011-09-07, 10:00:00 CST, with both parcel trajectory and chemistry solvers activated.

Results

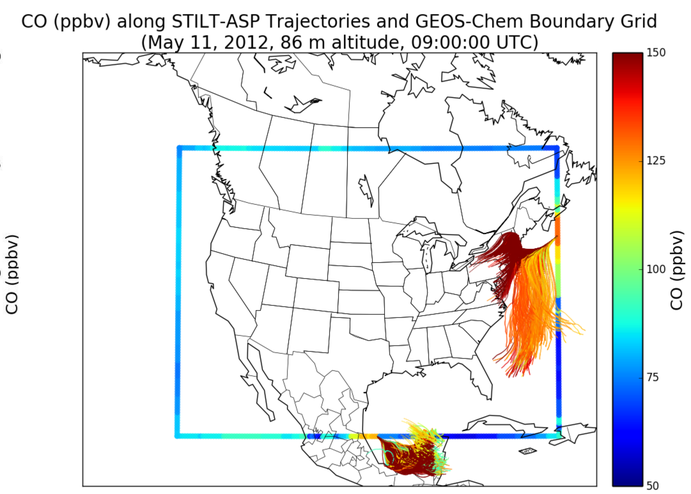
Without Chemistry – 5/11/2012, 86 m alt, 7-day back trajectory



STILT-ASP predicts many regions of flow where air parcels are located within the boundary layer **(shaded dark).**

This indicates that significant area-based emissions will be incorporated into the parcel chemistry when STILT-ASP is run with the chemistry mode activated.

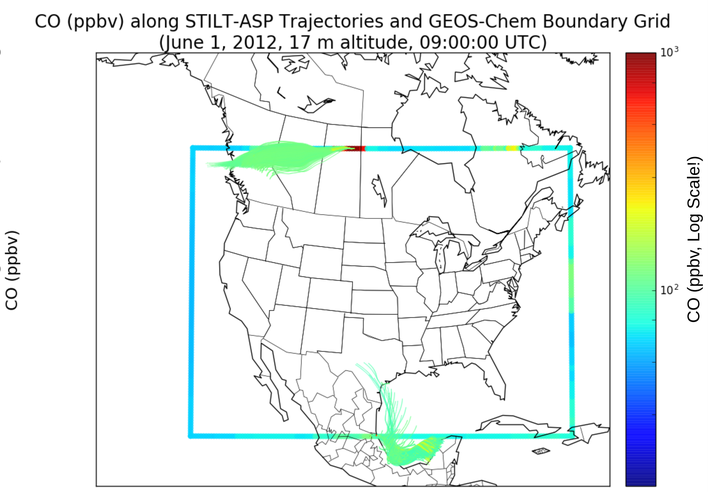
With Chemistry - 5/11/2012: 86 m alt, 2-day back trajectory



STILT-ASP predicts significant CO emissions over Eastern/Southeastern CONUS and a slight overestimation relative to GEOS-Chem at the Eastern receptor.

There is a larger overestimate of CO relative to GEOS-Chem over the southern border, though both models are similar to within ~30 ppbv CO at both locations.

With Chemistry - 6/1/2012: 17 m alt, 2-day back trajectory



STILT-ASP predicts mean CO of approximately **120** ppbv at the northern SK boundary receptor, but GEOS-Chem shows CO levels in excess of **10^3 ppbv**.

Note that wildfires over Central America are captured in STILT-ASP and that it and GEOS-Chem predict similar levels of CO along the southern border of the grid.

Summary & Future Work

We have developed a Lagrangian parcel dispersion model**, STILT-ASP**, that is capable of estimating the effects of biomass burning on a particular location. Being a Lagrangian model, it is less susceptible to numerical diffusion than an Eulerian model.

We are currently modeling many receptors to see how well plume dispersion is captured in GEOS-Chem. Other development work includes:

- Simulating cases where more data on the gas/aerosol composition of the atmosphere is available
- Improving the estimates of non-fire emissions by running biogenic emissions models BEIS and MEGAN on-line in the tool and using anthropogenic emissions that follow TCEQ2012 guidelines
- Improving the speed of STILT-ASP through code parallelization and other techniques
- Adding the ability to import GEOS-Chem model output as boundary conditions

Acknowledgments

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