A Lagrangian Particle Dispersion Model Approach for Evaluating CarbonTracker

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CarbonTracker Overview

Optimization step is **Ensemble Kalman Filter**

http://carbontracker.noaa.gov
Fires = GFED2

http://carbontracker.noaa.gov
NOAA ESRL Carbon Cycle operates 4 measurement programs. Semi-continuous measurements are made at 4 baseline observatories and from tall towers. Discrete surface and aircraft samples are measured in Boulder, CO. Presently, atmospheric carbon dioxide, methane, carbon monoxide, hydrogen, nitrous oxide, sulfur hexafluoride, the stable isotopes of carbon dioxide and methane, and halocarbon and volatile organic compounds are measured. Contact: Dr. Pieter Tans, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.
An atmospheric perspective on North American carbon dioxide exchange: CarbonTracker


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http://carbontracker.noaa.gov
Sampling Footprints
Lagrangian Particle Dispersion Modeling
Stochastic Time Inverted Lagrangian Transport Model

\[
CO_2^{\text{meas}} = CO_2^{BC} + \frac{1}{N} \sum_{p=0}^{N} \sum_{t=0}^{t_f} SENS \cdot FLUX
\]

Initial Condition (CarbonTracker)

Footprint [ppm per unit flux]
Sensitivity = 0

PBL height

Sampling Footprints
Lagrangian Particle Dispersion Modeling
Stochastic Time Inverted Lagrangian Transport Model

\[ CO_2^{meas} = CO_2^{BC} + \frac{1}{N} \sum_{p=0}^{N} \sum_{t=0}^{t_f} SENS \times FLUX \]

Initial Condition (CarbonTracker)

Footprint [ppm per unit flux]
Normalized Footprint: Linear Color Scale
Composite: MAY-JULY 2004 LEF, 19GMT

Note: Footprints are time-resolved, but shown as 10-day composite
Cumulative Footprint 19:00 GMT: LEF 396m May–July 2004

Normalized Footprint: Log10 Color Scale
Composite: MAY-JULY 2004 LEF, 19GMT
Cumulative Surface Sensitivity
STILT BOUNDARY LAYER RESIDENCE TIME

<2km
<1km
< Model Mixed Layer Height

Fraction of Particles

Days

0.0 0.2 0.4 0.6 0.8 1.0
-10 -8 -6 -4 -2 0
LEF TOWER: PARK FALLS, WI
396 magl

LEF: MAY–JULY 2004 19:00 GMT (TOWER)
LEF: MAY–JULY 2004 19:00 GMT (TOWER)

OBS
CT
STILT-WRF-CT

CT ~4KM
AC OBS >3.5 KM
STILT-BKGRD
LEF: MAY–JULY 2004 19:00 GMT (TOWER)

OBS
CT
STILT

CT ~4KM
AC OBS >3.5 KM
STILT-BKGRD
CT $R^2 = 0.87$

STILT $R^2 = 0.89$
AMT: JUNE-JULY 2004 19:00 GMT (TOWER)

OBS
CT
STILT

CT ~4KM
AC OBS >3.5 KM
STILT-BKGR

+ COBRA 2004
(HARVARD)
AMT: JUNE-JULY 2004 19:00 GMT (TOWER)

OBS
CT
STILT

CT ~4KM
AC OBS >3.5 KM
STILT-BKGRD

JULY 19, 19:00 GMT
COBRA-MAINE: HARVARD UNIVERSITY/NSF & NOAA
7 MAY – 16 AUGUST 2004
33 FLIGHTS
Wyoming King Air
NSF paid for equipment & establishing AMT tower site under this project
COBRA: 2004-07-30
AMT OVERFLIGHT
Free troposphere has much smaller surface sensitivity than boundary layer → strongly driven by initial condition.
July/Aug 2004
OBS
STILT-WRF-CT
CT interp

May/Jun 2004
OBS
STILT-WRF-CT
CT interp

Altitude, m above ground level

Carbon Dioxide, ppm

0 1000 2000 3000 4000

360 365 370 375 380 385
More/Earlier drawdown needed in Spring?
• Differences are due to model transport.
• Keep in mind that fluxes have been optimized using CT.
• Aircraft data were not optimized.
Summary Points

• Lagrangian models can provide insight into the mechanics of CarbonTracker
  • Diagnose patterns and residuals
  • Footprint information can inform decisions about how to weight different types of data

• Generally good agreement between STILT-WRF-CT and CarbonTracker is encouraging—STILT tends to predict lower CO₂ near the surface

• “Campaign” data are valuable independent datasets for CarbonTracker evaluation: e.g, COBRA-2003, COBRA-2004, TEXAS AQS 2006, ARCPAC-2008, START-08, HIPPO

• Footprints are generic and can be used to interpret mixing ratio measurements of other species (halocarbons, COS, isotopes, etc.)

• Other LPDMS are in use around ESRL: FLEXPART, CSU LPDM, HYSPLIT

• We are working toward building an archive of footprints that can be linked to the GMD database
WKT: MAY–JULY 2004 19:00 GMT (TOWER)

CO2, ppm

OBS
CT
STILT

CT ~4KM
AC OBS >3.5 KM
STILT-BKGRD

WKT: MAY–JULY 2004 19:00 GMT (TOWER)
OBS
CT
STILT

CT ~4KM
AC OBS >3.5 KM
STILT-BKGRD
Nominal Radius of Footprint, 19:00 GMT: LEF 396m May–July 2004
LEF: MAY–JULY 2004 19:00 GMT (TOWER)