EARTH SYSTEM RESEARCH LABORATORY

Serving Society through Science

CarbonTracker

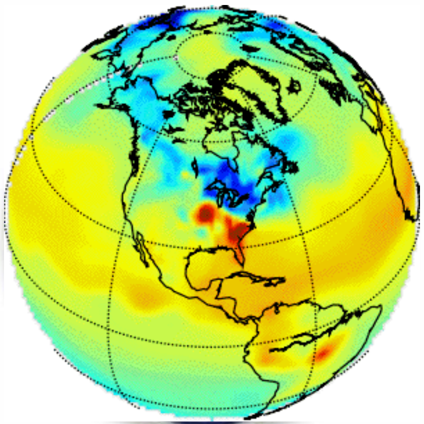
The NOAA ***CarbonTracker*** team:

Wouter Peters, Andy Jacobson, Ken Masarie, Pieter Tans, John B. Miller, Arlyn Andrews, Colm Sweeney, Tom Conway, Lori Bruhwiler, Gabrielle Pétron, Adam Hirsch

External collaborators:

Doug Worthy, Jim Randerson, Guido van der Werf, Britt Stephens

- **What is *CarbonTracker*?**
- **How is it used?**
- **How well does it work?**
- **How will it be improved?**
- **Summary: *Why?***

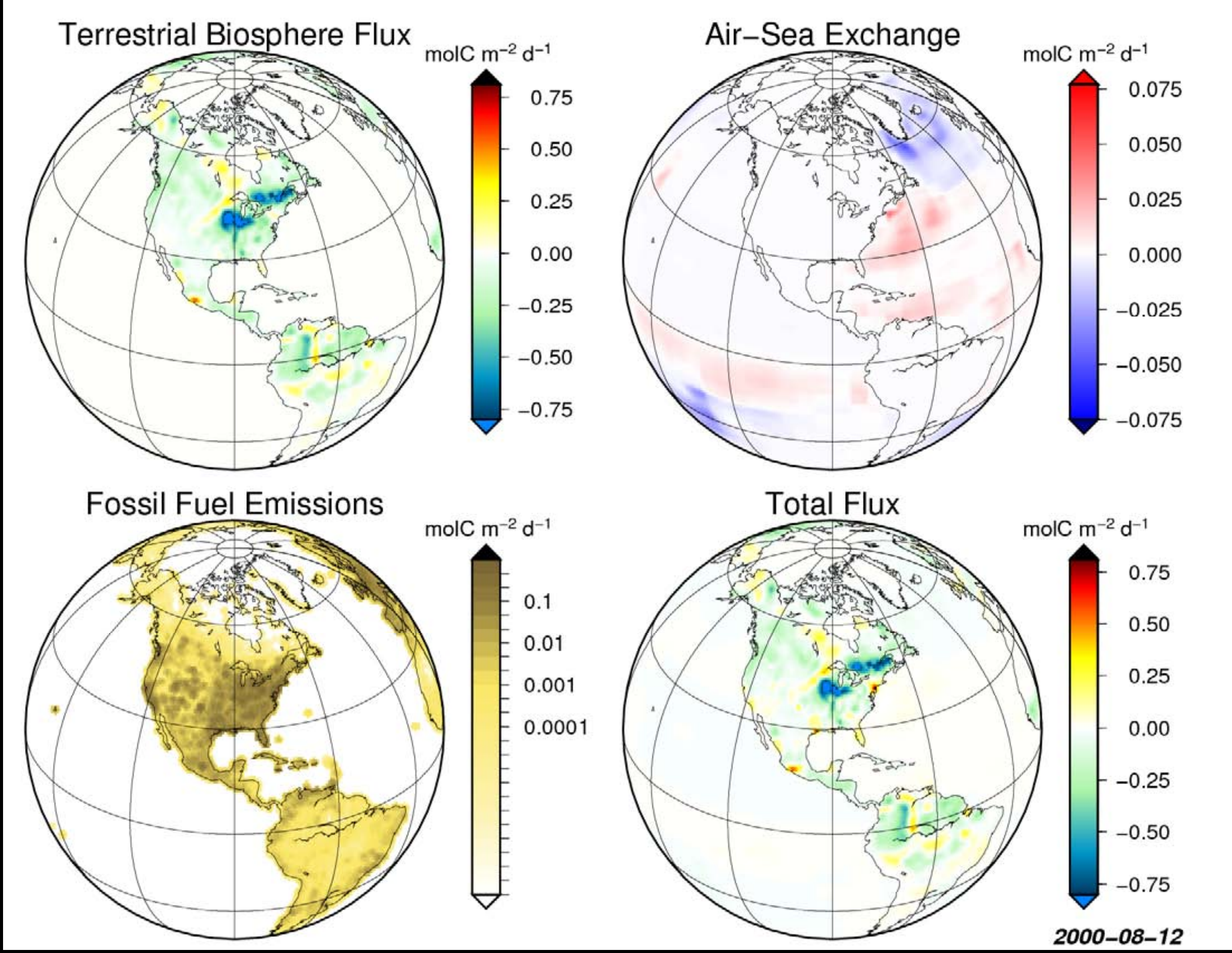


ESRL Atmospheric Chemistry Review

January 29-31, 2008 ~ Boulder, Colorado

CarbonTracker is:

- **A global surface flux inversion**
- **NOAA's estimate of N. American fluxes**
- **Our final screen for data quality**
- **A "reference" solution**
- **An outreach tool**



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PNAS

An atmospheric perspective on North American carbon dioxide exchange: CarbonTracker

Wouter Peters*†‡, Andrew R. Jacobson*†, Colm Sweeney*†, Arlyn E. Andrews*, Thomas J. Conway*, Kenneth Masarie*, John B. Miller*†, Lori M. P. Bruhwiler*, Gabrielle Pétron*†, Adam I. Hirsch*†, Douglas E. J. Worthy§, Guido R. van der Werf¶, James T. Randerson‖, Paul O. Wennberg**, Maarten C. Krol††, and Pieter P. Tans*

*National Oceanic and Atmospheric Administration Earth System Research Laboratory, 325 Broadway R/GMD1, Boulder, CO 80305; †Cooperative Institute for Research in Environmental Sciences, UCB 216, Boulder, CO 80303; §Environment Canada, 4905 Dufferin Street, Downsview, ON, Canada M3H 5T4; ¶Faculty of Earth and Life Sciences, Vrije Universiteit, 1081 HV, Amsterdam, The Netherlands; ‖Department of Earth System Science, University of California, Irvine, CA 92697; **Division of Engineering and Applied Science and Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125; and ††Department of Meteorology and Air Quality, Wageningen University and Research Center, 6708 PB, Wageningen, The Netherlands

Communicated by A. R. Ravishankara, National Oceanic and Atmospheric Administration, Boulder, CO, September 27, 2007 (received for review May 23, 2007)

We present an estimate of net CO_2 exchange between the terrestrial biosphere and the atmosphere across North America for every week in the period 2000 through 2005. This estimate is derived from a set of 28,000 CO_2 mole fraction observations in the global atmosphere that are fed into a state-of-the-art data assimilation system for CO_2 called CarbonTracker. By design, the surface fluxes produced in CarbonTracker are consistent with the recent history

CarbonTracker 2007B: N. America fluxes in PgC yr^{-1}.

Year	First Guess NEE	**Final NEE**	Fires	FF	Total
2000	-0.16 ± 0.89	-0.64 ± 0.65	0.04	1.91	1.31 ± 0.65
2001	-0.16 ± 0.90	-0.45 ± 0.64	0.02	1.92	1.50 ± 0.64
2002	0.03 ± 0.85	**-0.17 ± 0.55**	0.03	1.92	1.78 ± 0.55
2003	-0.21 ± 0.84	-0.64 ± 0.52	0.03	1.94	1.33 ± 0.52
2004	-0.19 ± 0.90	**-0.79 ± 0.48**	0.02	1.98	1.20 ± 0.48
2005	-0.20 ± 0.87	**-0.76 ± 0.48**	0.02	1.99	1.26 ± 0.48
2006	-0.04 ± 0.84	-0.56 ± 0.37	0.02	1.99	1.45 ± 0.37

sions or to even continue at its present-day magnitude. Moreover, natural emissions themselves might increase as a result of already observable rapid warming in parts of the Arctic (1), where large carbon reservoirs are buried beneath the permafrost. Major national and international programs to study the carbon cycle are therefore underway.

The National Oceanic and Atmospheric Administration's (NOAA's) Earth System Research Laboratory (ESRL) monitors CO_2 in the atmosphere as a contribution to the North American Carbon Program (NACP) (2). Mole fractions of CO_2

In addition, carbon exchange is monitored locally (≈1 km^2) from a worldwide collection of surface flux measurements in different ecosystems and through periodic inventories of carbon in oceans, forests, and soils. The latter provide long-term constraints on the size of the different carbon pools. Monitoring of the carbon cycle through satellites mostly targets specific processes such as biomass burning, land-use change, or seasonal

In this work, we introduce CarbonTracker and analyze the recent flux history it produces. We compare its regional estimates for North America with an independent "bottom-up" estimate that is part of the State of the Carbon Cycle Report (SOCCR) (8). This document, created as part of the U.S.

Author contributions: P.P.T. designed research; C.S., A.E.A., T.J.C., D.E.J.W., G.R.v.d.W., J.T.R., and P.O.W. contributed data; A.R.J., K.M., J.B.M., L.M.P.B., G.P., A.I.H., and M.C.K. performed research; and W.P. wrote the paper.

The authors declare no conflict of interest.

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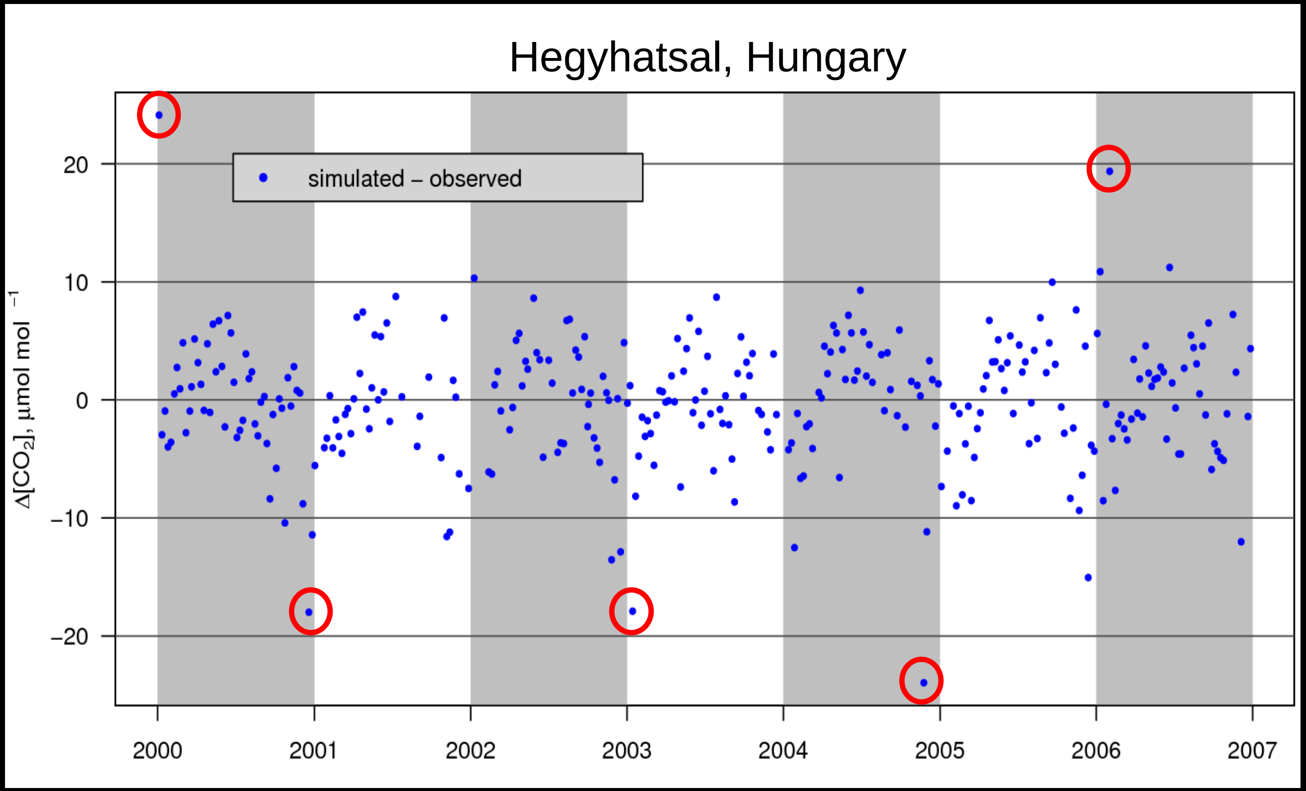

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Atmos. Chem. Phys., 7, 4249–4256, 2007
www.atmos-chem-phys.net/7/4249/2007/

Atmospheric Chemistry and Physics

First direct observation of the atmospheric CO_2 year-to-year increase from space

M. Buchwitz, O. Schneising, J. P. Burrows, H. Bovensmann, M. Reuter, and J. Notholt
Institute of Environmental Physics (IUP), University of Bremen FB1, Bremen, Germany

Received: 13 April 2007 – Published in Atmos. Chem. Phys. Discuss.: 16 May 2007
Revised: 19 July 2007 – Accepted: 25 July 2007 – Published: 20 August 2007

Abstract. The reliable prediction of future atmos
concentrations and associated global climate char
an adequate understanding of the CO_2 sources and
sparseness of the existing surface measurement n
its current knowledge about the global distribut
surface fluxes. The retrieval of CO_2 total vertic
from satellite observations is predicted to impro
ation. Such an application however requires very
racy and precision. We report on retrievals of t
averaged CO_2 dry air mole fraction, denoted X
the near-infrared nadir spectral radiance and sola
measurements of the SCIAMACHY satellite ins
tween 2003 and 2005. We focus on northern h
large scale CO_2 features such as the CO_2 seasona
show - for the first time - that the atmospheric
crease of CO_2 can be directly observed using sa
surements of the CO_2 total column. The satelli
are compared with global XCO_2 obtained from N
assimilation system CarbonTracker taking into
spatio-temporal sampling and altitude sensitivity
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northern hemispheric CO_2 seasonal cycle agrees with CarbonTracker within about 2 ppm with the retrieved amplitude being systematically larger. The analysis demonstrates that it is possible using satellite measurements of the CO_2 total column to retrieve information on the atmospheric CO_2 on the level of a few parts per million.

surements of the CO_2 total column. The satellite retrievals are compared with global XCO_2 obtained from NOAA's CO_2 assimilation system CarbonTracker taking into account the spatio-temporal sampling and altitude sensitivity of the satellite data. We show that the measured CO_2 year-to-year increase agrees within about 1 ppm/year with CarbonTracker. We also show that the latitude dependent amplitude of the northern hemispheric CO_2 seasonal cycle agrees with CarbonTracker within about 2 ppm with the retrieved amplitude being systematically larger. The analysis demonstrates that

eral assumptions related to the required smoothness, the initial conditions, and the global flux field. Synthetic inverse modeling studies have suggested that satellite measurements of the column-averaged CO_2 dry air mole fraction, XCO_2, as possible using nadir measurements in the near-infrared spectral region, have the potential to significantly improve the determination of source/sink distributions of CO_2 (Rayner and O'Brien, 2001; Houweling et al., 2004). This results primarily from the large amounts of data that satellites produce, but also because nadir satellite remote sensing measurements in the near-infrared spectral region can observe the CO_2 molecules in the entire air column. As a result vertical transport modeling errors are less critical compared to inversions based on in-situ observations only.

Correspondence to: M. Buchwitz
(michael.buchwitz@iup.physik.uni-bremen.de)

Published by Copernicus Publications on behalf of the European Geosciences Union.

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From: Chris Measures <chrism@soest.hawaii.edu>
To: carbontracker.team@noaa.gov
Subject: Re: CarbonTracker updated: new release
Created: 12/21/2007 19:30:04

Dear Pieter et al:

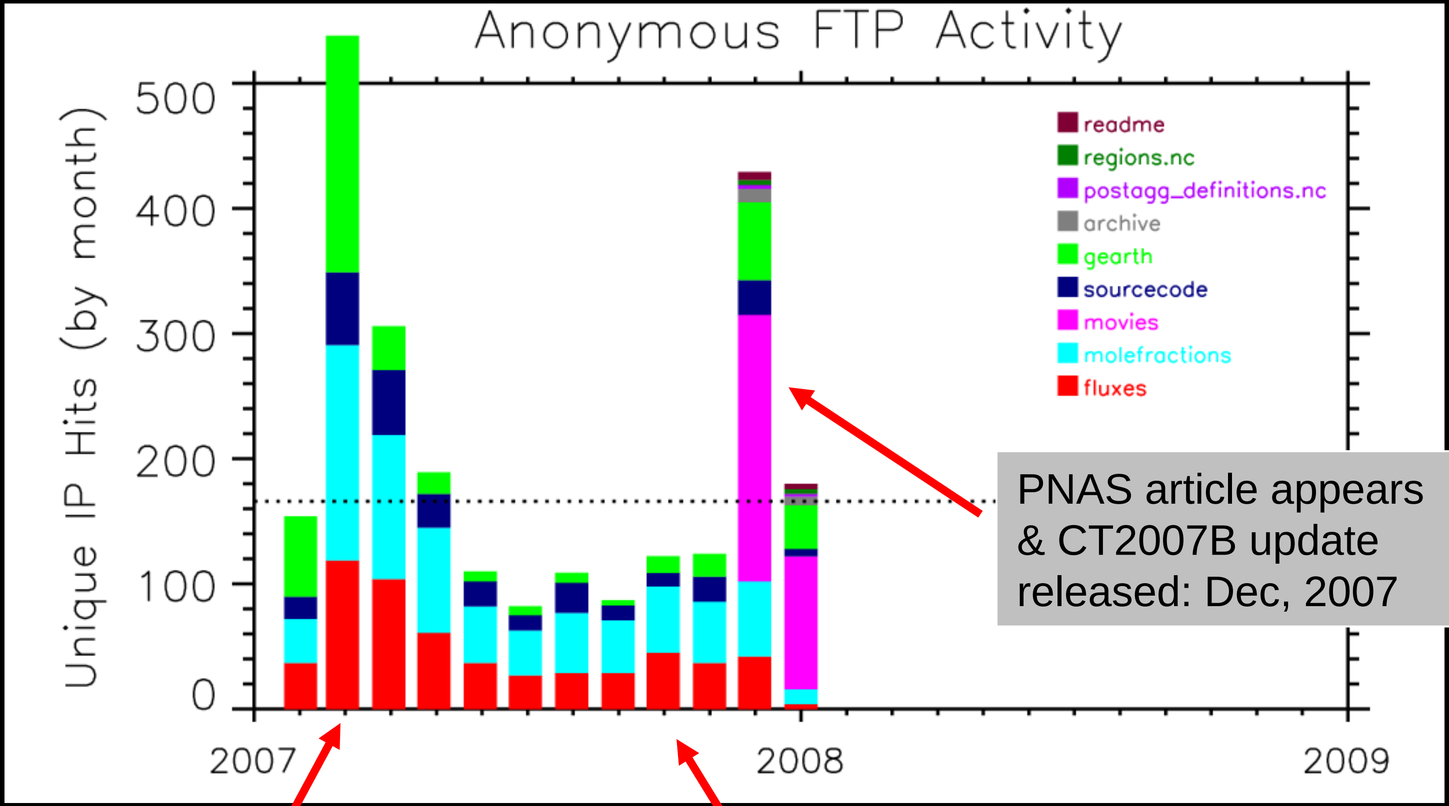
This is really great, thank you for putting this together. I will certainly be using your figures and explanations in the lectures I give to my undergraduates about the CO2 system. They really want to know the facts and the most recent data are always of great interest to young people since it conveys the immediacy of the problem. I had found it increasingly difficult to get hold of some of the most recent
basic information over the last few years, this web resource has made it much easier.

I am particularly happy to get the Mauna Loa data
through 2006.

Thanks for facilitating teaching as well as research,

Cheers, Chris Measures
Oceanography, University of Hawaii

How is *CarbonTracker* used?



PNAS article appears & CT2007B update released: Dec, 2007

First release, February 2007

“pre-AGU bounce”, Nov-Dec 2007

How is *CarbonTracker* used?

Collaborations

CarbonTracker **for other regions**

- Europe - *Wageningen Univ.*
- Asia - *Korean Met Agency*
- South America - *CPTEC, Brazil and LBA, NASA*

Regional inversions

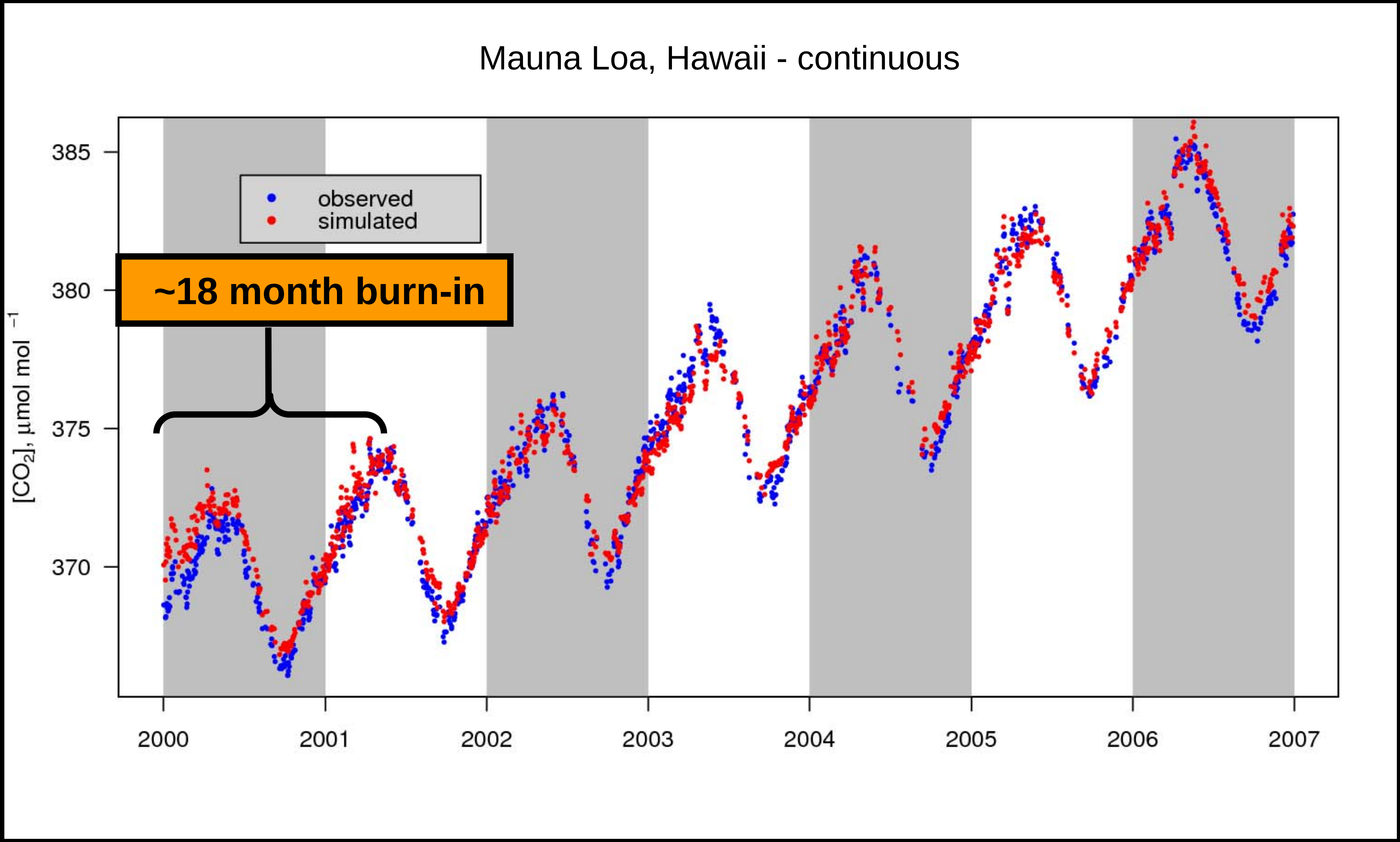
- North America (with U. Michigan)
- Africa (with NASA's ACE-2 project)
- Japan (with Osaka University)

Satellite missions

- Ongoing comparison with TCCON network
- CSU OCO inversion
- SCIAMACHY methane and CO_2

NACP, Ameriflux, Canadian Flux net

How well does *CarbonTracker* work?



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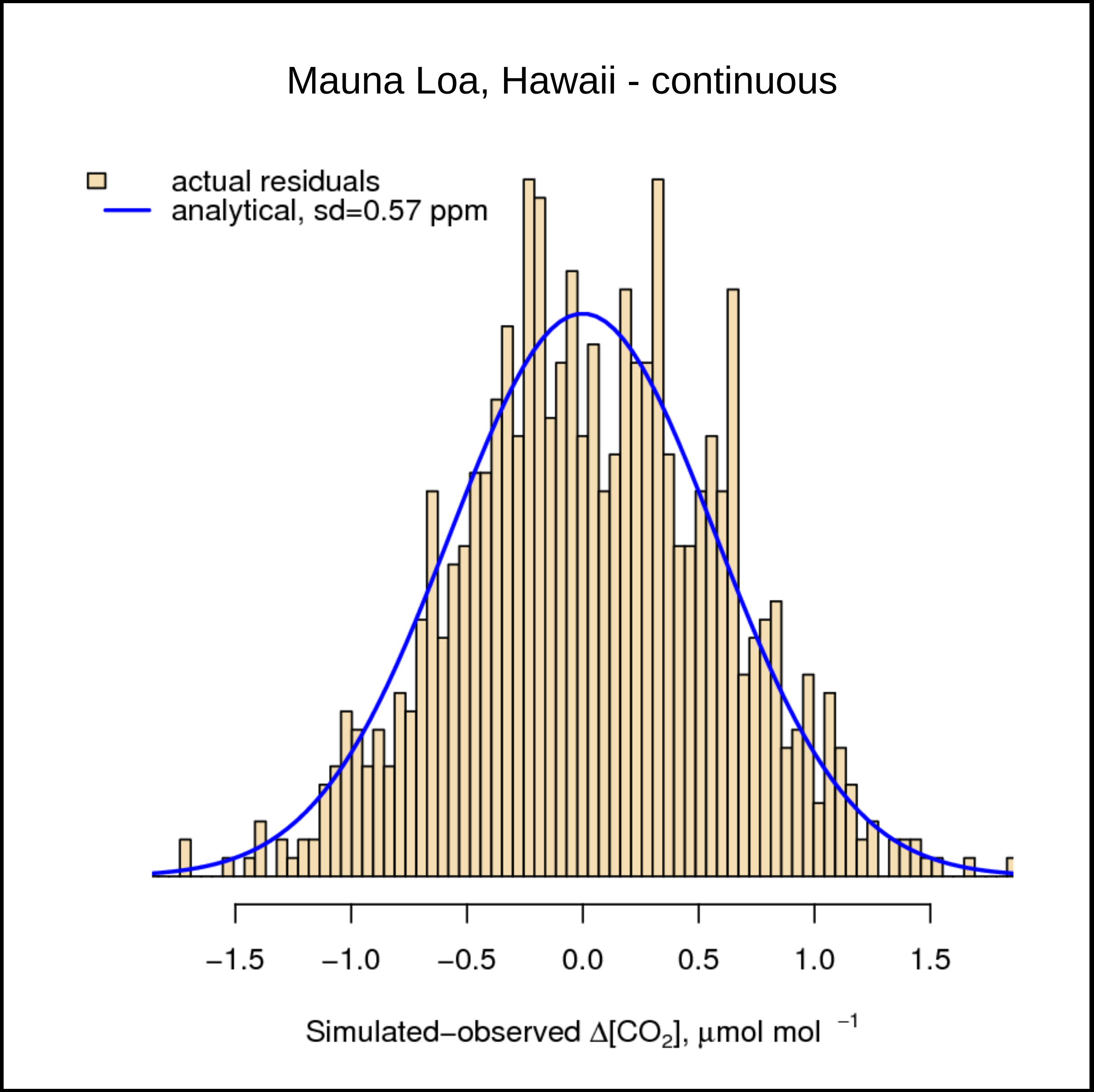

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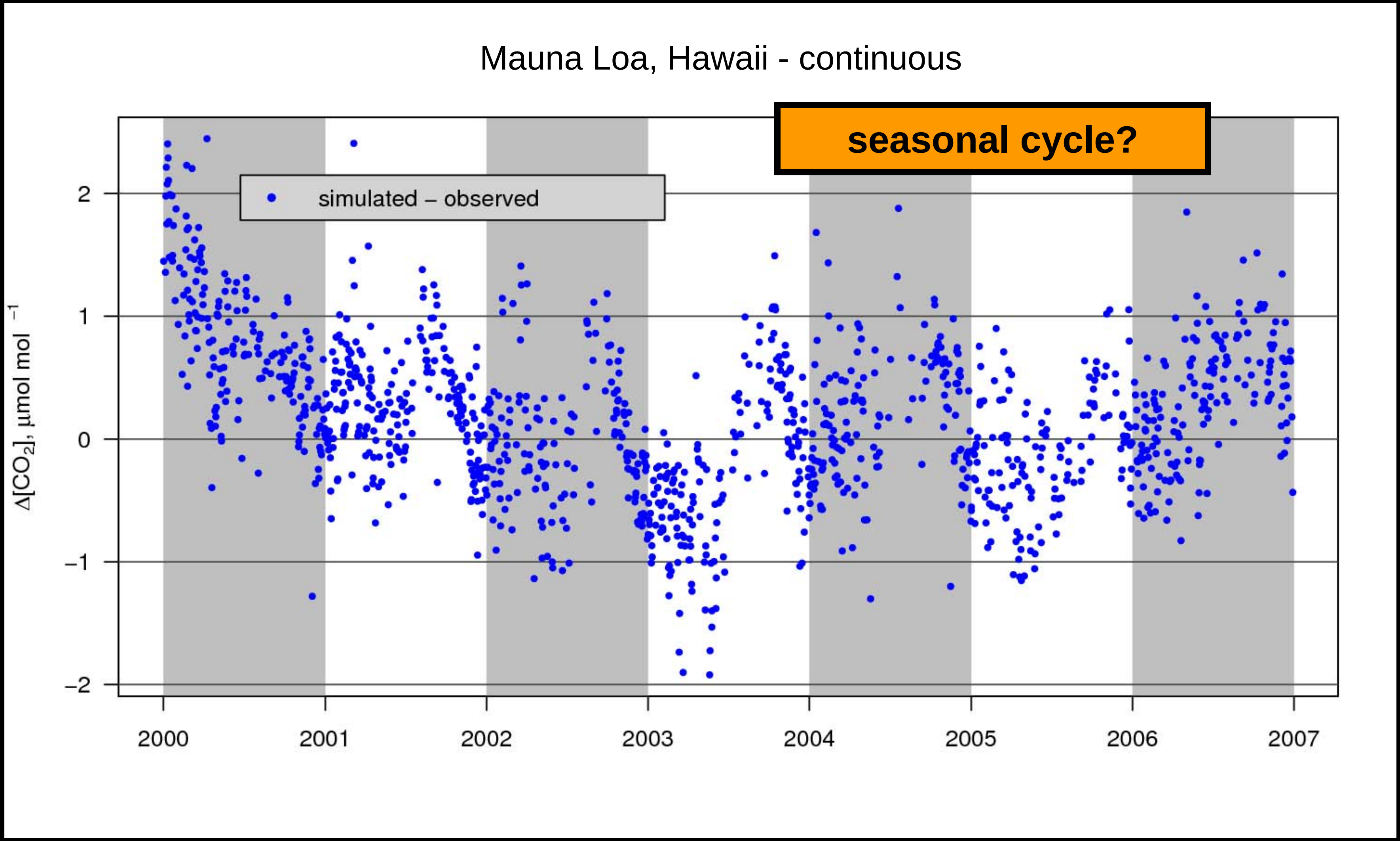

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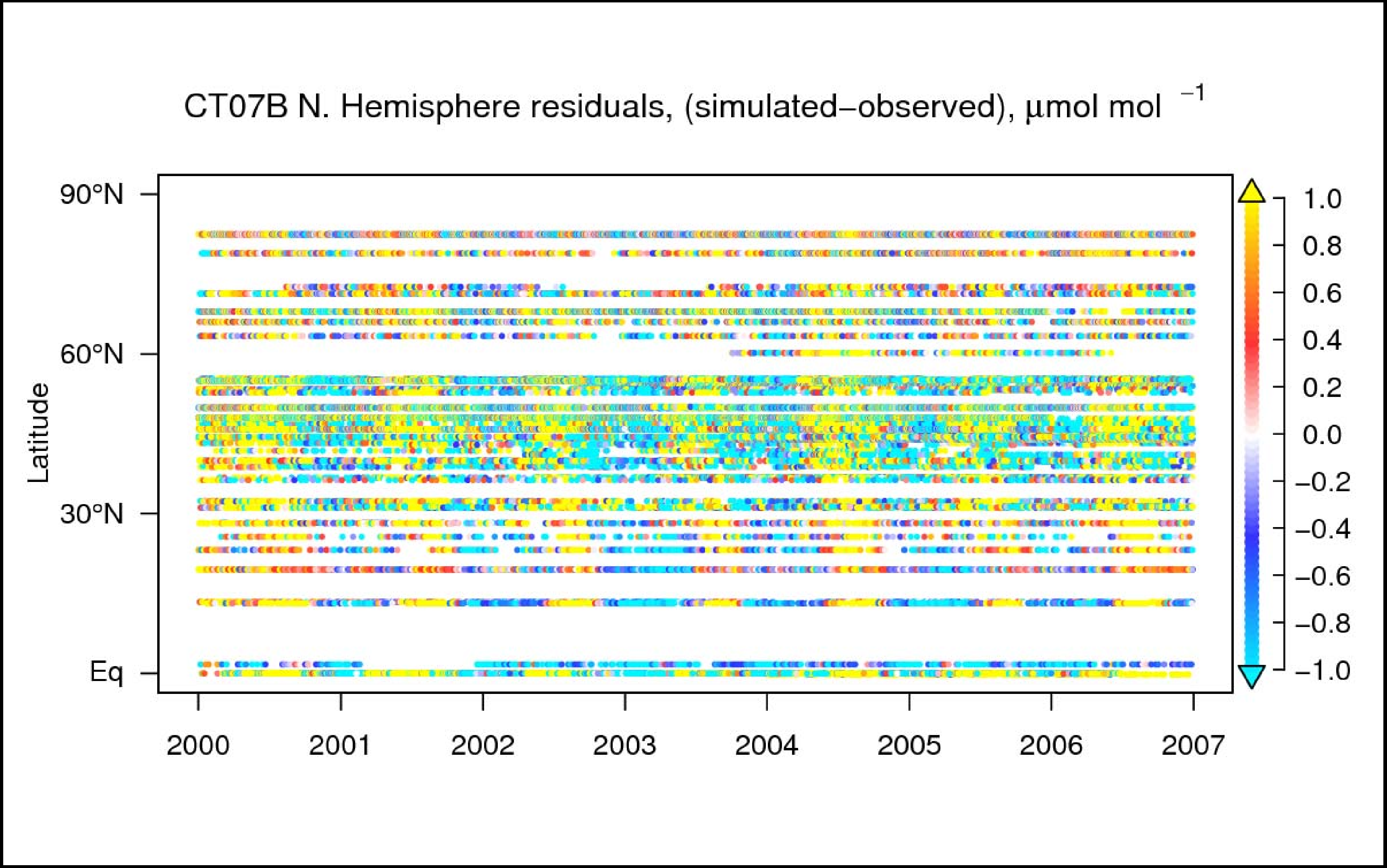
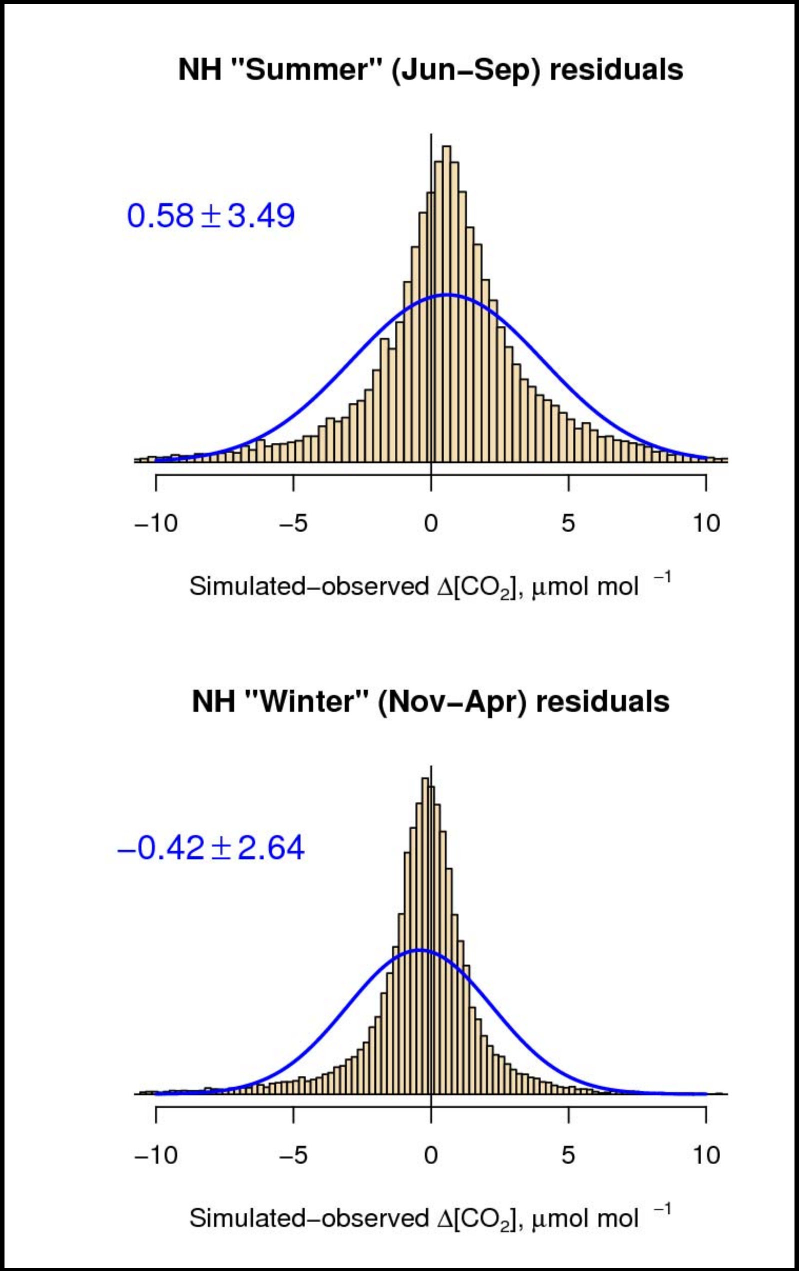


How well does *CarbonTracker* work?

Model biased high in summer
too diffusive?
too little uptake?



Model biased low in winter
too diffusive?
too little outgassing?

Leptokurtic: distribution dominated by big outliers

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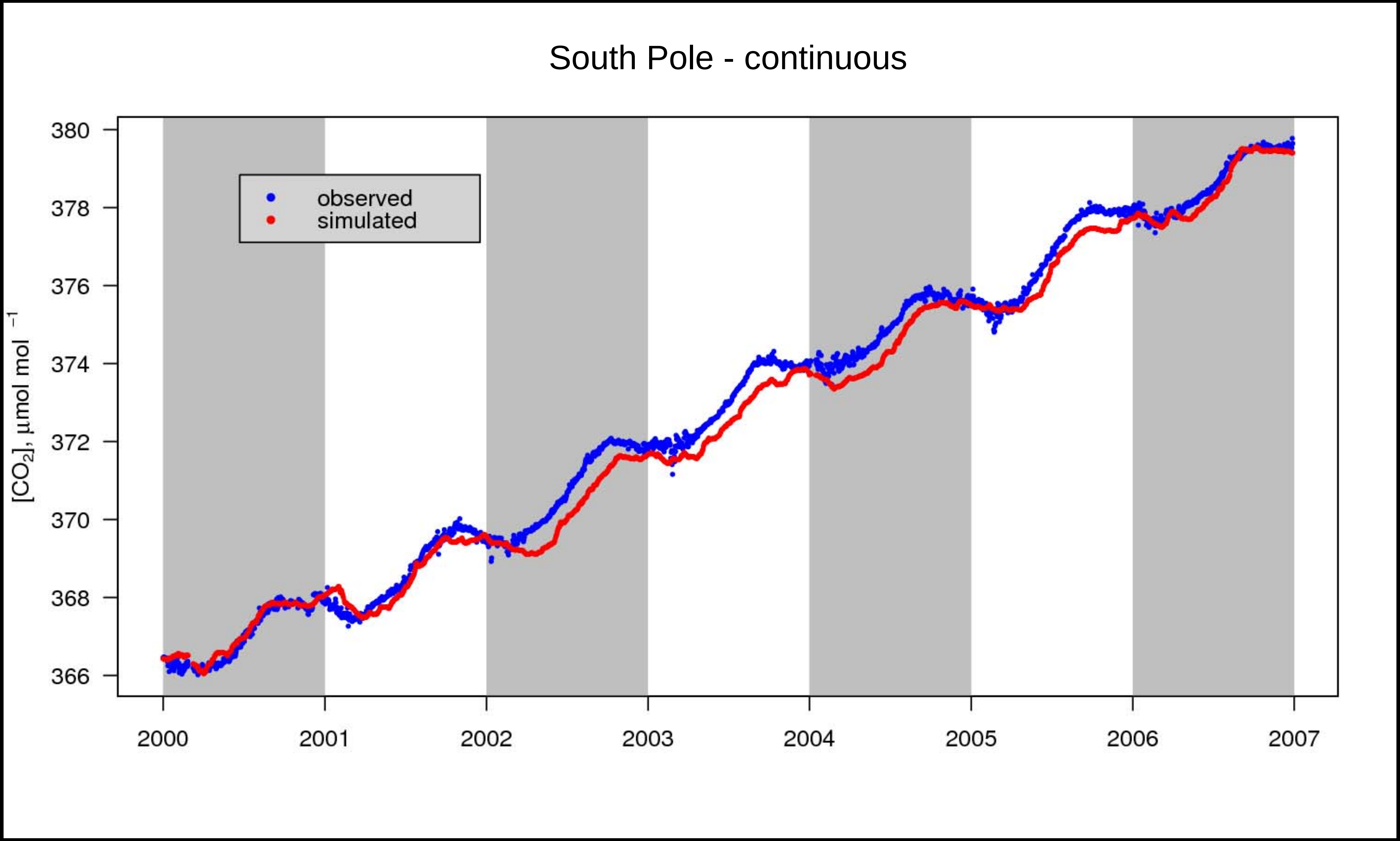

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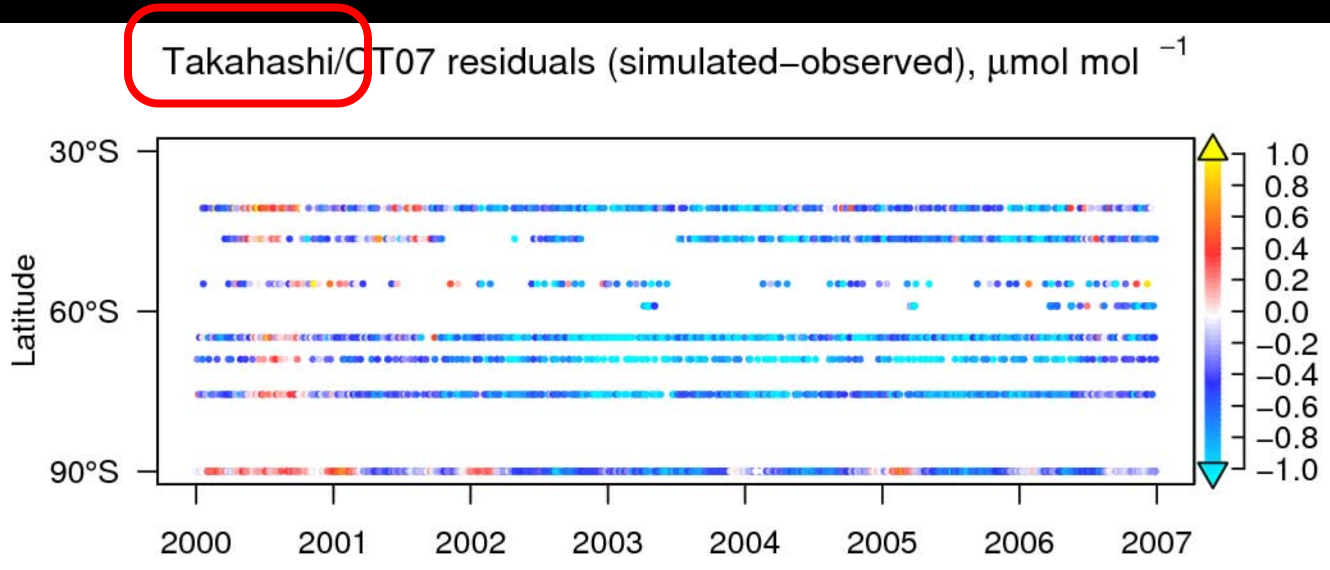

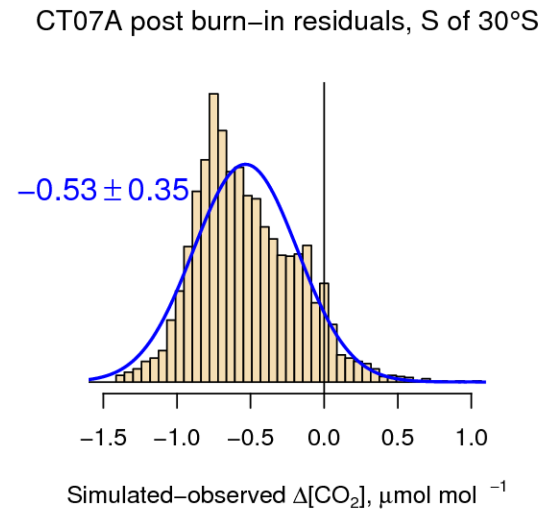

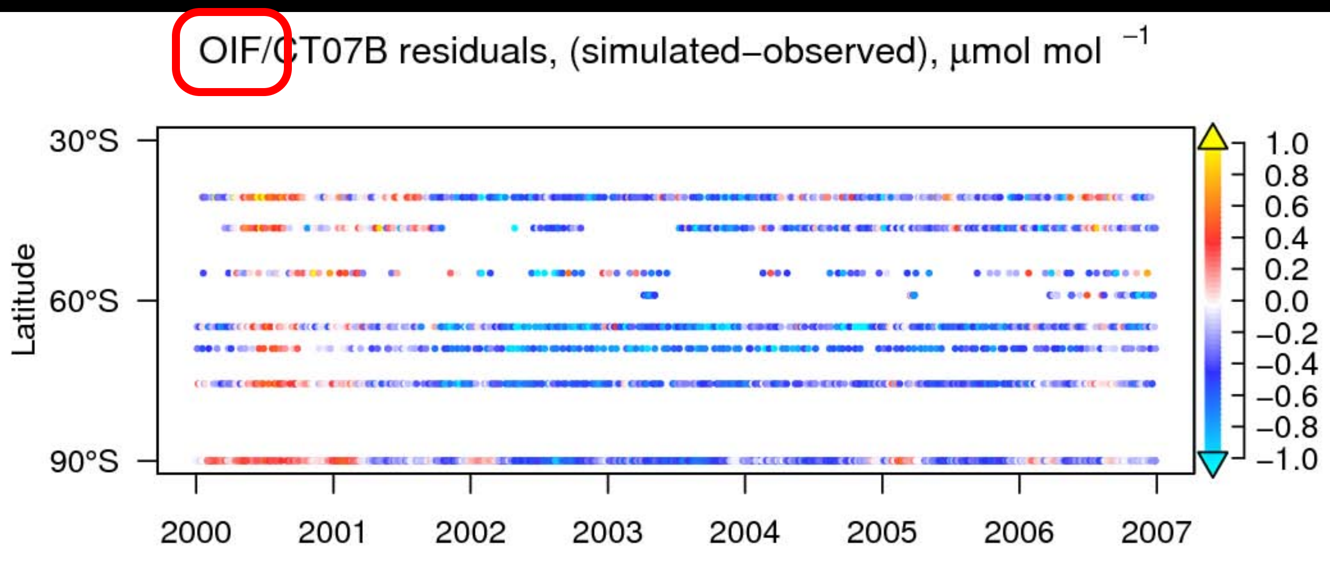

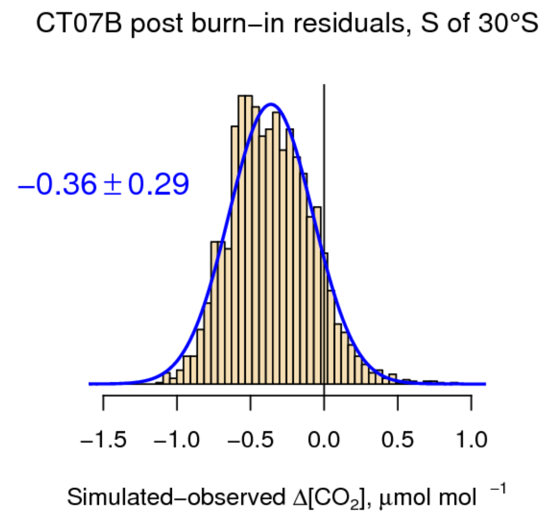

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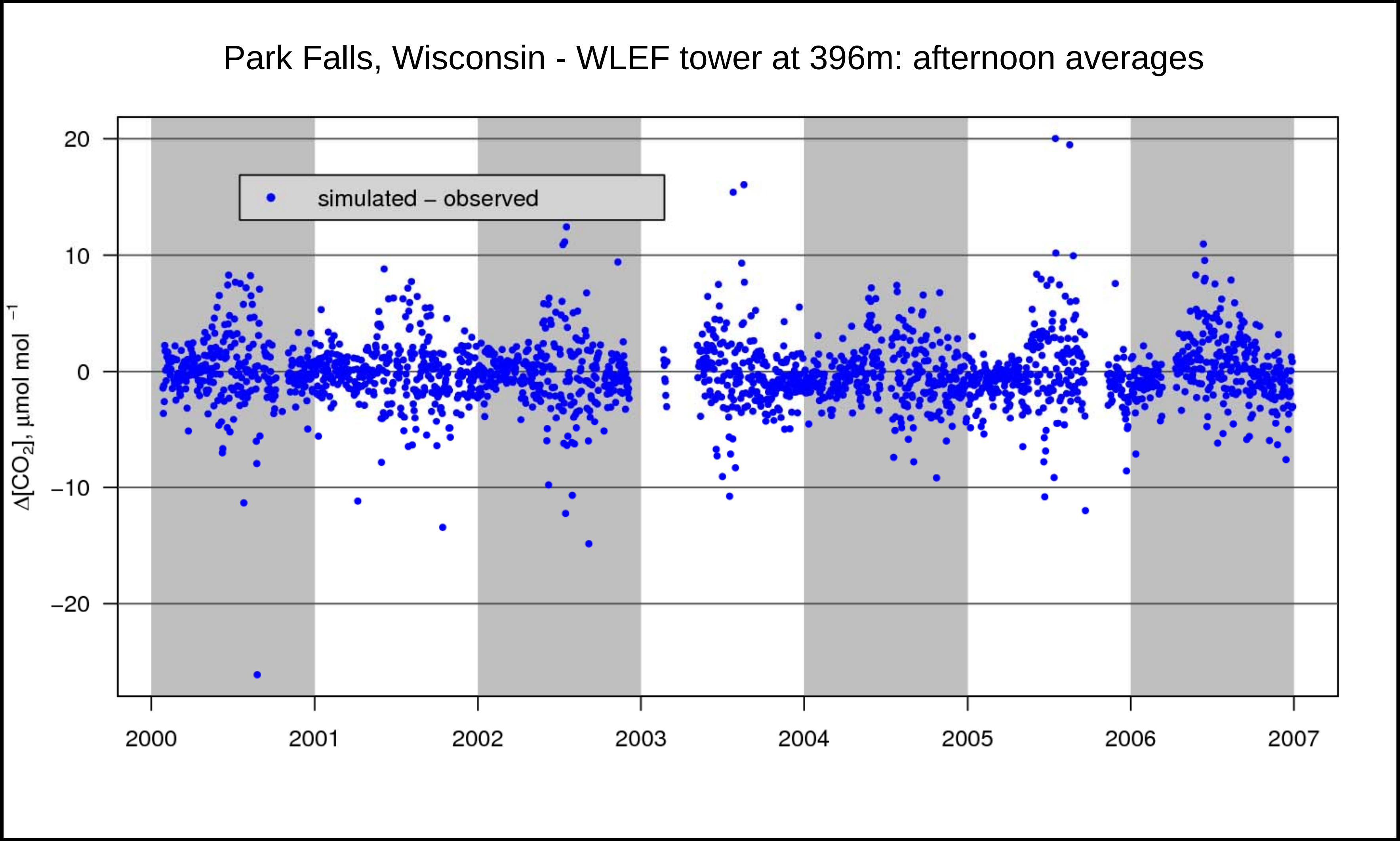

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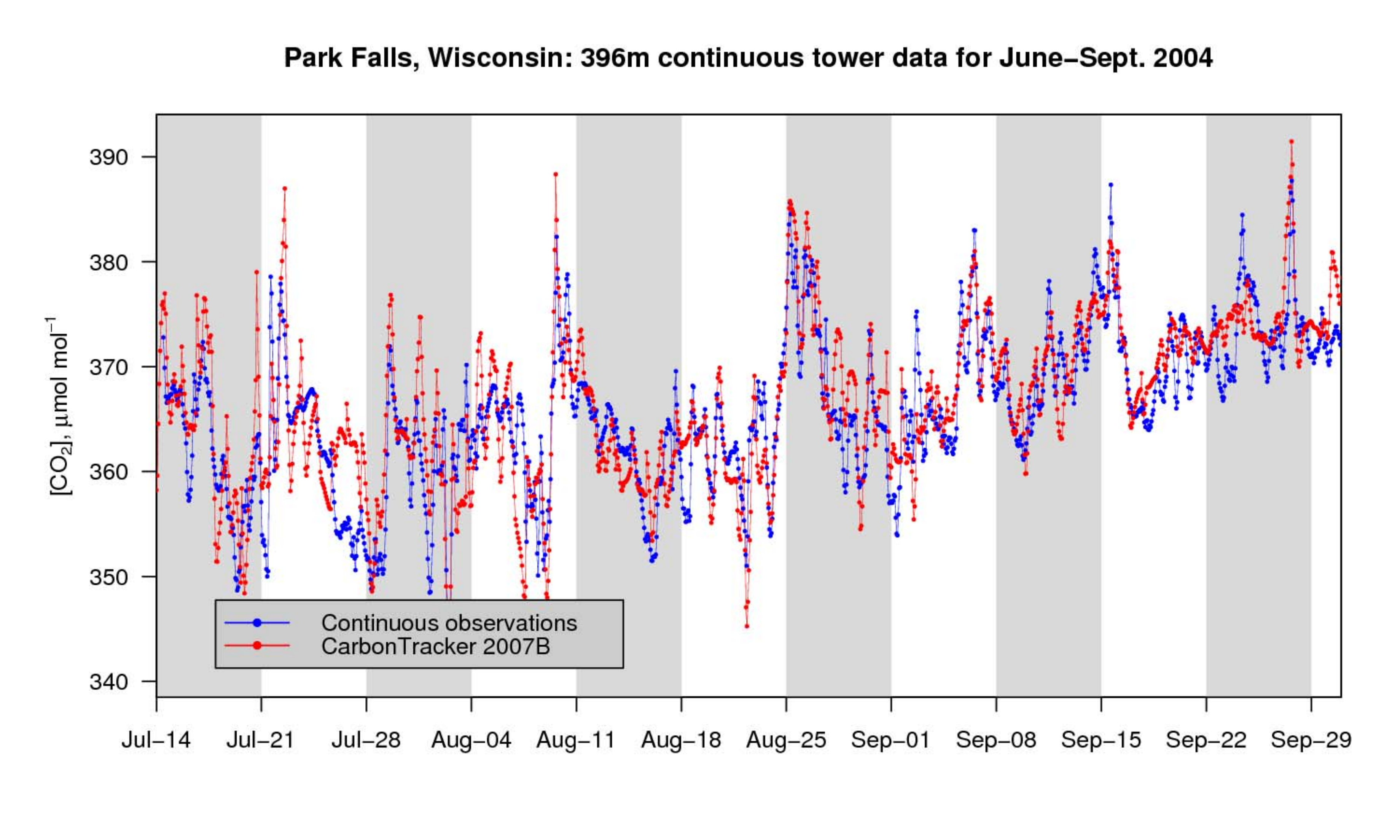

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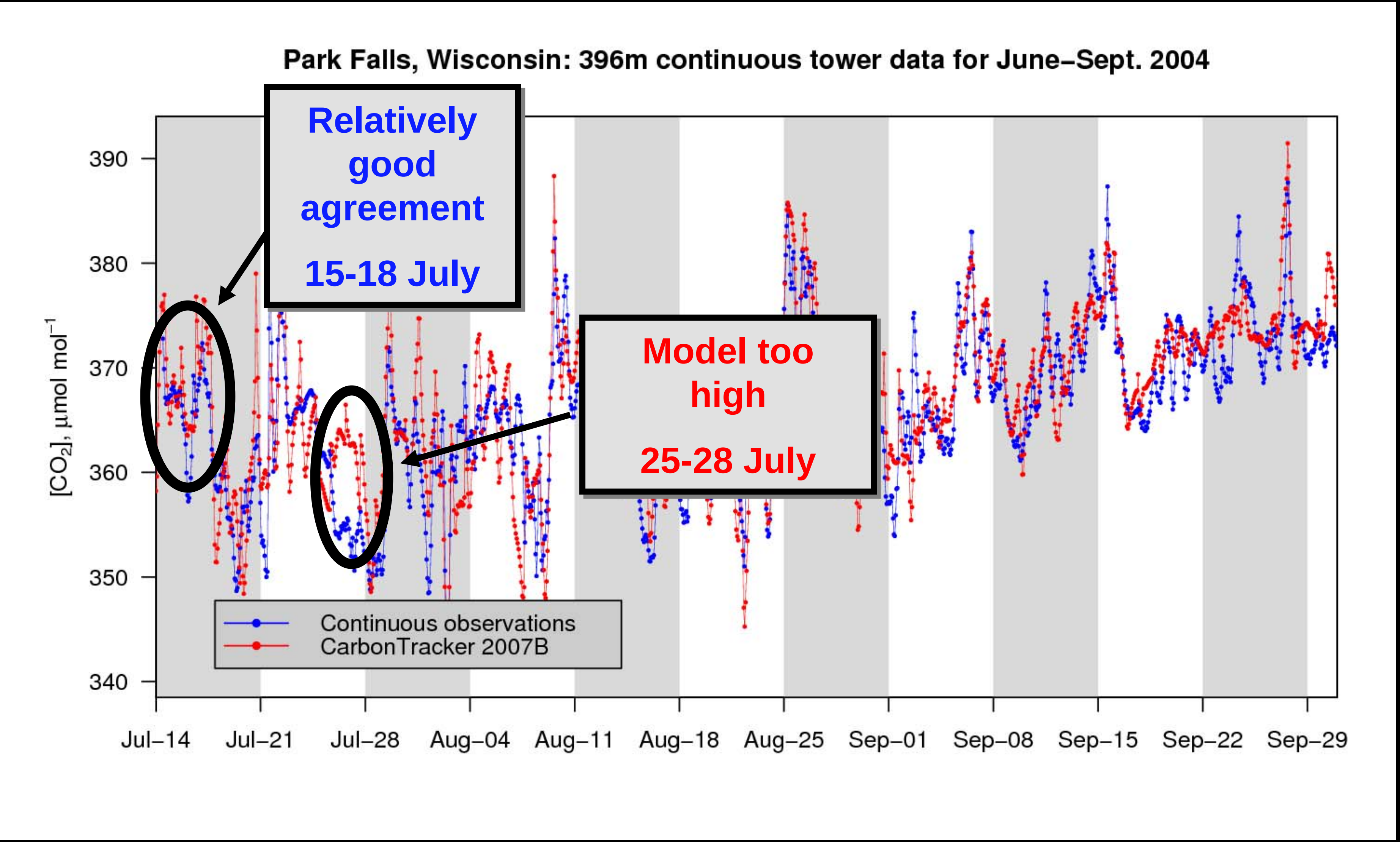
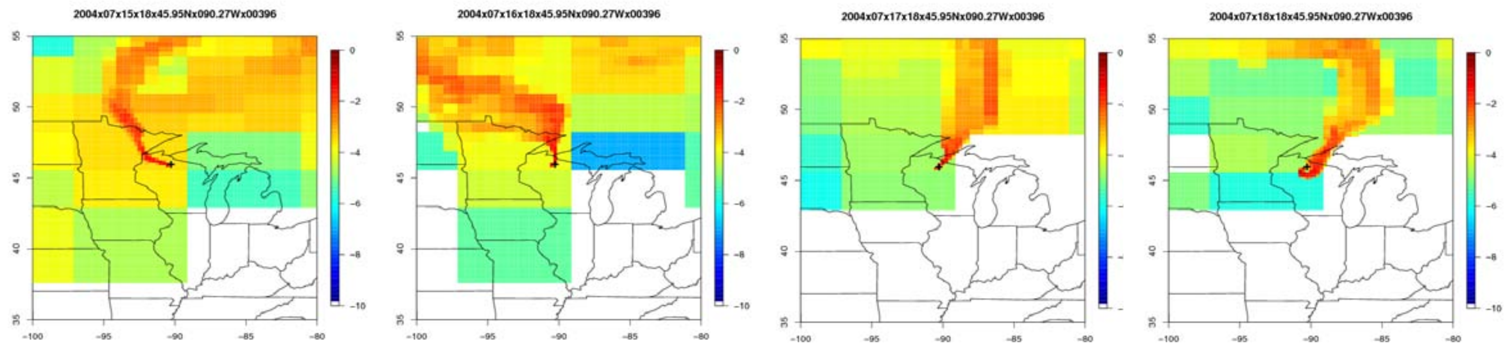


How well does *CarbonTracker* work?

STILT footprints for WLEF 396m afternoon averages

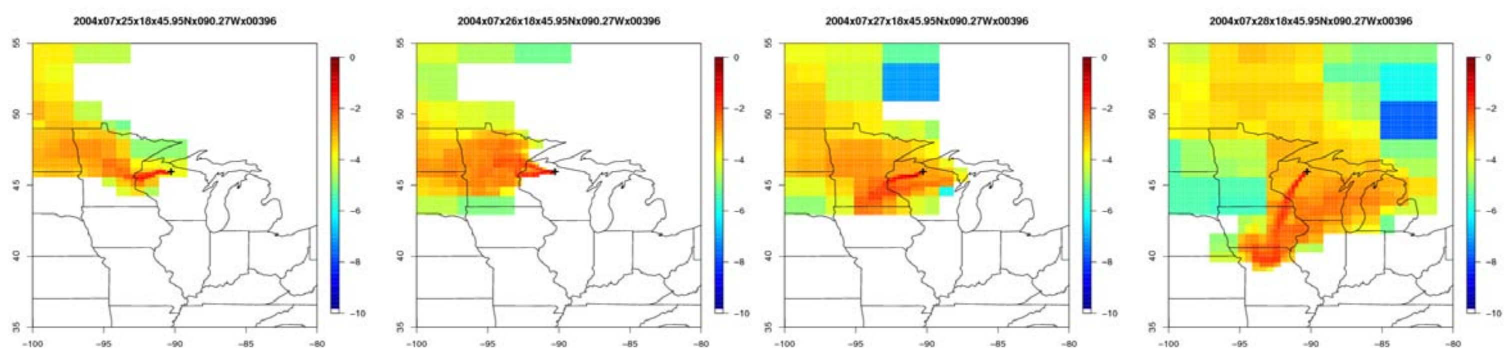
Relatively good agreement

15-18 July



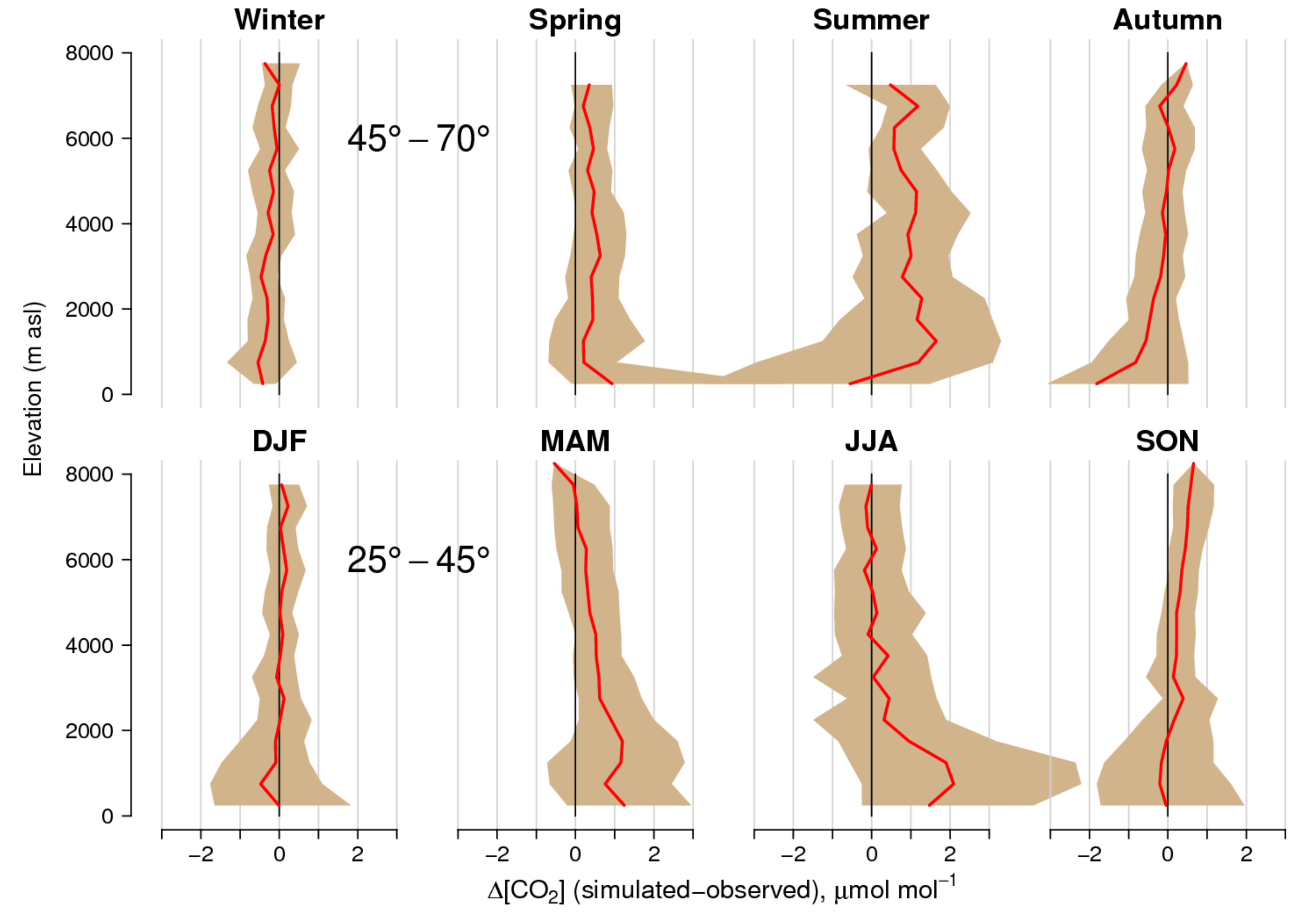
Model too high

25-28 July



How well does *CarbonTracker* work?

Aircraft residuals by latitude band and season



Improving *CarbonTracker*

Better meteorology

- higher resolution ECMWF
- adding NWS GFS to ensemble (underway)
- optimizing for vertical transport (underway)
- new NOAA models - WRF and FIMM

Add more observations

- light aircraft (underway)
- expanded N. American network for 2007 (underway)
- TCCON & OCO
- GlobalView partners (underway)

Other species

- methane (underway)
- carbon monoxide, isotopes?

Better subsystems

- land (underway), ocean (underway)
- fossil fuels: better prior (underway); optimization?

Couple with LPDM inversions

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Why *CarbonTracker*?

For NOAA

- as part of a functional observing system
- to understand changes
- to look for issues in data
- as a synthesis of the global carbon cycle

For science

- to learn about transport deficiencies
- to improve the terrestrial, oceanic, and fossil fuel process models
- to quantify how well we can resolve fluxes (synthetic data experiments)
- to evaluate new observational sites and sampling methods via OSSEs

For the public

- as an educational tool
- to provide policy-relevant information on CO_2

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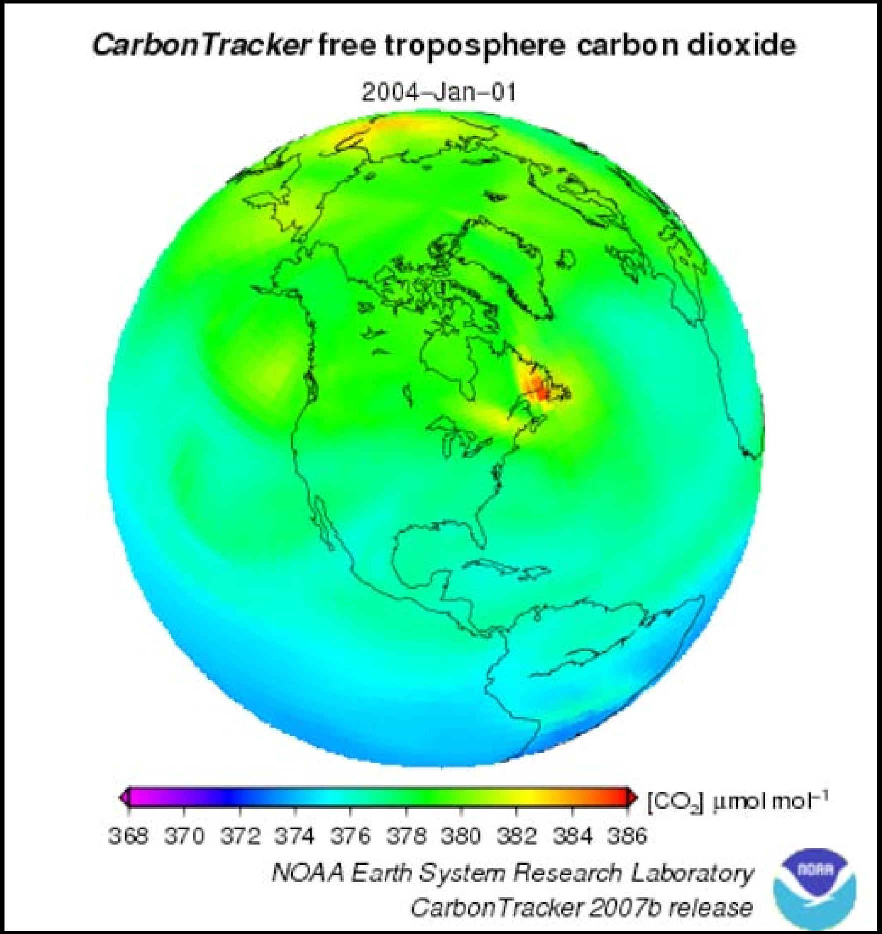

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