

The Carbon Cycle: Budgets, Trends, and Lessons from Southern Hemisphere Measurements

- A. Modelling and Interpretation
- B. Baring Head surface CO₂ data
- C. Lauder ground based remote sensing CO₂ measurements
- D. Lauder surface CO₂ data
- E. Rainbow Mountain surface CO₂ data

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... and TCCON collaborators at CalTech, JPL, and KIT

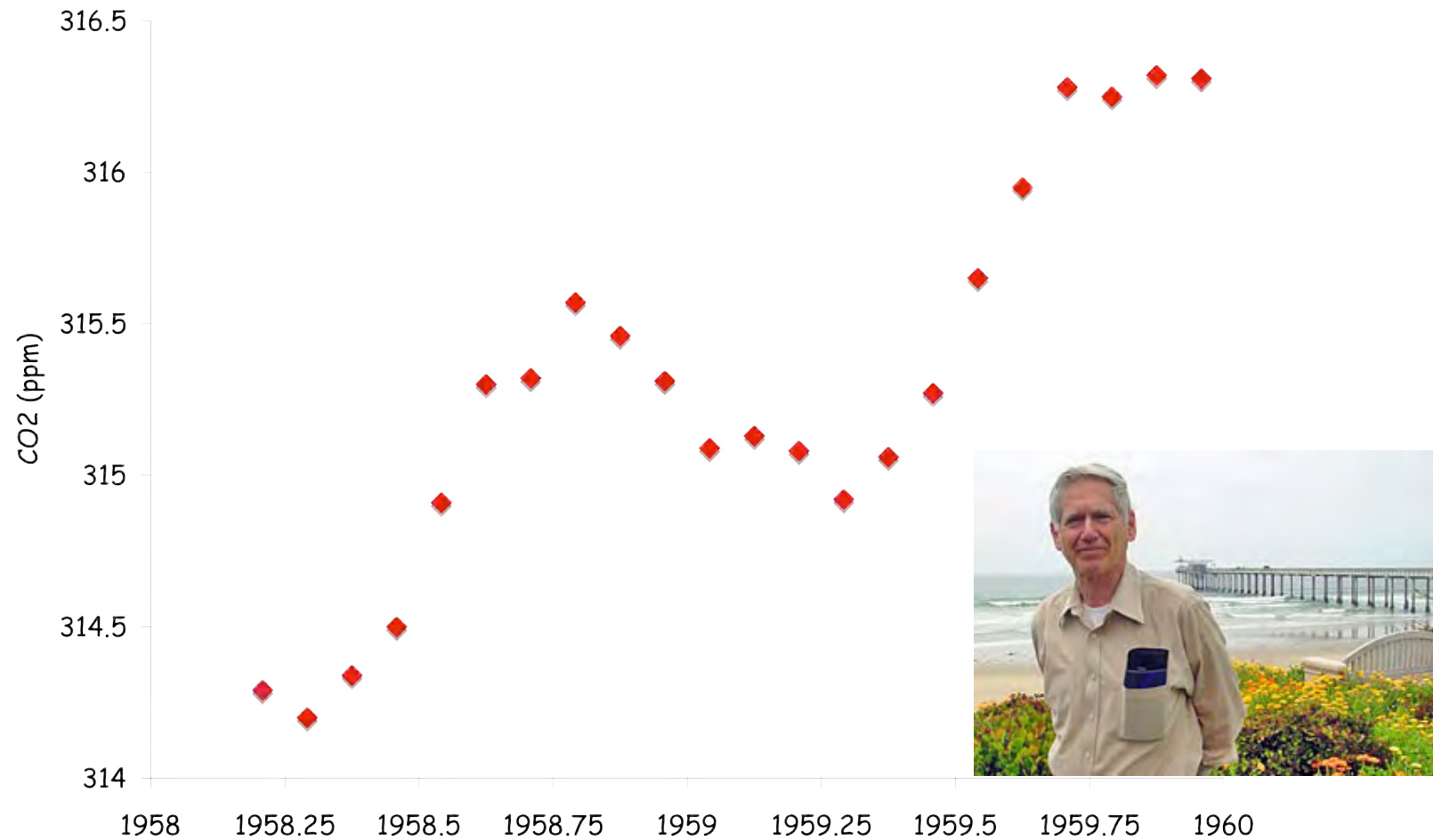
1. NIWA, NZ; 2. University of Wollongong; 3. BC Consulting, NZ; 4. National Center for Atmospheric Research (NCAR), USA

* Now at University of Bremen, Inst. Of Environmental Physics.

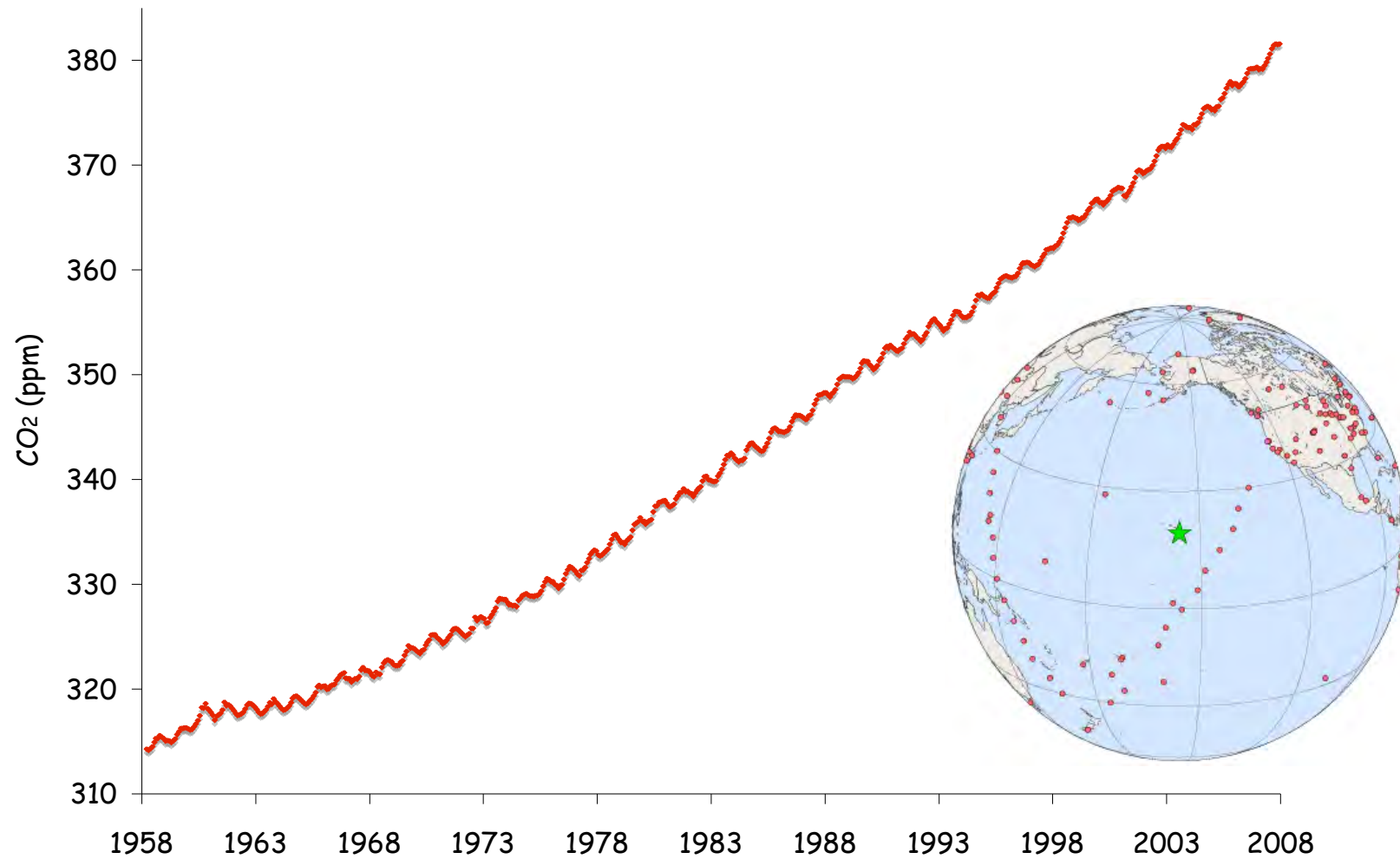
Overview

- Regional and global CO₂ fluxes to the atmosphere: overview and key science questions
- Using atmospheric trace gas measurements to infer regional carbon fluxes
 - Surface measurements
 - New remote sensing data
- Case study: Southern Hemisphere surface and remote sensing data as a new window onto biomass burning emissions

The Early Keeling Curve Atmospheric CO₂ at Mauna Loa, Hawaii

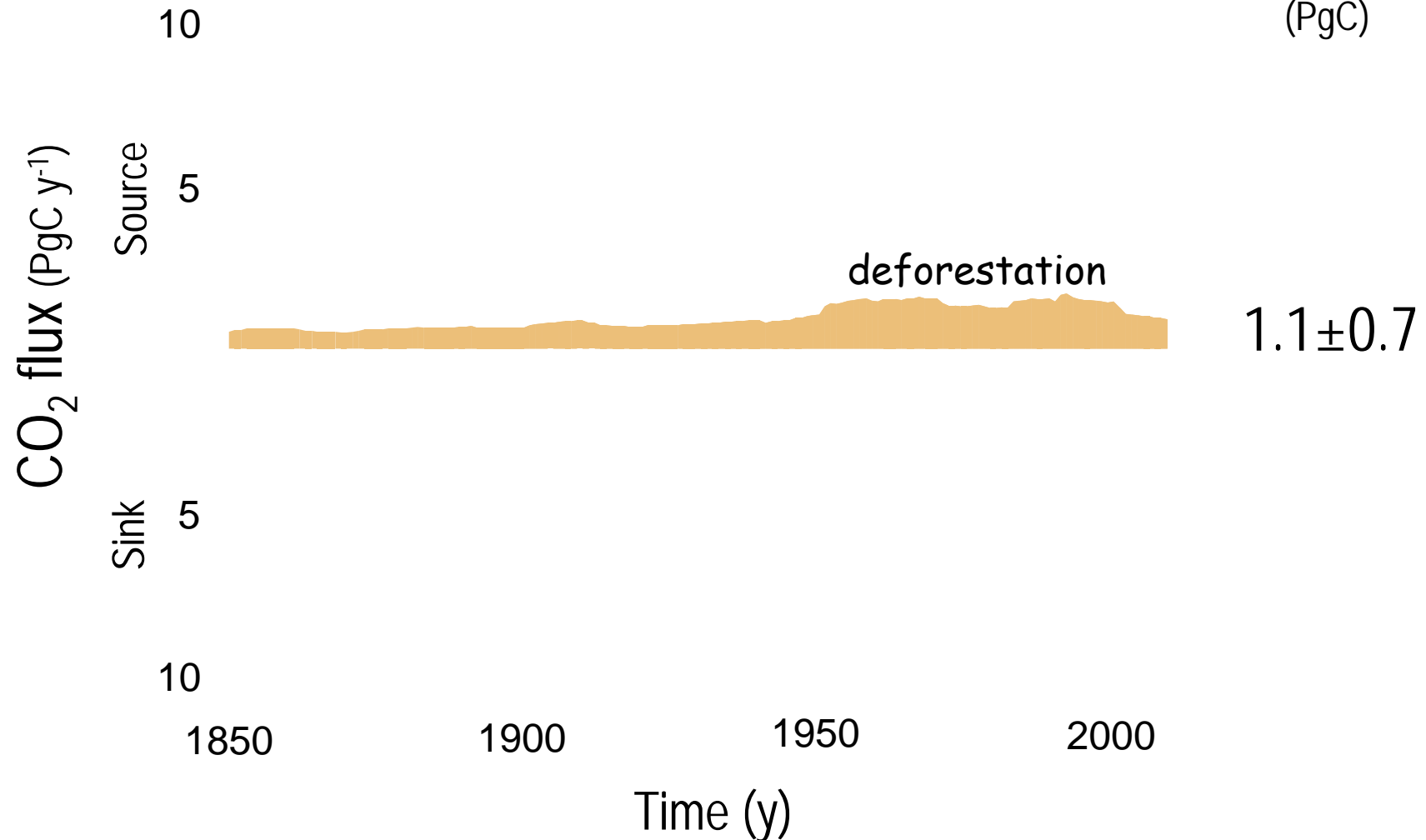


Atmospheric CO₂ at Mauna Loa, Hawaii



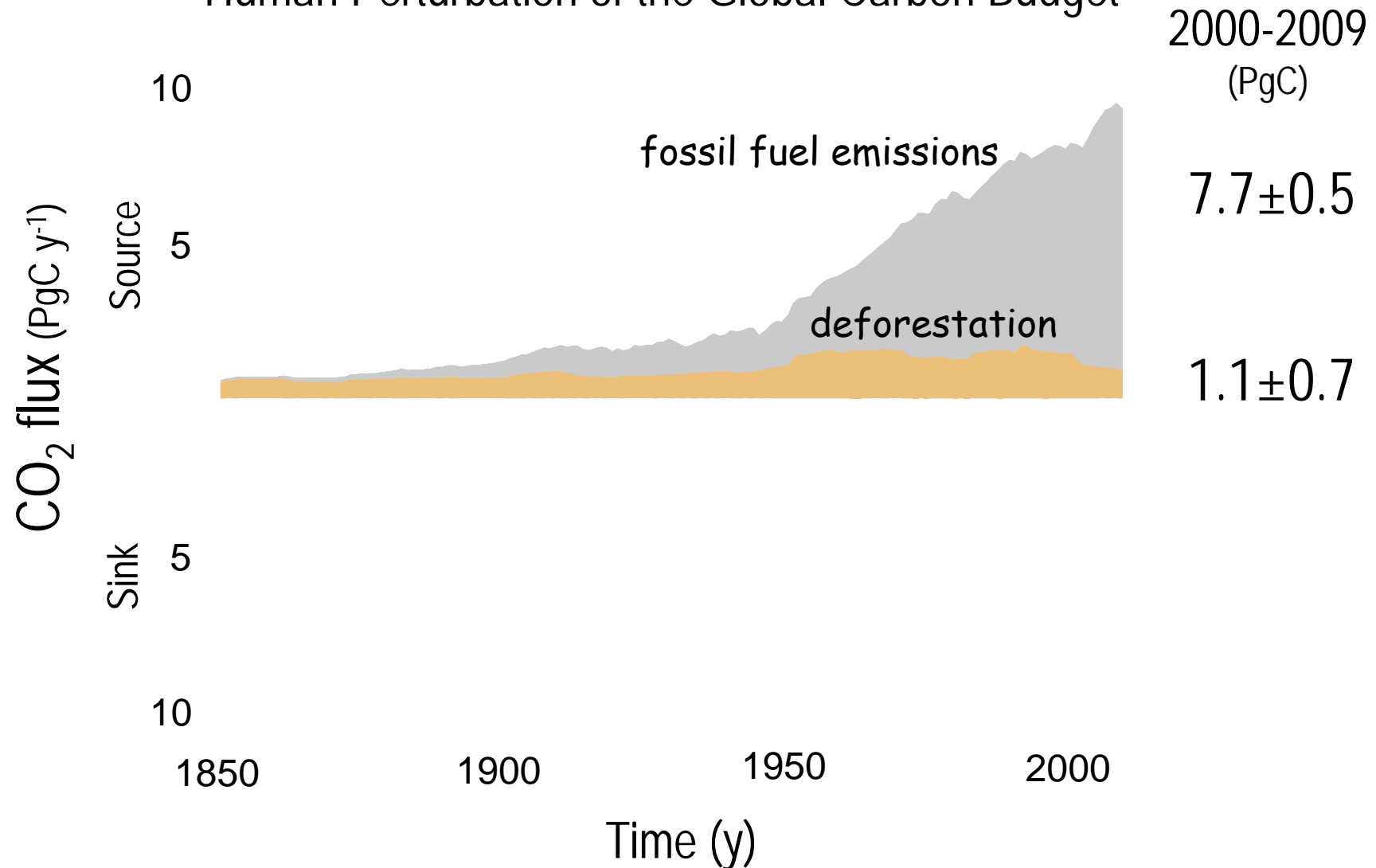
Human Perturbation of the Global Carbon Budget

2000-2009
(PgC)



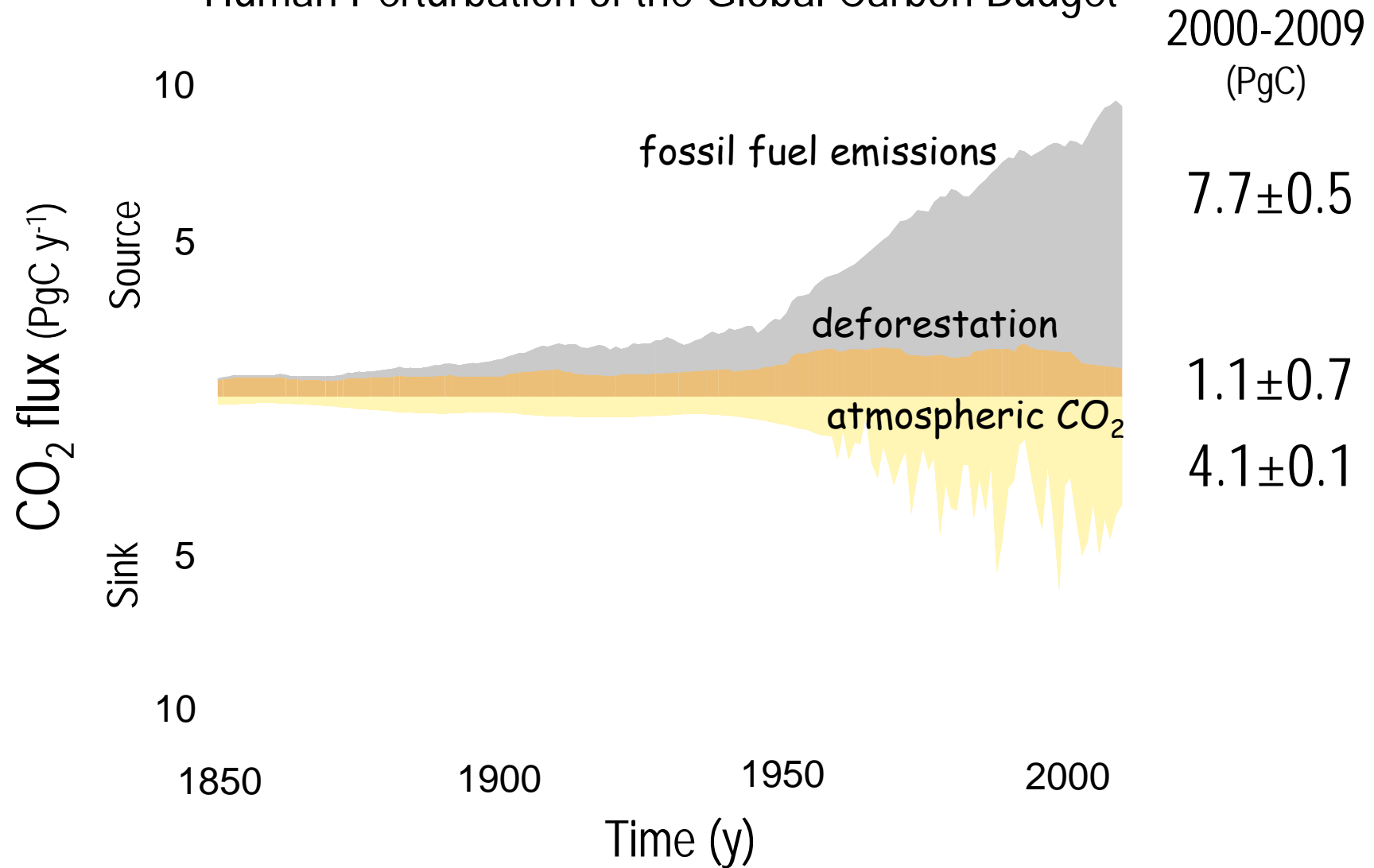
1 Petagram of carbon (PgC) = 1 billion metric tons of carbon

Human Perturbation of the Global Carbon Budget



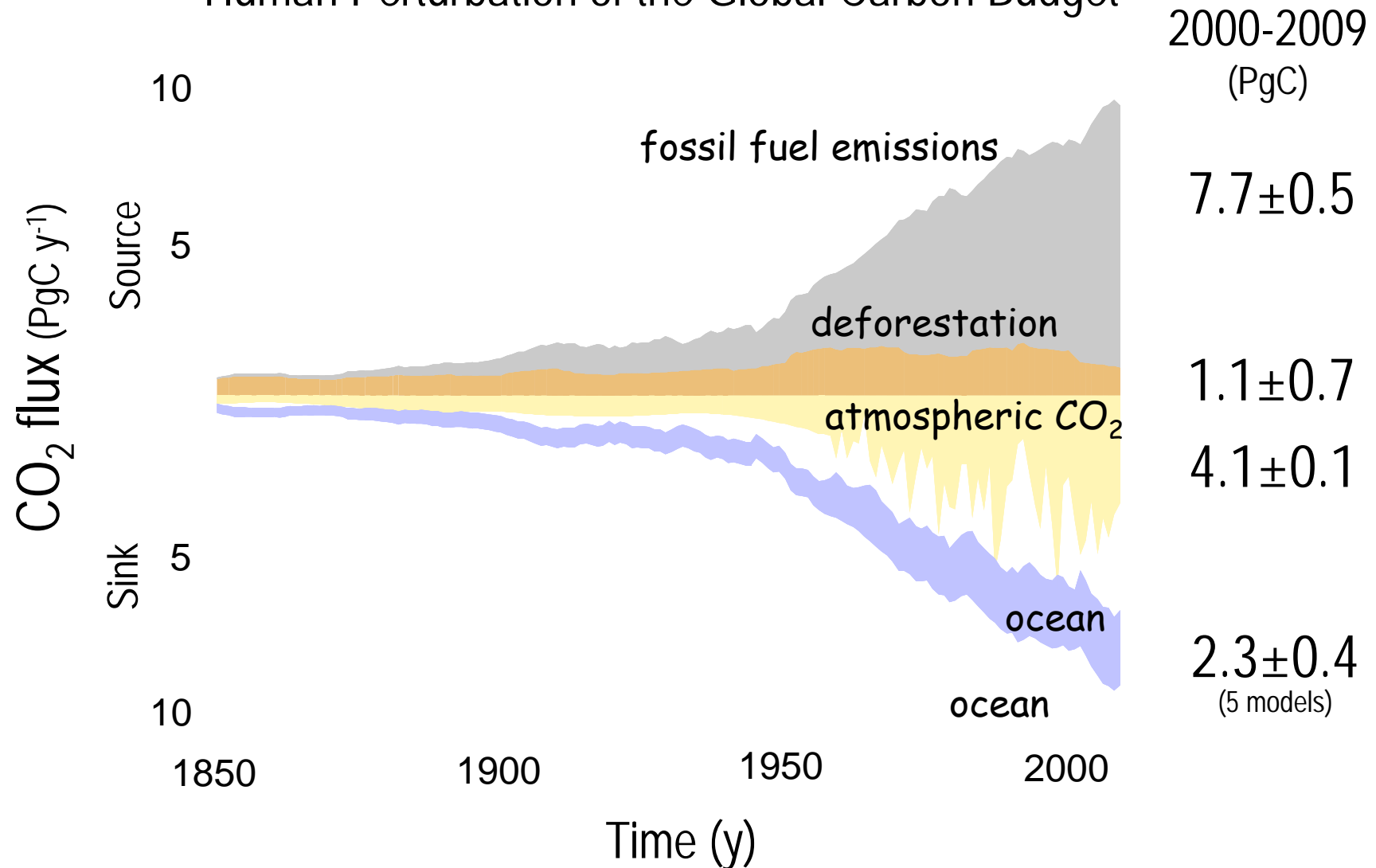
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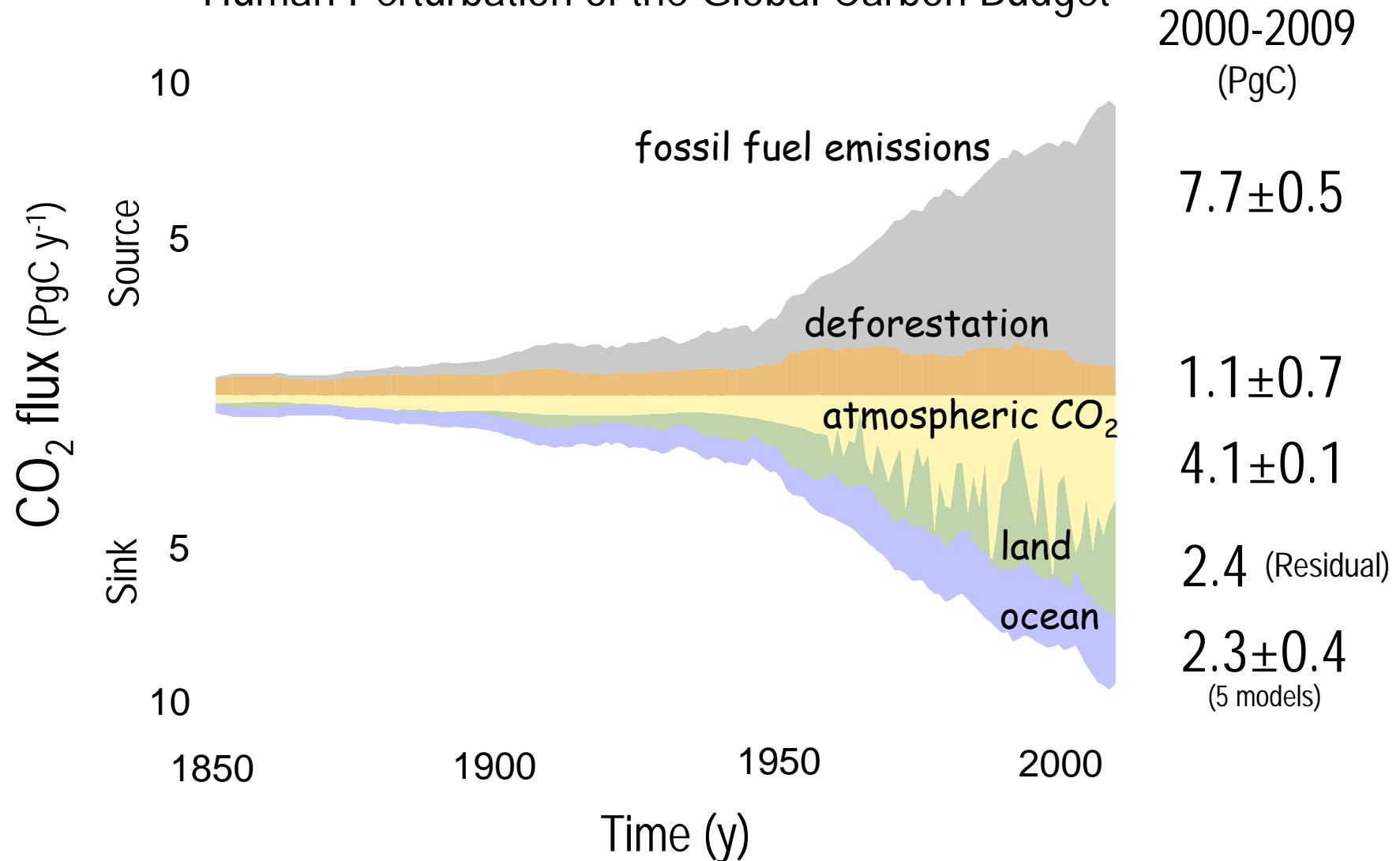
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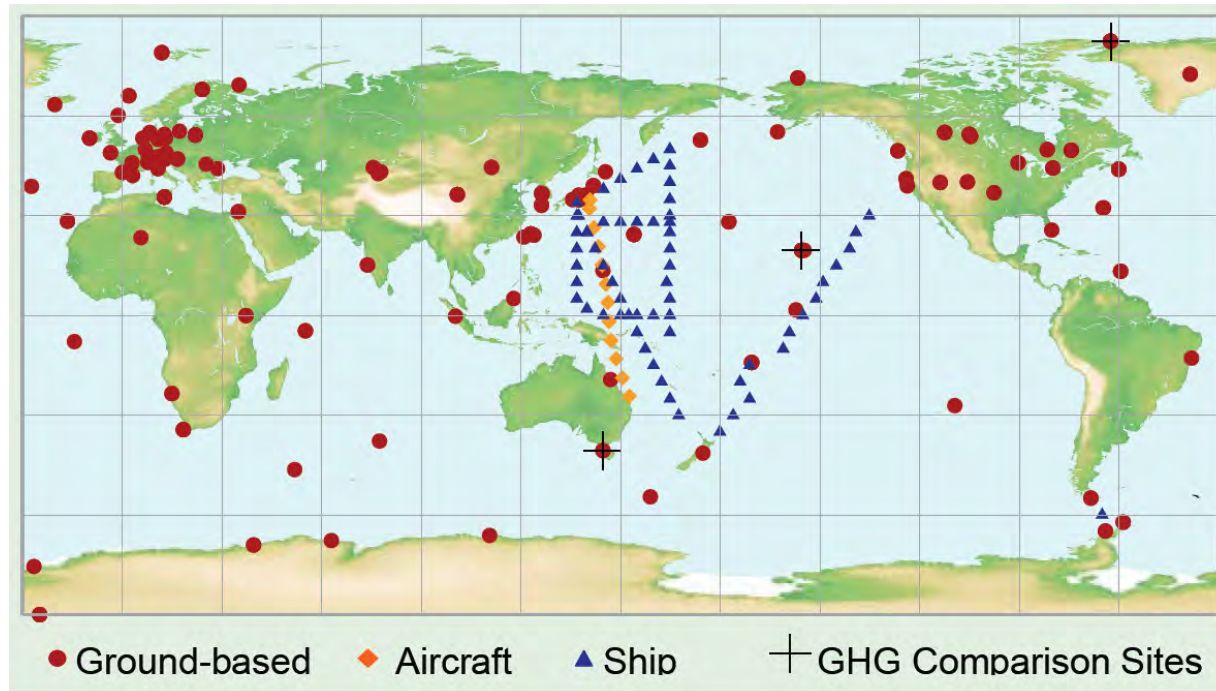
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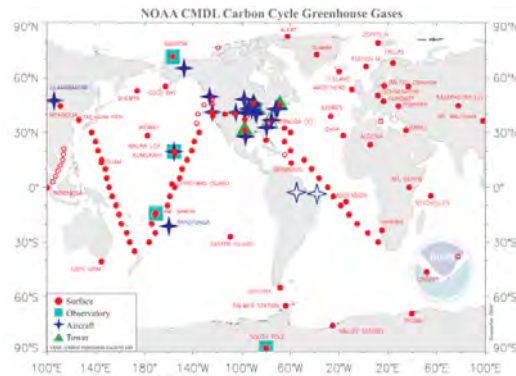
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Inferring Fluxes from Observations

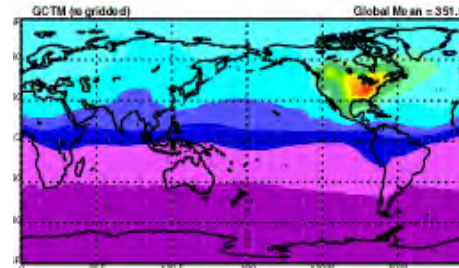


- Typically done using a network of ~100 surface sites
- Strongly limited by the observing network, especially in the tropics and Southern Hemisphere

Atmospheric Inversions

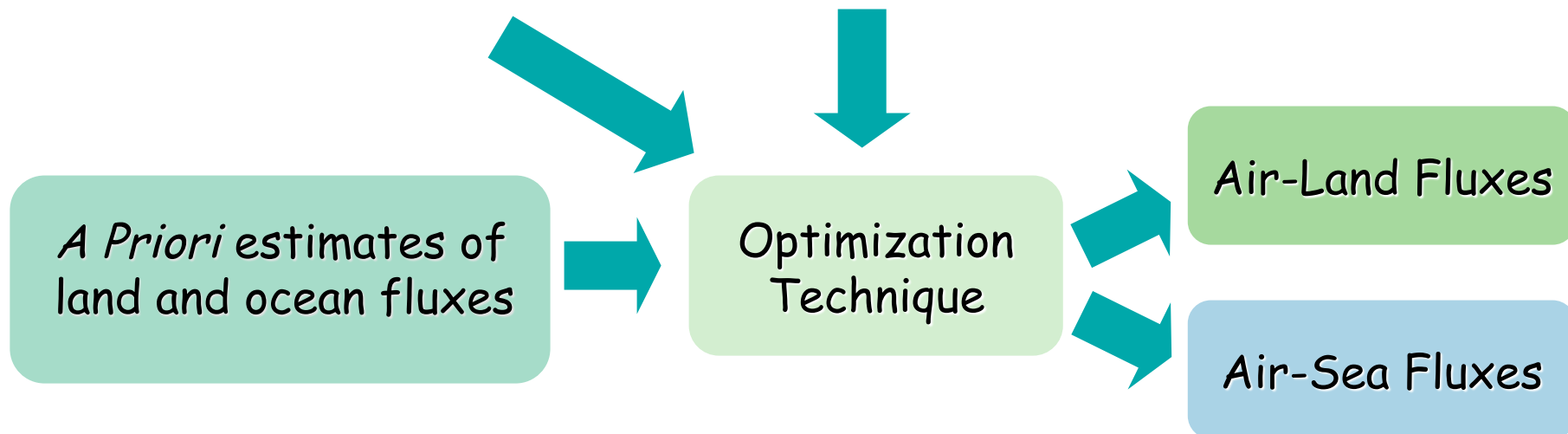


Atmospheric surface observations



North American Basis Function, courtesy of Transcom

Basis functions from atmos. transport model



Key Questions

- What are the natural sources and sinks of CO₂ to the atmosphere?
 - Tropical and southern hemisphere regions particularly uncertain
- Can atmospheric measurements be used to validate anthropogenic emissions reductions?
- What processes control variability and trends in the natural fluxes?
- What does this imply for feedbacks between climate change and the global carbon cycle?

New Zealand's Greenhouse Gas Budget

- “In 2008, New Zealand’s total greenhouse gas emissions were 74.7 million tonnes of carbon dioxide equivalent (Mt CO₂-e), which means total emissions are now 13.9 Mt CO₂-e (22.8%) higher than the 1990 level of 60.8 Mt CO₂-e.”*
- “In 2008, net removals from afforestation, reforestation and deforestation under the Kyoto Protocol were -14.4 Mt CO₂-e.”*
- Atmospheric measurements and modeling provide an opportunity for independent, top-down verification of carbon sequestration in forests

* New Zealand’s Greenhouse Gas Inventory 1990-2008
Ministry for the Environment, April 2010

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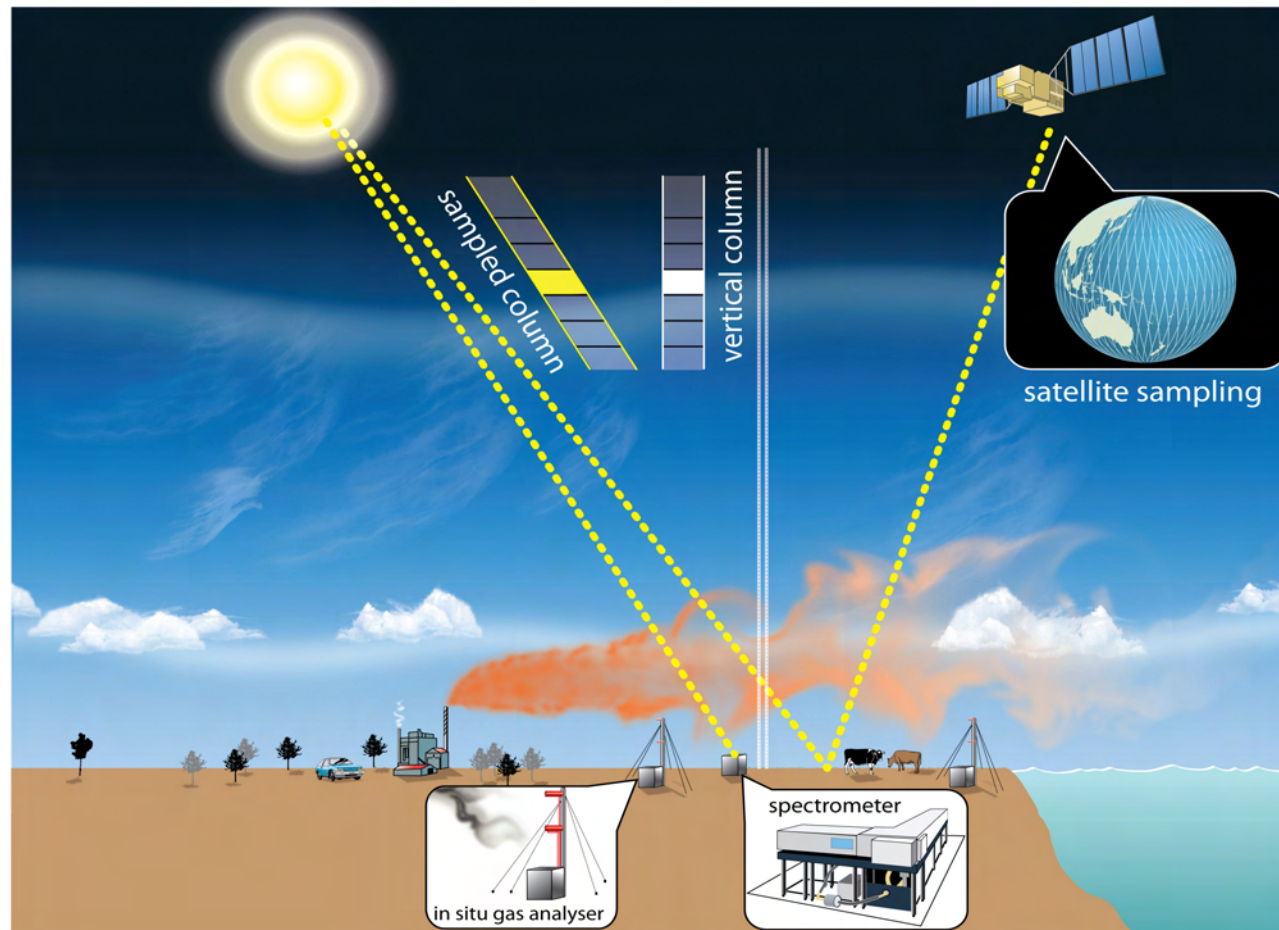
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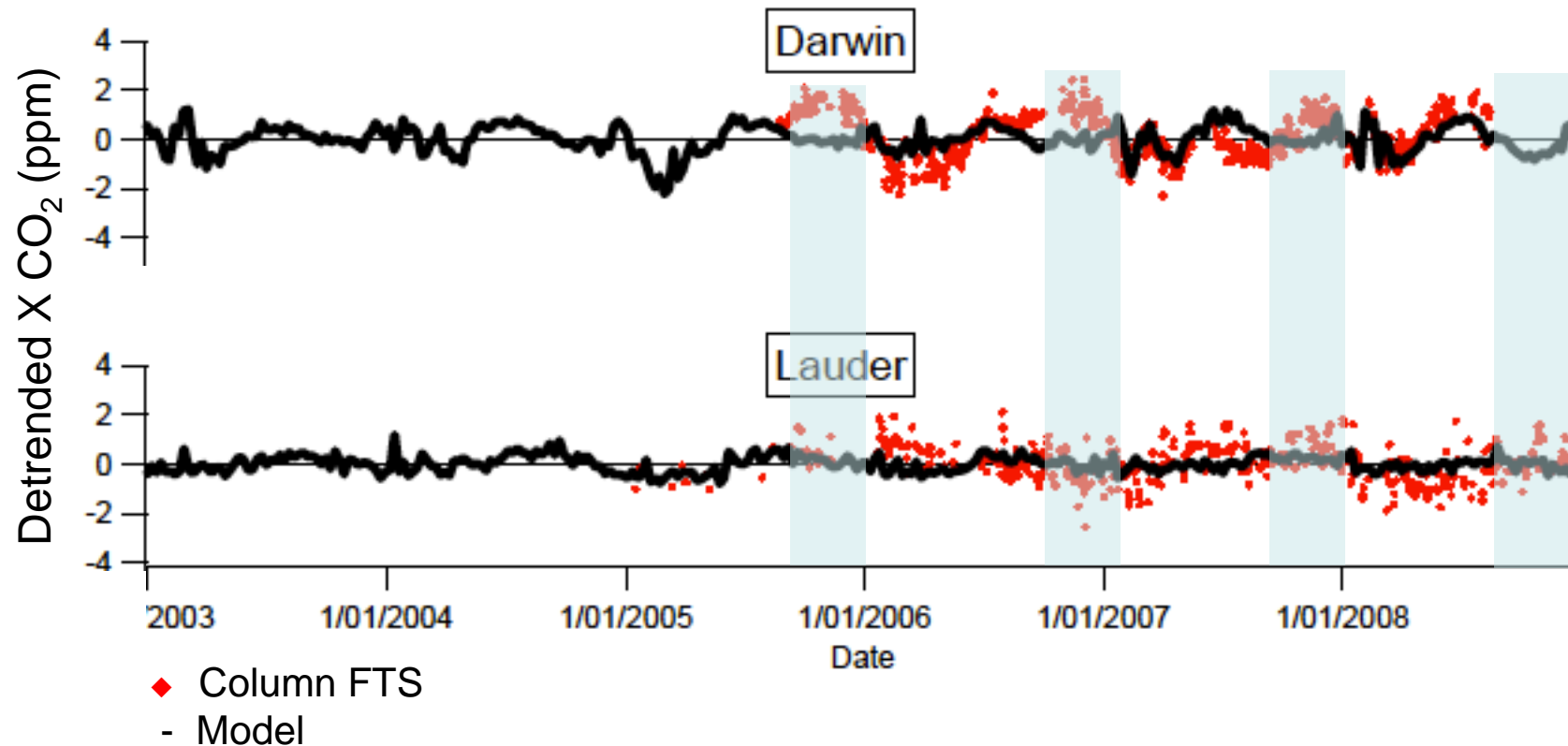
Contrasting Column and Surface Measurements



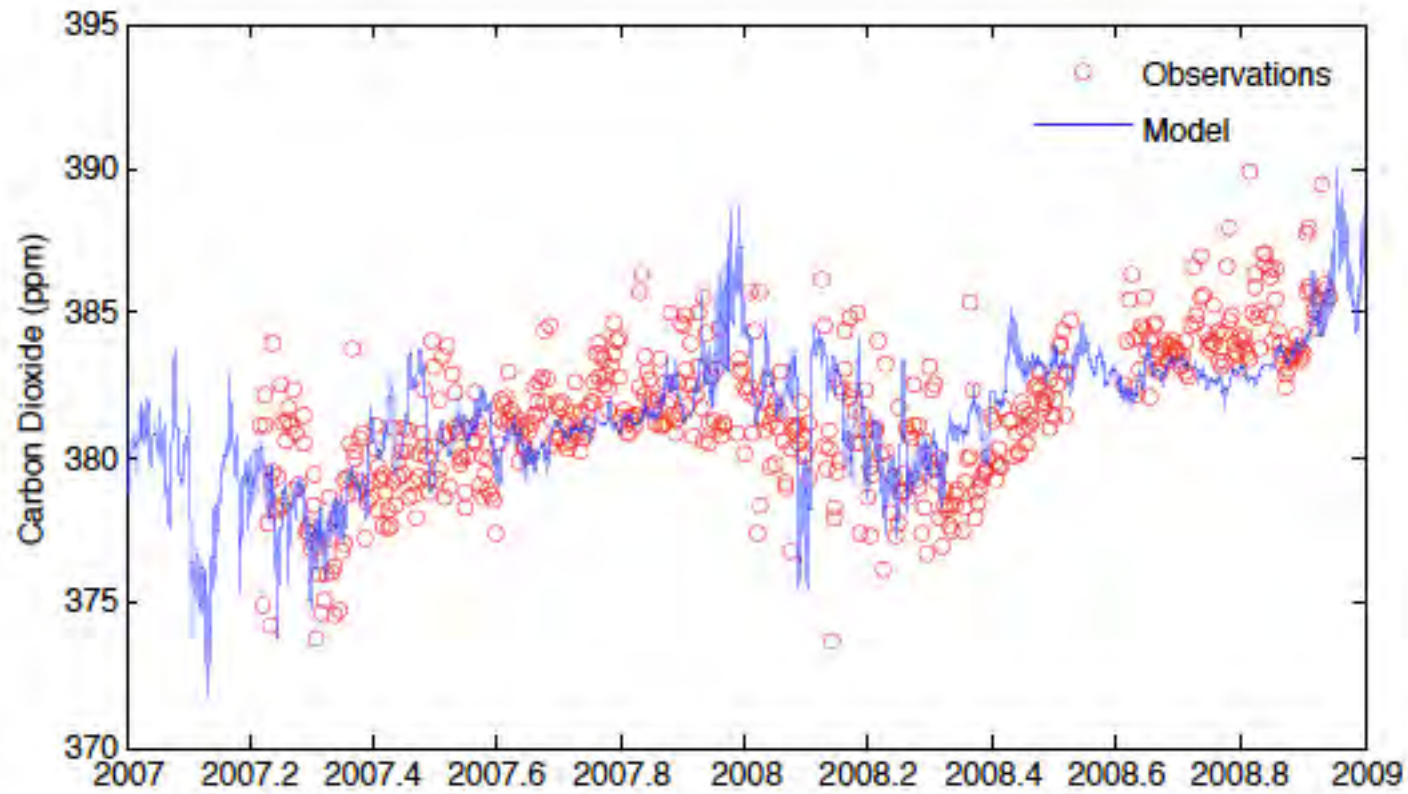
Southern Hemisphere TCCON stations



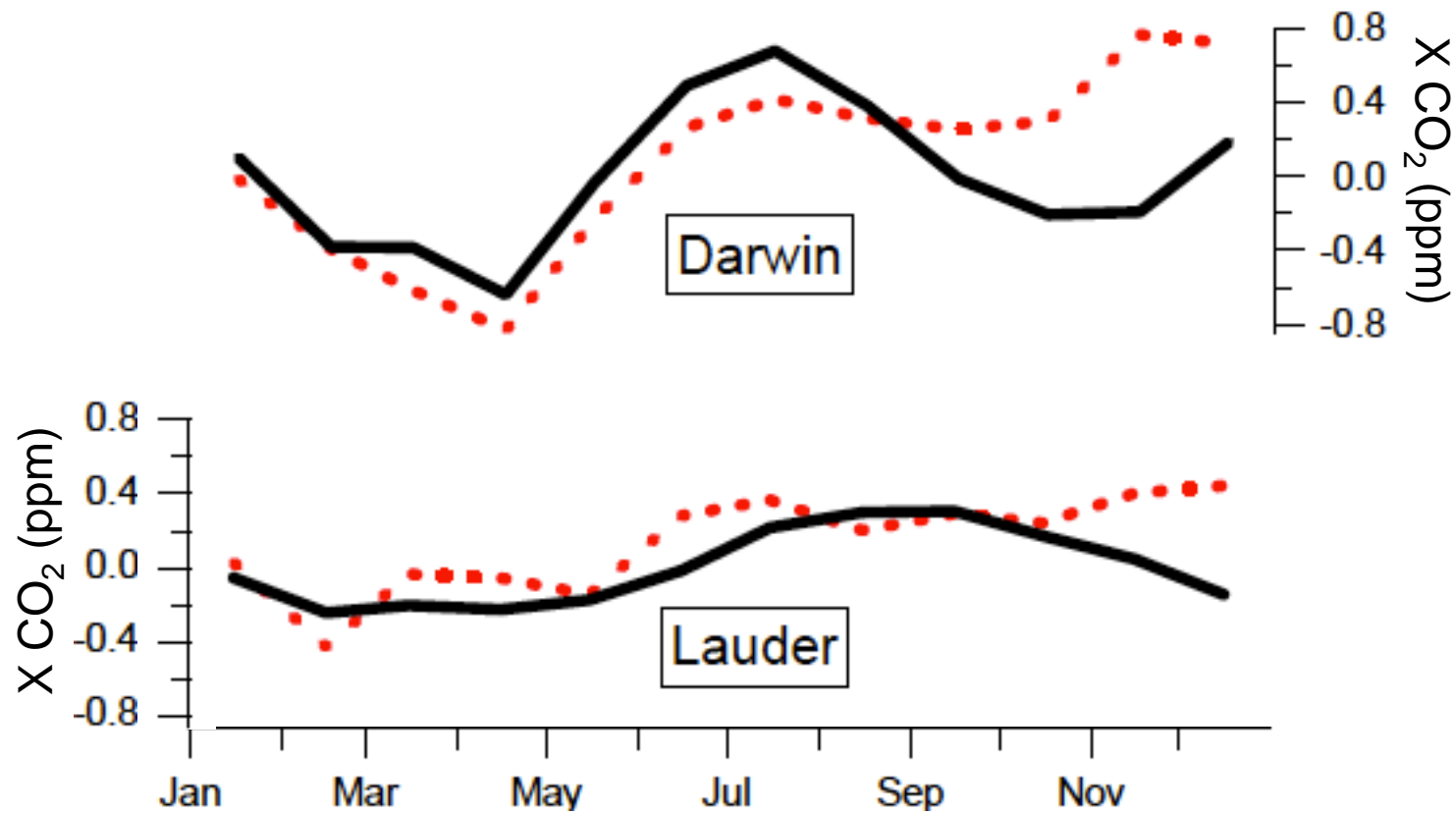
A Puzzle in the Southern Hemisphere Data



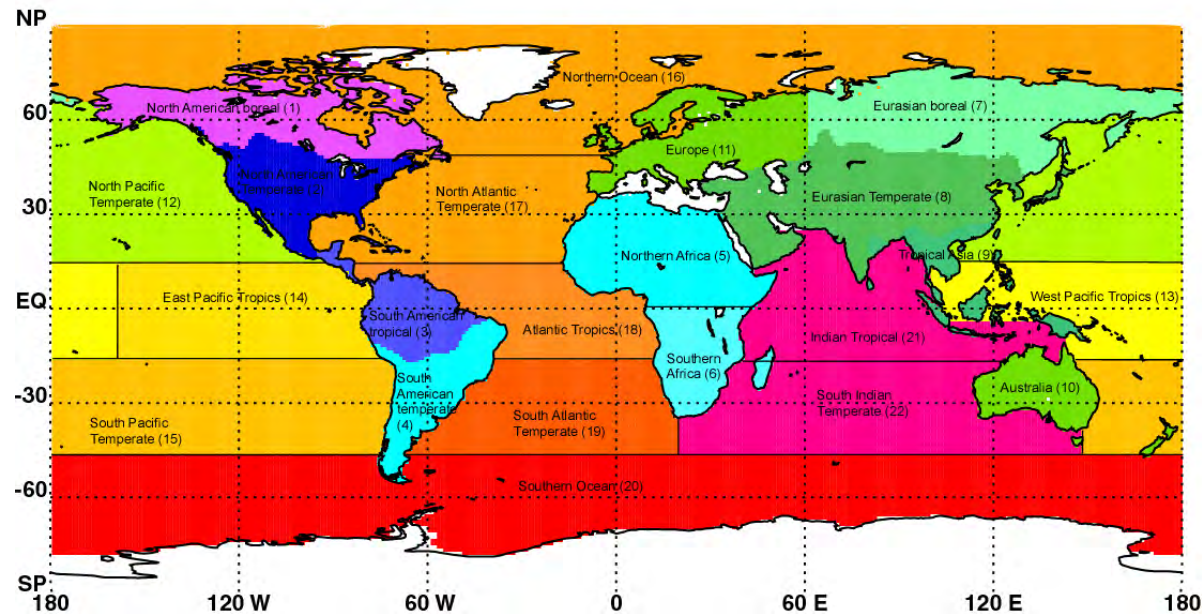
Surface *In Situ* CO₂ at Darwin, AU



The Seasonal Cycle in the Column Observations

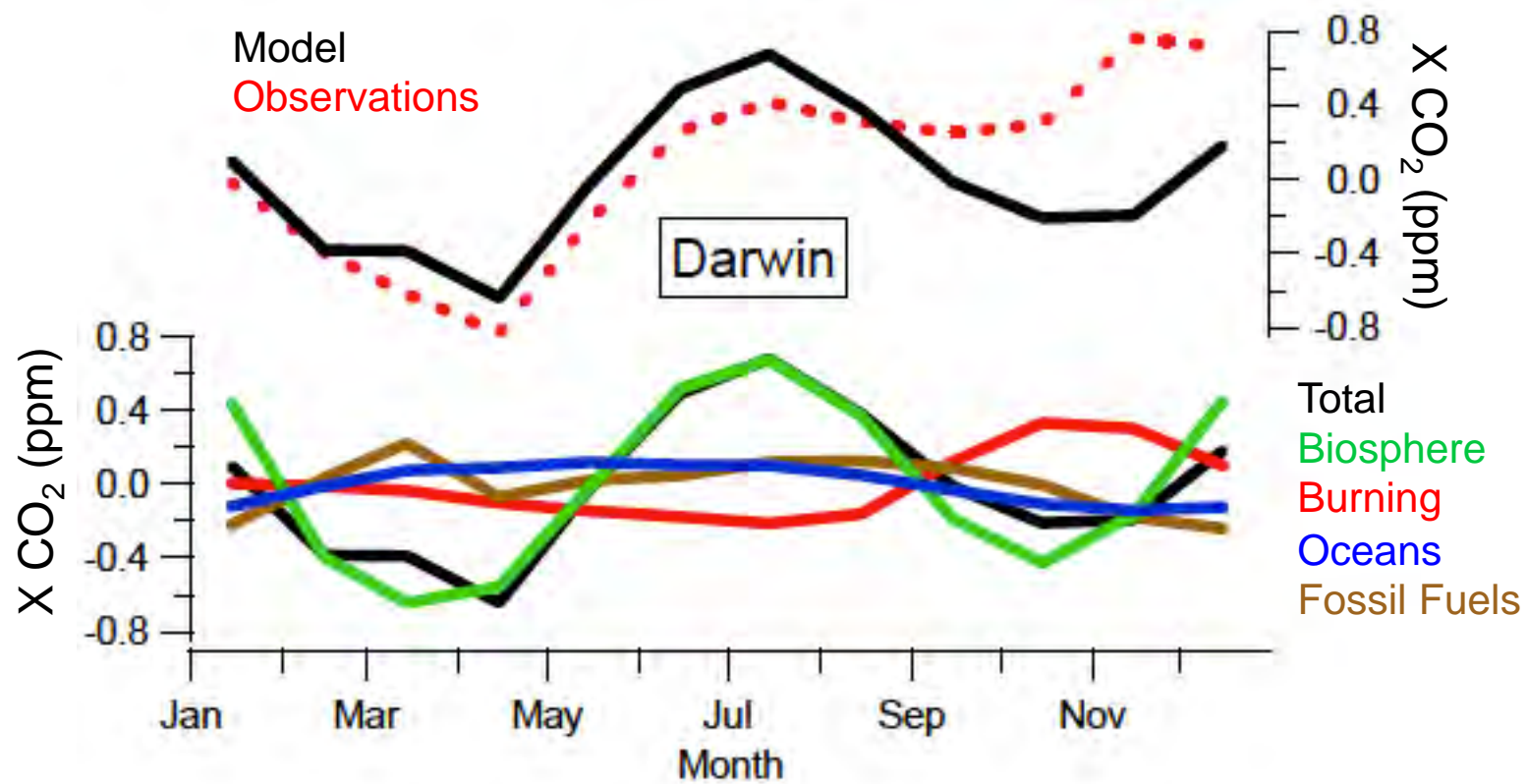


CarbonTracker Tagged Tracer Simulations

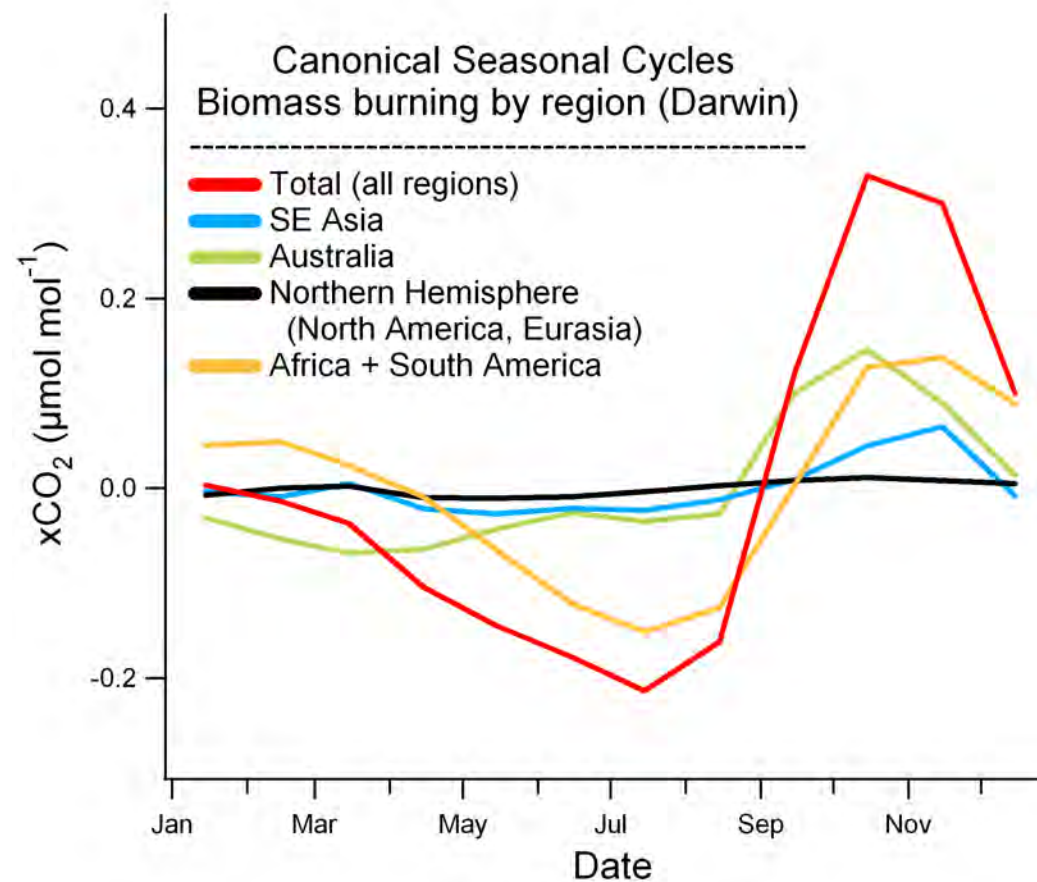


- CarbonTracker fluxes optimized against the surface network
 - Tagged forward simulations with optimized 2009 CT fluxes
- Separate tracer tags for:
 - each of the 22 Transcom regions + AU/NZ split
 - fossil fuel, biomass burning, terrestrial biosphere, ocean flux

Contribution of Source Processes to the Column Seasonal Cycle



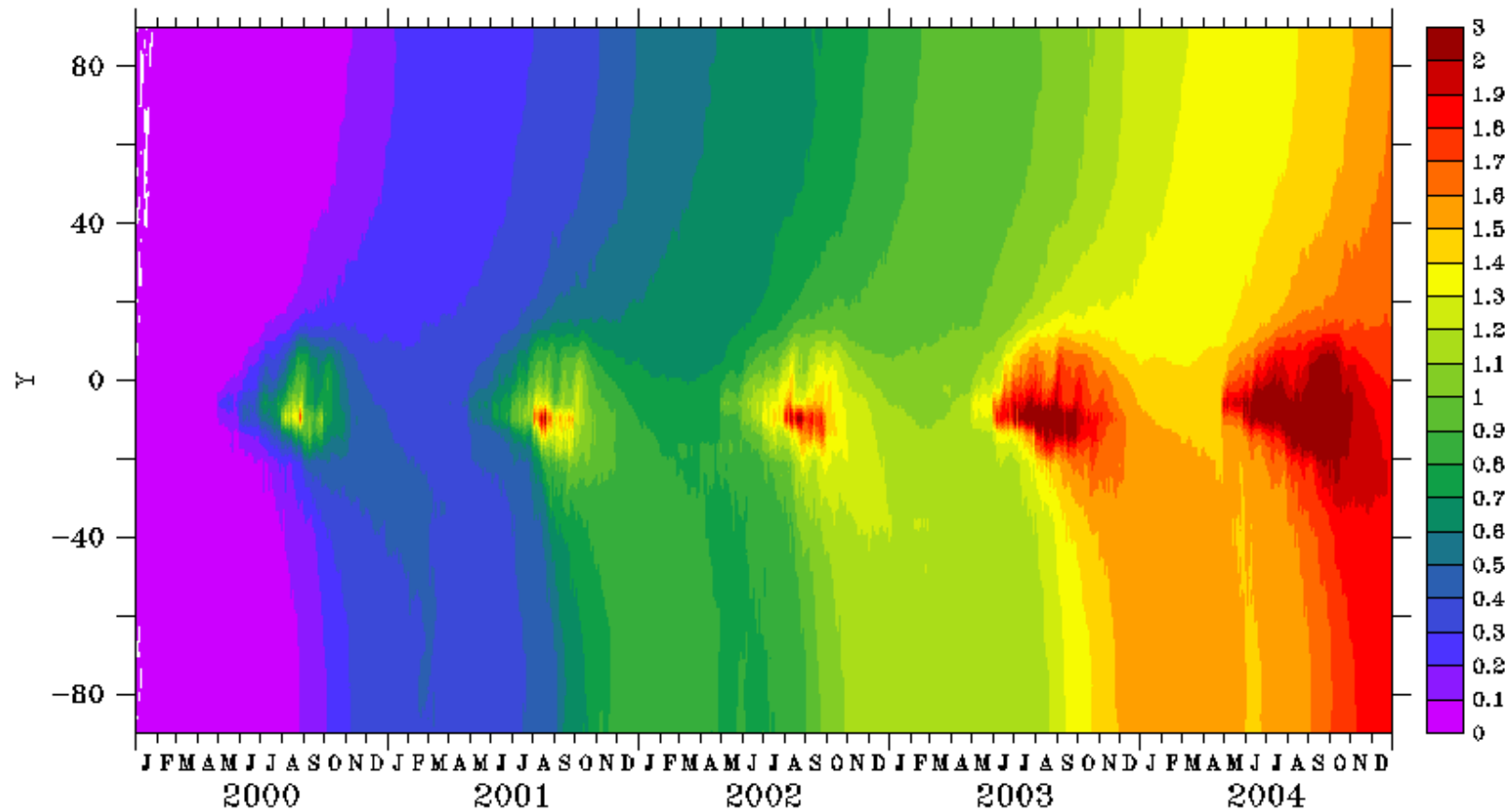
Where Does the Biomass Burning Signal in the Column Data Come From?



How does this fit with what is known about biomass burning emissions?

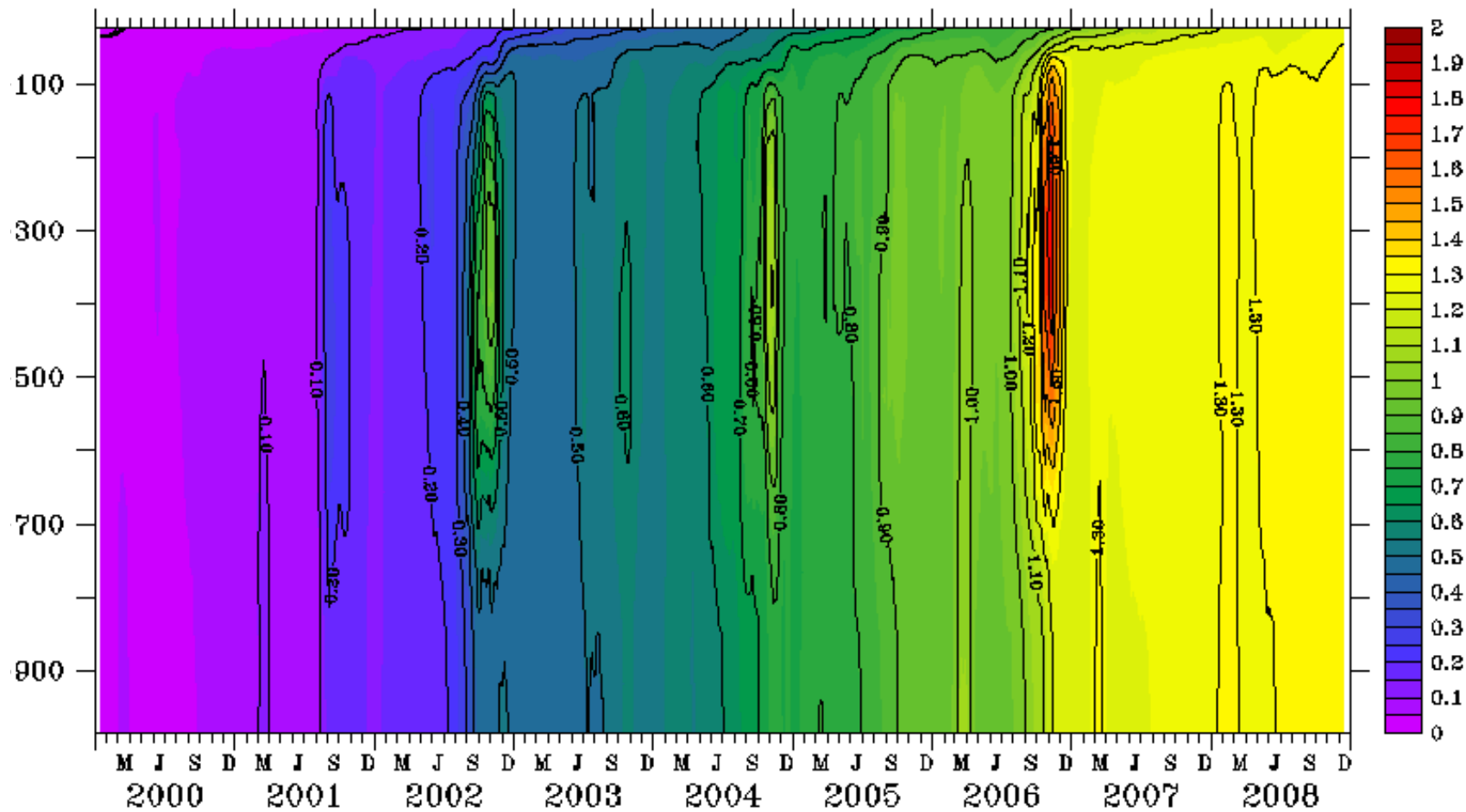
- If the model-data mis-match is due to biomass burning alone, it would imply that the South American+African biomass burning emissions are under-estimated by nearly a factor of two
- The GFED emissions are based on satellite data, and generally considered to under-estimate biomass burning emissions
- CarbonTracker doesn't optimise biomass burning emissions
- However, other tracers associated with biomass burning peak at Darwin and Lauder ~2 months earlier than the seasonal model-data mismatch in CO₂...

Zonal Mean Biomass Burning Emissions From South America and Africa



Temperate South America and Africa

Vertical Profile of South East Asian Biomass Burning Footprint at Darwin (ppm)



Could this be due to a bias in the model transport?

- *Houweling et al. [2010]* compared TCCON data to four atmospheric models using the CT fluxes as boundary conditions
- They found similar seasonal biases at Darwin for all of the models
- However, there could be biases common to all the models or the the reanalysis fields forcing them
- Comparisons with aircraft data may provide a degree of independent validation

Conclusions and Outlook

- Between 2000-2009, human beings emitted 7.7 ± 0.5 PgC/yr to the atmosphere from fossil fuel burning and cement production and another 1.1 ± 0.7 PgC/yr from land use change
- The natural sinks took up over half of these emissions, with the ocean absorbing 2.3 ± 0.4 PgC/yr and the terrestrial biosphere taking up 2.4 PgC/yr
- Model simulations suggest that the combination of surface and column data in the Southern Hemisphere may provide a new window onto terrestrial fluxes from South America and Africa
- Future work will focus on
 - Analysis of atmospheric CO₂ simulations to understand observations
 - Assimilating new column and surface data using CarbonTracker

Thanks to:

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 - NIWA: FRST, ISAT
 - UoW: ARC
 - NIES
 - NASA, CalTech