
Global carbon budget from three atmospheric inversions

Ingrid van der Laan-Luijkx

Wageningen University & Research and ICOS-Carbon Portal

Christian Rödenbeck, Frédéric Chevallier,
Corinne Le Quéré, Philippe Ciais, Wouter Peters

Global Carbon Budget



Global Carbon Budget 2015

Open Access Earth System Science Data

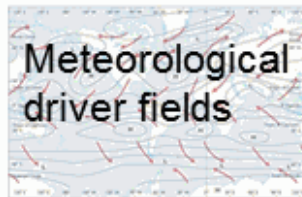
C. Le Quéré¹, R. Moriarty¹, R. M. Andrew², J. G. Canadell³, S. Sitch⁴, J. I. Korsbakken², P. Friedlingstein⁵, G. P. Peters², R. J. Andres⁶, T. A. Boden⁶, R. A. Houghton⁷, J. I. House⁸, R. F. Keeling⁹, P. Tans¹⁰, A. Arneth¹¹, D. C. E. Bakker¹², L. Barbero^{13,14}, L. Bopp¹⁵, J. Chang¹⁵, F. Chevallier¹⁵, L. P. Chini¹⁶, P. Ciais¹⁵, M. Fader¹⁷, R. A. Feely¹⁸, T. Gkritzalis¹⁹, I. Harris²⁰, J. Hauck²¹, T. Ilyina²², A. K. Jain²³, E. Kato²⁴, V. Kitidis²⁵, K. Klein Goldewijk²⁶, C. Koven²⁷, P. Landschützer²⁸, S. K. Lauvset²⁹, N. Lefèvre³⁰, A. Lenton³¹, I. D. Lima³², N. Metz³⁰, F. Millero³³, D. R. Munro³⁴, A. Murata³⁵, J. E. M. S. Nabel²², S. Nakaoka³⁶, Y. Nojiri³⁶, K. O'Brien³⁷, A. Olsen^{38,39}, T. Ono⁴⁰, F. F. Pérez⁴¹, B. Pfeil^{38,39}, D. Pierrot^{43,14}, B. Poulter⁴², G. Rehder⁴³, C. Rödenbeck⁴⁴, S. Saito⁴⁵, U. Schuster⁴, J. Schwinger²⁹, R. Séférian⁴⁶, T. Steinhoff⁴⁷, B. D. Stocker^{48,49}, A. J. Sutton^{37,18}, T. Takahashi⁵⁰, B. Tilbrook⁵¹, I. T. van der Laan-Luijkx^{52,53}, G. R. van der Werf⁵⁴, S. van Heuven⁵⁵, D. Vandemark⁵⁶, N. Viovy¹⁵, A. Wiltshire⁵⁷, S. Zaehle⁴⁴, and N. Zeng⁵⁸

Le Quéré et al. 2015

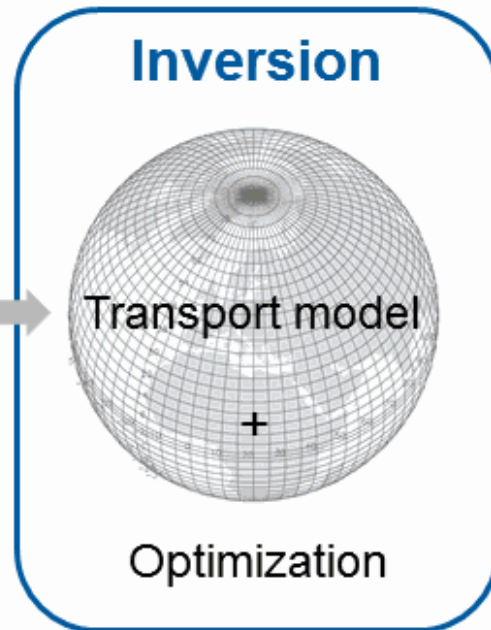
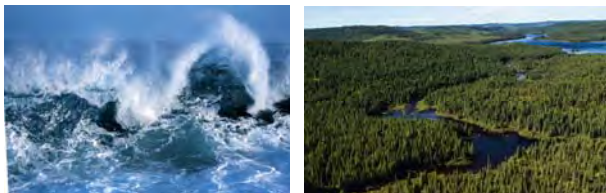
- Annual updates since 2006, next exp. mid November
- Data products for atmosphere, LUC, Fossil fuels
- Oceans: Observations + 8 Ocean biogeochemistry models (anomalies + trend)
- Biosphere: Residual + comparison to 10 Dynamic Global Vegetation Models
- Since 2014: 3 atmospheric inversions

Atmospheric inversions

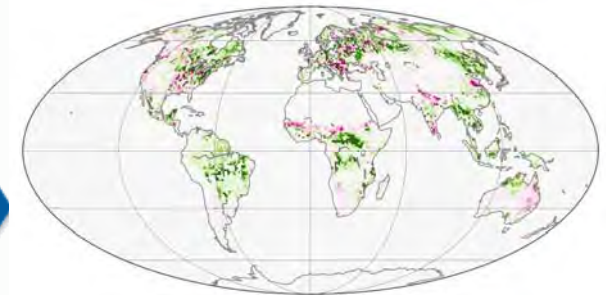
Atmospheric observations



Prior fluxes



Optimized flux estimates



- + uncertainty estimates
- + optimized 3-d concentrations

Atmospheric inversions in GCP

- Copernicus Atmospheric Monitoring Service (CAMS)
v15r2
Frédéric Chevallier



- Jena CarboScope
s81-v3.8
Christian Rödenbeck



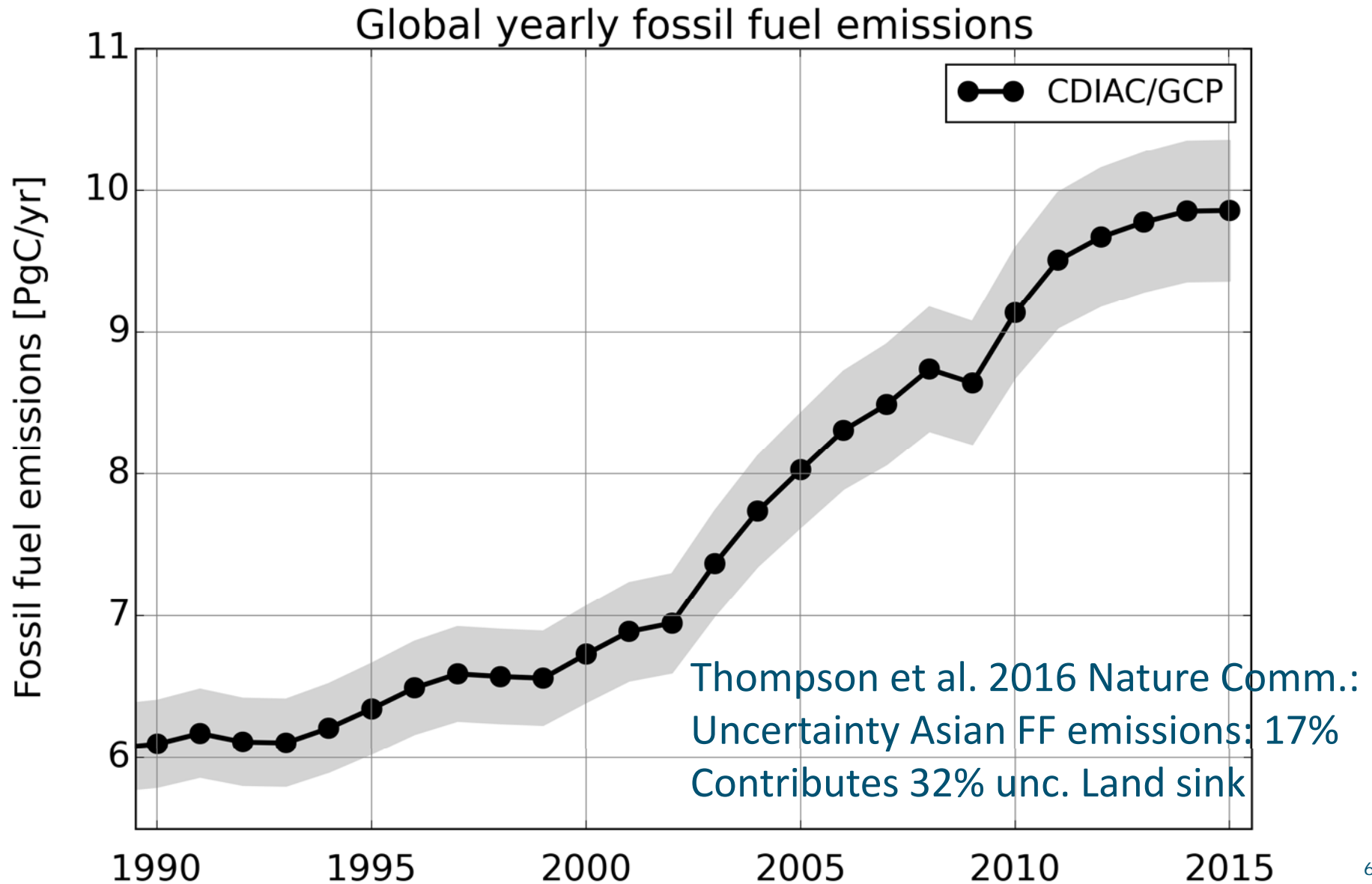
- CarbonTracker Europe (CTE)
CTE2016-FT
Ingrid van der Laan-Luijkx, Wouter Peters



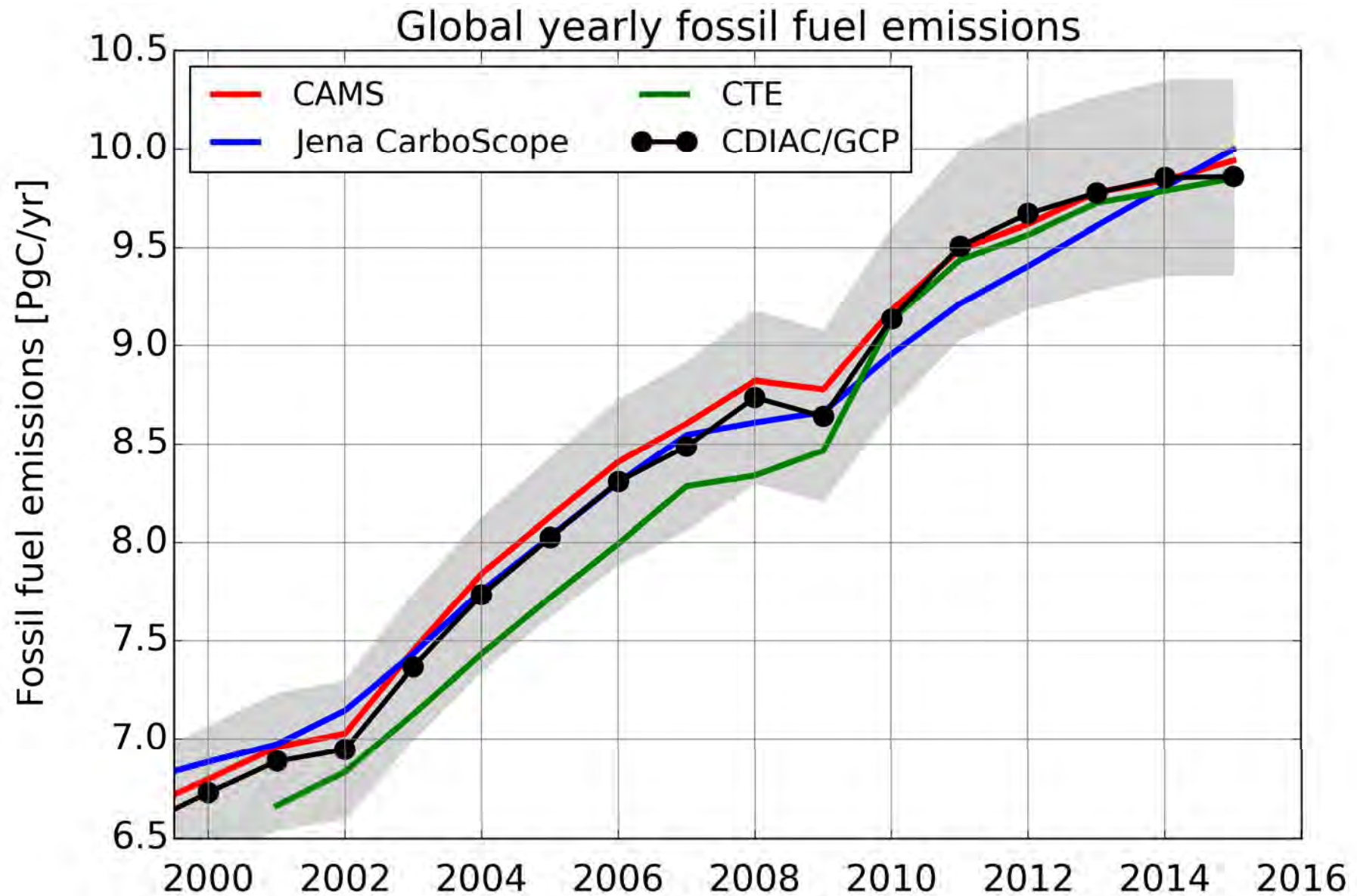
Atmospheric inversions in GCP

	CAMS	Jena CarboScope	CTE
Time period	1979-2015	1981-2015	2001-2015
Transport	LMDZ	TM3	TM5
Resolution (degrees)	Glb3.75x1.875	Glb4x5	Glb3x2, eur1x1, nam1x1
Fossil fuels	EDGAR scaled to CDIAC	EDGAR	EDGAR+IER, scaled to CDIAC (2010-2015)
Biosphere and fires	ORCHIDEE (climatological) + GFEDv4	Constant (from LPJ)	SiBCASA-GFED4
Ocean	Takahashi et al. (2009)	Interior Inversion by Mikaloff-Fletcher et al. (2006)	Jacobson et al. (2007) OIF
Observations	Half-hourly resolution (well-mixed cond.)	Flask and hourly	Hourly resolution (well-mixed cond.)
Optimization	Variational	Conjugate Gradient (re-orthonormalization)	Ensemble Kalman Filter

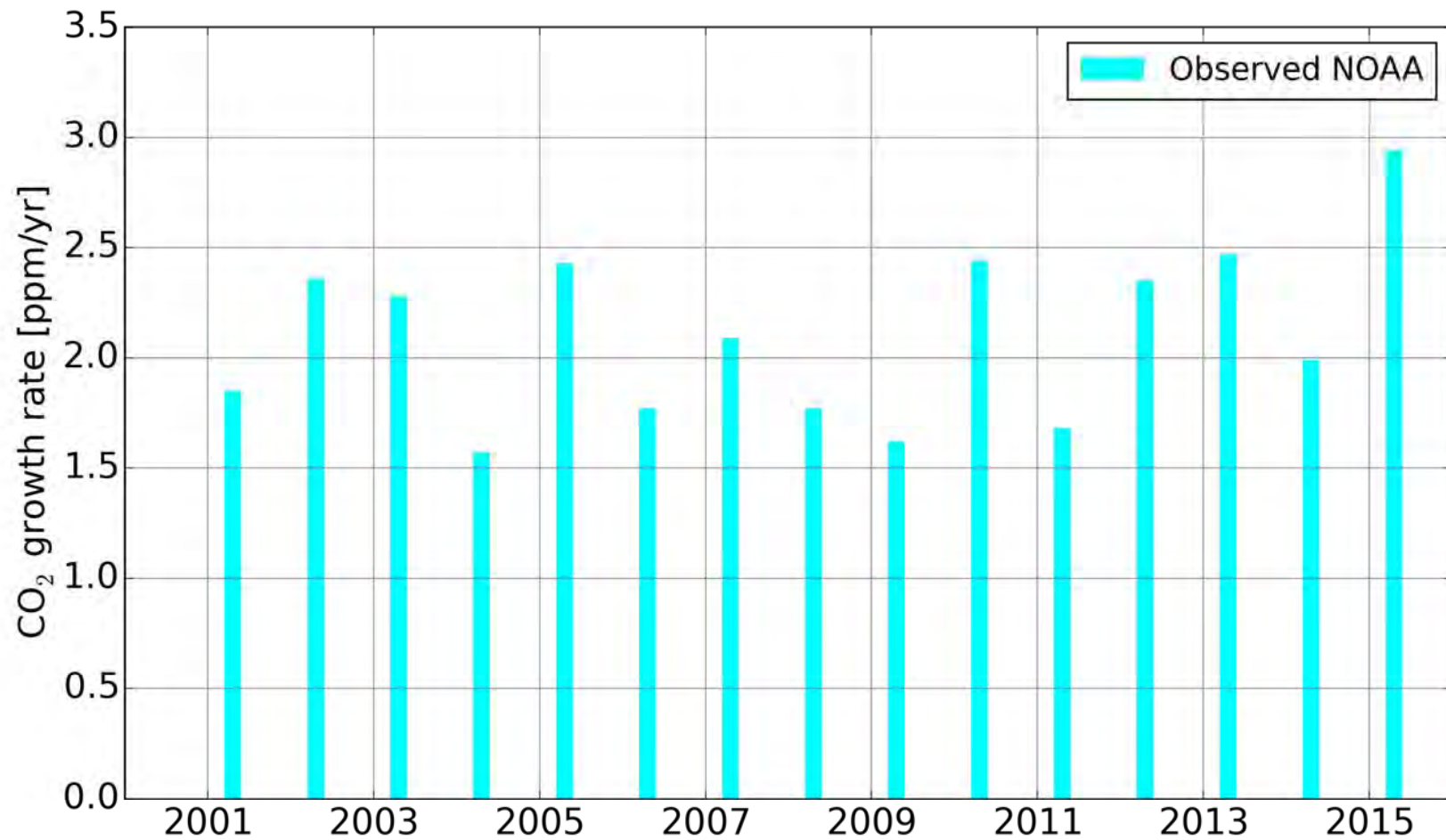
Fossil fuel emissions (CDIAC)



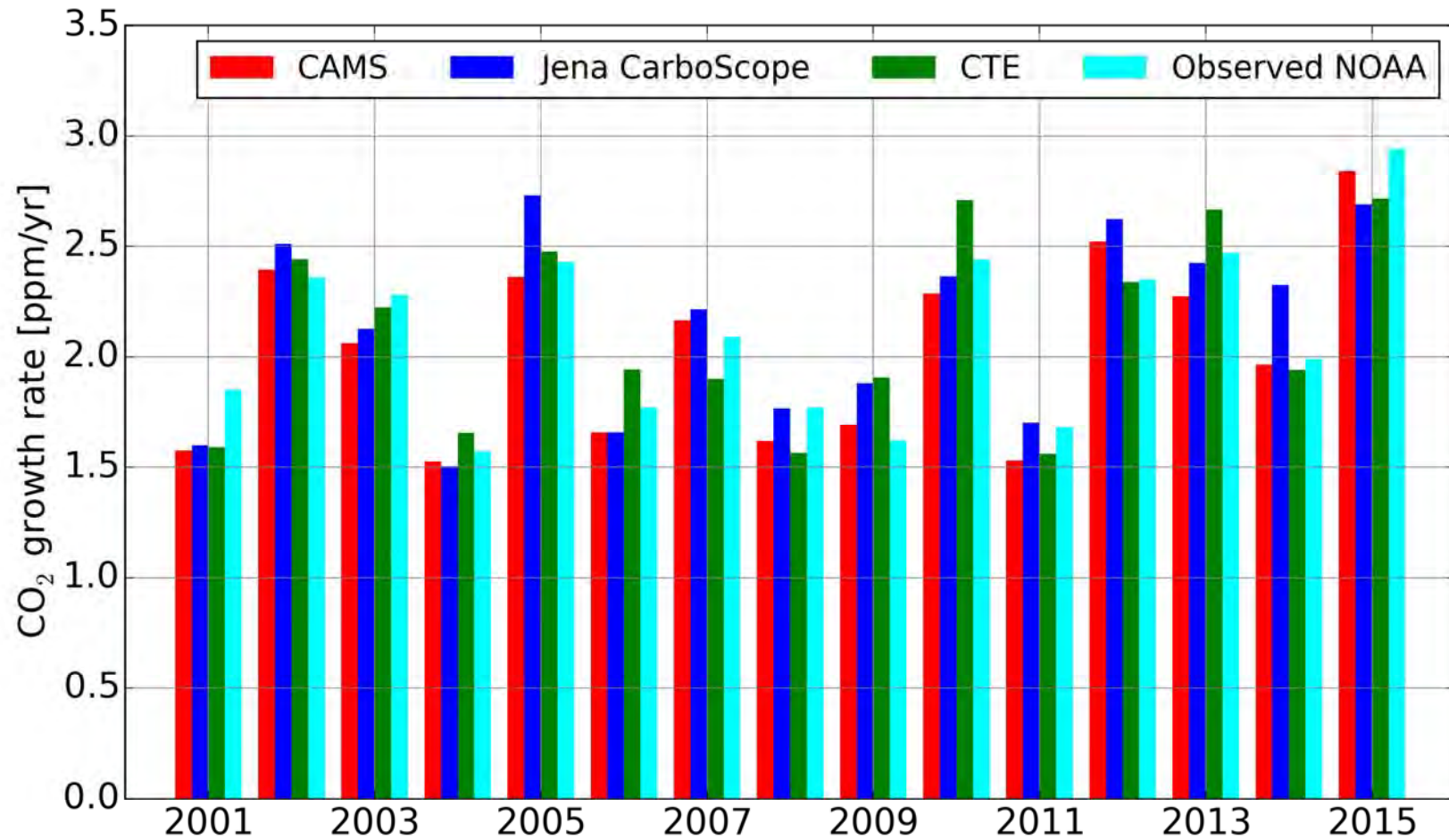
Fossil fuel emissions used in inversions



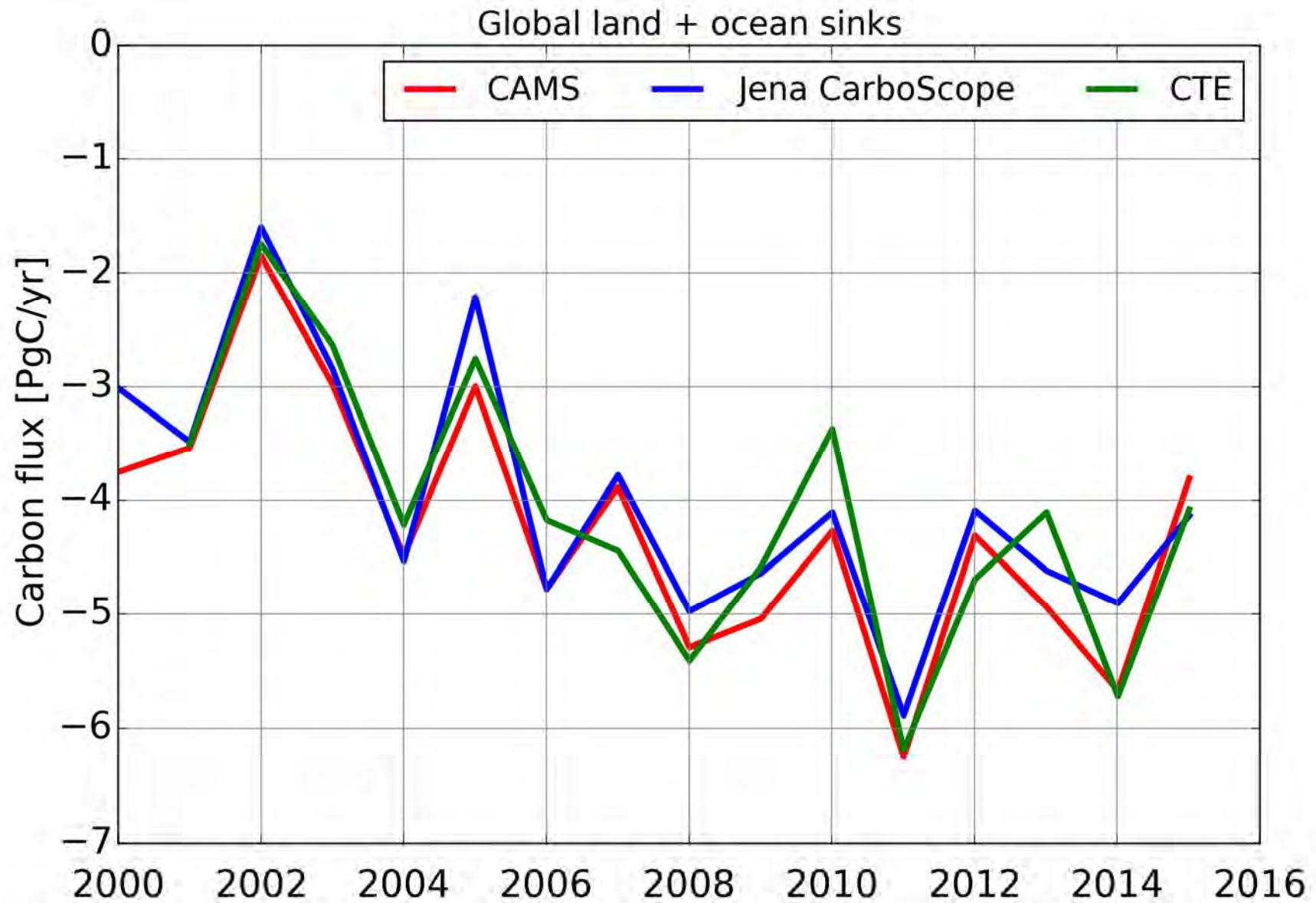
Global annual growth rate atmospheric CO₂



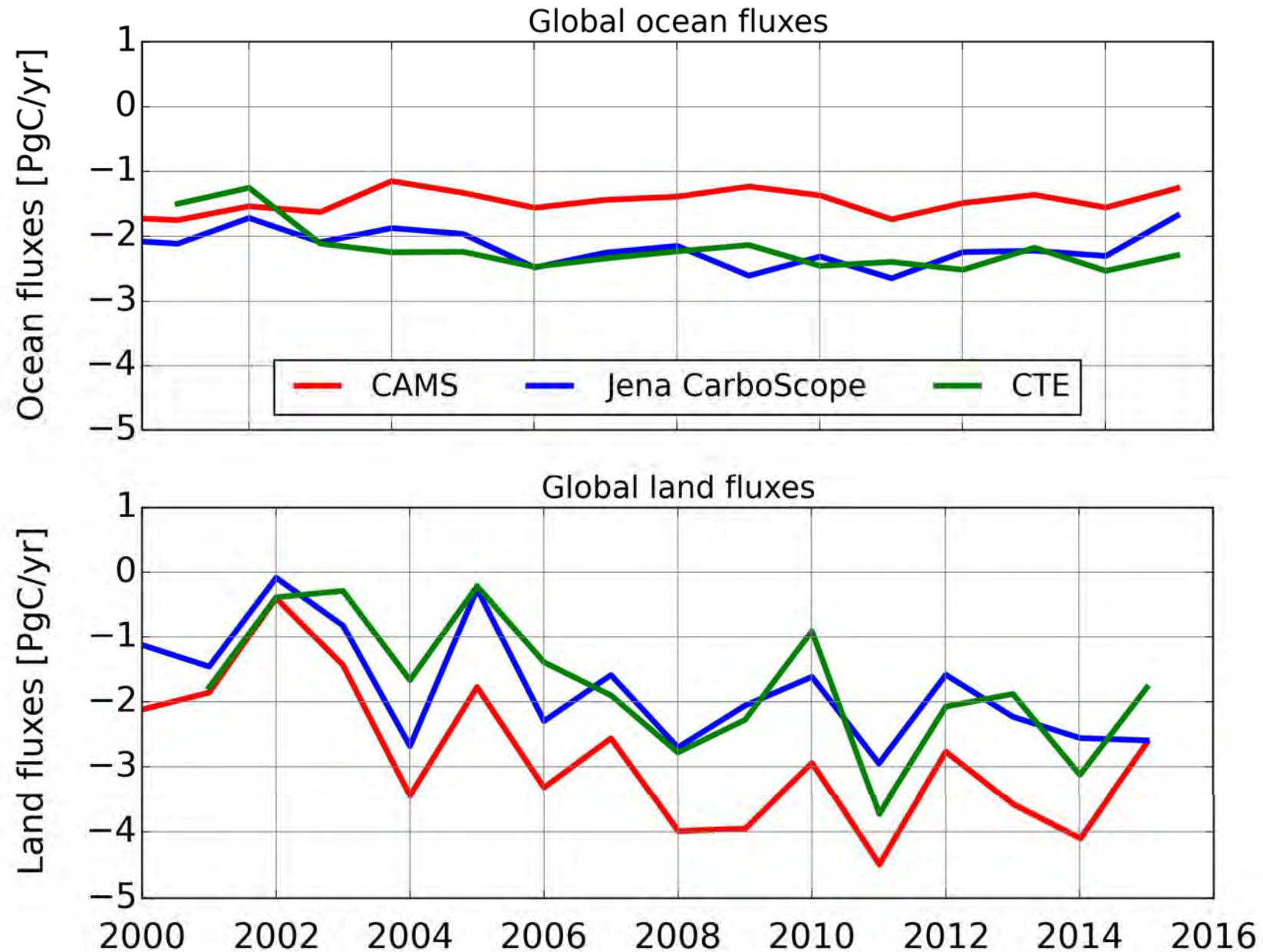
Global annual growth rate atmospheric CO₂



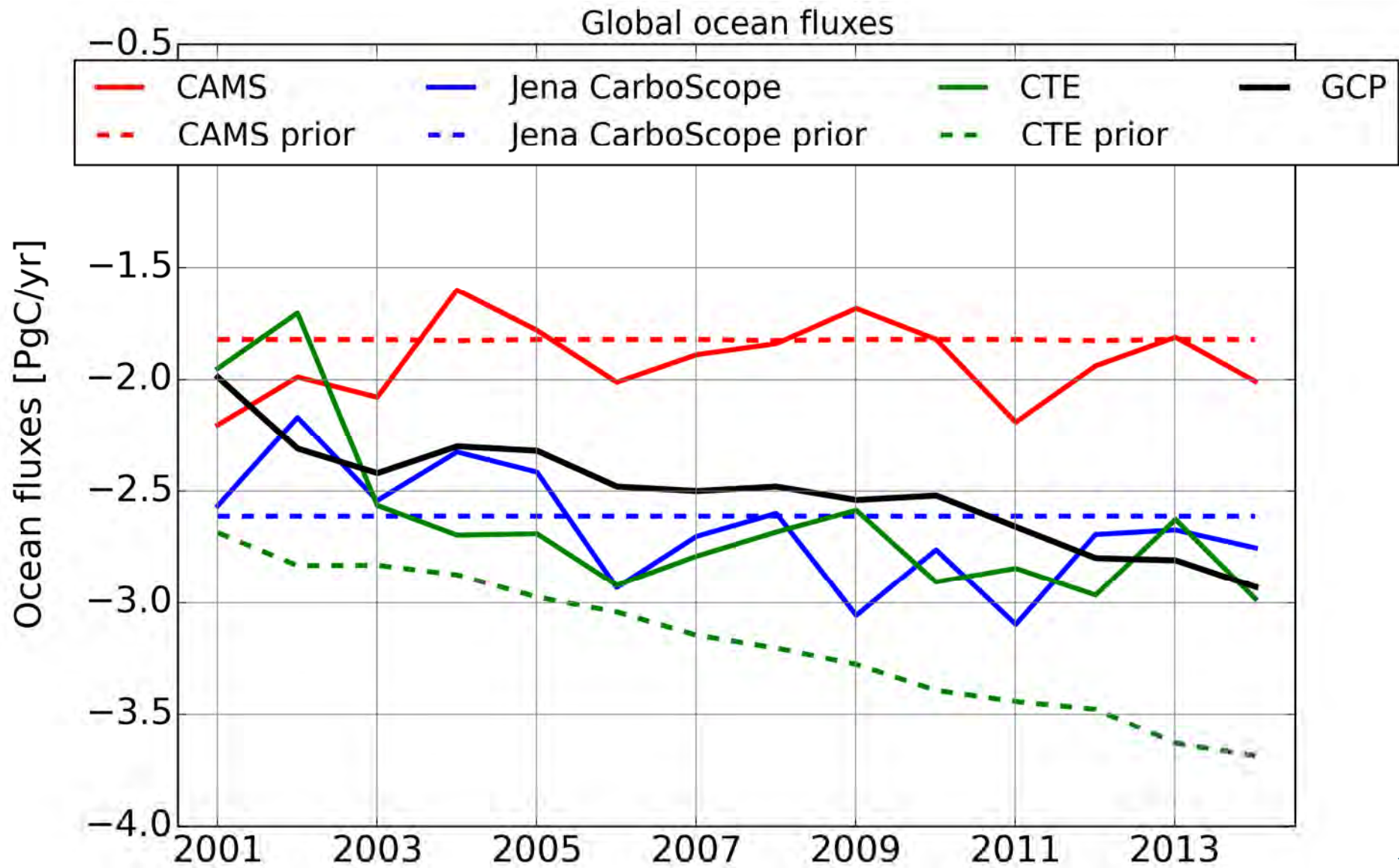
Global total annual carbon sinks



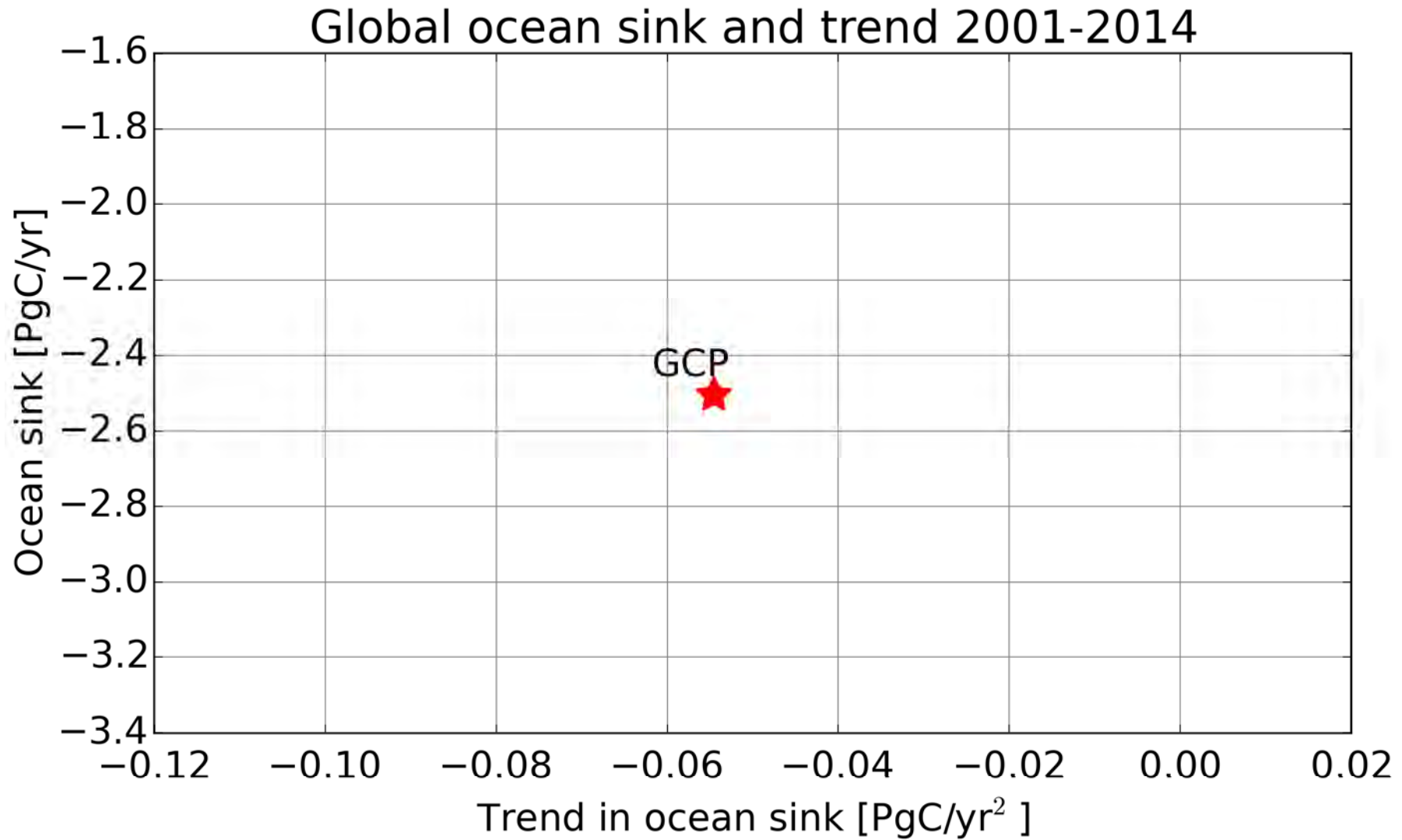
Global land-ocean flux partitioning



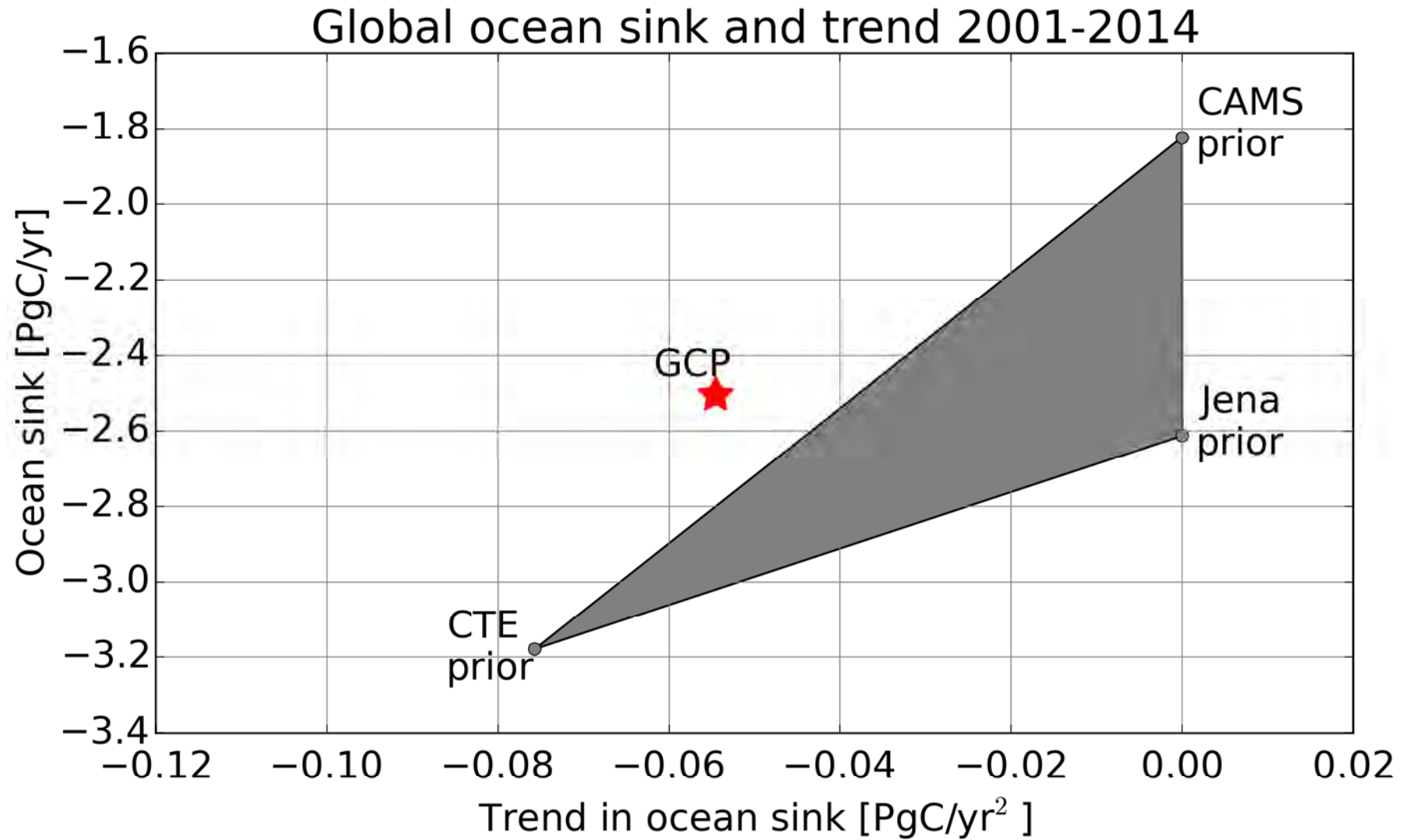
Global ocean sink 2001-2014



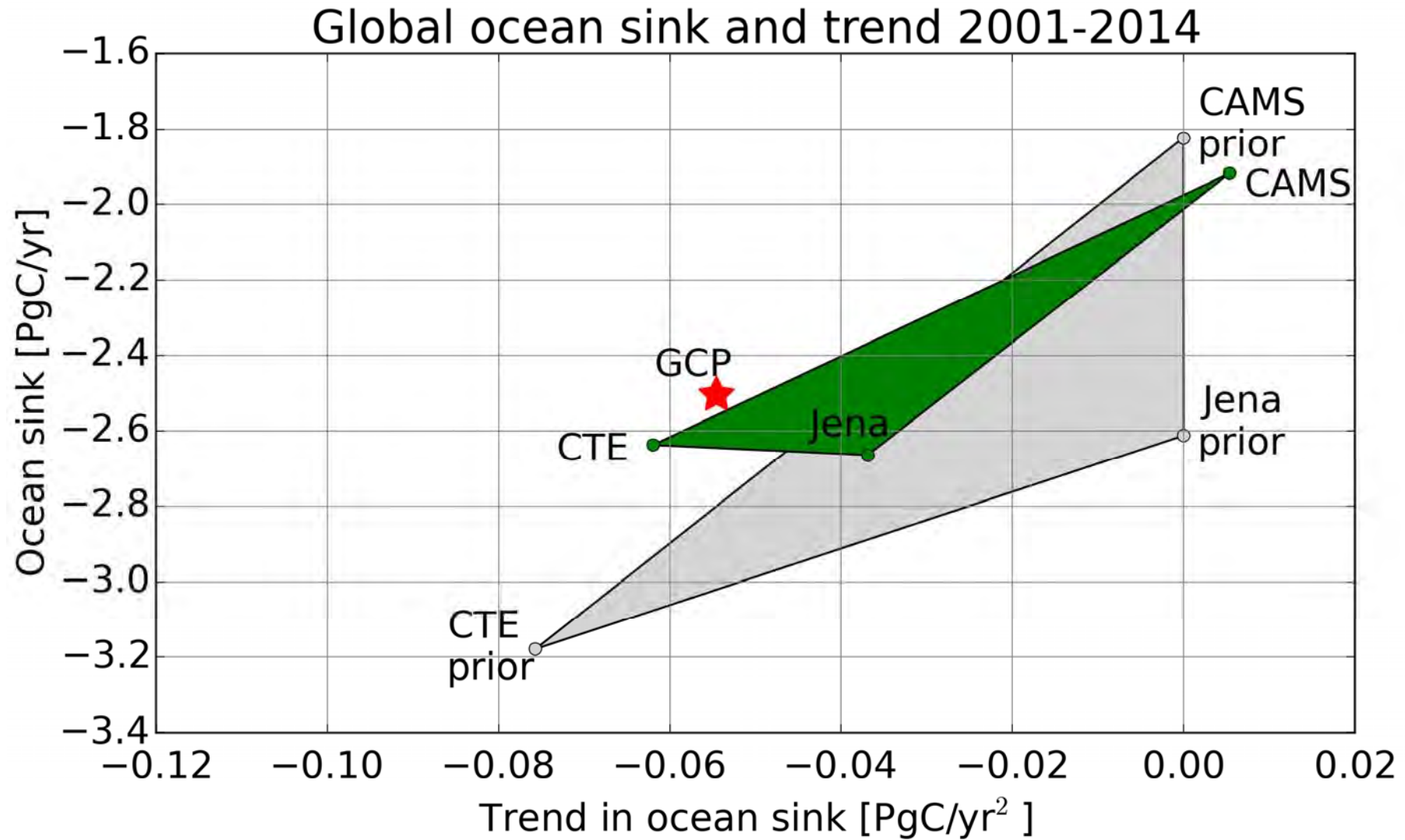
Global ocean



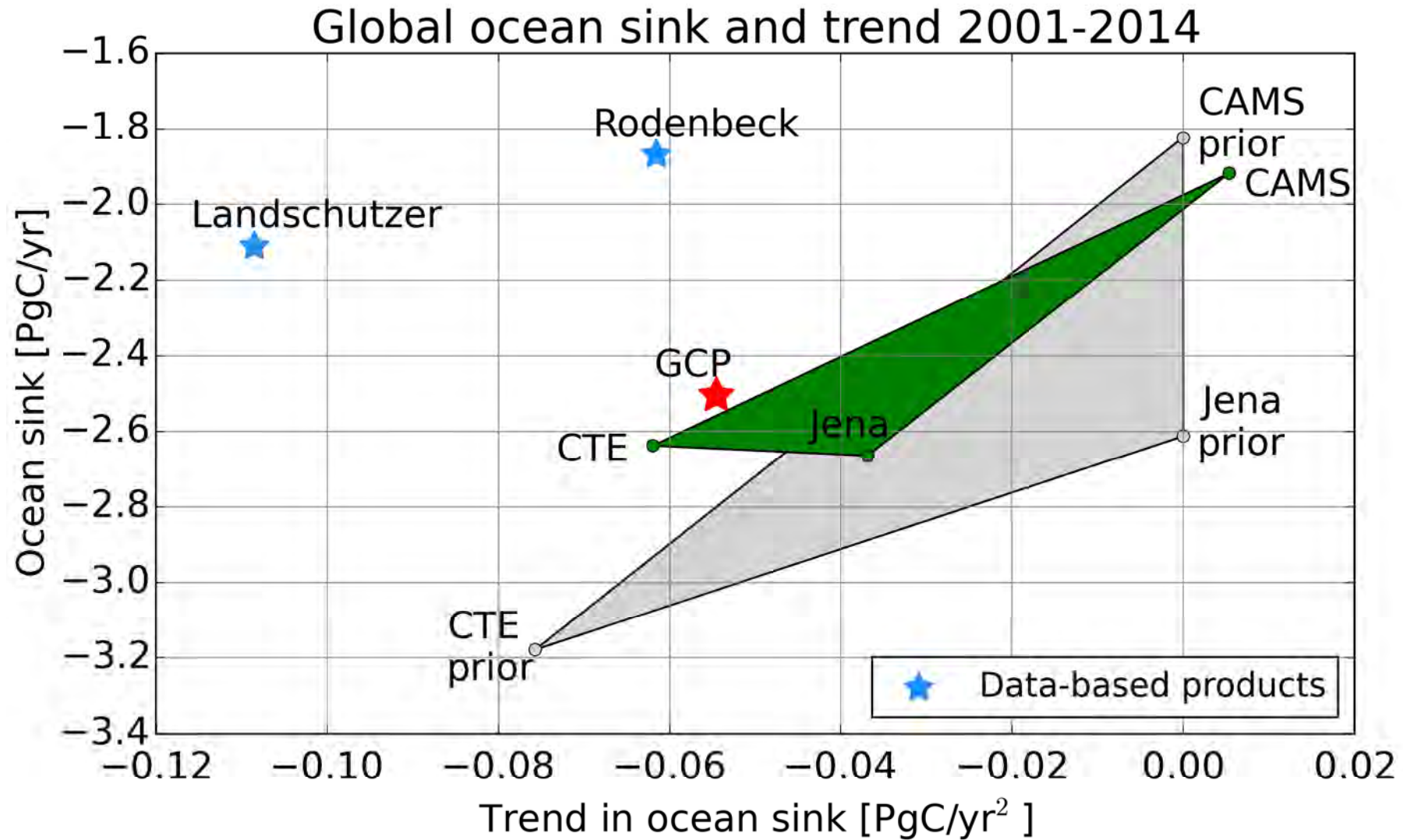
Global ocean



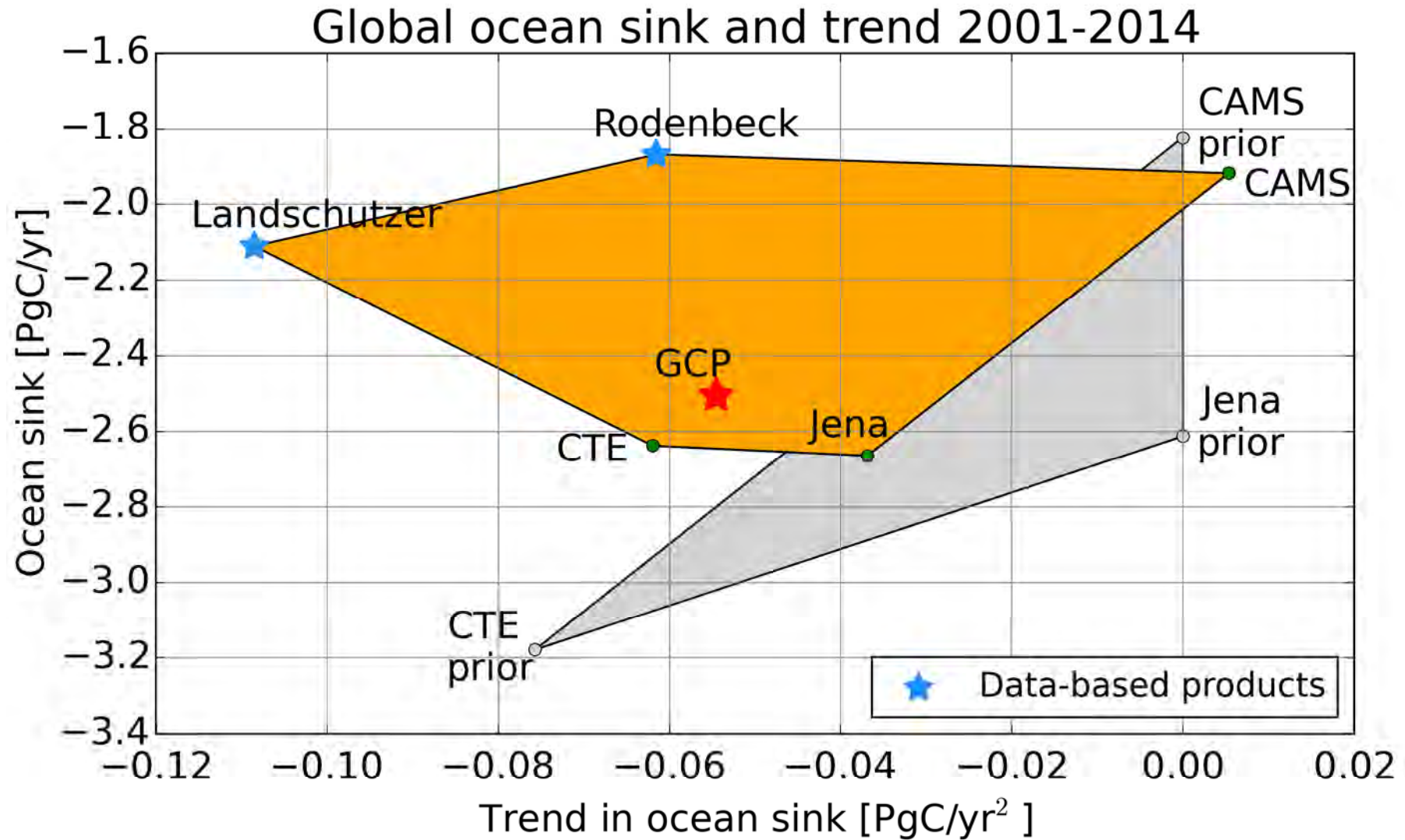
Global ocean



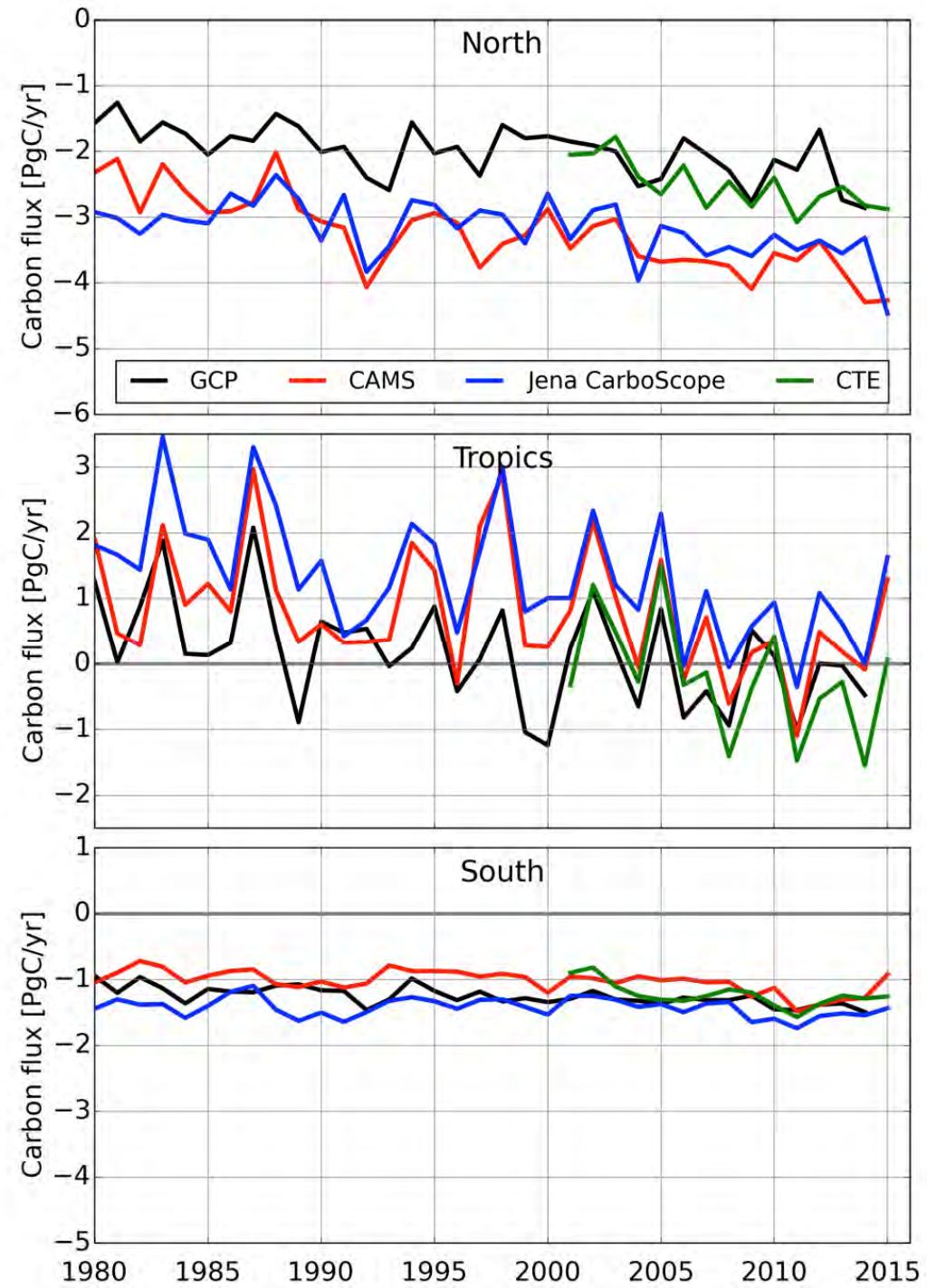
Global ocean



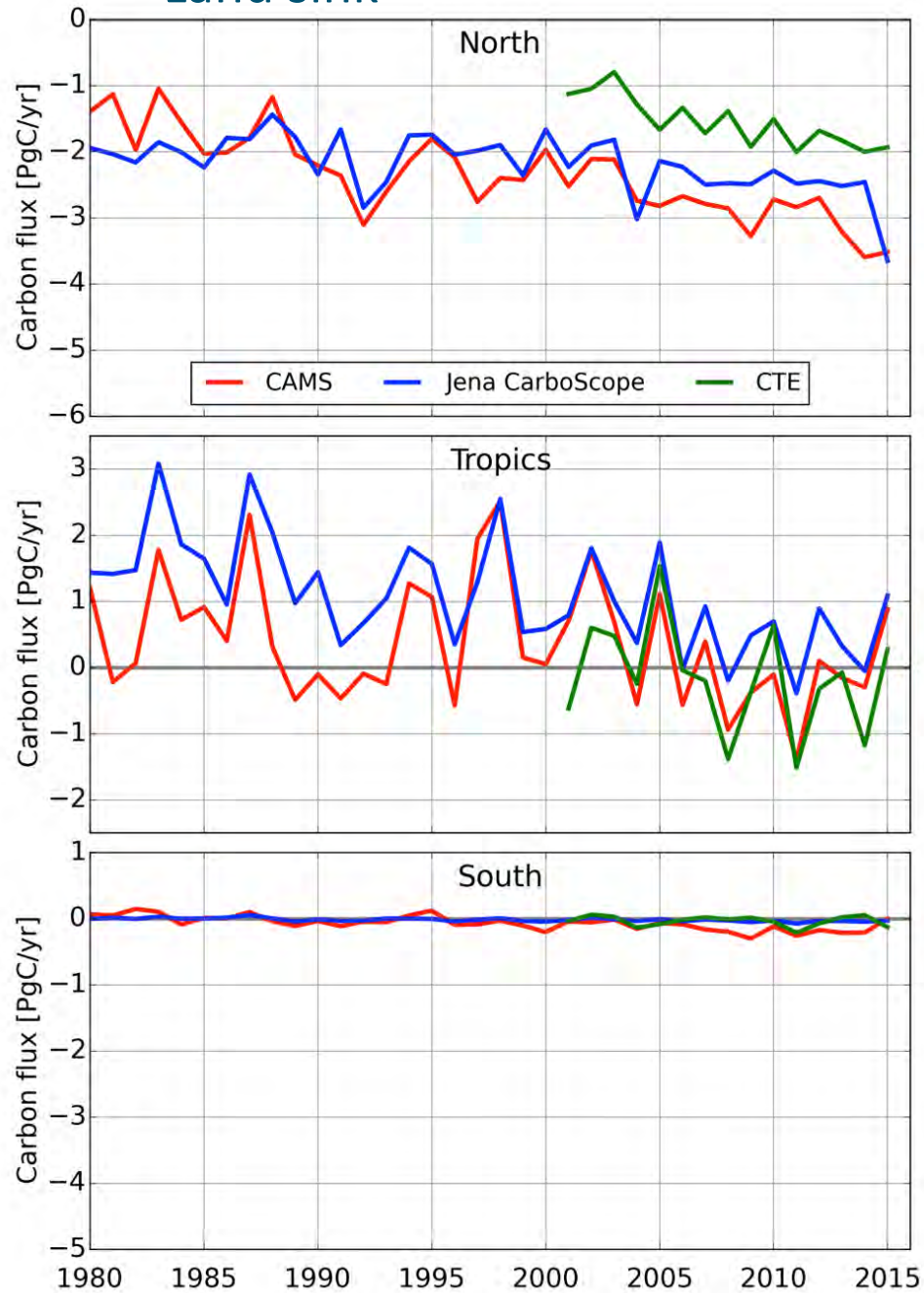
Global ocean



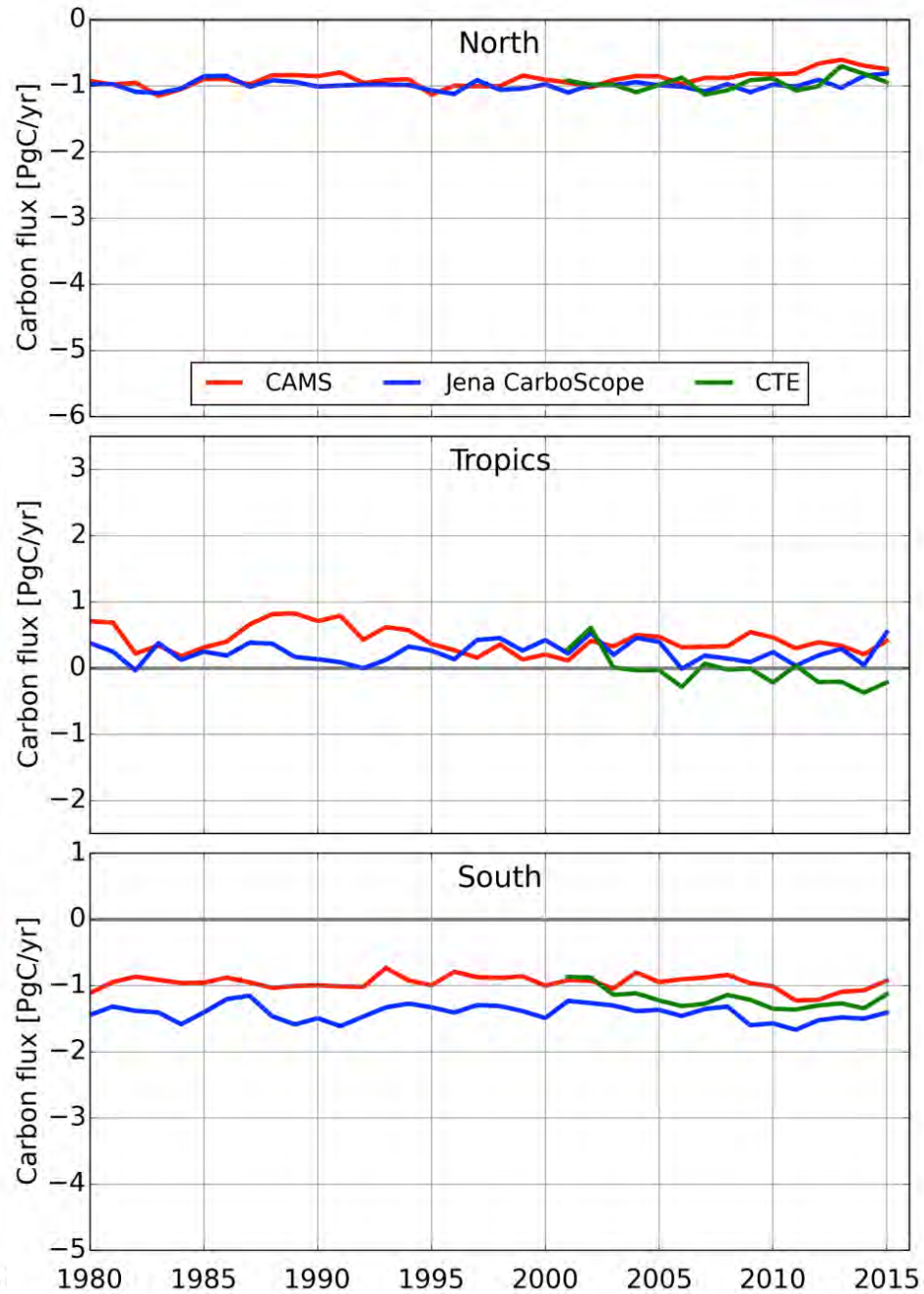
Regional distribution



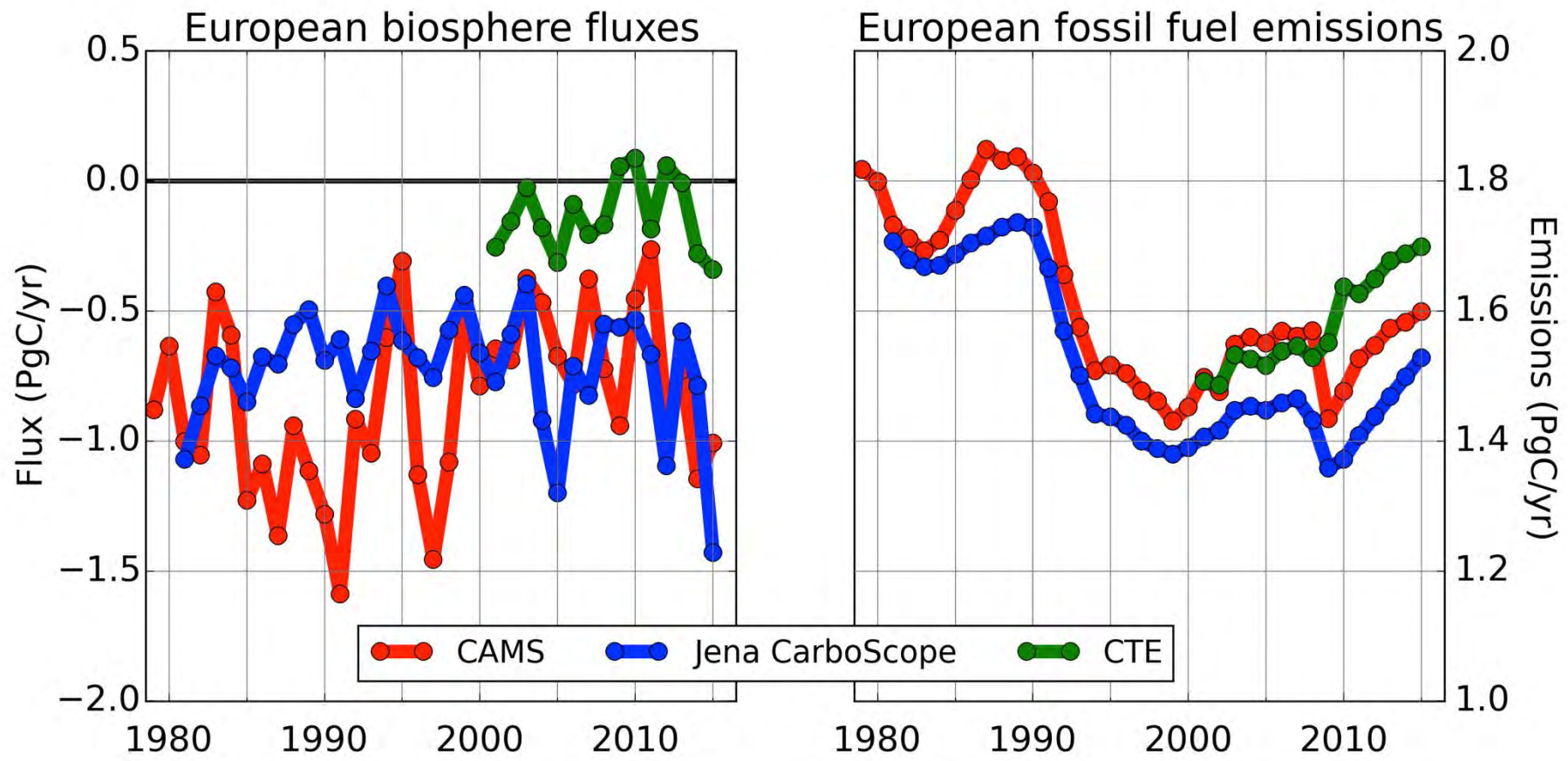
Land sink



Ocean sink



European fluxes



Reuter et al. 2016 BAMS:
'How much CO₂ is taken up by the European terrestrial biosphere?'

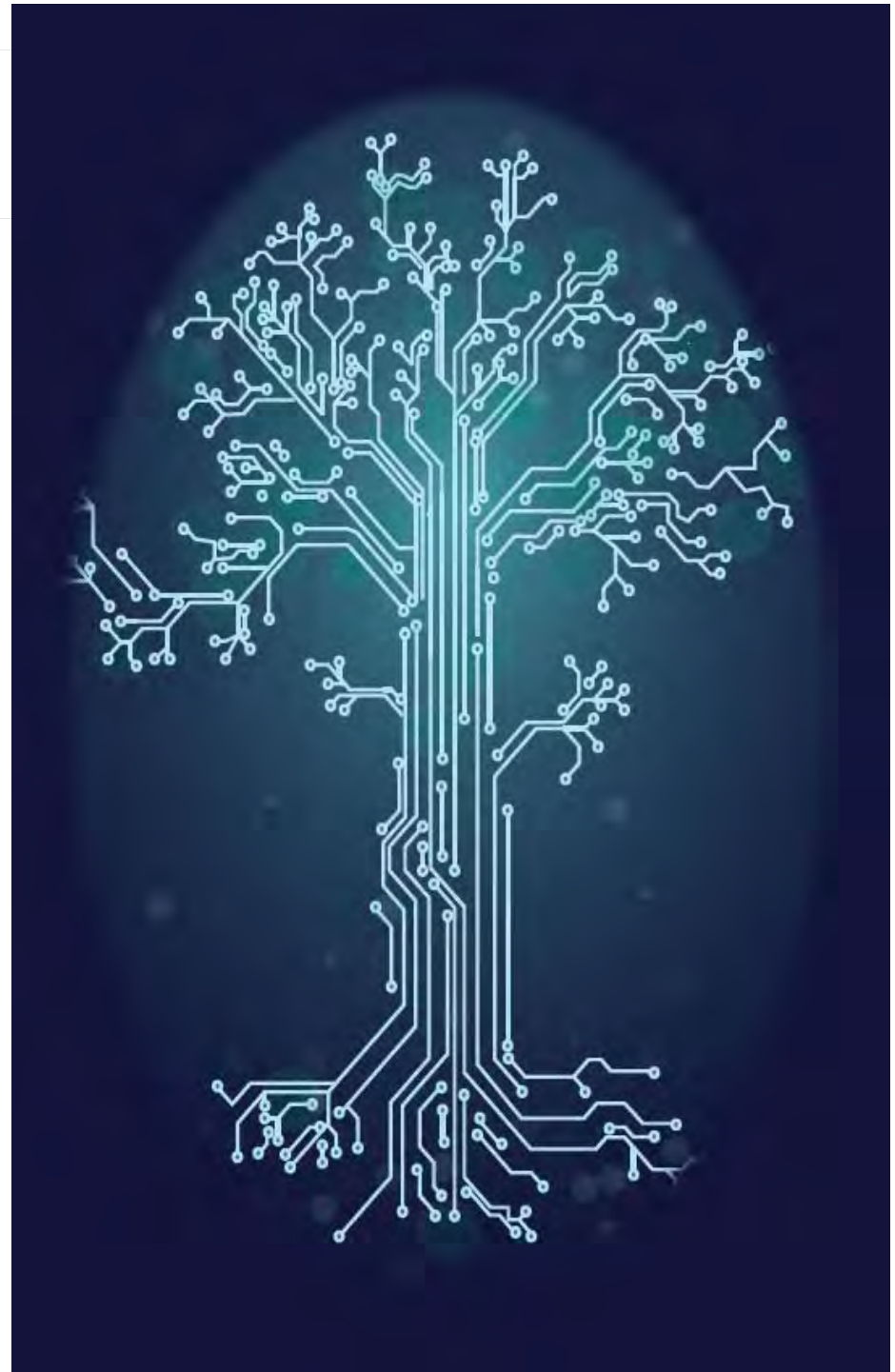
Summary

- Global ocean sink better known than land sink, but still considerable differences in sink strength and trend.
- Besides tropical land sink, also the ocean and European land sinks are important to understand the global carbon budget.

ICOS Carbon Portal

- The central data portal of ICOS-RI
- Inversions will be available from ICOS-CP in the near future
- Service for advanced users of ICOS data

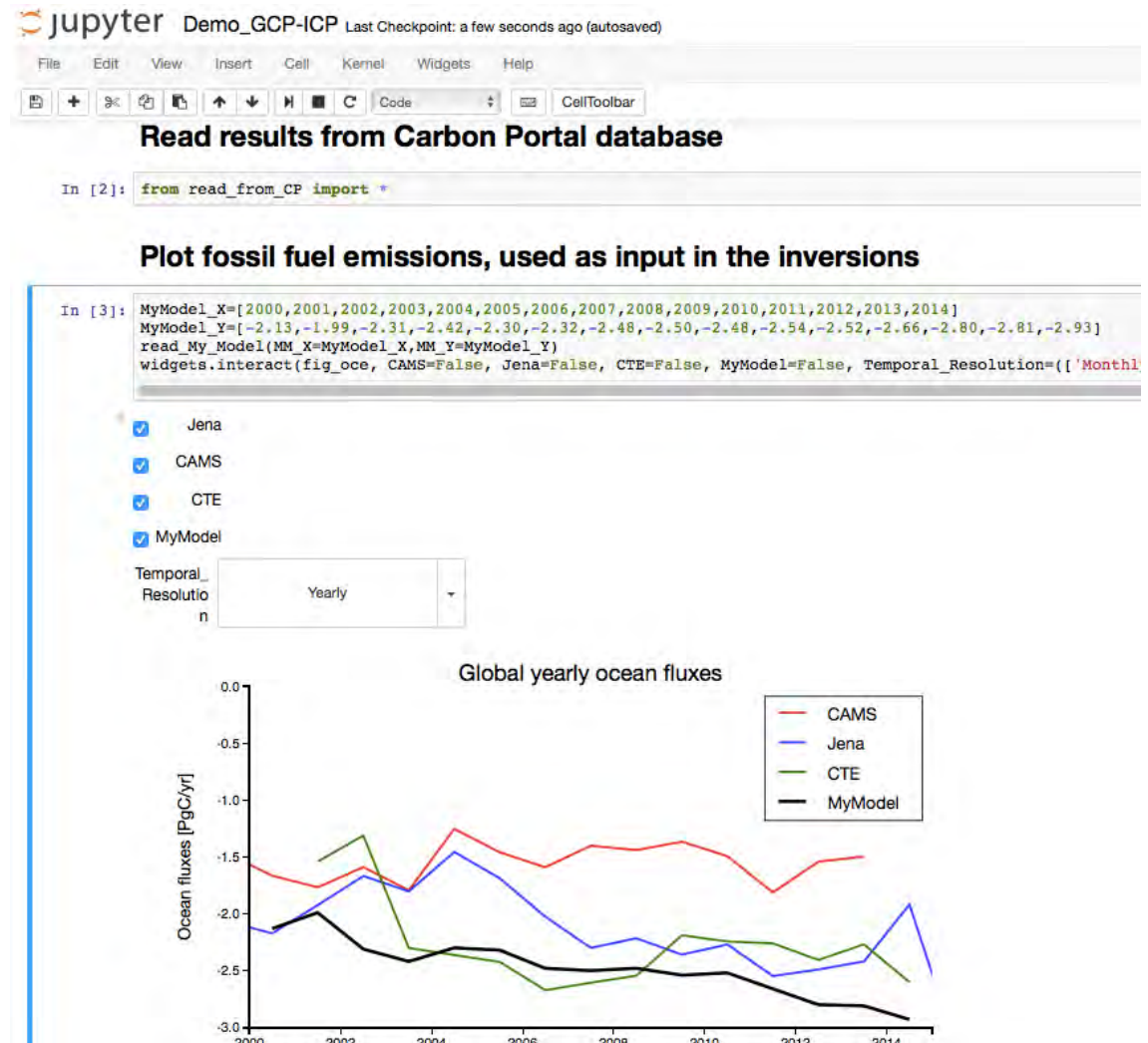
<https://www.icos-cp.eu>



Elaborated products and services

- Interactive python notebook
- Complete analysis available online
- See also poster by Ute Karstens (Wednesday 141)

<https://www.icos-cp.eu>

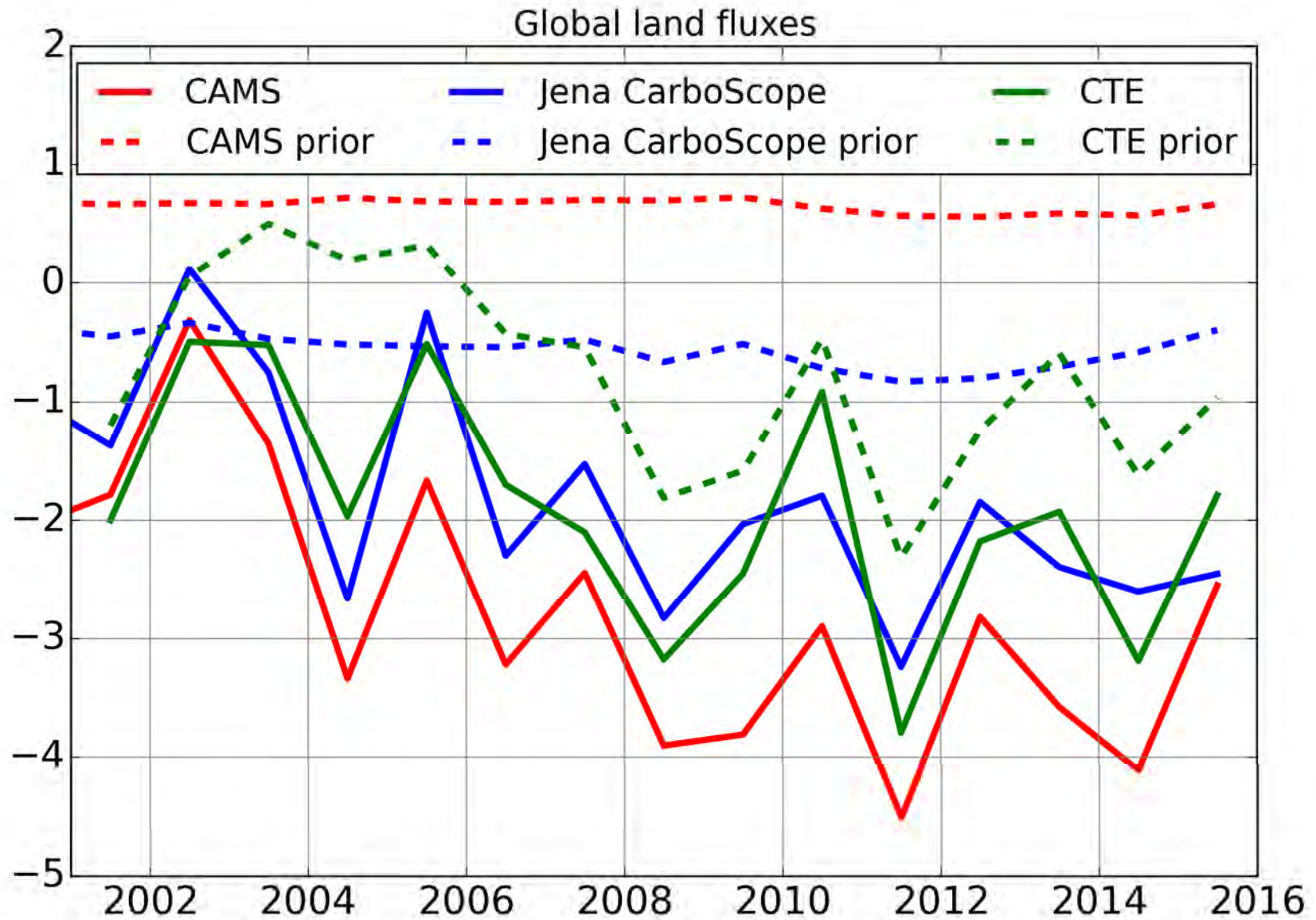


Summary

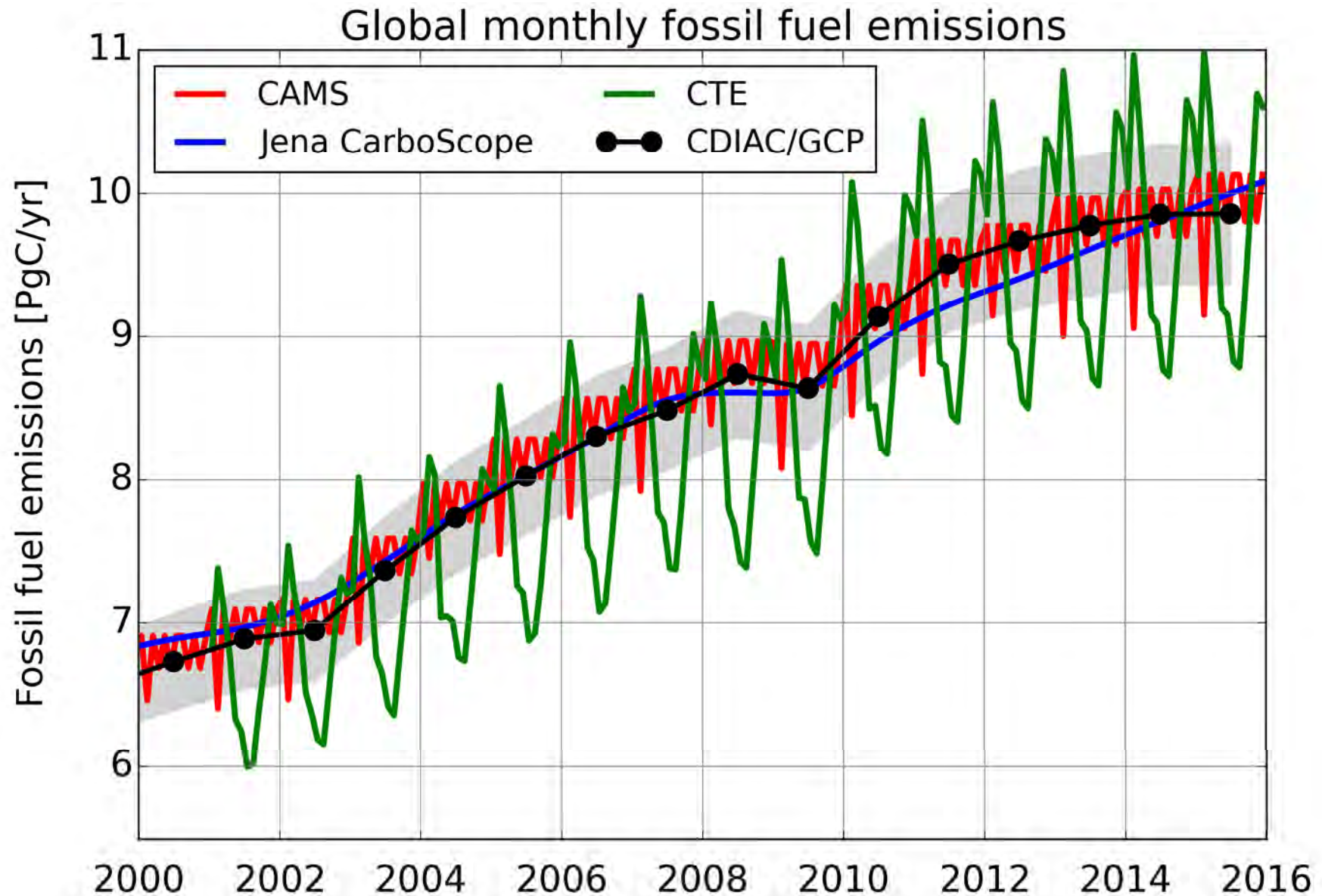
- Global ocean sink better known than land sink, but still considerable differences in sink strength and trend.
- Besides tropical land sink, also the ocean and European land sinks are important to understand the global carbon budget.

Additional slides

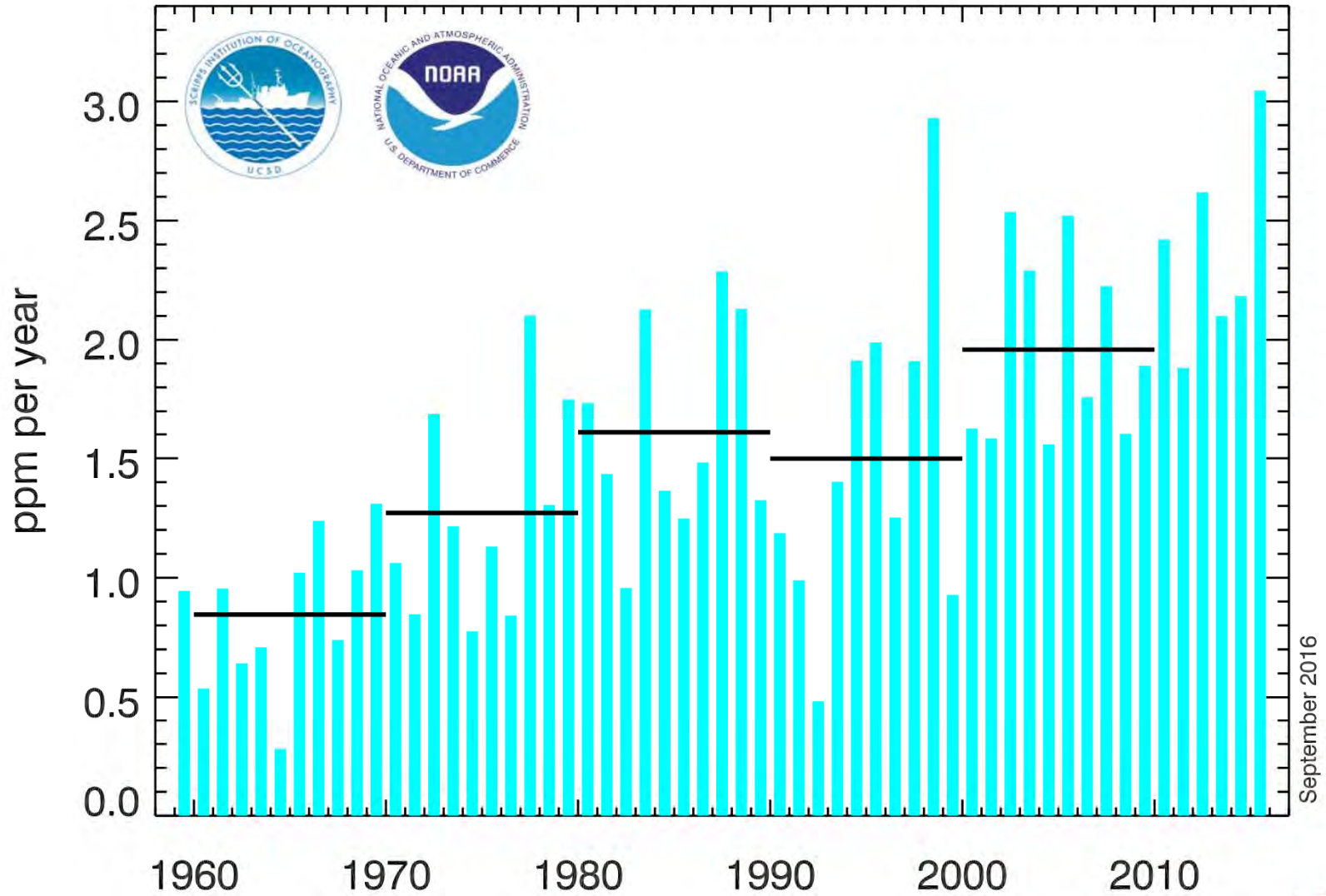
Global land fluxes



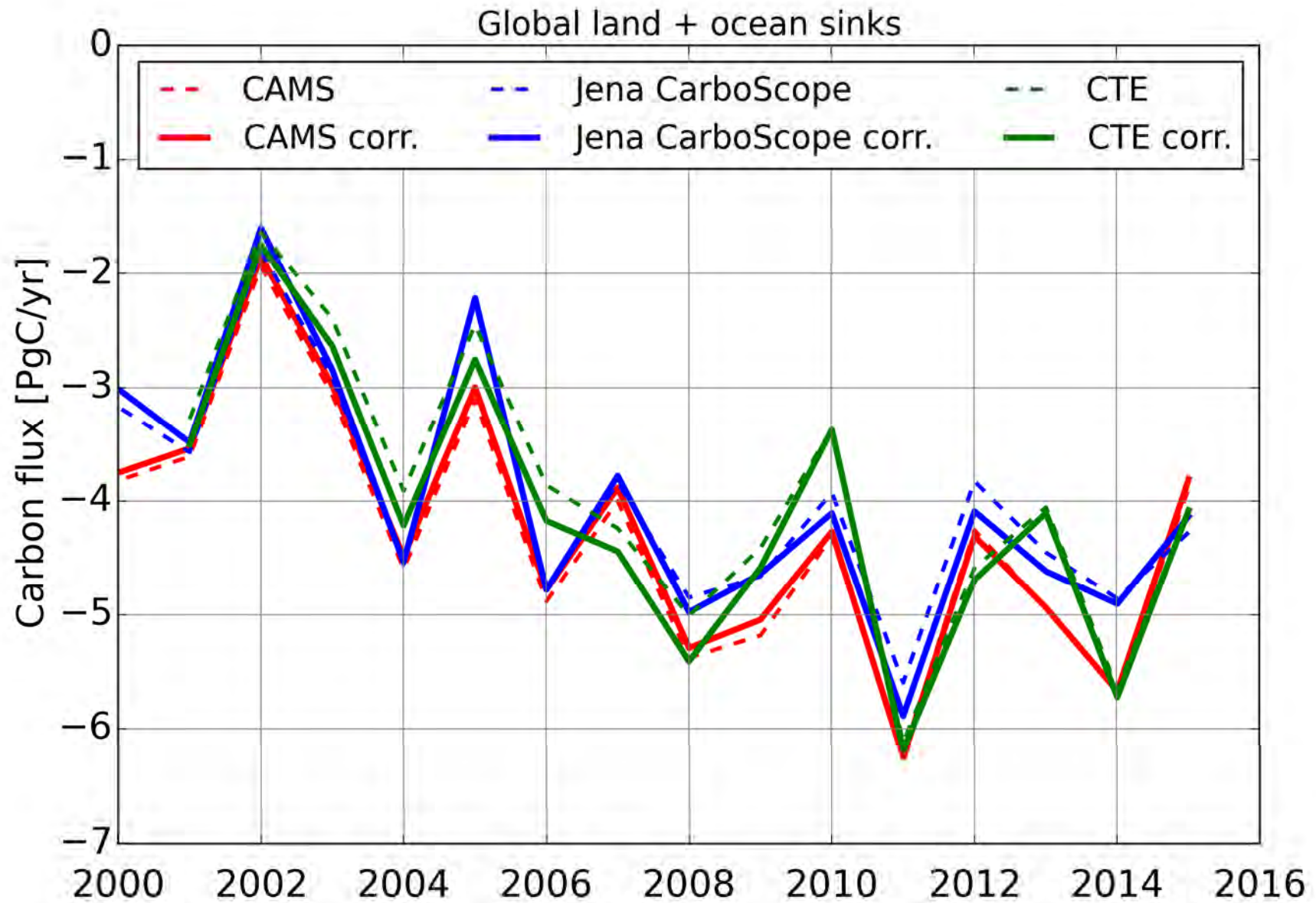
Fossil fuel emissions used in inversions



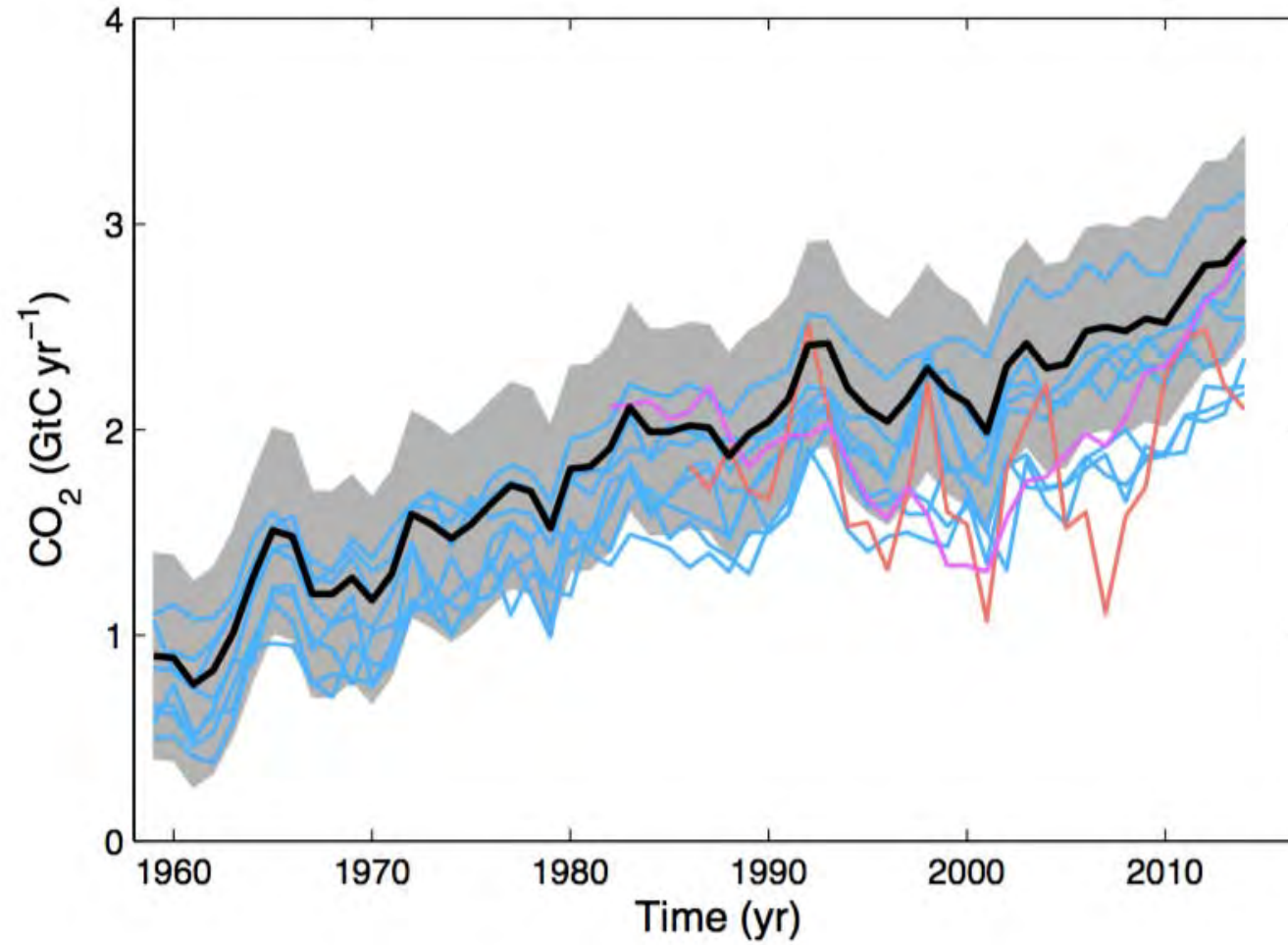
annual mean growth rate of CO₂ at Mauna Loa



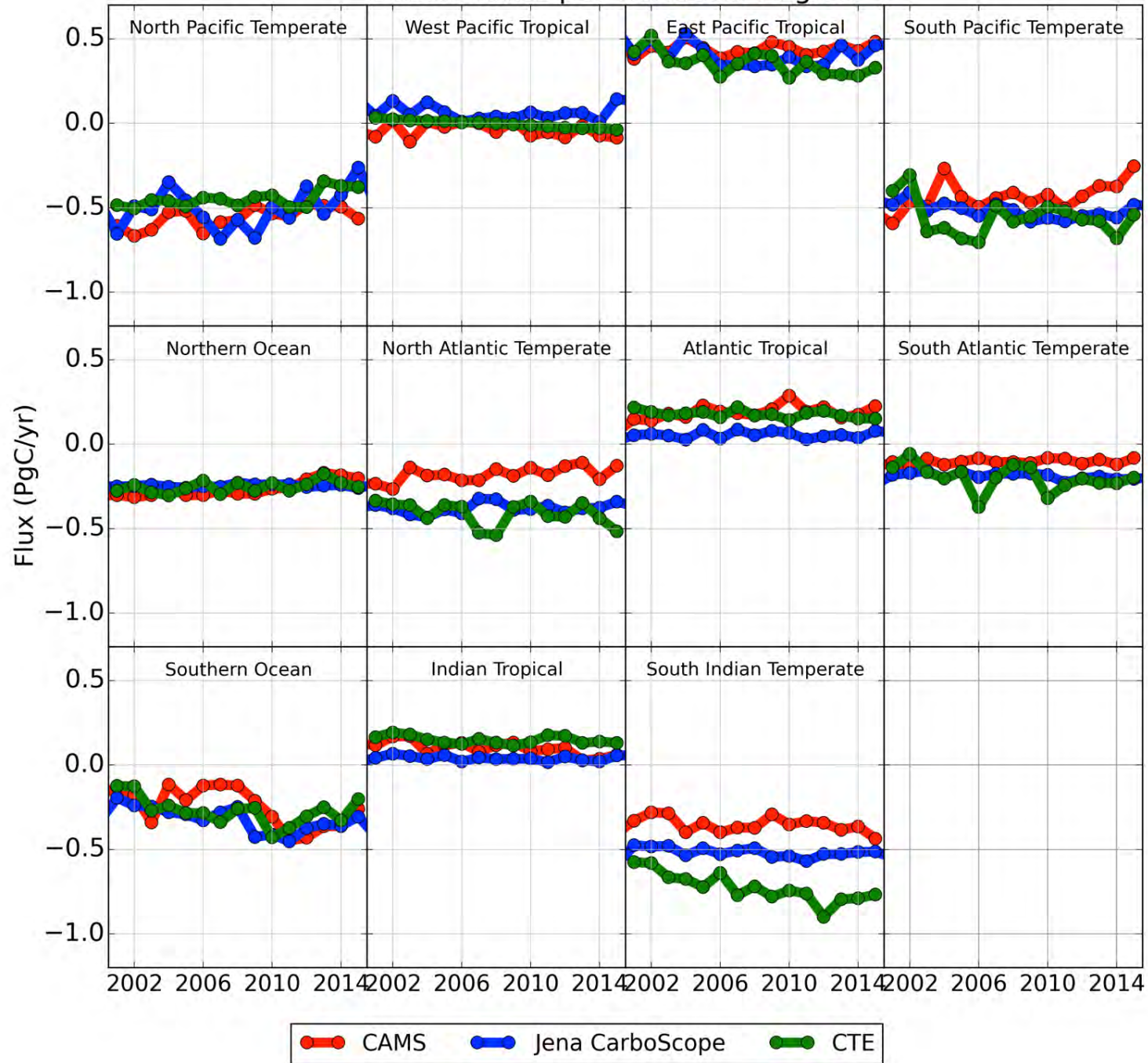
Global sinks fossil fuel correction



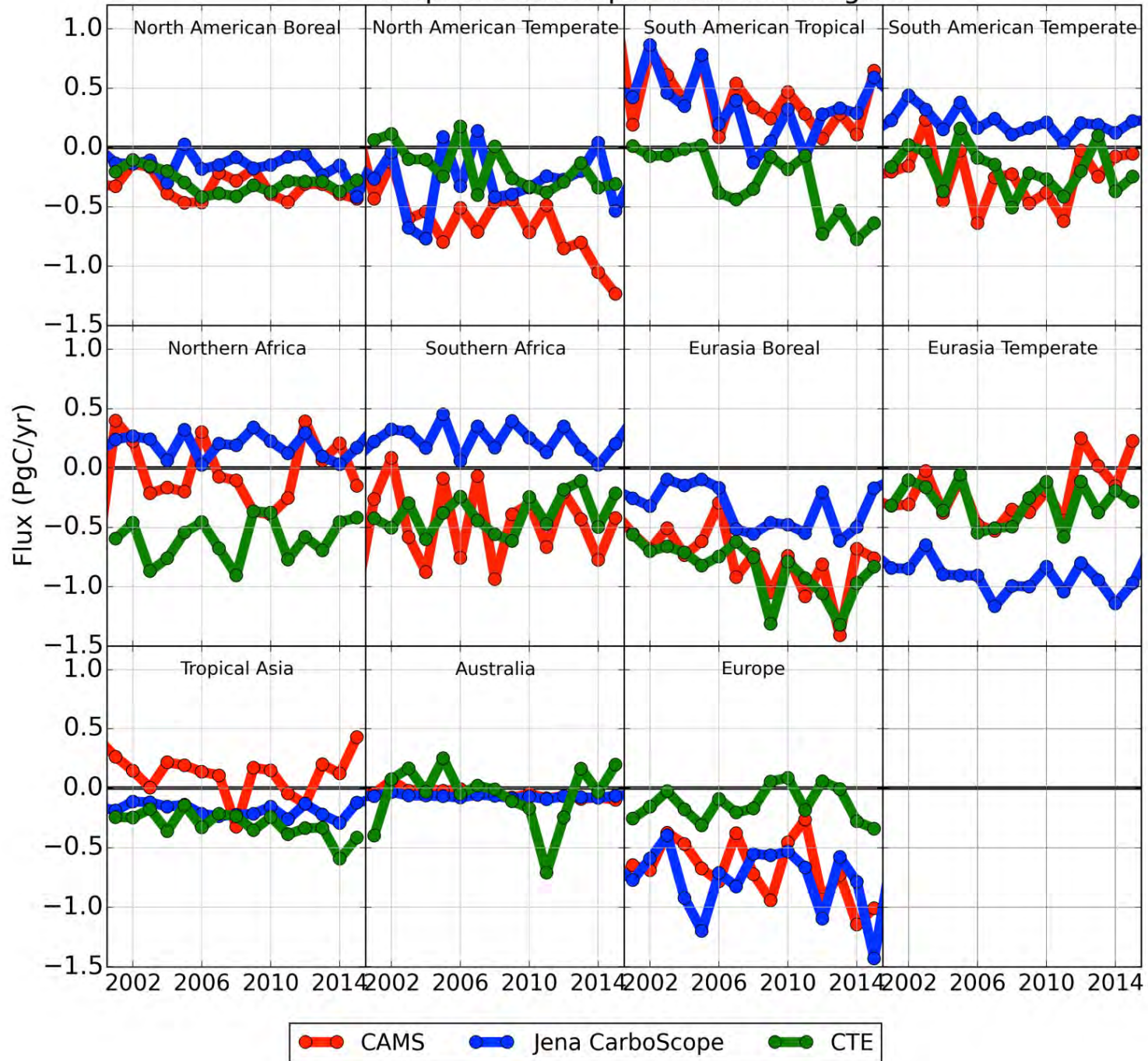
GCP ocean sink



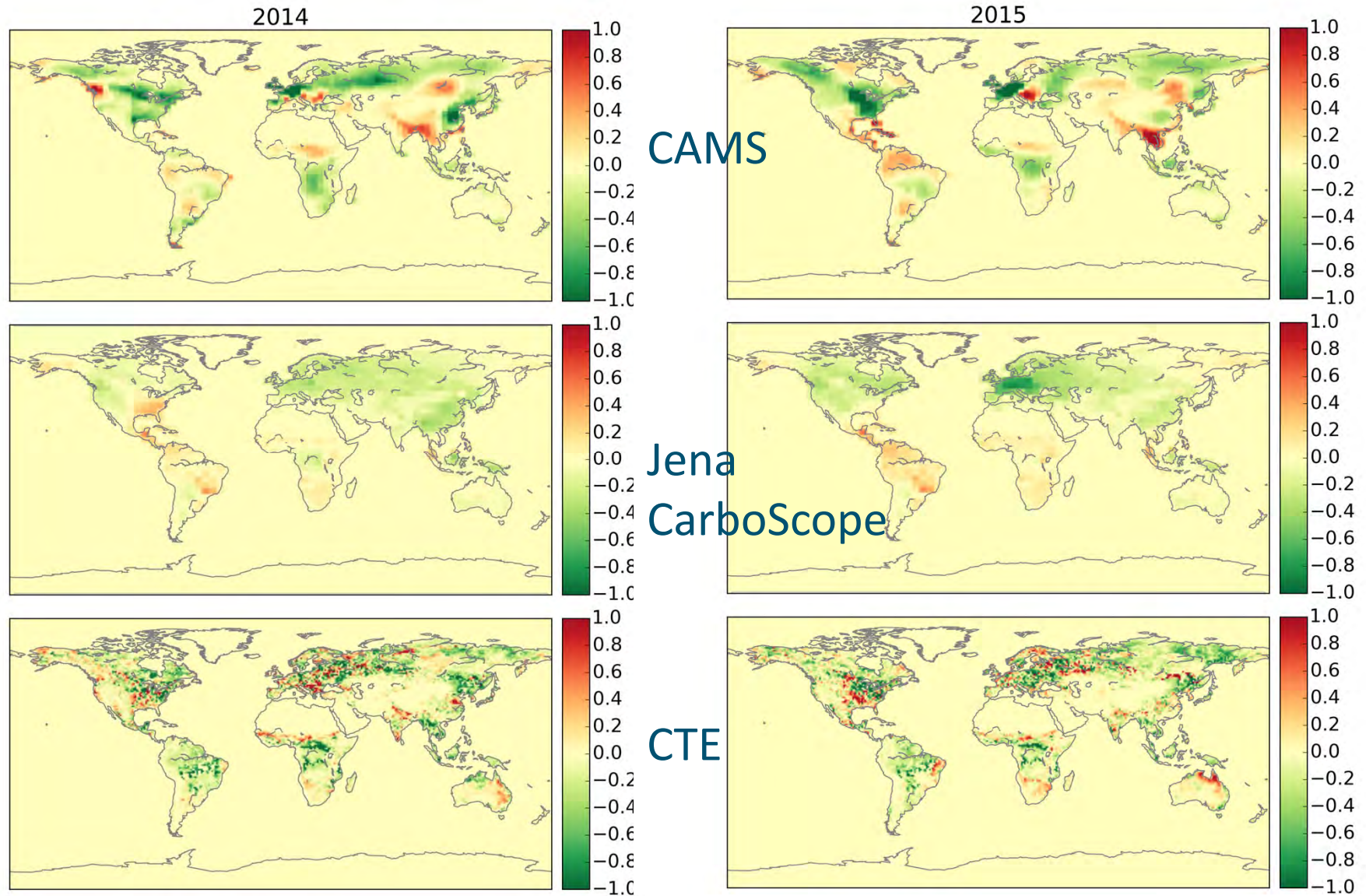
Ocean fluxes per Transcom Region



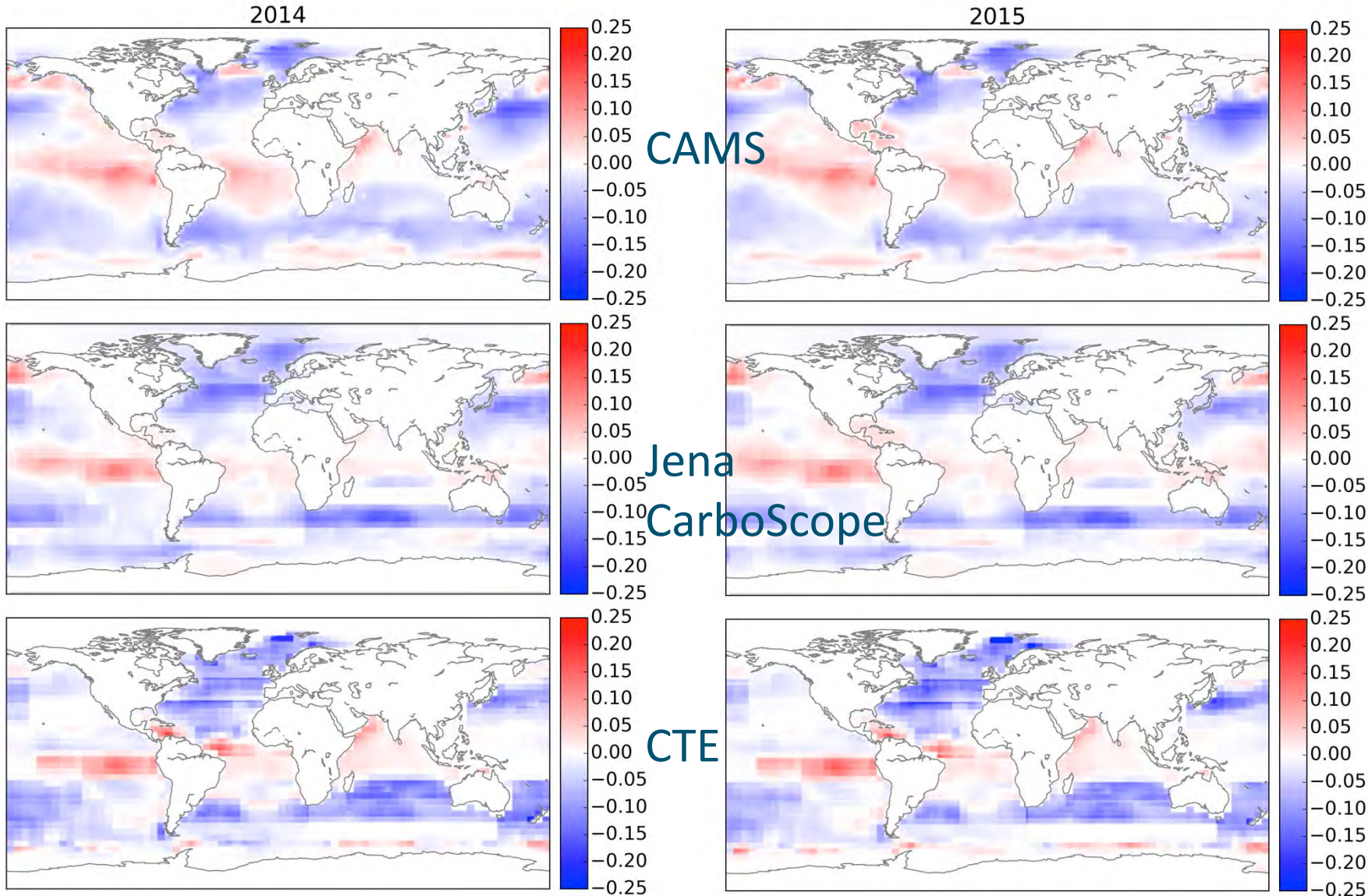
Biosphere fluxes per Transcom Region



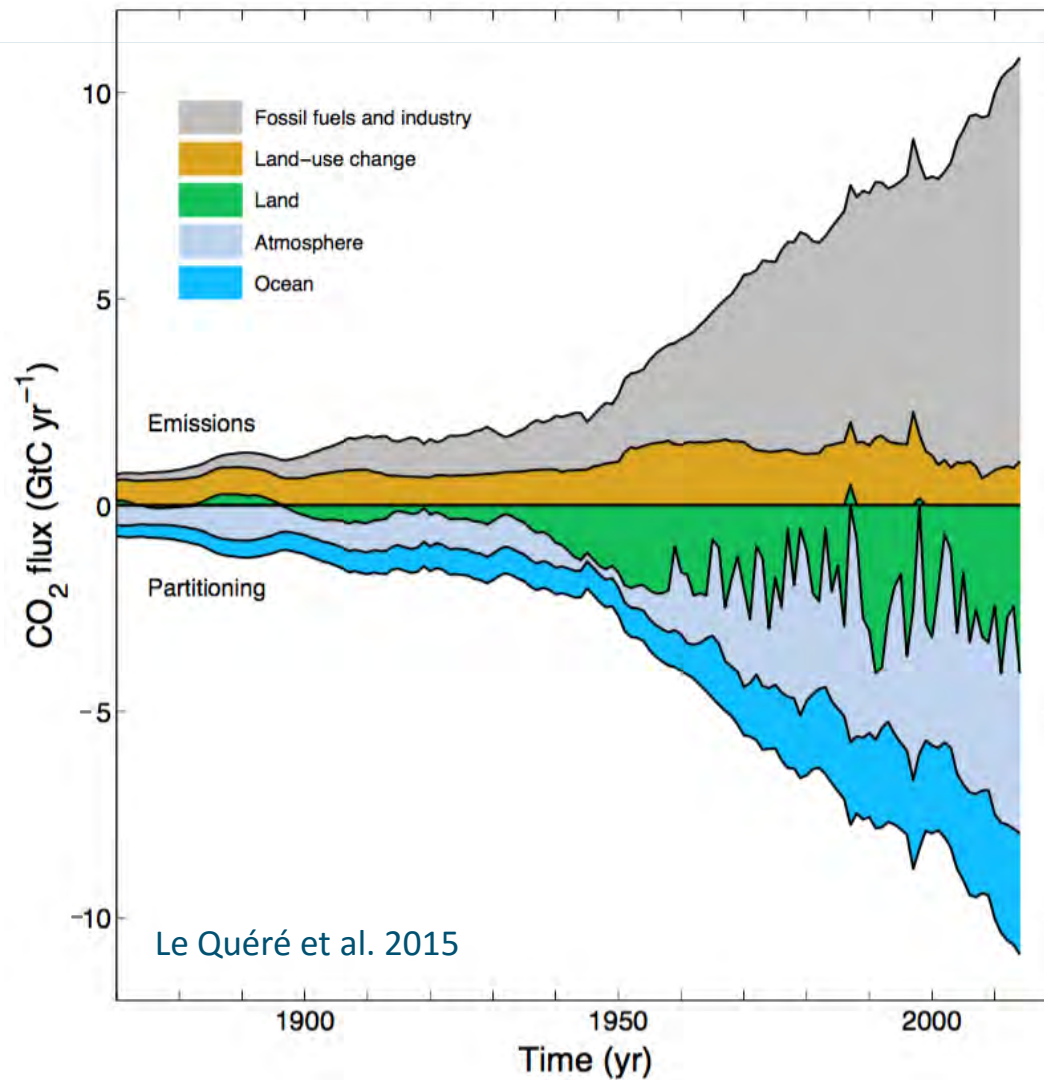
Land fluxes



Ocean fluxes



Global Carbon Budget 2015



Fossil Fuels

Land-use change

Residual land sink

Atmosphere

Ocean