regional carbon variations

Inversions & biogeochemistry

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The Global Carbon Cycle

Units: billion tons of C = 1 Gt C

Atmosphere
760 + 3 /yr

Ocean
38,000

~90+2 /yr
~90 /yr
~8 /yr

Humans
6.3 /yr
1.7 /yr

~120+3 /yr
~120 /yr

Land
2000

“Missing” carbon is hard to find!
Why Care about the Missing Sink?

- Further the understanding of carbon biogeochemistry
  - Human impact
  - Microbial respiration
  - Biospheric turnover times
  - etc.

- Crucial for predicting the evolution of $CO_2$ in the atmosphere
  - Were the missing sink to saturate or weaken, it would effectively *double* the emitted amount retained in the atmosphere each year!
  - With feedbacks this could be *much worse*!
Inversion Schematic

\[ \frac{\partial}{\partial t} (\rho C) = -\nabla \cdot (\rho CV) + S_c \]

- Concentration (observe)
- Transport (model)
- Sources and sinks (solve for)
The Inversion Methodology of TransCom

“background” or fixed fluxes - fossil, neutral bio
11 land, 11 ocean “adjustable” fluxes
1) Northern land sink *evenly spread* (Gt C/yr):
   - Temperate NA: $-0.83 \pm 0.5$
   - Europe: $-0.62 \pm 0.4$
   - Temp. Asia: $-0.61 \pm 0.7$
   - Boreal Asia: $-0.52 \pm 0.5$
   - Boreal NA: $+0.26 \pm 0.4$

2) Southern ocean flux ~50% of prior flux

   $-0.80 \pm 0.7$

3) Relative uncertainties

4) Rectifier has large impact on uncertainty and northern land fluxes.

*(Gurney et al., *Nature*, 2002)*
Interannual signature (deseasonalized)

- El Chichon eruption
- Pinatubo eruption

- Model mean
- Non fossil
- No transport variability
- 23 CO$_2$ stations
Biogeochemistry?

Can the spatiotemporal patterns of the interannual inversion results indicate mechanism?

Inversions unravel this (OK, we try)

BUT NOT THIS!

PPT, T, fpar, N

photosynthesis

respiration

fire

mixing

CO₂

Observed quantity

PPT, T, humans

But not this!
Deseasonalized, detrended, standardized net flux

Standardized ENSO index (MEI) + (0.55 \mu m) optical thickness (20 - 25 km)
Carbon - ENSO/Tau correlations

$N_{\text{eff}}$ using lag 1 autocorrelation and Bretherton et al., 1999.
Carbon and direct climate

Tropical Asia

NCEP reanalysis, aggregated to TransCom regions (air temp & precipitable water)
C, T, PPT lagged correlations

Trop Land: T↑, GPP↓, HR↑, fire?

Boreal NA:
warm, wet - F↓
cold, dry - F↑

Boreal Asia:
warm, wet - F↓
cold, dry - F↑
Spatiotemporal correlations

Method:

- Deseasonalize gridded time series of T and PPT (deviation from mean year)
- Remove long-term mean, detrend, standardize gridded time series of T and PPT
- Correlate (2 years lag and 2 years lead) gridded time series to each of 22 TransCom regional carbon exchange time series
- Compute $N_{\text{eff}}$ from lag-one autocorrelation
- Compute $t$ statistic from Bretherton et al., 1999
- Plot only correlations achieving 2-tailed at 5%

- The carbon flux in many regions have significant correlations with subregional structure within the region and sometimes structure outside
Spatiotemporal correlations

Southern Africa

QuickTime™ and a Cinepak decompressor are needed to see this picture.
Boreal Asia C vs T & PPT

Boreal Asia Fall (SON) precip vs carbon flux anomalies
significant (95%) Pearson r

Boreal Asia Fall (SON) T vs carbon flux anomalies
significant (95%) Pearson r
**Conclusions**

**Speculation on mechanisms:**

- Inverse-estimated carbon flux correlates to ENSO, tropical land \( r \) improves when aerosol considered
- Tropical Land carbon fluxes strongly correlated to \( T \) (“bio conspiracy”)
- The two major boreal regions respond in an anticorrelated fashion
  - Boreal NA +ve F with cold/dry in West: Spring
  - Boreal Asia +ve F with warm/wet across central N. Asia: Fall

**What next??**

- Fire, fpar
- Multivariate statistical model
- With gridded carbon - EOF/PC analysis (coming with OCO satellite)

*Inversions can do Biogeochemistry!!*
Spatiotemporal Correlations cont.

South America