Linking Atmospheric Carbon, Surface Water, and Water Storage using Multiple Satellite Remote Sensing Datasets

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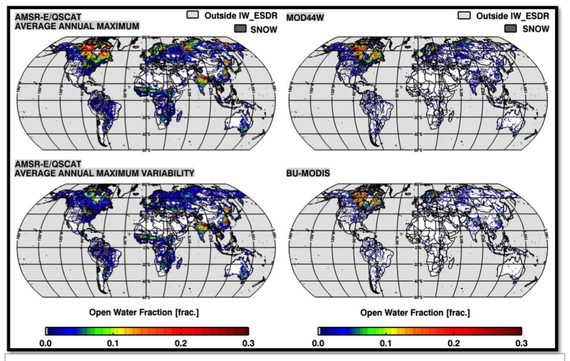
The sensitivity of Earth's wetlands to observed shifts in global precipitation and temperature patterns and their ability to produce large quantities of climate-active gases are key global change questions. Surface inundation is a crucial state variable that affects the rate of land-atmosphere carbon exchange and the partitioning of carbon between CO2 and CH4. Ground observation networks of large-scale inundation patterns are sparse because they require large fiscal, technological and human resources. Thus, satellite remote sensing products for global inundation dynamics, as well as total water storage and atmospheric carbon, can provide a complete synoptic view of past and current carbon - surface water dynamics over large areas that otherwise could not be assessed. Here we present results from a correlative analysis between spaceborne measurements of CO2, CH4, water storage (derived from gravity anomalies), inundated water fraction. A general assessment is conducted globally, and further time-series analysis is focused on four regions of interest: north Amazon, Congo, Ob, and Ganges-Brahmaputra river basins.

Datasets

Surface Water

Global maps of inundation extent at ~25 km grid spacing are derived from combined passive-active microwave remote sensing data sets from the AMSR-E and QuikSCAT instruments. We apply these data with ancillary land cover maps from MODIS to: 1) define the potential global domain of land inundation; 2) establish land cover driven predictive equations for implementing a dynamic mixture model adjusted to total column water vapor obtained from NASA's Modern Era Retrospective-Analysis (MERRA); and 3) construct a continuous, global record of daily surface water fraction dynamics. This the Inundated Wetlands Earth Science Data Record – IW_ESDR.



Global average AMSR-E/QSCAT (left) coarse-resolution (25 km) inundation fraction from IW_ESDR: average annual maximum (top left) and average annual range (bottom left) computed from daily 18.7 GHz, V and H polarization brightness temperature (Tb) data from the Advanced Microwave Scanning Radiometer on EOS (AMSR-E) and daily Ku-band (13.4 GHz) radar backscatter data from SeaWinds-on-QuikSCAT over the period 2003 – 2008. Static maps of global high-resolution (100 – 250m) open water fraction is shown on the right from MOD44W (top) and BU_MODIS (bottom), respectively. Areas outside the domain of IW_ESDR as well as areas covered with snow are masked out and appear as grey.

Total Water Storage

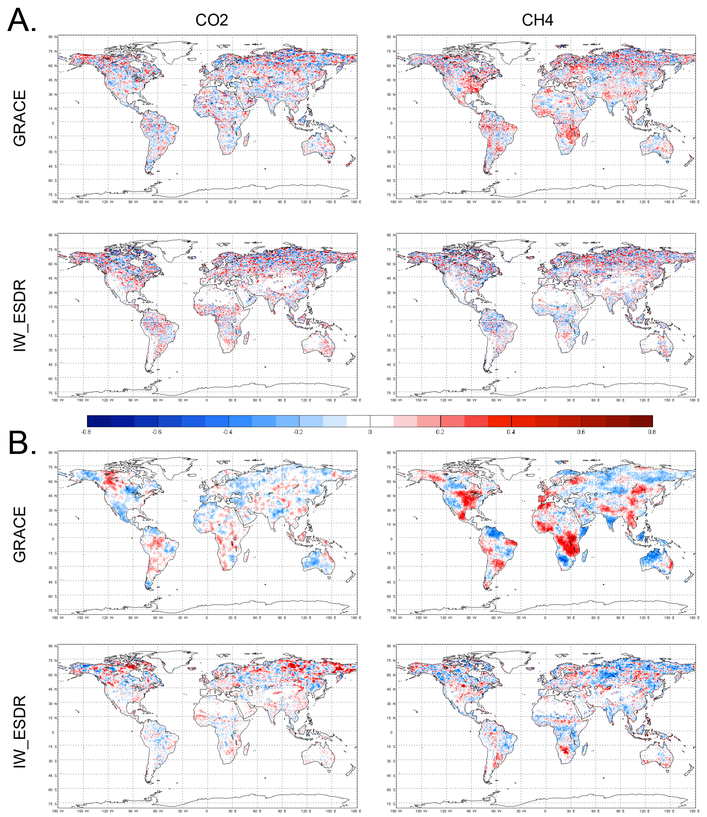
The Gravity Recovery and Climate Experiment (GRACE) mission consists of twin satellites whose orbits measure the temporal change in the Earth's gravitational field. The global gravity field is described as a geoid height, the deviation of the gravitational equipotential surface from a reference, "Equivalent water thickness" (or total water storage) is derived as a weighted sum of the geoid spherical harmonics with respect to spherical degree and the Earth's load deformation coefficients. We use the monthly, 1˚ x 1˚ "equivalent water thickness" product.

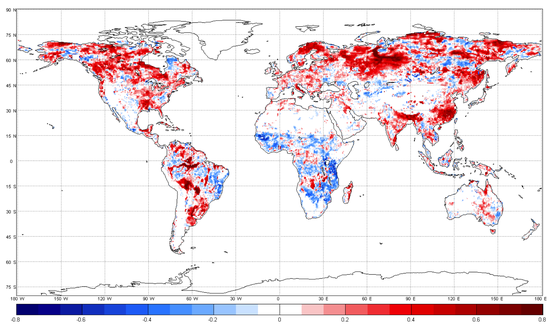
Atmospheric Carbon (CO_2 and CH_4) from 2 sources

- *SCIAMACHY* (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) instrument aboard ENVISAT: uses the absorption spectra of solar radiation in the near-infrared (1630 to 1679 nm) and is sensitive to the total methane column amount. We use the monthly, gridded 0.5˚ x 0.5˚ dry air column-averaged mole fractions for both CO_2 and CH_4. .

- *AIRS* (Atmospheric Infrared Sounder) instrument aboard EOS/Aqua: AIRS is a nadir cross-track scanning infrared spectrometer with 2378 channels covering from 649 to 2674 cm-1 at high spectral resolution and is most sensitive to CH_4 in the middle to upper troposphere. A gridded 2.5˚ x 2˚ total column average CO_2 mole fraction product is available. No column average product is available for methane, so we use the 1˚ x 1˚ mid-tropospheric (~309 hPa) volume mixing ratio for CH_4 measurements.

Global Correlations between Atmospheric Carbon and Surface Water Products





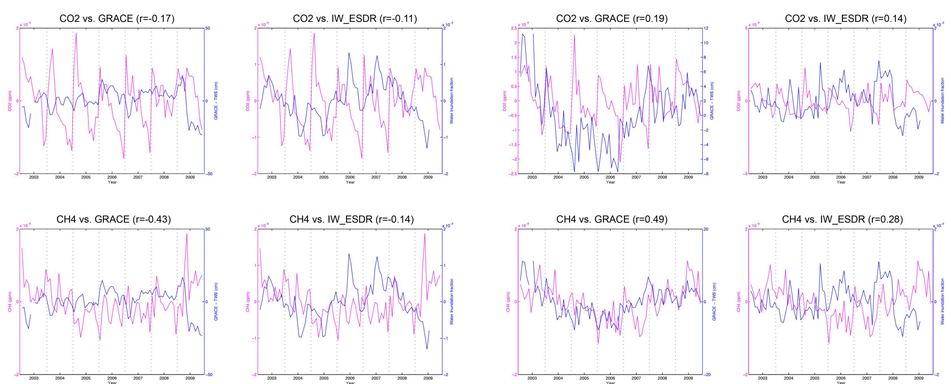
Correlations (r) between CO2 column volume mixing ratios (VMRs) (in parts per million), CH4 VMRs (in parts per billion) – and equivalent water thickness (in centimeters) determined from GRACE gravity anomalies and the Inundated Wetlands Earth Science Data Record (IW_ESDR). Carbon measurements from **(A)** SCIAMACHY and **(B)** AIRS. **(C)** displays the correlation between GRACE gravity anomalies and IW_ESDR. Correlations calculated over a 0.5˚ x 0.5˚ grid for 2003—2009. All data has been converted to monthly anomalies and detrended.

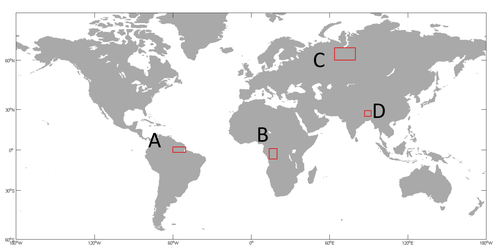
- GRACE and IW_ESDR demonstrate generally positive correlation except over parts of Africa **(C)**

- SCIAMACHY and AIRS CH4 relationship with GRACE and IW_ESDR show comparable correlation results **(A-B)**

- Since carbon measurements from AIRS generally appear to demonstrate stronger correlations, time series analysis (below) with AIRS was chosen.

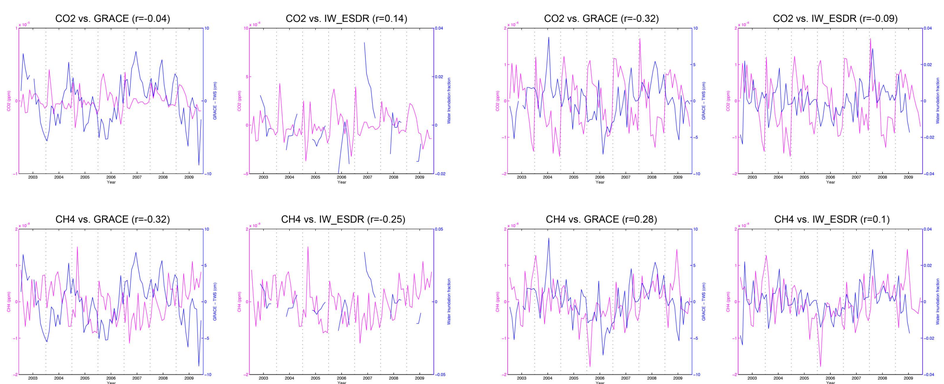
Regional Time Series Analysis





Time series of atmospheric carbon (AIRS) volume mixing ratio (magenta) and surface water products (blue), spatially averaged over **(A)** North Amazon, **(B)** Congo, **(C)** Ob, and **(D)** Ganges-Brahmaputra river basins, 2003 – 2009. All data converted to monthly anomalies and detrended. Vertical dashed lines indicate the start and end of each calendar year.

Correlation coefficient (r) is included in each plot title. These plots warrant a more robust lag analysis.



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