Multi-modal Flux Inversion Comparison with OCO-2

Sean Crowell, University of Oklahoma

With contributions from the OCO-2 Science Team and Flux and Uncertainty Quantification Subgroups

Acknowledgements: Sander Houweling (SRON), Prabir Patra (JAMSTEC)
Reducing Bias in OCO-2 Observations with Bayesian Preprocessing

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Acknowledgements: David Baker (NOAA/CSU), Brad Weir (NASA/GSFC), Junjie Liu (JPL), Andy Jacobson (NOAA/GMD)
Motivation

• OCO-2 observations contain information at unprecedented spatio-temporal resolution (i.e. we want to use them)

• Unfortunately, the bias corrected XCO2 product still contains bias relative to independent model estimates and observations -> bias in flux estimates that does not decrease with warn level

• Similar situation in storm scale NWP using polarimetric radar obs
  • Radar data is at much higher spatial resolution than NWP state
  • Assimilating radar data as is induces bias in the NWP state
  • Preprocessing obs to a coarser resolution helps to reduce these issues

• A pre-processing step might be able to reduce bias in flux estimates
Lots of Models!
Reducing Bias with a Least Squares Pre-processing Step

- Andy Jacobson has compiled 14 model concentration fields, sampled at OCO-2 locations
- Seek the minimizer of
  \[ J(x) = (x - x_b)^T B^{-1} (x - x_b) + (x - x_o)^T R^{-1} (x - x_o) \]
  where \( x_b \) is the inter-model mean (or something else) and \( x_o \) is the vector of bias corrected OCO-2 observations.
- O’Dell: “Posterior uncertainty is probably not too far off for bias-corrected XCO2” -> \( R \) is taken to be the diagonal matrix of OCO-2 posterior errors, inflated by 2
- \( B \) is taken to be the diagonal matrix with inter-model variances on the main diagonal
- \( x_a = (\sigma_b^2 + \sigma_o^2)^{-1} (\sigma_b^2 x_o + \sigma_o^2 x_b) \), \( \sigma_a^2 = (\sigma_b^2 + \sigma_o^2)^{-1} (\sigma_b^2 \sigma_o^2) \)
In each case, the large scale absolute coherent biases are either removed or reduced.

Kerpow!
Can see directly the impact of the different assumptions about uncertainty – is the high latitude NH uncertainty too small for OCO-2, or is that N/S variability real?
Flux Inversions

- TM5-4DVAR inversion with ERA Interim Meteorology – 6x4 lon/lat resolution, monthly fluxes
- Prior flux – CT-NRT Posterior (assimilates in situ obs, no remote sensing obs)
- Prior uncertainty – Land=|CASA-SiB|; Ocean=|Doney-Takahashi|
- Simulation time period: 6/1/2014-12/1/2015
- Observations
  - LN: Land Nadir “yellow”;
  - OG: Ocean Glint “blue”;
  - LG: Land Glint “red”;
  - OG+LG+LN: OCO-2 “black”, Inter-model Mean “grey”
- Single sounding errors inflated to have a noise floor of 0.6ppm
Updated Results – Global Totals

"As Is" With Preprocessing

Annual Emissions (PgC per year)

CT-NRT
LN WL15
LG WL15
OG WL15
OG LG LN WL15
Inter-model Mean
Updated Results – Regional Totals (Land)

"As Is"

With Preprocessing

Now with Better Agreement!
Updated Results – Regional Totals (Ocean)

"As Is"

The signs are the same!

Annual Emissions (PgC per year)

CT-NRT
LN WL15
LG WL15
OG WL15
OG LG LN WL15
Inter-model Mean
Diver down plots (Global Land vs. Global Ocean)

- Fossil = 11PgC
- Fossil = 9PgC
- Nov 2014 - Oct 2015 (3ppm growth rate)

Circle = WL 15
Diamond = WL 10
Star = WL 15 Preprocessed

Global Land (PgC per year) vs. Global Ocean (PgC per year)
TCCON Comparisons

• Forward sampling at selected TCCON sites through Nov/Dec 2015
• XCO2 is computed using the TCCON prior and averaging kernel

*Correlations and Standard Deviations are for the full record. Monthly values are noisier.
TCCON Comparisons

Dryden

North American Model-TCCON diffs are insensitive to the pre-processing.

*Correlations and Standard Deviations are for the full record. Monthly values are noisier.
Comments

Preprocessing the obs

• leads to somewhat more realistic fluxes, especially in the Southern Hemisphere

• brings the results from different observing modes into better agreement with one another (also with the inter-model mean inferred fluxes)

• implies greater combined land and ocean sinks

• improves TCCON agreements in the Southern Hemisphere

The inter-model mean XCO2 fields are *not* independent of the other observation sets, since CT-NRT is one of the models, and others use TM5
Future Plans

• Repeat this analysis with a statistically independent prior XCO2 field ($x_b$) and updated uncertainty for $x_b$ and $x_o$ that include a comparison to TCCON

• Independent comparison for regional fluxes (fires, upscaled eddy covariance fluxes, suggestions welcome)

• Online method for addressing bias: add bias parameters to the inversion state vector
  • distributions on bias correction coefficients
  • raw vs. bias corrected XCO2

• OSSE to determine posterior flux dependence on observing mode

Thanks for your attention!