Multi-m … ersion Comp … OCO-2 … a

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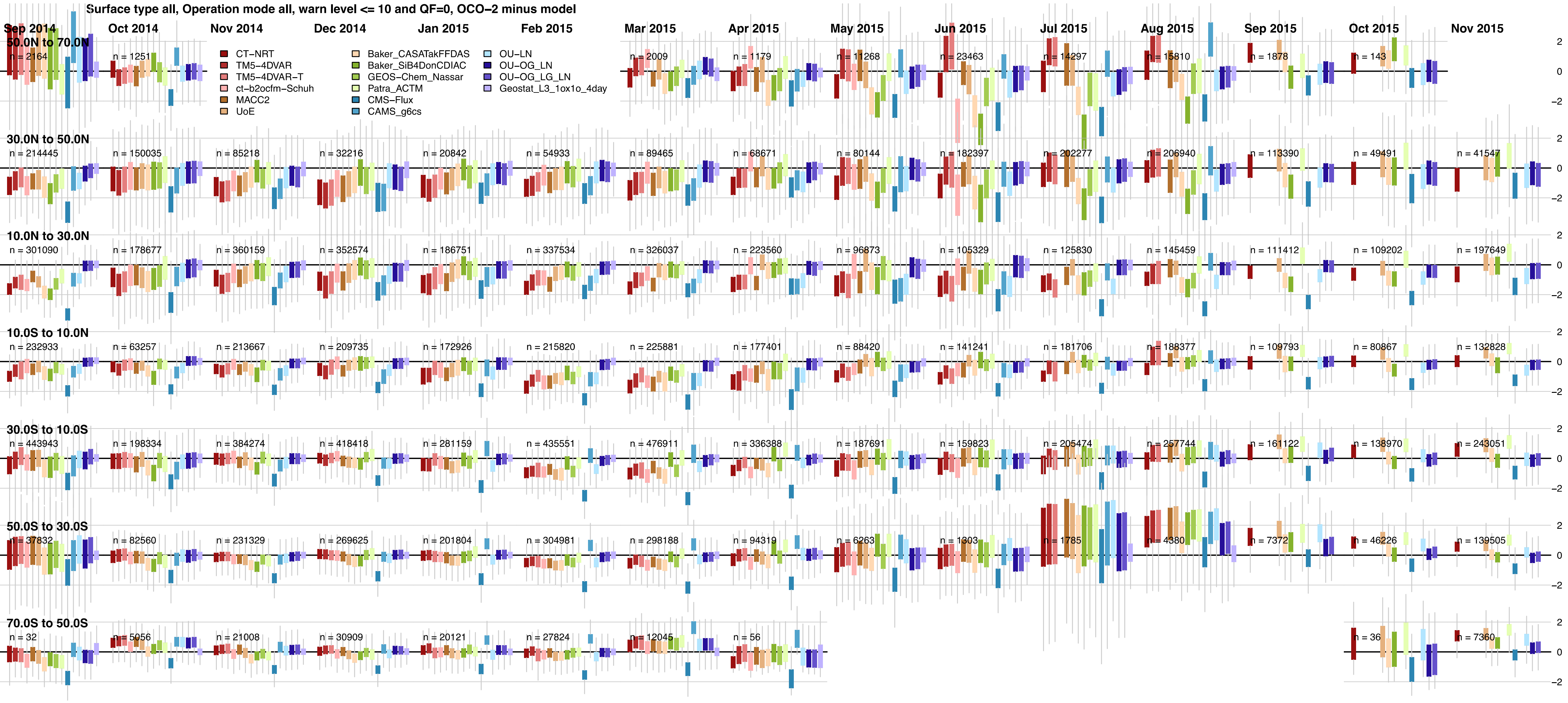
With contributions from the OCO-2 Science Team and Flux and Uncertainty Quantification Subgroups

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

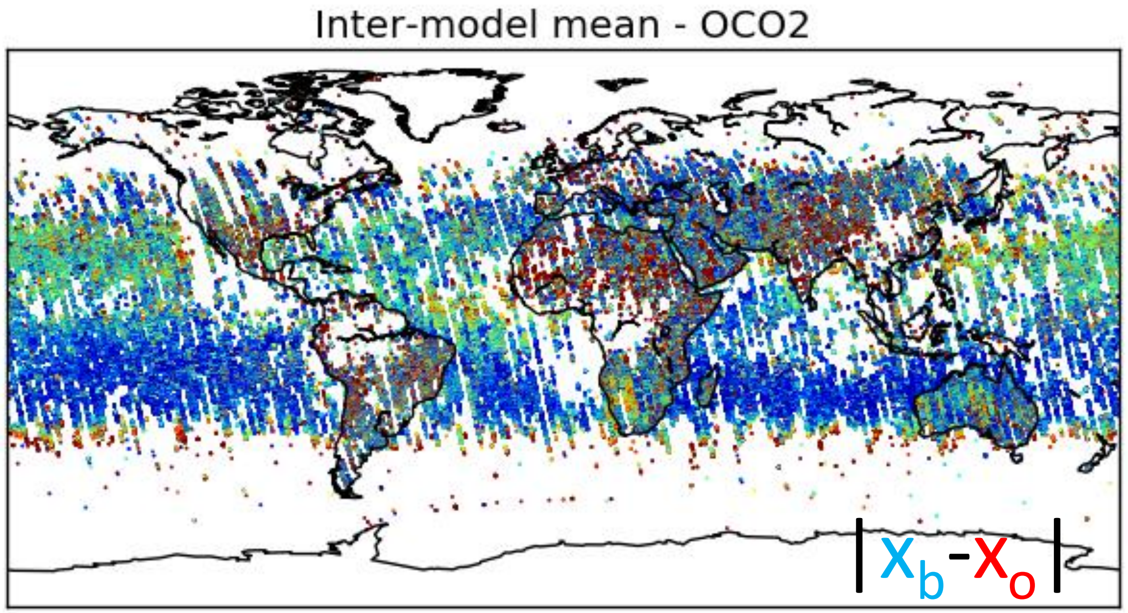
- Andy Jacobson has compiled 14 model concentration fields, sampled at OCO-2 locations
- Seek the minimizer of

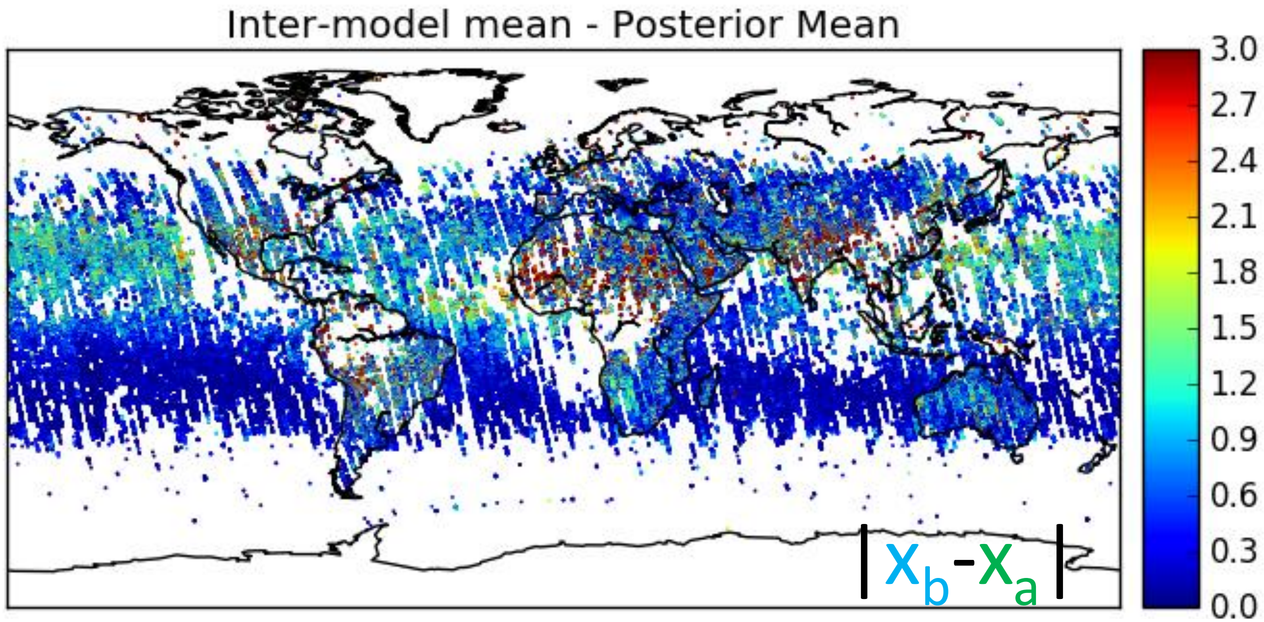
$$J(x) = (x - x_b)^{\mathrm{T}}\mathbf{B}^{-1}(x - x_b) + (x - x_o)^{\mathrm{T}}\mathbf{R}^{-1}(x - x_o)$$

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
- $x_a = (\sigma_b^2 + \sigma_o^2)^{-1}(\sigma_b^2 x_o + \sigma_o^2 x_b)$, $\sigma_a^2 = (\sigma_b^2 + \sigma_o^2)^{-1}(\sigma_b^2\sigma_o^2)$

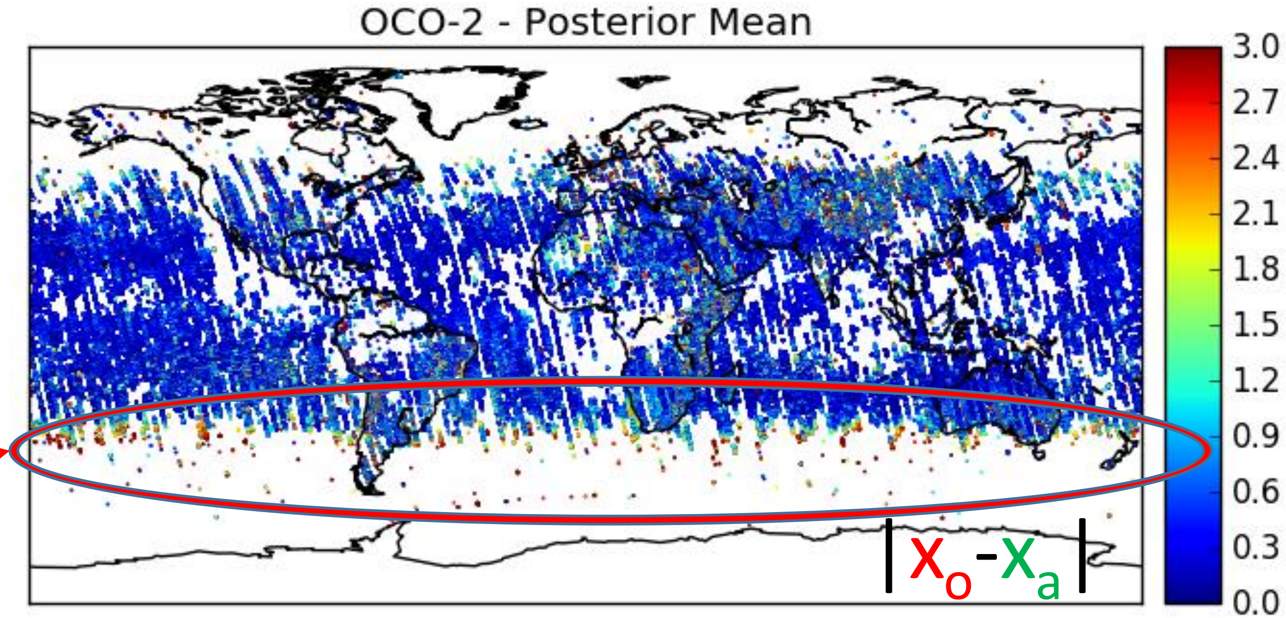
Sample Results – September 2014



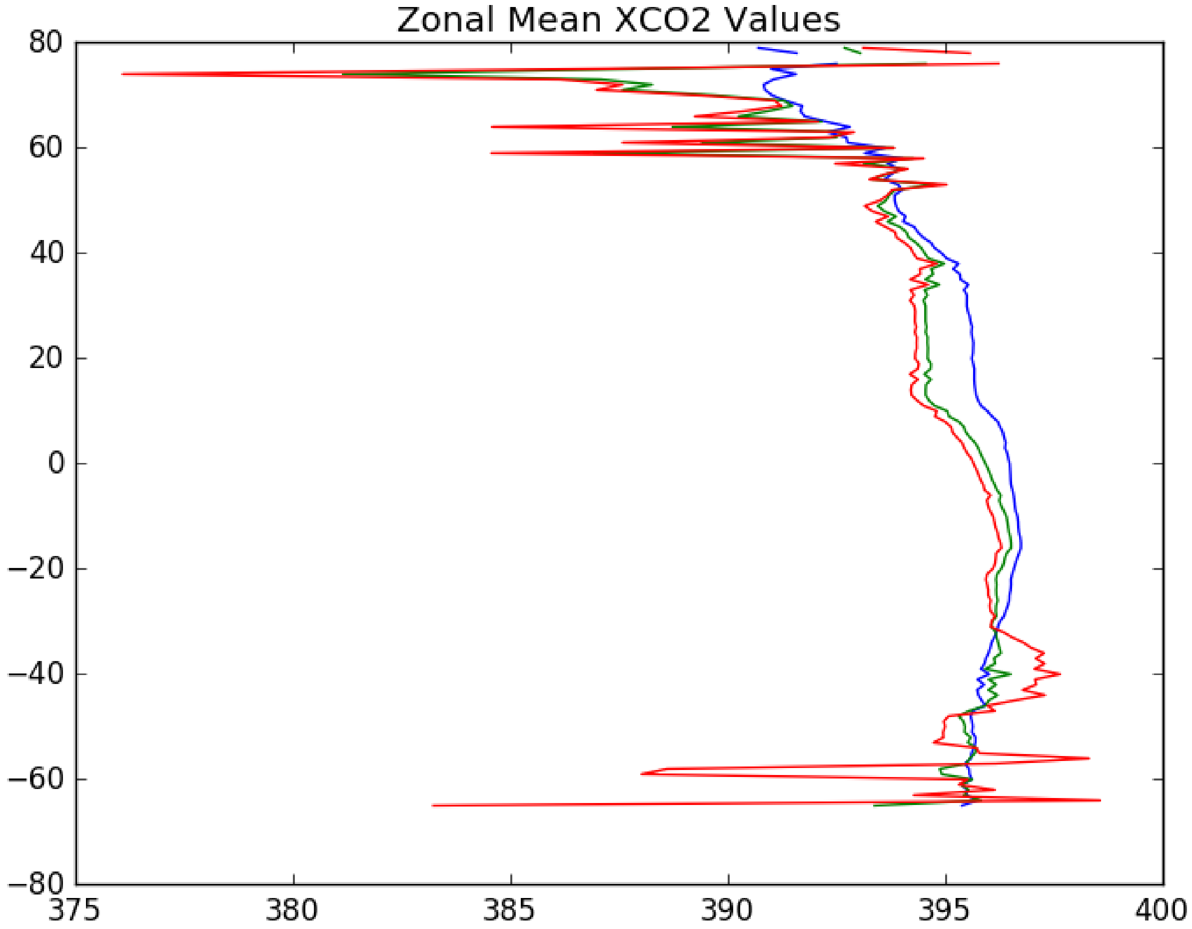


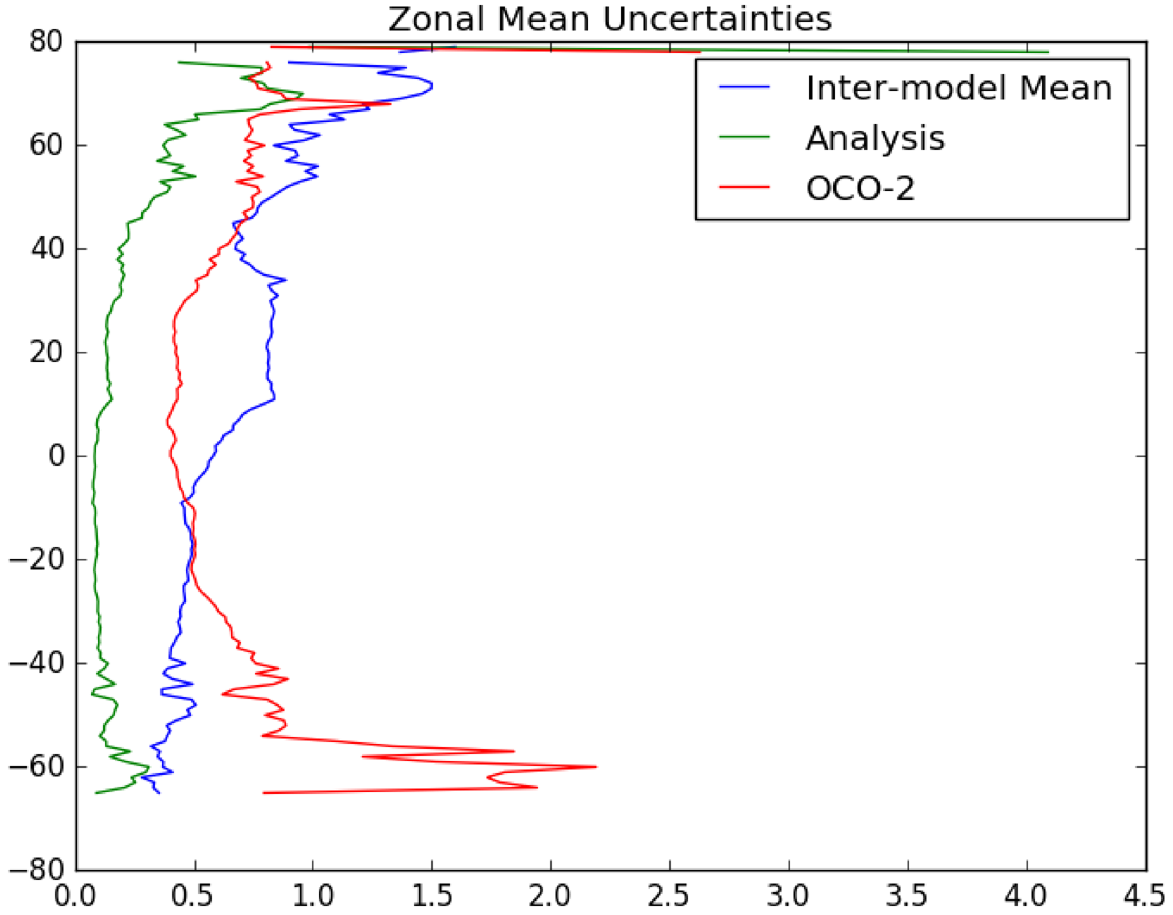
In each case, the large scale absolute coherent biases are either removed or reduced.

Kerpow!



Zonal Means and Standard Deviations – September 2014



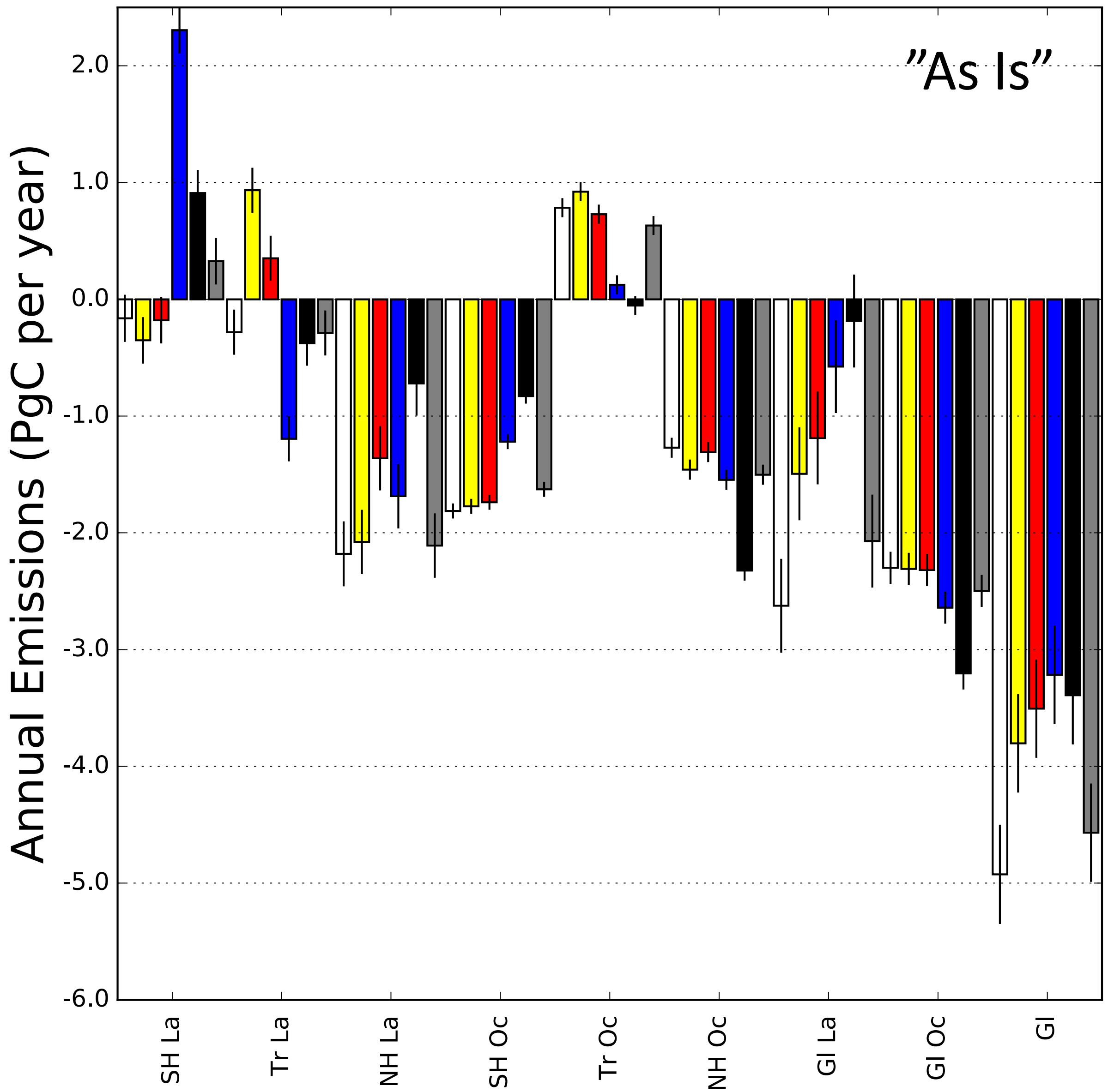


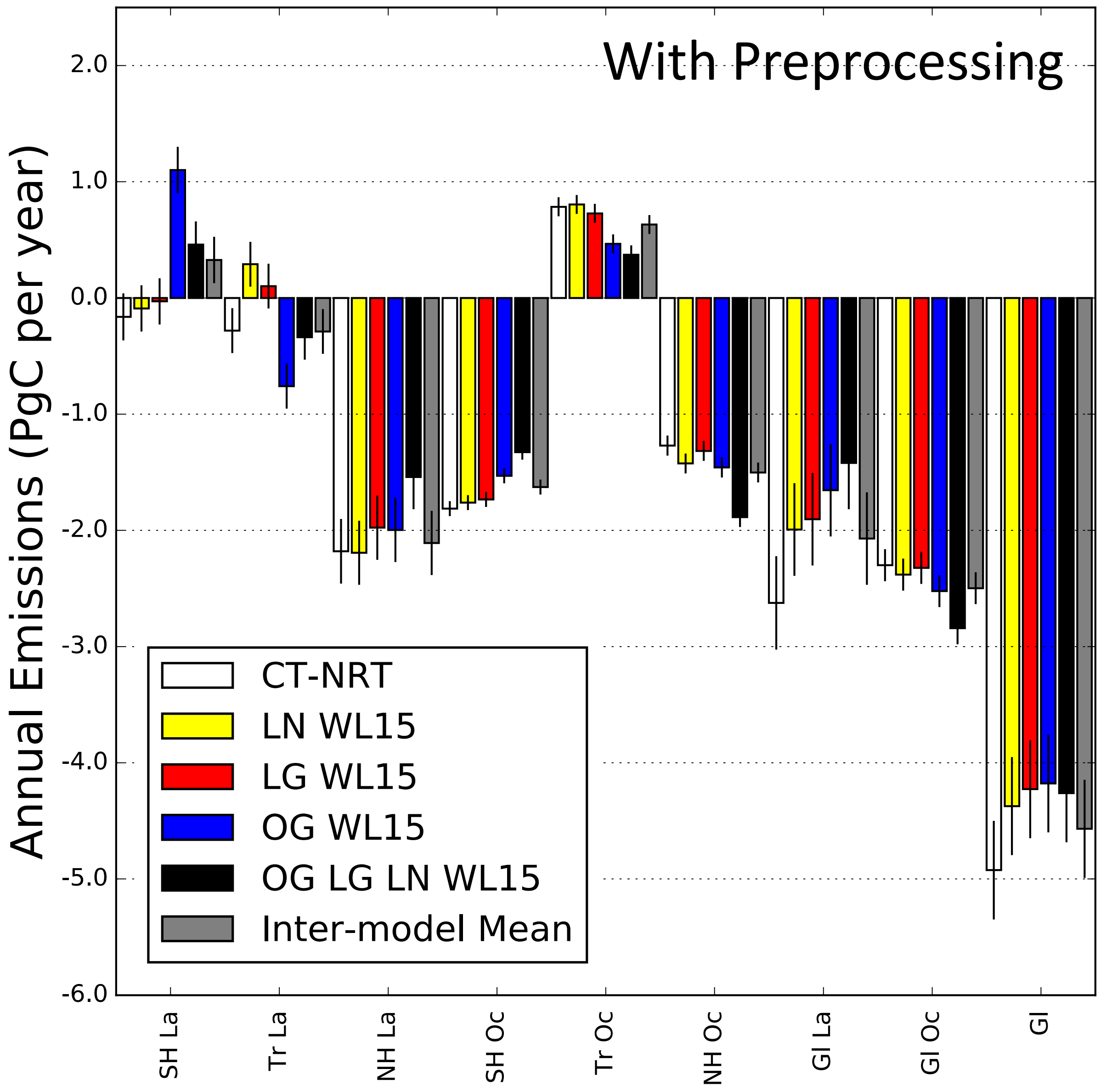
Can see directly the impact of the different assumptions about uncertainty – is the high latitude NH uncertainty too small for OCO-2, or is that N/S variability real?

Flux Inversions

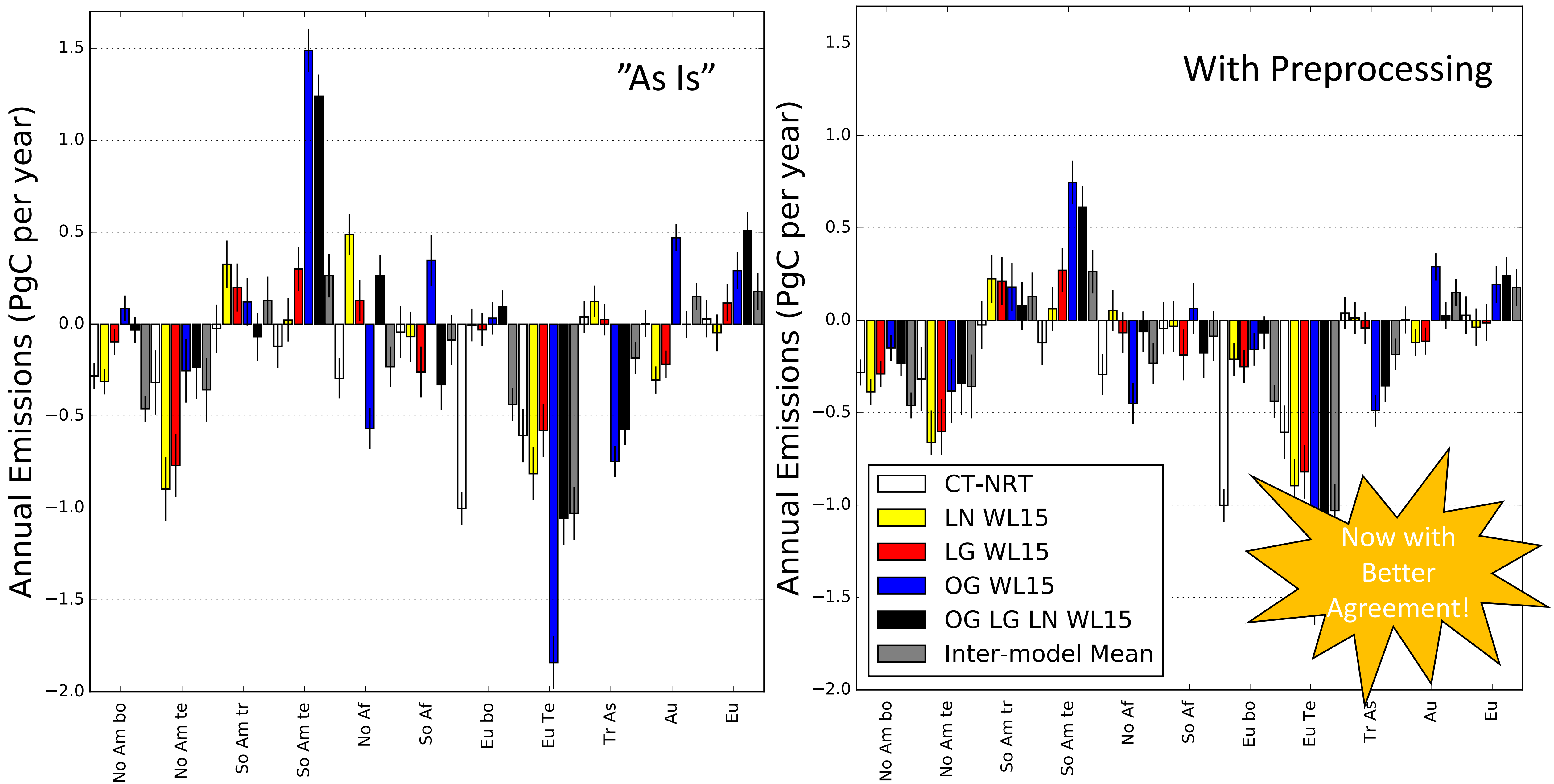
- TM5-4DVAR inversion with ERA Interim Meteorology – 6x4 lon/lat resolution, monthly fluxes
- Prior flux – CT-NRT Posterior (assimilates in situ obs, no remote sensing obs)
- Prior uncertainty – Land=|CASA-SiB|; Ocean=|Doney-Takahashi|
- Simulation time period: 6/1/2014-12/1/2015
- Observations
    - 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

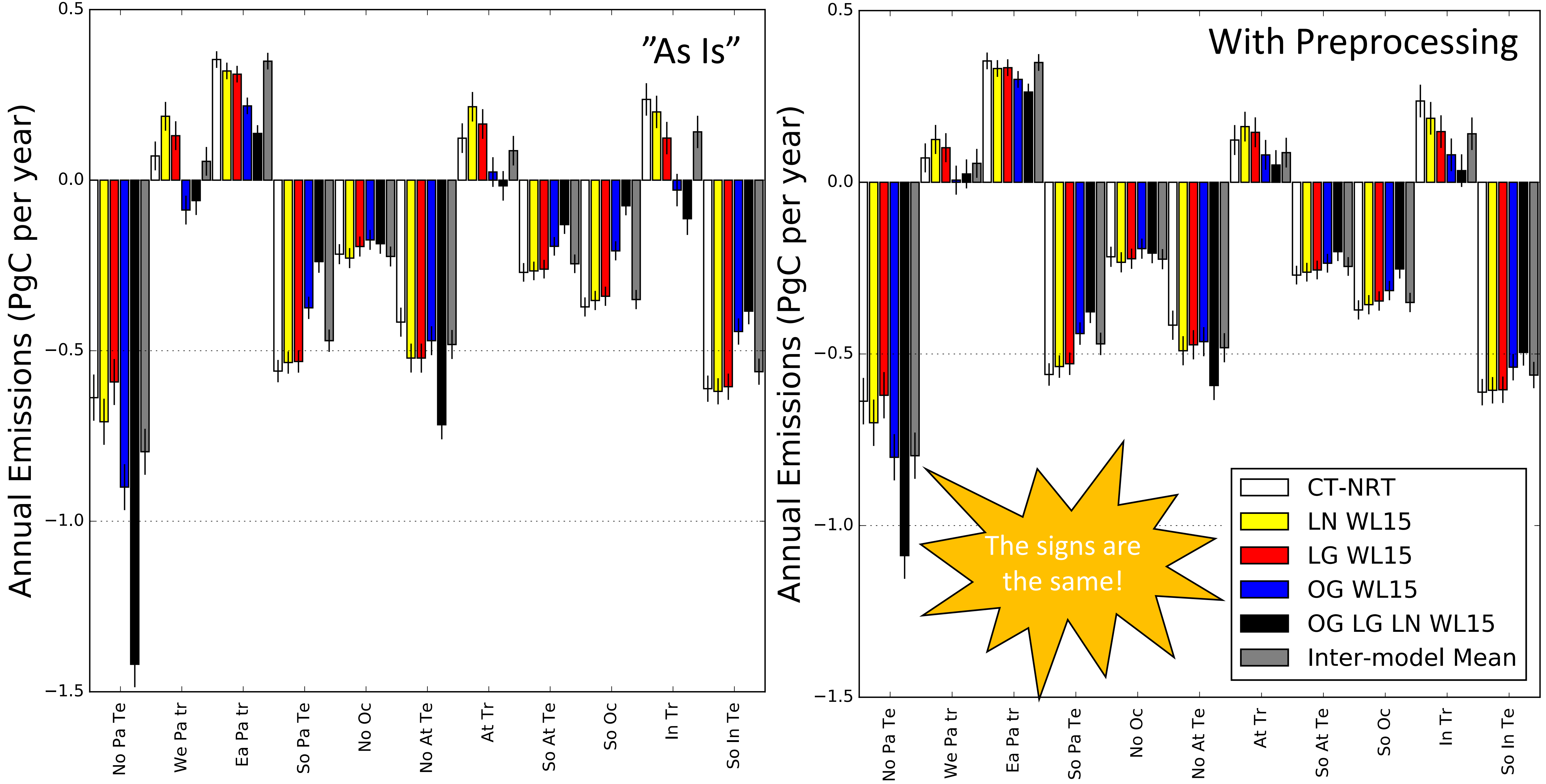




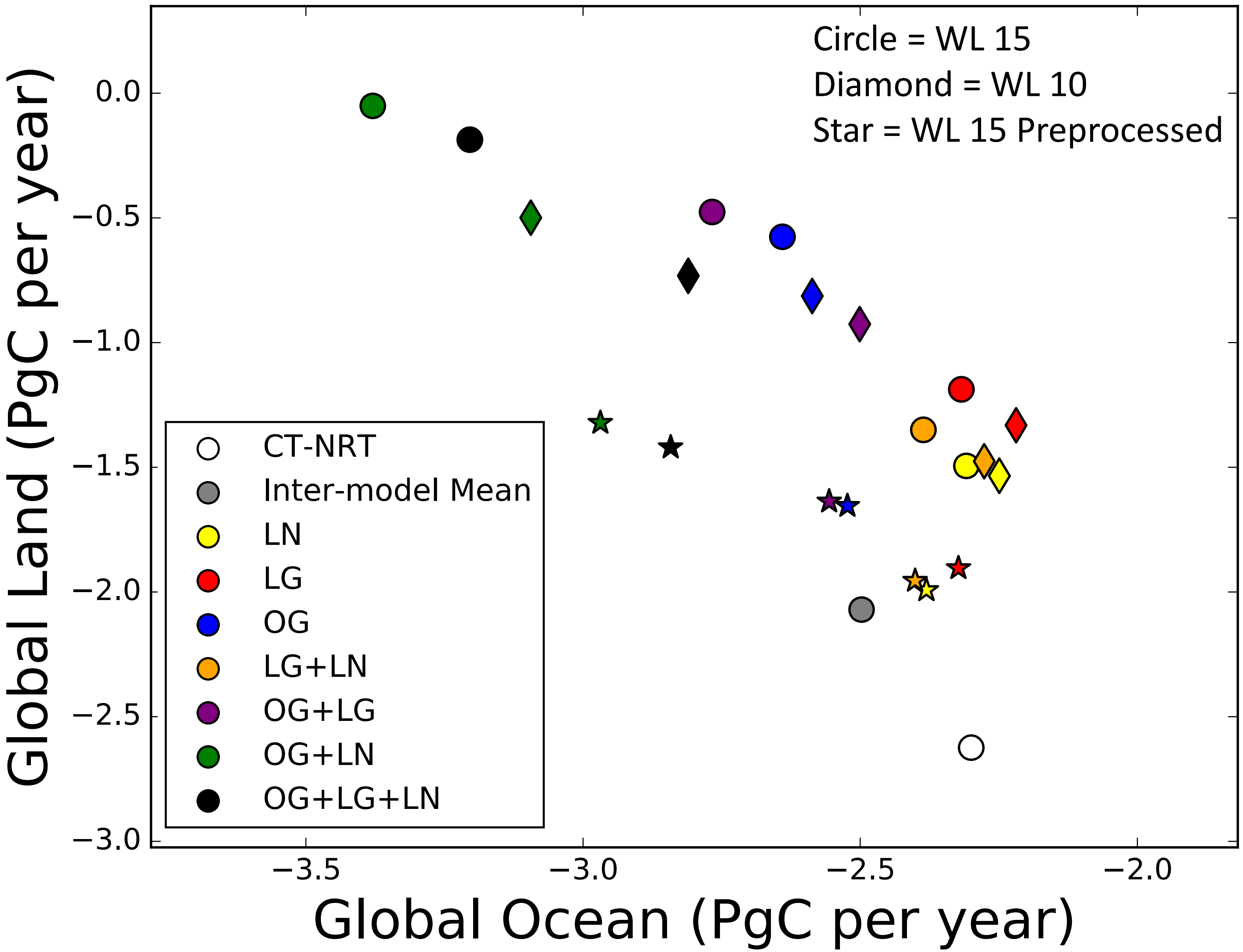
Updated Results – Regional Totals (Land)



Updated Results – Regional Totals (Ocean)



Diver down plots (Global Land vs. Global Ocean)



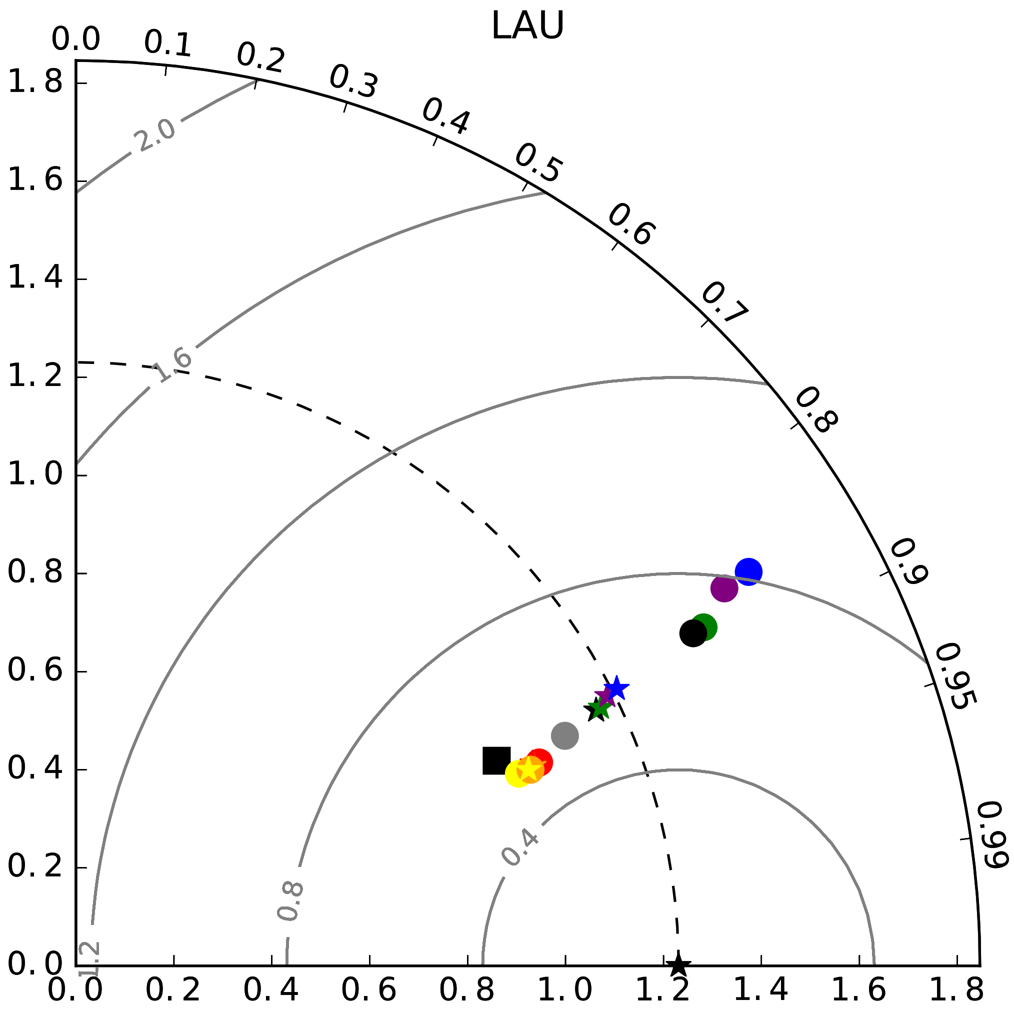
Fossil = 11PgC

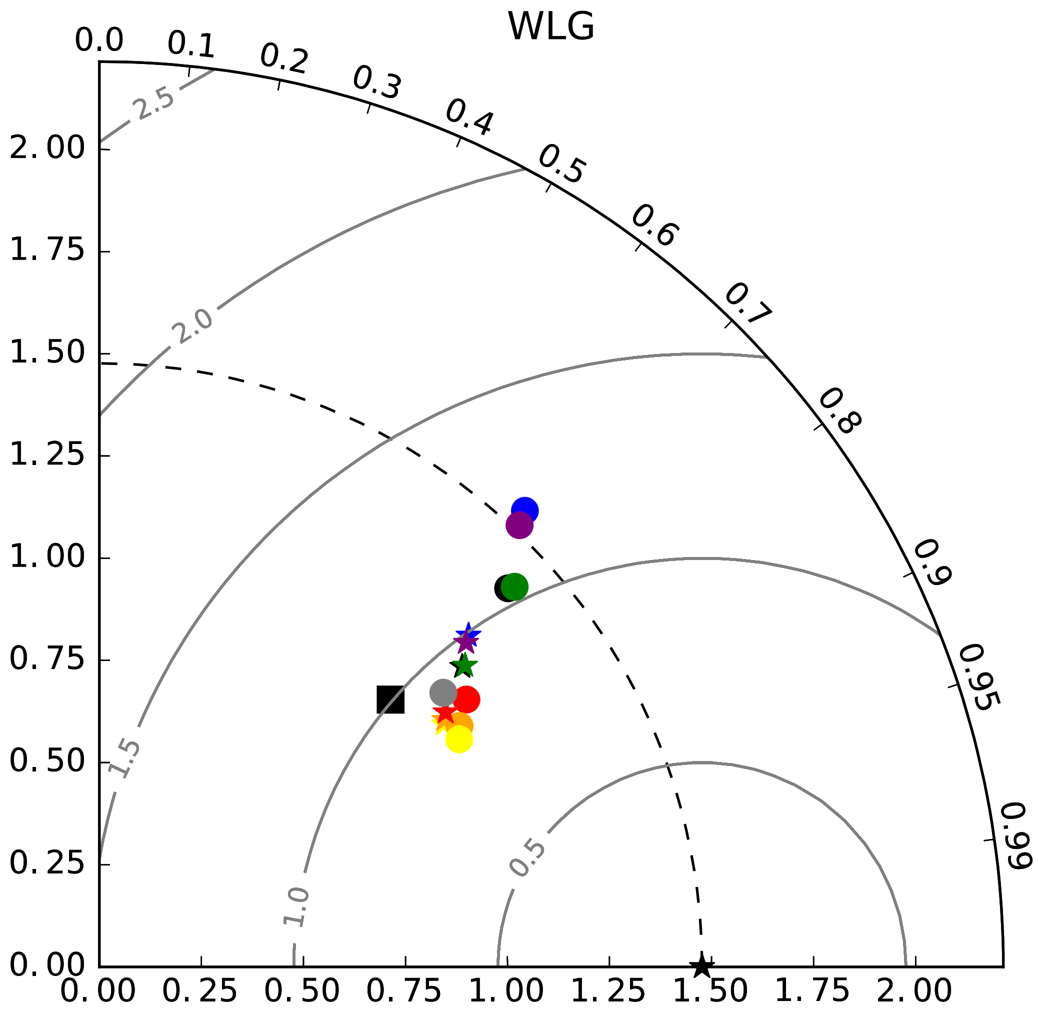
Nov 2014 - Oct 2015
(3ppm growth rate)

Fossil = 9PgC

TCCON Comparisons

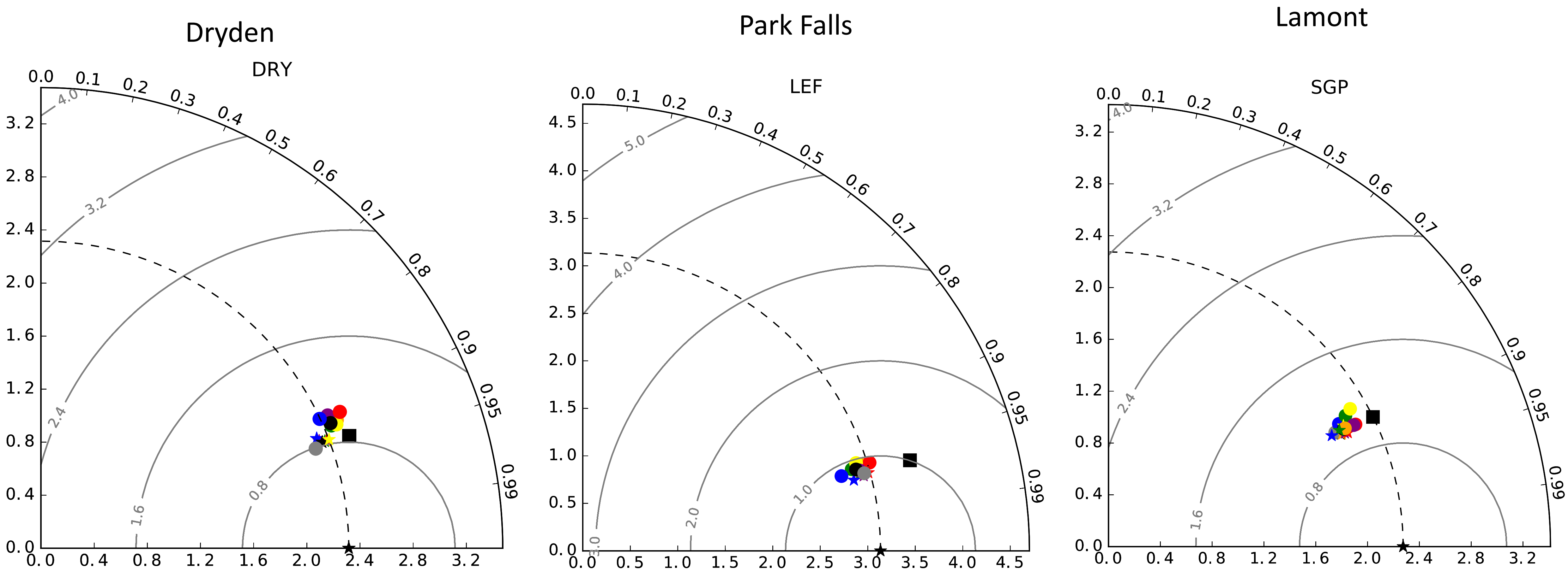
- Forward sampling at selected TCCON sites through Nov/Dec 2015
- XCO2 is computed using the TCCON prior and averaging kernel





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

TCCON Comparisons



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

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

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!