Derivation of Carbon Fluxes for 2003 and 2004 Using Maximum Likelihood Ensemble Filter

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INTODUCTION

We used an ensemble based data assimilation system, Maximum Likelihood Ensemble Filter (MLEF), which has been coupled with Parameterized Chemistry Transport Model (PCTM), to estimate Carbon fluxes for years 2003 and 2004. We assimilated 49 flask sites and 20 continuous sites to estimate separate multiplicative biases (βs) in photosynthesis, respiration, and air-sea gas exchange. Spatial covariance in the biases was updated in the assimilation process. Biases were defined in 10° longitude by 6° latitude spatial resolution, where as transport was run at 2.5° longitude by 2° latitude spatial resolution with 25 vertical levels.

$$F(x,y,t) = [1+\beta_{Res}(x,y)]Res(x,y,t) - [1+\beta_{GPP}(x,y)]GPP(x,y,t) + [1+\beta_{Ocean}(x,y)]Ocean(x,y,t) + FF$$

METHODS

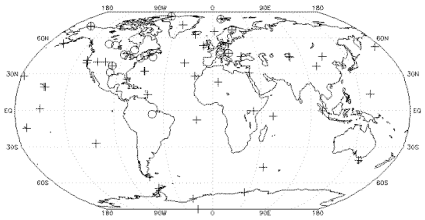
Minimize the cost function:

$$C(\boldsymbol{\beta}) = \frac{1}{2}[\boldsymbol{y} - H(\boldsymbol{\beta})]^T \boldsymbol{R}^{-1}[\boldsymbol{y} - H(\boldsymbol{\beta})] + \frac{1}{2}[\boldsymbol{\beta} - \boldsymbol{\beta}_b]^T \boldsymbol{P}_f^{-1}[\boldsymbol{\beta} - \boldsymbol{\beta}_b],$$

were $\boldsymbol{\beta} = \begin{bmatrix} \boldsymbol{\beta}_{GPP} \\ \boldsymbol{\beta}_{RES} \\ \boldsymbol{\beta}_{Ocean} \end{bmatrix}$

- In each cycle, minimize the cost function by maximum likelihood method.
- Minimization is done in a reduced space (preconditioned space).
- The average of analysis from the previous cycle and the background is taken as the forecast for the current cycle.
- Covariance smoothing was introduced (only at the first cycle) using an exponential covariance function with de-correlation length scales 800 km over the land and 1600 km over the ocean.
- Localization was done based on the sigma ratio (prior/posterior). Changes to the biases are allowed based on the upper tail vales of the ratio distribution.
- 8-week β's with 4-week overlap windows.

Observation Sites



+ -Flasks O -Continuous (sampled from 11 to 16 hrs)

Prior:

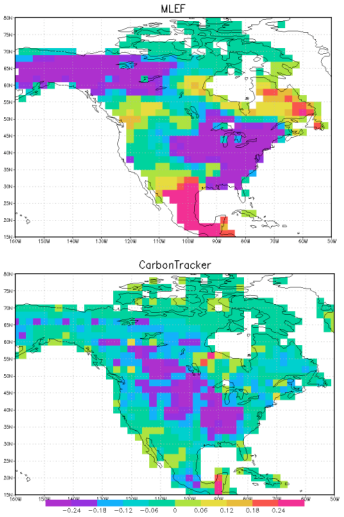
β = 0 (unbiased case), $\sigma_{GPP} = \sigma_{RESP} = 0.2$, $\sigma_{Ocean} = 1.0$

Number of Ensemble Members = 200

3 year spin-up (2000-2002) before assimilation of observations from 2003-2004.

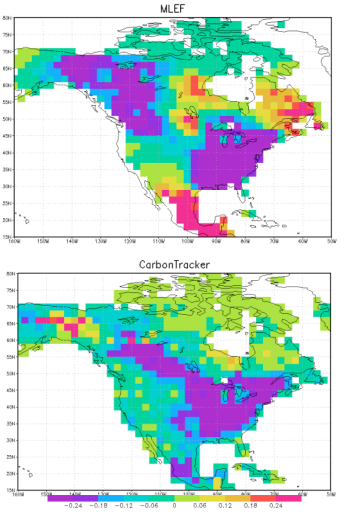
RESULTS

Mean Annual NEE for 2003



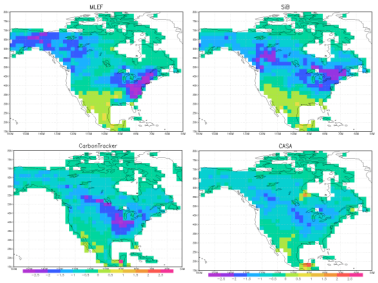
µmoles/m²/Sec.

Mean Annual NEE for 2004



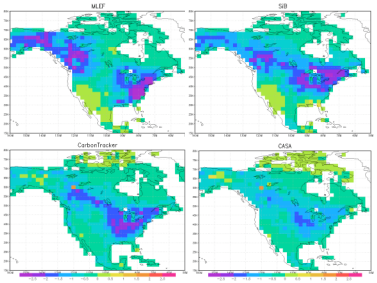
µmoles/m²/Sec.

SUMMER NEE for 2003



µmoles/m²/Sec.

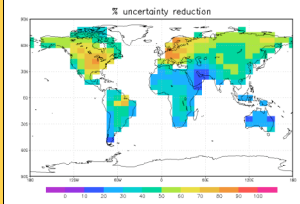
SUMMER NEE for 2004

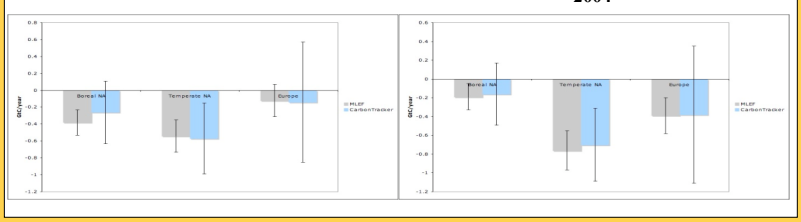


µmoles/m²/Sec.

Net Ecosystem Exchange for North America and Europe

	2003		2004	
units: GtC/year	MLEF	Carbon Tracker	MLEF	Carbon Tracker
Boreal NA	-0.38 ± 0.15	-0.26 ± 0.37	-0.19 ± 0.14	-0.16 ± 0.33
Temperate NA	-0.54 ± 0.19	-0.57 ± 0.42	-0.76 ± 0.21	-0.70 ± 0.39
Europe	-0.12 ± 0.19	-0.14 ± 0.71	-0.39 ± 0.19	-0.38 ± 0.73





SUMMARY AND CONCLUSIONS

We estimated carbon fluxes for years 2003 and 2004 using the ensemble based MLEF method. According to the percentage uncertainty reduction, densely observed North American and European regions show good constraint on flux estimates. Hence we chose to show results only from those regions. We compared our results with CarbonTracker, another existing ensemble based data assimilation system. Both models showed similar results when averaged up into large (TransCom) regions. However, the spatial patterns were quite different. These differences could be due to difference in the treatment of biases in two methods. CarbonTracker solves for predefined ecoregions, whereas MLEF doesn't use any predefined spatial structures. Also the spatial pattern of the flux estimates tends to dominate by that of prior fluxes. Posterior uncertainties could be under estimated due to consideration of tight prior uncertainties around the biases.

See T4-056 for a satellite application of this model.

References:

CarbonTracker 2008, http://carbontracker.noaa.gov

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Acknowledgements: This research is supported by the grants from National Aeronautics and Space Administration (NNX06AC75G & NNX08AM56G). We would like to thank Arlyn Andrews (NOAA GMD), Birgitta Noone (SU), Claudio Vannini (CESI), Douglas Worthy (MSC), Ingeborg Levin (UHEI-IUP), Karin Uhse (UBA), Larry Flanagan (University of Lethbridge), Phillipe Ciais (CarboEurope), Sebastien Biraud (LBNL), Steve Wofsy (WMO WDCGG), Tuula Aalto (FMI), and William Munger (Harvard University) for providing data. We would also like to thank NOAA GMD for providing flask observations.