CarbonTracker Asia 2016: an Estimation of CO$_2$ Fluxes Centering on Asia

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CO₂ in atmosphere keeps increasing

We need a tool quantitatively estimating CO₂ flux

But, the dynamics are not well known!

TM5 met EnSRF then, they turned into the CarbonTracker (by NOAA ESRL)!

An Asian variation: CT Asia

https://www.ersl.noaa.gov/gmd/ccgg/trends/

Lord Kelvin
I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind.
Today I will show you ..

- The latest update of the CT-Asia
- The impact of observation data (JMA & CONTRAIL which are only assimilated in the CTA)
- Demonstration of the CTA2016
- What to do next in order to visit here again
- The vision of NIMS in the CTA Development
Inverse modeling for CO$_2$ flux estimation

\[ x^a = x^p + \left( H P^b H^T + R \right)^{-1} P^b H^T (y - H x^p) \]

\[ F = \lambda_r (F_{bio} + F_{ocn}) + F_{ff} + F_{fire} \]

- Transport model: TM5
- Model-data mismatch Covariance(\(R\)) is known
- Background error covariance (\(P^b\)) is calculated by TM5
- Adopting nested grid(1°×1°) in Asia$^1$)
- JMA continuous observation and CONTRAIL data were assimilated


The CarbonTracker Asia 2016
The impact of JMA observation

- MDM values of them are set to 3.0 (for a continuous site)

- Hourly averaged data were assimilated

- There is a prominent flux difference before and after assimilation

- Bias, RMSE, and $R^2$ at Ryori are highly improved

- Fluxes around Japan seem to be estimated better!
The impact of CONTRAIL observation

- CONTRAIL data\(^1\) are assimilated in CTA-2016
- For each bin, observation values are spatially and temporally(\textit{daily}) averaged
- Referred to H. F. Zhang et al\(^2\)
- Developed based on CT-2013B by YSU
- Modified to CT-2016 by NIMS

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<table>
<thead>
<tr>
<th>Exp. Name</th>
<th>Observation</th>
<th>MDM</th>
<th>Assimilation period</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTRL</td>
<td>Surface only (RYM added)</td>
<td>CT-NOAA : adoptively ryo, mnm, yon : 3 ppm</td>
<td>2005.11.05~2014.12.31</td>
</tr>
<tr>
<td>CONT</td>
<td>Surface (RYM added) + CONTRAIL</td>
<td>same as CTRL for surface 2 ppm for CONTRAIL</td>
<td>2005.11.05~2014.12.31</td>
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</table>


The impact of CONTRAIL observation

<table>
<thead>
<tr>
<th>Exp. name</th>
<th>Period</th>
<th>Eurasia Boreal</th>
<th>Eurasia Temperate</th>
<th>Tropical Asia</th>
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<tbody>
<tr>
<td></td>
<td>2006~2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTRL</td>
<td></td>
<td>-1.47±0.96</td>
<td>-0.45±0.73</td>
<td>-0.09±0.19</td>
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<tr>
<td>CONT</td>
<td></td>
<td>-1.35±0.82</td>
<td>-0.58±0.59</td>
<td>-0.09±0.37</td>
</tr>
</tbody>
</table>

Terrestrial biosphere flux during the period (PgCyr⁻¹)

CTRL CONT

<table>
<thead>
<tr>
<th></th>
<th>RMSE</th>
<th>R²</th>
<th>bias</th>
<th>RMSE</th>
<th>R²</th>
<th>bias</th>
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<tbody>
<tr>
<td>AZV</td>
<td>5.16</td>
<td>0.83</td>
<td>-0.34</td>
<td>4.83</td>
<td>0.85</td>
<td>-0.54</td>
</tr>
<tr>
<td>BRZ</td>
<td>4.94</td>
<td>0.84</td>
<td>-0.50</td>
<td>4.94</td>
<td>0.84</td>
<td>-0.40</td>
</tr>
<tr>
<td>DEM</td>
<td>4.91</td>
<td>0.84</td>
<td>-0.85</td>
<td>4.78</td>
<td>0.85</td>
<td>-0.96</td>
</tr>
<tr>
<td>IGR</td>
<td>8.04</td>
<td>0.68</td>
<td>-3.06</td>
<td>7.51</td>
<td>0.71</td>
<td>-2.72</td>
</tr>
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<td>KRS</td>
<td>5.22</td>
<td>0.84</td>
<td>-1.26</td>
<td>5.15</td>
<td>0.85</td>
<td>-1.29</td>
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<td>NOY</td>
<td>5.03</td>
<td>0.84</td>
<td>-1.55</td>
<td>5.18</td>
<td>0.82</td>
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<tr>
<td>SVV</td>
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<td>-1.02</td>
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<td>VGN</td>
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<td>1.16</td>
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<td>1.09</td>
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<tr>
<td>YAK</td>
<td>7.37</td>
<td>0.71</td>
<td>-2.56</td>
<td>6.45</td>
<td>0.77</td>
<td>-1.72</td>
</tr>
</tbody>
</table>

better  worse  So so
Results

Global natural (bio+fires+ocean) fluxes averaged over 2001-2015 [gC/m²/yr]

Latitudinal distribution of the averaged posterior for flask observation residuals and their standard deviations (Summer & Winter)
Conclusion

- The CTA has been updated!
- The impact of JMA and CONTRAIL observation data is presented.
- We demonstrated the new version of CTA: The CarbonTracker Asia 2016.
- **Siberia observation data** assimilation for CTA-2016 in progress\(^1\)
- **Adoptive MDM** is applied to JMA, CONTRAIL, and JR siberia data.
- CTA-2017 will be released.
- Webpage for CTA will be updated.

Thank you for your attention!
Uncertainty reduction (CONT vs CTRT)
Averaged for 2006~2014
(a) Vertical profile of modeled (black) and observed (red) CO2 concentration for whole airports and their differences (green) with its 1-sigma range (dashed grey), (c) and (d) are same plot with (a) and (b) respectively at Haneda airport. (e) and (f) are at Narita airport. Then, (g) and (h) are results for the airports with exclusion of Haneda and Narita airports.
ICN vertical profile