Validation of TES Methane with HIPPO Observations

Application to Adjoint Inverse Modeling of Methane Sources

Aura Science Team Meeting

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Adjoint Inverse Modeling of Methane Sources

TES Methane *(Worden, Kulawik)*

Validation

GEOS-Chem CTM

HIPPO Methane *(Wofsy, Kort)*

Apriori Sources

GEOS-Chem Adjoint

HIPPO Methane provides:
- Large number of profiles
- Wide latitudinal coverage
- Remote from sources (reduces colocation error)

Other Methane

Adjoint inverse analysis

OPTIMIZATION OF SOURCES

*EDGAR v4, Kaplan, GFED 2, Yevich and Logan [2003]*
• Methane retrieval 7.658 – 7.740 μm
• Averaging kernels peak 200-400 hPa
• Degrees of Freedom for Signal 0.5-2.0
• ~50% of TES observations pass CH$_4$ quality filter
• Unit of comparison for this work is Representative Tropospheric Volume Mixing Ratio (RTVMR)

Reduce all profiles to 1 piece of information representative of tropospheric mixing ratio.
HIAPER Pole-to-Pole Observation Program (HIPPO)

HIPPO I

HIPPO II

HIPPO I - interpolated methane

Pacific transect (flights 3-7 of 10)
Dominant variability with latitude
Little variability in vertical

• Five missions:
  - Jan, Nov 2009
  - April 2010, June & Aug 2011
• > 700 vertical profiles by finish
  - 80% surface – 330 hPa
  - 20% surface – < 200 hPa
• Methane Instrument Properties
  - Frequency: 1 Hz
  - Accuracy/Precision: 1.0/0.6 ppb
Using HIPPO to Define Coincidence Criteria

Validation characterizes mean bias and residual error. Residual error contains contributions from:
1) error in the retrieval
2) colocation error

HIPPO profiles: ~ 250 km
TES observation: 5 x 8 km

Coincidence requirements of +/- 750 km and +/- 24 h are sufficient.

Mean Bias
Residual Standard Dev.
# Observations
HIPPO v. TES by Latitude

**HIPPO 1**
Jan 9-30, 2009

**HIPPO 2**
Oct 22 – Nov 20, 2009

Positive bias and significant noise, but latitudinal gradient roughly captured.
HIPPO v. TES Difference by Latitude

HIPPO 1
Jan 9-30, 2009

HIPPO 2
Oct 22 – Nov 20, 2009

HIPPO I:
- bias = 73.7 ppb,
- residual std dev = 43.1 ppb
- ≈ 3 x self-reported error

HIPPO II:
- bias = 59.9 ppb,
- residual std dev = 48.4 ppb
- marginally sig. land-ocean diff
Distribution of TES Residual Errors

HIPPO I
1/9 - 1/30, 2009

HIPPO II
10/22 – 11/20, 2009

Error distributions

Scatterplots

Normally distributed errors are important for derivation of inverse cost function.
The Ability of TES to Capture Latitudinal Gradients

TES captures HIPPO I & II latitudinal gradients on a scale of ~20°
Twin Tests for Inversion of Methane Sources

Why perform twin tests?
- Test the inverse calculation
- Understand the effects of TES error and apriori
- Find optimum length of assimilation period

The twin test methodology
- “Observe” GEOS-Chem with TES
- Add error to pseudo-observations of magnitude determined by HIPPO validation
- Begin adjoint inversion with incorrect apriori
- Goal: to recover original emission field.

# of Observations    July 2008    total = 22038
Twin Test Results

Optimize July 2008 emissions, assimilating data for variable lengths of time.

<table>
<thead>
<tr>
<th>Assimilation Length</th>
<th># observations</th>
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<tbody>
<tr>
<td>Top</td>
<td>1 month</td>
</tr>
<tr>
<td>Middle</td>
<td>2 months</td>
</tr>
<tr>
<td>Bottom</td>
<td>1 year</td>
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Tradeoff between number of observations and spatial resolution of emissions
TES V004 alone is not sufficient for use in a global adjoint inversion.
Next Steps

- Assimilate TES V004 CH$_4$
- Evaluate inversion results with NOAA GMD surface observations
- Validate new TES CH$_4$ retrieval by John Worden
  - sensitivity near surface
- Assimilate more satellite products (New TES CH$_4$, SCIAMACHY, AIRS, GOSAT).
- Zoom in on North America using GEOS-Chem nested grid capability (0.5° x 0.667°)

I will simultaneously assimilate multiple satellite data sets
• TES captures latitudinal gradient in HIPPO data at ~20° resolution
• TES is biased high and residual instrument error is 3 x self-reported range
  – 73.7 ± 43.1 ppb during HIPPO I
  – 59.9 ± 48.4 ppb during HIPPO II
• Colocation error in validation is negligible
• Intend to publish results of HIPPO comparison.
• Enabling Inverse Modeling:
  – Quantification of bias, characterization of error
  – Robust latitudinal gradient with greater coverage than surface stations
  – Assimilation period ≥ 1 month required.
  – Tradeoff between length of assimilation period and spatial scale of interpretability of results
• Begin inversion with TES CH₄
• Evaluate inversion results with NOAA GMD surface observations
• Incorporate additional satellite CH₄ products and focus on N.A.