The need for atmospheric chemistry products from CrIS

Ask not what CrIS can do for the country, but what the country expects from CrIS

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May 14, 2014
Atmospheric composition data from space: facts and questions

- Data available since 1999. How much more data can we expect from current instruments?
- Is the data accurate and useful? How can we tell?
- Do we need more data and for what applications?
- Early products from CrIS
What (CO) data is available and how much more can we expect?

Launched in 1999

Launched in 2002, stopped working ~ 2006/2013

Launched in 2002

Launched in 2004

Launched in 2006 and 2012 (3rd one in 2016)
CO data from space: is it accurate?

Which one of these is “the best”?

Long term record? **MOPITT**  
High accuracy? **TES**  
Dense global coverage? **AIRS**  
Sensitivity near the surface? **SCIAMACHY**

Kopacz et al. 2010
CO data from space: is it accurate?

Which one of these is “the best”? 

- Long term record? MOPITT
- Dense global coverage? AIRS
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Kopacz et al. 2010
Is the data accurate? How can we tell?
Chemical Transport Model (CTM) as a comparison platform

- **SATELLITE DATA**
  - satellite 1
  - satellite 2
  - satellite 3

- **global Chemical Transport Model (CTM) → forward model**
- **in situ observations**

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TRUTH
but very sparse in time and space
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**NEED AVERAGING KERNELS!**
GEOS-Chem Chemical Transport Model (CTM): the comparison platform

EMISSIONS  CTM  CONCENTRATIONS

Compare with in situ data

Compare with satellite data

\[ \hat{y} = y_a + A(y - y_a) \]

MOPITT CO columns

EMISSIONS

CONCENTRATIONS

MOZAIC

Northern midlatitudes (Ireland)

Northern tropics (Hawaii)

GEOS-Chem+ MOPITT AK
May 2004 – April 2005 global daytime columns (averaged on 2°x2.5° resolution of GEOS-Chem)

*TES data for 2005-2006

Measure of information content: degrees of freedom (DOFs) ↔ color dimension

Unit: $10^{18}$ molec/cm²

Kopacz et al. 2010

Model: satellite correlations
Is the data useful?
Inverse estimates of CO sources

**GEOS-Chem CO column:** \( F(x_a) \)

**satellite CO column:** \( y \)

\[ J(x) = (F(x) - y)^T S^{-1} (F(x) - y) + (x - x_a)^T S^{-1}_a (x - x_a) \]

**a priori sources:** \( x_a + \varepsilon_a \)

**satellite data (MOPITT, AIRS, SCIAMACHY Bremen):** \( y + \varepsilon_o \)

**model concentrations:** \( F(x) + \varepsilon_m \)

**observation error:** \( \varepsilon_e = \varepsilon_o + \varepsilon_m + \varepsilon_r \)

RESULT: monthly CO source estimates at 4º x 5º resolution
Seasonal variability of emissions: largely missing in \textit{a priori} estimates

* Streets et al. [2006] did not include \textit{Streets et al.} [2003] seasonality
Regional CO source estimates: N. America

**Previous study**

GEOS-Chem w/ NEI99 emission inventory > INTEX-A observations

Hudman et al. [2008]

NEI99 60% too high (in the summer)

**Conclusion:** Hudman et al. [2007] correction to NEI99 inventory ok in the summer, not in fall-winter

**Current study w/ 60% correction**

- **winter (DJF):** Emissions too high
- **spring (MAM):** Emissions too low
- **summer (JJA):** Emissions too high
- **fall (SON):** Emissions too low

GEOS-Chem w/ NEI99 emission inventory

INTEX-A observations

Hudman et al. [2008] NEI99 60% too high (in the summer)
CrIS product (being) developed with AC4 support

Surface and **CrIS NH$_3$** in DISCOVER-AQ 2013

- Open path Quantum Cascade Laser (QCL) on a moving platform collected data almost directly under TES transect (red symbols) in the San Joaquin Valley on January 28, 2013

- Hotspot measured near Tipton

- Satellite and QCL NH$_3$ measured in January 2013 are spatially well correlated

*Credit: Matt Alvarado and Karen Cady-Pereira*
Conclusions

• CrIS needs to provide long term high quality CO retrieval to continue CO monitoring from space, and to continue addressing a large array of air pollution transport, source and chemistry problems
• CrIS should and will provide NH$_3$ retrievals
• CrIS can and does provide a range of species that are currently being retrieved from TES, AIRS and IASI
• CrIS products need to be developed with averaging kernels for comparison with other data and for validation purposes
• CrIS products need to be and can be validated with future NOAA and other field campaigns
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A priori emissions ($x_a$): fossil fuel, biofuel and biomass burning

Global inventories:
- Fossil fuel EDGAR 3.2 (global)
- Biomass burning GFED2 (global)

Regional inventories:
1. US fossil fuel: NEI99 – 60%
2. Mexico fossil fuel: BRAVO
3. Europe fossil fuel: EMEP
A posteriori estimates of CO sources: emissions too low

Annual mean a posteriori/a priori emission ratio

Annual total: 1350 Tg
Regional CO source estimates: Europe

**Findings:** Similar seasonality and spatial inhomogeneity as in N. America

Possible **reasons** for underestimate: residential heating, “cold starts”
Regional CO source estimates: Asia

**Findings:**
Stronger seasonality in China than in N. America, no considerable seasonality in India

Possible **reasons** for underestimate: residential heating, “cold starts”
Improvement in model-data agreement from source inversion

Fractional model bias: \( \frac{(\text{model-data})}{\text{data}} \) during sample period: Sept-Oct-Nov 2004

Conclusion: a balance of information, but AIRS dominates due to data density AND regional instrument inconsistencies
Comparison with independent surface measurements (GMD network)

Northern Hemisphere:
great improvement

Southern Hemisphere:
still a challenge to match obs.

Model \textit{a priori}  Model \textit{a posteriori}

Obs (2004-2005)  Obs (climatology)
Comparison with independent aircraft measurements (MOZAIC)
Major conclusions

1. GEOS-Chem CTM is a useful intercomparison platform for analyzing satellite data consistency

2. MOPITT, AIRS, TES and SCIAMACHY CO concentrations are generally consistent, especially in the northern hemisphere

3. Global annual CO emissions are found to be 1350 Tg

4. CO emissions in N. America, Europe and China exhibit strong seasonality, consistent with surface and aircraft observations

5. Tropical (mostly biomass burning) sources in S. America and Africa are estimated to be 183 and 343 Tg, mostly driven by AIRS data (larger than MOPITT or SCIAMACHY in southern hemisphere)

6. Regional satellite inconsistencies in southern hemisphere result in overestimated sources → motivation for more accurate data
Amount of *a priori* information in model-satellite correlations

Measure of information content: degrees of freedom (DOFs)

**Note:** DOFs not available for SCIA; reprocessing with MOPITT a priori does not change SCIA correlations