Continuous GHG Monitoring at Local to Statewide Scales

William Callahan, Elena Novakovskaia and Christopher Sloop
Northeast CO2 Model
Models require a detailed understanding of atmospheric dynamics
Earth Networks Surface Observation Network
Global Lightning System

Over 600 Sensors Installed and Growing
Landward (off-zenith) retrievals 29 Mar 2010
Greenhouse Gas Network Plans

- Install & operate 100 advanced GHG instruments.
- ~50 in U.S., ~25 in Europe, ~25 around remaining continents
- Measure CO2 (carbon dioxide) & CH4 (methane)
Sampling System

Front View

Side View

“Calibration Box”
Typical Tower: Lewisburg, Pennsylvania
Site Data...

San Diego, CA

**LIVE WEATHER AND GHG DATA FROM SCRIPPS**

Tuesday, January 11, 2011 1:03:46 PM +00:00 GMT -8

Temp: **61.2°F**

Switch to Celsius

**CO₂ (ppm)** | **CH₄ (ppb)**
---|---
**SCRIPPS** | **417.4** | **1968**
Global Average | 366.3 | 1366

Site Status: Provisional

**CARBON SOURCE MAP**

1/11/11 1:00 PM (GMT -8)

**Time Interval:** 10 Minutes, 30 Minutes, 8 Hours, 24 Hours, 48 Hours, 1 Week

**Carbon dioxide (CO₂) Levels**

<table>
<thead>
<tr>
<th>Time (GMT -8)</th>
<th>13:00</th>
<th>15:00</th>
<th>17:00</th>
<th>19:00</th>
<th>21:00</th>
<th>23:00</th>
<th>01:00</th>
<th>03:00</th>
<th>05:00</th>
<th>07:00</th>
<th>09:00</th>
<th>11:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPM</td>
<td>370</td>
<td>380</td>
<td>390</td>
<td>400</td>
<td>410</td>
<td>420</td>
<td>430</td>
<td>440</td>
<td>450</td>
<td>460</td>
<td>470</td>
<td>480</td>
</tr>
</tbody>
</table>

Earth Networks™

Taking the Pulse of the Planet™
Earth Networks Data Sets

- Level 0 – Raw Atmospheric, Operational and Metadata
- Level 1 – QC flags included
- Level 2 – Calibrations applied
- Level 3 – Filter information included
Calibration

March 2012
Variance Filter

SIO CH4 January 2012

All data

Filtered data

* Heather Graven, UCSD
Turbulence Filter

Thunderstorm passing by...
Emissions Estimate Example...
Relevance to Gas and Oil Wells in PA

Source:
http://www.americanrivers.org/our-work/protecting-rivers/endangered-rivers/endangered-susquehanna.html?gclid=CLC1oq-fj68CFUXc4AodTSv0zA
Inversion Methodology: Region Analysis

Following LBNL’s approach (Zhao et al., JGR, 2009):

An *a priori* emission maps from different spatial regions in the domain are linearly scaled by factors $\lambda$, to provide *posterior* emissions that are optimally consistent with the tower measurements, $C$, and background air, $C_{BG}$, and predicted footprints, $f(x, y, z, t)$. $\lambda_{prior}$ is the *a priori* scaling factor, typically assumed unity.

$$\hat{\lambda} = \left( K^T S^{-1} K + S^{-1}_{prior} \right)^{-1} \left( K^T S^{-1} y + S^{-1}_{prior} \lambda_{prior} \right)$$

$$\hat{S}_{\lambda} = \left( K^T S^{-1} K + S^{-1}_{prior} \right)^{-1}$$

where:

- $X_r$ - location of the sensor,
- $t_r$ - Time of measurement $C$,
- $y = C - C_{BG}$
- $K_{\hat{\lambda}} = \sum_{i,j,m} f(X_r , t_r | x_i , y_j , t_m) \cdot F(x_i , y_j , t_m)$ - footprint-flux sums over space and time,
- $S_{\epsilon}$ - measurement error covariance matrix
March 2012 monthly averaged 3-day backward footprints for mixing ratio measured at each tower
Recent Northeast Data

- Timeseries of CO$_2$ (top) and CH$_4$ (bottom) at the sites in MD, PA, NY and NJ on March 15-30, 2012 (top of the tower measurements)
- Line of lower points shows calibration data (once per day)
Spatial Regions in the Domain
Initial Inversion Results
(Preliminary)
April – May Data

Posterior Emissions by Region
Prior Emissions = 1