Top Down Objective: Retrieve regional scale fluxes from atmospheric CO$_2$ concentration measurements with source/sink attribution

Backbone Observations:
Tower
Aircraft
“Permanent” Virtual Tall Tower

Campaign Observations:
COBRA-style Aircraft
Supplemental Backbone Aircraft
Temporary Virtual Tall Towers

Analysis:
Carbon Budget by Mass Balance
Eularian Model Data Assimilation – 4D-var, Kalman filter
Lagrangian Particle Dispersion Analysis – e.g., STILT
Bayesian Synthesis Inversion – e.g., TRANSCOM
Any of above with Parameter Estimation
Overview of the draft Mid-continental regional intensive science plan: Top-down perspective

Bottom-up:
- Flux-tower -- very local
- Biometry -- labor-intensive, long-term

Top-down:
- Can provide direct constraint on regional scale fluxes
- Inverse methods can be applied over a range of spatial and temporal scales
- Discrepancies between top-down & bottom up provide insight into processes
- Regional scale is most policy relevant--need to provide seasonal, annual & decadal flux estimates to evaluate carbon management strategies

Need combination to elucidate mechanisms!
Concentration Measurement Footprints:
From Adjoint to GSFC 3-D Parameterized Chemistry & Transport Model, Kawa et al.
Total Surface Sensitivity (ppm/ppm)

Time, days

250m
1km
4km
10km
Backbone:

Planned NOAA ESRL Tall Tower Network

Continuous CO2, CO, met at ~30m, 100m, ≥400m
Daily Flask Samples: CO2, CO, CH4, SF6, H2
Planned NOAA ESRL Aircraft Network

Average wind vectors at 500mbar: Jan.
Tower

Continuous Observations:
CO₂, CO, horizontal wind, T, RH
3 levels: 30, 100, 500m
PAR, Rainfall, Surface Pressure

Flask Samples:
Daily mid-afternoon from top level
(+5 extra per week)
Weekly aircraft profiles

Species: CO₂, CO, CH₄,
N₂O, SF₆, isotopes,
Halocarbons, COS, ...

Aircraft

Flask Samples:
Weekly aircraft profiles
(right now every 3 weeks)

Species: CO₂, CO, CH₄,
N₂O, SF₆, isotopes,
Halocarbons, COS,
limited ¹⁴CO₂

GPS, temperature, pressure

Continuous Observations on some flights: CO₂, O₃
Aircraft Measurements:

NOAA/ESRL: Aircraft Observations

PRELIMINARY
Virtual Tall Tower Measurements:

\[
\Delta C = -\frac{w c_0}{w_* z_i} \int_{z_0}^{z_{VTT}} g_b \left( \frac{z - d}{z_i} \right) dz - \alpha \frac{w c_0}{w_* z_i} \int_{z_0}^{z_{VTT}} g_t \left( \frac{z - d}{z_i} \right) dz
\]

where
\( \Delta C \) is the correction to the 30m CO\textsubscript{2} mixing ratio
\( g_b \) and \( g_t \) are the bottom-up and top-down gradient functions from the empirical fit of Wang et al. (in preparation)
\( z_0 \) is the measurement height, 30m
\( z_{VTT} \) is the virtual tall tower height, 396m
\( z_i \) is the boundary layer depth calculated after Yi et al. (2001)
\( \alpha \) is a fraction of the surface flux representing entrainment flux

From Butler et al., ICDC7, Sept 2005
Virtual Tall Tower Test at WLEF:
Calculated VTT based on 30m data vs actual 396m data

**Spring**
- Mean: 0.13
- s.d.: 0.31
- n: 1927 hours

**Summer**
- Mean: 0.98
- s.d.: 0.56
- n: 2020 hours

**Correction**

**Bias**
- Spring Bias [ppm]: Mean -0.03, s.d. 0.43
- n: 1981 hours
- Summer Bias [ppm]: Mean -0.16, s.d. 1.05
- n: 2018 hours

Butler et al., ICDC7, Sept 2005...
Butler et al., ICDC7, Sept 2005…
VTT WLEF TEST SUMMARY

<table>
<thead>
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<th>CORR</th>
<th>BIAS</th>
<th>~n</th>
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<tbody>
<tr>
<td>Spring:</td>
<td>0.13±0.31</td>
<td>-0.03 ±0.43</td>
<td>1900</td>
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<tr>
<td>Summer:</td>
<td>0.98 ±0.58</td>
<td>-0.16 ±1.05</td>
<td>2000</td>
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<td>Fall:</td>
<td>0.38 ±0.44</td>
<td>0.04 ±0.89</td>
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<td>Winter:</td>
<td>-0.05 ±0.18</td>
<td>0.43 ±1.44</td>
<td>500</td>
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Cautions:
Winter & Summer Bias relatively large.
Correction & Bias Distributions not Gaussian
Only _ number of obs/criteria met cases in Winter

Butler et al., ICDC7, Sept 2005…
Campaign: e.g. COBRA 2000

From Gerbig et al., 2003
Top-Down Critical Needs For Mid-continent Intensive:

Funding & schedule for the backbone deployment—NOAA/ESRL has available hardware, but no money for tower leases (~40K/year/site) & installation (~20K/site).

Funding & schedule for campaign-style aircraft measurements.

Mesoscale meteorological data products that avoid some of the known pitfalls of currently available operational products from numerical weather prediction models (lack of mass conservation, failure to output convective mass fluxes).