Can one sounder meet the needs of the weather and composition community? Should it?

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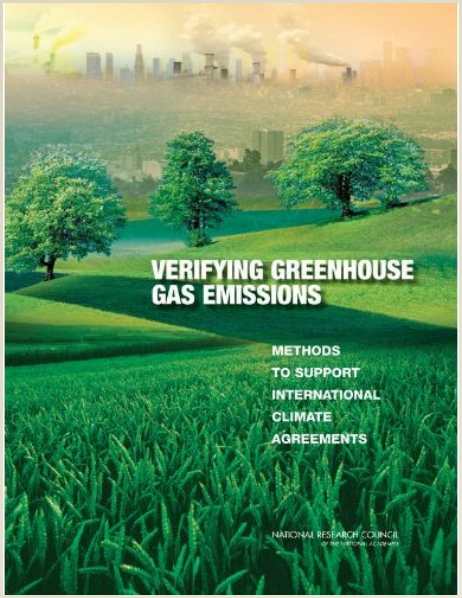
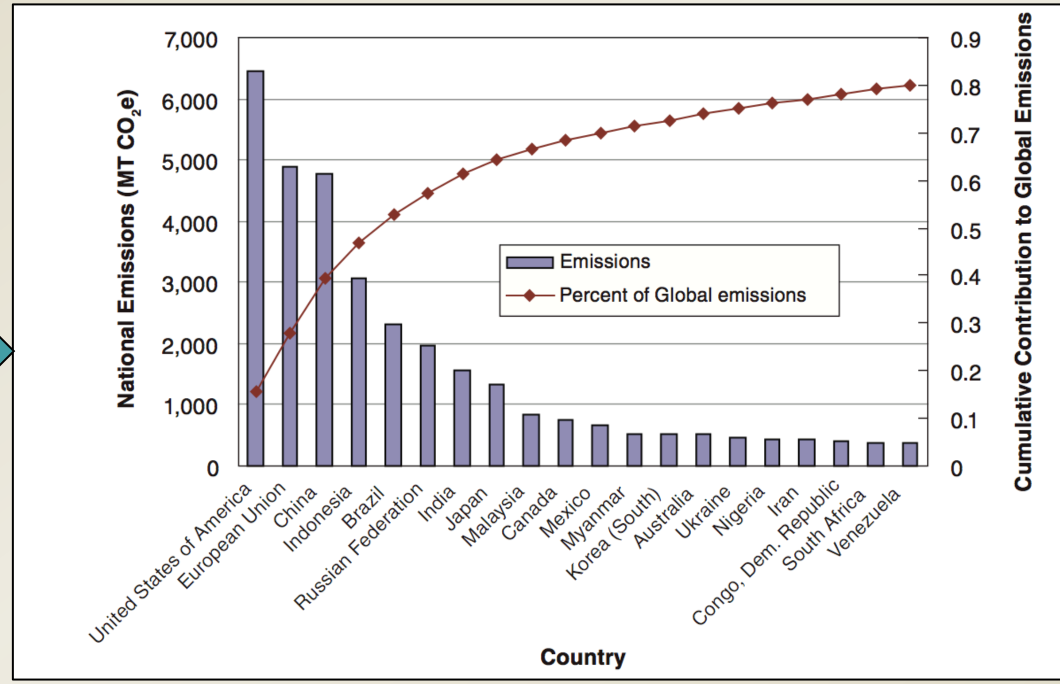
Synergy of weather and composition

- The ability of a single sensor depends critically on the problem to be addressed.
- The operational requirements for weather have been extensively studied.
- What are the operational requirements for composition in general and greenhouse gases in particular?

Greenhouse gas prediction, monitoring, or both?



Policy?



World Resources Institute, 2010

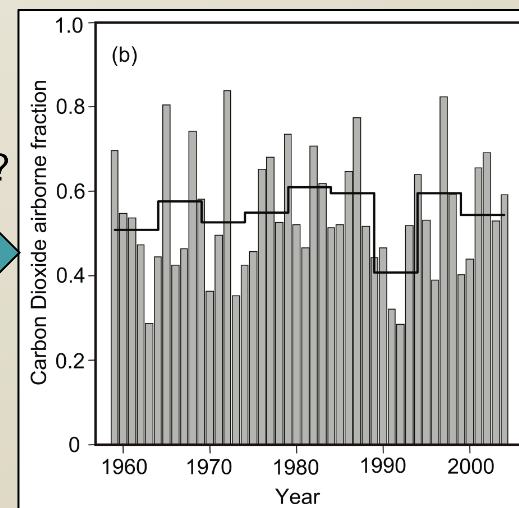
Supporting verification of national emissions?

Estimation, attribution, and prediction of carbon dioxide airborne fraction?

Estimation requires precise knowledge of the carbon cycle signal
Attribution requires precise knowledge of transport
Prediction requires a precise knowledge of carbon cycle processes

Carbon Cycle?

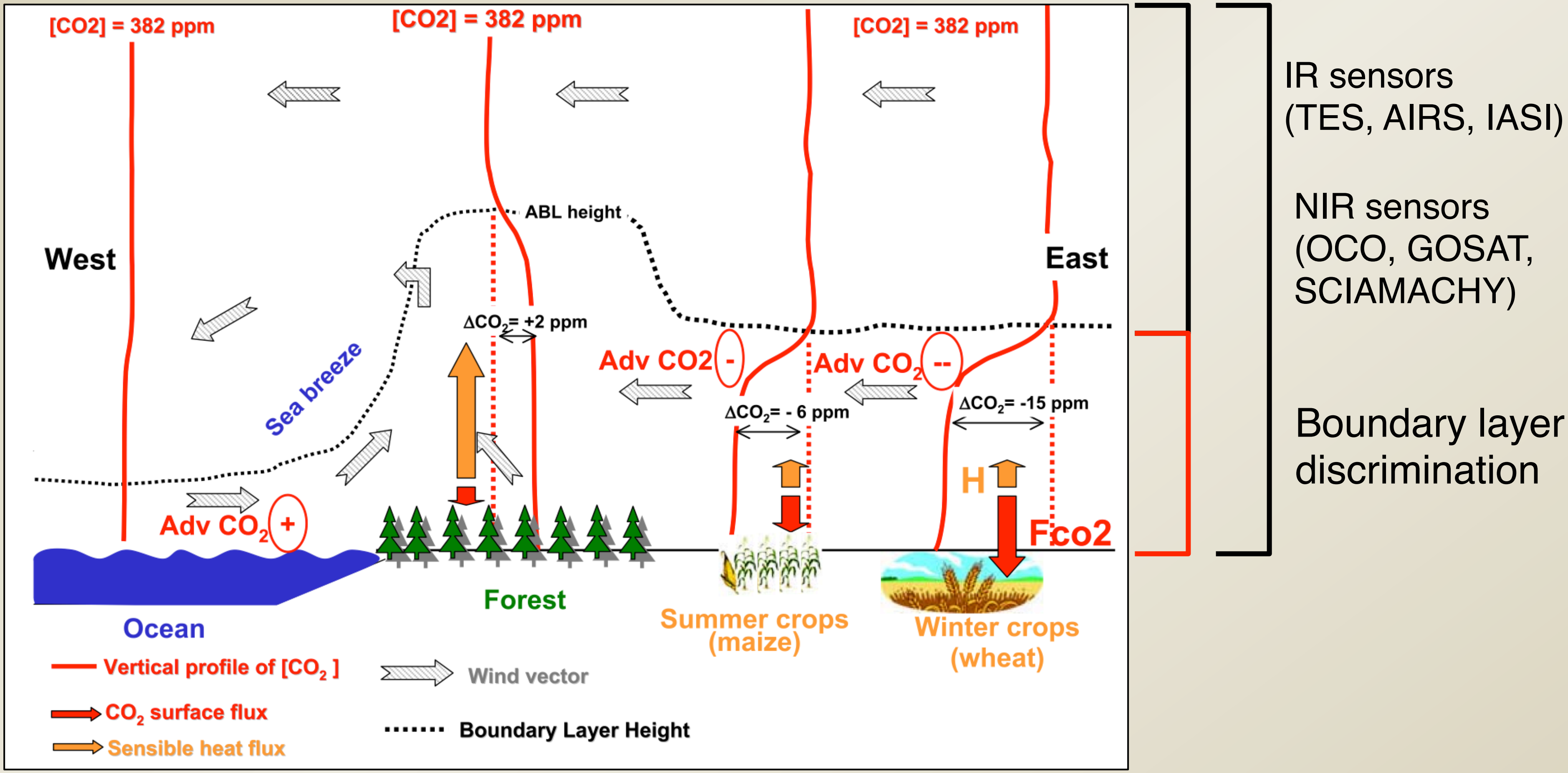
IPCC 2007



Race to the bottom

- NASA Science Community Workshop on Polar Orbiting IR and MW Sounders held in Nov 2010
  - Specifically focused on weather, climate, and composition from hyperspectral sounders
- A common theme between weather and composition is the need for greater sensitivity to boundary layer processes at higher spatial resolution

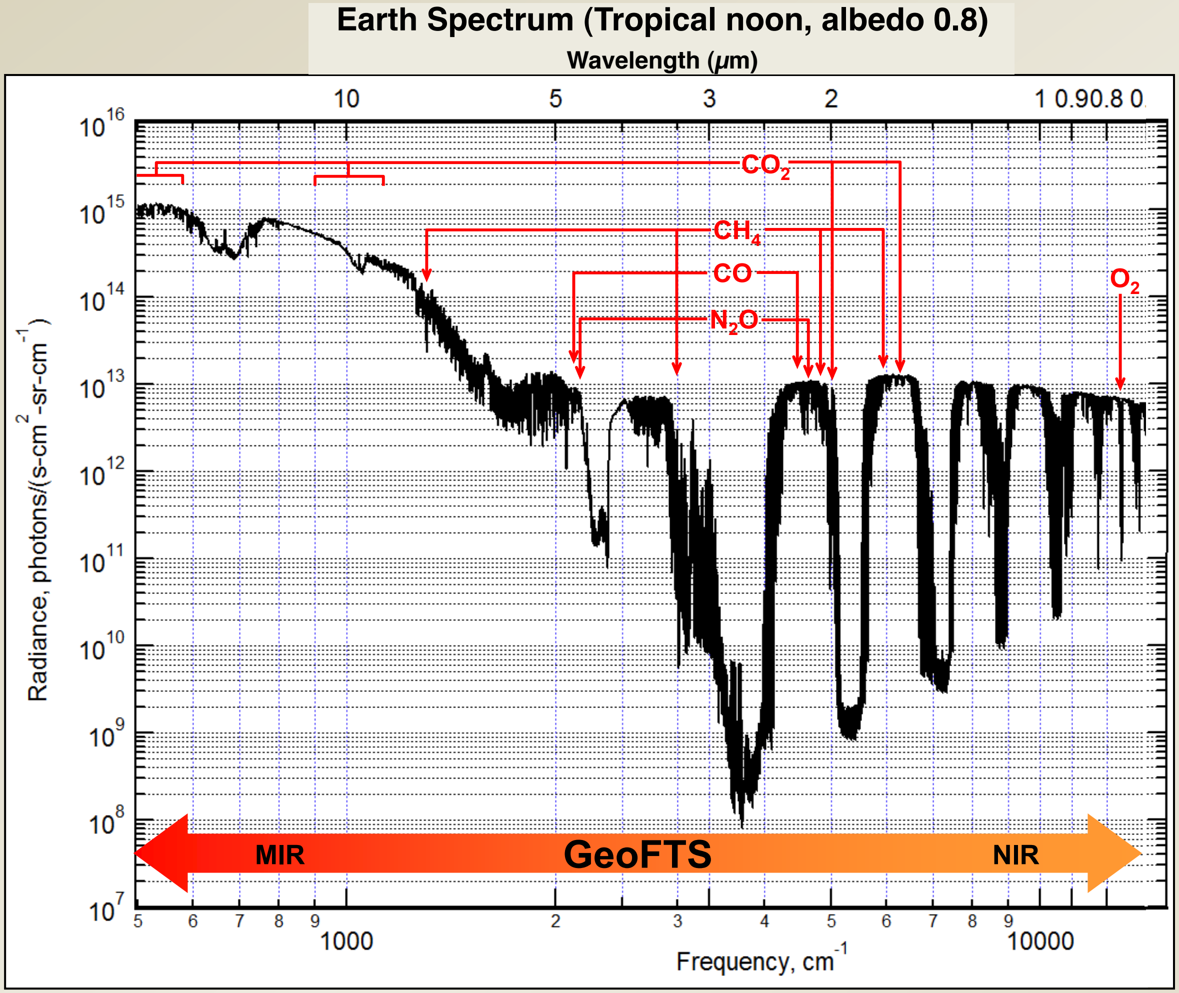
Interplay of dynamics and carbon



Sarrat *et al*, 2007

Spatially-resolved attribution of eco-system, oceanic, and anthropogenic source distribution from atmospheric CO2 concentrations depend on knowledge of tracer advection, vertical mixing and planetary boundary level (PBL) height.

Multi-spectral sounding strategy



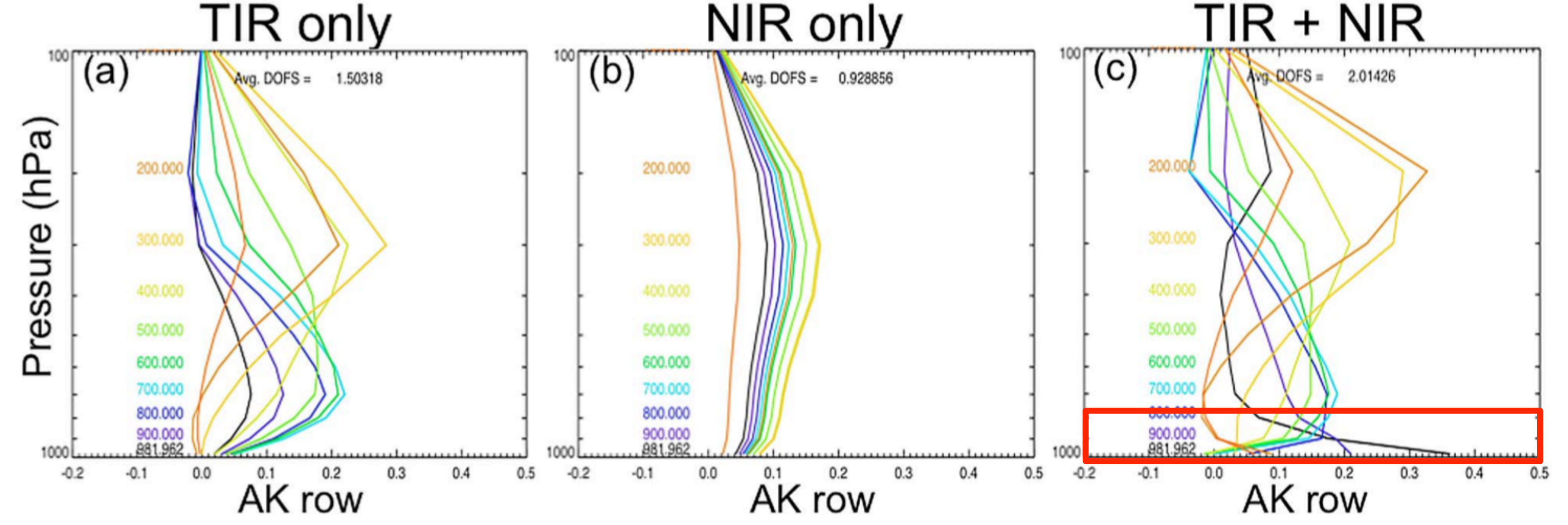
Combination of Thermal IR with NIR channels can be used to discriminate boundary layer CO2.

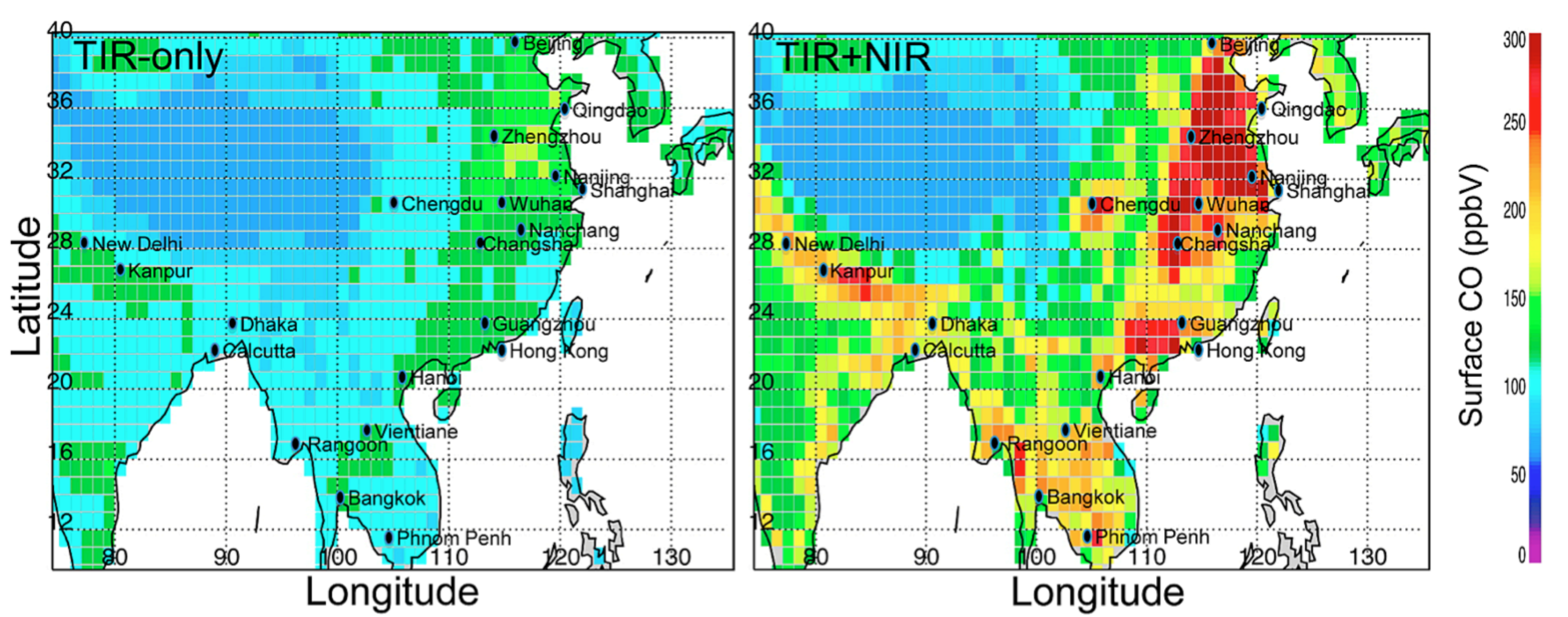
Strategy has been proposed by Christi and Stephens, 2004

Thermal IR + NIR approach has been demonstrated for MOPITT CO

MOPITT Boundary Layer CO

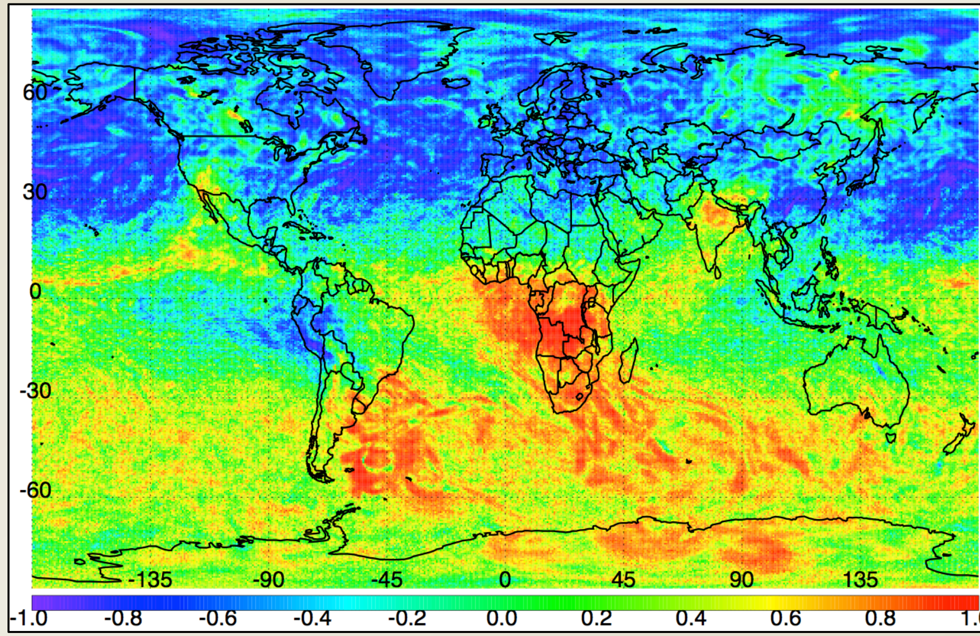
Worden *et al*, 2010





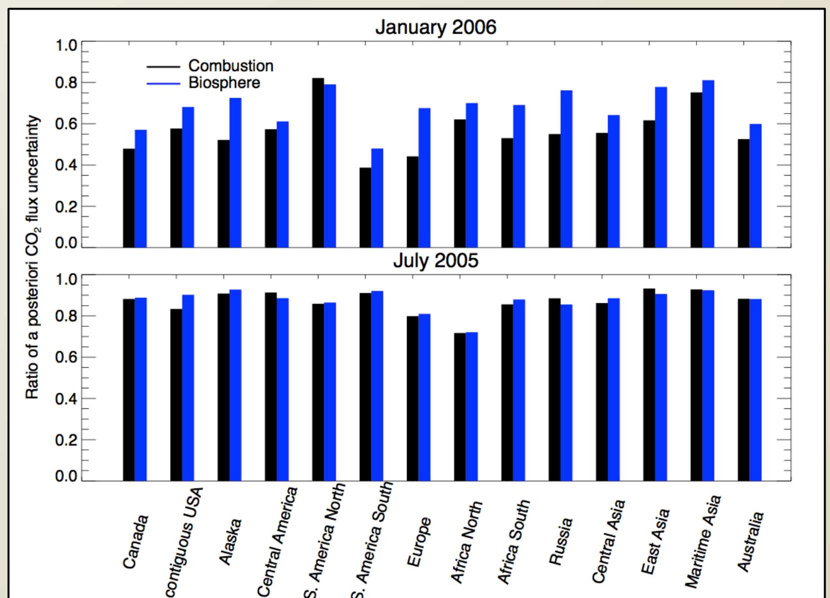
Impact of CO-CO_2 correlations

Correlations between CO-CO_2 induced through common dynamical processes can significantly improve CO_2 flux estimates. (Wang *et al*, 2009, JGR)



Correlations between errors in paired CO and CO_2 species between 24 and 48 hour forecasts, i.e., $E[\Delta CO \Delta CO_2]$ (NMC method)

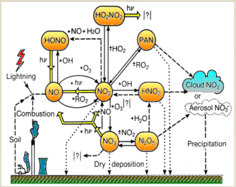
Application of correlations to flux estimate results in improvements up to 60% relative to using CO_2 alone



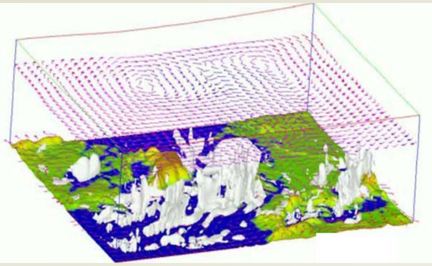
Exploitation of correlations in combustion sources depends on source homogeneity and knowledge of scale factor

NASA Carbon Monitoring Flux Pilot Project

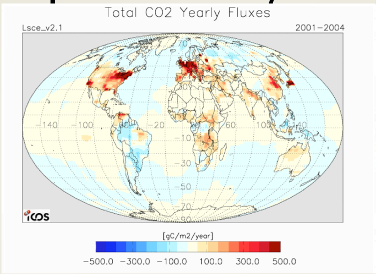
Chemical production



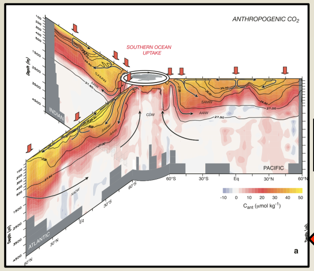
Transport (GEOS-5)



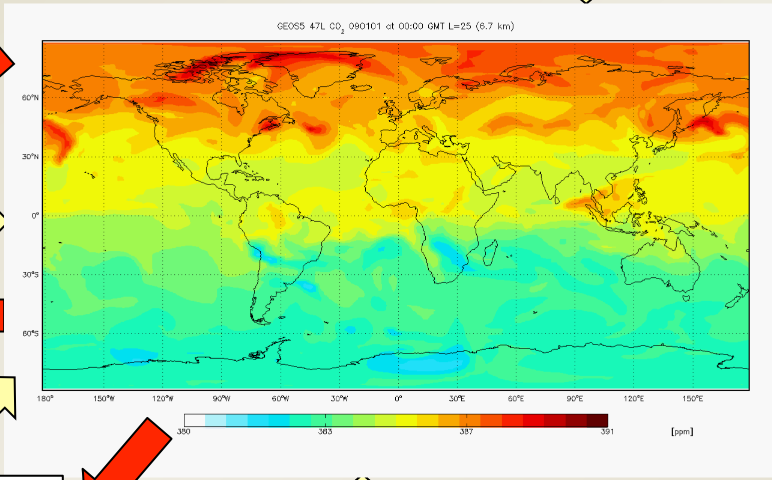
Optimal flux/state



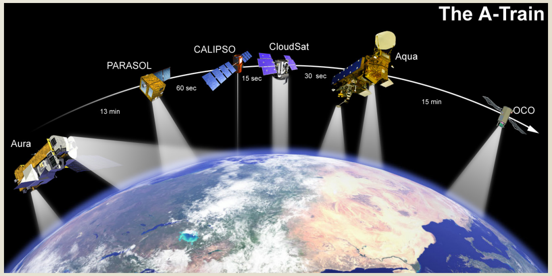
Oceans



Gruber *et al*, 2009

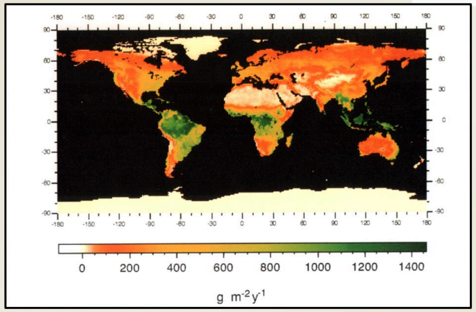


Observations



Optimal flux and state estimation

Terrestrial Biosphere



Potter *et al*, 1993

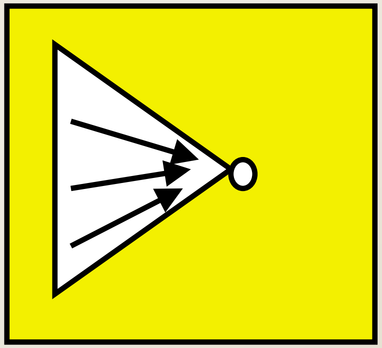
Anthropogenic

$$\min_{\mathbf{x}_0} C(\mathbf{x}) = \left\{ \sum_i (\mathbf{y}_i - \mathbf{F}_i(\mathbf{x}))^\top (\mathbf{S}_n^i)^{-1} (\mathbf{y}_i - \mathbf{F}_i(\mathbf{x})) + (\mathbf{x}_0 - \mathbf{x}_a)^\top \mathbf{S}_a^{-1} (\mathbf{x}_0 - \mathbf{x}_a) \right\}$$

Fluxes are estimated using a 4D-var implementation of tracer transport at 2x2.5 -> .5 x .66

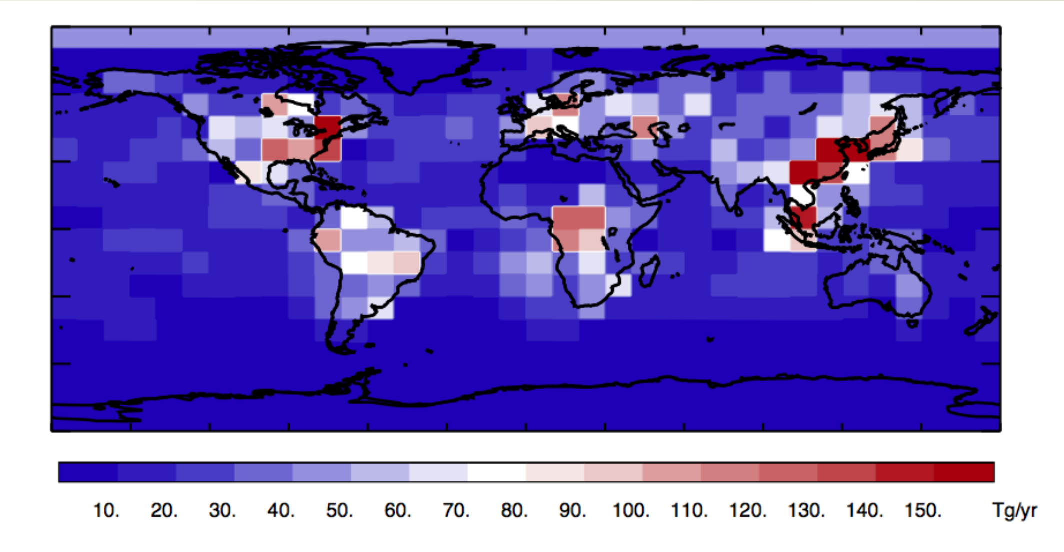
Impact of tracer transport

$$\left(\frac{\partial \mathbf{x}^i}{\partial \mathbf{x}^0}\right)^\top = \left(\frac{\partial \mathbf{M}_0}{\partial \mathbf{x}_0}\right)^\top \cdots \left(\frac{\partial \mathbf{M}_{i-1}}{\partial \mathbf{x}_{i-1}}\right)^\top$$



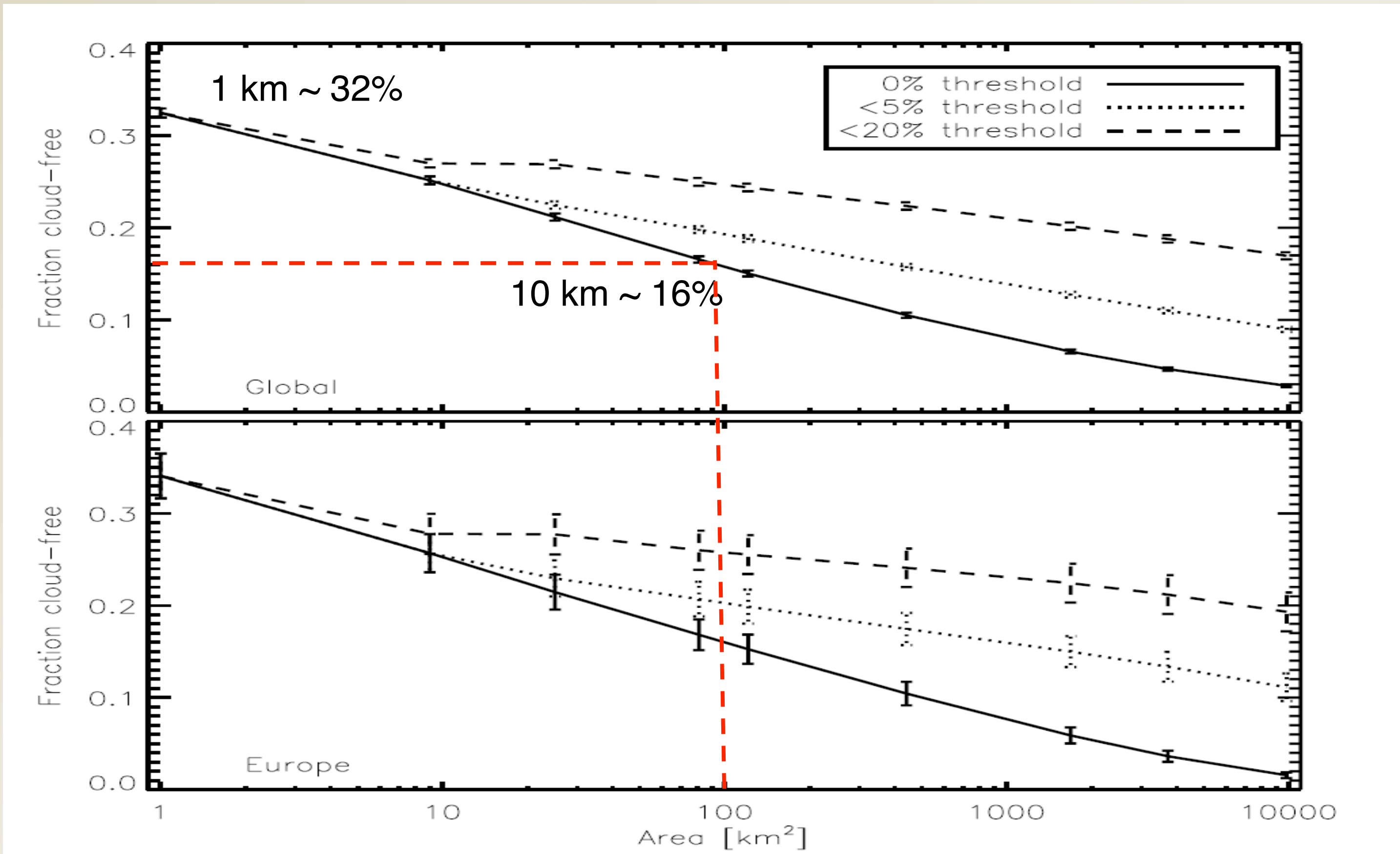
Spatially resolved attribution of CO_2 fluxes depend on
- Spatial-temporal distribution of the observing system
- Accuracy of *tracer* transport (meteorology) in the adjoint

Differences in tracer transport can lead to flux estimate uncertainties that exceed the uncertainties from the observing system



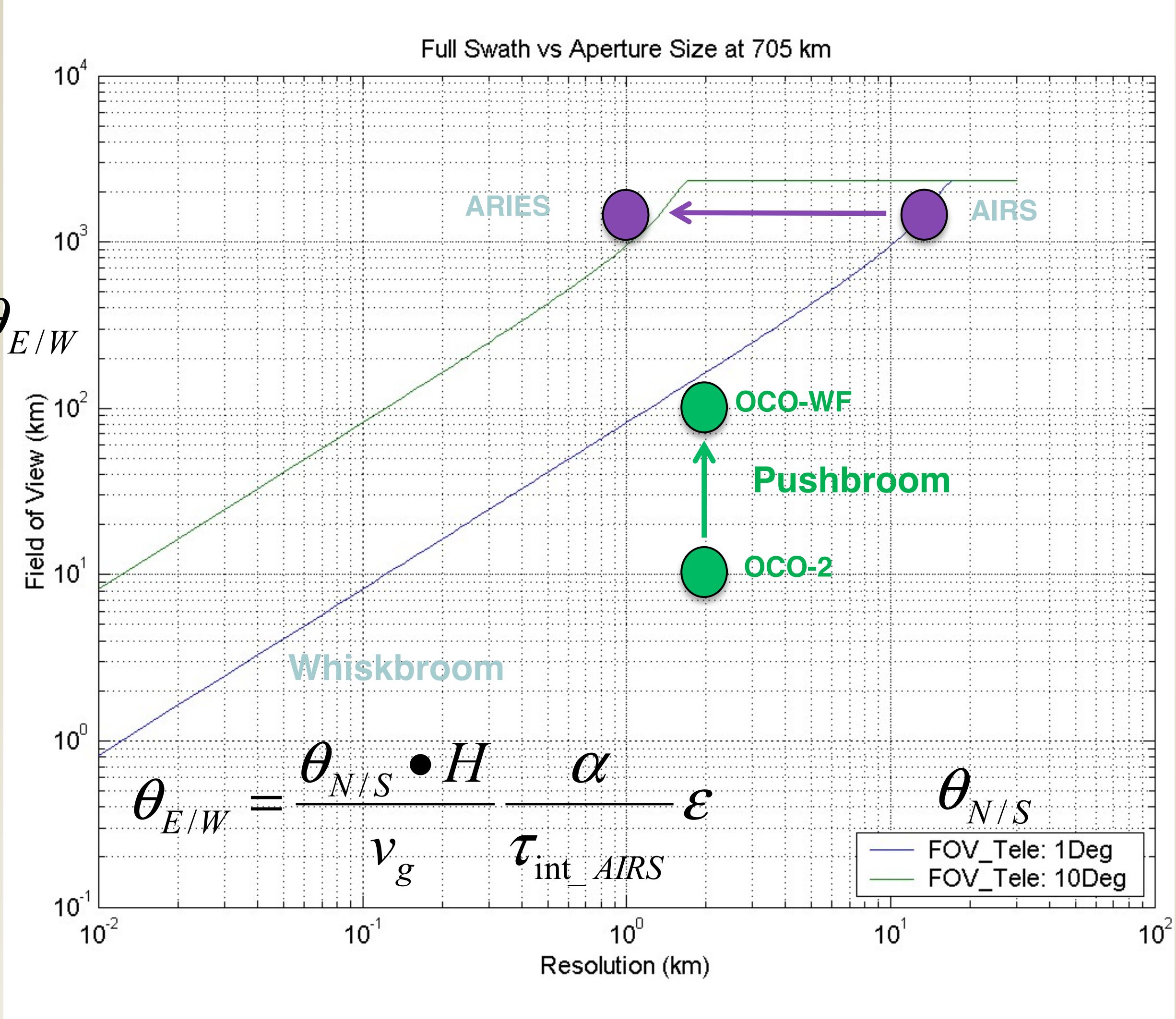
Houweling *et al*, 2010

Spatial Footprint has a big impact on throughput for CO_2



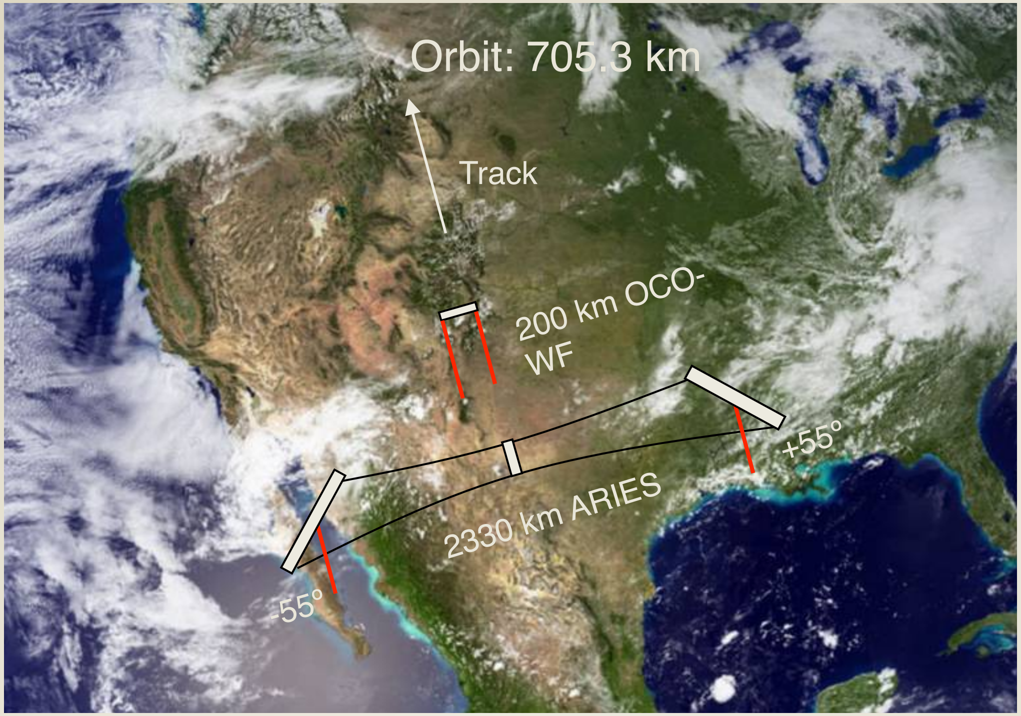
[1] J. Krijger et. al, The effect of sensor resolution on the number of cloud-free observations from space, Atmos. Chem. Phys. Discuss., 6, 4465-4499, 2006, www.atmos-chem-phys-discuss.net/6/4465/2006

Trade between Spatial Resolution and/or Coverage



- **Whiskbroom: Wide field slows scan, enabling higher spatial resolution**
- **Pushbroom: Wide field directly extends E/W Swath**

LEO approaches for a multispectral strategy



Evolutionary Approach using New Technology:
Wide Field Optics +
Large Format FPA's =

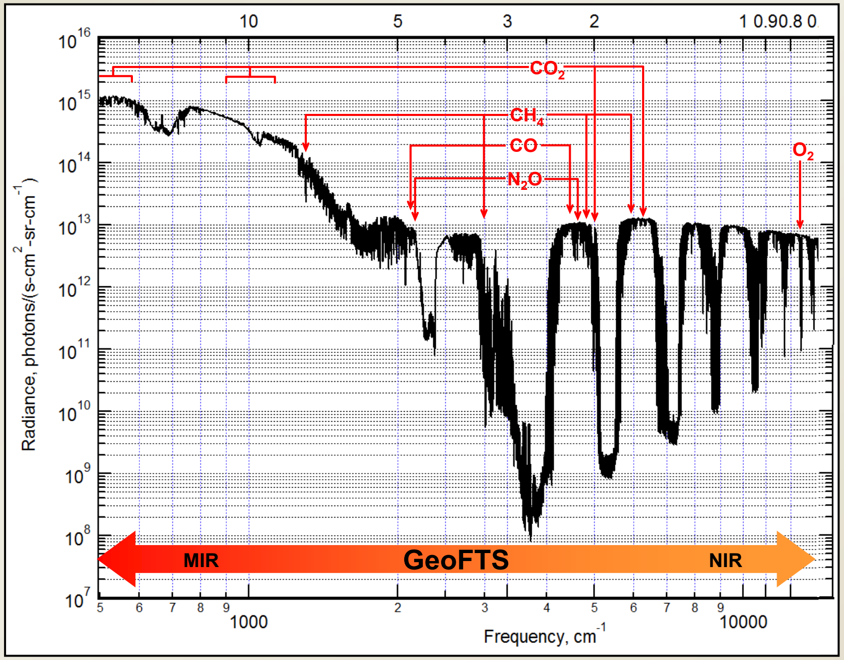
- Wide Field OCO
- High Resolution AIRS (Atmospheric Remote-sensing Imaging Emission Sounder (ARIES))

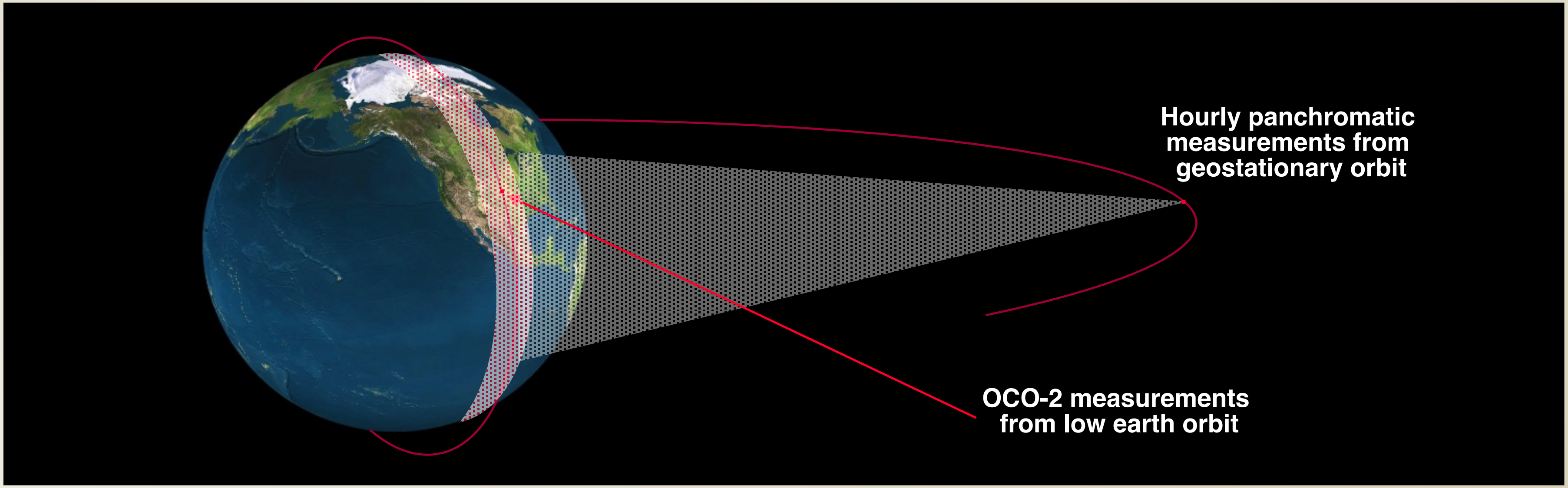
Note: OCO-WF requires 15x higher spectral resolution than ARIES hence reduced swath

	OCO	OCO-WF	AIRS	ARIES
IFOV	2 km	2 km	**13.5 km**	**1 km**
Swath	**10 km**	**200 km**	1750 km	2330 km
Nchan	3048	3048	**2378**	**4096**
SNR/NEdT	360	360	0.2K	0.2K
Polarization	**Linear**	**Dual**	N/A	N/A

GEO approaches

Simultaneous measurements of meteorological variables along with greenhouse gases and atmospheric chemical species in geo-stationary orbit could dramatically improve regional scale flux estimates

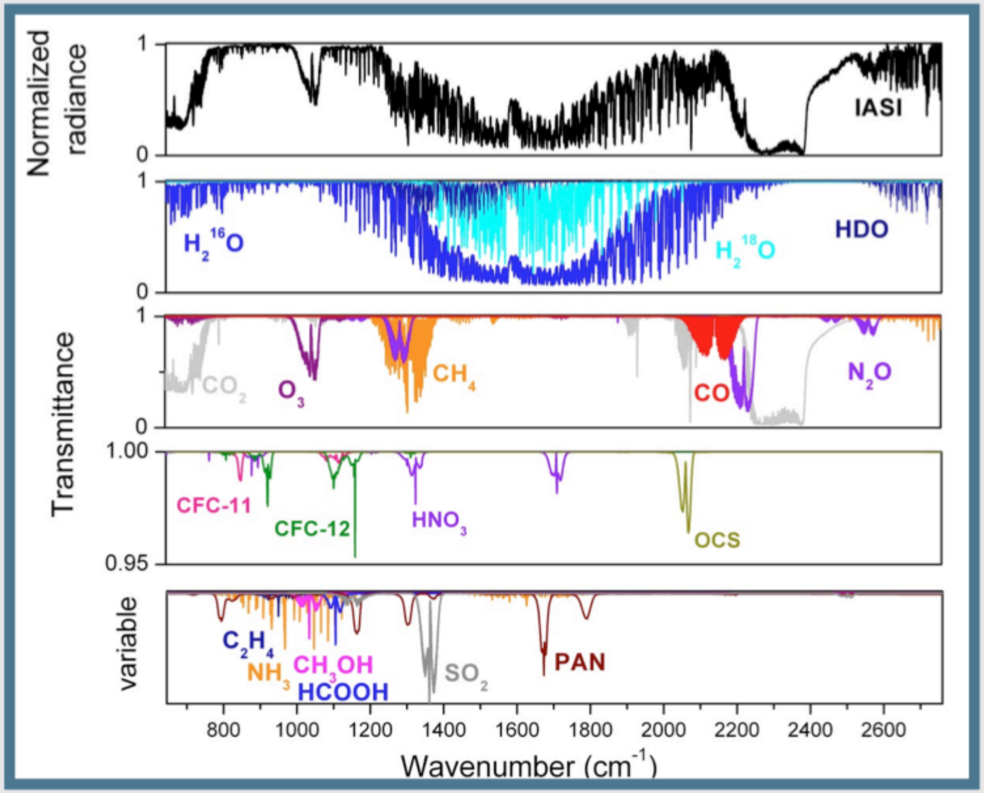


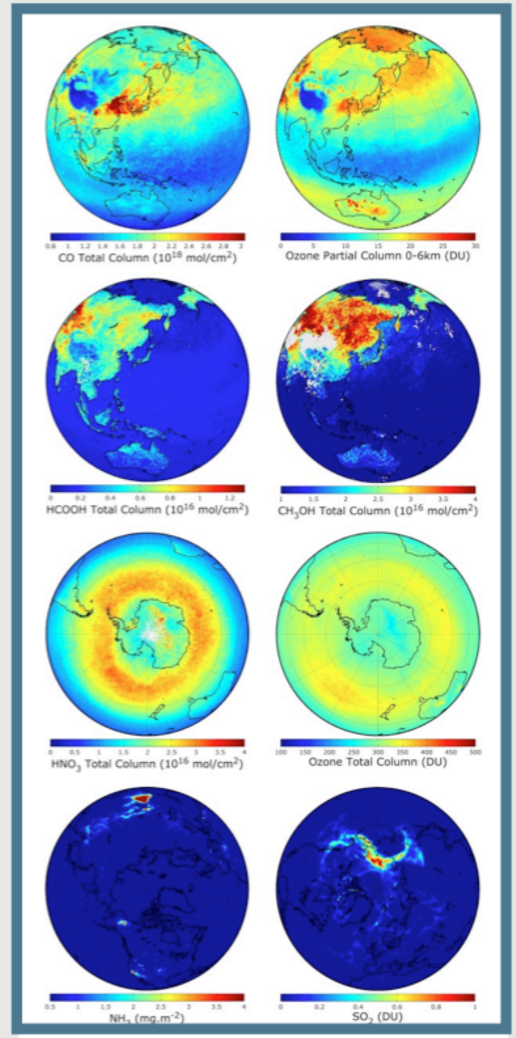


Conclusions

- The inference of surface fluxes from CO2 concentrations requires both accurate measurements and transport models
- A multi-spectral strategy that combines IR and NIR capabilities constrains the CO2 profile
- Correlative tracer measurements, e.g., CO, can help reduce flux uncertainties
- High spatial resolution reduces cloud contamination and PBL variability
- Improved meterological constraints are needed for tracer transport.
- There are technical solutions in both LEO and GEO that could combine these capabilities into a single instrument.

Earth System Sounding





1/ Meteorology
2/ Climate/Atmospheric chemistry
3/ Operational applications

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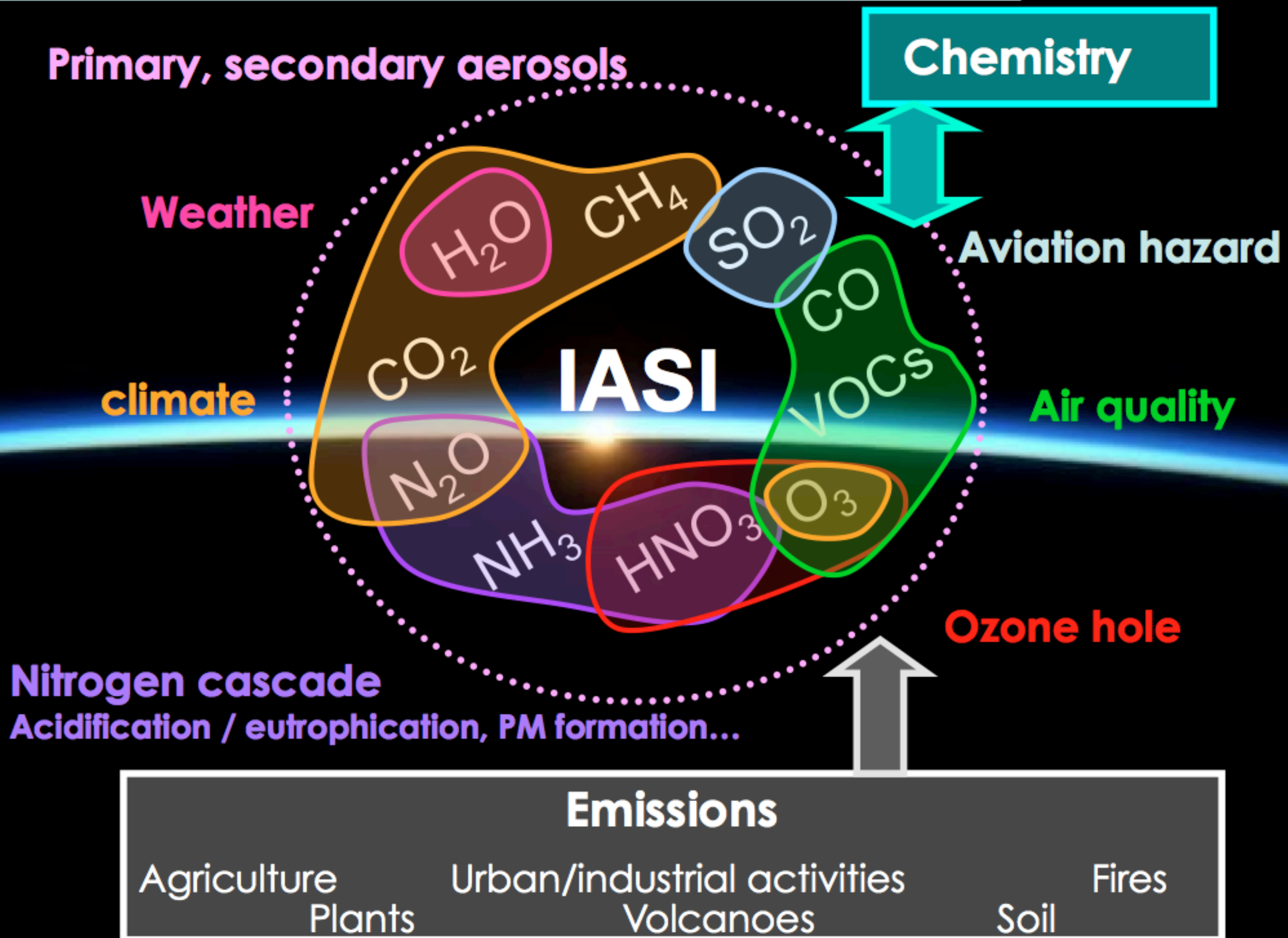
Coupling of Earth System Observations

IASI operational and science processing



Cathy Clerbaux (LATMOS ULB)

- Requirements depend on the goal.
- NASA workshop results?
- Higher spatial resolution for Weather→clouds
  - High spatial resolution for composition→clouds
- Boundary layer processes are becoming a key driver of requirements for both weather and composition
- Key differences from an assimilation perspective
  - weather prediction is driven by an initial condition problem
  - atmospheric composition is driven equally by a boundary value problem
- Role of Earth System Modeling to understand and predict changes in the Earth System
  - Need for Earth System Assimilation
  - Need for an Earth System Observing Network (ESON)
  - Hyperspectral sounders provide the foundation and the glue of an ESON.
  - Schlussel-EUMETSAT “Evolution of NWP models from atmospheric data assimilation towards Earth system analyses and