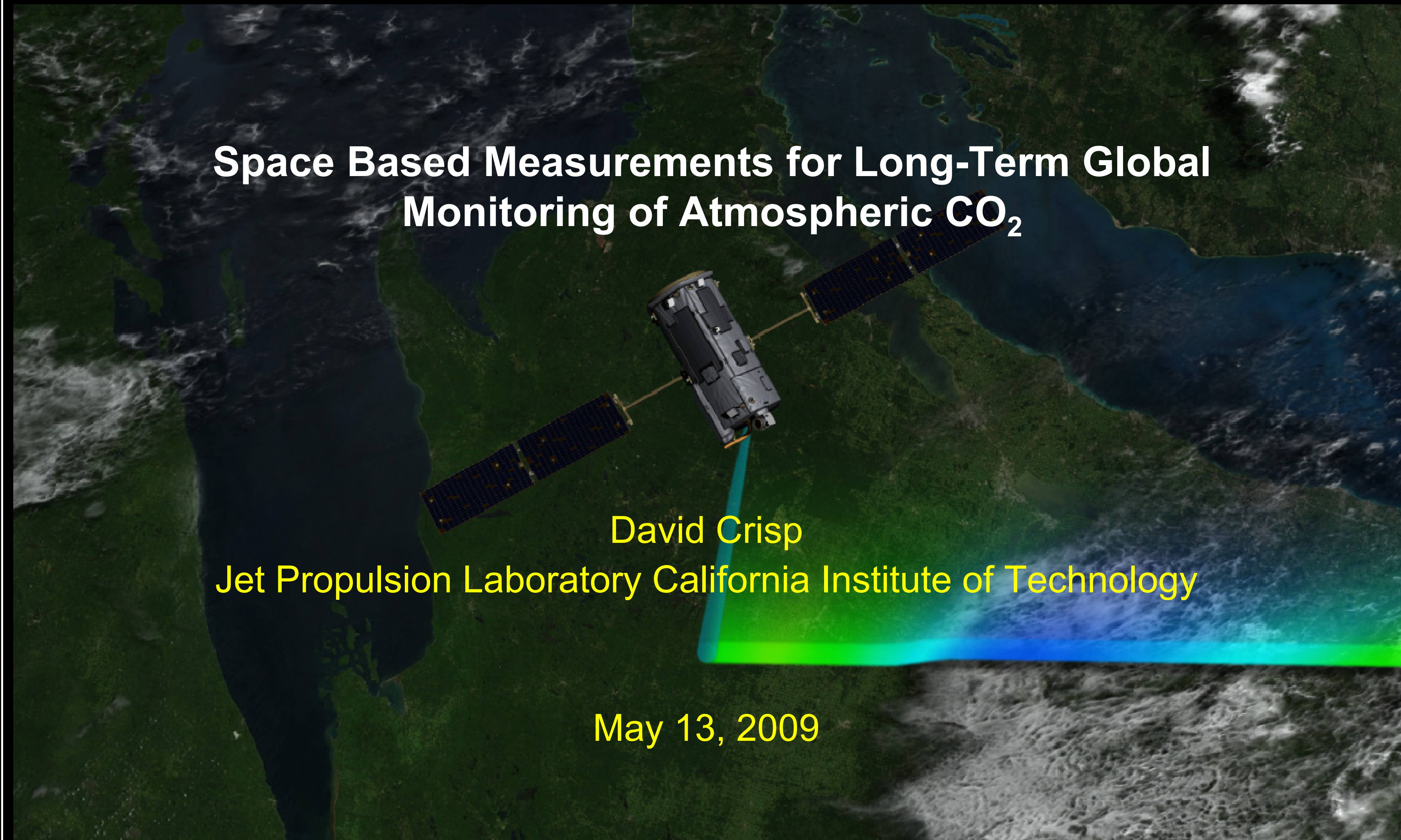
2009 ESRL Global Monitoring Annual Conference



Space Based Measurements for Long-Term Global Monitoring of Atmospheric CO_2

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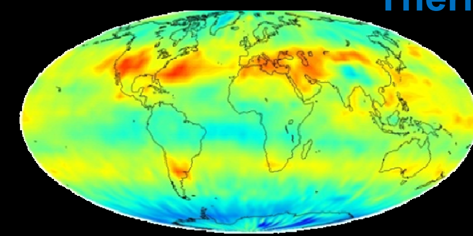
Requirements for Observing CO_2 from Space

- Precise in situ measurements of CO_2 and other greenhouse gases are now being made from a global network of ground based stations.
- This network has expanded continuously over the past 50 years and now provides the accuracy and coverage needed to define global CO_2 trends.
- It still lacks the spatial and temporal resolution needed to map CO2 sources and sinks on regional scales over the globe.
  - The network is particularly sparse in the tropics and over the oceans.
- One way to fill these gaps is to make global measurements of atmospheric CO2 from space.
- This is a particularly challenging remote sensing measurement because the presence of surface sources and sinks must be inferred from the small spatial and temporal variations that they produce in the background CO_2 distribution.

Solar Near IR and Thermal IR CO_2 Sounders

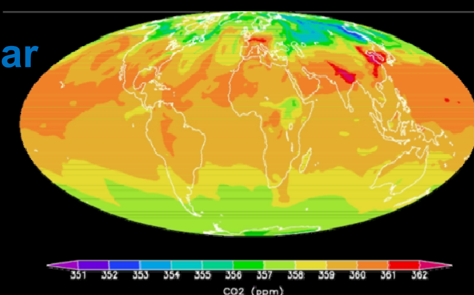
- Solar and thermal IR measurements of CO_2 address complementary science issues
  - AIRS,TES (NASA) and IASI (ESA) measure CO_2 above the mid-troposphere
    - Describe the vertical profile of CO_2 in the upper troposphere and lower stratosphere
    - Directly measure the greenhouse forcing by CO_2 in the present climate
  - Solar NIR instruments (SCIAMACHY, GOSAT, OCO) are most sensitive to CO_2 near the ground
    - Optimized for identifying and quantifying surface sources and sinks
    - Provides insight needed to predict future rates of CO_2 buildup and climate impacts
  - Combining solar NIR and thermal IR measurements could provide insight into atmospheric transport

Thermal

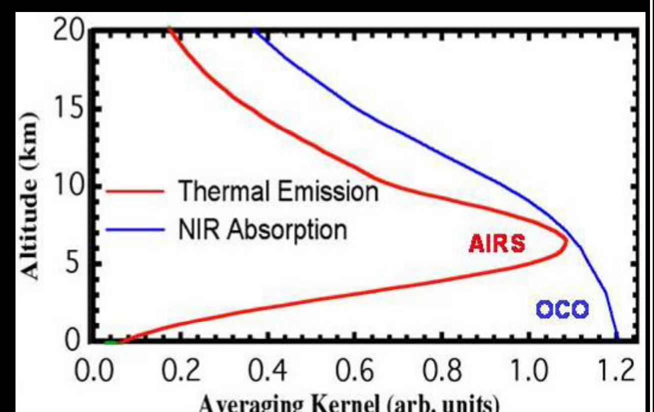


M. Chahine 2008

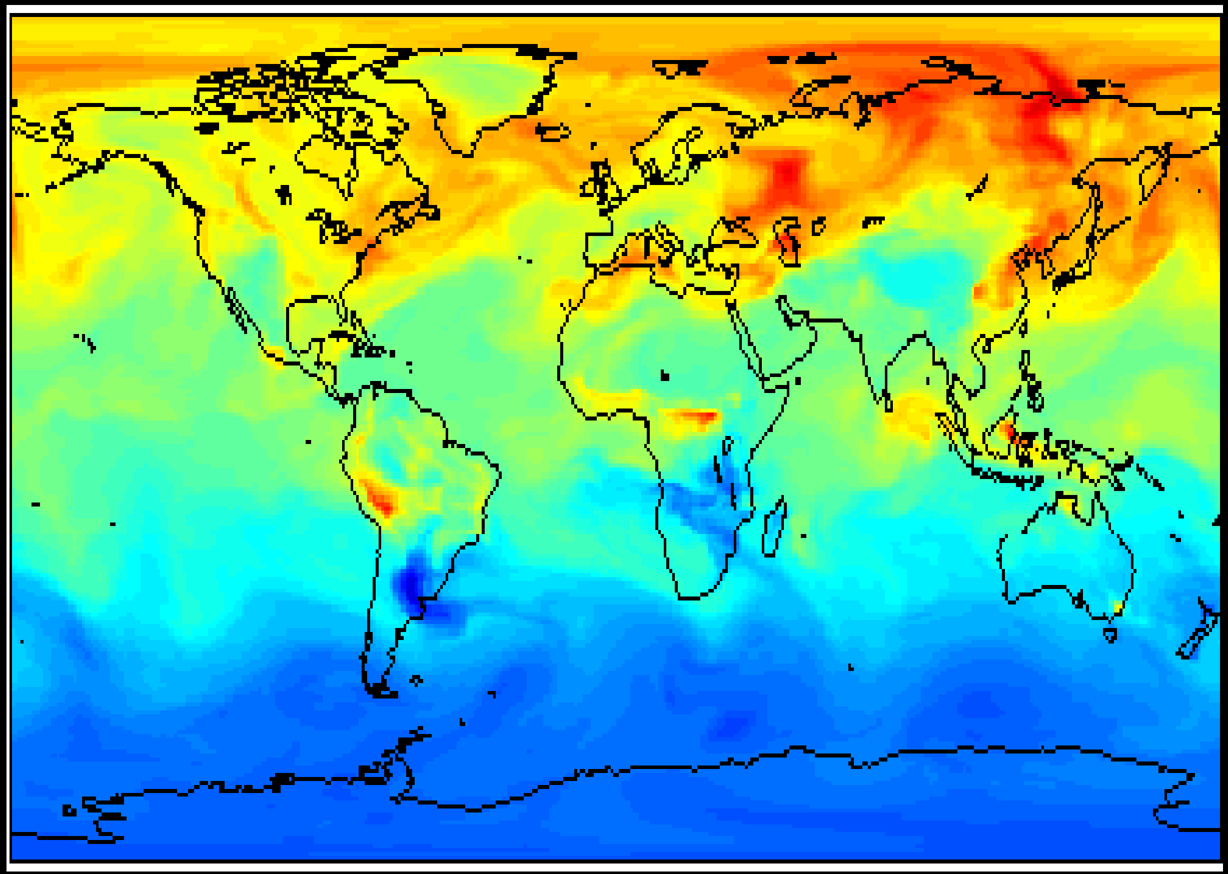
Solar



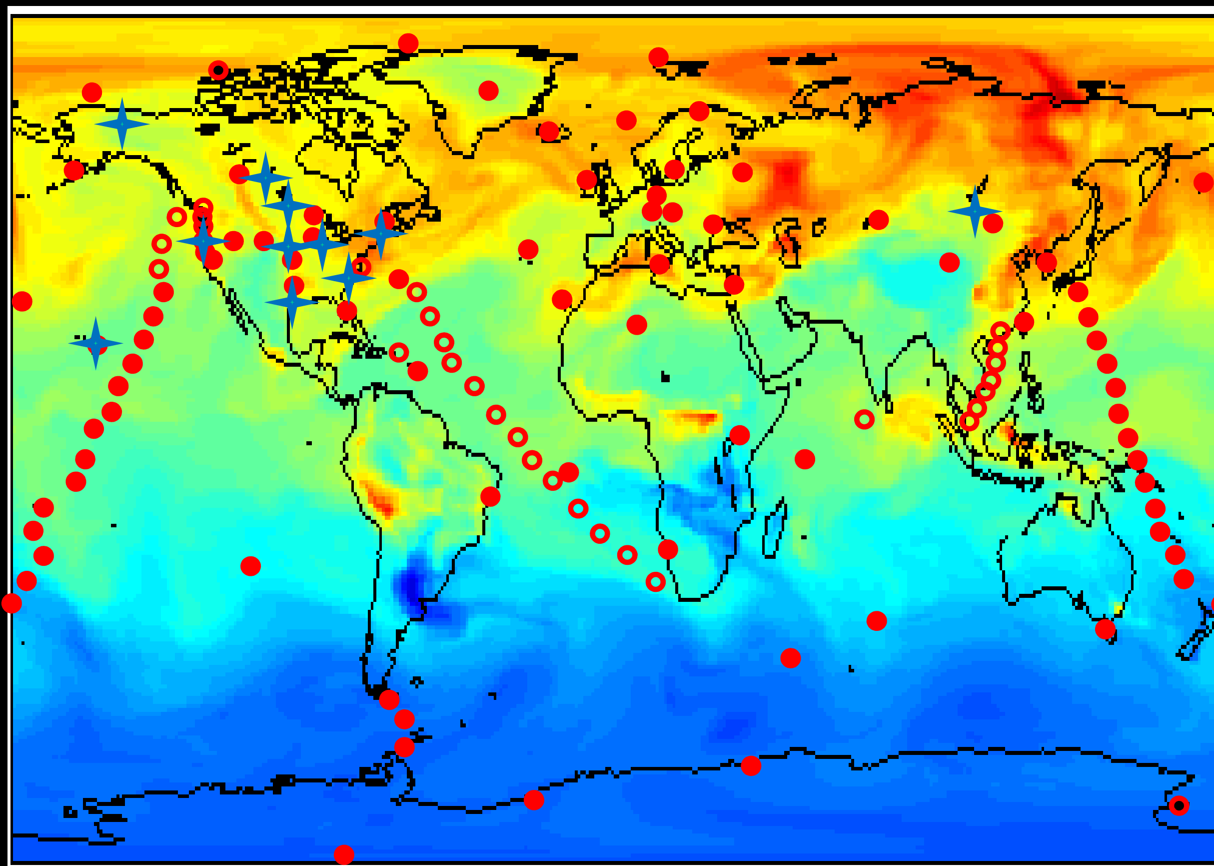
R. Kawa 2008



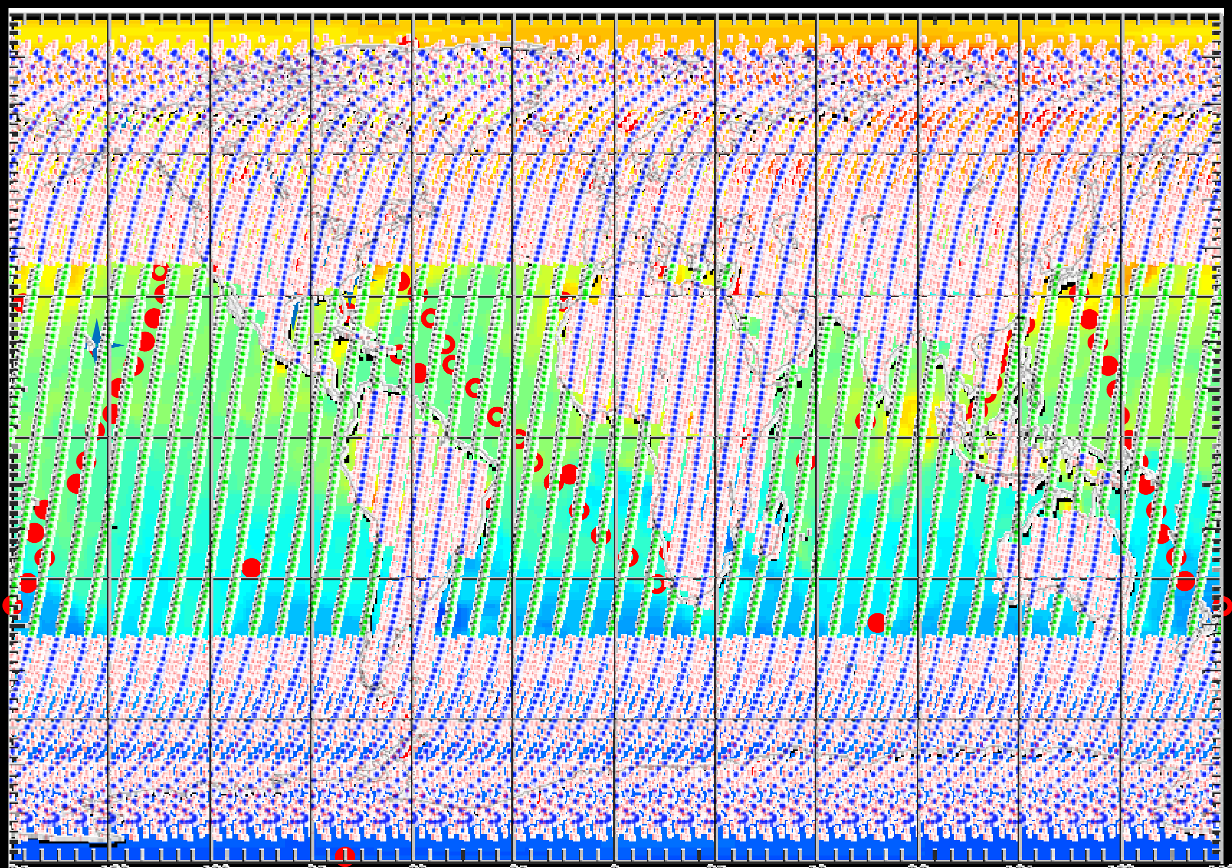
Spatial Sampling Needs: CO_2 Weather



Cooperative Air Sampling Network

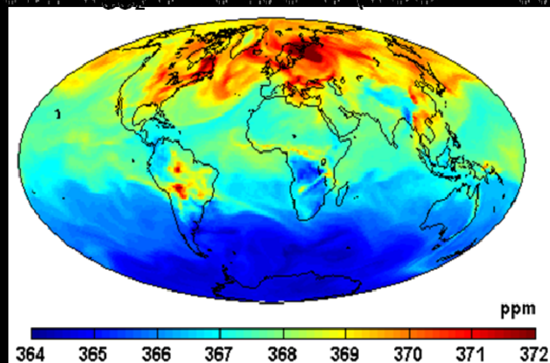


Spatial Sampling by GOSAT (Ibuki)



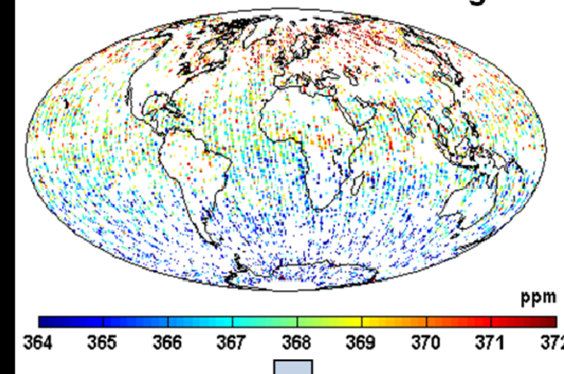
- GOSAT will collect ~56000 soundings over its 3-day ground repeat cycle
- At least 10% of these are expected to be sufficiently cloud free to retrieve X_{CO2}

Effects of Clouds

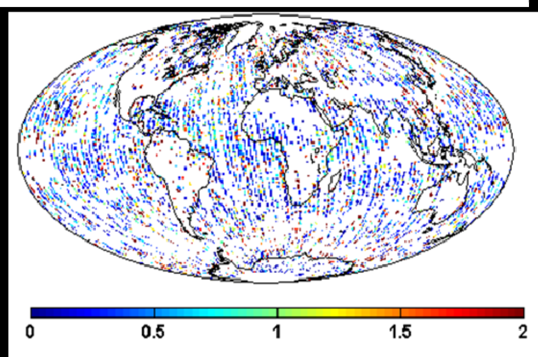


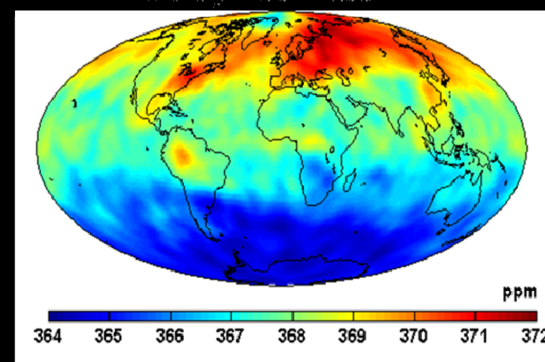
PCTM/GEOS-4
(Randy Kawa, GSFC)

Simulated OCO soundings



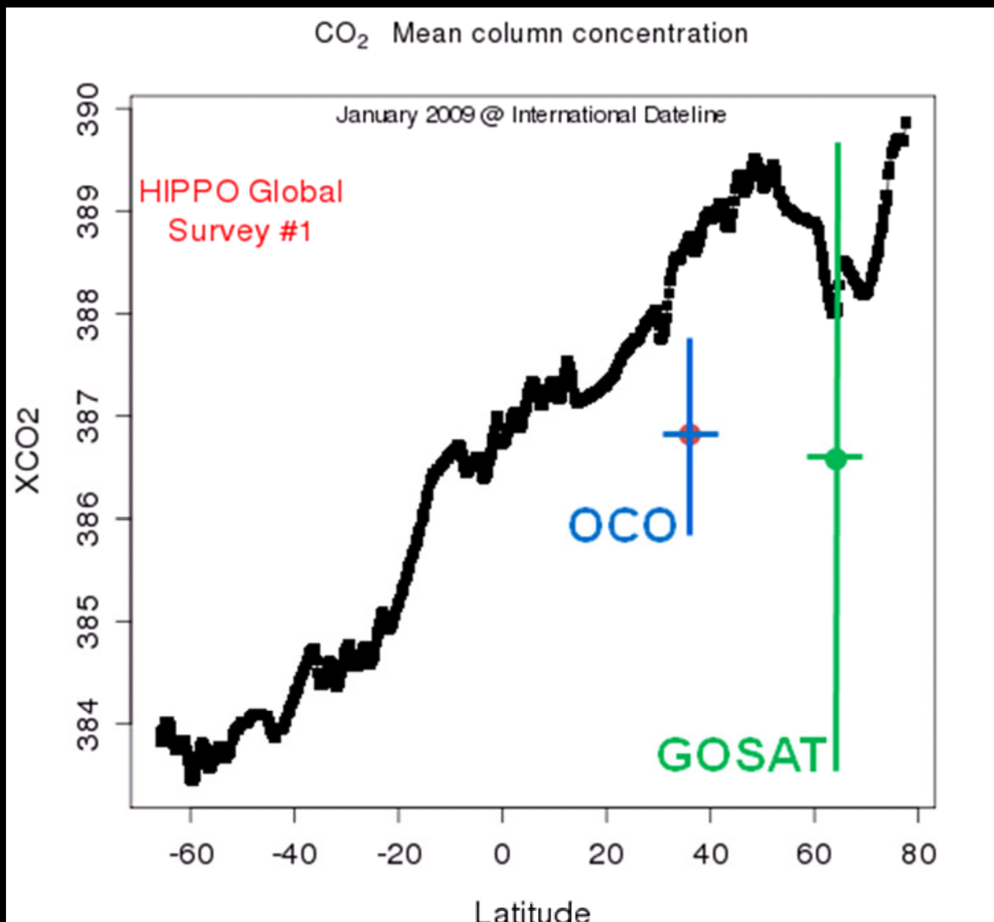
Total Optical Depth - CALIPSO





Clouds and aerosols reduce the spatial sampling, making it harder to resolve the spatial variations in CO_2 associated with “carbon weather.”
[Anna Michalak and Alanood Alkhaled, U. Michigan].

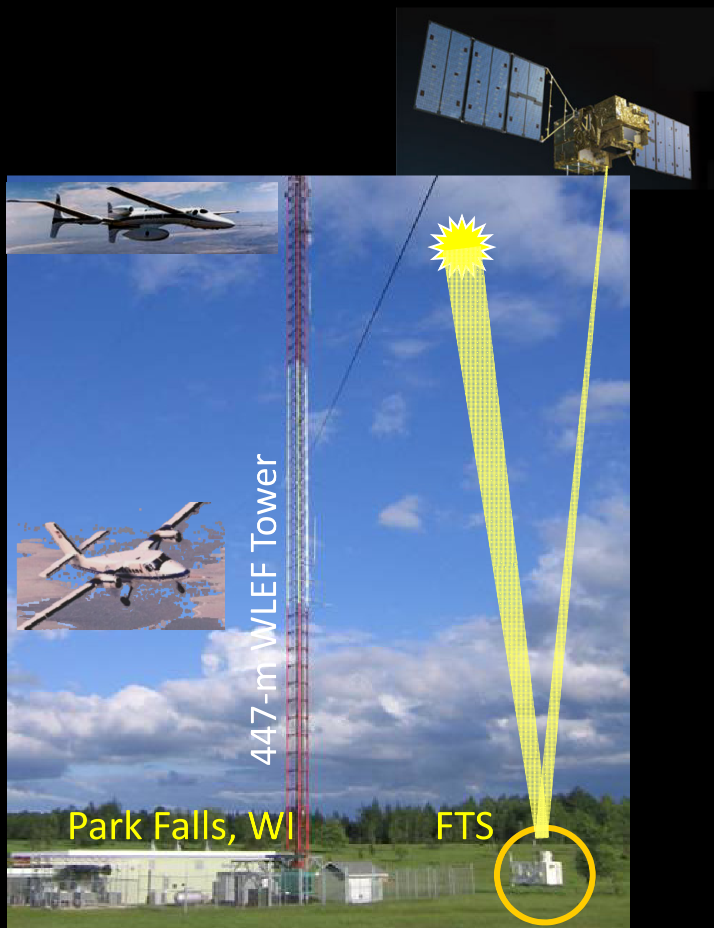
The Importance of Precision



The nominal, regional scale X_{CO2} precision targets for the OCO and GOSAT instruments (blue and green, as indicated) are compared to the X_{CO2} cross-section measured by recent transects of the NSF HIAPER aircraft (S. Wofsy, private communication, 2009).

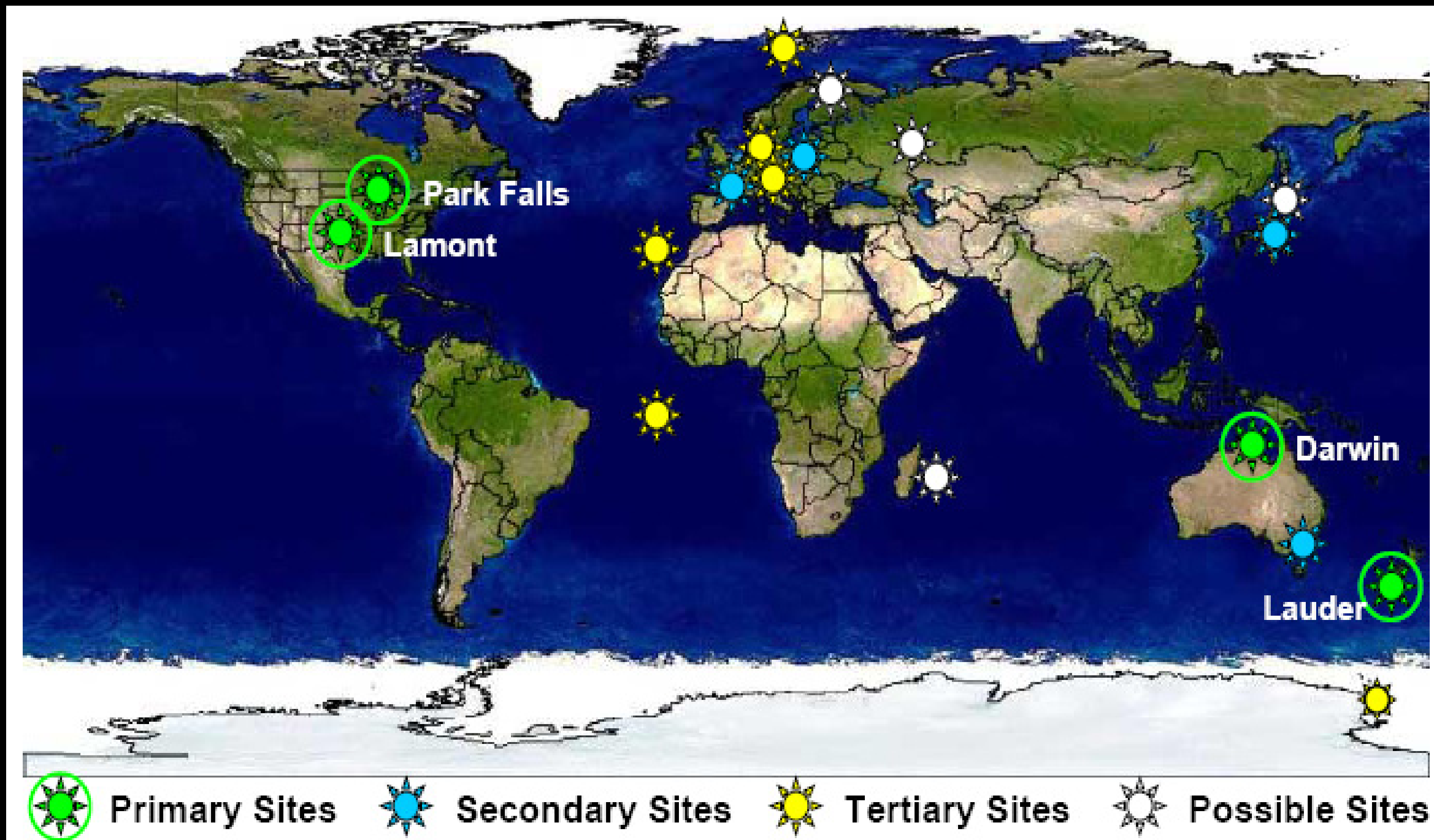
While both missions were expected to improve on their minimum accuracy requirements, OCO was optimized to resolve the subtle latitude dependent variations in CO_2, like those shown here.

Connecting the Space Based CO2 Measurements to the Ground-Based Standard: TCCON



- A critical element of this strategy was the Total Carbon Column Observing Network (TCCON)
  - High resolution FTS's measure the absorption of direct sunlight by CO_2 and O_2, in the same spectral regions used by the TANSO-FTS.
  - Over-flights of TCCON stations by aircraft carrying *in situ* instruments calibrated with WMO referenced gases used to validate TCCON results.
    - Aircraft CO_2 profiles extending from the boundary layer to the middle troposphere are integrated to derive a value of X_{CO2}.
  - Simultaneous TCCON FTS and TANSO-FTS measurements will be compared to transfer the WMO standard to the spacecraft measurements.

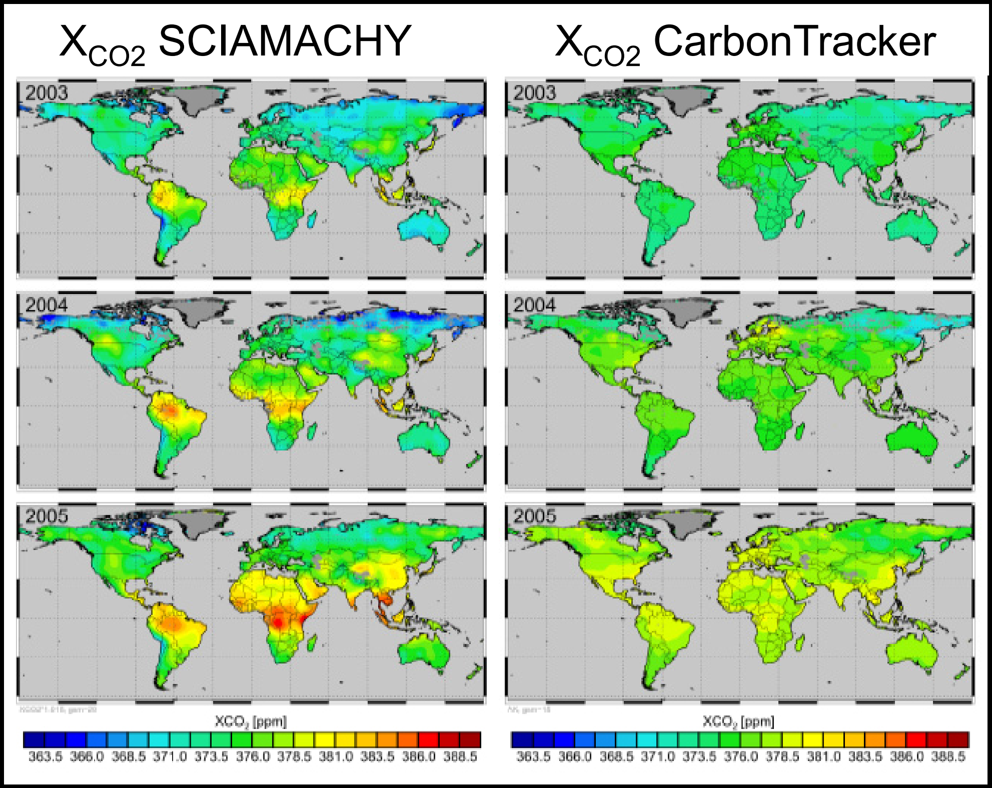
Current Coverage of the TCCON Network



The TCCON Network now includes stations, spanning latitudes from 79 N (Spitsbergen Ny) to Lauder New Zealand, and is expanding.

Validating Space based CO_2 measurements against the Ground base in situ Network

- To further validate these space-based measurements, they can be assimilated into global carbon source/sink inversion models to derive near-surface CO_2 fields that can be validated against measurements from the Cooperative Air Sampling Network.



Measurements of X_{CO2} from SCIAMACHY for three years (2003 to 2005) compared to estimates of total X_{CO2} from the NOAA Carbon Tracker data assimilation system. Annual averages are shown [Schneising *et al.,* 2008].

Note: The color scales reflect higher variability in SCIAMACHY X_{CO2} (±12.5 ppm) compared to CarbonTracker X_{CO2} (±6.0 ppm).

Conclusions

- Space-based remote sensing instruments hold substantial promise for future long-term, space-based monitoring of CO_2 and other greenhouse gases
  - The principal advantages of these systems are
    - Spatial coverage (especially over oceans and tropical land)
    - Sampling density (needed to resolve CO2 weather)
- To reach their full potential, the space based measurements must be thoroughly validated to demonstrate their accuracy and range of validity.
- Ground based in situ and remote sensing instruments will continue to play an essential role, providing
  - Ground truth for the space based instruments
  - Insight into processes controlling surface fluxes of CO_2