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Greenhouse Gas Measurements from Geostationary Orbit

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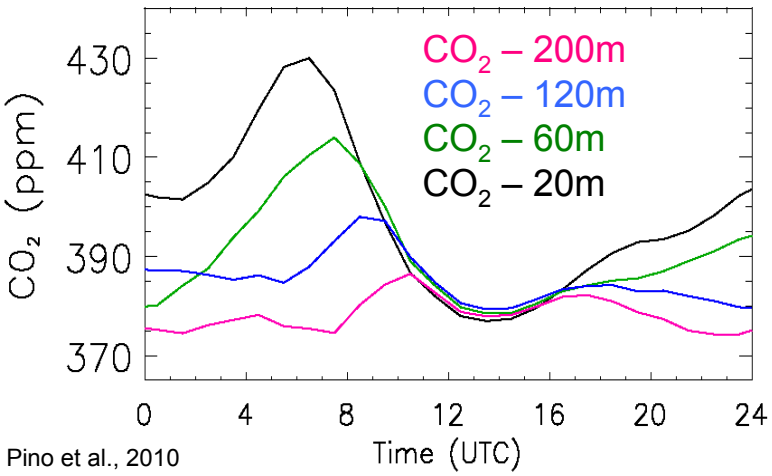
Overview

- Our understanding of sources and sinks of CO_2 is limited by the number of observations, as well as uncertainty in vertical transport
- Geostationary satellites could be used to make hourly observations, and with the combination of NIR and IR wavelengths, and vertical profiles of CO_2 could be obtained.
- Detailed simulations of retrievals show that the vertical sensitivity that is needed can be achieved with a combination of NIR and IR wavelengths.
- An instrument concept has been developed, PanFTS, that can make these needed measurements from a geostationary orbit.
- In addition to measuring the key greenhouse gases, CO_2 and CH_4, PanFTS can also measure transport tracers such as CO, H_2O, and HDO, which are critical to constrain transport characteristics and combustion sources of these gases.

Diurnal Cycle: Emissions and Biosphere Uptake



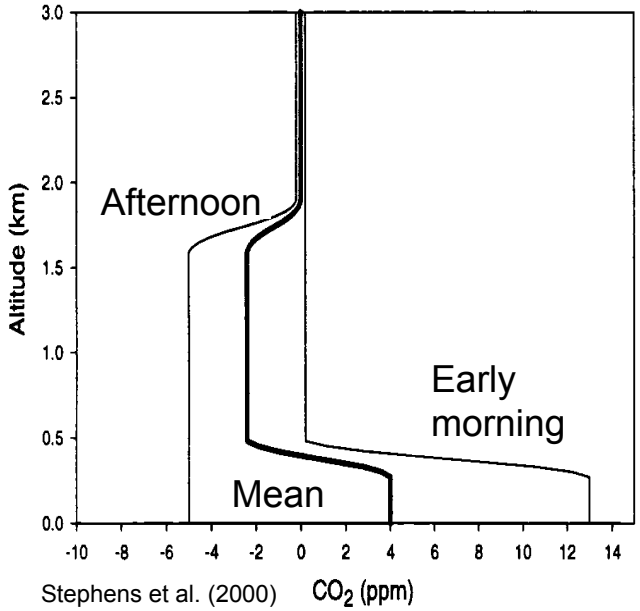
Pino et al., 2010

The diurnal cycle of CO_2 reflects emissions, uptake by the biosphere, and atmospheric mixing

•DAYTIME
- **Plants take up CO_2**
- **Turbulence mixes the PBL**
- **Results: low CO_2 throughout the lowest 2 km of the atmosphere**

•NIGHTTIME:
- **Little turbulent mixing**
- **Plants are respiring**
- **Results: in high CO_2 concentrations trapped near the surface.**

Surface measurements can not distinguish between these diurnal changes and a net CO_2 source.
A profile measurement at a single time can not separate the surface flux from mixing.



Stephens et al. (2000)

Errors in Flux Estimates from Vertical Profiles

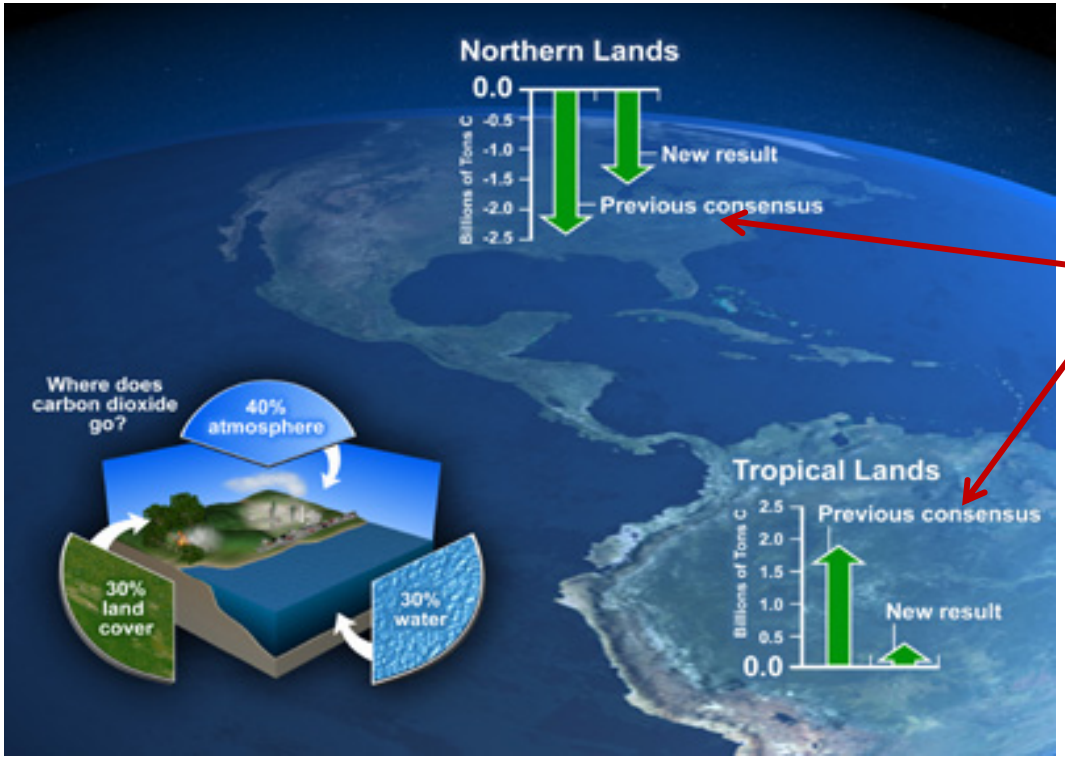


Illustration by Steve Deyo, UCAR

Analysis of surface data and models show:

-- Northern biosphere is a strong sink for CO_2

-- Tropics are a strong source (e.g. Gurney et al., 2004)

-- but there are large differences between these results and direct estimates from soils and plants.

Models with the wrong vertical gradient of CO_2

-- estimate more NH land uptake

-- estimate a larger Tropical land source to balance the budget (Stephens et al., 2007).

Frequent high spatial and temporal resolution measurements that can distinguish between free troposphere and lower troposphere concentrations are needed to constrain vertical mixing and improve flux estimates.

Profiles of Greenhouse Gases and Transport Tracers Provide More Source Information

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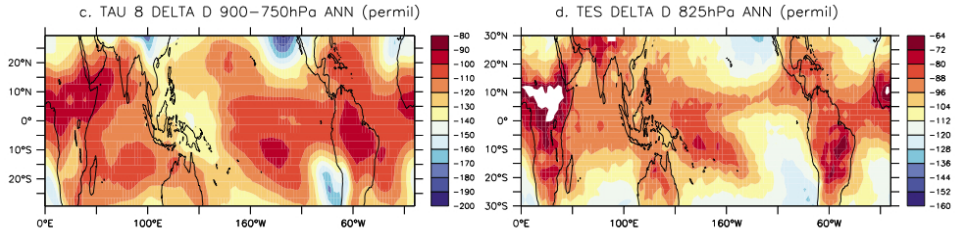
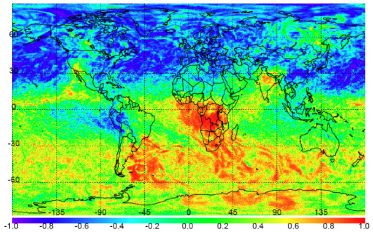
H_2O and HDO profiles can constrain quantification of boundary layer heights, atmospheric transport, and vertical mixing which are key uncertainties in carbon flux estimation

(Gurney et al., Nature 2002; Stephens et al., Science 2007; J. Worden et al., Nature 2007; Lee et al., GRL, 2009)

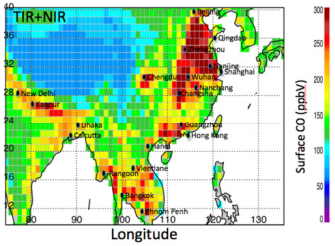


TES water vapor isotope measurements used to constrain parameterization of shallow convection (Lee et al., GRL 2007)

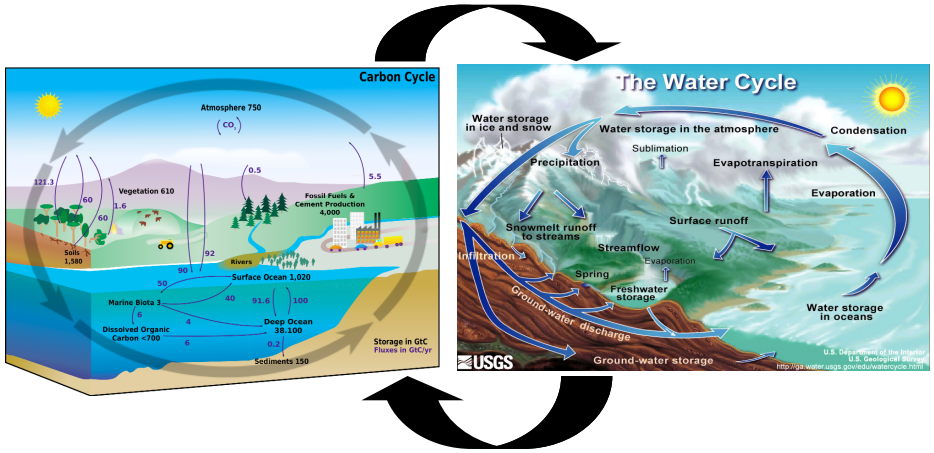
Transport characteristics can be derived from dynamical tracers such as CO, which can also be used to separate combustion sources of CO_2 from natural sources and sinks (Wang et al., 2009; H. Worden et al., 2010)



CO_2/CO correlations can reduce transport errors in CO_2 flux estimates (Wang et al., ACP 2009)



MOPITT near IR and thermal radiances reveal surface pollution (H. Worden et al., JGR 2010)



Panchromatic measurements with high spectral resolution and broad spectral coverage enables measurement of key tracers of the Carbon cycle (CO_2 and CH_4), the Water cycle (H_2O and HDO), and the Nitrogen cycle (N_2O and NH_4)

Analysis of Expected Sensitivity for CO_2

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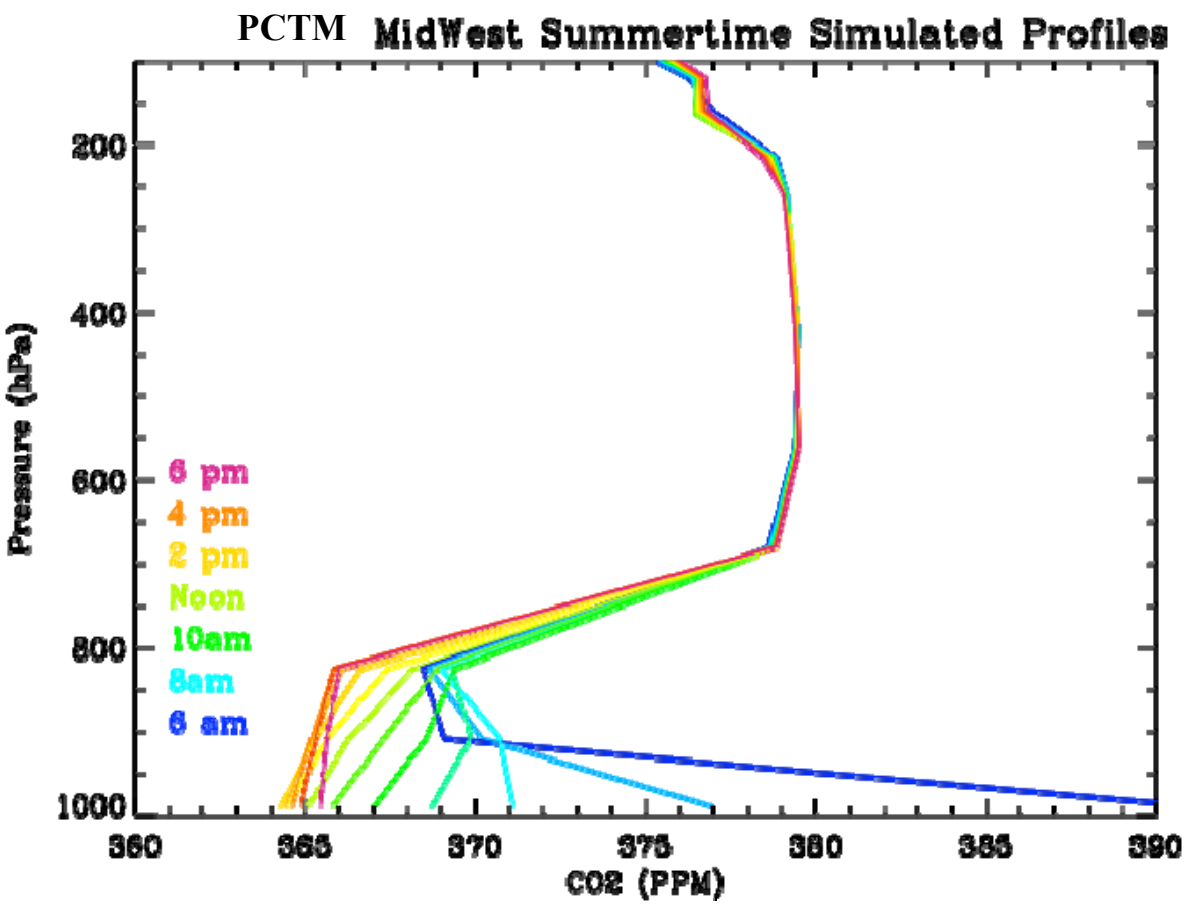
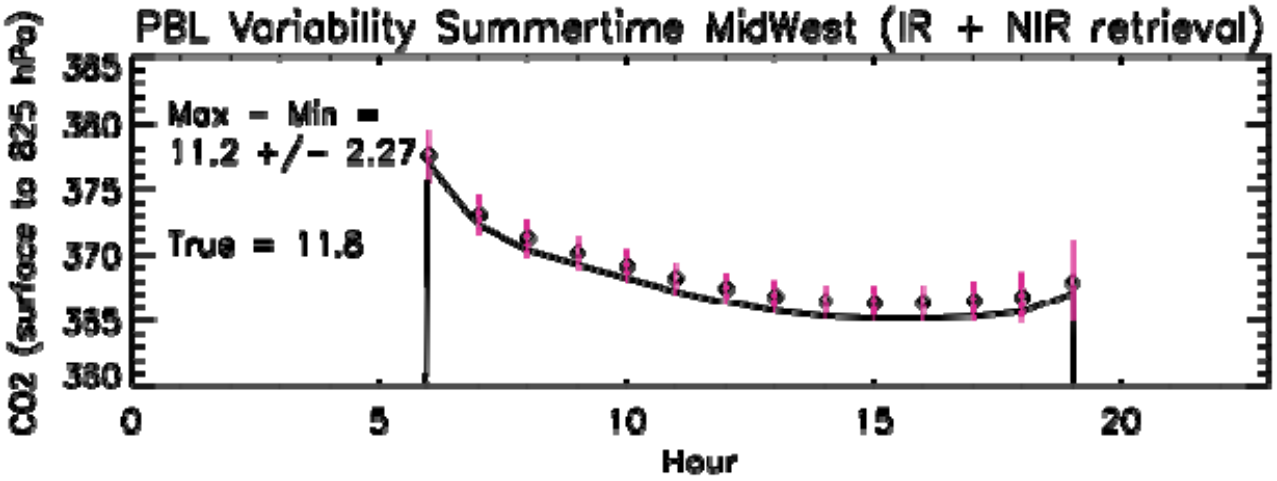
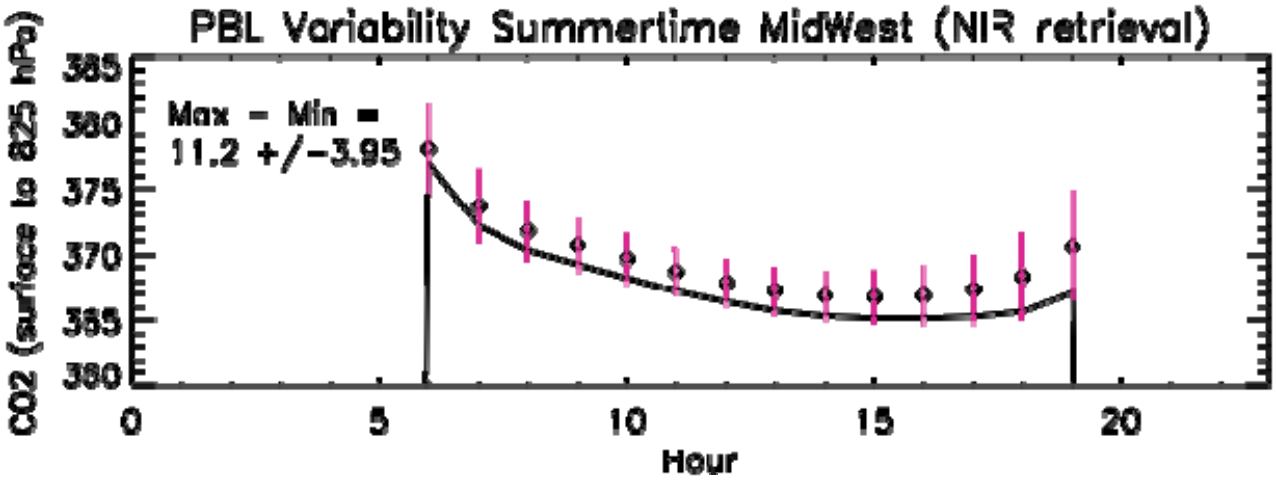


- PCTM (courtesy of R. Kawa) simulation for Midwest – challenging profiles
- Calculated viewing geometry for a 95 W geostationary satellite
- Ran RT simulations with VLIDORT for the NIR and IDL-ELANOR for the IR (cloud and aerosol free)
- Performed linear retrieval analysis to get sensitivity characteristics

PBL Variability is Detected

- Combined NIR and IR can correctly characterize the PBL variability.





CO_2 profiling with combined wavelengths

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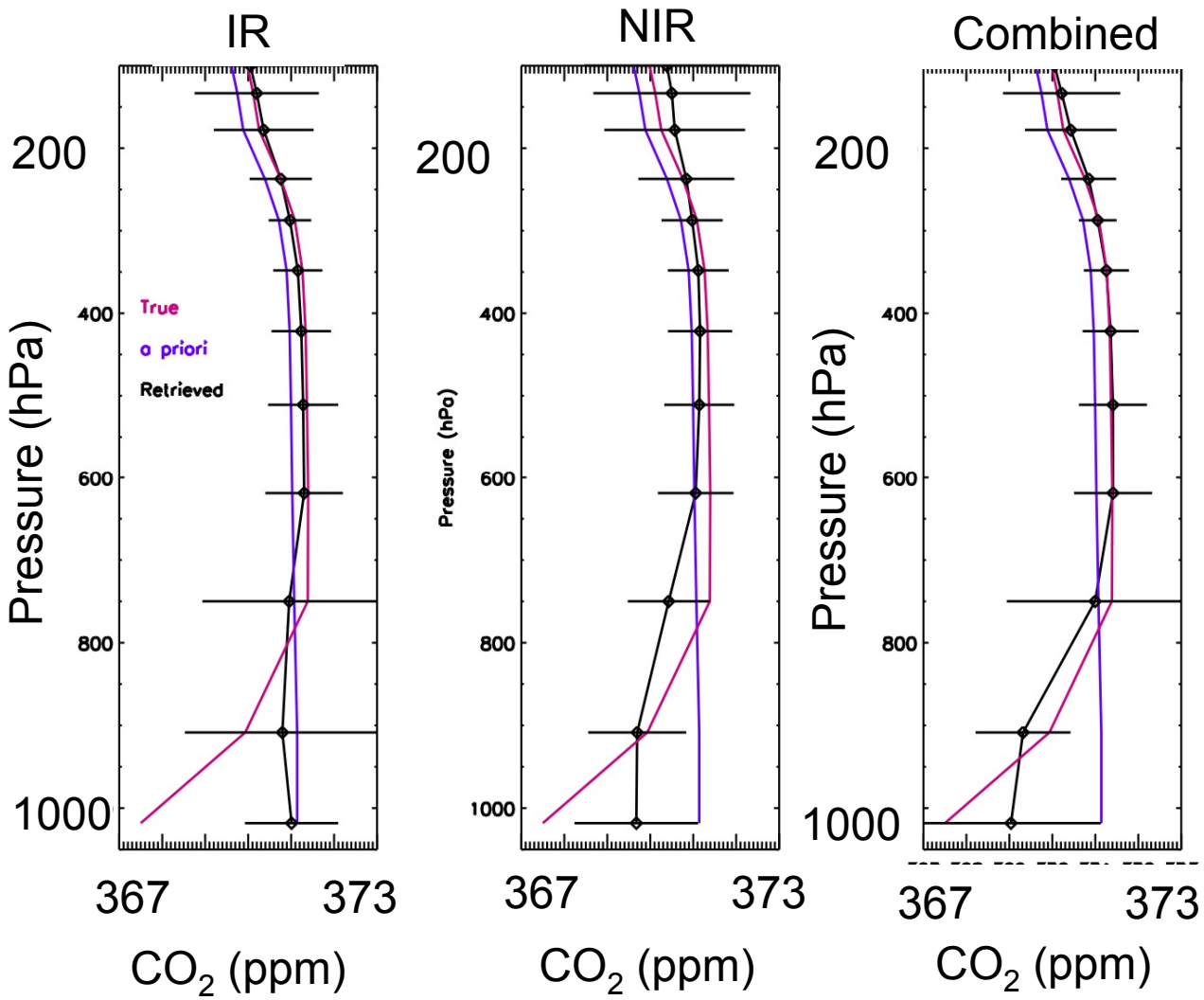
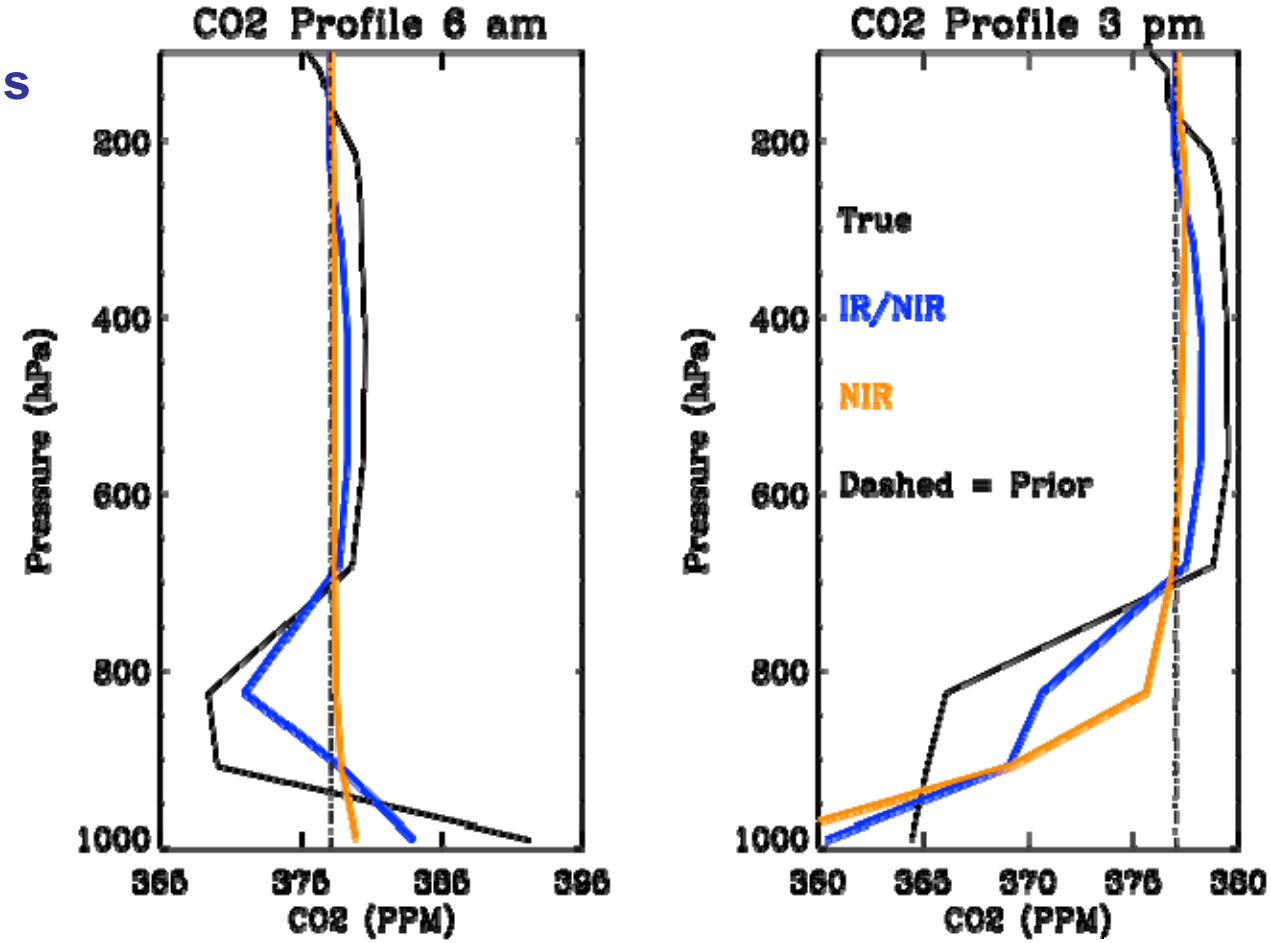


For this tropical profile, the combined wavelength retrieval captures more of the features of the vertical profile of CO_2

CO_2 profiles over the Midwest

- Midwest profiles have drastic vertical structure
- Combined wavelengths provide improved capability to measure vertical structure



Measurements from Geostationary Orbit

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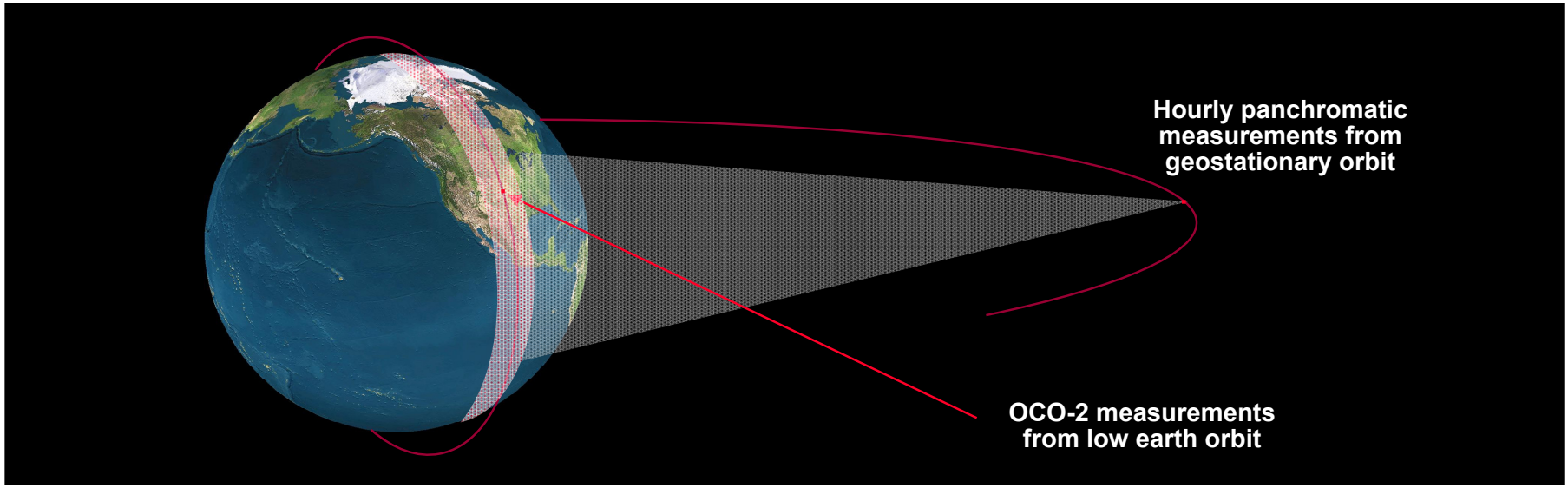
Greenhouse Gases:
CO_2, CH_4, N_2O, O_3, H_2O

Transport Tracers:
HDO, O_2, CO, CH_3OH, HCHO

Nighttime measurements:
CO_2, CH_4, O_3, H_2O, HDO, CO

- Hourly measurements with vertical information will complement global coverage of LEO measurements.
- The suite of tracers are needed to quantify transport terms which can confound flux estimates



Panchromatic measurements from geostationary orbit will complement measurements from OCO-2 for quantifying the global carbon budget and monitoring anthropogenic emissions

Summary

- Critical errors in flux estimates could be addressed with high temporal resolution measurements from GEO
- Panchromatic retrievals improve the vertical sensitivity for CO_2, CH_4, O_3, and HDO with discrimination of the free troposphere and boundary layer
- Work is continuing to advance the retrieval framework and instrument technology