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Greenhouse gases as air pollutants: opportunities for GEO-CAPE

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ABSTRACT

The air quality objective of Geostationary Coastal and Air Pollution Events mission (GEO-CAPE) is to satisfy basic research and operational needs for:

1. air quality assessment and forecasting to support air program management and public health,
2. emission of ozone and aerosol precursors including human versus natural sources,
3. pollutant transport into, across, and out of North America

GREENHOUSE GASES (GHGs)

"Because greenhouse gases fit well within the Clean Air Act's capacious definition of "air pollutant," we hold that EPA has the statutory authority to regulate the emission of such gases from new motor vehicles."

MASSACHUSETTS *v. EPA*
Opinion of the Court, April 2nd, 2007
Justice Stevens

The US Environmental Protection Agency (EPA) now has the mandate to regulate GHGs as "air pollutants" and air pollutants as GHGs.

GEO-CAPE can help provide the scientific basis for co-benefits strategy of air quality and climate.

Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases under the Clean Air Act, Federal Registry, April 24th , 2009

The Administrator signed a proposal with two distinct findings regarding greenhouse gases under section 202(a) of the Clean Air Act:

The Administrator is proposing to find that the current and projected concentrations of the mix of six key greenhouse gases-carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)-in the atmosphere threaten the public health and welfare of current and future generations. This is referred to as the endangerment finding.

The Administrator is further proposing to find that the combined emissions of CO_2, CH_4, N_2O, and HFCs from new motor vehicles and motor vehicle engines contribute to the atmospheric concentrations of these key greenhouse gases and hence to the threat of climate change. This is referred to as the cause or contribute finding.

9/15/2009 - DOT and EPA propose national program to reduce GHGs

• Reduce greenhouse gas emissions by nearly 950 million metric tons.

• "The combined EPA and NHTSA standards would **reduce carbon dioxide emissions** from the light-duty vehicle fleet by about 21 percent in 2030 over the level that would occur in the absence of any new greenhouse gas or fuel economy standards."

CO_2

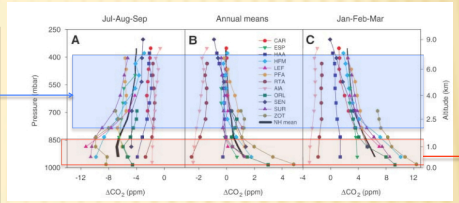
• Inverse estimates of CO_2 budgets that depend primarily on PBL CO_2 have significant errors in free-troposphere CO_2. Errors in free tropospheric CO_2 drive errors in the global CO_2 mass-balance which in turn result in errors in surface emissions (*e.g., Stephens et al., Science, 2007*).

• **Transport errors**: inter-hemispheric, mixing between PBL and free troposphere, and movement in the PBL are dominant errors besides a priori **errors in surface emissions**. (*e.g. Peylin et al. JGR 2001; Jones et al., JGR, 2003*).

• **Resolving the planetary boundary layer (PBL)** CO_2 from free-tropospheric CO_2 in remotely sensed CO_2 measurements will increase sensitivity to surface fluxes and reduce errors due to **transport**. *(e.g., Denning et al., Nature, 1995; Gurney et al., Nature, 2002; Chan et al., JGR 2008).*

Free-tropospheric CO_2 depends on PBL to Tropospheric mixing and intercontinental/ inter-hemispheric **transport**..

e.g., Jiang et al., JGR 2004, Chan et al., JGR 2008



CO_2 concentrations in the PBL are primarily sensitive to **surface fluxes**, mixing within the PBL, (and PBL height).

from Stephens et al., Science, 2007

Ex: Boundary Layer CO_2 from IR and NIR

Simulated retrieval approach using IR, NIR, and combined radiances

•Jointly estimate T_{ATM} , H_2O, T_{surf} , and CO_2 using Optimal Estimation so as to fully characterize errors and sensitivity of the estimate to a simulated "True" CO_2 distribution

• Assume IR SNR= 500 ; NIR SNR = 100

(e.g., TES + OCO or a new instrument concept)

• Assume for now no aerosol scattering and no clouds

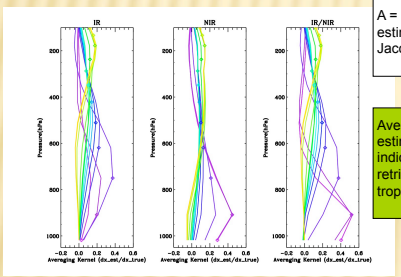
• Albedo and emissivity not retrieved (next study)

• Albedo = 0.18 (land)

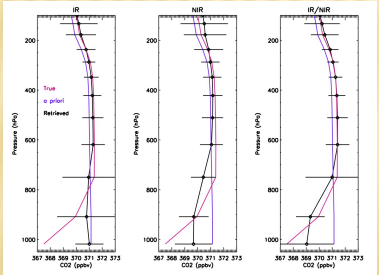
Use "linear retrieval" to examine impact of using different spectral bands on a CO_2 estimate

$x_{retrieved} = x_a + A(x_{true} - x_a)$

A = averaging kernel = sensitivity of estimate to "true state": depends on Jacobians and choice of constraint



Averaging Kernels (sensitivity of estimate to the true distribution) indicate that combined radiance retrieval can resolve PBL from lower troposphere.



Error bars describe random errors

noise + temperature

For IR/NIR combination: need to average ~4-10 profiles to reduce BL random error to ~ 1 ppm

GEO-CAPE

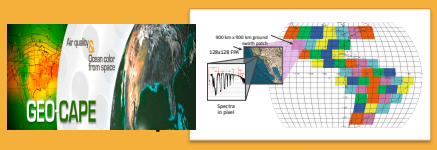
•CO_2 emissions, transport and PBL issues can be addressed by the orbital and instrument characteristics of the GEO-CAPE mission.

• Low Earth Orbit (LEO) observations, AIRS or OCO-like have repeat times of at best twice a day and often several or many days, often obscured by clouds..

• Continuous GEO observations can capture **the diurnal variation** for natural and anthropogenic CO_2 emissions.

• Higher temporal resolution data (hourly intervals) are critical to understanding **CO_2 transport**.

• Moreover, higher spatial coverage improves chance of **cloud-free pixel**.



As seen above, the ability to observe the lower troposphere (LT) is a priority for characterization of pollutant sources, especially in the planetary boundary layer (PBL).

The GEO-CAPE Pan-Spectral approach has several advantages for CO_2 measurements:

- In the TIR, high spectral resolution is necessary to achieve sensitivity to the vertical structure.
- The general lack of thermal contrast with the surface which limits the sensitivity to the LT and PBL can be compensated by the high resolution spectroscopic measurements of reflected sunlight in near IR CO_2 bands.

- **Multi-spectral observations (NIR, TIR)** may increase the sensitivity to PBL and provide average concentrations for some species (especially CO, O_3 and CO_2).

- Recent work is exploring **combined retrievals** from synergistic observations (UV-VIS, NIR for O_3; **NIR and IR for CO_2**).

CONCLUSIONS - PERSPECTIVES

• GEO-CAPE could provide precise global measurements of CO_2 over the range of scales needed to monitor CO_2 fluxes on regional to continental scales.

• Retrievals using NIR and IR radiances have the potential to resolve free tropospheric CO_2 from Boundary Layer CO_2: Increases sensitivity to surface fluxes and reduces transport error.

• Next steps are to examine range of CO_2 estimates for a range of CO_2 variability in the free troposphere and PBL

• In future work we will examine the GHGs retrievals in the presence of clouds