Error Analysis for Space-borne IPDA Lidar Measurement of Atmospheric CO_2

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Introduction

CO2 is a long-lived trace gas which acts as the most important greenhouse to the global climate. A stringent precision of space-borne CO2 data, for example 1 ppm or better, is required to address the largest number of carbon cycle science questions. A high measurement sensitivity and global covered observation is expected by space-borne IPDA (Integrated Path Differential Absorption) lidar which has been designed as the next generation measurement. A global simulation is used to investigate the sources of errors associated with the configurations of lidar system and the environment parameters which could improve the investigation of CO_2 fluxes and distributions.

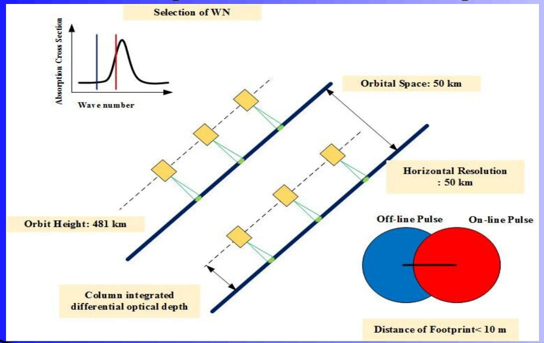


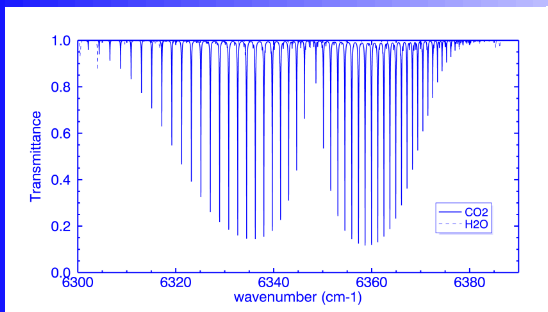
Table 1 Instrument parameters for IPDA

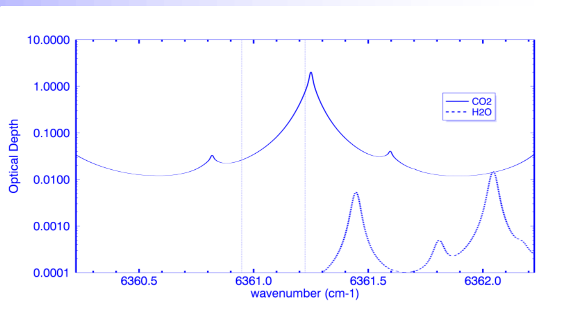
Laser pulse energy [mJ]	50	Receiver FOV [urad]	250
Telescope diameter [m]	1	Optical efficiency	41%
Spacecraft altitude [km]	481	Horizontal resolution [km]	50
Pulse rep. rate [Hz]	50	CO_2 ratio [ppm]	390
Laser pulse width[nsec]	10	Atmosphere model	US standard atmosphere

Theory

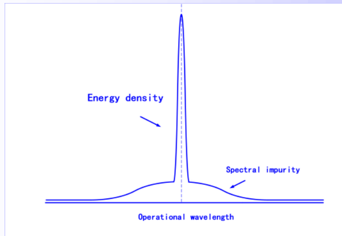
IPDA lidar method does not provide range-resolved measurements, the information on the vertical distribution of CO2 can be obtained from examination of vertically weighted column volume mixing ratio. The total column-weighted dry air mixing ratio of CO2 is defined as the equation.

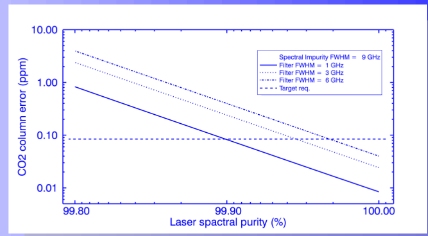
$$XCO_2 = \frac{DAOD}{\int_{p_{top}}^{p_{surf}} WF(p)\,dp} \equiv \frac{\ln \frac{P_{off}}{P_{on}}}{2\int_{p_{top}}^{p_{surf}} WF(p)\,dp}$$

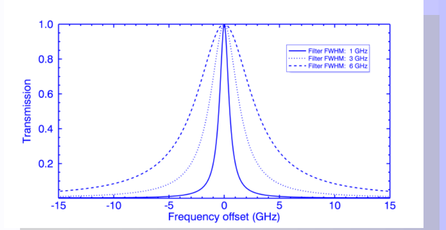


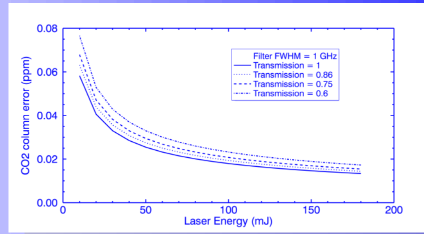


System error



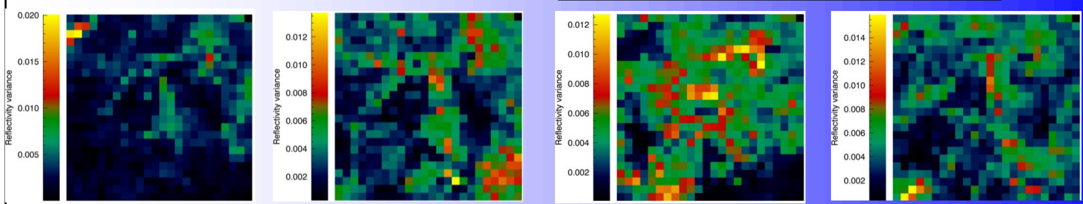


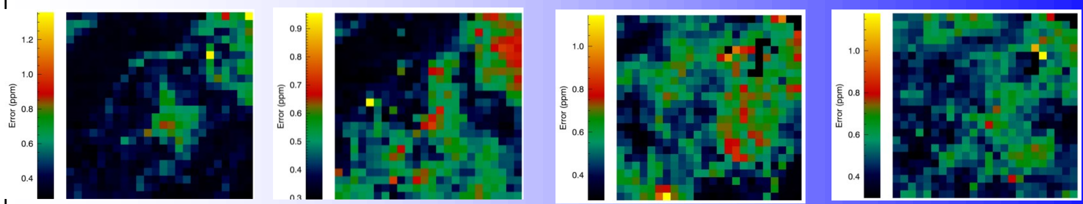




Reflectance error

Reflectivity variance of MODIS at Amazon for four seasons.





Reflectance error caused by difference reflectivity of on– and off-line footprint at Amazon for four seasons.

Reference: Miller, C. E. et al. Precision requirements for space-basedXCO2data. Journal of Geophysical Research 112, doi:10.1029/2006jd007659 (2007). Ehret, G. et al. Space-borne remote sensing of CO2, CH4, and N2O by integrated path differential absorption lidar: a sensitivity analysis. Applied Physics B 90, 593-608, doi:10.1007/s00340-007-2892-3 (2008). Caron, J. & Durand, Y. Operating wavelengths optimization for a spaceborne lidar measuring atmospheric CO2. Appl Optics 48, 5413-5422, doi:10.1364/AO.48.005413 (2009). IPCC. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (Cambridge University Press, 2013).