Instrument Incubator Project: Infrared Correlation Radiometer for GEO-CAPE

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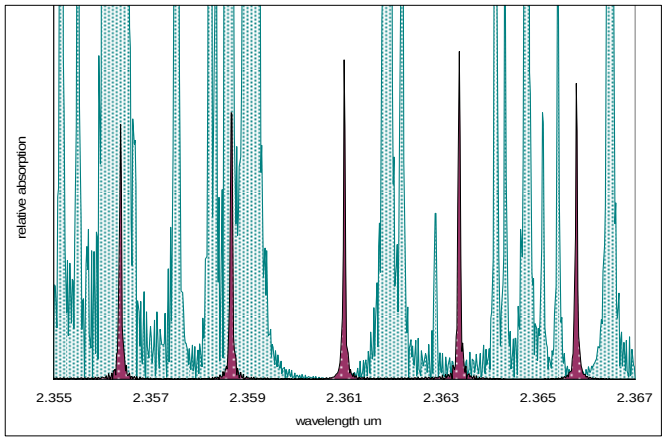
Infrared Correlation Radiometer Goal: Characterize the performance of a 2.3 μm infrared correlation radiometer (IRCR) prototype subsystem designed specifically to measure carbon monoxide from geostationary orbit.

The challenges for GEO-CAPE are to improve precision and accuracy of existing 2.3 μm CO capability, while using the well-validated IRCR technique at GEO, nearly 50 times farther away than the Terra orbit.

Technique

Below: CO lines (red) are embedded within stronger lines of CH4 and other interferants at 2.3 microns. Other measurement techniques use only the few "clean" lines in the region. The IRCR measures the contribution of all CO lines, and selects the target gas (CO) lines cleanly from the interferants.

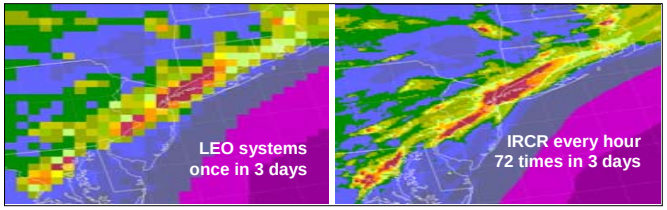


IRCRs resolve spectral lines using the gas of interest as a "perfect" spectral filter and) integrate radiance across a spectral passband (~60 cm-1 wide) much larger than the interval Δλ (~0.2 cm^{-1}) used by spectrometers, thereby increasing the signal while **clearly distinguishing between the target gas and all interfering gases.**

IRCRs return the total line-by-line intensity, and the "not CO" intensity of everything except CO, combing out the CO signal (every line in the pass band) from all interfering constituents. The individual interfering gases cannot be explicitly retrieved from this information, but the CO signal has **outstanding specificity and SNR.**

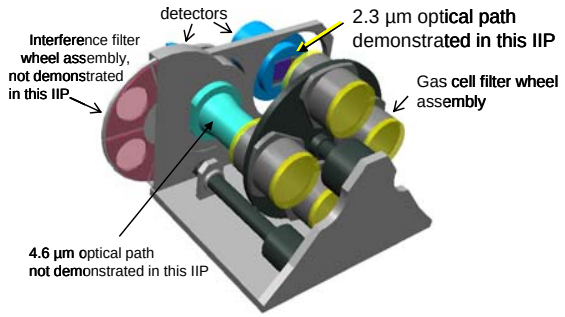
The spectral line matching of IRCRs is only exact for gas at the same pressure (in the atmosphere, pressure is altitude) as the gas in the instrument filter. High pressure matches low altitude air pollution, low pressure matches the upper troposphere.

Synthetic Data



*Above: We depict a **synthetic IRCR data** frame (right), showing modeled surface CO over the northeastern US at the 1-hour time sampling and a 4-km spatial resolution case studied with our performance models. The left panel provides the same model data, averaged into a 20 x 20 km^2 spatial footprint similar to existing MOPITT CO measurements (SCIAMACHY footprints = 30 x60 km^2).*

Infrared Correlation Radiometer Concept



Below: The IRCR flight instrument will provide 20 spectral channels. The focus of this IIP is the subset of channels at 2.3 μm.

Filter	Center Frequency, cm^{-1} (Filter width, cm^{-1})	Required NEN (W m^{-2} sr^{-1})	Channel Number	Gas Cell Content (cell pressure, hPa)	Information content of combined filter and gas cell
F5	4290 cm^{-1} (60) 2.3 μm	1 x 10^{-6}	17	CO (100)	CO gas filter, water vapor
			18	CH_4 (1000)	CH_4 gas filter, water vapor
			19	CO (400)	CO gas filter, water vapor
			20	N_2O (200)	"vacuum" cell, water vapor

Parameter	Target Value	Parameter (continued)	Target Value (continued)
Capability	SWIR	Readout Time	40 msec
Signal-to-Noise Ratio (Low Radiance)	2500	Total Exposure Time	18.74 minutes
Signal-to-Noise Ratio (High Radiance)	9500	Fraction of Well Capacity Utilized	0.9
Minimum Scene Radiance	0.0036 watts/cm2/sr	Focal Plane Temperature	120 K
Maximum Scene Radiance	0.50 watts/cm2/sr	Dark Current	19 e-/pixel/sec
Wavelength	2.3 μm	Analog-to-Digital Converter	16 bit
Detector Array	HgCdTe 1024x1024	Quantization Noise	15 e-
Readout	TCM8050	Total Samples Acquired	5621
Focal Plane Wavelength Cutoff	2.5 μm	Dynamic Range	139
FPA Format	1024 x 1024 pixels	Aperture Diameter	6.8 cm
Pixel Pitch	18 μm	Focal Length	20.57 cm
Quantum Efficiency	0.60 e-/photon	F-number	3.03
Well Capacity	5 x 105 e-	Pixel Instantaneous Field-of-View	87.5 μrad
Read Noise	75 e-	Instrument Field-of-View	5.13 deg
Single-Sample Integration Time	10 msec	Optics Temperature	170 K

We focus on characterizing the 2.3 μm IRCR subsystem, although both 2.3 μm and 4.6 μm subsystems are required to obtain boundary layer CO. MAPS and MOPITT performed robustly at 4.6 μm; we have been involved in these programs from the start. The Decadal Survey refocused tropospheric chemistry goals toward the lowest layers of the atmosphere, placing new emphasis on the 2.3 μm measurements. This IIP responds directly to the Decadal Survey.

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The Decadal Survey specifies infrared correlation radiometry to measure CO in two spectral regions for GEO-CAPE.

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