I. Background

Infrared sounders currently use the long-wave IR (LWIR), 15 μm CO₂ band for temperature retrievals. However, measurement of LWIR radiation requires large optical apertures and cold detectors, driving up the size and complexity of the instrument.

Here we show instrument trade studies for mid-wave IR sounder, illustrating potential for temperature and humidity sounding exclusively in mid-wave IR (MWIR).

A. What is sounding?

Altitude sampling
- Absorption spectrum of chemical determines amount of light absorbed as a function of wavelength
- Atmospheric penetration proportional to absorption

Mapping between wavelength and altitude in atmosphere

Temperature measurement
- Increase in temperature results in increased observed radiance
- Change occurs in several parts of spectrum

Mapping between temperature and radiance (light)

B. Instrument design consideration for IR sounders

CO₂ drives LWIR requirements
- Can also measure CO₂ in MWIR

More radiance from atmosphere in LWIR

LWIR requirements drive optical aperture size and cooling requirements

Focal plane array (FPA) technology advancement
- Large area enables pushbroom collection and improves spectral sampling

Dispersive optical design with FPA filter
- Selective sampling of spectrum
- Only interested in discrete bands of spectrum

Dispersive optical designs and custom filters on focal plane array enables high spectral resolution in bands of interest

Design re-orders bands on focal plane to optimize focal plane real estate

C. New technologies enable sounding in MWIR

FPA filter with spectral areas of interest

IV. Mid-wave IR sounder trade studies

Trade studies were performed under ideal conditions to provide a proof-of-concept for a mid-wave sounder. Simulated tropical ocean nighttime soundings were performed on NOAA-88 profiles taken from the CIMITS clear sky global training database [4]. It was assumed that surface properties, atmospheric pressure, and CO₂ levels were known a priori. For reference, current sounders measurement accuracy requirement is ~1K for temperature accuracy and 20 ppmv error for humidity retrieval accuracy with a goal of 10%.

A. Spectral coverage trades

CO₂ band spectral coverage

CO₂ resolution trade studies – Temperature, H₂O
Constant spectral resolution (0.35 nm), Reference water band

H₂O resolution trade studies – Temperature, H₂O
Constant spectral coverage (4.15 – 4.23 um), Reference CO₂ band

B. Spectral resolution trades

CO₂ resolution trade studies – Temperature, H₂O
Constant spectral coverage (4.15 – 4.23 um), Reference water band

H₂O resolution trade studies – Temperature, H₂O
Constant spectral coverage (4.15 – 4.23 um), Reference CO₂ band

C. Noise scaling factor trades

Reference CO₂

- Reducing noise below reference design does not significantly improve retrieval accuracy
- Large increases in noise factor degrade retrieval accuracy, especially around 750 mb
- Reference design is shot noise limited

Reference Design

CO₂ Band
Spectral Coverage (um) 4.18 – 4.23
Spectral Resolution (nm) 0.35

H₂O Band
Spectral Coverage (um) 5.1 – 5.45
Spectral Resolution (nm) 0.42

IV. Conclusions

- Sounding exclusively in mid-wave IR reduces instrument requirements
- Developed full end-to-end sounder modeling tool
- Demonstrated successful proof of principle for temperature and humidity sounding using solely mid-wave IR

References

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Analysis of Temperature and Humidity Sounding Using Compact Mid-Wave Infrared Instruments

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