A GEO Venture Class tropospheric O3 and HCHO measurement concept based on the TIMS

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The USA National Research Council Decadal Survey (NRCDS) Report for Earth Science :

- –describes requirements for improved atmospheric measurements to gain crucial understanding for air quality, climate change, and weather.
- –We are developing compact multi-channel grating mapping spectrometers (GMS) to meet this challenge.

In this presentation we will describe:

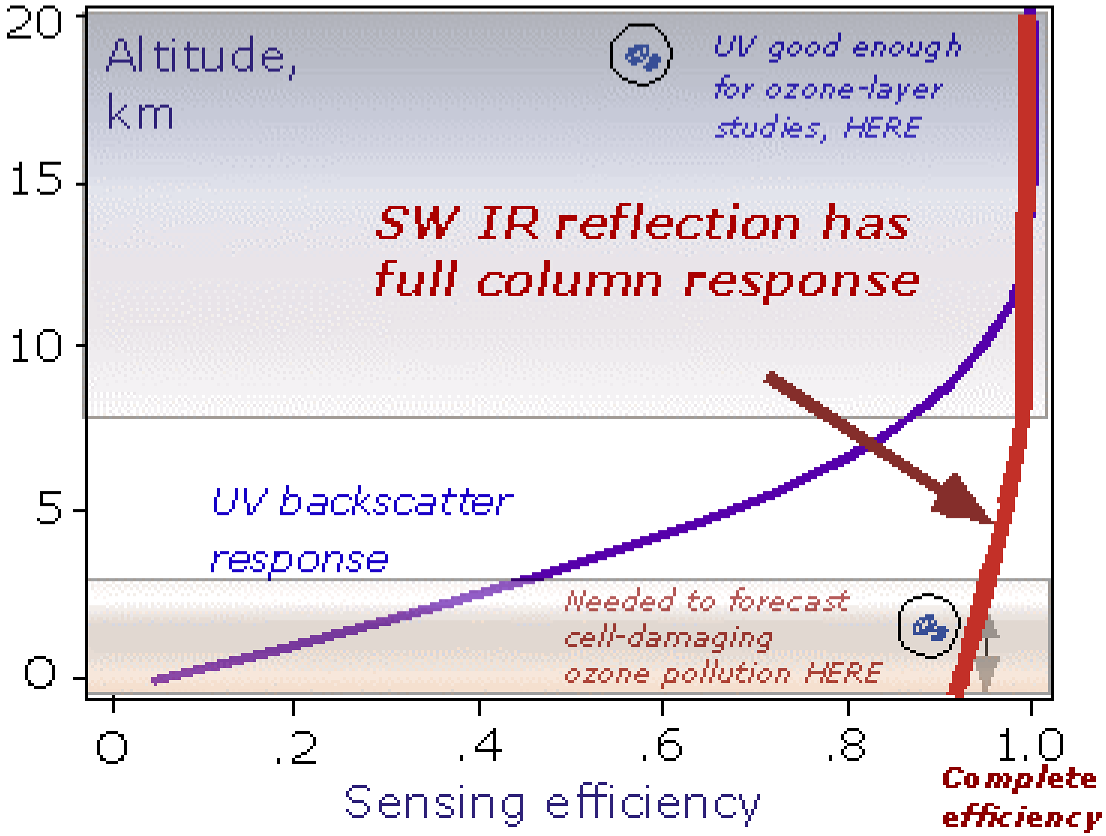
- –measurements of atmospheric spectra that we have made with a proto-type GMS with $\lambda/\Delta\lambda$ = 6000 in the midwave infrared region. [we refer to the projected space application of this GMS as "TIMS"]
- –a potential application in a pathfinder mission for the NRCDS Geostationary Coastal and Air Pollution Events (GEO-CAPE) Mission. It would provide:
- –measurements of column O_3 and HCHO on the Continental USA (CONUS) with
  - hourly refresh and on contiguous double sampled 5 km north-south by 10 km west-east footprints
- –Input to the grating mapping spectrometer would be provided by a
  - front end consisting of a scan mirror and telescope with 4.5 cm aperture
  - The scan mirror would west to east pushbroom the slit on a CONUS wide swath in 5 km steps
  - Using 7s per step provides full CONUS coverage with 2-hour refresh
  - The O_3 and HCHO would be retrieved from spectra measured on two regions centered near 3.28 and 3.56 μm, respectively.

Based on the demonstrated measurement capability of our proto-type GMS

–retrieved O3 column should have precision 1 to 2 % depending on albedo and pollution amount

- but with the added benefit of sensitivity to boundary layer (BL) O3.
- In principle, when combined with the UV measurements, it could provide a measure of the BL O3.

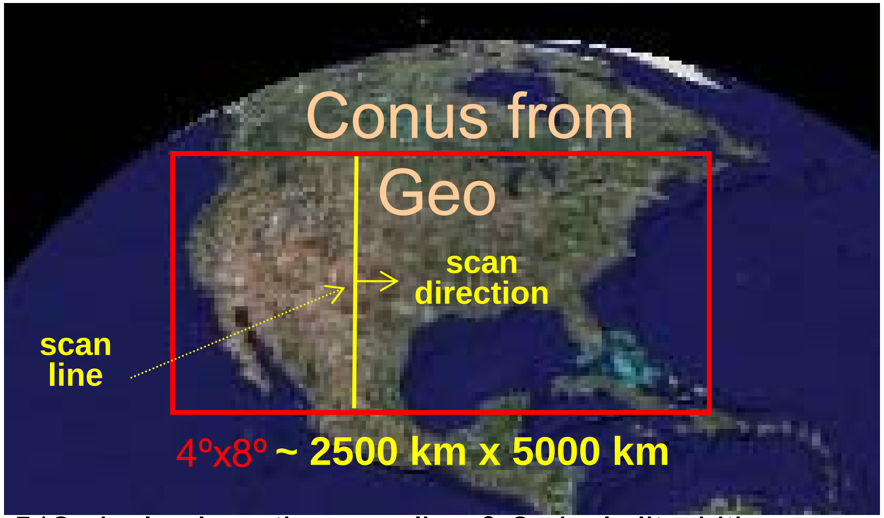
Figure below from P. K. Bhartia, et al, http://www.knmi.nl/omi/research/project/meetings/ostm10/presentations.html



- Options other than UV include the thermal infrared bands @ 9.6 & 4.7μm
  - » These options are more costly than UV & this is a major consideration for the proposed pathfinder mission
  - » Further more it remains to judge whether these options would be as effective as the UV

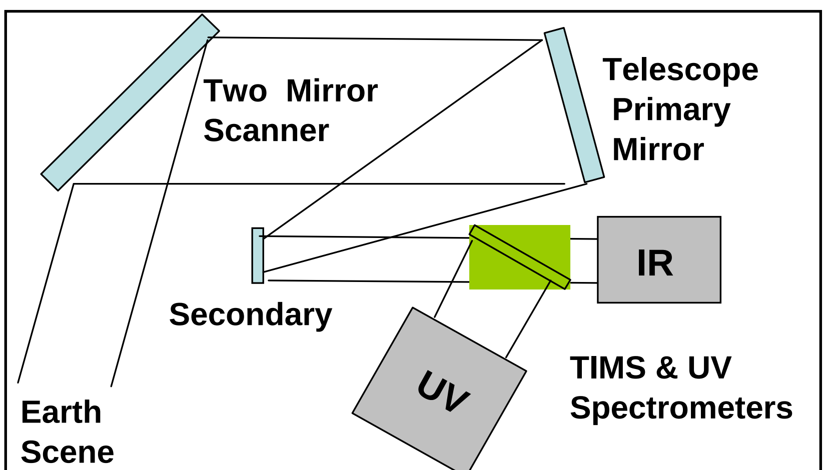
–The HCHO retrieval should have precision 3 to 15 % depending on albedo and pollution amount

Geo measurement approach & spectral regions

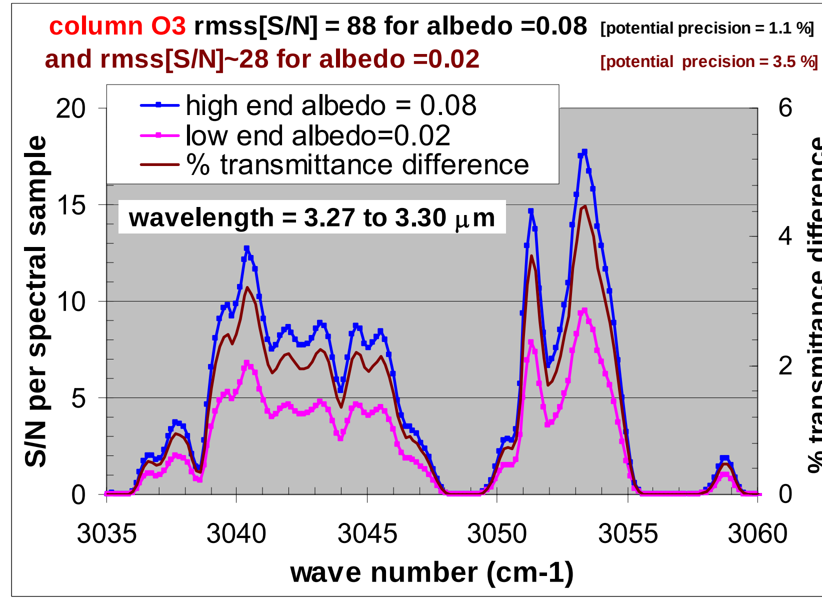


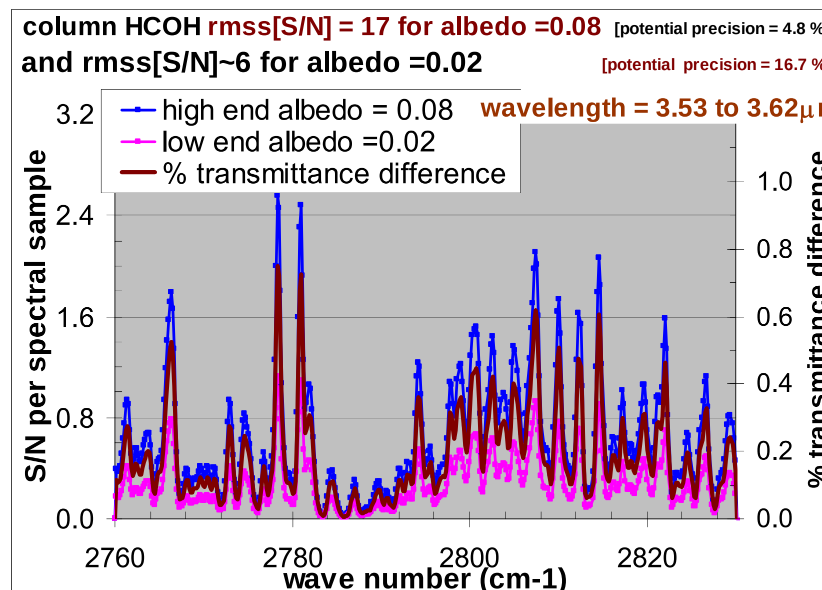
- 512 pixels along the scan line & 2 pixel slit width
  Smallest footprint (ELF) is 5 km NS x 10 km WE
- 1000 5 km steps provide complete CONUS scan in 2 hours using 7s integration per step

Below: schematic of geo deployed tropospheric infrared mapping spectrometer TIMS, and UV mapping spectrometer. A 4.5 cm aperture is required.

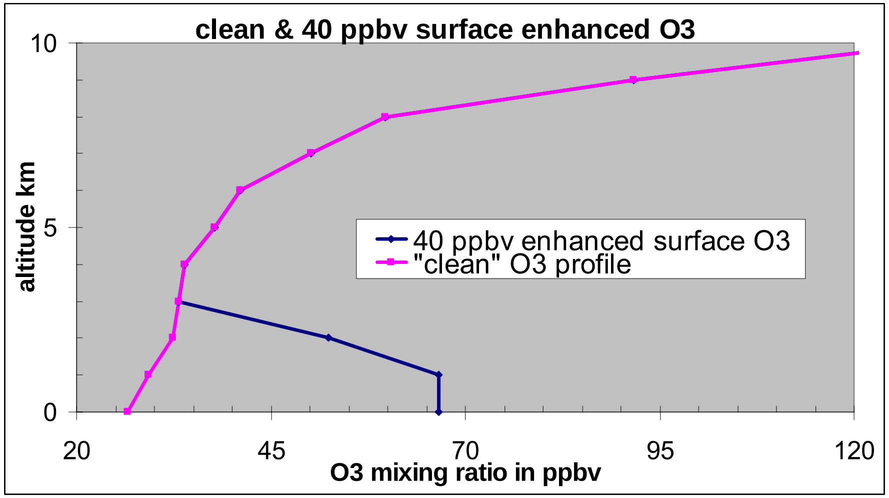


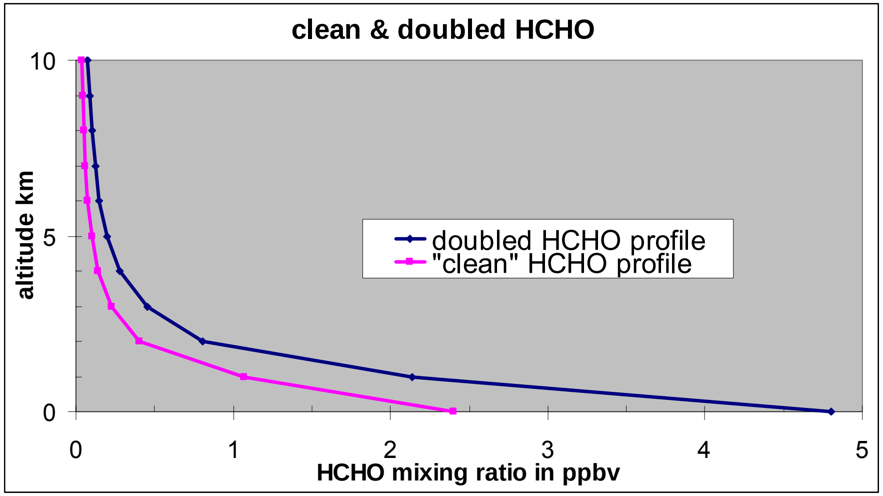
Plots below of S/N per sample on a 5 x 5 km footprint and the transmittance difference in units %





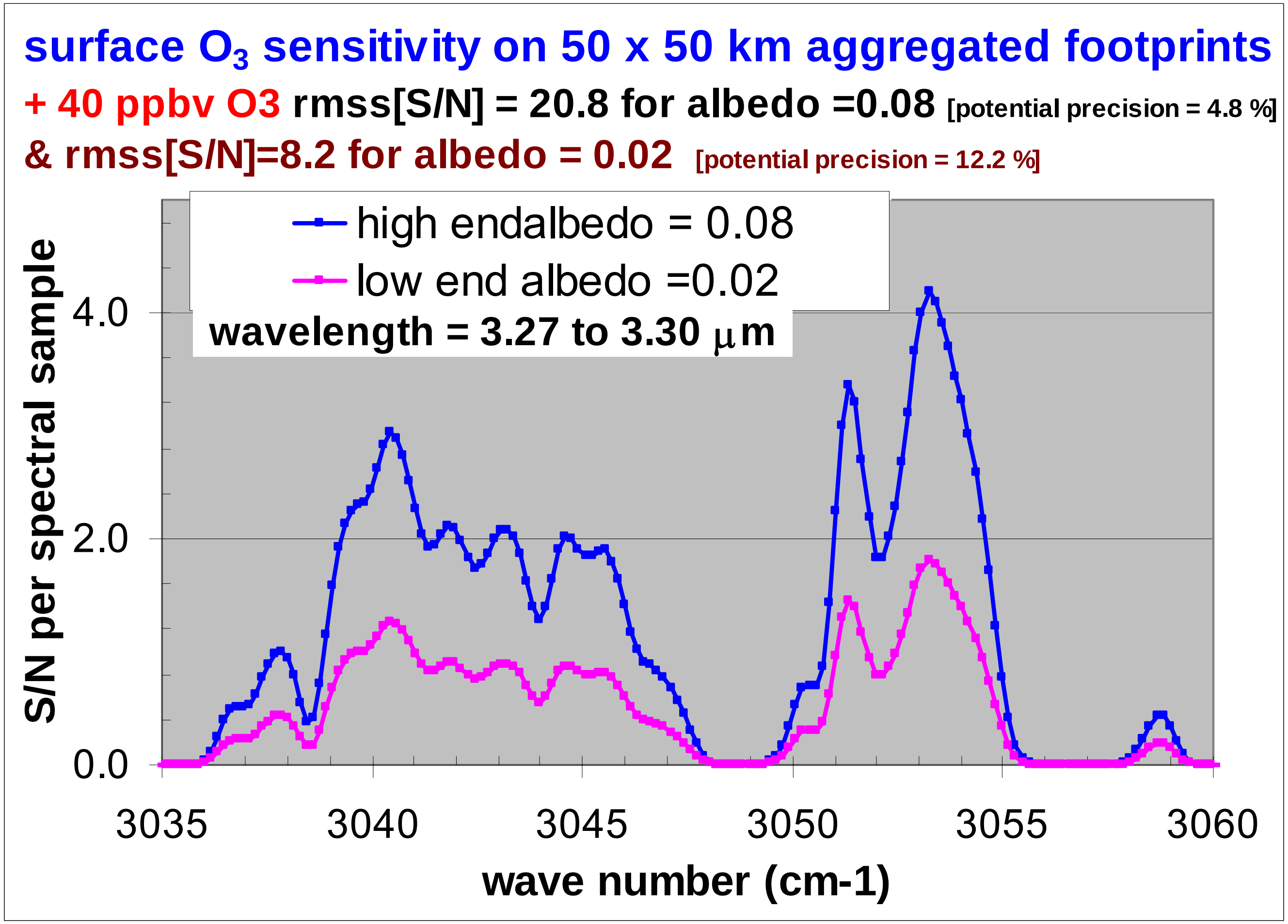
O3 & HCHO, the clean models are from the on line GATS browser





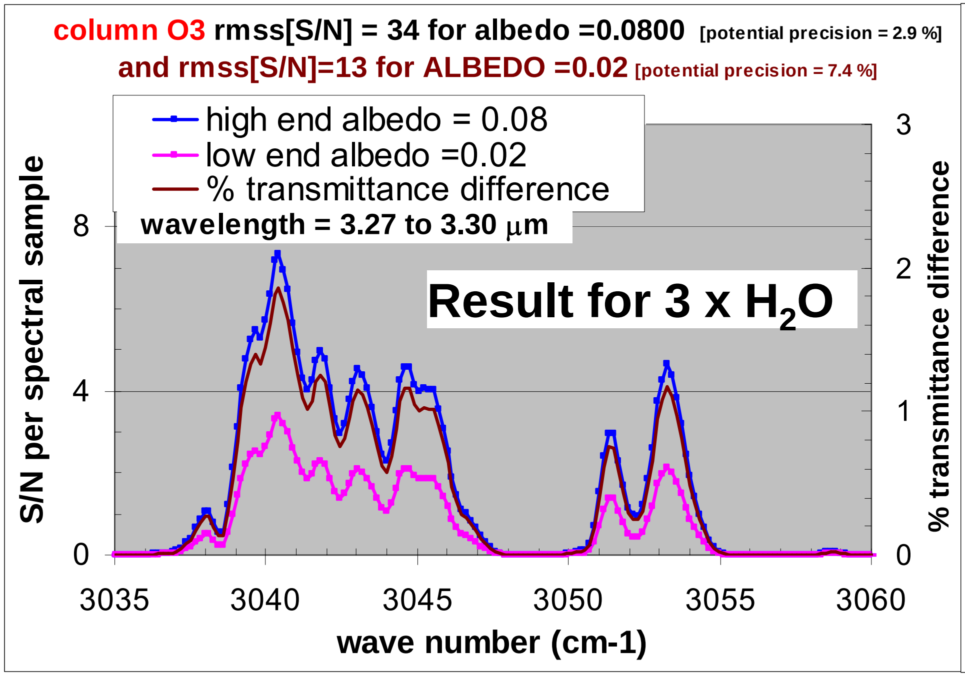
rmss[S/N] for 40 ppbv surface enhanced O3 on large aggregated footprints

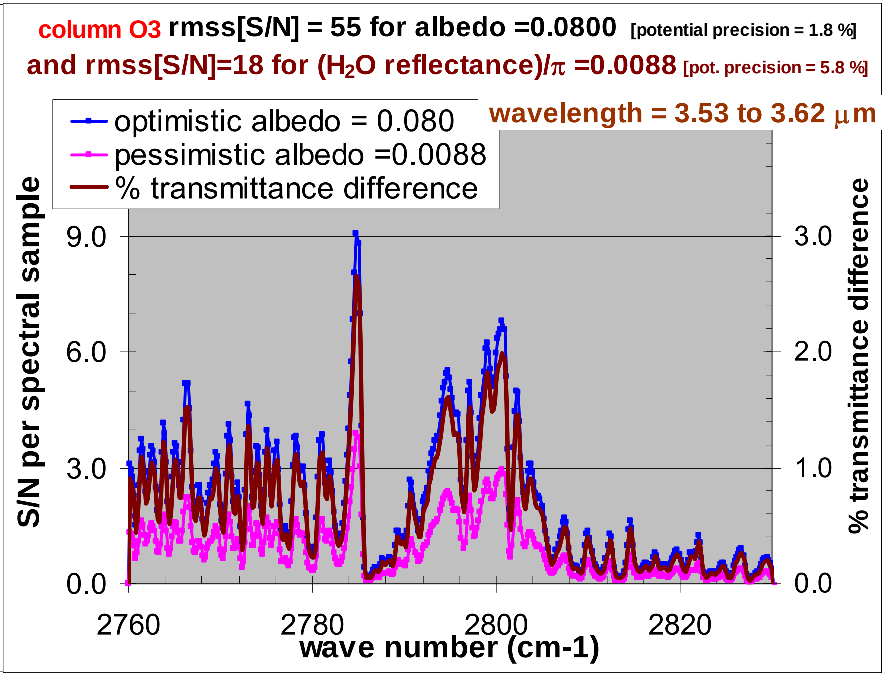
albedo	50 x 50 km AG-footprint		25 x 25 km AG-footprint	
	rmss(S/N)	"precision'	rmss(S/N)	"precision'
0.080	20.8	4.8	10.4	9.6
0.020	8.2	12.2	4.1	24.4



O3 total column on double sampled 5 km x 10 km footprints in wet atmospheres & at 3.6 μm

- From above for the 3.3 μm region and for a standard atmosphere the total O3 can be retrieved at 1 to 3 % precision, depending on albedo, here we investigate
  - The effects in the 3.3 μm region of tripling the atmospheric H2O content
    - The total O3 column precision is degraded to 3 to 7%, depending on albedo
  - The total O3 column precision obtained from the data in the 3.6 μm region that is relatively insensitive to atmospheric H2O content
    - This turns out to be the order 2 to 6 % precision, depending on albedo
- Data simultaneously obtained in the *two regions* will together provide the order 1.5 to 4.6 % precision





Summary and conclusions

From Geostationary deployment it is important to diurnally map O3 and HCHO column in the CONUS with

- footprints the order 5 to 10 km and with a two hour refresh

It is most important to sense O3 in the boundary layer

We have demonstrated a tropospheric infrared mapping spectrometer (TIMS) lab demonstration grating mapping spectrometer GMS that when operated in the reflective SWIR address these requirements and provide measurements of

- O3 column the order 1.5 to 4.6 % precision on double sampled 5 km NS by 10 km WE footprints with 2 hour refresh and with

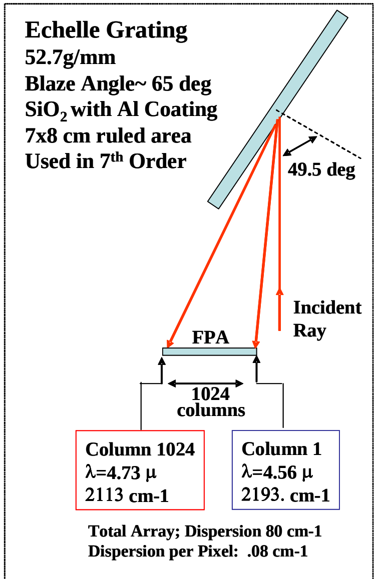
S/N the order 5 to 12 % for 40 ppbv near surface enhanced O3 on 50 x 50 km footprints

- Together with O3 retrieved from UV, the two measurements can provide a measure of the BL O3
- The geo deployed TIMS would also provide HCHO measurements with precision the order 5 to 17 % and intrinsically better than in the UV

Next we discuss our laborotory demonstration **(Lab Demo)** grating mapping spectrometer that these performance estimated are based upon

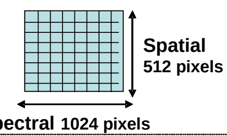
Lab Demo GMS description

The Basic Technique

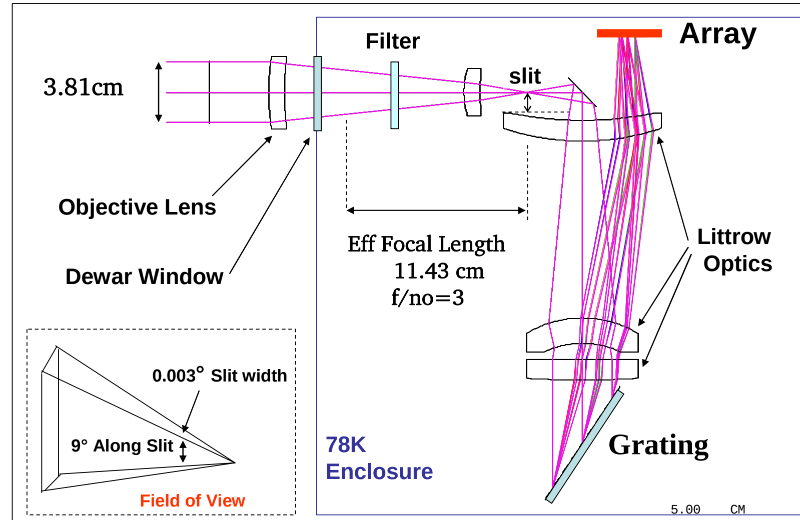


HAWAII HgCdTe MBE Array

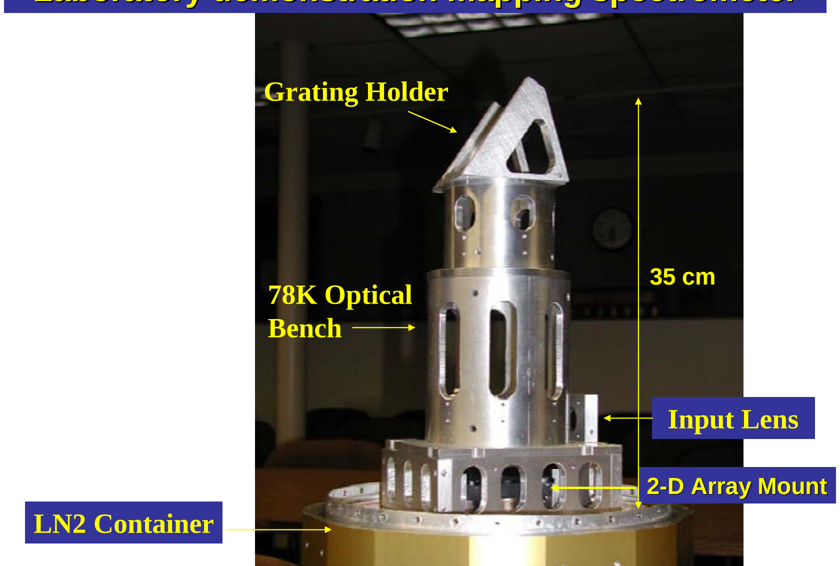
Format	1024x1024
Pixel Pitch	18.5 µ
QE (78K)	~60%
Long Wave cutoff	5.1µm
Short Wave Cuton	0.95 µ
Read Noise (e rms)	<60 CDS
Dark Current (e/s) at 78K, 0.5V Bias	~ 190
Well Capacity (e)	10^5
Temperature	78K



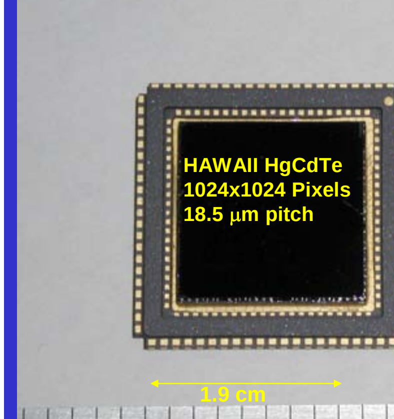
Laboratory demonstration grating mapping spectrometer (GMS) Optical schematic



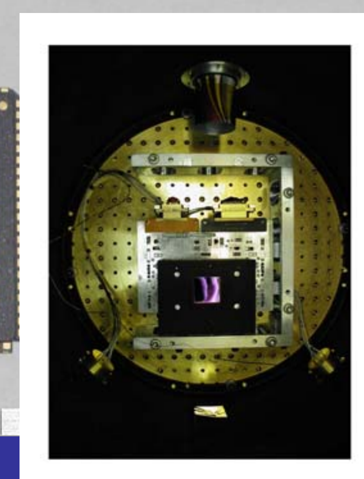
Laboratory demonstration mapping spectrometer



Large Format 2-D Infrared Array

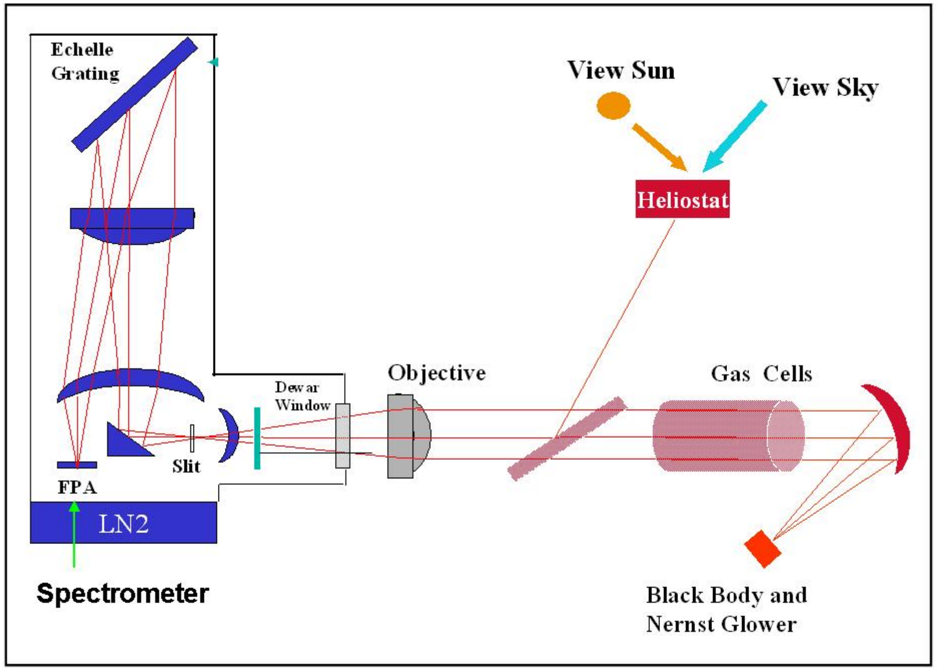


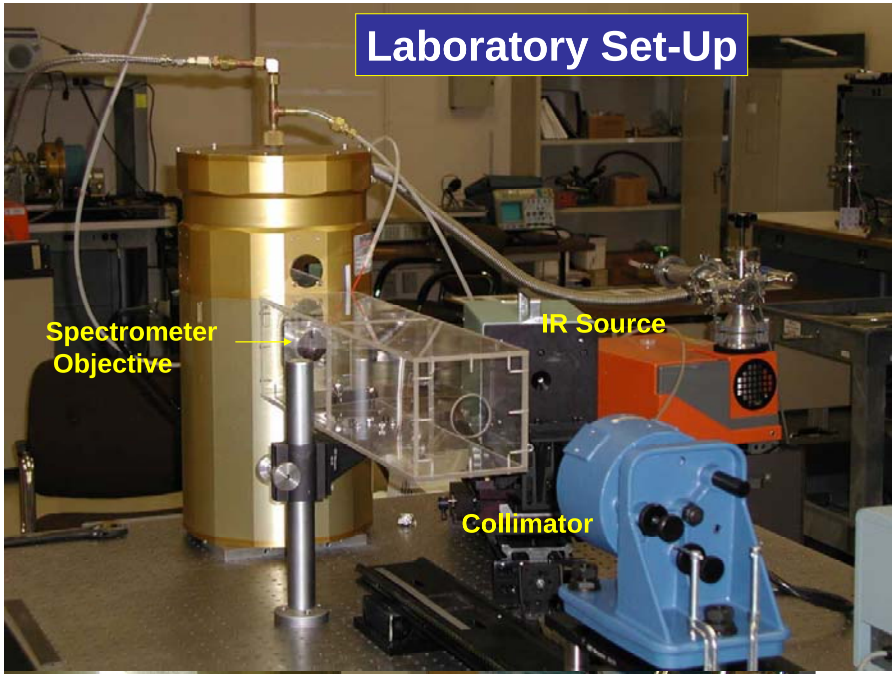
HAWAII 4-Quadrant Chip



Array at spectrometer focal plane on LN2-cooled base plate

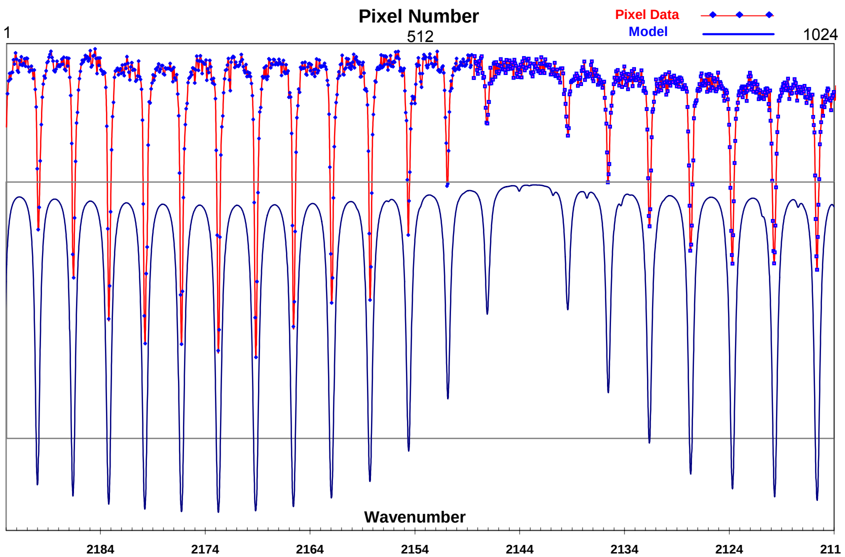
Lab Demo GMS test setup



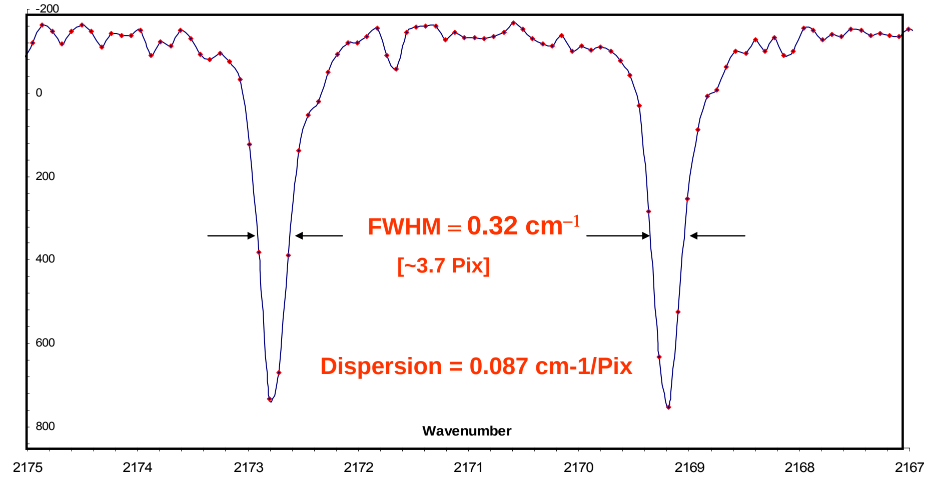


Lab Demo GMS performance, gas cell absorption & noise

Spectral Calibration Using CO Absorption Cell Data



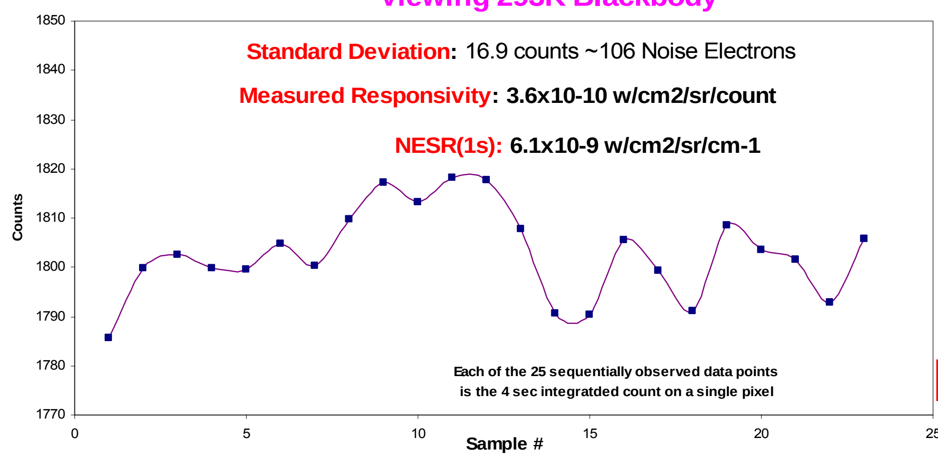
Assessing Spectral Line Shape Using CO absorption lines



Design Prediction: FWHM ~ 0.28 cm^{-1} for 60 μm Slit

Sensitivity Performance

Viewing 293K Blackbody



Extrapolated to
Flight design
for single pixel

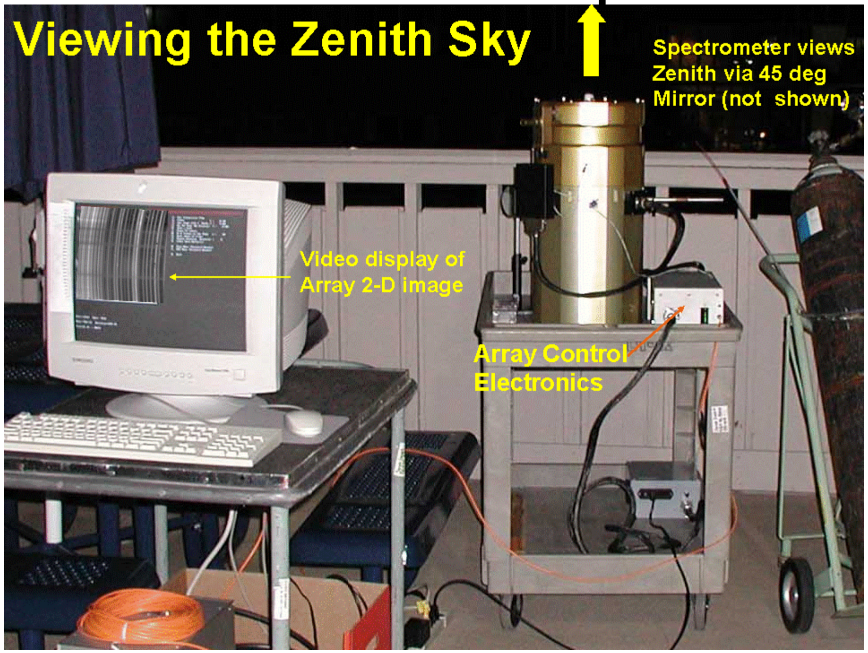
NESR 1.1x10-9

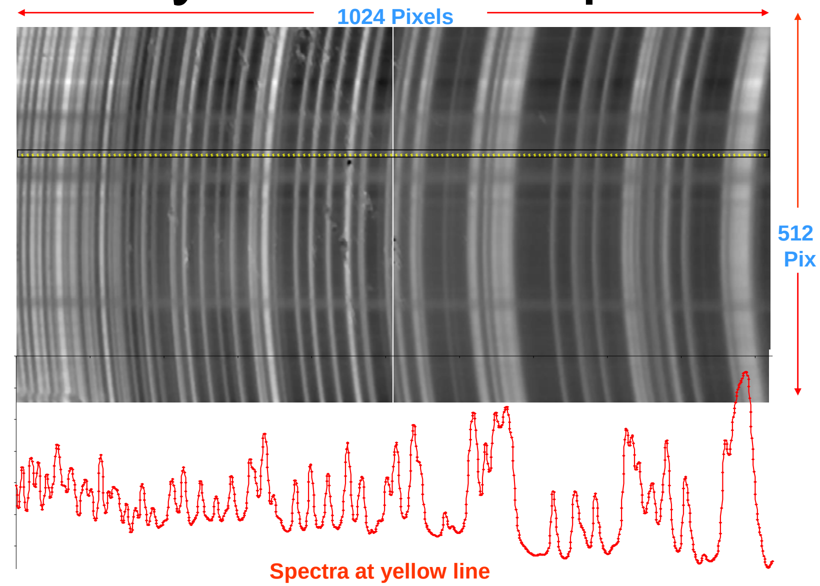
Extrapolated to
Flight design
for 36 pix aggregated
footrpintl

NESR 1.8x10-10

•This observed noise performance is consistence with our noise performance model
Therefore the model can be used with confidence to extrapolate to the SWIR conceptual flight design
The S/N estimates presented above on slides 3 to 7 are based on that extrapolation of these data

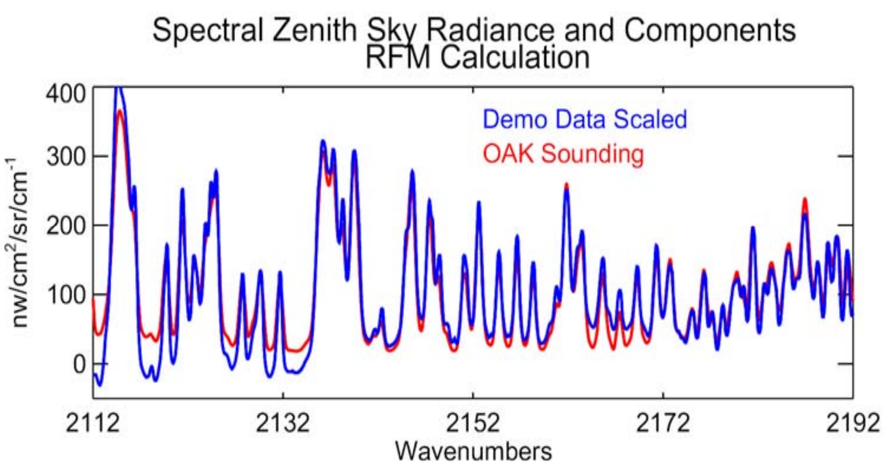
Lab Demo GMS performance sky emission spectra

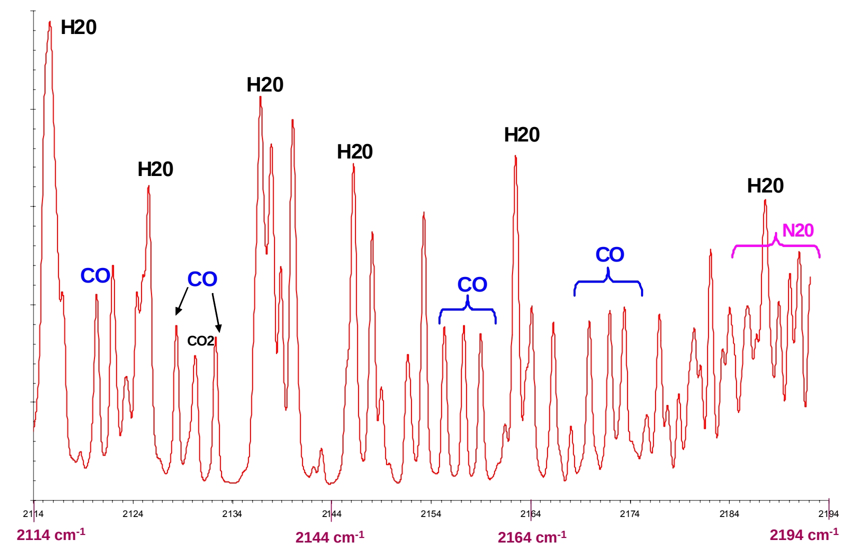




2-Quadrant Image of Zenith SKY IR Emission Spectra

A First-Order Fit to the Data



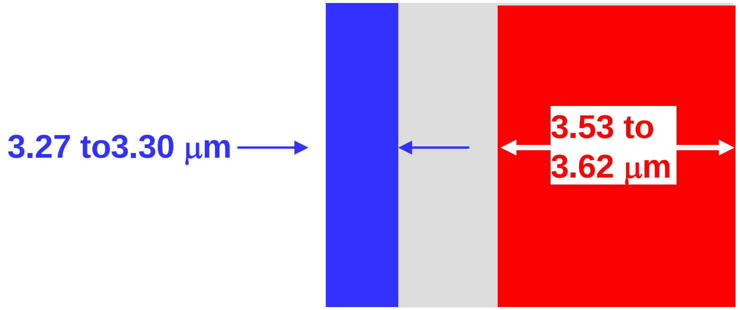


Identification of atmospheric emission spectral features in the lab demo measurement range from ~ 4.56 to 4.73 µm

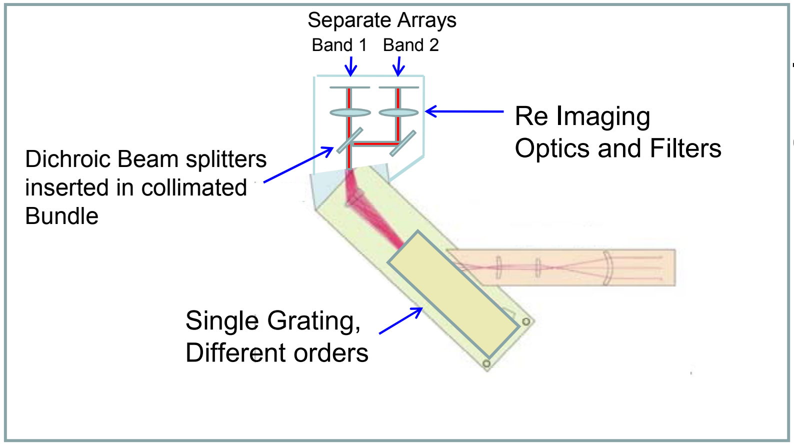
Concept for geo SWIR application using the Lab Demo

To achieve the measurements as discussed on slides 1 through 7 above the demo GMS would be used for the IR spectrometer component (slide 3)

- –It would have two slits for the 3.27 – 3.30, and the 3.53 to 3.62 μm regions, respectively
- –These would be
  - •in the orders 9 and 8, respectively of the demo grating (slide 8)
  - •directed to separated regions on the focal plane as shown schematically below
- –Separate order sorting filters for each would either be mounted on the respective slits, or on the focal plane, TBD

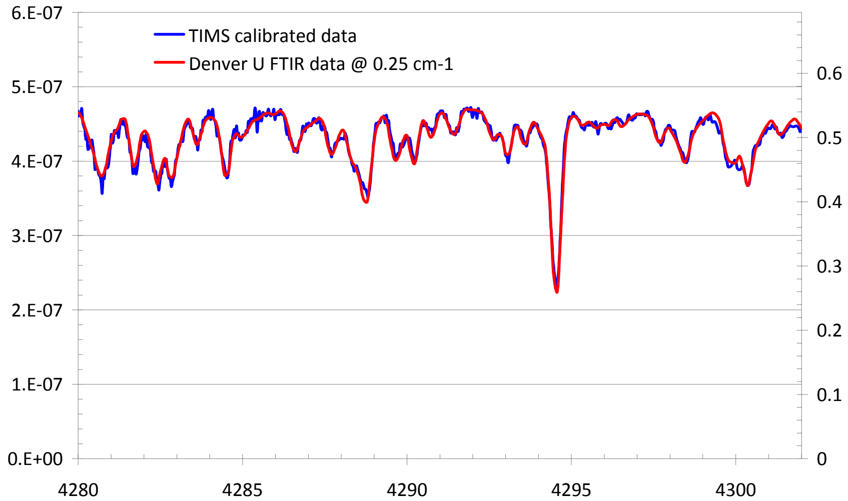


The IIP VSWIR design is an attractive option to the Lab Demo design



The IIP VSWIR design facilitates multiple channel measurements by utilizing
- a beam spilitter in the re-imaging arm
- Sorting different grating orders in each branch
- A detector array per branch

The IIP VSWIR design has been demonstrated:
- To the right, note the validation of calibrated VSWIR data against the Denver University FTIR data



Trade off advantages of the IIP design include
- Utilization of entire [both arrays], rather than just ½ of HAWAII 1rg, as does the Demo based design
- Spectral resolution improved by a factor two, improved spatial resolution
- Requires a factor two larger aperture, therefore S/N increases by a factor two

Trade off disadvantage of the IIP design
- Increased complexity and therefore cost

estimates for emissivity near 3.3 & 3.6 um (1 of 3)

AIRS Land Surface Temperature and Infrared Emissivity Validation

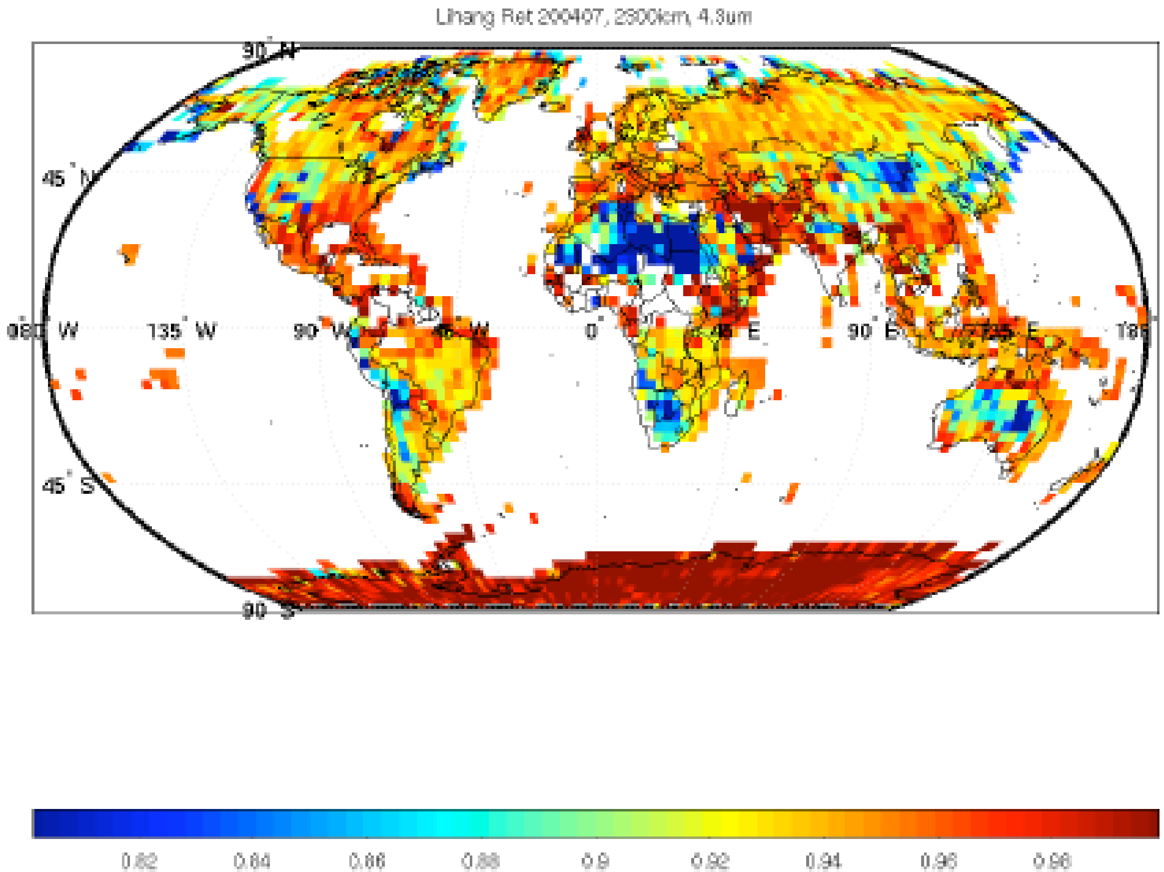
Bob Knuteson, Leslie Moy,
Hank Revercomb, Dave Tobin

University of Wisconsin-Madison
Space Science and Engineering Center (SSEC)
Cooperative Institute for Meteorological Satellite Studies

September 28, 2006
AIRS Science Team Meeting, Greenbelt, MD

Barnet Physical

4.34 μm (2300 cm^{-1})

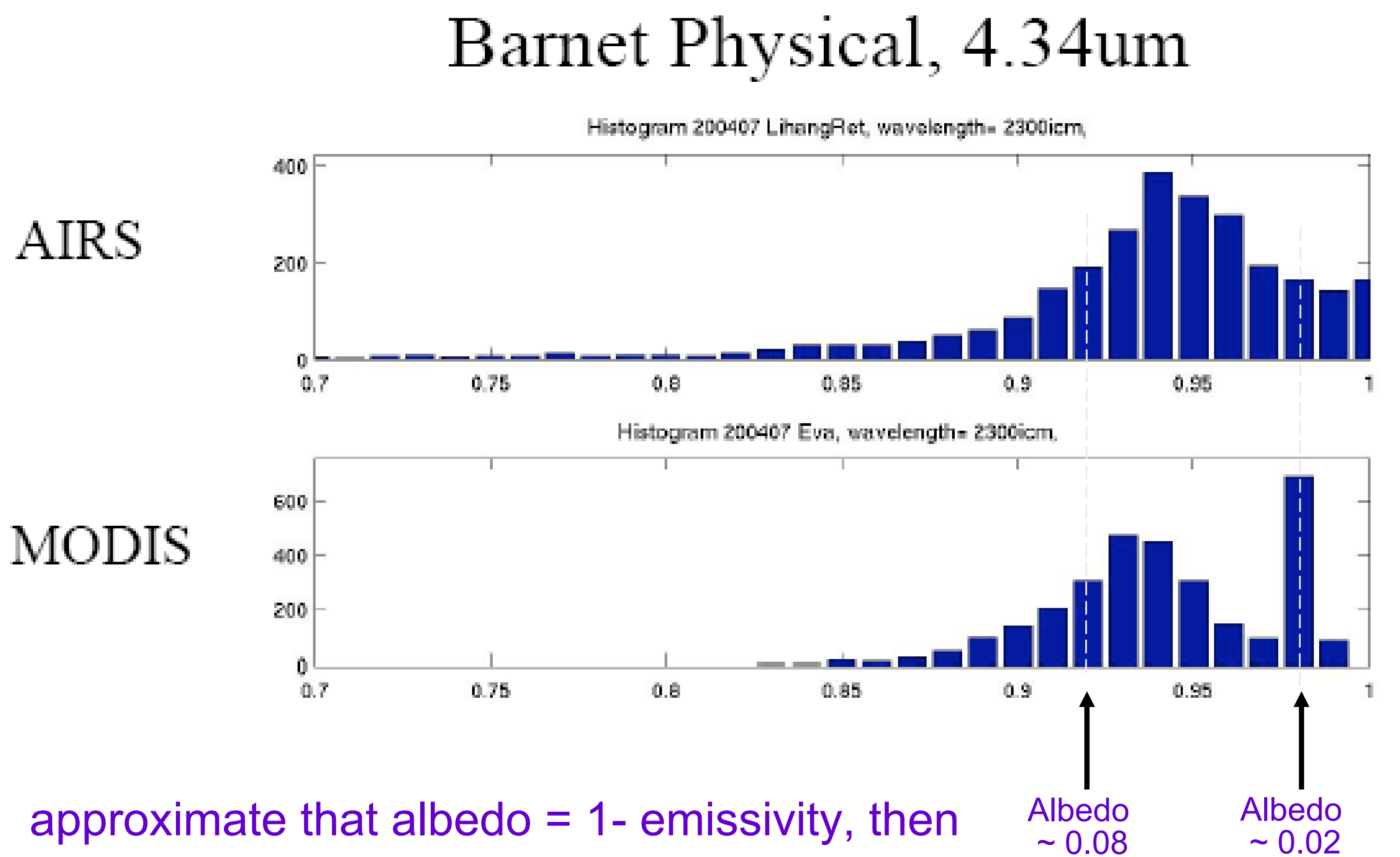


Albedo ~ 0.08

Albedo ~ 0.02

approximate that albedo = 1- emissivity, then

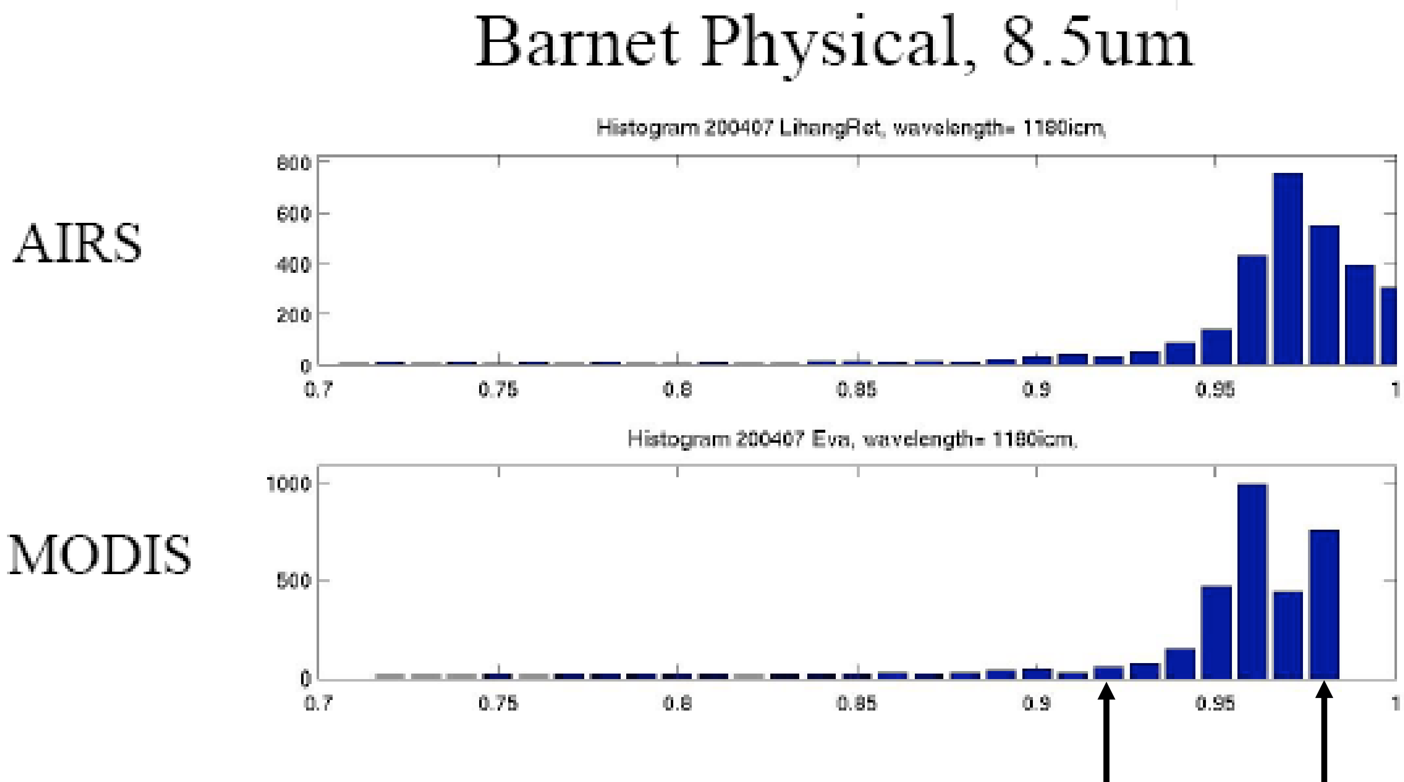
estimates for emissivity near 3.3 & 3.6 um (2 of 3)



approximate that albedo = 1- emissivity, then

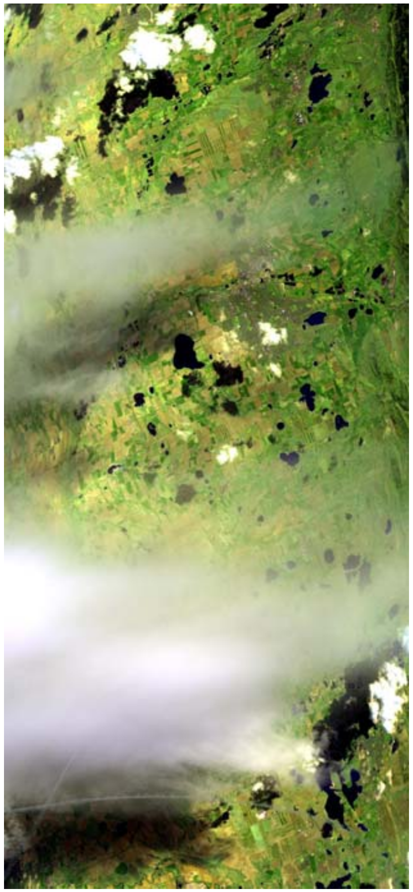
estimates for emissivity near 3.3 & 3.6 um (3 of 3)

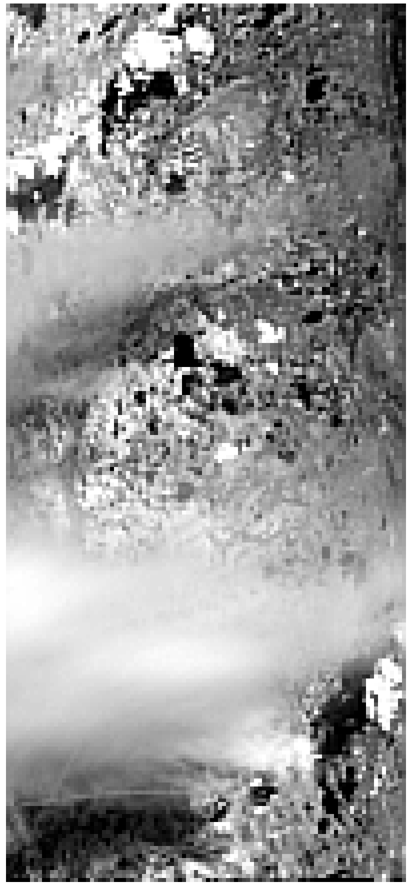
- illustrates trend to smaller albedos at larger wavelengths
- assuming this holds on going from 4.3 to 3.3 – 3.6 um, then the large majority of the albedo in the latter region will be > 0.02, and a significant fraction will be > 0.08



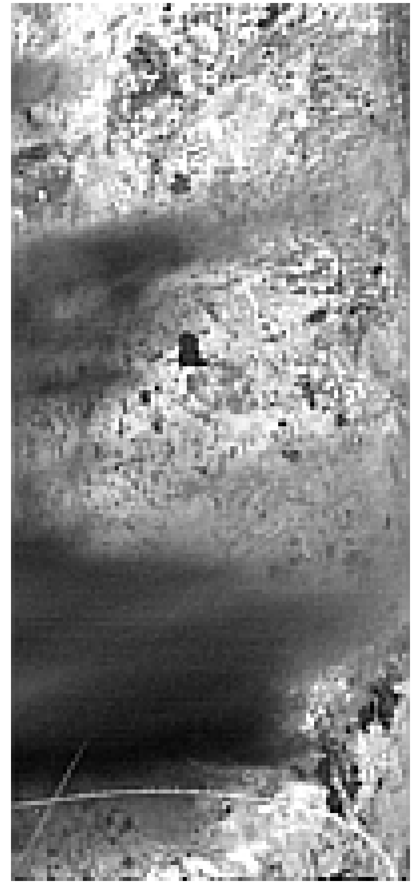
approximate that albedo = 1- emissivity, then

MAS images VIS, 2.10, 3.35 and 11.04 um

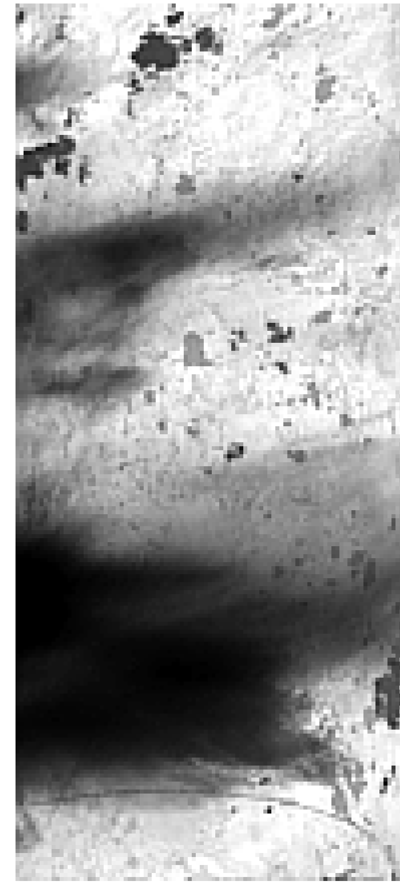




19 = 2.10 μm



29 = 3.35 μm



45 = 11.04 μm