Atmospheric Correction Using Hyperion

Progress and Issues

Investigation: Correlative Analysis of EO-1, Landsat, and Terra Data of the DOE ARM CART Sites: An Investigation of Instrument Performance and Atmospheric Correction

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- **Objectives**
  - **Primary goal of this investigation is to develop improved atmospheric correction codes through:**
    - **better separation of surface and atmospheric effects,**
    - **more accurate radiative transfer calculations**
    - **more complete treatment of gaseous opacity**
    - **rigorous modeling of aerosol and cloud extinction**
  - **Secondary goal is to provide an atmospheric correction code that will work with hyperspectal sensors that have variations in spectral response across the focal plane (i.e., Hyperion).**

- **Status**

  - **Had hoped to have a Beta version of the atmospheric correction algorithm available for distribution at this meeting … but we're not there yet**

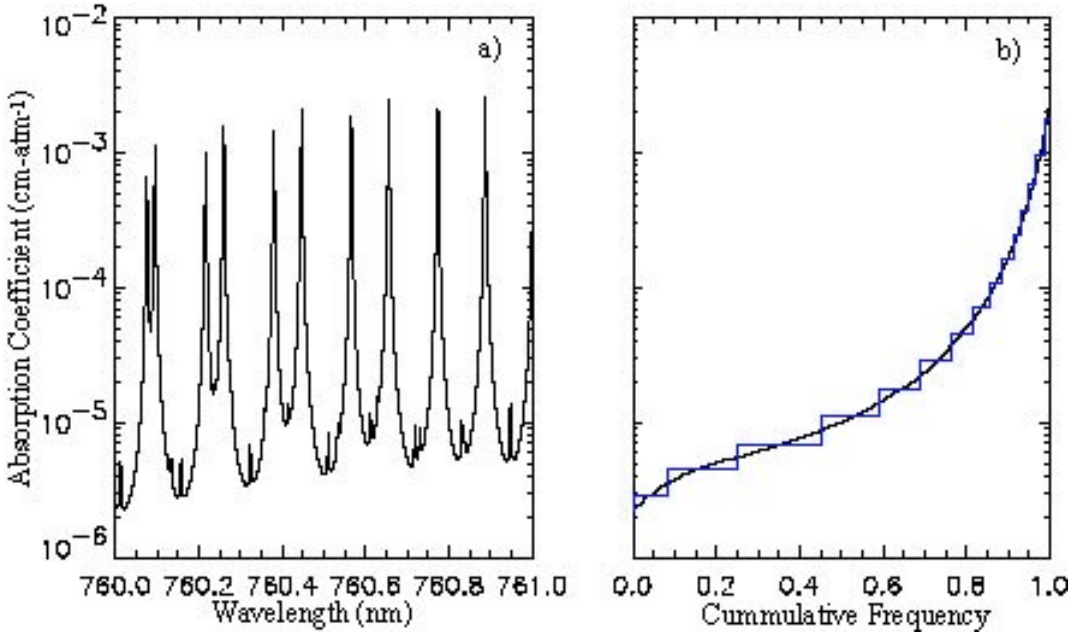
What we have been doing-

Build on existing atmospheric correction and in-house retrieval algorithms to incorporate the following improvements:

- **Absorption**
  - **modified correlated k-distribution for gaseous opacity**
  - **improved treatment of continuum absorption**

• Treatment of Absorption

- **Line absorption has rapid spectral variations and is treated using the correlated *k* distribution method with 1 nm bands for H_2O, O_2, CO_2, CH_4, CO, and NO**



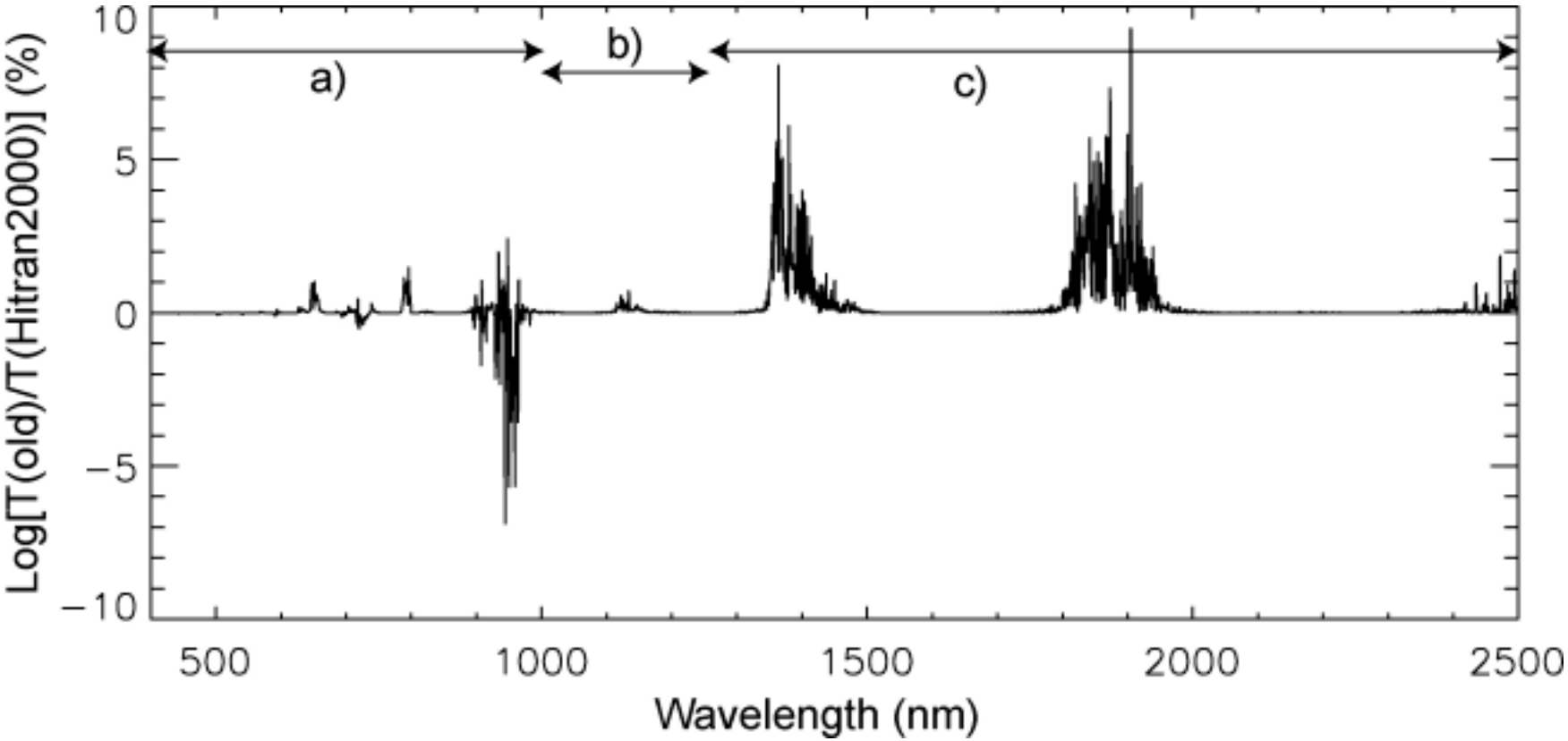
This figure shows the variation of the O_2 absorption coefficient as a function of wavelength between 760 and 761 nm in the A-band (left panel) and plotted as a cumulative histogram (right panel) with a set of *k* values based on 15 intervals.

Scattering

- by spherical and nonspherical particles
  - calculated on a coarse spectral grid and interpolated
  - minimize required number of quadrature points
  - speed and accuracy fixes:
    * doubling/adding - use extra point and separate treatment of single scattering
    * discrete ordinates - use Stamnes interpolation

Algorithm tested using data from the DOE ARM CART Sites

Absorption Issues



- Comparison between “old” and new k-distributions for water
- Originally we used a mixture of sources as described in the following slide for our “old” *k* distributions
- Have updated our k-distributions using Hitran2000 for entire spectral range.

Absorption Issues

- The three parts of the “old” line spectra are:
  - Belmiloud *et al*. (*GRL* 27, 3703-3706, 2000)

    new measurements find 720, 820, 940, and 1130 nm band intensities all too weak in HITRAN96-Corr (10, 15, 6, and 38%)

    http://www.badc.rl.ac.uk/data/esa-wv/
    Not adopted by HITRAN2000.
  - Unit conversion errors 460-1250 nm, fixed; Giver *et al*. (*JQRST* **66**, 101-105, 2000). Provided as hitran_96_jpl_ext_0_cor starting with LBLRTM 5.10 (also 5.20 and 5.21).

    Adopted by HITRAN96-Corr and HITRAN2000.
  - HITRAN 1996

Absorption Issues

- Changed in HITRAN 2000

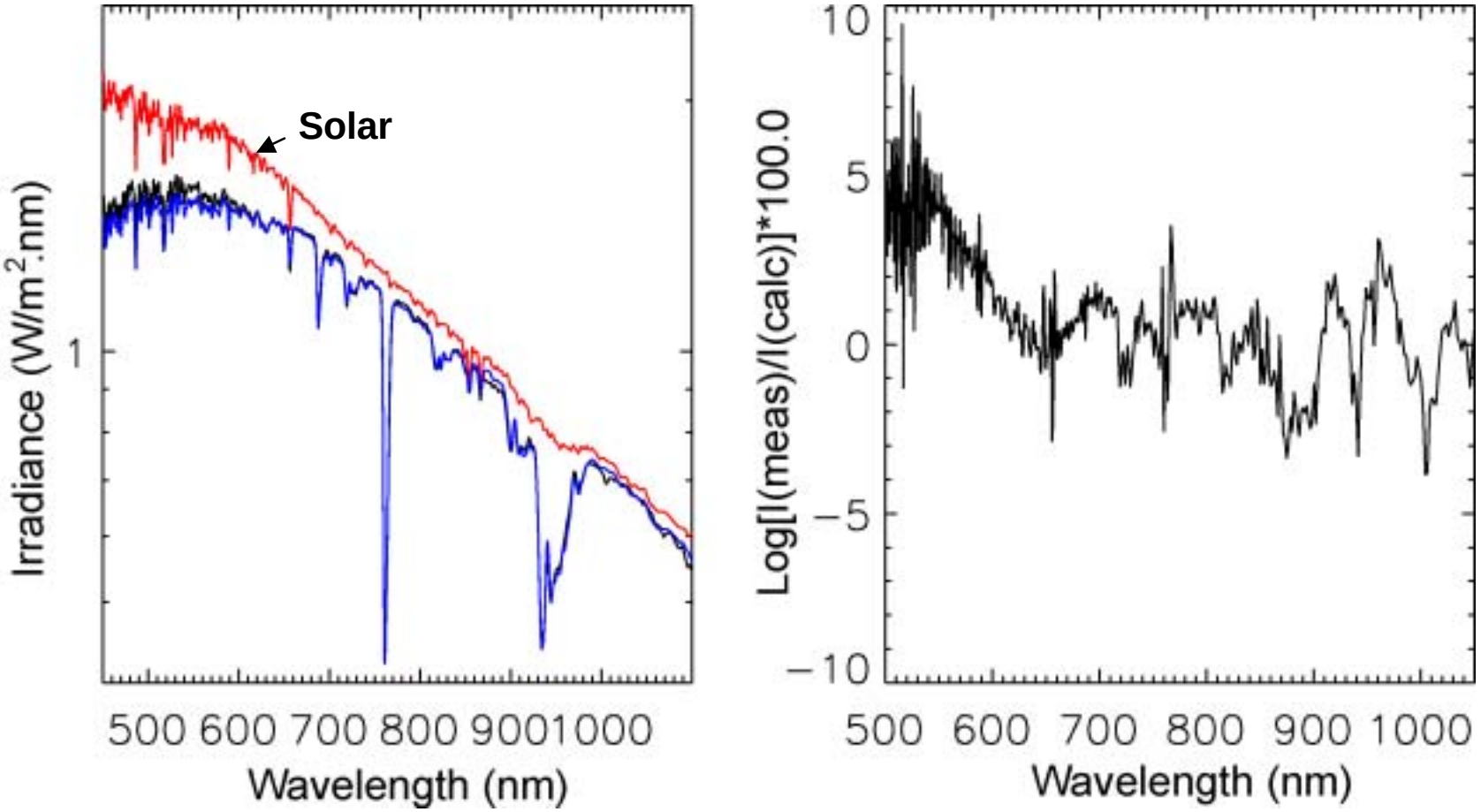
  Addition of Kitt Peak FTS measurements for the 940 nm band. Linda Brown *et al.* (J. Mol. Spec., submitted).

  Another absorber with many changes in number of lines is methane.

- To evaluate the accuracy of the calculation of gaseous absorption and separate instrument and model effects we evaluated the accuracy of the k-distribution calculations through comparison of Rotating Shadowband Spectroradiometer (RSS) data

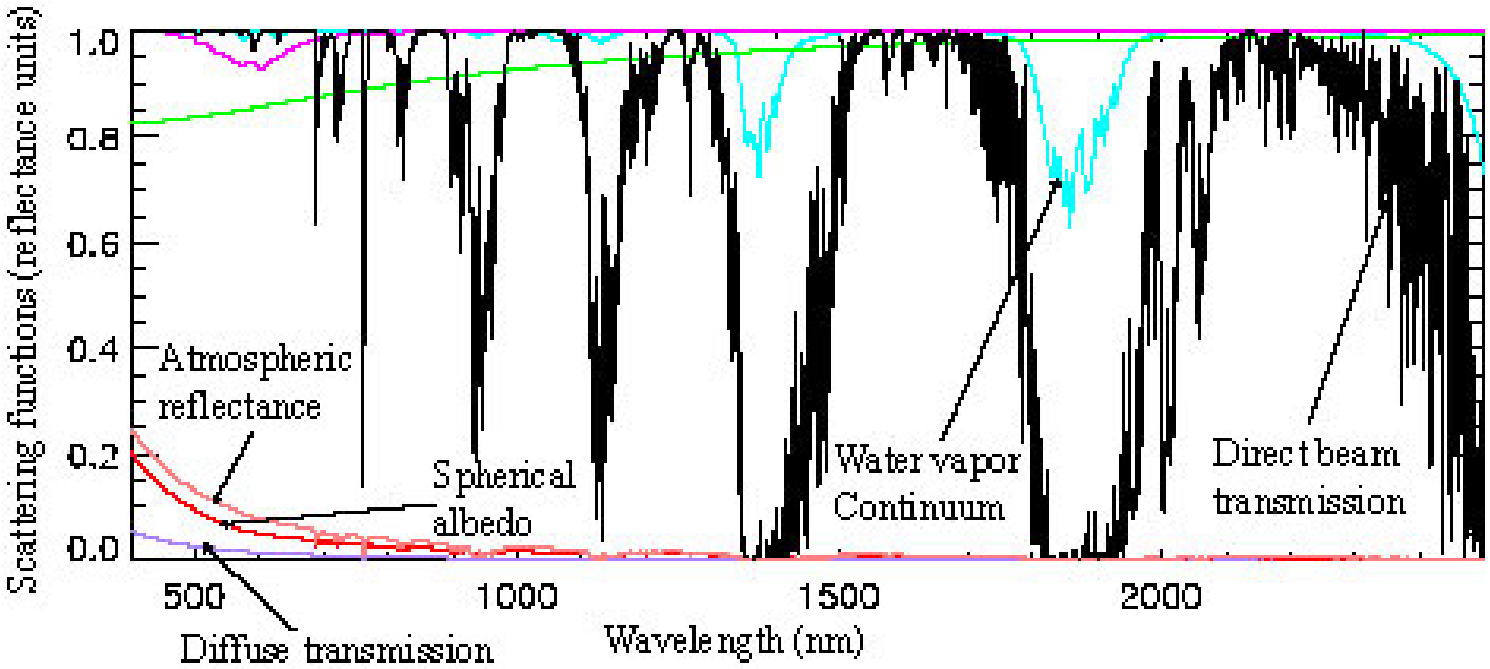
  The RSS has 1040 channels between 360 and 1020 nm spectral resolution varies from 0.2 nm (@360 nm) to 2 nm (@ 1020 nm).

Absorption Issues



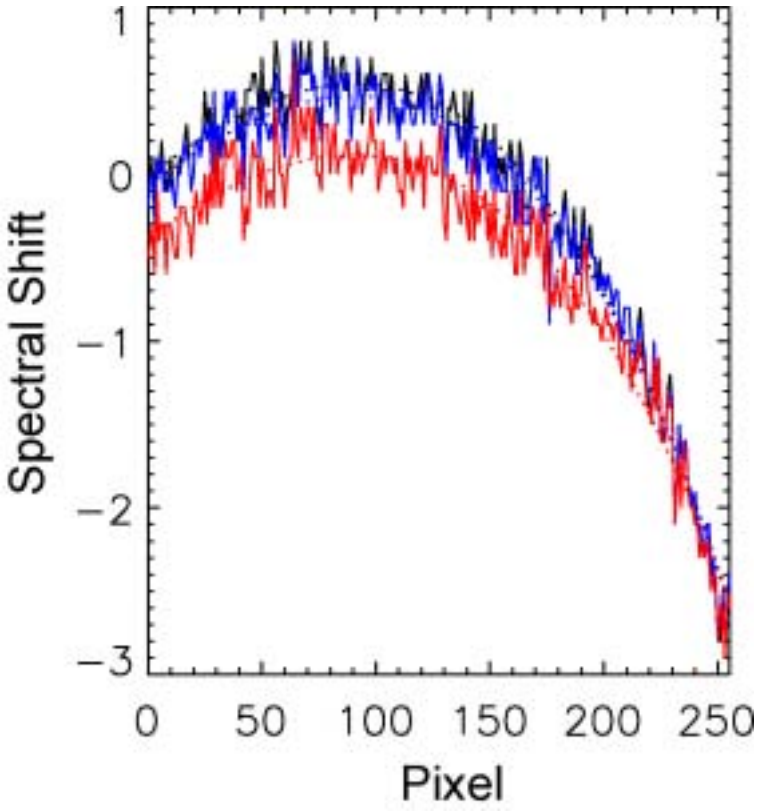
Comparison of RSS measurements and model calculations. Measured (black) and calculated (blue) spectra are shown above (left) along with the differences (right) shown as log[I(meas)/I(calc)]*100. Solar features still present in the difference - updating solar spectrum with new data from Judith Lean includes SUSIM data

⊙Other Issues



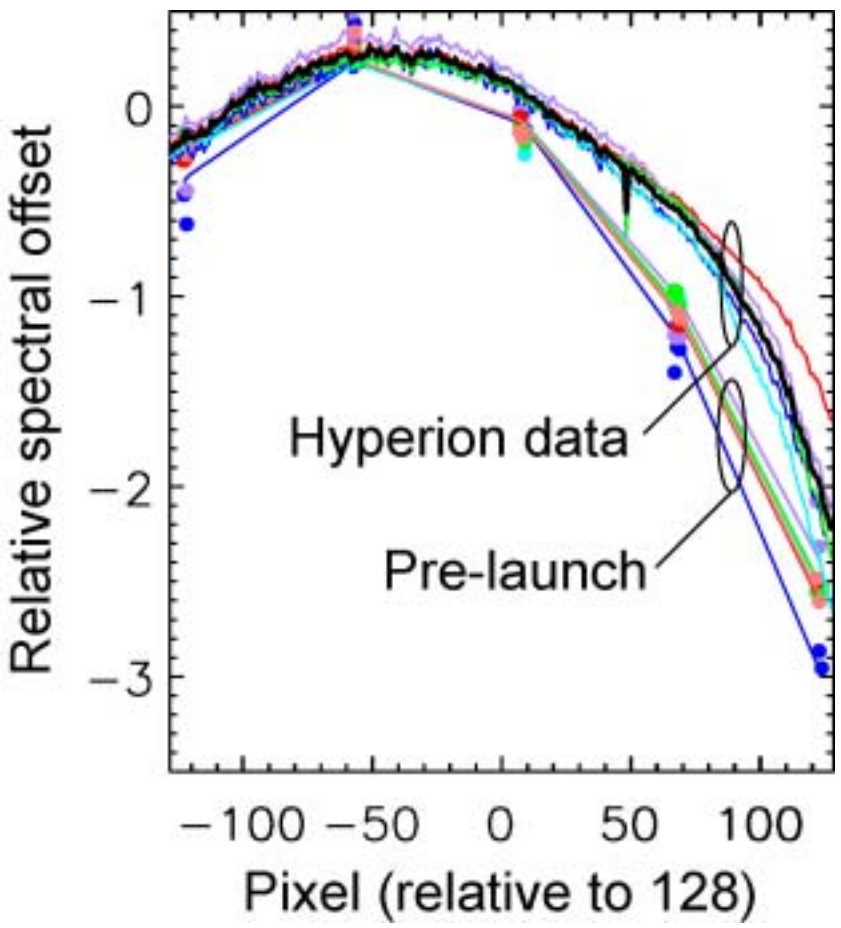
- **Typical output at 1 nm resolution before convolution with instrument response function**
- **The instrument response can introduce its own issues if the instrument focal plane is not adequately characterized.**

A-band analysis



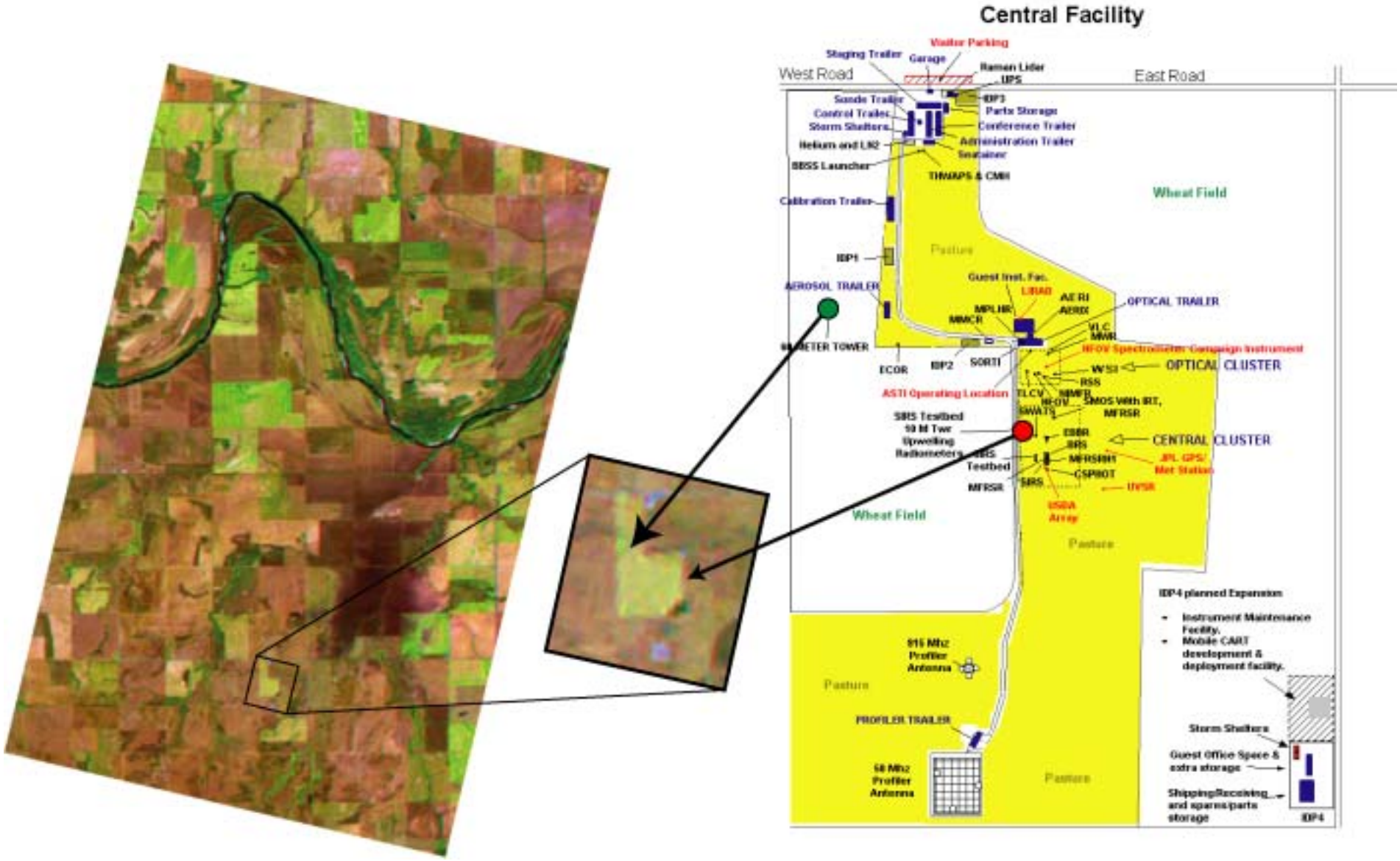
- This figure shows shifts estimated from a single line of data.
- The three lines corresponds to different assumptions about the spectral variation of surface albedo:
  - Linear in black
  - Quadratric (+ linear) in blue
  - Cubic (+ others) in red
- This indicates the effects of surface spectral variability, or errors in assumptions on the estimate of spectral location.
- The standard deviations of the spectral shifts from a smooth polynomial fit through the data are 0.165182, 0.15860, 0.176959 for linear, quadratic and cubic surface spectral albedoes.

A-band analysis

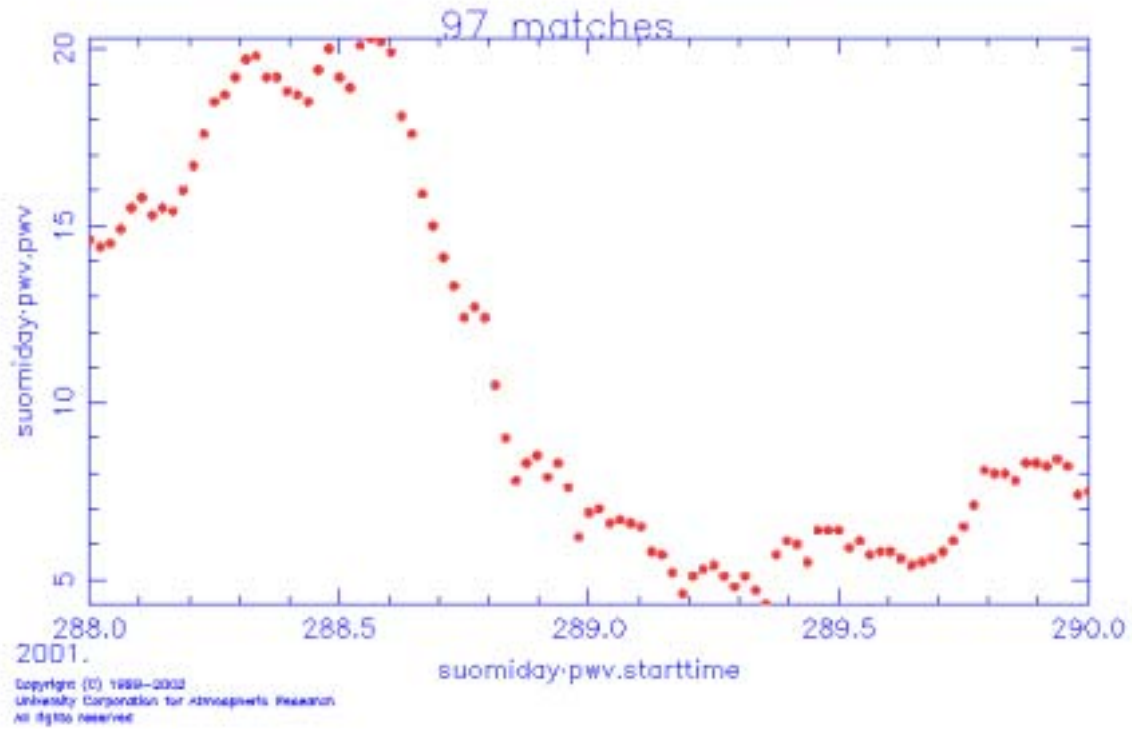


- **This figure shows shifts estimated using 400 lines of data from for GVWD (blue), Coleambally (mauve and turquoise), ARM SGP (green), Arizario (red) and mean (black).**
- **The pre-launch analyses are for a number of bands (11, 31, 39, 40, 48, and 49) across the spectral dimension of the VNIR focal plane shown as (blue, mauve, turquoise, green, red and orange) symbols with lines linking them.**

ARM SGP Central Facility

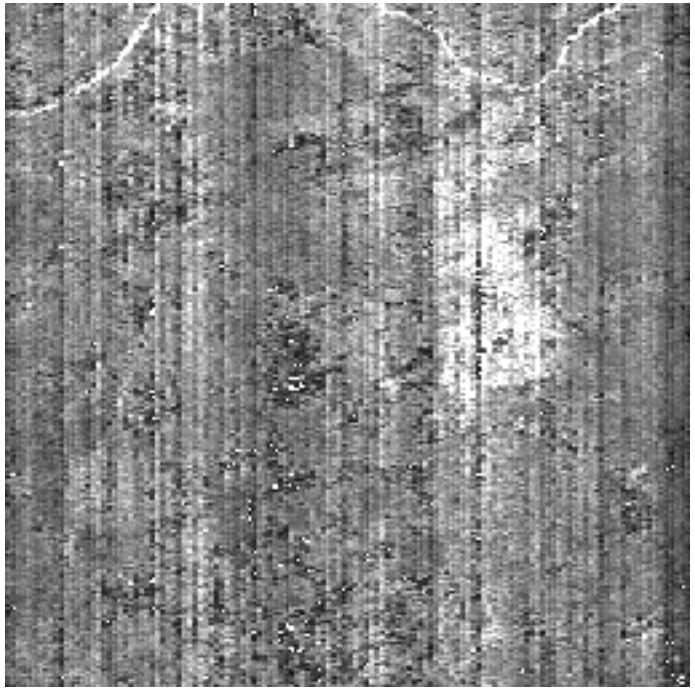


Using ARM SGP Central Facility Data



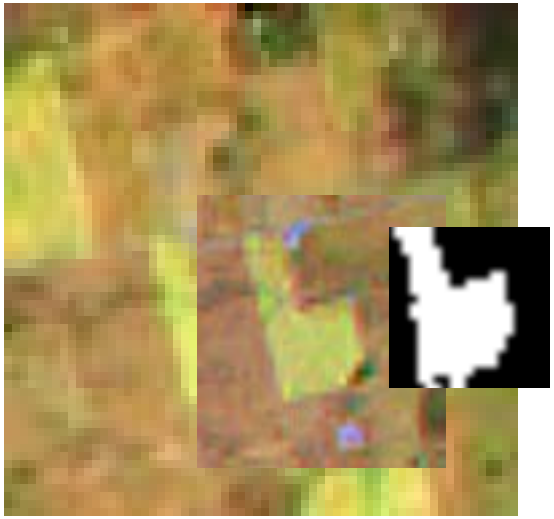
- **MWR was not functioning on the 16th October 2001.**
- **GPS water vapor column from SUOMINET suggest a water vapor column of between 0.5 and 0.9 precipitable cm with 0.6 cm at overpass time and increasing water vapor column.**

Using ARM SGP Central Facility Data



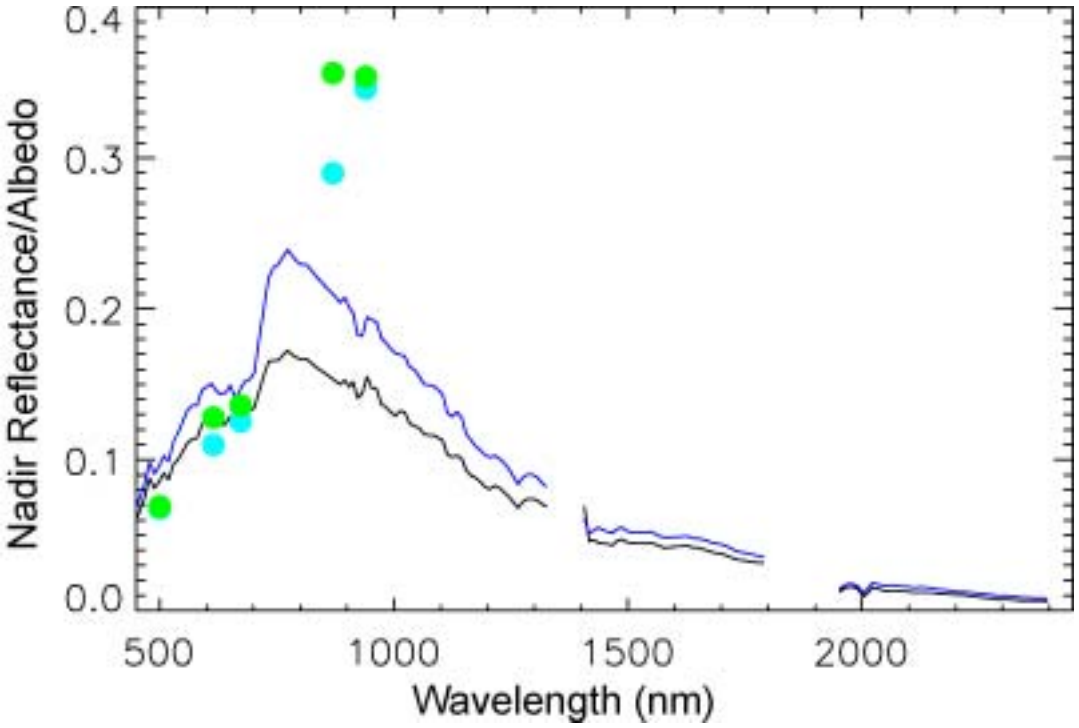
- **Water vapor (left) and false color (right) images.**
- **Mean water vapor is 0.763 cm with a standard deviation of 0.072 cm. Obvious problem over dark surfaces (e.g., water). Unresolved calibration issues produce striping in water vapor retrieval.**

Using ARM SGP Central Facility Data



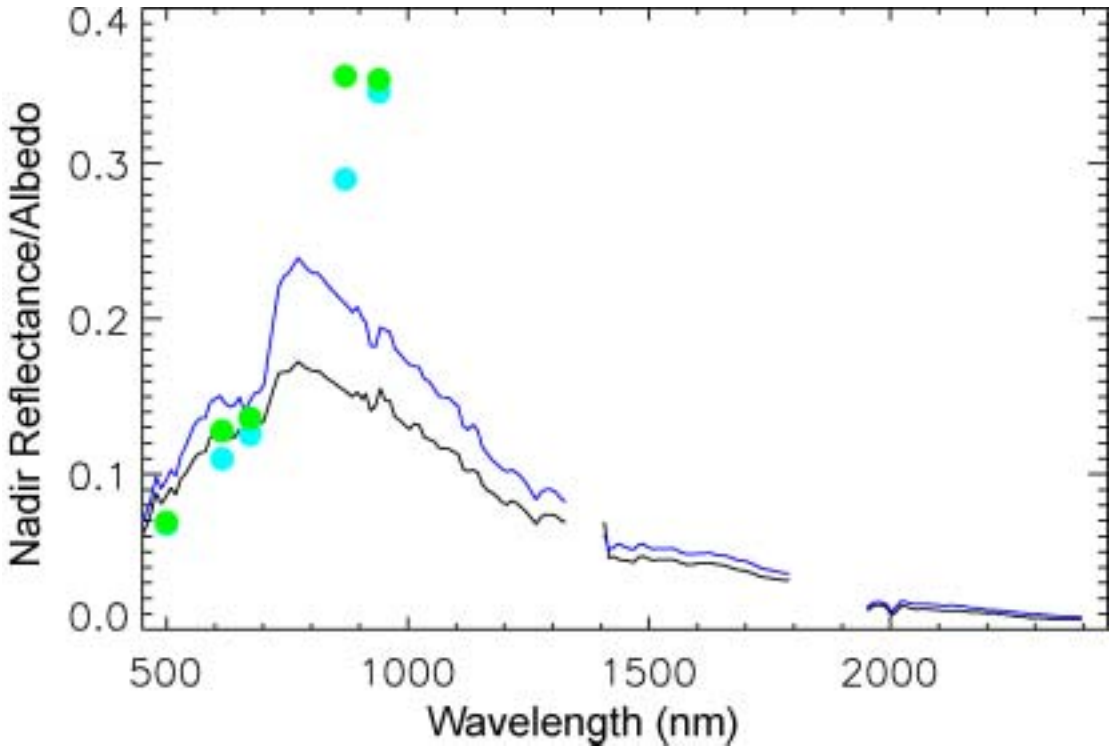
- To compare the tower albedo observations, that use downlooking MFRSR heads, we did a cluster analysis of the area around the towers and then averaged cluster members together to improve SNR.
- We used a 20x20 pixel area around the CF shown in the cluster skeleton above.

Using ARM SGP Central Facility Data



- The symbols are albedo measurements made at the 10 m (blue) and 25 m (green) tower at the time of the satellite overpass. These measurements use diffuser heads with reasonably Lambertian responsivity.
- Lines are the averages of the atmospherically corrected spectra based on a cluster classification.
- There is reasonable agreement in the 500-680 nm range, but very poor agreement for the measurements at 865 and 940 nm. Given that the aerosol optical depth on this day was approximately 0.04 at 865 nm it is not possible to correct for this difference based on the atmosphere.
- Perhaps the grass is greener on the other side of the fence. We have seen “dark” spots near backscatter in this spectral region and the reflectance of the vegetation may be less near nadir.

Using ARM SGP Central Facility Data



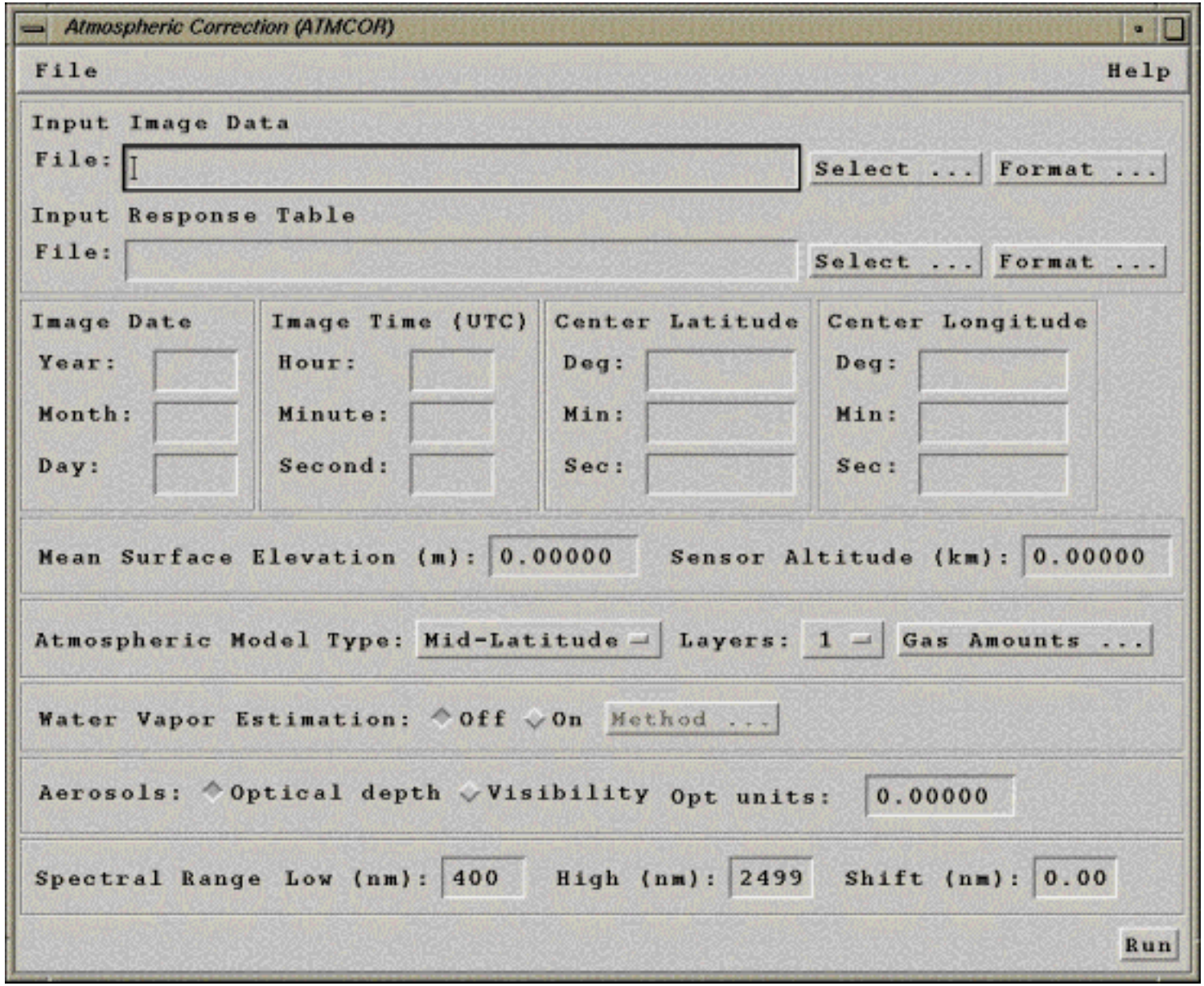
- Spectra (left) look qualitatively correct for scene. Mixture vegetation and soil shown above.

- Will be able to better model the surface using BRDF data from MISR that are currently being processed.
- There are still residual issues with the CO_2 band at 1950 nm which are not obvious for this surface on this scale but may be calibration.
- There is also an issue with the correction of O_2 in the SWIR at around 1270 nm which cannot be reconciled with the VNIR oxygen bands.

Wrapping up loose ends

- **Calculation of absorption**
  - Investigate the source of the spectral differences that we have found
  - Document possible calibration issues
  - Verify overlap assumptions
- **Atmospheric Correction Code**
  - Complete implementation of modifications
  - Complete testing of GUI
  - Optimize code

Graphical User Interface for Atmospheric Correction Code

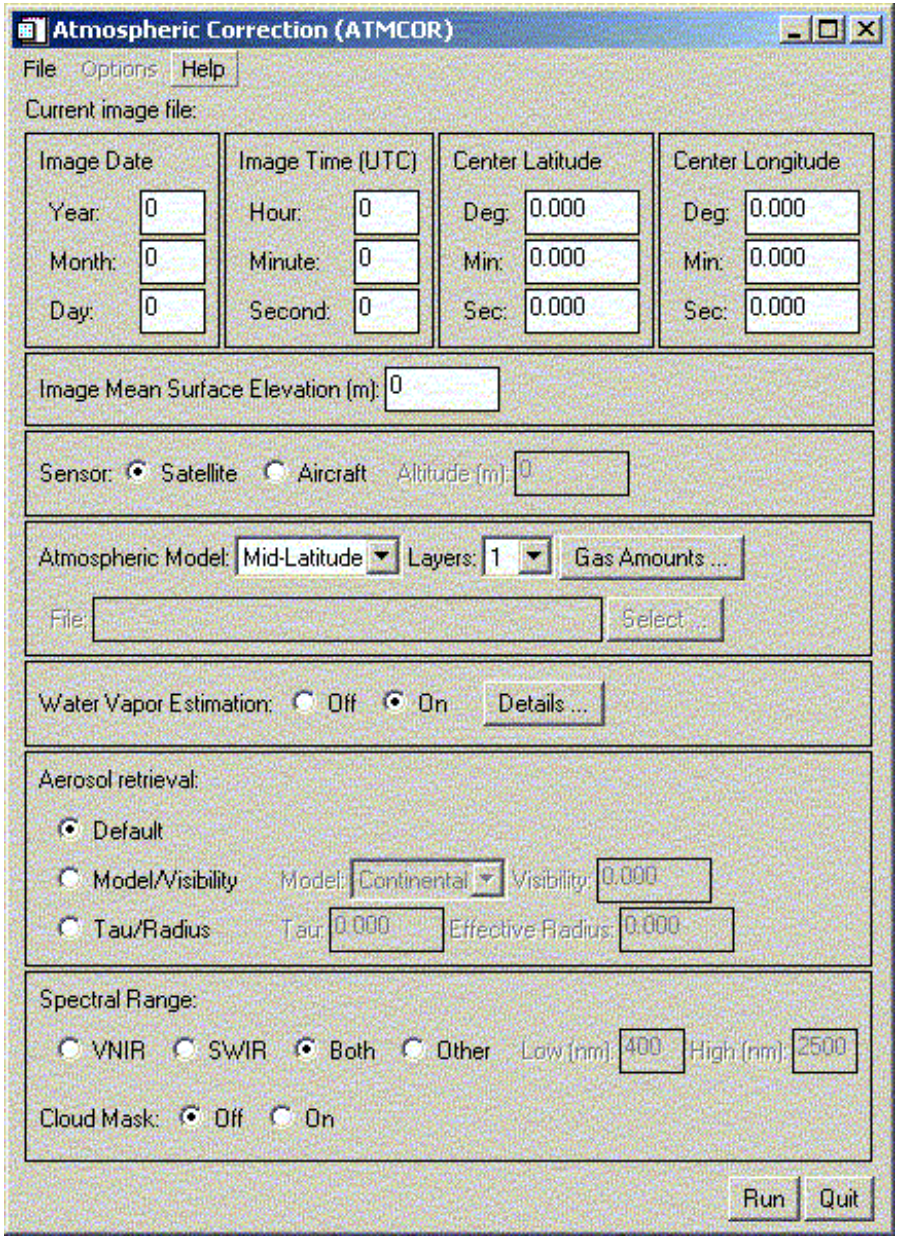


Old version

Works…

but wanted more features

Graphical User Interface for Atmospheric Correction Code

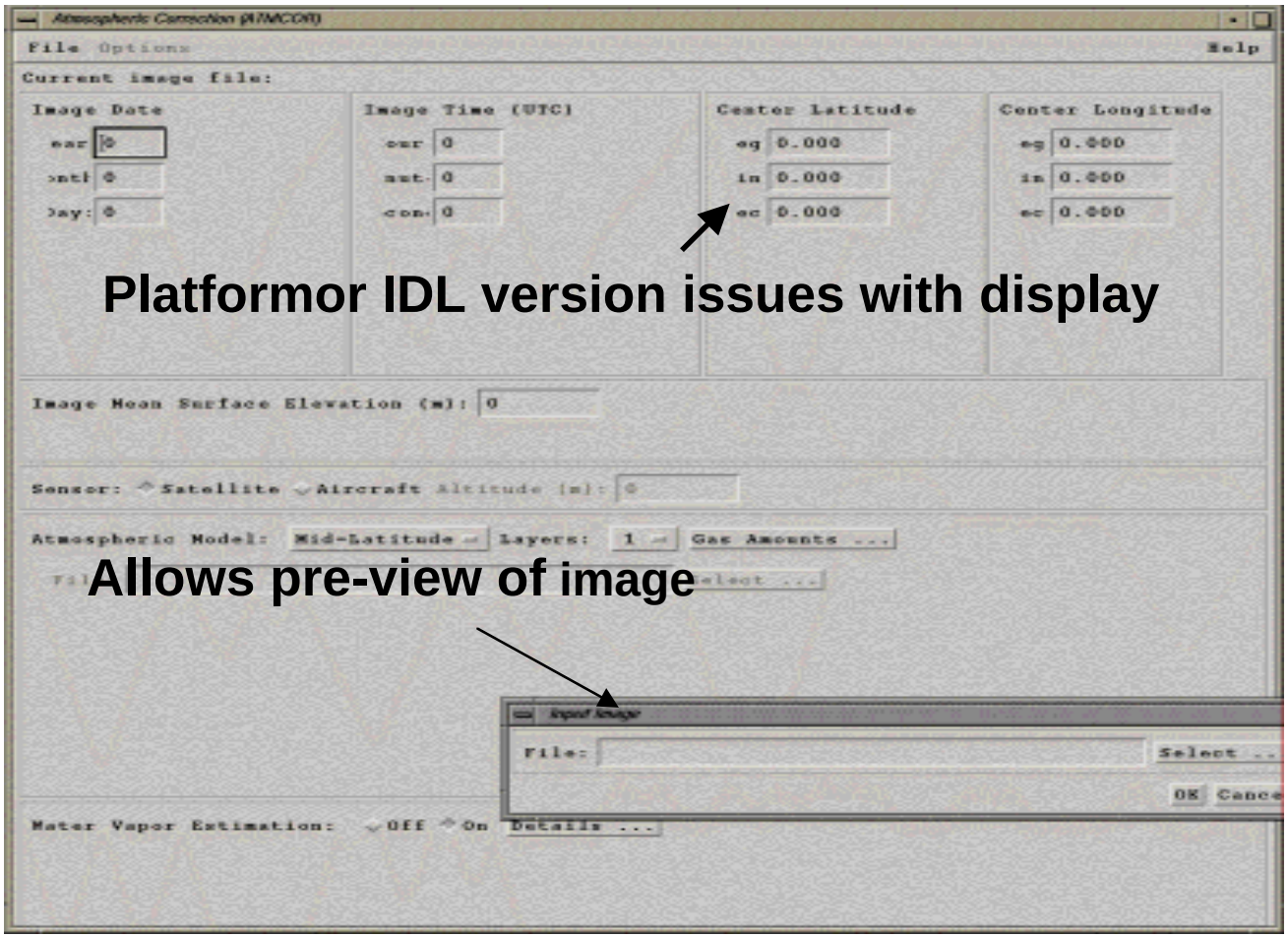


How it is looks now but...

Graphical User Interface for Atmospheric Correction Code

not on every machine

- need to resolve these issues before distribution



Atmospheric Correction Code

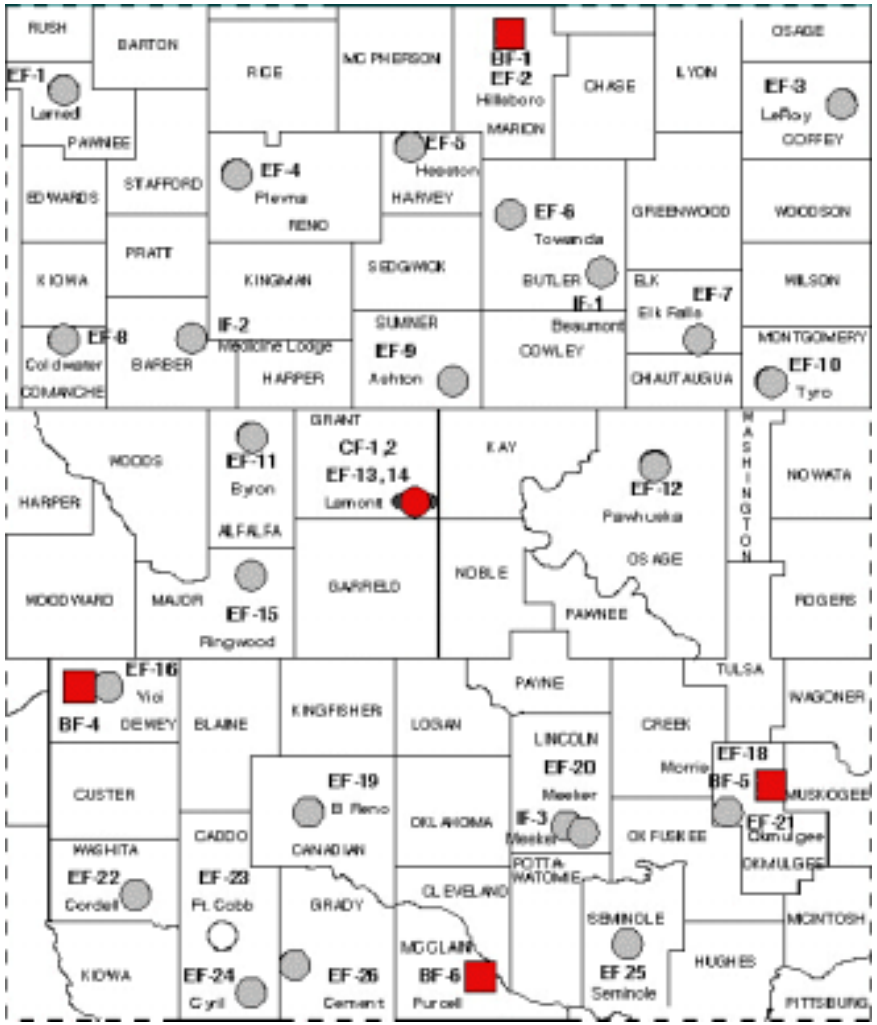
Adding features:

- **Preview Image**
  - **With cursor select region of image to correct**
- **Greater flexibility**
  - **Increased user ability to alter model settings**
- **Cloud Clearing**
  - **Flag cloudy pixels, create cloud mask, display cloud mask**
- **Added Data**
  - **Incorporating HITRAN 2000**
  - **New solar spectrum**
  - **Model uses TOMS ozone as default column ozone**
  - **More built in profiles**
- **Display results**
  - **Originally going to output result to file, adding options to display corrected image or spectrum**

Wrapping up loose ends

- **Have focused on atmospheric part**
  - **Look at BRDF to complete surface part**
- **Have focused on correcting Hyperion data**
- **Proposed to use Hyperion to correct ALI**
  - **Complete error analysis for Hyperion-based correction of ALI due to FOV variability using extended facility and MODIS data.**

Distribution of the ARM Extended Facility Sites



US DOE ARM CART site at the SGP Site
- Occupies approximately 55,000 square miles (3º x 4º) in northern Oklahoma and southern Kansas

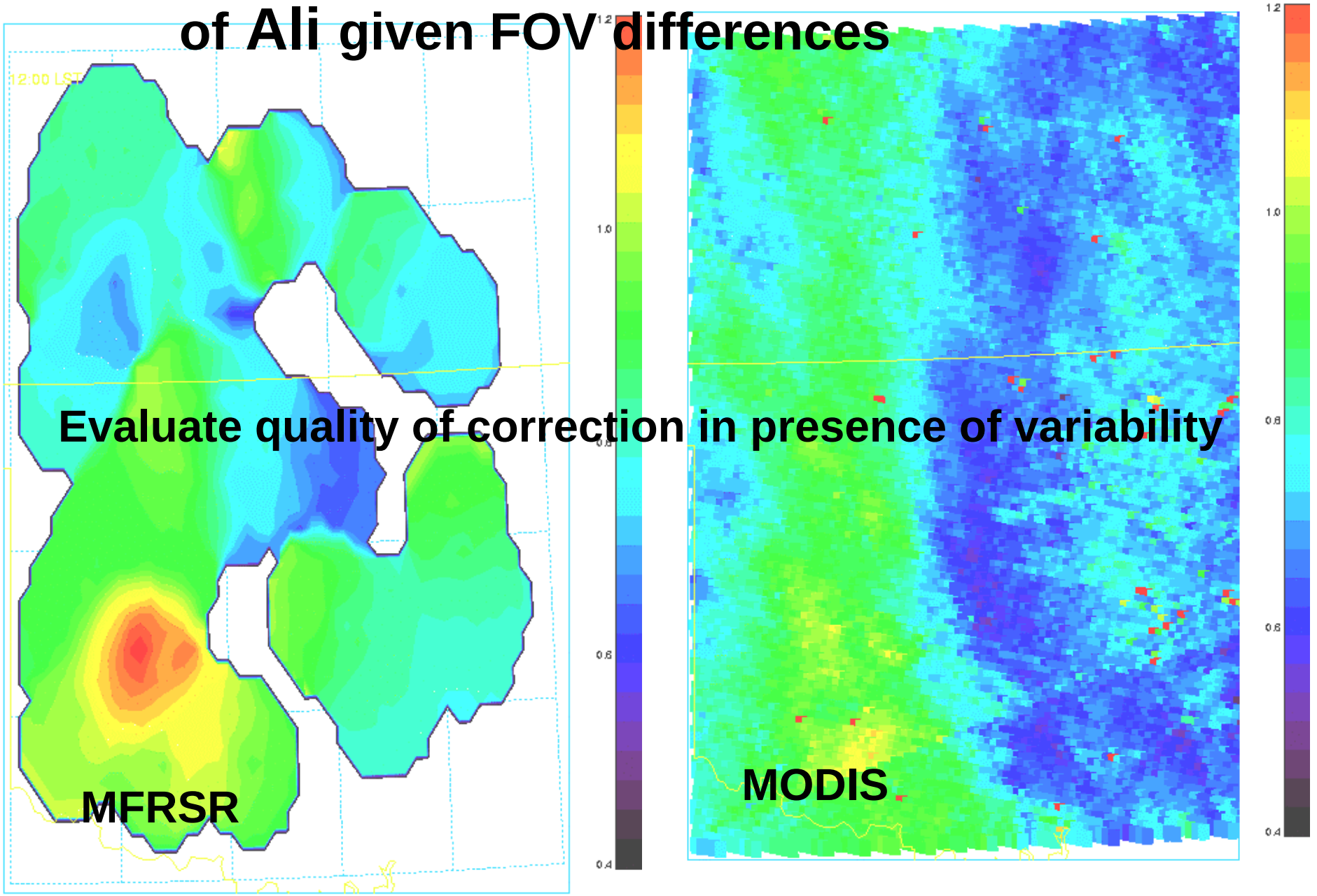
MFRSR network consists of 21 Extended Facility Instruments

Individual MFRSR data are processed to retrieve aerosol properties, H_2O, O_3 and NO_2 column amounts

In constructing the 2D image:
- Couple the instantaneous retrievals with the values transported from surrounding locations (future and past)
- Use ground-level winds for transport

Using this approach we can enhance the spatial coverage

Evaluate quality of Hyperion-based correction of Ali given FOV differences



Evaluate quality of correction in presence of variability