PCA and surface emissivities

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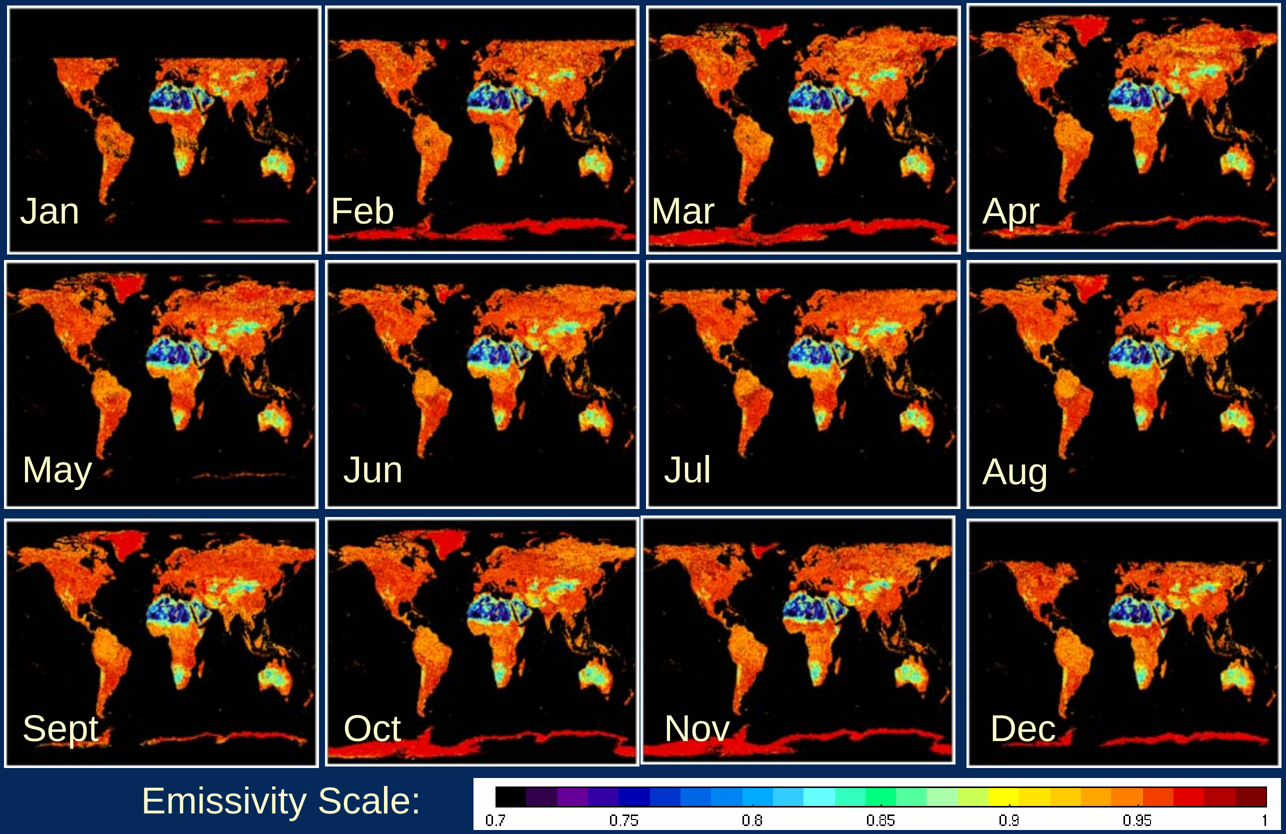
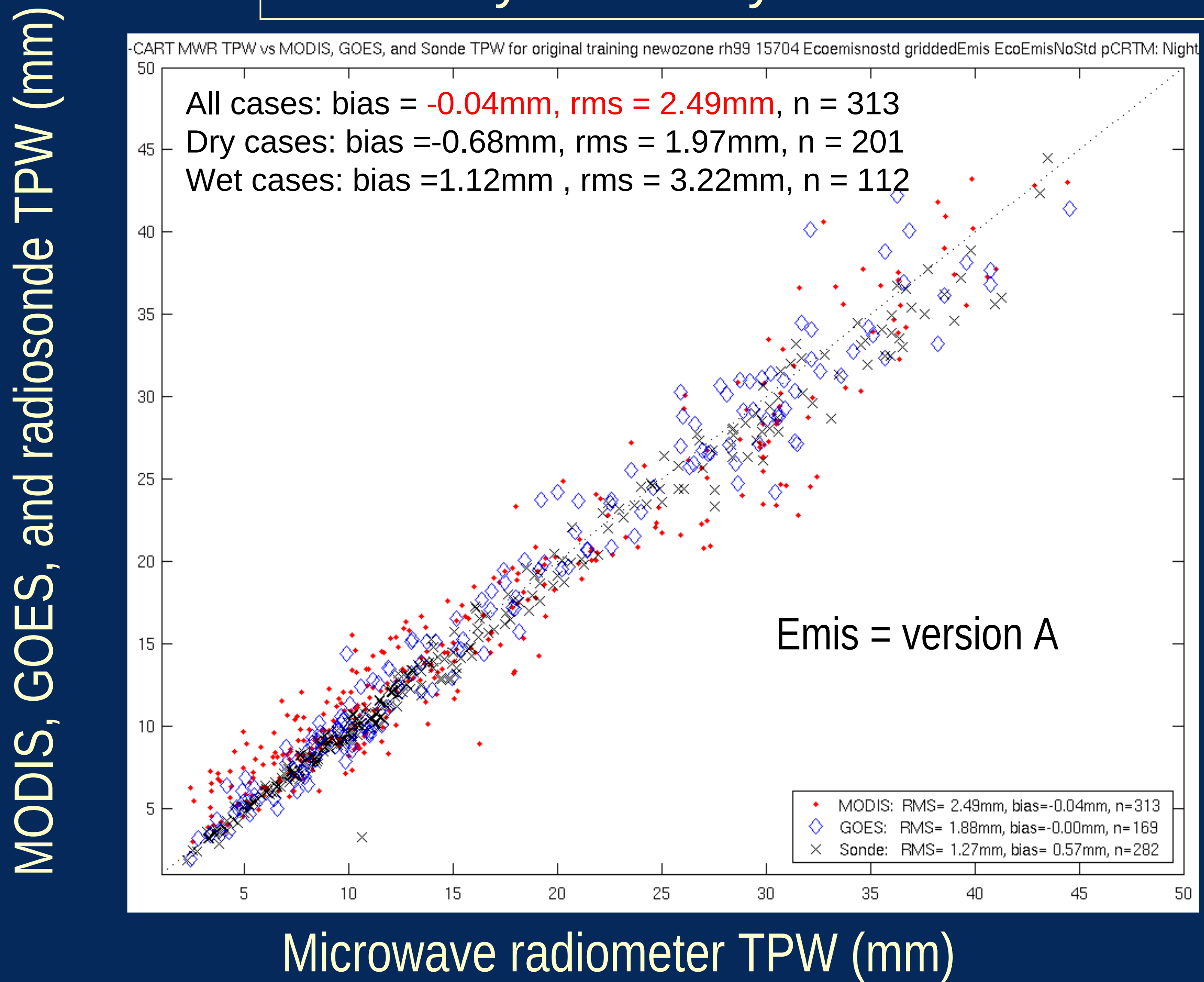
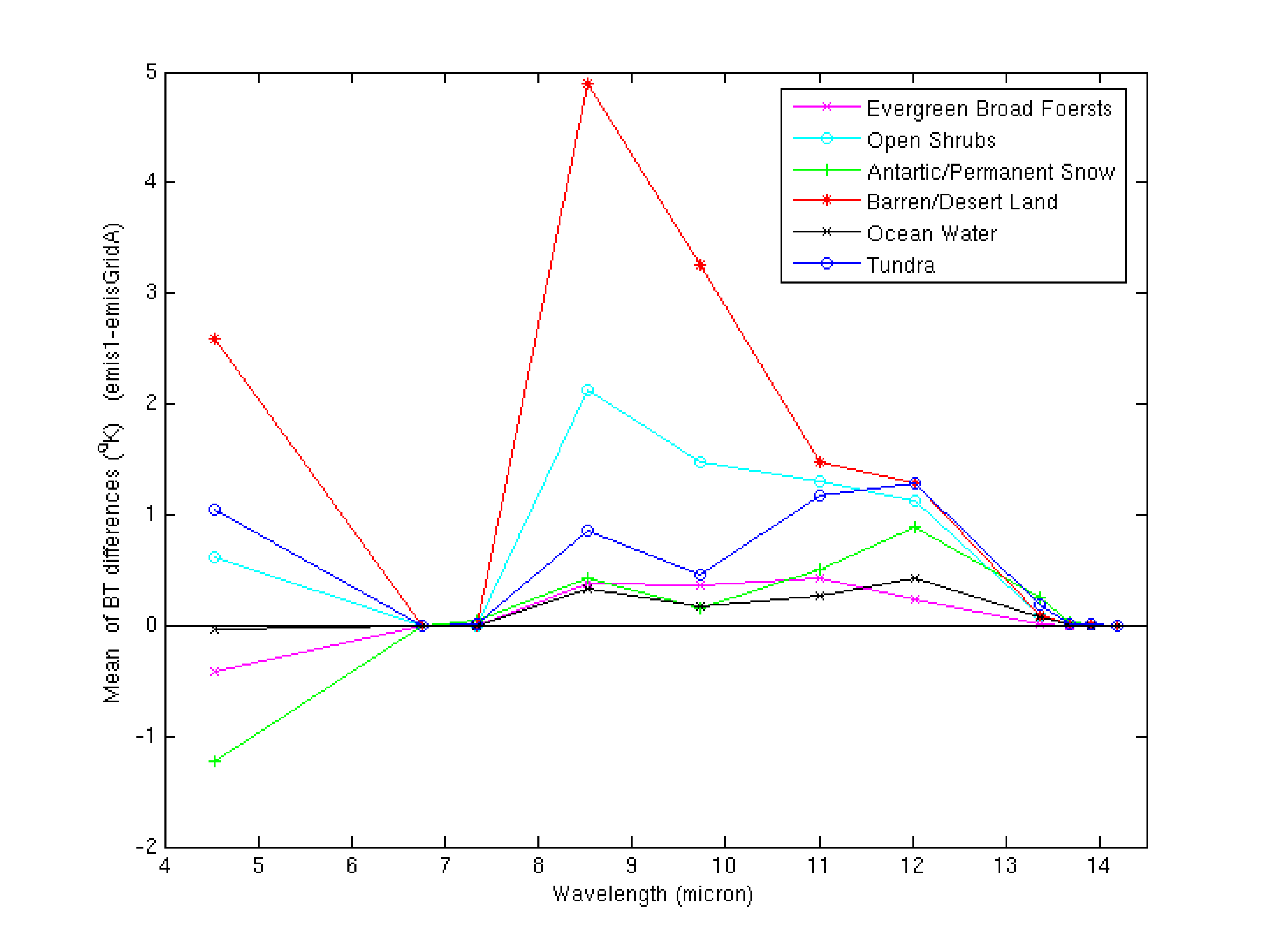


Applications
Emissivity sensitivity test on MOD07 TPW products



Comparison of total precipitable water (mm) at the ARM SGP site from Terra MODIS (red), GOES-8 and -12 (blue), and radiosonde (black), with the ground-based ARM SGP microwave radiometer for 314 clear sky cases from 4/2001 to 8/2005.

Average BT differences over all training profiles by ecosystem for all IR MODIS bands with wavelength greater than 4.3 μm



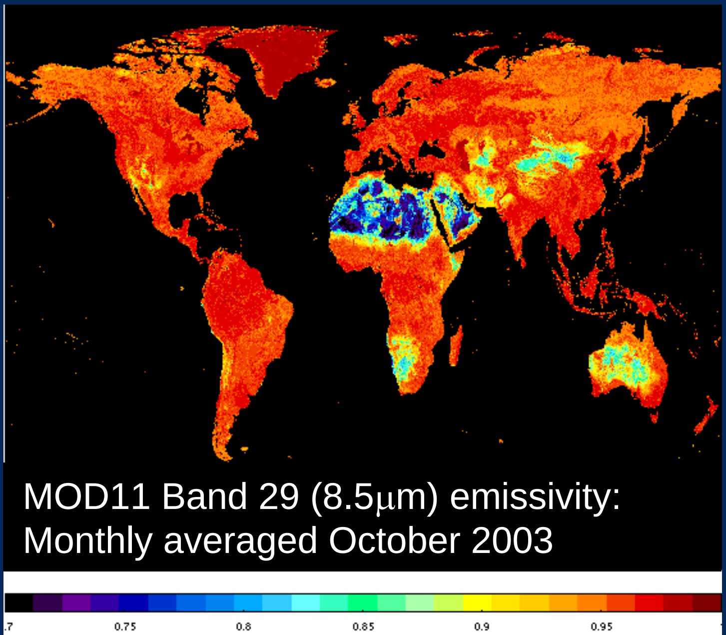
We need:

A gridded, global surface emissivity database at high spectral and high spatial resolution

We have:

- MODIS MOD11 emissivity, but only at 6 wavelengths (only 4 distinct wavelength regions): 3.7, 3.9, 4.0, 8.5, 11, 12 μm

- Laboratory measurements (UCSB, Dr. Wan, MODIS land team) of emissivity at high spectral resolution, but not necessarily representative of the emissivity of global ecosystems as viewed from space



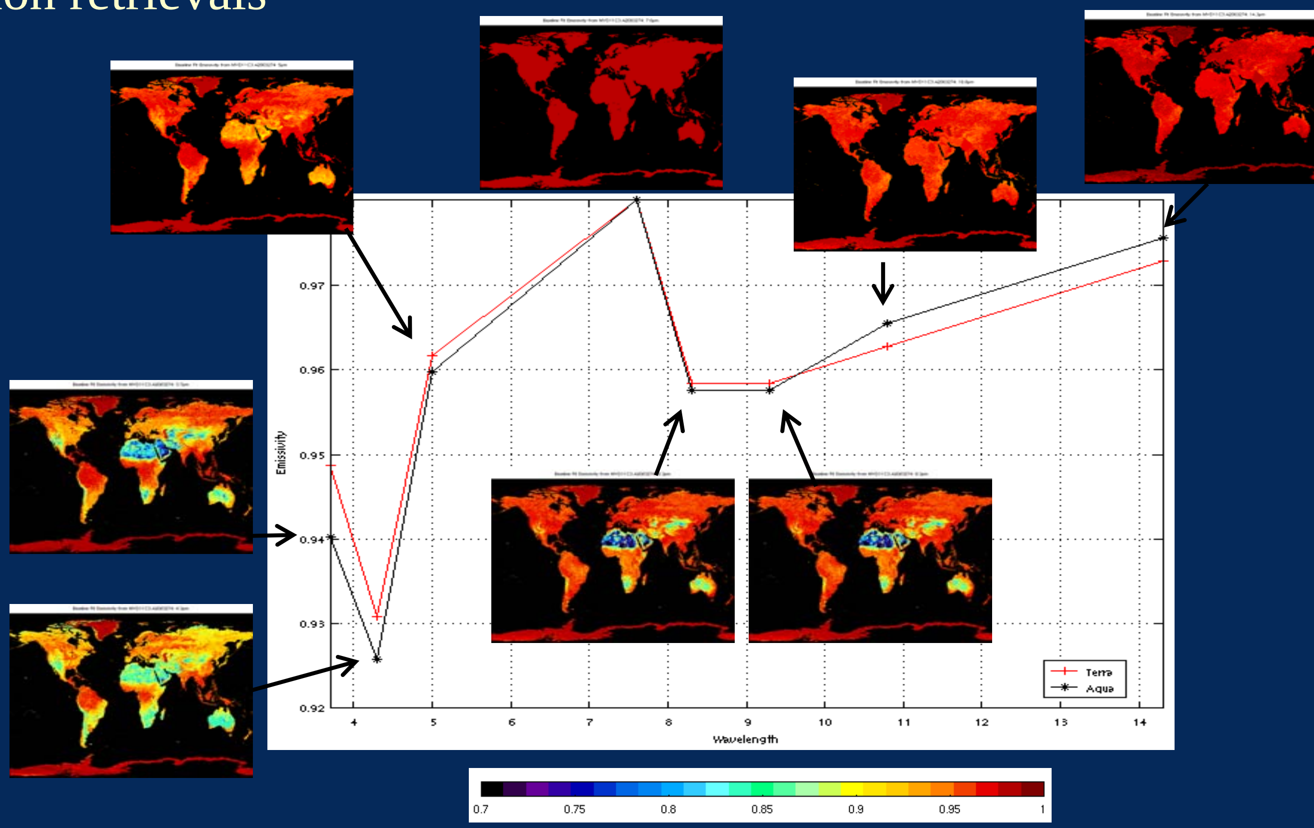
MOD11 Band 29 (8.5μm) emissivity: Monthly averaged October 2003

Approach A:

Adjust a laboratory-derived “baseline emissivity spectra” (BES) based on the MOD11 values for every global latitude/longitude pair.

Dataset available: http://cimss.ssec.wisc.edu/iremis/

Paper will be submitted soon:
Seemann et al.: Infrared global emissivity estimates for clear sky atmospheric regression retrievals



Using Principal Component Analysis to get high spectral resolution emissivity database

Approach B

1. Selection of laboratory measurements (322) and interpolate them into 413 wavenumbers, with resolution 5 cm-1

2. Compute eigenvectors of lab spectra

3. Choose the number of PCs (30) for >0.999 explained variance

4. Create coefficients for 10,000 (also 20,000 and 200,000) simulated spectra randomly.

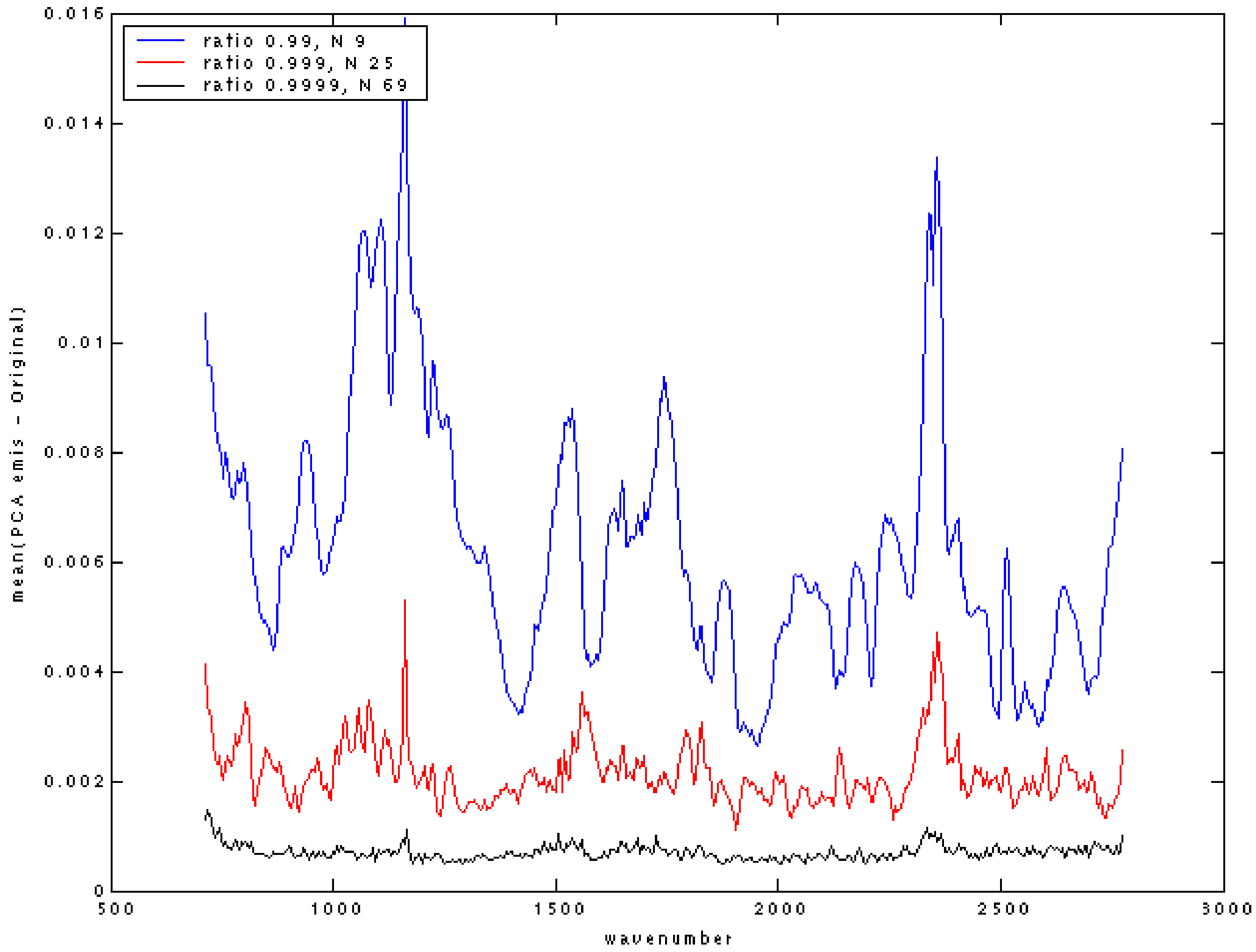
$$\mathbf{C}_{i,npc} = \mathbf{X}_{i,npc} \bullet \sqrt{\lambda_{npc}}$$

5. Filter out the spectra with values larger than 1: this leaves approximately half of original.

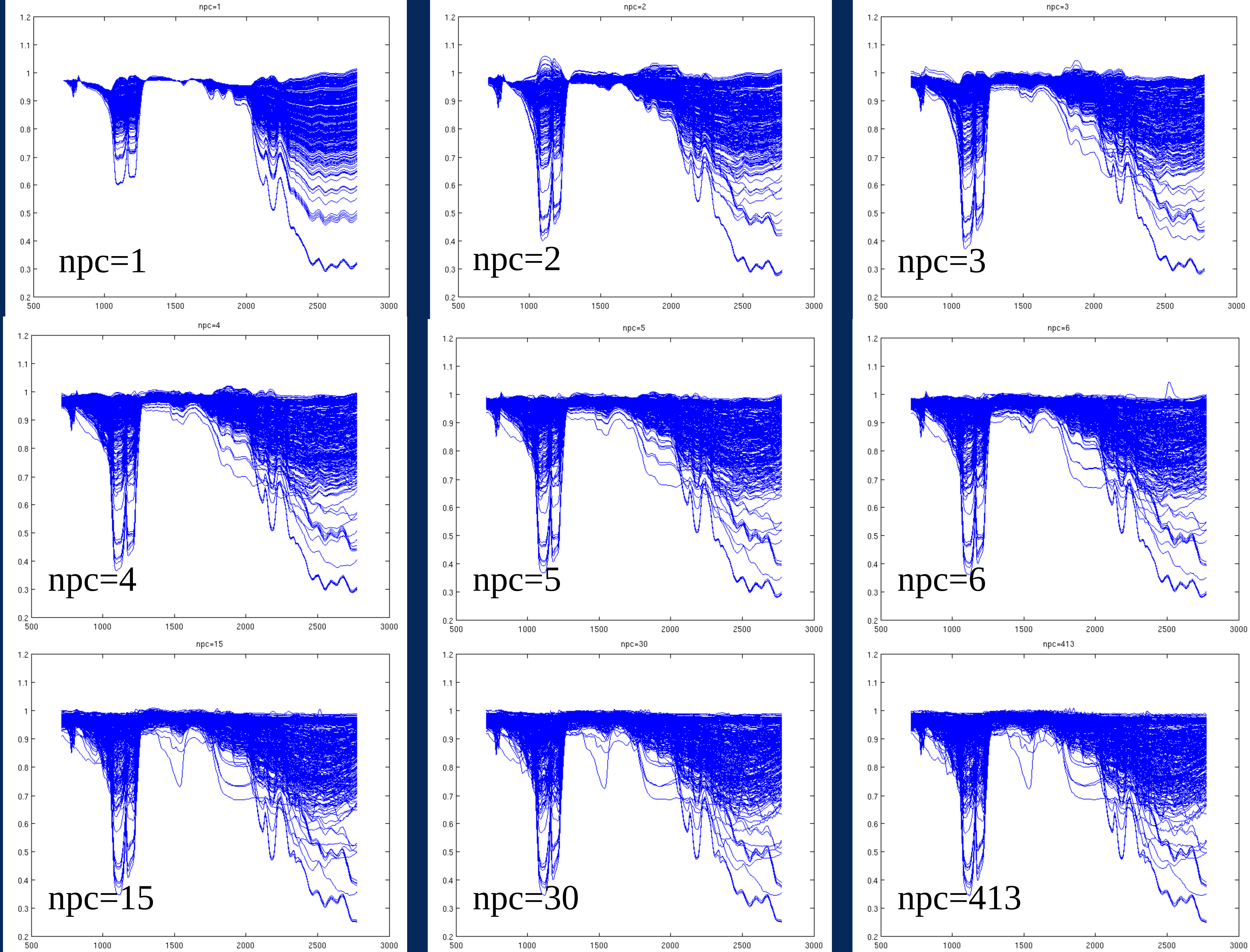
6. Find the best-fit simulated spectra globally for each MOD11 emissivity spectra by using a least squares method. The laboratory measurements were convolved with the MODIS SRF before hand.

The retrieved emissivities:

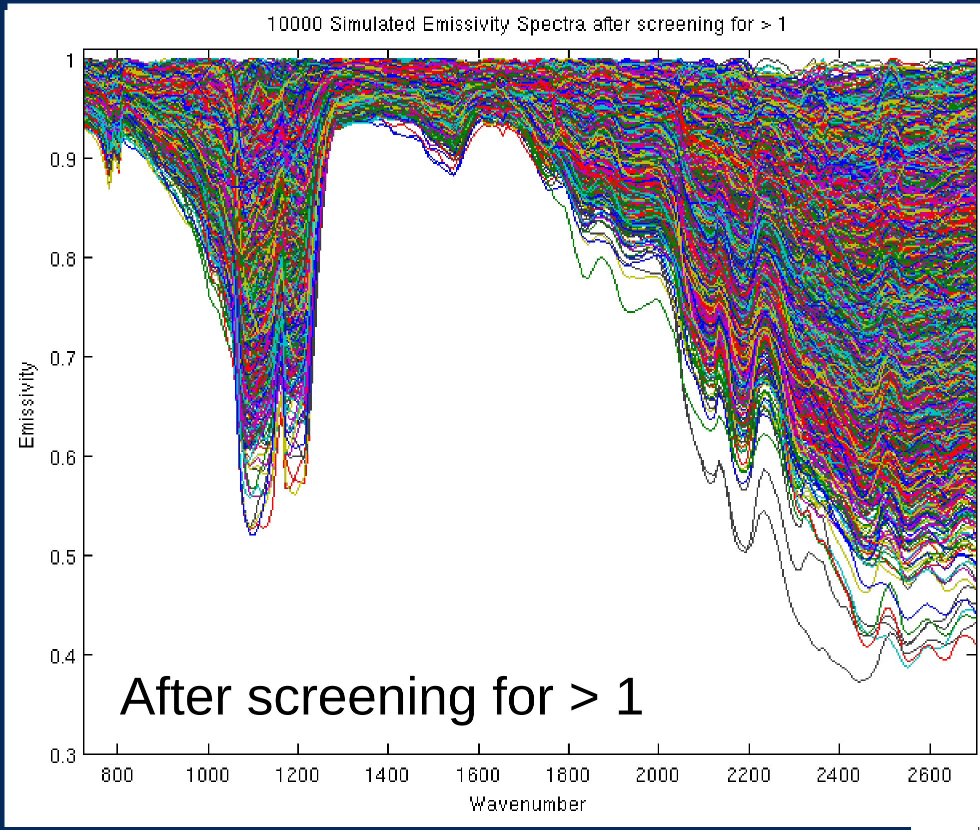
- Are linear combinations of Lab high resolution emissivity spectra
- Match the MOD11 data for the 6 MODIS available (emissivity) channels
- Allow for determination of which lab spectra are actually contributing to the retrieved values (back tracing)
- Have high spatial resolution (MODIS resolution) and can be validated with AIRS data
- Drawback: Laboratory data may not be representative of actual ecosystems as seen from space, uncertainty in regions between MOD11 wavelengths.



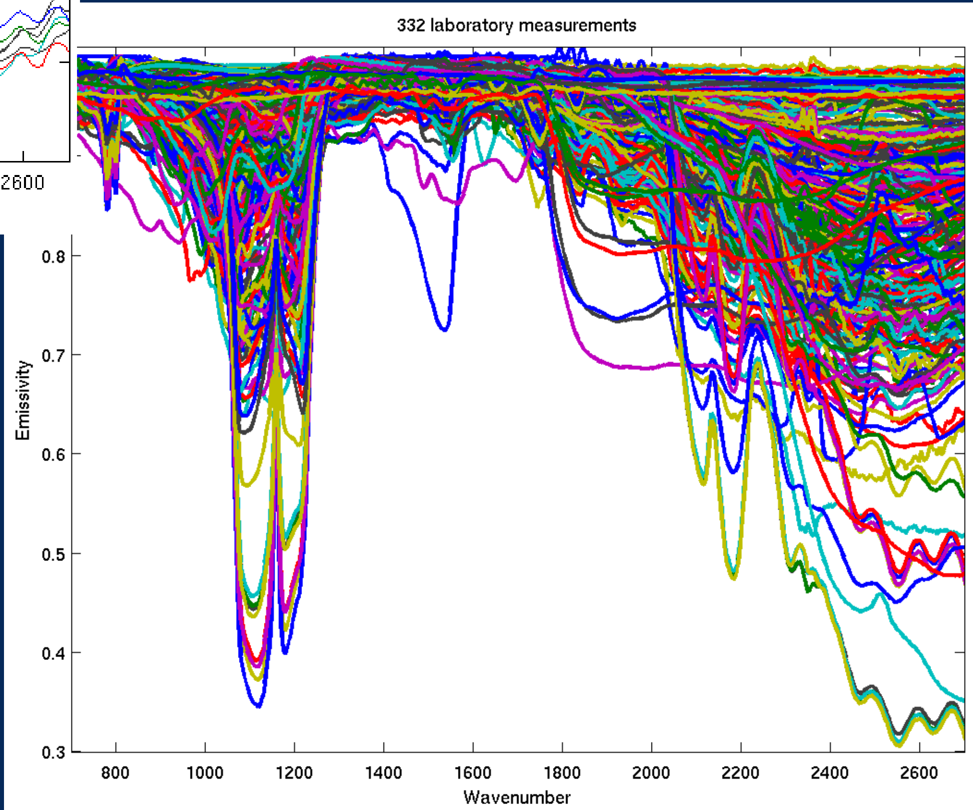
Mean absolute difference between the original emissivity and that reproduced using the first 9, 25, and 69 principal components (blue, red, and black, respectively). The number of PCs was chosen to represent 0.99, 0.999, and 0.9999 fraction of the total variance.


npc=1
npc=2
npc=3
npc=4
npc=5
npc=6
npc=15
npc=30
npc=413
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
500
1000
1500
2000
2500
3000

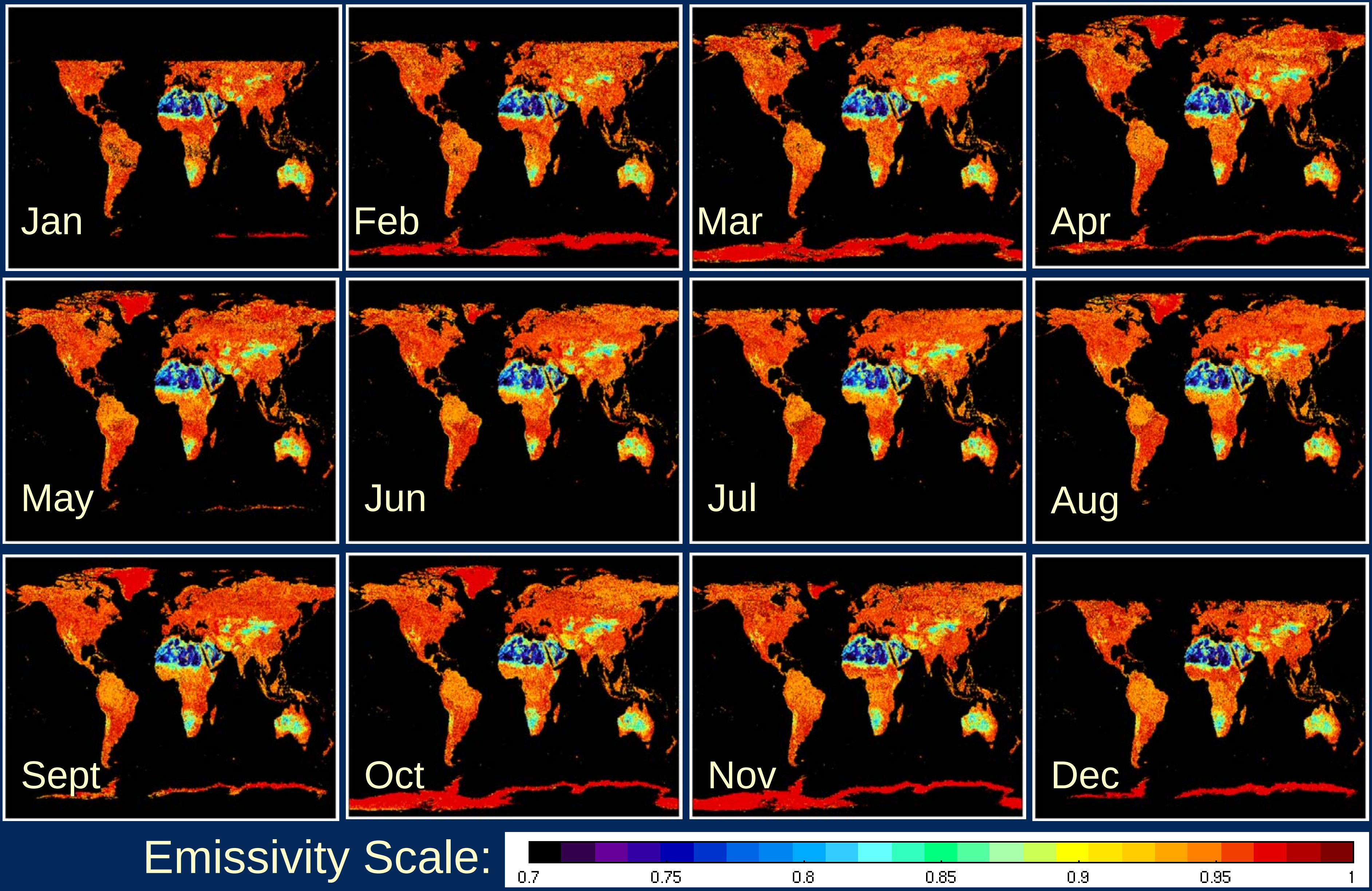
Simulated spectra



Lab spectra

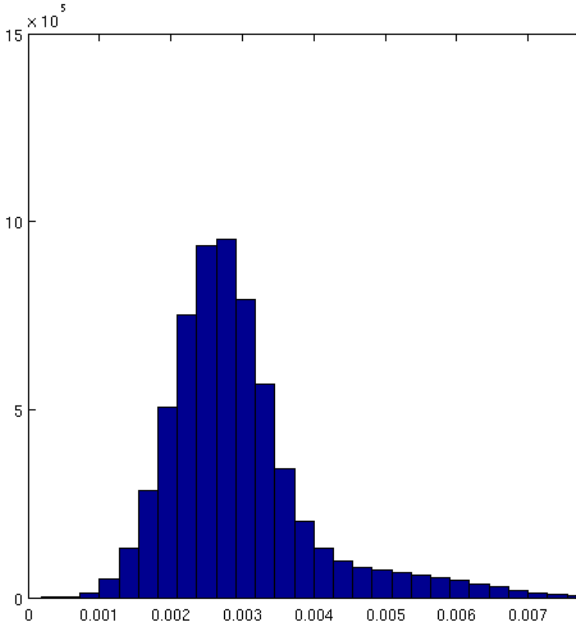


Grid B Aqua 2003 – 8.3μm

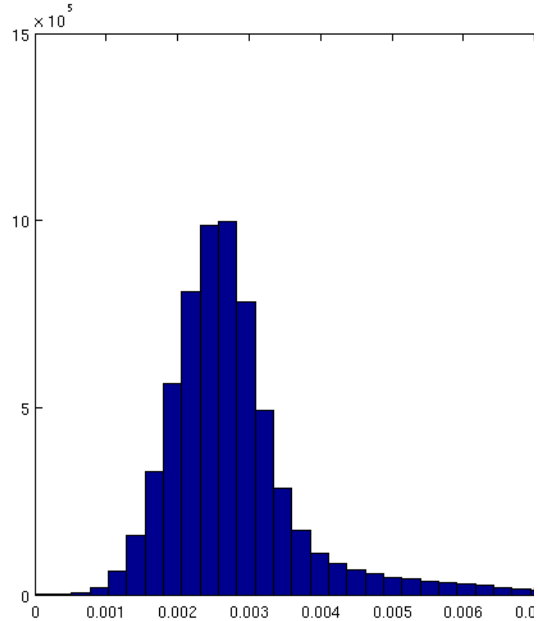


Histogram of least squares minimum differences with different number of simulated spectra

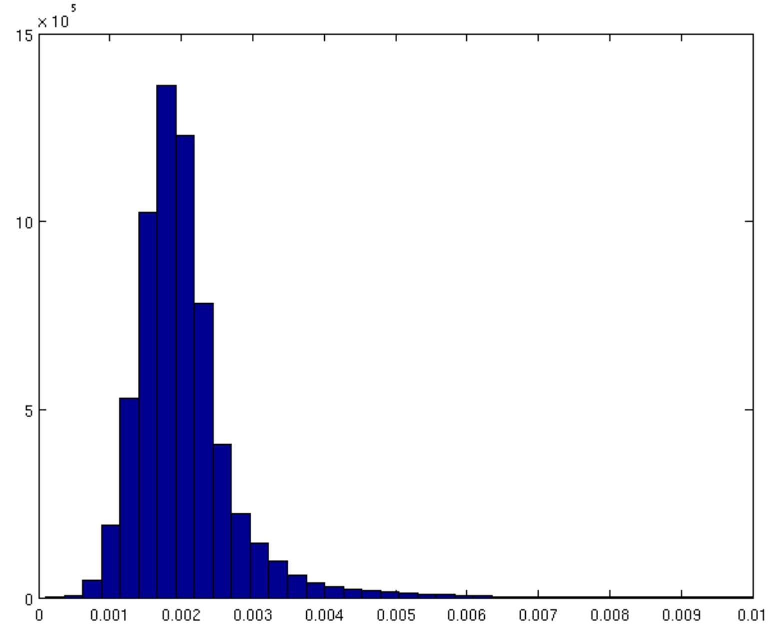
N10000_4861



N20000_9580



N100000_48102



Approach C

Step 1: assumption

$$\varepsilon(\nu_h)=\mathbf{c}^*\ \mathbf{u}\ (\nu_h) \quad \text{(eq. 1)}$$

ν_h is the vector of high resolution wavenumbers

$\mathbf{u}(\nu_h)$ is the first *n* eigenvectors of the laboratory measurements (332,413)

Step 2: calculate regression coefficients

$$\varepsilon(\nu)=\mathbf{c}^*\ \mathrm{SRF}\otimes\mathbf{u}\ (\nu_h)$$ for each MODIS pixel

ν is the vector of wavenumbers for the 6 MODIS channels

$\varepsilon(\nu)$ MODIS emissivity [6]

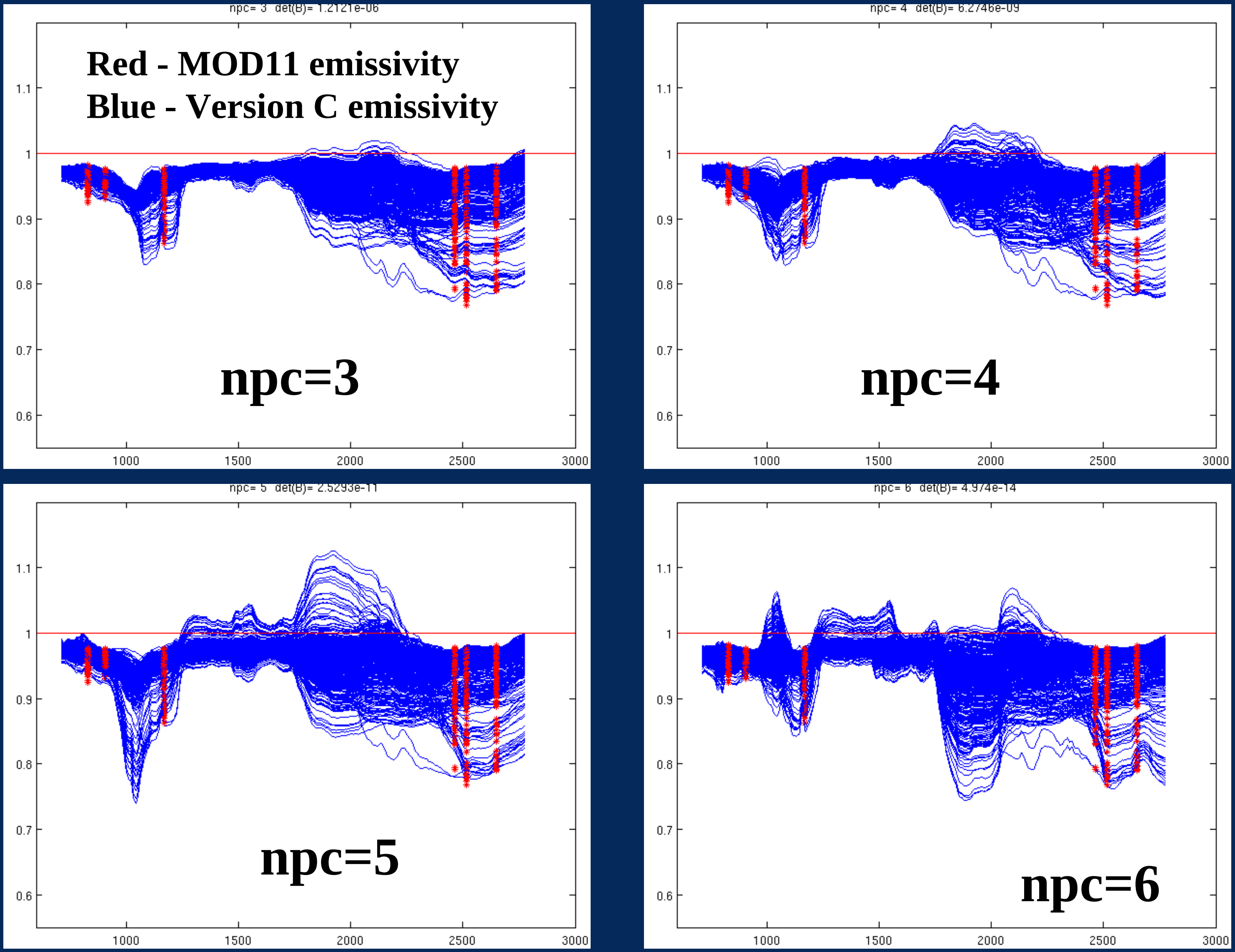
$\mathbf{c}$ Regression coefficient [*n*]

$\mathrm{SRF}\otimes\mathbf{e}\ (\nu_h)=\mathbf{A}$ the matrix of the first *n* eigenvectors convolved with MODIS SRF

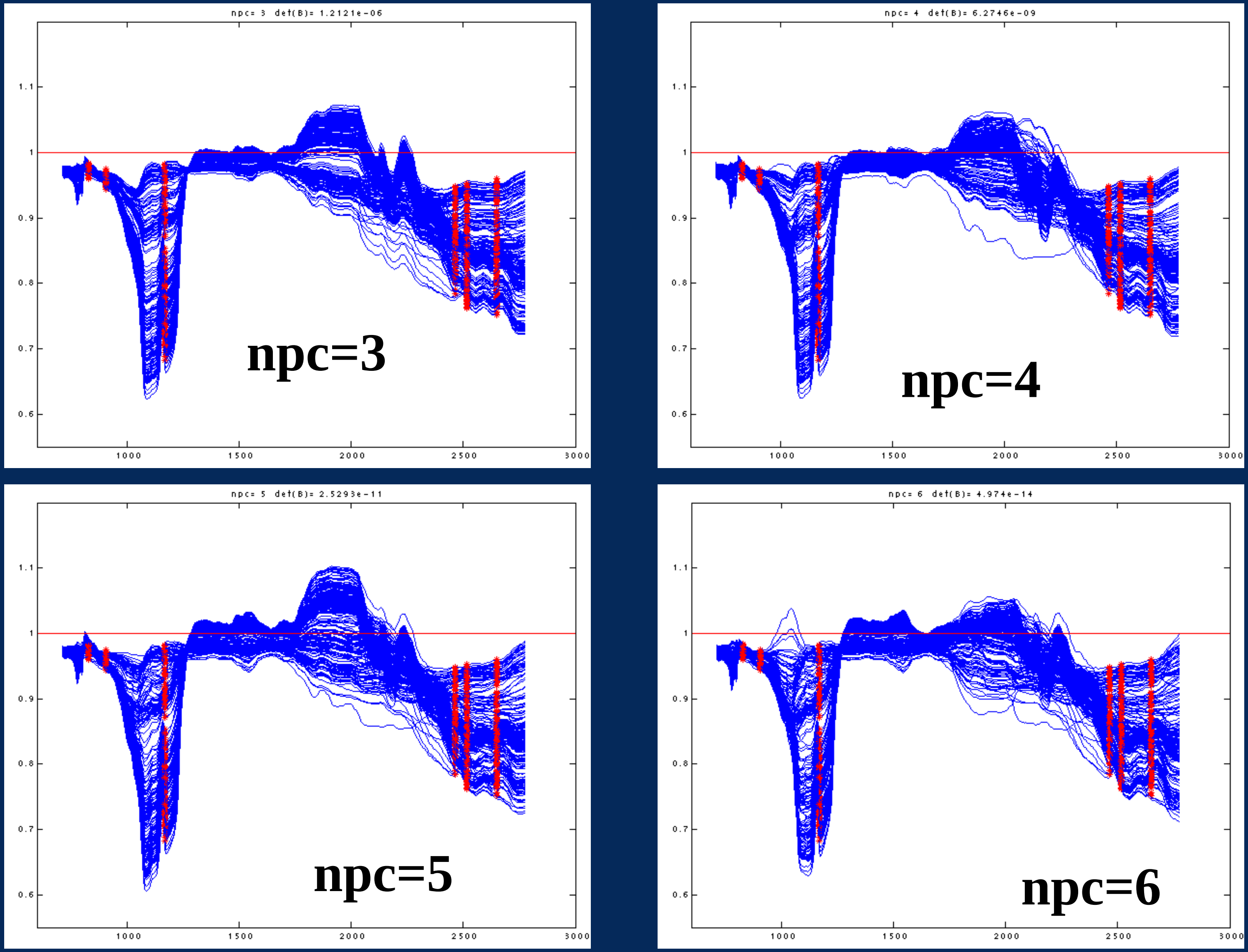
$$\mathbf{c}=\varepsilon(\nu)^*\mathbf{A}^T(\mathbf{A}\mathbf{A}^T)^{-1}$$

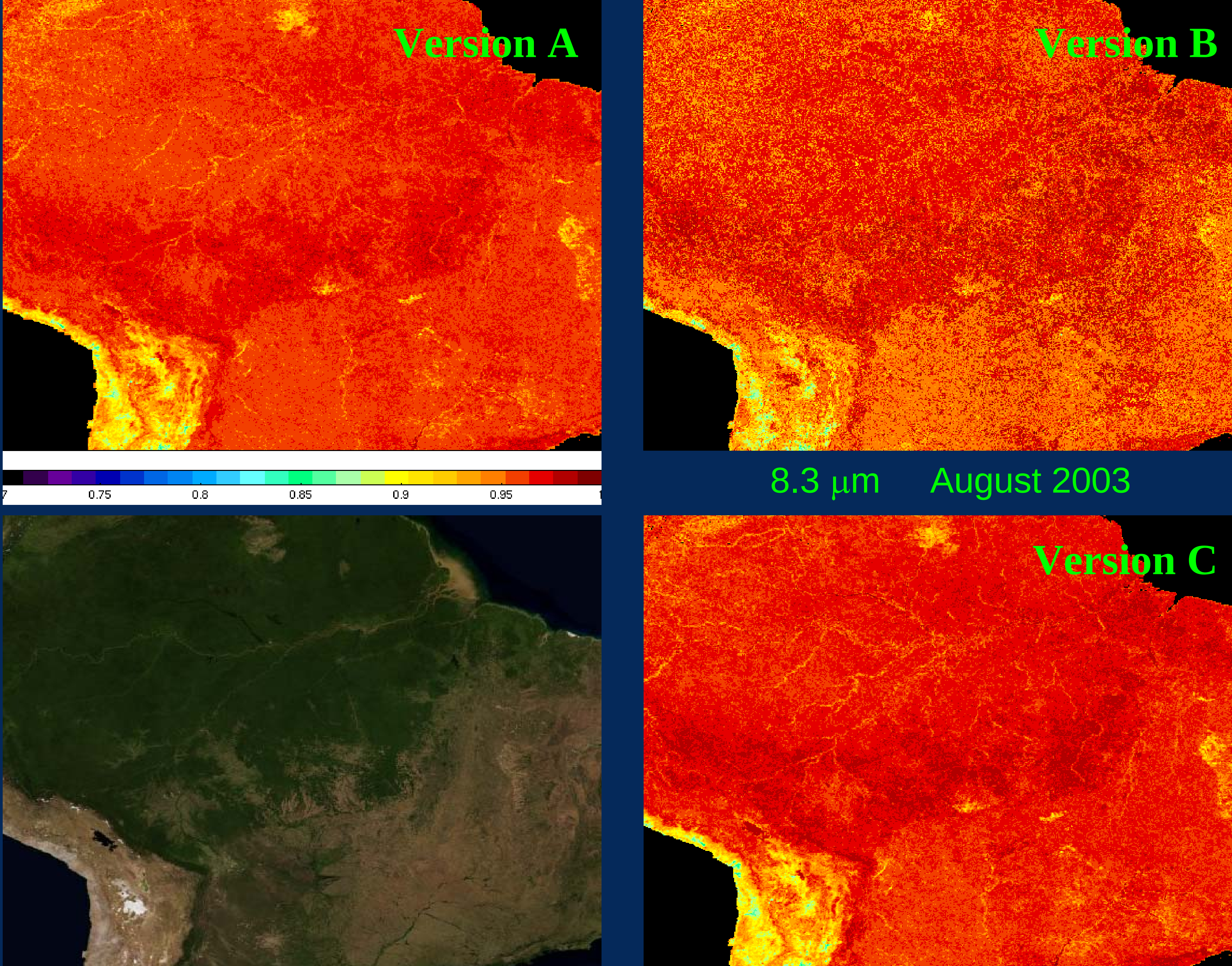
Step 3: apply C to (eq. 1)

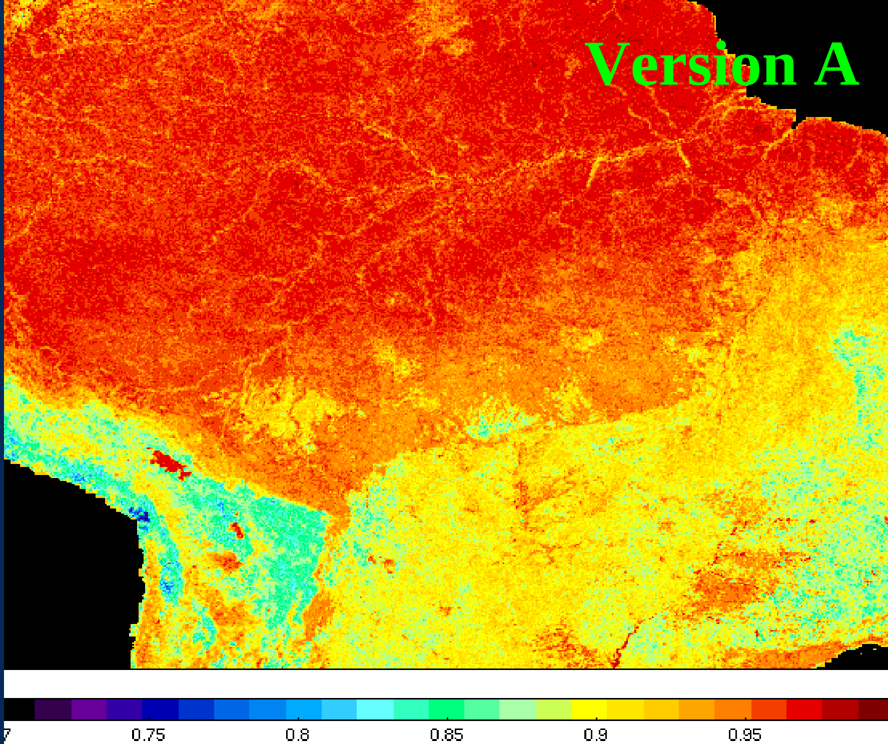
Comparison of emissivity spectra using different number of PCs over the area of Amazon (400X400 grid points), August 2003

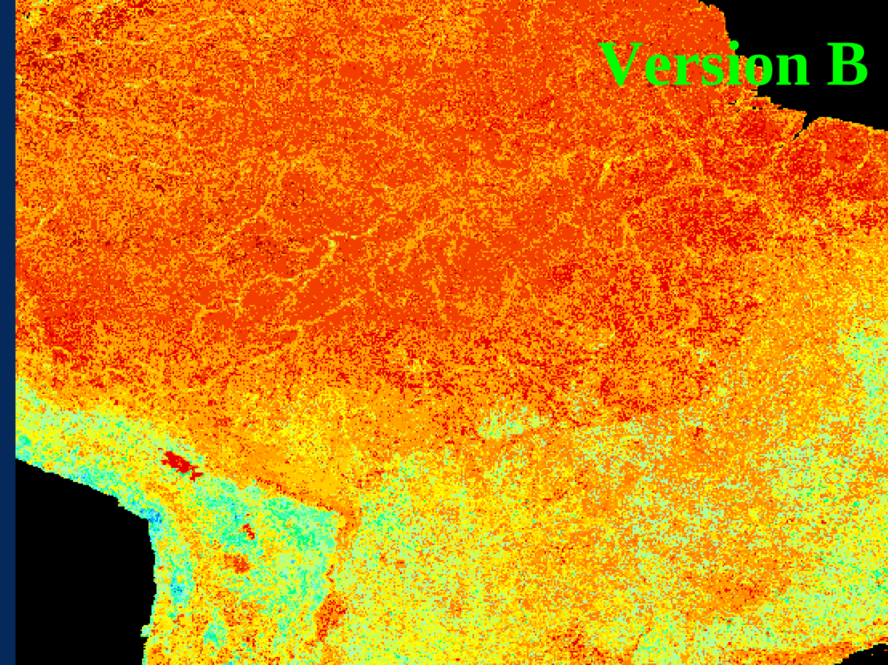


Comparison of emissivity spectra using different number of PCs over the area of Nile Delta, August 2003

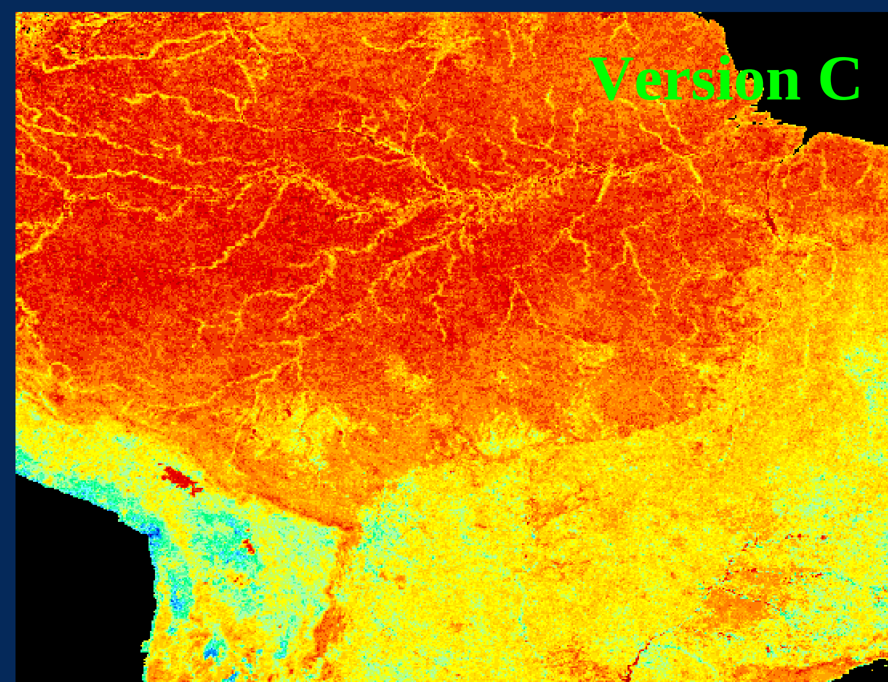


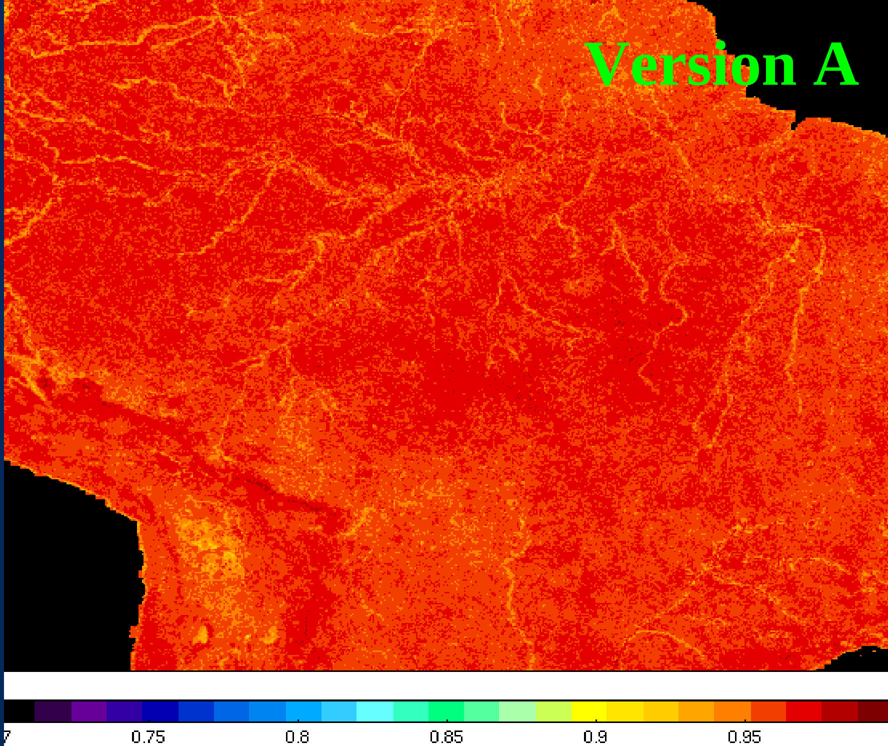

Version A
Version B
Version C
0.75
0.8
0.85
0.9
0.95
8.3 μm
August 2003

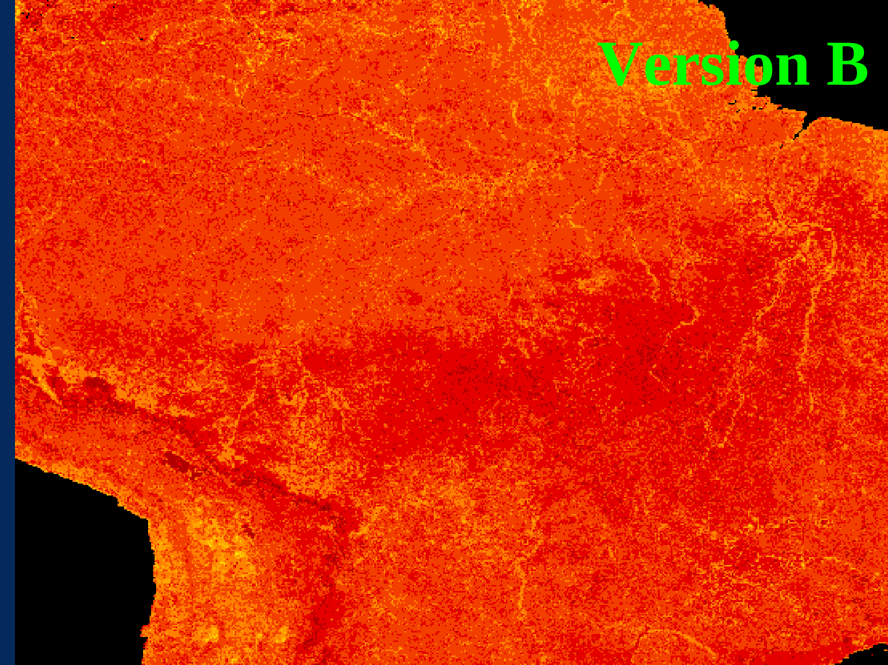




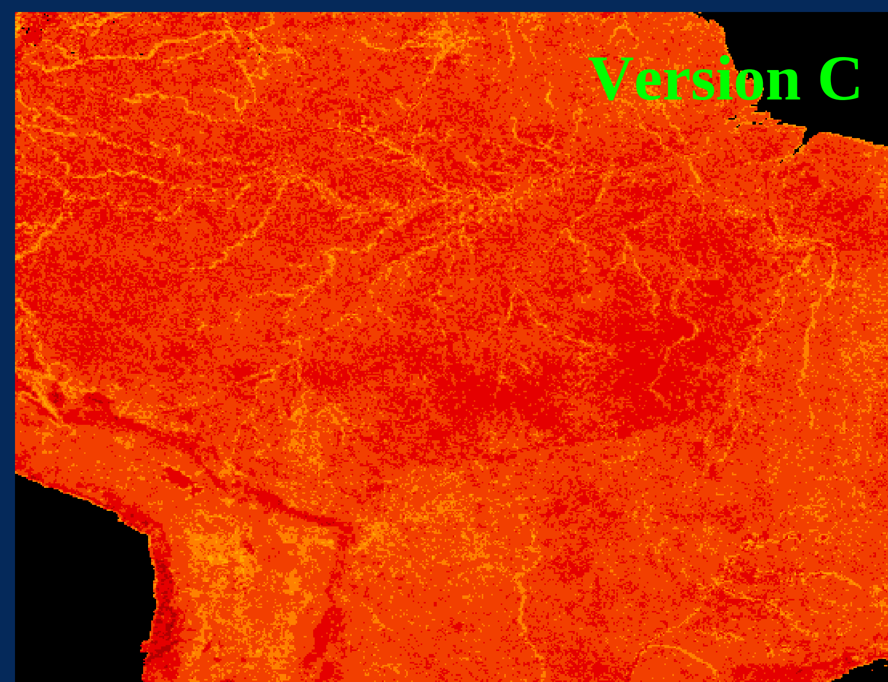
4.3 μm August 2003

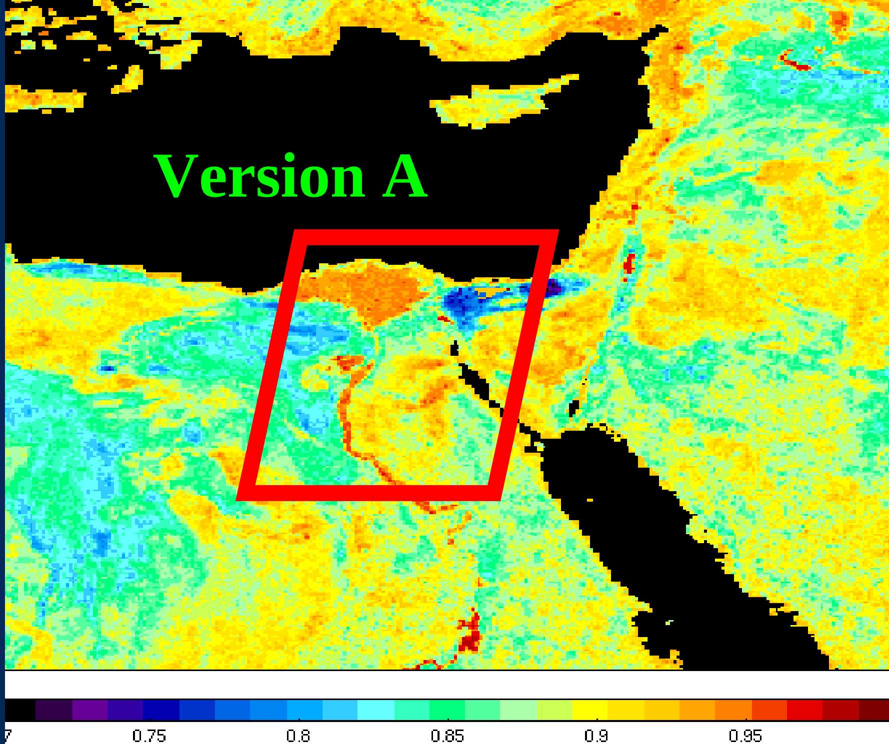


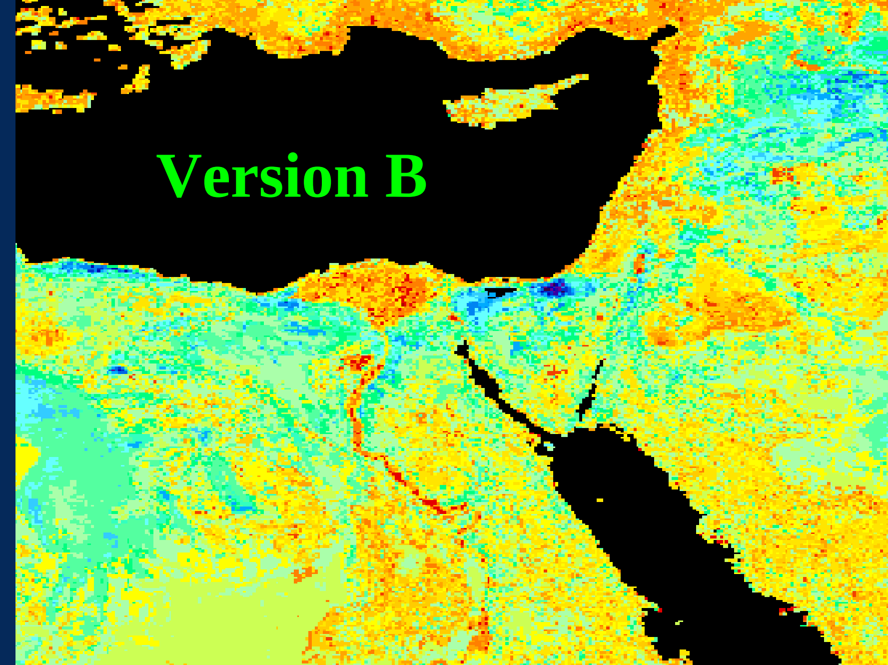




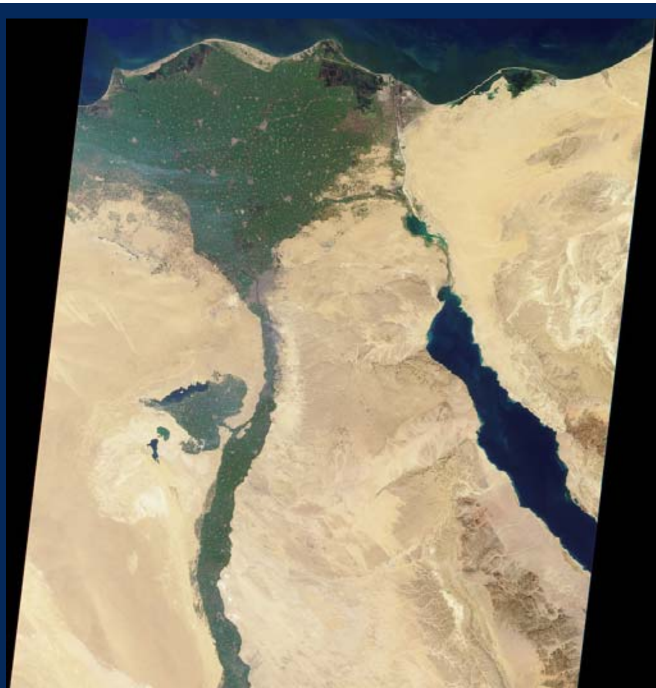
10.8 μm August 2003

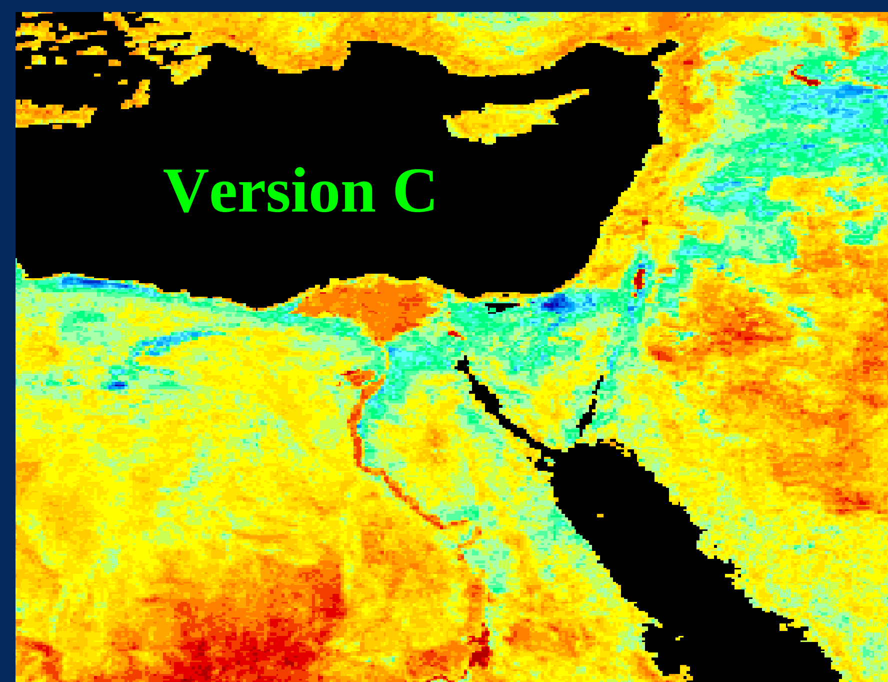


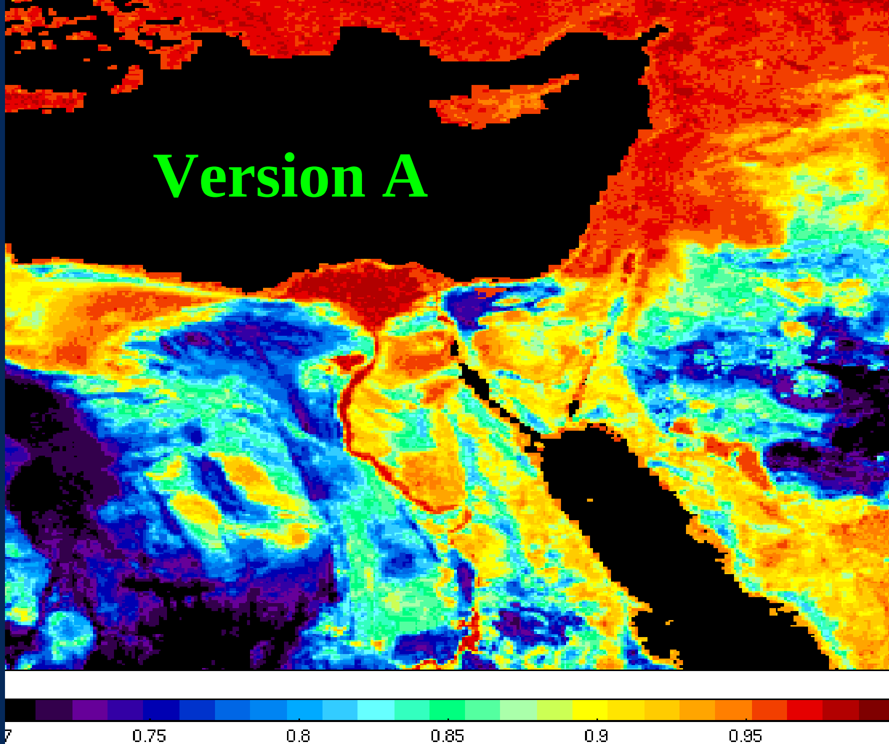


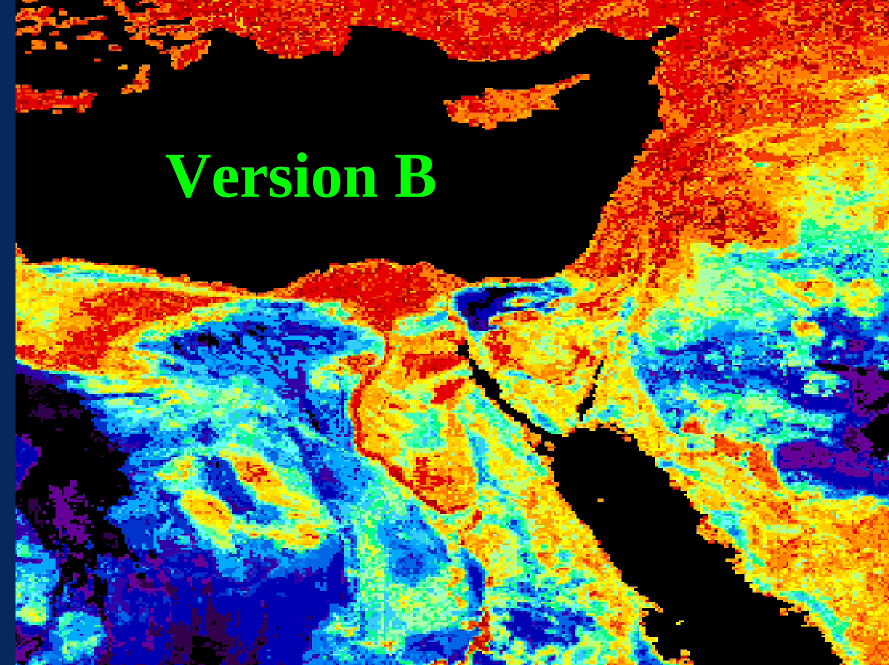


4.3 μm August 2003

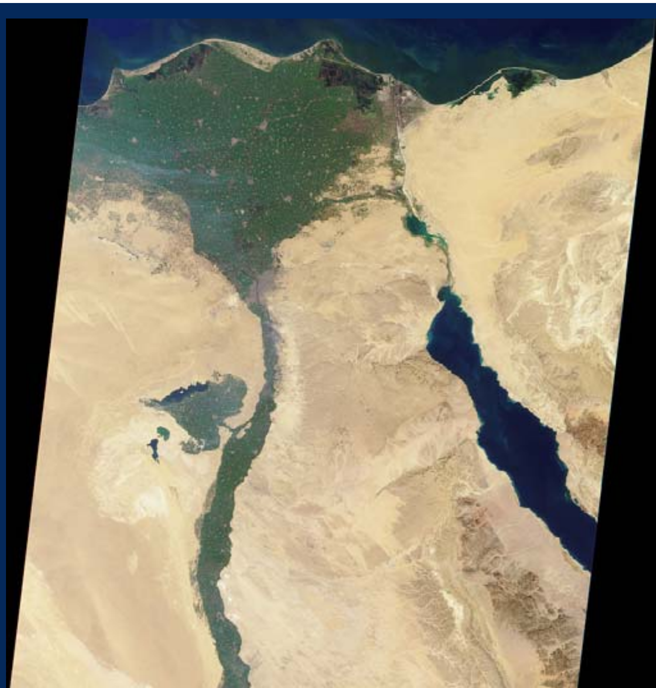


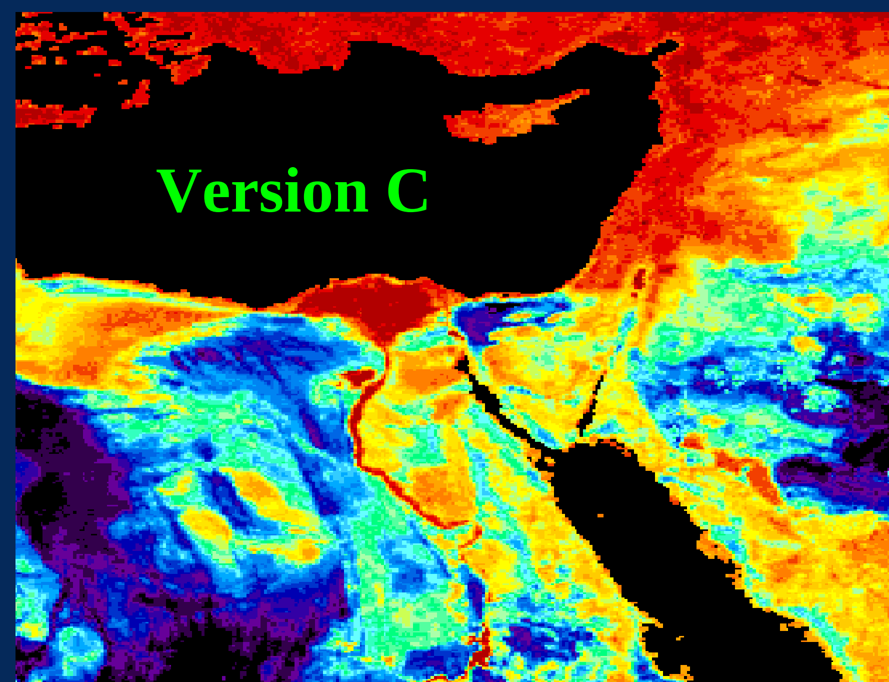


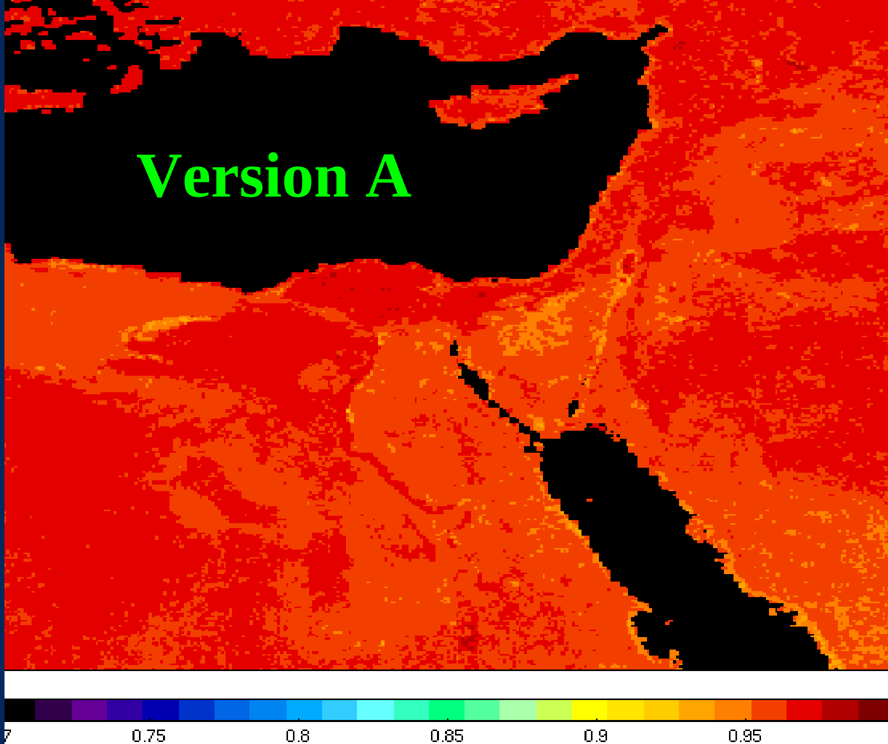


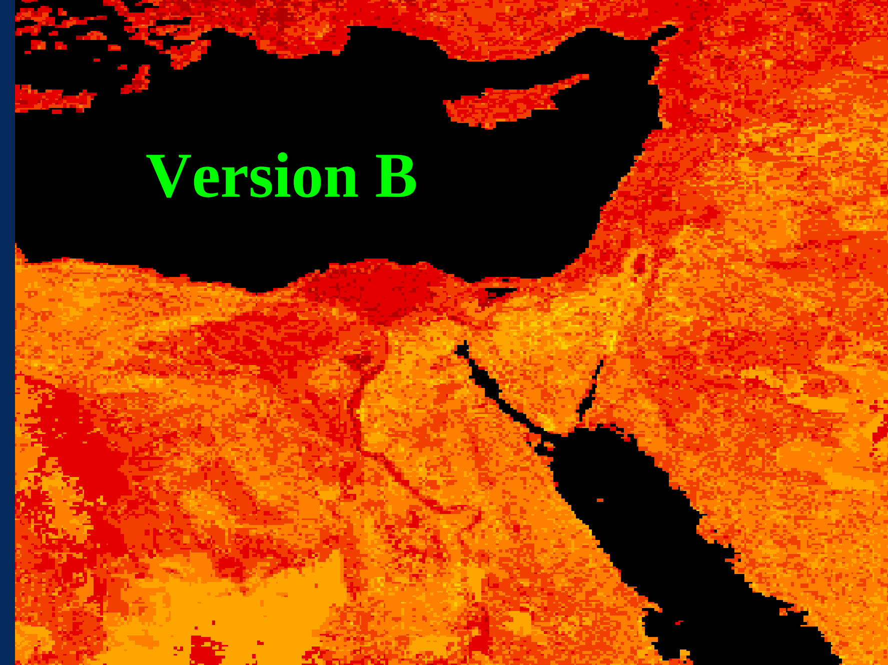


8.3 μm August 2003

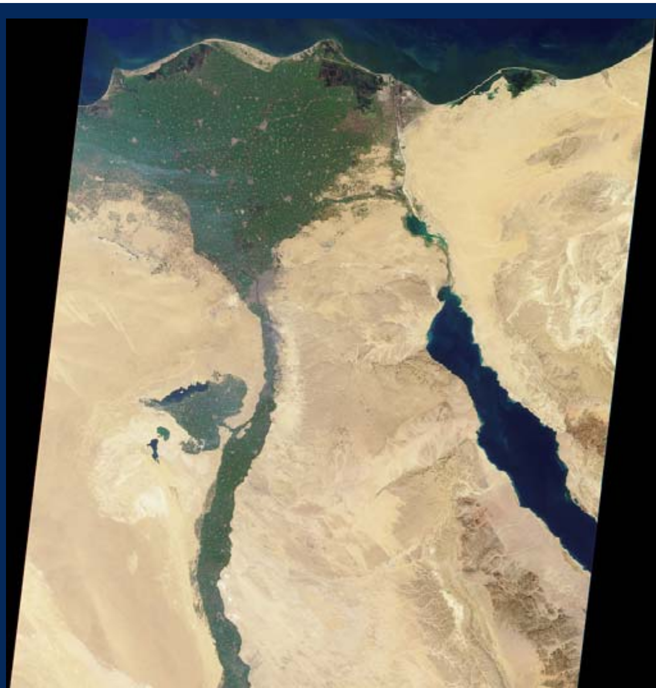


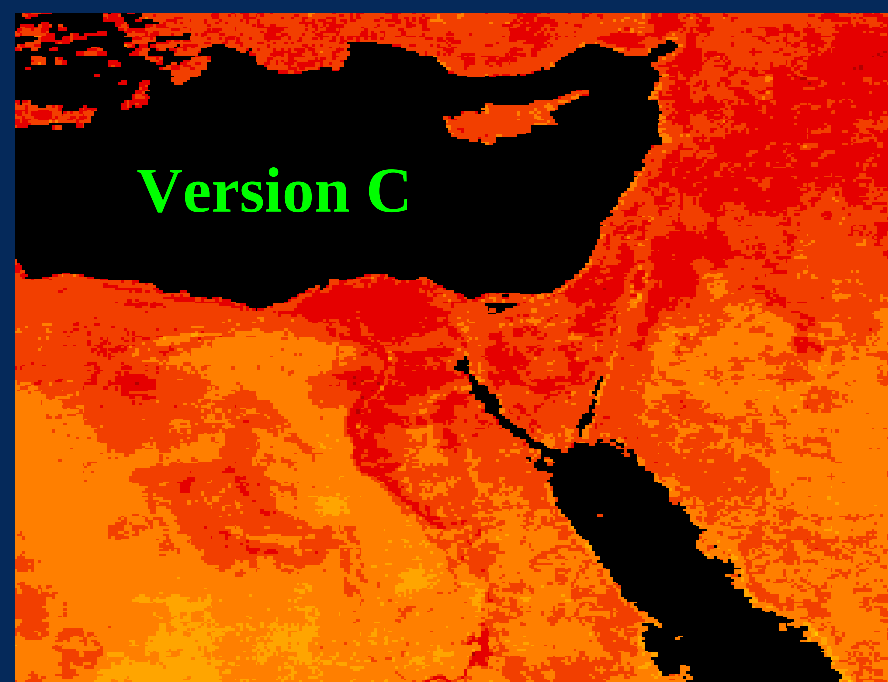




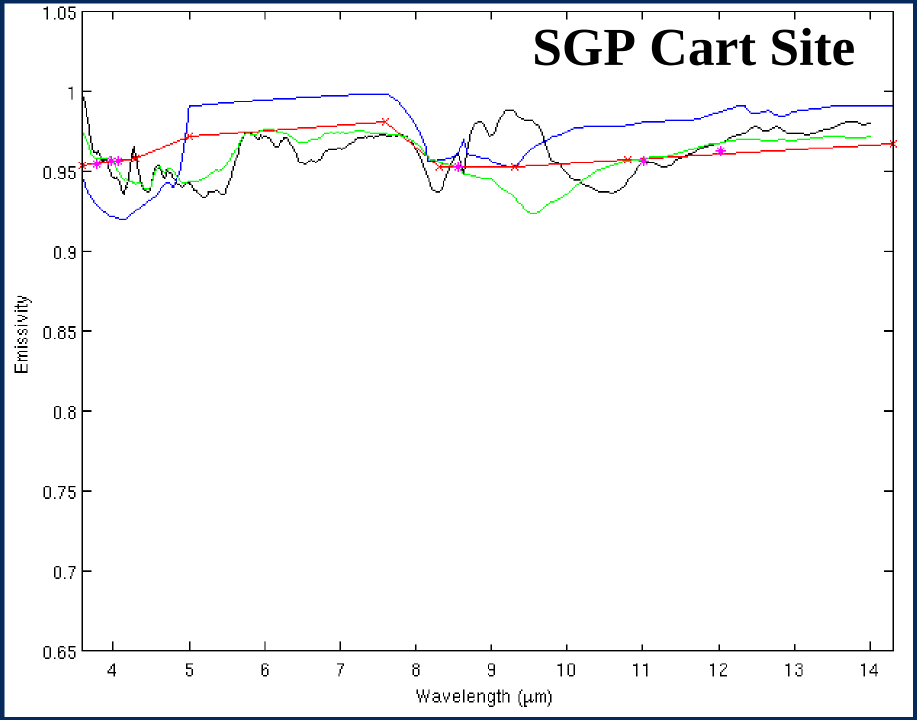


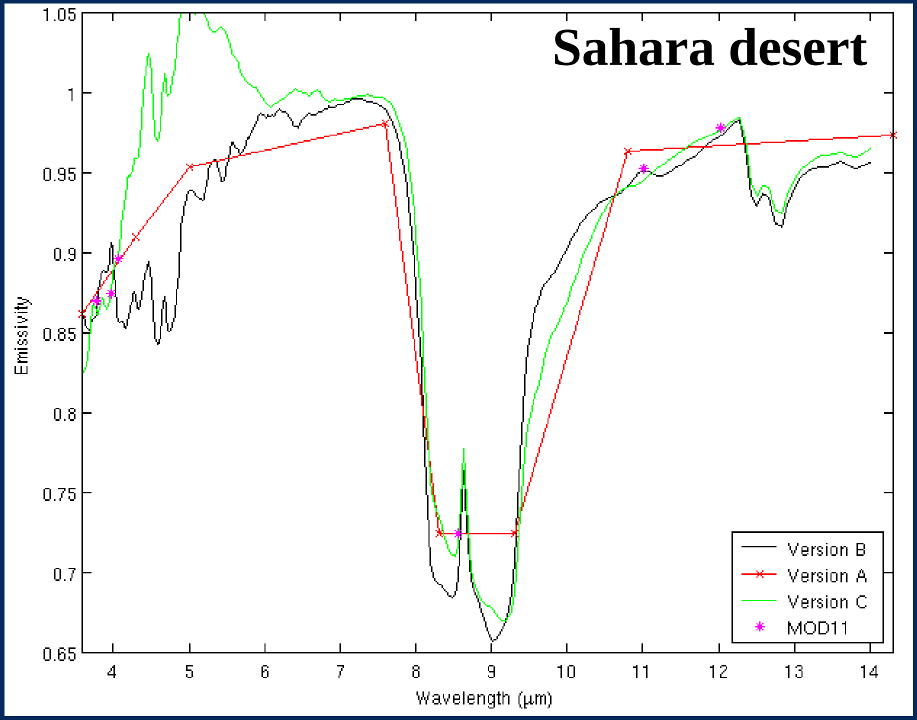
10.8 μm August 2003





Comparison A & B & C





Comparison of emissivity spectra derived by the Version A baseline fit method (red), the Version B PCA/MOD11 matching method (black) and the PCA/MOD11 regression method (blue) for the ARM SGP site in Oklahoma (left), and a Sahara desert location (Lat: 23.5N, Lon: 30.0E) (right). Dave Tobin and Bob Knuteson's best estimate emissivity spectra (blue) is also plotted over the ARM site (left panel).

Future Plans

- Investigate the problems:
  - emissivity greater than 1 (version C)
  - experiments with different number of PCs (version C)
  - discontinuous emissivity fields (version B)
- Apply similar techniques using AIRS retrieved emissivity spectra
- Validation, validation, validation - we are looking for any available measurements to compare with (evab@ssec.wisc.edu)
- Continue to evaluate the impacts of an improved surface emissivty value on retrieved MODIS and AIRS products