IR Land Surface Emissivity Validation

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AIRS Science Team Meeting, Maryland, Dec. 1, 2004

Topics

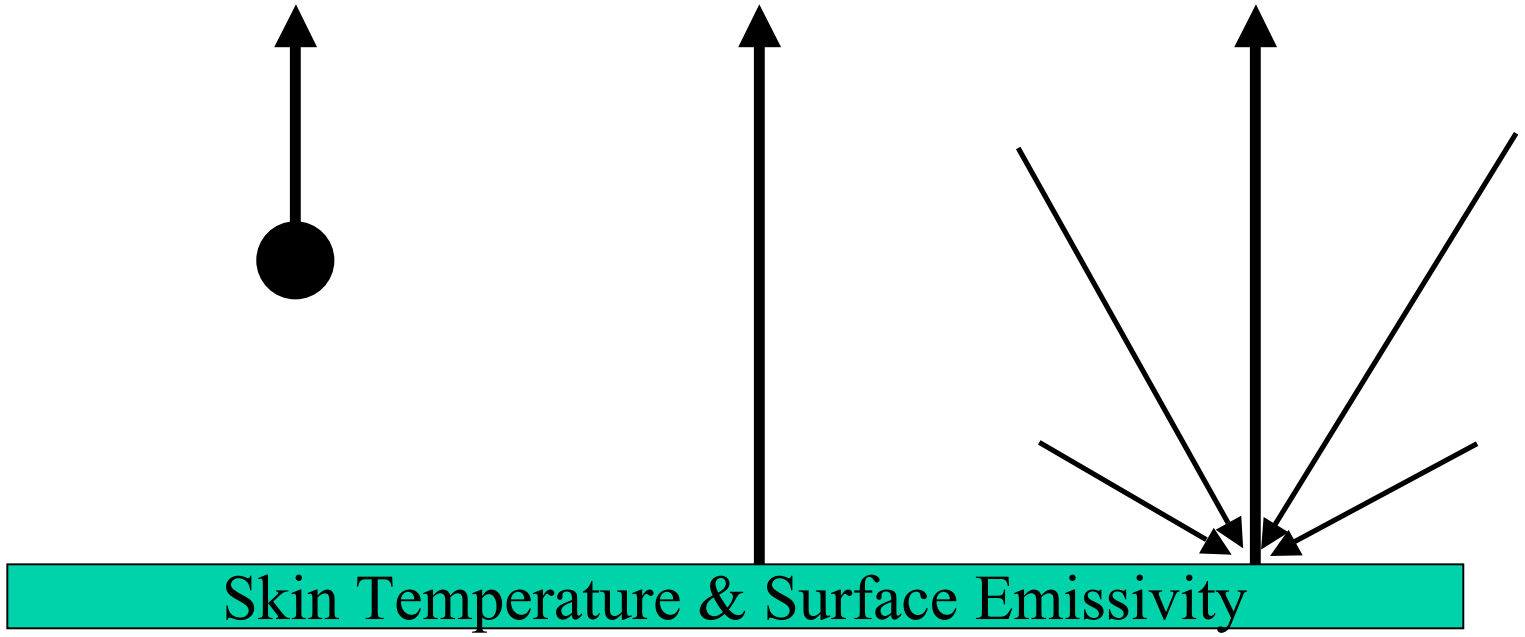
- IR Land Surface Spectral Signatures
- UW Validation Data
- Validation of AIRS Cloud Clearing over Non-Uniform Land Surfaces and Standard Emissivity Product (V3.5.0.0)
- Future Work

IR Spectral Emissivity

Land Surface

Infrared Radiative Transfer Equation (lambertian surface)

$$N_\nu^{\uparrow} = \underbrace{\int B_\nu(T(P))d\tau_\nu}_{N_\nu^{atm\uparrow}} + \underbrace{\tau_\nu^{tot} \cdot e_\nu \cdot B_\nu(T_S)}_{\text{Surface Emission}} + \underbrace{\tau_\nu^{tot} \cdot (1 - e_\nu) \cdot \overline{N_\nu}^{\downarrow}}_{\text{Surface Reflection}}$$



$$N_\nu^{\uparrow} = \int B_\nu(T(P))d\tau_\nu + \tau_\nu^{tot} \cdot e_\nu \cdot B_\nu(T_S) + \tau_\nu^{tot} \cdot (1 - e_\nu) \cdot \overline{N}_\nu^{\downarrow}$$

Approximate Solutions:

$$e_\nu = N_\nu^{\uparrow} / B_\nu(T_S)$$

(spectral relative)

$$e_\nu = (N_\nu^{\uparrow} - \int B_\nu(T(P))d\tau_\nu) / (\tau_\nu^{tot} \cdot B_\nu(T_S))$$

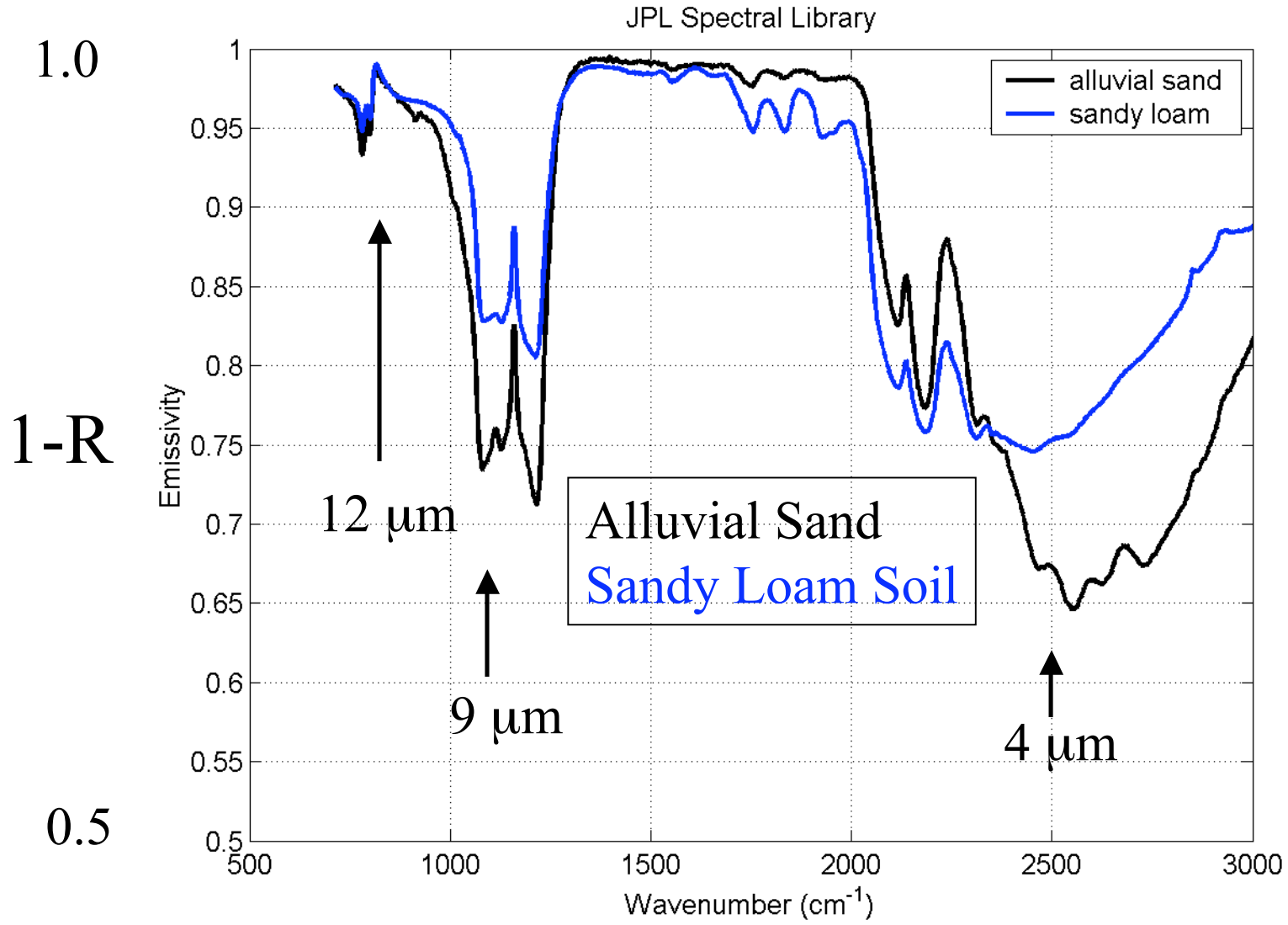
(atmospheric corrected spectral relative)

$$e_\nu = [(N_\nu^{\uparrow} - \int B_\nu(T(P))d\tau_\nu) - \tau_\nu^{tot} \cdot \overline{N}_\nu^{\downarrow}] / [\tau_\nu^{tot} B_\nu(T_S) - \tau_\nu^{tot} \cdot \overline{N}_\nu^{\downarrow}]$$

(formal solution - known atmosphere
- unknown skin temperature)

IR Land Surface Signatures: QUARTZ Mineral

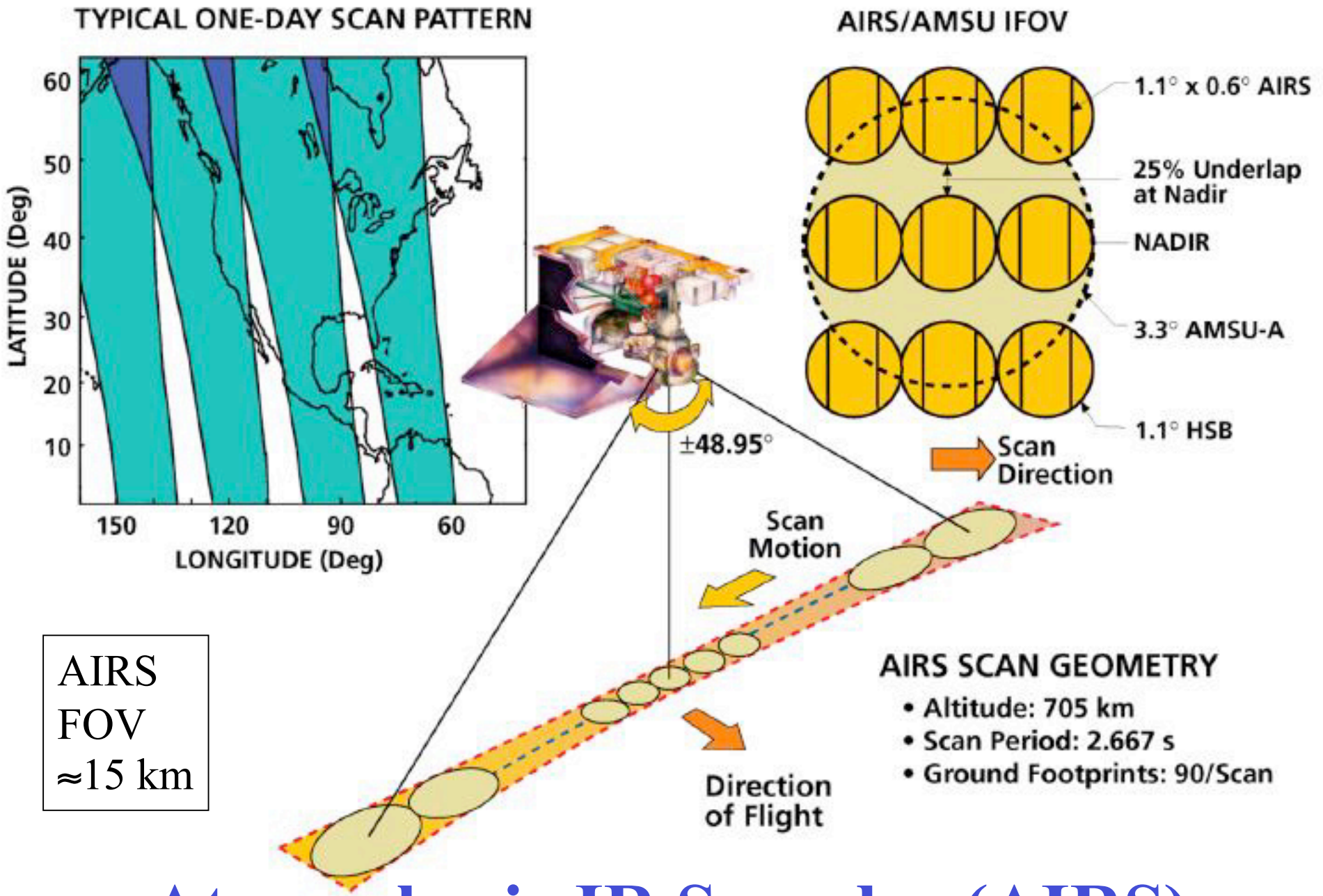
JPL Spectral Library – Laboratory Measurements



AIRS Observations

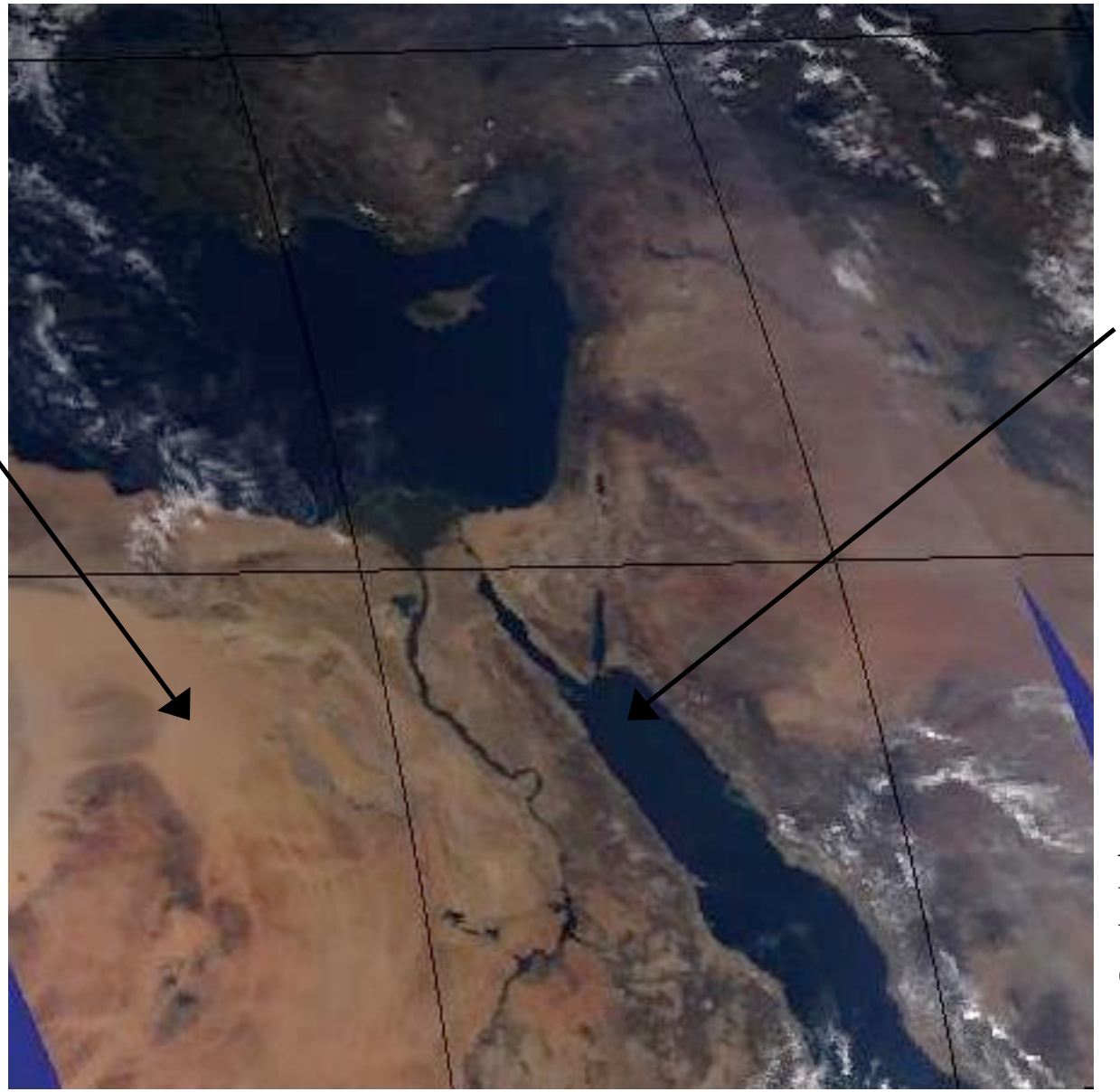
NASA Aqua Satellite

(Launched May 4, 2002)



Atmospheric IR Sounder (AIRS)

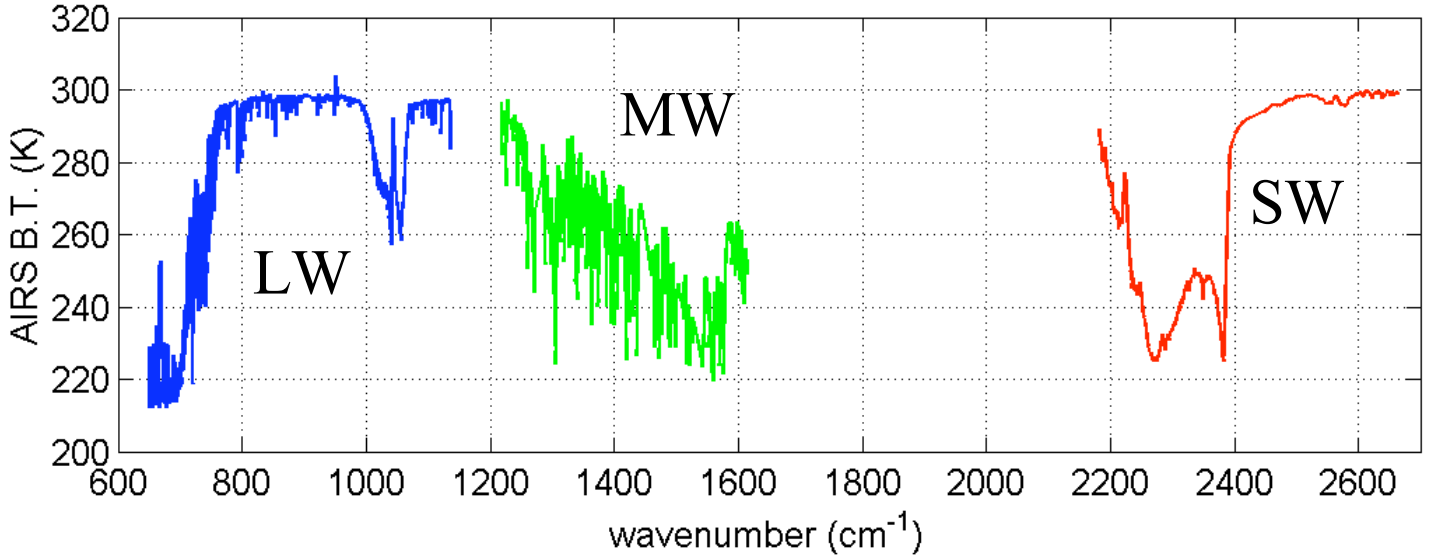
MODIS Image of Egypt & Nile River



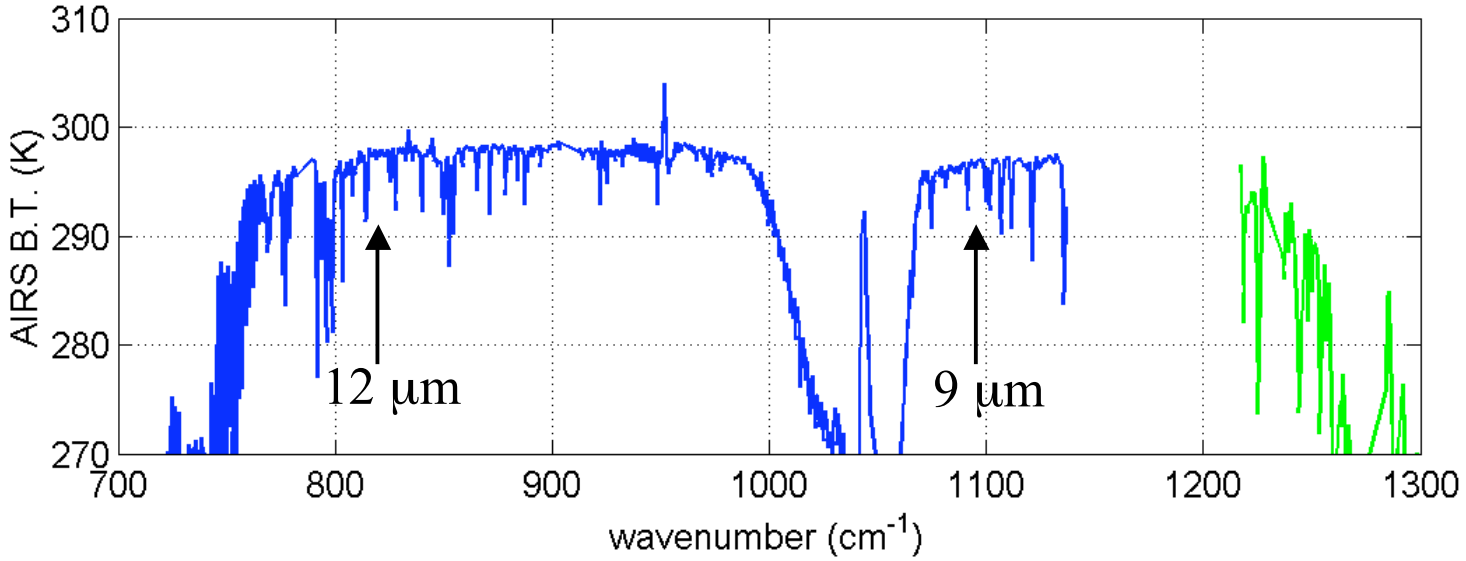
Daytime Overpass: 11:03 UTC on 16 Nov. 2002

AIRS Observation 16 Nov 2002 11 UTC: Red Sea

B.T.(K)



B.T.(K)



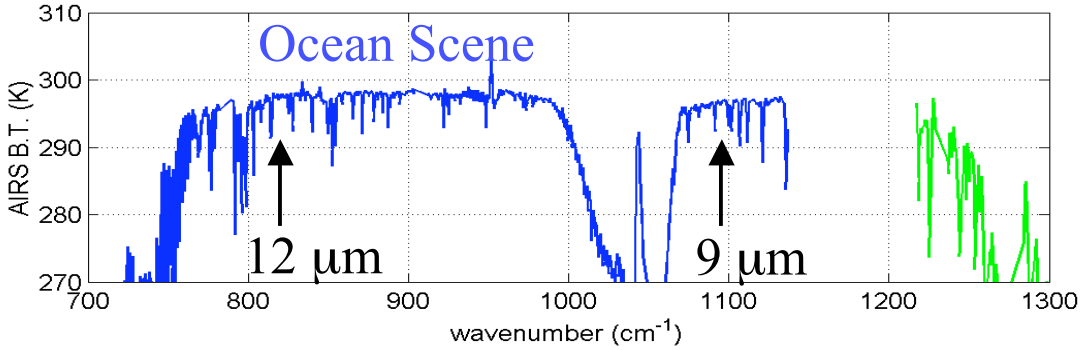
- Microwindows are used to look "between" absorption lines.

AIRS Relative Emissivity and Temperature

16 November 2002

Focus Day

Methodology:
Relative & Absolute Emissivity



- Use 12 μm region (830-832 cm^{-1}mean) as reference wavelength.

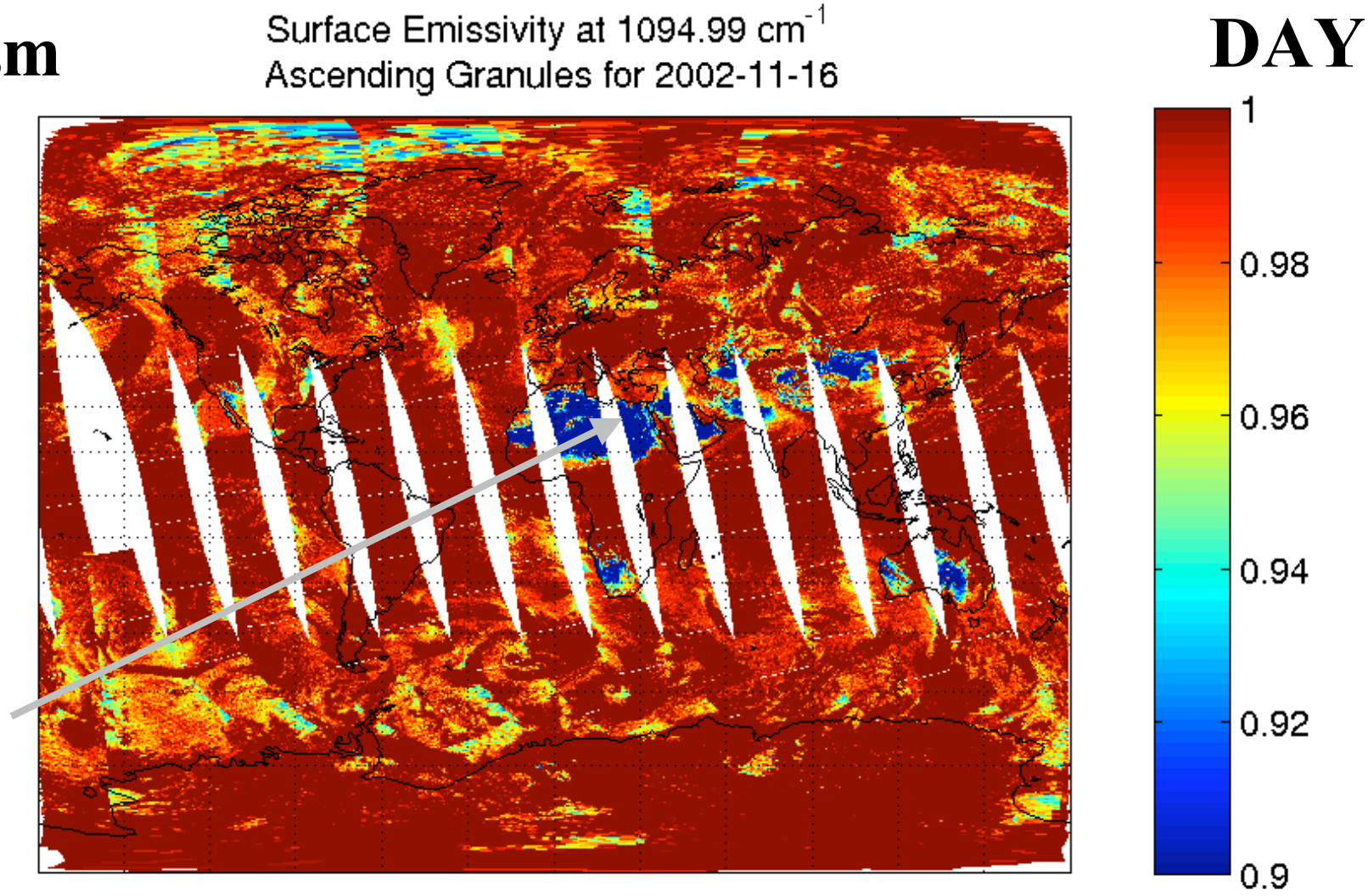
- Divide observed spectrum by planck radiance computed using the 12 μm "micro-window" brightness temperature.

- Compute "atmospheric corrected" spectral relative emissivity using ECMWF six hour analysis fields.

- Compute absolute emissivity obtained by formal solution of full radiative transfer equation using UW technique that takes advantage of High Spectral Resolution reflected infrared. *(Knuteson, et al., Adv. Space Res., 33 (2004) 1114-1119.)*

AIRS Spectral Relative Emissivity

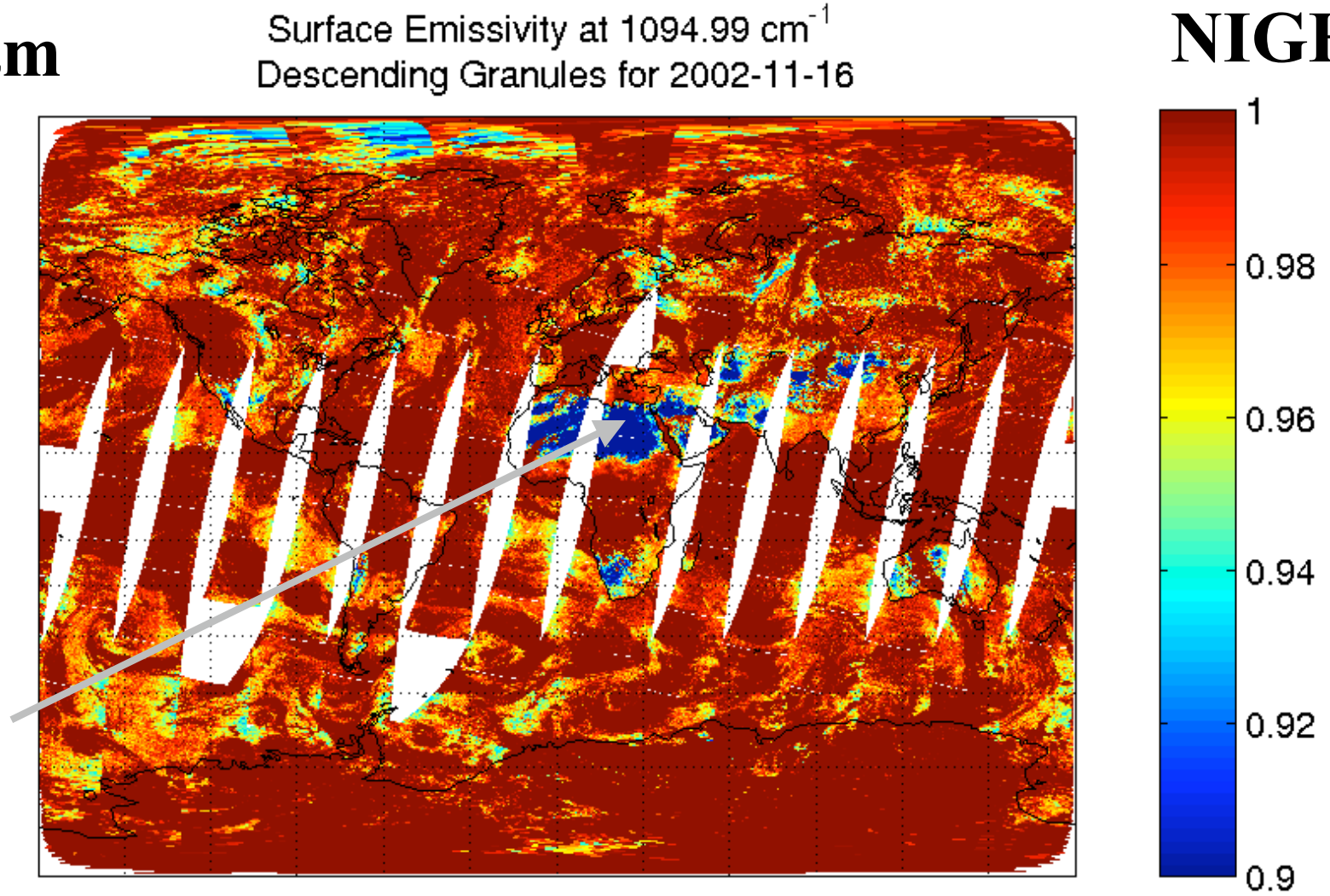
9 μm



AIRS Focus Day: 16 November 2002 --Ascending

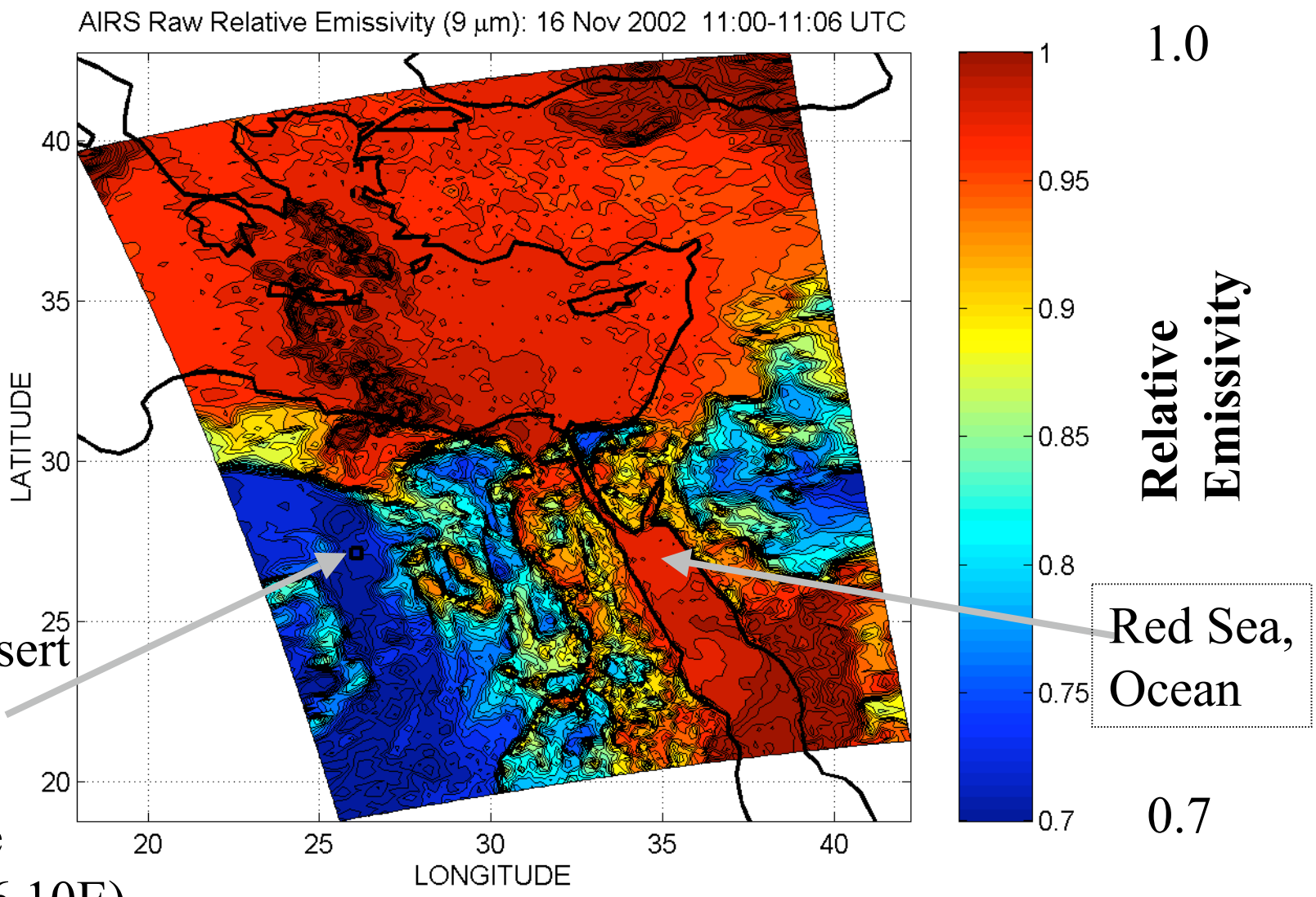
AIRS Spectral Relative Emissivity

9 μm



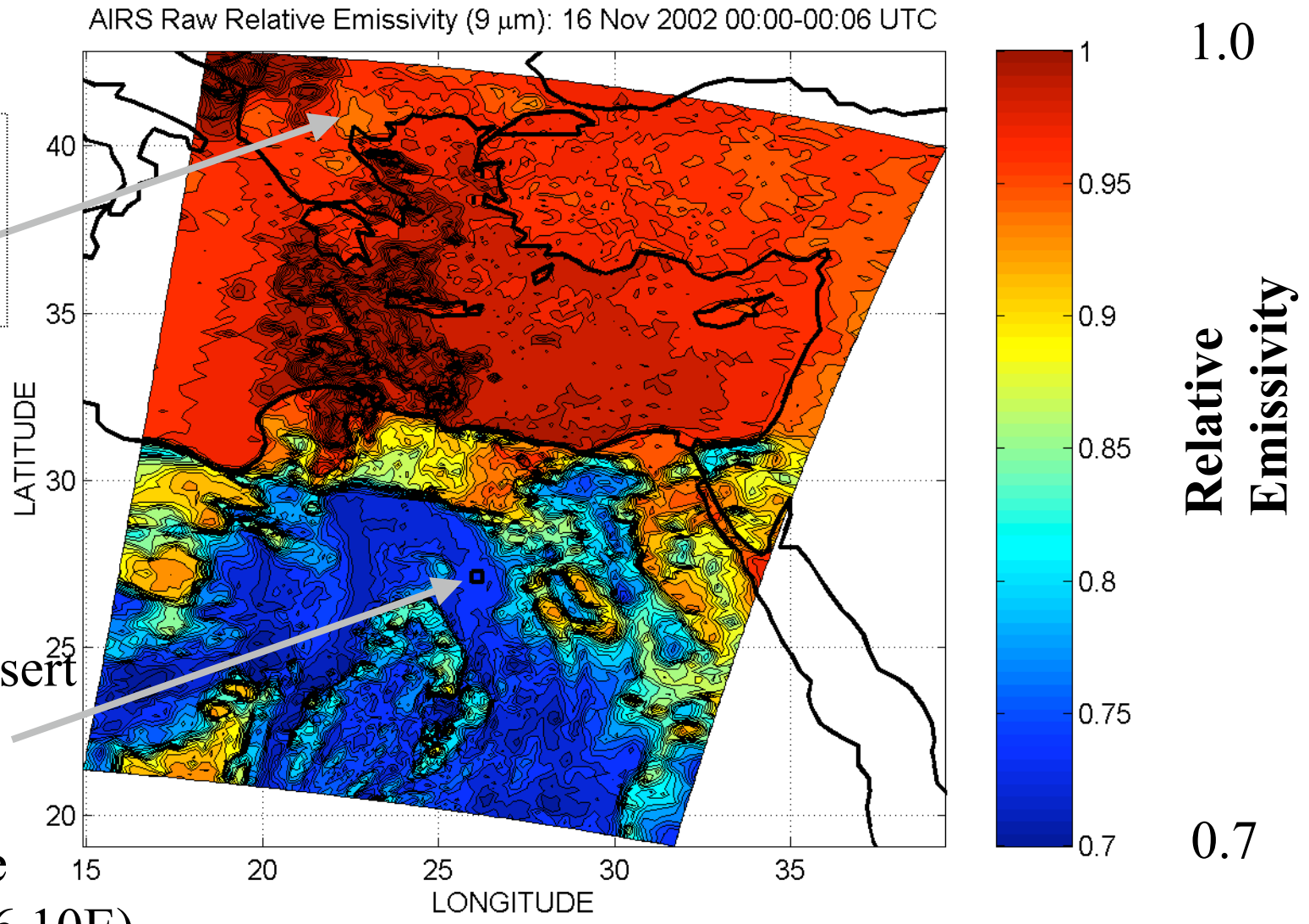
AIRS Focus Day: 16 November 2002 --Descending

DAY -- 9 μm relative to 12 μm



16 November 2002 11:00-11:06 UTC (15-km FOV)

NIGHT -- 9 μm relative to 12 μm

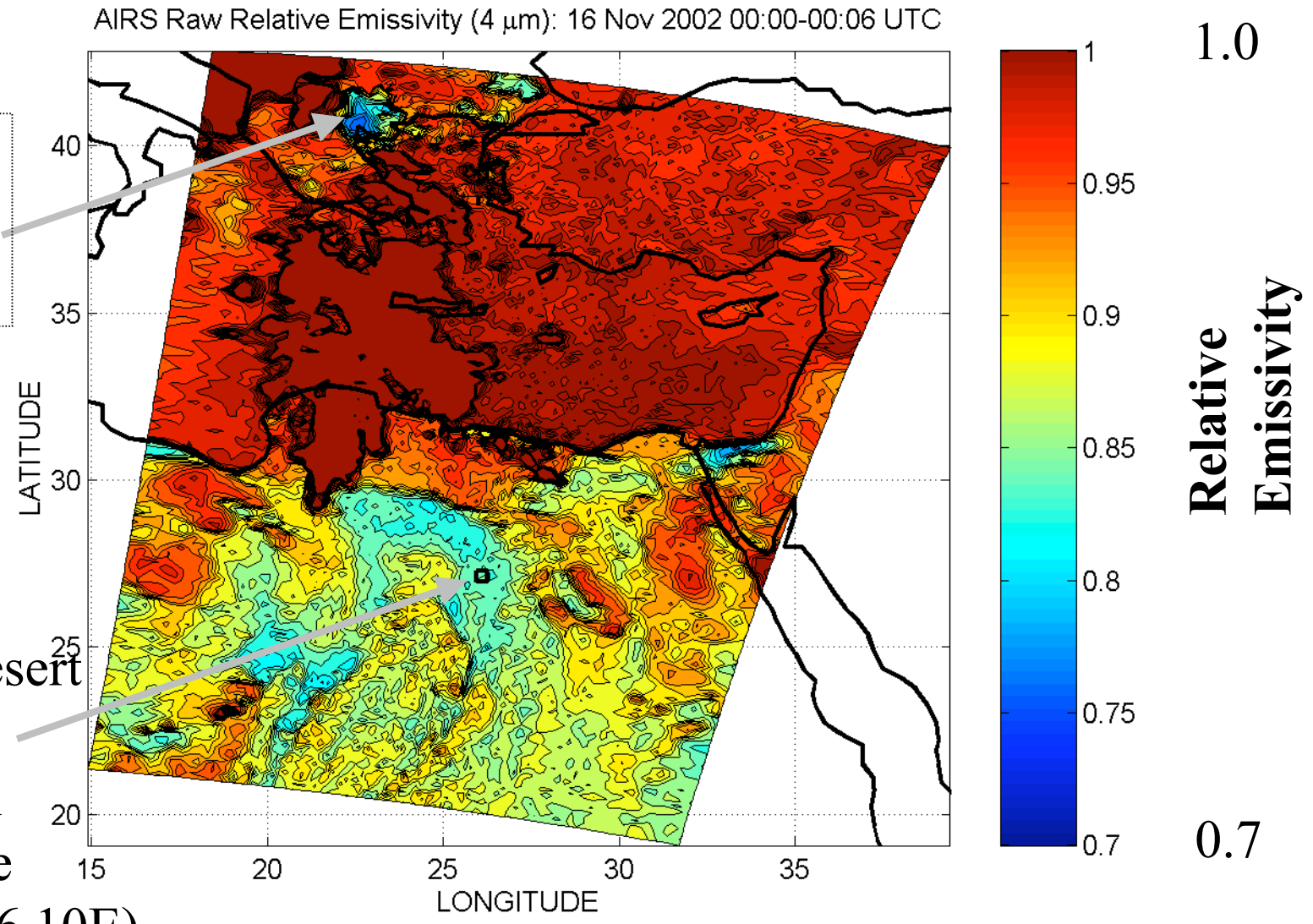


Thessaly Plain, Greece

Libyan Desert Satellite Validation Target Site (27.12N,26.10E)

16 November 2002 00:00-00:06 UTC (15-km FOV)

NIGHT -- 4 μm relative to 12 μm

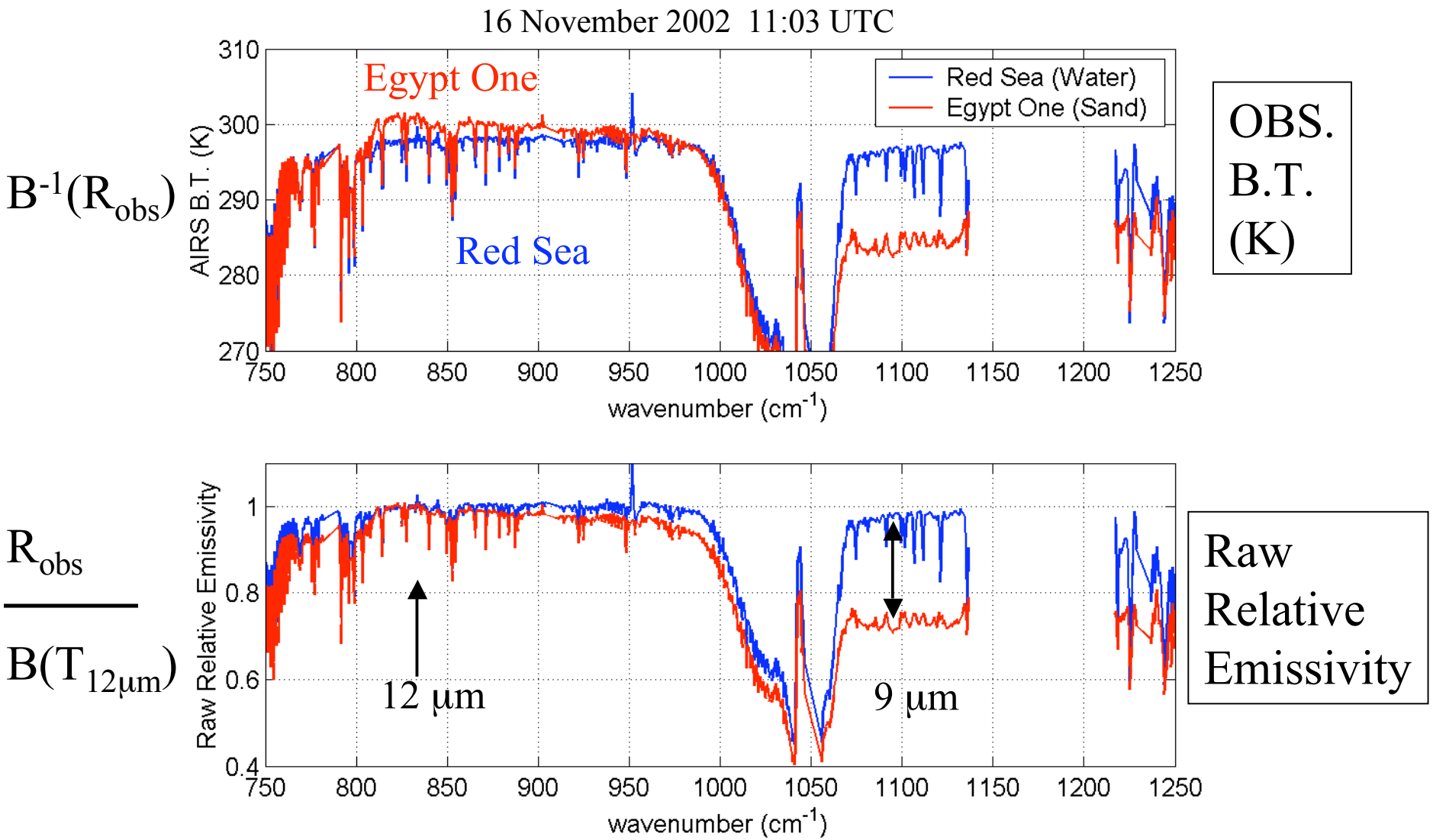


Thessaly Plain, Greece

Libyan Desert Satellite Validation Target Site (27.12N,26.10E)

16 November 2002 00:00-00:06 UTC (15-km FOV)

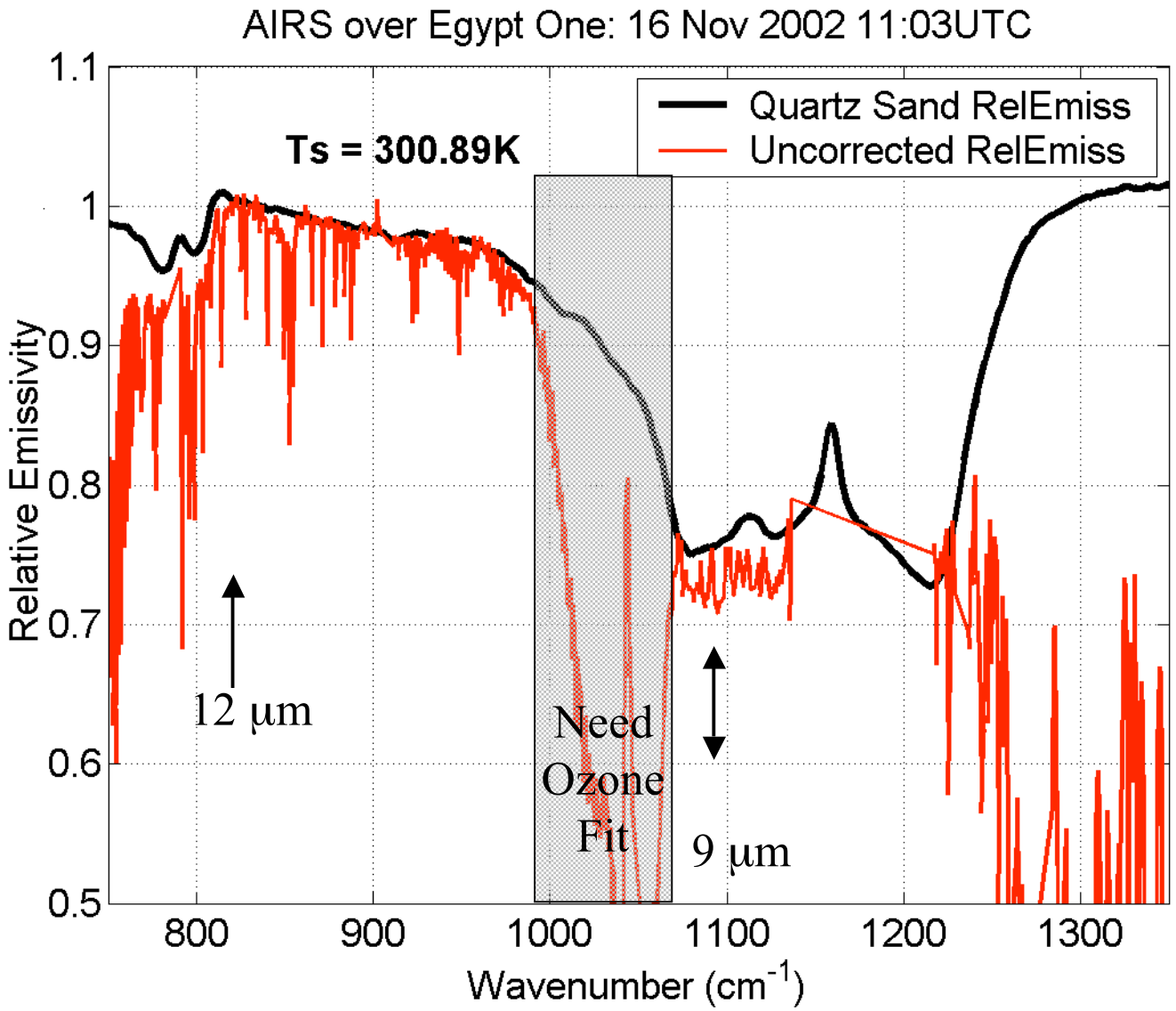
AIRS Spectral Relative Emissivity: Egypt One



- Relative emissivity is derived only from AIRS radiances.

AIRS Spectral Relative Emissivity: Egypt One

$$\frac{R_{obs}}{B(T_{12\mu m})}$$



Raw Relative Emissivity

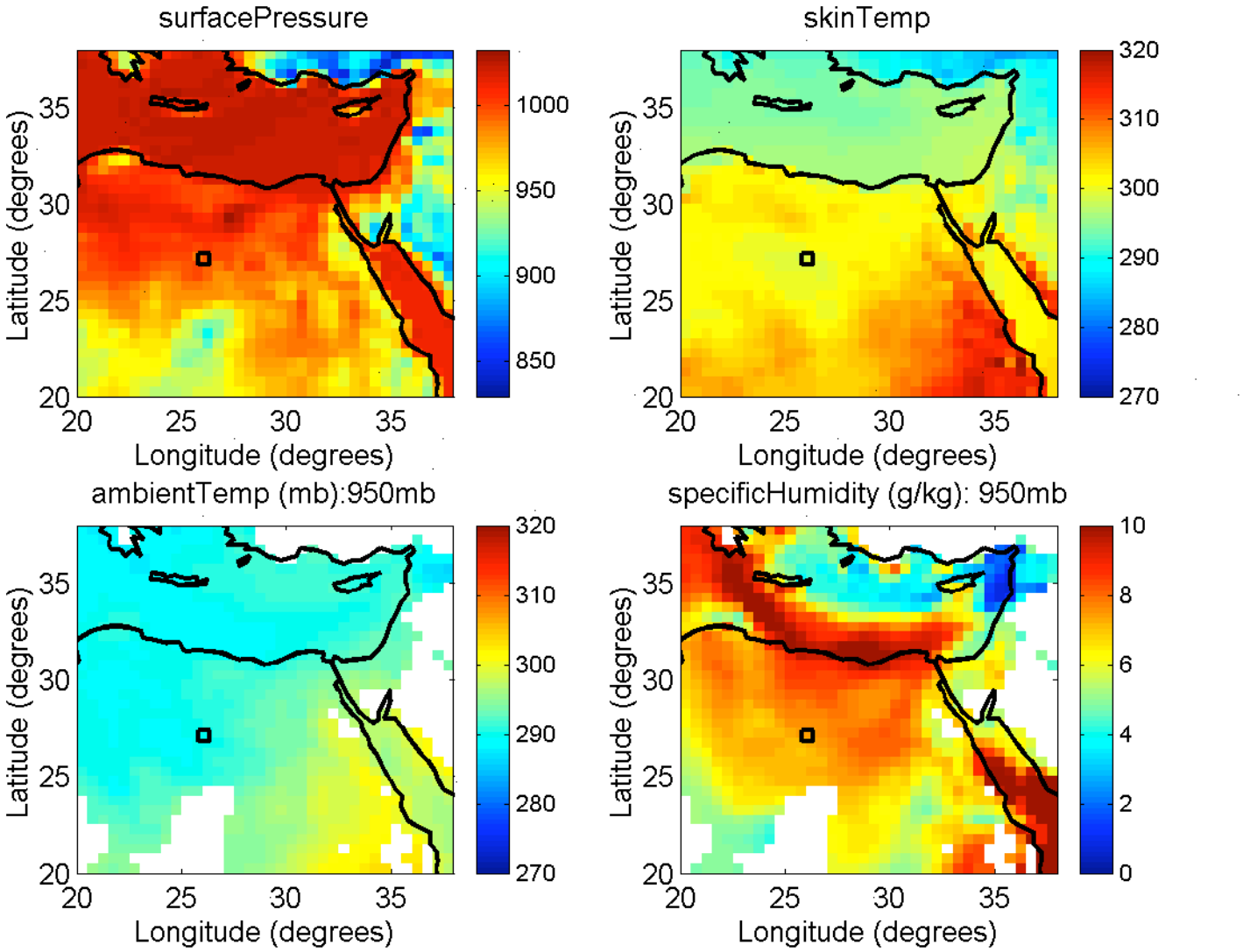
- Quartz reflectivity features are apparent in the desert case.

AIRS Relative Emissivity and Temperature with Atmospheric Correction

16 November 2002

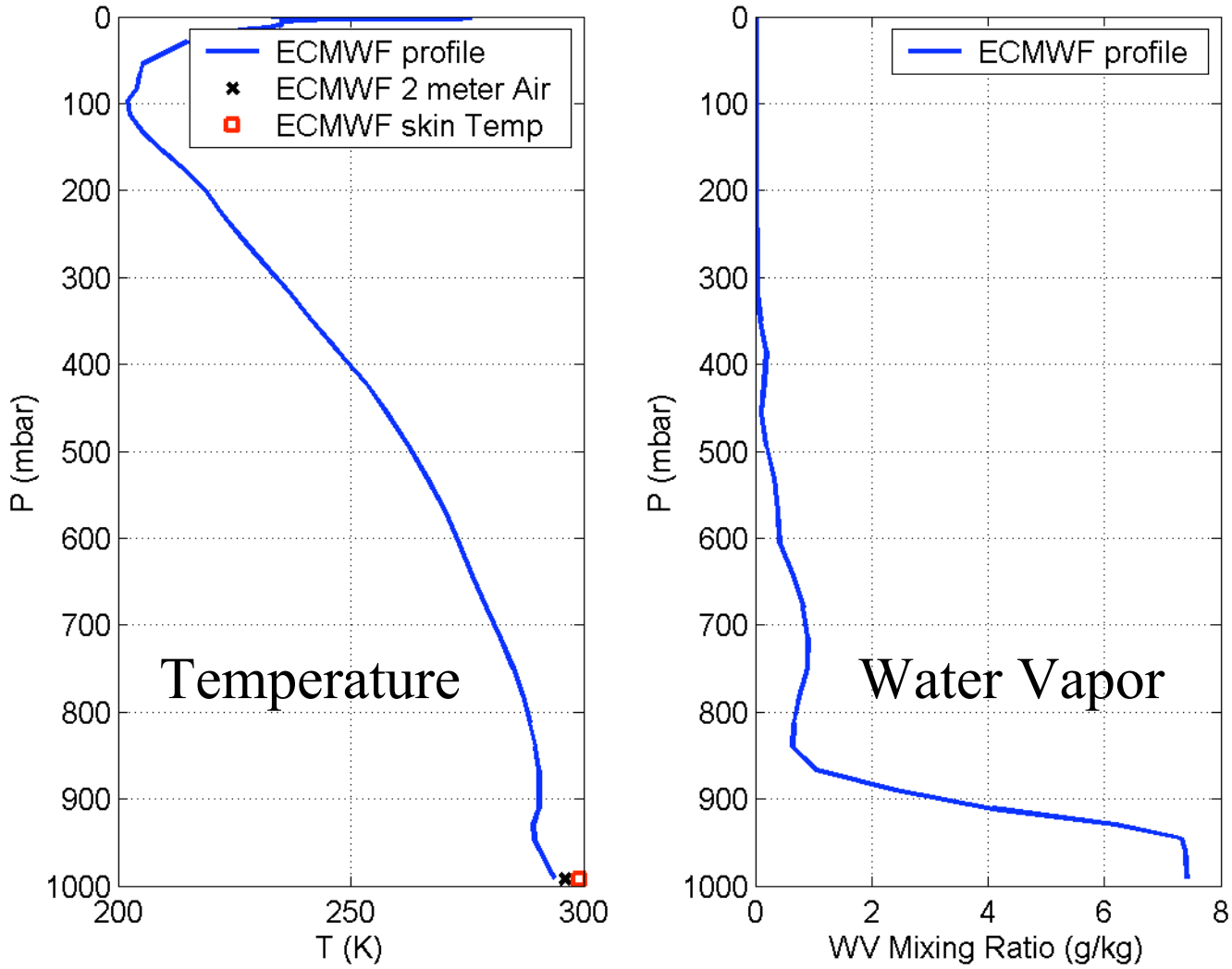
Focus Day

ECMWF Analysis: 16 Nov. 2002 12 UTC



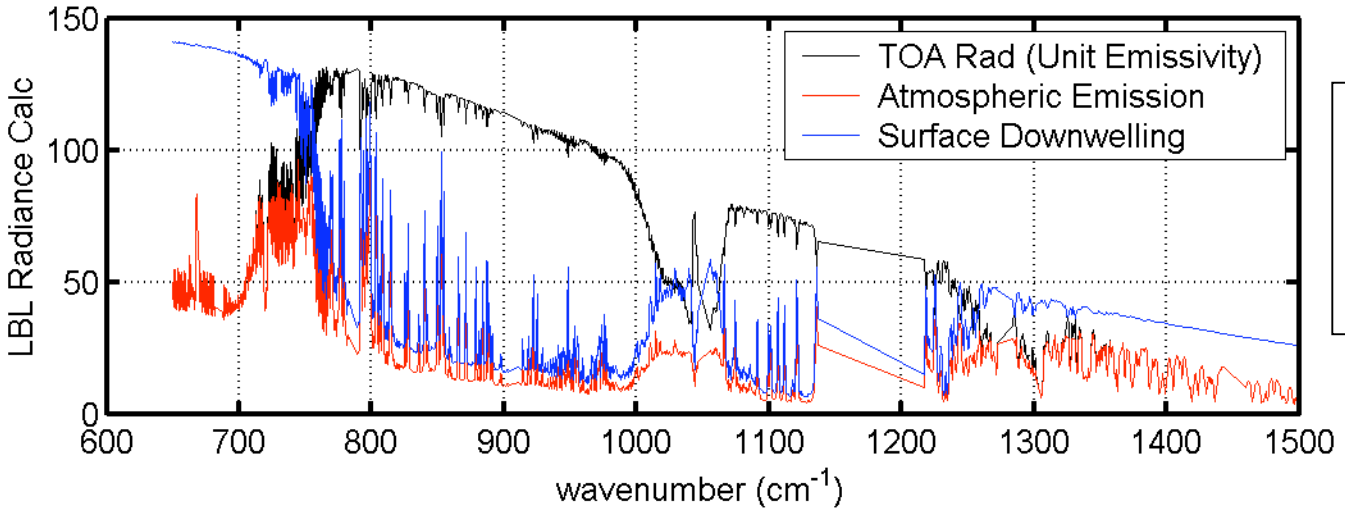
- Square symbol marks Egypt One site in Libyan Desert

ECMWF Analysis: 16 Nov. 2002 12 UTC

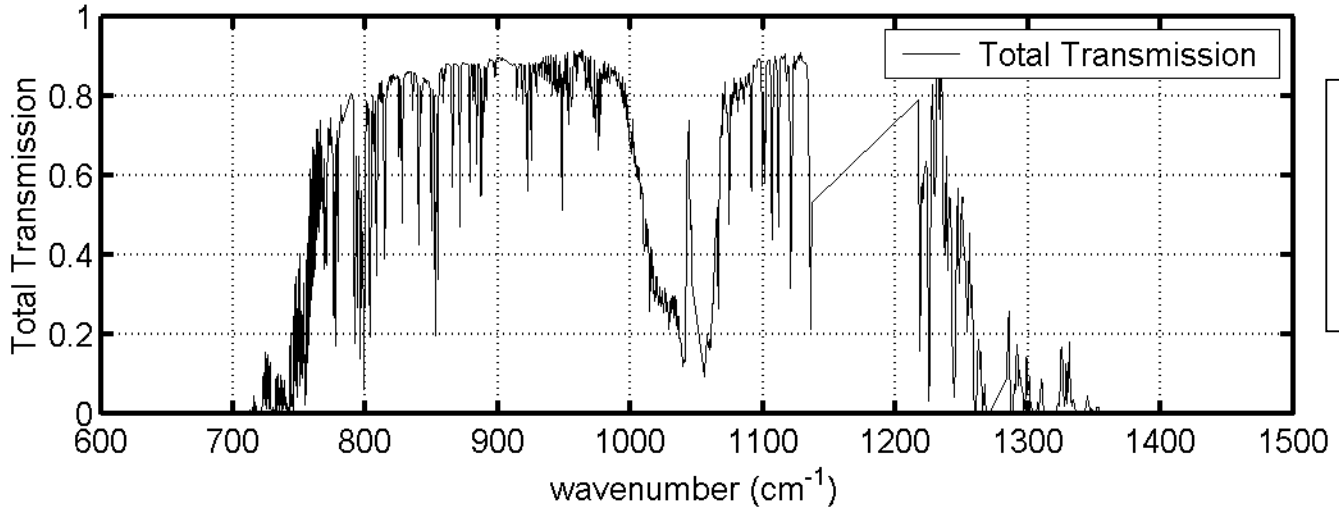


- ECMWF profile over Egypt One site in Libyan Desert

LBL Calculation Using ECMWF Model Profile



Up Down Radiance

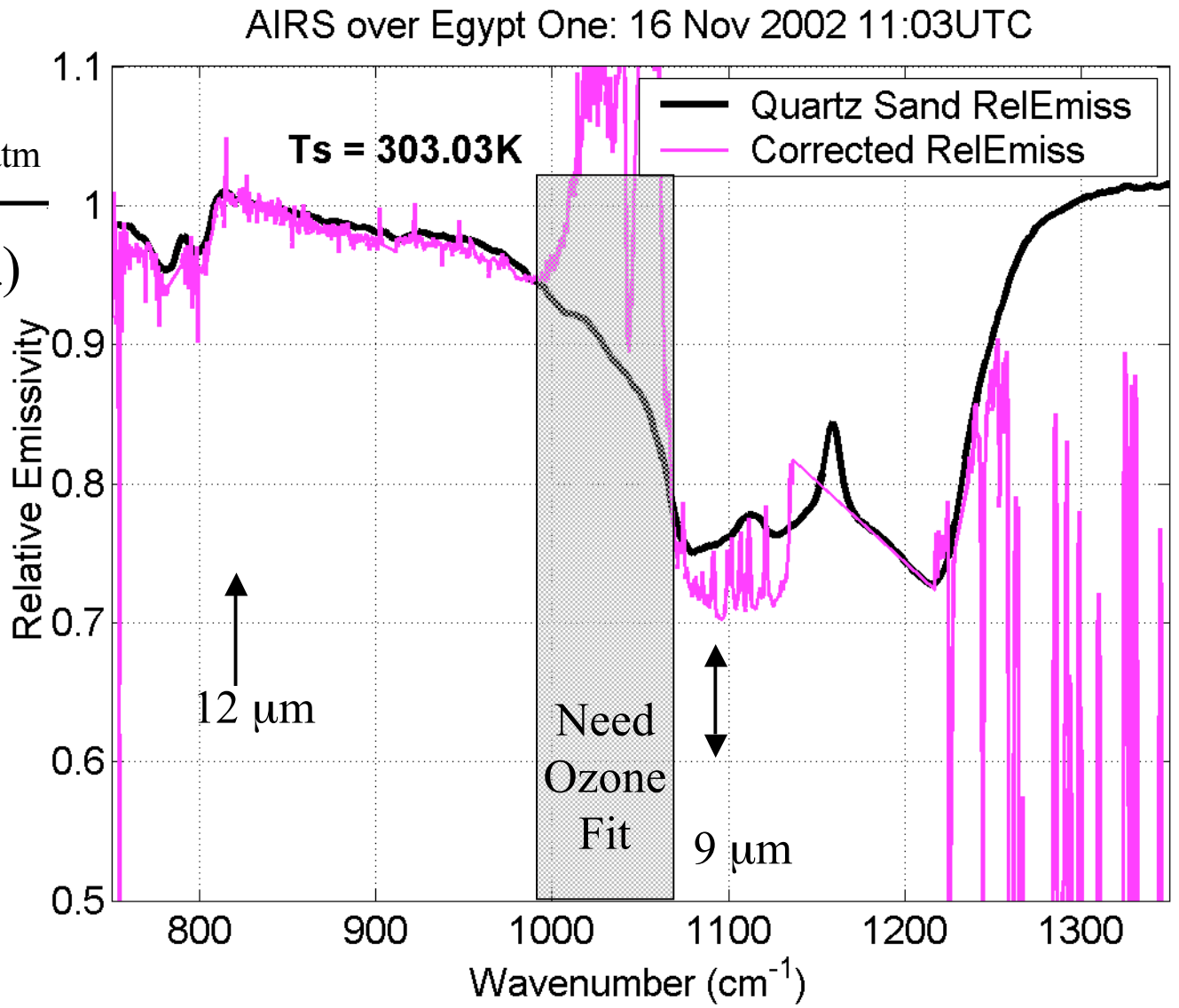


Total Trans-mission

- LBLRTM calculations reduced to AIRS spectral resolution.

AIRS Atmosphere Corrected Relative Emissivity

$$\frac{R_{obs} - N_{atm}}{\tau\, B(T_{corr})}$$



Atmos. Corrected Relative Emissivity

- Atmospheric Correction uses ECMWF model T & WV profiles.

AIRS Absolute Emissivity and Surface Temperature (including Surface Reflection)

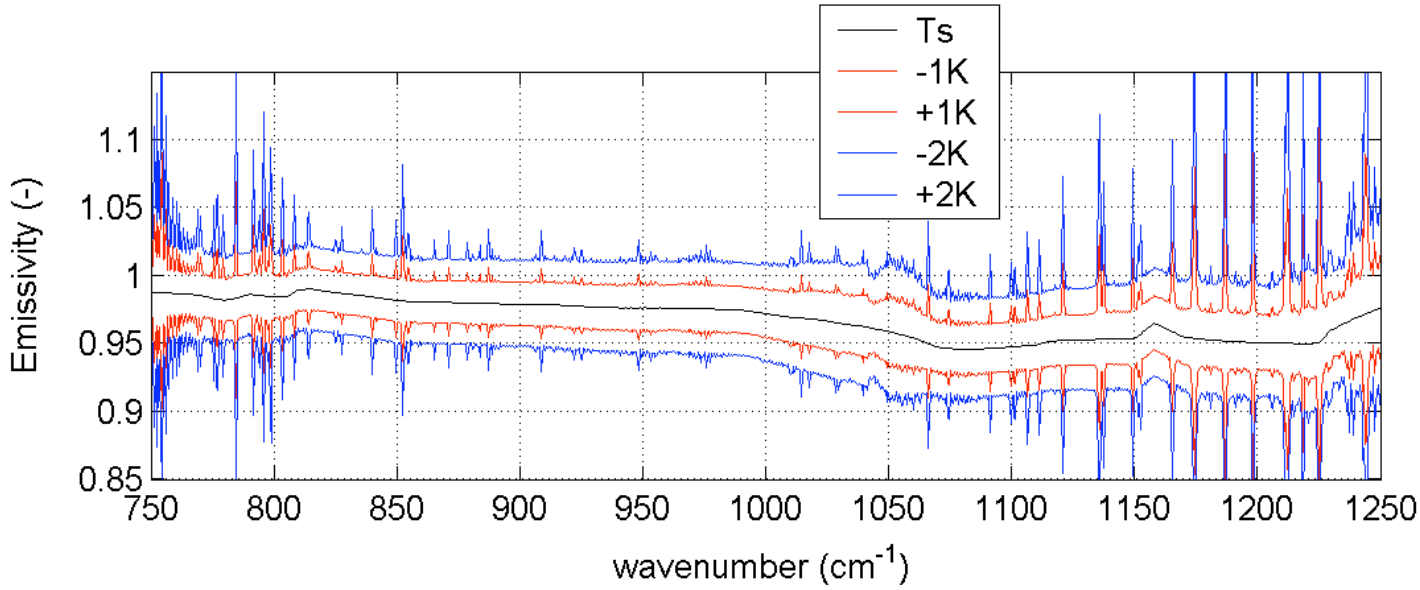
16 November 2002

Focus Day

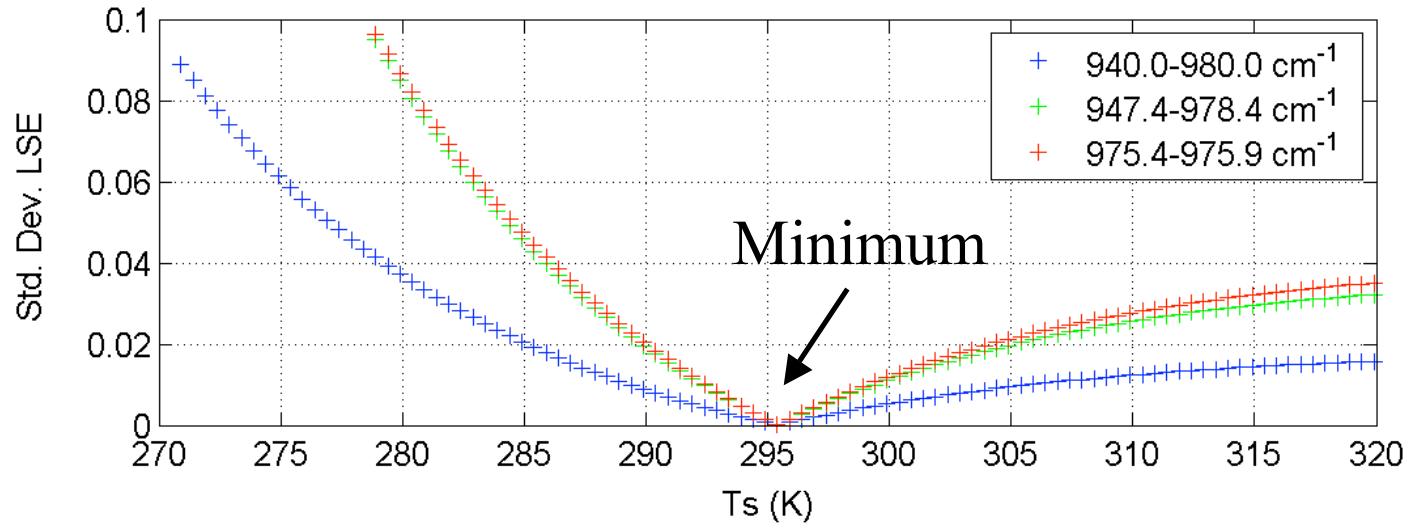
Technique follows that described in Knuteson, et al., Adv. Space Res., 33 (2004) 1114-1119.

Constraint: Emissivity solution should be smoothly varying across atmospheric absorption lines!

E_ν



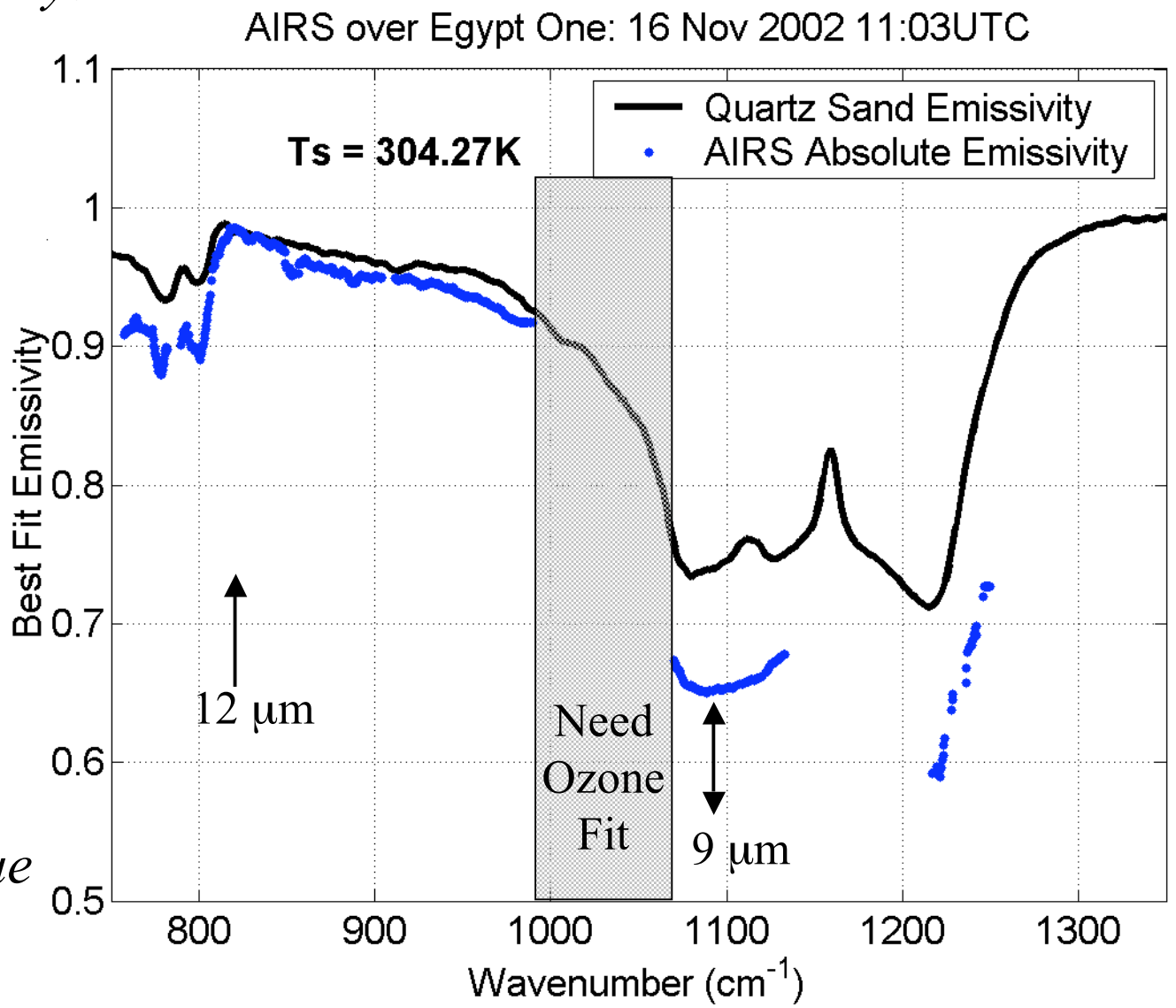
Std. Dev. E(Ts)



- Minimum Std. Deviation is at the true <u>skin temperature</u> !!

Preliminary!

AIRS Absolute Emissivity



UW Online-Offline Technique

AIRS Observ. & JPL Spectral Library Alluvial Sand

- Reflection calculation uses ECMWF model T & WV profiles.

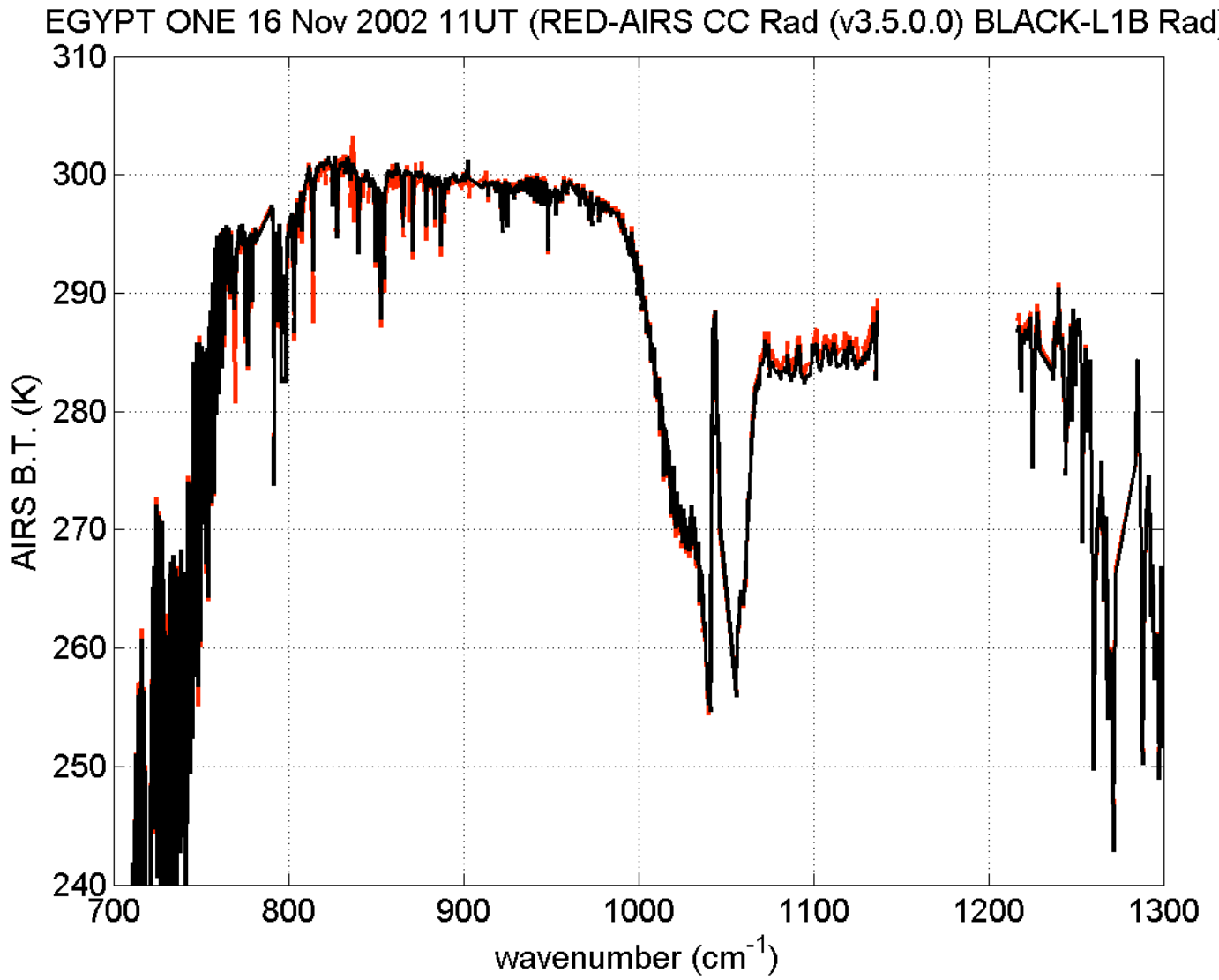
AIRS Cloud Cleared Radiance and IR Emissivity Product Validation

16 November 2002

Focus Day

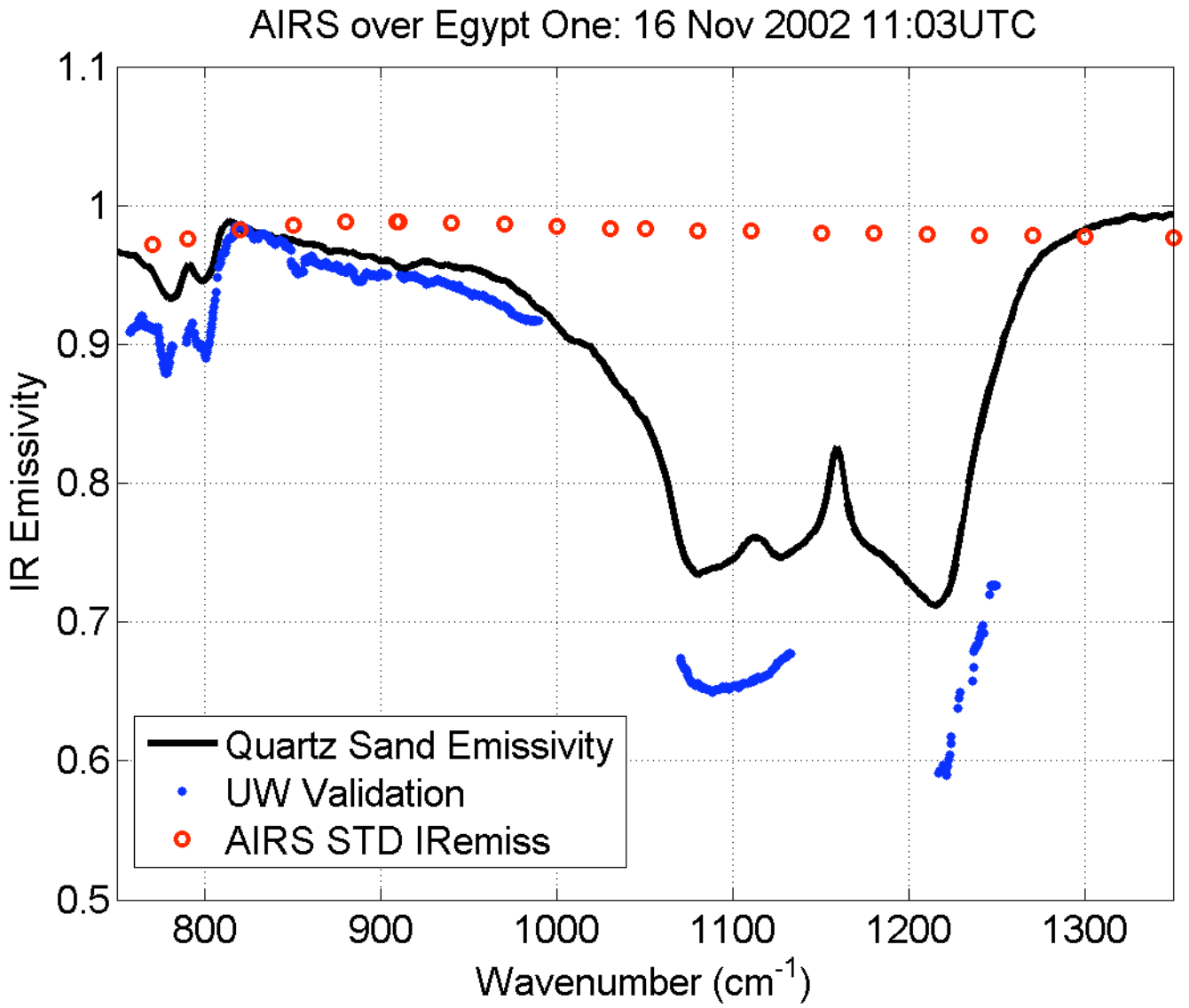
***NOTE**: PGE Version 3.5.0.0 was a beta version used in testing only! (AIRS.2002.11.16.001.L2.RetStd.v3.5.0.0.Test3_5_0.T04058043022.hdf)*

Validation of AIRS Cloud Radiance Product: Egypt One Site



- For uniform desert scenes the AIRS CC radiances agree with L1B

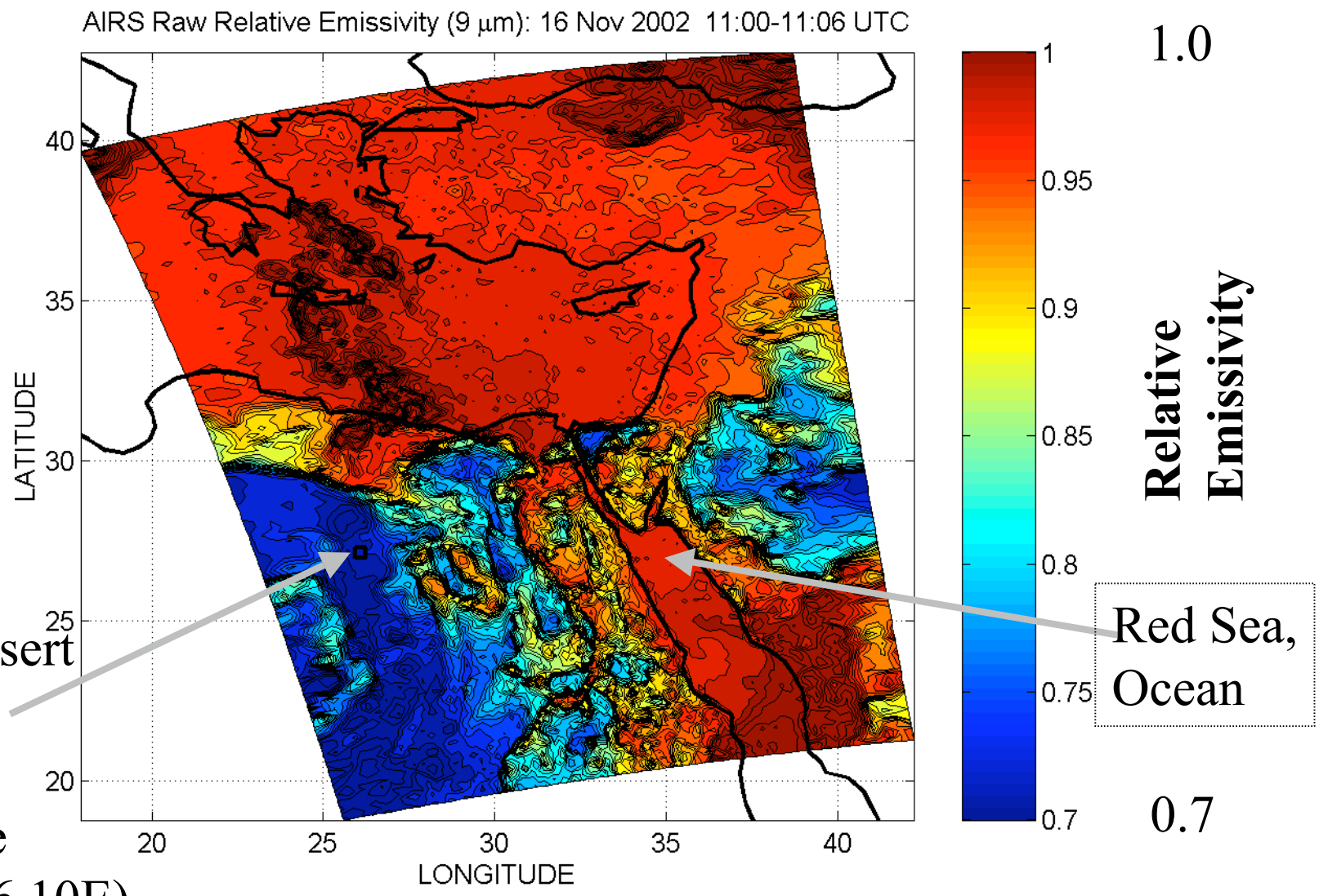
Validation of AIRS IR Emissivity Product: Egypt One Site



- The AIRS Std IRemiss (v3.5.0.0) is fixed to “ocean” conditions.

DAY -- 9 μm relative to 12 μm

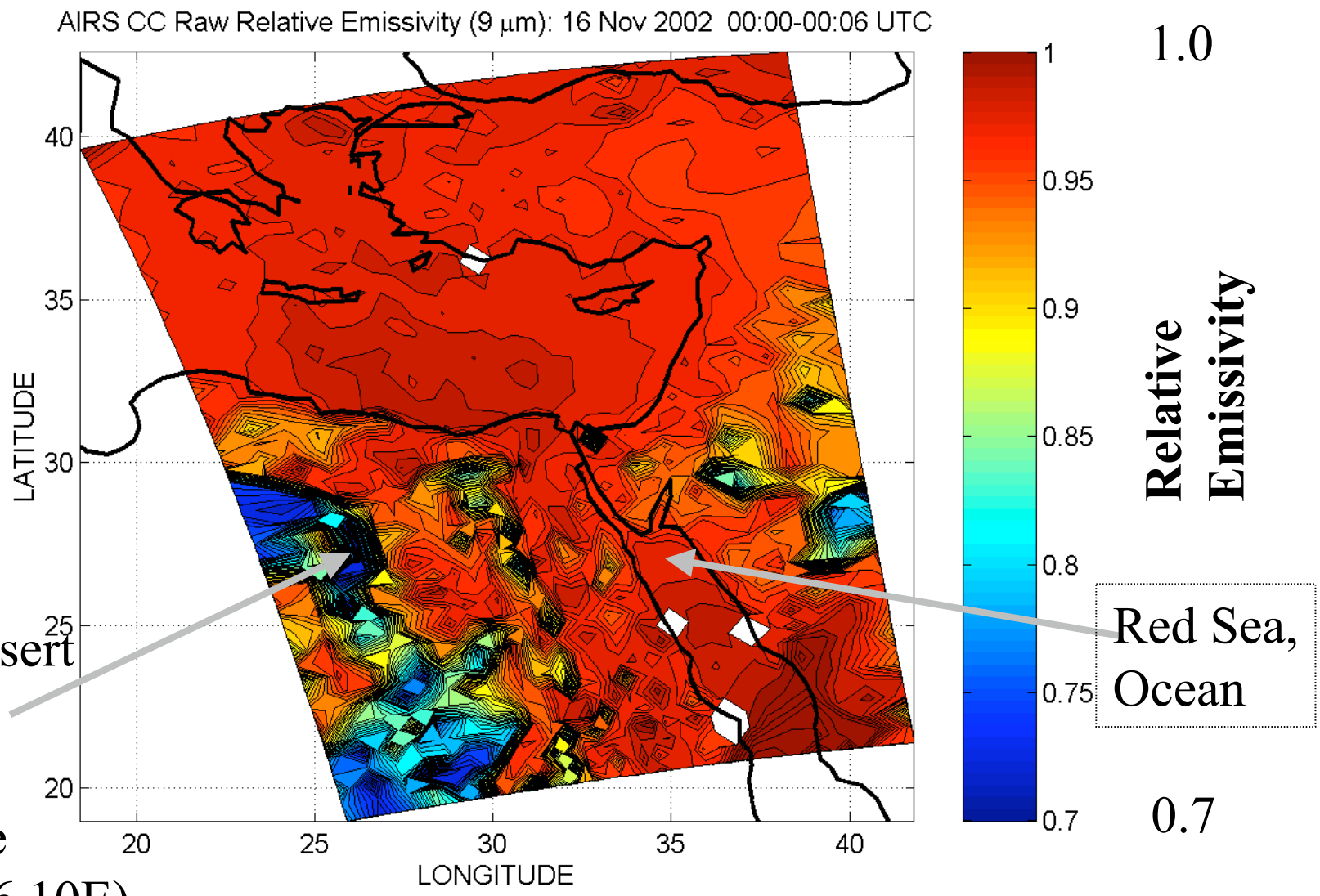
AIRS L1B Rad.



16 November 2002 11:00-11:06 UTC (15-km FOV)

DAY -- 9 μm relative to 12 μm

AIRS MW-CC Rad.

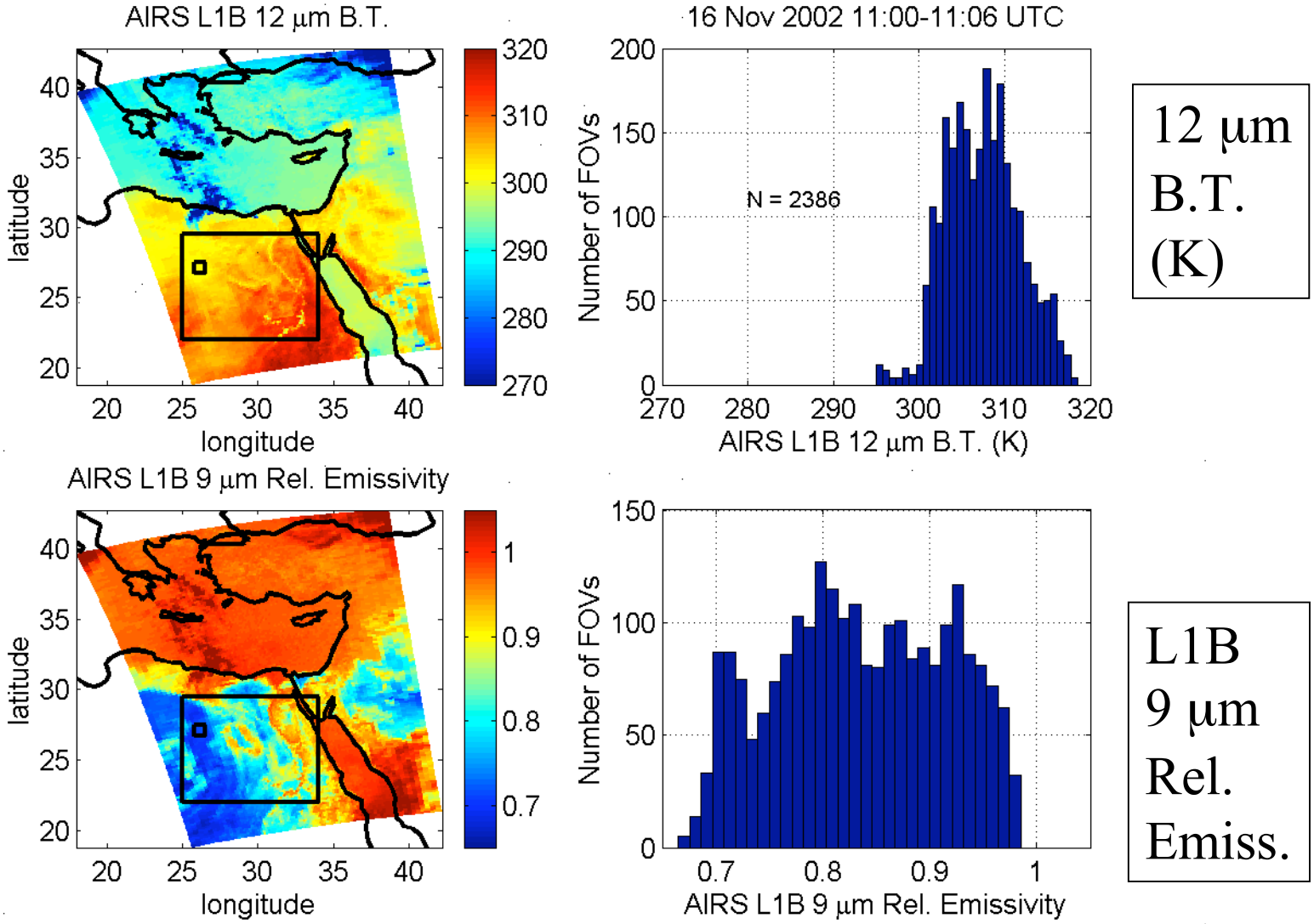


Libyan Desert Satellite Validation Target Site (27.12N,26.10E)

Red Sea, Ocean

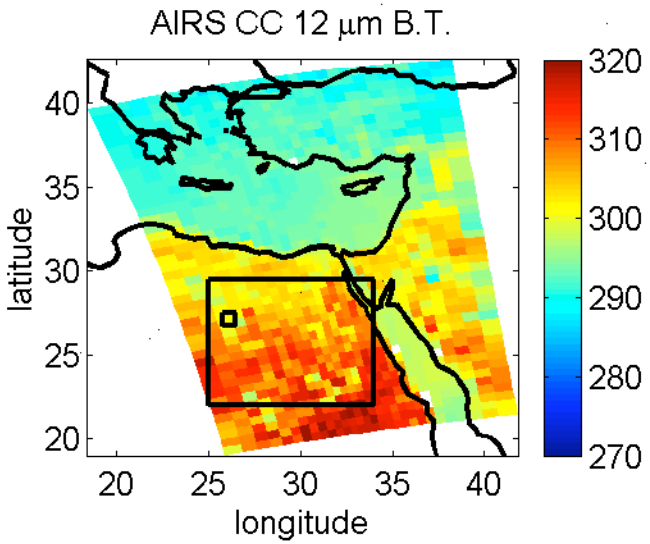
16 November 2002 11:00-11:06 UTC (15-km FOV)

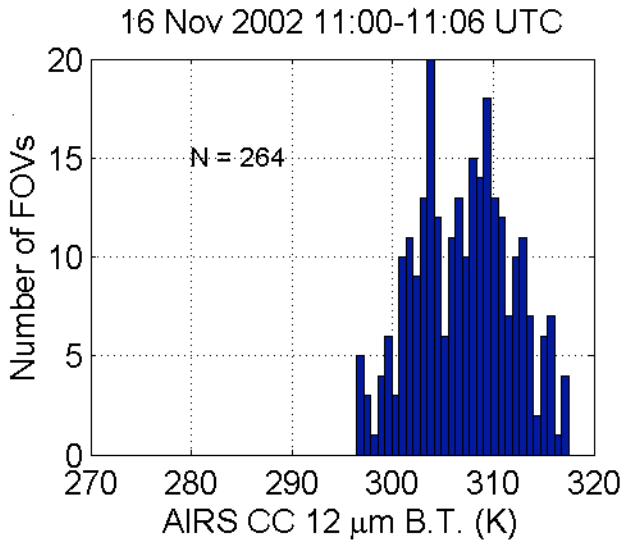
AIRS L1B Observation: 16 Nov 2002 11 UT (DAYTIME)



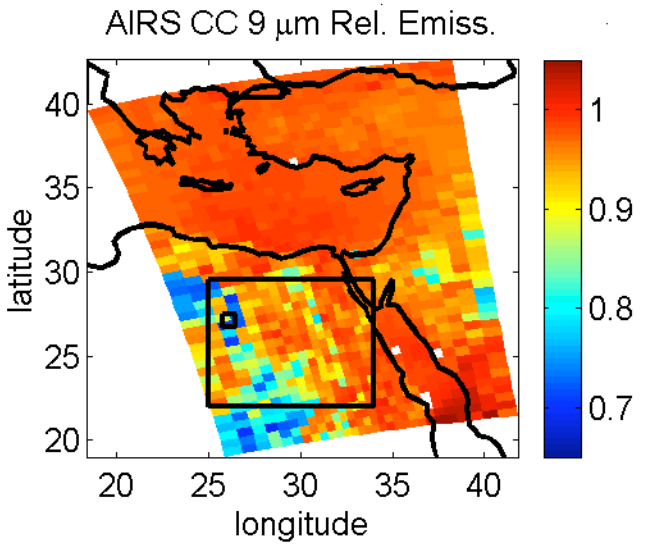
- AIRS L1B shows large variations in Relative Emissivity.

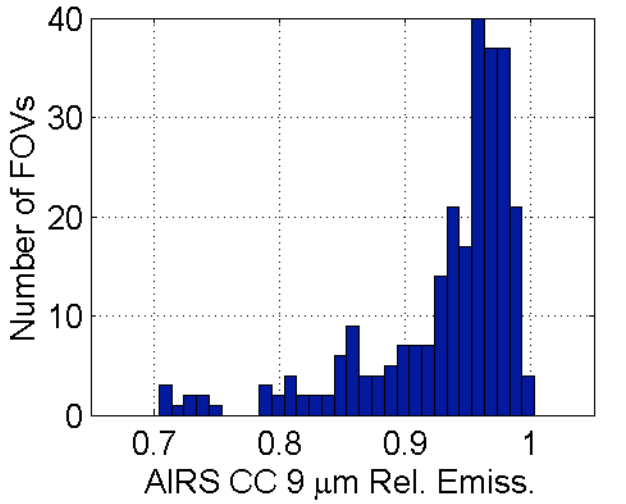
AIRS MW-CC Radiance





12 μm B.T. (K)

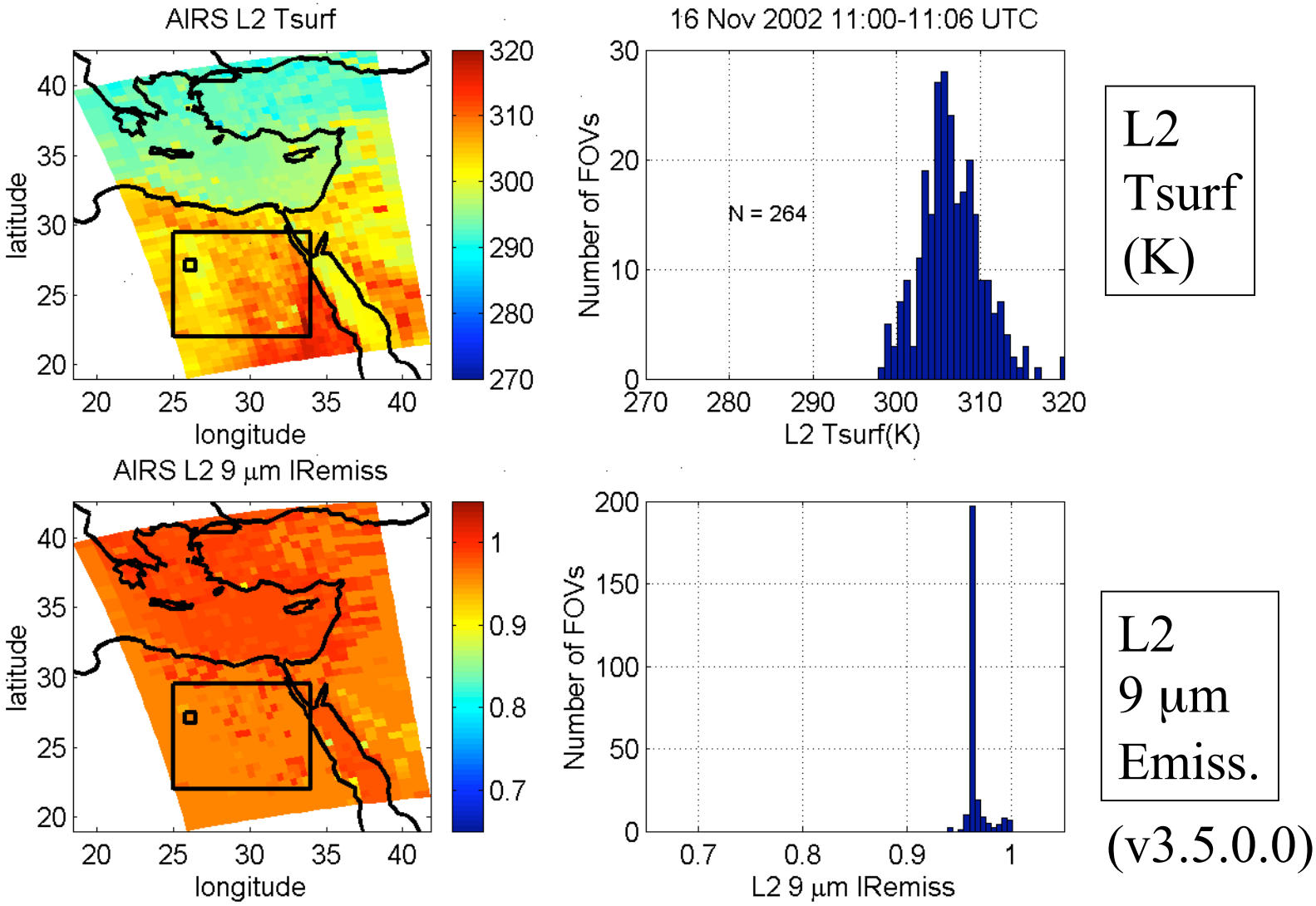




MW-CC 9 μm Rel. Emiss. (v3.5.0.0)

- MW-CC algorithm "clears" the desert IR surface emissivity!

AIRS L2 Products



- "Old" algorithm retrieves a nearly constant emissivity.

Case Study: Libyan Desert

- In the vegetated coastal zone the MW-CC radiances seem to remove clouds as well as the nearby ocean scenes.
- Even in clear sky scenes over the desert the MW-CC algorithm interprets the variation on the 3x3 IR grid as clouds and "clears" the land surface emissivity spectral signal, effectively removing it. (Is this good or bad?)
- Only where the desert sands are uniform on the scale of a 3x3 AIRS grid (about 50 km) does the MW-CC algorithm preserve the land surface IR signature.

- The following slides illustrate these points.

Suggestions for a new AIRS Team Algorithm:

1. Go to an IR only Cloud Clearing algorithm over land. Avoid Microwave uncertainties over land.

2. Use only FOV "pairs" in the Cloud Clearing that have the same land surface emissivity characteristics, as determined from a priori information.

3. Create a special IR emissivity product that captures the signals seen in the L1B data.

4. Upgrade the RTA (fast model) to include an accurate surface reflection model.

Role of Land Surface Validation:

1. Determine when CC radiances work and when they don't work.

2. Create validation datasets over land that can be used by researchers to develop improved algorithms that work over land.

3. Validation algorithms point the way toward algorithms that make use of the reflected IR surface contribution to determine both an absolute emissivity and an effective land surface temperature.

MODIS U.S. 16 day Vegetation Index Product

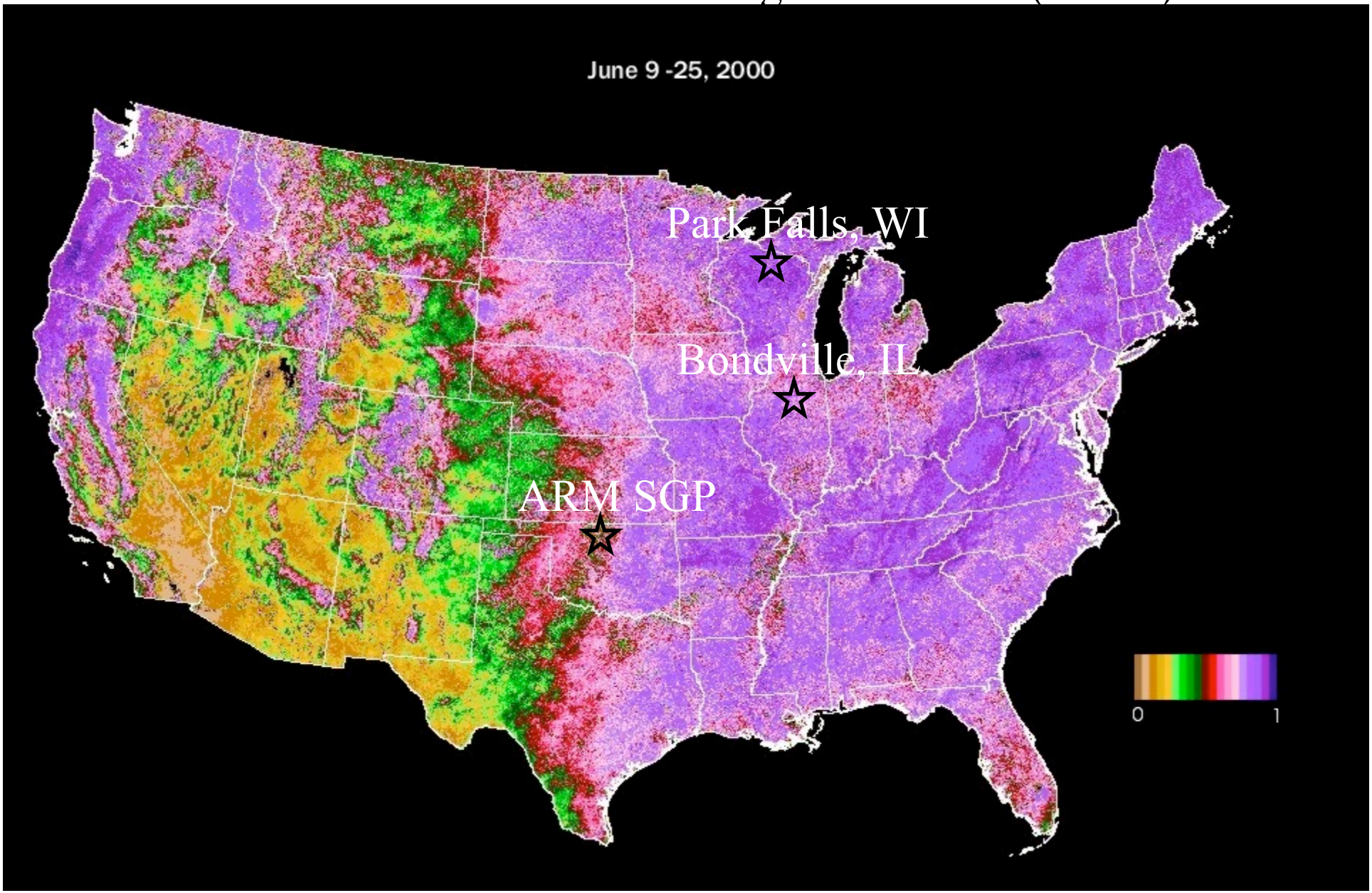
• NDVI is a ratio of the red and near infrared reflectance.

• NDVI is useful for assessing the health and density of vegetation. NDVI values near 0 indicate very sparse vegetation. Dense vegetation is indicated by NDVI values approaching 1. MODIS product is a 16 day composite.

• By using a time-series of NDVI observations, one can examine the dynamics of the growing season and monitor phenomena such as drought (at 250 meter resolution).

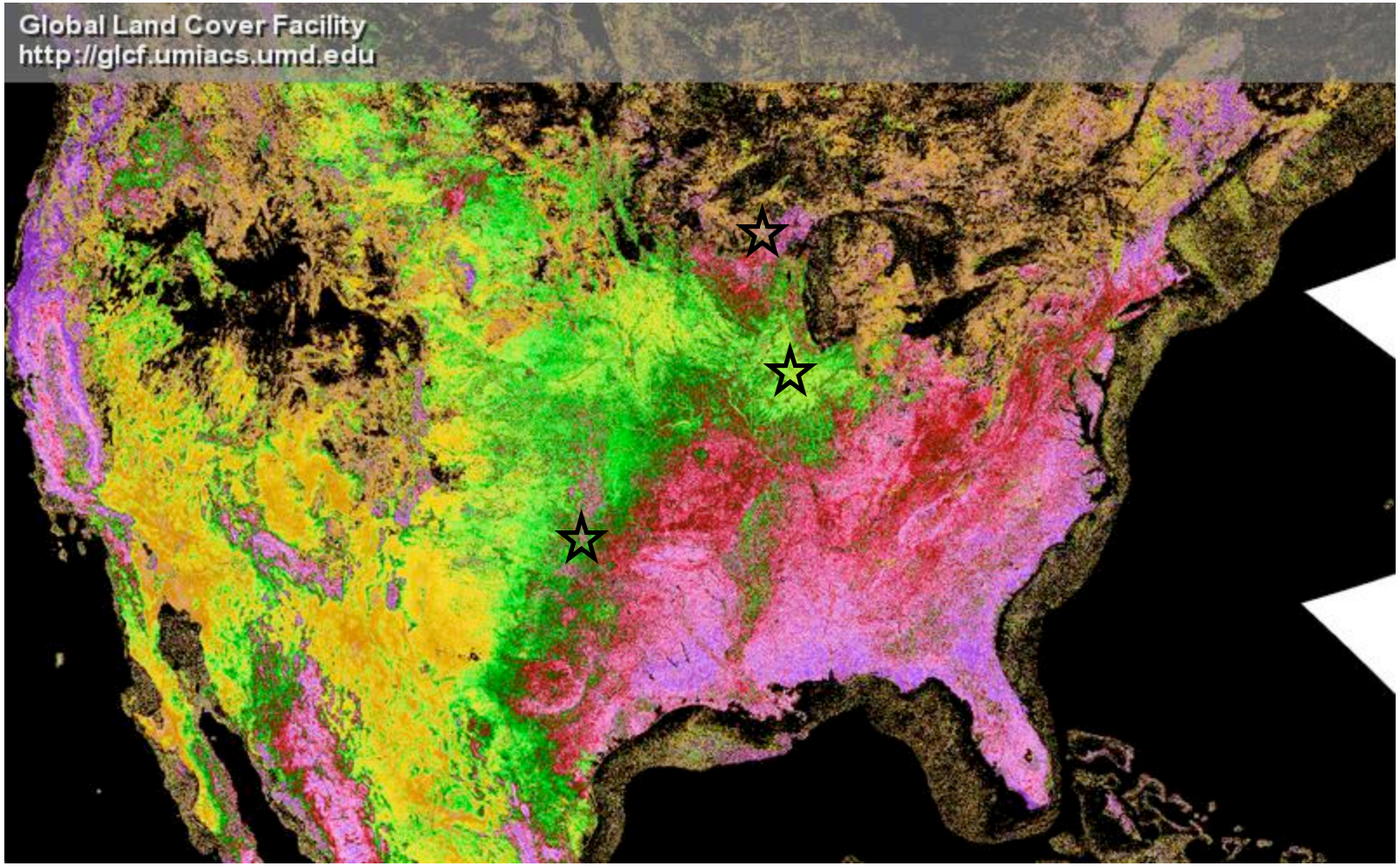
Global Land Cover Facility, University Of Maryland (http://glcf.umiacs.umd.edu/research/)

MODIS Normalized Difference Vegetative Index (NDVI)

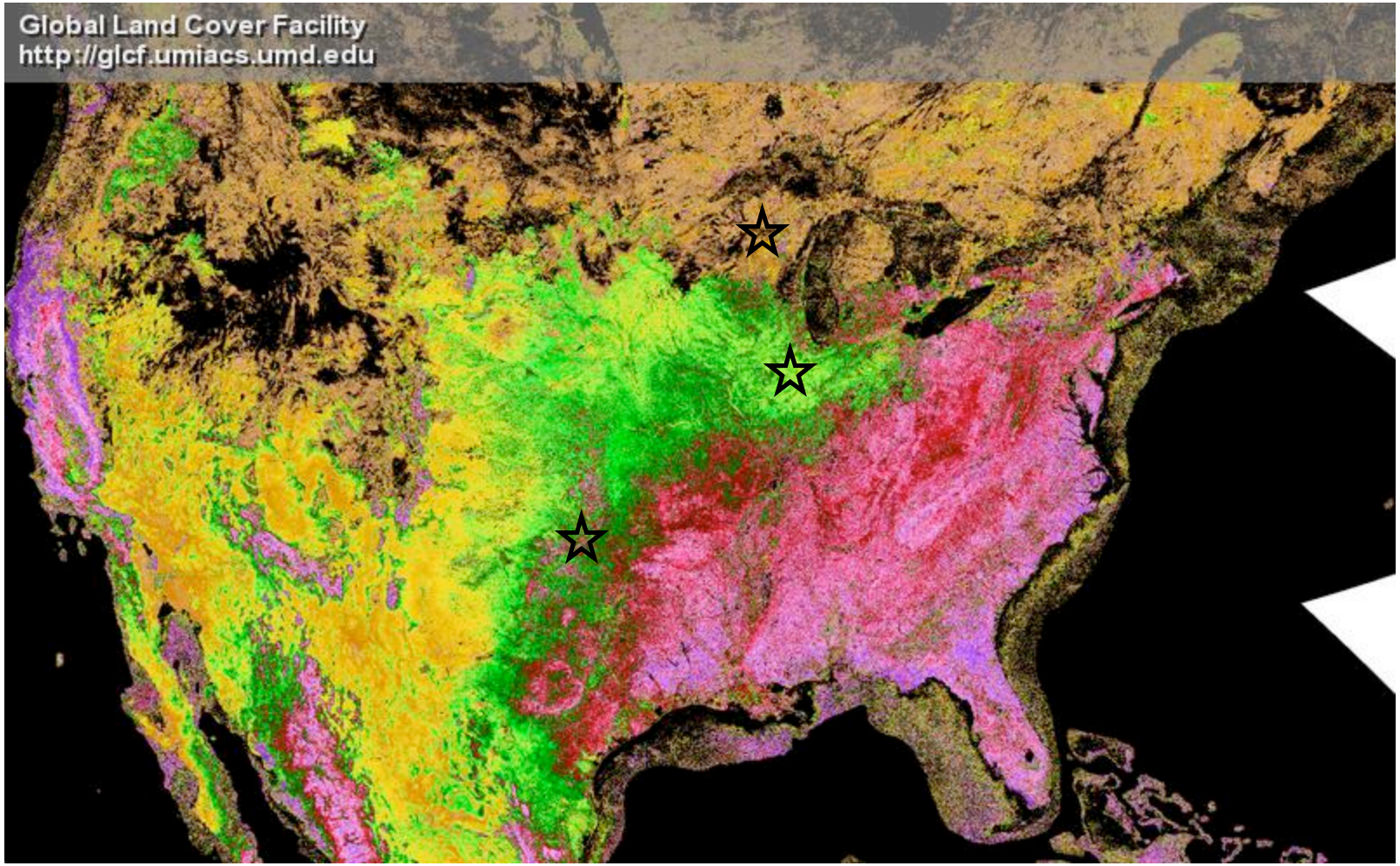


Brown/Green = Sparse Vegetation; Purple = Growing Vegetation

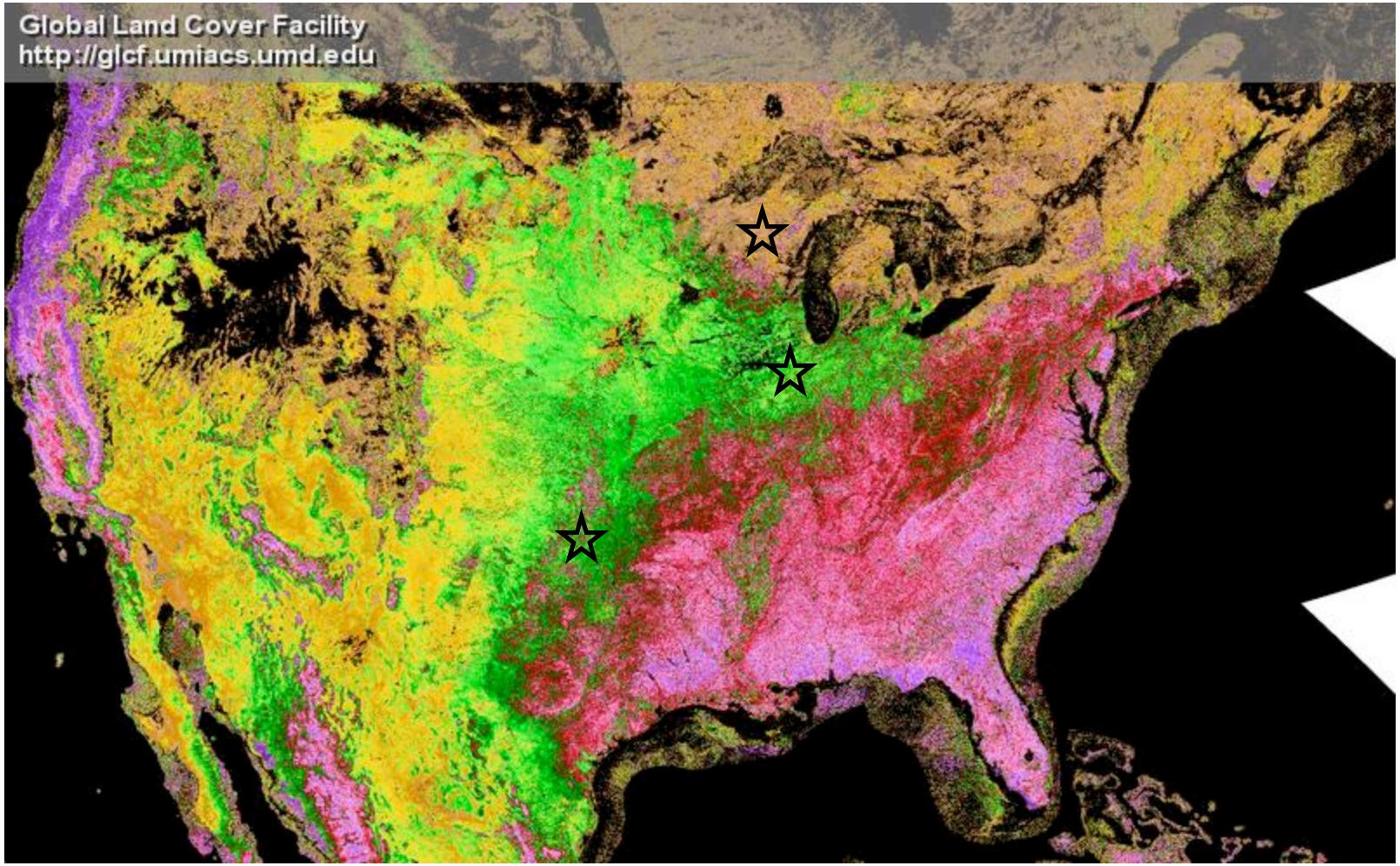
MODIS NDVI 01 JAN – 16 JAN 2002



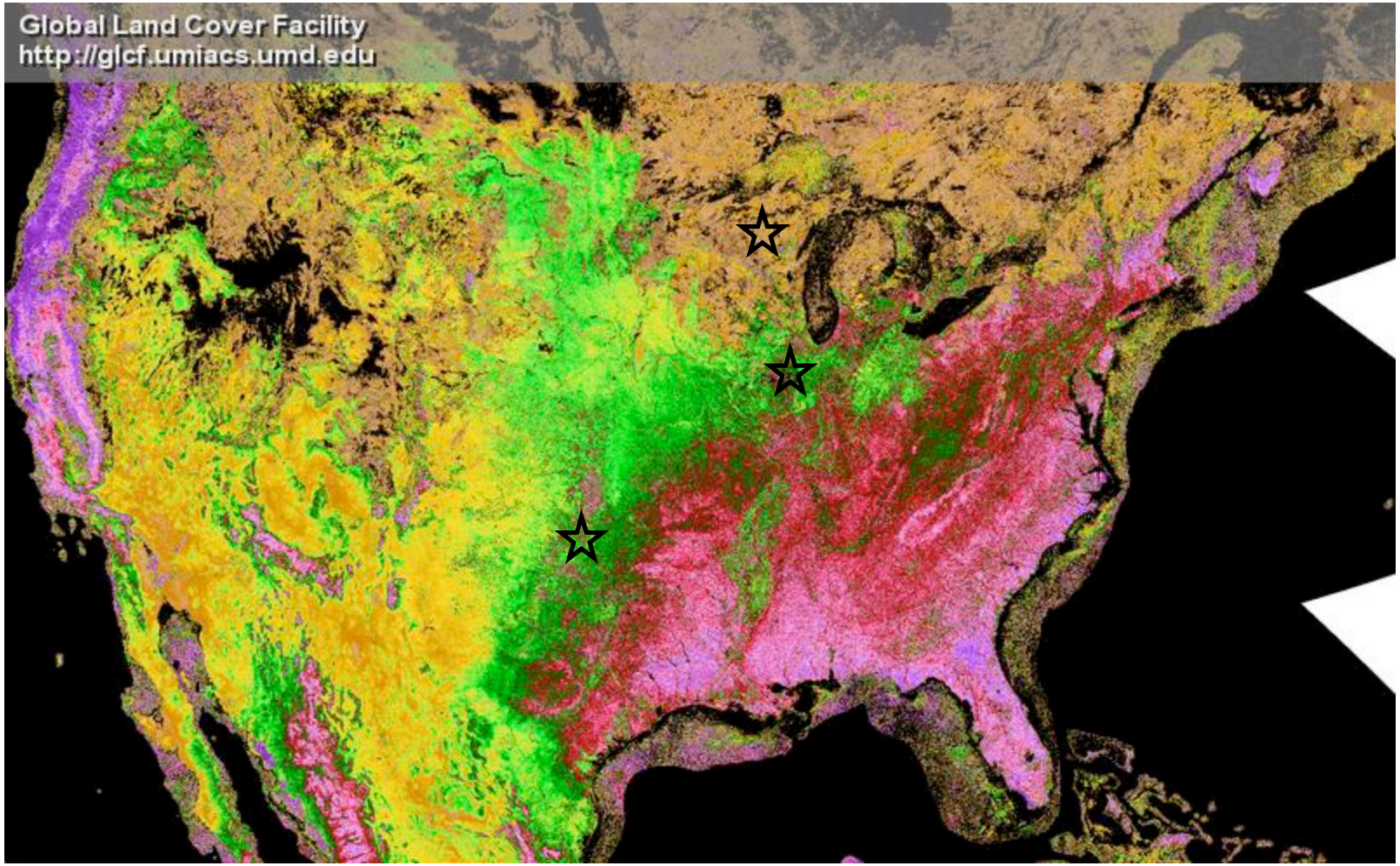
MODIS NDVI 17 JAN – 02 FEB 2002



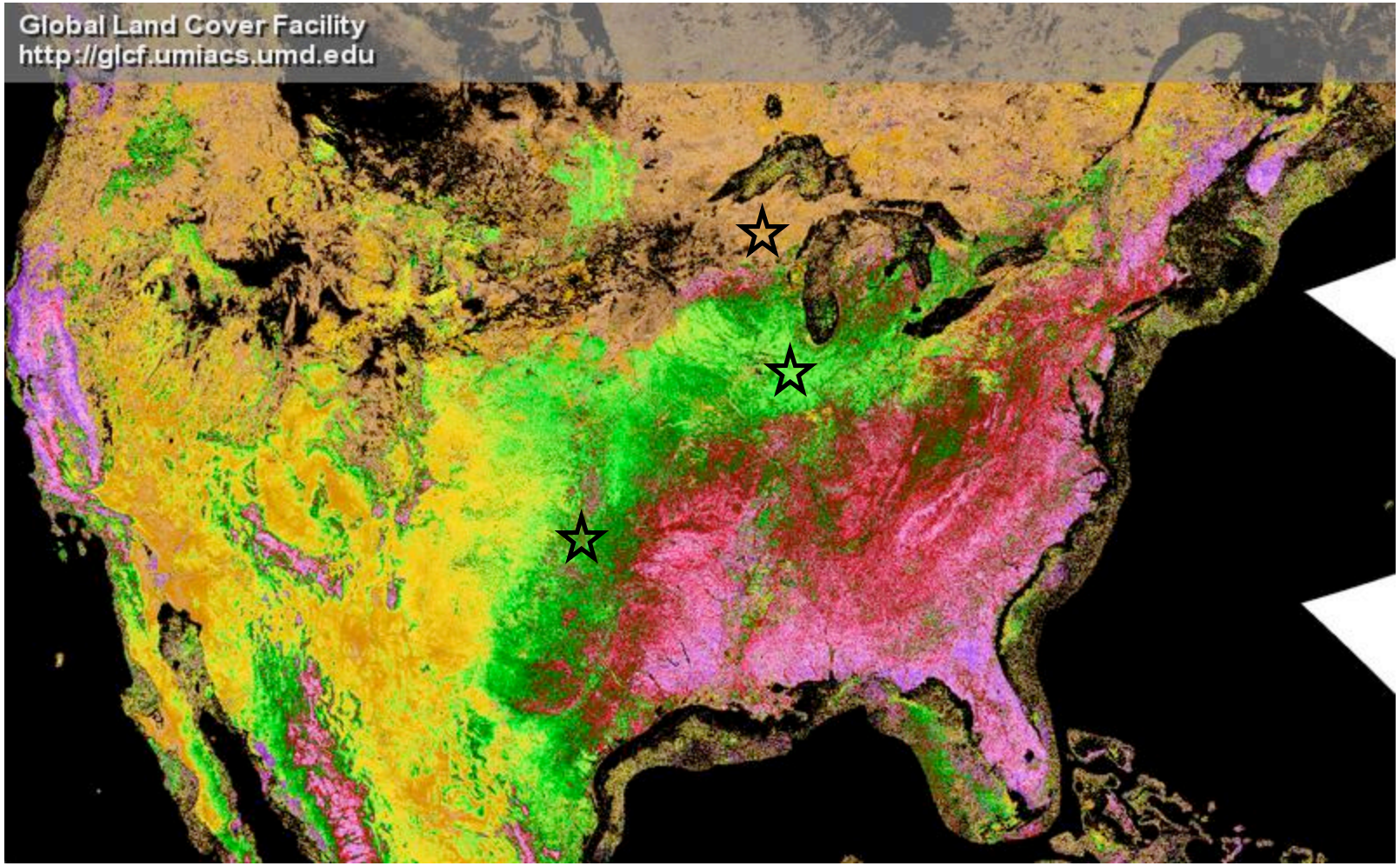
MODIS NDVI 02 FEB – 17 FEB 2002



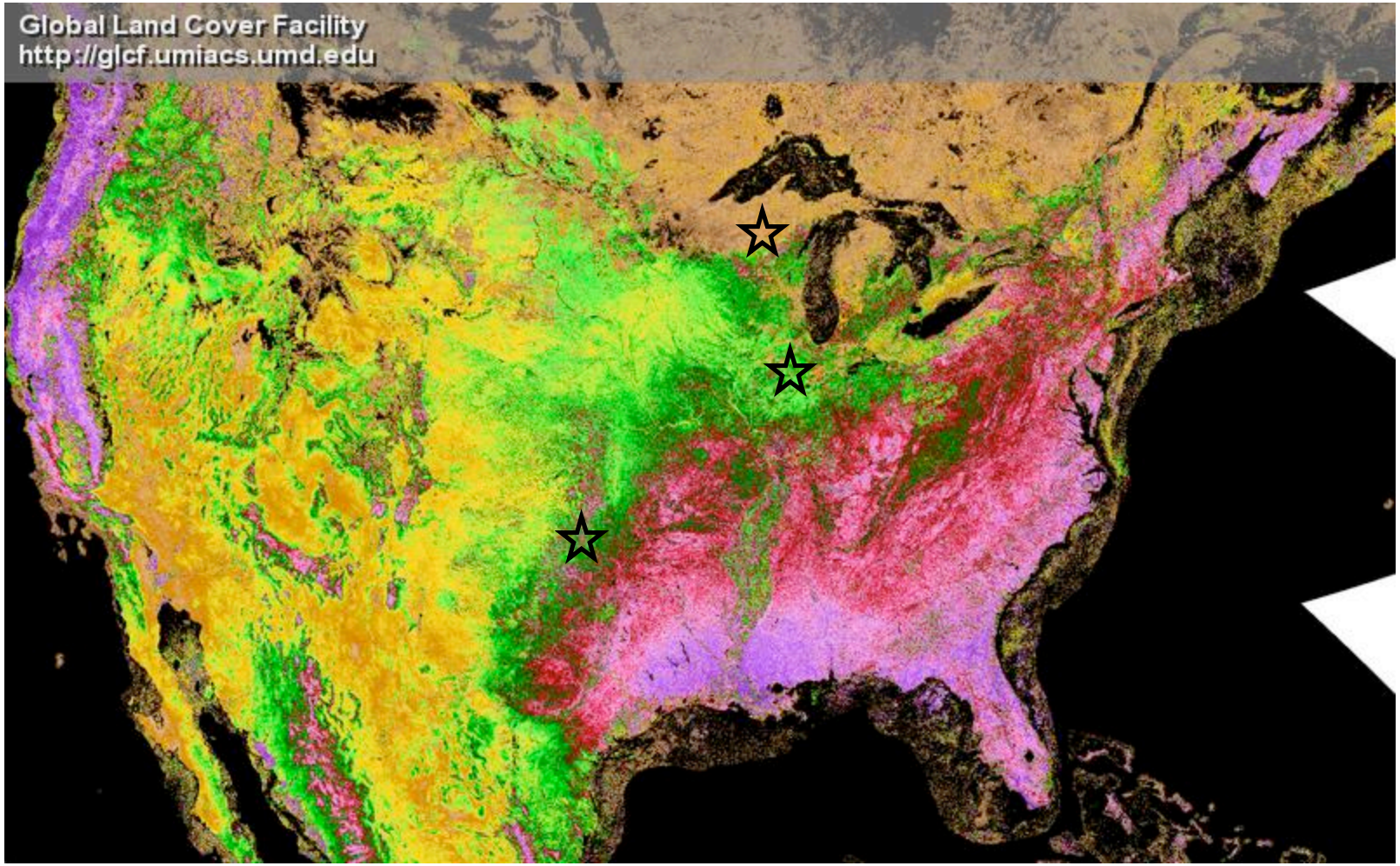
MODIS NDVI 18 FEB – 05 MAR 2002



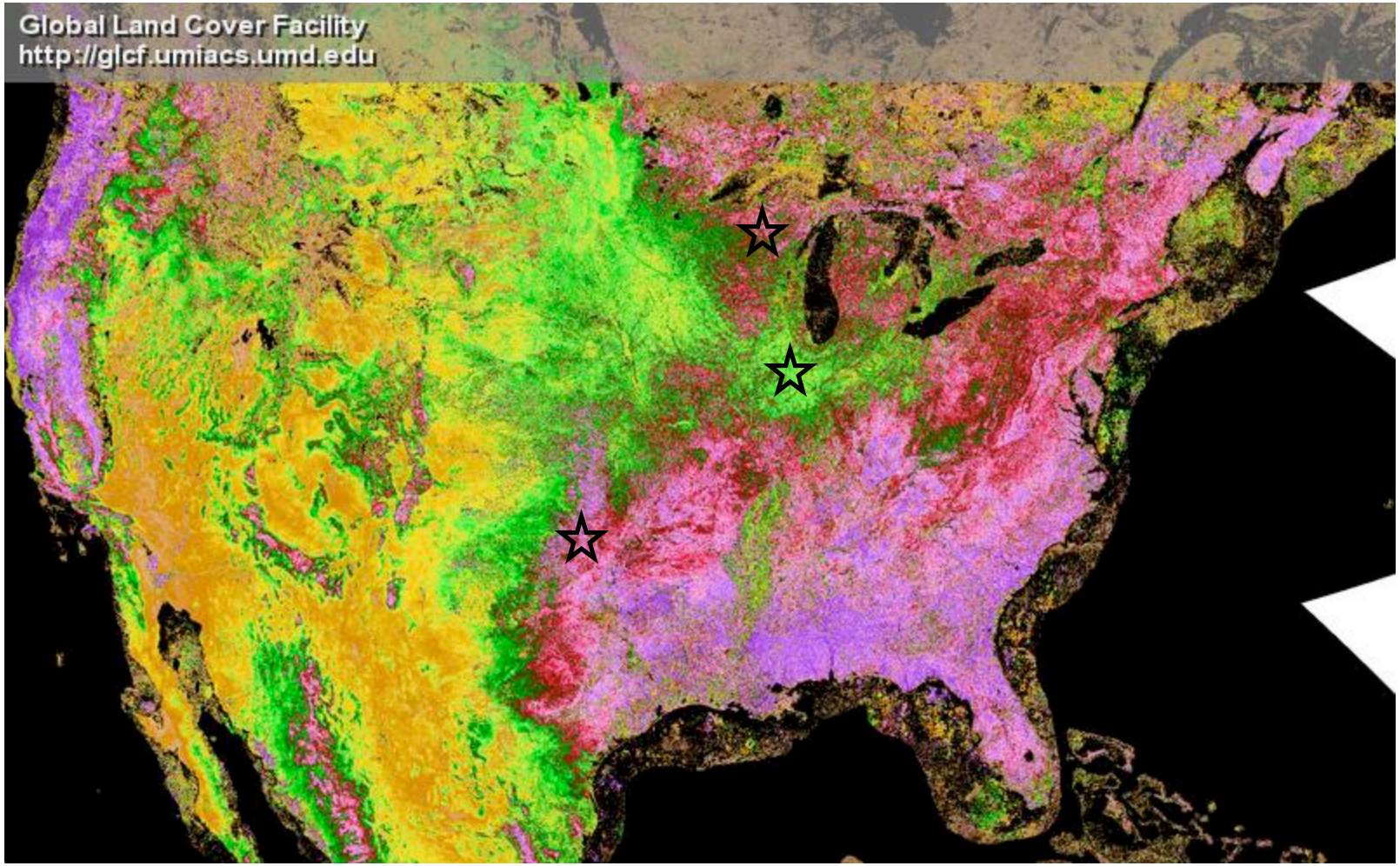
MODIS NDVI 06 MAR – 21 MAR 2002



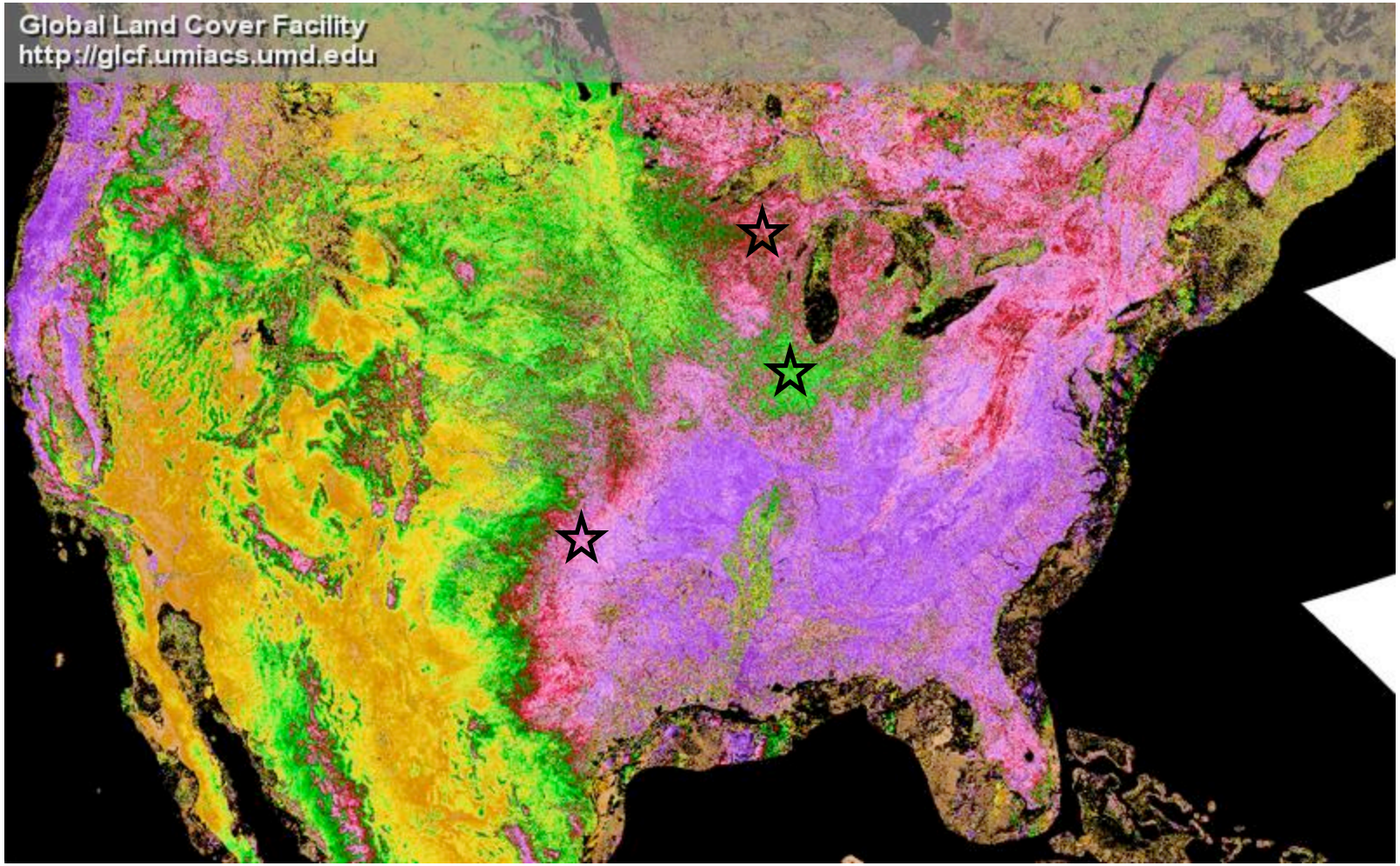
MODIS NDVI 22 MAR – 06 APR 2002



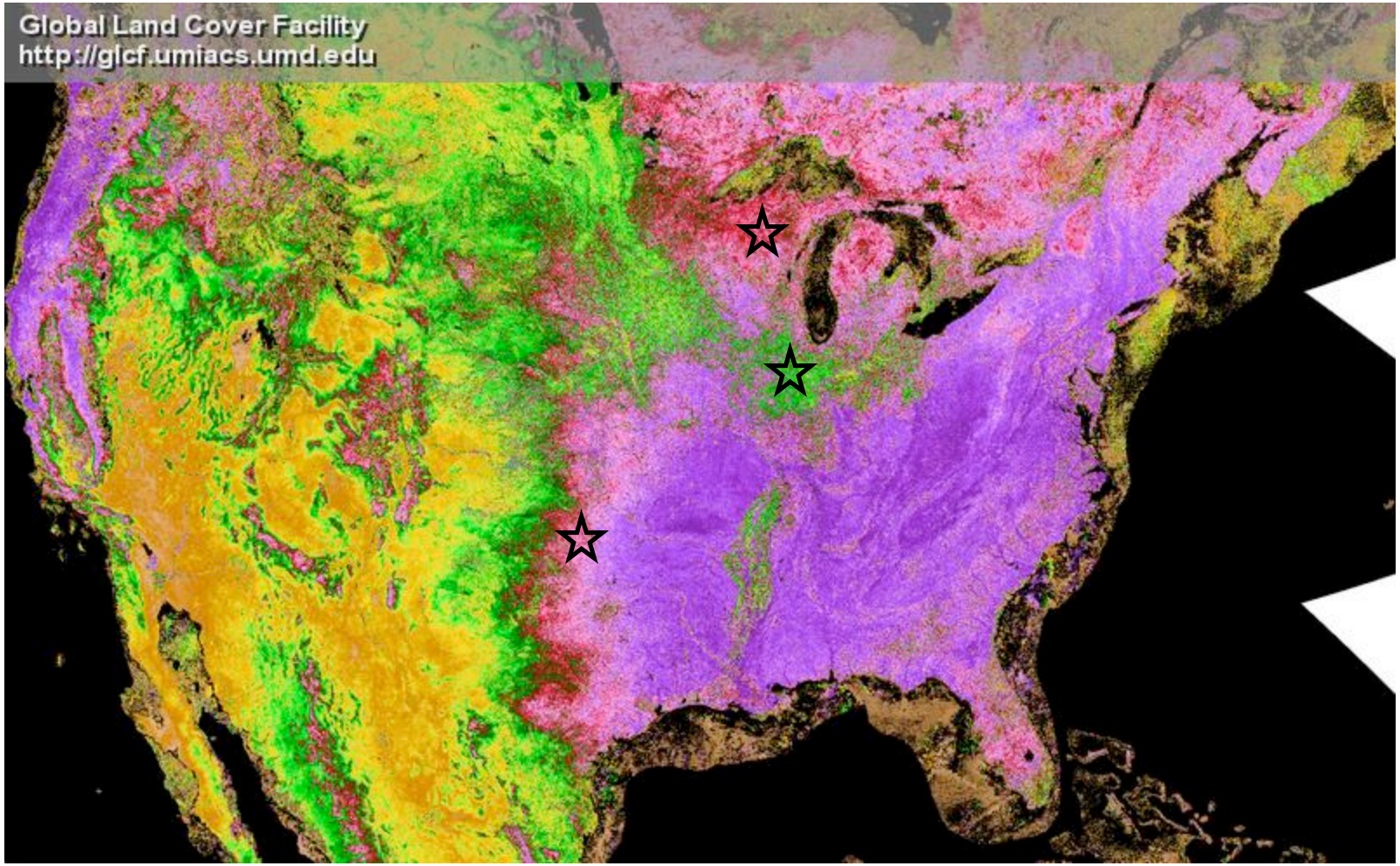
MODIS NDVI 07 APR – 22 APR 2002



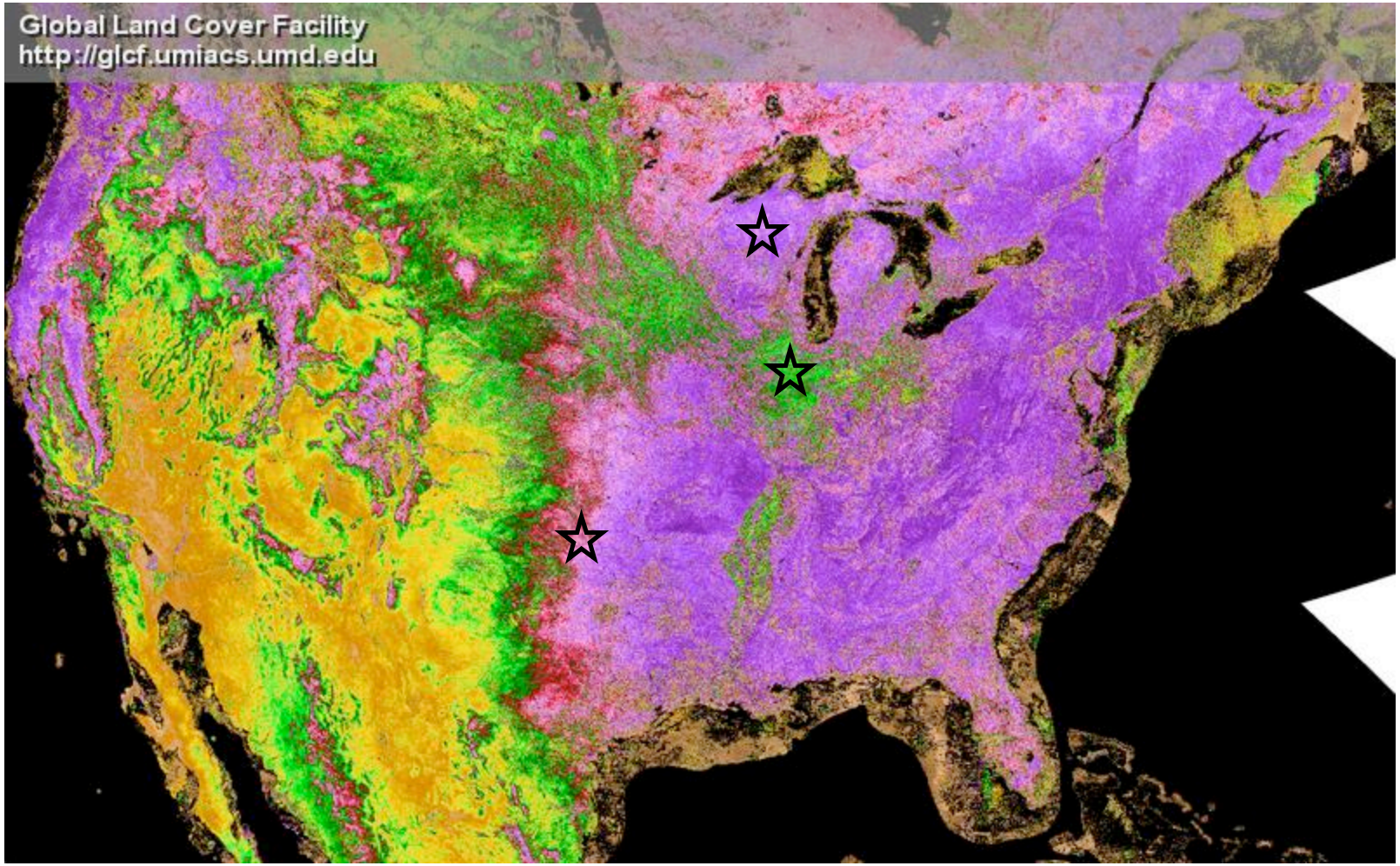
MODIS NDVI 23 APR – 08 MAY 2002



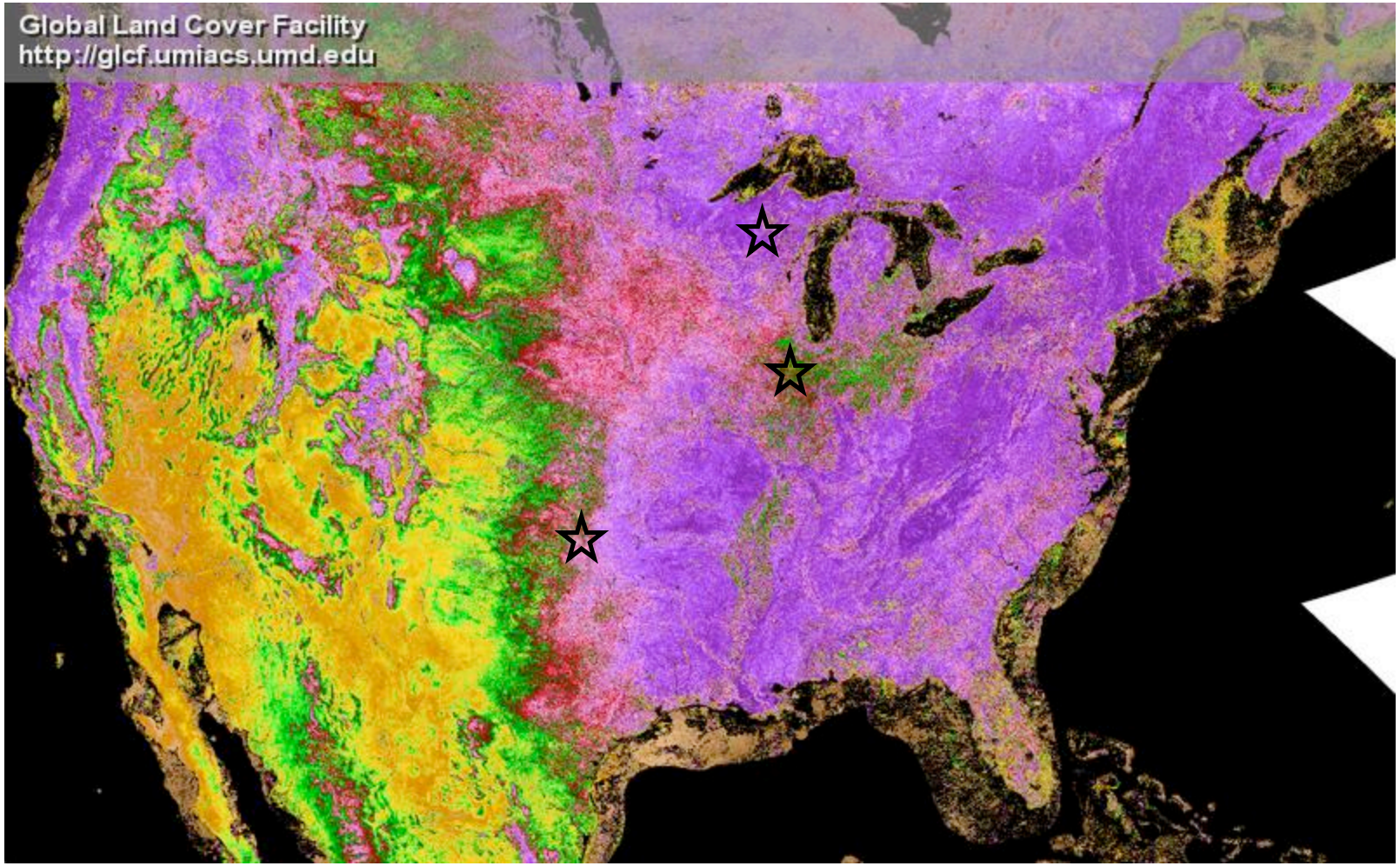
MODIS NDVI 09 MAY – 24 MAY 2002



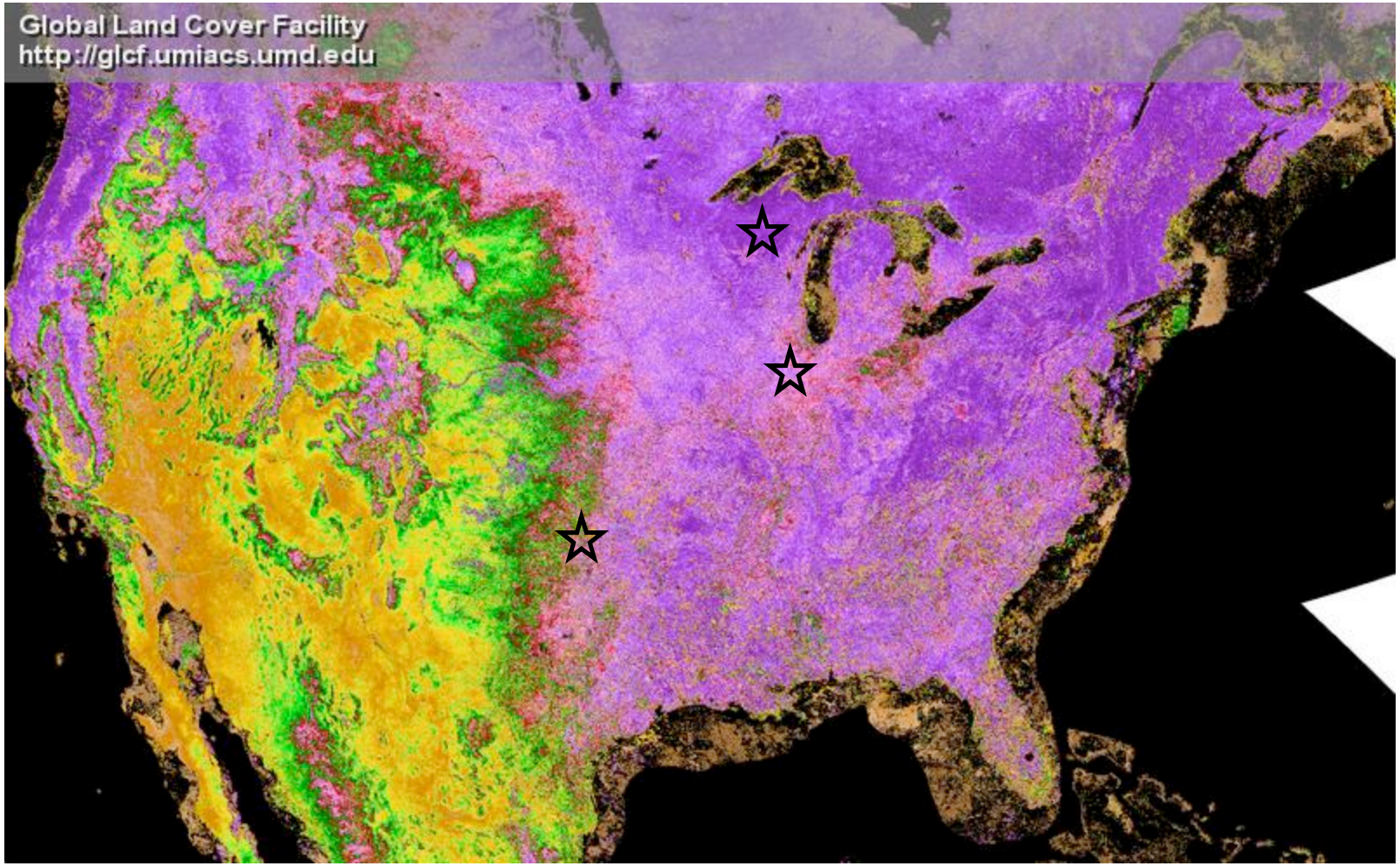
MODIS NDVI 25 MAY – 09 JUN 2002



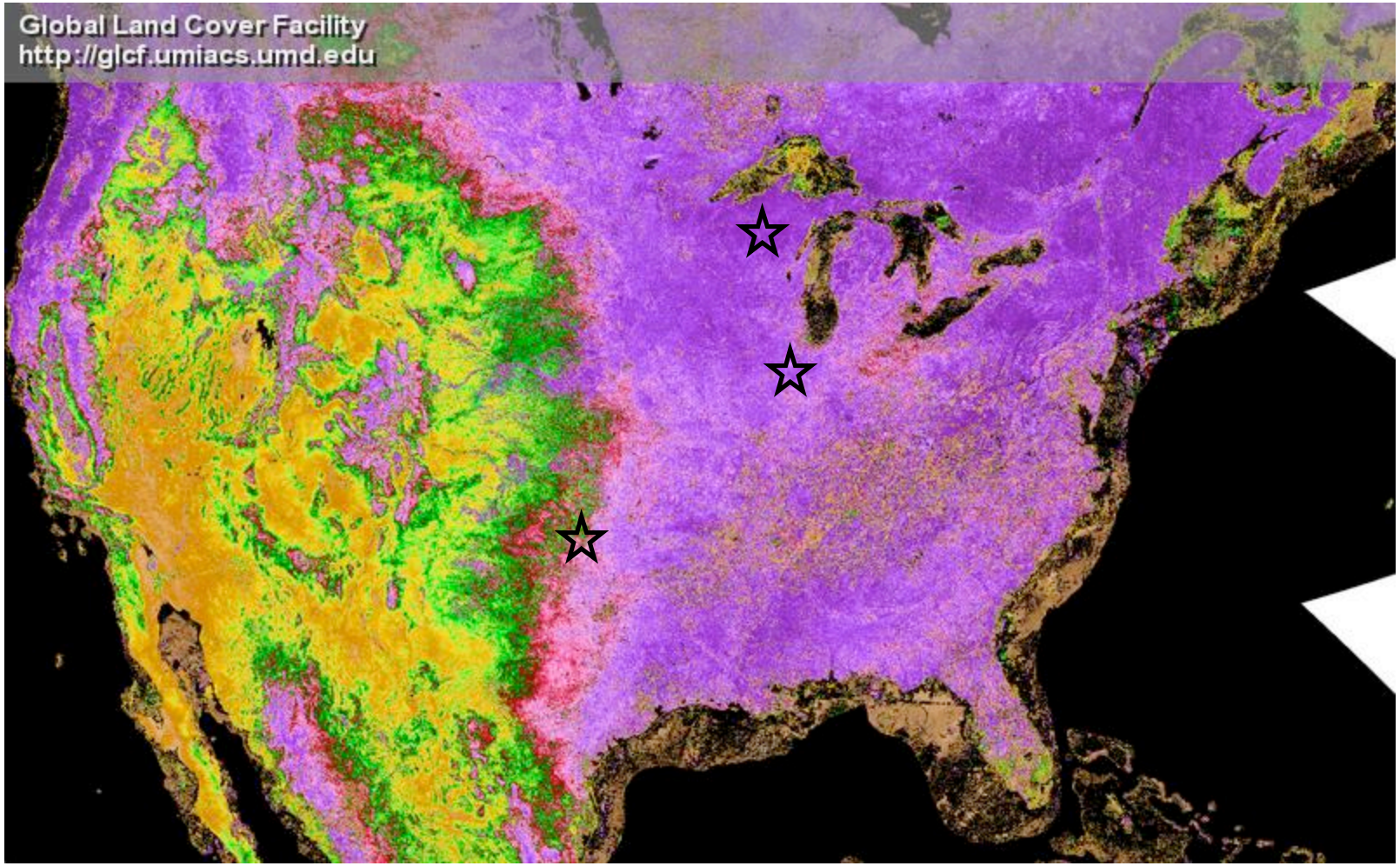
MODIS NDVI 10 JUN – 25 JUN 2002



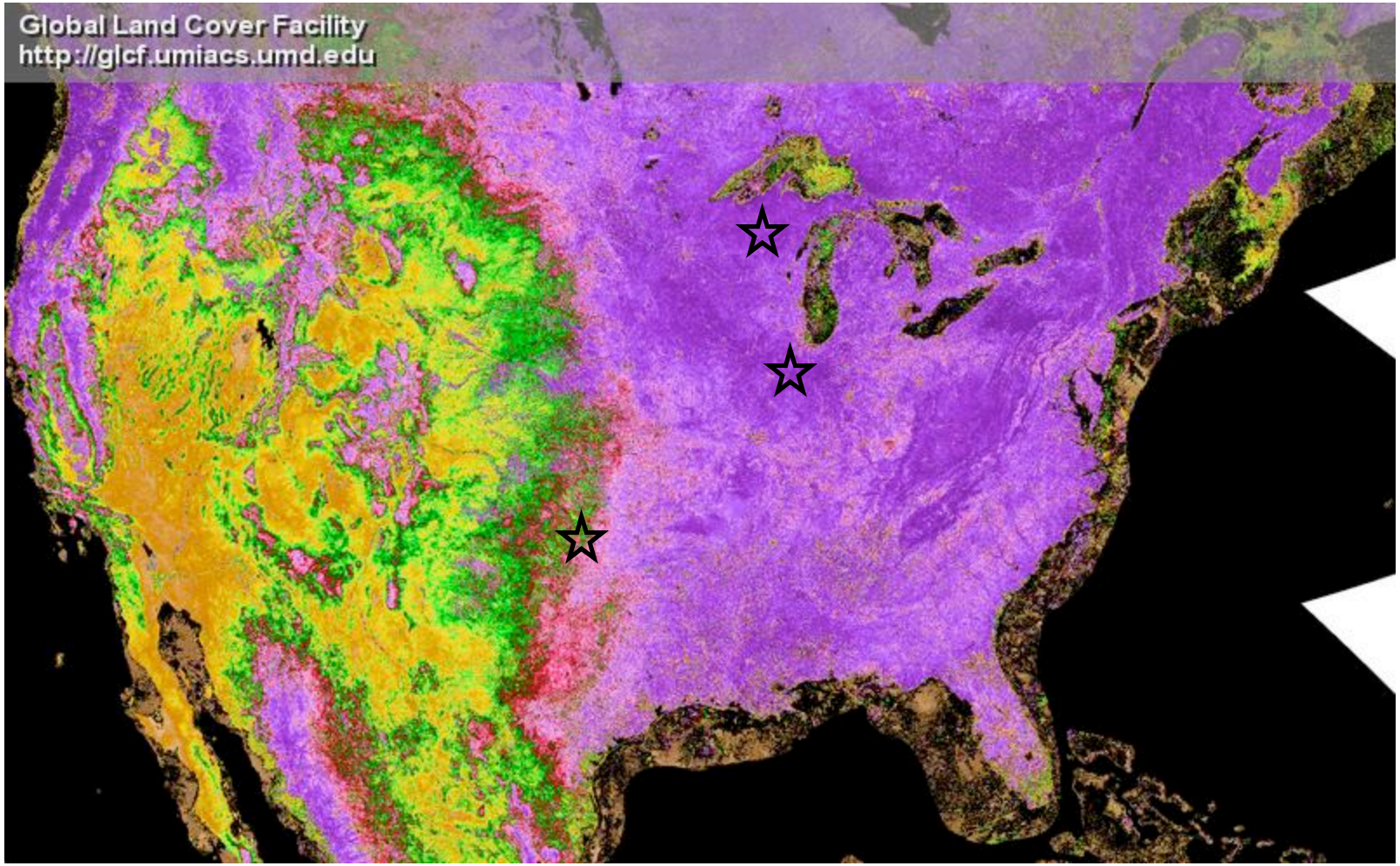
MODIS NDVI 26 JUN – 11 JUL 2002



MODIS NDVI 12 JUL – 27 JUL 2002



MODIS NDVI 28 JUL – 12 AUG 2002



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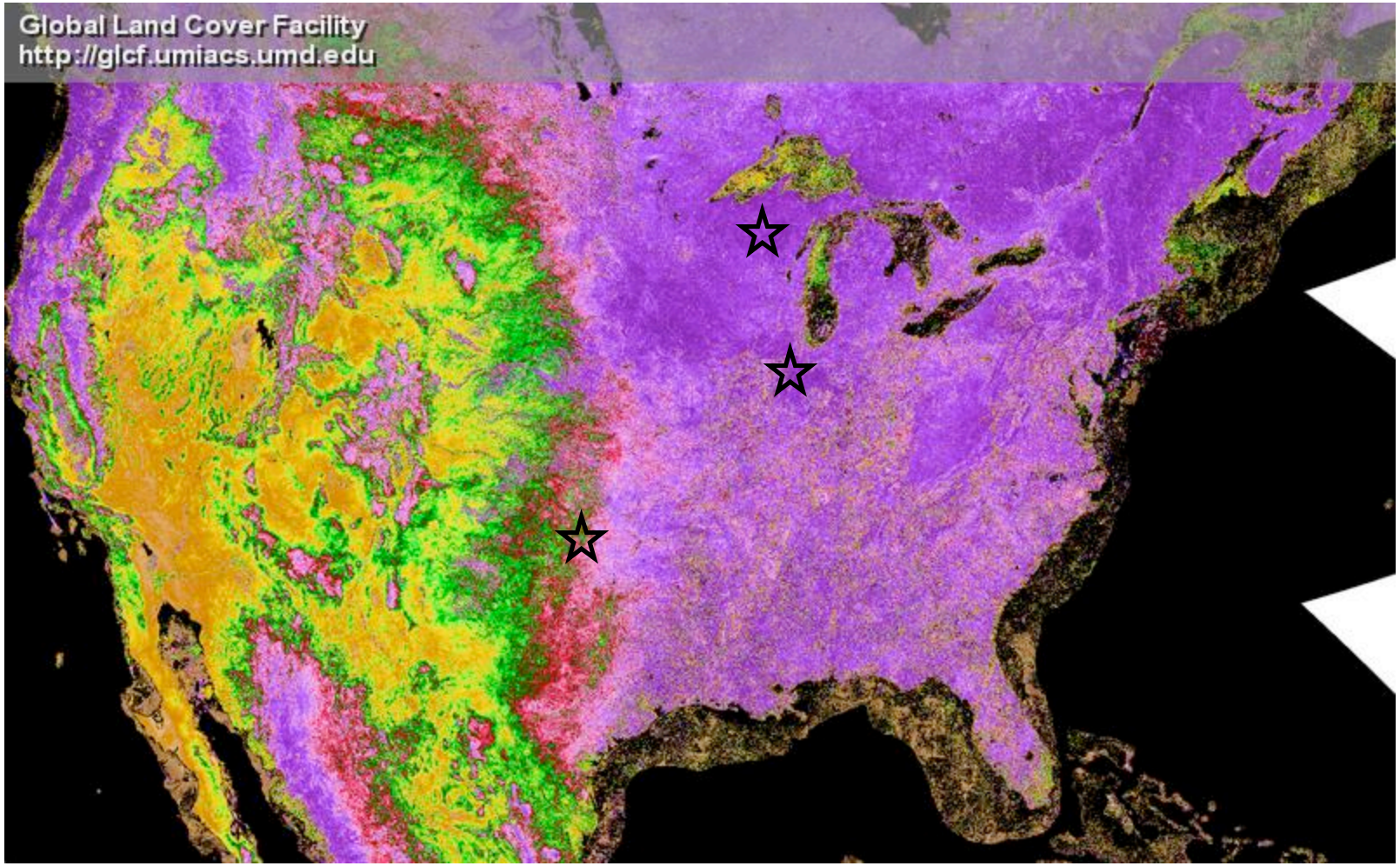

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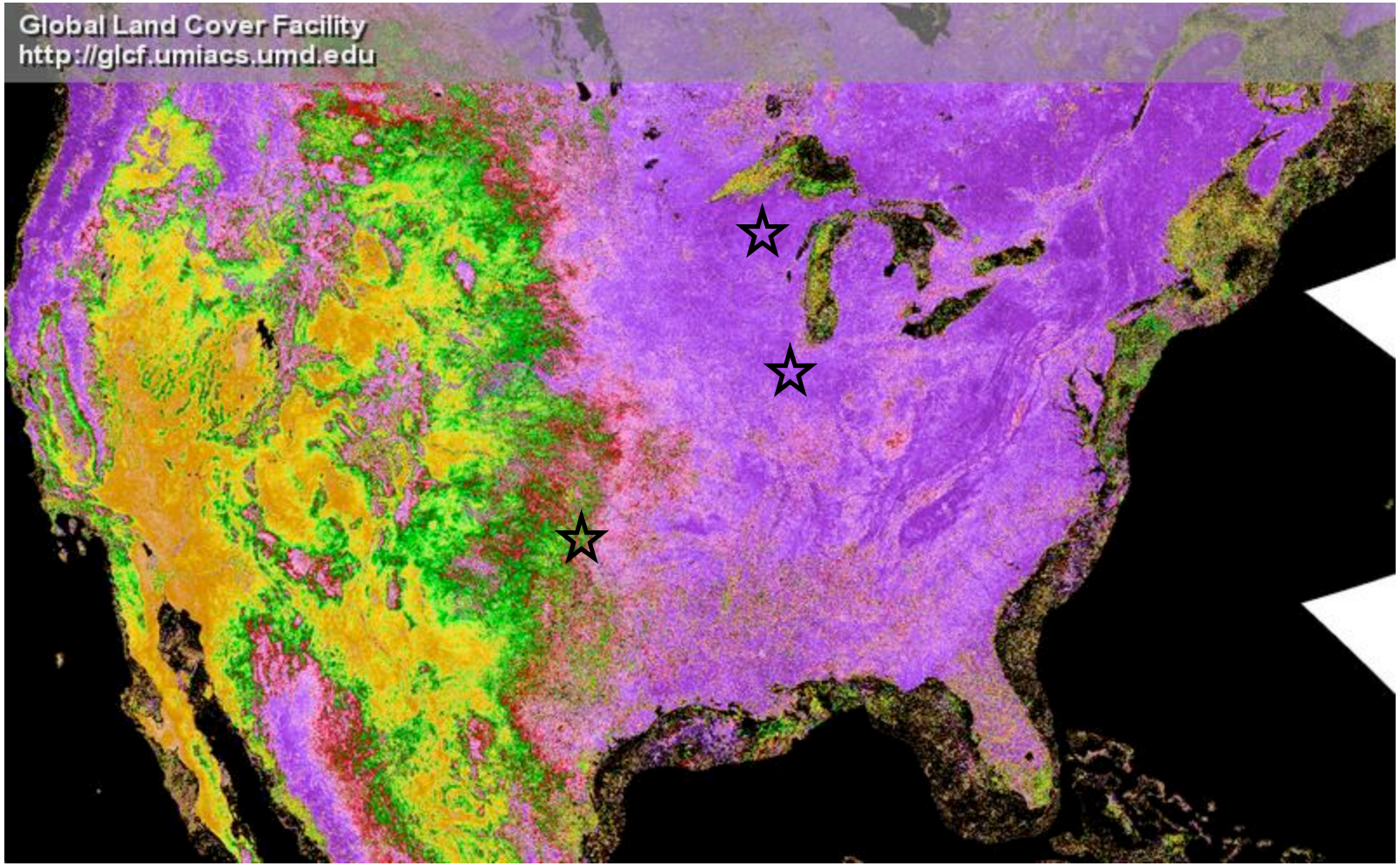

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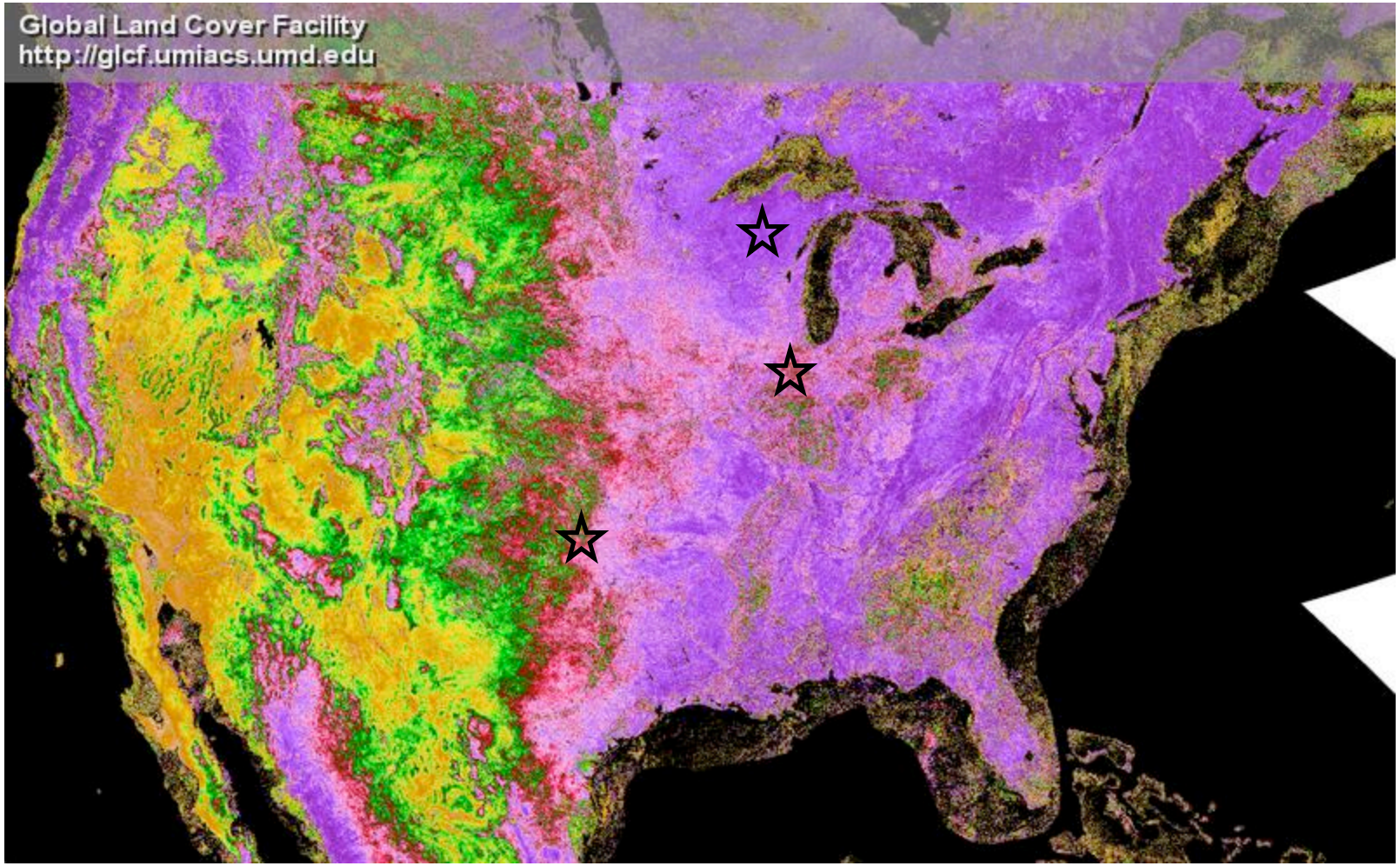
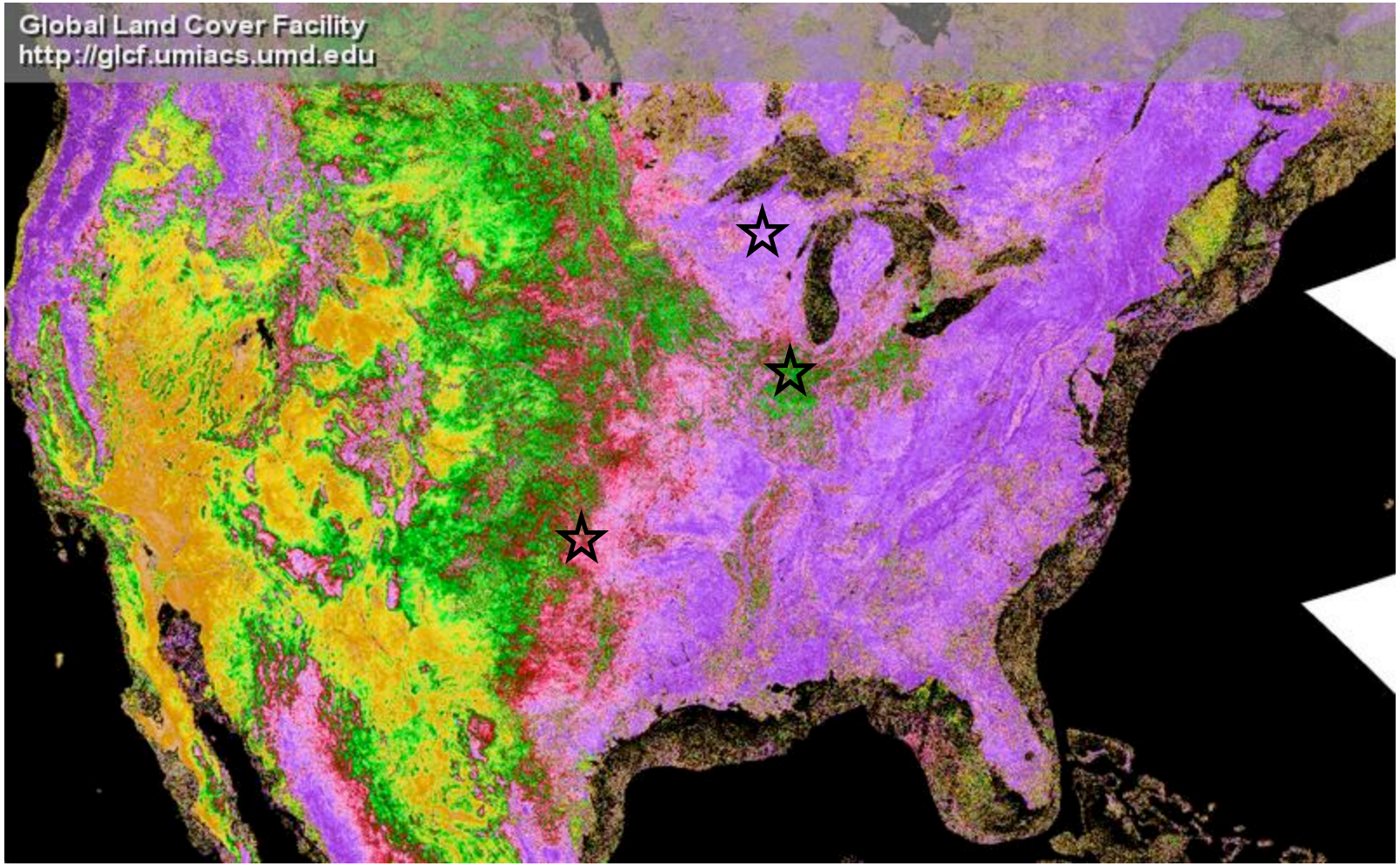
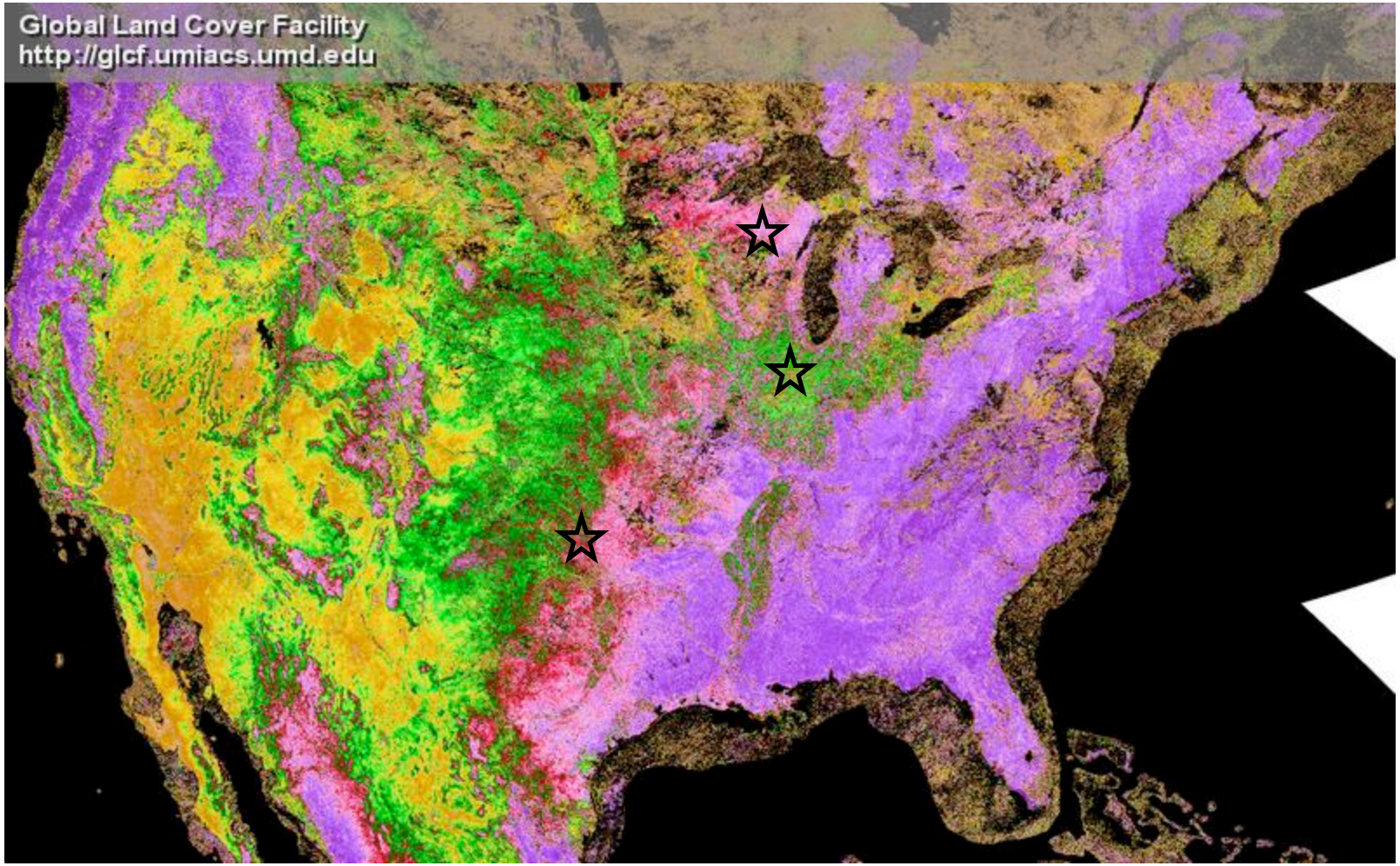


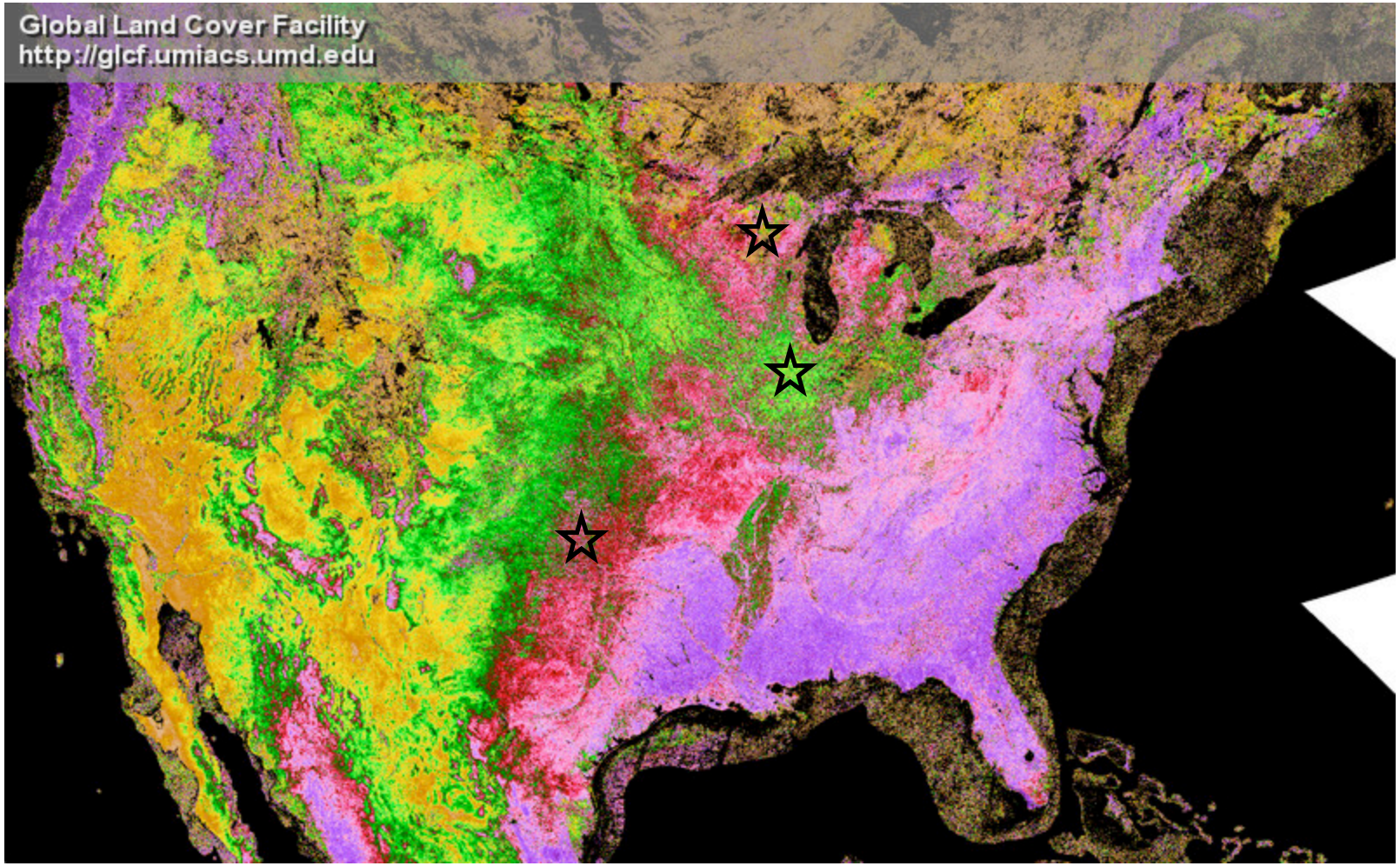
MODIS NDVI 30 SEP – 15 OCT 2002



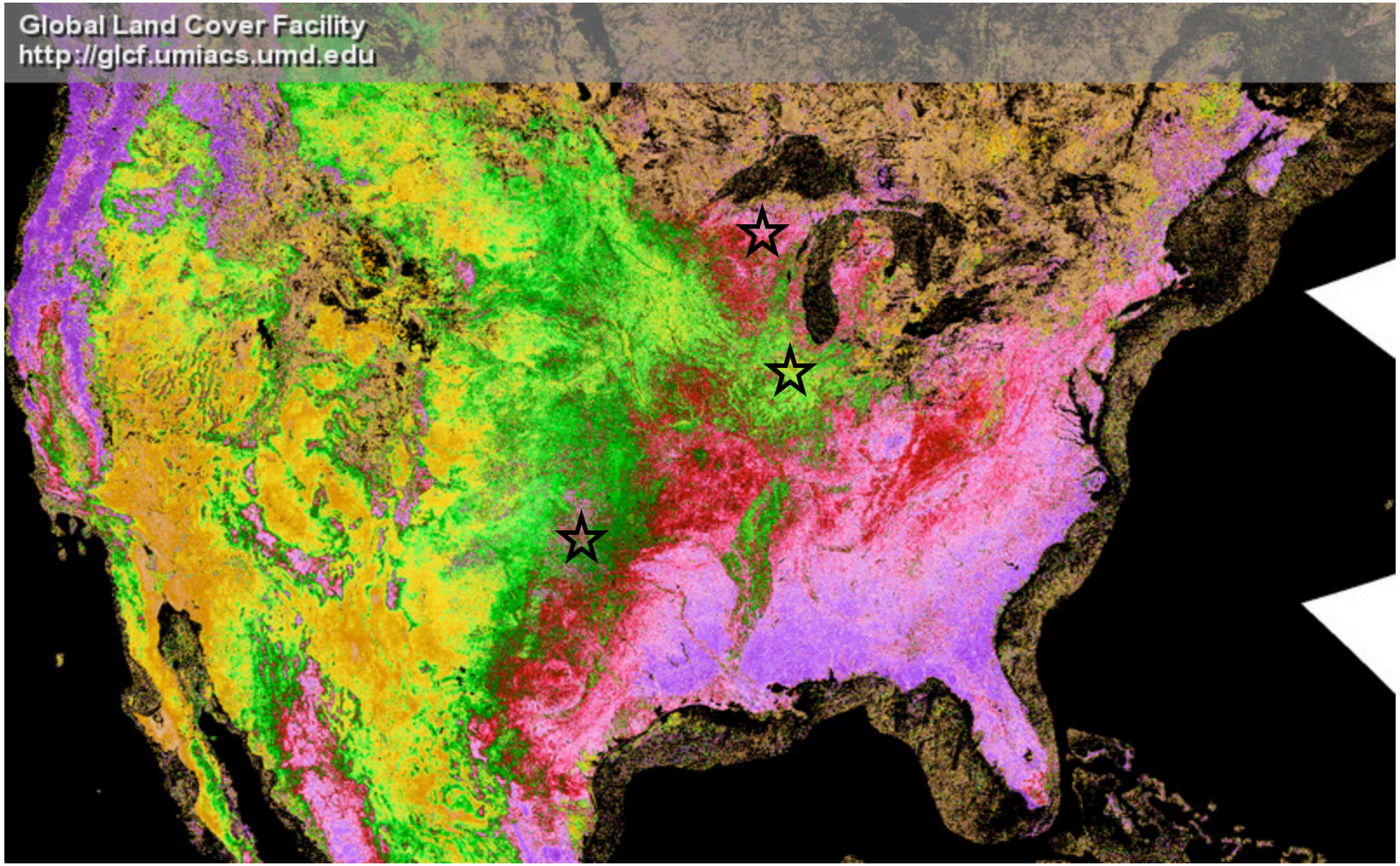
MODIS NDVI 16 OCT – 31 OCT 2002



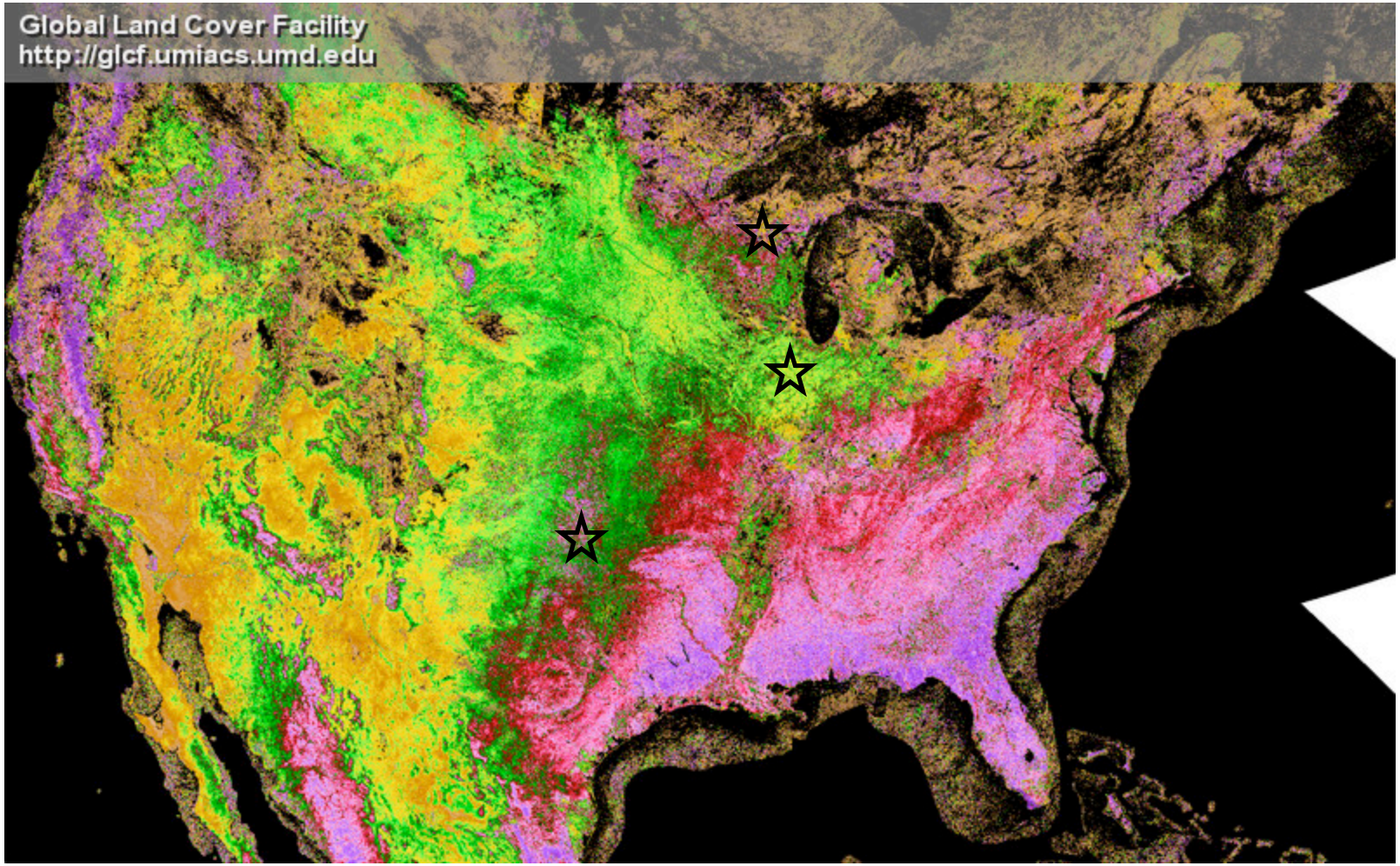
MODIS NDVI 01 NOV – 16 NOV 2002



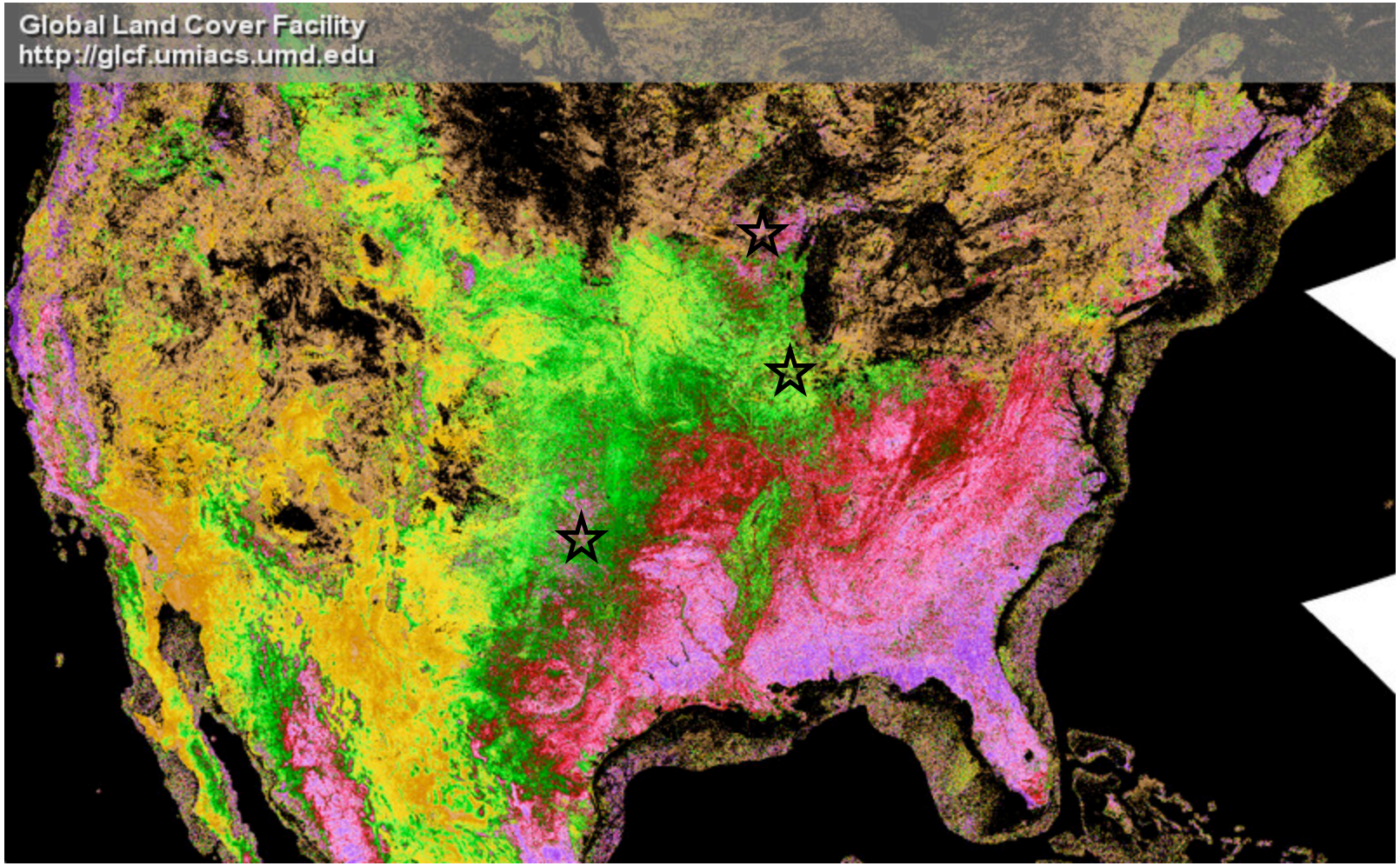
MODIS NDVI 17 NOV – 30 NOV 2002



MODIS NDVI 03 DEC – 18 DEC 2002

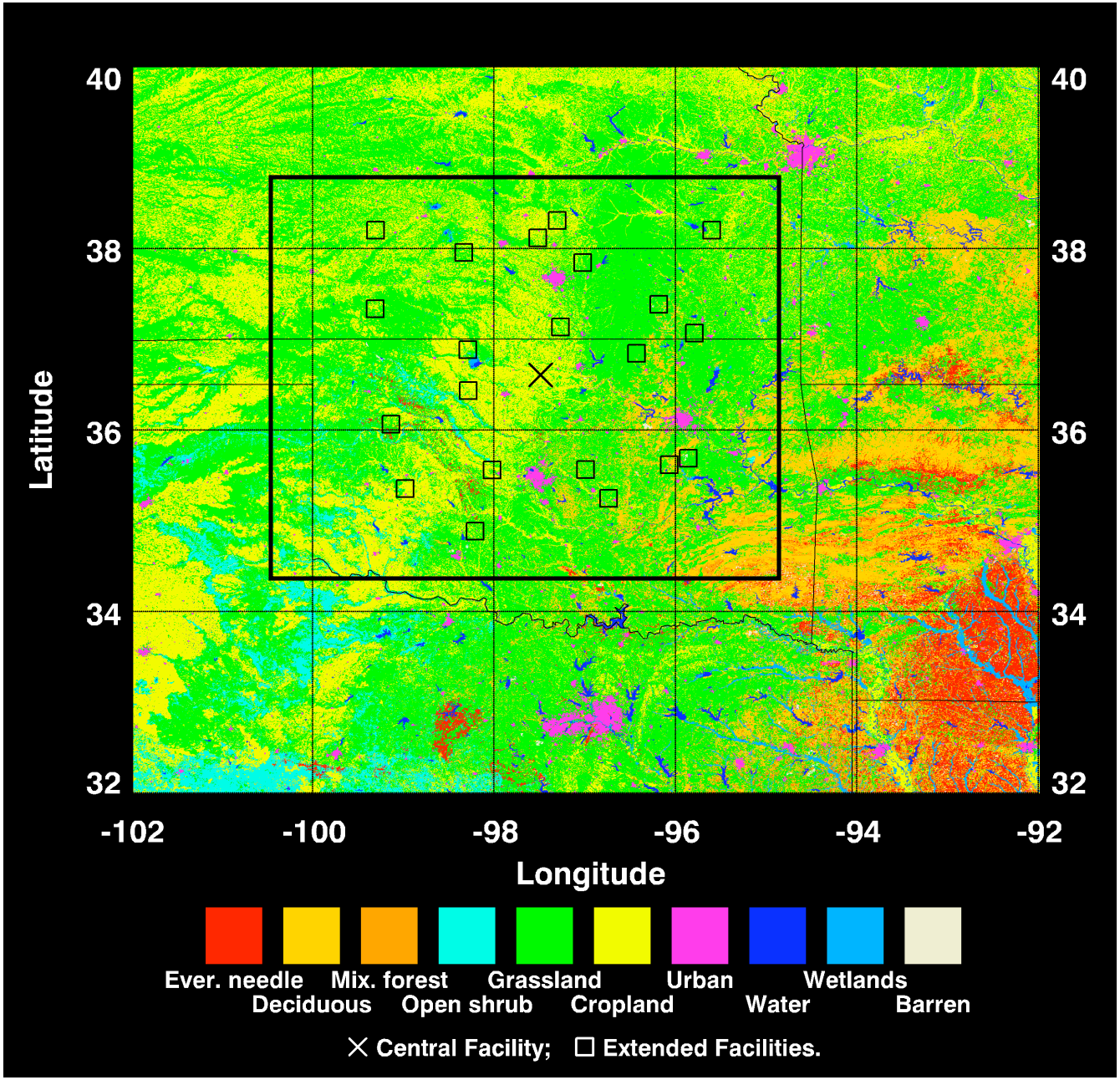


MODIS NDVI 19 DEC – 31 DEC 2002



DOE ARM Southern Great Plains (SGP) Site

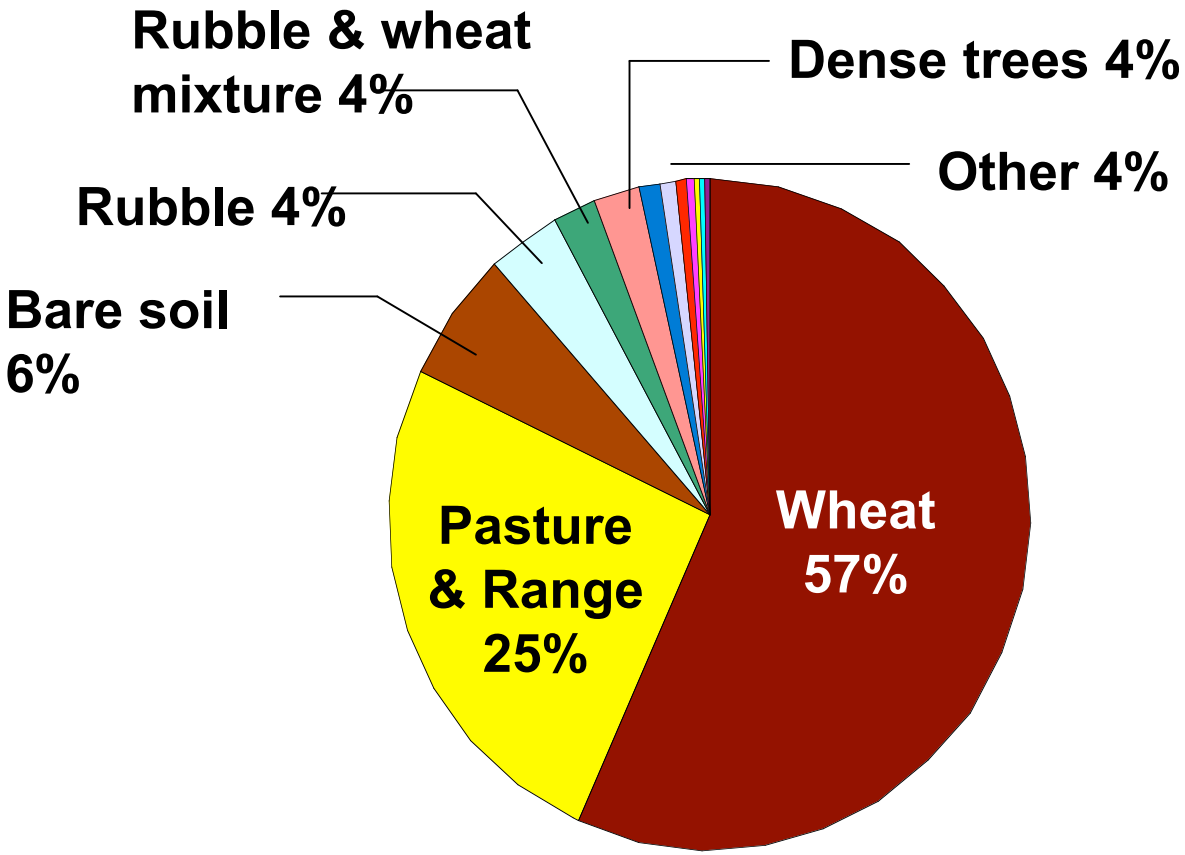
Land Cover From MODIS Data



Courtesy of A. Trishchenko

ARM Site Land Use Survey

(Osborne, 2003)

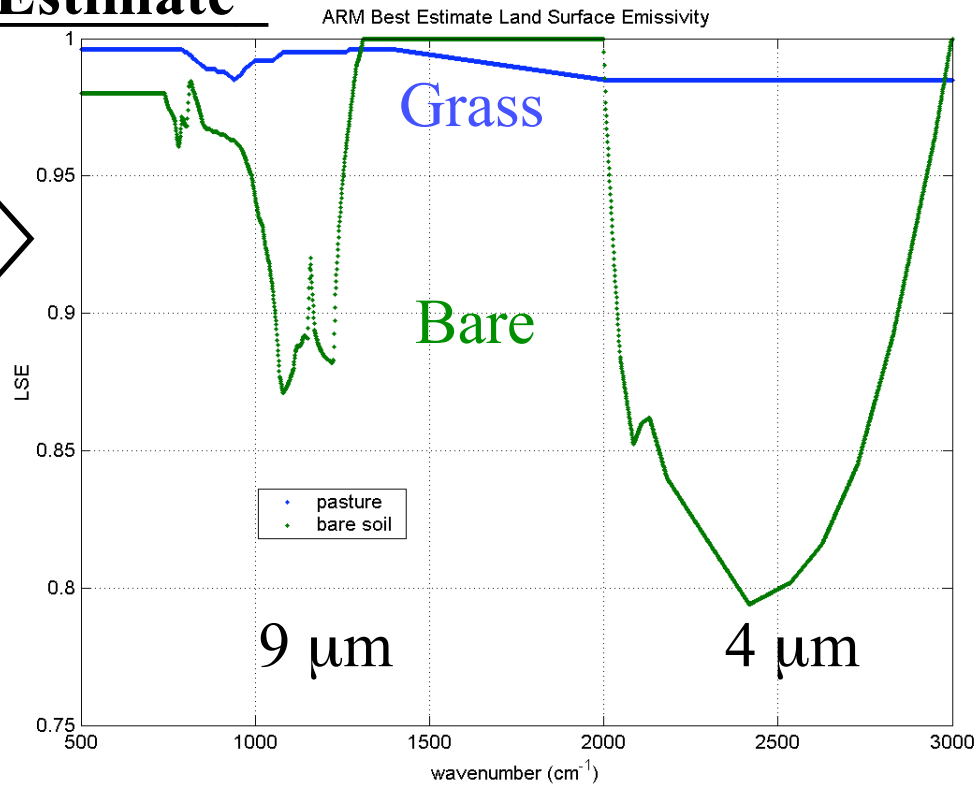


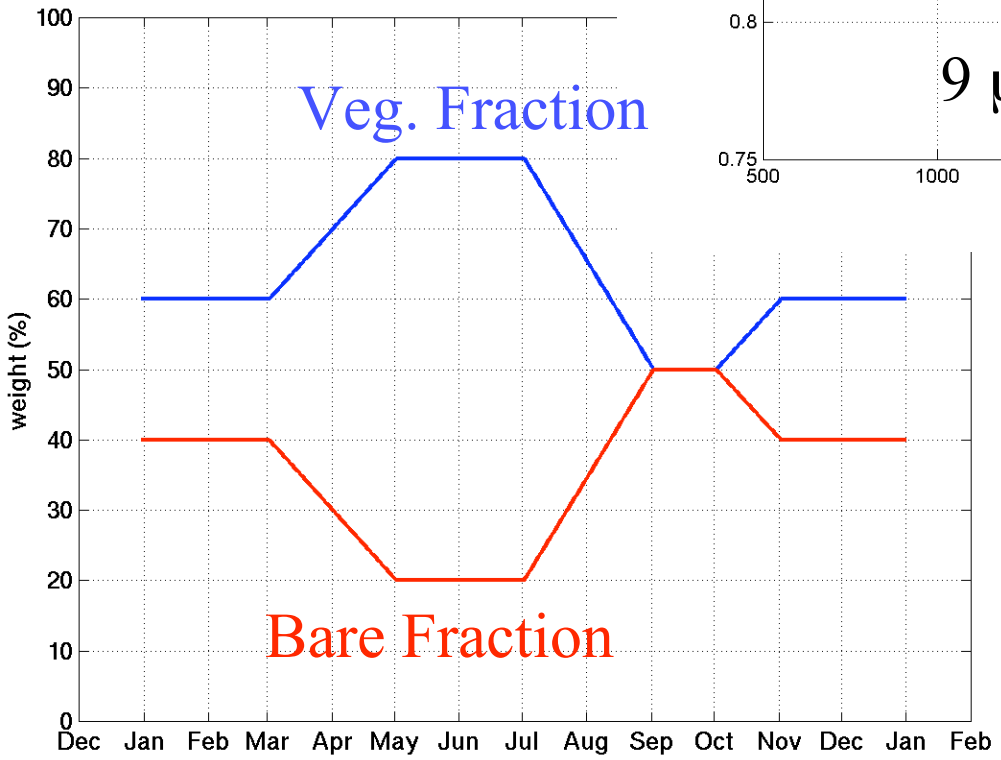
November 2002; 63 square mile area.

- Two land cover types dominate: wheat fields and pasture (grassland).

ARM SGP LST/LSE "Best Estimate"

UW Measured
IR Emissivity:
Bare Soil & Grass

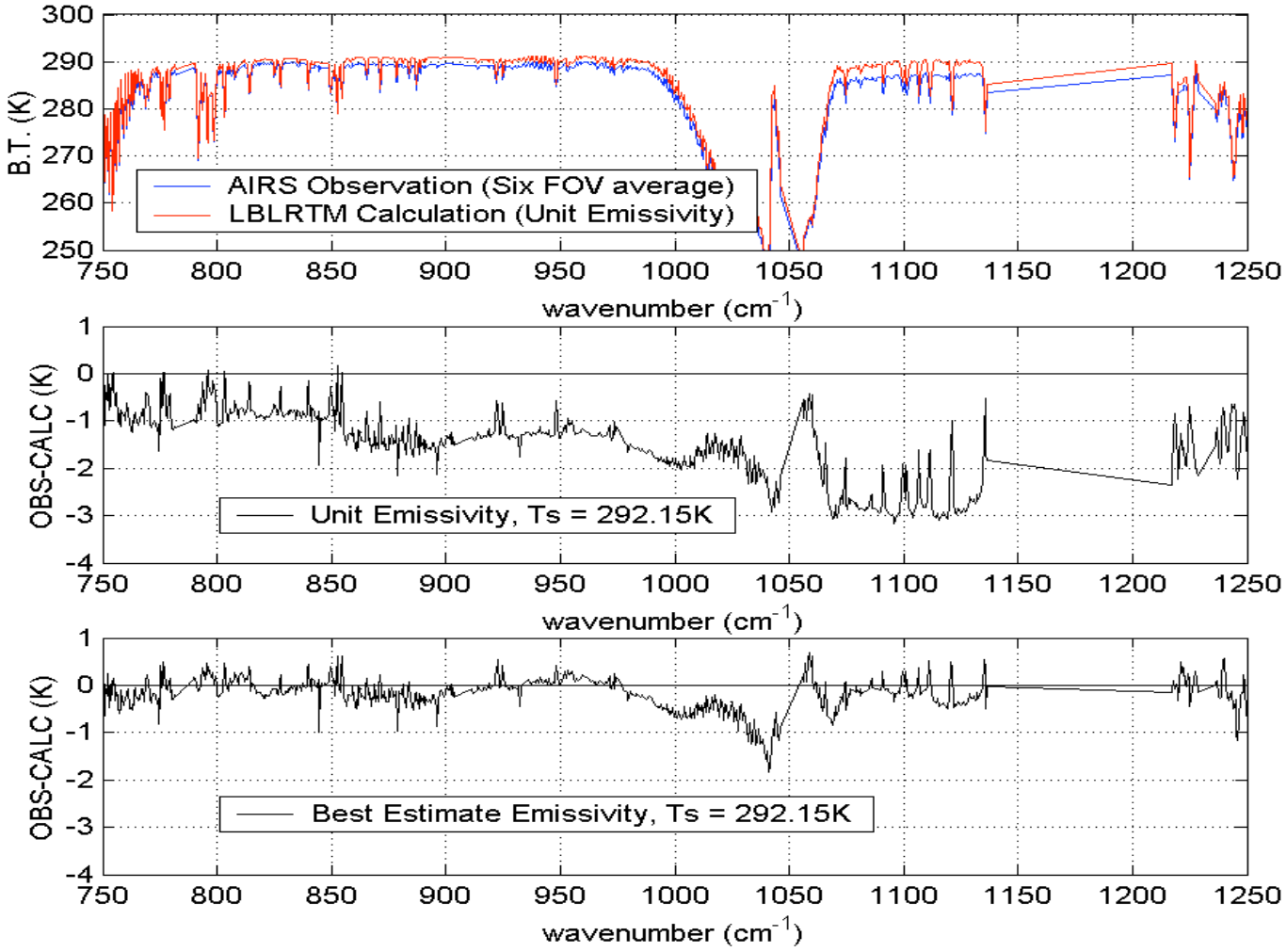




Replace Model
With AIRS Derived
Vegetation Fraction

ARM SGP LST/LSE "Best Estimate"

- Formulated in April 2001 to supply the surface contribution to the ARM/AIRS validation product developed by D. Tobin.



Future Work

- Use clear sky AIRS, MODIS, and METEOSAT-8 data to determine regional surface emissivity maps for use in data assimilation and retrieval.
- Create a “truth” dataset over the U.S. Oklahoma ARM site with two years of AIRS L1B data for use in development of improved IR sounding algorithms over land.
- Prepare to validate AIRS Version 4 products.