Development of a global dynamic AMSR-E land surface emissivity database

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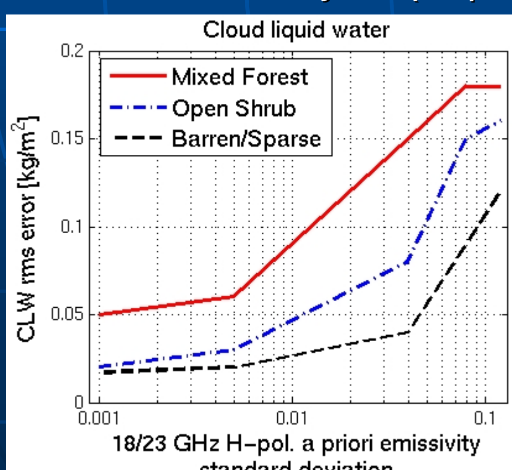
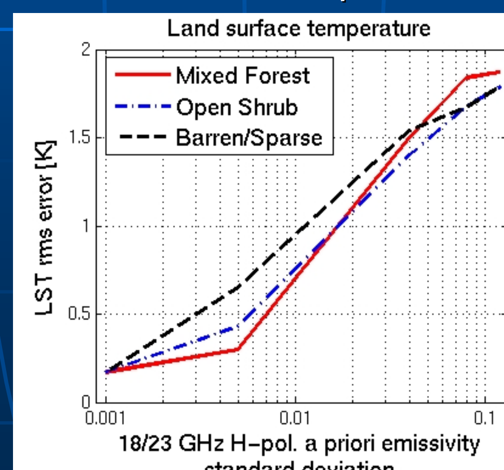
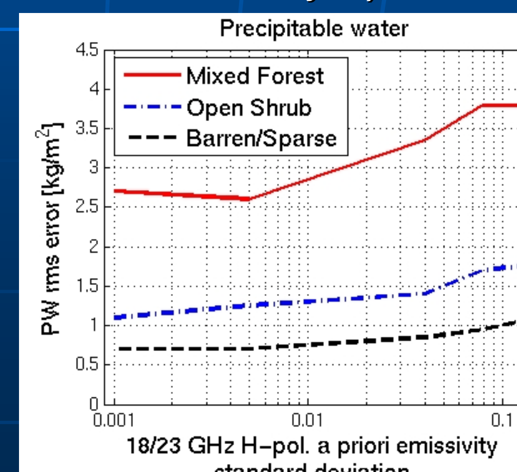
Goals

- Provide emissivity constraint for lower tropospheric (PW, CLW) and LST (cloudy conditions) retrieval over land
  - Other benefits include:
    - Enhanced precipitation detection capability
    - RFI monitoring
  - Target accuracy: < 0.01
- Applications:
  - Climatology (PW, CLW, LST - cloudy conditions)
  - Assimilation (surface emissivity model/LSM validation)
  - Hydrology
  - Agriculture/Land use/surface change monitoring
  - Carbon studies (LST, vegetation health)
  - IR cloud analysis (improved IR detection, liquid cloud underneath ice layer)

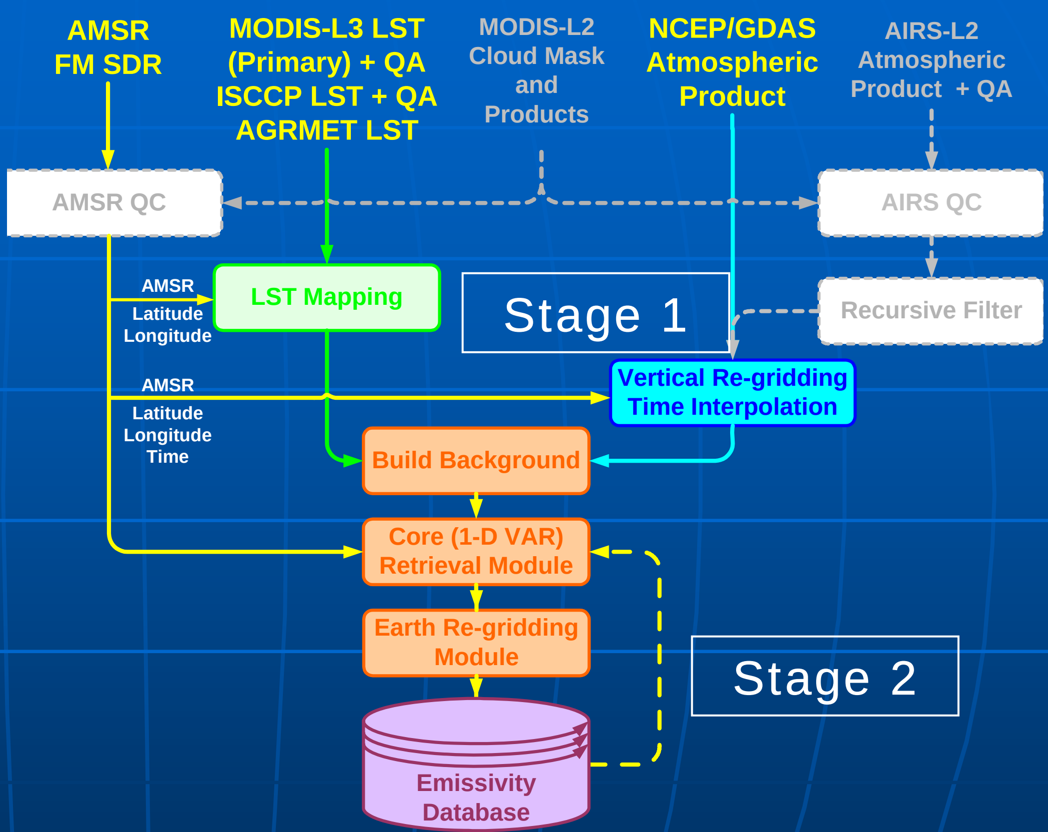






EOS Processing System Overview

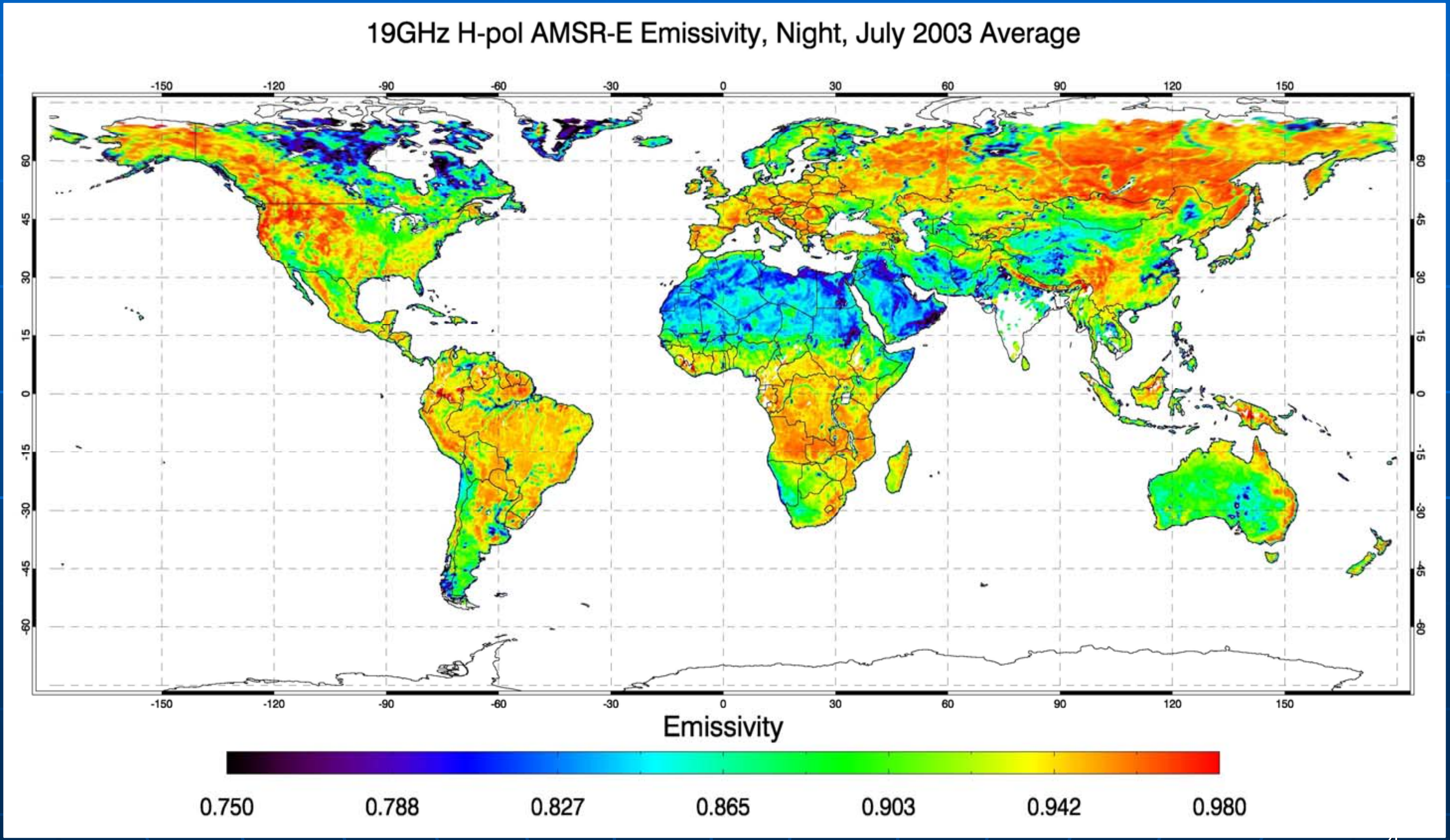
- **Stage 1 (clear-sky):**
  - LST and cloud mask from V.4 MODIS algorithms
  - Water vapor and temperature from NCEP/GDAS (current) or AIRS product
  - Emissivity retrieved on individual AMSR-E FOV's (prior to Earth gridding)
  - Surface information updated at each overpass at all locations within swath
- **Stage 2 (cloudy):**
  - Use Stage 1 data as background in 1D-VAR retrieval algorithm (NPOESS/CMIS heritage)
  - Surface emissivity constraint based on recent history at each monitored location



F-13 and F15 SSM/I added to process

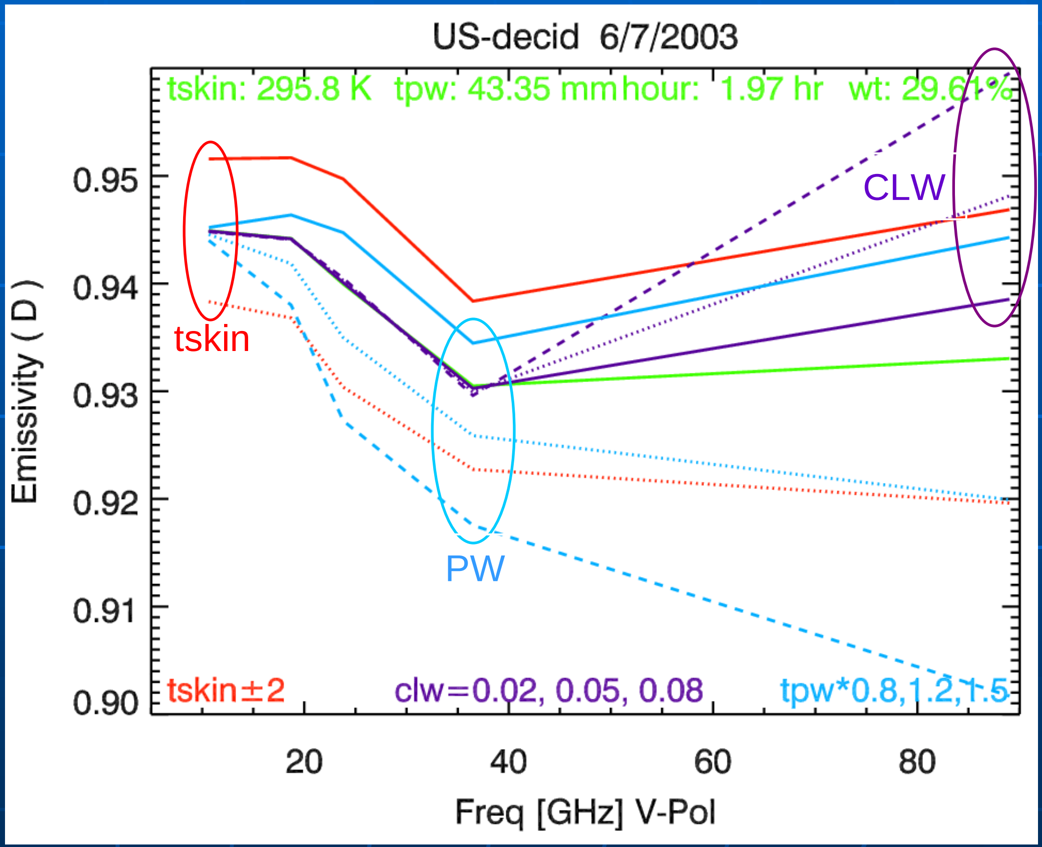
- 3-hourly ISCCP product used for LST and cloud mask
- Tie to Prigent's heritage work
- Better sampling of diurnal cycle (see below)

19H AMSR-E Emissivity Map 07/03
(38 km resolution – nighttime only)



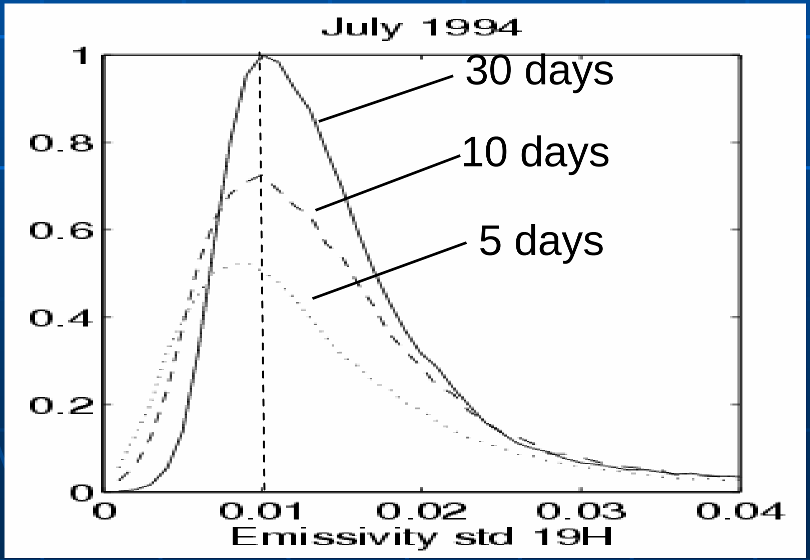
Sources of uncertainty/variability

- LST errors
  - Include mixed pixels effects (preeminent during day time)
- PW errors
  - Appear to dominate in certain areas (e.g. US)
- Residual cloud contamination (higher at night)
- Inhomogeneities (spatial gridding)/topography (azimuthal direction)
- Random errors minimized by time averaging (trade off between uncertainty and temporal resolution)
- Other:
  - Natural emissivity changes (transient events)

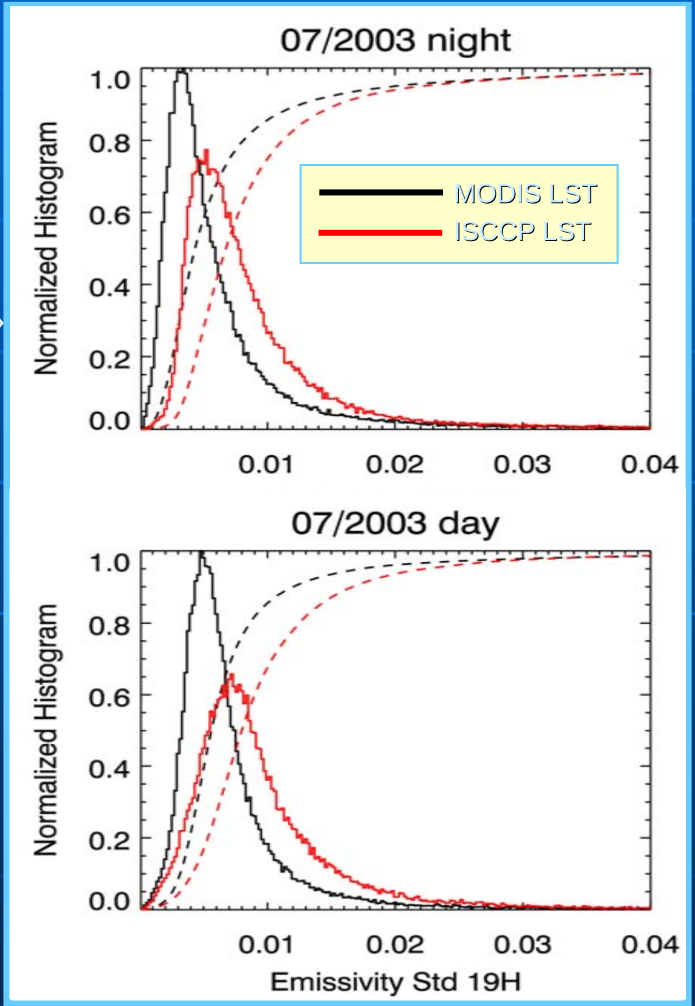


AMSR emissivity standard deviation (month of July)

- **Low standard deviations (>70% with std dev < 0.01 for month of July)**
  - Day and night aggregated separately
  - Good consistency between MODIS LST and AMSR-E
  - No LST time interpolation
  - Timely cloudiness information

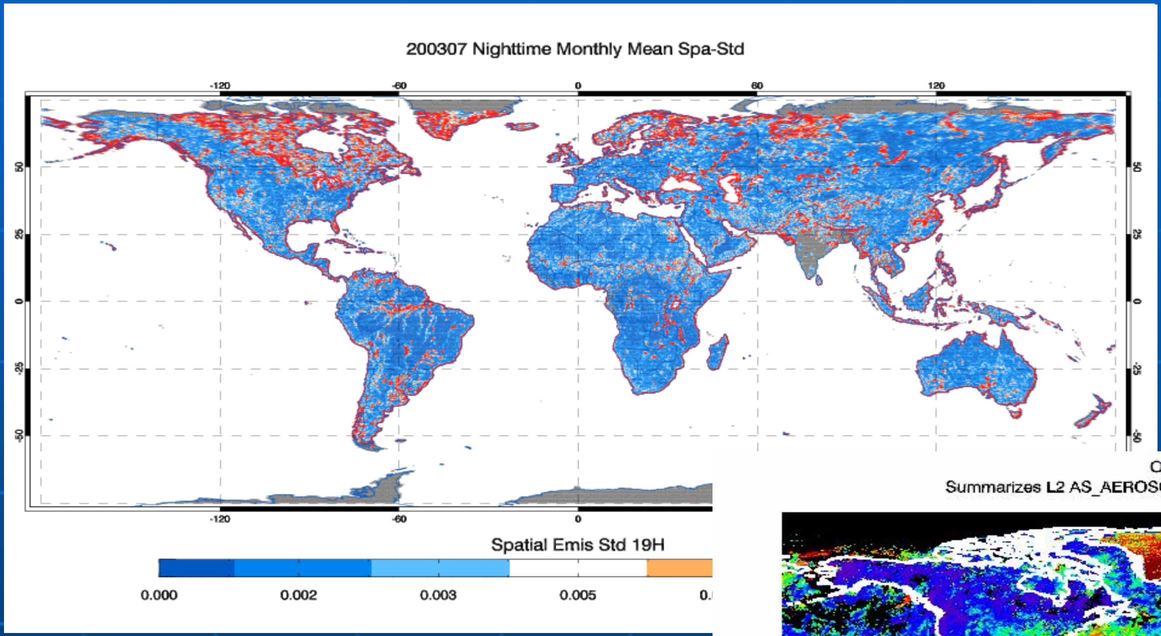


SSM/I (ISCCP LST/Cloud mask)



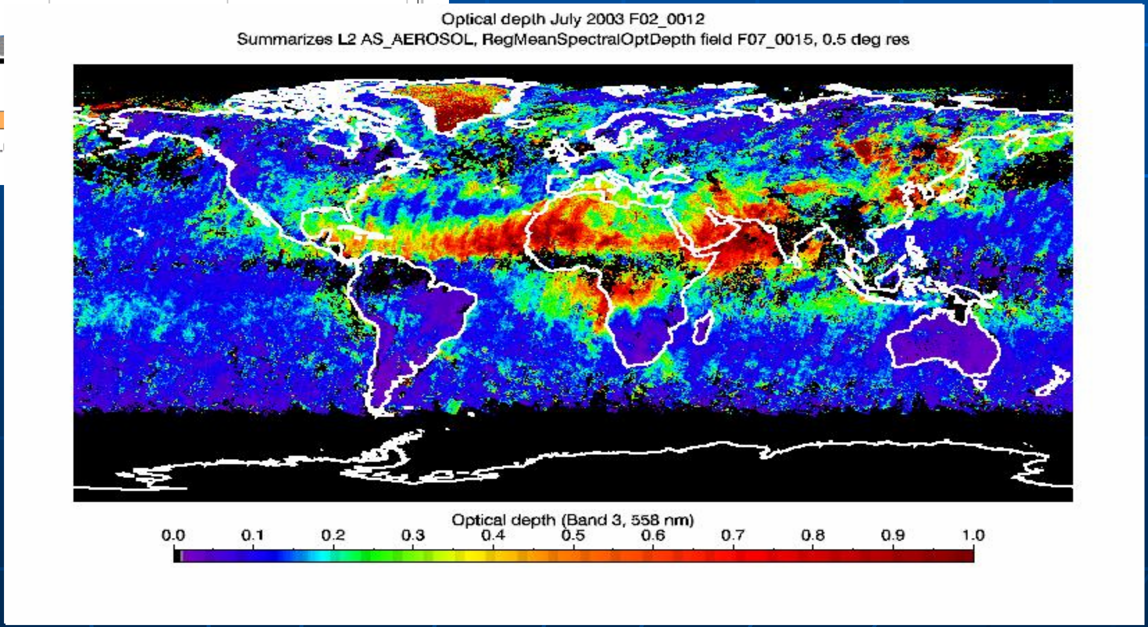
AMSR (MODIS LST/Cloud mask)

Geographical distribution of variance



Night Time 07/2003

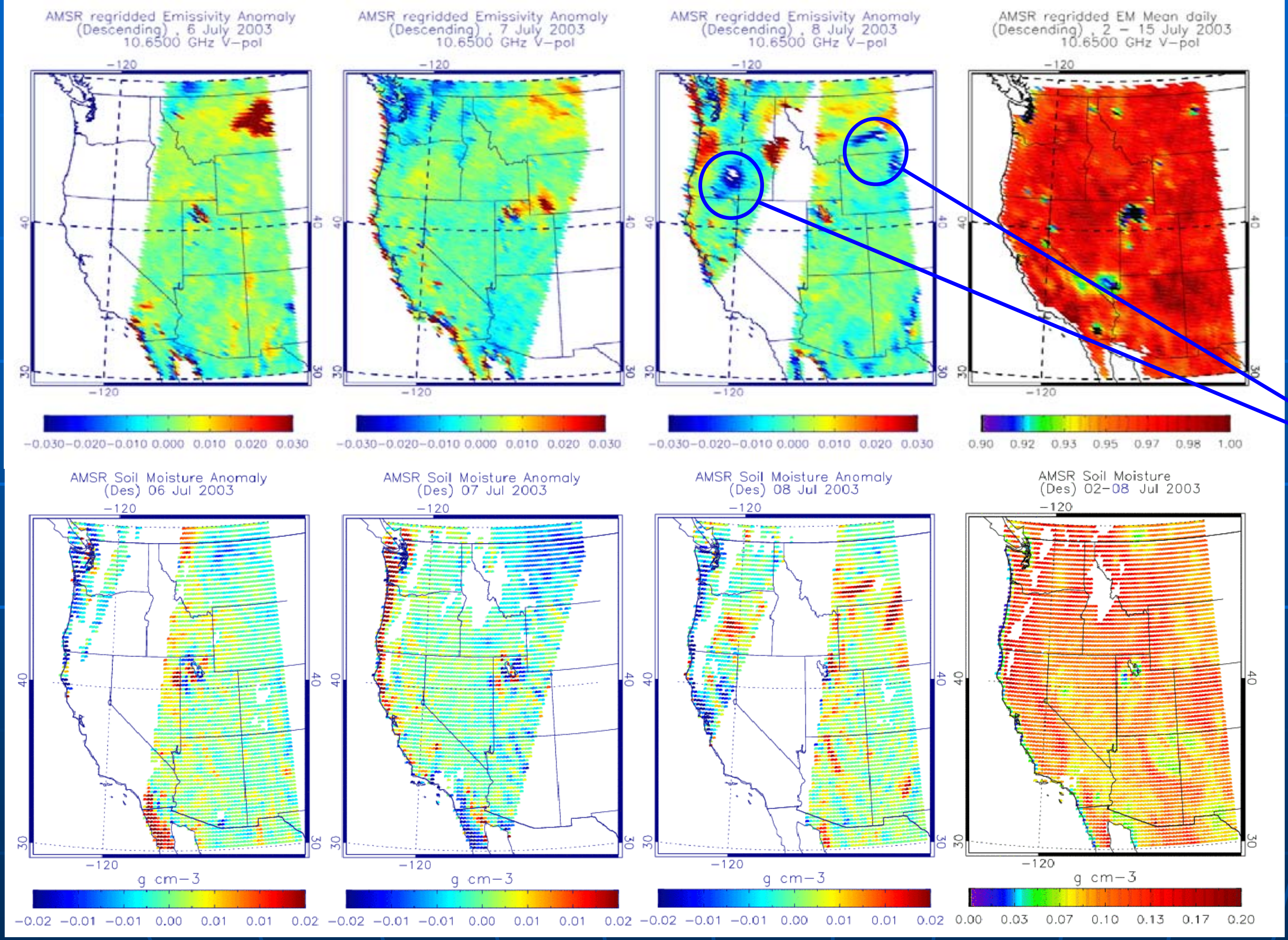
Day Time 07/2003



Quality Control

- EOS products
  - Level 2A AMSR-E QA flag (AMSR_E_L2A B01)
  - MODIS cloud mask/cloud product (MYD06_L2 V004)
    - Initial system used MODIS cloud mask to monitor quality of AMSR measurement and, in case AIRS is used, provide additional QC for AIRS product
    - V4 cloud mask has some known deficiencies, especially at night
  - MODIS level3 LST flag (MYD11B1 V004)
    - Similar to MODIS cloud mask (used as a substitute)
- Inhomogeneous areas flagged using *local spatial variance*
  - Generally low far away from major water bodies (lakes, rivers)
- Outliers
  - Removed by "cluster" analysis
  - Common causes:
    - Residual cloud/precipitation contamination
      - problem over nighttime tropics due to high frequency of occurrence
    - Wetted surfaces due to e.g. precipitation events
    - Dew?
    - Dust/aerosols contamination (through impact on LST ?)
- Stage 2 retrieval convergence

Wet surface characterization



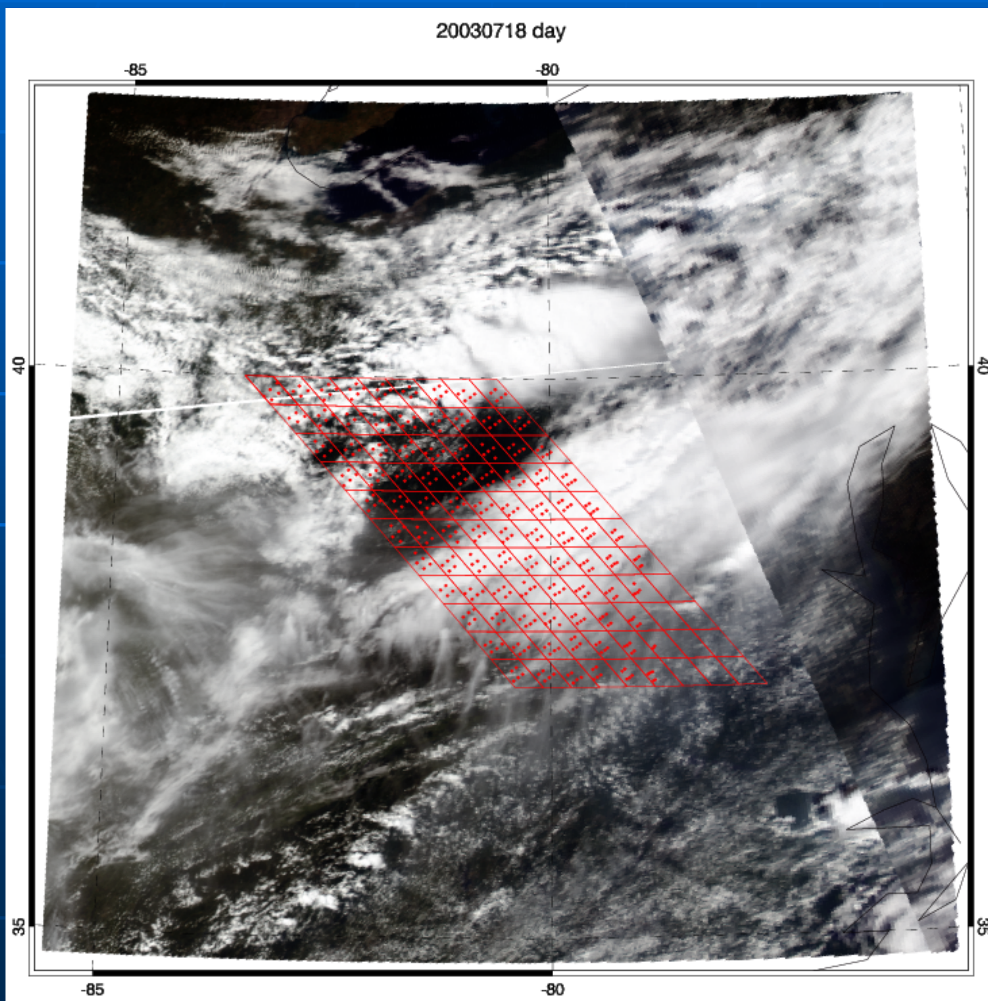
AMSR-E/MODIS derived emissivities (no QC: clouds appear yellow/red)

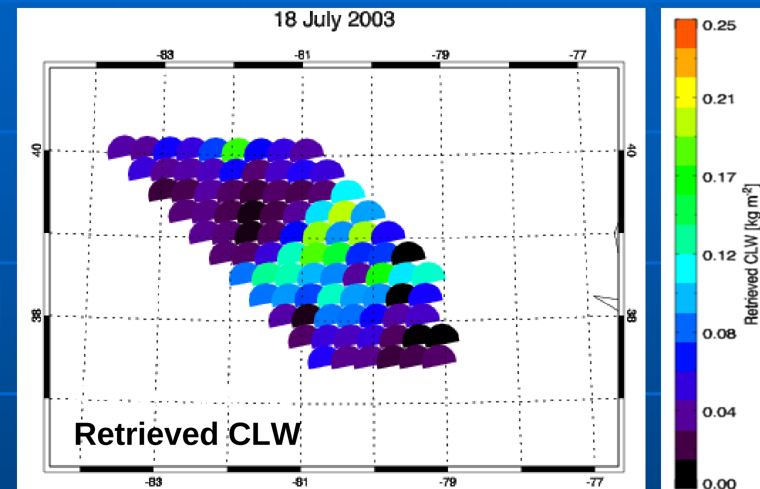
Wetted surfaces (in storm trail)

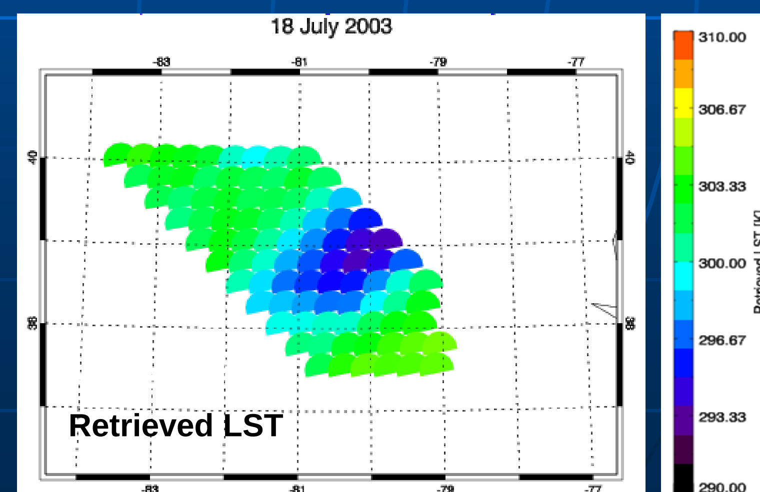
Cloudy land retrieval application

MODIS imagery

West Virginia (July 2003)

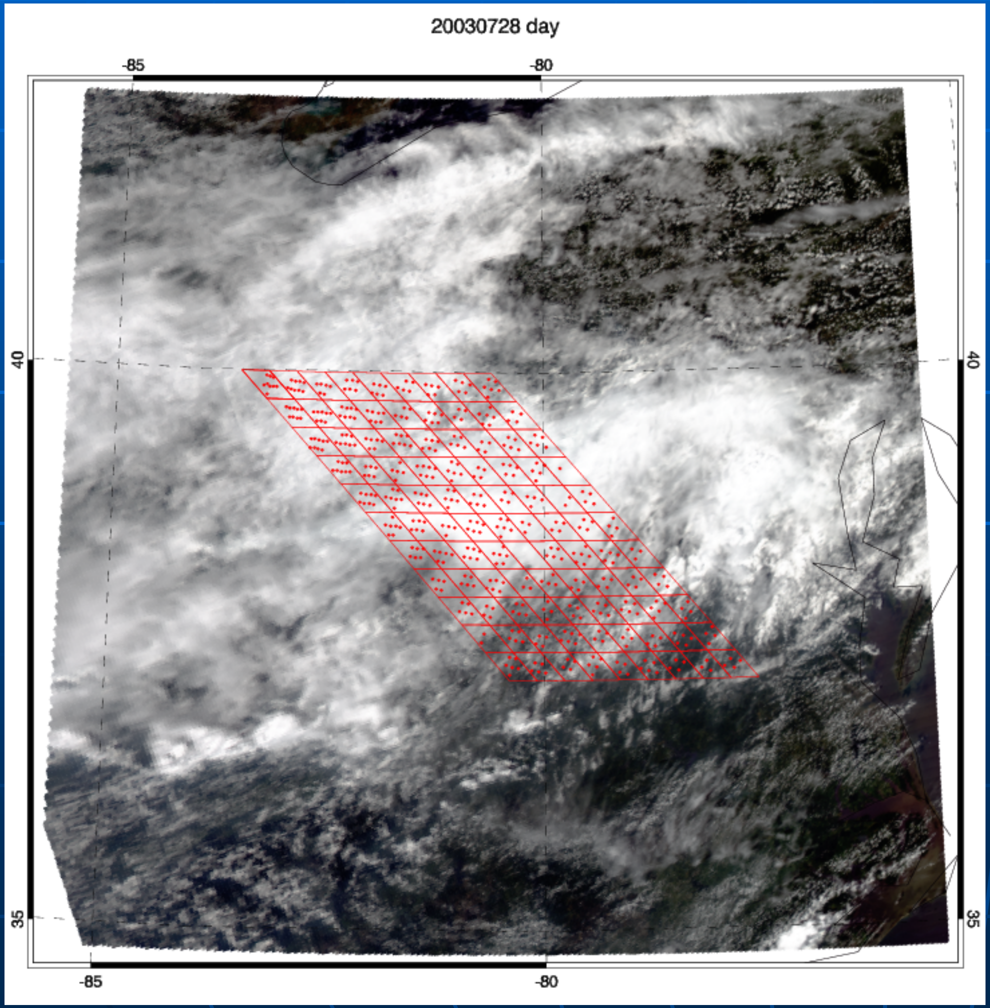




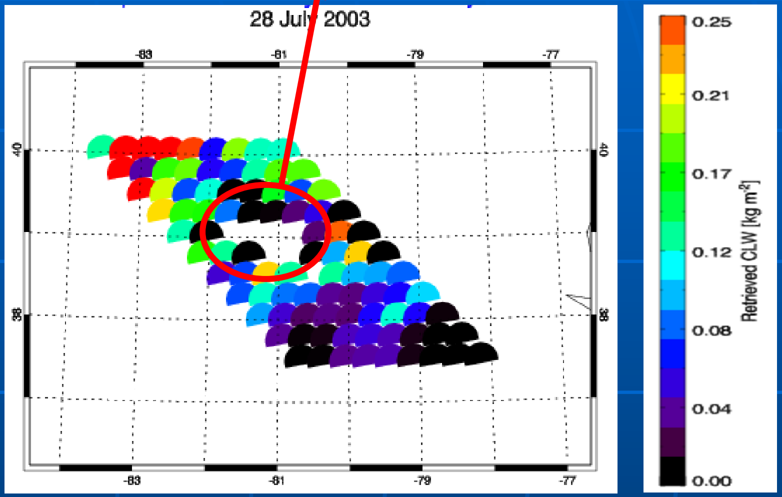


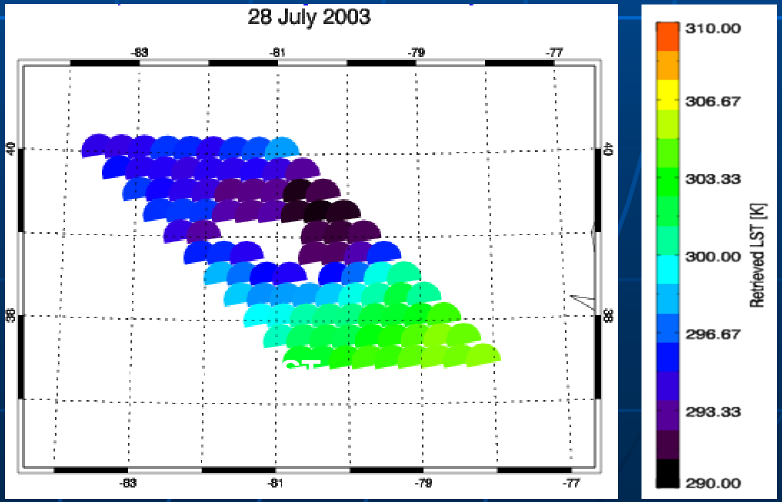
Cloudy land retrieval application (cont.)

MODIS imagery

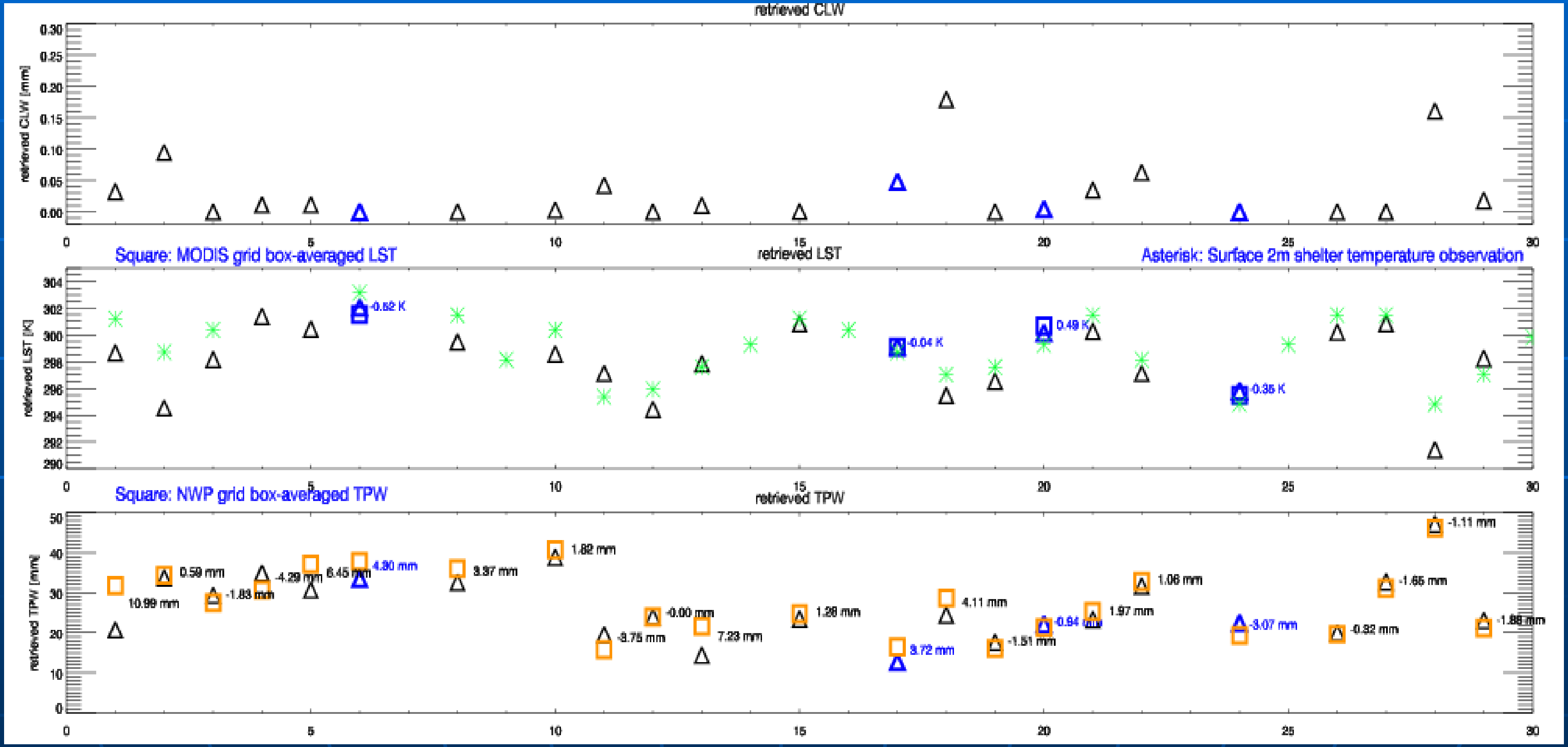


Precipitation (no convergence)



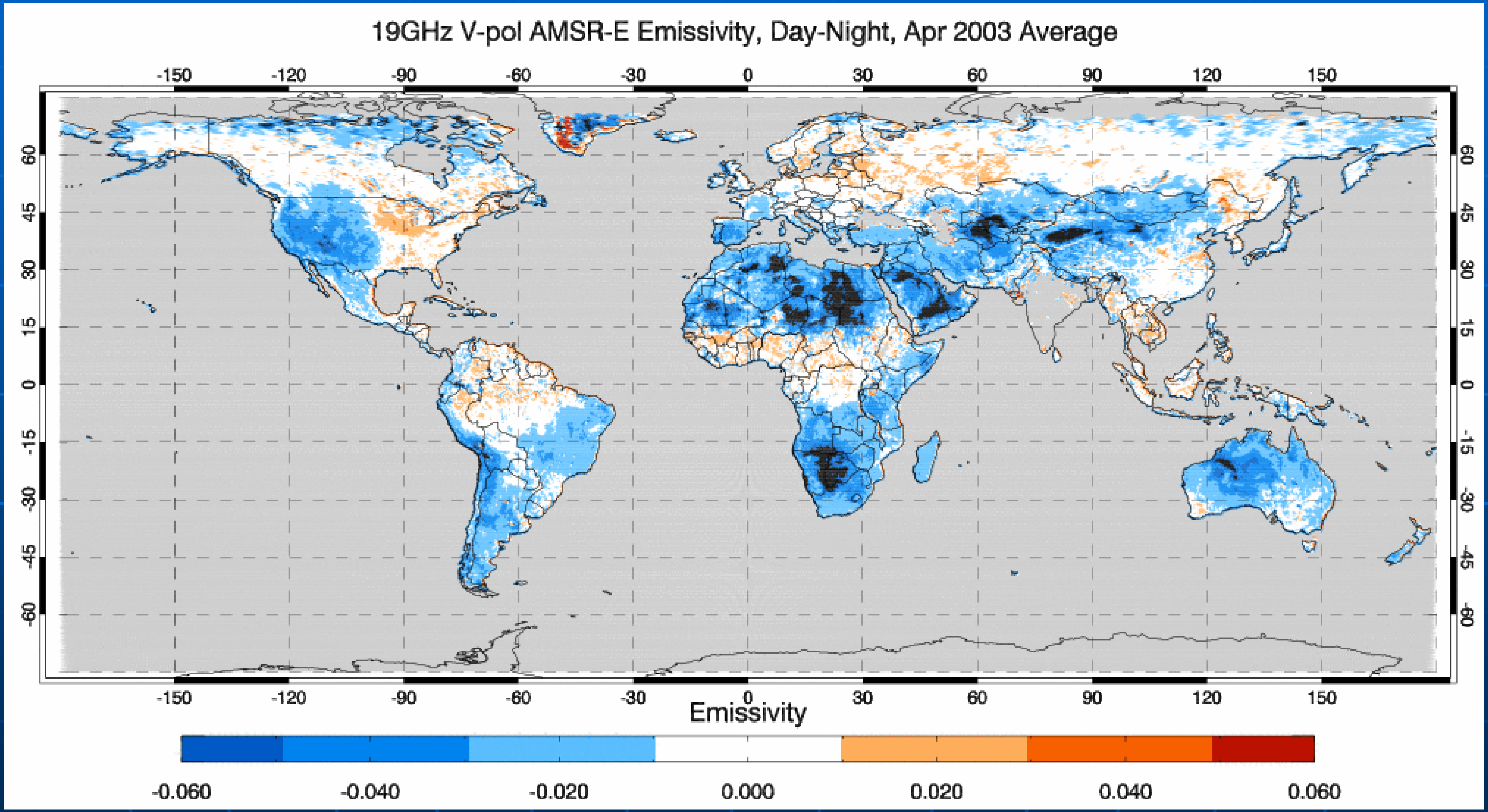


Comparison with NCEP water vapor and KCKB (W. Va.) surface air observations

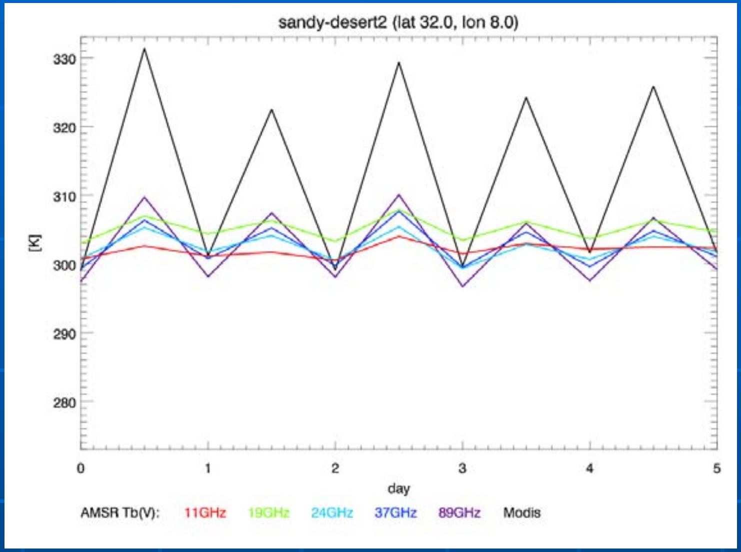


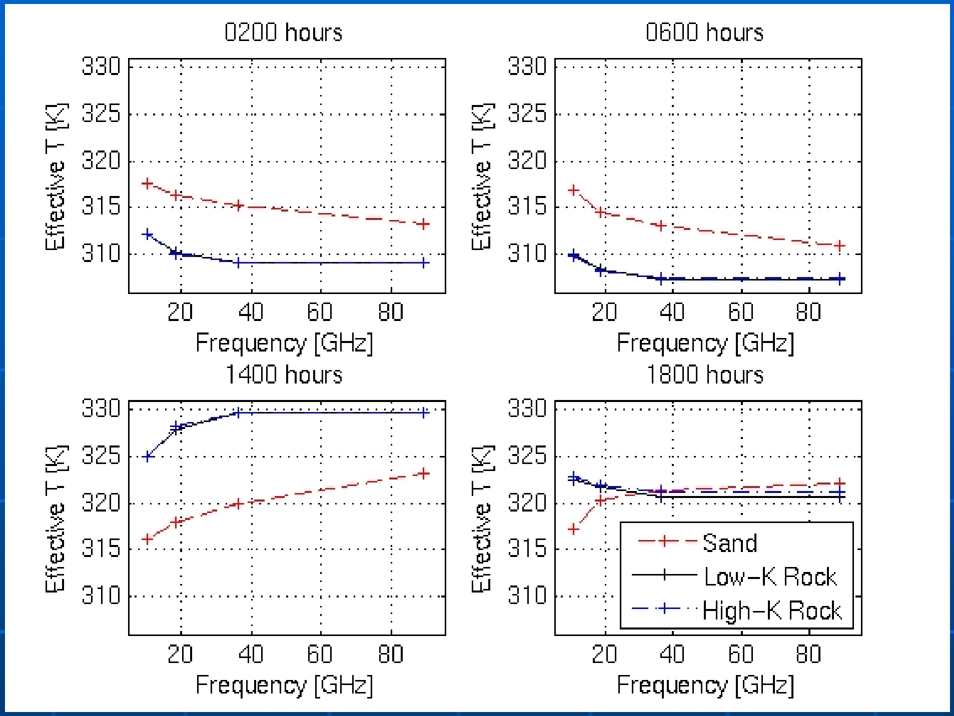
Sub-surface Penetration

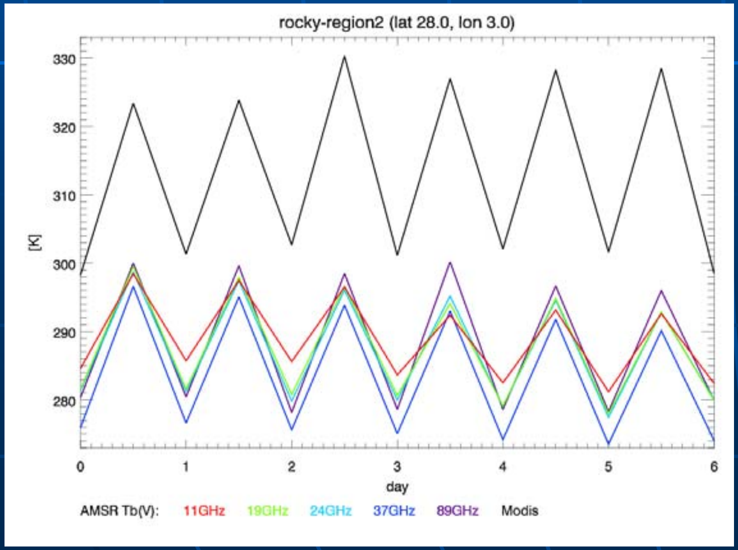
Emissivity from direct retrieval: ascending/descending differences

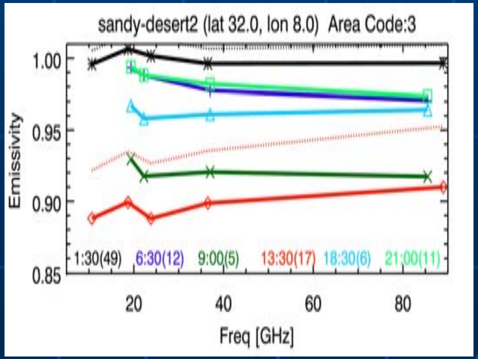


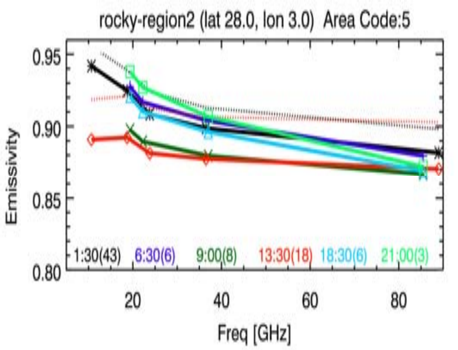
Ascending/descending emissivity differences



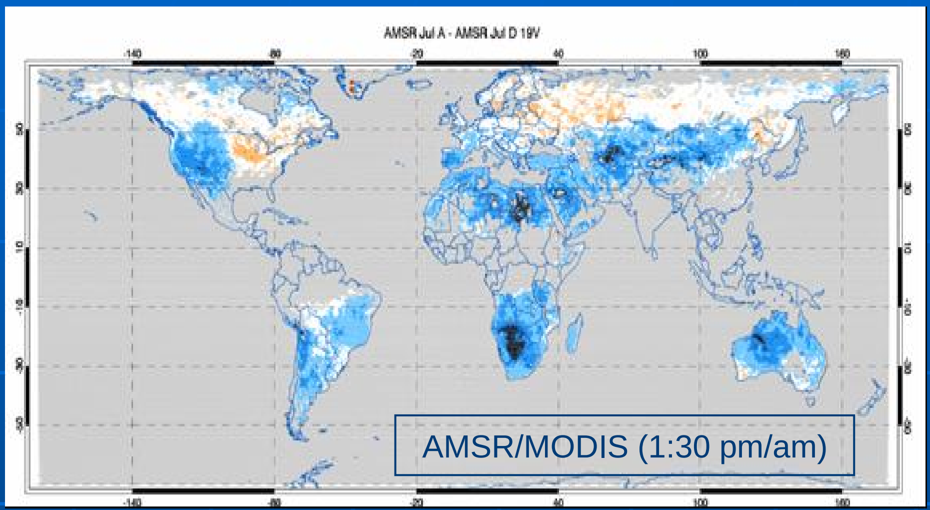


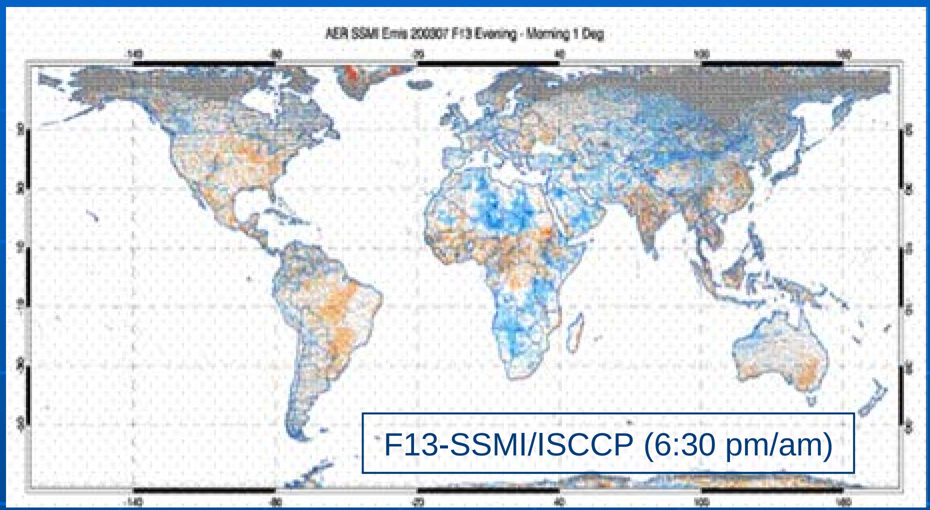


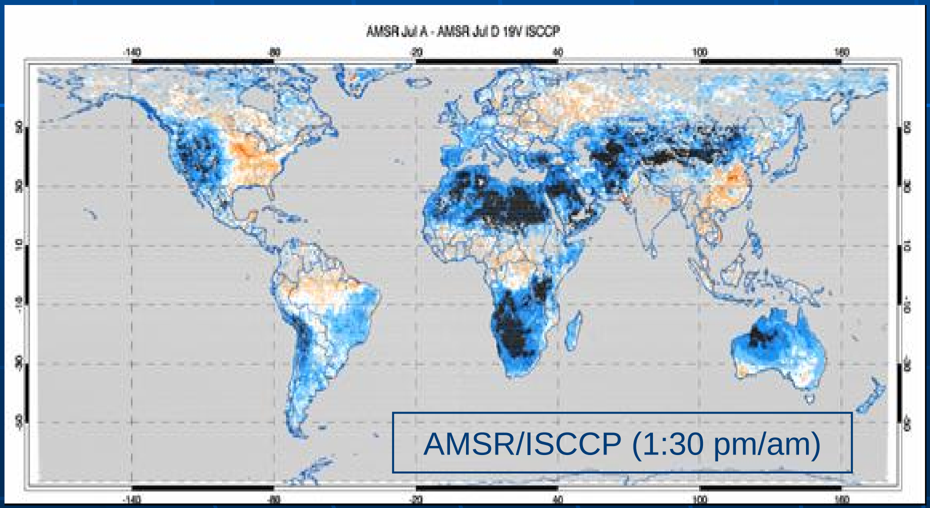


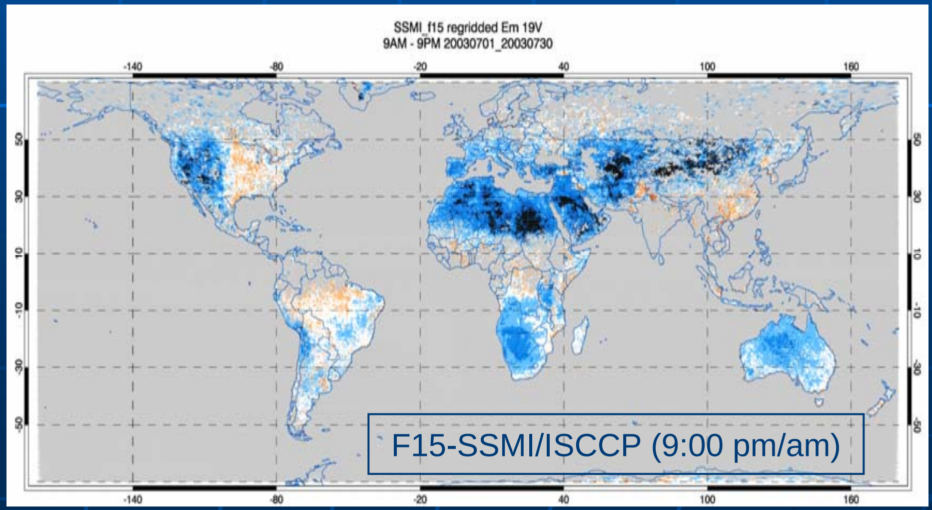


Emissivity differences vs. time of the day

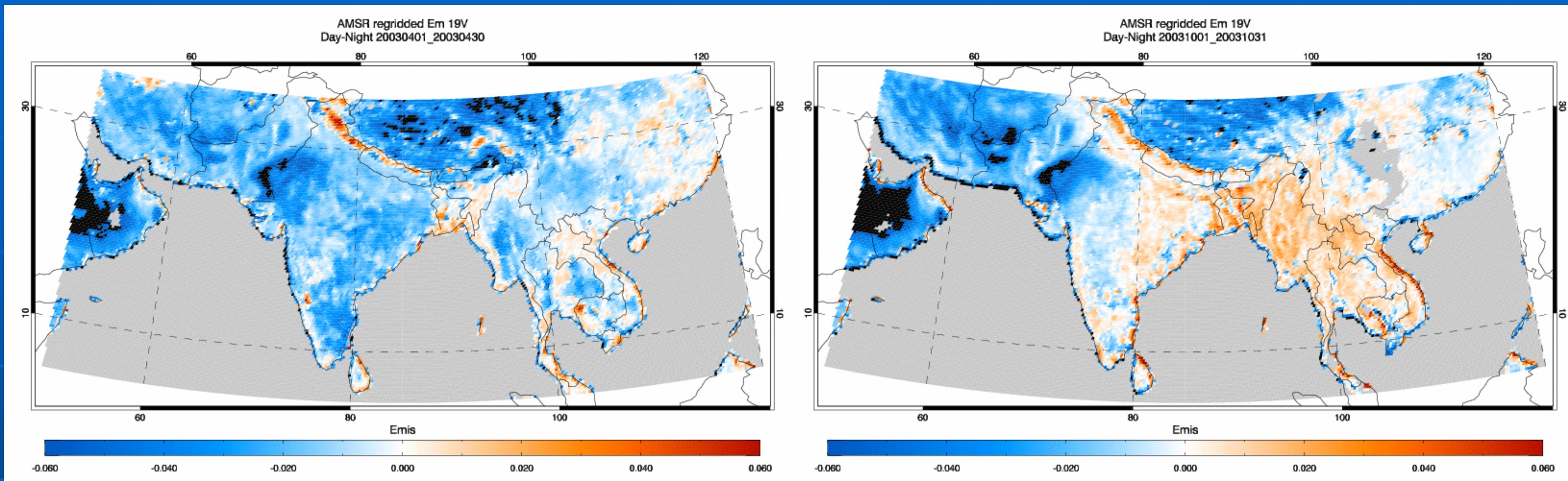


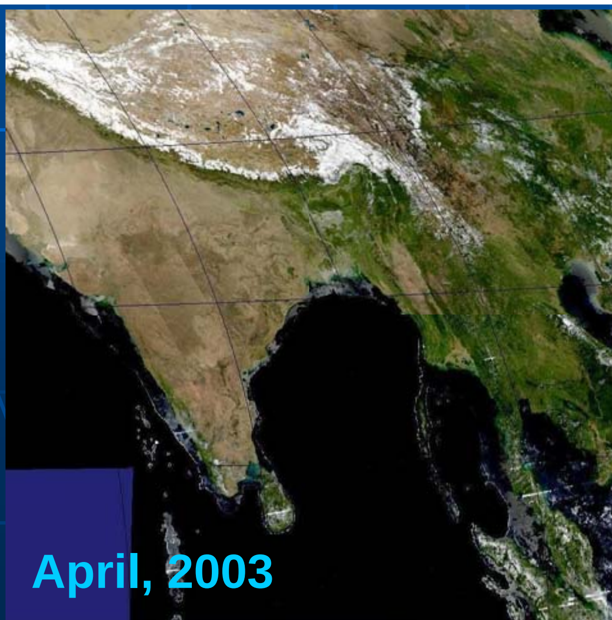






Seasonal variations - correlations with visible reflectance





Retrieval approaches

A. Ignore IR/MW temperature differences
   - Impact of differences carried in emissivity covariance matrix

B. Same but split day and night

C. Estimate emissivity/reflectivity from diurnal cycle response over prescribed time window
   - Retrieve T_{eff} spectrum
     - Relies on V-H emissivity differences to separate soil temperature from cloud water
   - Assumptions:
     - Depth unchanged so long as surface characteristics (hence emissivity) are unchanged
     - Same temperature (“depth”) for V and H

Emission Depth Effects and Mitigation

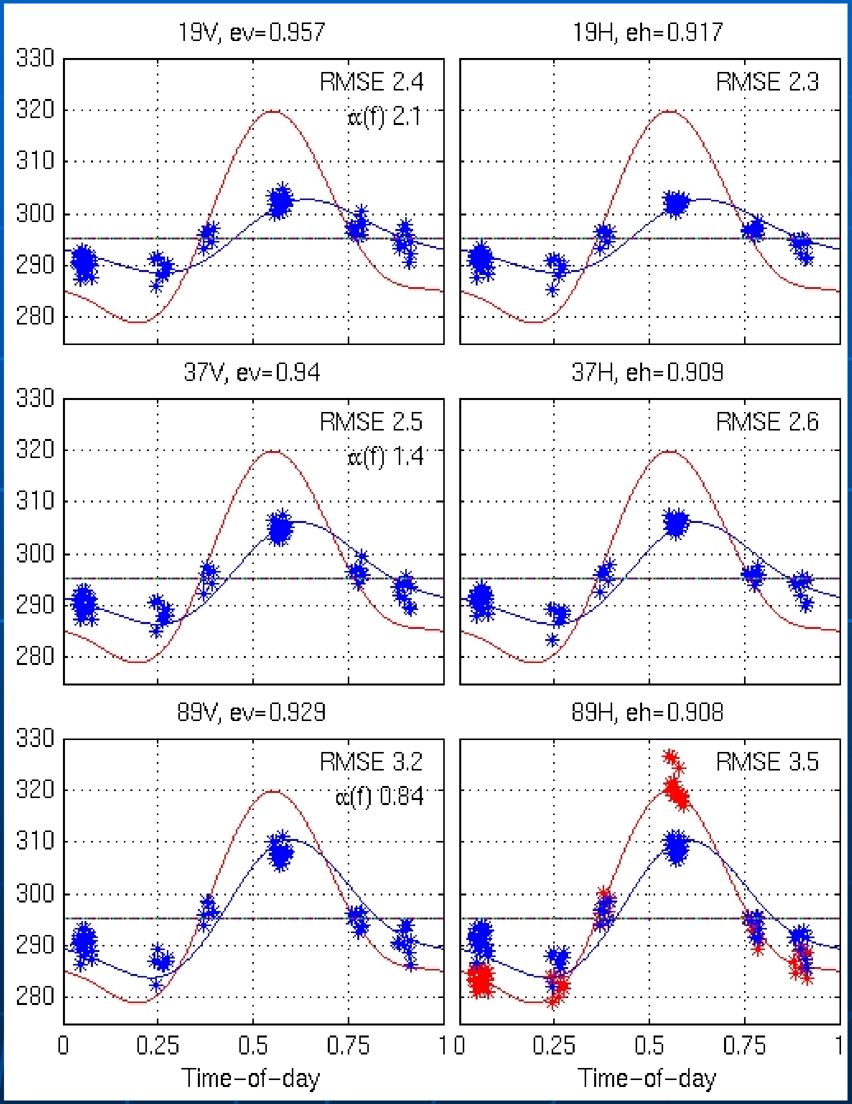
- **Diurnal thermal model (after Prigent et al., 1999):**

$$T_{eff}(\alpha_1,\alpha_2,t) = T_0 + \sum_n \frac{A_n \exp(-\alpha_1\sqrt{n})}{2\Delta\alpha\sqrt{n}}\left[\cos(n\omega_0 t+\phi_n-\alpha_1\sqrt{n})+\sin(n\omega_0 t+\phi_n-\alpha_1\sqrt{n})\right] - \sum_n \frac{A_n \exp(-\alpha_2\sqrt{n})}{2\Delta\alpha\sqrt{n}}\left[\cos(n\omega_0 t+\phi_n-\alpha_2\sqrt{n})+\sin(n\omega_0 t+\phi_n-\alpha_2\sqrt{n})\right]$$

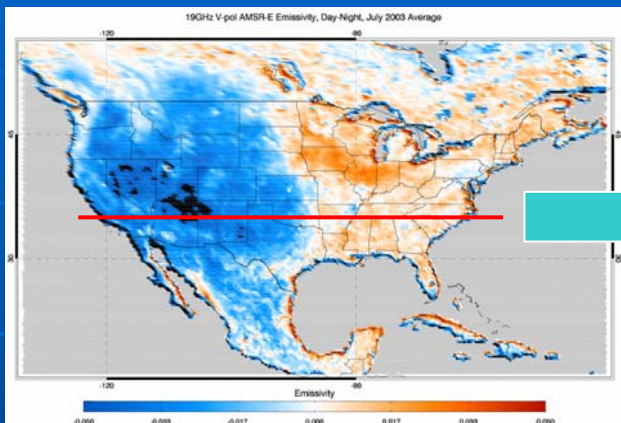
  - ***A1, A2, ϕ_1, ϕ_2, T_0* derived by fitting surface eq. (i.e., α_2=0) to LST inputs**
  - **ε_v, ε_h and α_2 derived from AMSR-E measurements**

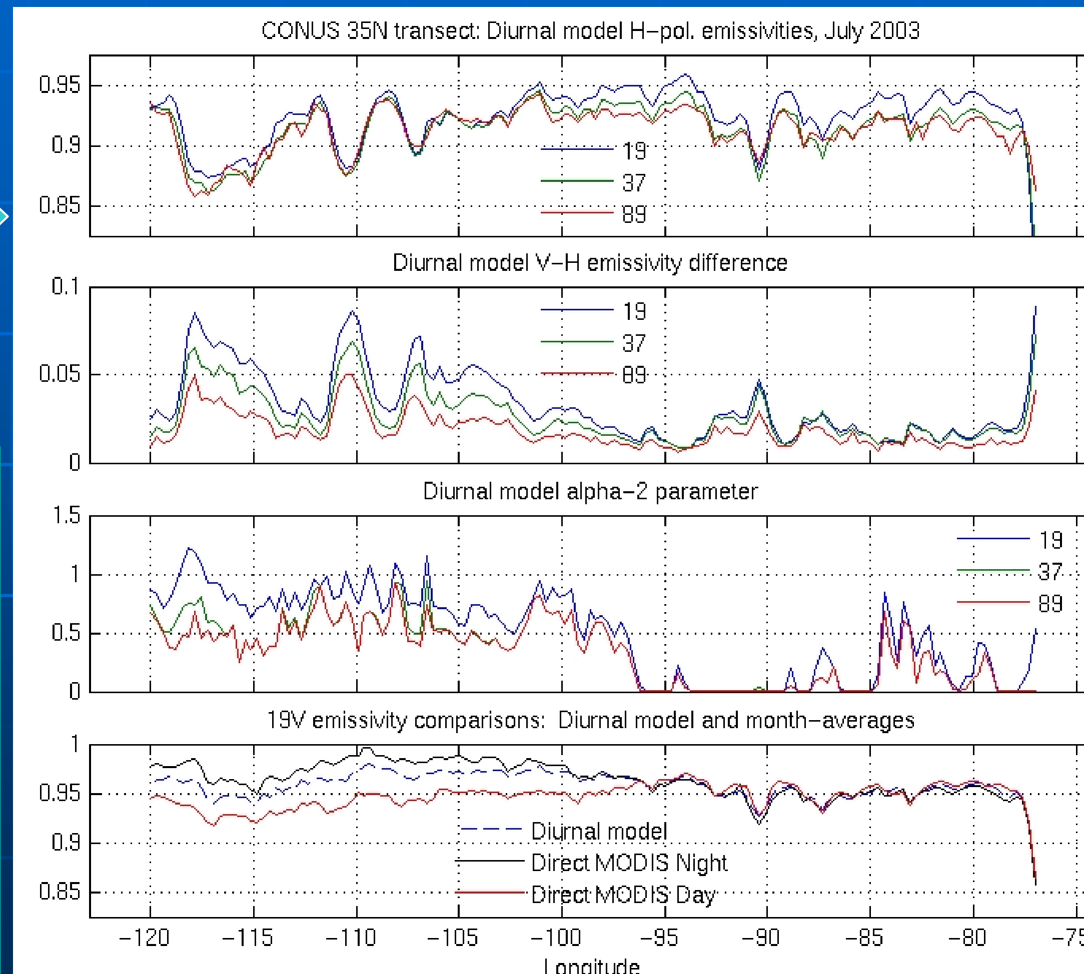
$$\hat{T}_{effi} = \left[\left(T_{Bp} - T_{UP}\right)/\tau_a - (1-\hat{e}_p)T_{DN}\right]/\hat{e}_p$$

α_2 = emission depth parameter (α_1 =0)
***t* = time of day, ω_0 = 2π/day, *n* = 1,2**
ε_p, TB_p = Emissivity/TB at pol. *p*
T_{UP}, T_{DN} = Up/downwelling atm. brightness
τ_a = Atmospheric transmittance



Example of emissivity retrieval



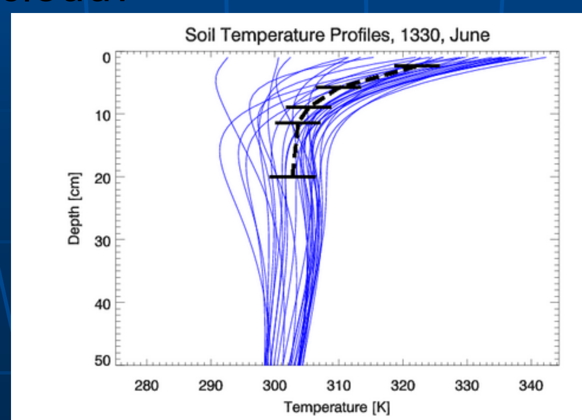


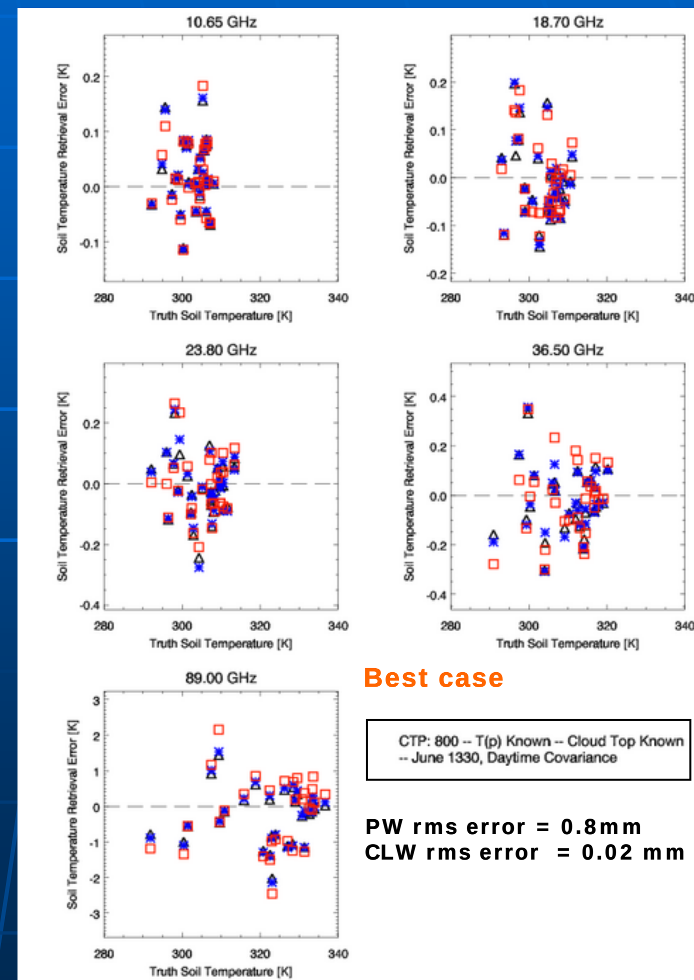
Requirements:

- **Multiple satellites (e.g. Aqua, DMSP, TRMM, Windsat) with different overpass times**
  - Viewing angle correction
  - Sensor inter-calibration
- **LST source:**
  - No MODIS-consistent GOES/Meteosat product
  - Scale ISCCP diurnal amplitude using Aqua/Terra MODIS
  - Alternative: Try fitting 89V

Information content (high penetration depth areas): preliminary assessment

- **PW**
  - Good performance
- **Sub-surface temperature (AMSR + SSM/I)**
  - Good skills using frequencies up to 37 GHz (~5-10 cm) in <u>all conditions</u>
  - up to 89 GHz <u>in presence of cirrus clouds/dust</u>
  - Degraded performance at 89 GHz <u>in presence of CLW</u>
  - Surface change detection capability
- **CLW (and 89 GHz T_{eff} below water clouds)**
  - Requires a priori knowledge of emission temperature of cloud:
    - Atmospheric temperature constraint – NWP model, AIRS
    - Vertical LWC distribution – MODIS (cloud top), A-train (?)





Summary and future work

- Some encouraging results
  - Significant accuracy improvement over previous attempts (due to good MODIS/AMSR-E consistency, timeliness and co-location) – potential for more improvements (QC, PW)
    - Allows us to focus on phenomenology
    - Shorten averaging time scales
  - Identification/treatment of high P-depth regions and retrieval impact analysis
    - Requirements for future systems
- Coming year
  - Complete/integrate preliminary Stage 1 QC and Stage 2 retrieval
  - Test/integrate emissivity estimation algorithm over arid areas
  - Produce Stage 1 emissivities for 2003 (full year)
  - Stage 2 Validation at ARM site + examination of globally selected sites
  - Immediate challenges/issues:
    - Tropical regions: frequent cloudiness; deserts: dust (?)
    - Semi-arid (vegetated) areas: small 37/89GHz polarization differences
    - Snow/ice
- Proposed follow-up tasks:
  - Continue/extend validation, refine processing/QC
  - Test retrieval in arid areas, finalize Stage 2
  - Switch new AMSR calibration, V.5 MODIS cloud mask (LST not reprocessed yet)
    - MW + IR emissivity to NOAA/JCSDA (model validation)
  - Extension to polar regions
  - SM algorithm calibration + vegetation index (CO2 mapping/monitoring– NACP funded)