Lunar Hydrogen Sequestration towards Poleward facing slopes

Lunar Ice Detection Workshop
California Institute of Technology
Pasadena CA

July 22 - 25, 2013

Tim McClanahan
The LEND Team

Outline:

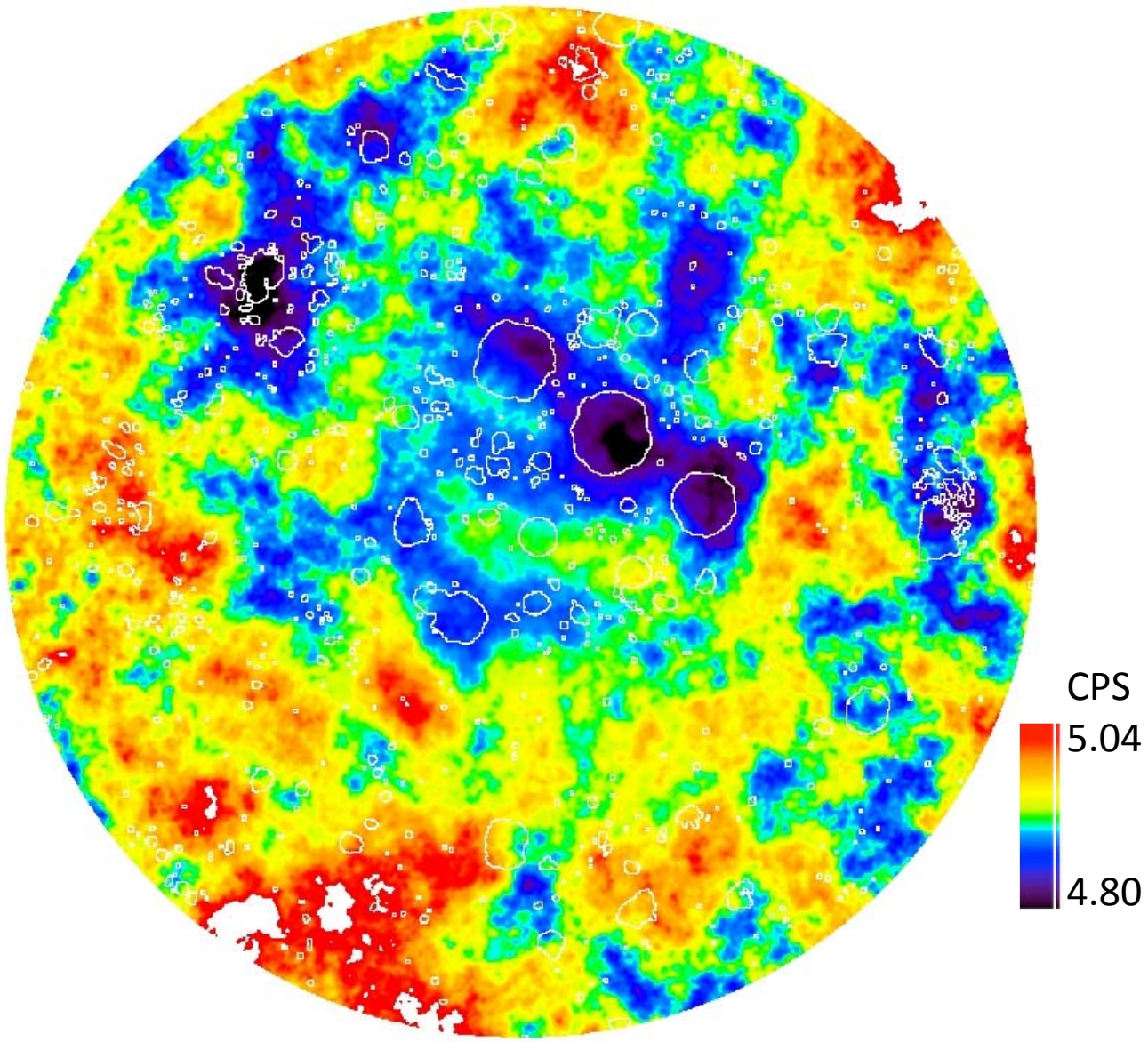
1. LEND SP Videos and New SP Map
2. Hydration Effects in Mid-Latitudes M^3
3. Comparative Planetology: Insolation and H Volatiles
   - Latitude and Topography
   - Insolation Model from slope
4. Multi-scale analysis: Altitude, Scale and SNR
   Factors: LPNS (30km) Uncollimated
   LEND (50km)
   - SETN UnCollimated, SP vs NP
   - CSETN Collimated
5. Mid-Latitude Pole-Facing Slope Hydration
6. Conclusions

LEND South Pole Coverage

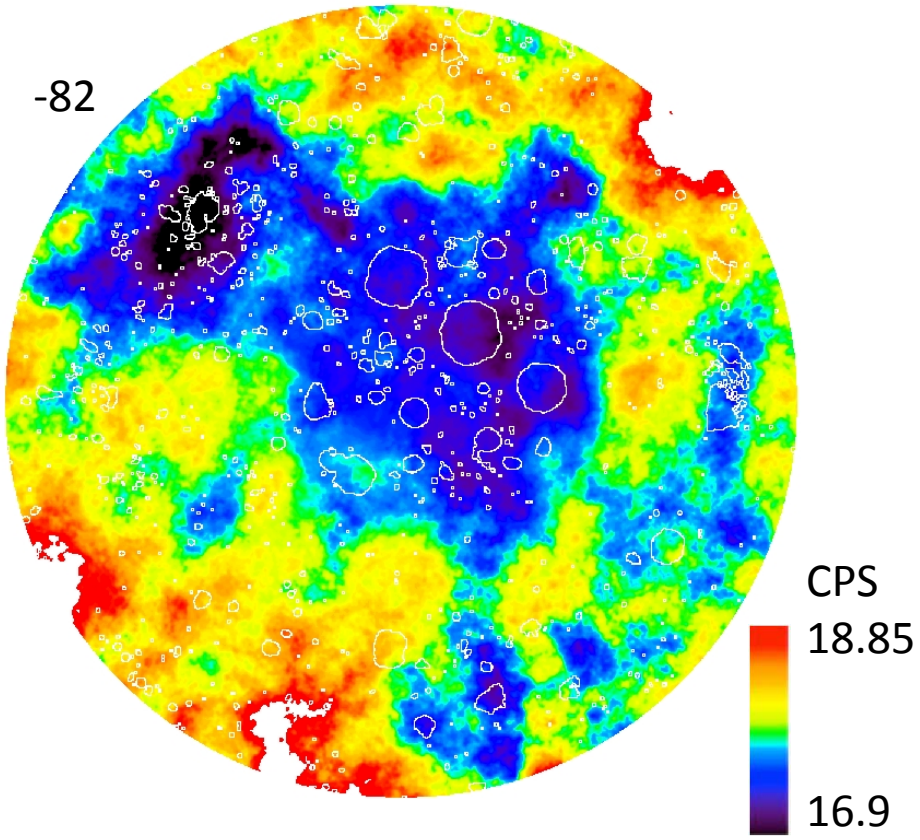
Goddard Science and Visualization Studio

LEND:
-82 to -90

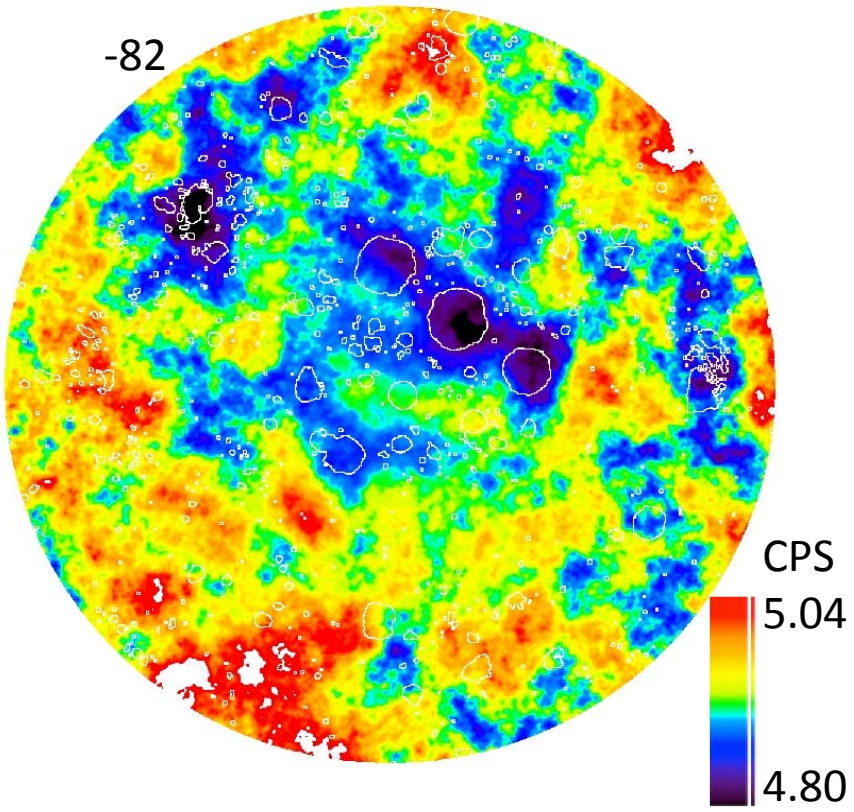
July 2, 2009
To
July 17, 2014



LPNS* SP Low Altitude

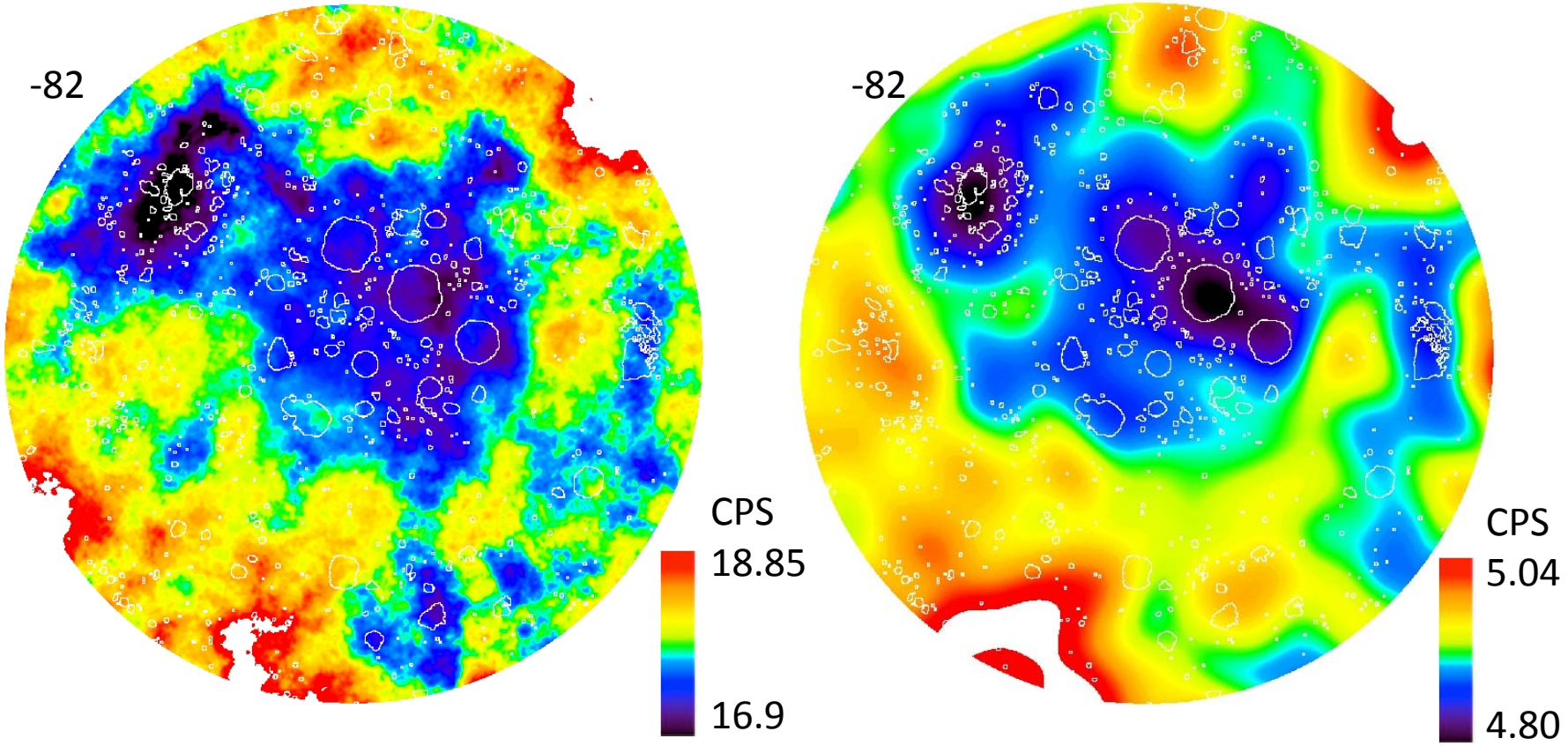


CSETN SP



LPNS* SP Low Altitude

CSETN SP Blurred (40km FWHM)



Detailed Modeling of LEND: 2 Papers

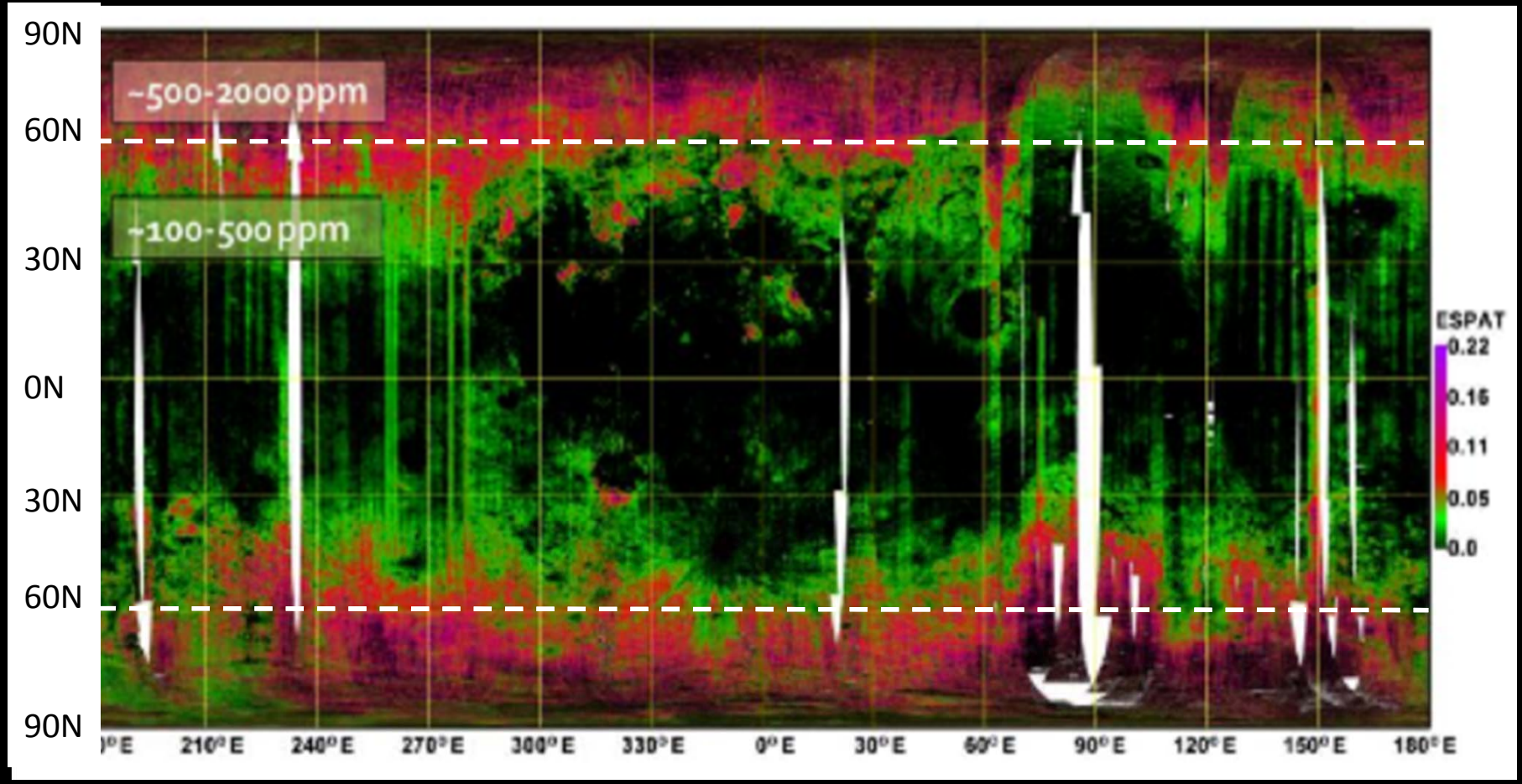
Updated Calibration techniques: 1 paper, Science papers 2

Stay tuned!

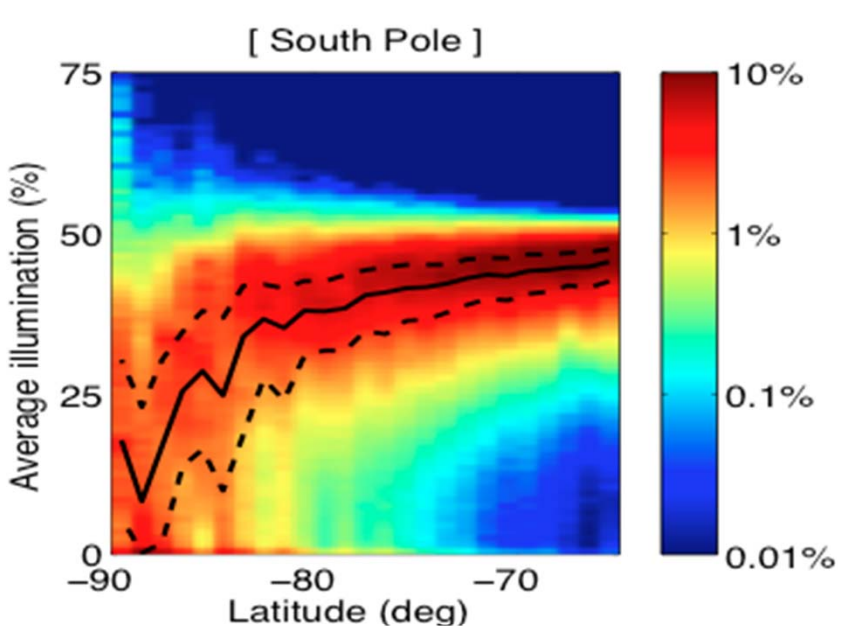
Insolation and Surface Hydration

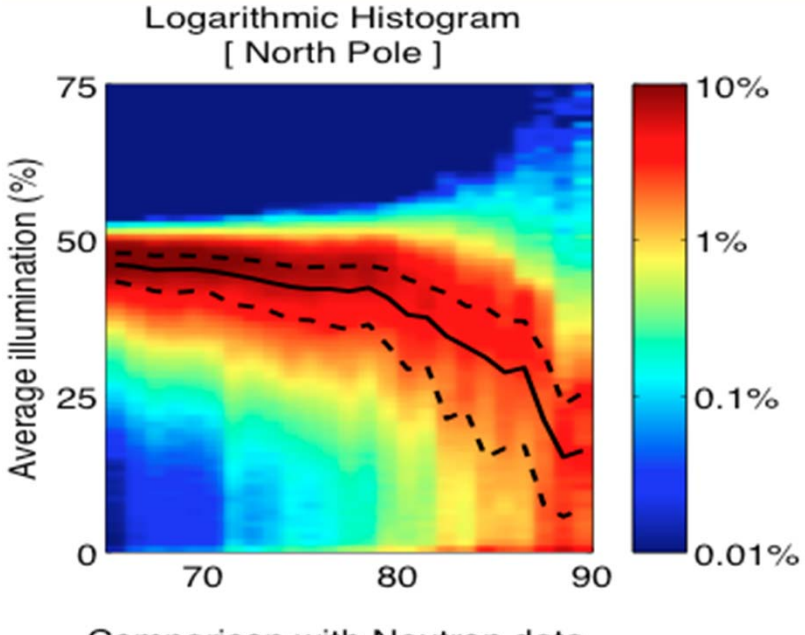
Pieters et al, 2010, Mid-latitude Crater slopes, M^3 3-µm

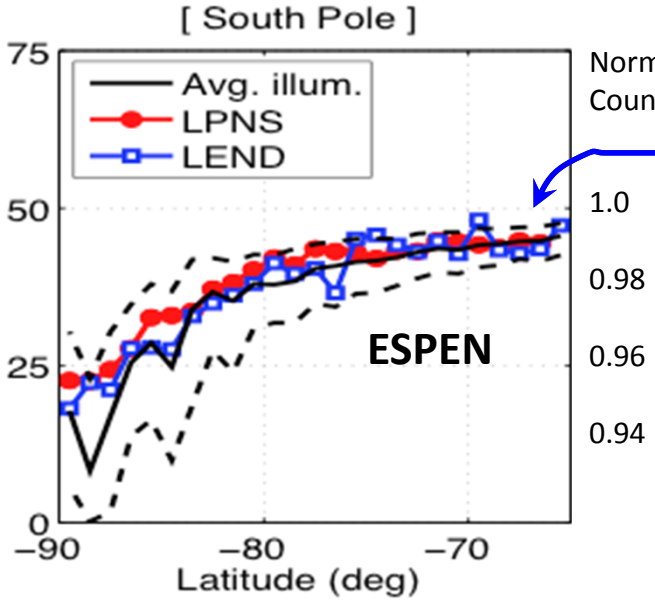
Li et al., LPSC 2013, H increases as F(Latitude) > ±60°



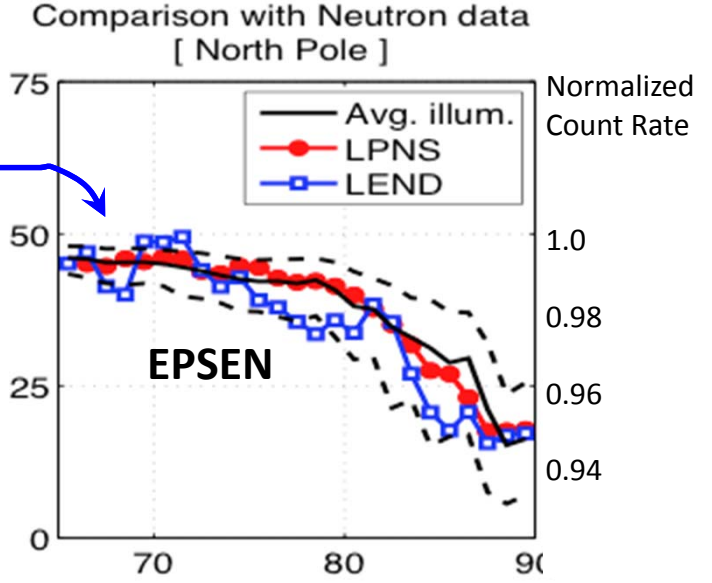
Insolation and "Extended Polar Suppression of Epithermal Neutrons"







PSR = 0.1%



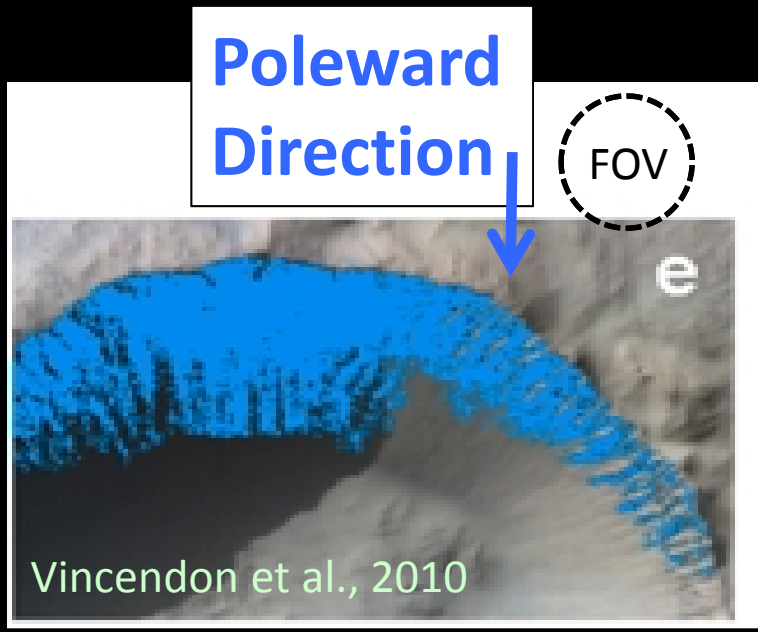
(Feldman et al. 1998, Mitrofanov et al. 2010)

E. Mazarico

Illumination / Thermodynamic Effects on Hydrogen in Cratered Topography

Hypothesis: Epithermal Rates in:

1. **Pole Facing** < **Equator Facing**
2. East Facing = West Facing
3. High Slope Contrast > Low Slopes
4. North = South

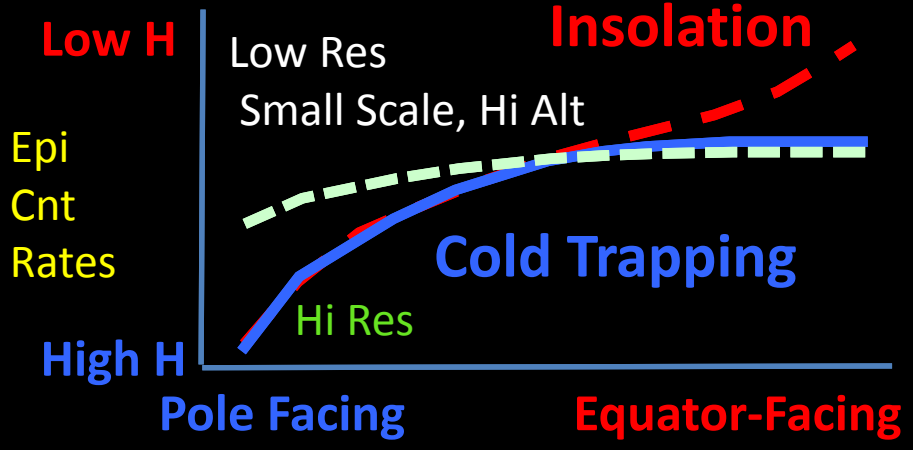


Mars CRISM: Thin water frosts on poleward-facing slopes.

- Indirect FOV comparison

LowRes FOV: CT ~linear curve

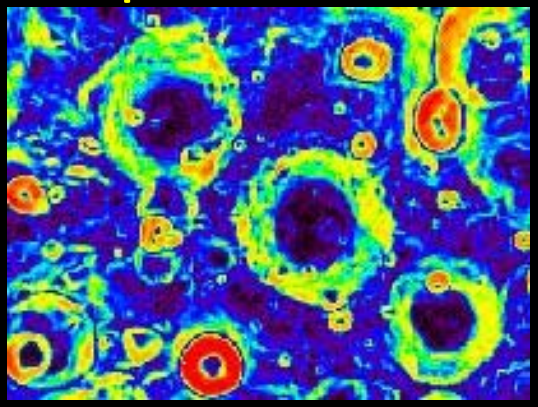
HiRes FOV: CT sharper curve



LOLA DEM Insolation Processing Methods:

1. Transform Topo to Insolation model, I (average)

I(θ, Φ) = Slope θ

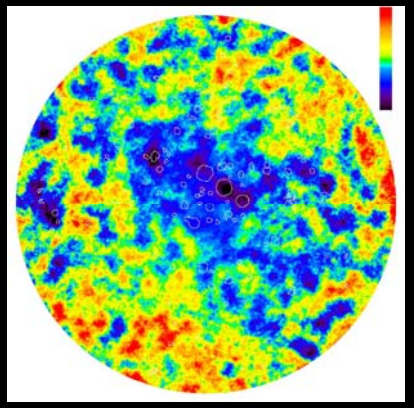


Slope Azimuth Φ to pole

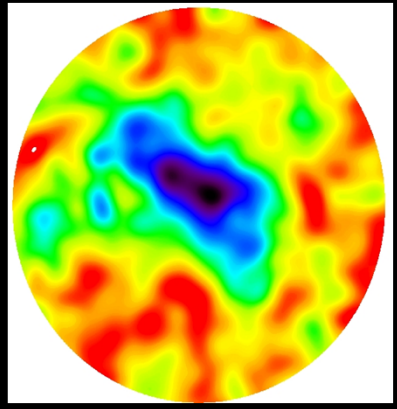
- Scale Invariant Transform

2. High Pass Filter Epi Maps Removes EPSEN

Map

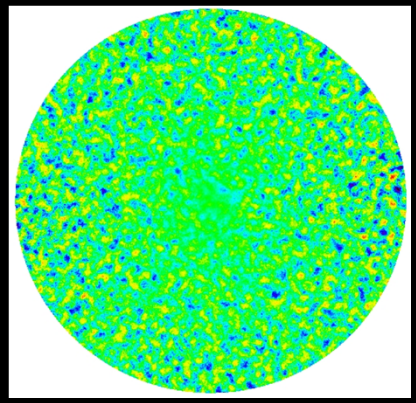


Smooth



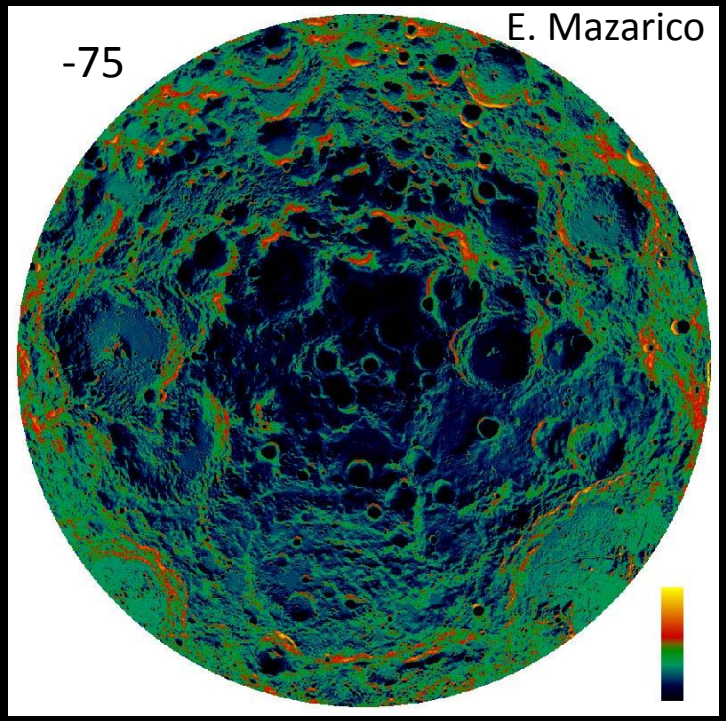
Map-Smooth

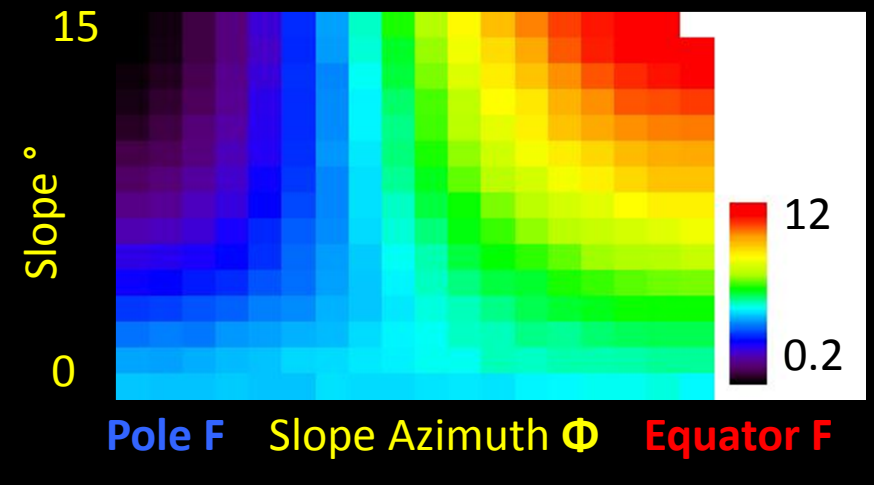
Uncerts and Topo



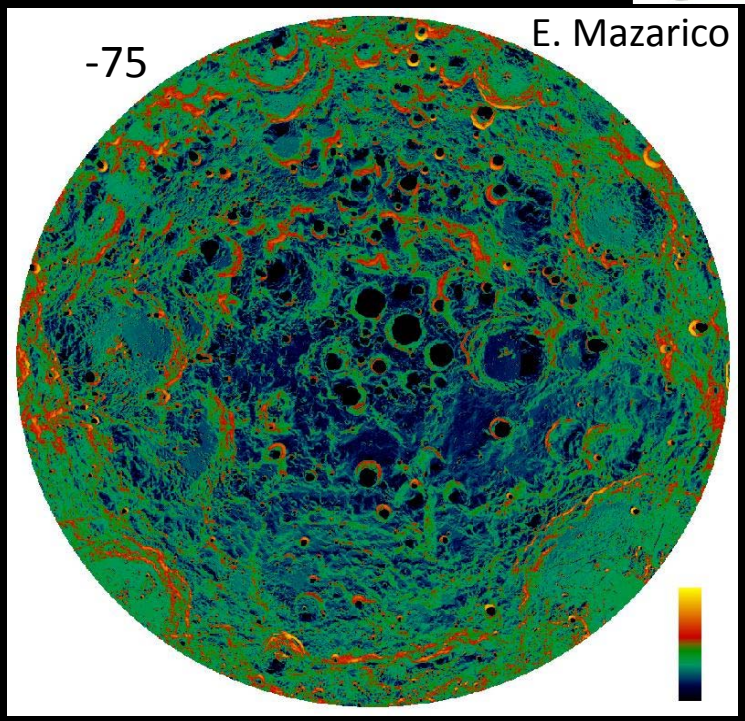
LOLA SP Illumination to Insolation Model: I(Φ,θ)

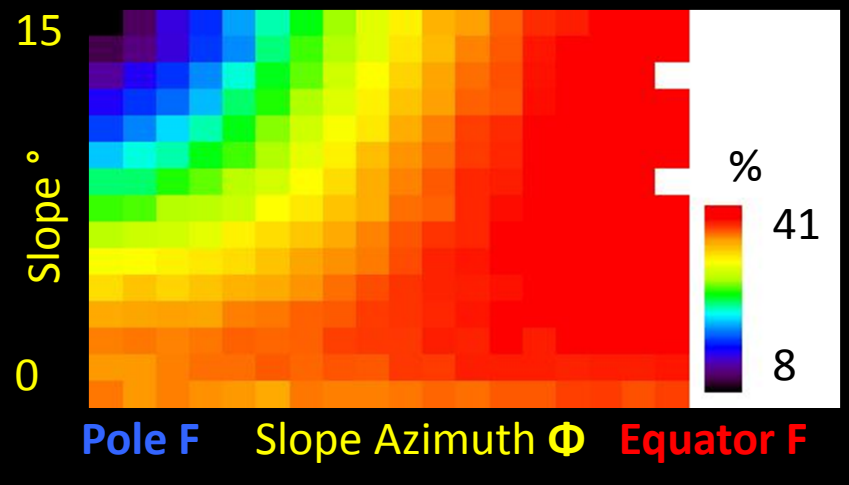
Average Flux (Cos weighted)



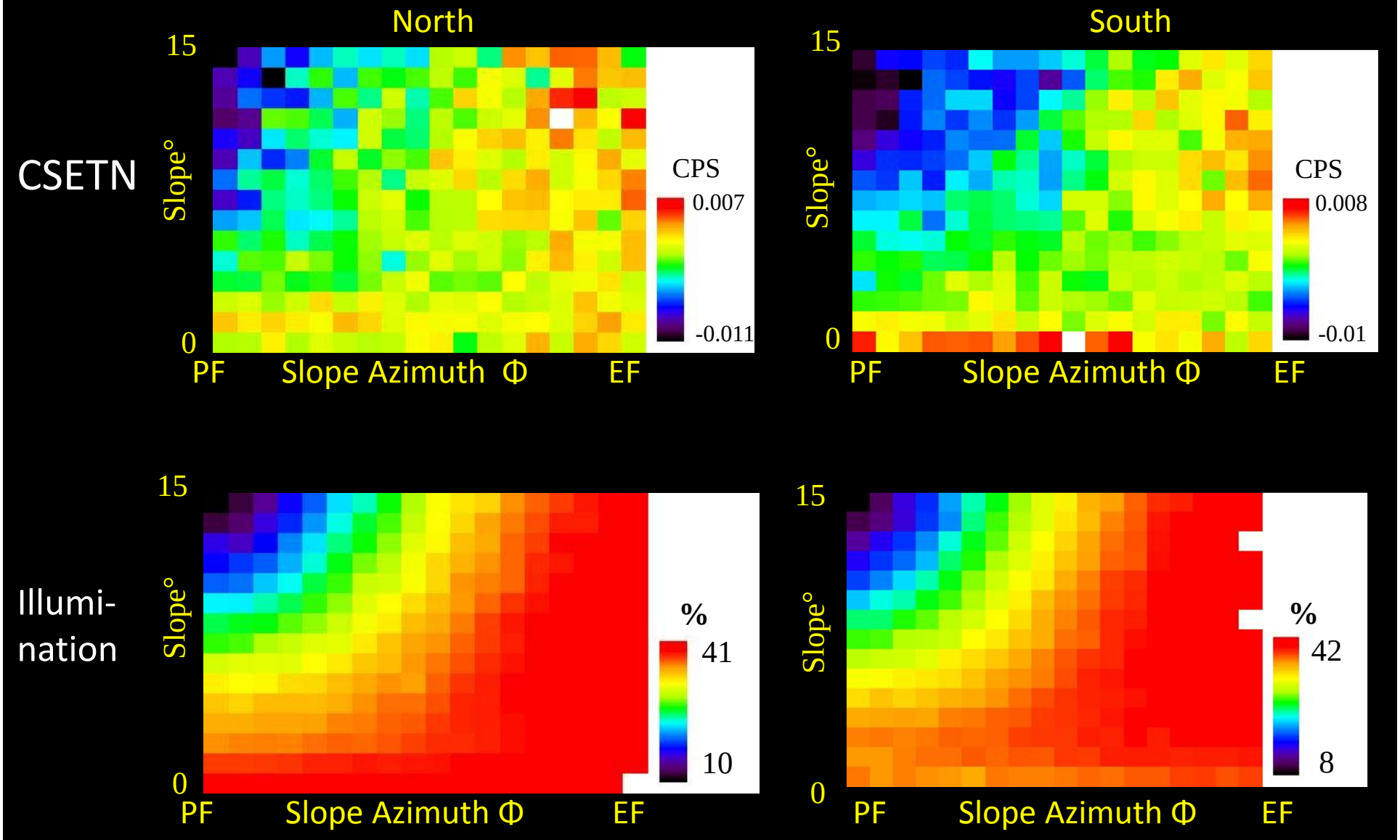


Average Illumination



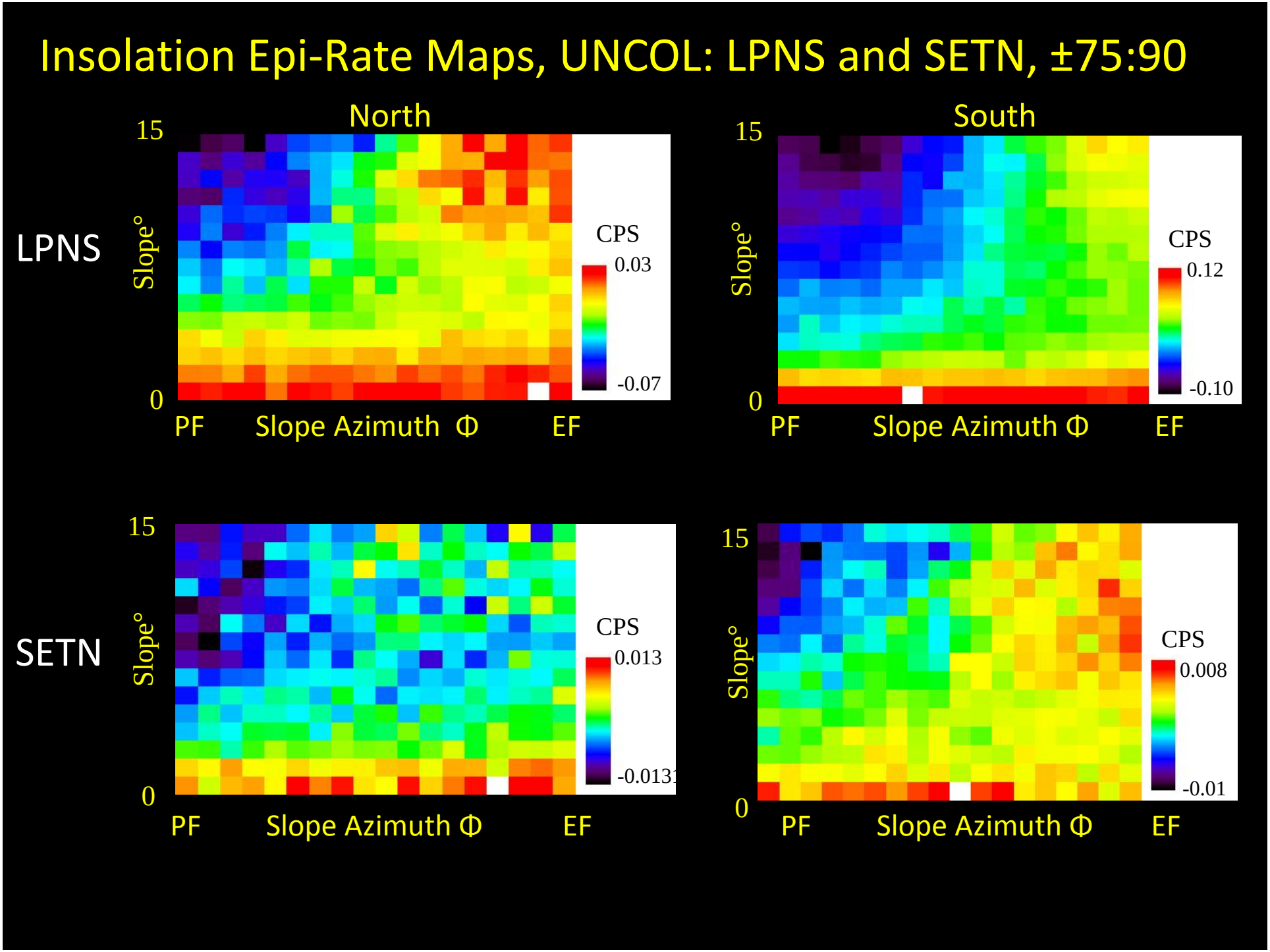


Insolation Epi-Rate Maps: CSETN vs Illumination, ±75:90

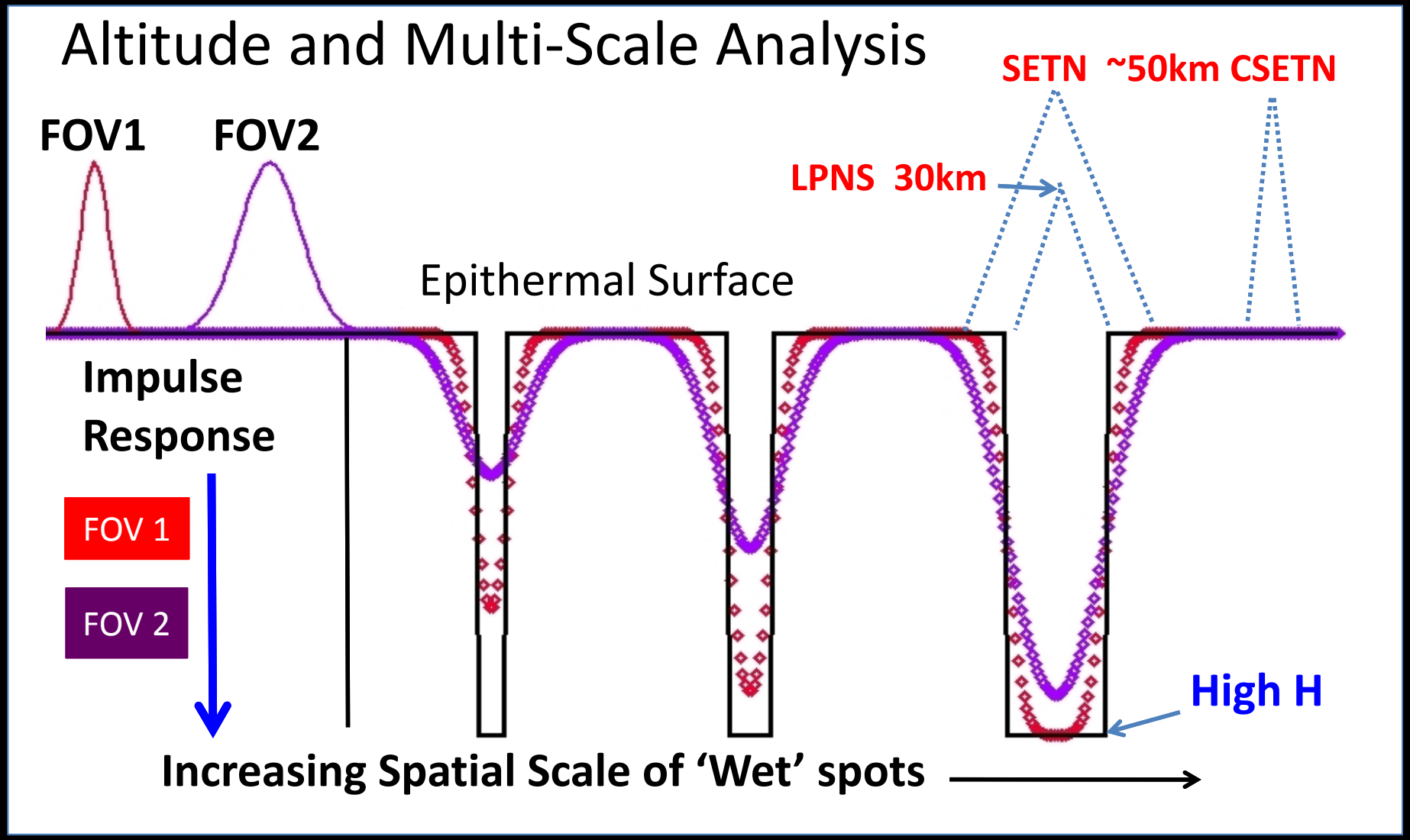


- Insolation Pattern: Epithermal rates suppressed on PF slopes vs EF

Insolation Epi-Rate Maps, UNCOL: LPNS and SETN, ±75:90

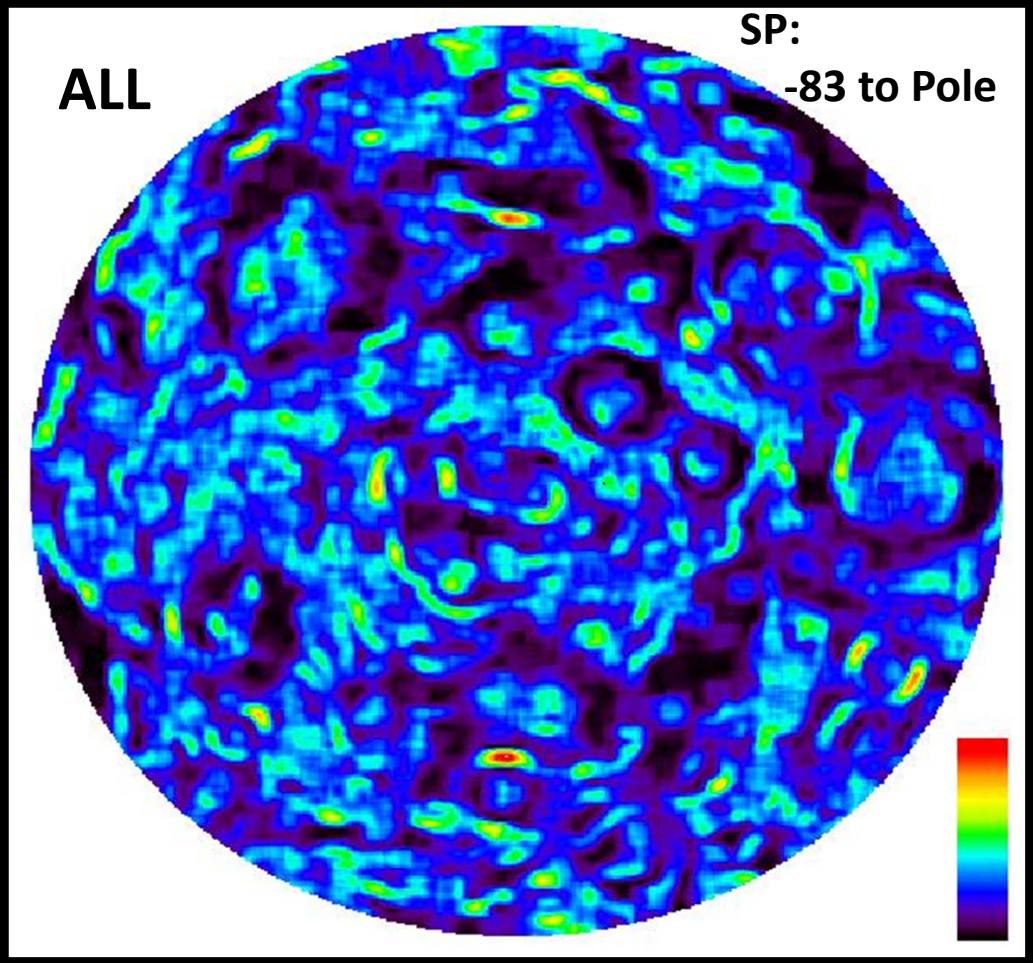


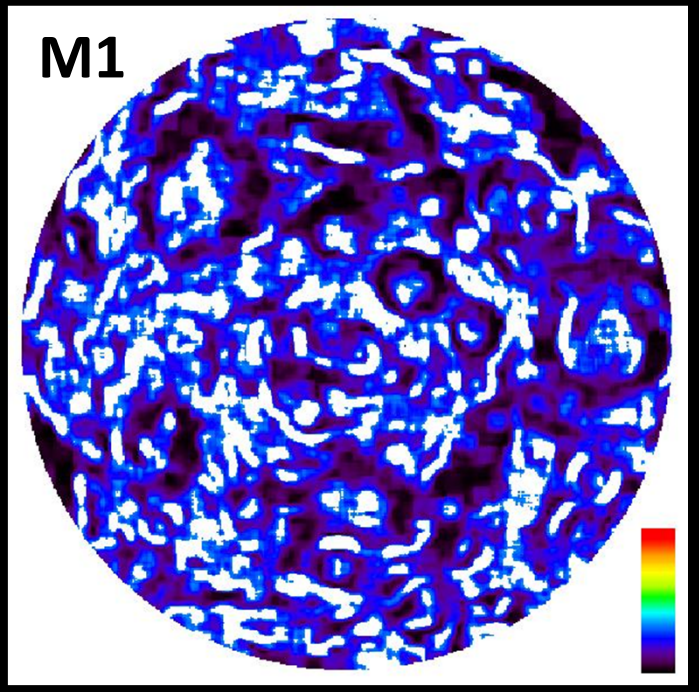
Convolution: Impulse Response

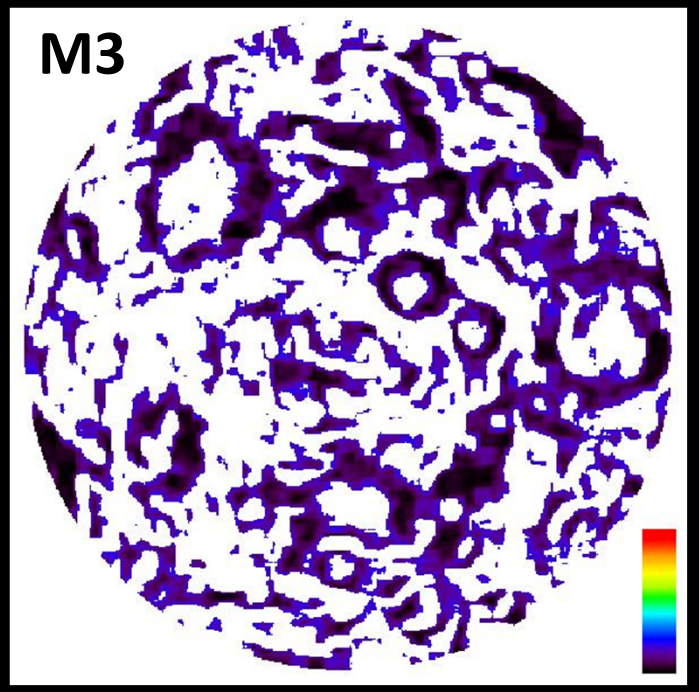


- FOV's: LEND SETN (50km) vs LPNS (30km), Collim CSETN?
- Improve SNR: Mask out small scale features

Improve Signal to Noise Ratio:
Systematically mask
Off hi to low spatial freq pixels.

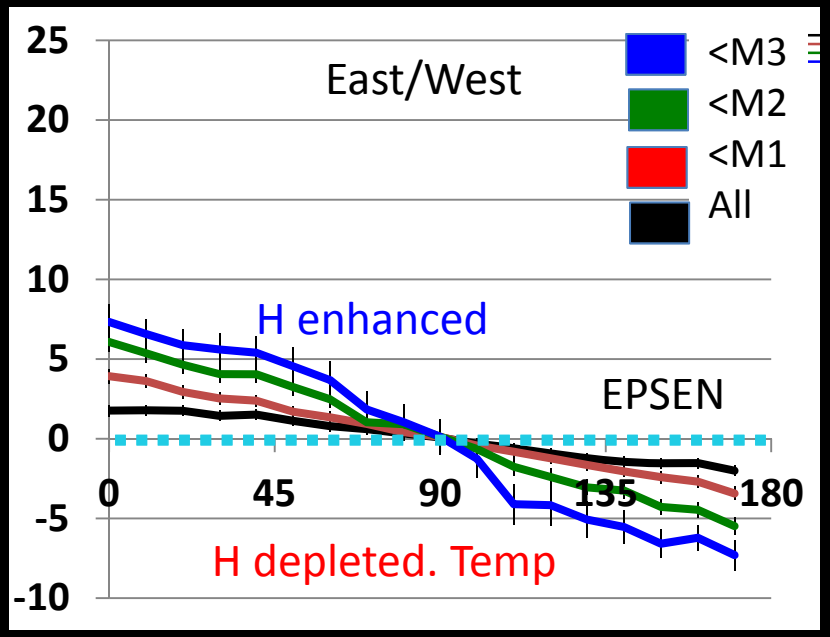




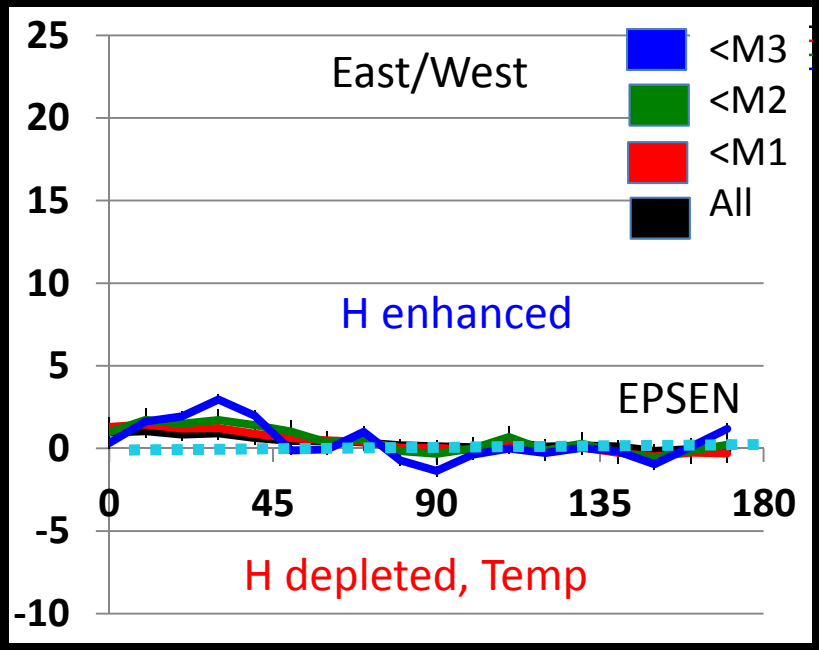


UnCollim:

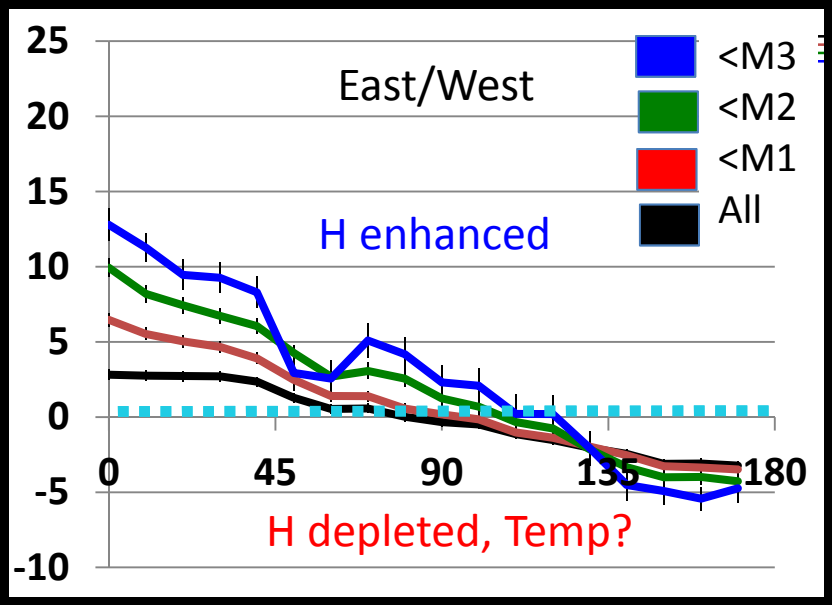
LPNS: Ref Rate 19.5 cps



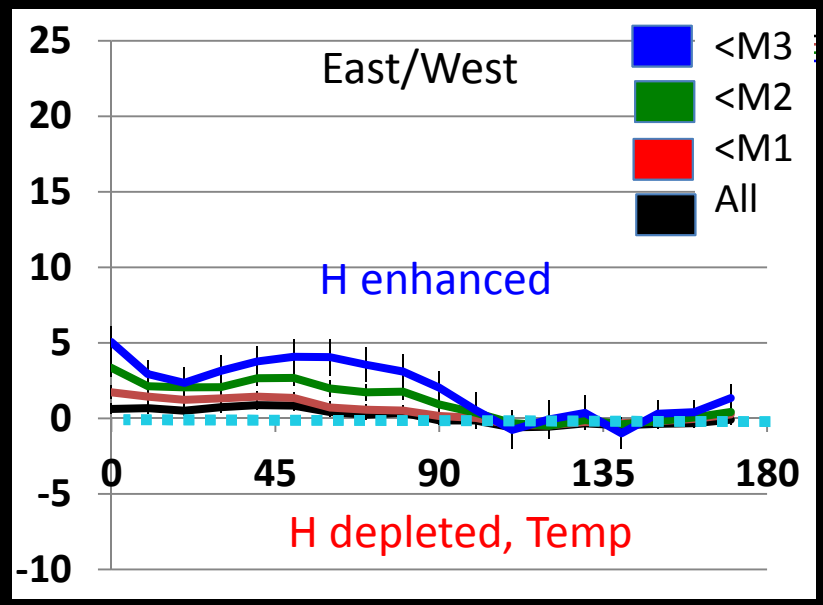
LEND SETN: Ref Rate = 9.5 cps



PF Azimuth Φ EF



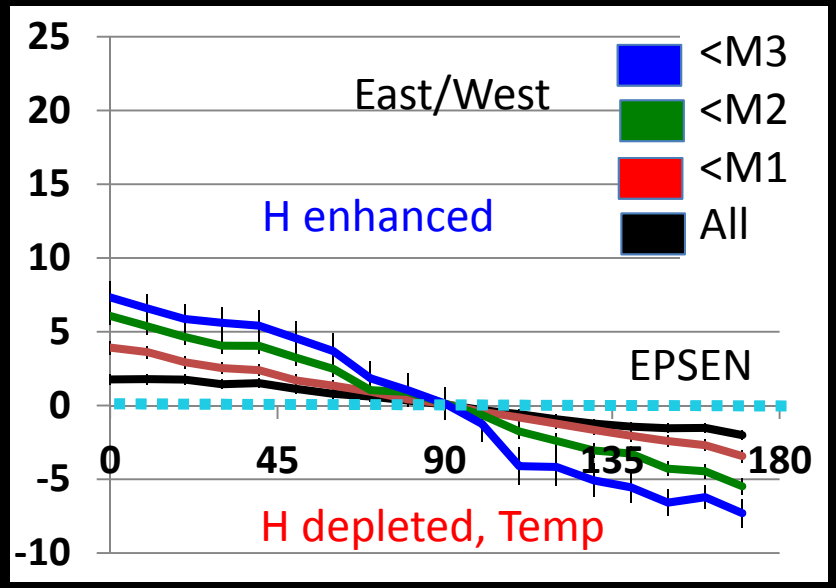
PF Azimuth Φ EF

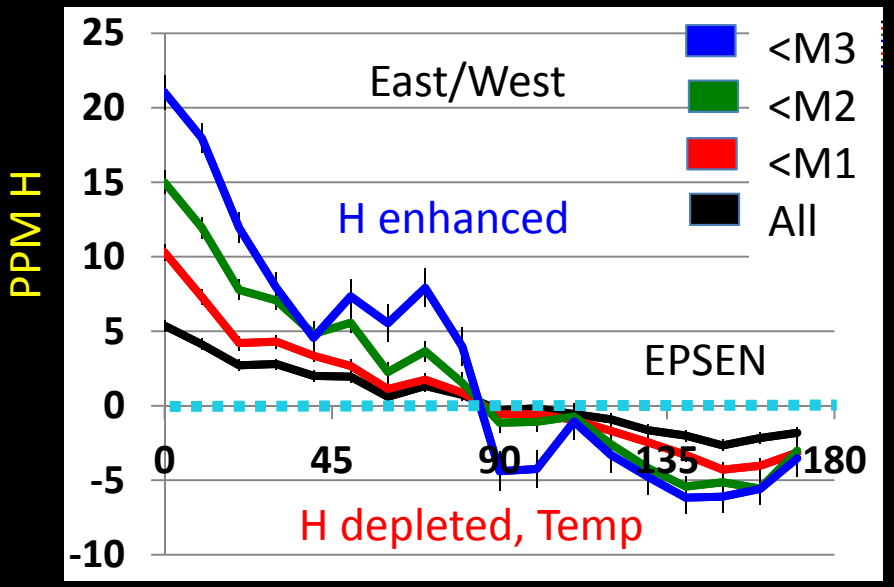


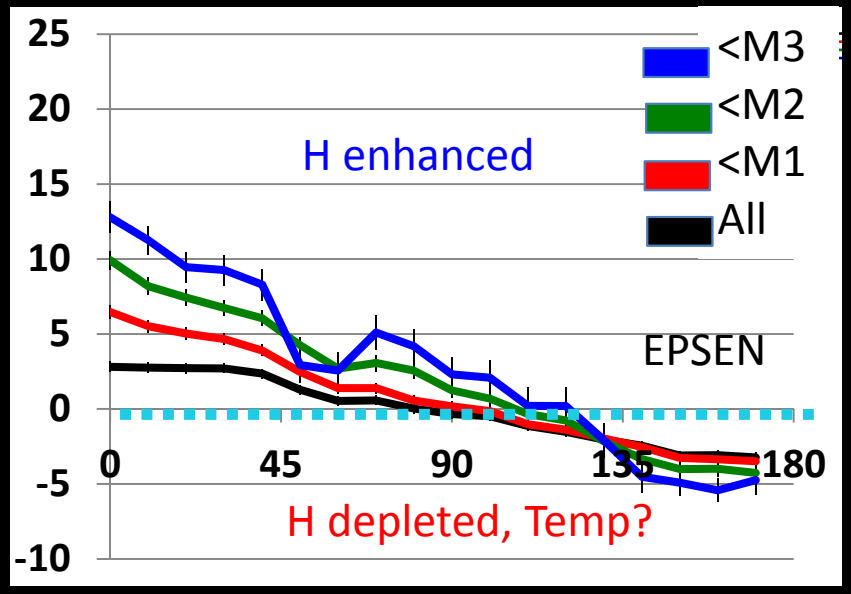
LPNS vs LEND Collimated Results (75:90): LPNS vs CSETN

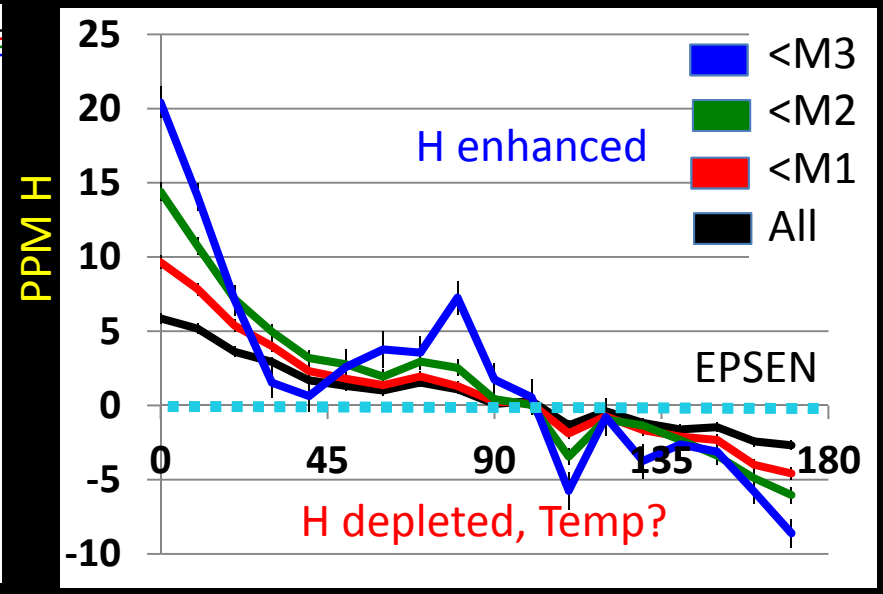
LPNS Rate: 19.5 cps

LEND CSETN: Rate = 1.7 cps





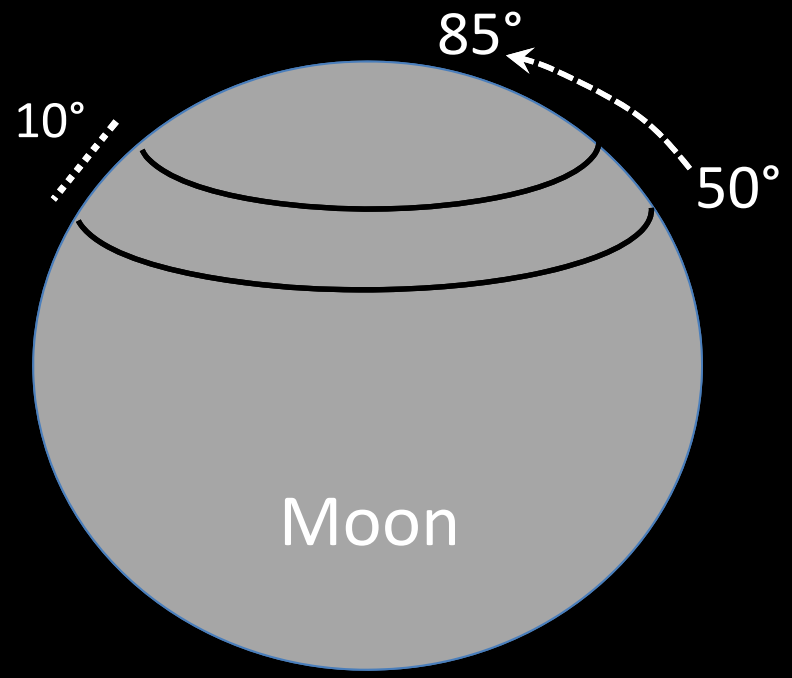




Mid-Latitude Insolation Model Analysis

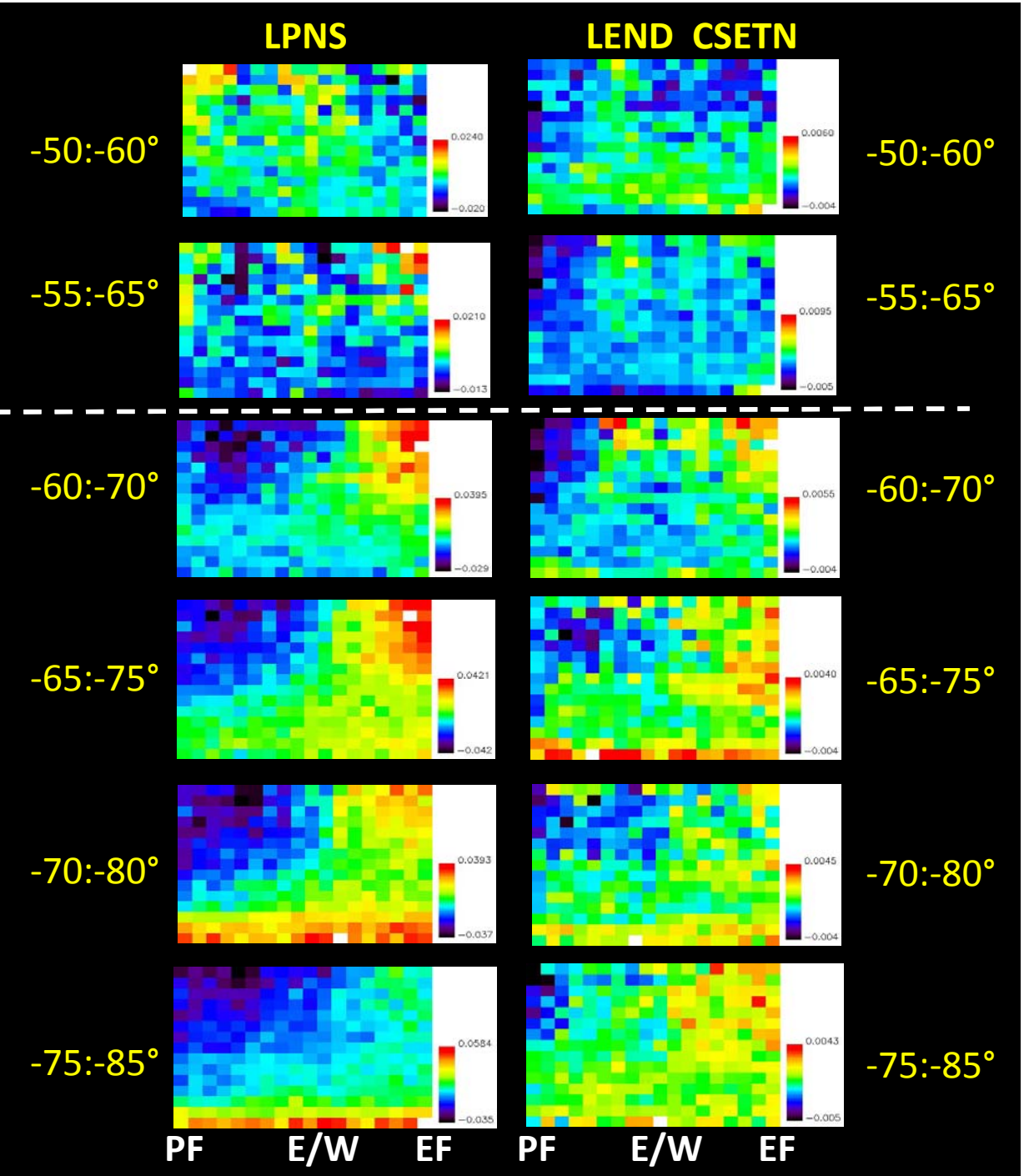
- At what latitudes does hydration start?
- LPNS and CSETN Detectors
  Epithermal Maps, No Masks
- North and South
- Each 10° Latitude window
  Reaverage Epi Maps into
  Insolation Model, I(θ,Φ)

- Shift window ±50° to ±85° in
  - 5° increments.
  - 6 maps produced

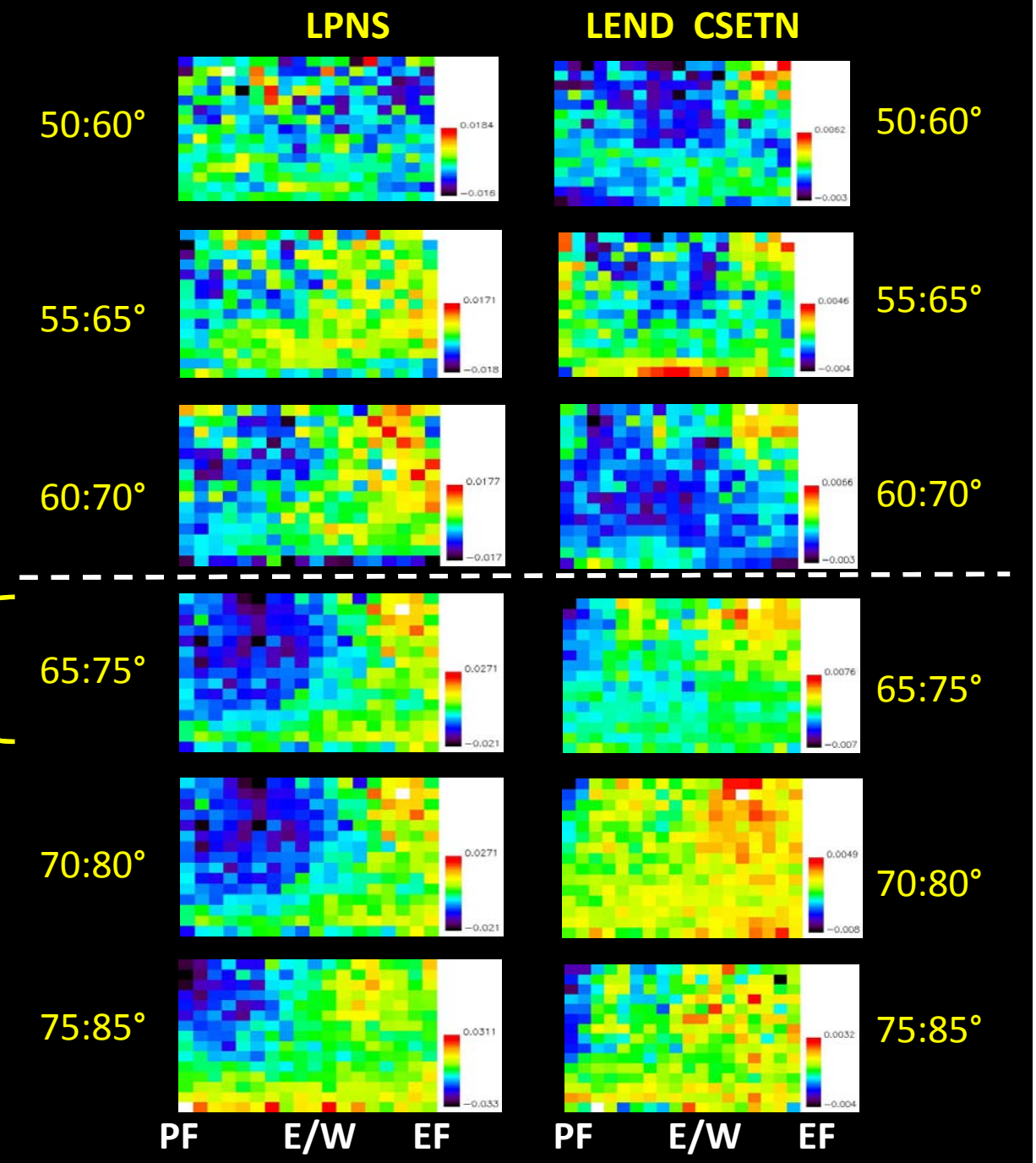


South Polar Mid-Latitude Band Insolation Analysis 10° bands

Epithermal Hydration
Latitude: -60: -70°
65:70°: PSR = 0.1 %



North Polar Mid-Latitude Band Insolation Analysis 10° Bands



Epithermal Hydration
Latitude: < 65-75°
65:70°: PSR = 0.1 %

Conclusions:

- SP CSETN Maps are high resolution and consistent.
  Blurred CSETN → LPNS

- Suggests H distributions correlated to the continuum of insolation.
  (Possible contribution: diurnal temperature variation: EF slopes)

- Lats < ±65°: NO definitive insolation pattern, CSETN, LPNS

- Persistent diurnally stable hydration line ~ ±65° to ±70°

- Lats > ±65°: Correlated insolation patterns: PF higher H vs. EF slopes.

- PSR% Area ±65 to 70° = ~0.1%, Not a likely factor in epi suppression
  Suggests effects from low end of insolation continuum

Conclusions Continued:

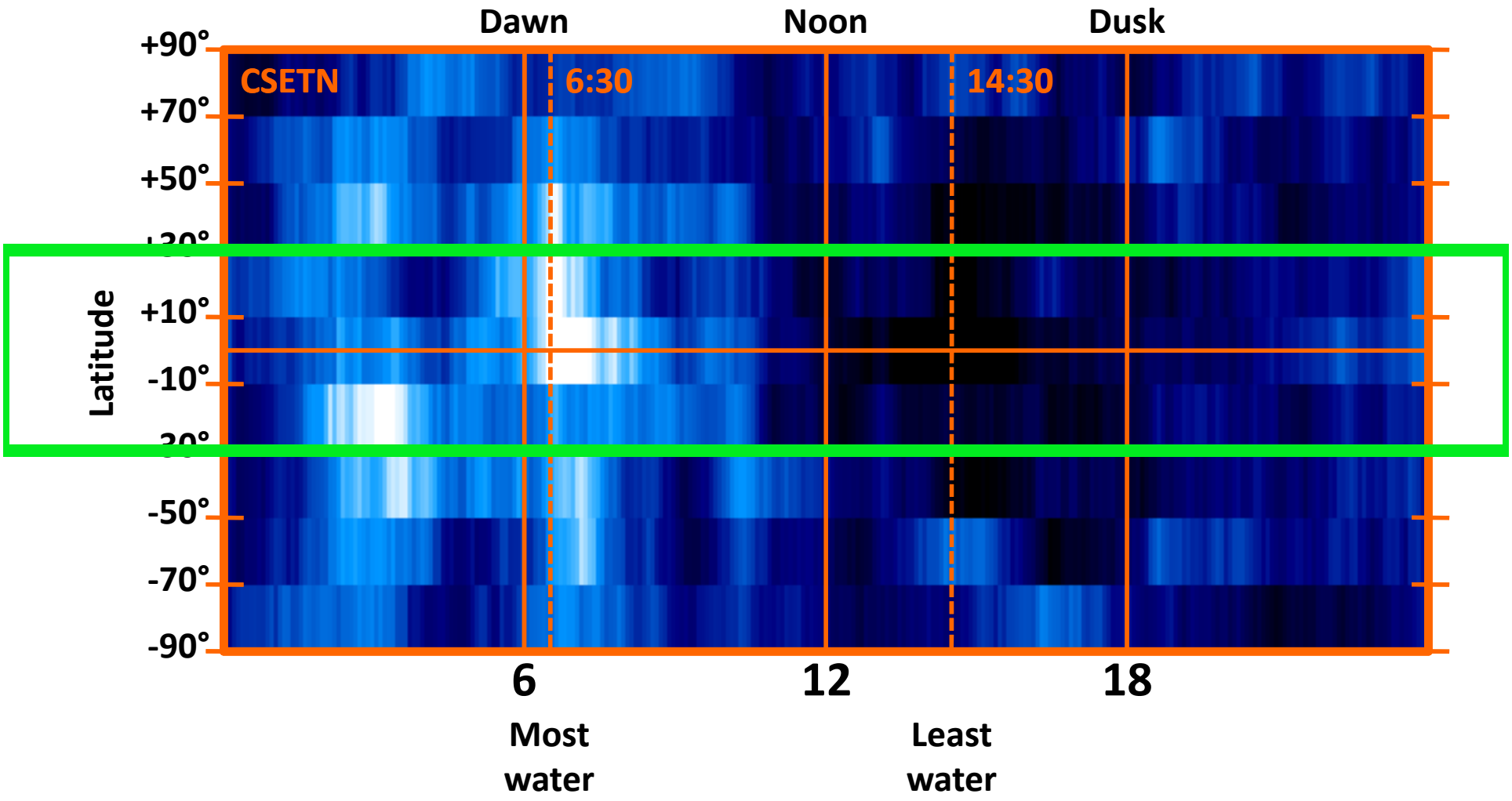
- Insolation Pattern: ~ Uniform effect suggests H → Solar wind source.

- Insolation patterns: Consistent polewise comparisons

- EPSEN suppression > ±70°:
  * Polewise symmetric, LPNS and LEND ~4%
  * H is enhancement /trapping related to locally low distributions of insolation and H increases towards poles.
  * H cold traps occur in a continuum of spatial scales (diffusion) Most traps <<< scale of LEND and LPNS resolutions (blurred)

- LEND CSETN upwards curved impulse response plots suggests a higher resolution FOV than the Uncollimated (LPNS and SETN)

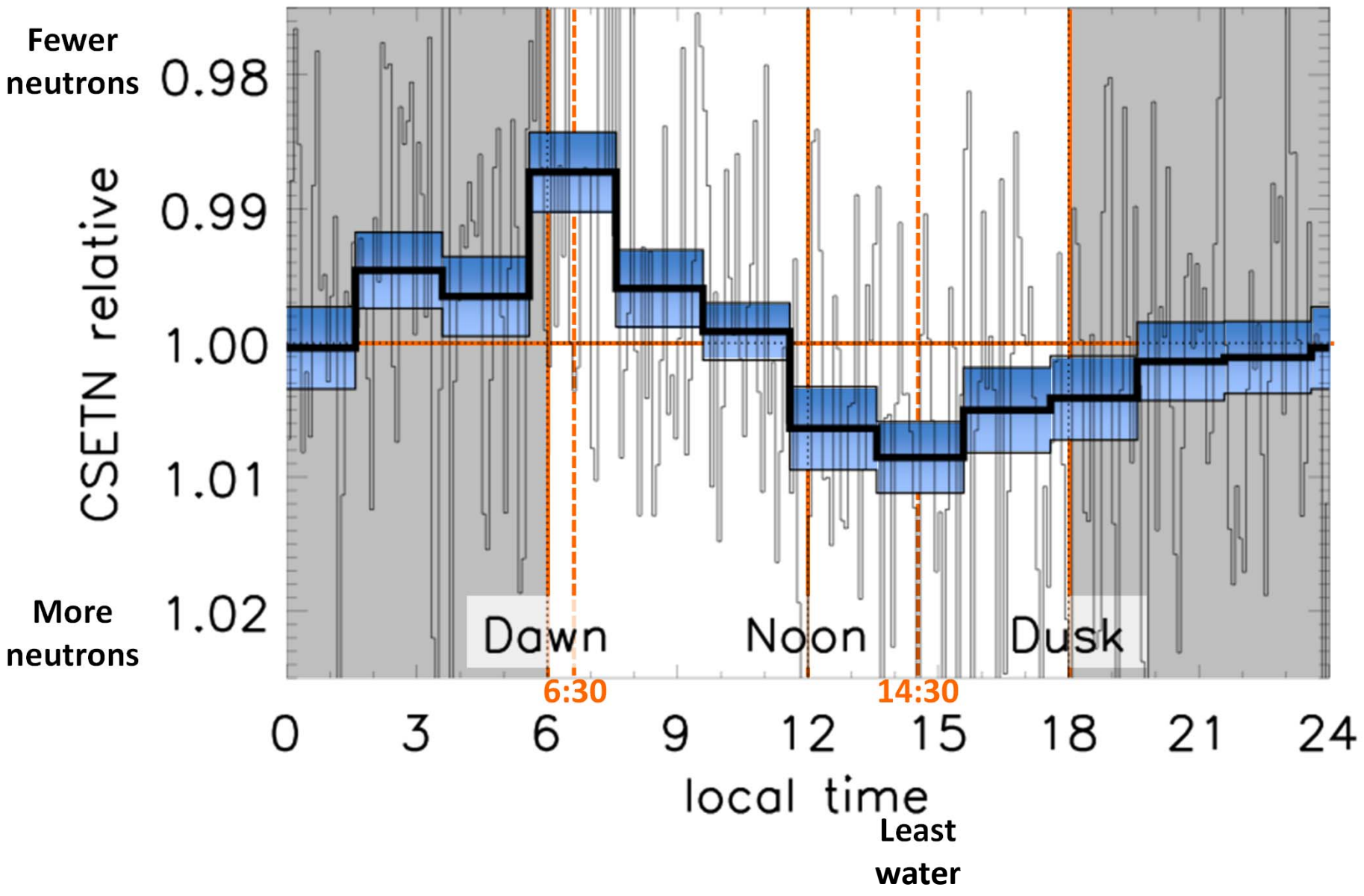
LEND CSETN Diurnal Hydration



SETN observes this too!

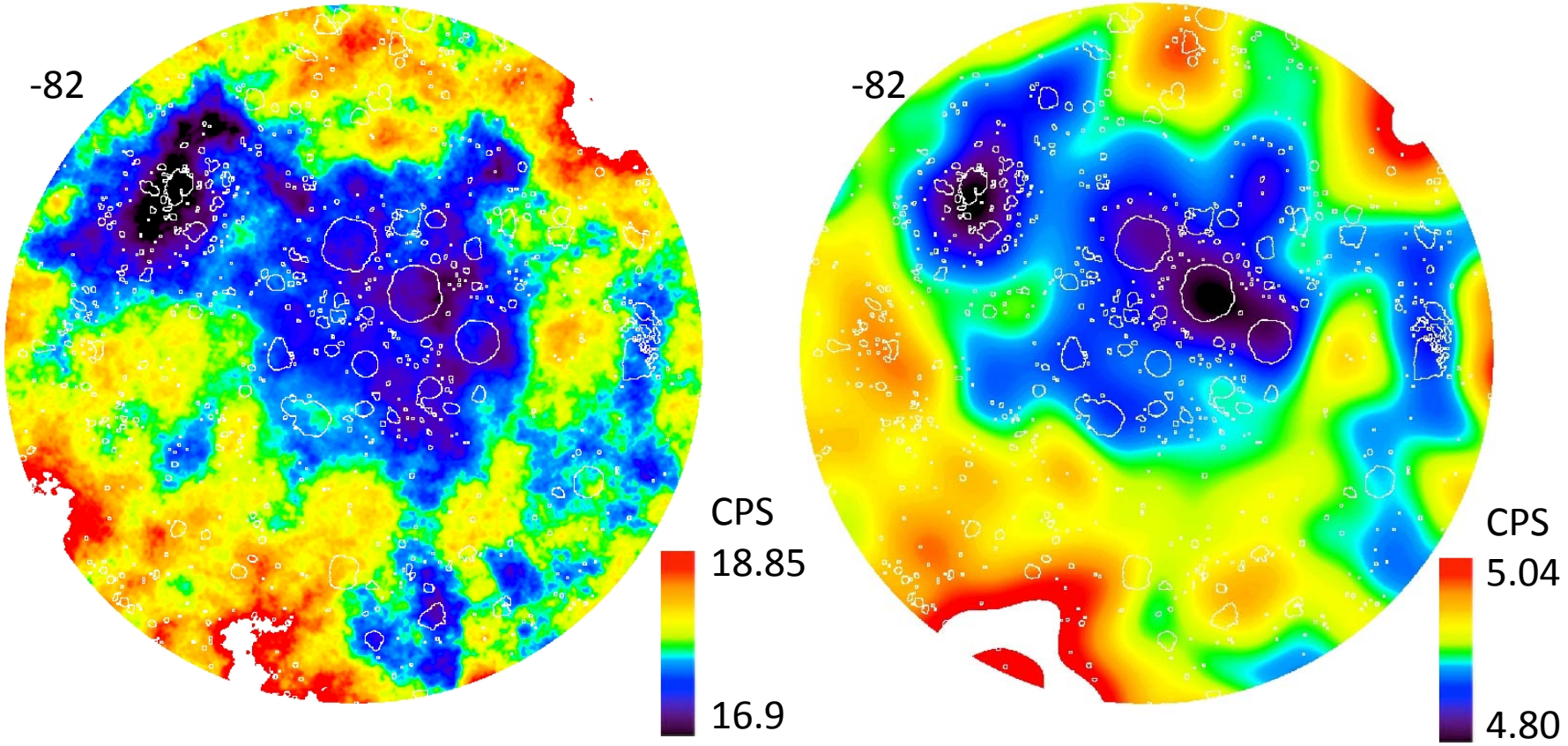
Livengood et al., 2012 Lunar Volatiles Conference

CSETN Diurnal Hydration



LPNS* SP Low Altitude

CSETN SP Blurred (40km FWHM)



Detailed Modeling of LEND: 2 Papers

Updated Calibration techniques: 1 paper

Stay tuned!

Epithermal Reference Rates: ER

LEND CSETN:	1.7 cps	Mitrofanov et al., 2010
LEND SETN:	9.5 cps	Inspection
LPNS:	19.5 cps	Inspection
LPNS*:	18.5 cps	Inspection

*Epithermal Map correction 6.8% thermal, Maurice et al. 2004

Band Mean: A = Mean(Azimuth-band)
Band Std Dev = A_sd Std(Azimuth-band)
N = number of pixels in band

Water Equivalent Hydrogen

WEH = 1.91*((ER/(ER+A))-1.)
WEH_SEM = 1.91*((ER/(ER+A_sd))-1.)
WEH_SEM = WEH_SEM / sqrt(N)

WEH to PPM

PPM = (WEH * ((1.e6)/900.))
PPM_SEM = (WEH_SEM * ((1.e6)/900.))

Method: Mitrofanov et al, 2010