Insolation Effects on the Moon: Observations from LEND and LOLA

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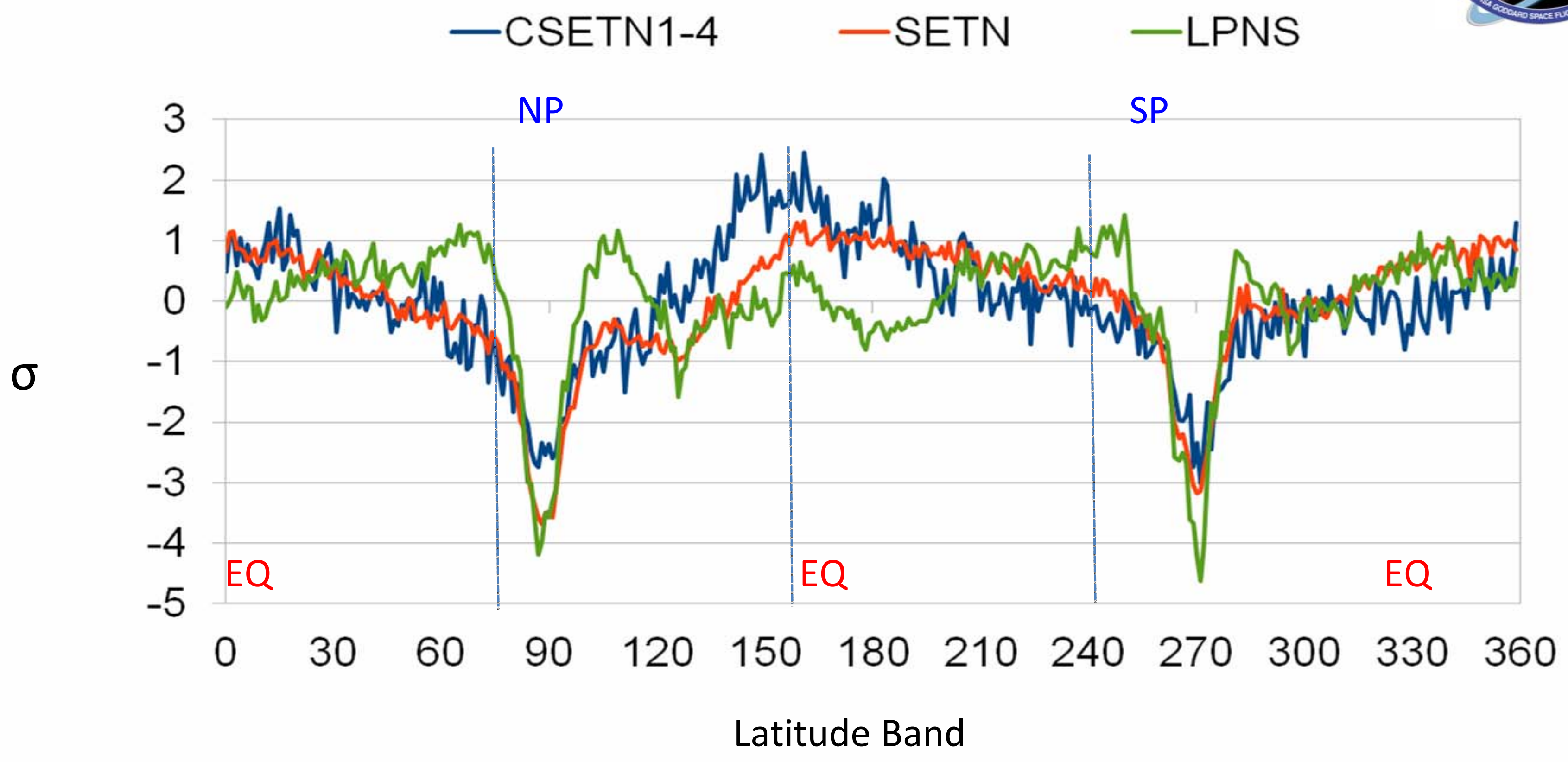
LEND (July 09 to Nov 10) vs LPNS (Low Alt PDS): Standardized scales for comparison



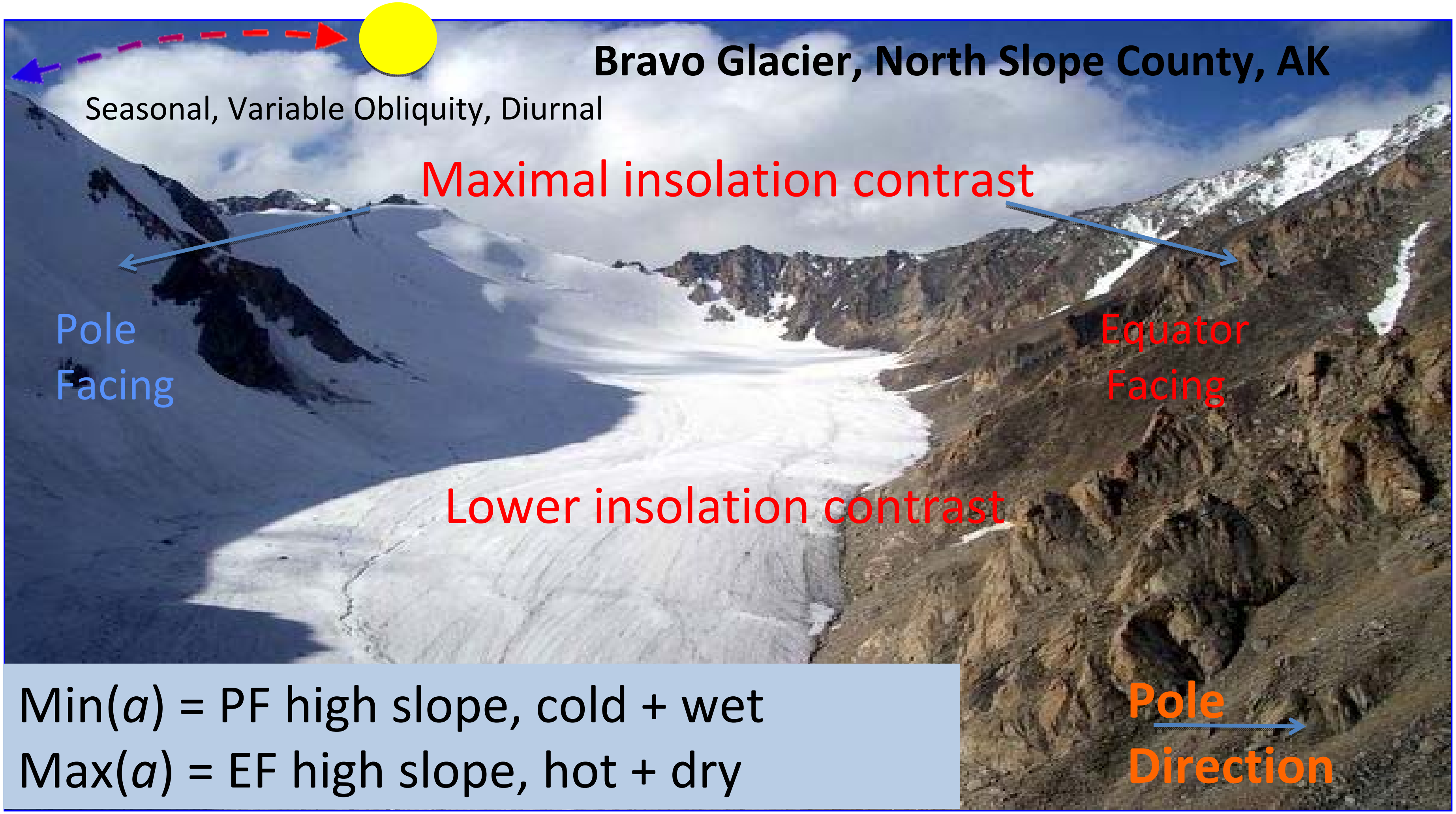
-- LPNS vs LEND: LEND similar variances, LPNS different, Can't compare extrema

-- Polar Suppression Trend:

LPNS: Suppression flat in mid-latitudes +/- 1σ, Enhanced +/- 70 to poles

LEND Epi rates peak near equator, Continuous to poles, symmetric, **Cos Effects?**

-- Regolith Temperature? LPNS corrected Poles 1.75%, LEND not



Insolation Effects: $a = I \cos \Theta$, Dominant H Loss /Redistribute

$\Theta = f$(latitude, slope, orientation)

Tall Poles: Uncertainties /Lat, LEND resolution

Local Insolation Detection Exp: LEND Epi's vs Topo

Problem Statement:

- Assume a uniform deposition / mixing process, e.g. solar wind (H^+) and meteoritic bombardment mixing. H deposition rates low.

- Assume high slopes same geomorphology, e.g. craters, North = South

- Assume desiccation processes (volatile H loss) are a dominant process driven by maximal thermal insolation effects, $a = I \cos \Theta$, where:

I = solar flux (constant)

Θ = locally a function of topographic slope, slope orientation, latitude, local occluding topography and max solar irradiance (local noon at polar summer solstice), From equator direction.

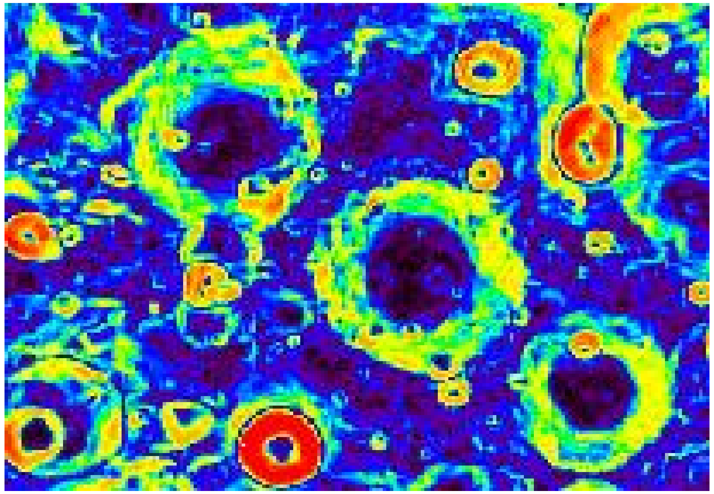
If Insolation:

- High polar facing slopes should be colder and wetter than equivalent equator facing slopes. Do we see this in LEND epithermals?

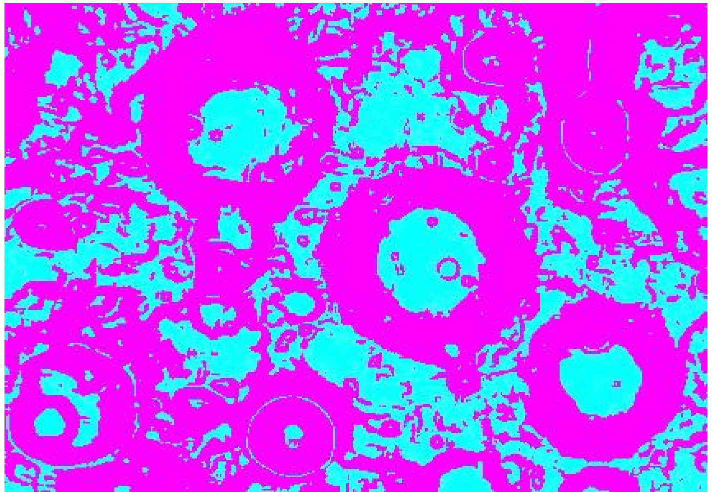
LOLA Slope Analysis: Two slope bands

A. Gradient Image, 1st derivative topo transform

B. Slope $G = \tan^{-1}(|Gradient|)$



A. LOLA SP Slope



B. Topo Slope discretized to 2 bands $G < 5$ and $G > 5$

Slope

<= 5

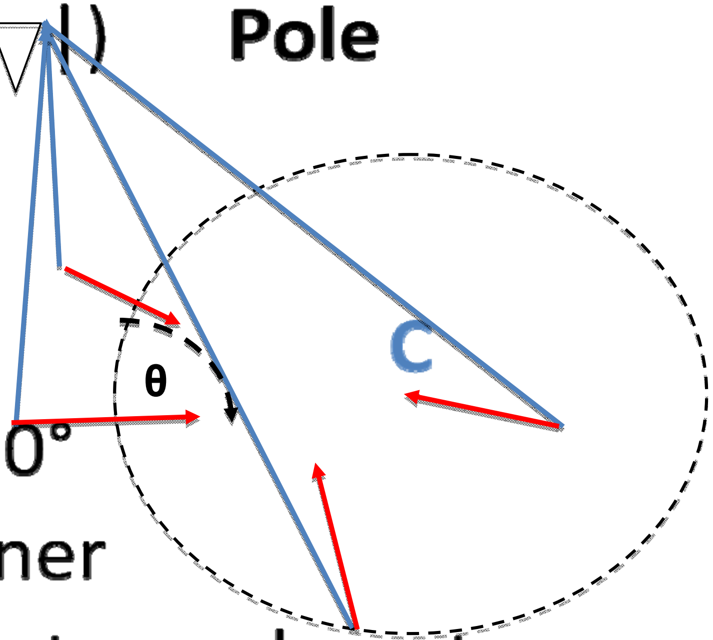
>5°

North:
9.2° +/- 0.23°
South:
9.3° +/- 0.23°

Slope Orientation Φ

- Given: LOLA 400m Digital Elevation Model (DEM)
- Topo gradient Image, with 1st derivative operator

  Result: ∇'s x-dir, y-dir, $G = f(|\nabla|)$



- Slope Direction Image:

  dir vector = **U**

  To Pole vector = **V**

Slope orientation angle = 0-180°

$$\theta = \cos^{-1}\left(\frac{(U \cdot V)}{|U| \cdot |V|}\right)$$

$\theta < 90$ *Pole facing*

$\theta > 90$ *Equator facing*

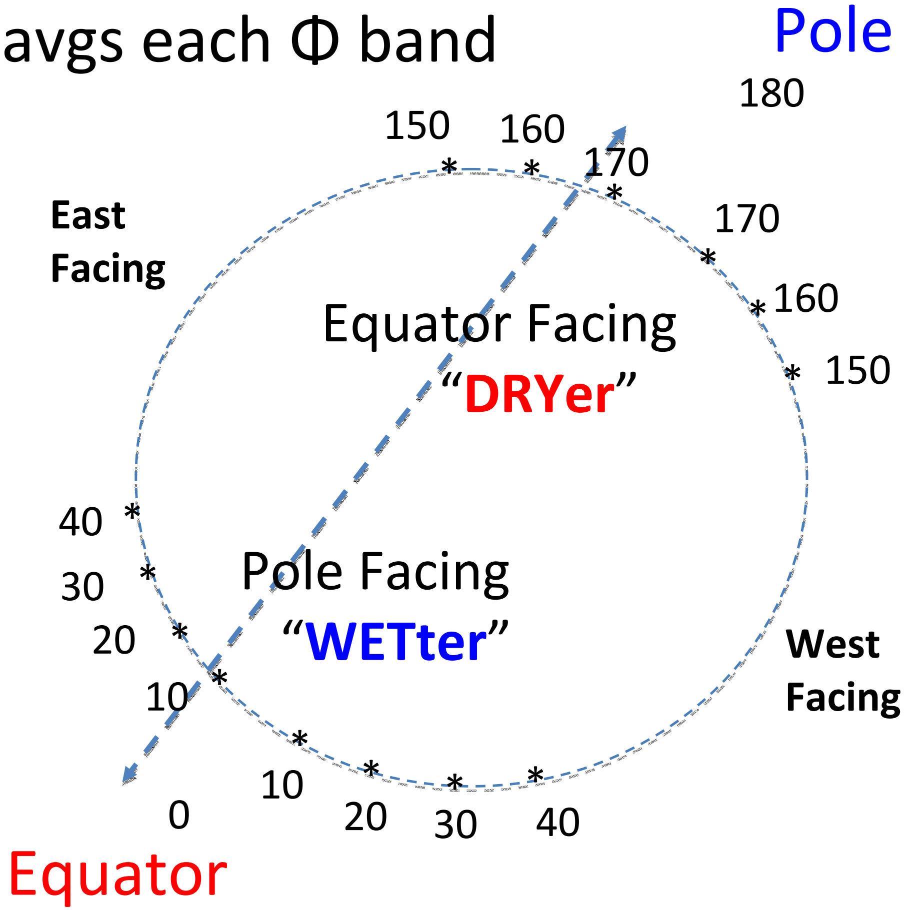
Crater inner slope dirs towards crater center, C

Slope Orientation Φ Method:

- Discretize Φ continuum: 18 slope orientation bands:
- Using LEND 400m Res. Maps: Registered to LOLA
- Generate Sparse Epithermal avgs each Φ band

1.0-10°
2.10-20°
3.20-30°
.
.
.
.
17. 160-170°
18. 170-180°

Pole Facing
↓
East –West
↓
Equator Facing



Slope Orientation Φ

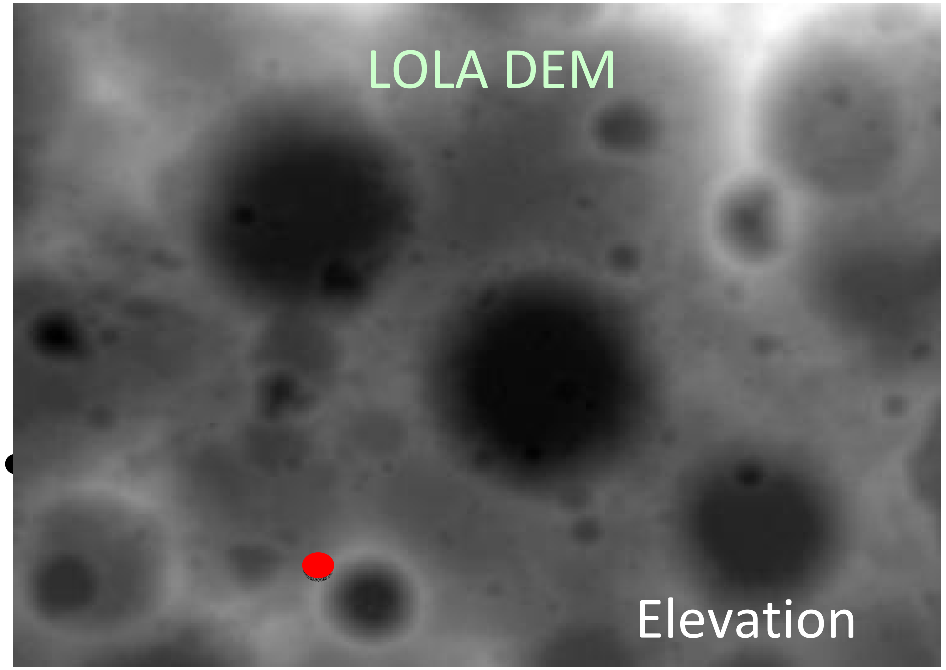
- Linearize slope orientation (pole/ equator ref frame)
- Orientation: Pole to Equator continuum

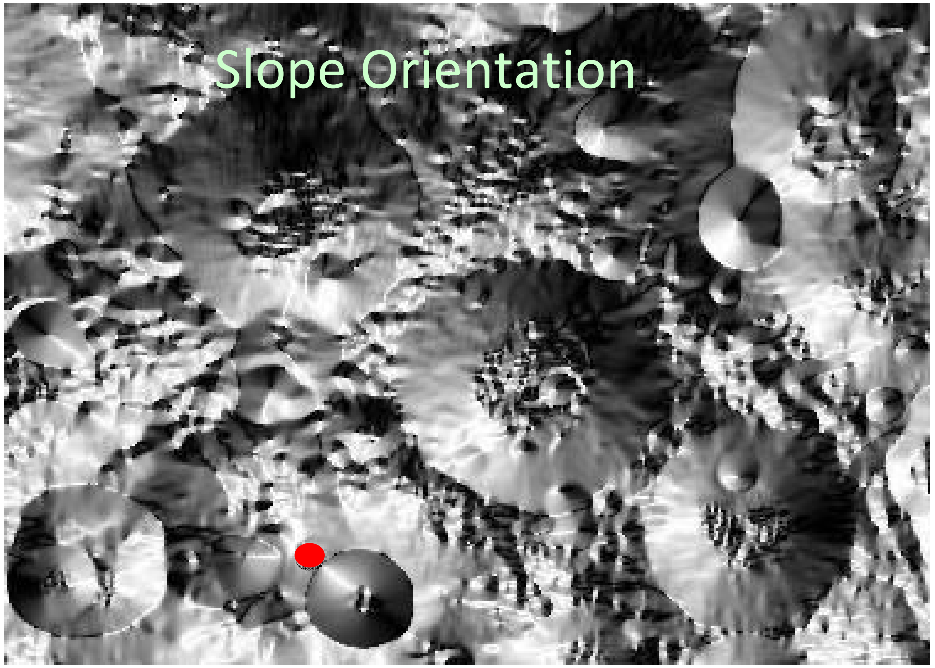
Also,

East vs West = Rotate v(90°)

Pole East –West Equator

0 90 180





South Pole (Haworth, Shoemaker, Faustini and Shackleton

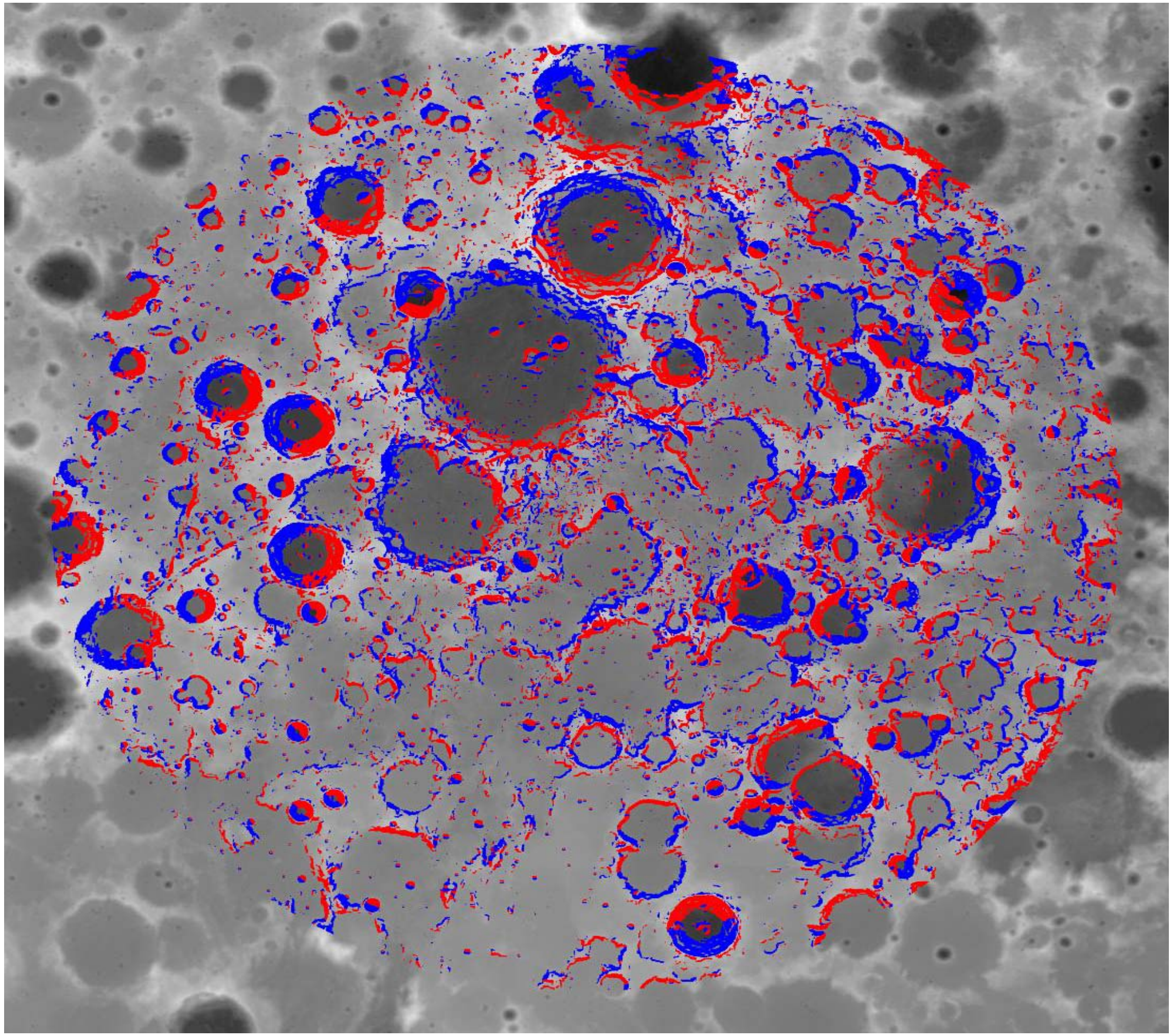
North Pole: LOLA Example: 75°-90°

Select and avg LEND Map pixels as f of:

1) High Slope

AND

2) Slope Orientation:
Pole Facing vs
Equator Facing
(0-90) vs (90-180)Φ
*East, West Included



Scale Invariant Transform
- Slopes for all craters mapped to 0 to 180° Φ

NP Example:
76° to pole

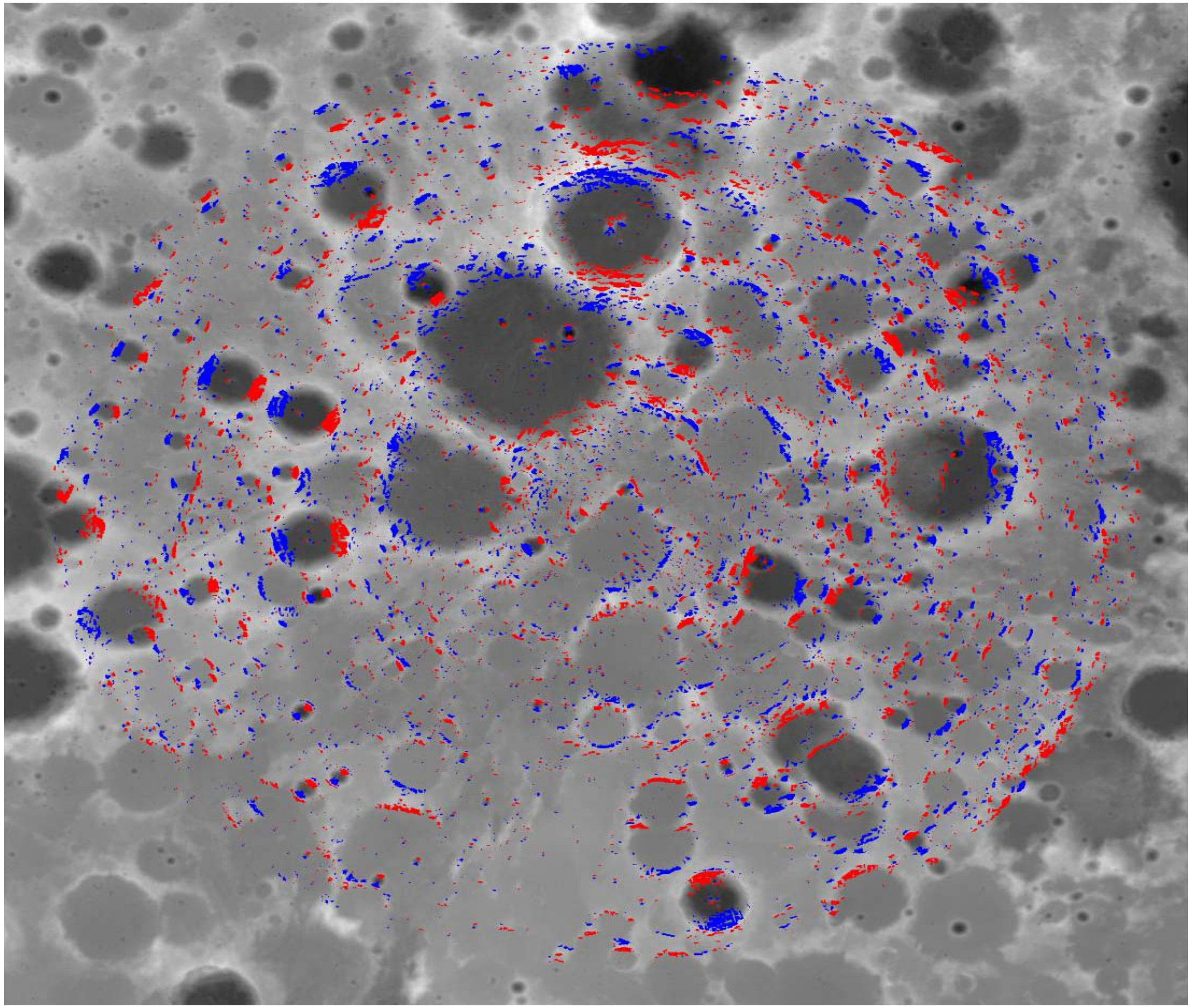
Pointing:

1.High Slope

AND

2. Pole Facing vs
Equator Facing
(0-30) vs (150-180)

No East, West
Avgs = improved
contrast



Hypothesis Testing for Insolation:

LEND Avgs. = 45° to Pole, 5° latitude bins, *18 bands Φ*

To accept a global lunar insolation effects hypothesis (H) the following H should be satisfied:

H1: PF < EF, (EF-PF) = ++ contrast

- Pole Facing Epi rates < Equator Facing

H2: North = South

- Macroscale analysis: *f*(geomorphology, compositionally homogeneous, illumination) same.

H3: East = West

- Same irradiance: No difference between E, W

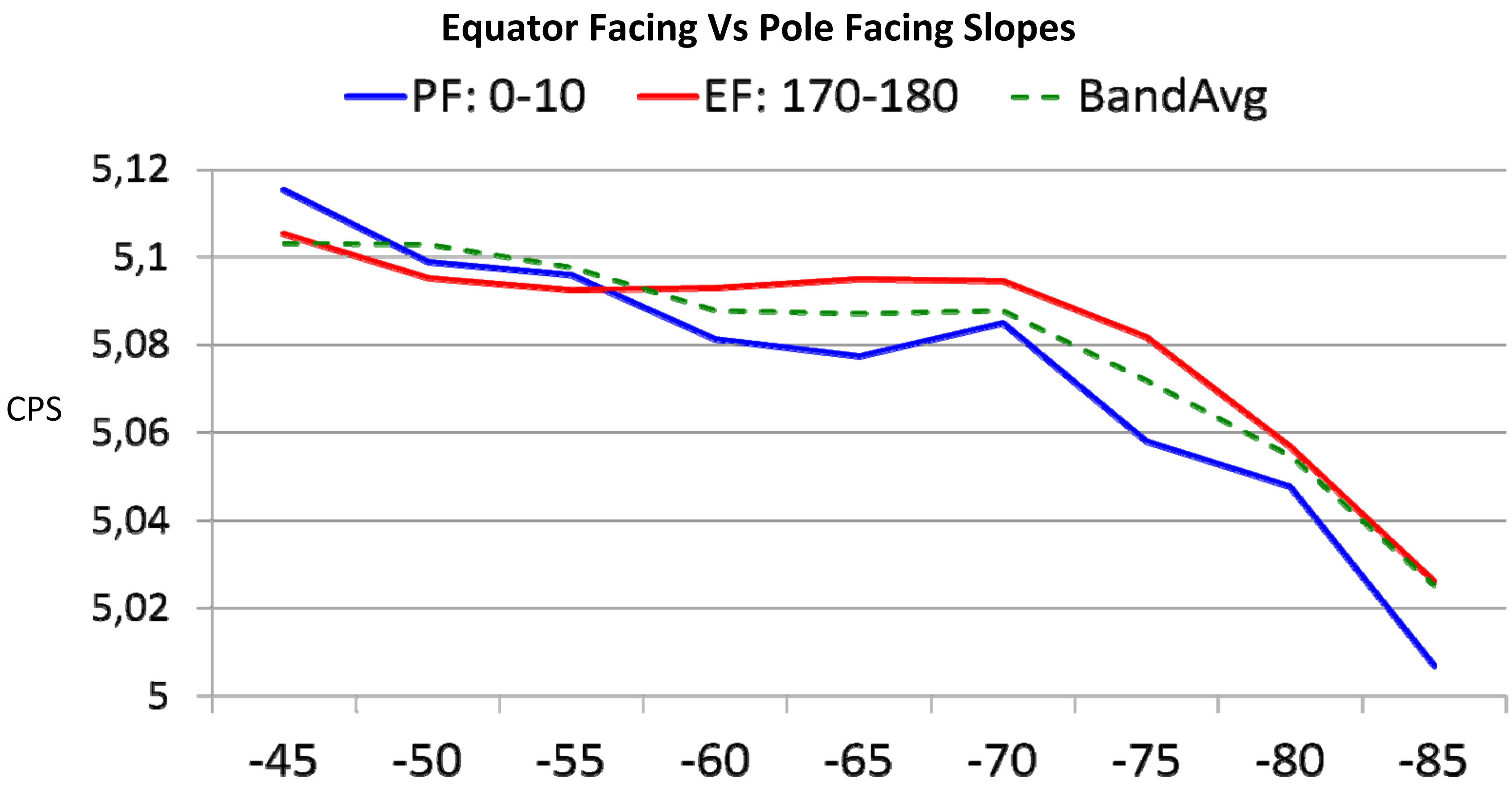
H4: High Slope conrast ++ > Low Slope contrast +

- High slope Epithermal Rate Continuum, PF to EF

Results

South Pole Slope Analysis: 5° Latitude Band Avgs, -45: -90

- High Slope Slope G > 5°



H1: From -55 to SP, EF > PF, PF < BandAvg < EF

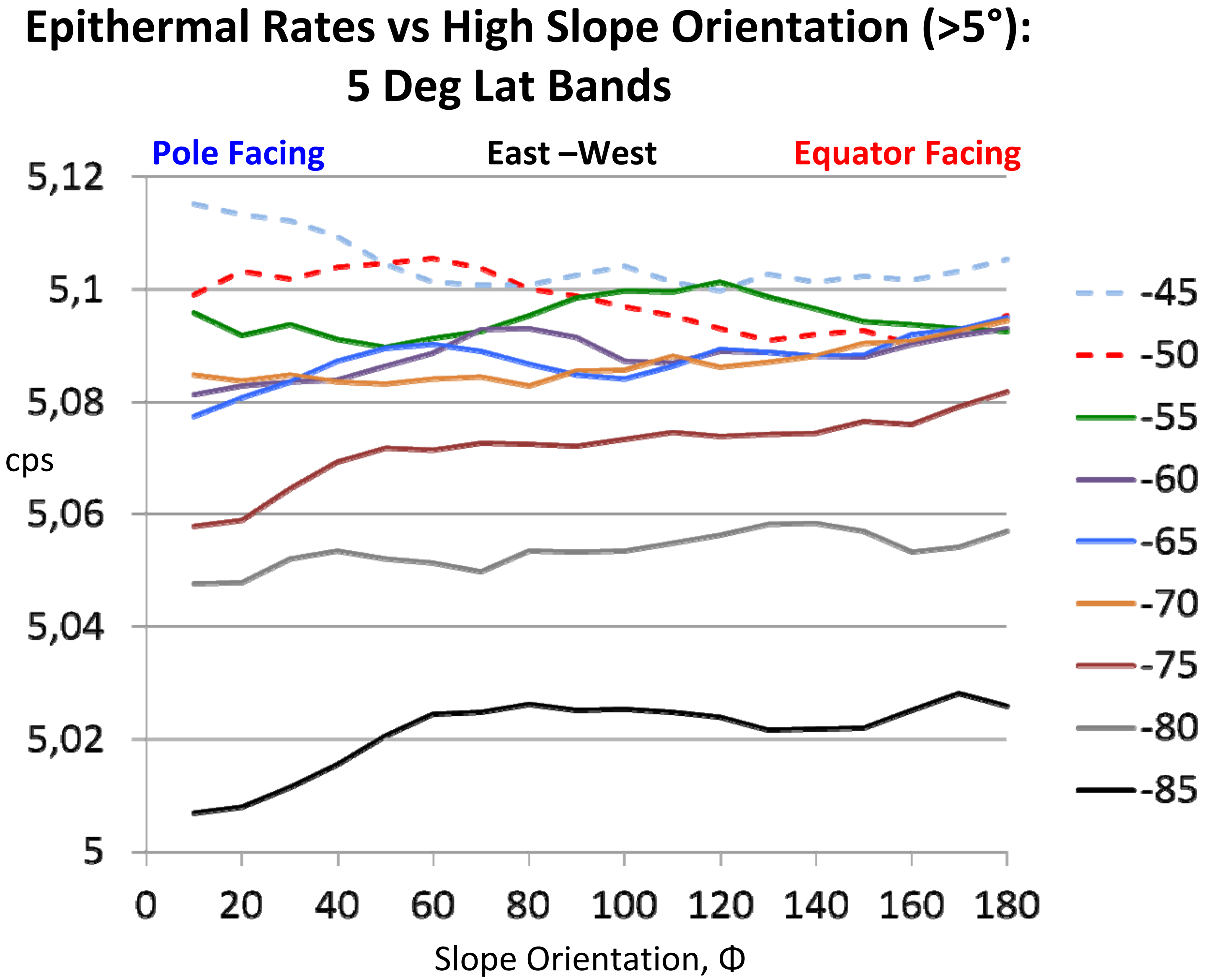
Slope Orientation, ρ: South Pole, -45 to -90

Gradient Neg
-45, -50, Dashed
Gradient Positive
-55 to pole (7)

7/9 Positive Slope

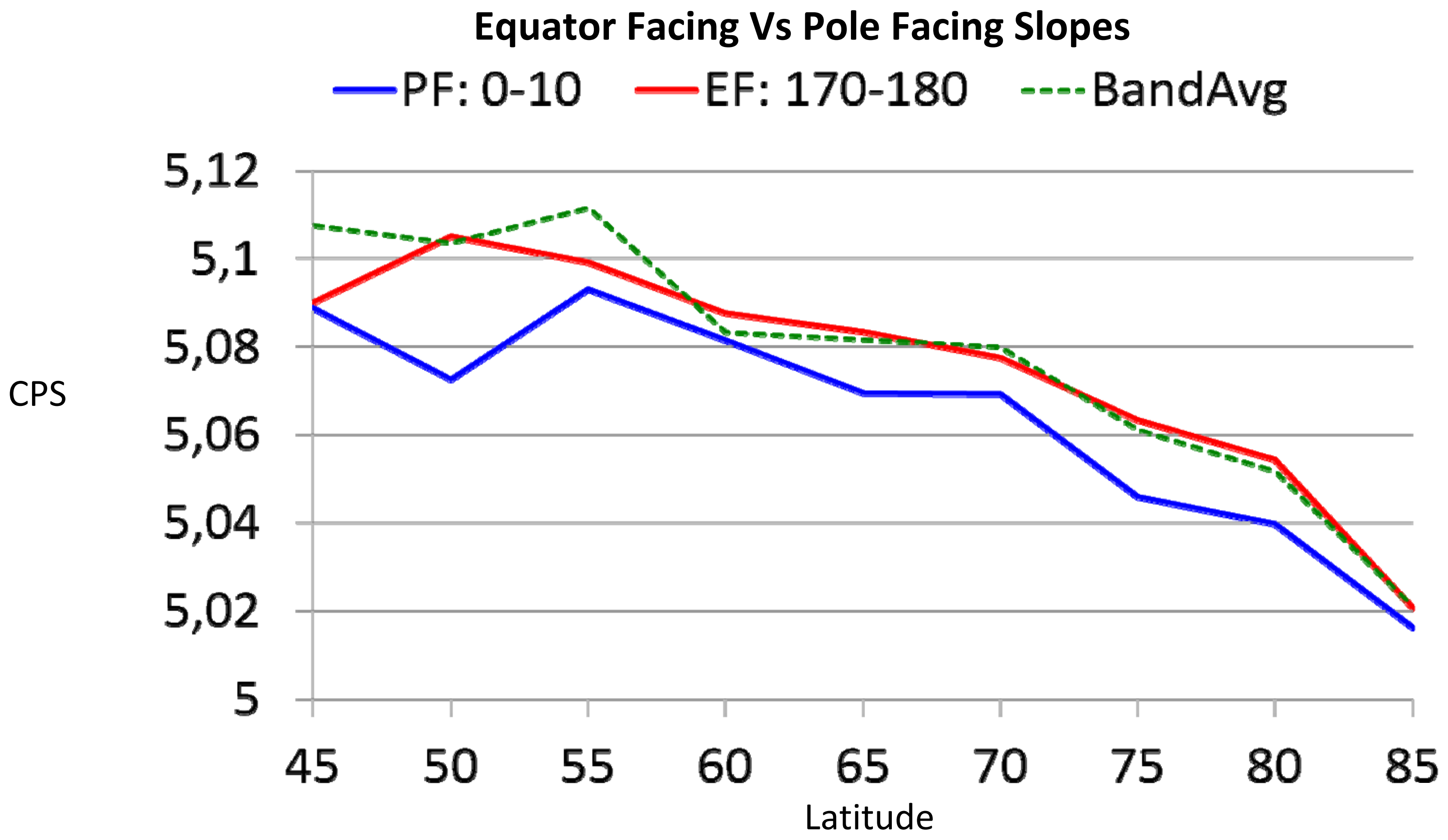
Oriention Epithermals Fit CPS/ 180°Φ

-45: -0.010
-50: -0.015
-55:   0.003
-60:   0.008
-65:   0.011
-70:   0.010
-75:   0.018
-80:   0.008
-85:   0.016



North Pole Slope Analysis: 5° Latitude Epi Avgs, 45 to 90

- Slope G > 5, Maximum local *a* contrast



Notes: Where G > 5 slopes are most oriented away (PF) and towards sun (EF) vs G > 5

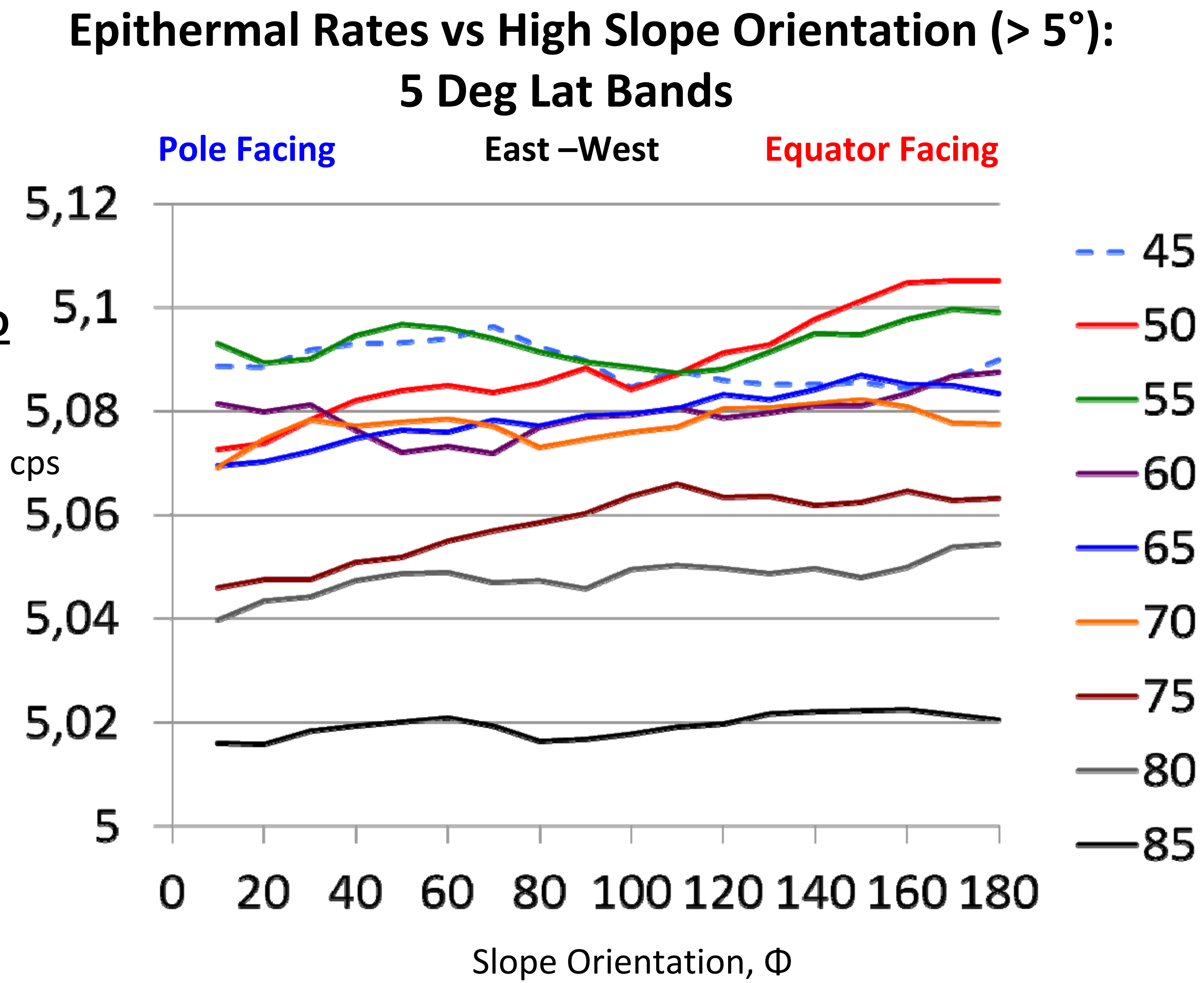
Slope Orientation Φ: North Pole, 45 to 90

Gradient Neg
45, Dashed

Gradient Positive
50 to pole (8/9)

<u>Gradient CPS /180°Φ</u>

45: -0.007
50: 0.033
55: 0.005
60: 0.008
65: 0.017
70: 0.007
75: 0.020
80: 0.010
85: 0.005



Hypothesis 1: Pole Facing to Equator Facing: PF < EF

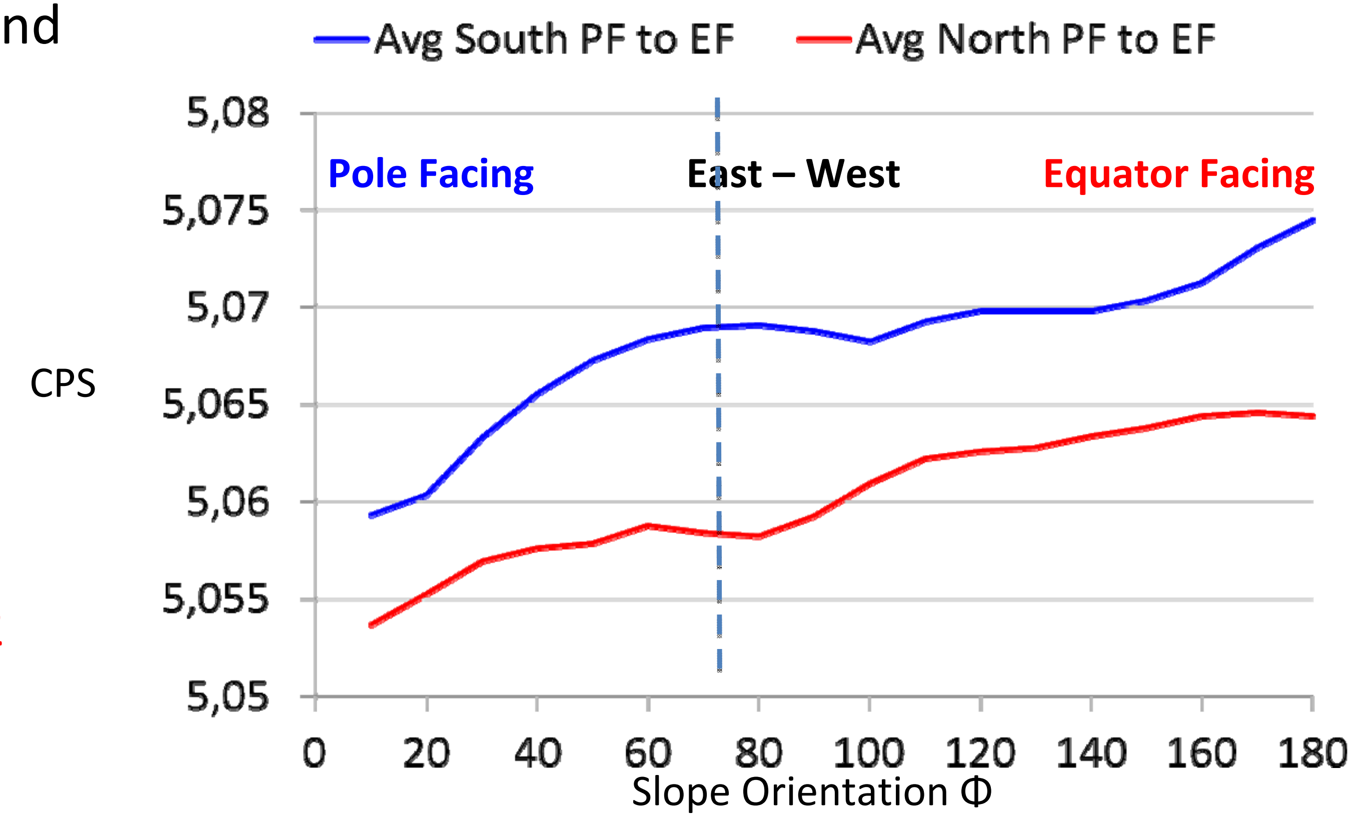
Slope Orientation Φ, High slope epi rate continuum

Avg Continuum Band
> +/-60° Lat

Removes Latitude Component

Offset = Due to Normalization

N Fit Slope = 0.012
S Fit Slope = 0.011



H: North and South
PF rates < EF rates

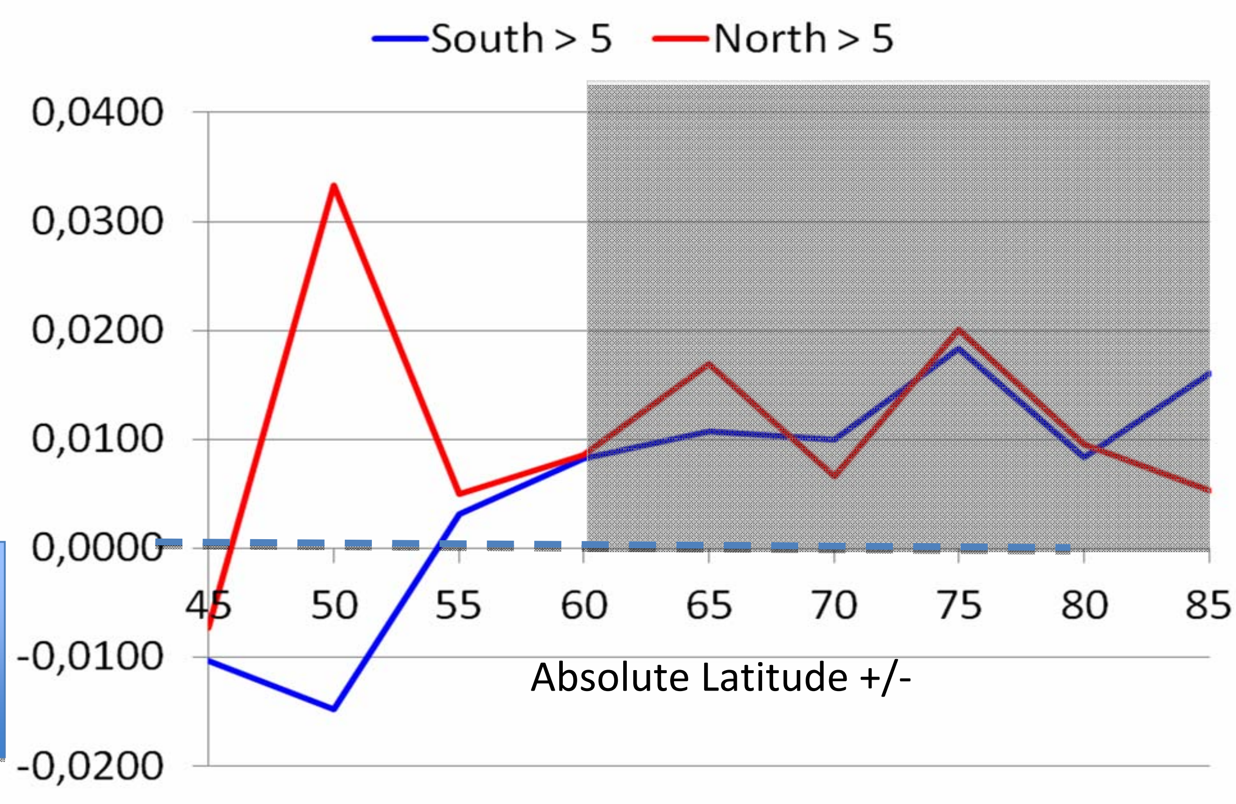
α = 0.05	T-Test	F-Test
North	0.0029	0.082
South	4.3E-07	0.287

Hypothesis H2: North vs South, High Slope , (EF-PF)

- Assuming LEND Macroscale Analysis > 60 deg

- Slopes > 5

N HS Contrast = S HS Contrast



α = 0.05

	South PF-EF	North PF-EF
μ	0.0119	0.0112
σ	0.0043	0.0060

	T-Test	F-Test
N vs S	0.3763	0.4768

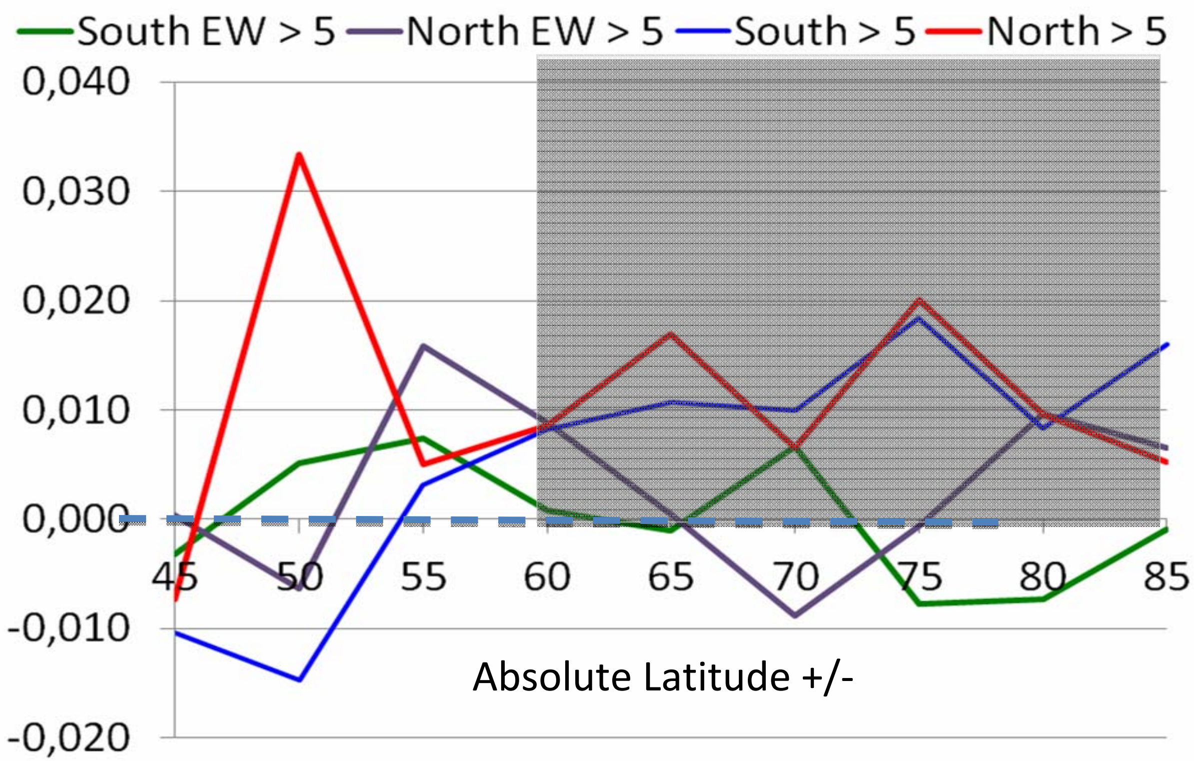
Hypothesis Testing H3: East = West, High Slope, (EF-PF), > 60 deg

Conditions:

A. East, West < (EF-PF)

B. NPEW = SP EW

East = West Rates



South:PF > South:EW

North:PF > North:EW

South:EW = North:EW

α = 0.05

	South EW	South > 5	North EW	North > 5
μ	-0.0016	0.0119	0.0026	0.0112
σ	0.0054	0.0043	0.0070	0.0060

E W tests	T-Test	F-Test
S EW vs S PoleEq	0.0044	0.619
N EW vs N PoleEq	0.0464	0.722
N EW vs S EW	0.1884	0.567

Hypothesis Testing H4: Contrast < 5° vs Contrast > 5°, >= 60 deg latitude

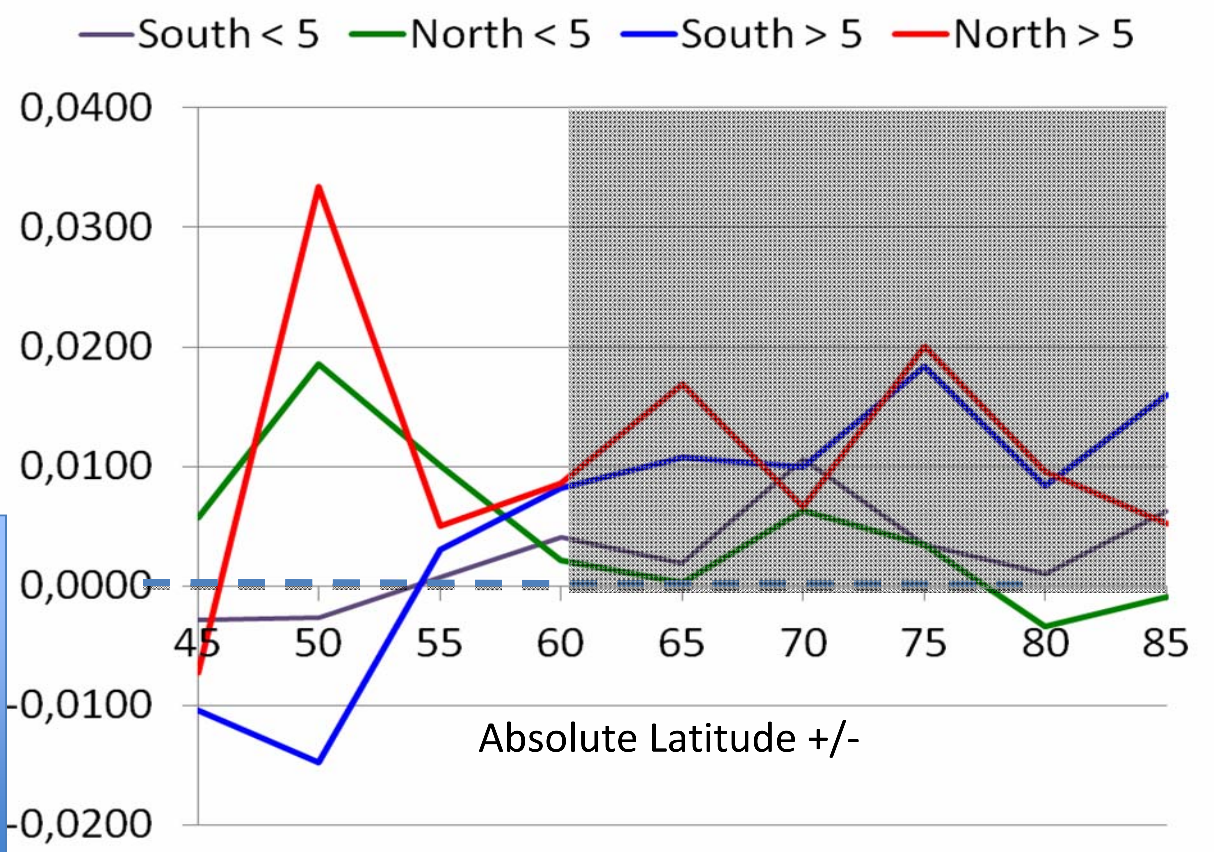
Conditions:

A. Low Slope: (EF-PF)

- Small Positive

B. Low Slope (EF-PF)
< High Slope (EF-PF)

H: North, South Epi Contrast Slope LT 5° < Slope GE 5°



α = 0.05

	South < 5	South > 5	North < 5	North > 5
μ	0.0045	0.0119	0.0013	0.0112
σ	0.0035	0.0043	0.0046	0.006

High G vs Low G	T-Test	F-Test
South	0.0092	0.6672
North	0.0242	0.2508

Conclusions:

- Regolith temperature does not appear to be a factor influencing collimated epis. Epi rates appear partly due to insolation thermal effects loss / redistribution of (volatile H).
  Still under evaluation………

- Both LEND Collimated and Uncollimated detectors suggest global insolation effects hypothesis influencing epi neutron fluxes.
  LPNS possible range for detection is polar (> +/- 70 Lat)

- All 4 slope analysis hypothesis tests are consistent with expected insolation effects on Epi rates: > 60 deg lat. Epi Rates: H1) PF < EF H2) East = West H3) North = South H4) High slope > Low Slope

- < 60 lat global evidence for insolation. Slope evidence not consistent. Slope: LOLA / LEND high resolution uncertainties? Registration? Physics? Future examination of Low latitudes.

Conclusions:

- Macroscale analysis does not preclude localized variances in insolation effects due to other geophysical and geochemical factors. e.g. (EF-PF) contrast goes down near arctic circles!

- Insolation effects hypothesis defines a continuum of irradiation / thermal effects on volatile H (Loss and redistribution).
  Important: Includes PSR hypothesis at low end of thermal continuum.

- Insolation effects: Predict PSR should have highest H concentrations.
- PSR theory is discrete distribution assumption:

Assuming these Insolation (Epi neutron) detections due to H:

Then:

Suggests Lunar image restoration techniques that assume all regional H is in PSR are *likely incorrect* transform priors.