The Science behind Mimas' Pac-Man

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&
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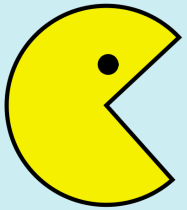
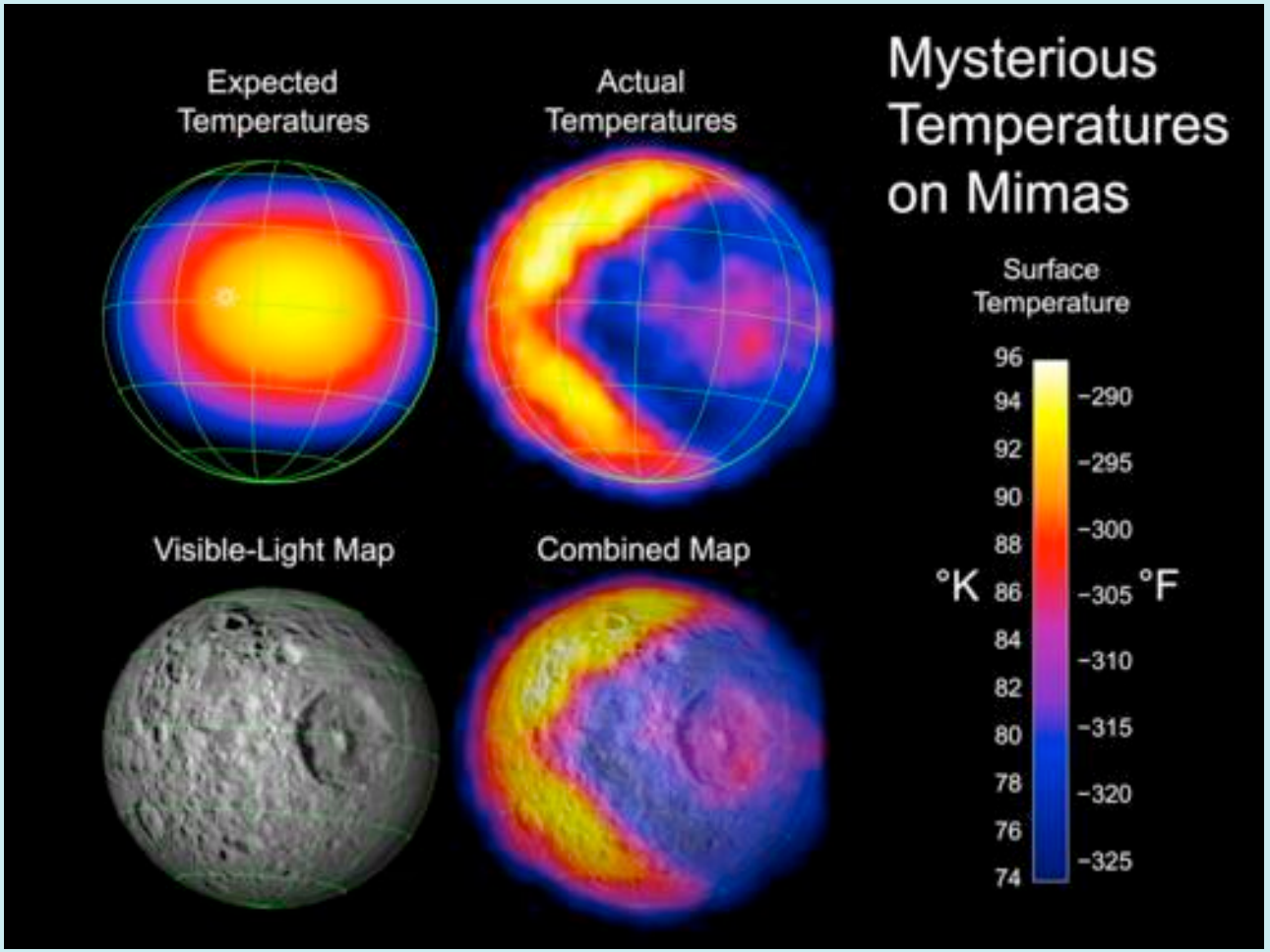


Introduction

CIRS data taken on 14th Feb 2010 showed unexpected daytime temperature variations were observed on Mimas



JPL Press release from 29th March 2010

Introduction - Mimas

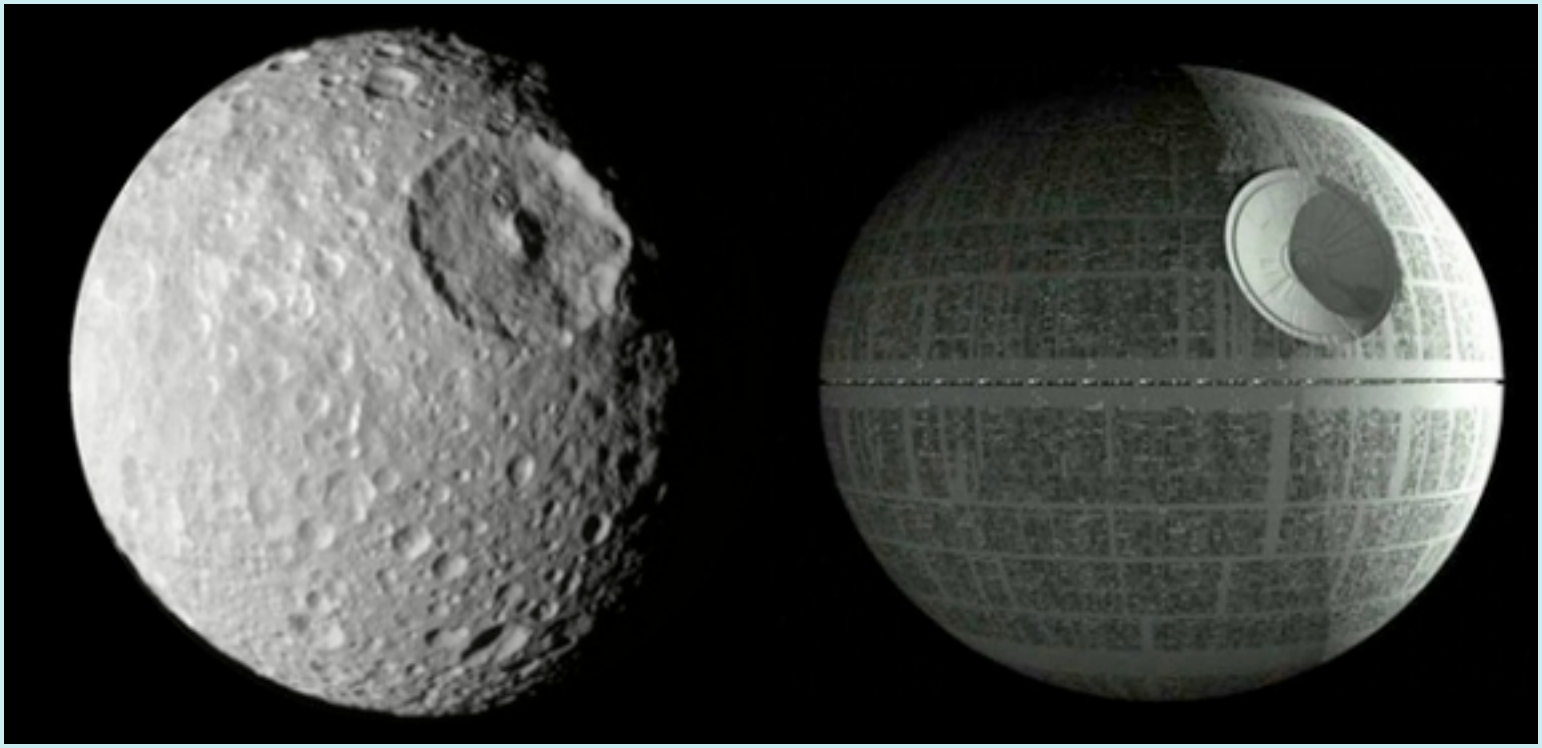
Mimas

Mimas is Saturn's closest and smallest icy satellite

The surface appears to have uniform coloration and is dominated by the giant Herschel crater

Previously it was thought the most interesting things about Mimas was it's resemblance to the……

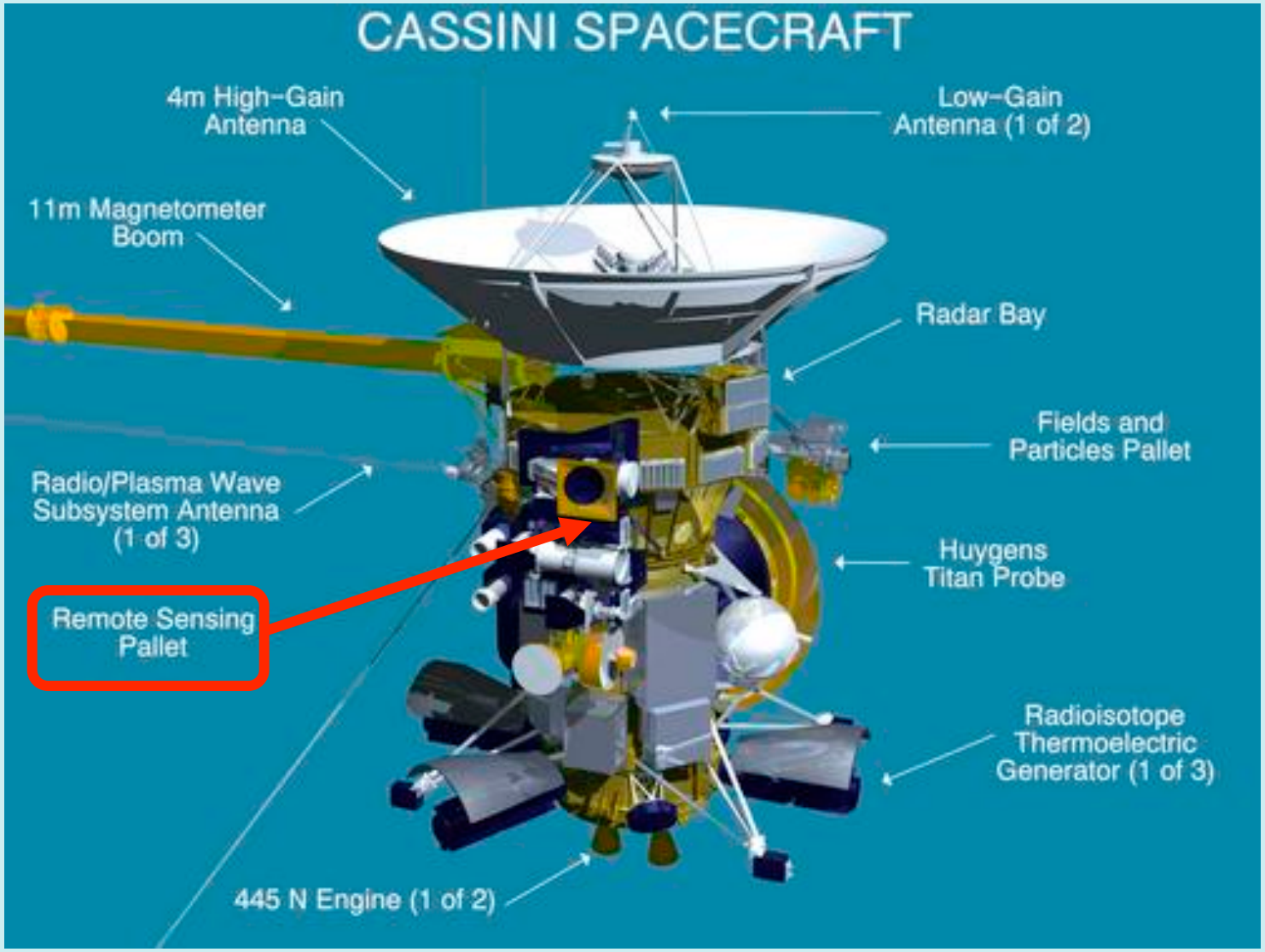
Introduction - Mimas



Mimas ⟷ *Death Star*

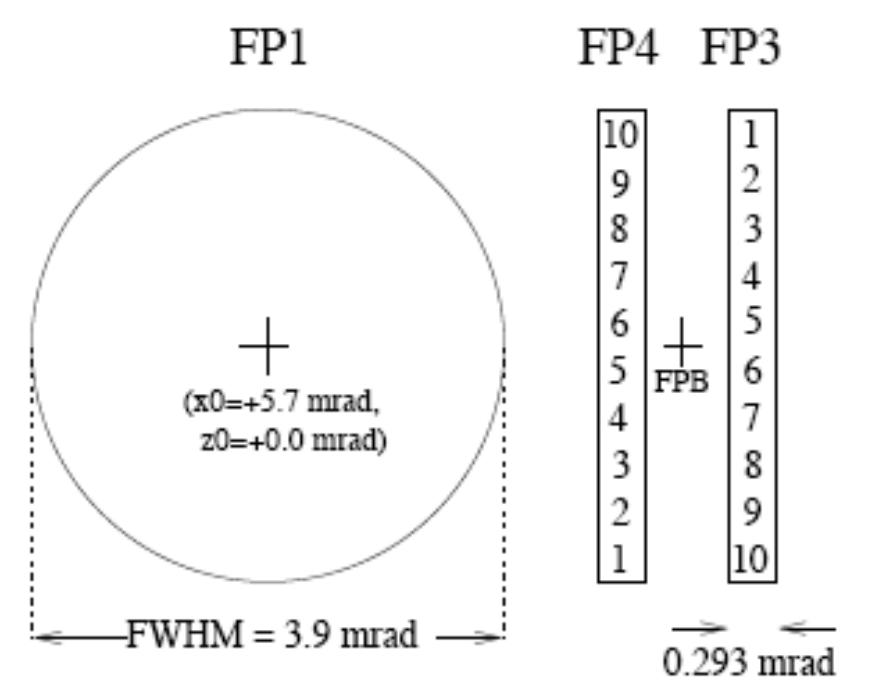
?!

Introduction - Cassini



Introduction - CIRS

- Cassini's Composite Infrared Spectrometer (CIRS) is a dual interferometer covering the far- and near-infrared (10 to 1600 cm^{-1} which is equivalent to 7.16 - 1000 microns)
- CIRS has 3 focal planes, known as FP1, FP3 & FP4

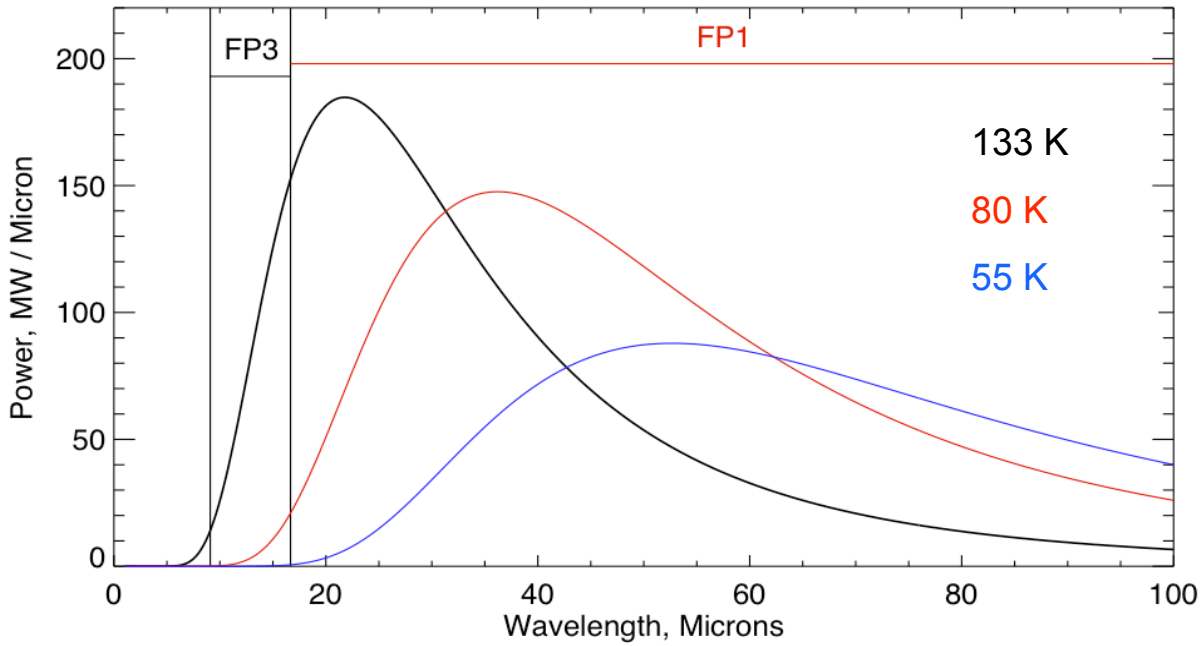


FP1 and FP3 are most sensitive to the surface temperatures of the icy satellites.

FP3 (and FP4) have a higher spatial resolution than FP1 and for this reason FP3 results are currently used in this analysis.

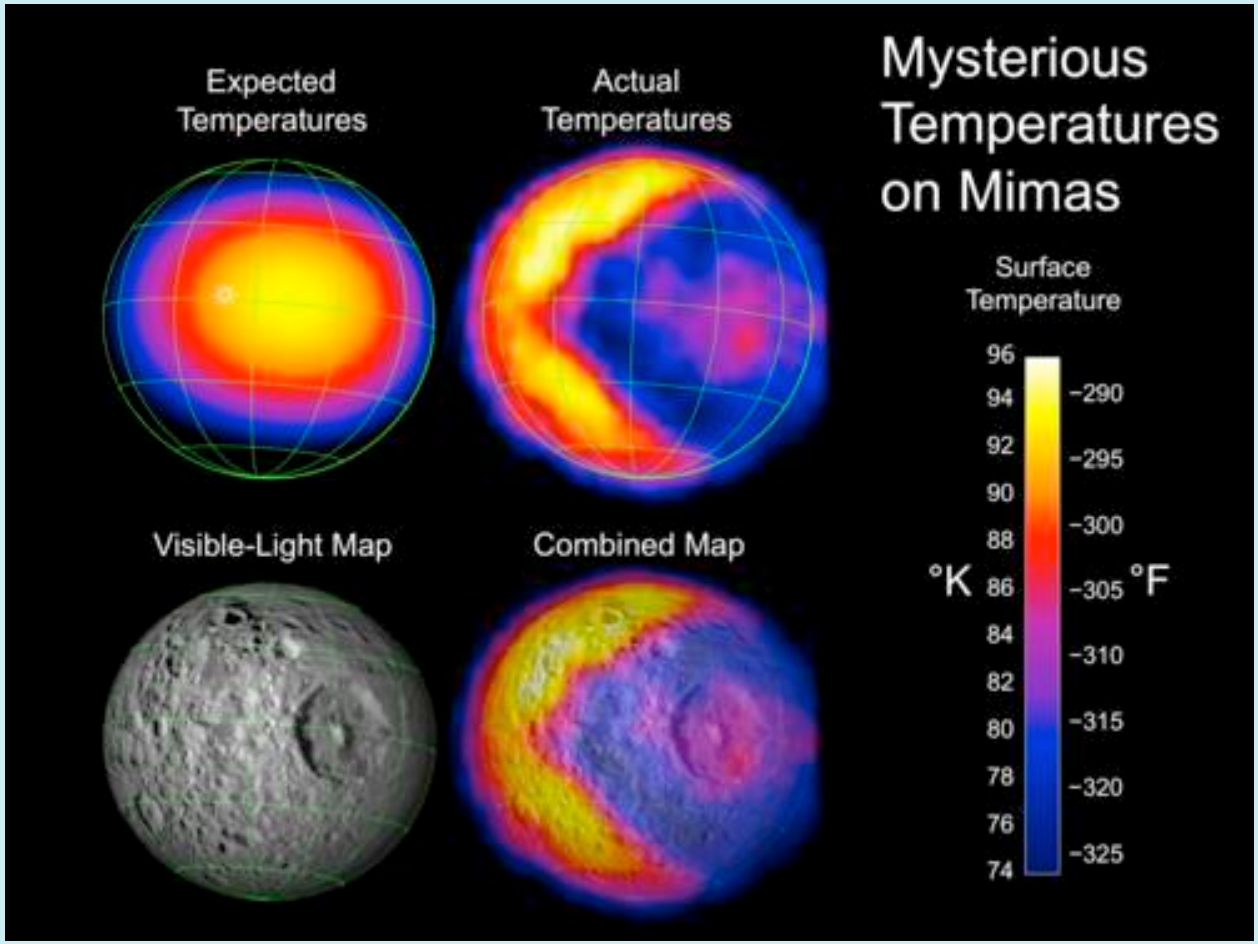
Introduction - CIRS

However, the wavelength range of FP3 renders it sensitive to only temperatures > 80 K.



Which for icy satellites usually restricts its use to daytime observations.

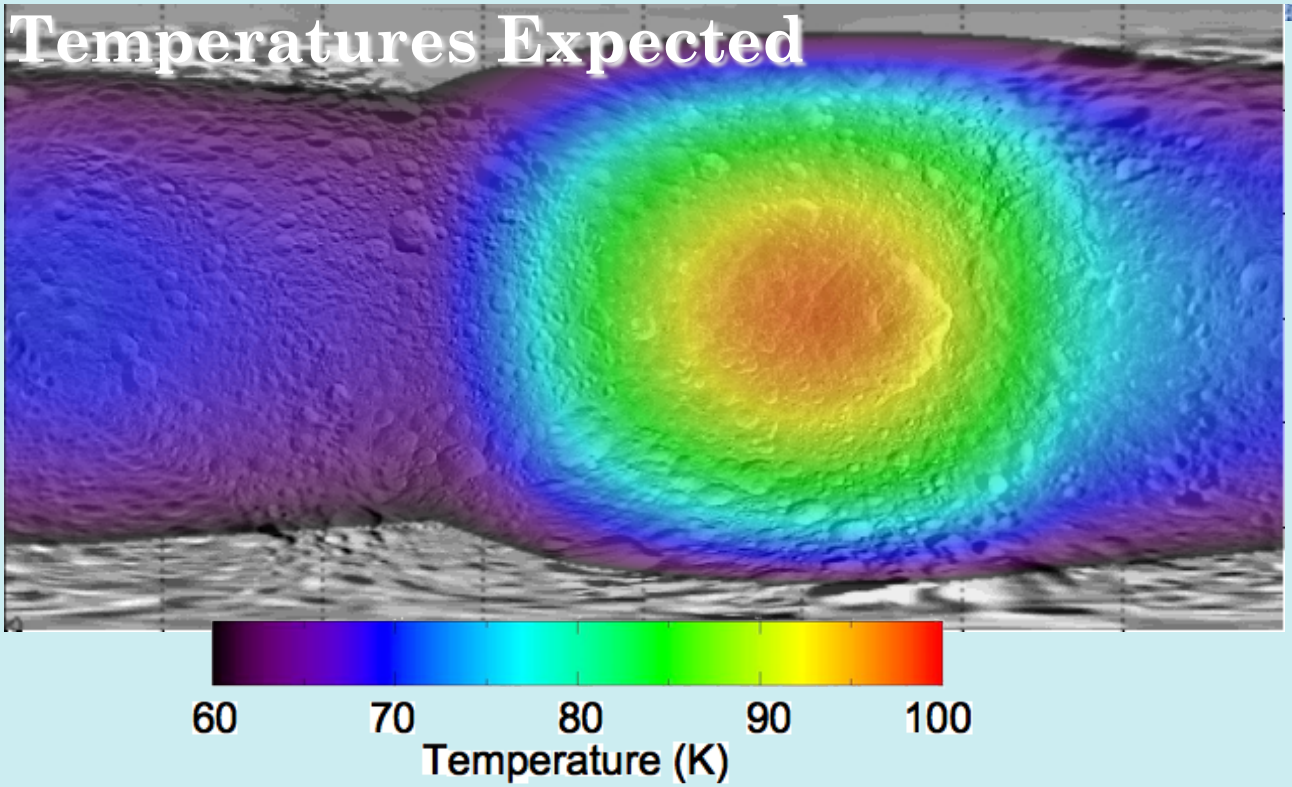
Introduction



The observed temperature variations have an amplitude of ~15 K (comparable to the amplitude of daytime temperature variations on Iapetus!)

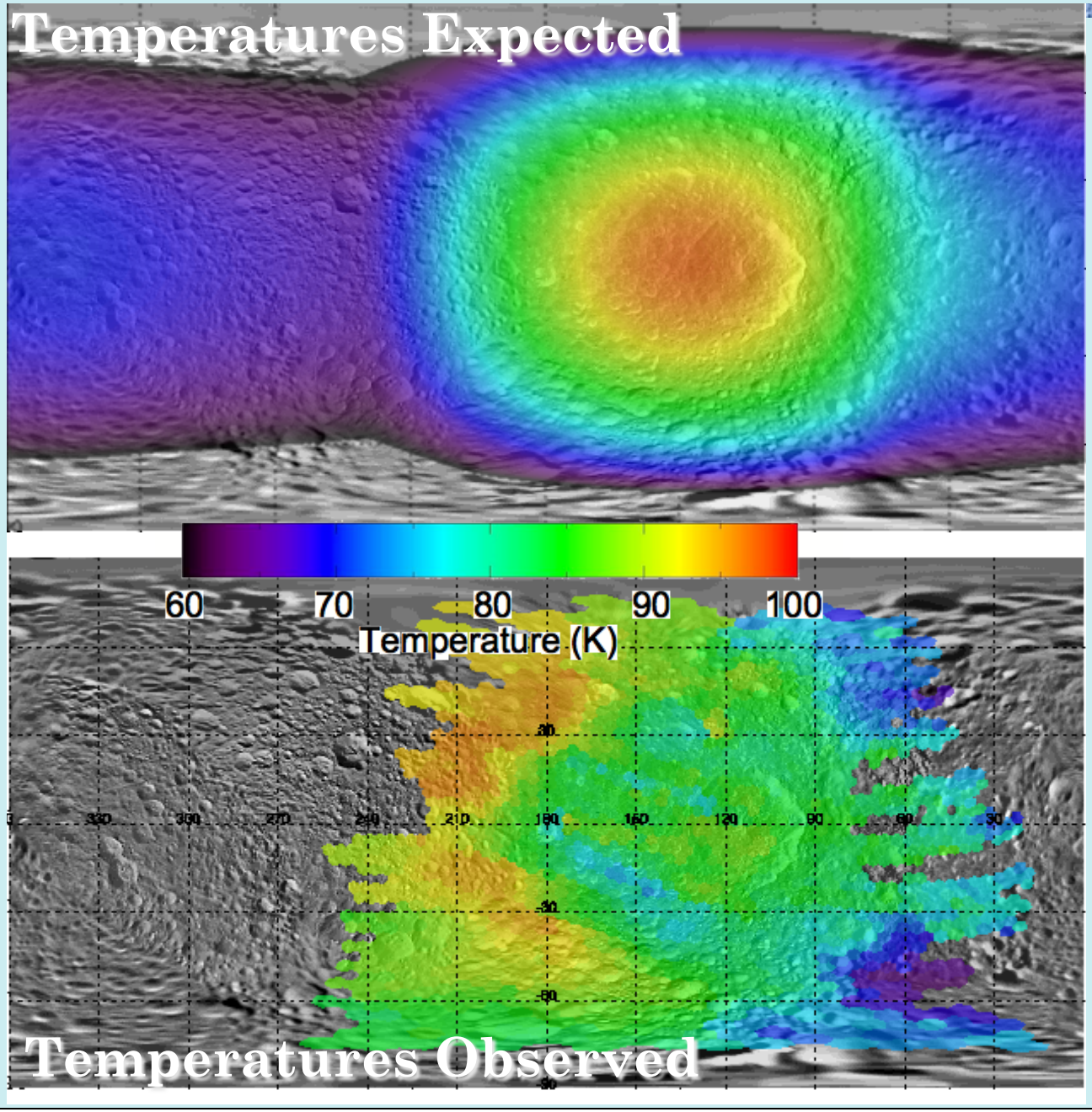
- There is a sharp temperature boundary at CIRS resolution (~15 km)
- No dramatic change in the visible surface albedo over this boundary

Introduction : Rev 126 Data



Surface temperatures predicted assuming an albedo of 0.49 and thermal inertia of 19 MKS (Howett *et al.*, 2010)

Introduction : Rev 126 Data

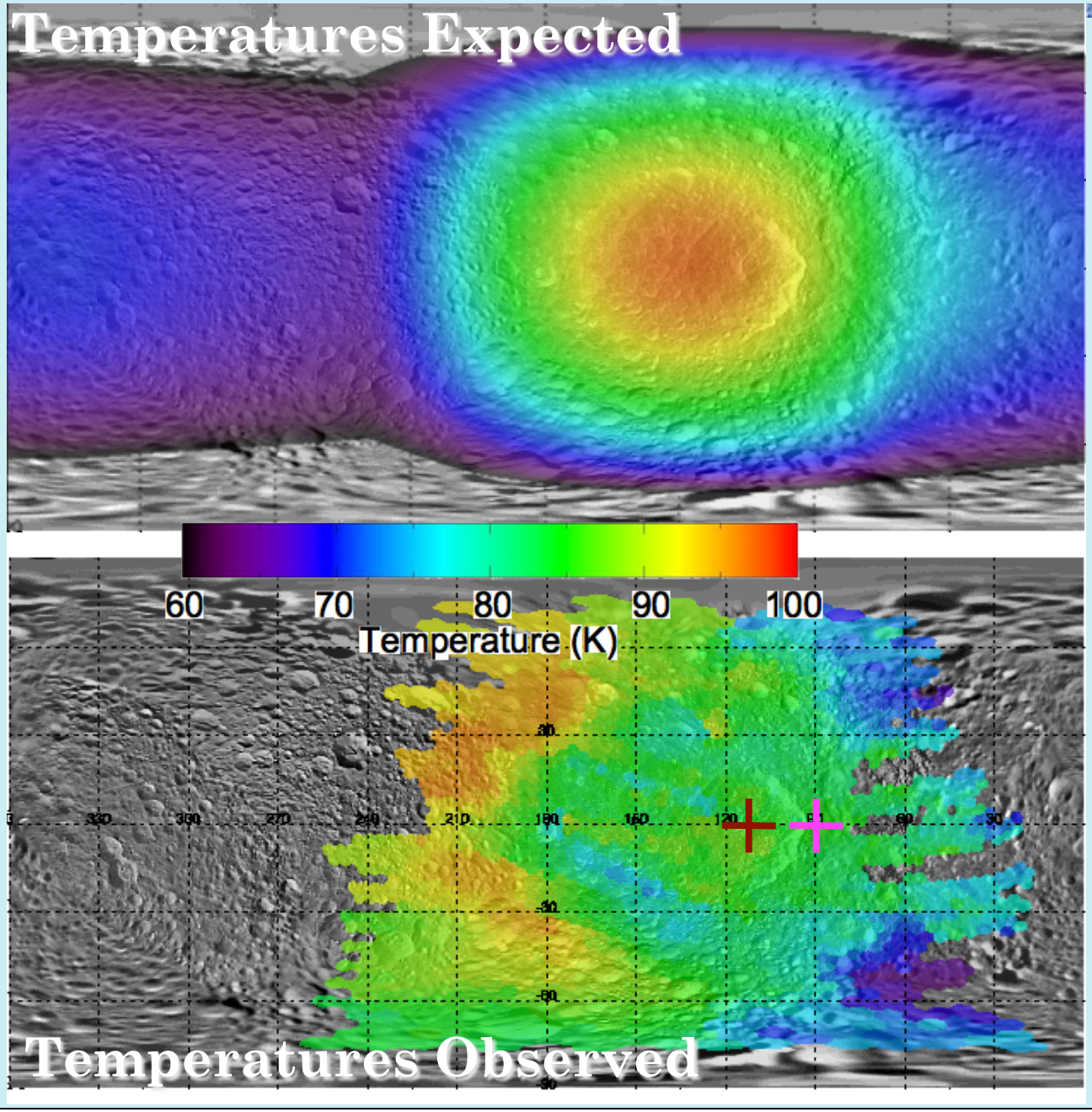


Surface temperatures predicted assuming an albedo of 0.49 and thermal inertia of 19 MKS (Howett *et al.*, 2010)

Sharp lens-shaped temperature anomaly of cooler daytime temperatures is clearly seen.

Mimas' diurnal skindepth (depth to which CIRS data are sensitive) is only ~0.5cm.

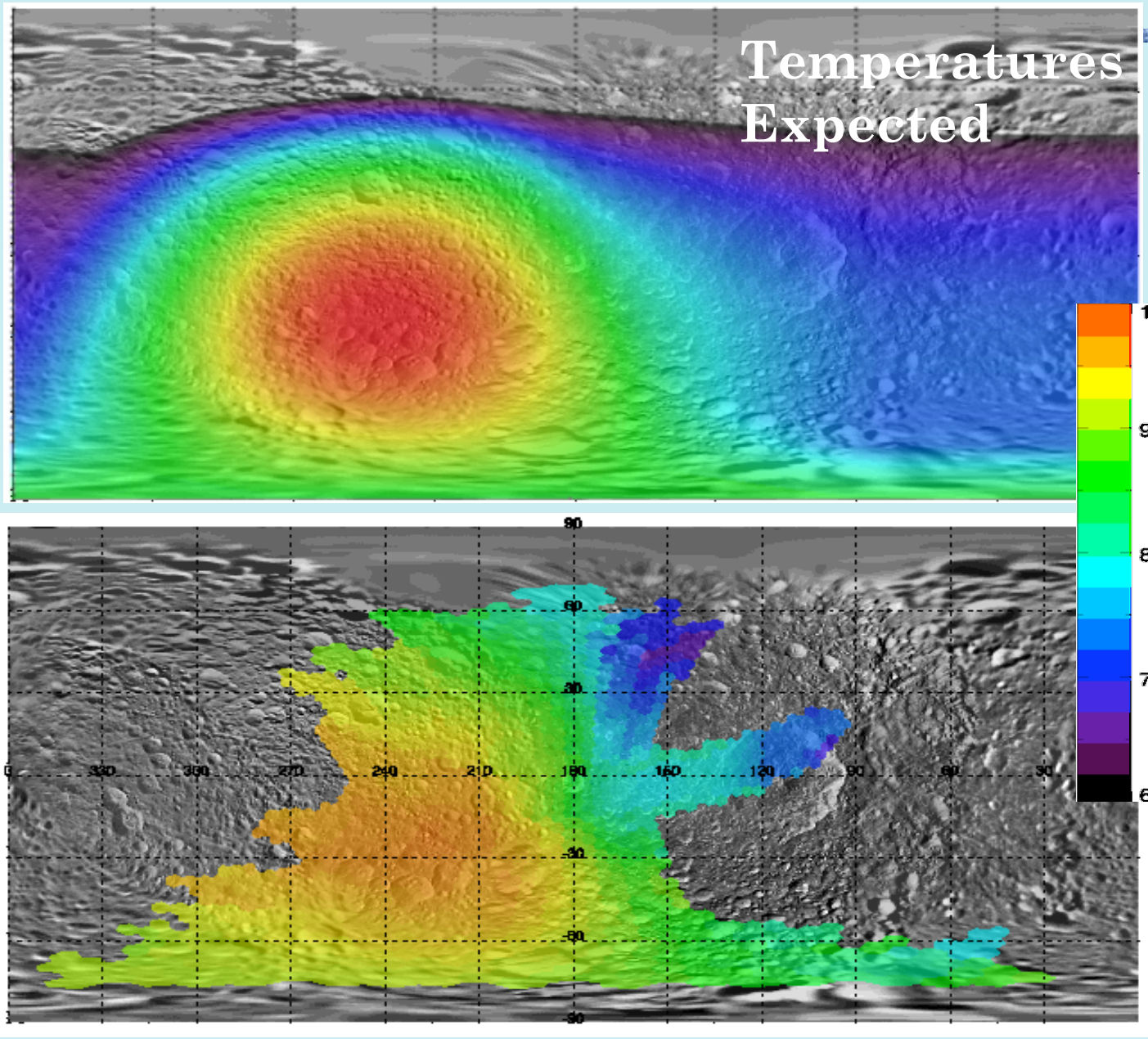
Introduction : Rev 126 Data



Unclear whether the anomaly is centered on the **leading hemisphere apex** or the **Herschel crater**.

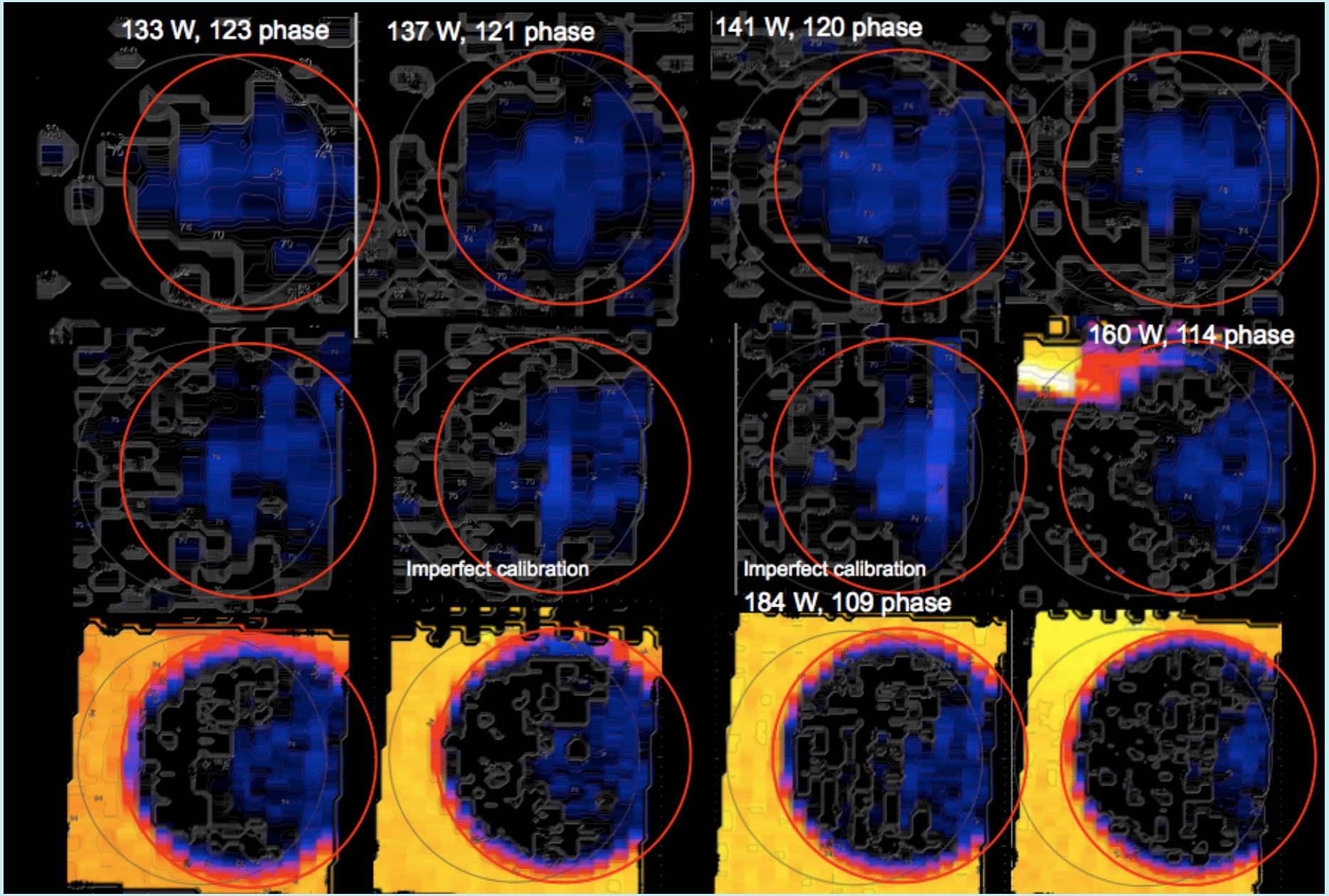
This has important implications for the mechanism of formation

Rev 12 data (2 Aug 2005)



- Lower spatial resolution observation
- Coverage is of Mimas' dayside anti-Saturn hemisphere
- Thermal anomaly boundary is still apparent at ~ 180° W.
- Global coverage is still not achieved

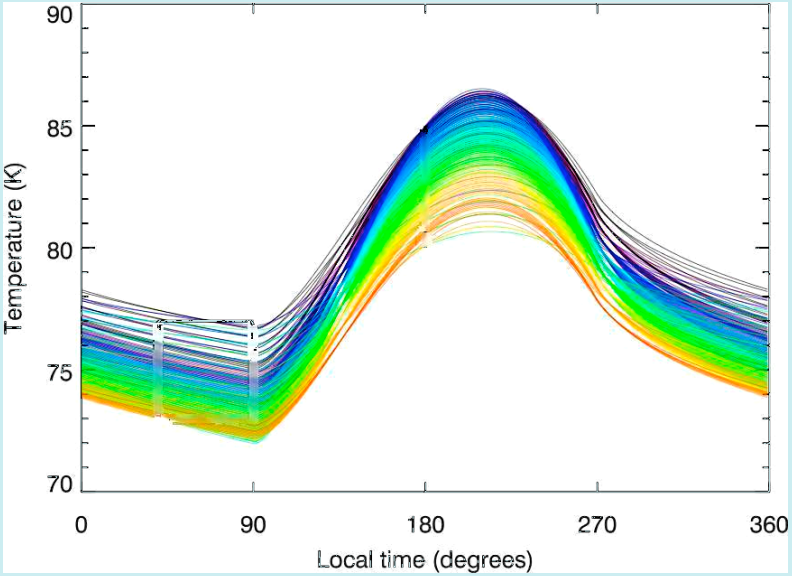
Rev 139 data (16 Oct 2010) - Predicted Geometry



Constraining Thermal Inertia and Bolometric Bond Albedo

Use a 1-D surface thermal model to predict surface temperatures

The temperatures are determined by calculating conductive heat flow into and out of the subsurface



The model accounts for:

- Different bolometric Bond albedo and thermal inertias
- Latitude variations
- Changes in heliocentric distance resulting from Saturn's orbital eccentricity

It does not account for:

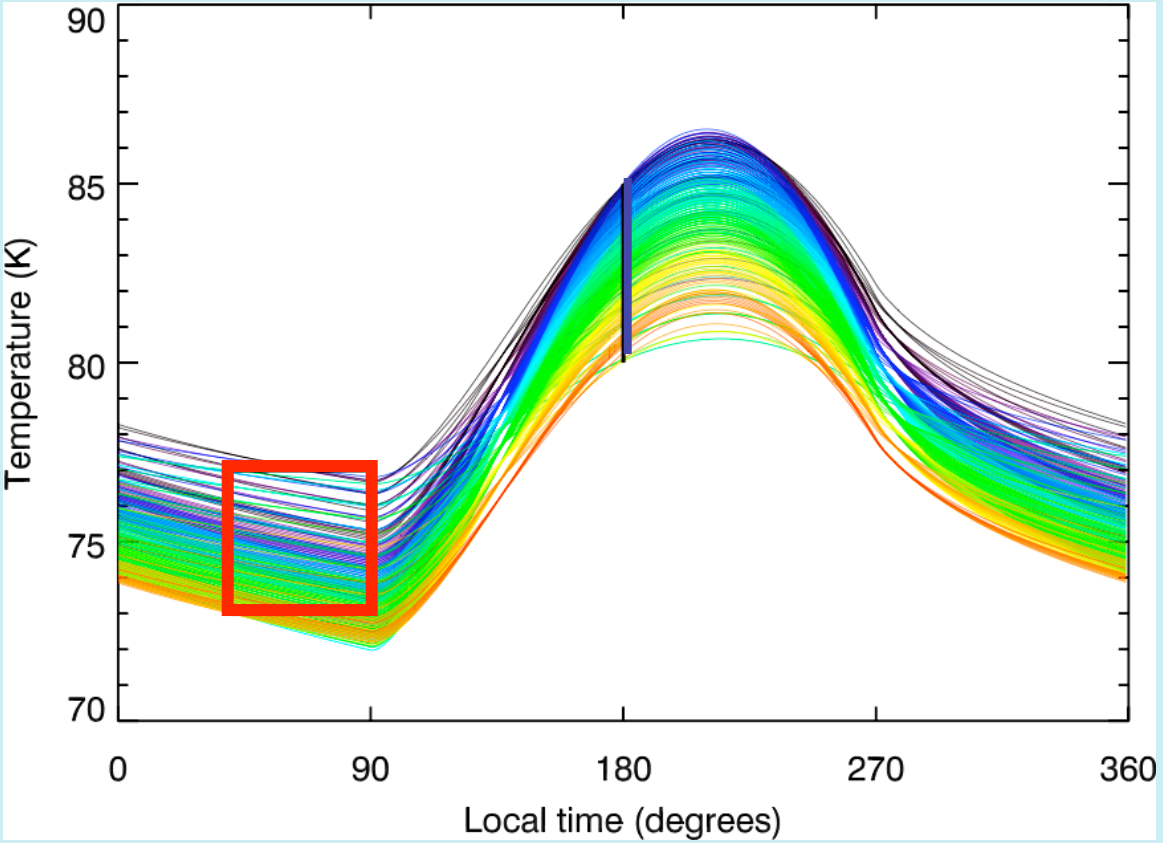
- Albedo variations with incidence angle
- Saturn heating
- Solar eclipses by Saturn

Constraining Thermal Inertia and Bolometric Bond Albedo

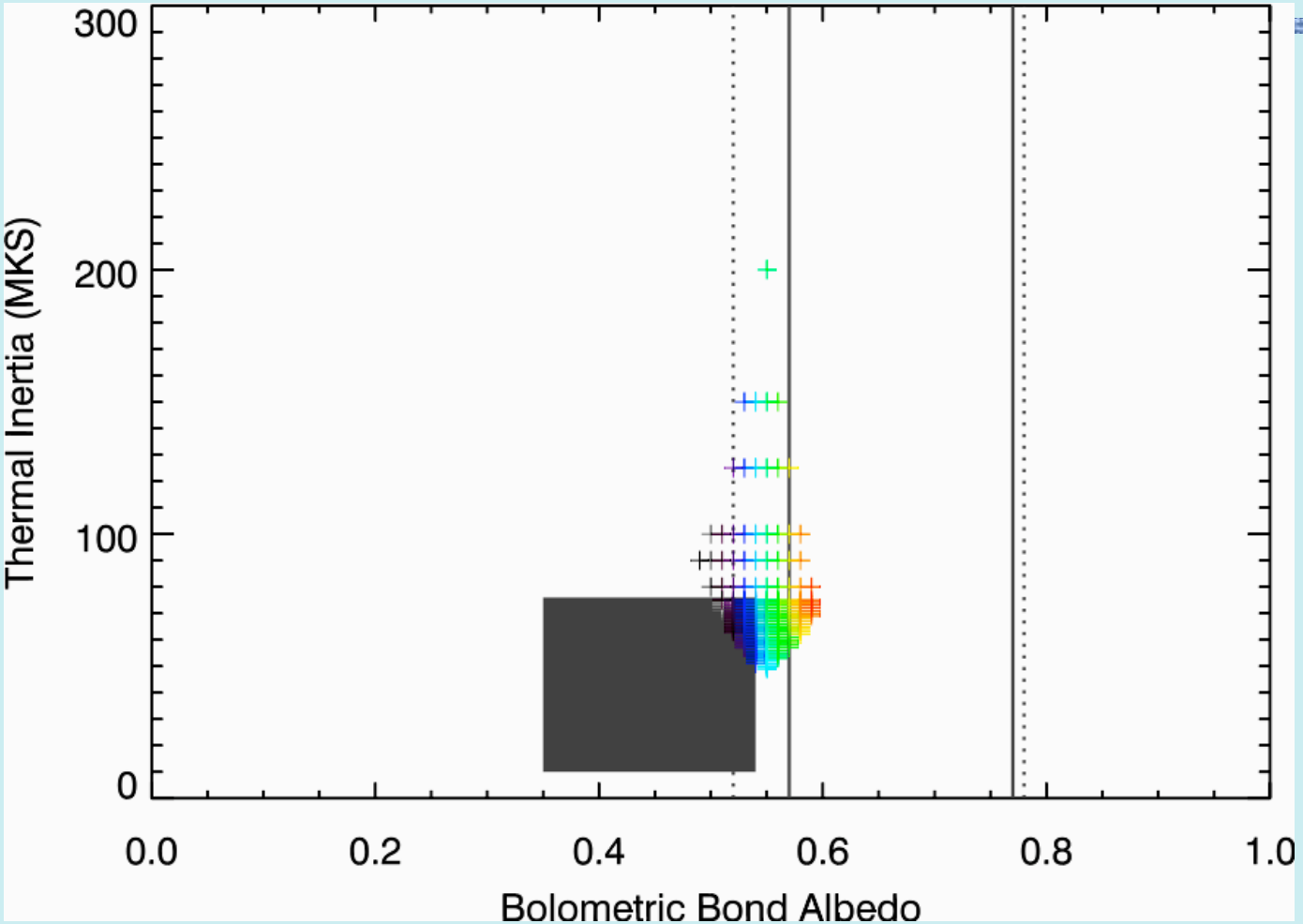
The model was run for the geometry of Rev 139 and 126 for a suite of thermal inertia and bolometric Bond albedo combinations.

Models had to fit the following criteria:

- Night time temperatures from **Rev 139** data of ~ 73 - 77 K
- Day time temperatures from the **Rev 126** data of ~ 80 - 85 K



Constraining Thermal Inertia and Bolometric Bond Albedo



Bolometric Bond Albedo is constrained to 0.49 - 0.59

Thermal Inertia is 49 - 250 MKS

Global limits of Howett *et al.* (2010)

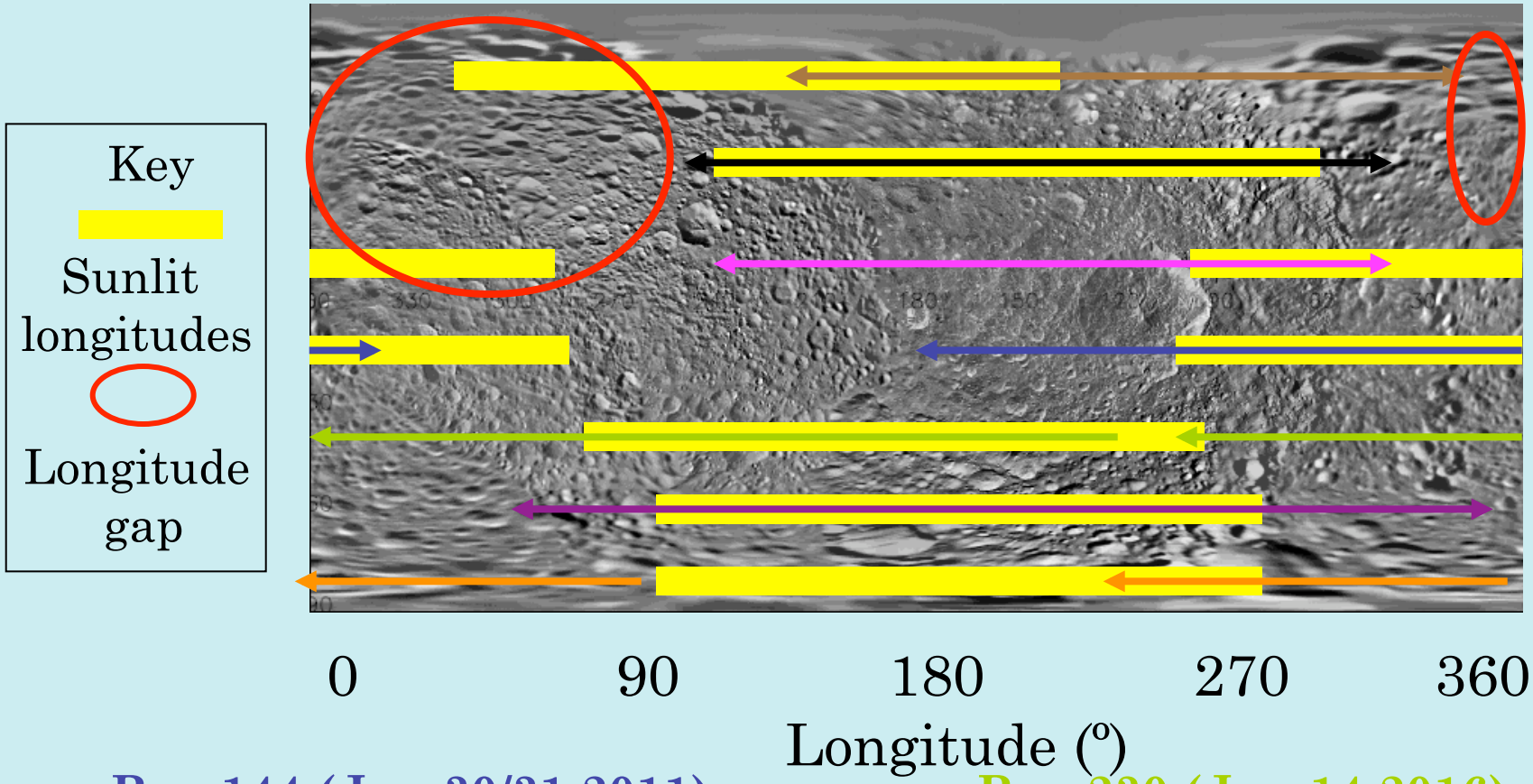
Limits of Pitman *et al.* (2010)

(Solid - Global ; Dashed - Leading hemisphere)

Mimas Observing Opportunities

Current and Future Coverage

Rev 12 **Rev 126** **Rev 139**



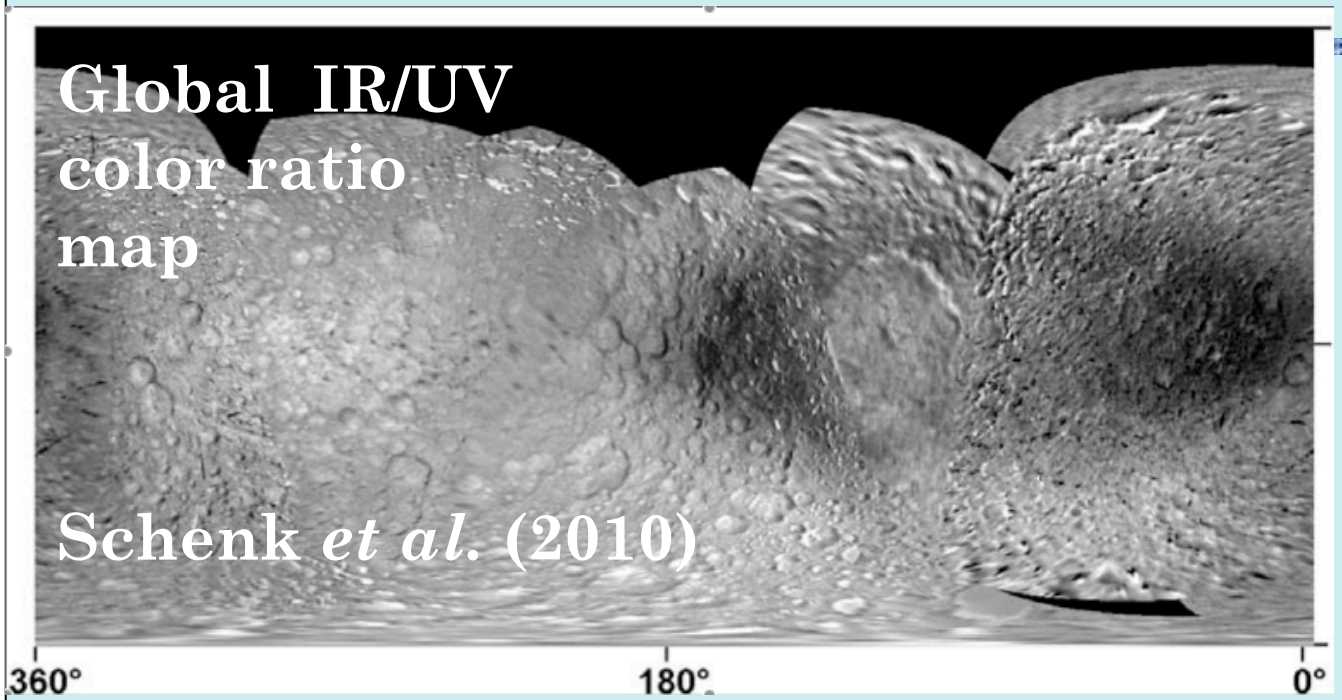
Rev 144 (Jan 30/31 2011)

Rev 230 (Jan 14 2016)

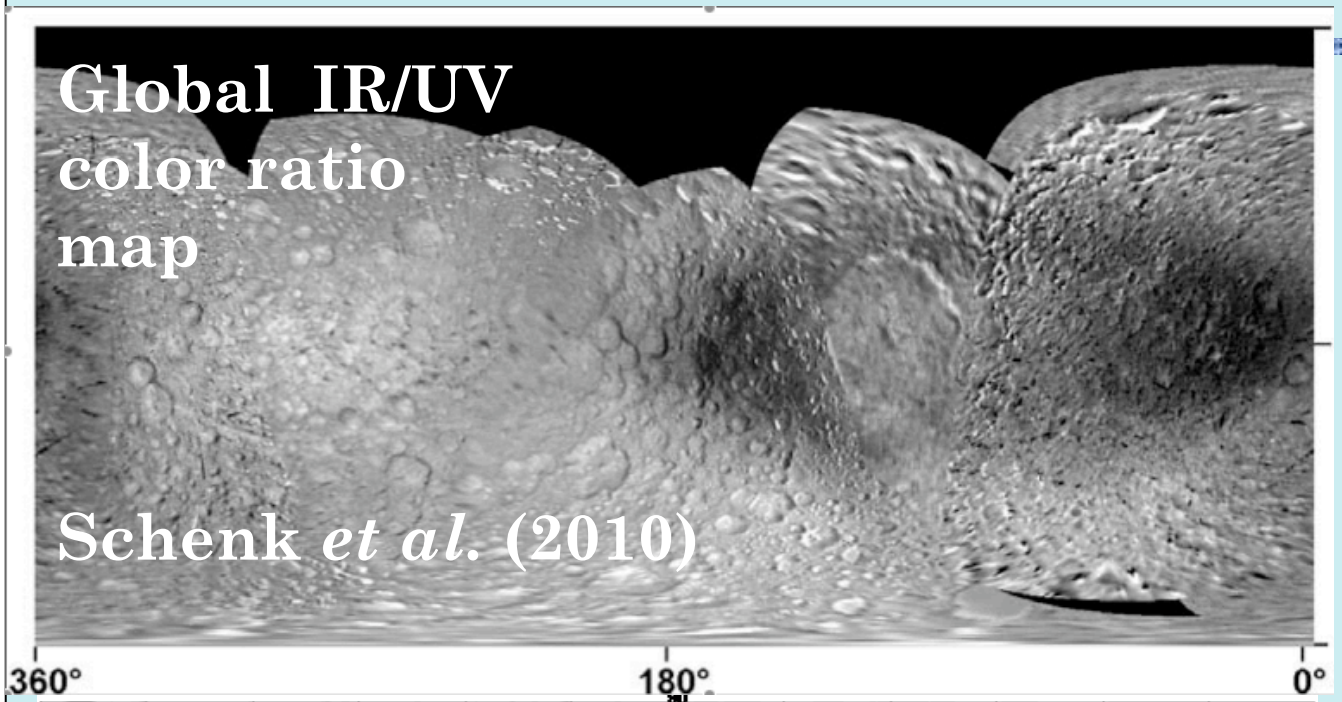
Rev 249 PIE (Nov. 19 2016)

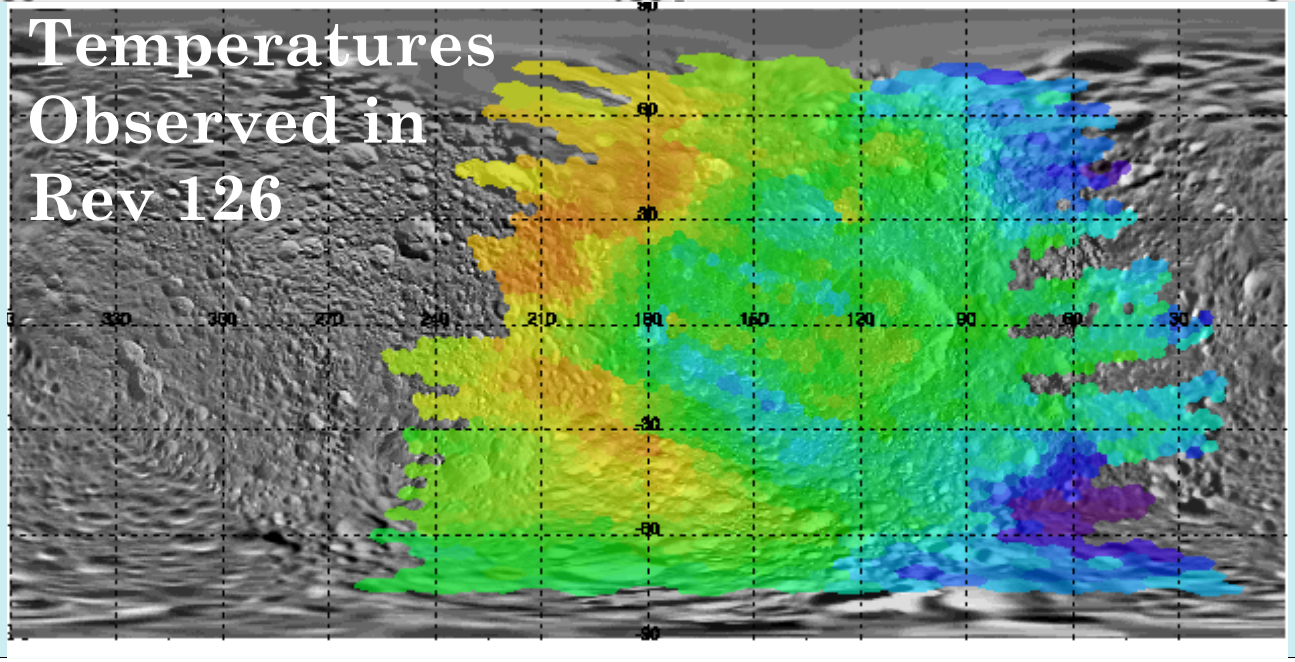
Rev 254 (Dec. 26 2016)

Correlation between Surface Thermal and Color Variations

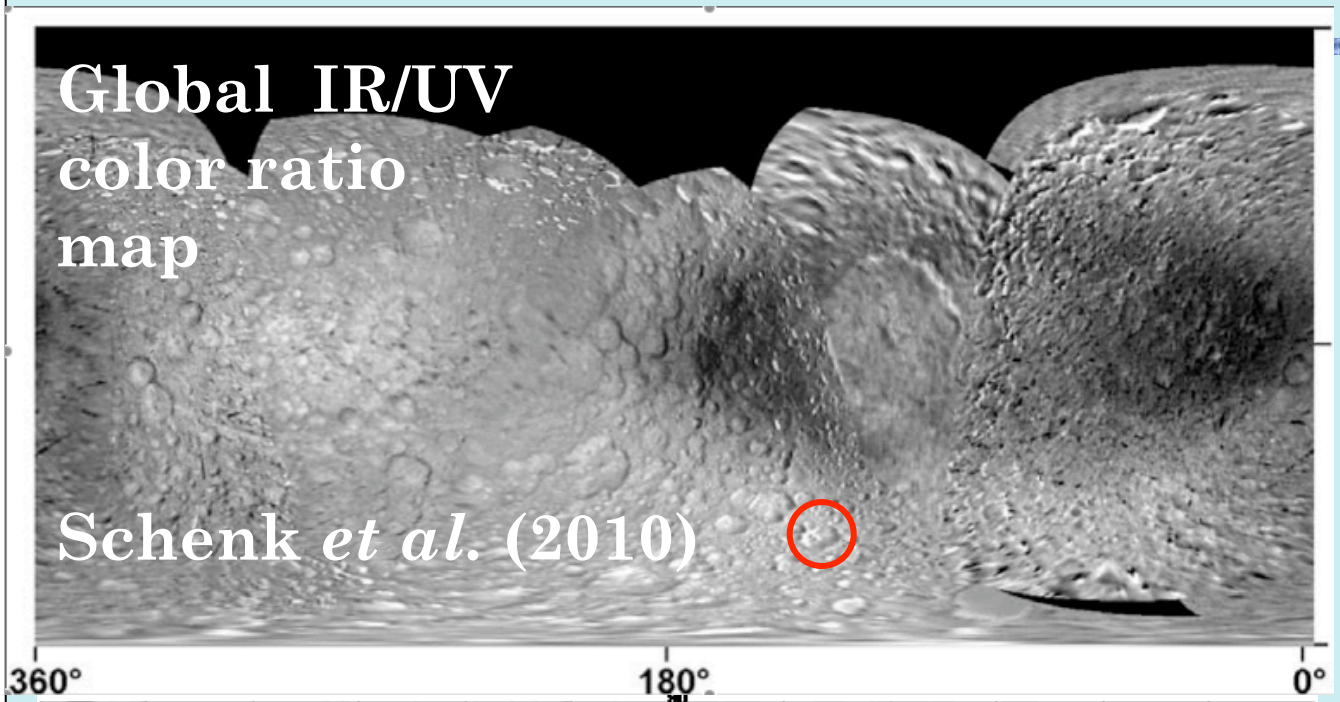


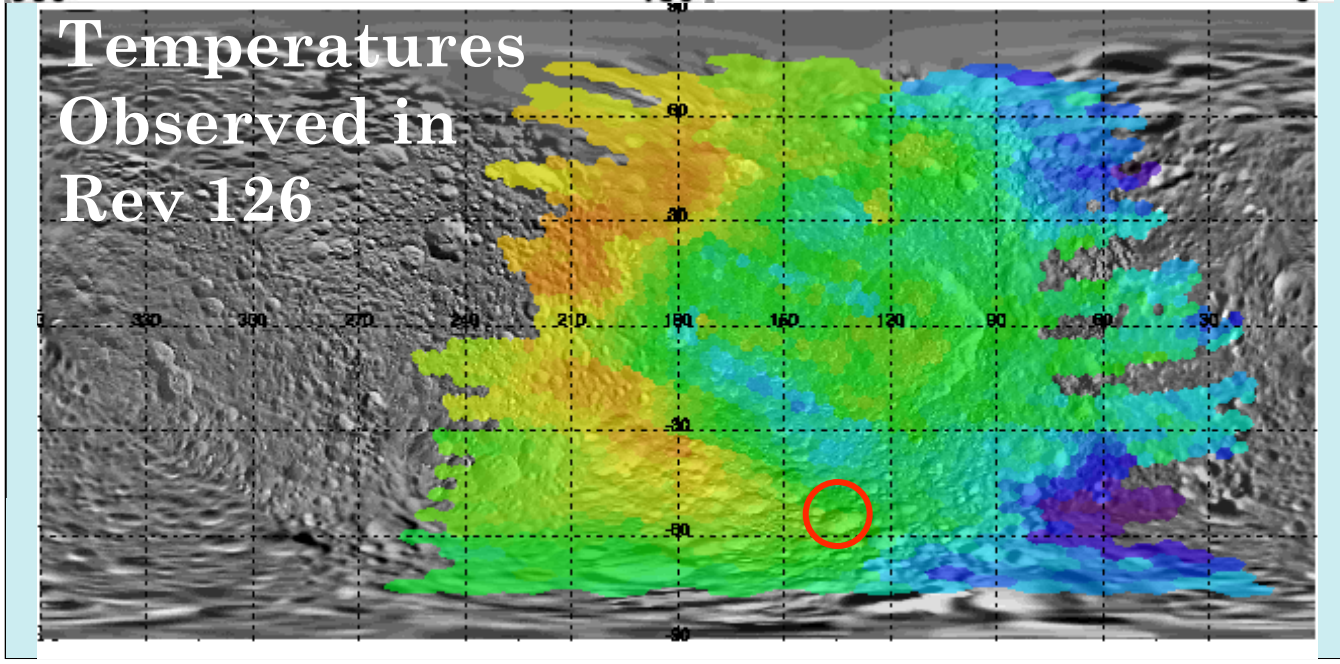
Correlation between Surface Thermal and Color Variations





Correlation between Surface Thermal and Color Variations

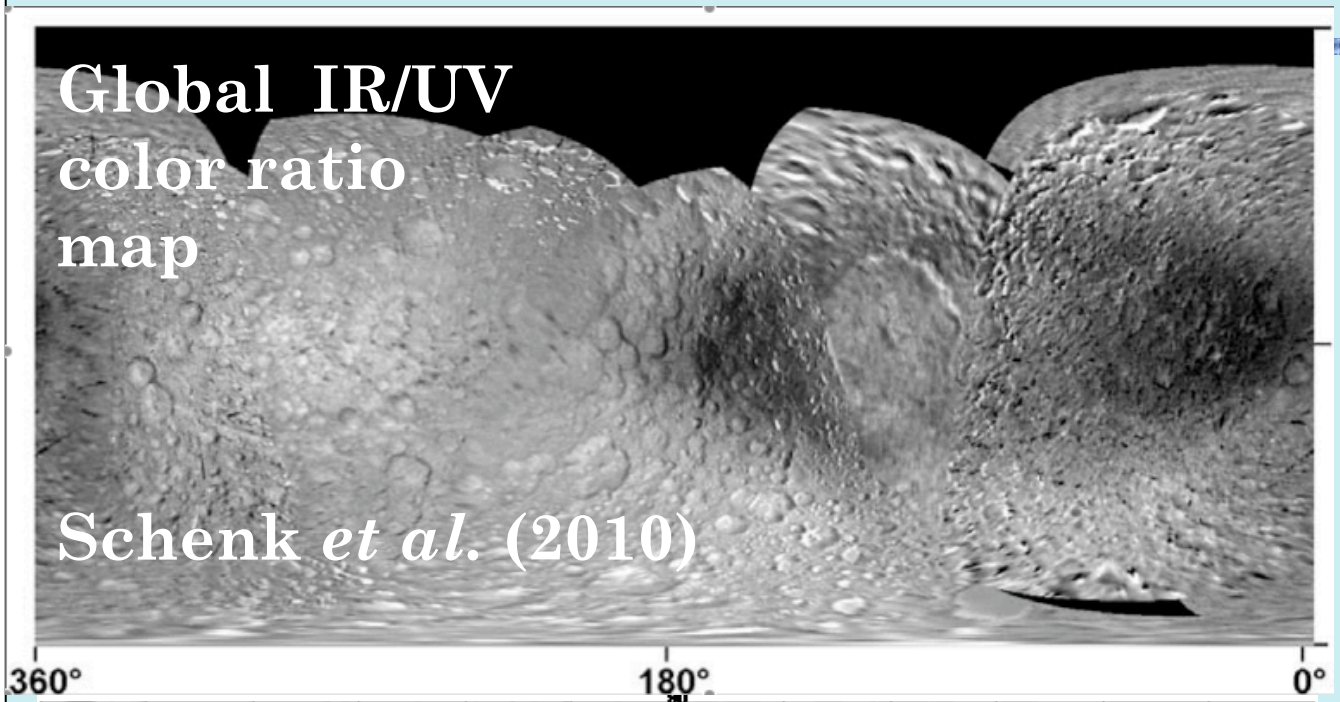


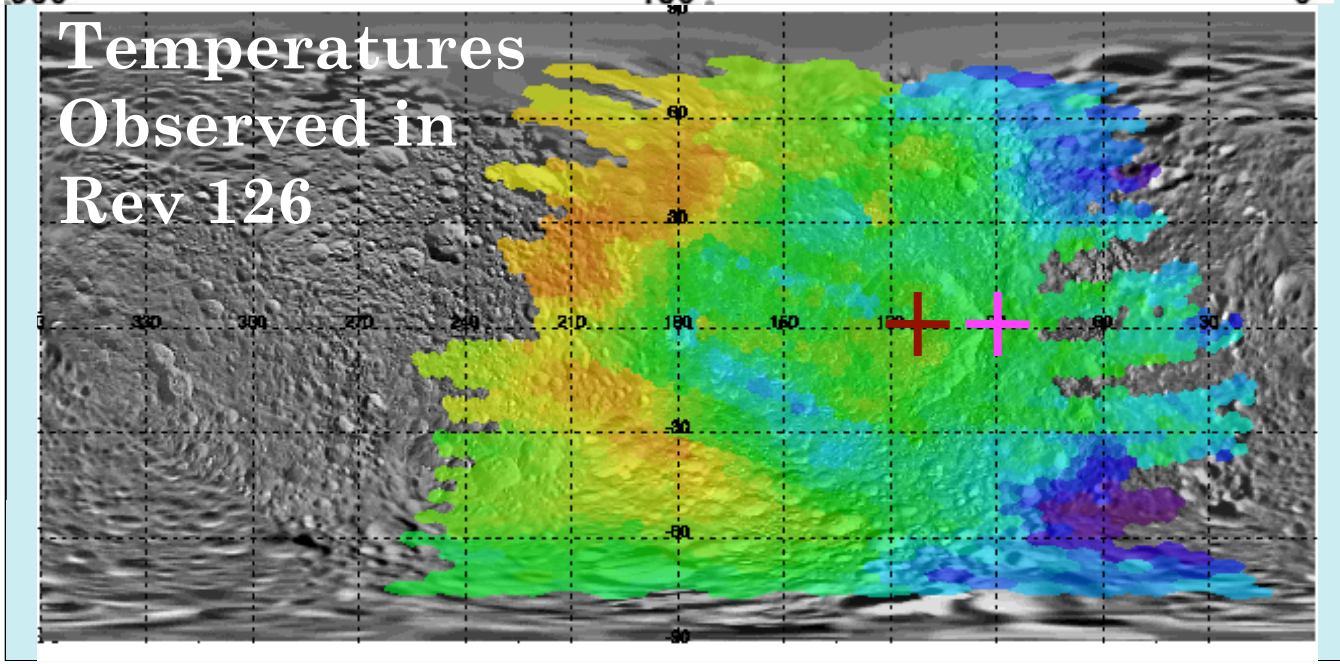


Presently it is not clear how well the thermal anomaly and region of dark IR/UV are correlated.

The red circles highlight the same crater, which appears to be on the edge of the thermal anomaly but outside the region of dark IR/UV ratio

Correlation between Surface Thermal and Color Variations



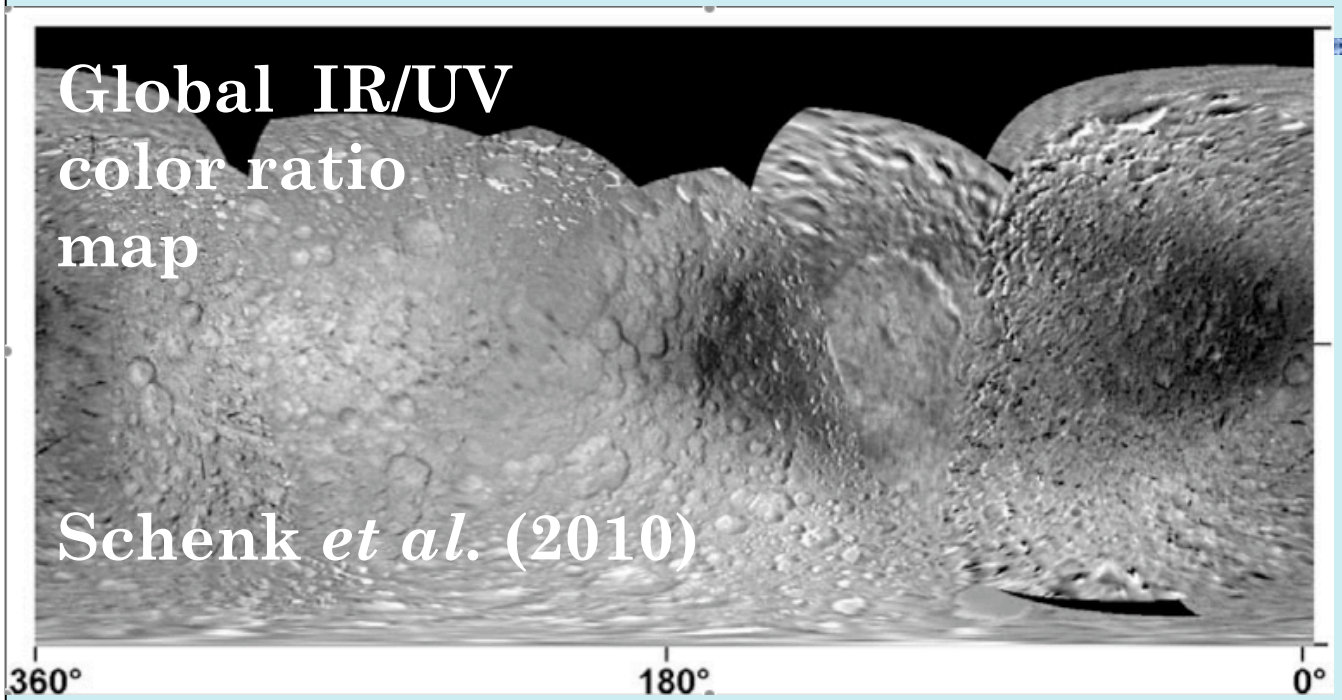


The color anomaly is centered on the apex of motion, but it's still unknown whether the thermal anomaly is centered here or on the Herschel crater

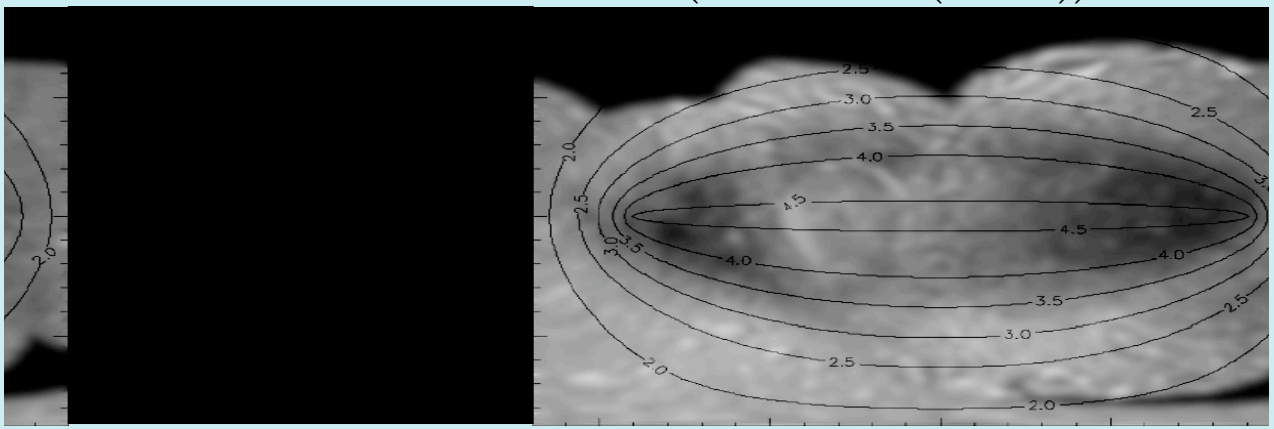
- if centered on Herschel the crater forming process is implicated

- if centered on the apex of motion, surface modifications by exogenic processes such as plasma, micro meteorites, or E-ring deposition are implicated

Correlation between Surface Thermal and Color Variations



Power into the surface per unit area from high energy electron bombardment (10^x MeV / (cm^2/s))



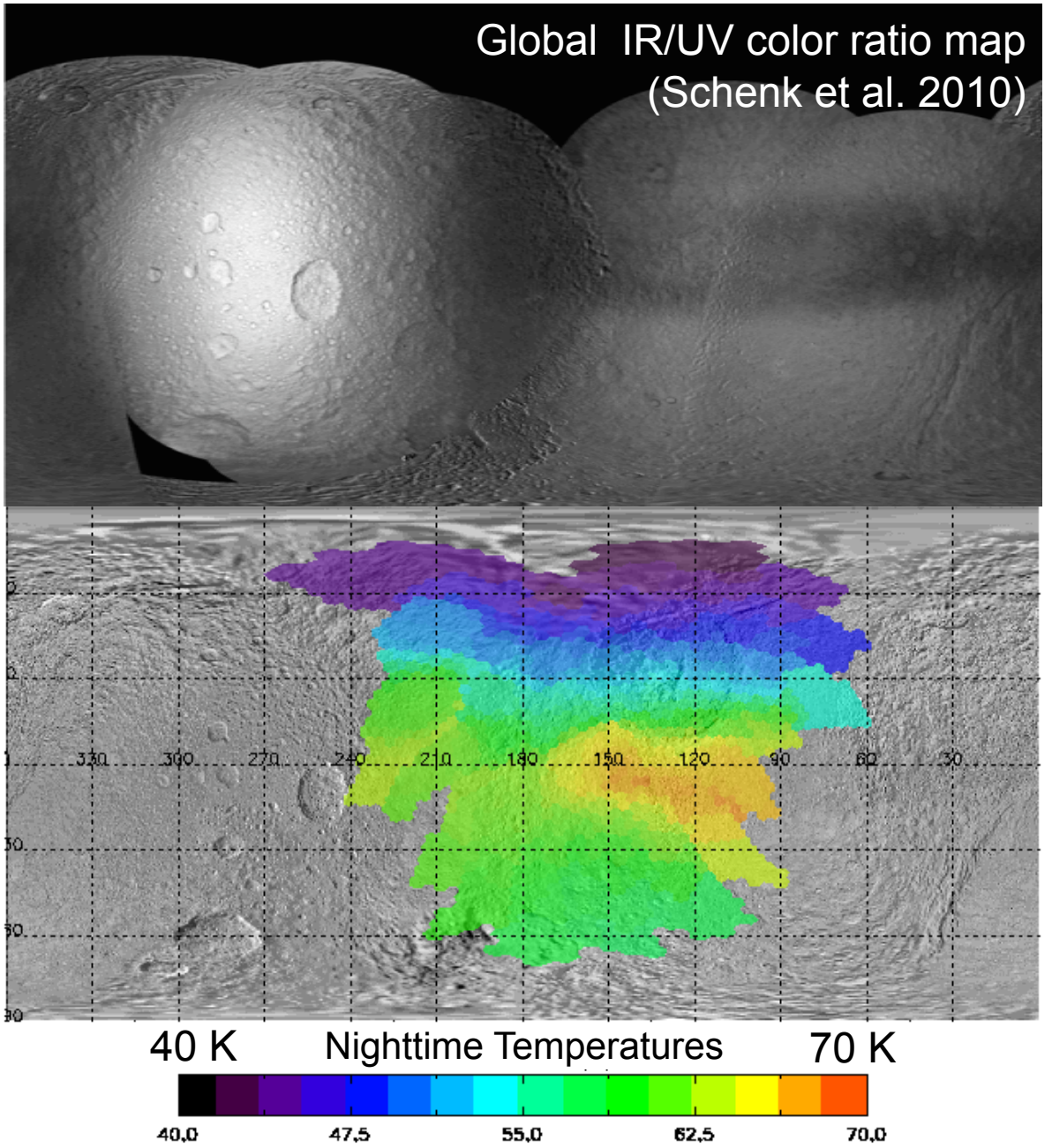
- Schenk *et al.* (2010) suggest high-energy electron bombardment explain the color anomaly

-since the color anomaly is the the same shape as the region bombarded by electrons

- how this process works and whether it can also dramatically increase thermal inertia in the surface 0.5 cm is currently unknown.

Similar Anomaly on Tethys?

- Similar leading-side color anomaly
  - Also ascribed to electron bombardment by Schenk *et al.* (2010)
- 2007 CIRS night time temperature maps show corresponding warm anomaly, also implying high thermal inertia
  - Tentative indications of low daytime temperatures in the same region



Conclusions

- Mimas exhibits a significant V-shaped thermal anomaly on its leading hemisphere at equatorial latitudes.
- Low latitudes on the leading side have a dramatically higher thermal inertia in the top ~0.5 cm of the surface than elsewhere on Mimas
- Now we have dayside and nightside coverage of the anomalous region, which have enabled the thermal surface properties to be further constrained:
  - **Bolometric Bond Albedo is constrained to 0.49 - 0.59**
  - **Thermal Inertia is 49 - 250 MKS**
- Global CIRS coverage of Mimas will not be achieved until Jan 2011. So the correlation in the extent and shape of the color and thermal anomalies are not currently completely known.
- The shape of the thermal anomaly is similar to that observed in the IR/UV maps derived by Schenk *et al.* (2010), with the higher thermal inertia regions corresponding to lower IR/UV ratios.
- Global coverage will show whether the thermal anomaly is centered around the giant crater Herschel or, as the color anomaly is, Mimas' leading hemisphere.
- Similar anomaly on Tethys?…….