IceCube 883-GHz Cloud Radiometer

Adventure and Performance in Space

Dong L. Wu and The IceCube Team

NASA Goddard Space Flight Center

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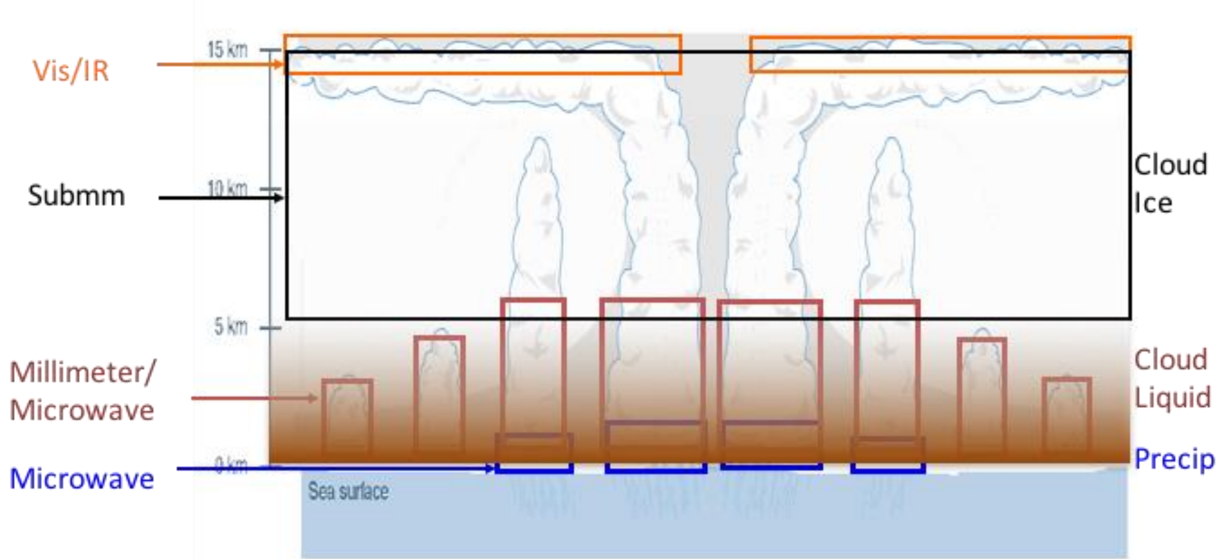
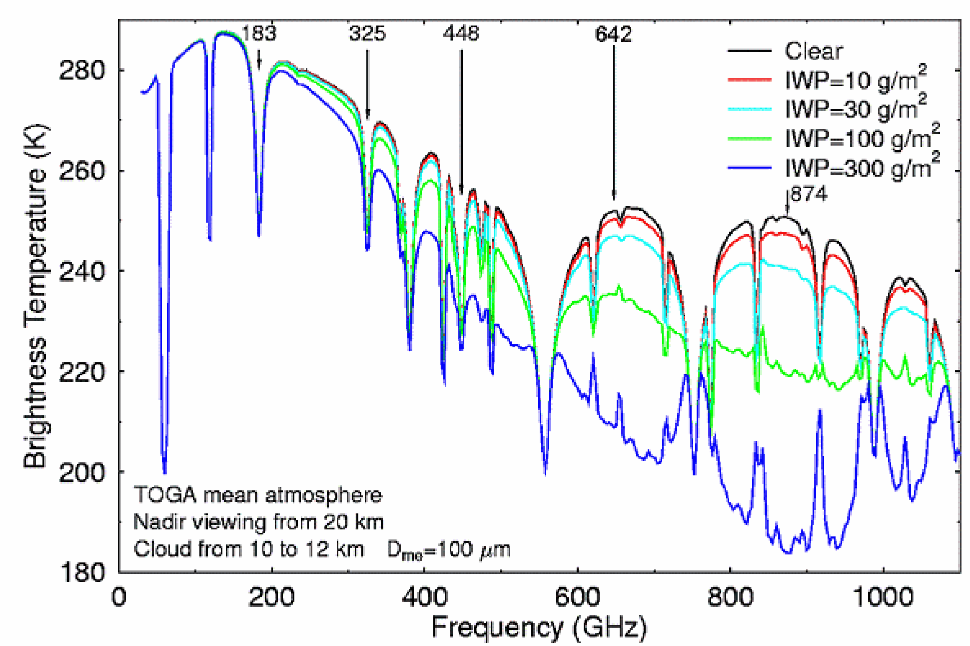
Motivations

- Submm-wave cloud radiometer to fill cloud ice gap in the atmosphere
- Spaceflight demonstration of a commercial 883-GHz receiver for technology maturation (TRL 5->7)
- Utilization of emerging cubesat platform for space access and fast development cycle

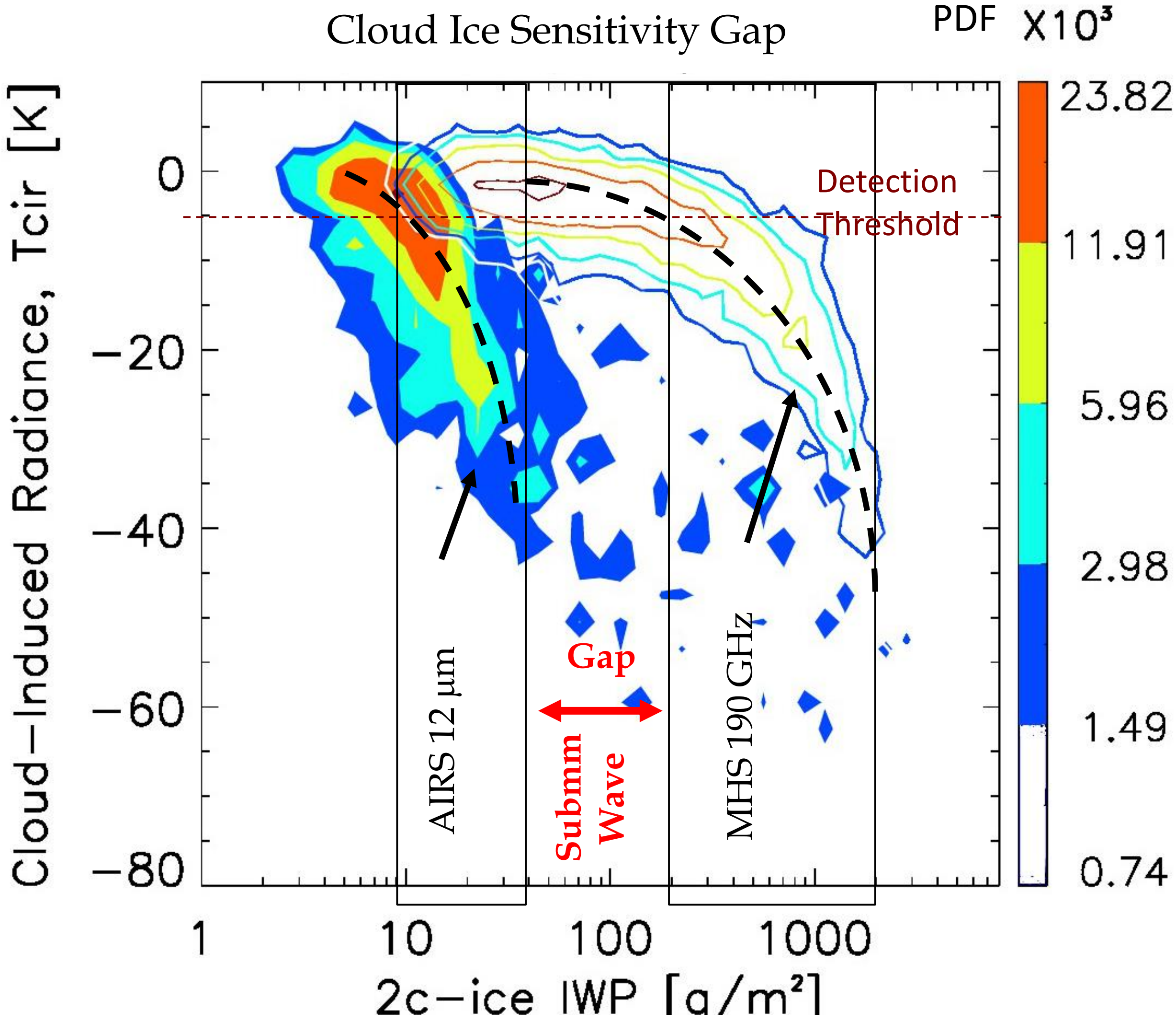




Cloud Ice Sensitivity Gap

- Clouds, ice clouds in particular, are a major source of uncertainty in climate models
- Submm-wave sensors fill the sensitivity gap between MW and IR.
- Cloud microphysical properties (particle size) account for ~200% of measurement uncertainty.

$$T_{cir} = T_b - T_{b\_clear}$$



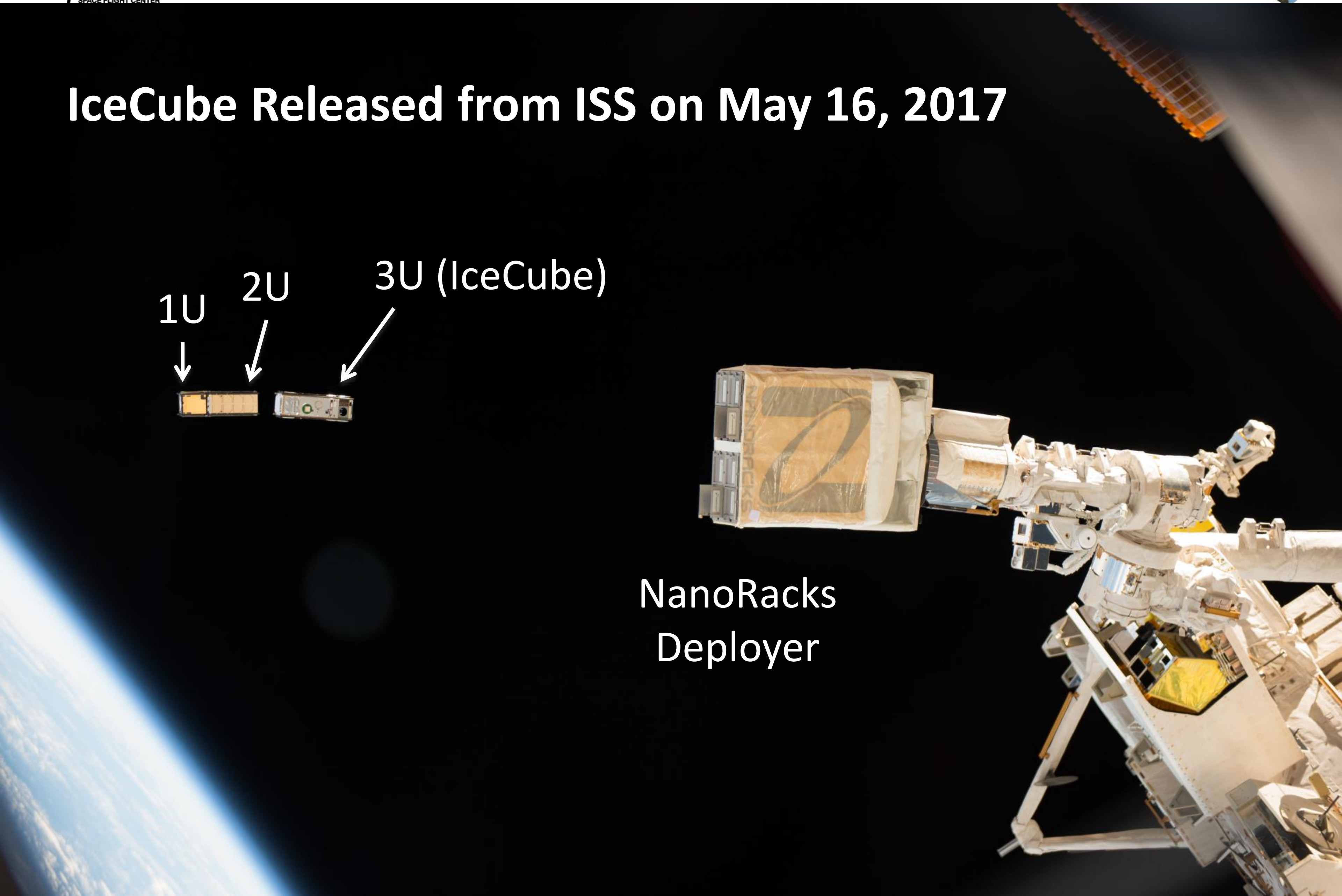
Ice Water Path (IWP) from CloudSat/CALIOP

IceCube’s Journey to Space

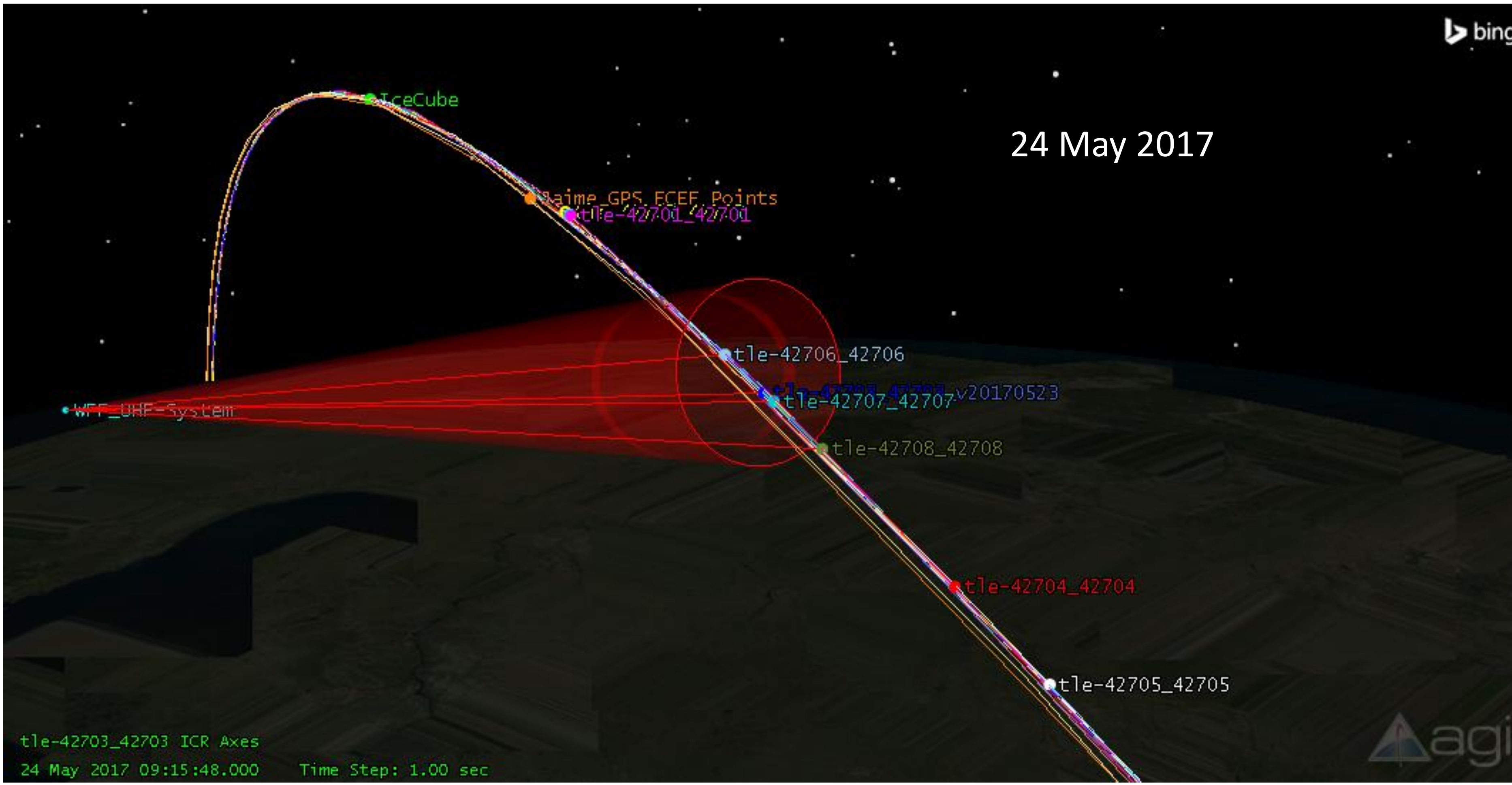
A Successful Story for Fast-Track Technology Development and Science Research

• 04/2014	Project start
• 04/2016	Payload delivered
• 12/2016	Delivery to NanoRacks (cubesat launcher)
• 4/19/2017	Launched to ISS
• 5/16/2017	Jettisoned from ISS and contacted at WFF
• 6/6/2017	First light
• 6/9-18:19:49	IceCube within 23m from CubeSat HOOPEO
• 6/18-7/20	Daytime-only observations
• 7/17/2017	First 883-GHz cloud radiance map
• 8/2-present	Daytime-only observations

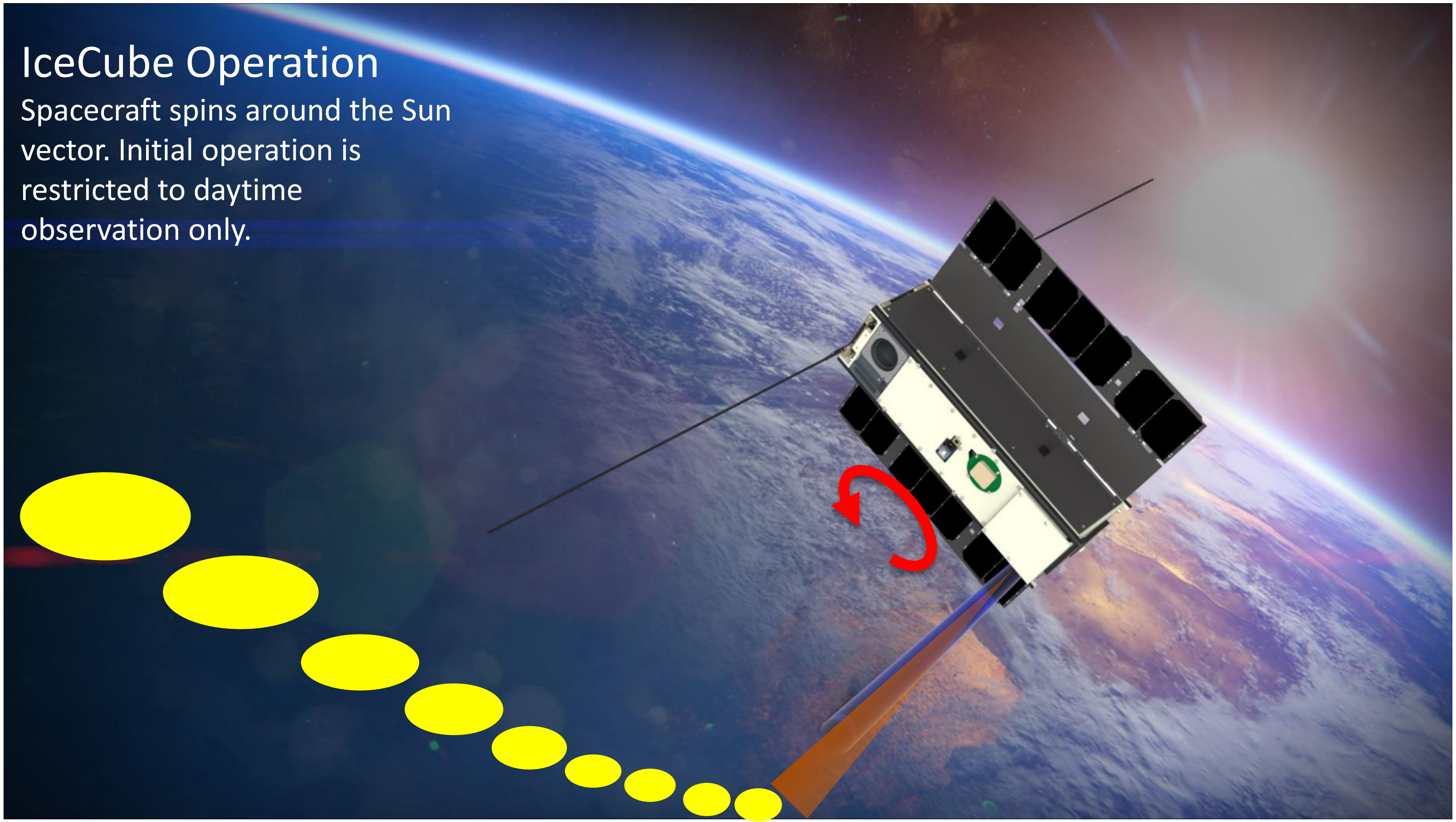
IceCube Released from ISS on May 16, 2017



Telemetry Ground Station: Wallops Flight Facility (WFF)



Operation


IceCube Operation
Spacecraft spins around the Sun vector. Initial operation is restricted to daytime observation only.

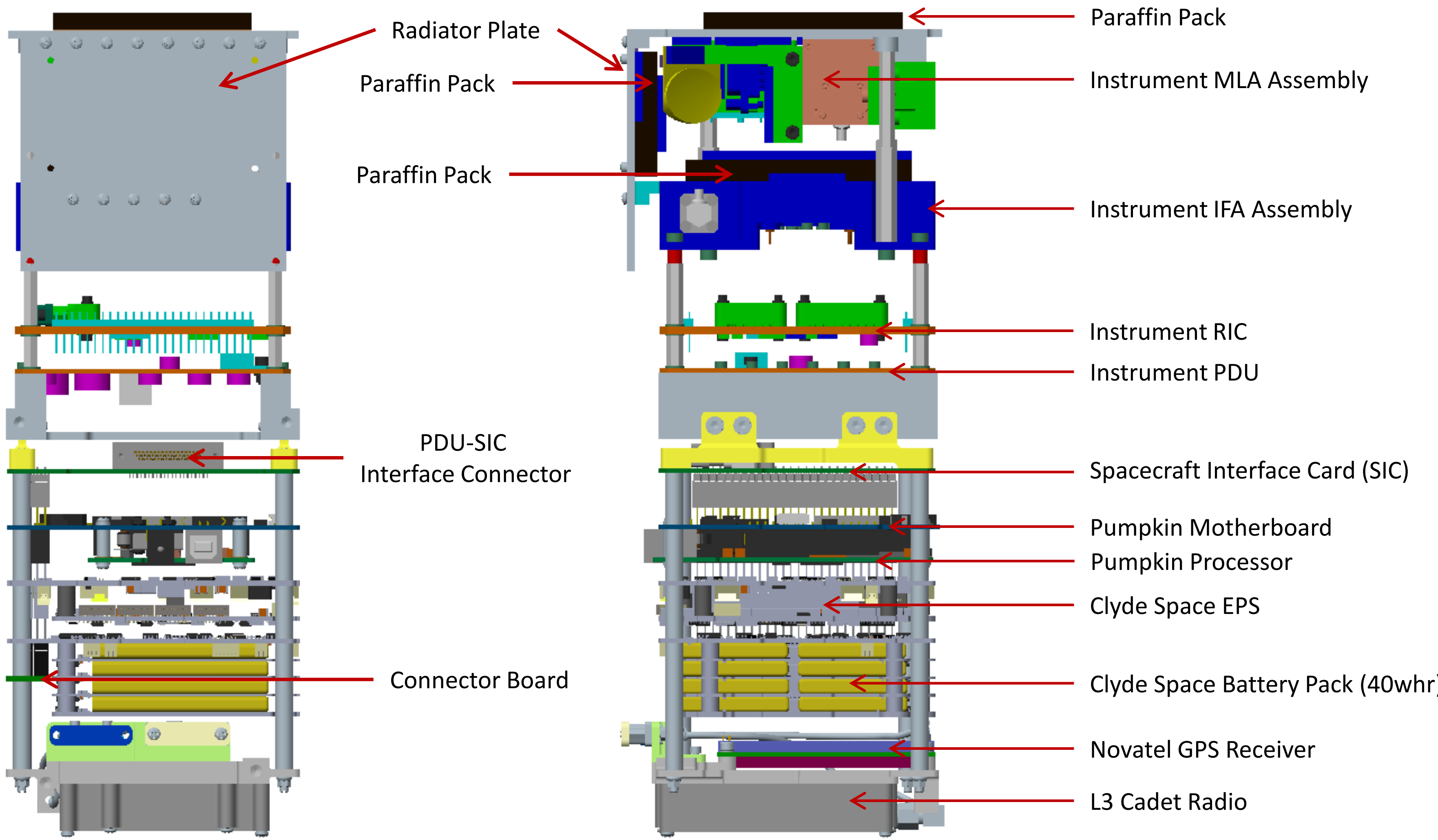
CubeSat Internal Layout

Total

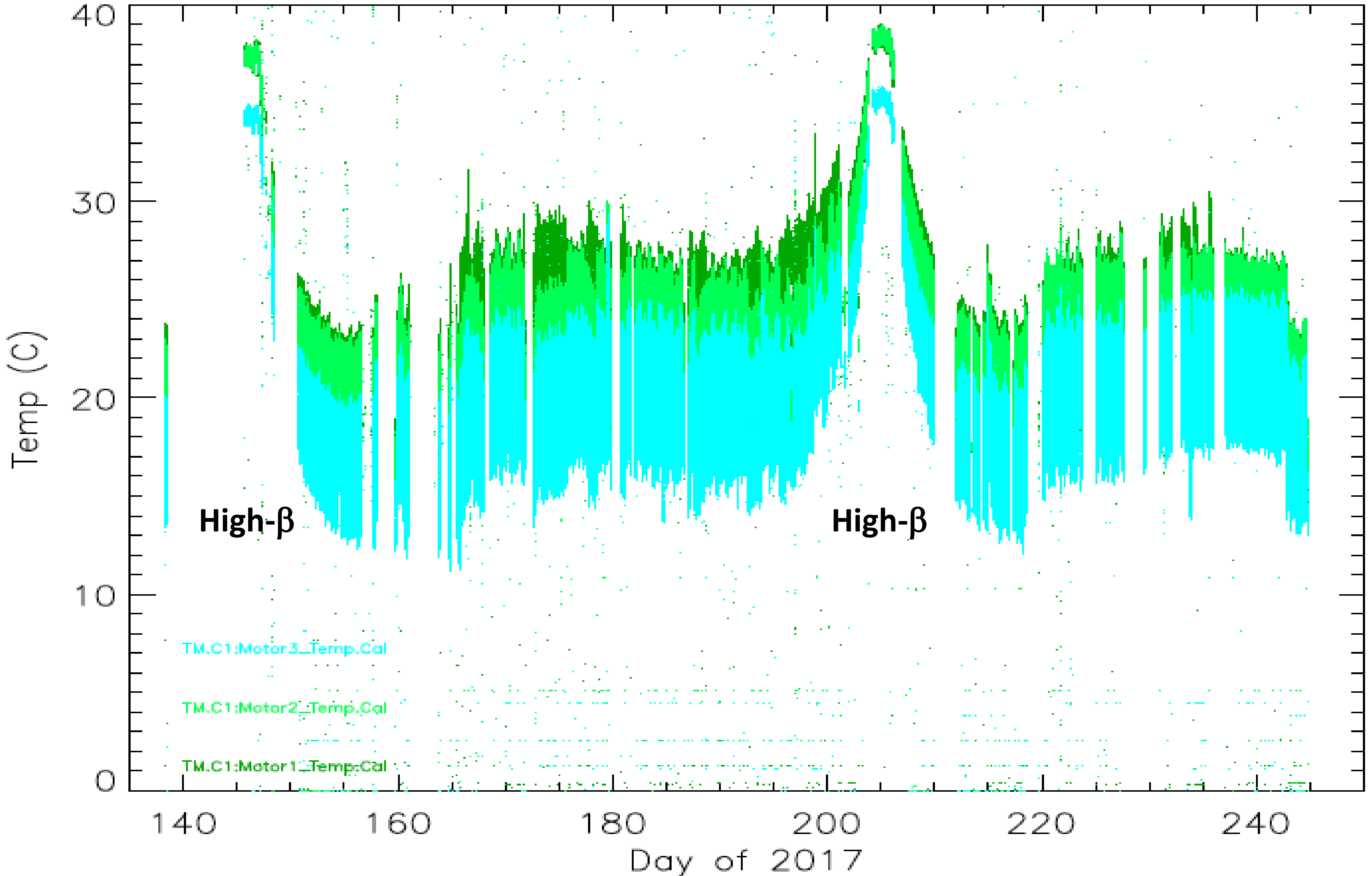
Mass: 4 kg
Volume: 3 U
Power: 18 W

Instrument:

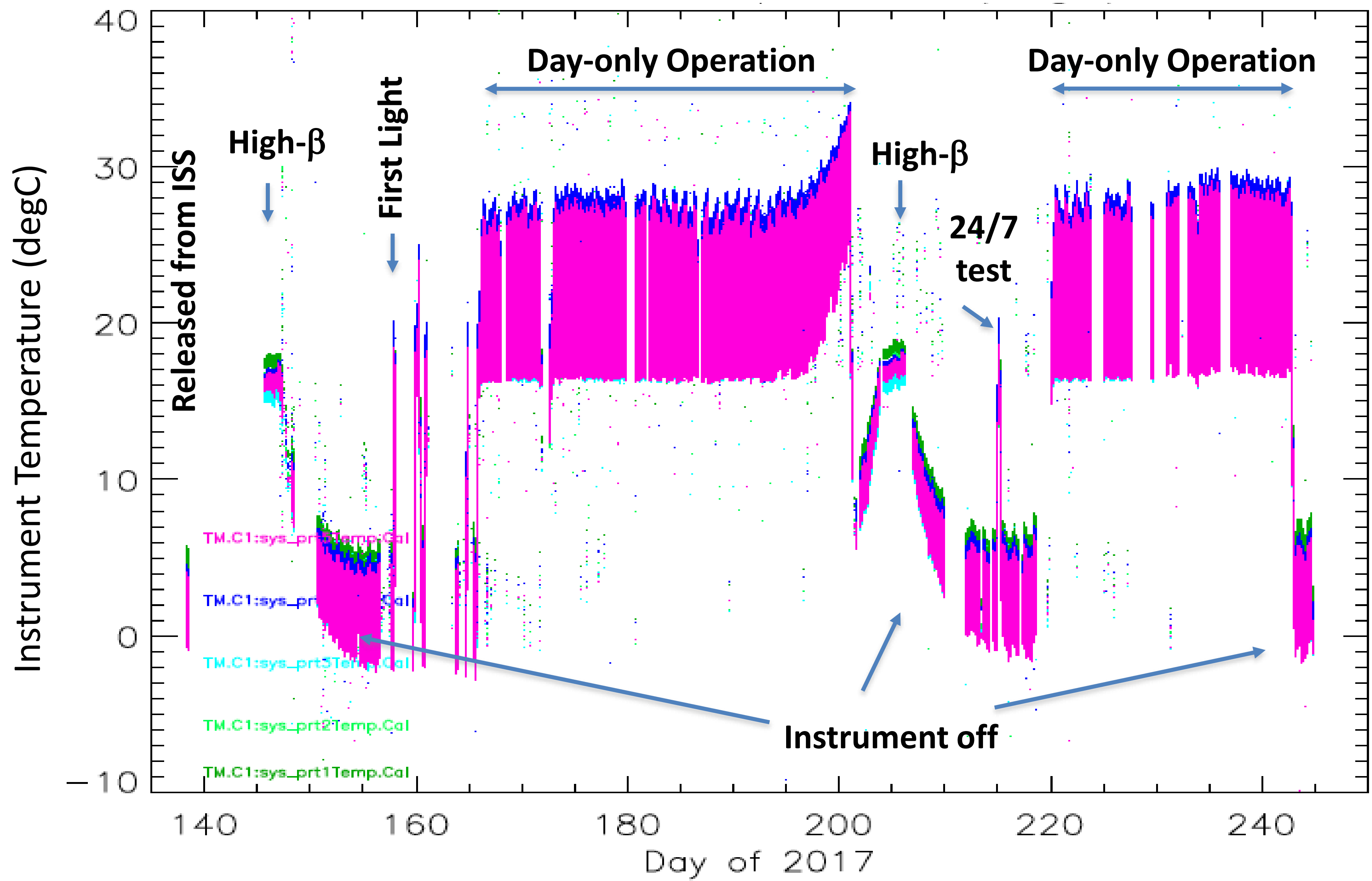
Mass: 1.0 kg
Volume: 1.3 U
Power: 5.6 W



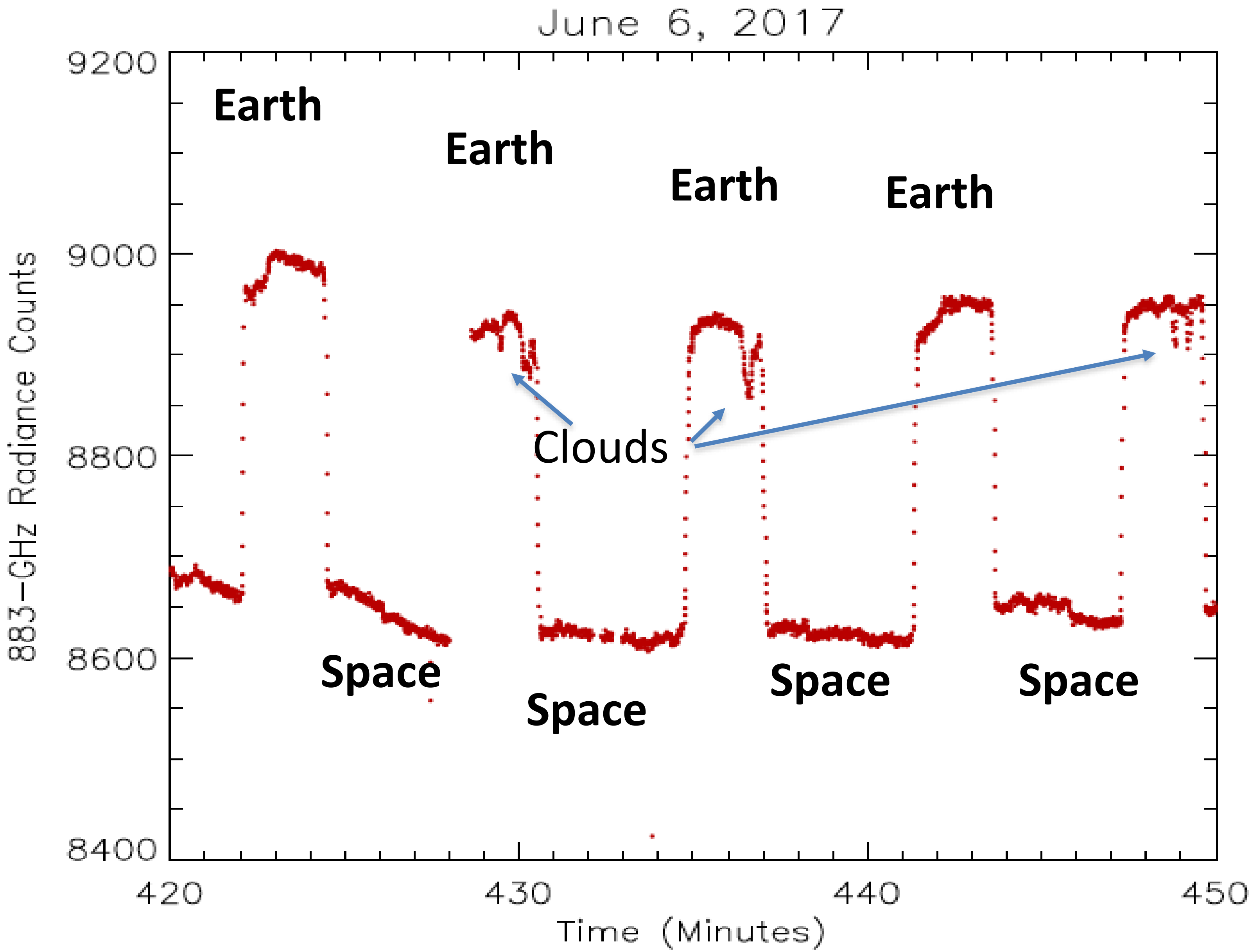
Motor Temperature



Instrument Temperature

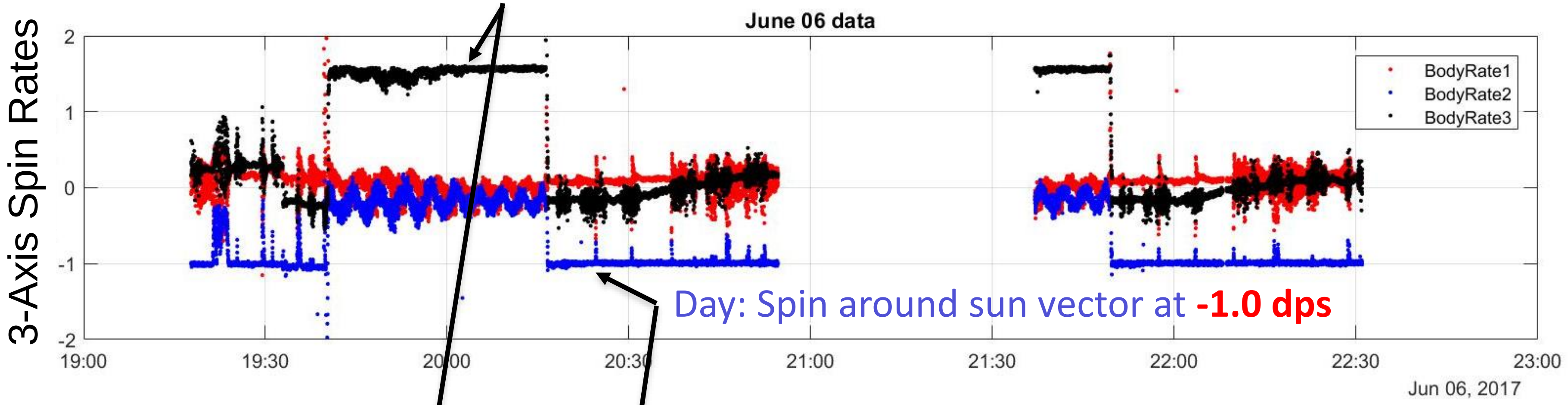


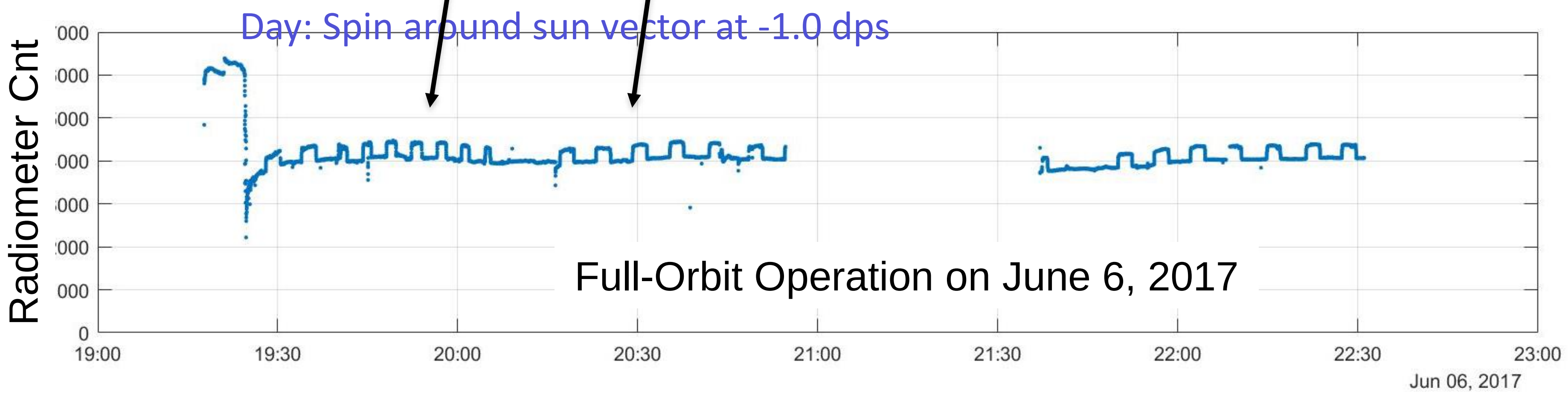
First Light from the 883-GHz Radiometer



First Light Operation: Spin Rates

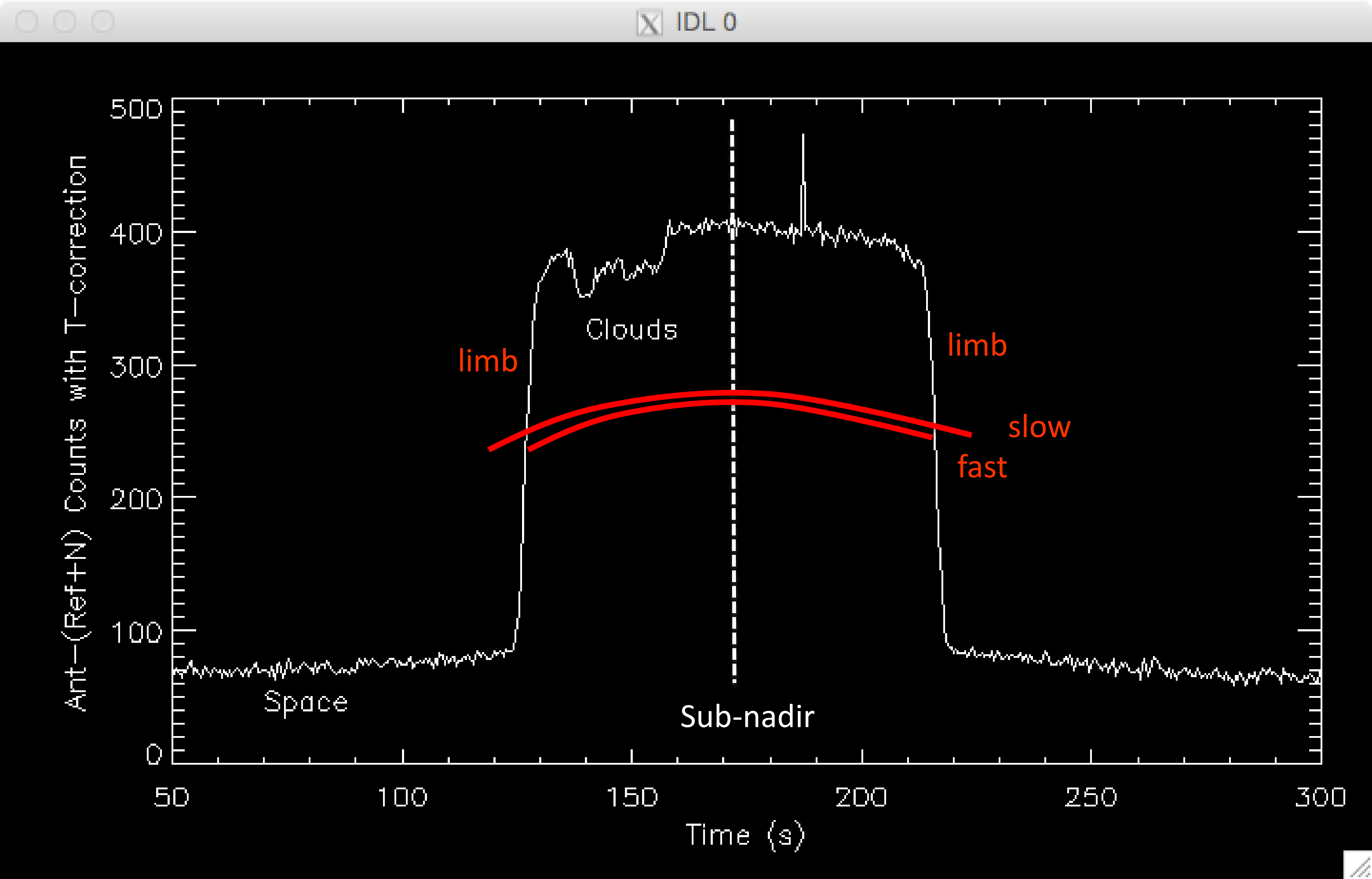
Night: Spin around geomagnetic field at **1.5 dps**



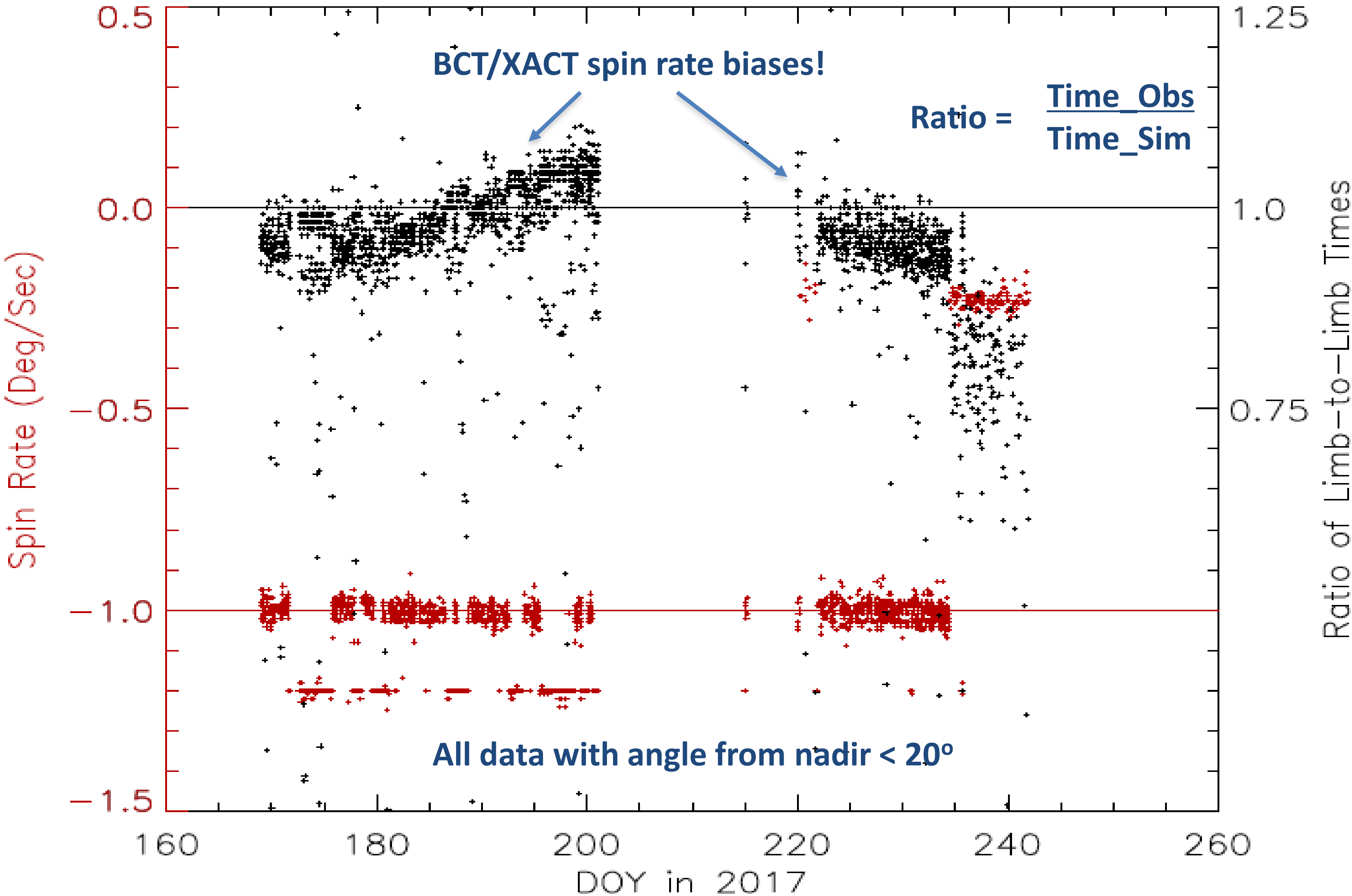


Courtesy of Jon Bensman

Pointing: Limb-to-Limb Time



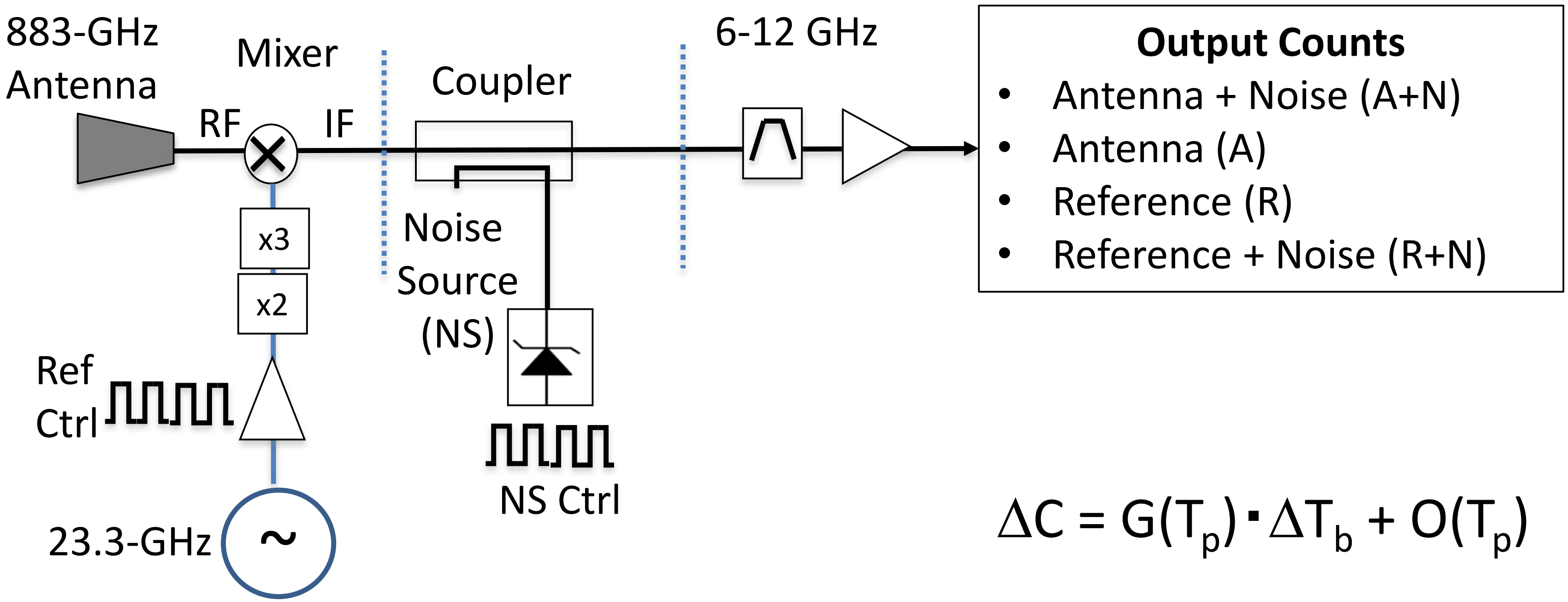
Spin Rate Errors



Radiometric Calibration and Cloud Detection with the 883-GHz Radiometer

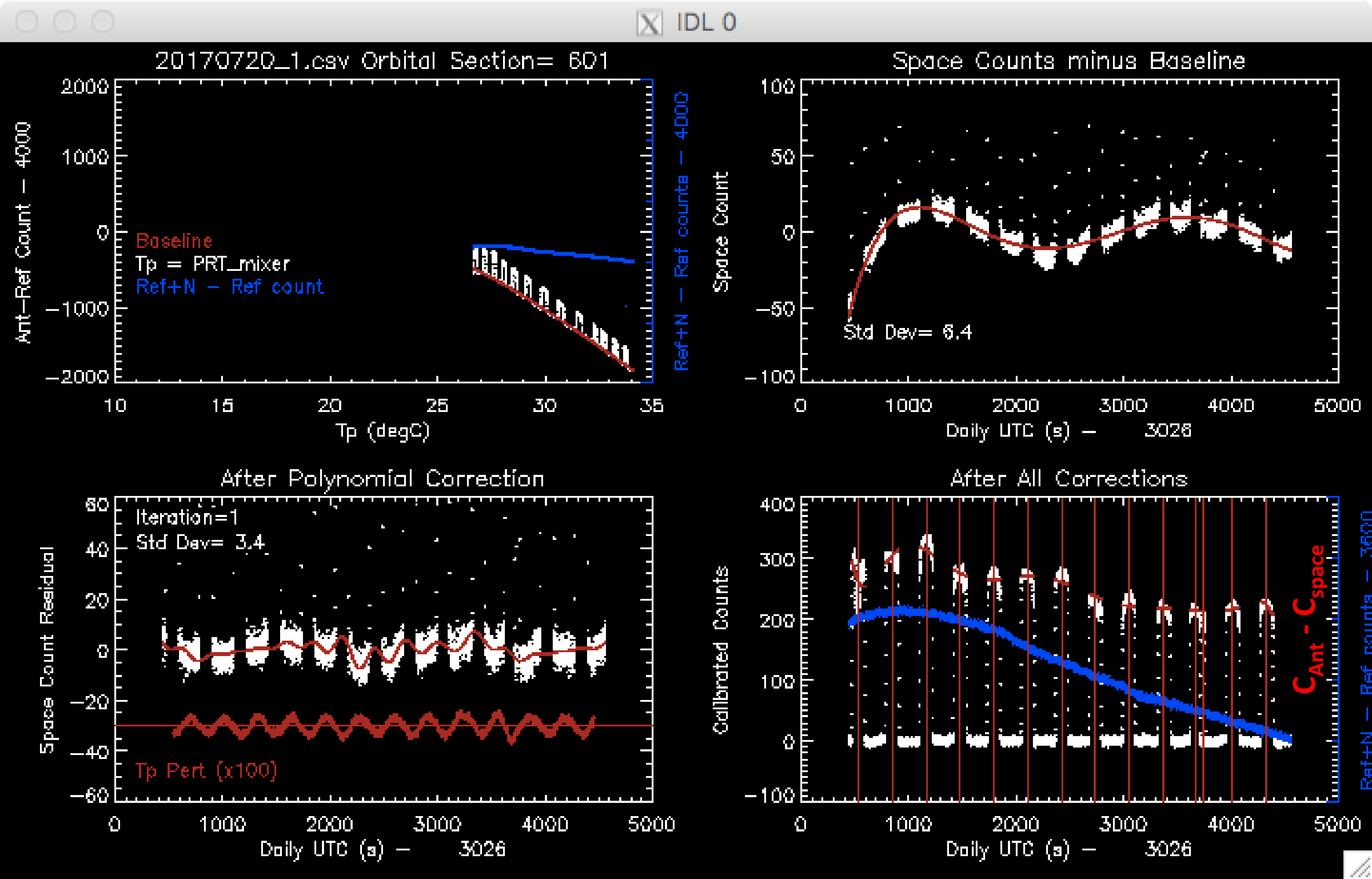
IceCube 883-GHz Radiometer

Gain model: $G(T_p)$



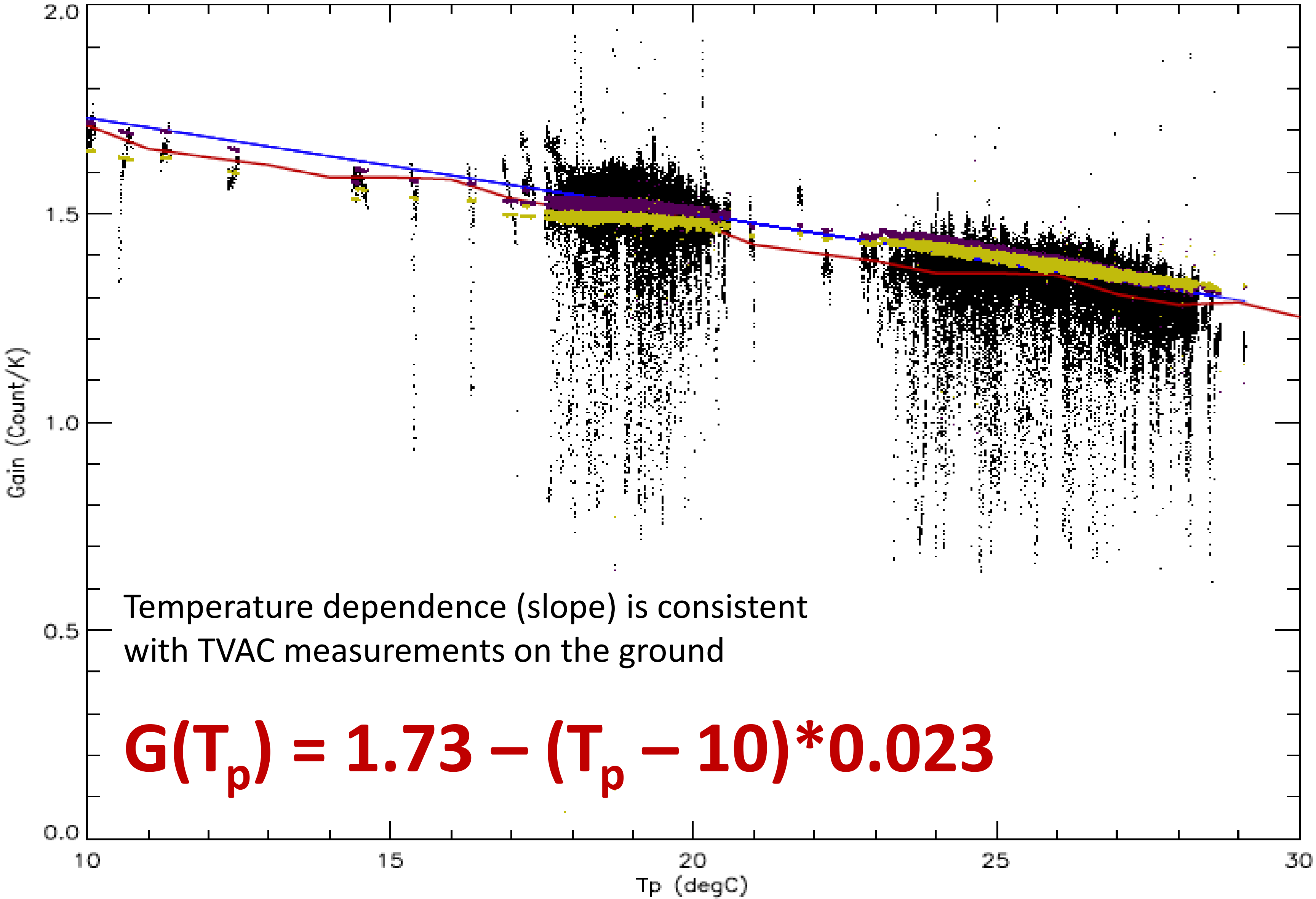
$$\Delta C = G(T_p) \cdot \Delta T_b + O(T_p)$$

Space Radiance Calibration



883-GHz Receiver Gain Model

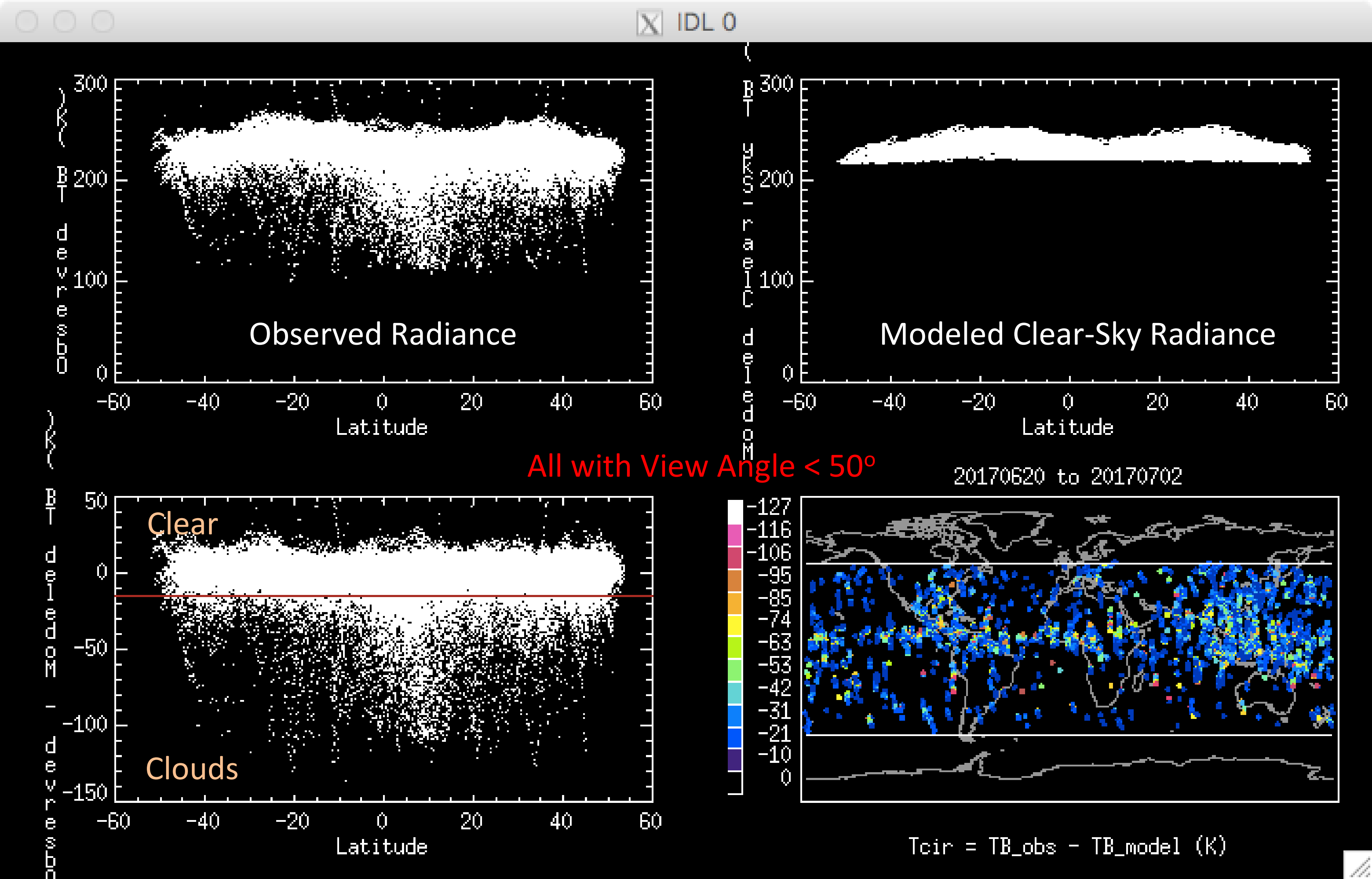
(A Function of Temperature Tp)



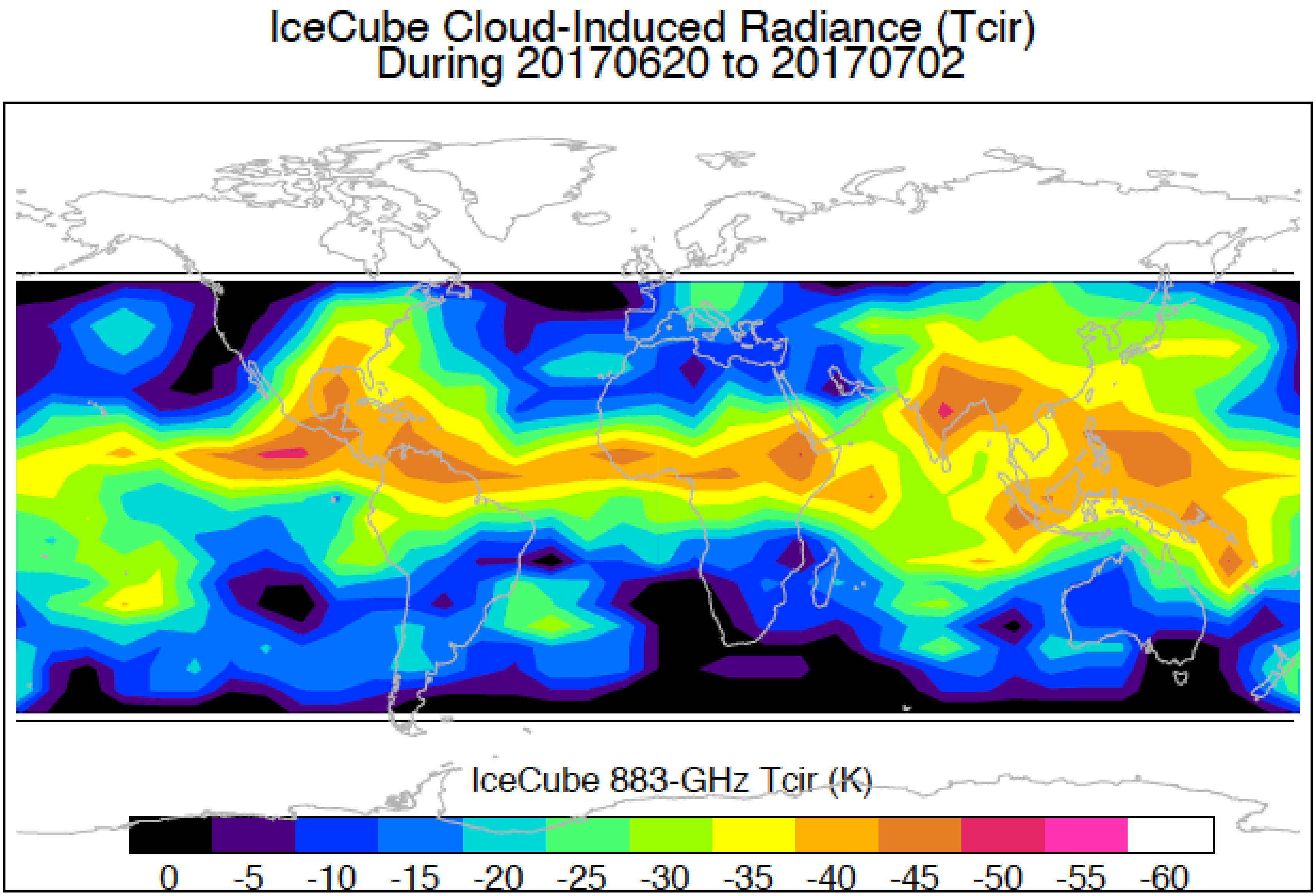
Temperature dependence (slope) is consistent with TVAC measurements on the ground

$$G(T_p) = 1.73 - (T_p - 10)*0.023$$

Cloud Detection



First 883-GHz Cloud Radiance Map



Summary

- IceCube is a pathfinder to use risky cubesat platforms for tech demo and future science constellation missions.
  - All ground tests suggested that it SHOULD WORK.
  - Fast (<3 years from TRL5) development and return on investment
- Cubesats can spin and deliver science! IceCube is challenging many advertised specs of BCT/XACT for a better product.
- In-flight thermal variability of IceCube is larger than expected.
  - Instrument is calibratable for cloud sciences.
  - More stable system is preferred and achievable.
- Calibration for future constellation missions:
  - Balance between flag-ship (fewer, complex, and expensive) and cubesat sensors (multiple, simple, and inexpensive)
  - Radiometric calibration transfer (i.e., accuracy) using radiative transfer models and simultaneous nadir overpass (SNO)

IceCube Team

Payload

Du Toit, Nelis	MEI
Ehsan, Negar	555
Fetter, Lula (Lu)	562
Horgan, Kevin	555
Hudson, Derek	555
Lucey, Jared	555
Lu, Daniel	555
Macmurphy, Shawn	562
Marlow, Steven	544
Pellerano, Armi	563
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Racette, Paul	555
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Wong, Mark (Englin)	564

Abresch, Brian	569
Azimi, Behnam	596
Choi, Mike	545
Coleman, Alexander	569
Cervantes, Ben	589
Corbin, Brian	569
Cote, Jerry	569/ASRC
Daisey, Ted	548
Davis, C. Ray	840/LJT
Duer, Con	569
Duran-Aviles, Carlos	564
Esper, Jaime	592
Flaherty, Brooks	569
Freeman, Jerry	569

CubeSat and Operation

Juan Rodriguez-Ruiz	545
Lewis, Christopher	569
Hart, Henry	569
Hudeck, John	548
Heatwole, Scott	598
Johnson, Tom	800
Mast, William	598
Parks, Timothy	840/LJT
Pollack, Eric	589
Purdy, Christopher	589
Simpson, Joel	598
Stancil, Robert K.	589
Reddersen, Kurt	ASRC

Resource Analysts: August, Marion (613/SSAI); Whetzel, Linda (610/InuTeq)

Virginia Diode Inc (VDI): Hesler, Jeff; Bryerton, Eric; Retzloff, Steven; Neff, Chuck

NanoRacks: Brown, Conor

Science/Algorithms: Aksoy, Mustafa (555/USRA); Gong, Jie (613/USRA); Liu, David (614/SSAI); Yang, Ping (TAMU);

Co-Op/Interns: Bain, Jessica; Bensman, Jonathan; Cooke, Caitlyn: Hudson, Margaret; Lafata, Brad; Stoker-Sprit, Eric;