Results from Three Years of Ka-band Propagation Characterization at Svalbard, Norway

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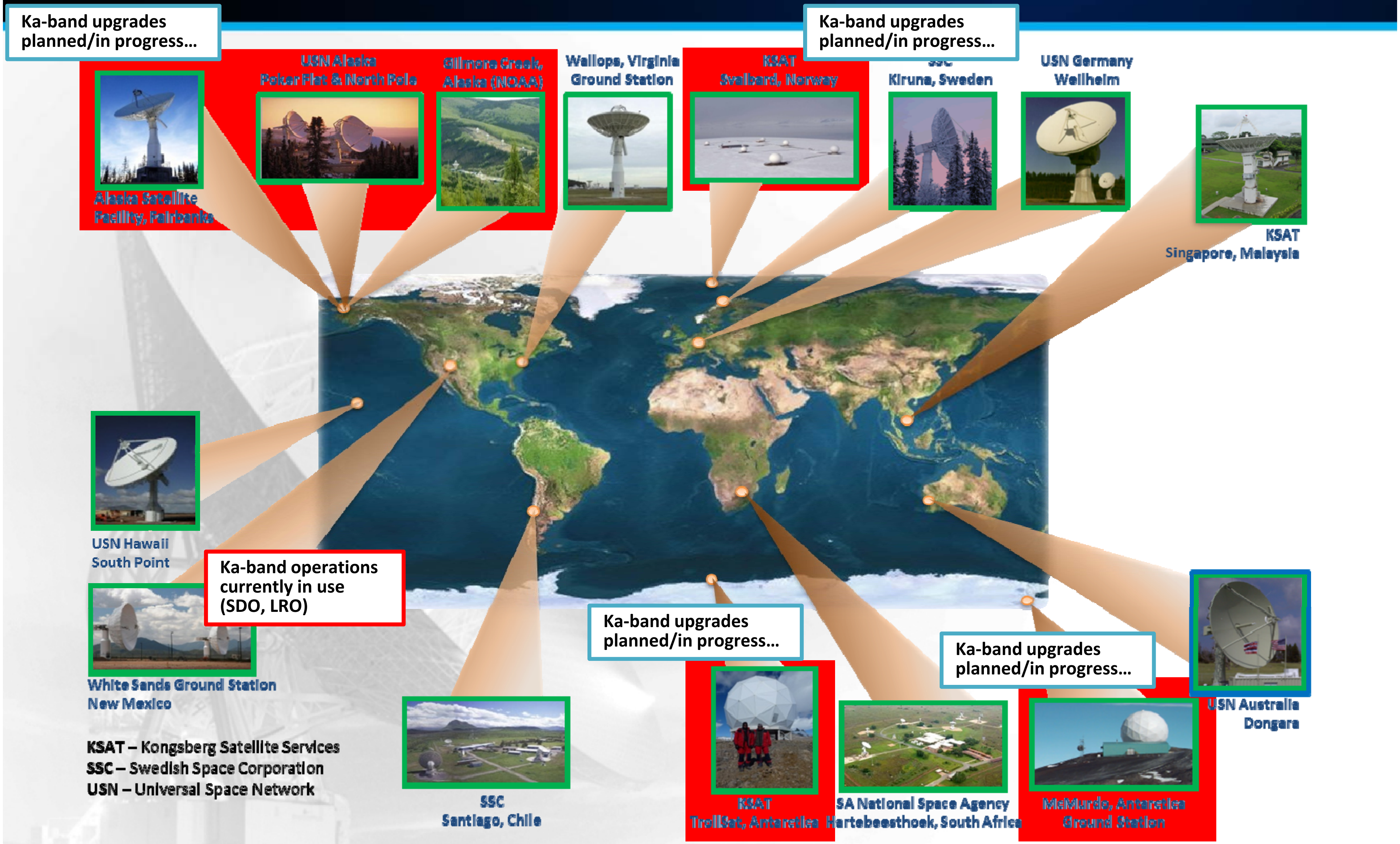
Outline

- Overview of LEO Ka-band Missions
- NASA Near Earth Network
- Svalbard
  - Site Description
  - Data Calibration
  - Measurement Results
  - Comparisons with ITU Model
- Application to JPSS-1/2 System Design
- Conclusions and Future Work

NASA's Near Earth Network (NEN)



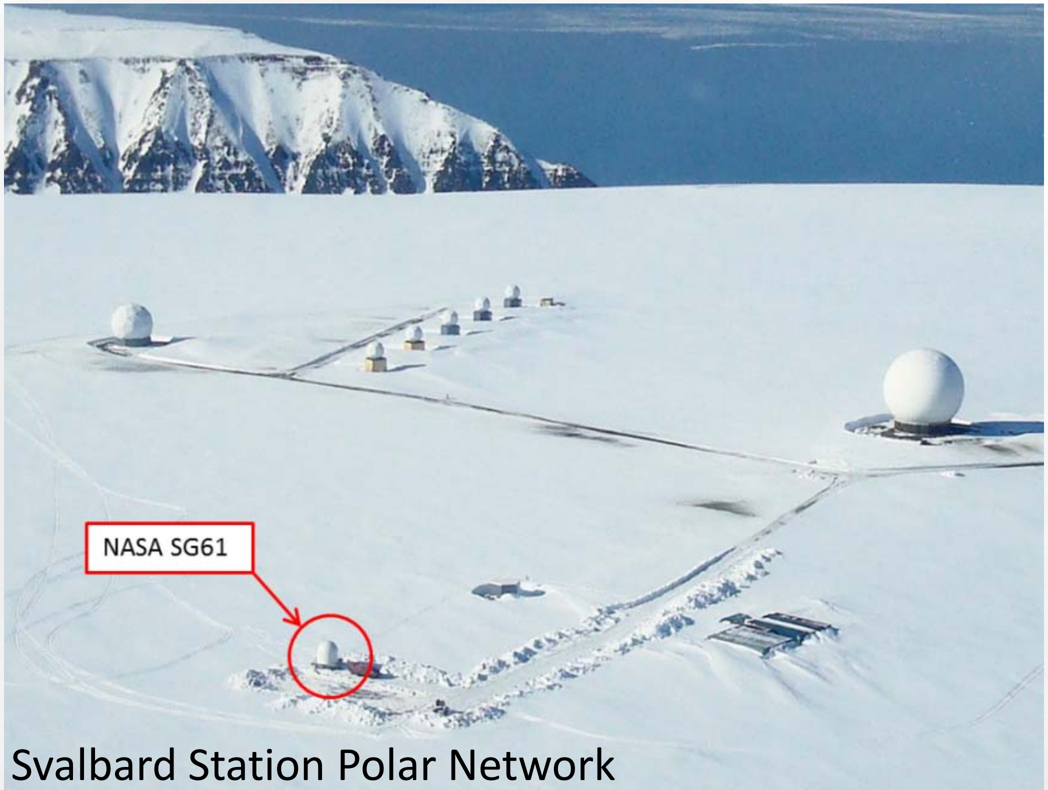
15 NASA and commercial-owned sites comprise the Near Earth Network

LEO Ka-band Missions

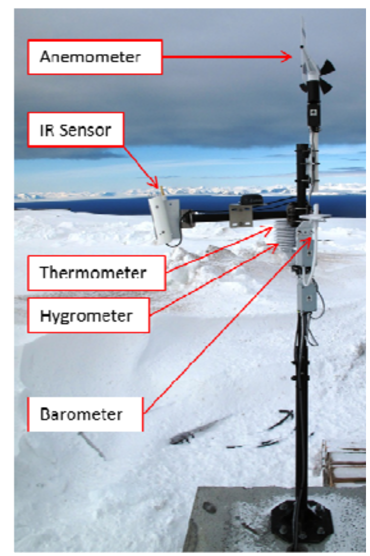
- Past/Current LEO Ka-band communications systems (SCaN Testbed, JEM, ALOS, Envisat) rely on space-to-space links
  - TDRSS (NASA)/Artemis (ESA)/DRTS (JAXA)
- The Interagency Operations Advisory Group (IOAG) has identified several upcoming LEO missions in the 2017-2020 timeframe with planned use of the direct-to-Earth Ka-band spectrum (26GHz) to polar networks
  - Up to ~10 Gbps data rates
  - NASA has pledged to transition current near Earth operations into the Ka-band, beginning with polar network sites (i.e., Svalbard, Fairbanks, McMurdo)

Orbit	Agency	Mission	Planned Launch	Link at 26 GHz
LEO	NOAA/NASA	Joint Polar Satellite System (JPSS)-1	2017	Transmit: space-to-ground (Svalbard, Norway; Fairbanks, AK; McMurdo, Troll) Transmit: space-to-space (secondary path)
	ESA/EUMETSAT	EPS-SG (2 satellite configuration with 3 MetOp SG satellite pairs)	2020, 2022	Transmit: space-to-ground (Svalbard, McMurdo)
	JAXA	Advanced Land Observation Satellite (ALOS)-2	2013	Transmit: space-to-space (DRTS)

Svalbard Site Description Overview



Svalbard Station Polar Network

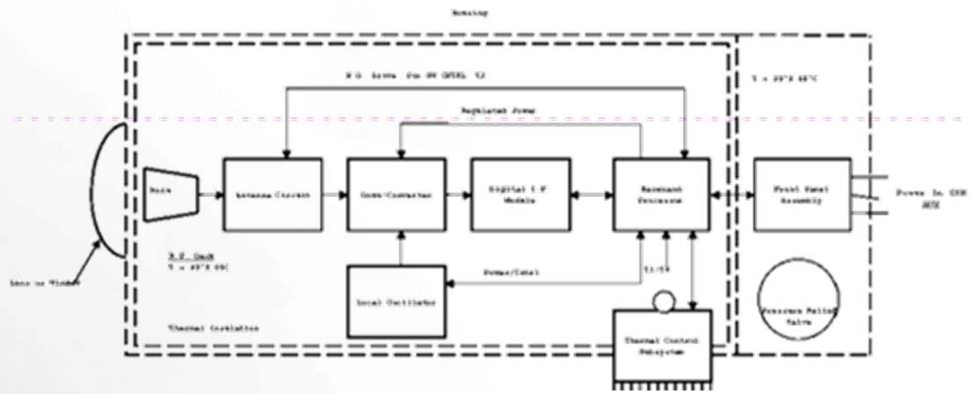


<u>Approach</u>

As the first Near Earth Network (NEN) site to be upgraded to operational Ka-band, NASA GRC was tasked with characterizing the propagation effects of Ka-band in a northern latitudes environment.

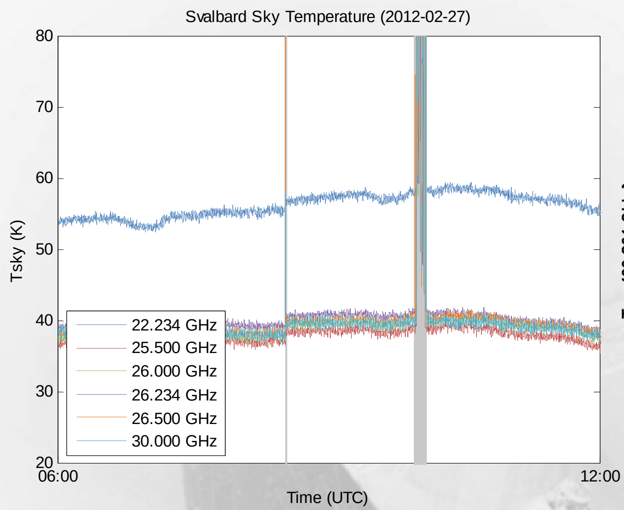
Measurements initiated in 2011 to measure passive radiometric attenuation in polar atmosphere to determine system planning requirements for Ka-band upgrades

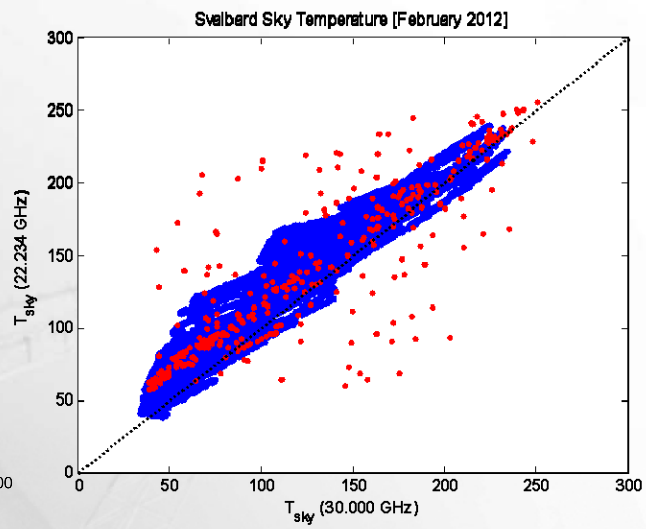
Svalbard Site Description
Radiometrics PR-2230

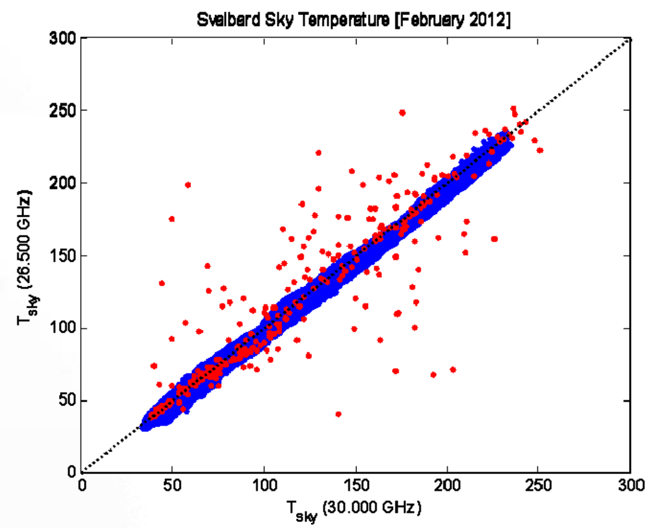


Parameter	Specification
Calibrated Brightness Temperature Accuracy	0.2 + 0.002*|Tref – Tsky| K
Long Term Stability	< 1.0 K/0.5yr (typ.)
Resolution (dependent on integration time)	0.1 to 1K
Integration Time (user selectable in 10 msec increments)	0.01 to 2.5 sec
Brightness Temperature Range	0 – 400K
Antenna System Optical Resolution and Side Lobes	3° / -24dB
Frequency Agile Tuning Range	22.0 – 30.0 GHz
Standard Calibrated Channels	21
Pre-detection Channel Bandwidth	300 MHz
Surface Sensor Accuracy Temperature (-50 to 50 °C) Relative Humidity (0-100%) Barometric Pressure (800 to 1060 mb) Infrared Thermometer (IRT)	 0.5 °C @ 25 °C 2% 0.3 mb (0.5 + 0.007*ΔT) °C
Calibration Systems Primary Standards Operational Standards	 TIP method Noise Diode + ambient Black Body Target

Data Calibration
Part 1: Bad Data Removal Procedure







- Occasionally, system instabilities, operator intervention, or physical issues (i.e., ice formation on radiometer antenna) will introduce erroneous data and requires removal
  - An automatic approach identifies and flags rms brightness temperature thresholds which exceed 10 K over a 1-min block period and removes uncorrelated channel events
  - A manual approach to validate automatic removal and visually inspect and isolate anomalous data is performed on daily files

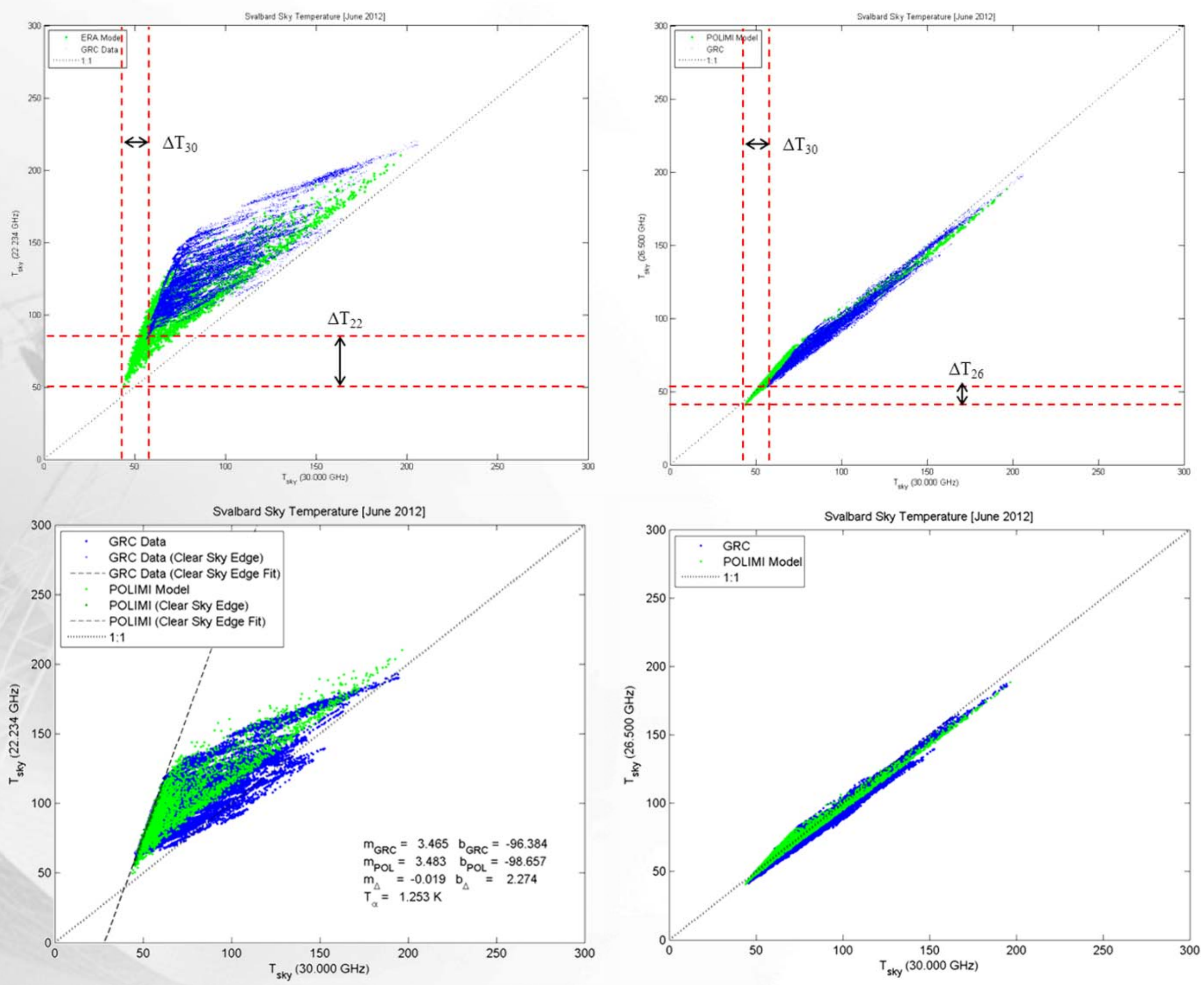
Data Calibration
Part 2: Ground Emission Correction Procedure

- Scatterplot comparison between T_B derived from ERA Interim profiles and radiometer measurements indicate common clear sky slope, but DC bias on channels.
- Bias identified as ground emission

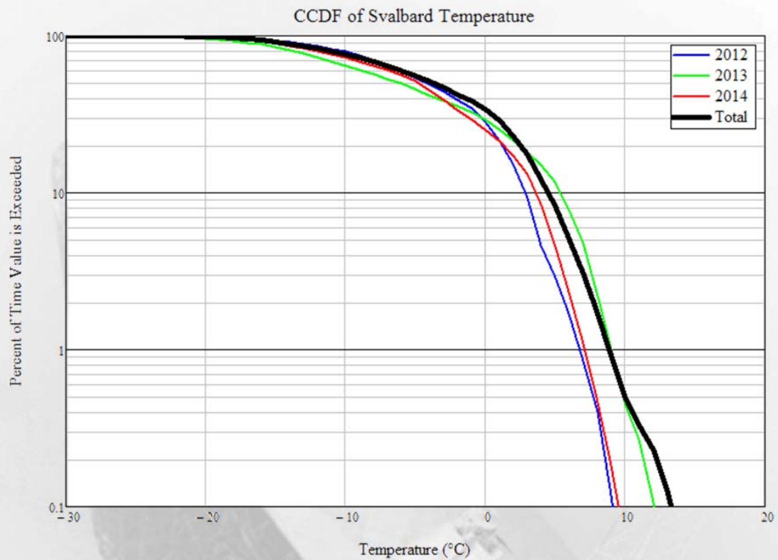
$$\Delta T = \frac{(1-H)T_{GND}}{H}$$

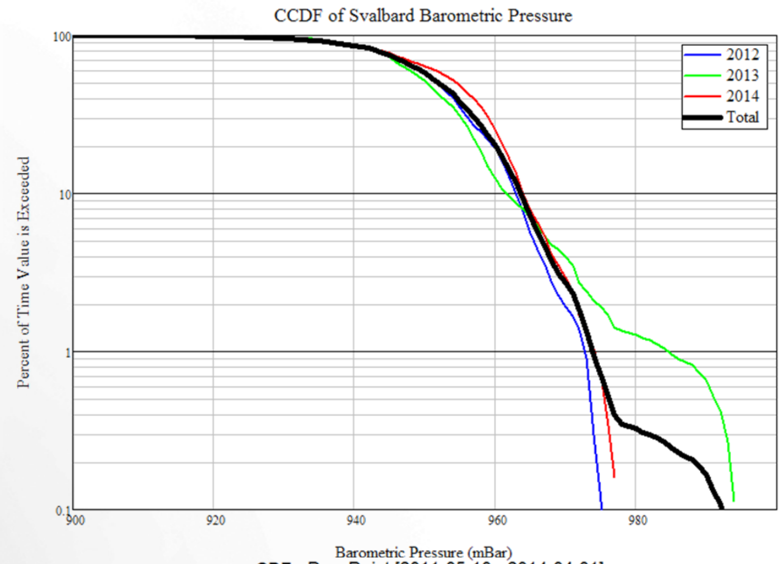
$$H_{22}=0.94$$
$$H_{26}=0.96$$
$$H_{30}=0.96$$

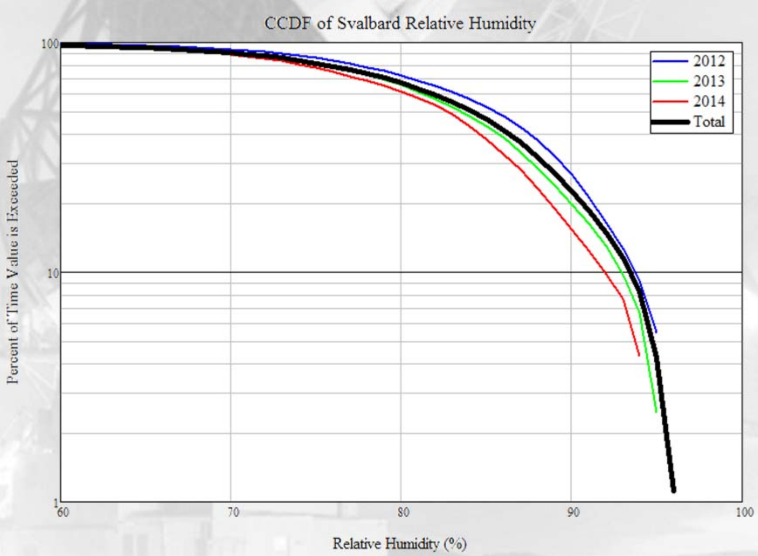
- Correction for ground emission contribution results in excellent agreement between radiometer measurement and profile-based model.

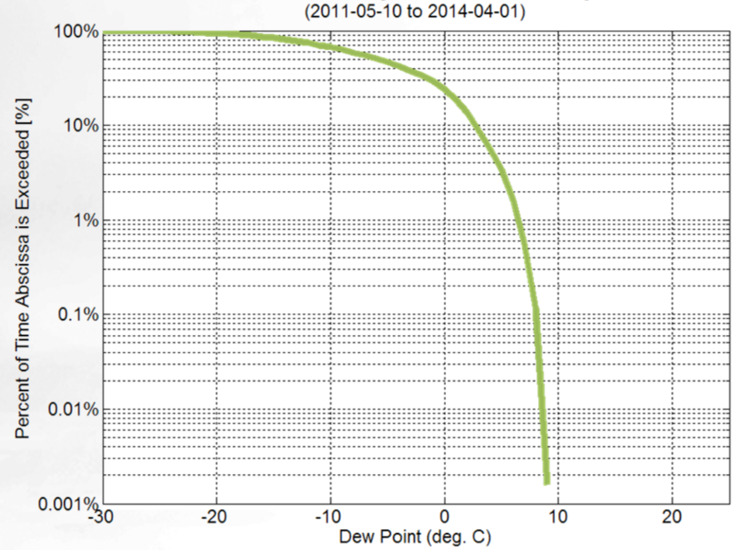


Statistical Results - Meteorology

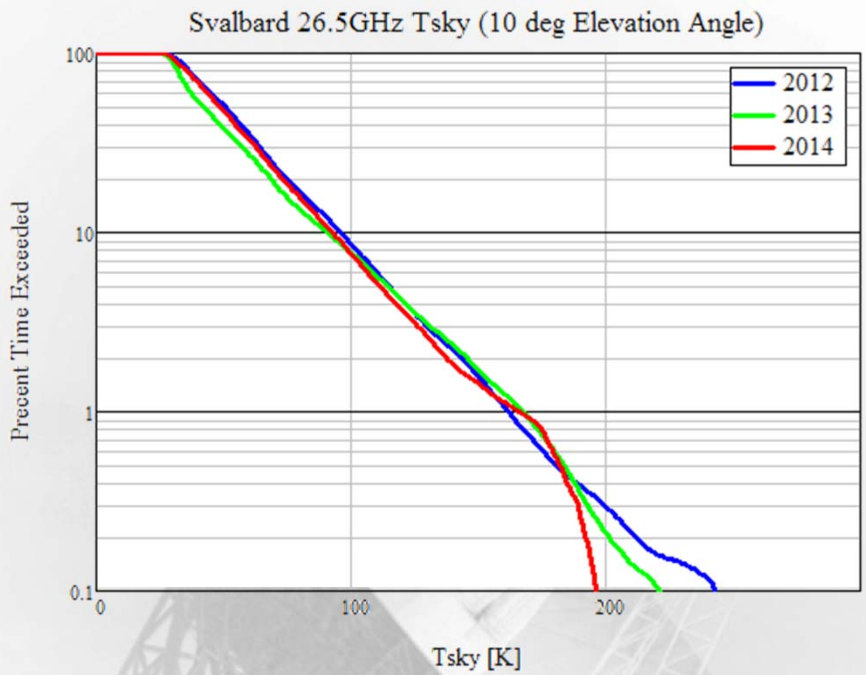


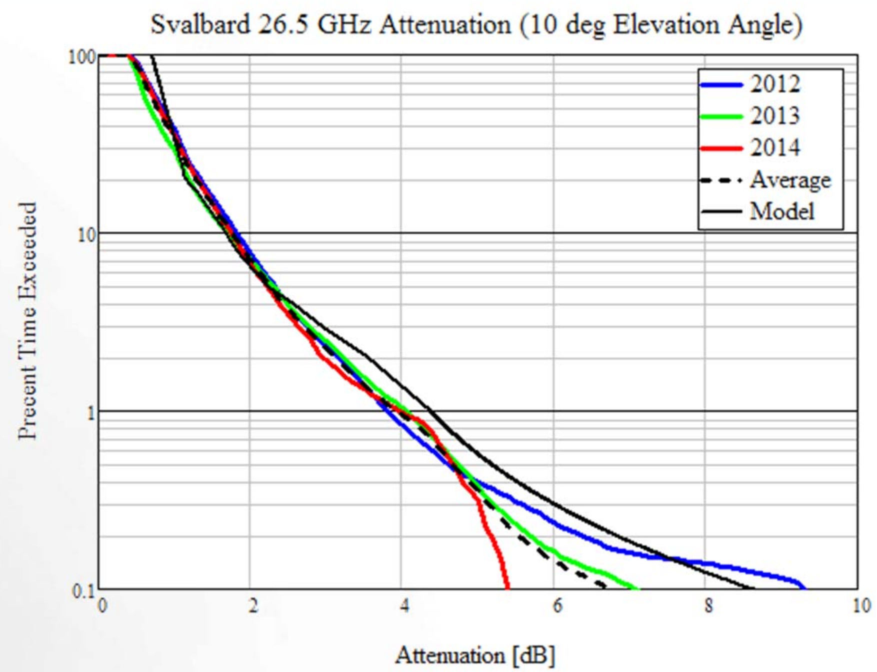






Statistical Results



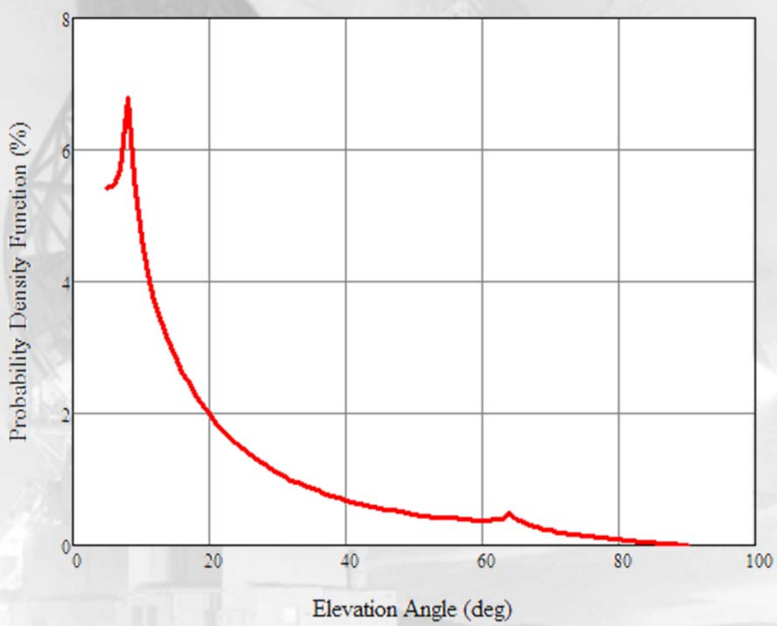


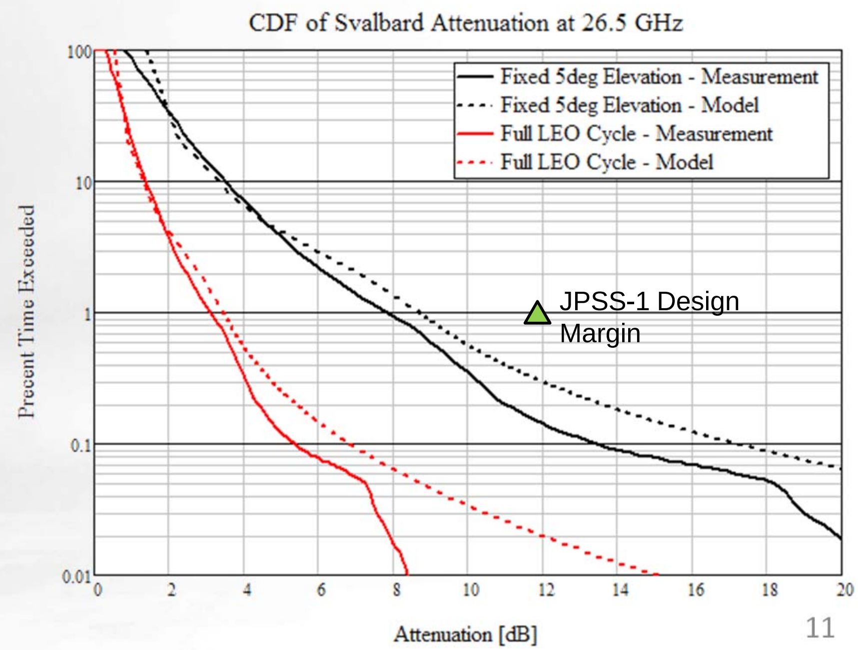
Model vs. Measurement @ 10 degree elevation		95 % Availability Attenuation	97 % Availability Attenuation	99 % Availability Attenuation
Svalbard	Measured (Actual)	2.5 dB	2.9 dB	4.1 dB
	Model 2010	2.3 dB	2.9 dB	4.3 dB
	Model 2013	3.1 dB	3.9 dB	5.5 dB
Difference between 2010 model and measured data w.r.t the measurements		8.0 %	0.0 %	4.9 %
Difference between 2013 model and measured data w.r.t the measurements		24.0 %	34.5 %	34.1 %
Difference in between models w.r.t 2010 model		34.8 %	34.5 %	27.9 %

- Model 2010 fits empirical data with an error of less than 10%
- Model 2013 is around 30 % apart from the empirical data
- Discrepancy related to the latest updates of the ITU maps
- Needs to be understood (which changes and in which way they influence the results).

Application to JPSS-1 Mission

- JPSS-1 link budget designed for 5° elevation angle at 99% availability for polar network operations (~12 dB margin for atmospheric propagation + 3 dB excess margin)
- Measurements at the Fairbanks, AK, site and the Svalbard site indicate that system was overdesigned by ~4 dB for worst case conditions (5° acquisition availability) and >7 dB for best case conditions (taking into account LEO orbit)





Concluding Remarks

- ITU attenuation availability model predictions at Svalbard site do not consistently agree with measured data
  - *2010 maps show good agreement with radiometer measurements (<10%), but updated 2013 maps show increased discrepancy (>30%)*
- Svalbard propagation campaign results indicate that the current JPSS-1 design margin for atmospheric attenuation is overdesigned by as much as 7 dB. Presently working with NASA/NOAA JPSS team to modify requirements for follow-on JPSS-2 mission to reduce design constraints
- Will continue to take propagation data at the Svalbard site for a minimum 2 more years…

Follow-on Work

- Validation of scintillation models at high latitudes (polar) sites has not been effectively performed by this measurement campaign
- Presently working with NASA to expand characterization activities to other NASA polar sites (i.e., Fairbanks, McMurdo Station) to ensure Ka-band availabilities for polar NEN network are realizable

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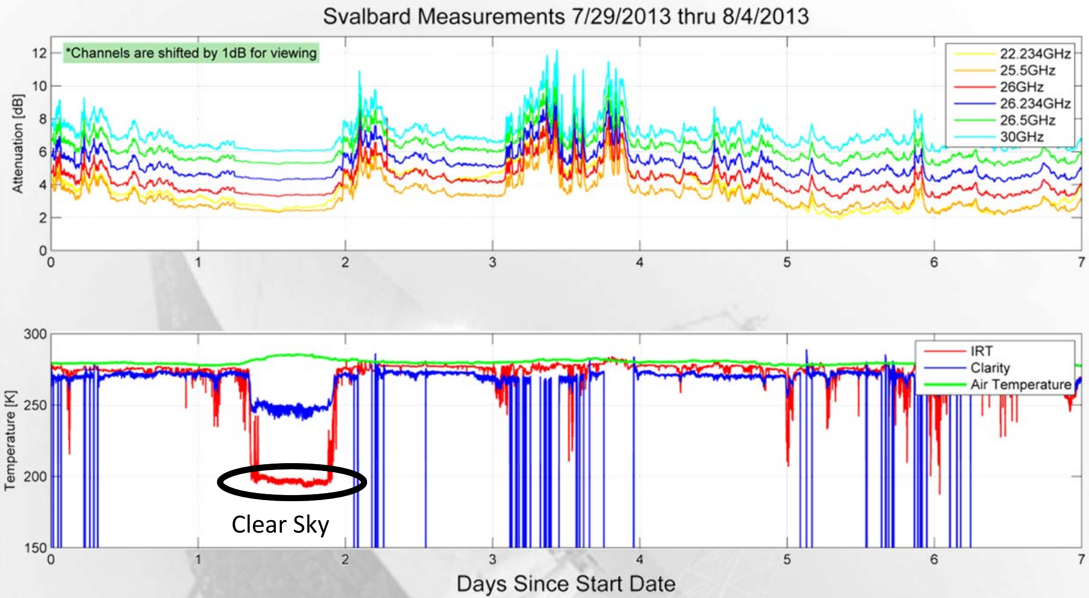
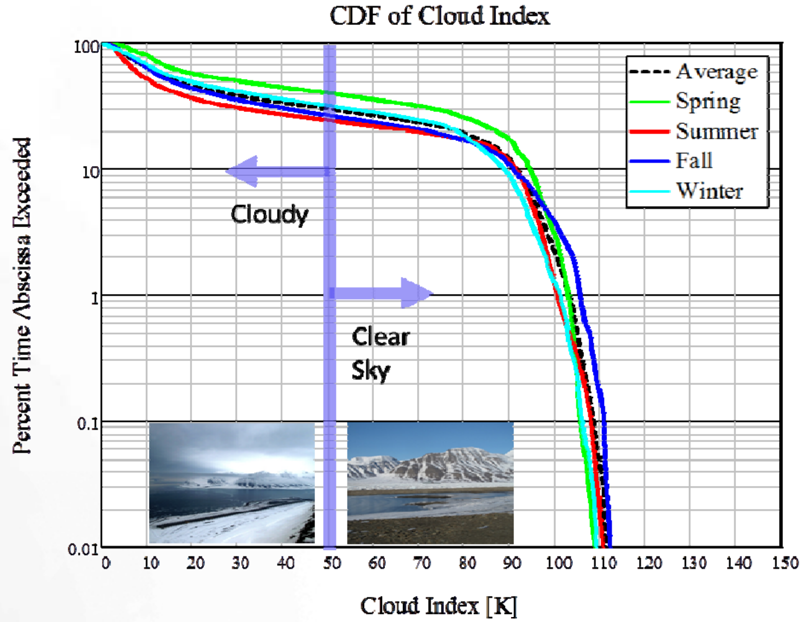
THANK YOU!

BACKUP CHARTS

Site Characterization: Ka-band in Polar Atmosphere
Svalbard



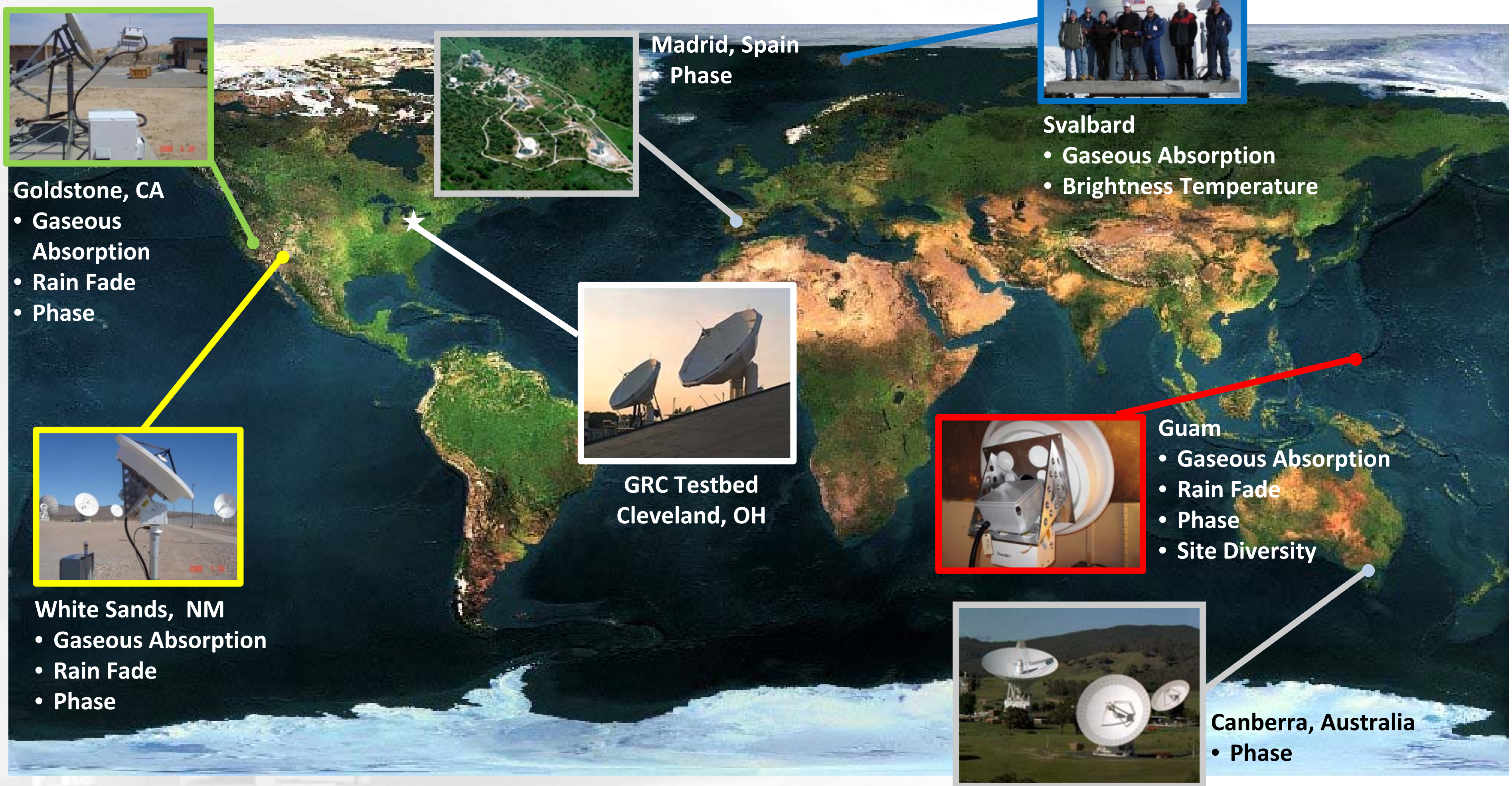


$$CI = T_{surface} - T_{IR}$$

- Clouds are the dominant attenuation mechanism at the Svalbard site, as cloud cover accounts for attenuation approximately 70% of the time.
  - Fall/Summer show slightly less cloud cover vs. Spring/Winter season
- Distinction between type of cloud difficult to determine from IR measurements

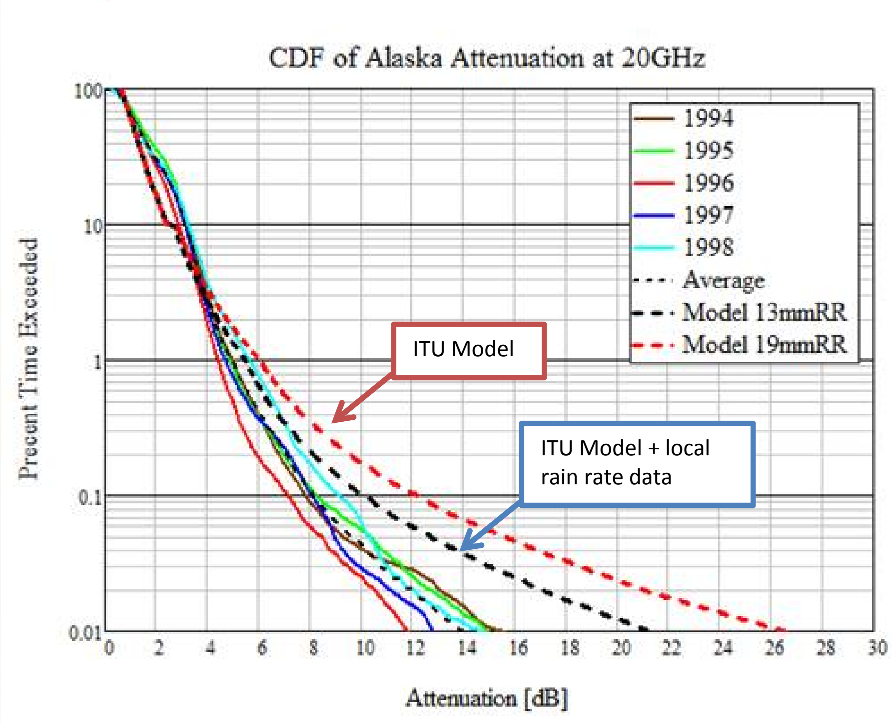
Current NASA Network Characterization Sites

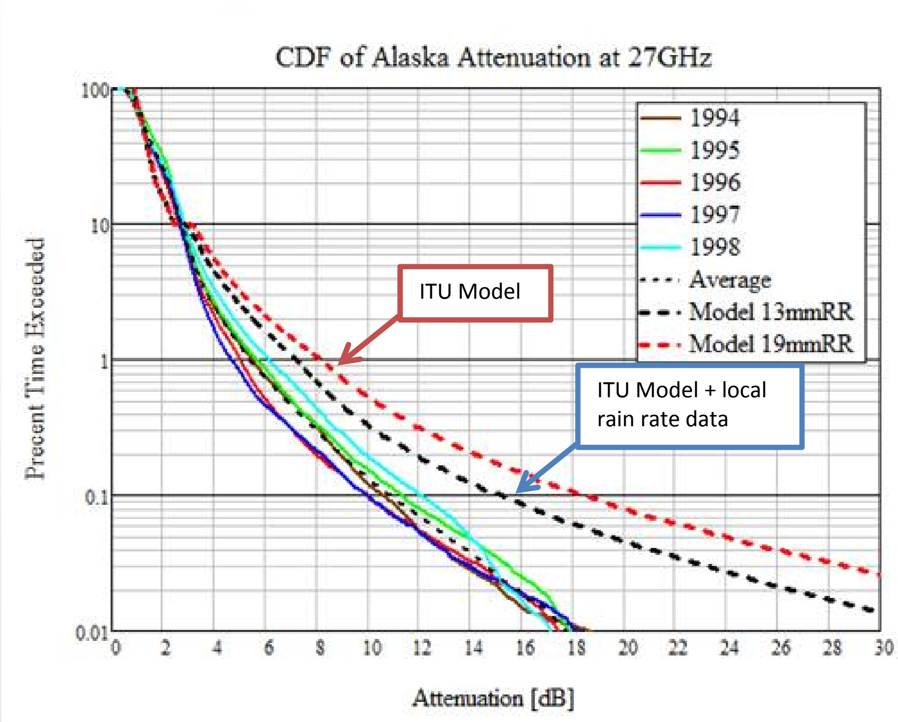
In the post-ACTS era, NASA propagation activities have primarily focused on site characterization of NASA operational networks throughout the world.



Site Characterization: Ka-band in Polar Atmosphere

Fairbanks, AK





Fairbanks Station Polar Network

During ACTS Experiment, data was collected at Fairbanks, AK from 1994-1998.

Measurement Parameters
Frequencies: 20/27.5 GHz
Elevation Angle: 8 deg

Model discrepancy between margin requirements between measured data and models. Model prediction improves with addition of local rain rate information, but still overpredicts attenuation effects.