Geostationary Passive Microwave Observation System Simulation Experiments for Hydrometric Tracking

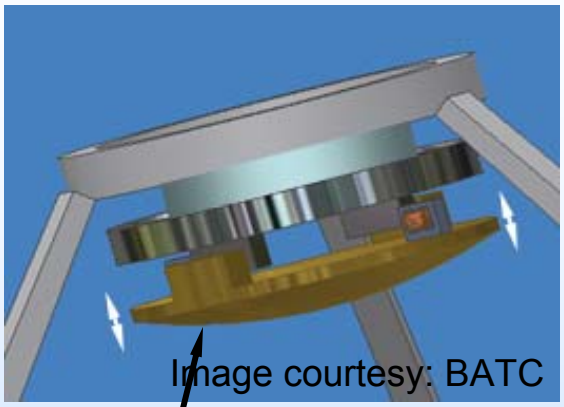
Albin J. Gasiewski[1]
Bob L. Weber[1]
Alexander G. Voronovich[2]
Jian-Wen Bao[2]

Presented by

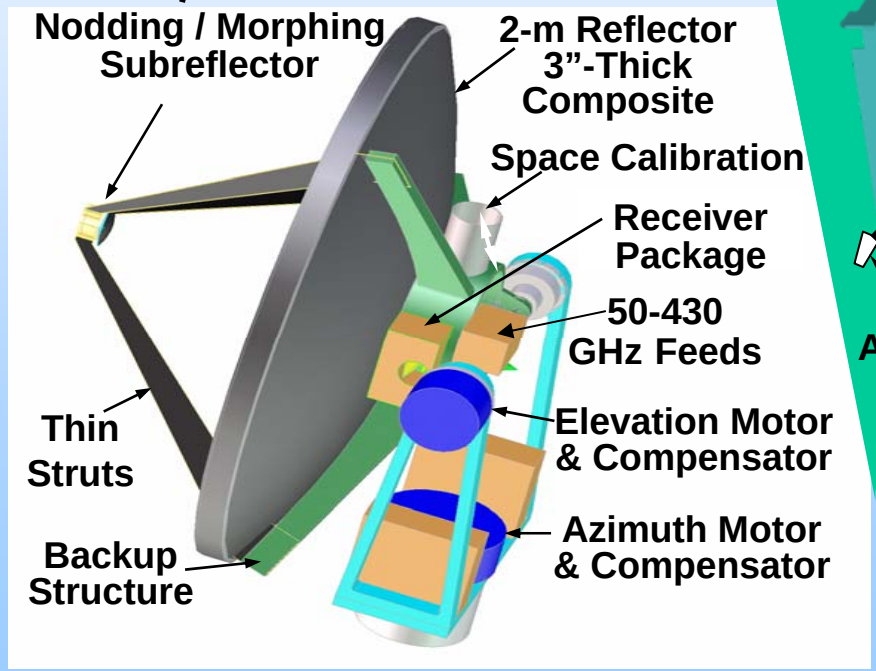
Ed R. Westwater[1]

1) University of Colorado, NOAA-CU Center for Environmental Technology and Dept of Electrical and Computer Eng, Boulder, CO
2) NOAA Earth Science Research Laboratory, Boulder, Colorado

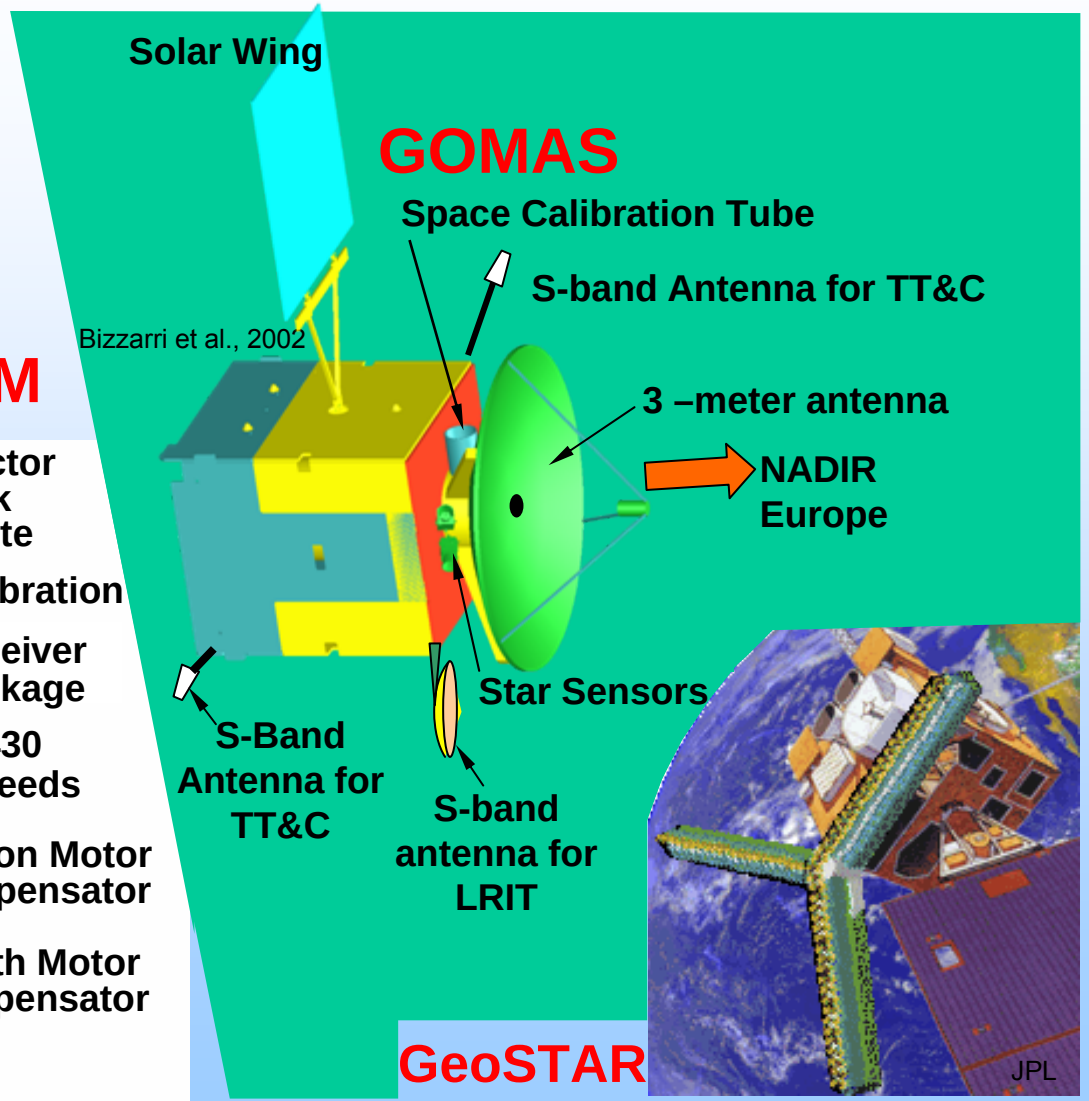
GeoMicrowave System Concepts



GEM

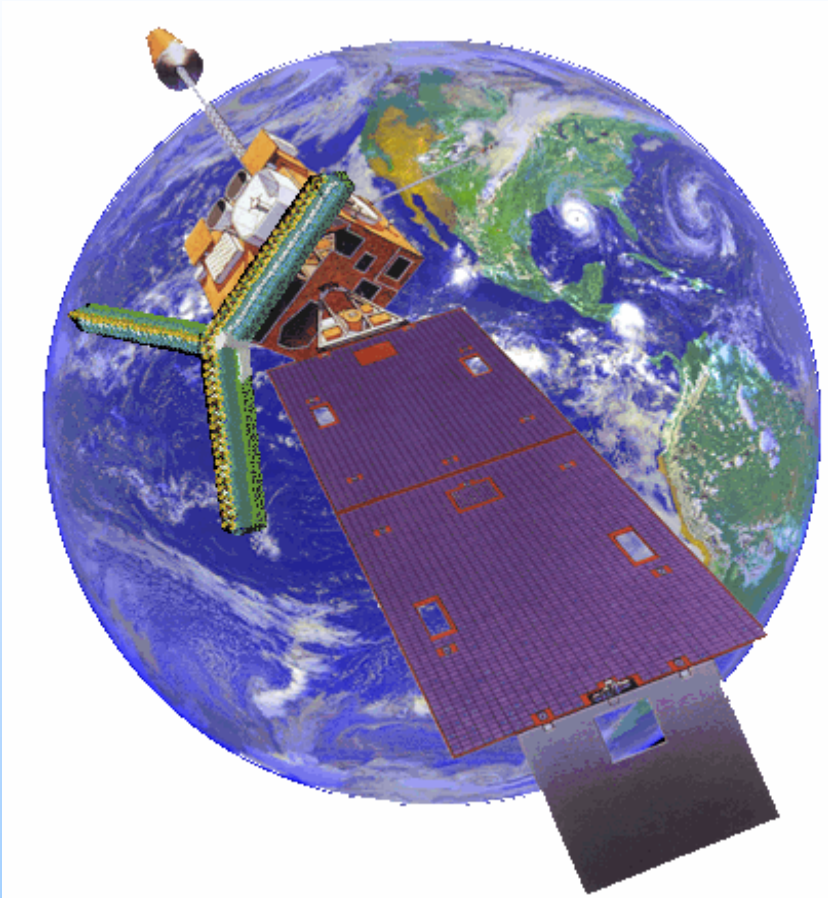


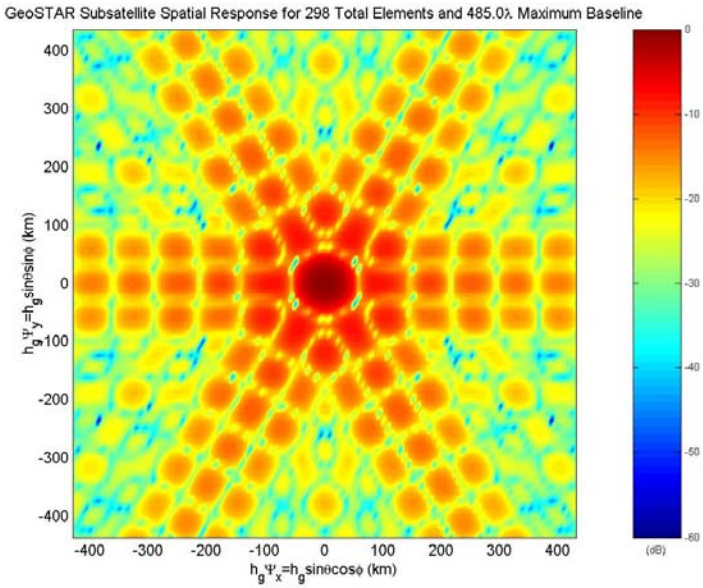
GOMAS



GeoSTAR Concept

2-D Geostationary Sounder/Imager





GeoSTAR spatial response pattern for 298 elements with 2.8lspacing

- **~50 km spatial resolution**
- **Full disk image every one hour**
- **No moving parts**
- **~2.5m maximum baseline**
- **NASA/JPL concept**

Y-Array of ~300-600 receiver elements and tens of thousands of one-bit correlators in each of three bands: 50-56, 89, and 183 GHz

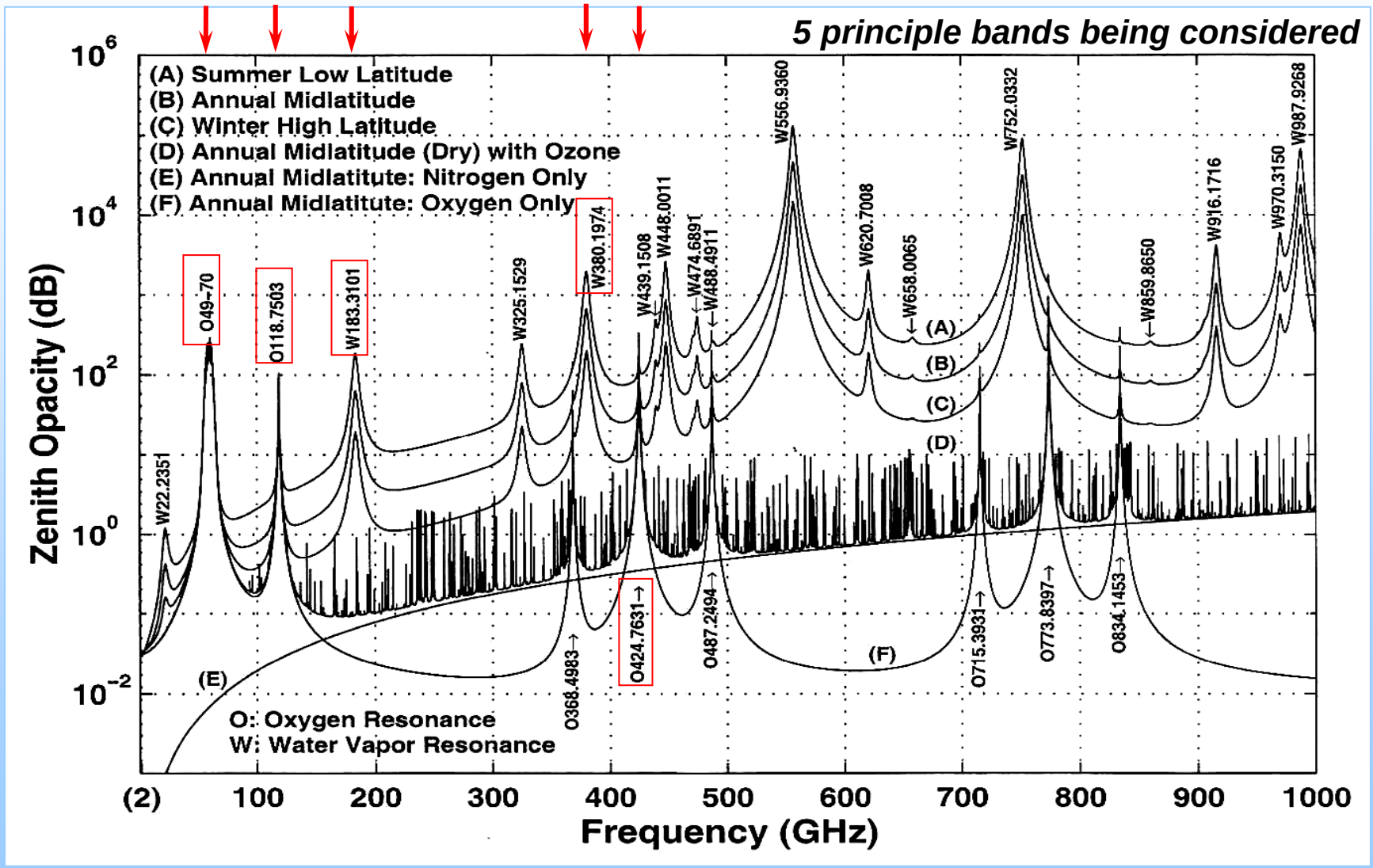
GeoMicrowave Pathway Study

- **Goal:** Provide an independent NOAA-led assessment of GEM and GeoSTAR systems based on NOAA operational forecasting requirements

- **Basis:** OSSEs using optimal precipitation and sounding retrieval and radiance assimilation techniques

- **Strategy:** Leads necessarily to concept of hydrometric tracking ("precipitation locking") introduced by Gasiewski at ITSC 13 in St. Adele, Quebec, Canada.

Geo-Microwave Spectral Selection



GeoMicrowave Pathway Study Issues

GEM/GOMAS

- Impact of reduced penetrability of 340/380 and 424 GHz channels on temperature and moisture soundings and precipitation retrievals
- Momentum transfer to the host platform, and how much can be compensated by the GEM/GOMAS drive mechanism
- Resolution improvement obtainable by beam deconvolution using GEM/GOMAS
- Reliability of GEM/GOMAS reciprocating scanning mechanism and comparison of risk with that of previous mechanically-scanned spaceborne sensors
- Impact of regional (vs full disk) imaging/sounding capability at best temporal resolution

GeoSTAR

- Required number of receiver elements, bands, channels, cost, and associated power requirements for NOAA applications
- Impact of limited channel bandwidth, observation time, and photon capture area on the accuracy of soundings and precipitation retrievals
- Impact of lower main beam efficiency of a synthetic versus filled aperture system on spatial resolution and sounding capability
- Oversampling and beam deconvolution capability, actual resolution using optimal apodizing function
- Impact of aliased off-disk sources (e.g., sun and moon) on temperature and humidity soundings
- Impact of correlator or receiver dropouts on sounding and imaging capabilities
- Impact of calibration errors for the single central (calibrated) element on soundings across the entire disk
- Use of LEO measurements from, e.g., ATMS or CMIS to cross-calibrate GeoSTAR
- Information lost by not using GEM/GOMAS channels at frequencies above 183 GHz

NWP Hurricane Example

- **Hurricane Bonnie, August 26, 1998, 0000-2430 UTC**
- **24-Hr simulation, 6-km innermost nested grid, 15-minute archived frames**
- **MM5/MRT Reisner 5-phase simulations, statistically validated***
- **DOTLRTv1.0b Fast DO Radiative Jacobian with 60 vertical levels****

*** Skofronik-Jackson, G.M., A.J. Gasiewski, and J.R. Wang, "The Influence of Microphysical Parameterizations on Microwave Brightness Temperatures," *IEEE Trans. Geosci. Remote Sensing*, vol. 40, No. 1, pp. 187-196, February 2002.**

**** Voronovich, A.G., A.J. Gasiewski, and B.L. Weber, "A Fast Multistream Scattering-Based Jacobian for Microwave Radiance Assimilation," *IEEE Trans. Geosci. Remote Sensing*, vol. 42, no. 8, pp. 1749-1761, August 2004.**

GOMAS/GEM Sensitivity & Scan Modes
- 2m Diameter Aperture -

- **Regional (1000 x 1000 km²) : ~15 minutes**

Band (GHz)	3-dB IFOV (km, SSP)	Deconvolved Resolution (km, SSP)	ΔT_{RMS} (K)	ΔT_{RMS} Required (K,SNR=100)	Probing Height (km)
50-56	138.6	~104	0.04-0.07	0.1-0.6	Surf
118.705	60.2	~45	0.03-0.6	0.1-0.6	Surf
183.310	41.9	~31	0.04-0.15	0.3-0.6	Surf
380.153	20.5	~16	0.2-2.1 *	0.3-0.5	~2.5
424.763	16.4	~12	0.5-5.3 *	0.4-0.6	~4

Assumptions:

- Midlatitude (30°-60° annual averaged atmosphere)
- Spatial sampling at native Nyquist sampled resolution for each specific band.

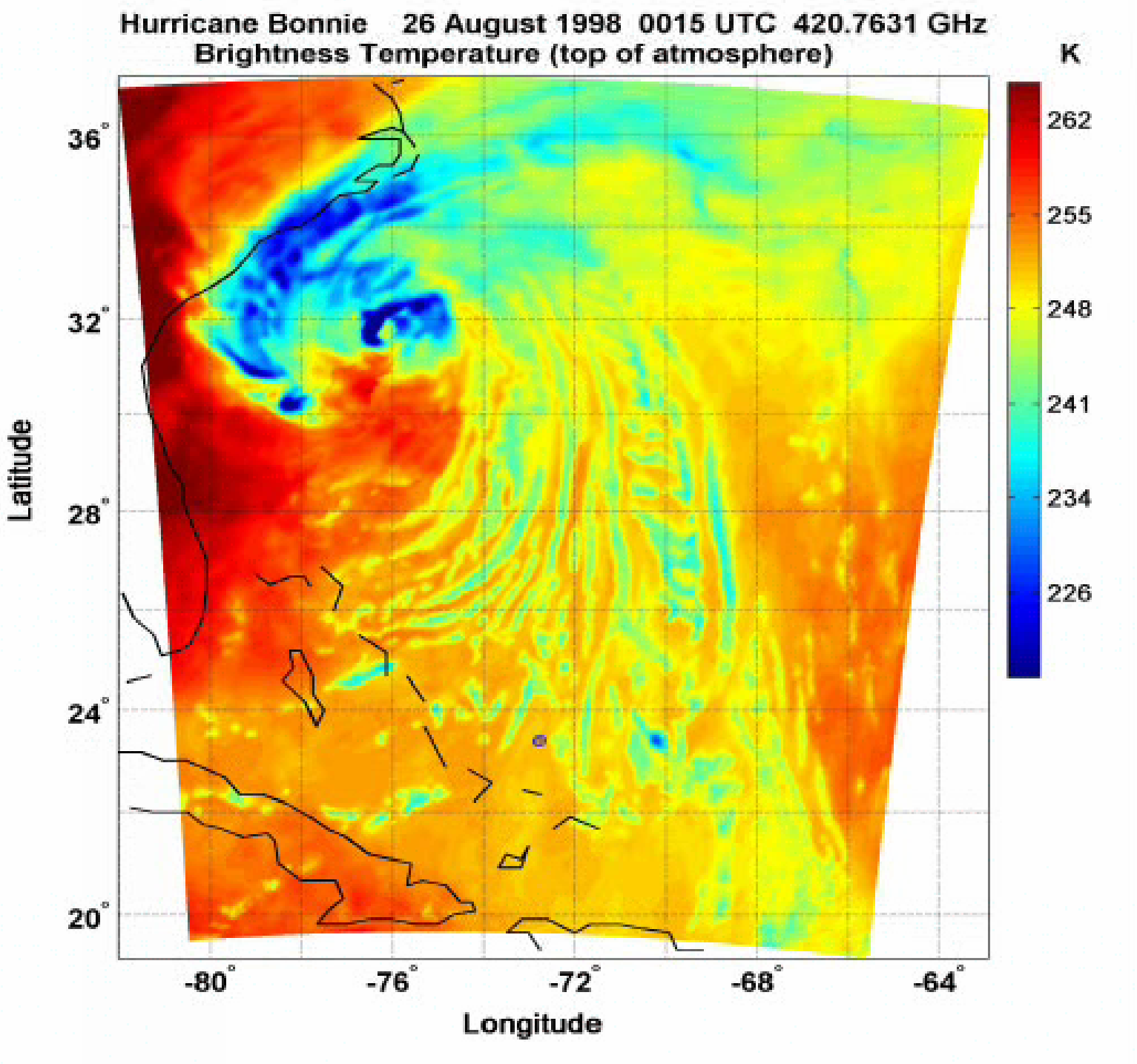
* Further reductions in ΔT_{RMS} achievable by further downsampling and/or time averaging.

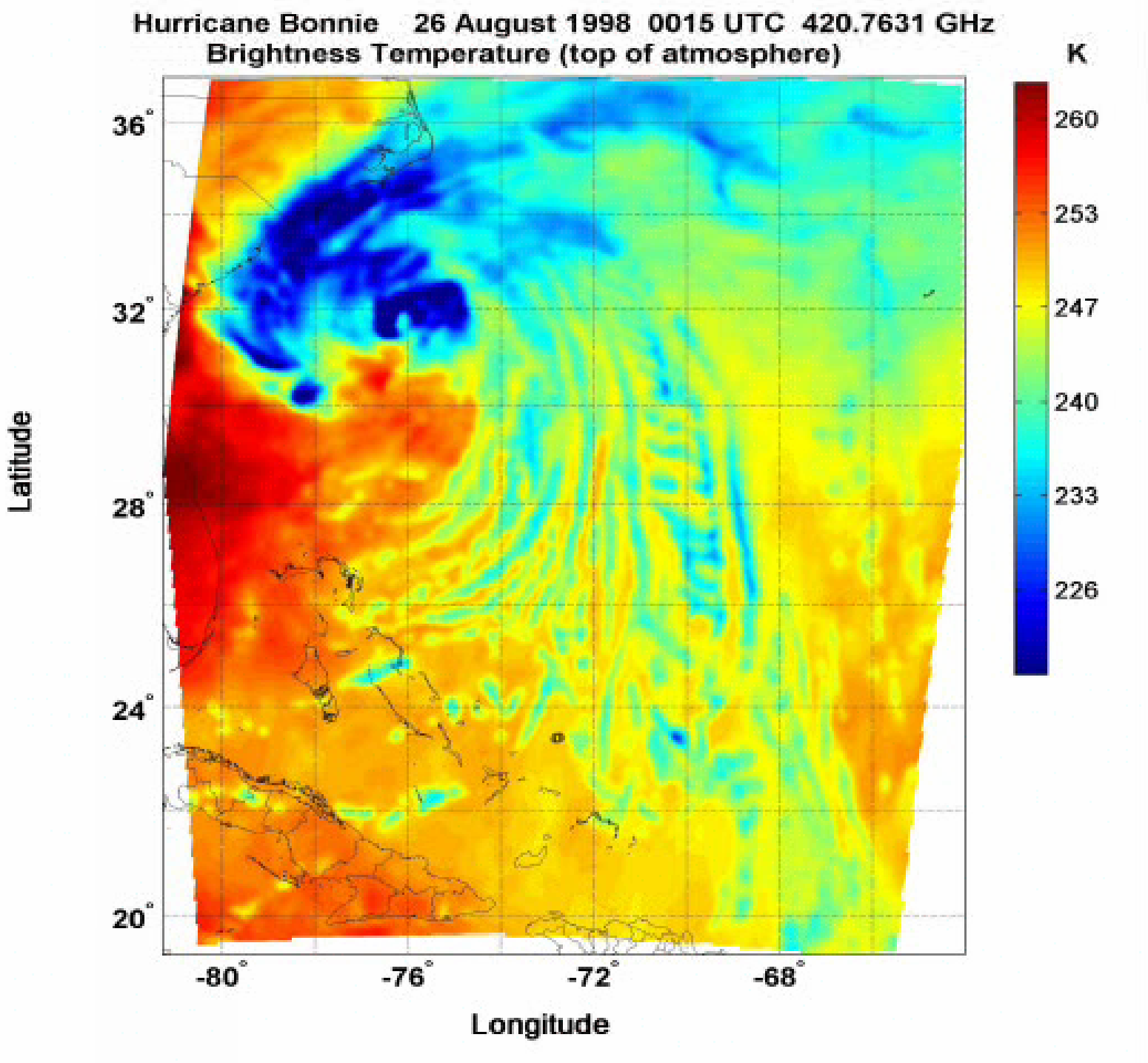
- **CONUS imaging time (3000 x 5000 km²) : ~80 minutes**

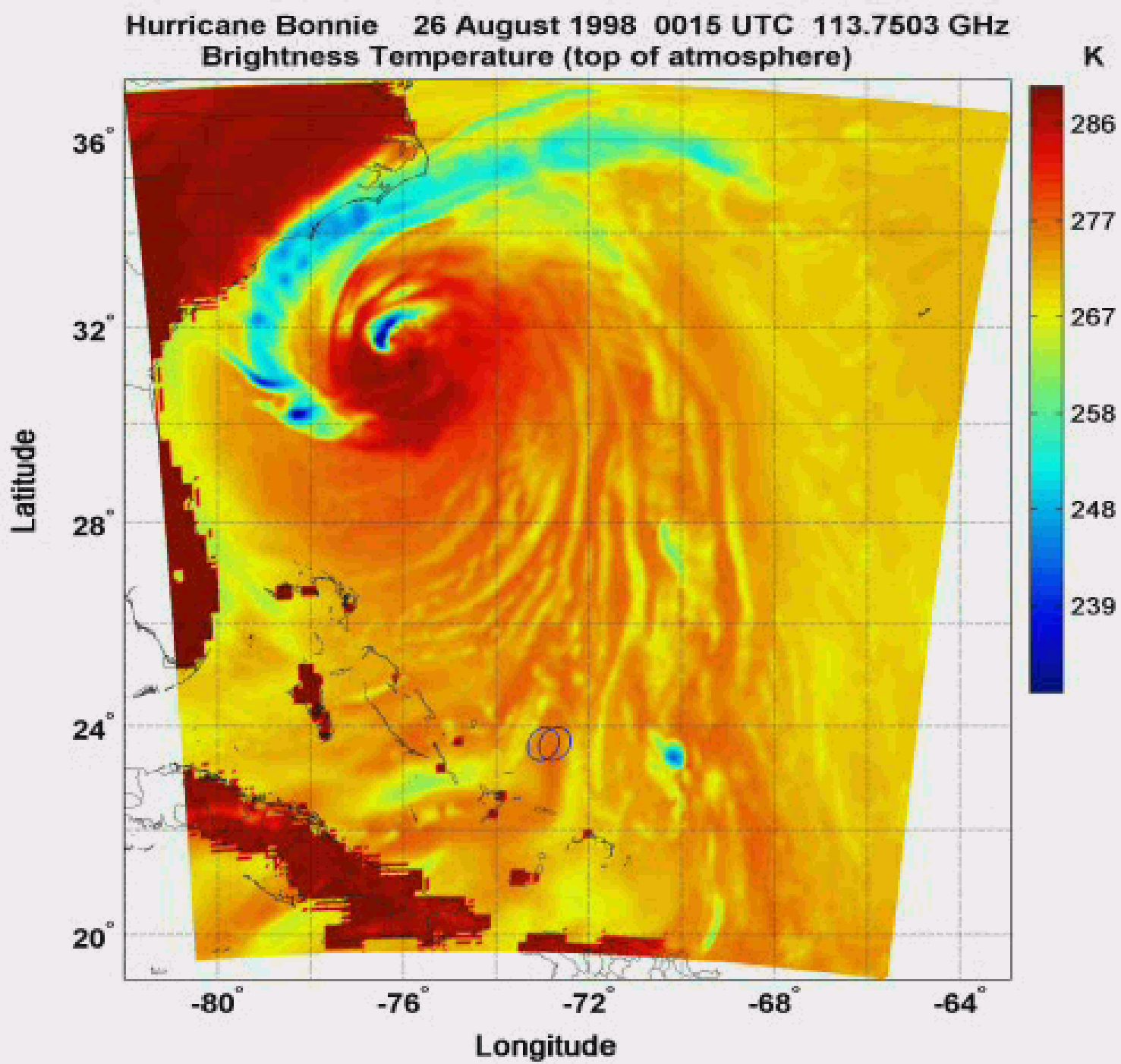
Downlink rate ~40 kb/sec at ~31 msec effective sample period

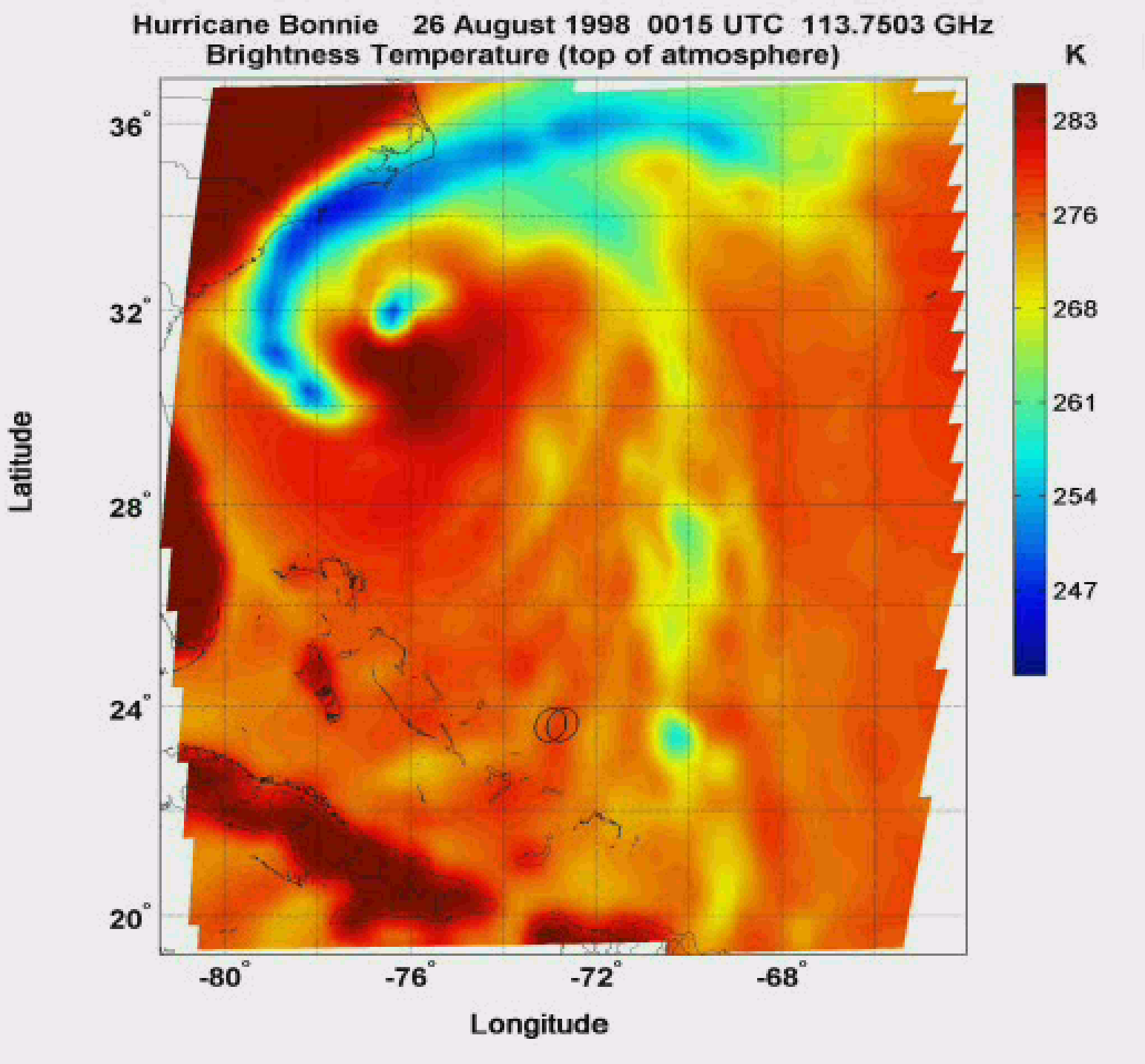
Hurricane Warm Core Observations

- Transparent 424 and 118 GHz Channels -


Hurricane Bonnie 26 August 1998 0015 UTC 420.7631 GHz
Brightness Temperature (top of atmosphere)
K
262
255
248
241
234
226
36°
32°
28°
24°
20°
Latitude
-80°
-76°
-72°
-68°
-64°
Longitude


Hurricane Bonnie 26 August 1998 0015 UTC 420.7631 GHz
Brightness Temperature (top of atmosphere)
K
260
253
247
240
233
226
36°
32°
28°
24°
20°
Latitude
-80°
-76°
-72°
-68°
Longitude


Hurricane Bonnie 26 August 1998 0015 UTC 113.7503 GHz
Brightness Temperature (top of atmosphere)
K
286
277
267
258
248
239
36°
32°
28°
24°
20°
Latitude
-80°
-76°
-72°
-68°
-64°
Longitude


Hurricane Bonnie 26 August 1998 0015 UTC 113.7503 GHz
Brightness Temperature (top of atmosphere)
K
283
276
268
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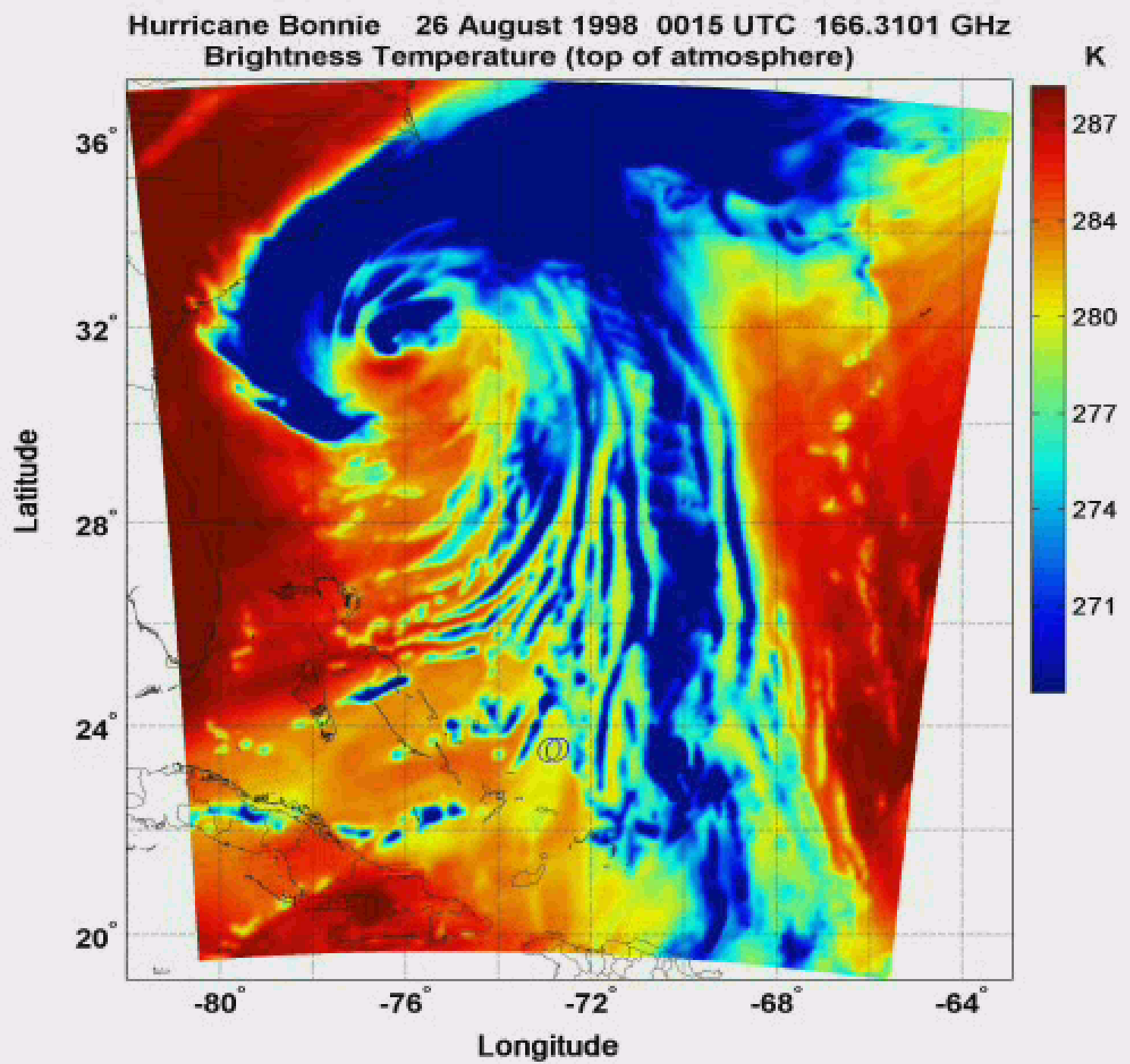
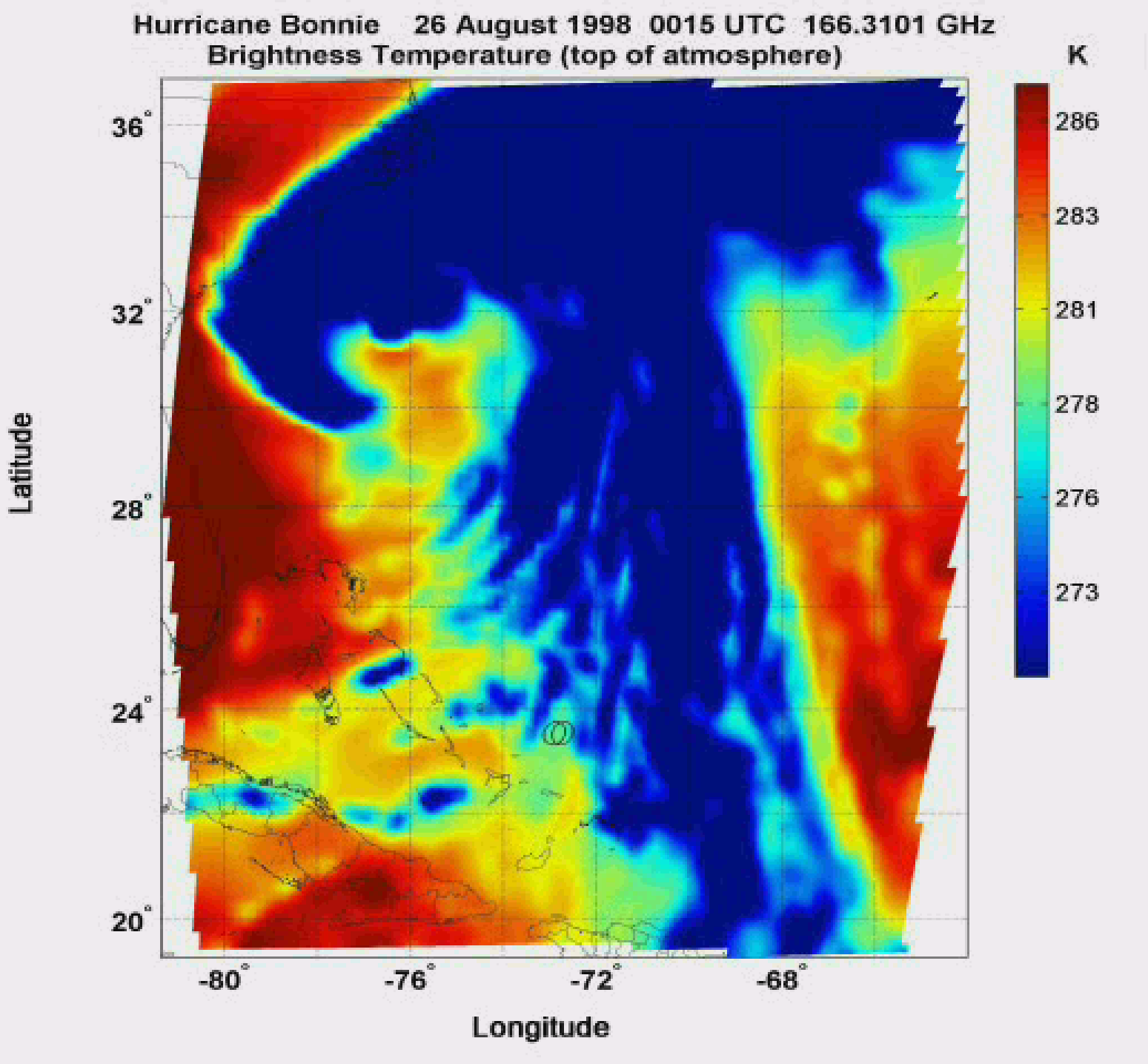
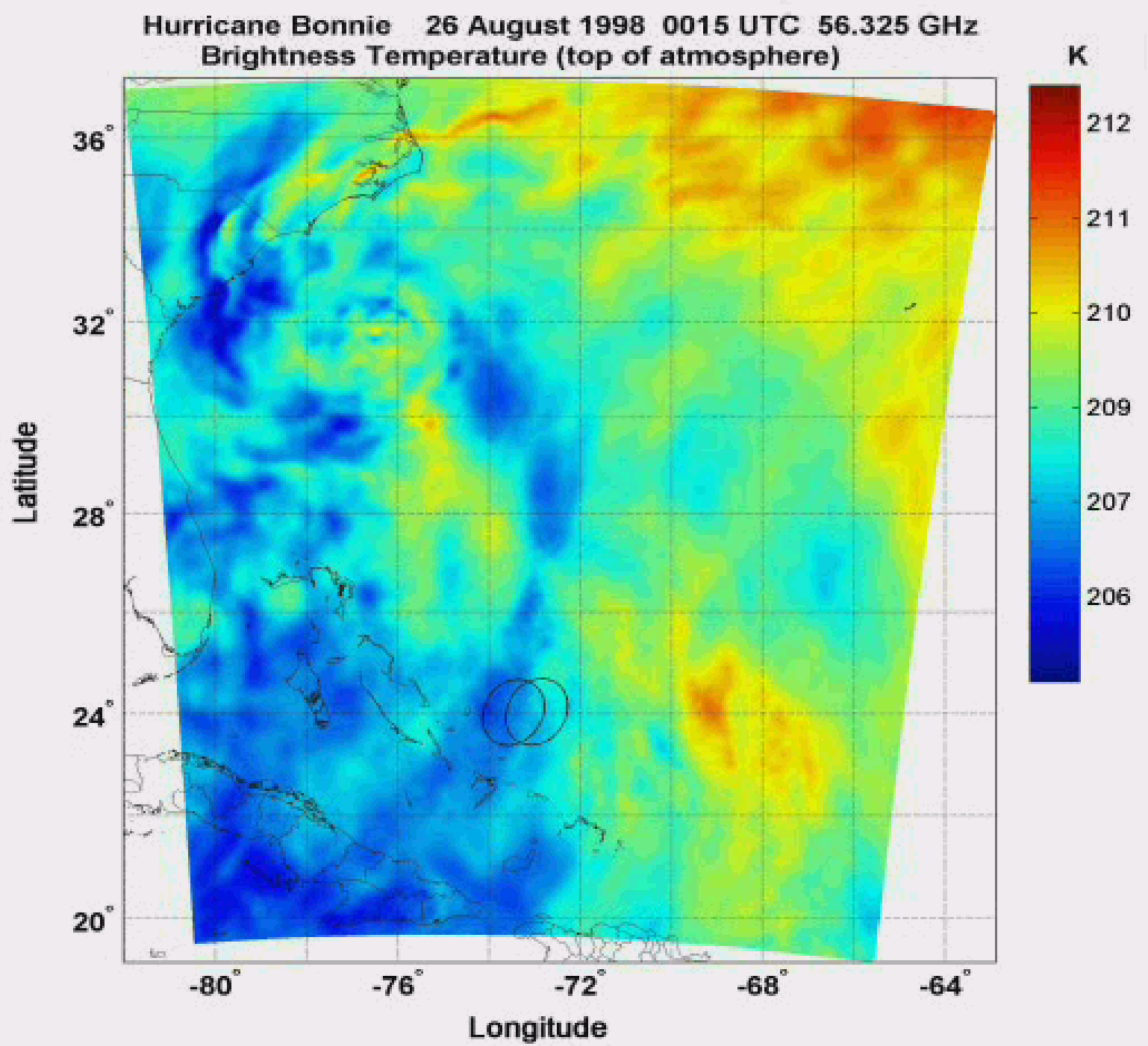
36°
32°
28°
24°
20°
-80°
-76°
-72°
-68°
Latitude
Longitude

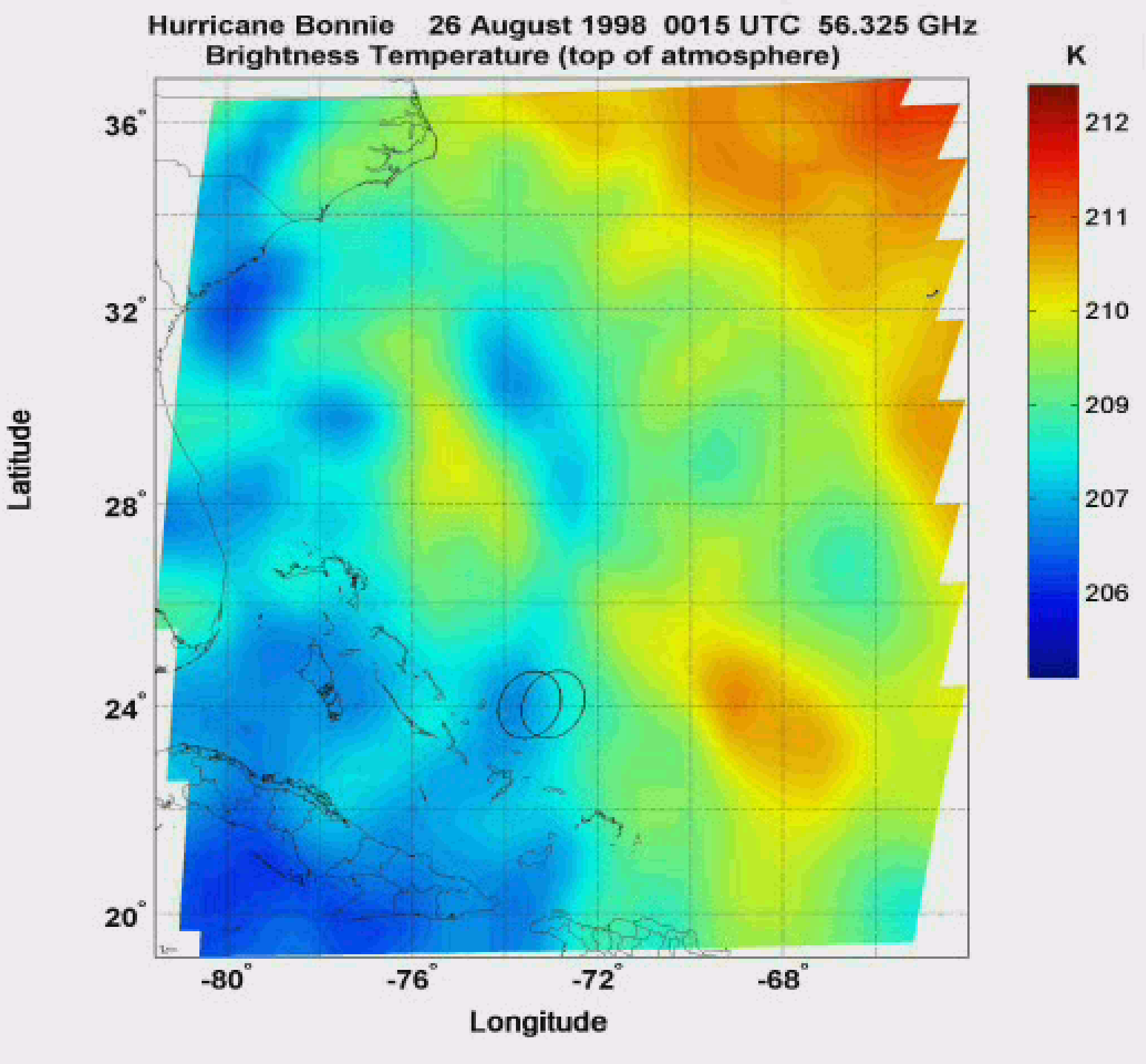
AMSU-B Moisture/Precipitation Imagery


Hurricane Bonnie 26 August 1998 0015 UTC 166.3101 GHz
Brightness Temperature (top of atmosphere)
K
287
284
280
277
274
271
Latitude
36°
32°
28°
24°
20°
-80°
-76°
-72°
-68°
-64°
Longitude


Hurricane Bonnie 26 August 1998 0015 UTC 166.3101 GHz
Brightness Temperature (top of atmosphere)
K
286
283
281
278
276
273
36°
32°
28°
24°
20°
Latitude
-80°
-76°
-72°
-68°
Longitude

AMSU-A Upper Atmosphere Temperature Imagery


Hurricane Bonnie 26 August 1998 0015 UTC 56.325 GHz
Brightness Temperature (top of atmosphere)
K
212
211
210
209
207
206
36°
32°
28°
24°
20°
Latitude
-80°
-76°
-72°
-68°
-64°
Longitude


Hurricane Bonnie 26 August 1998 0015 UTC 56.325 GHz
Brightness Temperature (top of atmosphere)
K
212
211
210
209
207
206
36°
32°
28°
24°
20°
Latitude
-80°
-76°
-72°
-68°
Longitude

NWP Hydrometric Tracking (Precipitation “Locking”)

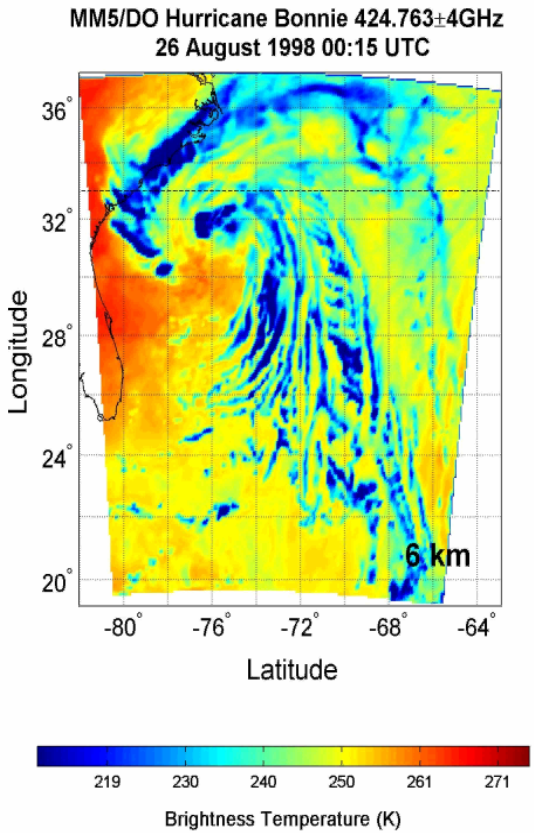
NWP Precipitation "Locking"

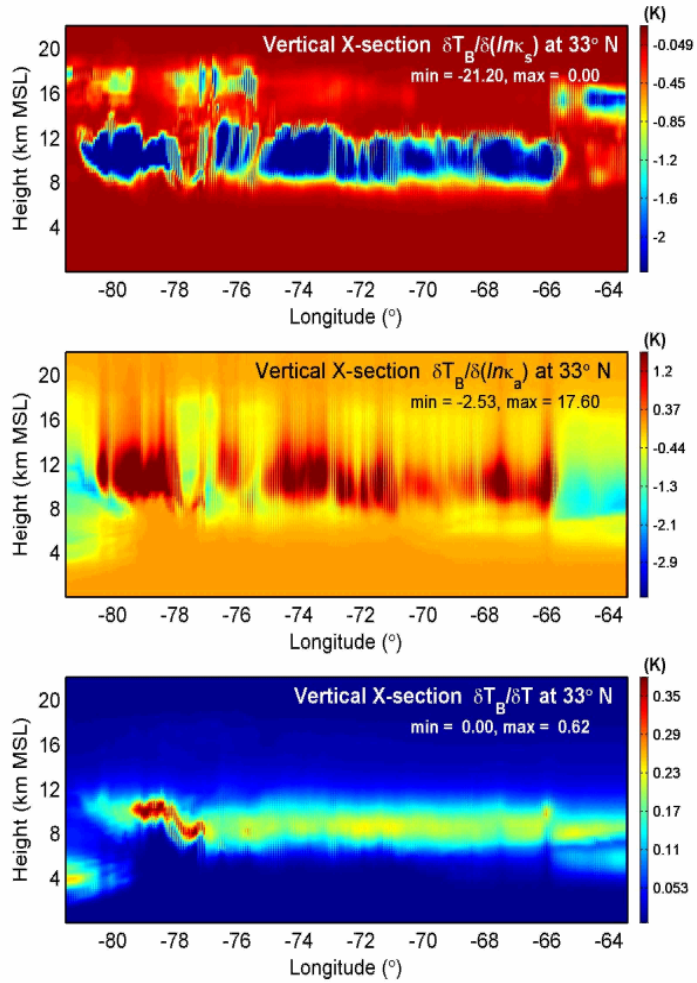
- To realize "locking" of an NWP model onto precipitation, observations are needed at time and space scales of order ~5-15 km and ~15 minutes.
- Locking is analogous to phase-locked loop in electrical engineering wherein linear phase differencing is achieved only when oscillator and signal remain within same phase cycle.
- Similarly, linear NWP model updates can be achieved provided that the cloud and precipitation state does not decorrelate between satellite observations.

MM5 24-Hr Simulation of GEM Imagery

Hurricane Bonnie August 26, 1998 424±4 GHz

15 min time steps





$\frac{\partial T_B}{\partial \kappa_S}$

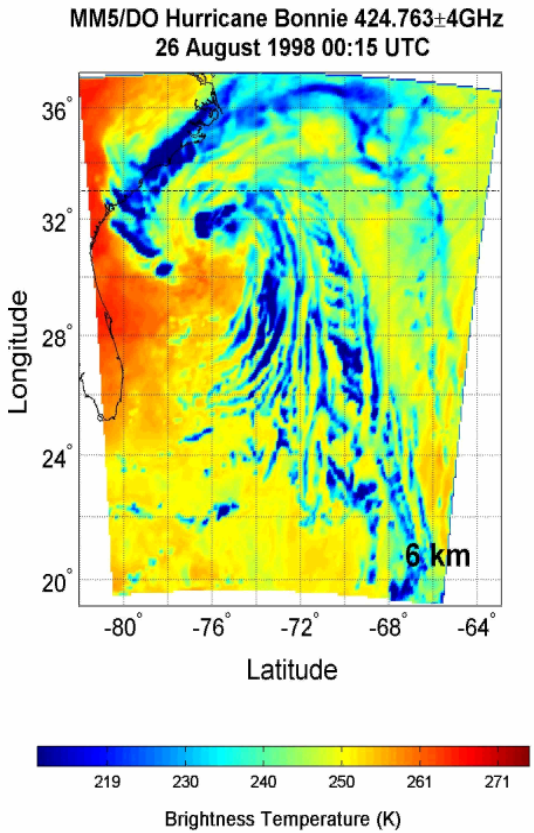
$\frac{\partial T_B}{\partial \kappa_A}$

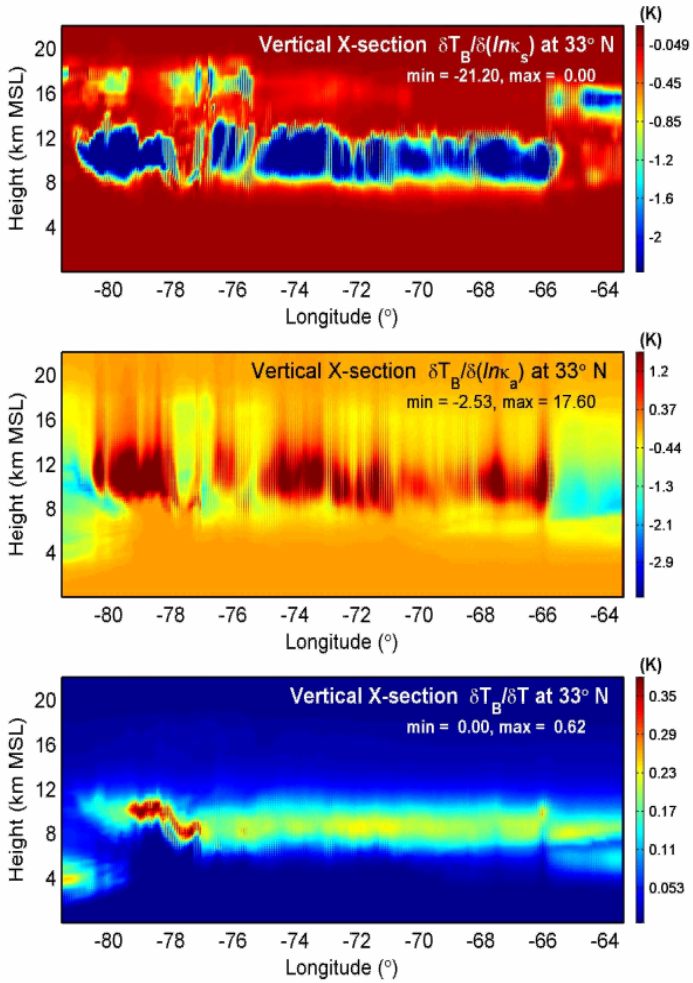
$\frac{\partial T_B}{\partial T}$

MM5 24-Hr Simulation of GEM Imagery

Hurricane Bonnie August 26, 1998 424±4 GHz

3 hour time steps



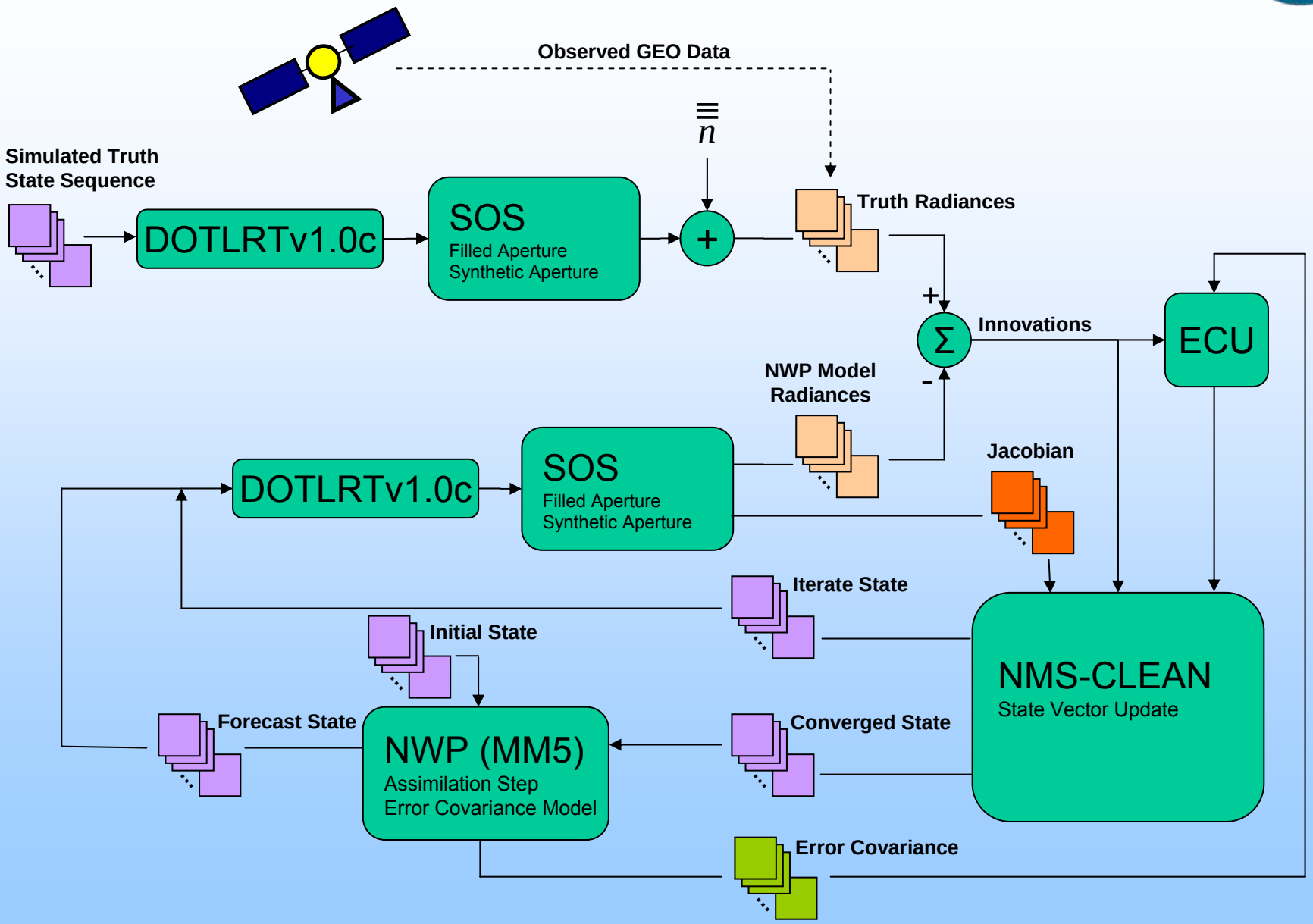


$\frac{\partial T_B}{\partial \kappa_S}$

$\frac{\partial T_B}{\partial \kappa_A}$

$\frac{\partial T_B}{\partial T}$

Hydrometric Tracking Simulator



Summary

- Detailed GEM/GOMAS and GeoSTAR simulations are underway within the NOAA GeoMicrowave Pathway study, now ongoing at the CU Center for Environmental Technology (CET).
- Simulations to date suggest dynamic information not present or utilized in retrievals may be valuable for nowcasting and forcasting using NWP models.
- We suggest that GEM or GeoSTAR 15-minute data will be key to facilitating hydrometric tracking
- Ongoing OSSE tasks include:
  - GeoSTAR full disk background field generation
  - GeoSTAR simulation (as per GEM simulations)
  - Error covariance update module
  - Hydrometric tracking demonstration