National Aeronautics and Space Administration

A Geostationary Microwave Sounder - Design and Applications

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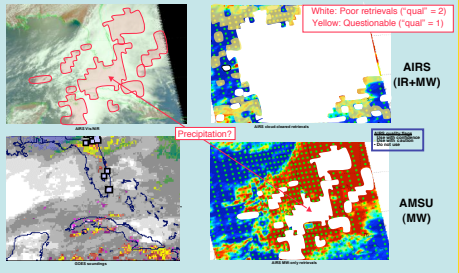
Abstract The Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) is a new concept for a microwave sounder for geostationary applications that has recently been developed at the Jet Propulsion Laboratory (JPL). Sponsored by the NASA Instrument Incubator Program a proof-of-concept prototype has been developed and tested at JPL in collaboration with partners at the NASA Goddard Space Flight Center and the University of Michigan and in close coordination with staff from the NOAA NESDIS Office of System Development as well as NASA to ensure that the GeoSTAR design will meet the needs and measurement requirements of both organizations. The prototype, which is a ground-based fully functional temperature sounder with capabilities similar to the Advanced Microwave Sounding Unit, shows excellent performance and serves as the intended proof of concept. This development represents a major breakthrough in remote sensing capabilities, since it finally makes it possible to deploy a microwave sounder as part of the Geostationary Operational Environmental Satellite (GOES) system - a long sought goal. GeoSTAR applications include the basic sounding functions of temperature, water vapor and liquid water profiling - possible even under fully cloudy conditions, which is not possible with infrared sounders, and which will soon also be possible under precipitating conditions. Emerging applications include rain and snow rate estimates, ice content and distribution in cloud systems, and convective intensity and atmospheric stability metrics in severe storms and tropical cyclones. These observations will be available as a continuous stream of 2-D "synoptic snapshots" covering the entire visible disc. With these capabilities, GeoSTAR would become the prime hurricane sensor, in addition to providing the basic sounding functions required by the National Weather Service and other operational agencies for regional weather prediction. As has been demonstrated in LEO, microwave sounders are also excellent tools for climate applications, with their superior stability and lack of sampling bias. Additional technology development as well as application studies are now under way, funded by NASA and NOAA, and GeoSTAR will be ready for a space mission in the 2014-15 time frame.

What is it, what does it do, and why is this important?

- GeoSTAR is a microwave sounder intended for geostationary (GEO) satellites
- It will have the same capabilities as current low-earth-orbiting (LEO) microwave sounders
  - tropospheric temperature profiles with < 50 km resolution
  - tropospheric water vapor and liquid water profiles with < 25 km resolution
  - rain rates with < 25 km resolution
- Unlike infrared sounders, microwave sounders work well under cloudy conditions
  - only 5-30% (depending on spatial resolution) of scenes are cloud free and suitable for IR sounders
  - microwave sounders must be used to complement IR sounders to achieve full coverage
- Numerical weather prediction centers have found microwave sounders to be extremely valuable
  - very large impact on forecast accuracy
  - ability to look inside hurricanes and other storm systems
- Climate researchers have found microwave instruments to be invaluable
  - long, stable time series are used to infer global warming/cooling
  - there is no sampling bias due to clouds as there is for IR sounders

The Trouble With IR Sounders



Why isn't there a GEO MW sounder already?

- GEO satellites are about 50 times farther away than LEO satellites
- To get the same spatial resolution, the antenna aperture must be 50 times larger: 5-6 m diameter
  - it is currently impossible to build such a large parabolic reflector that is sufficiently precise
  - even if it could be built, it would be nearly impossible to stow it into a launch vehicle
  - even if it could be launched, it would be very massive, and scanning it would be very challenging

So how does GeoSTAR solve these problems?

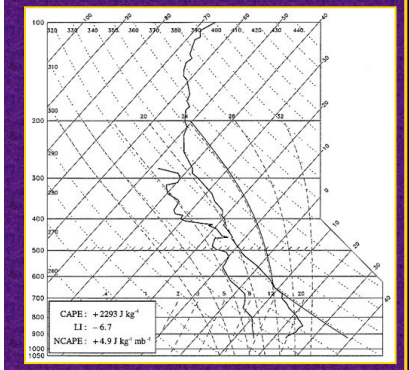
- GeoSTAR *synthesizes* a large aperture using a sparse array of miniature "antennas"
  - three linear arrays, each 2 m long, are placed in a Y shape, making an effective 4 m aperture
  - we operate this as a spatial interferometer, essentially measuring in the spatial Fourier domain
  - on the ground we then do an inverse Fourier transform to get 2D brightness temperature images
- Other significant advantages with the GeoSTAR approach:
  - no mechanical scanning is necessary
  - if a receiving element goes down, all is not lost -i.e. the array system is very fault tolerant
  - simultaneous imaging of the entire Earth disk every 5-10 minutes for rain mapping - no scan lag

Basic Sounding Functions

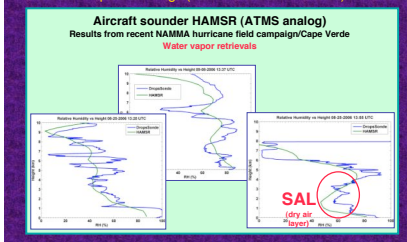
Bread-and-butter soundings

Parameter	Accuracy	Vert. resolution
Temperature (z)	1.5-2 K	2 km
Water vapor (z)	20%	2 km
Liquid water (z)	40%	3 km
TPW	10%	
TLW	20%	
SST	2 K	
Performance of current POES MW sounders		

Skew-T diagrams and stability indices everywhere

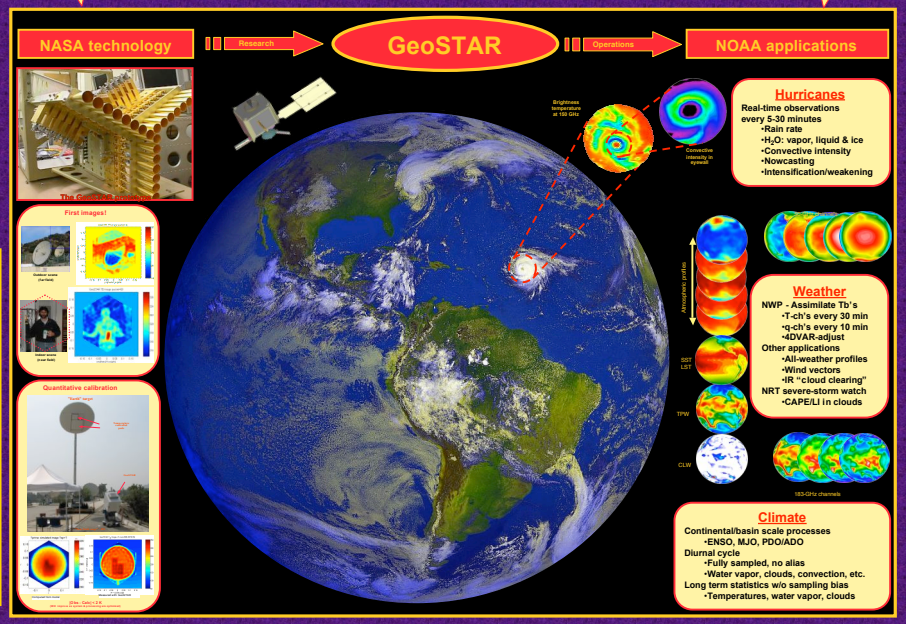


Example soundings (aircraft hurricane mission)



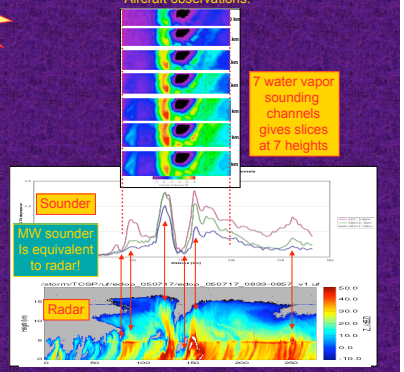
Geostationary Microwave Sounder

Hurricane Observing System!

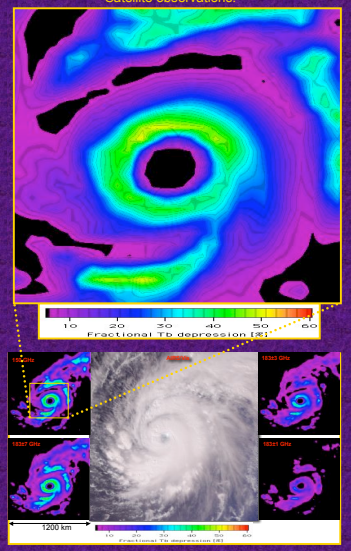


Vertical Slicing of Hurricanes

Aircraft observations:



Satellite observations:



Products, Applications and Synergies

Emerging products

- Rain rates & vertical precipitation profile
- Snow-fall rates
- Ice water path & vertical ice profile
- Convective intensity, vertically resolved
- Wind vector vertical profiles

Synergistic applications

- Complement GEO IR sounders: cloud clearing
- Complement LEO sounders: swath-gap & temporal-gap filling
- Complement GEO imagers: resolution enhancement of MW
- Global Precipitation Mission: provide spatio-temporal continuity

Applications

- Numerical weather prediction
  - Assimilation of radiances; 4DVAR applications
- Hurricane now-casting
  - Intensity assessment, detect rapid intensification/weakening
  - Observation of internal dynamics, kinematics & microphysics
- Severe storm development
  - Atmospheric stability (CAPE, LI, etc.) in cloudy regions
  - Detect/assess tornado precursor conditions
- Weather hazard assessment
  - Life cycle storm observations; total rainfall
  - Predict/observe flood conditions
- Climate studies
  - Continuous time series; diurnal cycle fully resolved
  - Basin-scale inter-seasonal to interannual analyses
  - Cross-calibration of LEO climate sensors & data series

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