National Aeronautics and Space Administration

GeoSTAR: A P^3I Payload for GOES-R

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Summary GeoSTAR is probably the most important pending P^3I addition to GOES-R

The Geostationary Synthetic Thinned Aperture Radiometer (GeoSTAR) is an exciting new concept that finally makes it feasible to put a microwave sounder in geostationary orbit and fill a serious gap in our remote sensing capability of long standing; it is intended for GOES-R. A ground based proof-of-concept prototype has been developed by the Jet Propulsion Laboratory and is now undergoing testing and characterization. Performance is outstanding, and images of the sun transiting the field of view – the first successful imaging with a 2D aperture synthesis system – demonstrate that the system is very stable and that aperture synthesis is a realistic and practical approach. This is a significant breakthrough. GeoSTAR provides all-weather temperature and humidity soundings, continuous rapid-update rain mapping, tropospheric wind profiling, measurement of convective intensity and real-time storm tracking. These observations will significantly enhance our ability to assess, track and predict hurricanes and other severe storms. GeoSTAR achieves very high spatial resolutions without having to deploy the large mechanically scanned parabolic reflector antenna that is required with t conventional approach. GeoSTAR is the only realistic way of getting a microwave sounder with adequa spatial resolution in GEO, and it also has a clear upgrade path to meet future requirements. The technology a system design required for GeoSTAR are rapidly maturing, and a space demonstration mission can be develop in time for GOES-R, where it could be flown as an Instrument Of Opportunity - if funding is made availab soon. It will be ready for operational transition 1-2 years after that. The GeoSTAR team has been collaborati closely with the NOAA Office of System Development, but there are programmatic barriers that make difficult for NOAA to sponsor and fund the development of new-technology payloads. Traditionally this h been the role of NASA, but both organizations are working on finding ways to implement a workable "resear to operations" model without negatively impacting their other objectives. GeoSTAR is a good candidate for th model, and it is likely to go forward as a joint NASA-NOAA space mission within the next decade.

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

- GeoSTAR is a microwave sounder intended for geostationary (GEO) satellites
- It has 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
  - —IR sounders must be matched with microwave sounders to achieve full coverage in cloudy regions
  - —GeoSTAR is the perfect complement to HES
- 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

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 "AMSU"
  - —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
  - —even if it could be scanned, it would take a long time to cover the entire Earth disc

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
  - —a 4 m GeoSTAR array gives equivalent performance as a 5-6 m parabolic antenna
  - —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: all points on the Earth disc are imaged simultaneously => rain maps every 10 n
  - —if a receiving element goes down, all is not lost -i.e. the array system is very fault tolerant

Enter NASA and JPL with partners

- A JPL proposal to build a GeoSTAR prototype as a proof of concept and to develop the required technology was funded under the Instrument Incubator Program operated by the NASA Earth-Sun System Technology Office (ESTO)
- This effort started in early 2003
- The prototype, which is a complete and fully functional temperature sounder operating in the 50-GHz oxygen absorption band (like AMSU-A), has now been completed and is undergoing testing to assess its performance
- Test results so far indicate outstanding performance and represent the desired proof of concept.
- *This is a major breakthrough that will fill a significant gap in the nation's remote sensing capabilities*
- This has been accomplished in record time - largely the result of a team effort between JPL, NASA/GSFC and U. Michigan.
- The NOAA/NESDIS Office of System Development has supported the GeoSTAR development since its inception, starting with a strong letter of endorsement for the GeoSTAR proposal and continuing with the funding of assessments of its effectiveness in meeting NOAA needs.

Applications

- **Hurricane diagnostics** — unique capabilities
  - —Convective intensity, real-time weakening/intensification detection, rain rate, internal temperature, humidity and cloud structure, wind profiles
- **Weather prediction** — get GOES on a par with POES
  - —Assimilate radiances: 4DVAR adjustments every 10 minutes for improved regional/short-term forecasts
  - —Retrieve standalone MW products: T, humidity, liquid, wind profiles, SST, rain/snow
  - —Complement HES: cloud-clearing to enable full-coverage all-weather soundings
- **Climate studies** — bring proven LEO capabilities to GEO
  - —Long stable time series of tropospheric temperature: global warming or cooling?
  - —Full resolution of the diurnal cycle: climate studies
  - —Interannual variability studies: ENSO, MJO
  - —Trends in storm frequency and intensity

The GeoSTAR Team

- At JPL: Bjorn Lambrigtsen (PI), Todd Gaier, Alan Tanner, Pekka Kangaslahti, Shannon Brown
- At NASA/GSFC: Jeff Piepmeier
- At U. Michigan: Chris Ruf, Boon Lim
- Others: Bill Wilson (JPL, ret.), Francisco Torres (U. Barcelona)

Acknowledgments

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NASA technology

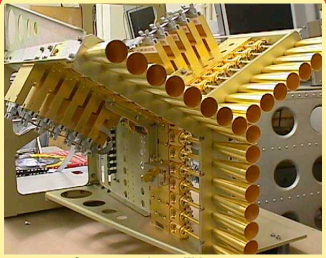
Research

GeoSTAR

Operations

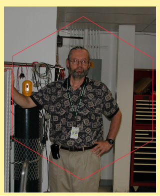
NOAA applications

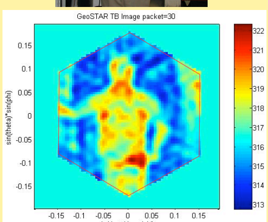
The GeoSTAR prototype



Space version will be more compact and have > 10x as many receivers

It works!

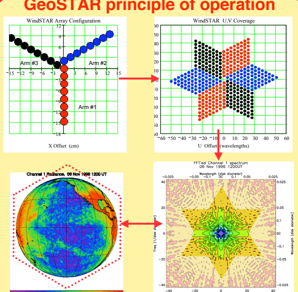


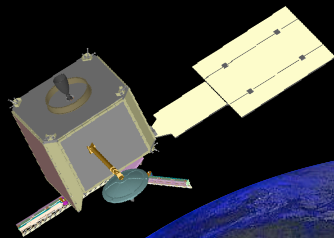


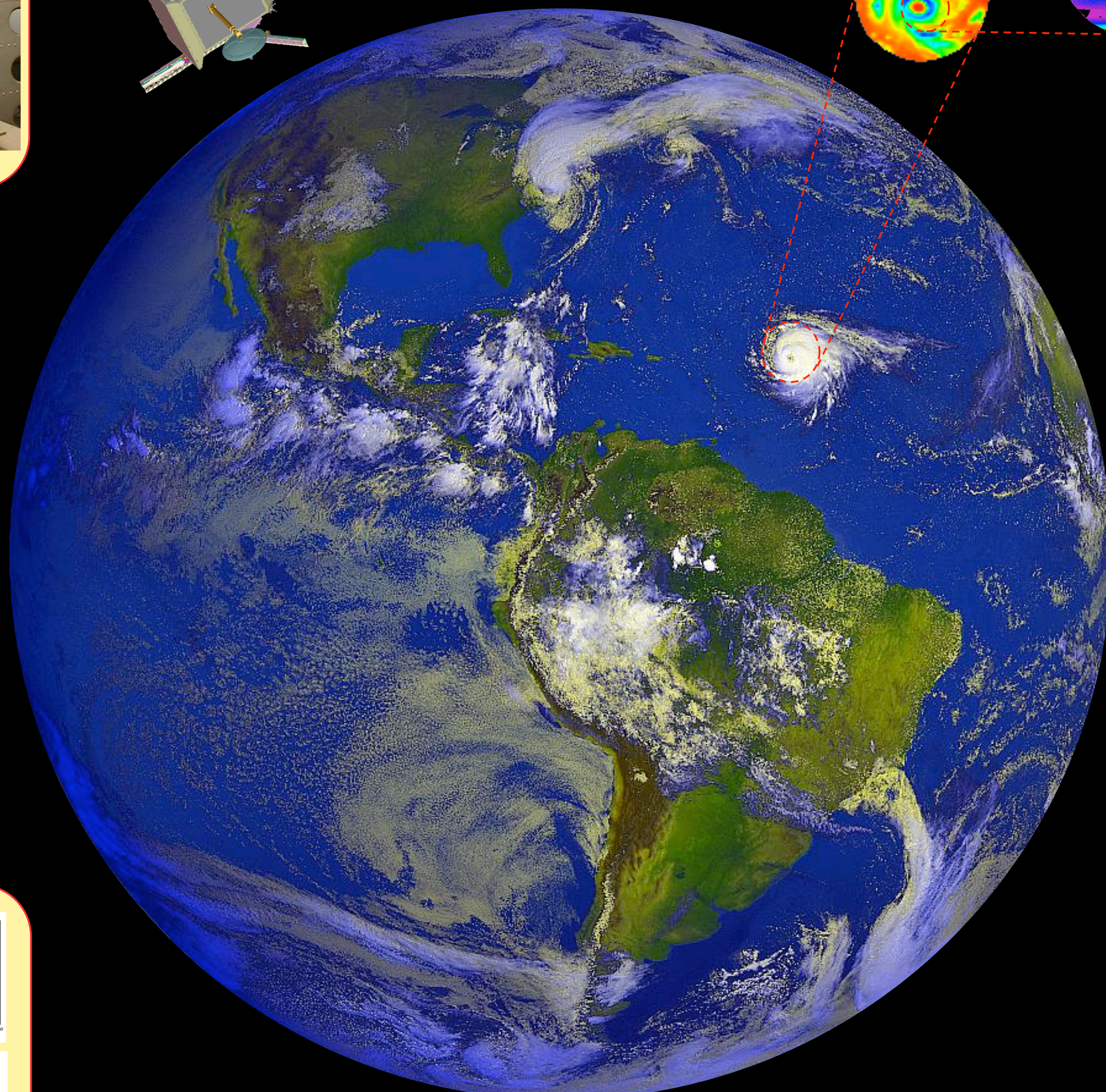
The PI at 50.3 GHz!

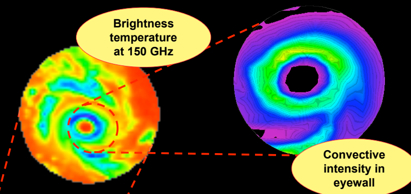
The prototype is designed to provide alias-free view of Earth from GEO

GeoSTAR principle of operation





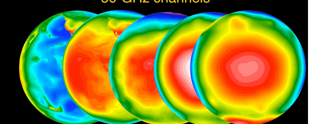


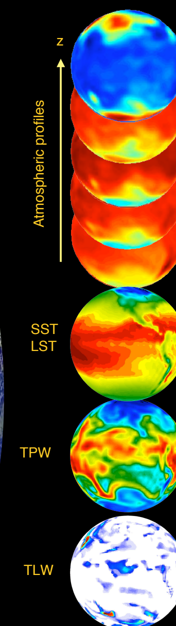


Hurricanes

Real-time observations every 5-10 minutes
- •Rain rate
- •Convective intensity
- •Nowcasting
- •Intensification
- •Weakening

50-GHz channels

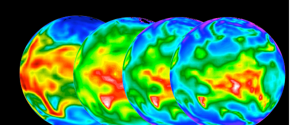




Weather

NWP - Assimilate Tb's
- T-ch's every 30 min
- q-ch's every 5-10 min
- 4DVAR-adjust

Other applications
- All-weather profiles
- Tropo. wind vectors
- HES cloud clearing
- Rain rate
- Snow rate
- Nat. disaster warnings



183-GHz channels

Climate

Regional/ocean-basin processes
- El Nino
- MJO

Long term trends (No sampling bias)
- Temperature
- Water vapor
- Clouds
- Storm statistics

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