Contributions of GPS Data to Severe Weather Forecasting

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Introduction

- Every successful weather forecast starts with atmospheric observations.
- While having good observations does not guarantee an accurate weather prediction…
- …not having them virtually guarantees a poor forecast.
- Nowhere is this more true than along the coasts of the U.S.
- In this presentation, I will describe how the data acquired at Nationwide and Maritime Differential GPS Service (N/MDGPS) sites are helping the National Oceanic and Atmospheric Administration (NOAA) to improve its severe weather forecasts.

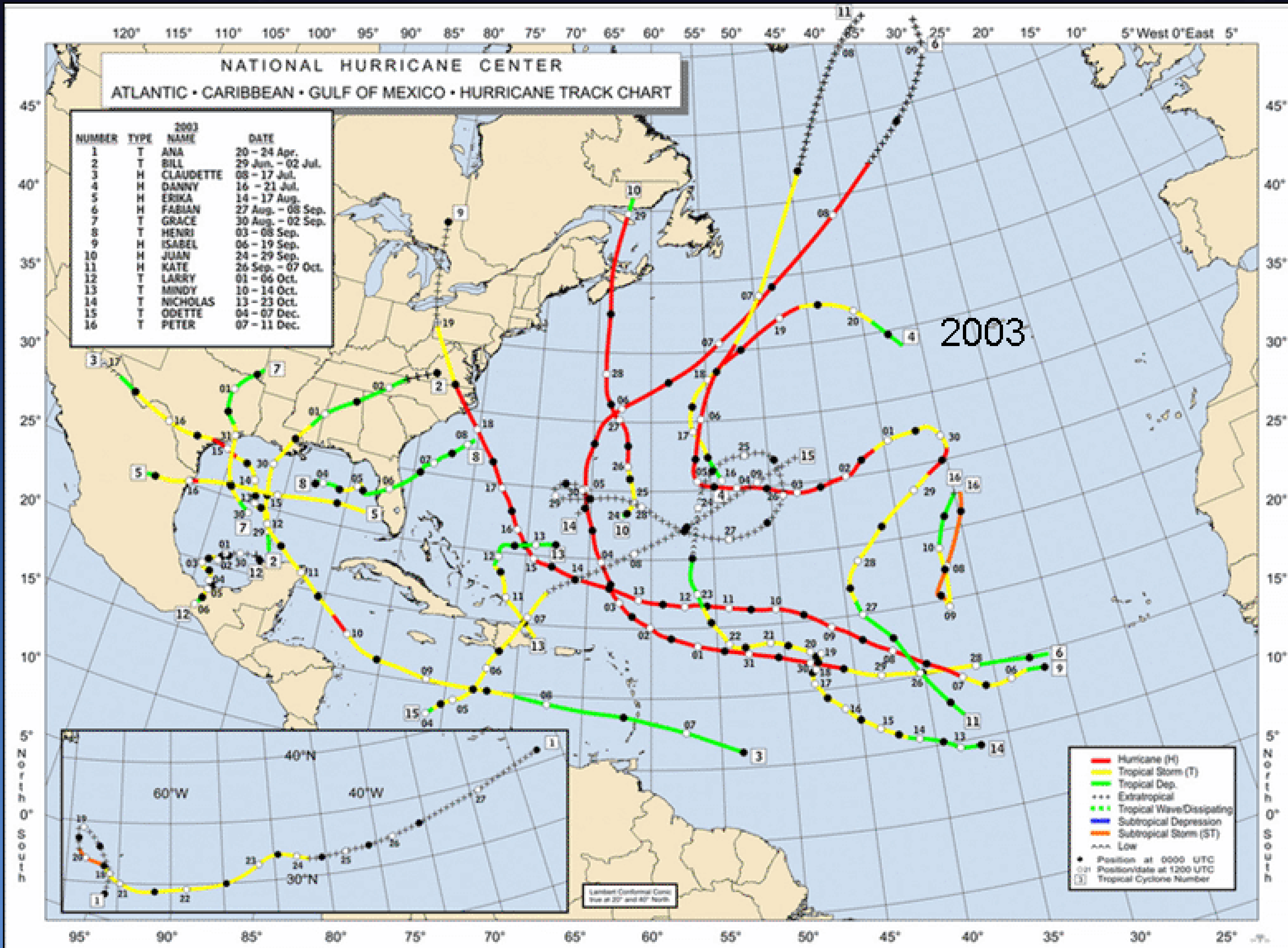
Let’s Talk About the Gulf of Mexico

- Most of the atmospheric moisture for the Eastern 2/3 of the U.S. comes from the Gulf of Mexico.
- Moisture flow off the Gulf is responsible for the generation of severe weather (thunderstorms, lightning, tornados) along the coast and farther inland.
- Water vapor derived from the evaporation of sea water is the “fuel” that drives tropical storms including hurricanes.
- One of the biggest gaps in current tropical storm forecasting is lack of knowledge about the water vapor flux over the open ocean.

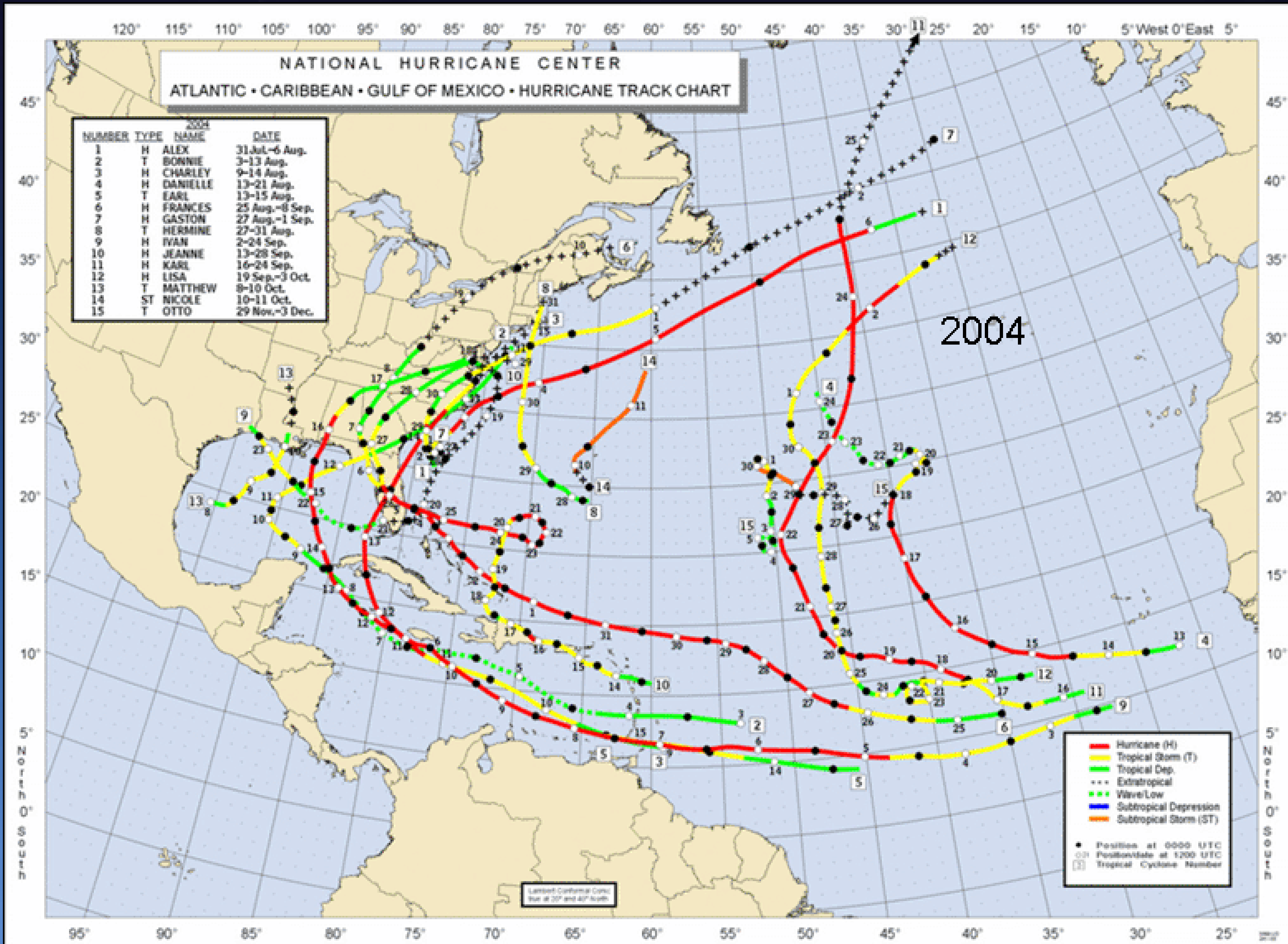
Tropical Storm Variability

- As the next few slides illustrate, there is lots of natural variability in severe weather originating from or coming in-to and out-of the Gulf.
- Few years were as memorable as 2005, but by any account 2007 was a very strange year.
- 2007 started off with ST Andria on May 9 and ended with TS Olga on December 12. Hurricane season officially starts on June 1 and ends on November 30.
- In between, two Category 5 hurricanes made landfall in the same year for the first time in recorded history, and Hurricane Humberto formed and intensified faster than any other tropical cyclone on record – 18 hours.

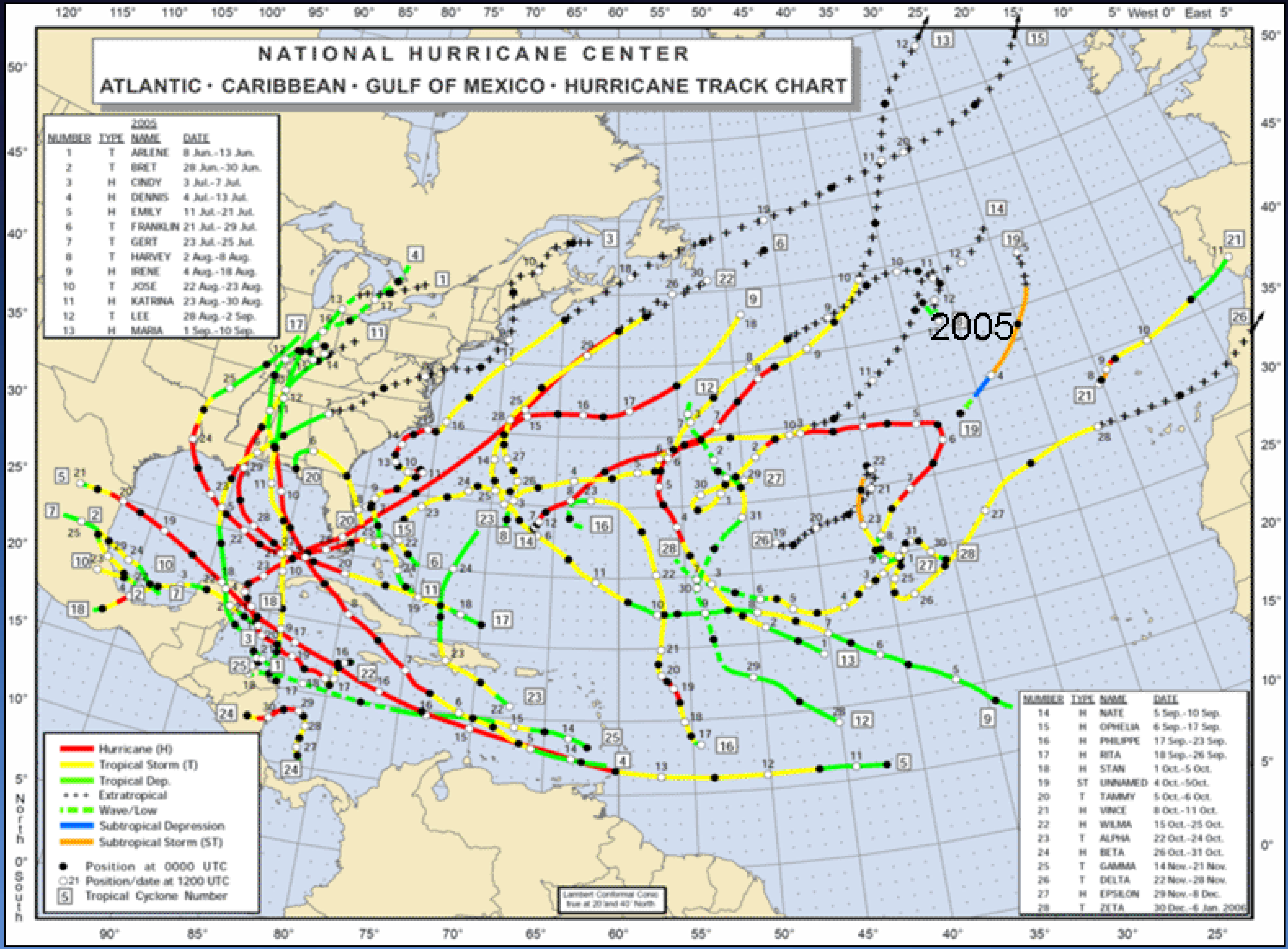
2003 Atlantic/IAS Tropical Storms



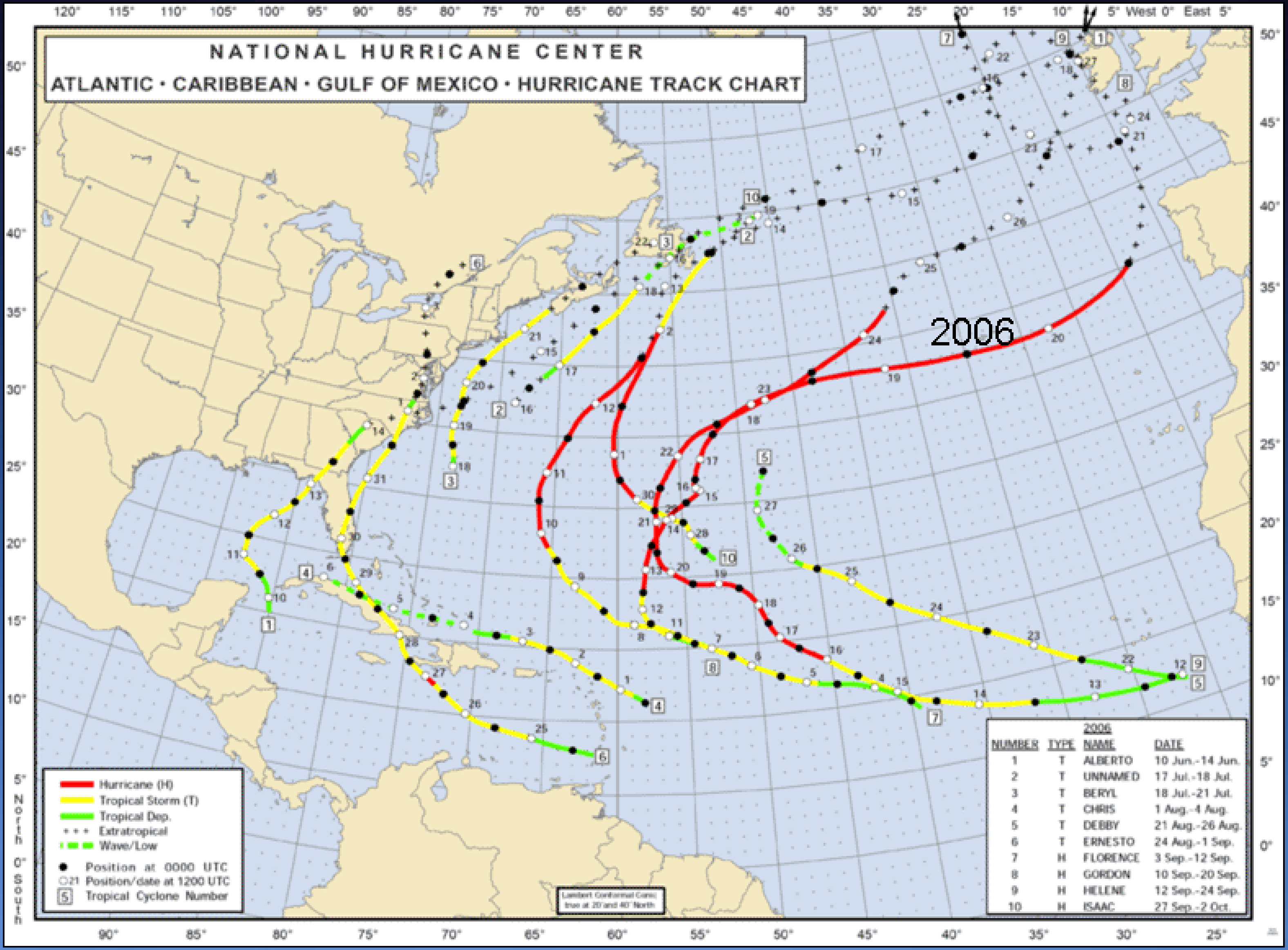
2004 Atlantic/IAS Tropical Storms



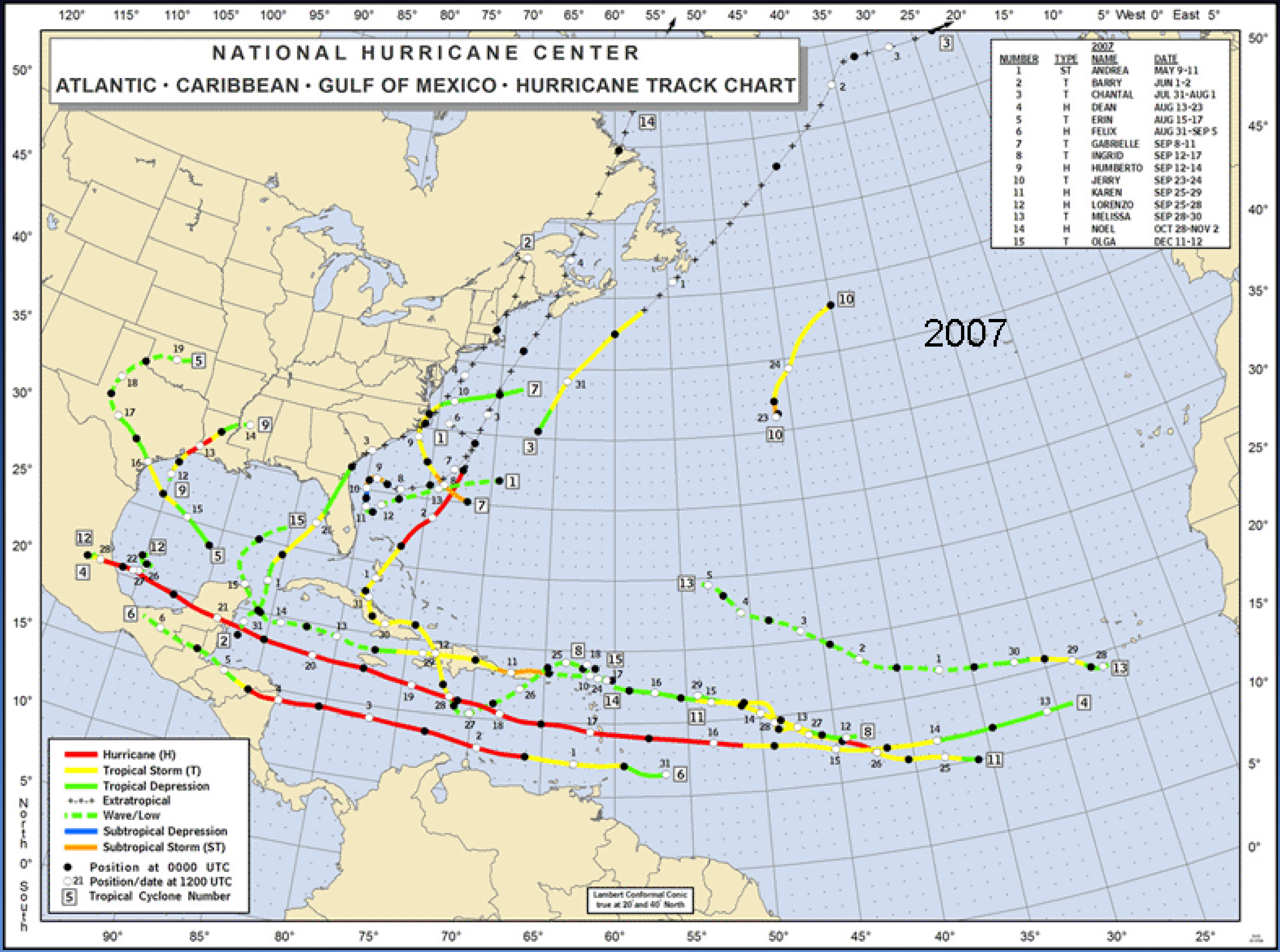
2005 Atlantic/IAS Tropical Storms



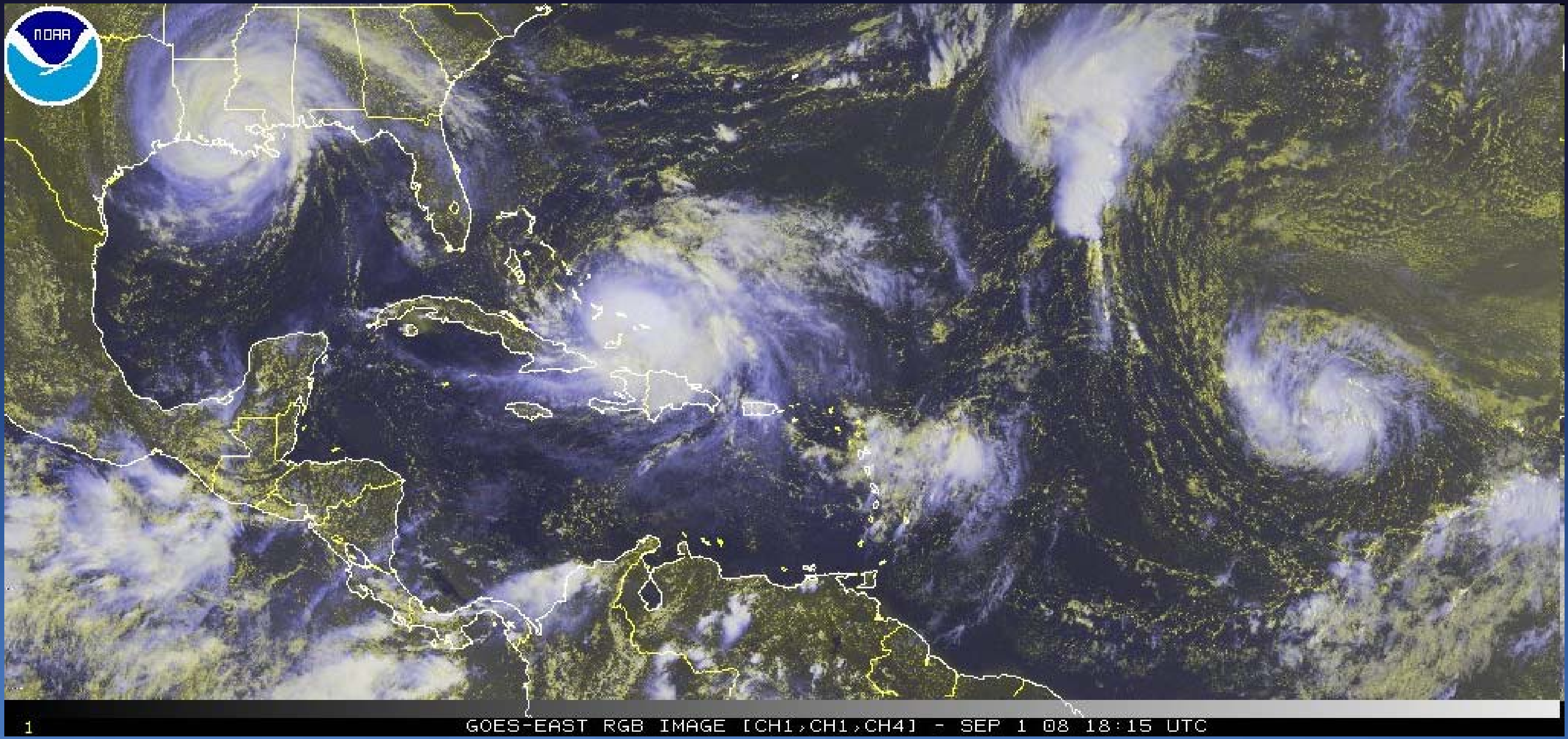
2006 Atlantic/IAS Tropical Storms



2007 Atlantic/IAS Tropical Storms



2008 Atlantic Hurricane Season

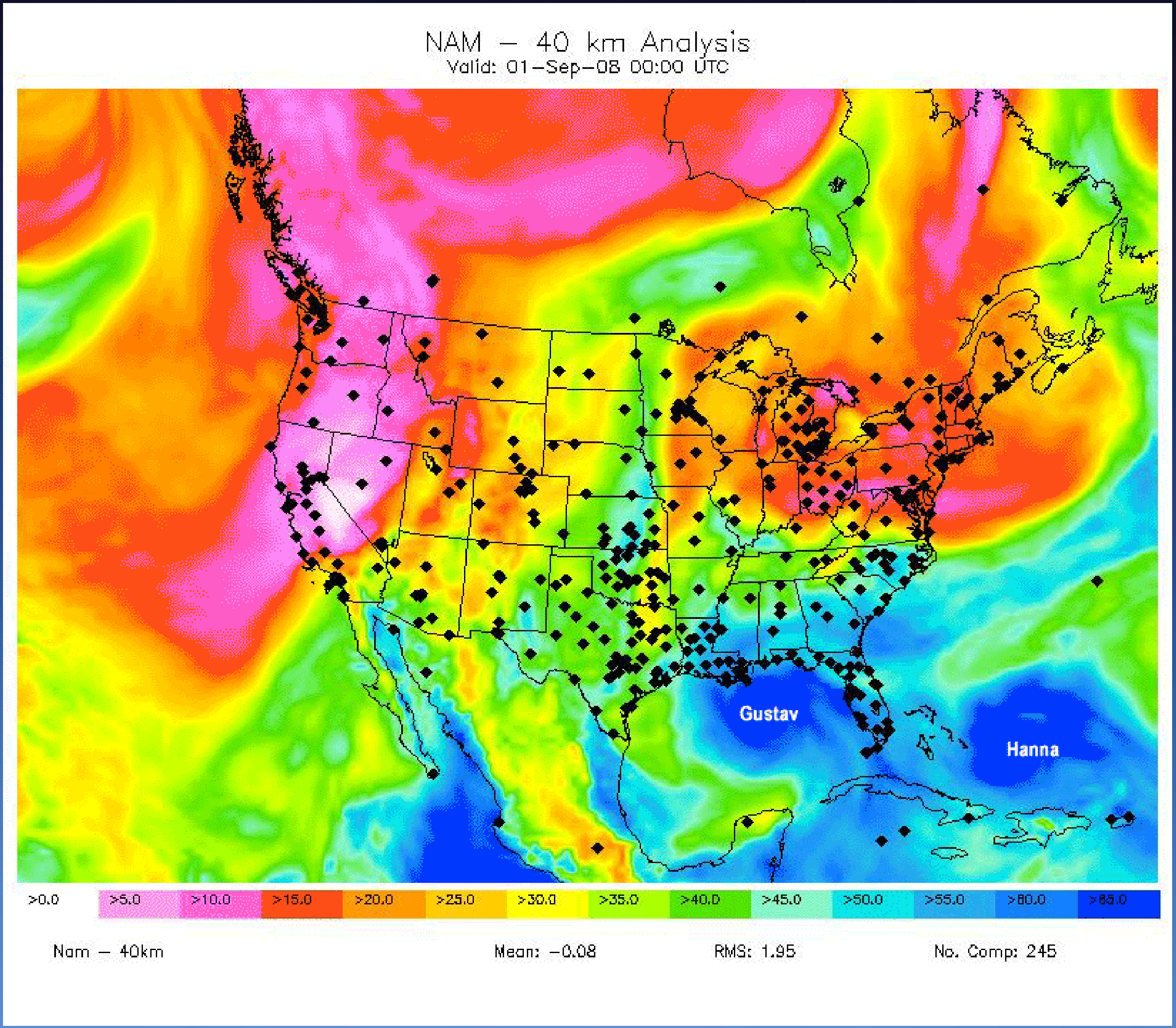


Hurricane Gustav

Hurricane Hanna

Hurricane Ike

Gustav, Hanna, and Ike



Why We Need Improved Observations

- Timely observations provide "situational awareness" to forecasters, decision makers and the general public.
- Observations help define the initial conditions for numerical weather prediction models that provide our long-range weather forecasts.
- Poor or absent observations usually result in erroneous forecasts.
- The need for observations with higher (temporal and spatial) resolution increases as the weather becomes more dynamic.
- GPS observations made under all weather conditions at N/MDGS sites provide critical moisture information when it's needed most.

Background

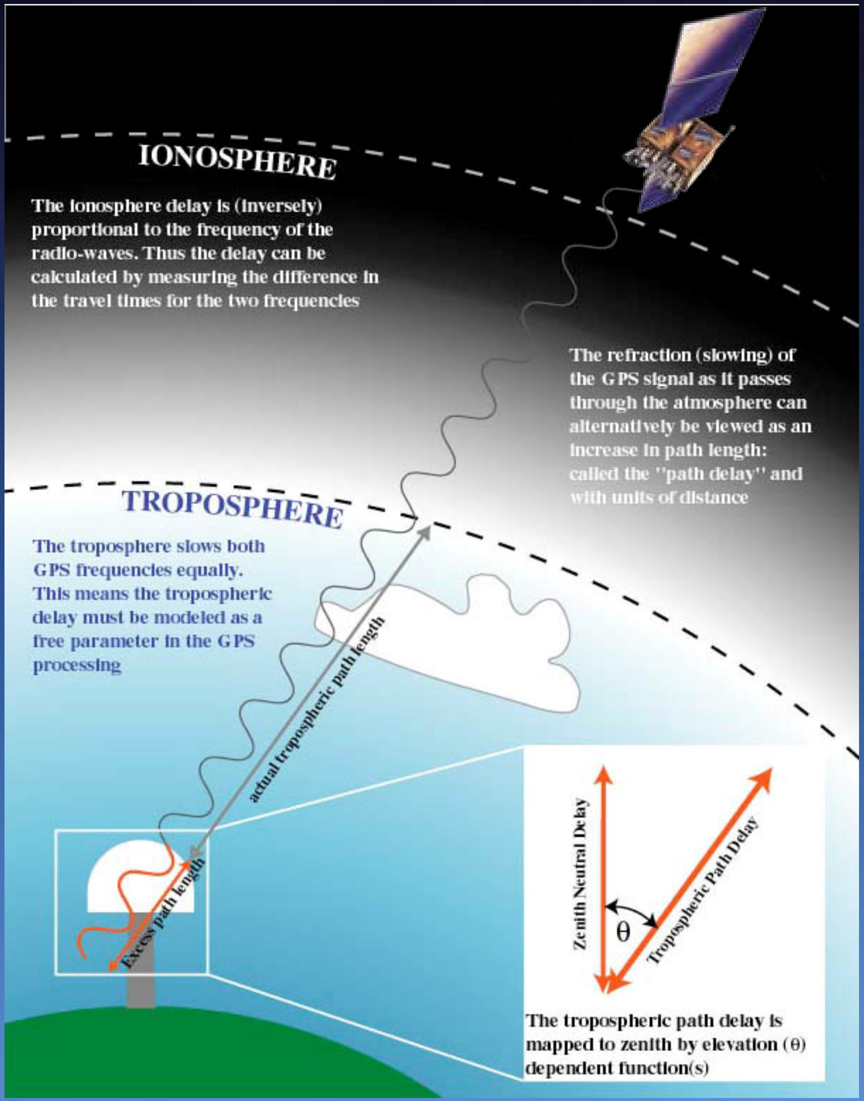
- The satellite Global Positioning System (GPS) was developed by the U.S. Military to provide high accuracy positioning, navigation & time transfer information anywhere on Earth under all weather conditions.

- The radio signals transmitted by the GPS satellites are refracted (i.e. slowed and bent) as they travel through the atmosphere.

- This introduces apparent delays in the arrival of the GPS signals that result in errors in the position of GPS receivers at or near the surface of the Earth.

NDGPS Site near Savannah

Background



- Geodesists developed techniques to model tropospheric signal delays as "noise" and remove them to improve survey accuracy.
- In 1992, Mike Bevis (then at NCSU) and others proposed that this noise was actually a "signal" that could be used to measure water vapor in the lower atmosphere.
- Understanding the implications of this for weather forecasting, NOAA collaborated with several universities to develop techniques to monitor water vapor using dual frequency GPS receivers.

Overview of GPS Meteorology

GPS SV

GPS Signal in Ionosphere

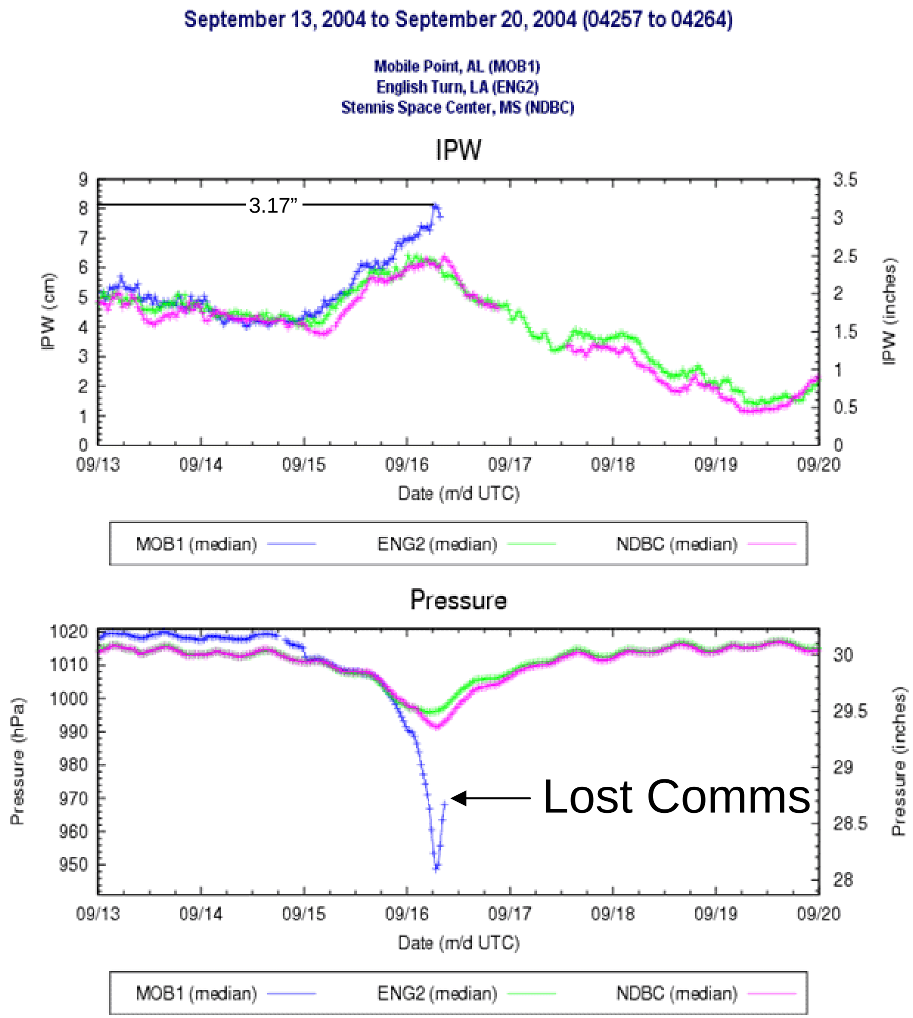
- Refractivity associated with changes in electron plasma density or TEC between 50 and 400 km AGL.
- Signal delays in dispersive media are inversely proportional to frequency.
- Ionospheric delays are estimated (or removed) using dual frequency receivers.

GPS Signal in Troposphere

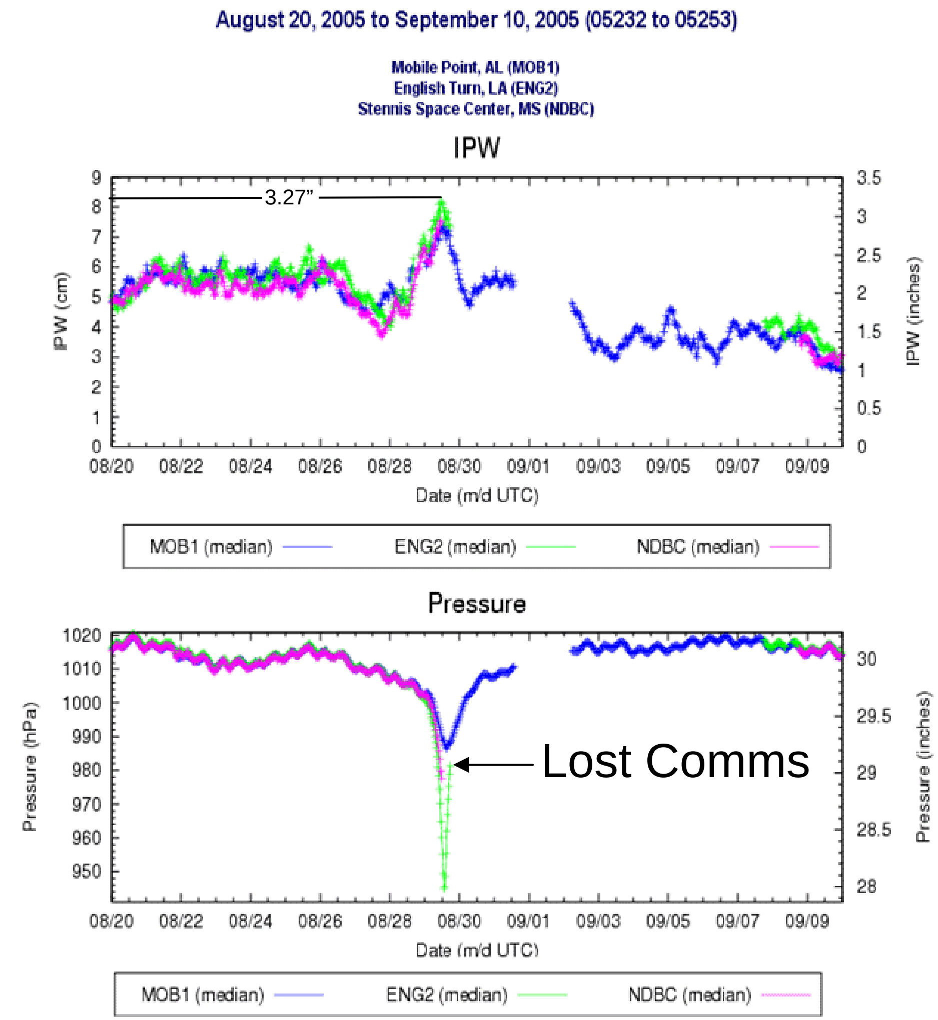
- Refractivity associated with changes in T,P,WV in neutral atmosphere.
- Signal delays are unrelated to frequency below 30 GHz.
- Delays are estimated as a free parameter in the calculation of antenna position.

DGPS Site
English Turn, LA

GPS Water Vapor Observations During Hurricanes Ivan (2004) & Katrina (2005)

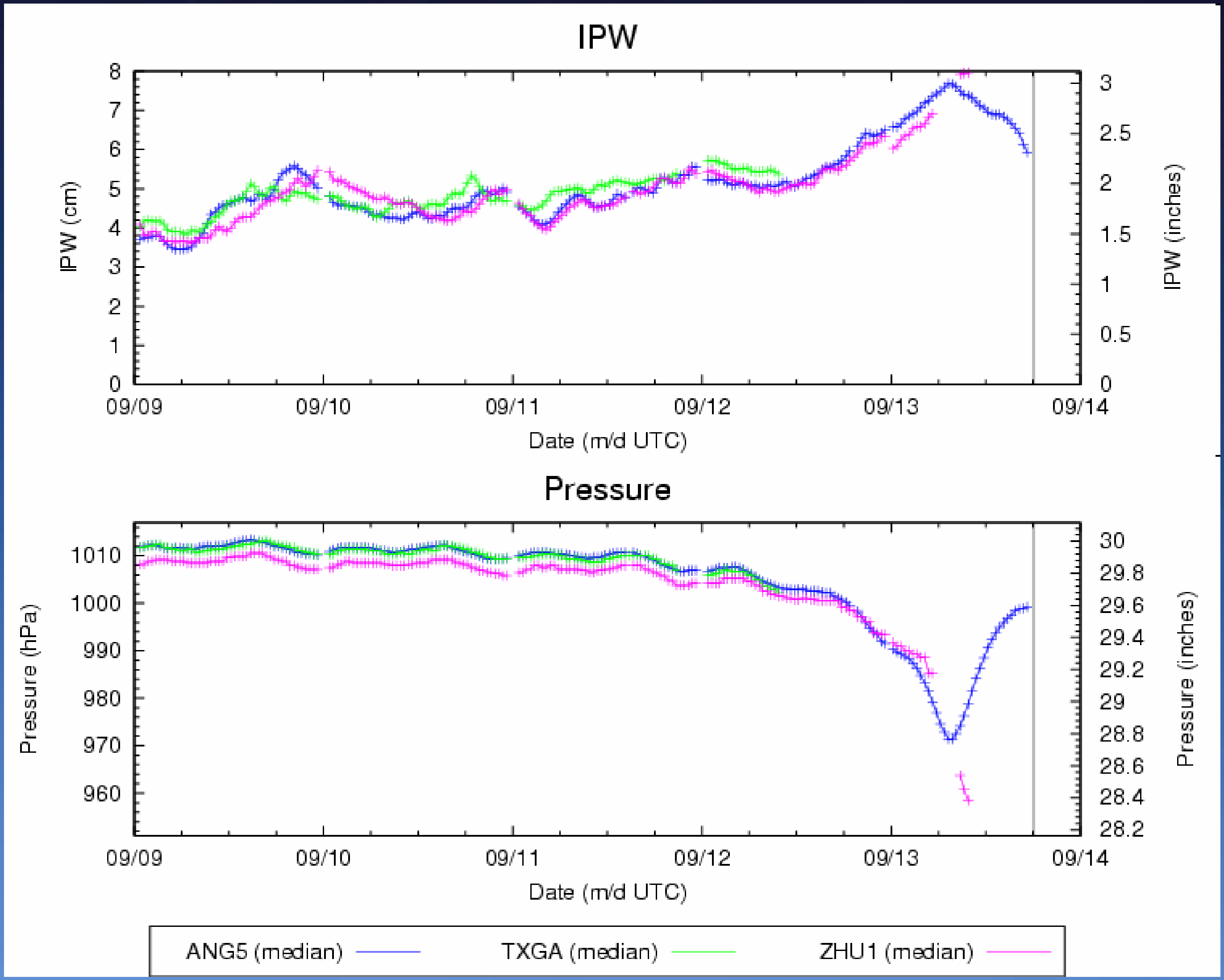


Hurricane Ivan



Hurricane Katrina

Here's What Hurricane IKE Looked Like From Three Sites in the Houston-Galveston Area



Lessons Learned

- Need more surface and upper-air observations.
  - ✓ Complete NDGPS.
  - ✓ Put GPS offshore: on islands & drilling platforms.
  - ✓ Expand GPS coverage along the coasts of the U.S., Mexico, the Caribbean, and Central America.
- Observing systems need to be more resilient.
  - ✓ Harden sites.
  - ✓ Ability to switch from local power and communications to backups (e.g. batteries and satellite communications).

Thanks for your attention!

Any questions?

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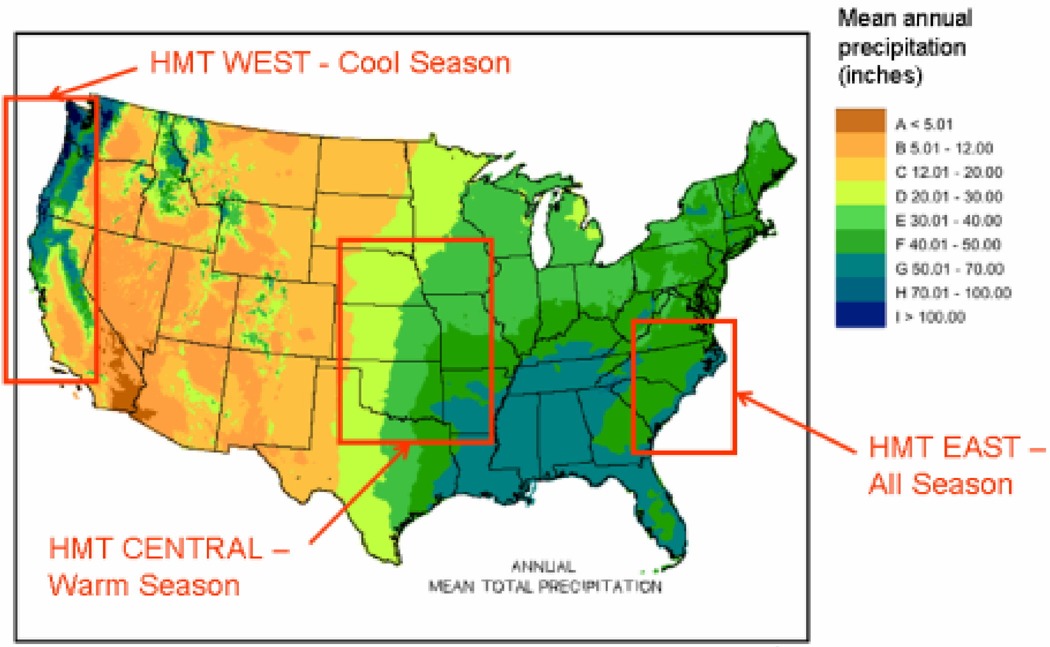
NOAA Hydrometeorological Testbed Program

Regional Implementation Strategy



The national Hydrometeorological Testbed program will be implemented incrementally in different regions of the U.S.

- Evaluate promising new observing systems and techniques to improve numerical hydrological prediction and nowcasting.
- Assess their value in terms of improvements in regional Flood/Flash Flood Warning and Quantitative Precipitation Forecast (QPF) performance.
- Use these results as an objective basis for making decisions on transitions to operations both in the test region and nationally.