Equatorial and Low Latitude Scintillation Initiated From Low Altitude Forcing via Hurricanes/Typhoons

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Outline

- Background: Evidence of Hurricane/Typhoon effects on the Ionosphere
- Theory of Low Altitude Coupling to the Ionosphere
- GPS data
- Observations of scintillation correlated with storms
- Summary

Evidence of Low Altitude Forcing on the Ionosphere.

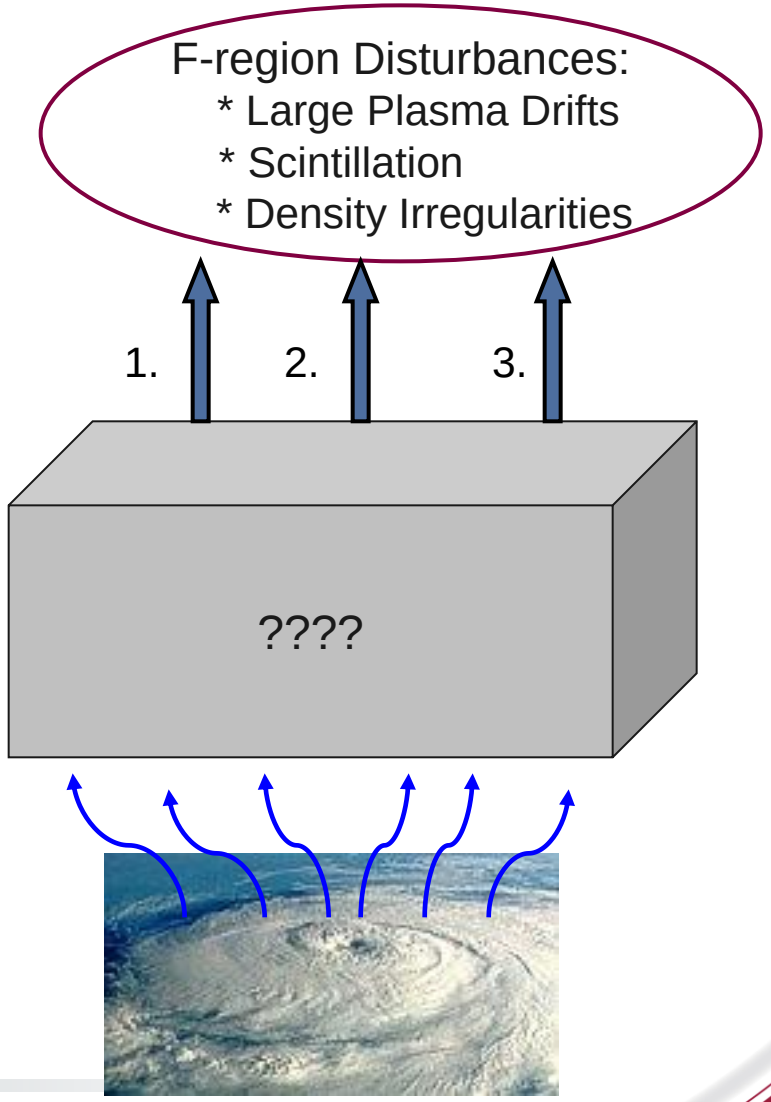
Hurricanes, Typhoons, Tropical Storms

- Bauer [1958] study
  - *F-peak density increased associated with nearby passage*
- Hurricane Eloise,1975
  - *Observed wave-like fluctuations at F region altitudes with horizontal wavelengths on order of 100 km. [Hung and Kao,1978]*
- Hurricane Dennis, Hurricane Floyd, 1999
  - *Night following B-field crossing MSF observed by WFF ionosonde.*
- T.S. Odette, 2003
  - *ISR, ionosonde, GPS occultation, microbarometer data obtained during close passage of storm to Puerto Rico.*
  - *Large, anomalous F-region plasma drifts observed [Bishop.*
- Other Storms:
  - *Variations in F-peak density, altitude preceding and following storm observed by ionosondes.*

Dynamical Coupling

The Picture So Far…

- Gravity waves generated at tropospheric altitudes propagate to the F-region
- Gravity waves generated from storms break near 100 km and produce secondary waves that continue to propagate upward
- Gravity waves modulate the E-region plasma producing polarization fields that map to F-region altitudes.

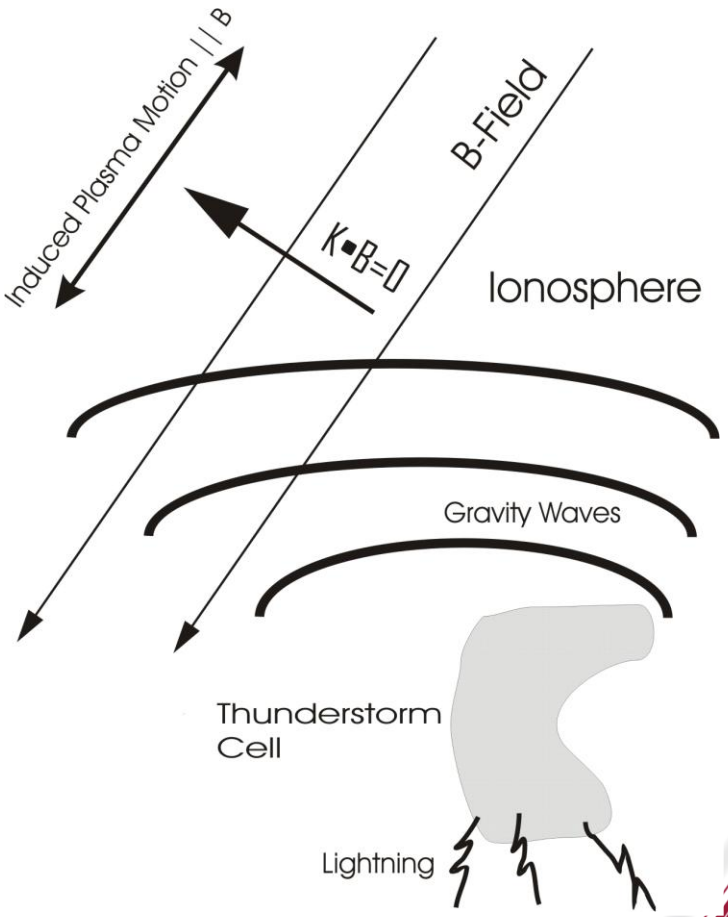


Courtesy of NOAA

Dynamical Coupling: Gravity Wave

Theory

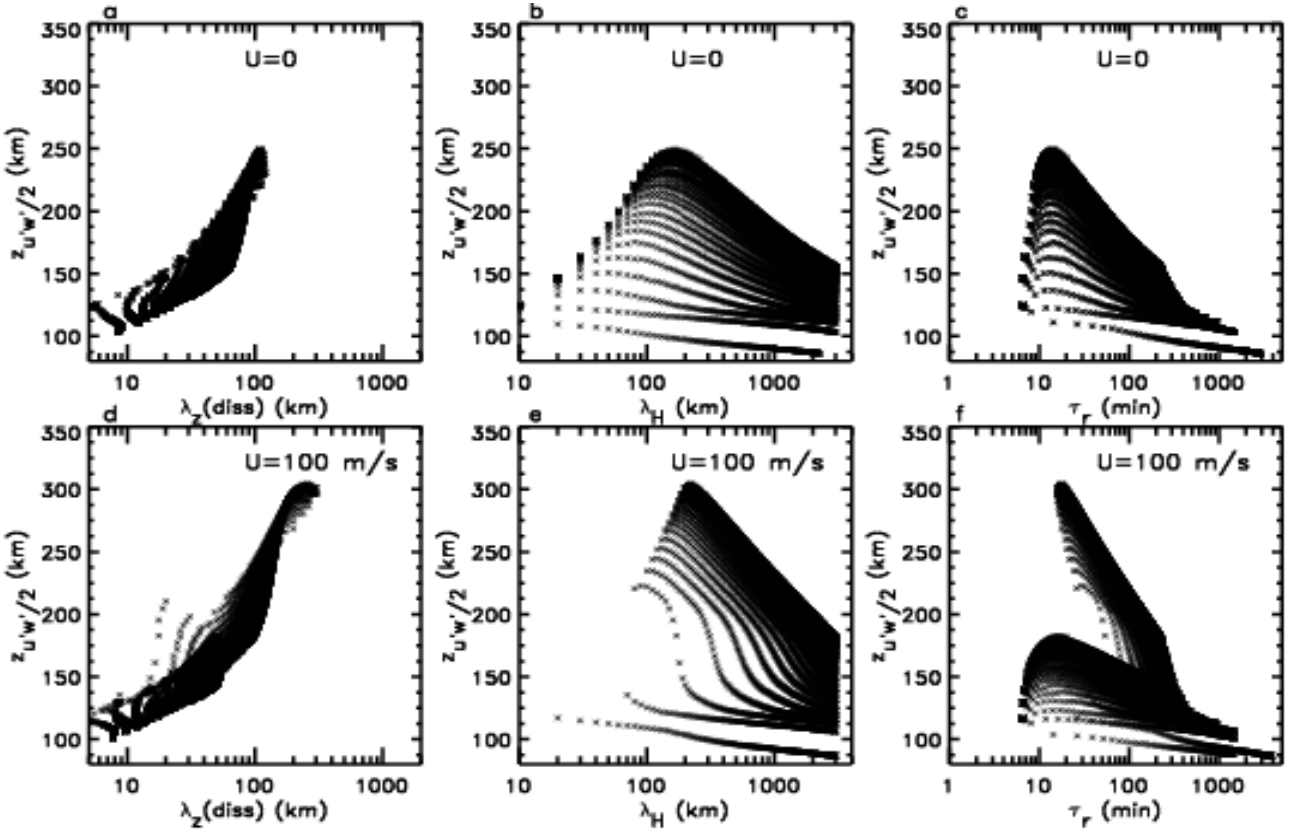
- Strong convection cells produce a wide spectrum of gravity waves
- Gravity waves increase in amplitude with increasing altitude and may become unstable
- Only waves propagating at the certain angles and with the correct amplitude can reach thermospheric altitudes
- Once in the thermosphere, only those waves oriented to the magnetic field in a particular manner may produce ionospheric disturbances



Dynamical Coupling: Gravity Wave

Model Results

- Efforts by Vadas et al. have shown gravity waves from convection cells (thunderstorms) capable of reaching the lower F-region.
- Depending on the background wind field, gravity waves may penetrate to 300 km altitude.

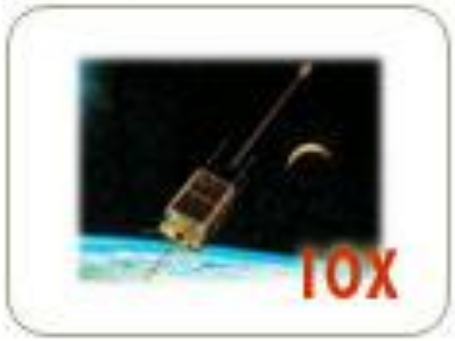


Courtesy of S. Vadas

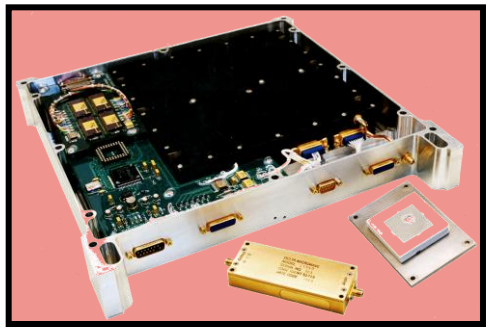
PicoSat Mission

IOX sensor

- Launched September 30, 2001 on Athena-1 rocket
- Orbit: 67 inclination, 800 km altitude
- Precesses through all local times in ~50 days
- Four Science instruments on-board
- GPS Instrument: Ionospheric Occultation Experiment (IOX)
  - *Lifetime: Oct. 21, 2001 to Nov. 25, 2004*
  - *Single aft-viewing antenna*
  - *PI: Dr. Paul Straus, The Aerospace Corporation*
- IOX data limited over North America due to spacecraft downlink



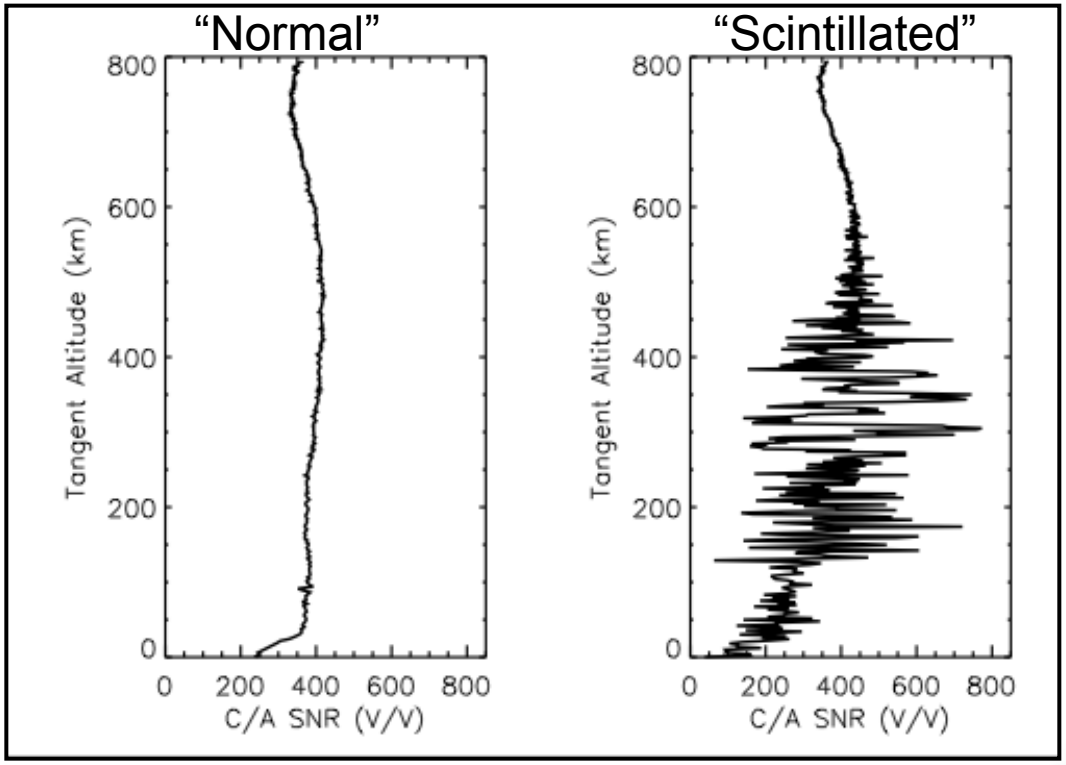
Courtesy NASA/JPL-Caltech



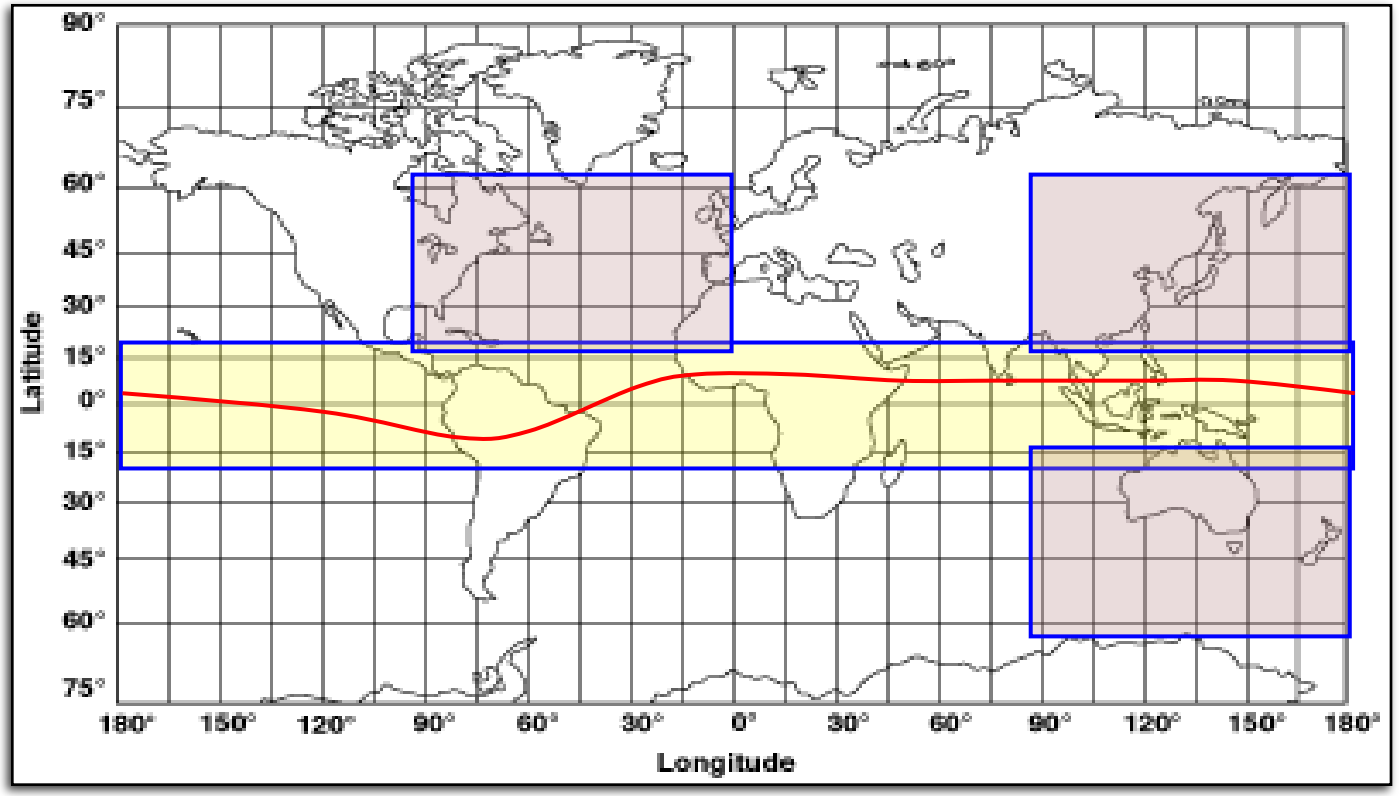
IOX GPS RO

IOX Classification of Scintillation

- Scintillation defined by large variations in C/A SNR.
- S4 calculated using data above 150 km
- Profile classified as scintillated when S4 $\geq$ 0.1
  - *IOX Noise Threshold: ~0.02*

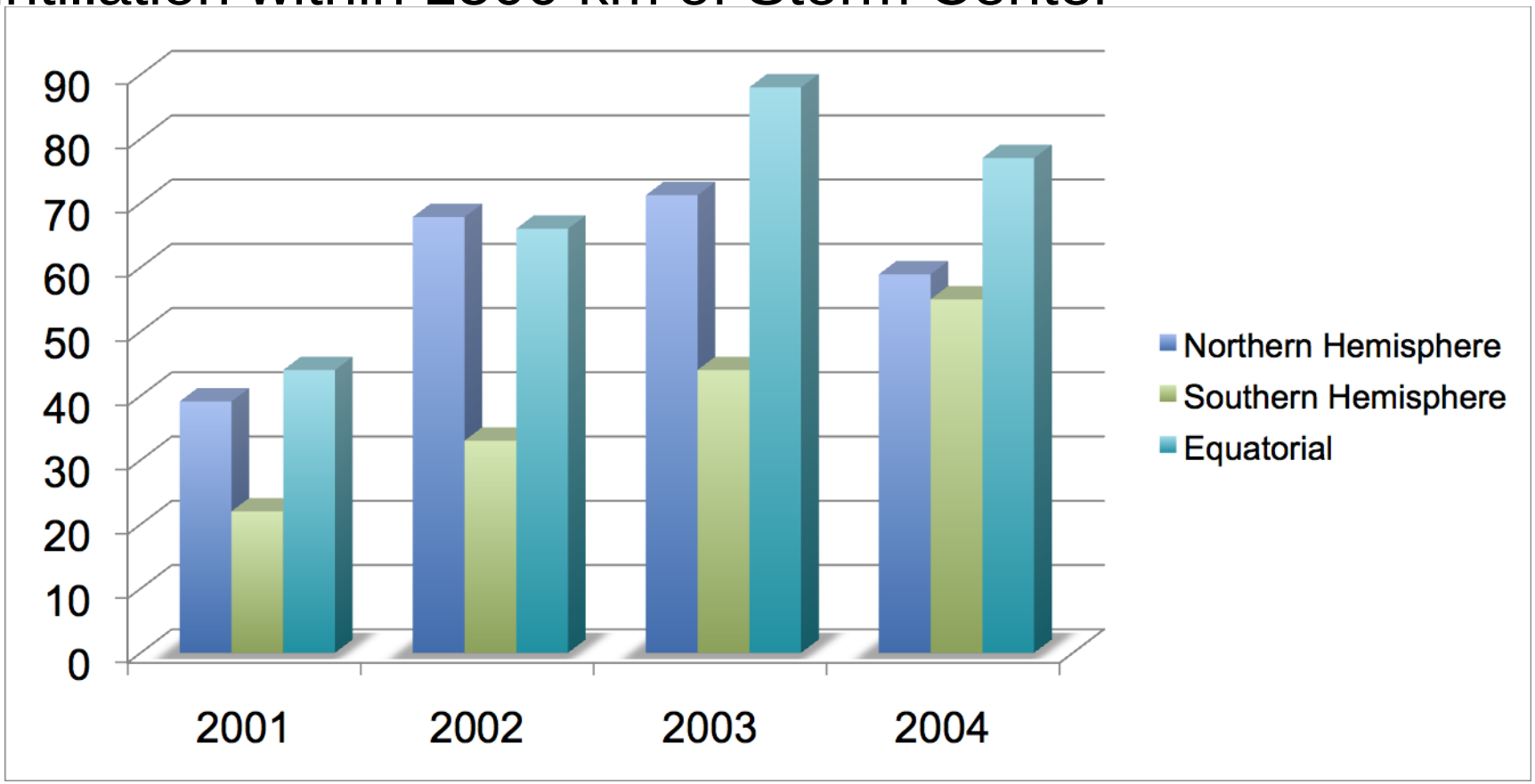


Region of Interest for Study



- Northern Hemisphere Storms: 152 (>600 days)
- Southern Hemisphere Storms: 76 (>300 days)
- Equatorial Hemisphere Storms: 287 (>400 days)

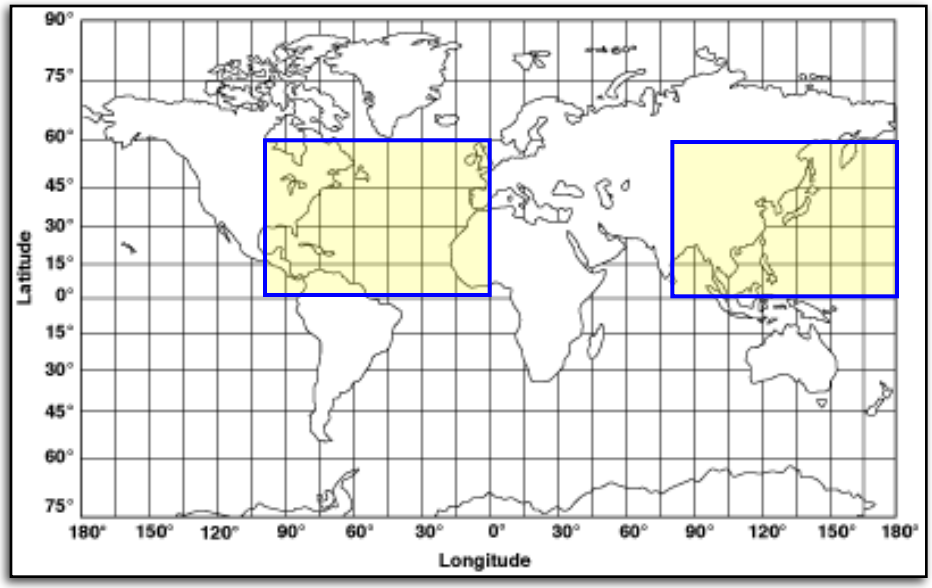
Scintillation within 1500 km of Storm Center

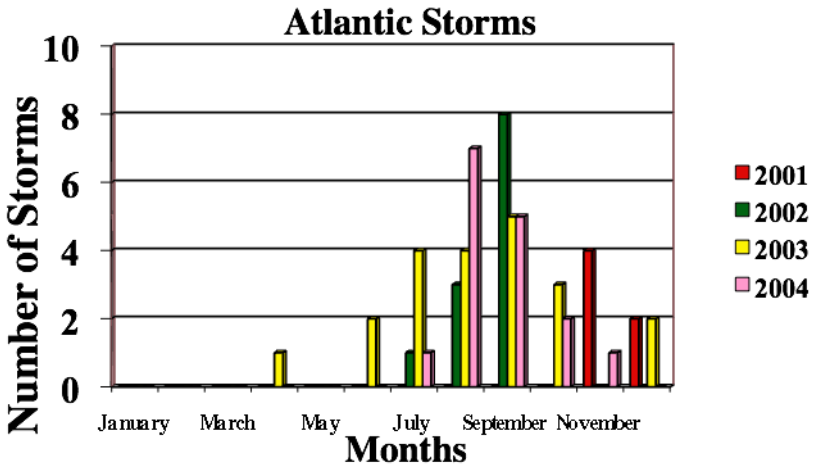


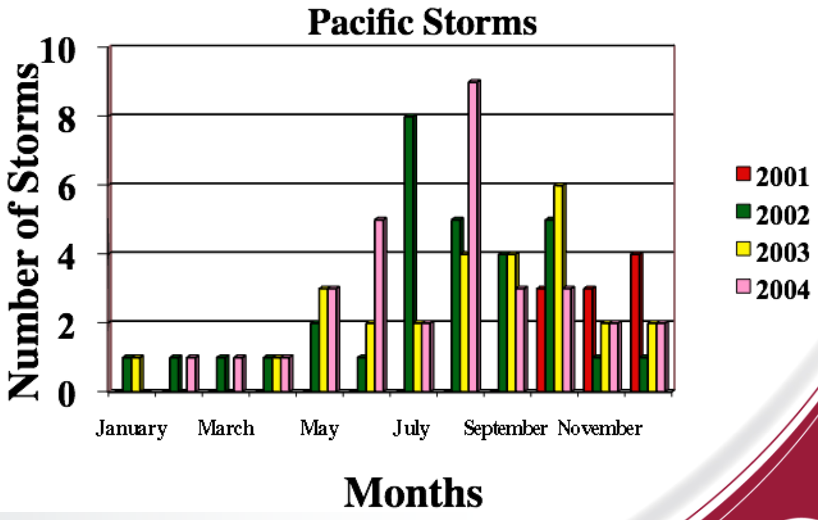
- Typically mid-latitude scintillation occurred ~10-30% of time
- Equatorial scintillation near storms occurs more frequently than at mid-latitudes
- Occultations near dawn/dusk terminator removed.

Atlantic vs. Pacific

Distribution of storms



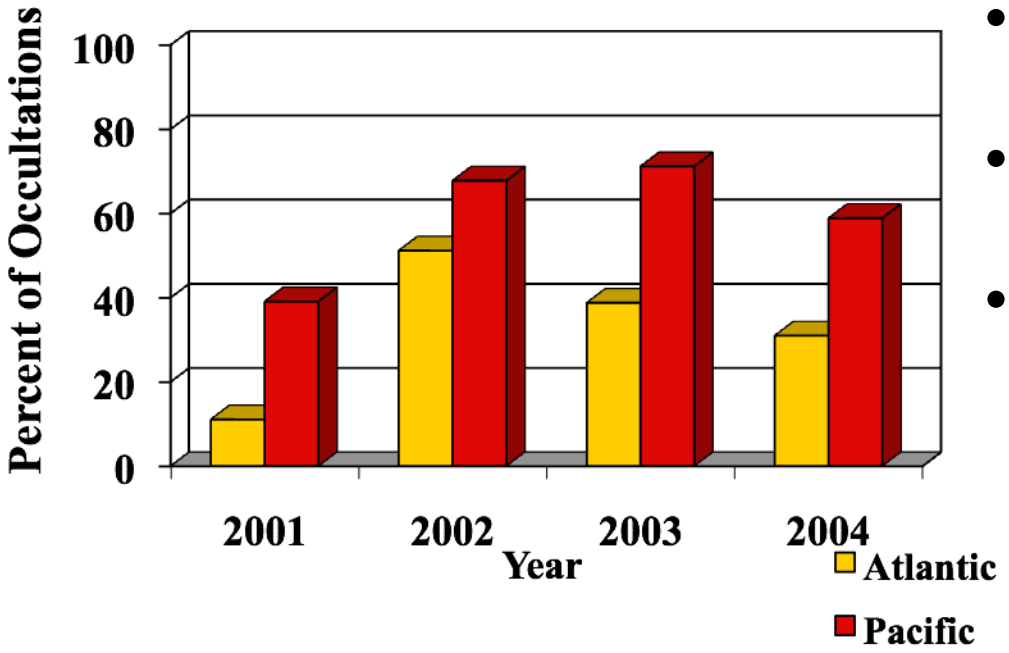




- Total Atlantic Storms: 55
  - *Total Days:215*
- Total Pacific Storms: 97
  - *Total Days: 540*

Atlantic vs. Pacific

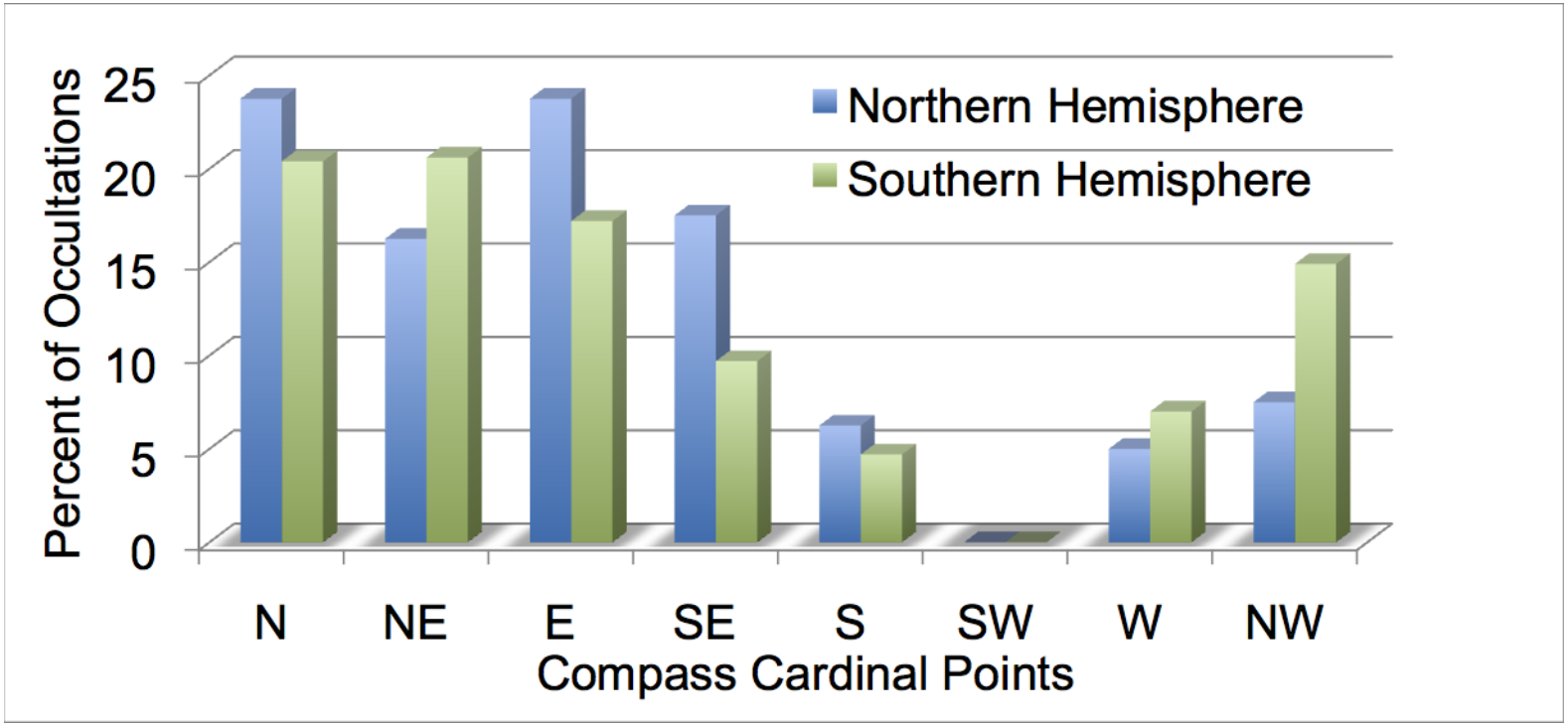
Scintillation Occurrence Statistics



- 2002-2004 Atlantic storms observe scintillation over 30%
- 2002-2004 Pacific storms observe scintillation over 50%
- 2001 had small number of nearby occultations, not statistically significant
  - *IOX operating only 2 months*

Northern vs. Southern Hemisphere

Orientation of Scintillation Occurrence



- Scintillation profiles sorted by relative position to storm eye
- Scintillation not observed southwest of the storm center.
- Pacific storms tend to move west, northwest, north, northeast
- Large percentage of scintillation occurs east of storms

Summary

- IOX GPSRO data was examined for areas in the Atlantic, Pacific, and equatorial regions that are dominated by tropical cyclones.
  - *287 storm periods used over a period of more than than three years*
- Total number of occultations within 1500 km of storm center: **>62000**
- If coupling occurs due to the storms, it is very localized.
- Scintillation occurs more than 60% of the time for occultations within 1500 km of storm center in the pacific
- Scintillation occurrence does not occur southwest of the storm center
- Scintillation occurrence shows no dependence on Kp, Dst

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- Hung, R. J., Kuo, J. P., Ionospheric Observation of Gravity-Waves Associated With Hurricane Eloise, J. Geophys., 45, 67-80, 1978.