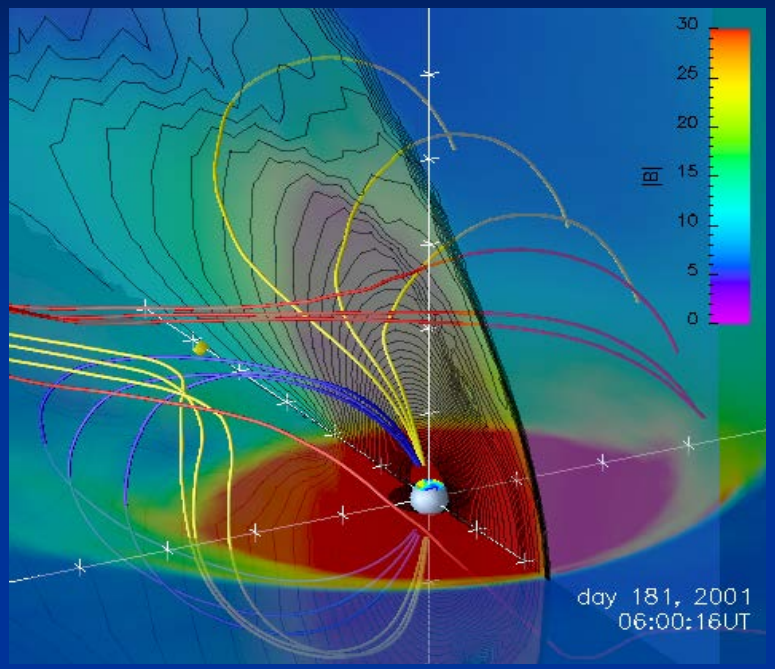
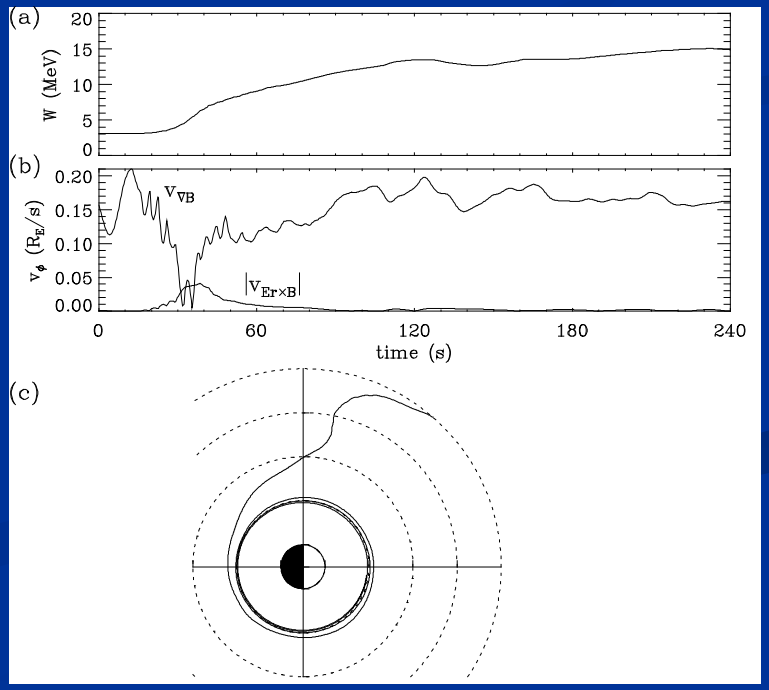
Geosynchronous observations and global models of the radiation belts



- MHD treats plasma as magnetized fluid
- Driven by upstream boundary conditions
- Includes reconnection, convection, external contributions to B, etc.
- Does not include high frequency waves, kinetic effects, Hall physics, multiple species, etc…



"Test particle" simulations track the equations of motion for a charged particle moving in a model electric and magnetic fields, in an attempt to better understand the physics and dynamics of the energetic particle environment.

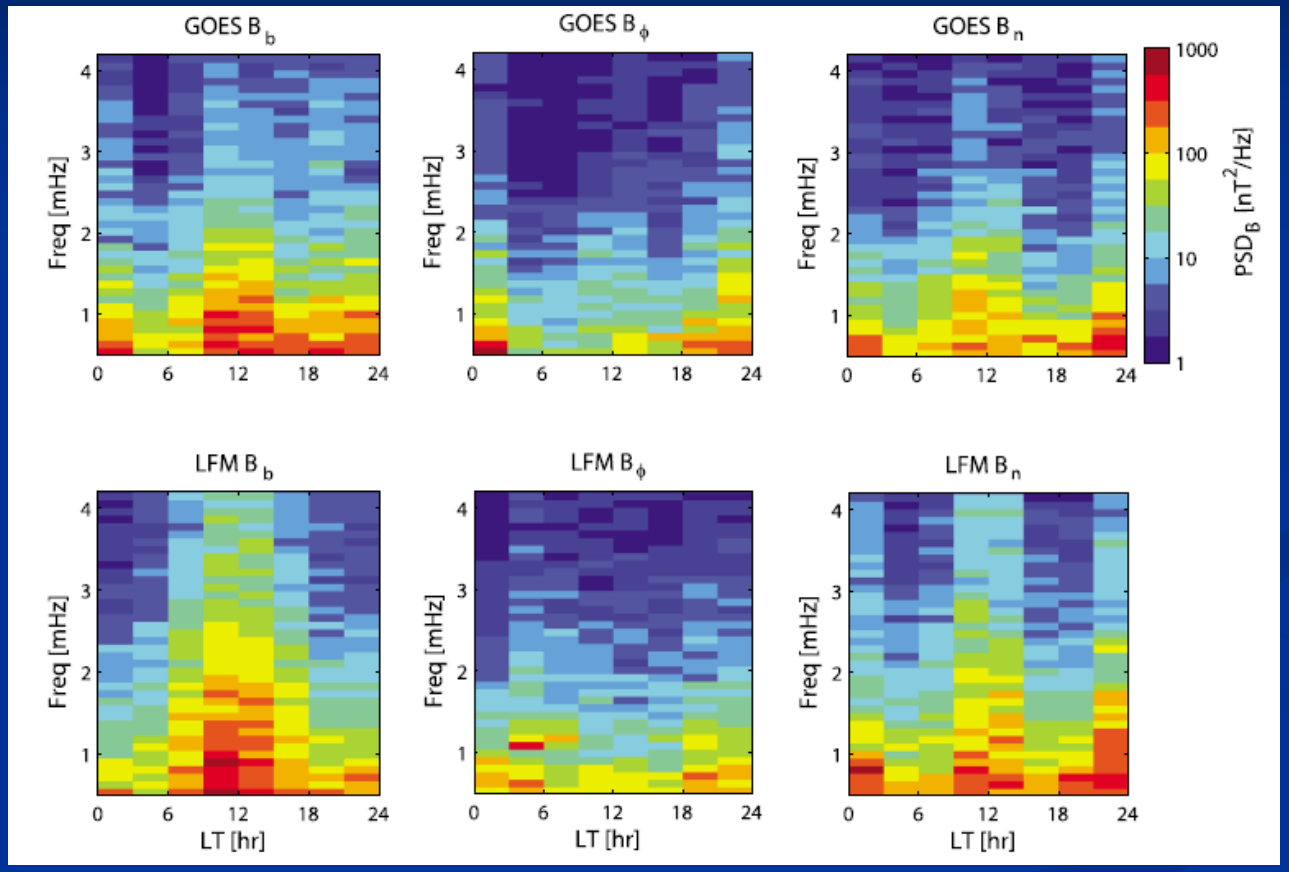
Particle energization and ULF waves

- Magnetospheric ULF (mHz) waves driven by the solar wind can effectively heat and transport energetic particles in geospace.
- Efficiency of particle energization depends on explicit physical properties of the induced waves.
  - ✓Frequency spectrum of the waves
  - ✓Radial extent of the waves
  - ✓Azimuthal propagation of the waves
  - ✓Azimuthal extent of the waves
  - ✓Mode structure of the waves
  - ✓Electromagnetic character of the waves

$$\omega = m\omega_D$$

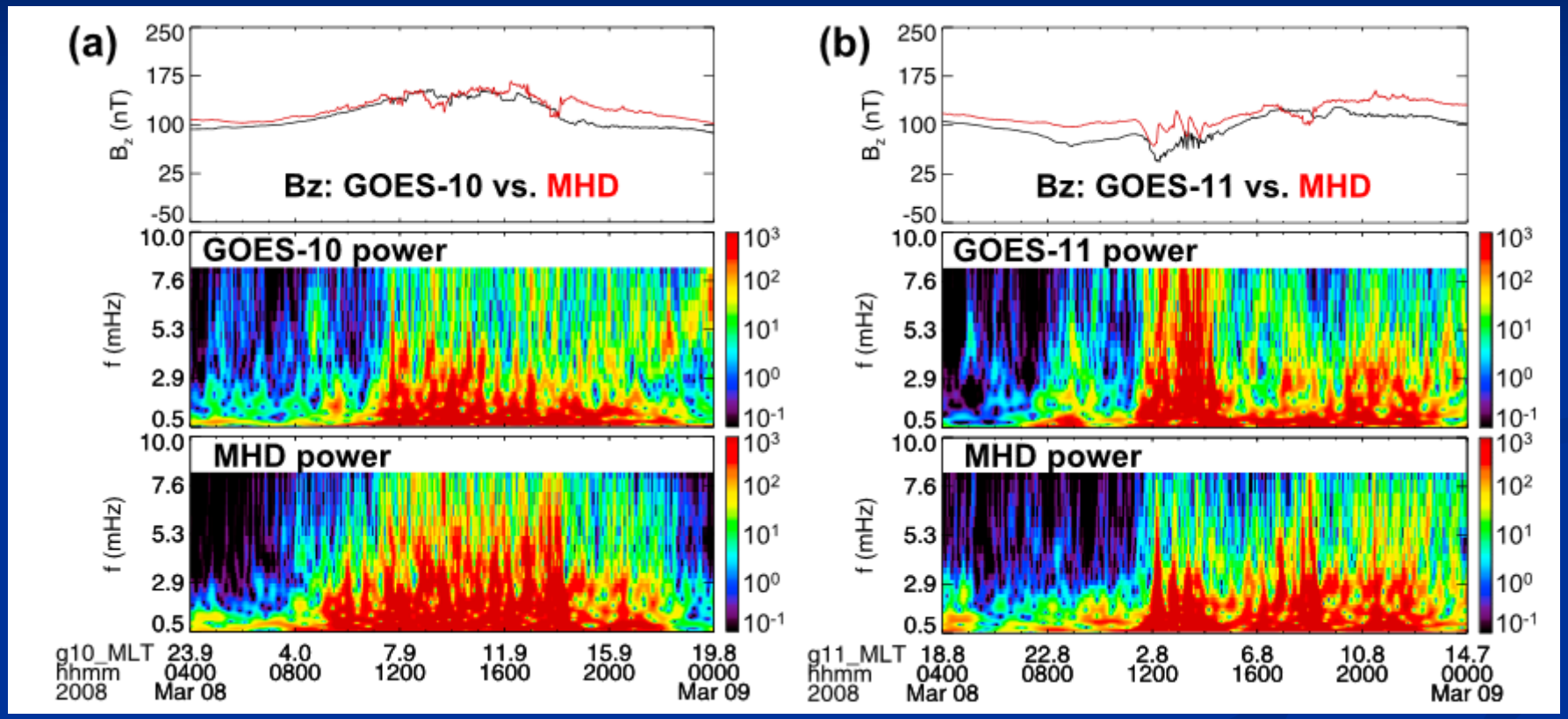
- Mode structure, spatial extent, and propagation characteristics are not easily obtained from single-point measurements of ULF waves.
- With N distributed measurements, you can determine the mode structure up to m=N/2.

Validating models with geosynchronous observations: statistical results



Huang et al. (2010a) compared 9 years of statistical GOES magnetometer data to a 27-day MHD simulation to understand the extent to which global simulations could correctly model ULF variations at geosynchronous orbit.

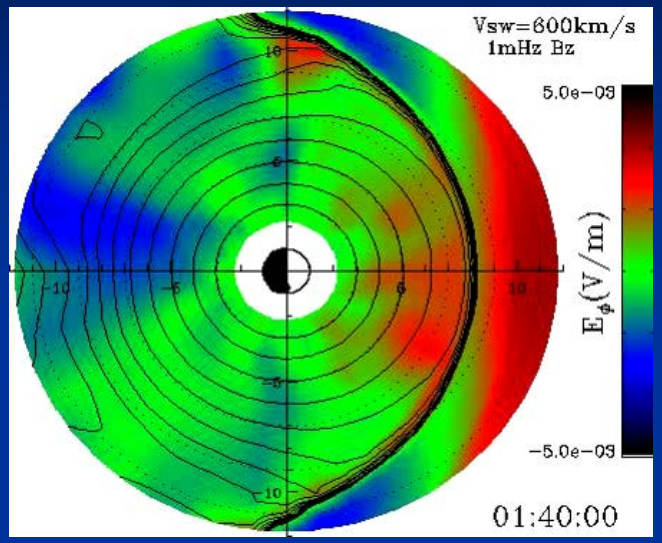
Validating models with geosynchronous observations: event studies

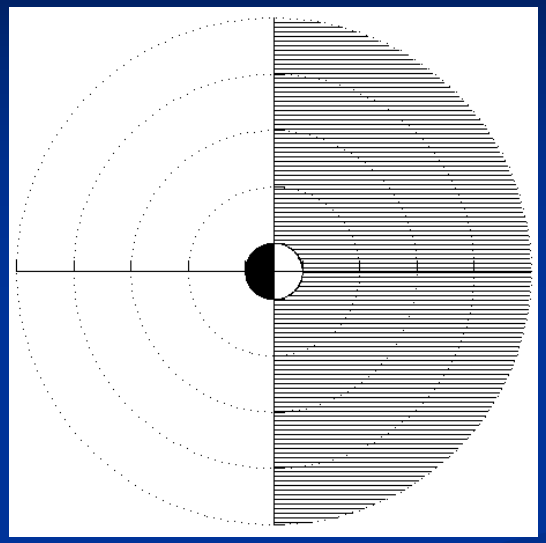


Tu et al. (2012) similarly compared GOES power spectral densities to simulation results in a detailed study of a single storm.

Mode structure visualized

m=1



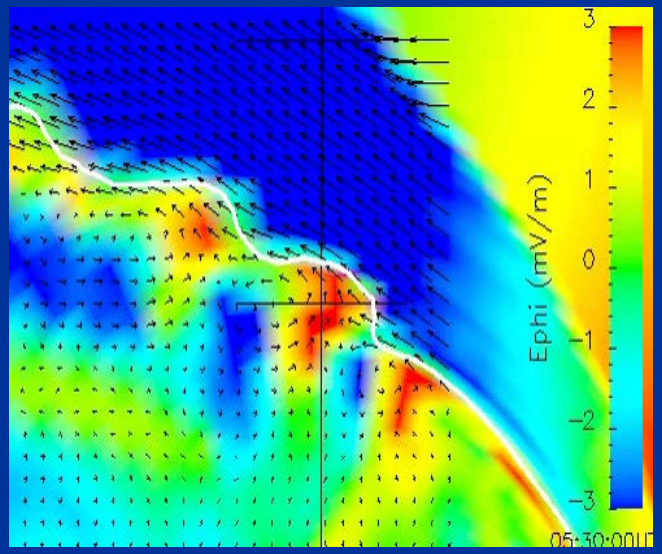


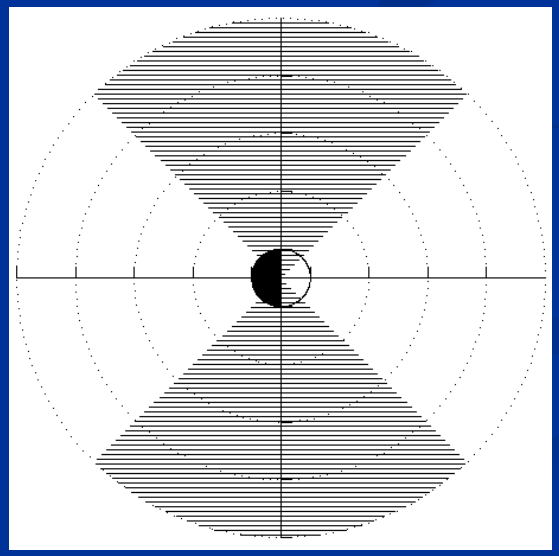
$$\omega = m\omega_D$$

m=1, possible sources:

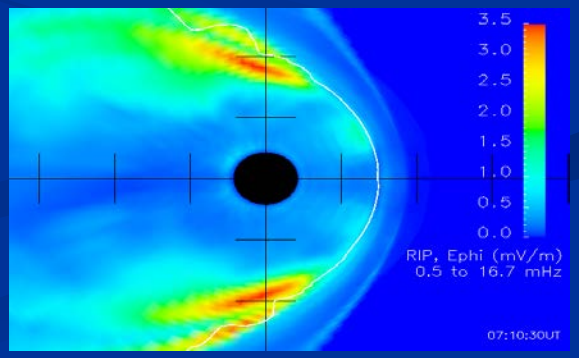
- Variations in dynamic pressure in SW=>changes in global field config.
- Variations in global reconnection=> changes in global convection.

m=2



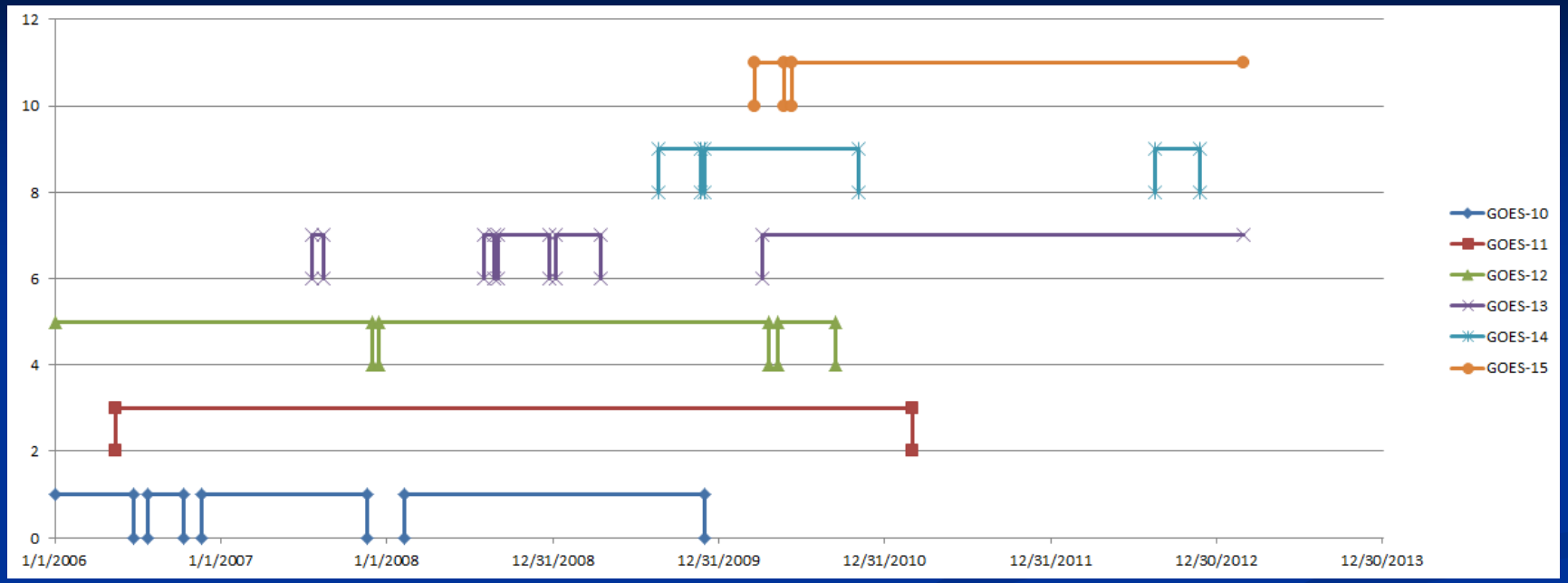


m=2, shear waves on flank



S. Elkington, 3/14/2015

Mode structure analysis and 'parked' GOES



In addition to the operational GOES-East and GOES-west, there are frequently other spacecraft 'parked' in orbits at various other longitudes.

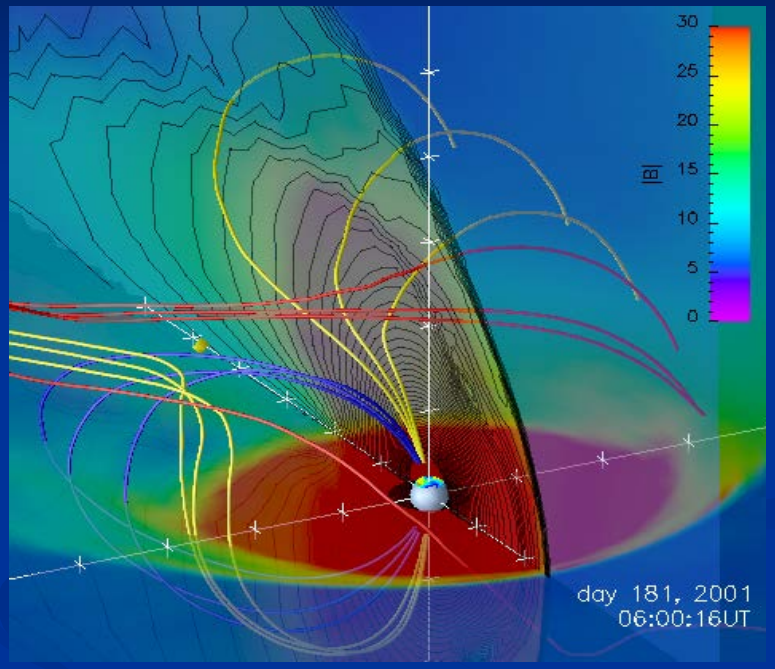
For example, for a 5 month period in 2010 there were 5 GOES spacecraft

The availability of data from these other spacecraft will provide a boon in constraining/determining the global mode structure of ULF waves in the magnetosphere.

Geosynchronous observations and global models of the radiation belts

GOES magnetic field and particle observations have considerable value to the research simulation community:

- Verifying simulations of magnetic field fluctuations
- Multipoint measurements of ULF waves
- Particle observations as input for boundary conditions



What would make GOES more valuable to the research simulation community?

- Electric field measurements
- Higher-frequency E & B observations (EMIC~5Hz, Chorus~kHz)
- Availability of data from parked spacecraft