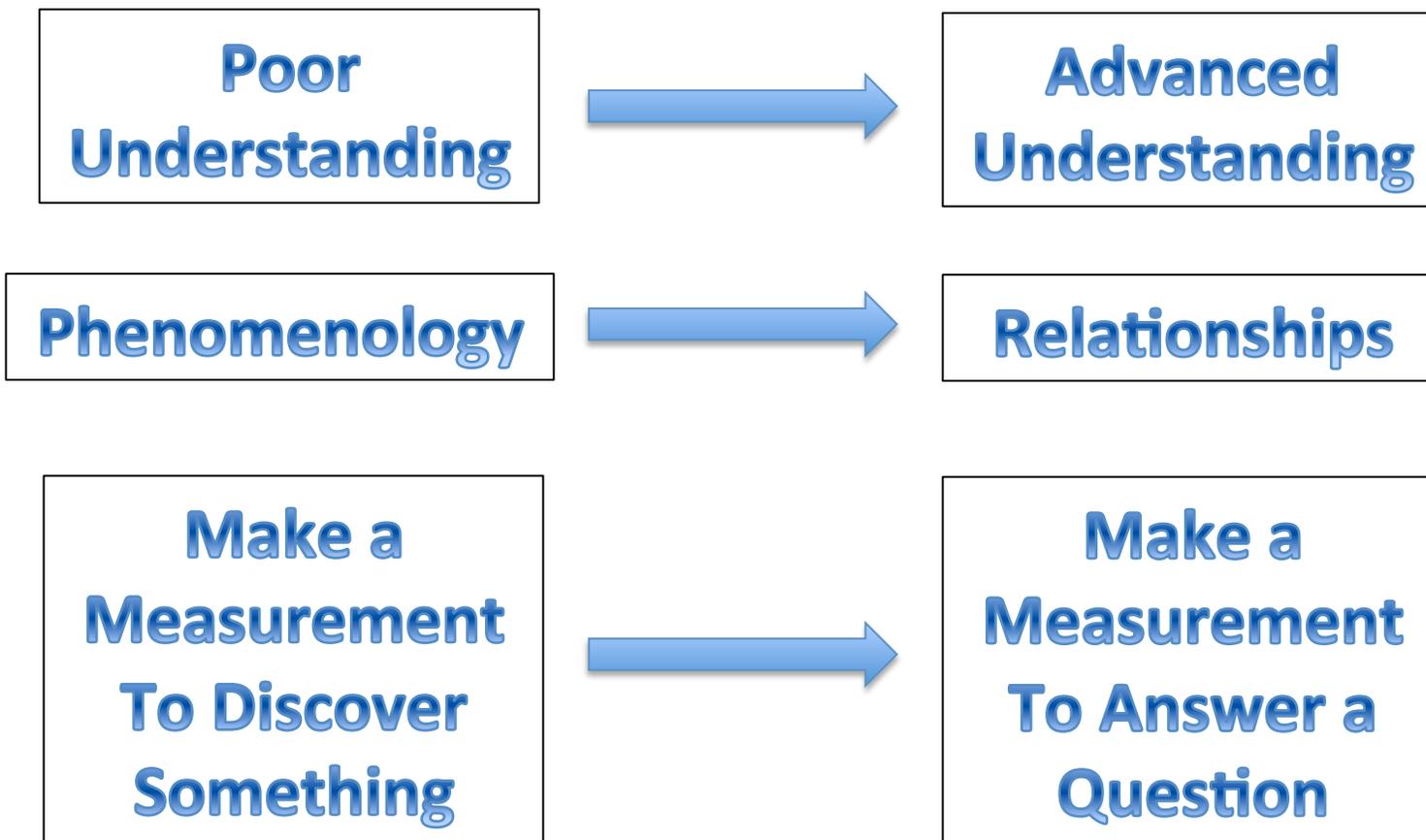


# FROM DISCOVERY TO SYSTEM SCIENCE

Rod Heelis  
University of Texas at Dallas

## Transitions



## A Change in Approach

**A Better something  
will produce  
something new**



**A Better something  
is required to  
elucidate an answer**

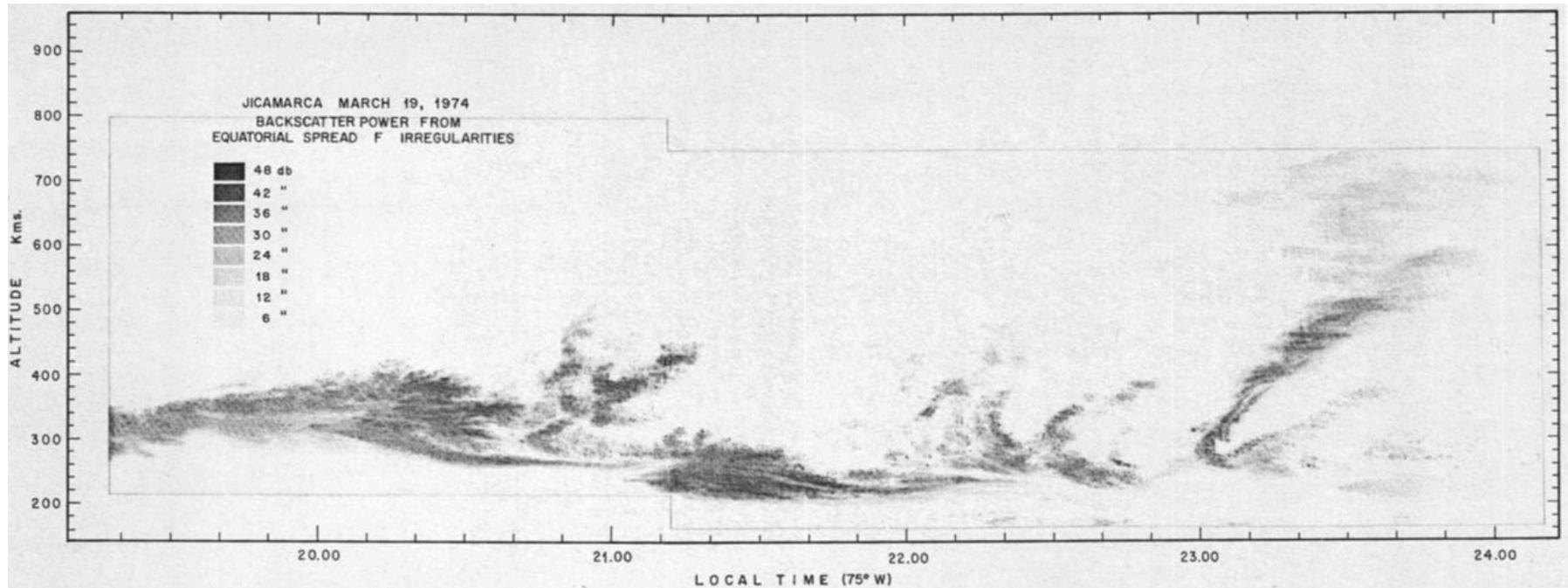
**This advance is the  
next step in the area**



**This advance is  
necessary to move  
forward**

## *Equatorial Ionospheric Irregularities*

Woodman & LaHoz JGR, 1976.



**The early seventies marked the beginning of digital processing that allowed RTI displays of spread-F to describe the shape of large-scale(100 km) envelopes (bubbles) containing small-scale (3m) irregularities.**

# DISCOVERY TO SYSTEM SCIENCE

## *The Explorer Program*



Explorer-1, 1958



Explorer-51 – Atmosphere Explorer-C, 1973

- **Many critical advances have been enabled by a regularly scheduled launch of space experiments supported by the Explorer Program.**
- **This program remains an important entry path for new scientists.**

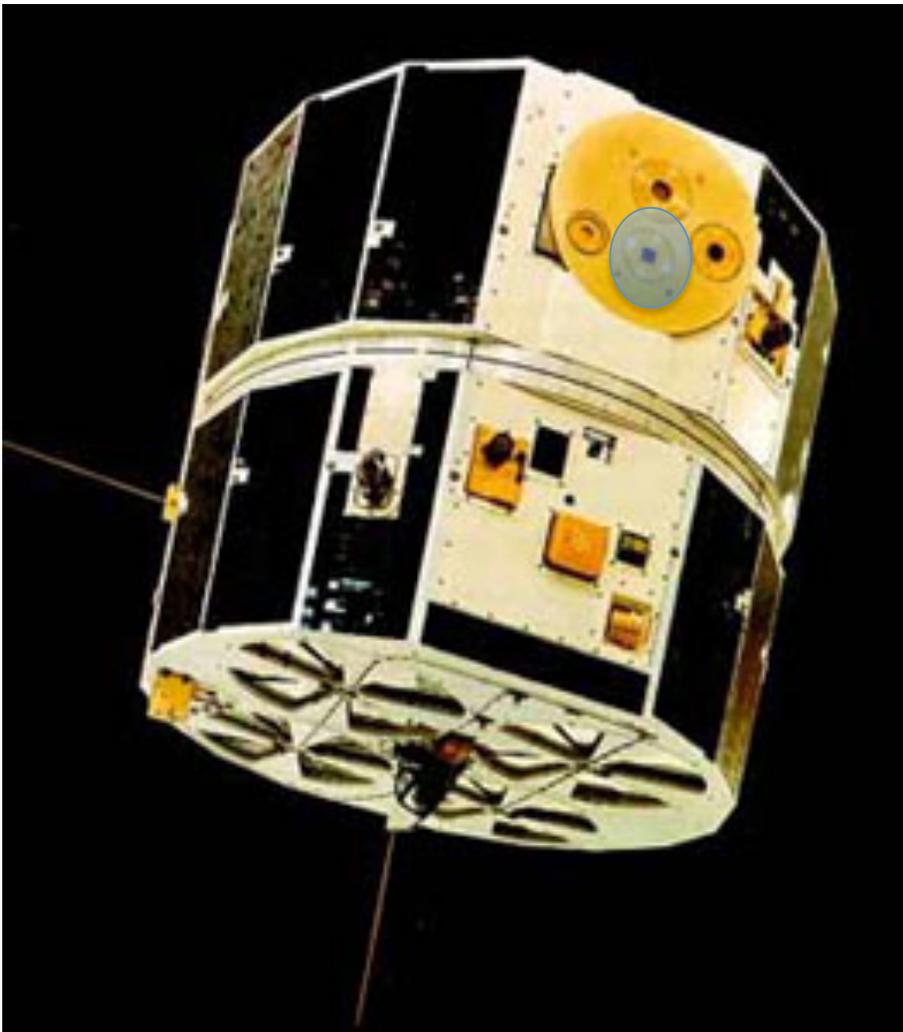
# DISCOVERY TO SYSTEM SCIENCE



*Bill Hanson and his infamous analog filing system*

# DISCOVERY TO SYSTEM SCIENCE

## *The Explorer Program*

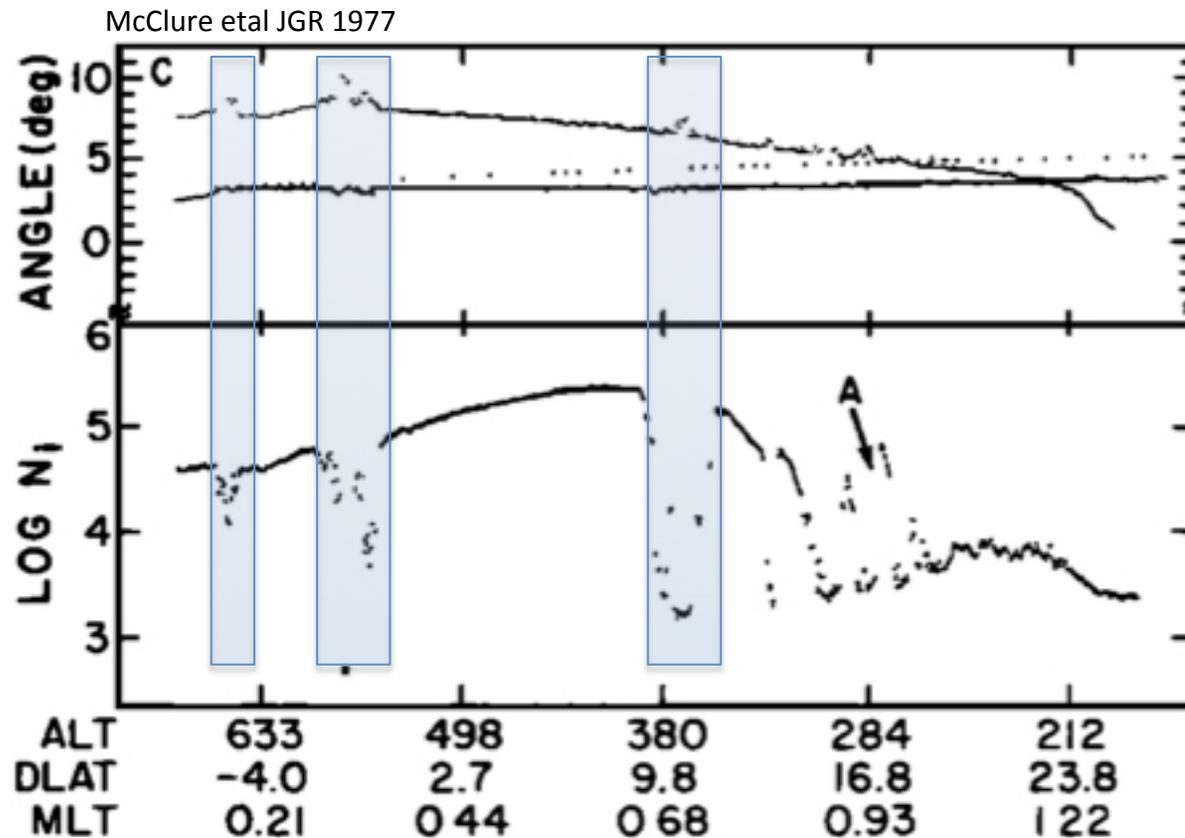


Atmosphere Explorer-C, 1973

- **Ion Drift Meter**
- 
- **New device added with little review.**
- **Large returns**

# DISCOVERY TO SYSTEM SCIENCE

## Equatorial Ionospheric Irregularities

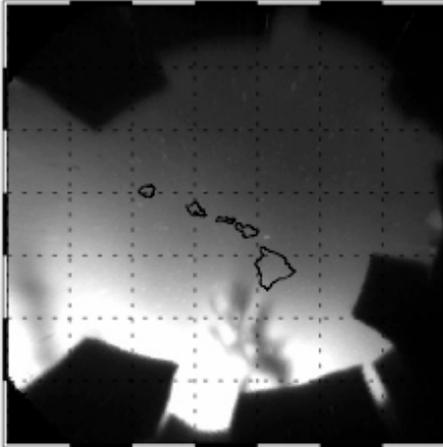


Early data from Atmosphere Explorer-C shows plasma within the bubble envelope moving upward at velocities greater than 150 m/s

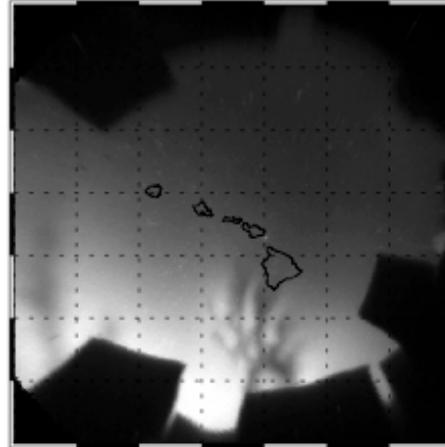
# DISCOVERY TO SYSTEM SCIENCE

## *Equatorial Ionospheric Irregularities*

630.0 nm, Feb 04, 2003 0933 UT



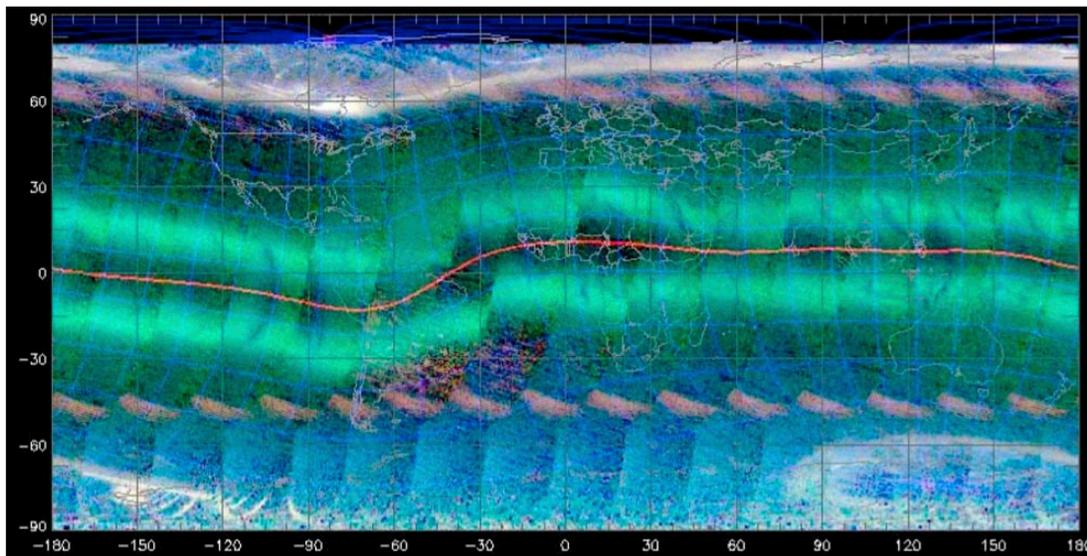
630.0 nm, Feb 04, 2003 0958 UT



Makela et al JGR 2006

Optical imagery from ground and space shows large-scale distribution of plasma depletions and small-scale bifurcations of single depletions.

Time-lapses allow envelope motions to be determined.



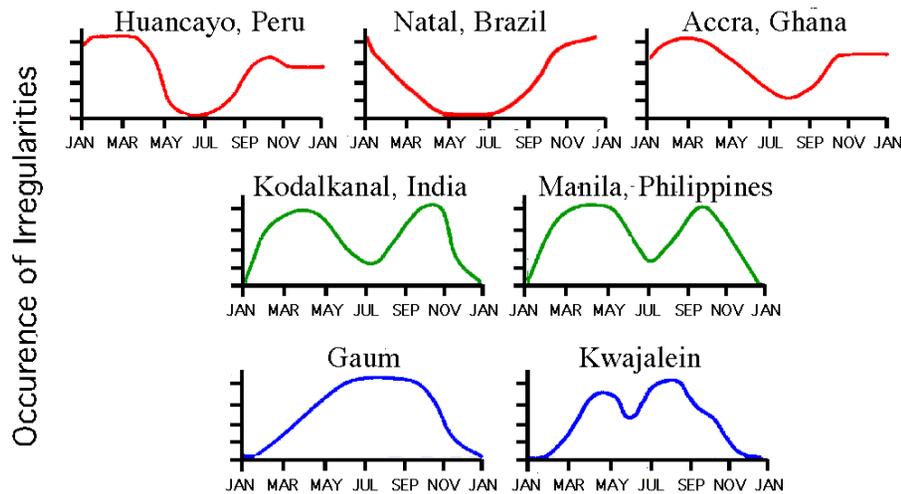
Comberiate&Paxton JGR 2010

- Where do we see them?
- What do they look like at other places?
- Can we model them?

# DISCOVERY TO SYSTEM SCIENCE

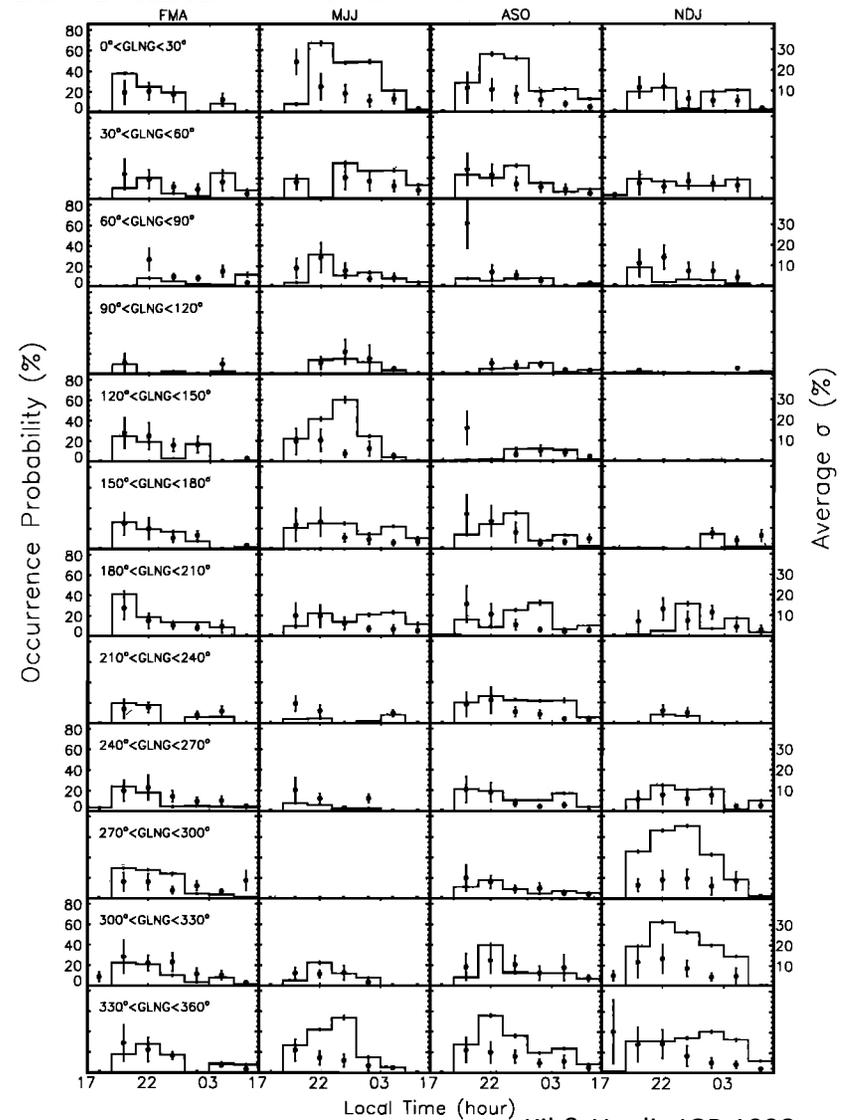
## Equatorial Ionospheric Irregularities

Aarons IEE 1977



**Examination of global occurrence of irregularities and associated radio scintillation reveals seasonal and longitudinal variations.**

ALTITUDE > 350 km: 1978-1981 YEARS:  $\sigma > 1\%$



Kil & Heelis JGR 1998

# DISCOVERY TO SYSTEM SCIENCE

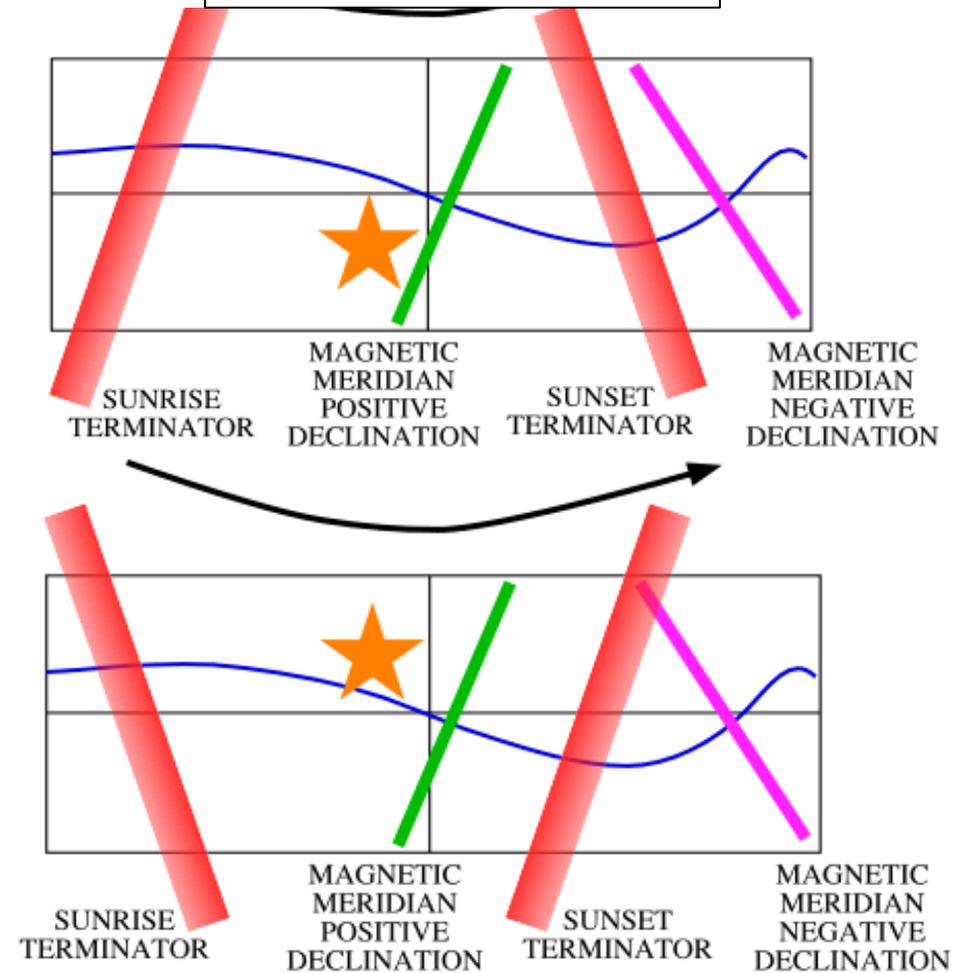
## Equatorial Ionospheric Irregularities

What, Where, When



How, Why

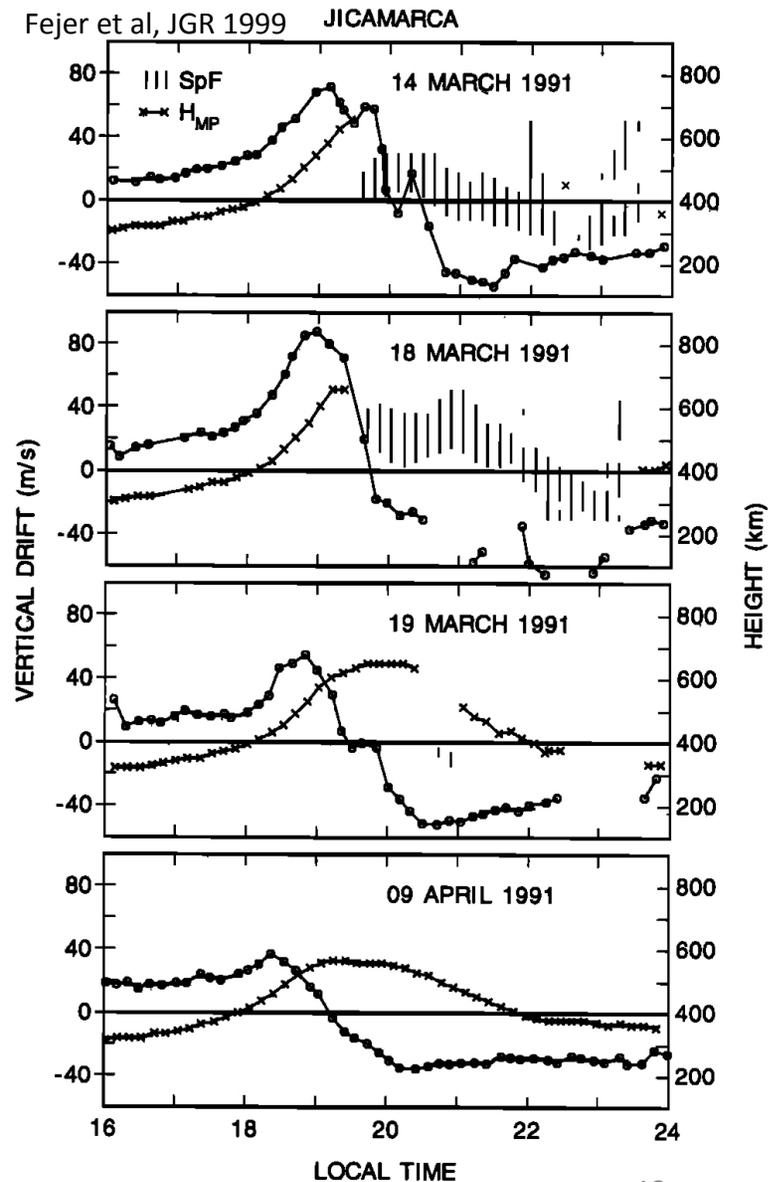
- Seasonal/Longitude variations in irregularity appearance are consistent with alignment between the magnetic meridian and the terminator.
- Assumption that E-region acts as a passive conductive element?



# DISCOVERY TO SYSTEM SCIENCE

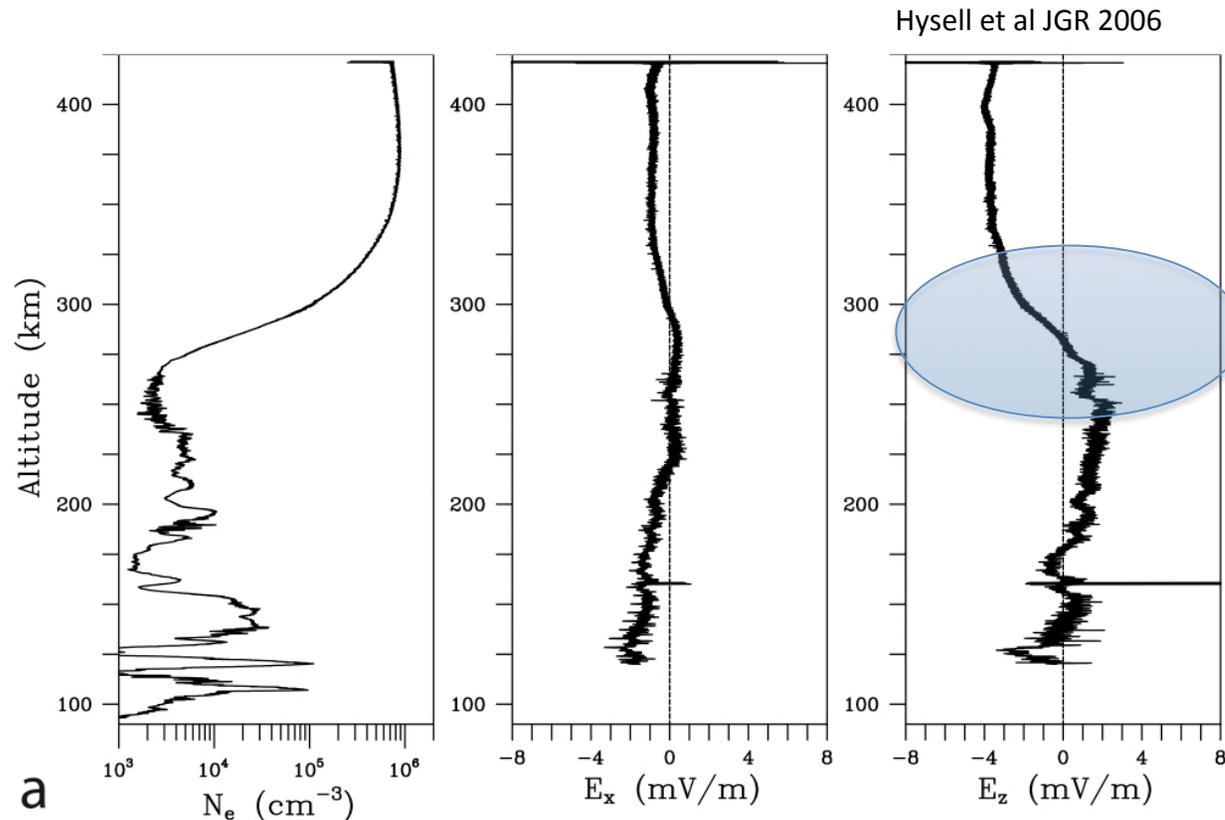
## Equatorial Ionospheric Irregularities

- The same alignment of the magnetic meridian and the terminator maximizes the effects of the pre-reversal enhancement.
- Irregularities penetrate the F-peak only when the F-region is lifted to altitudes sufficiently high that the R-T instability growth rate becomes large.
- *BUT what initiates the instability?*
- *Search for sources of energy*



# DISCOVERY TO SYSTEM SCIENCE

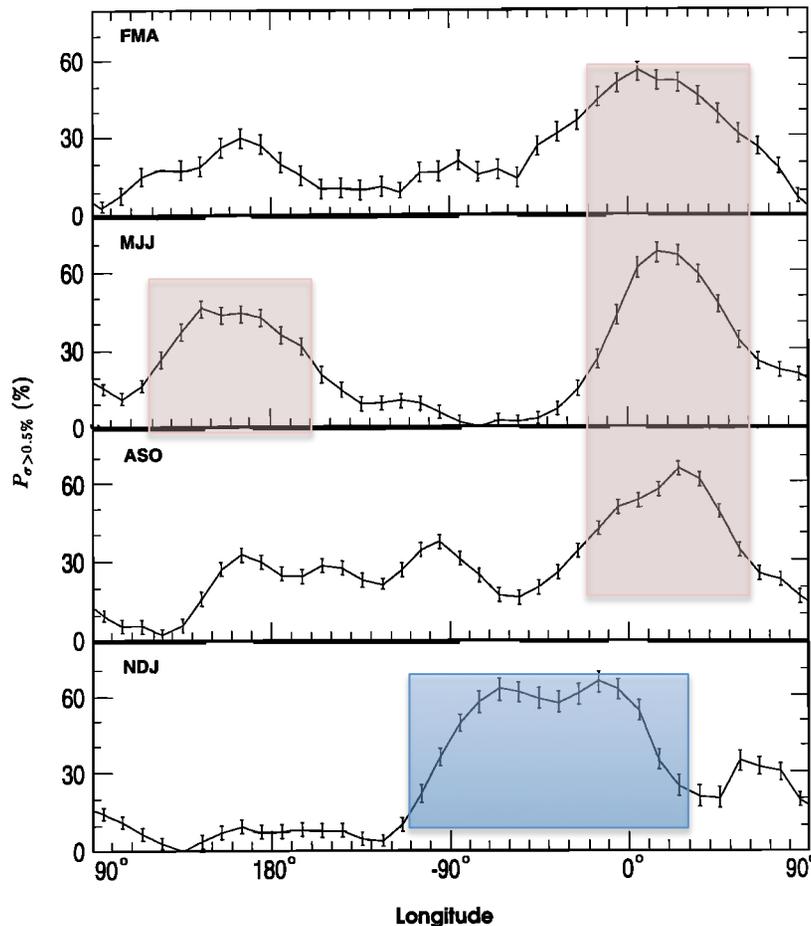
## Equatorial Ionospheric Irregularities



A shear in the zonal ion drift (vertical electric field) may provide the free energy for large scale perturbations in the bottomside F-region.

**What properties of the neutral wind are required to produce such a shear?**

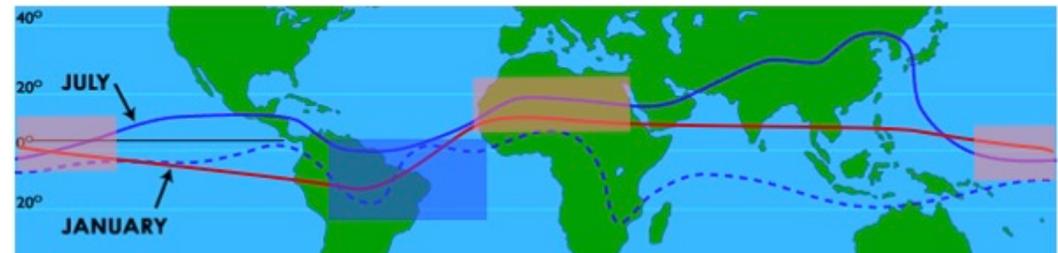
## Equatorial Ionospheric Irregularities



Seasonal/Longitude variations in irregularity appearance do not conform to terminator/sunset alignment.

Better coincidence with location of Inter-tropical Convergence Zone.

Propagating waves from the troposphere are an energy source for instabilities.



Tsunoda JGR, 2010 ; McClure et al JGR 1998

**Are these waves present and absent in accord with the appearance and absence of irregularities?**

# DISCOVERY TO SYSTEM SCIENCE

## *Equatorial Ionospheric Irregularities*

Phenomenology



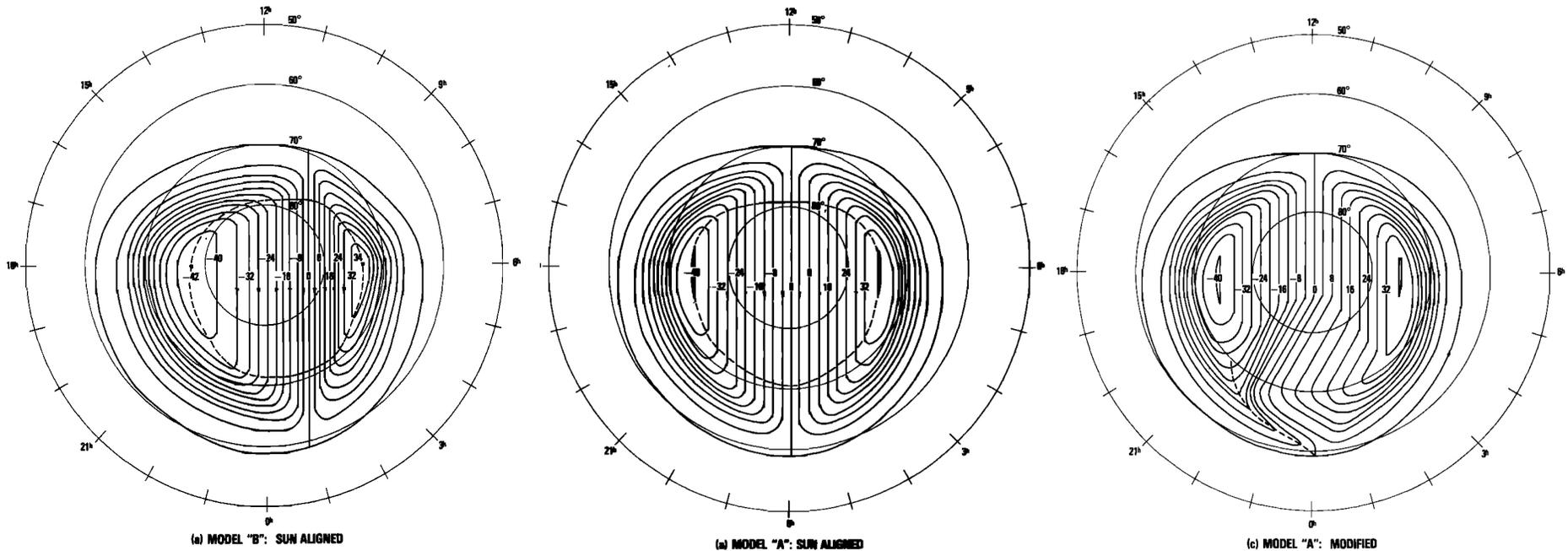
Relationships

- **Why** are plasma depletions sometimes present and sometimes absent?
  - Roles of gravity waves and velocity shear in producing instabilities.
  - Role of upward drift in changing the RT growth rate.
- **How** do wind systems give rise to currents and plasma motions that drive instabilities?
- **How** do winds and waves appear at the appropriate locations from local and remote sources?

**A rich environment for inquisitive researchers**

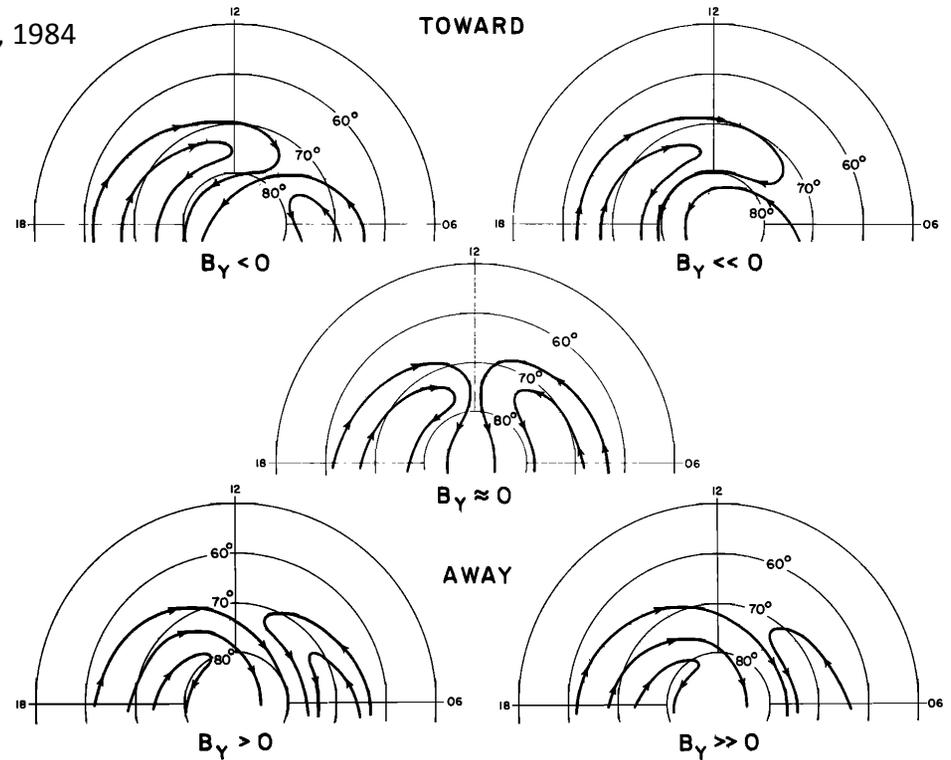
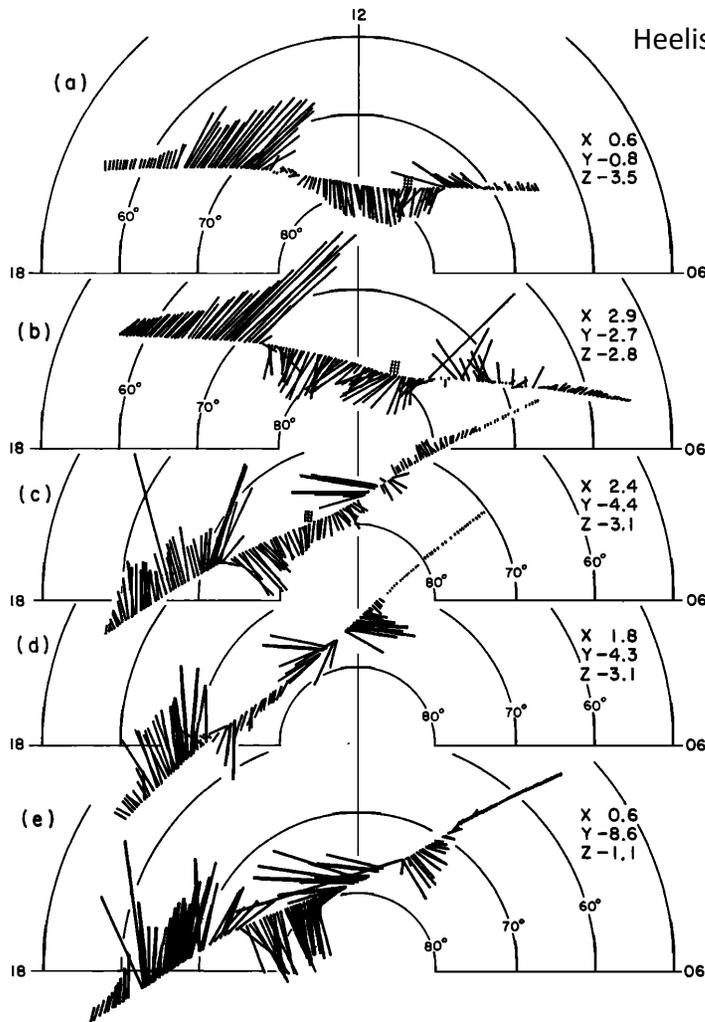
## High Latitude Ionospheric Convection

Heppner\_JGR 1977



Early visual inspection of satellite data provided first views of global convection at high latitudes in the ionosphere.

## High Latitude Ionospheric Convection



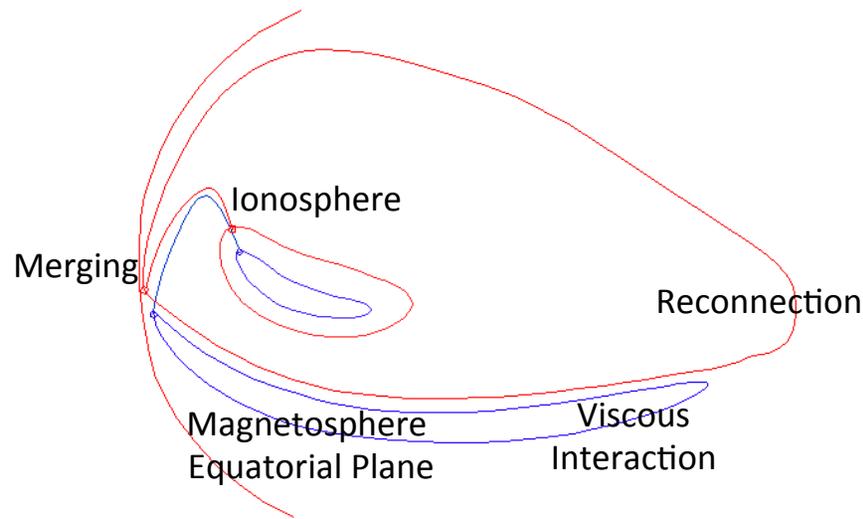
Large-scale east-west flows observed in the cusp modify the convection pattern and our view of the drivers.



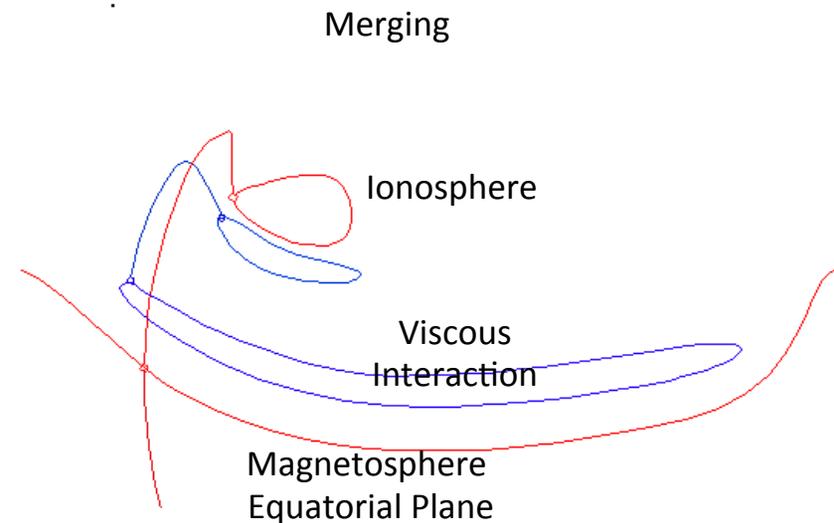
# DISCOVERY TO SYSTEM SCIENCE

Studies of ionospheric convection are now intimately linked to drivers at the dayside magnetopause at the flanks of the magnetosphere and in the tail

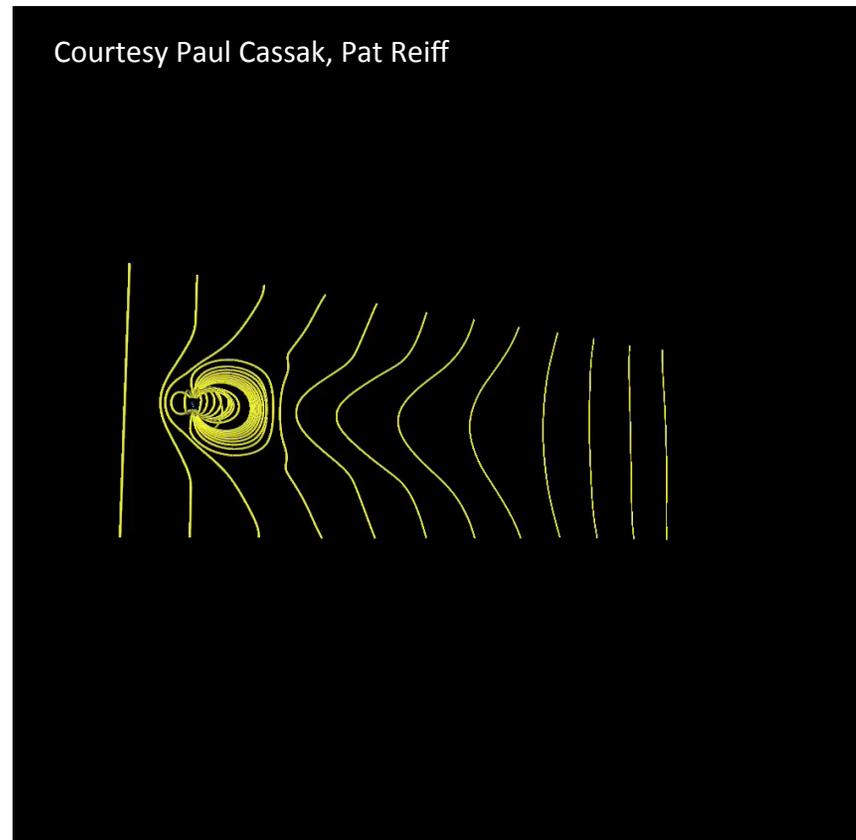
Southward IMF



Northward IMF

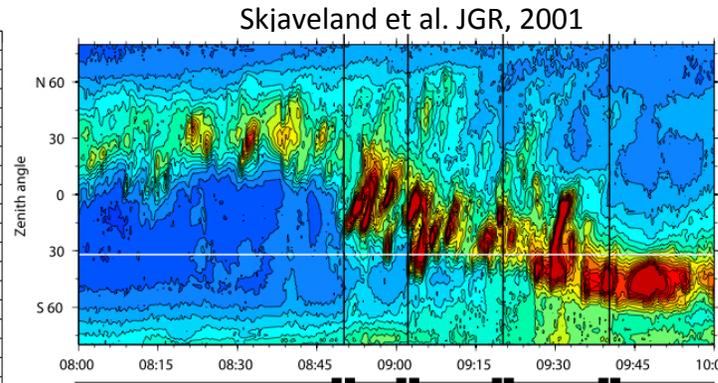
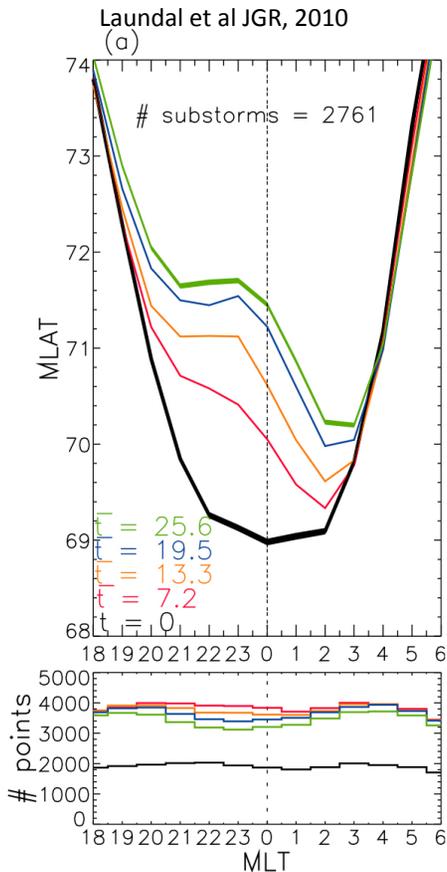


## *High Latitude Ionospheric Convection*



**Observations and computational tools used together to improve insights.**

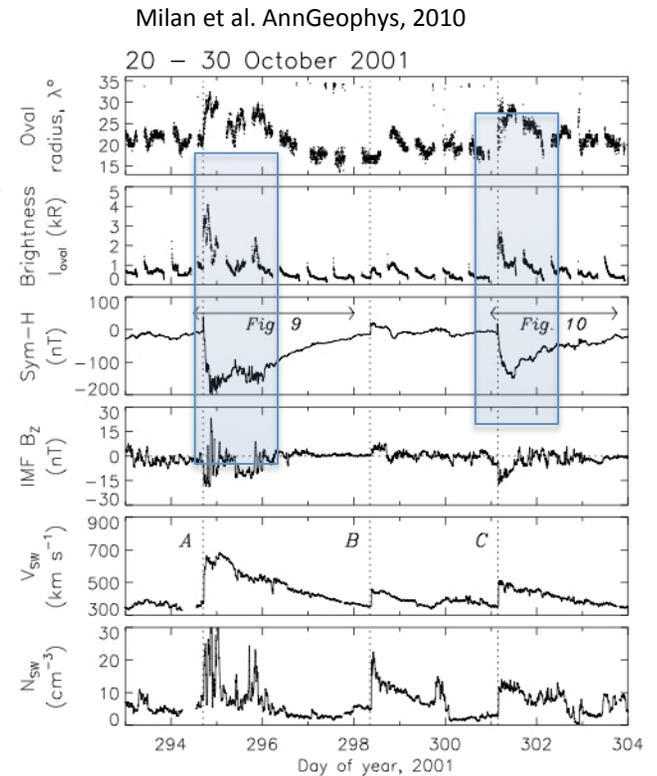
## Stand Still will 'e (Pink Floyd, 1979)



**Poleward moving auroral emissions associated with equatorward motion of OCB as open flux is added to polar cap**

**Removal of open flux associated with poleward motion of OCB.**

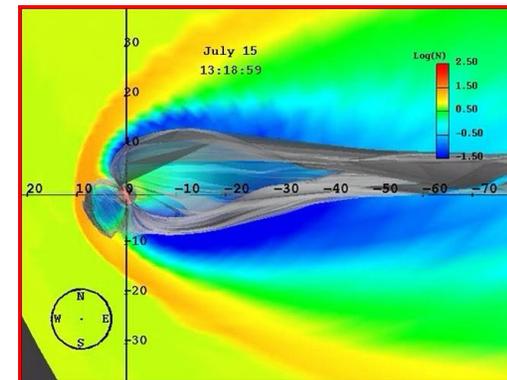
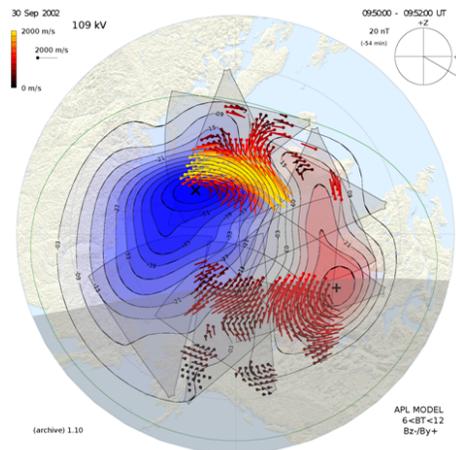
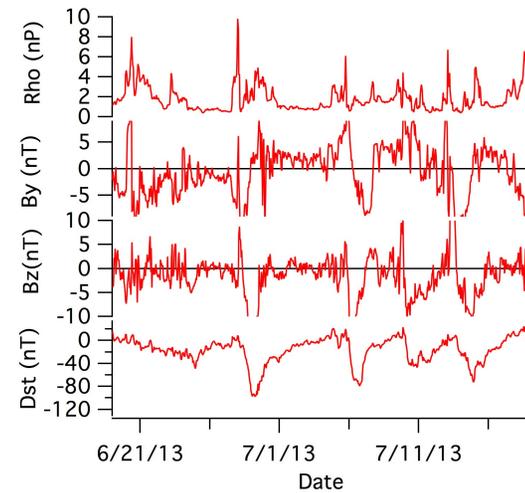
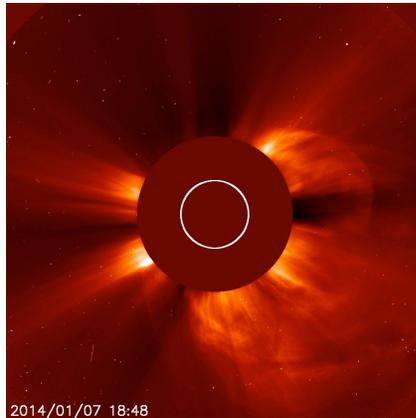
**How do we describe a dynamic system with observations at single location?**



**Added open flux results in expansion of OCB to lower latitudes**

# DISCOVERY TO SYSTEM SCIENCE

## High Latitude Ionospheric Convection



## *High Latitude Ionospheric Convection*

Phenomenology



Relationships

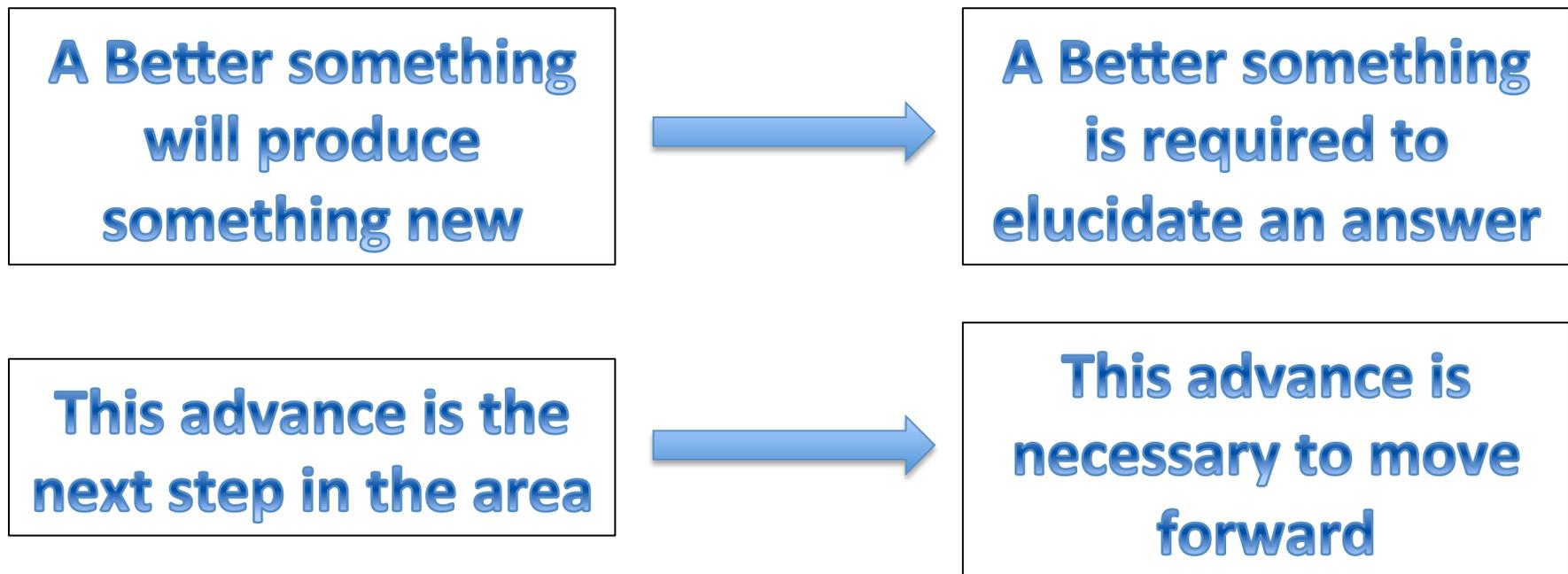
- How do changes in the convection pattern propagate through the system?
- How are changes in convection are related to changes in magnetic field topology?
- How does the present state of the ionosphere affect its response to changes in the solar wind?
- How are changes on the dayside and the nightside related?

**A rich environment for inquisitive researchers**

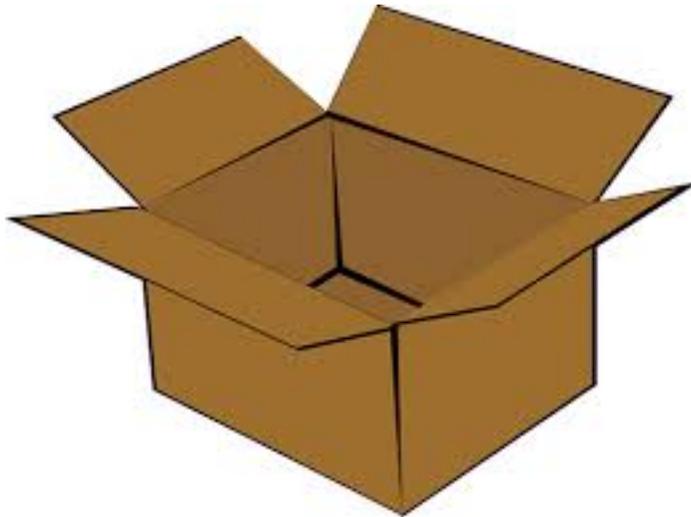
# DISCOVERY TO SYSTEM SCIENCE



## A Change in Approach



## **An Invitation**



**Make time to  
consider the entire  
picture.**



**Take pleasure in  
appreciating the  
science outside the  
box**