The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2025-51

Satellite Navigation Science and Technology for Africa

23 March - 9 April, 2009

GNSS

CARLSON Herbert C.
European Office of Aerospace Research and Develop.
223/231 Old Marylebone Road
London NW1 5TH
UNITED KINGDOM

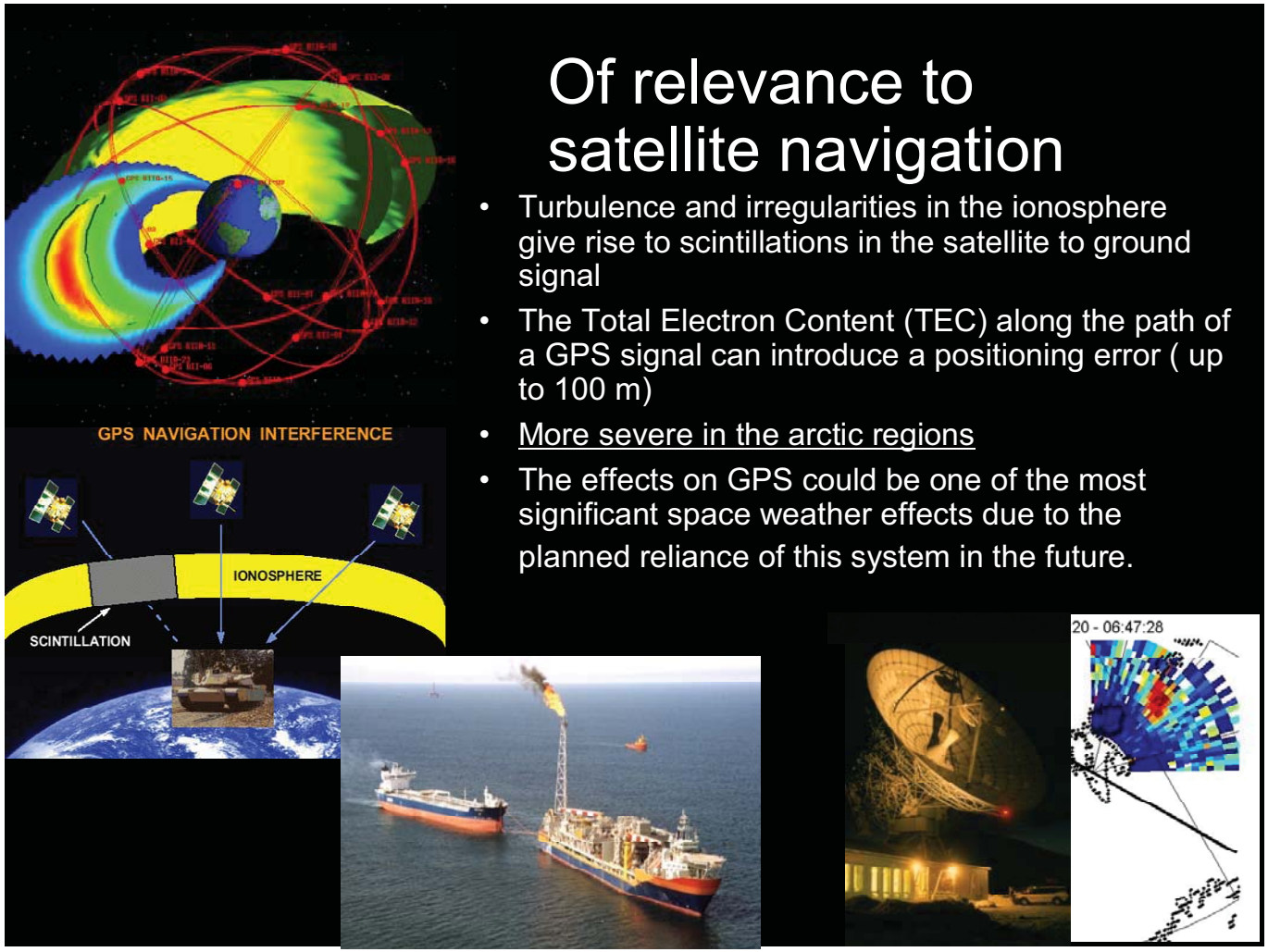
AFOSR

GNSS Workshop at ICTP

March 23 - April 9, 2009

Dr. Herb Carlson
Senior Scientist
AFOSR/EOARD
Air Force Office of Scientific Research

Why the international community cares about scintillation

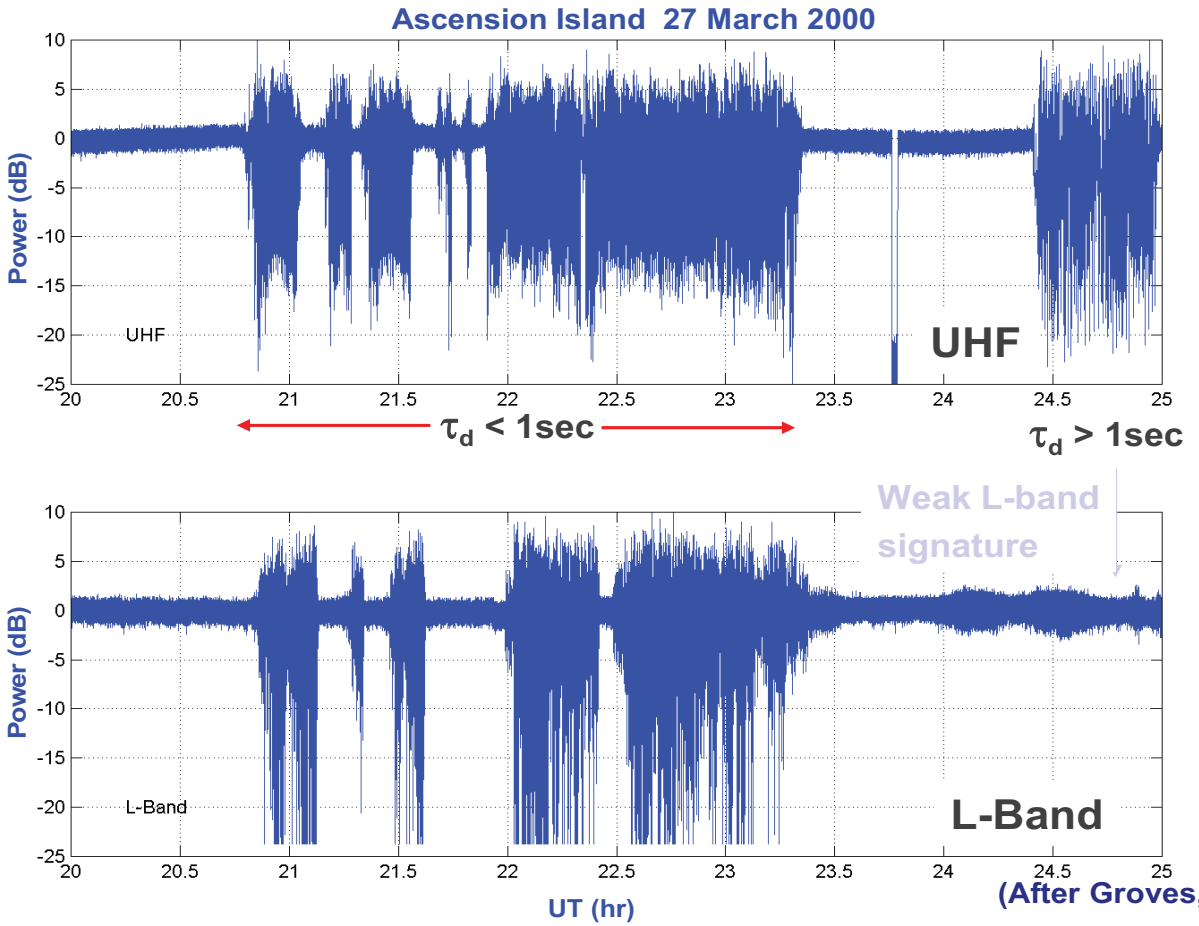


Of relevance to satellite navigation

- Turbulence and irregularities in the ionosphere give rise to scintillations in the satellite to ground signal
- The Total Electron Content (TEC) along the path of a GPS signal can introduce a positioning error (up to 100 m)
- More severe in the arctic regions
- The effects on GPS could be one of the most significant space weather effects due to the planned reliance of this system in the future.

Where in frequency: dependence of scintillation, stronger at lower frequencies

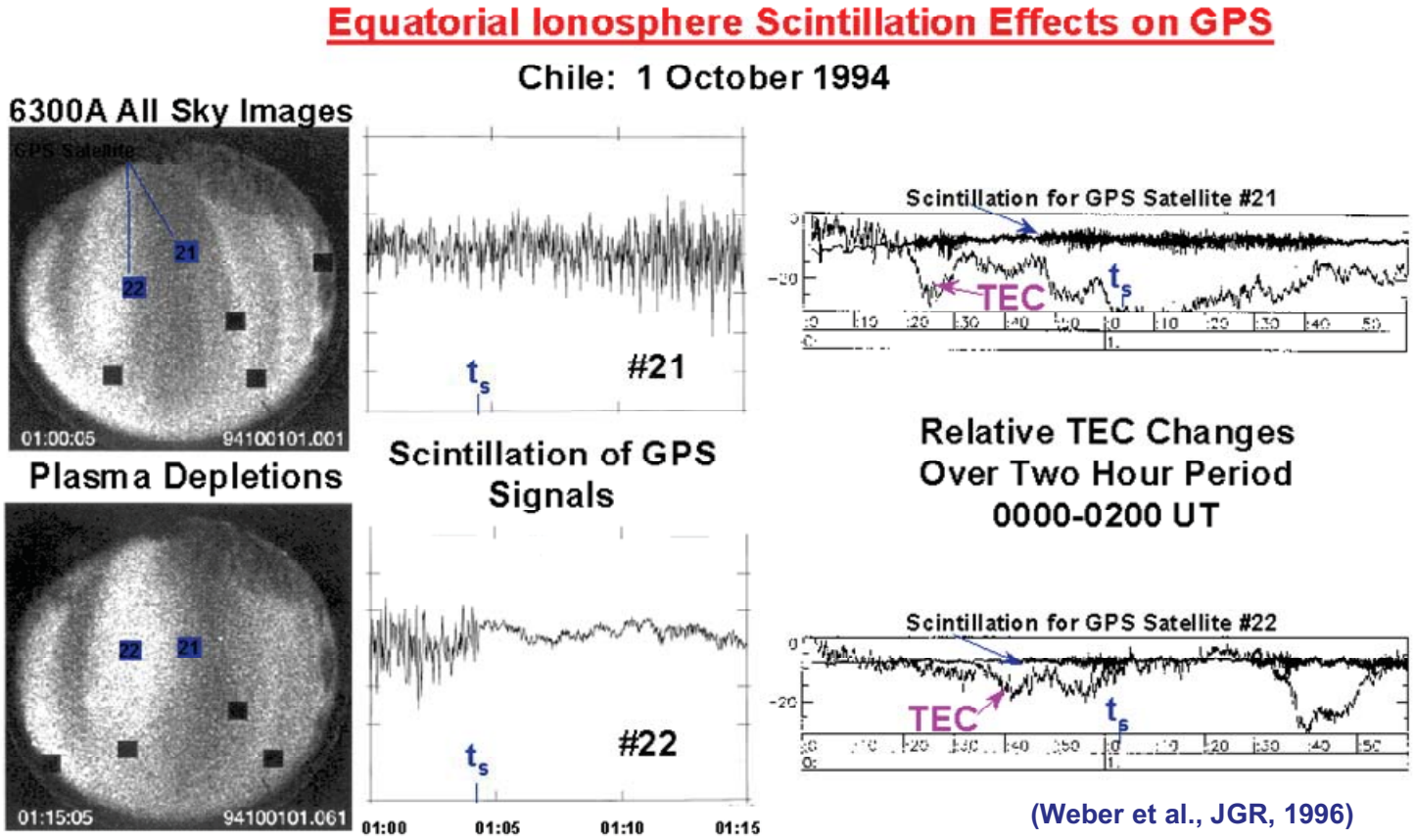
Solar Maximum Conditions at Ascension Island: UHF and L-Band



(After Groves, AFRL, 2000)

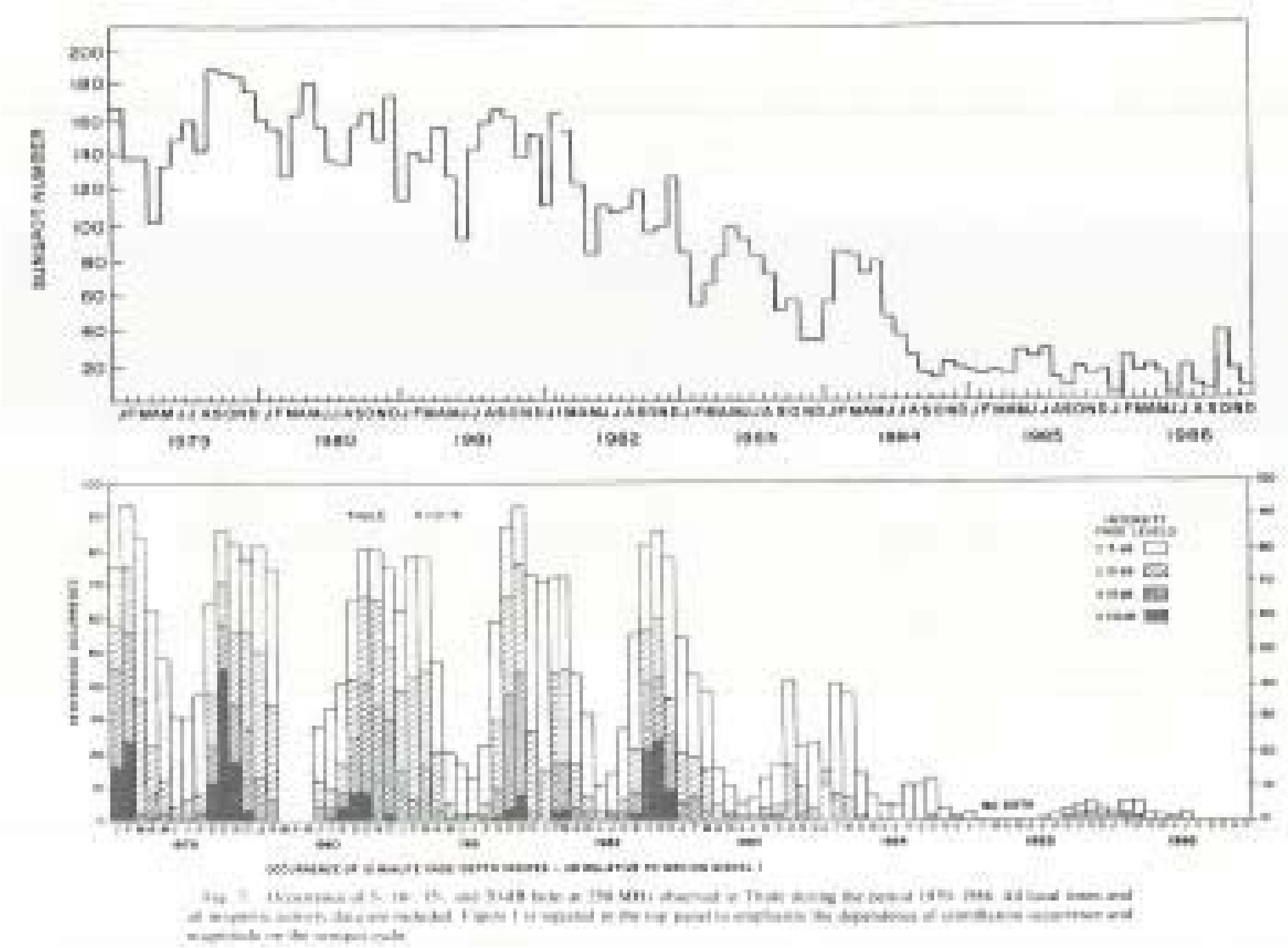
When in minutes: can we anticipate when to move from one look direction to another for continuous signal? We can track equatorial scintillation

Equatorial Ionosphere Plasma Depletions
Scintillation of GPS Signals
TEC Variations

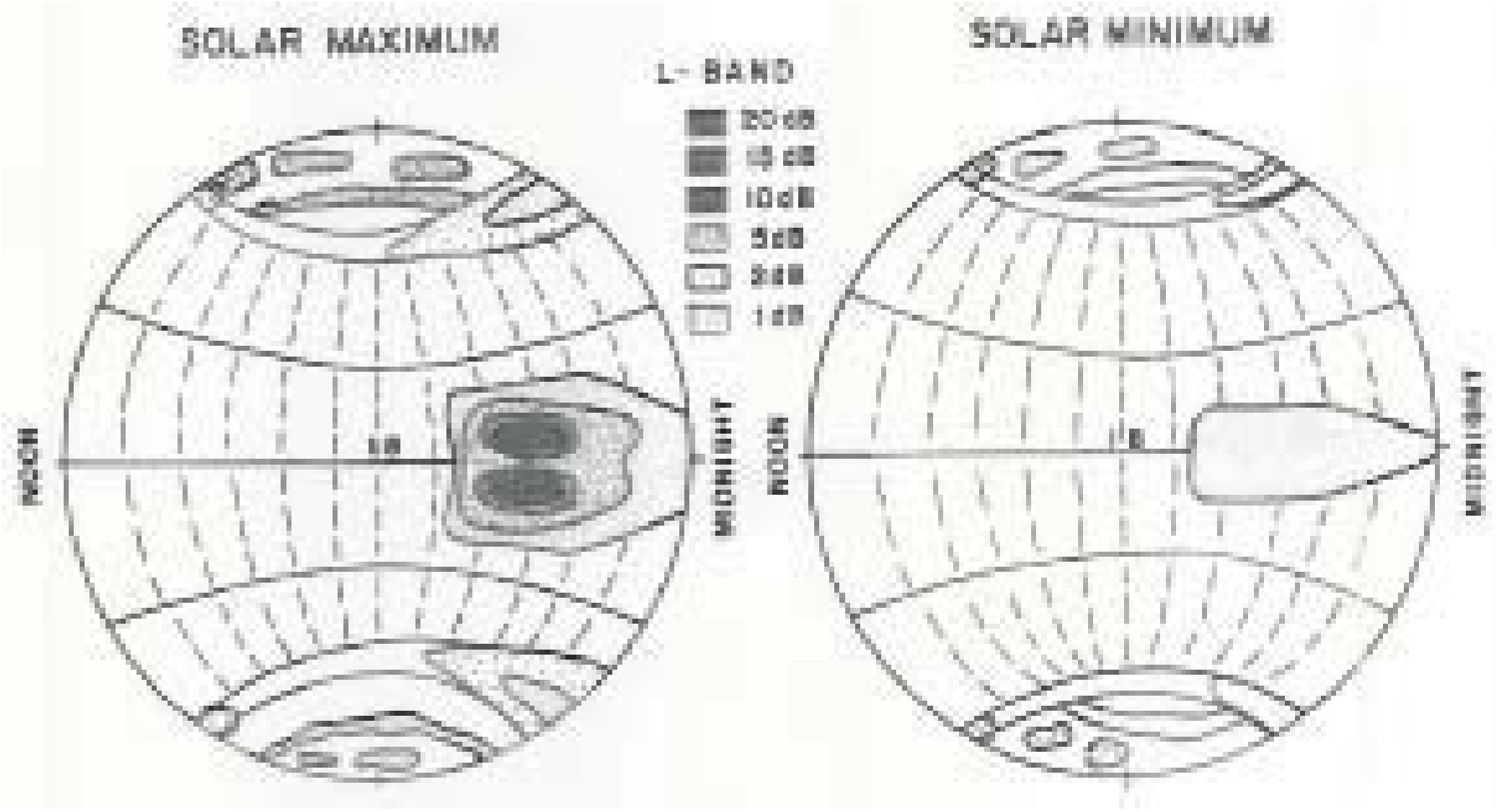


(Weber et al., JGR, 1996)

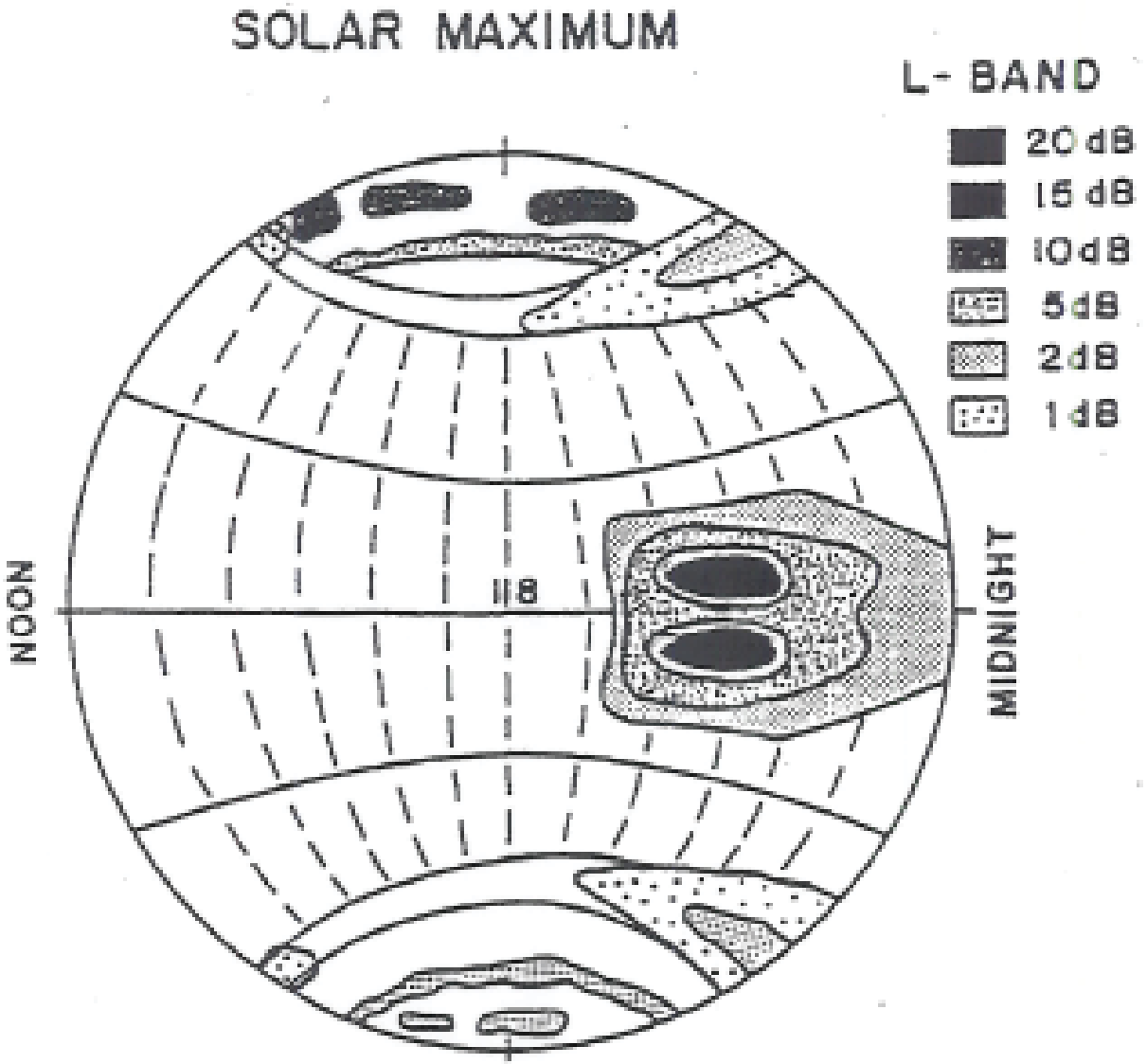
When in the 11 year solar cycle: the solar cycle dependence of scintillation, high at SSmax low at SSmin



So where in space at both Sun Spot max and Sun Spot min, on a global scale



A closer look at where it matters most



Why at the equator, lower look angles have more scintillation than higher look angles

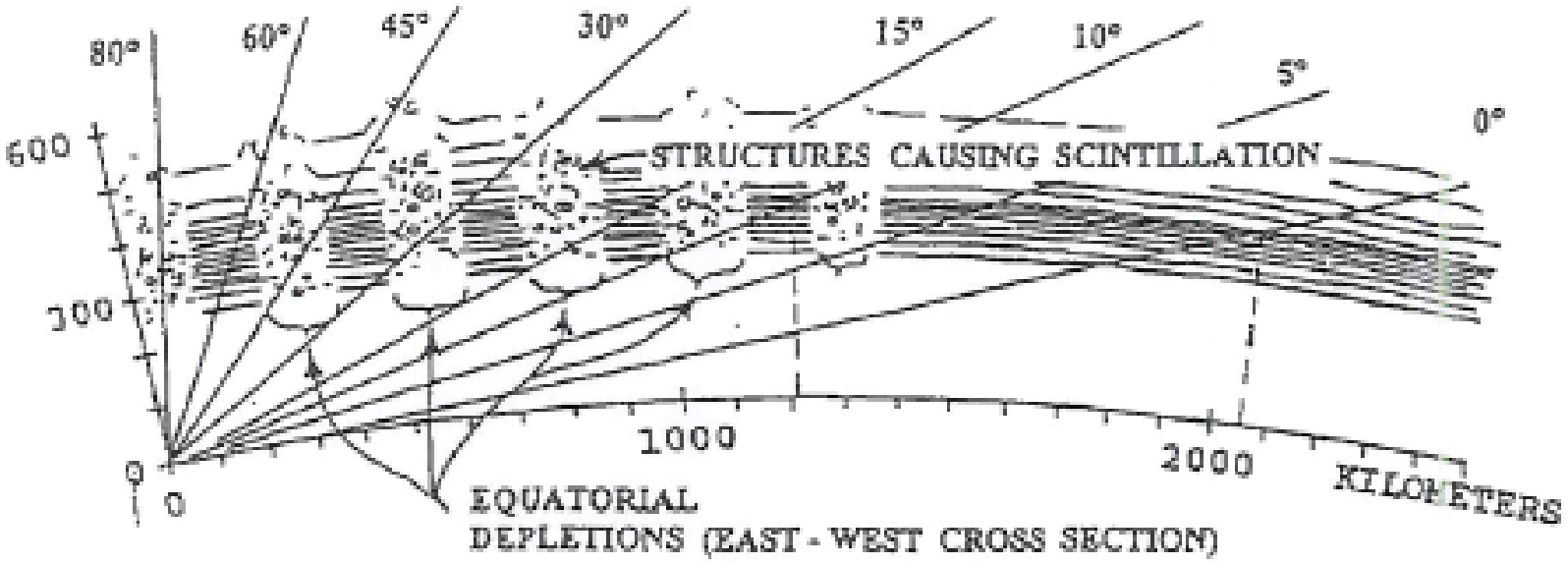
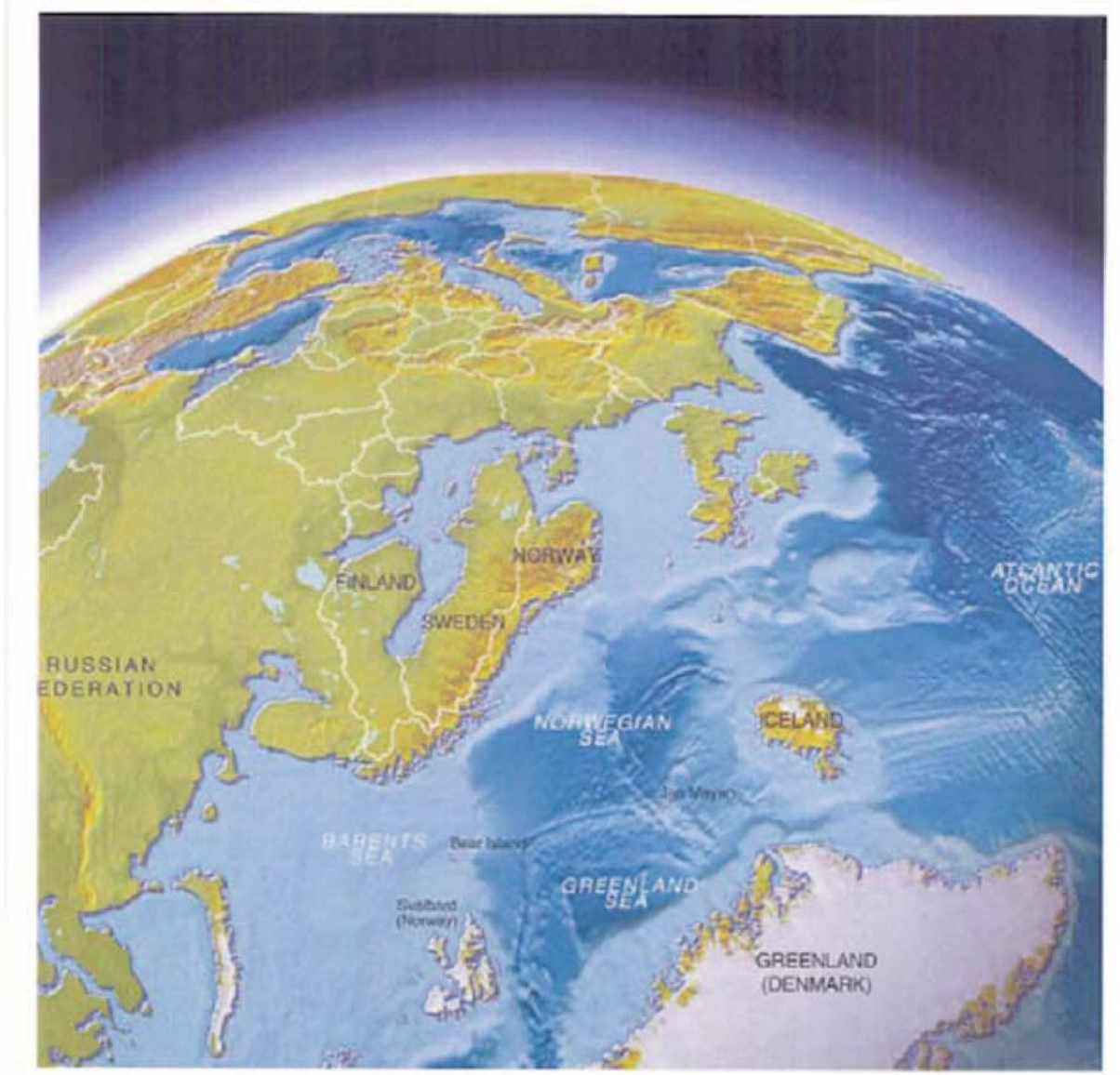


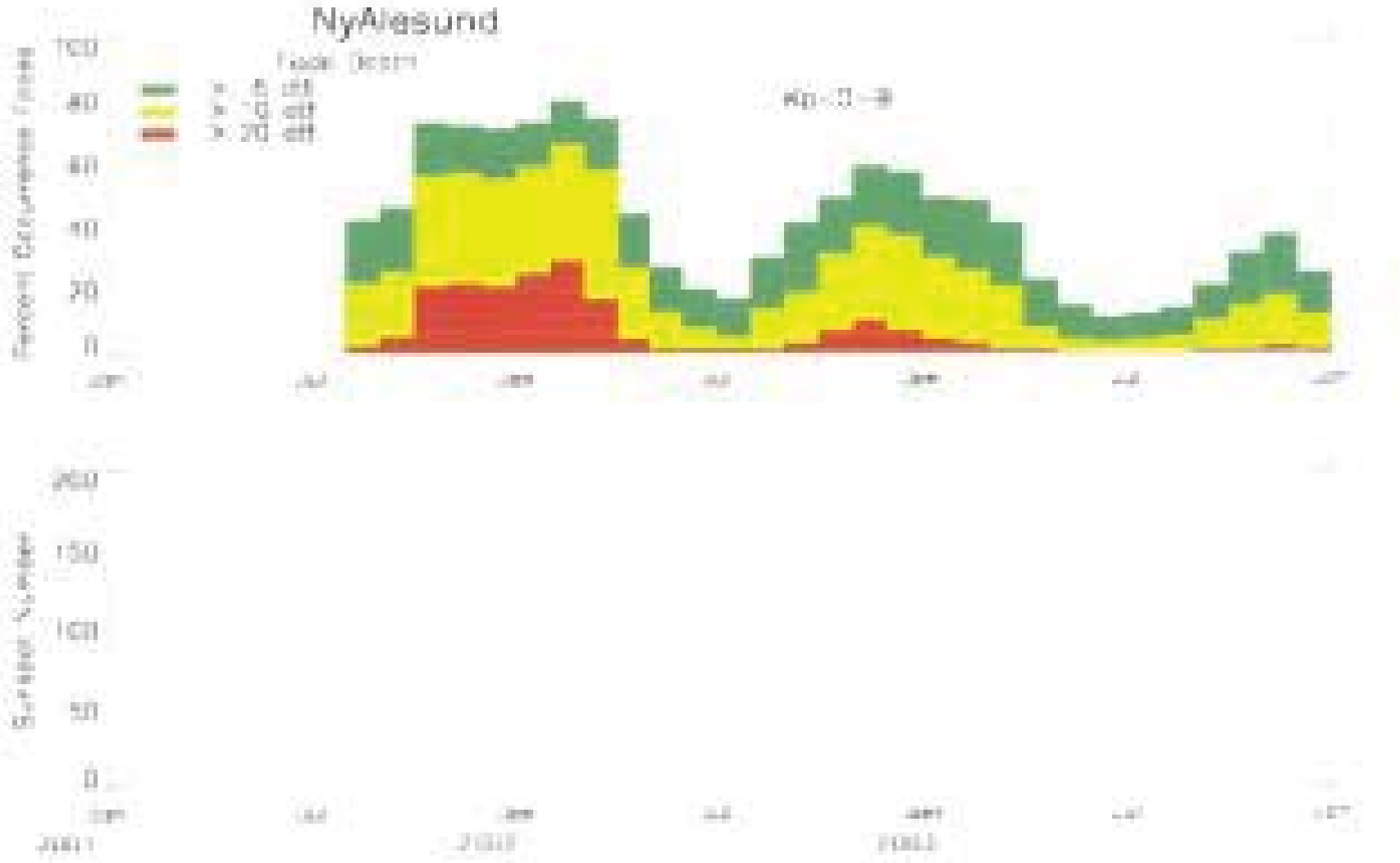
Figure 7. True-scale geometry of trans-ionospheric raypaths, showing east-west cross-section of large-scale equatorial depletion structures and "venetian blind" effect [14].

At high latitudes scintillation matters too, especially to sea going vessel navigation and communication

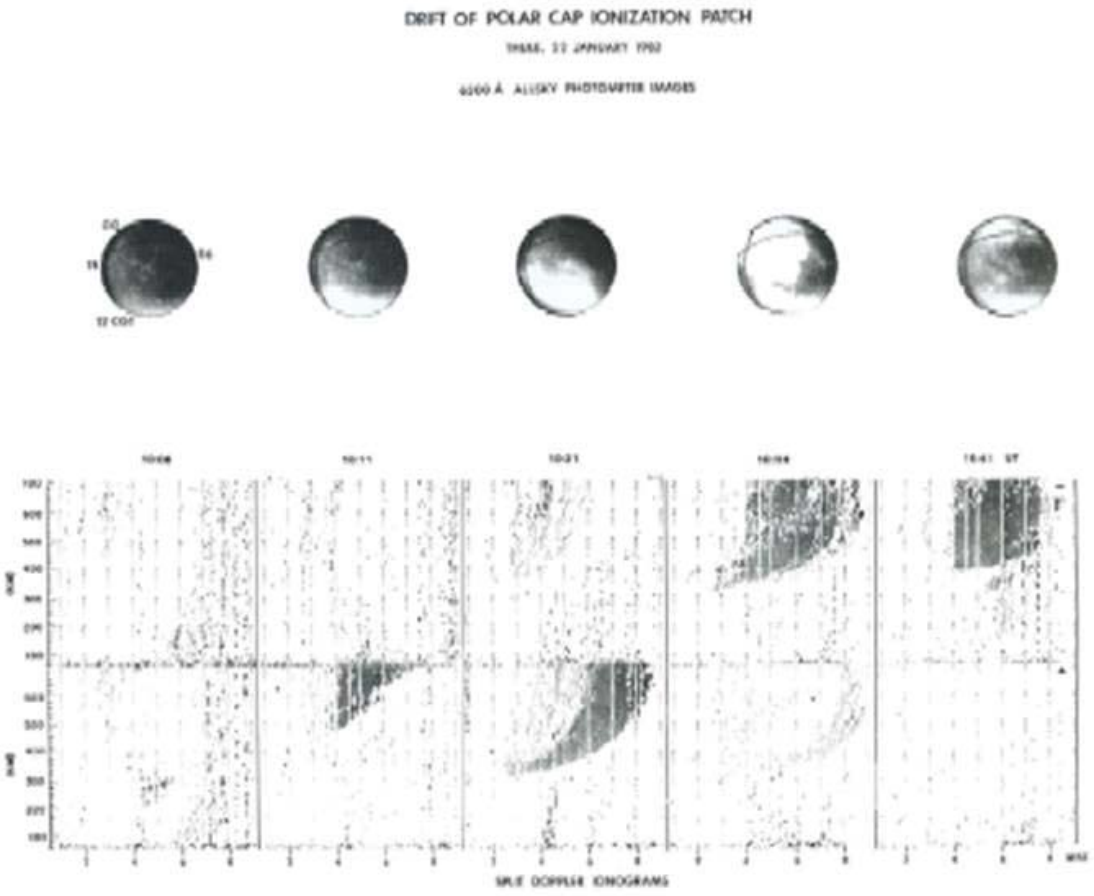
Coast and Sea



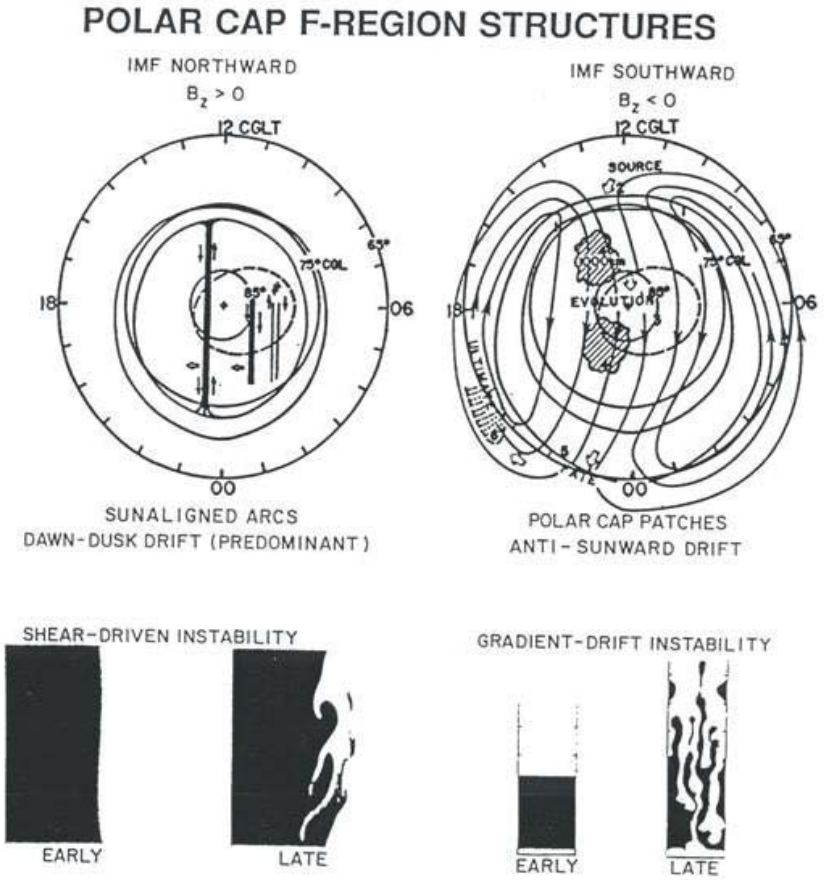
We've more recently studied high latitude scintillation to learn its solar cycle variation



We've looked in the polar cap too, the main driver for polar scintillation is dayside plasma entering the polar cap through the noon auroral region



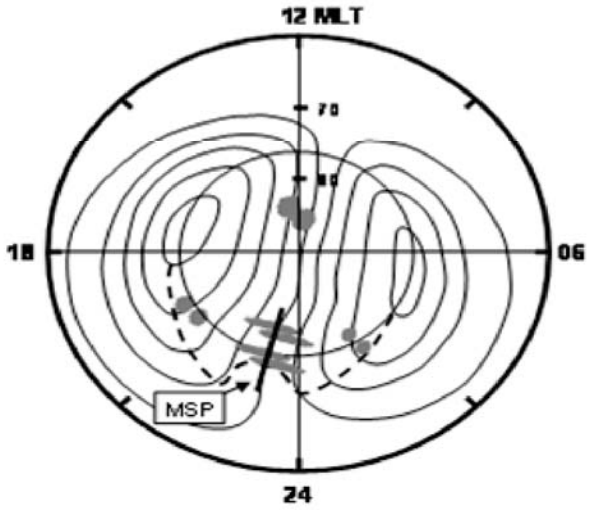
Two physical conditions contribute to polar cap scintillation: Patches and Arcs

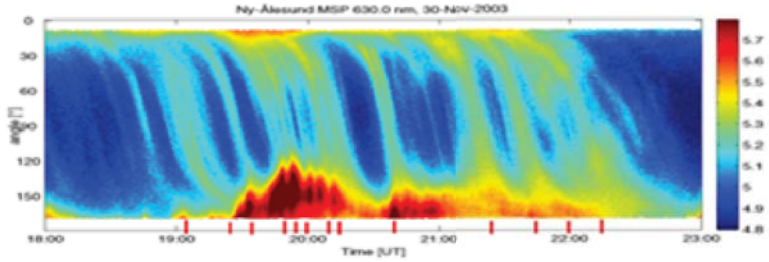


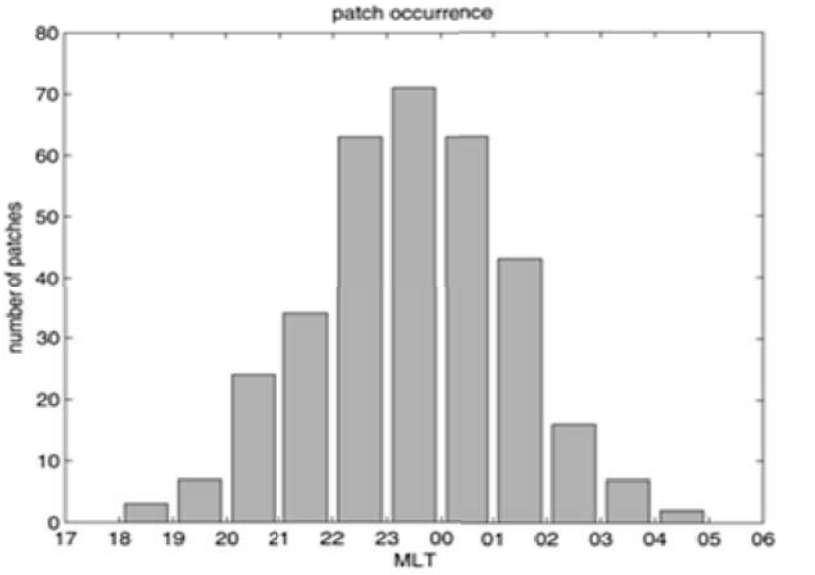
We can now track polar cap scintillation regions too

Occurrence rate of polar cap patches

- Eight winters (1997-2005) of MSP data from Ny-Ålesund have been analyzed
- 43 nights, 333 events
- About 60% of the patches exit the polar cap from 22-01 MLT, but patches was observed in the entire MLT range from 18:00-05:00.

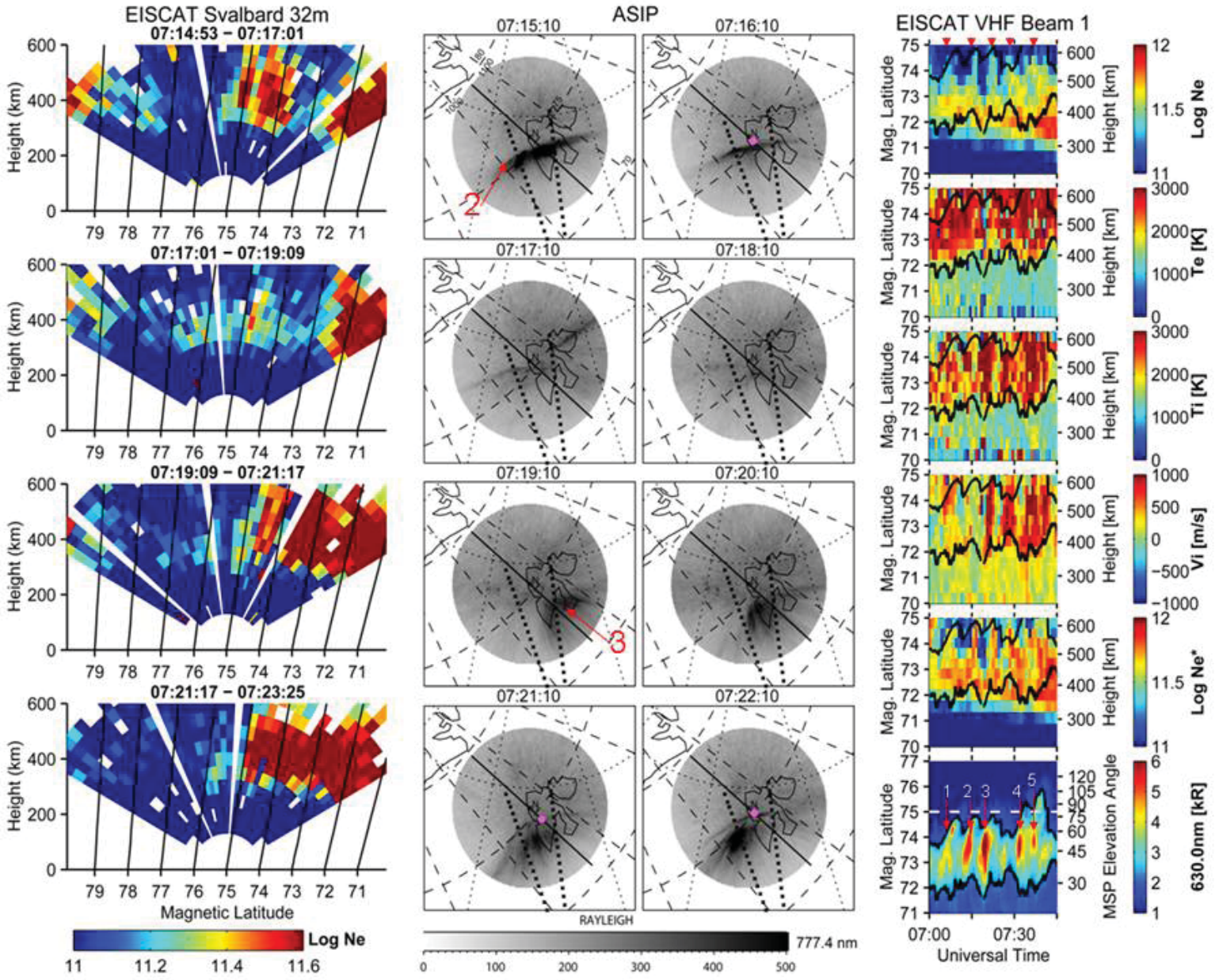




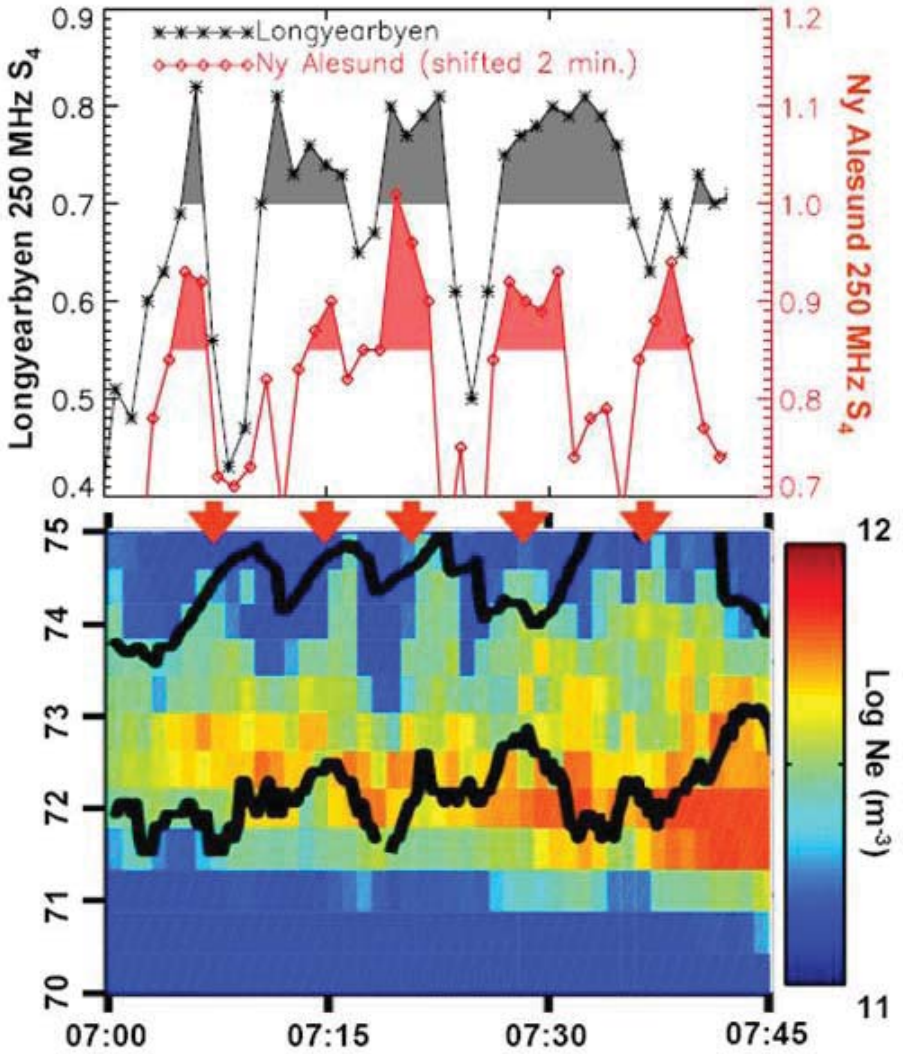


Moen et al., GRL, in press

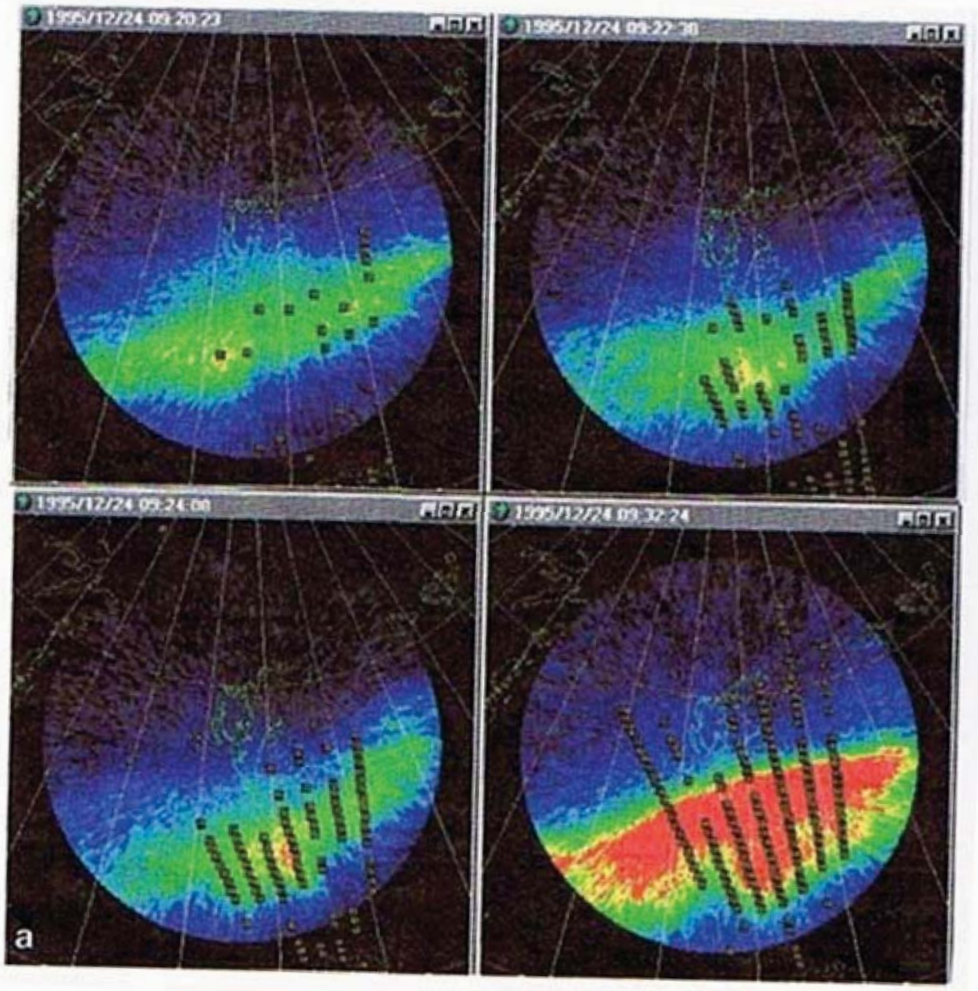
We have learned the physical process for how midlatitude plasma enters the polar cap, to help prediction



Studying this has let us prove that for the last 20 years everyone has used wrong physics to try to predict the polar onset of scintillation



This new understanding of the basic physics has also given us a new too to use to aid now-cast and forecast of scintillation



So where is basic research now in driving progress towards better physical understanding for future progress?

Where Do We Stand?

How Well Can We Mitigate Scintillation?

- “Night-side” hemisphere could be mitigated with focused research program.
- Difference between African and South American Longitude not adequately understood. Experiment will drive theory.
- Untested Theory of last 20 years said till ‘07 “Dayside” should be likewise (slow turn on).
- Recent Discovery of patch creation process (new experimental tests) proved that theory wrong. Dayside challenge needs reassessment.

What are recent milestones leading to where basic research should go next?

What is New as of 2009?

- Found Patch Creation Process (2004)
  - Injection of “midlatitude” plasma
  - Injection speed ~2km/s
- Learned Patch Creation Involves Shear (2006)
  - Process is magnetic reconnection
  - Transient plasma-surge onset in ~2 minutes
- Shears => Scintillation in Minutes (2007)
  - Shear theory predicts irreg. onset in minutes
  - Observations confirmed meso-scale areas of scintillation within minutes (new data)
  - onset in ~2 minutes
  - minutes
- Equatorial Focus with CNOFS and Africa (2009)

THANK YOU
FOR YOUR ATTENTION

ARE THERE ANY QUESTIONS?