Satellite navigation issues for the high Arctic

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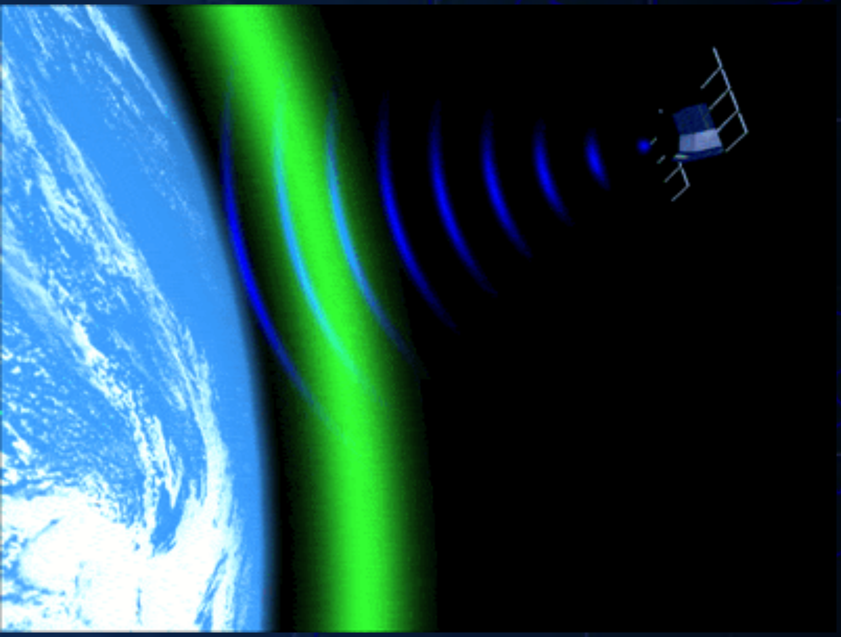
GPS accuracy depends on many things:

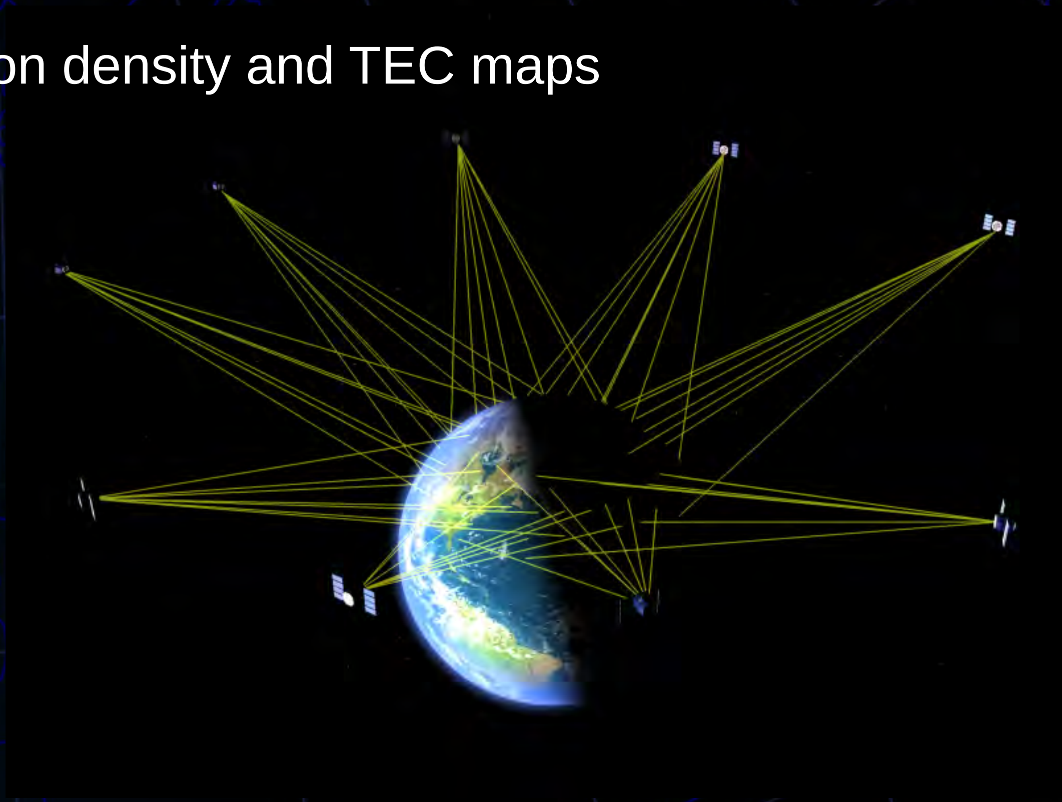
These include:

- satellite and receiver **timing**
- satellite **position**
- local factors such as **multipath** and interference
- **propagation** modelling - the ionosphere
    - delay
    - scintillation

Delay - Ionospheric Imaging / Data Assimilation

Production of electron density and TEC maps





Geodetic GPS data inputs, IMF, Kp, Kalman filter

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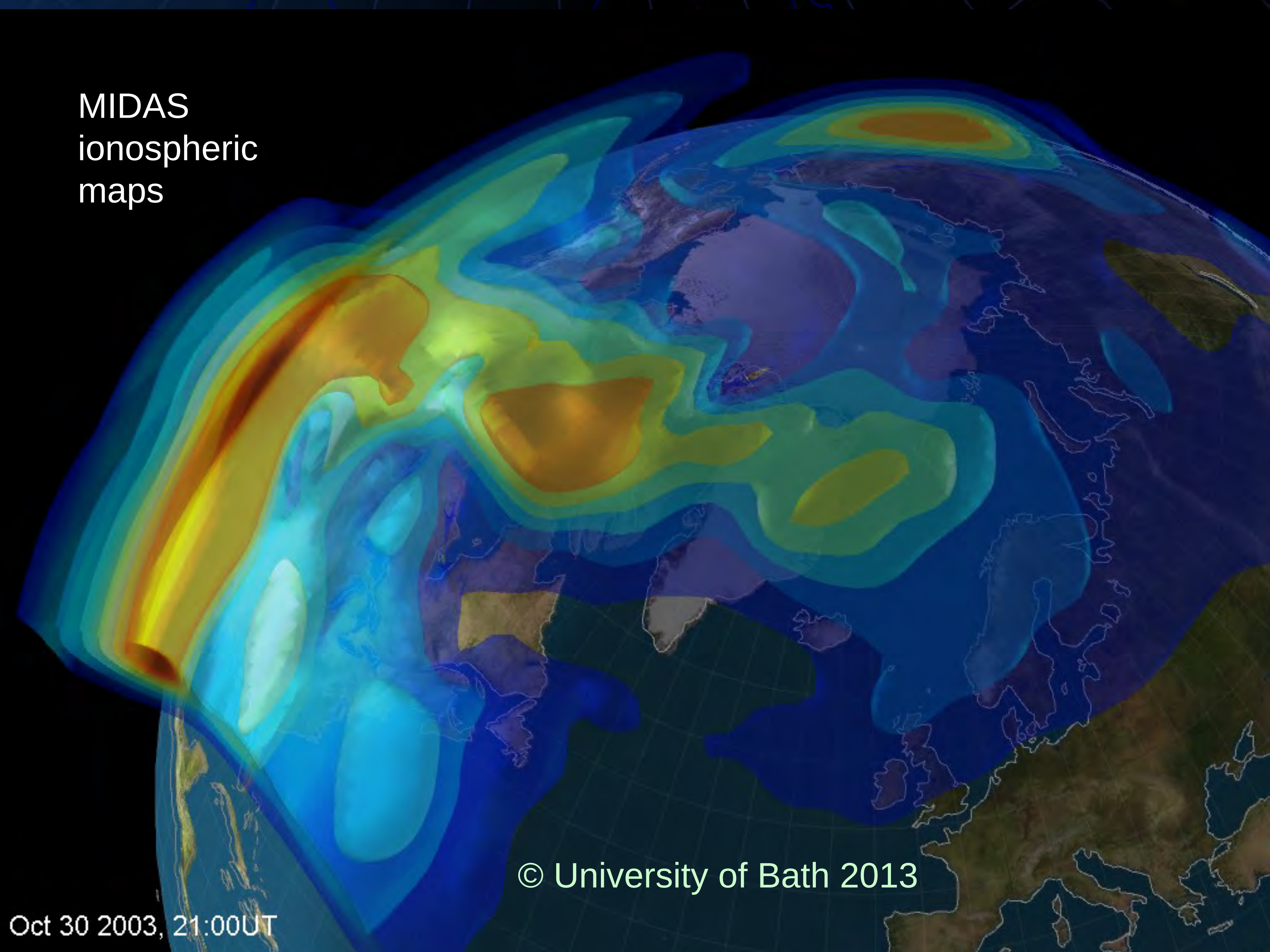
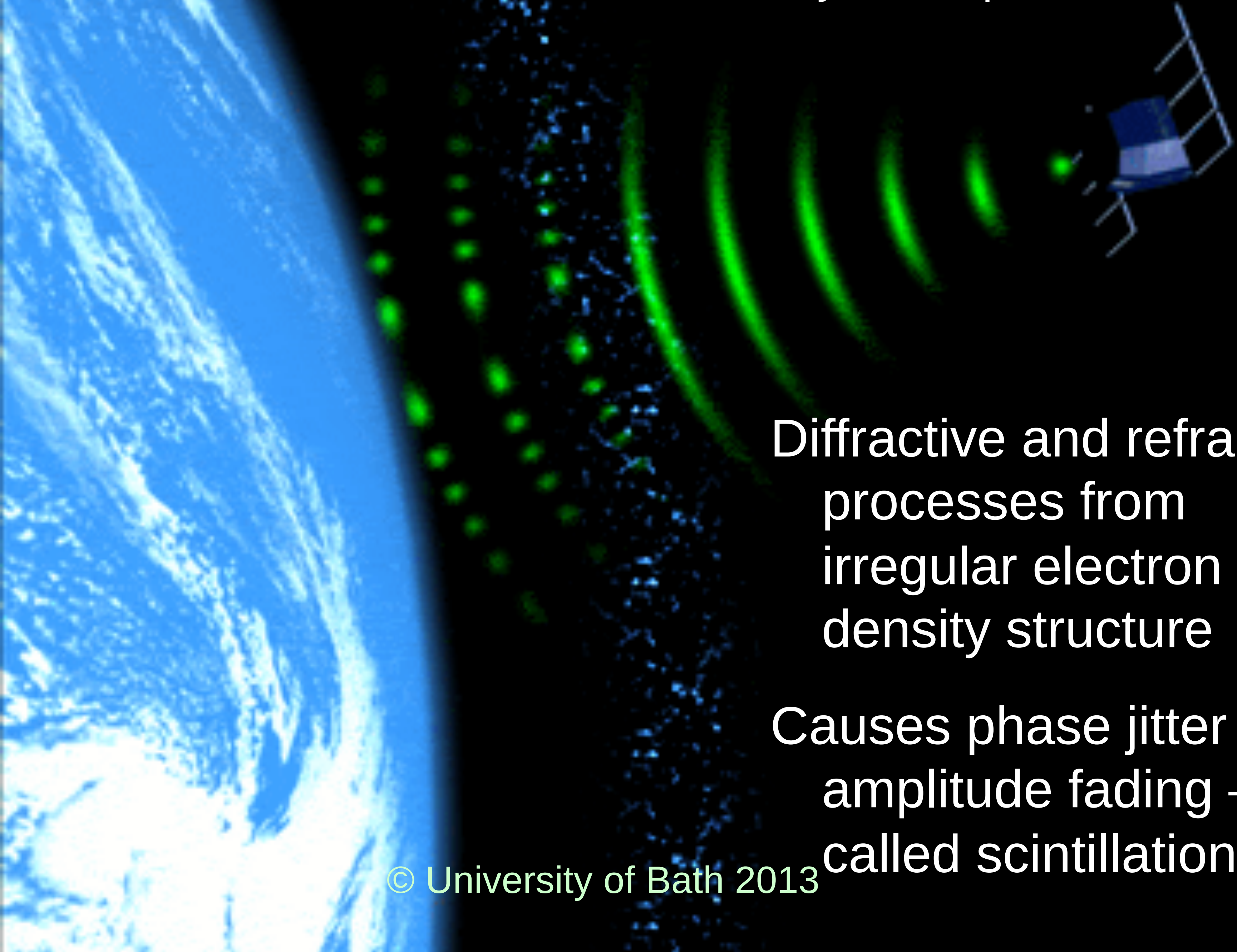
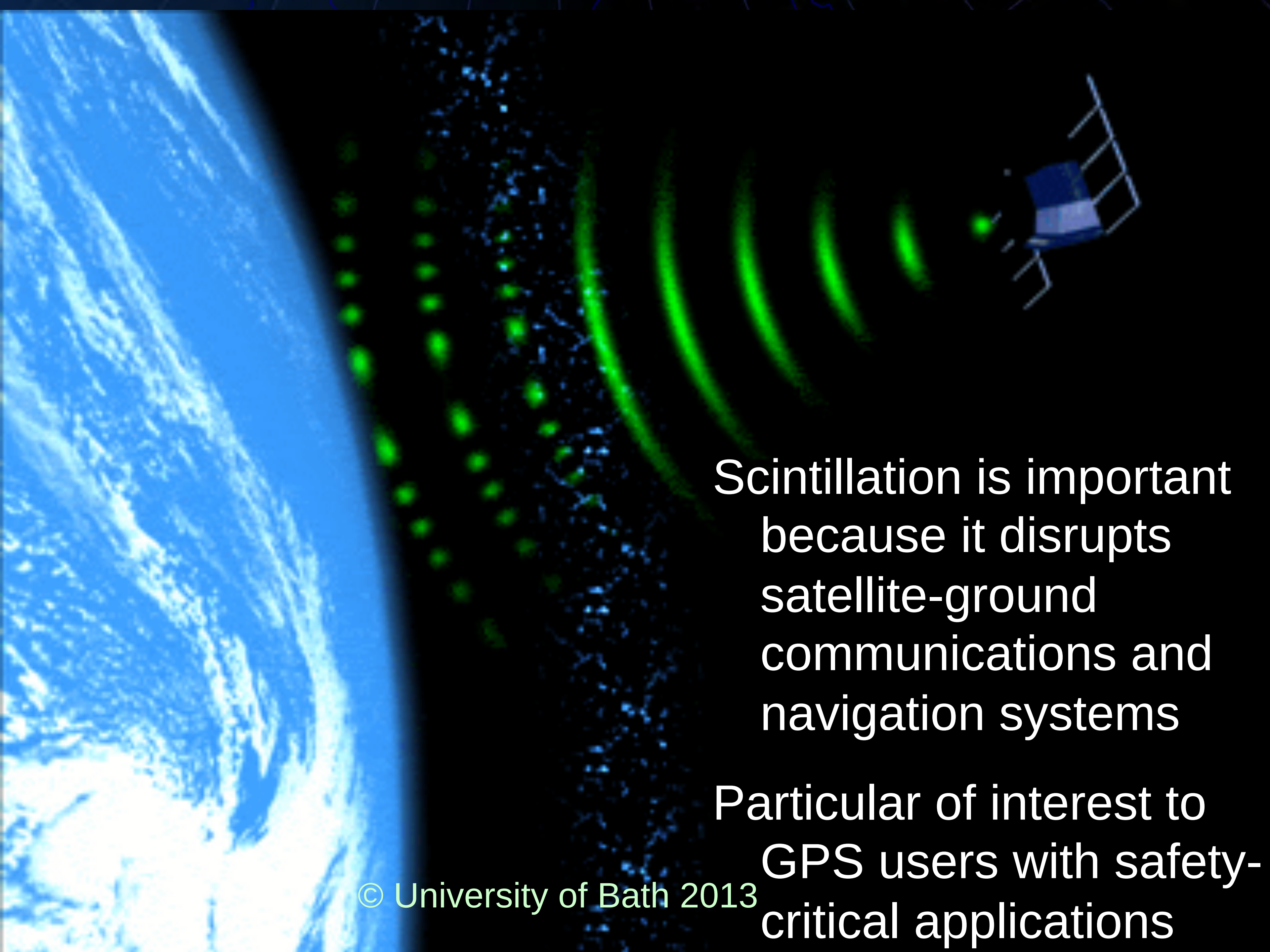

MIDAS
ionospheric
maps
© University of Bath 2013
Oct 30 2003, 21:00UT

What is scintillation and why is it important?



- Diffractive and refractive processes from irregular electron density structure
- Causes phase jitter and amplitude fading – called scintillation



- Scintillation is important because it disrupts satellite-ground communications and navigation systems
- Particular of interest to GPS users with safety-critical applications

Scintillation

Scintillation varies widely in significance – some users will see no effect whereas other will suffer complete signal loss

Two indices used to quantify the effects:

Sigma phi quantifies **phase** scintillation

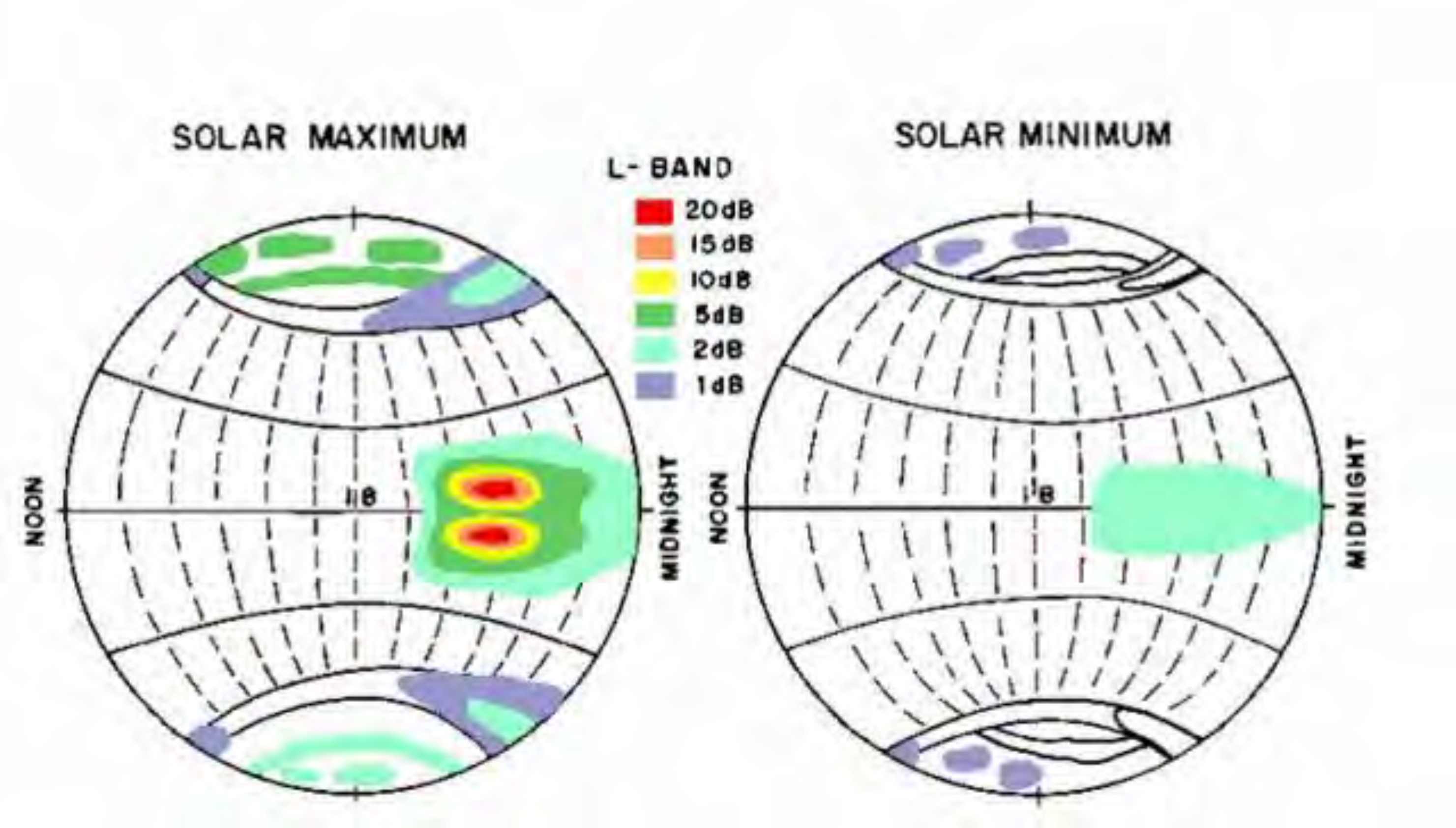
Phase scintillation is more common at **high latitudes**

S4 quantifies **amplitude** scintillation

Amplitude scintillation is more common at **equatorial latitudes**

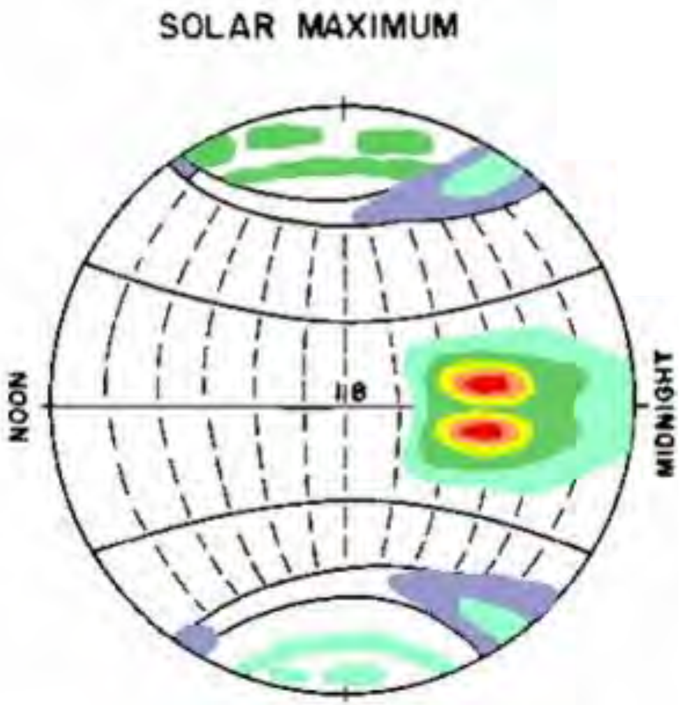
Scintillation is more severe at lower operating frequencies

Global Temporal and Solar Cycle View



Summary picture of scintillation activity at GPS frequencies (after Basu et al)

GPS Scintillation equipment deployed as of 2012



20+ receivers

70+ receivers

10+ receivers

Relate to Scintillation

Example showing scintillation on the edges of polar cap patches

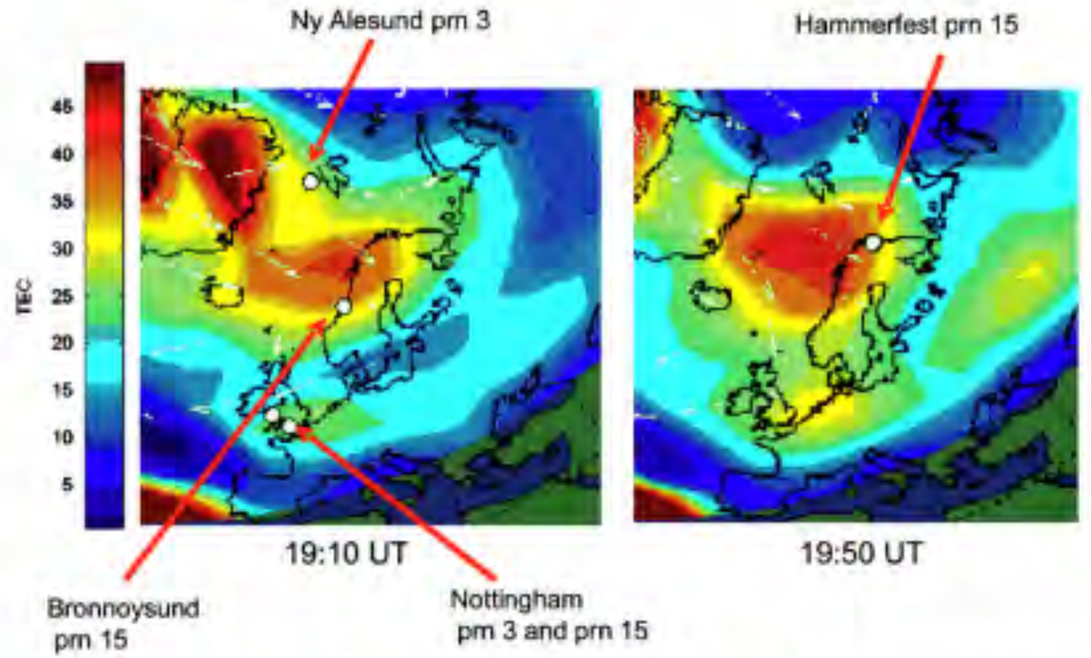
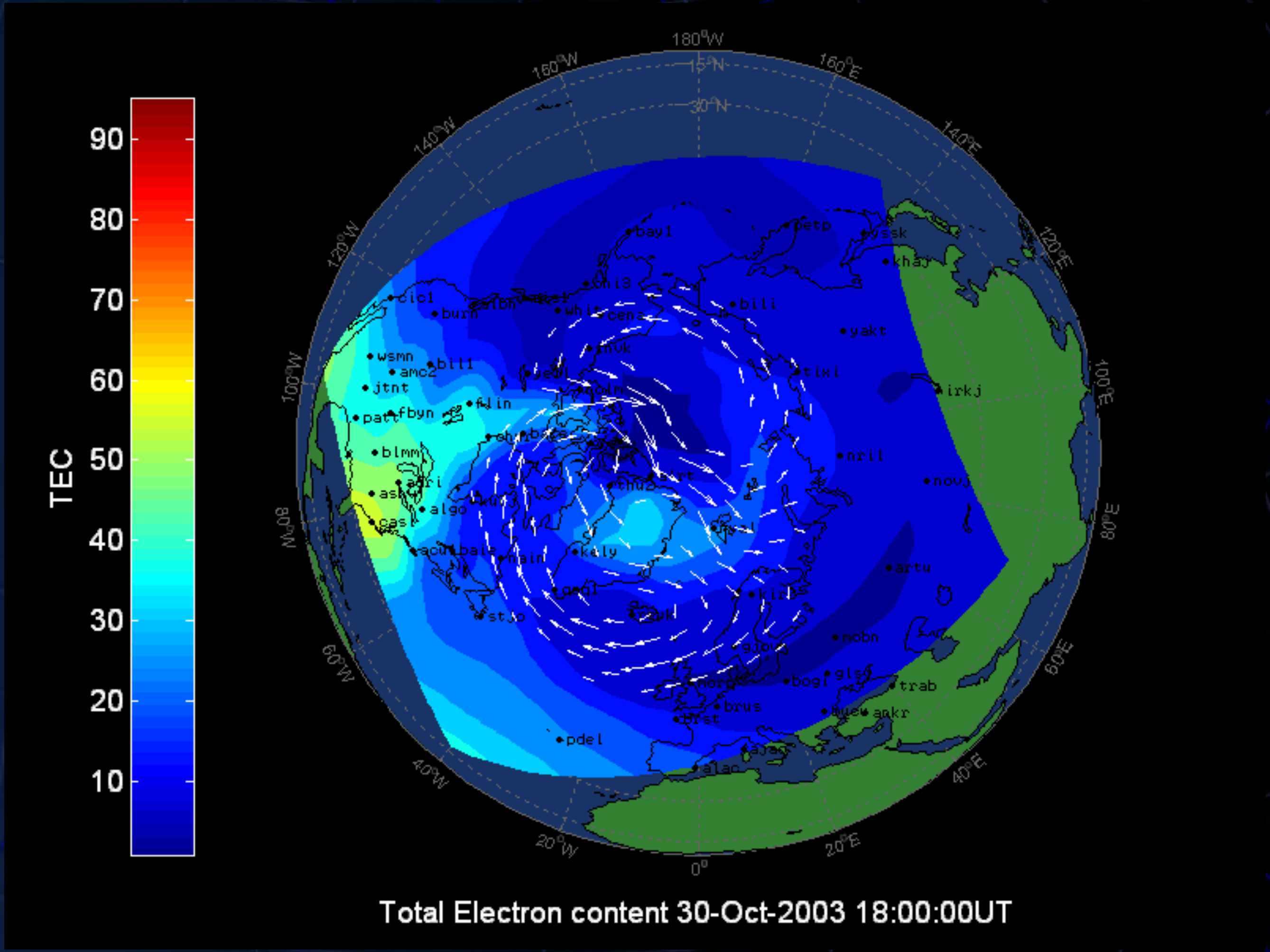


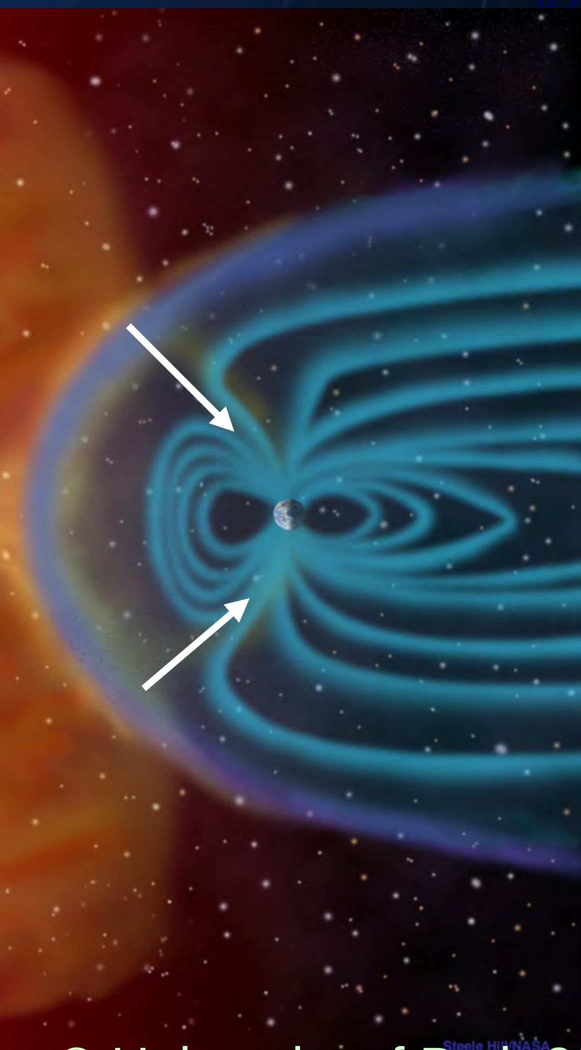
Fig. 4. Equivalent vertical TEC (TECU) snapshots by MIDAS for 30 October at 21:40 and 22:25 UT (top), and 20 November at 19:10 and 19:50 UT (bottom). σ_φ maxima for selected PRNs as recorded from the GISTM chain are superimposed.

G. De Franceschi et al. / Journal of Atmospheric and Solar-Terrestrial Physics

Possible approach to forecasting high-latitude scintillation



High-latitude scintillation



However, it is not always so simple

Second example:
Scintillation – **dayside** in the cusp

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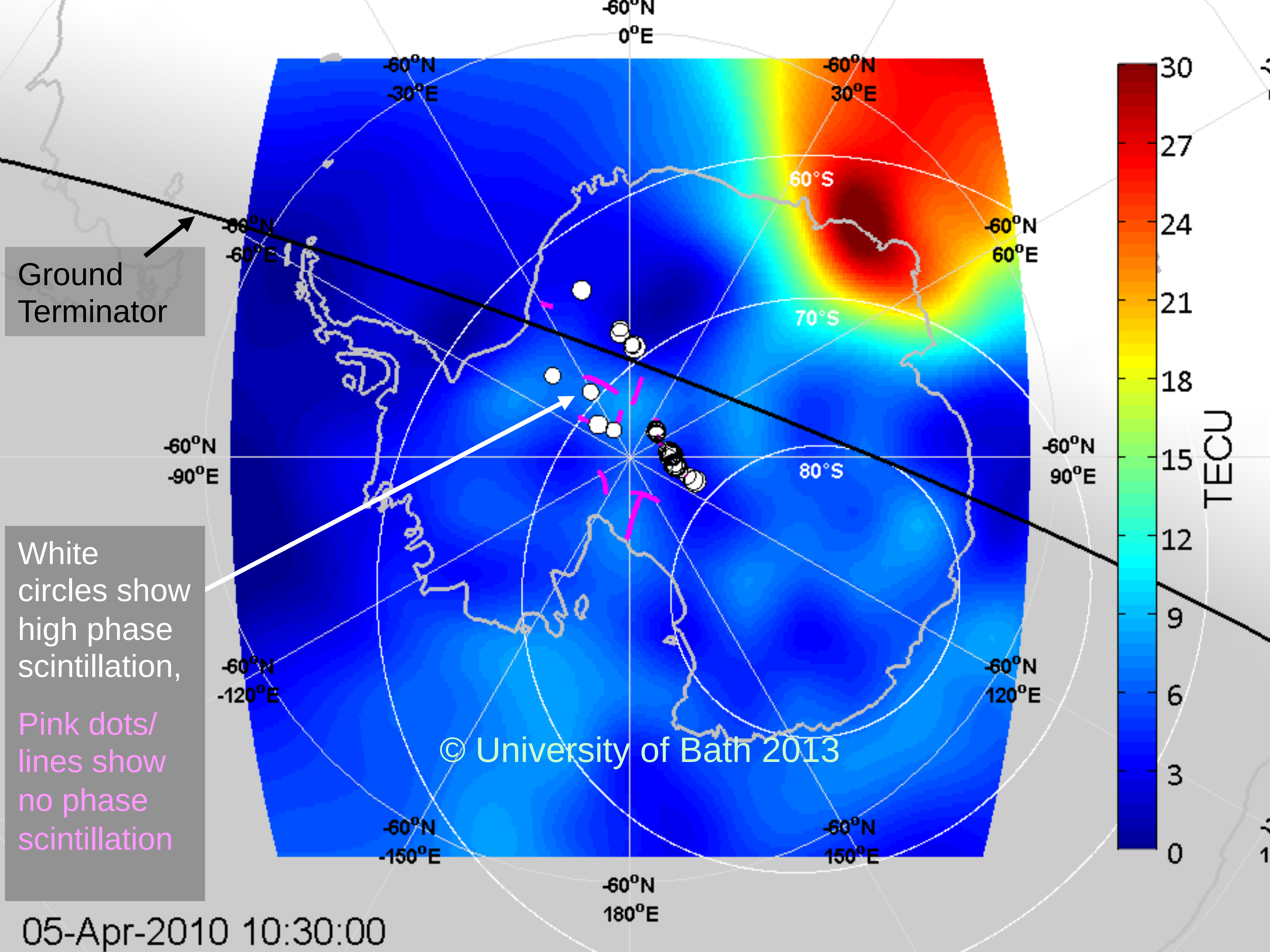
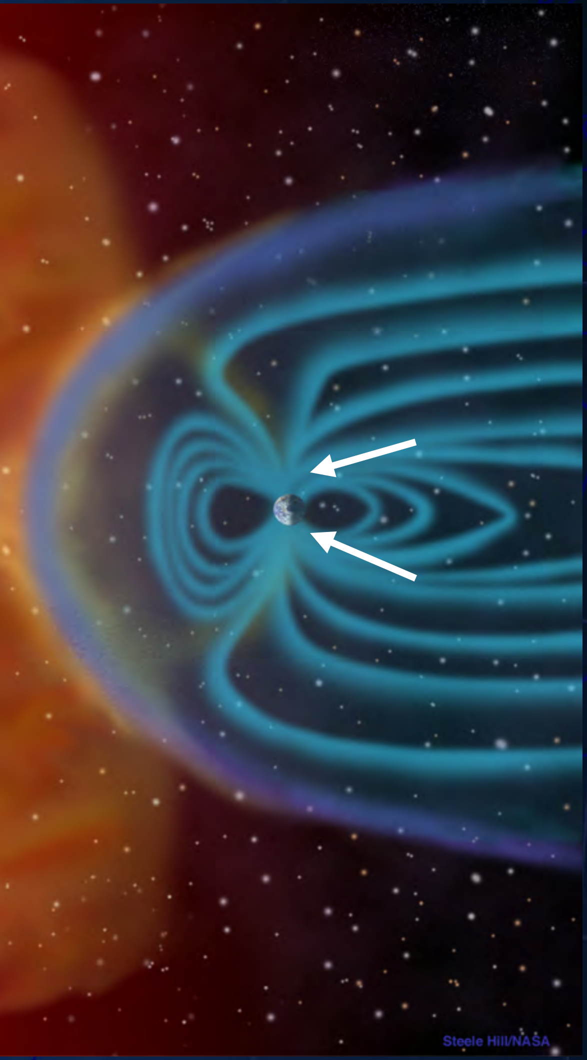


Ground Terminator
White circles show high phase scintillation,
Pink dots/ lines show no phase scintillation
-60°N 0°E
-60°N -30°E
-60°N 30°E
-60°N -60°E
-60°N 60°E
-60°N -90°E
-60°N 90°E
-60°N -120°E
-60°N 120°E
-60°N -150°E
-60°N 150°E
-60°N 180°E
60°S
70°S
80°S
TECU
30
27
24
21
18
15
12
9
6
3
0
© University of Bath 2013
05-Apr-2010 10:30:00

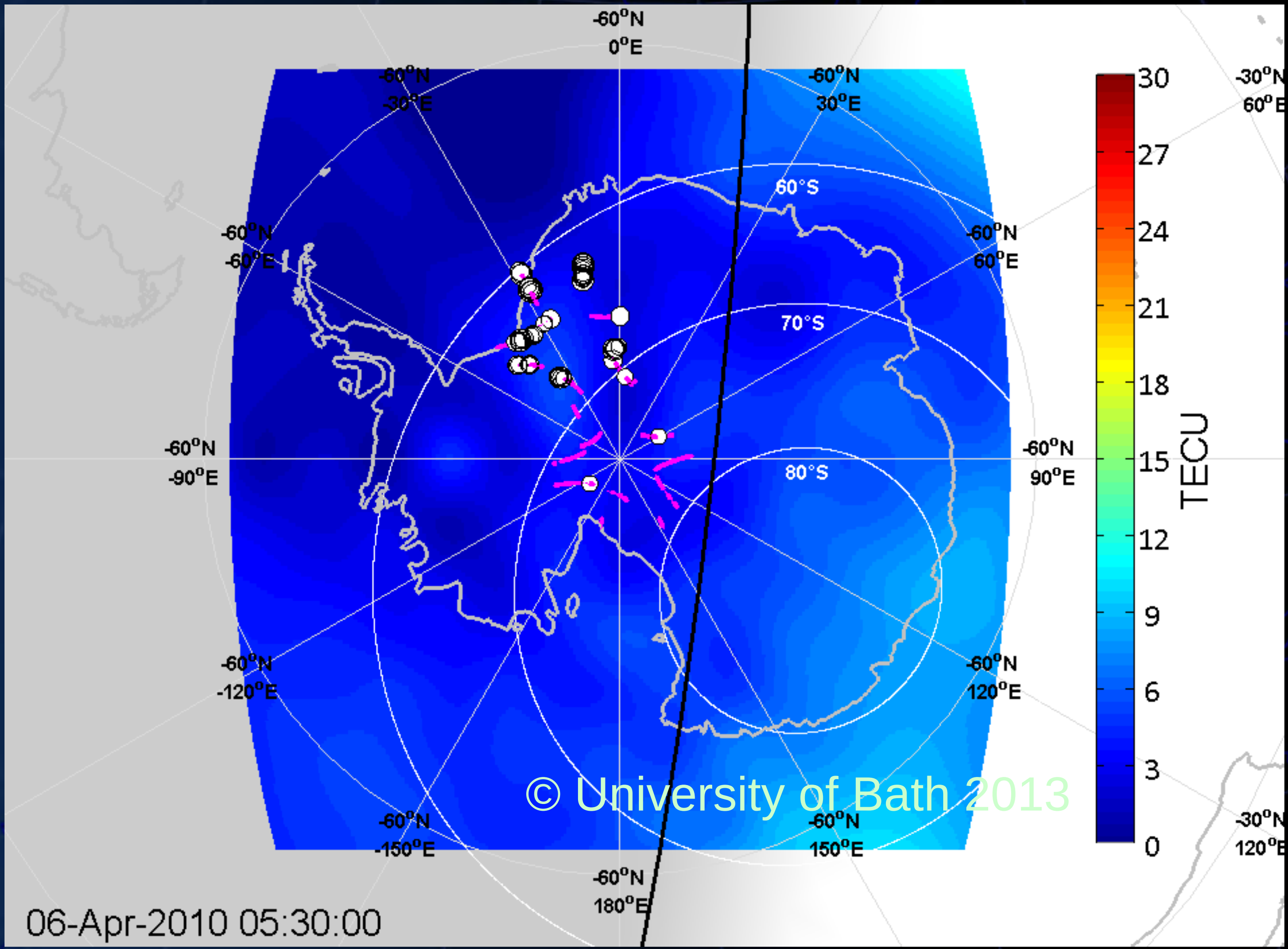
High-latitude scintillation



Third example:

Scintillation – **nightside in the auroral oval**

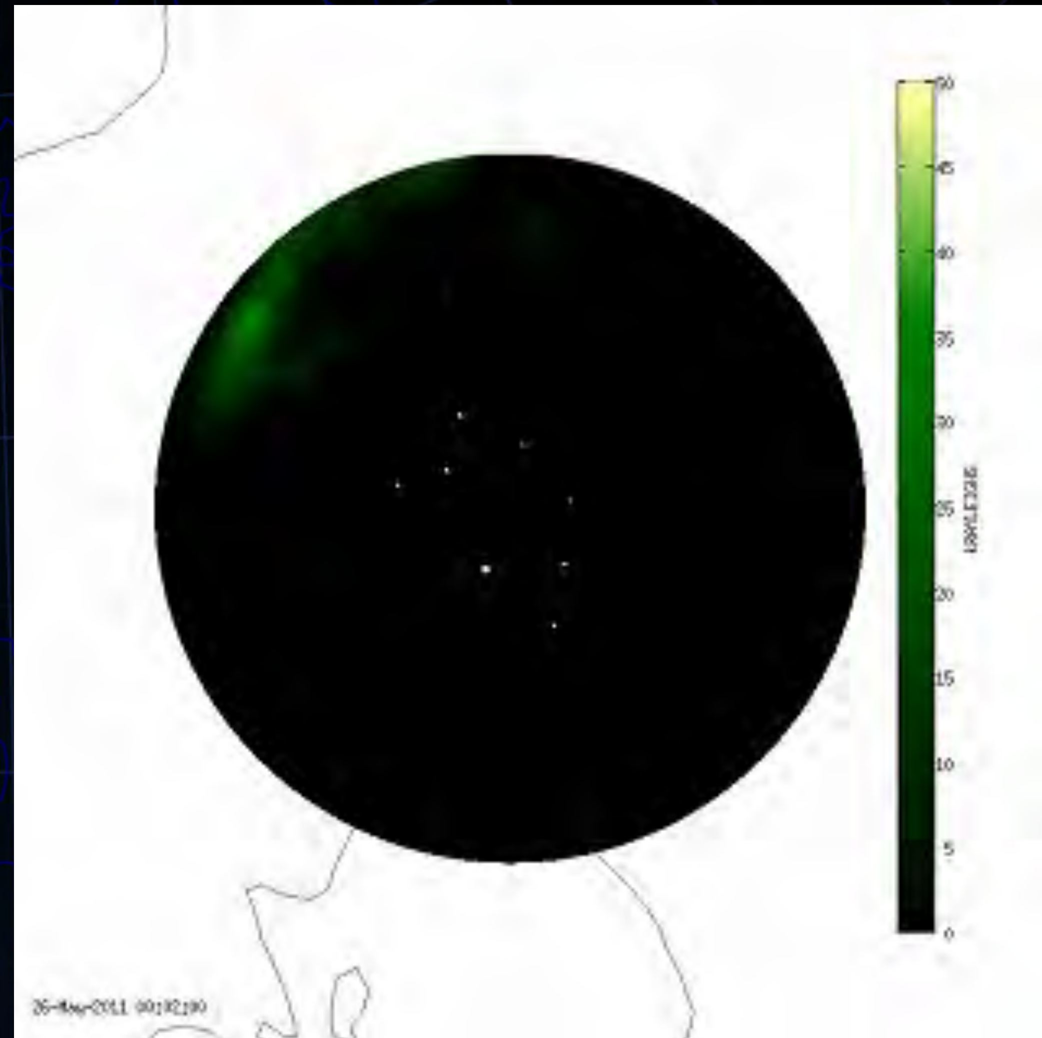
Nightside on 6 April 2010



South Pole Station, Field of view above 85 S

26 May 2011

0-2 UT



Acknowledgements: Auroral movie in collaboration with Yusuke Ebihara, Kyoto University, Gary Bust, ASTRA and Al Weatherwax, Siena College.

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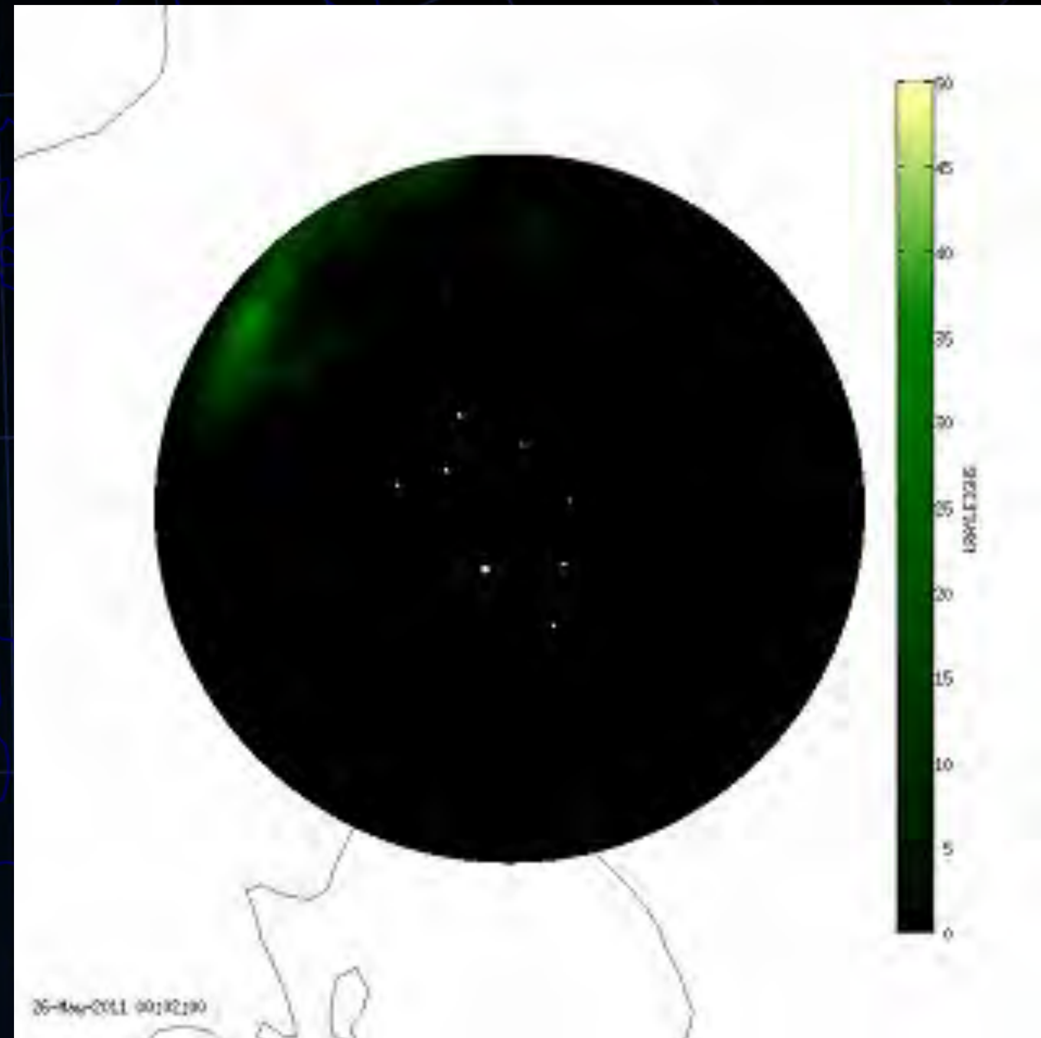

Difficult to predict which comms/nav link will have a problem

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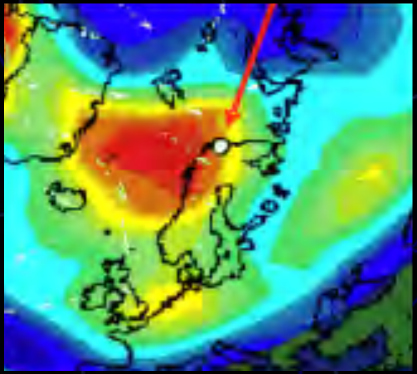
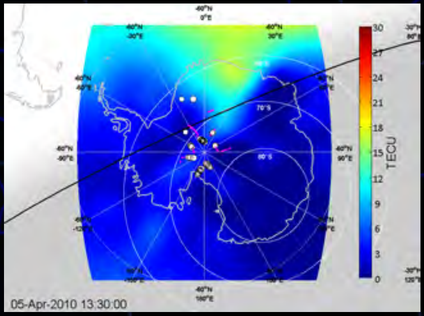
Summary

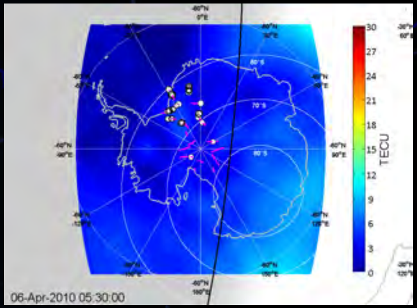
Three types of high latitude scintillation:



Convecting patches



Dayside cusp



Nightside auroral oval

Conclusions

To short-term forecast there are two very different challenges

Patch scintillation – can use ionospheric model to convect

Precipitation scintillation – very difficult to forecast details – magnetosphere probably too late – need to know upstream from ACE and use full data- driven coupled models of Sun-Earth system

Outstanding Issues

- We do not yet have any confidence to bound **ionospheric** effects on GPS navigation in the Arctic (Scientific unknowns)

- How can we predict the effects of a specific event on each of the many types of GPS receiver without taking them into the field to test? (Engineering question)