



Can we use space magnetometer data in operational ionospheric models?

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INTRODUCTION

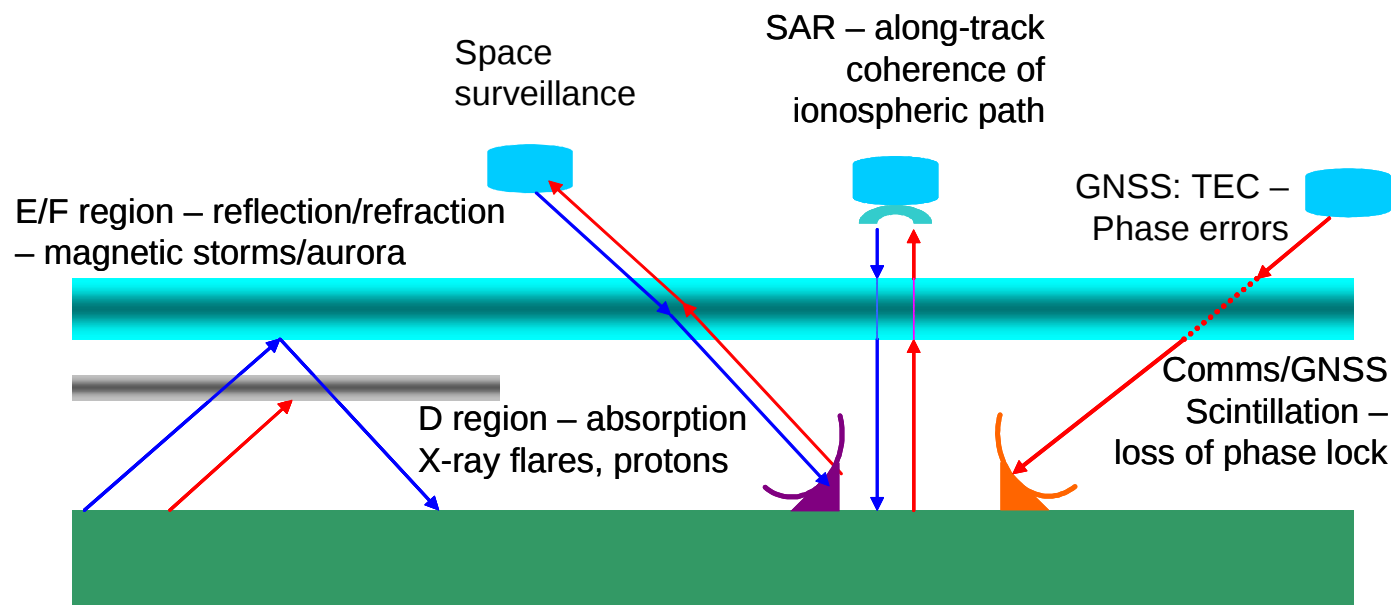
- Speculate how we might use satellite magnetic data in future models of thermosphere-ionosphere
- Raise ideas for future research
- Also set context on importance and impact



BACKGROUND and MOTIVATION (and IMPACT?)

The ionosphere matters!

- Many advanced technologies require radio wave propagation through ionosphere
 - Communications, navigation and surveillance
- Propagation has wide range of sensitivities to electron density structure and dynamics including:
 - Reflection, refraction, absorption, group delay, scintillation



Ionospheric space weather

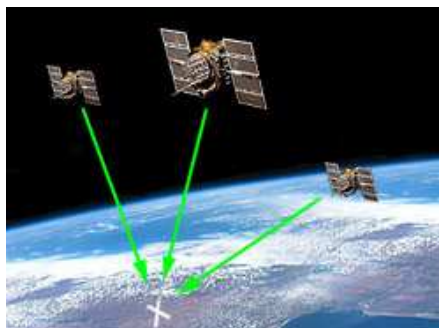
- Subject to many time-varying influences
 - Diurnal, seasonal, solar cycle, solar flares, magnetic storms, tides and gravity waves, electric coupling?, secular change of solar activity and geomagnetic field, climate change
- Users of sensitive technologies need range of ionospheric support:
 - Nowcasting (≤ 1 hr, operational control)
 - Diagnostic support (is my kit broken or is it the ionosphere?)
 - Medium-term prediction (hours or days, holy grail)
 - Long-term trends (statistical risks $\Rightarrow$ design margins)

Examples of users

Space surveillance



GPS/Galileo



Tactical comms

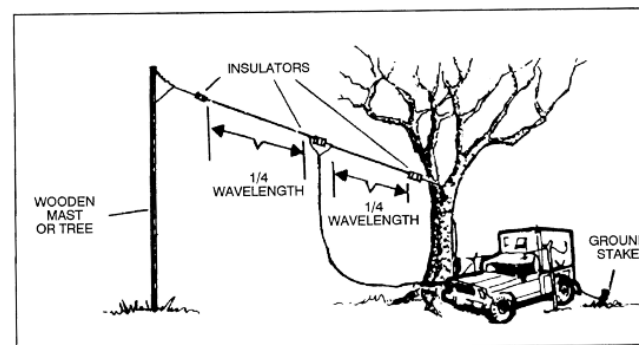
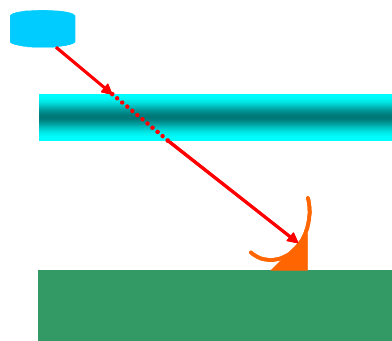


Figure D-9. Half-wave dipole antenna.

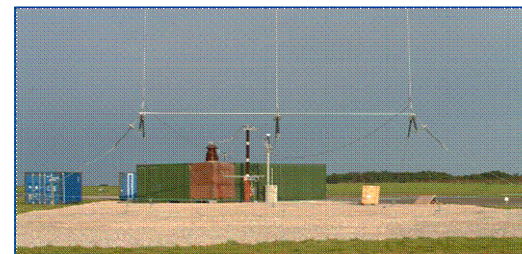
Strategic military
comms



Satcom

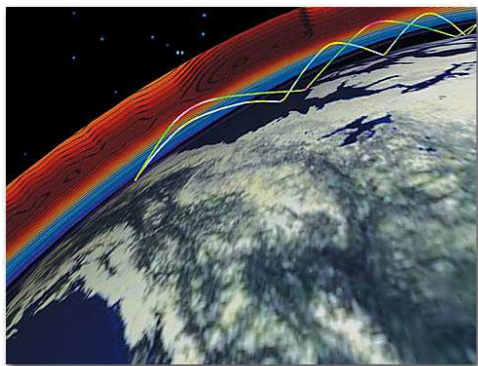


Next generation
VLF navigation



More examples

HF monitoring



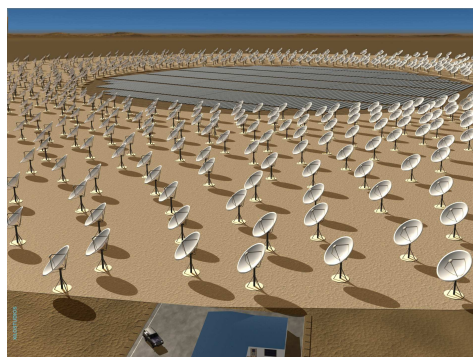
Space radar



Aircraft comms



Radio astronomy



VHF transmitter location



Charging environment



Space situational awareness

- Ionosphere effects increasing seen as part of space situational awareness (SSA)
 - knowing & understanding what is going on in space around our planet in order to provide timely & accurate data and information to decision makers & planners
 - ESA/EU SSA programme started Jan 2009
 - Also major element in current FP7 Space Call
 - Strong collaboration with US SSA programme
- Ionospheric requirements embedded in Euro SSA (& in end user requirements for ILWS)
 - Many applications directly relevant to space activities (Radar, GNSS, SAR, ...)
 - Others (HF comms, VLF nav) provide added-value



What is needed?

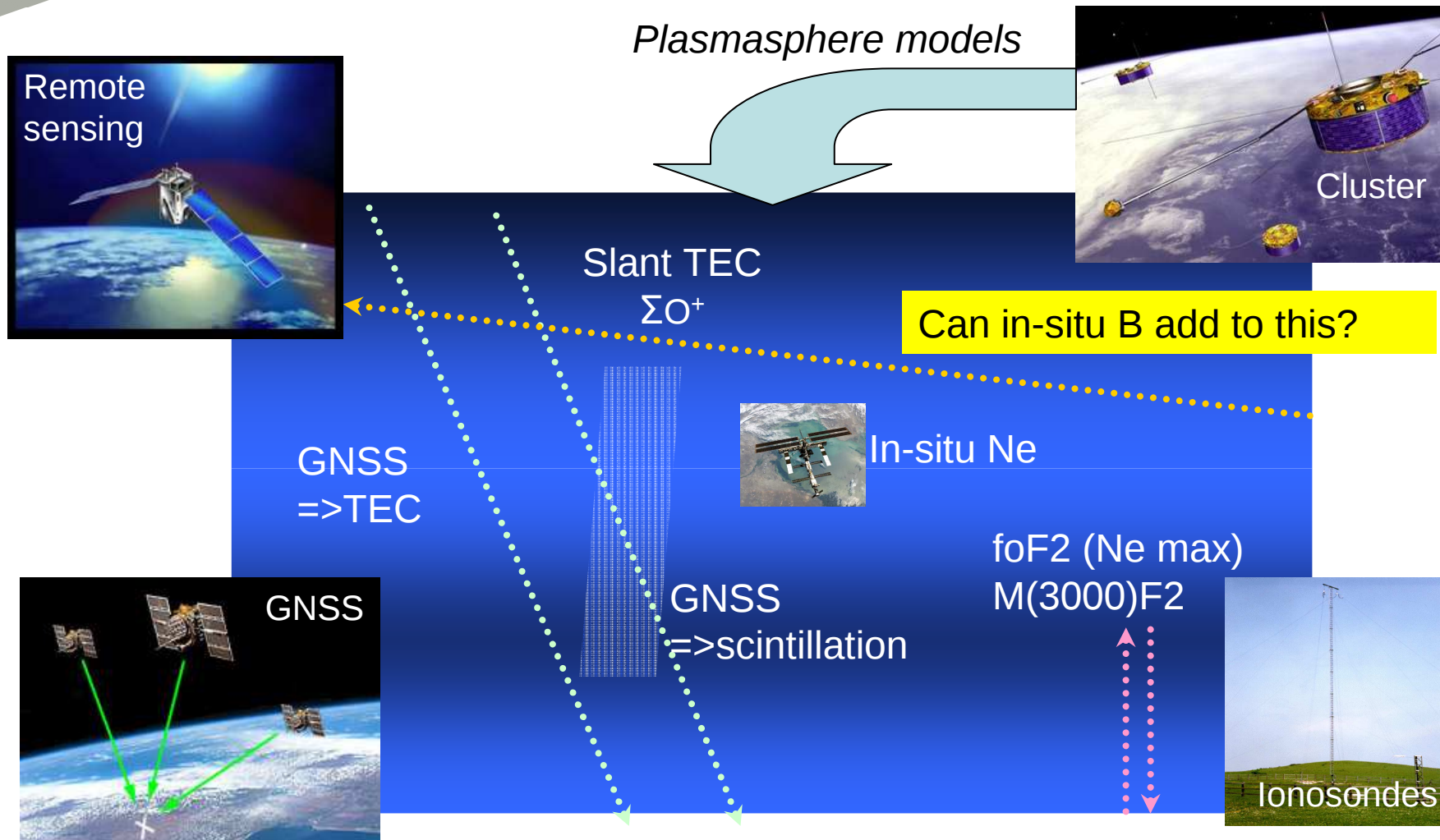
- Models of ionospheric conditions including:
 - Total electron content
 - foF2 and M(3000)F2
 - Scintillation forecasts
 - Topside profiles including plasmasphere (partition of TEC)
- Preferably based on physical understanding
 - Builds confidence, better inter/extrapolation of observations
 - But mathematical models ok (e.g. data mining)
- Data to drive these models
 - Near real-time (minutes)
 - Diverse types for better constraints on models
 - Good geographic coverage
 - Can we use SWARM to explore additional diversity?



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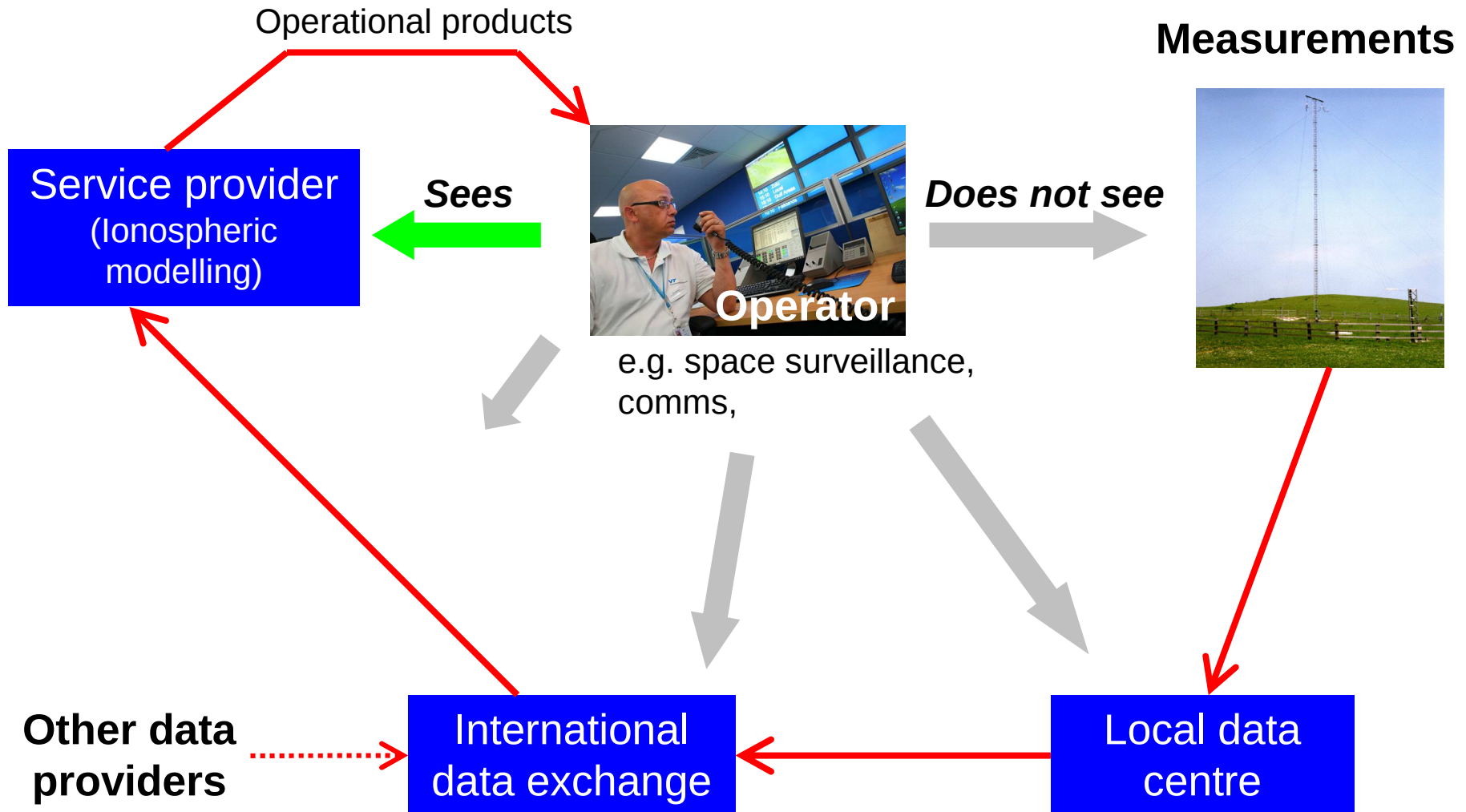
WHAT DATA DO WE HAVE?

Ionospheric monitoring





Data are global



Data are global 2



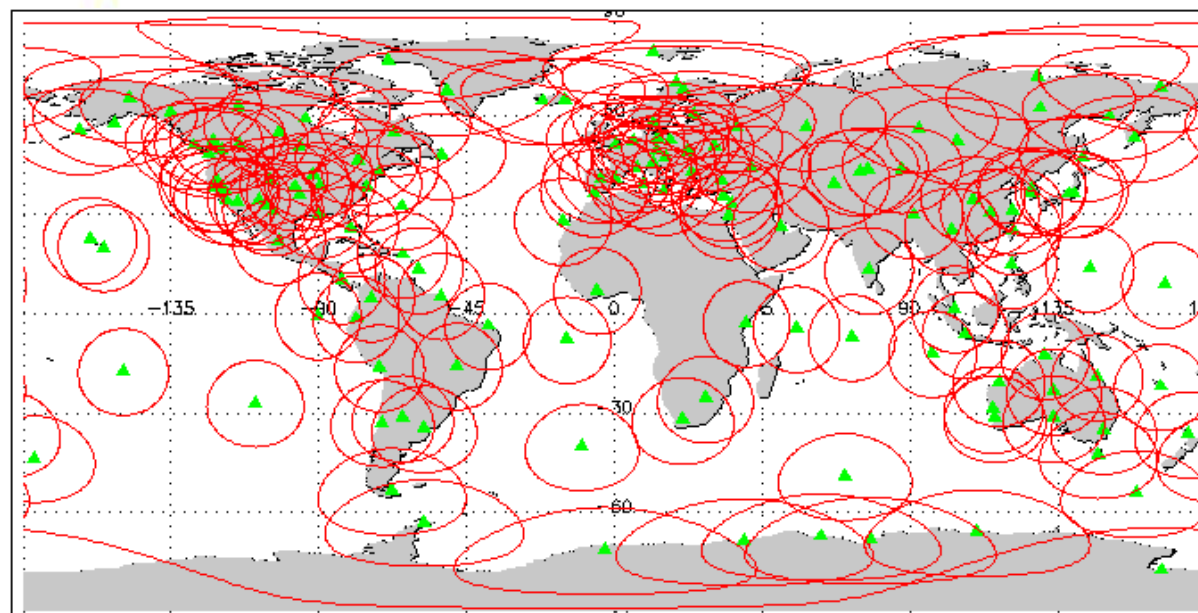
*US SSA view of global
ionosonde network*

Spacecraft measurements help



DISS

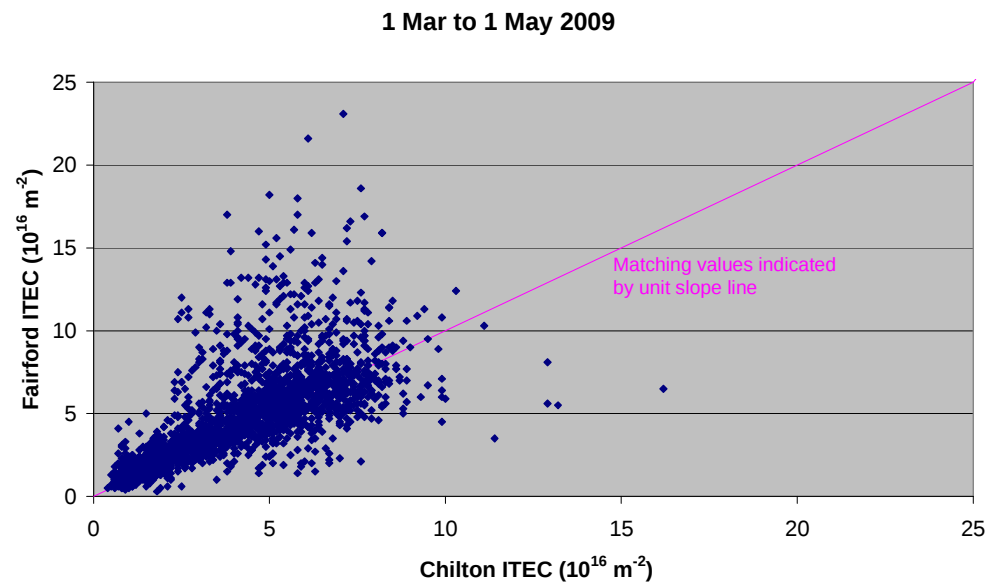
GPS network used by JPL



Sensitivity to errors

- Real-time data automated
 - Limited human QA checks increase risk of error
 - Can propagate into wrong nowcast or diagnostic
 - Diversity of data can help automated QA checks by highlighting inconsistencies

- Figure right shows comparison of ionosonde-derived TEC taken 50 km apart
 - Chilton vs Fairford
 - Excess of high values at Fairford due to auto-scaling errors





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HOW CAN WE USE MAGNETIC DATA?



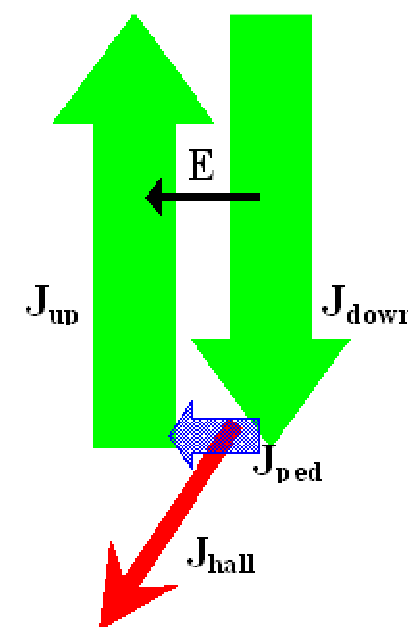
ROLE OF SWARM

- SWARM gives us the potential to explore possibilities
- Not an operational mission
- But may demonstrate what could be done
- Possible shape of an operational mission
 - Use nano/cubesats for low cost
 - Much work on low mass/power magnetometers
 - Can disperse several nanosats around each of a few orbit planes
 - See space weather nanosat study on <http://epubs.stfc.ac.uk/work-details?w=42988>

Space-based geomagnetic indices?

- Indices provide quantitative estimate of state of magnetosphere
 - Used in many space weather models including ionosphere
- Better proxy for energy deposition from aurora?
 - Much better global coverage for Kp (Eur + NA + Aus)
 - Better resolution on Dst/ring current?
 - But much knowledge on what to do
- Space-based indices discussed in ESA studies
 - May provide more consistent dataset (global coverage)
 - But will have very different characteristics
 - In Birkeland currents (right) spacecraft see sole field (E-W) field, but ground systems see N-S field from Hall current
- Can this new view help?
 - SWARM well-placed to generate new indices for use in ionospheric modelling
 - Will these perform better or worse than ground-based indices?

-70 years





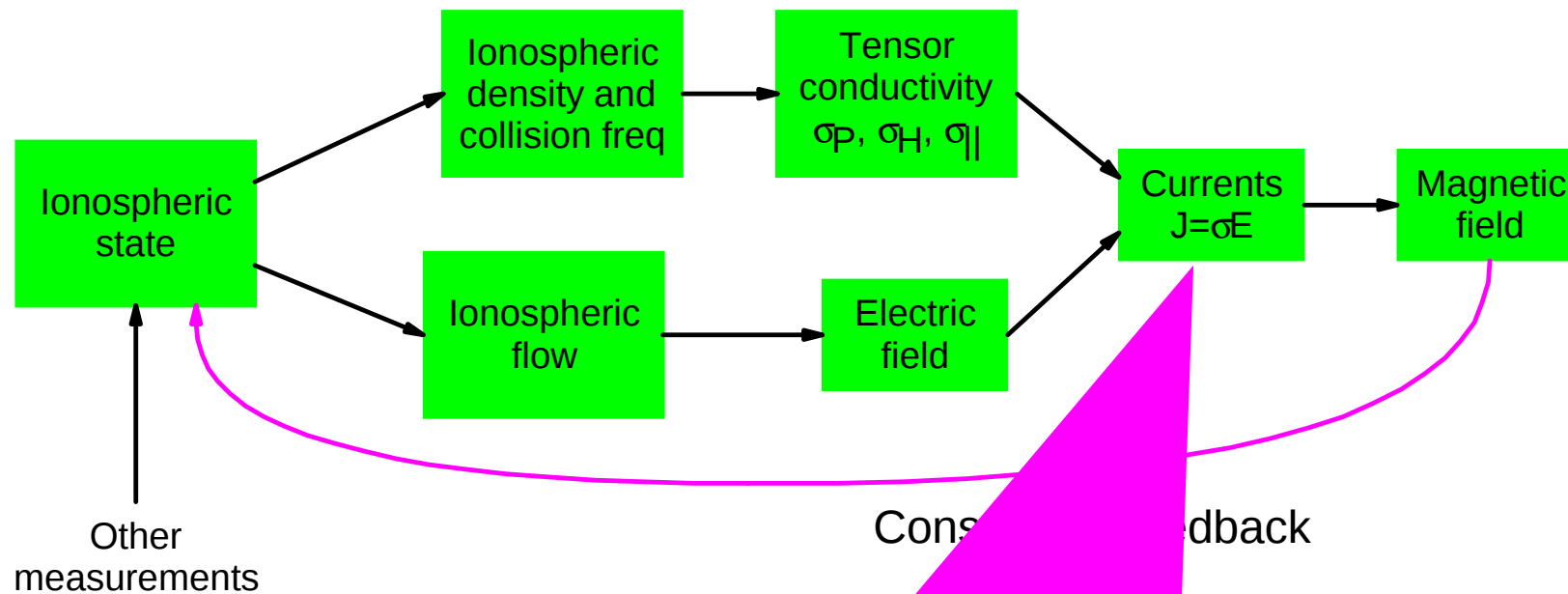
Constraint on assimilative models?

- Assimilative models now important in tracking and predicting state of complex physical systems
 - Underlying model (preferably physics-based)
 - Tune timeline with real data
 - Nowcasting, interpolation, re-analysis
 - Applications include meteorology, oceanography, orbit analysis
- Growing application to space environment
 - GAIM & DREAM in US,
 - QinetiQ ionospheric model (parametric)
 - Many discussions in UK and rest of Europe



How to use magnetic data?

$$\sigma_P = \left[\frac{N_e}{m_e \nu_e} \left(\frac{\nu_e^2}{\nu_e^2 + \omega_e^2} \right) + \frac{N_i}{m_i \nu_i} \left(\frac{\nu_i^2}{\nu_i^2 + \omega_i^2} \right) \right] |e|^2$$



- Can this provide horizontal resolution (along orbit) not available from ionosondes (vertical) or TEC (integral)?



SUMMARY

- Space magnetometer data has potential to provide novel constraints on models of upper atmosphere.
- SWARM can provide a test bed to explore this!



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SPARES

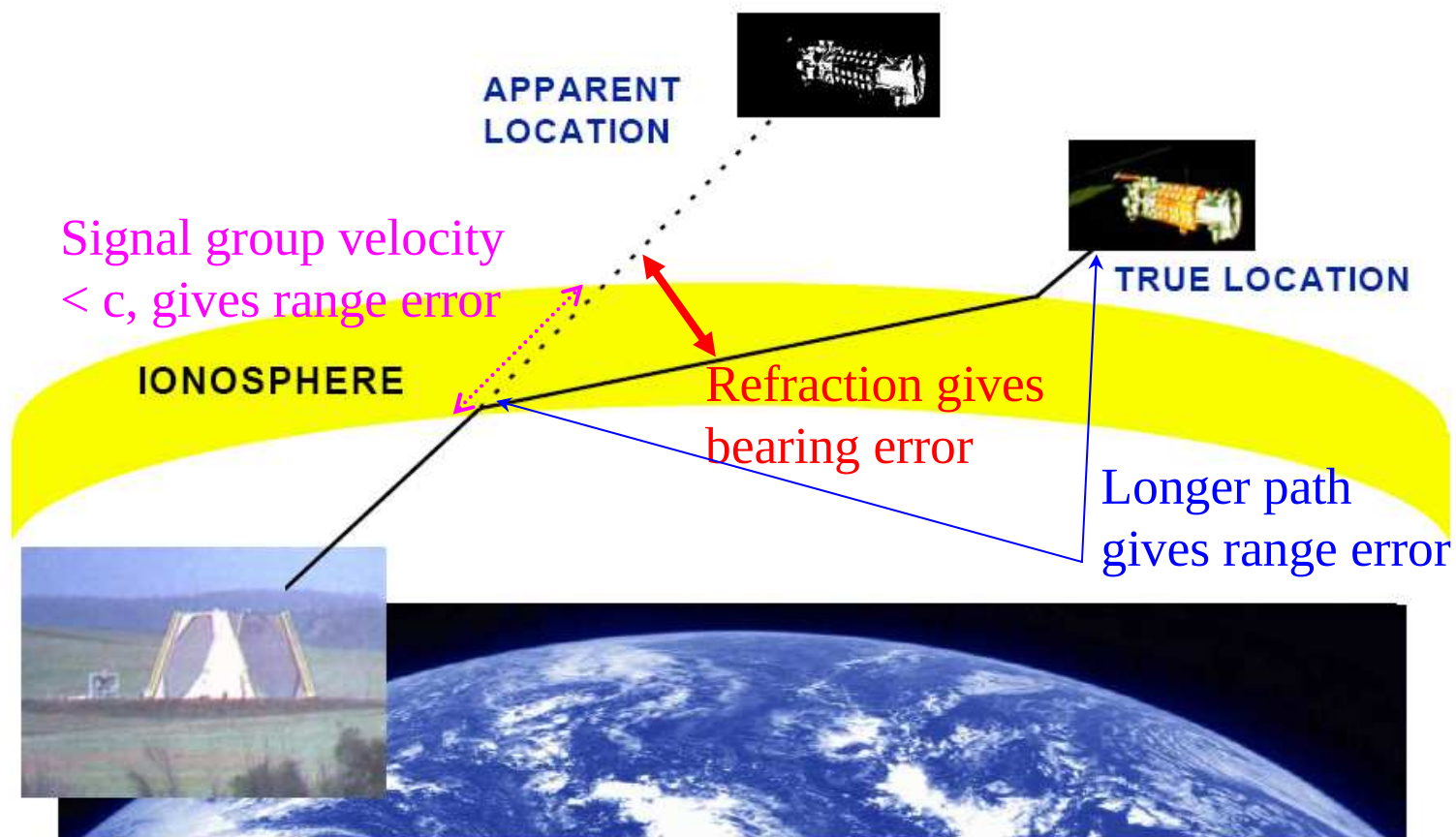


Image from Air University - Space Primer, Chapter 6, Space Environment,
http://www.au.af.mil/au/awc/space/primer/space_environment.pdf

Some UK interests

Forest Moor & Kinloss,
strategic comms

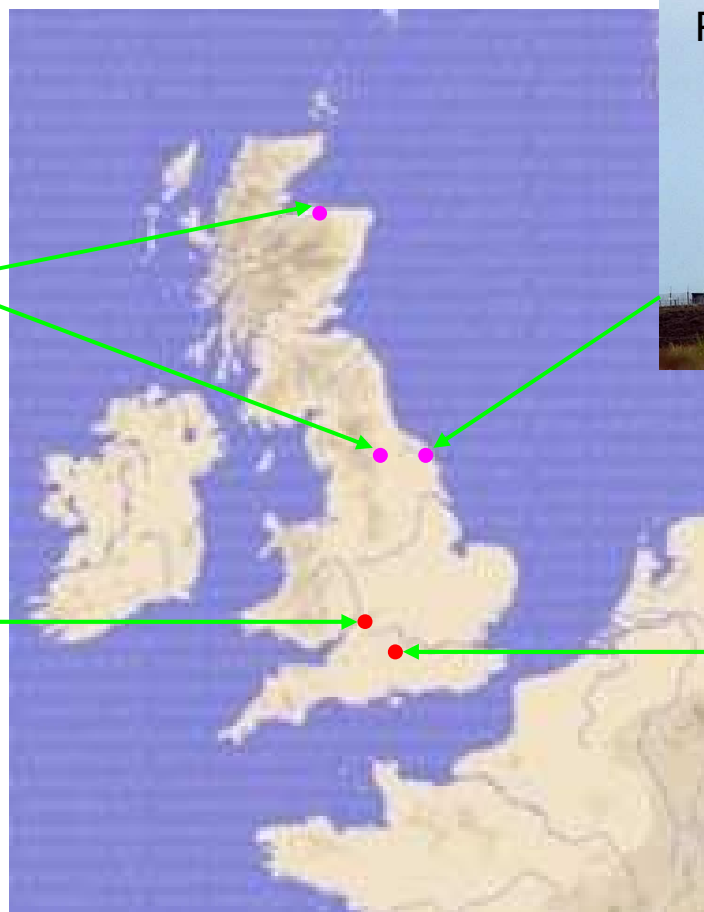


Fylingdales radar, ~420 MHz



Fairford 
ionosonde,
availability 70%

 Chilton
ionosonde
availability 97%



Availability based on foF2
for 1 Mar to 12 May 2009

More UK interests



Shanwick, oceanic ATC



Rampisham, BBC
World Service



Anthorn, e-LORAN



Chilton
ionosonde



More UK interests

Mount Pleasant,
strategic comms



Stanley
ionosonde

