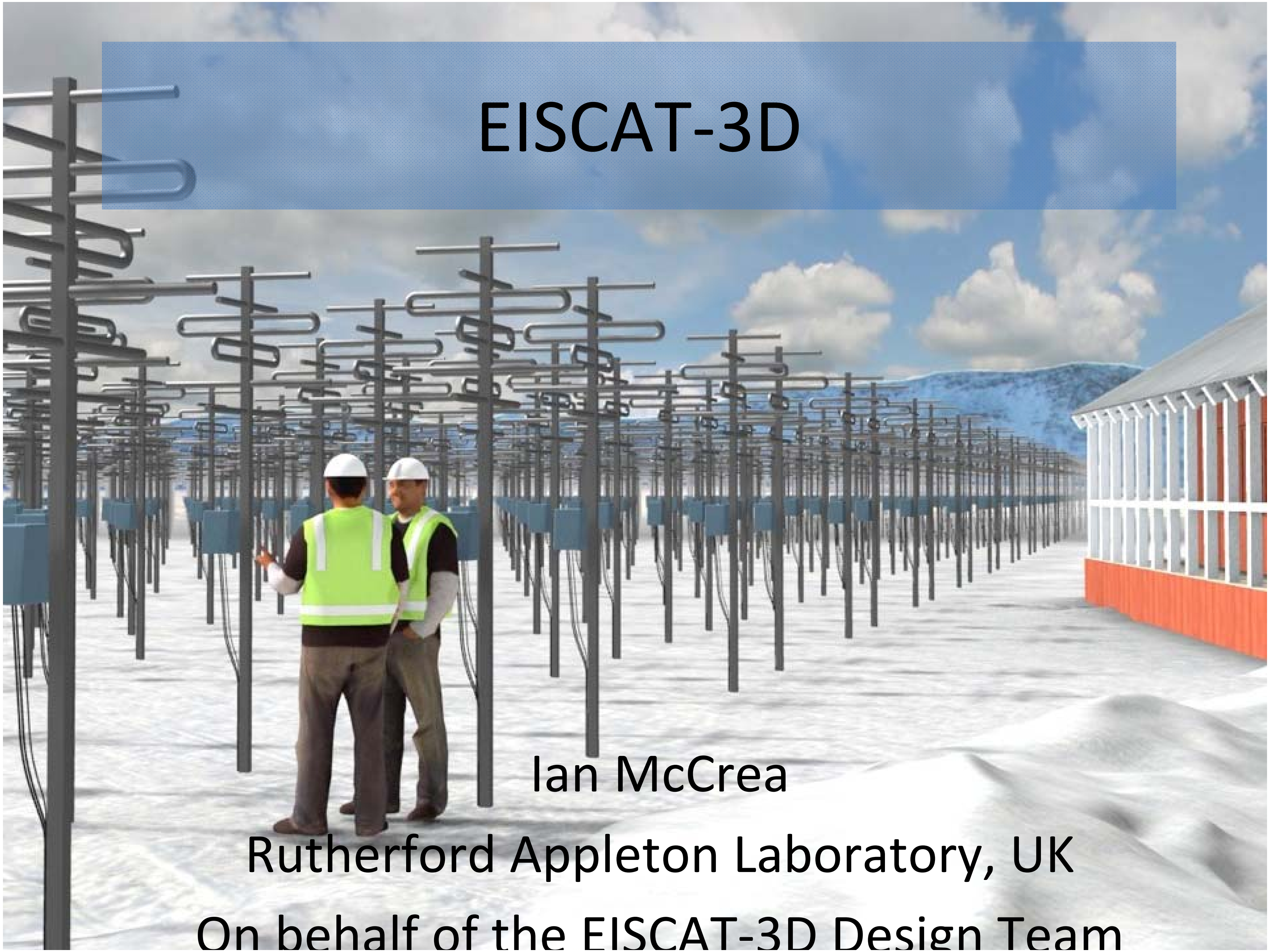
# EISCAT-3D



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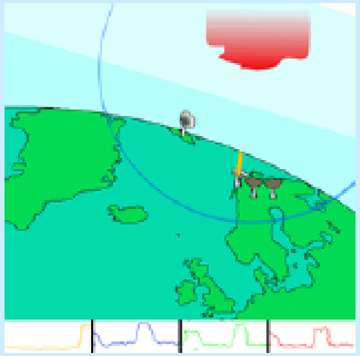
Rutherford Appleton Laboratory, UK
On behalf of the EISCAT-3D Design Team

# EISCAT, the European Incoherent SCATter Association -

a radar system for ionospheric and atmospheric research in northern Europe



Mainland system in operation since 1981 (UHF) and 1983 (VHF),

The UHF was then - and still is -the world's only multi-static ISR system,

but:

The systems are getting old and hard to maintain,

Performance is no longer good enough for cutting-edge work,

and the UHF spectrum will be lost from March, 2010...

and with that EISCAT's vector **E** field capability is also lost!

# What is EISCAT-3D?

•Europe's next-generation radar for upper atmosphere and geospace studies

•Project of the EISCAT Scientific Association – an international research organisation of seven countries

•Replaces current dish-based radar systems

•Multiple large phased arrays (active sites 16000 elements, passive sites 8000 elements)

•Much better resolution and higher sensitivity.

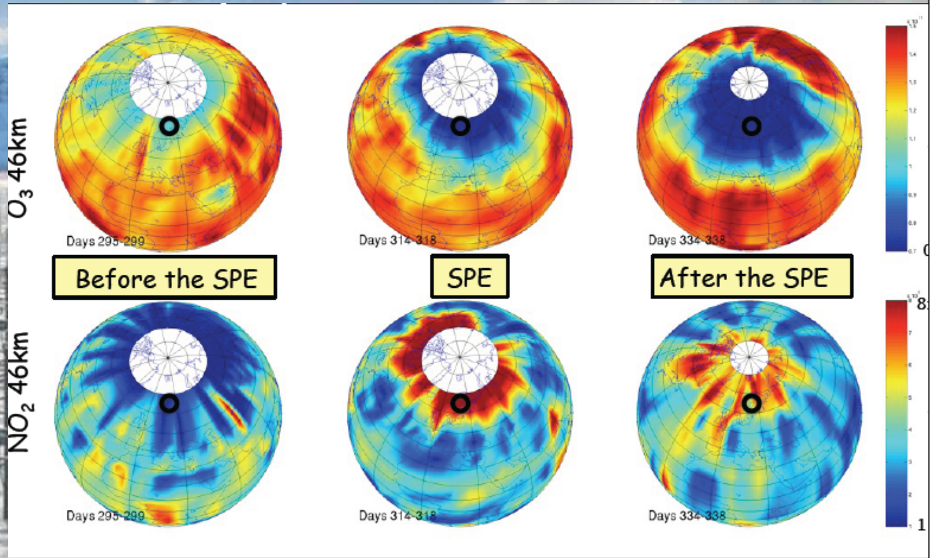
•New capabilities for volumetric imaging and interferometry

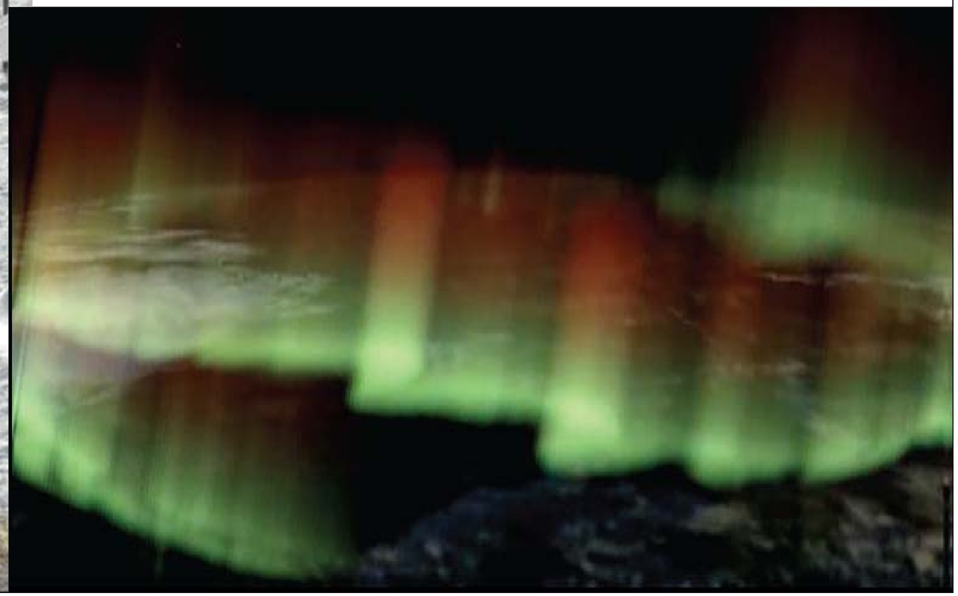
•ESFRI project since December 2008

# Why is EISCAT-3D important?

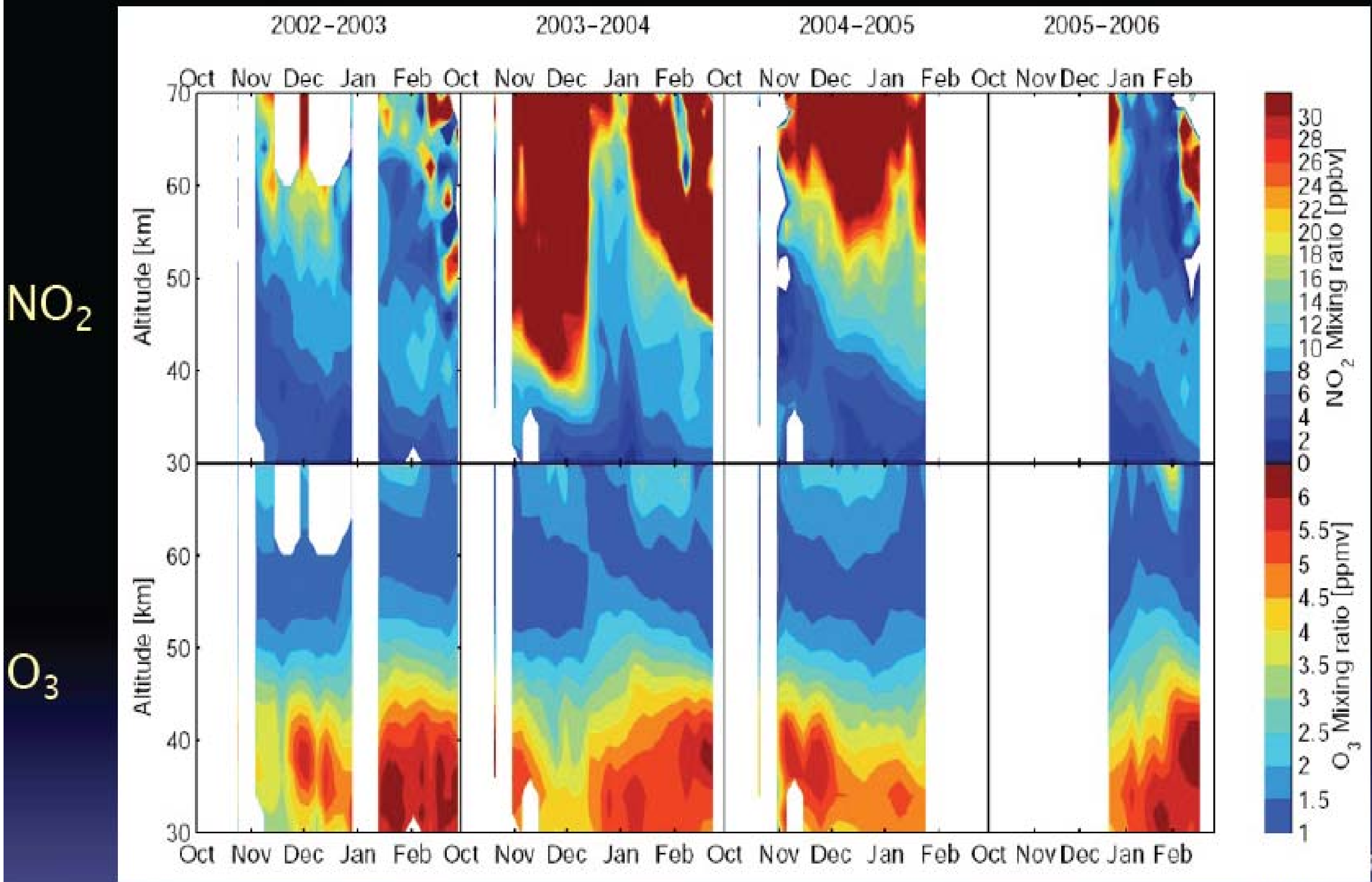
Major science questions:

- Coupling of the different atmospheric regions
- Effects of solar variability on climate
- Turbulence in the ionised and neutral atmosphere
- Atmospheric dust and aerosols
- Effects of meteoric material
- Importance of plasma outflow
- Space debris and satellite drag



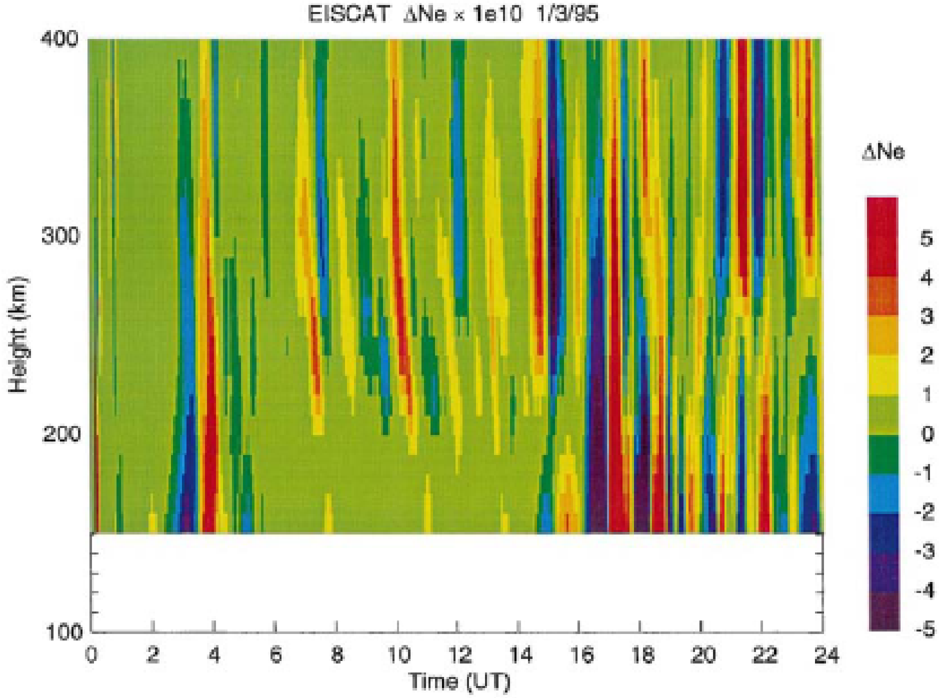



# NH: GOMOS $NO_2$ and $O_3$



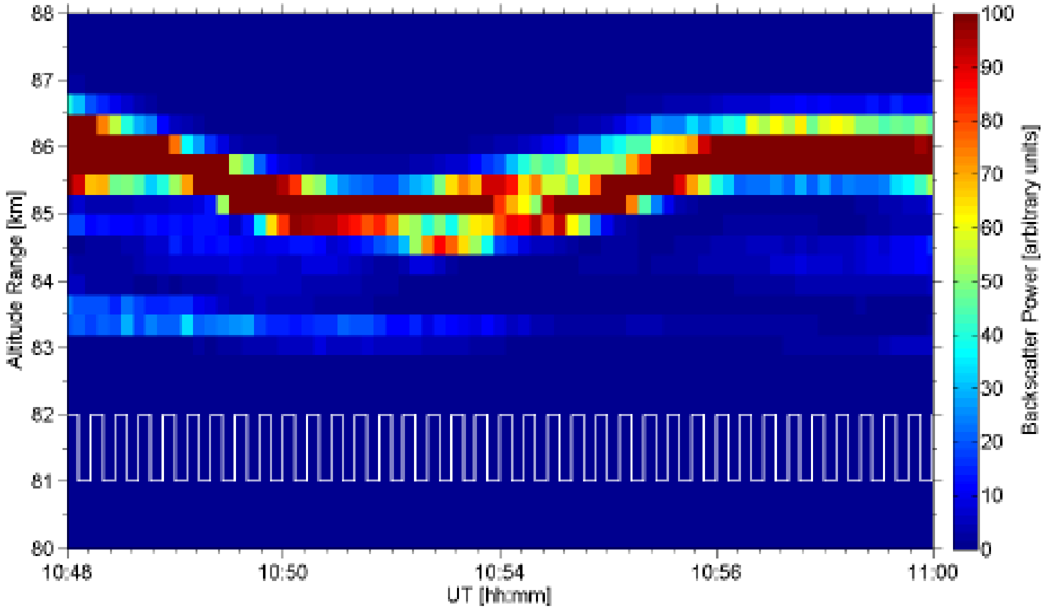
# Radar image atmospheric waves

Application: Propagation vector of atmospheric gravity waves and tides in thermosphere and middle atmosphere



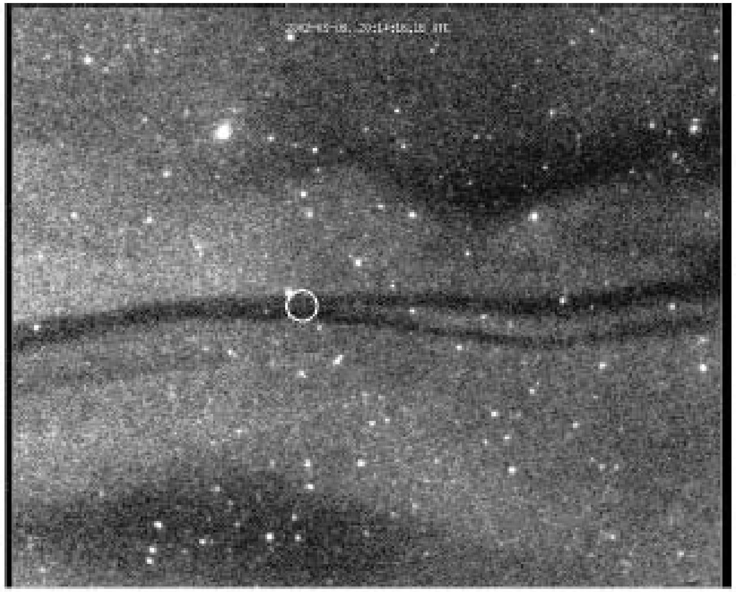
# Radar imaging of thin layers

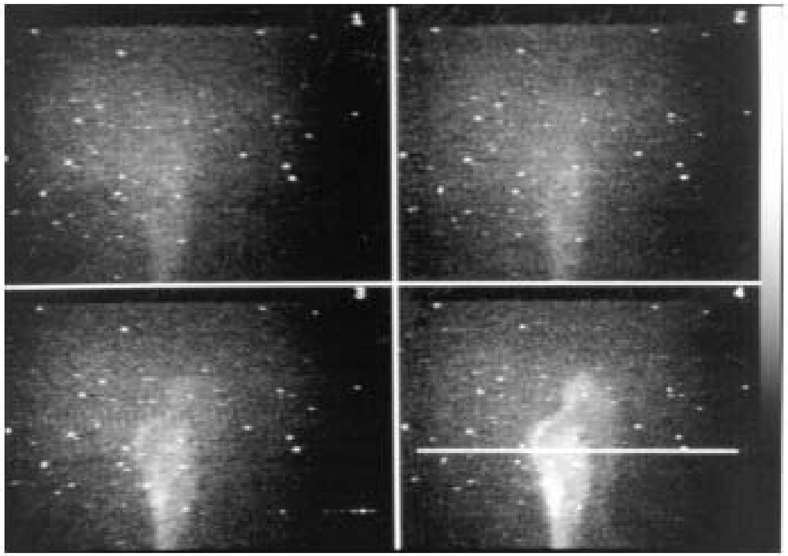
e.g. PMSE and PMWE, climate change




# Radar imaging of small-scale auroral phenomena

e.g. black aurora, pulsating aurora, curls, thin arcs etc.



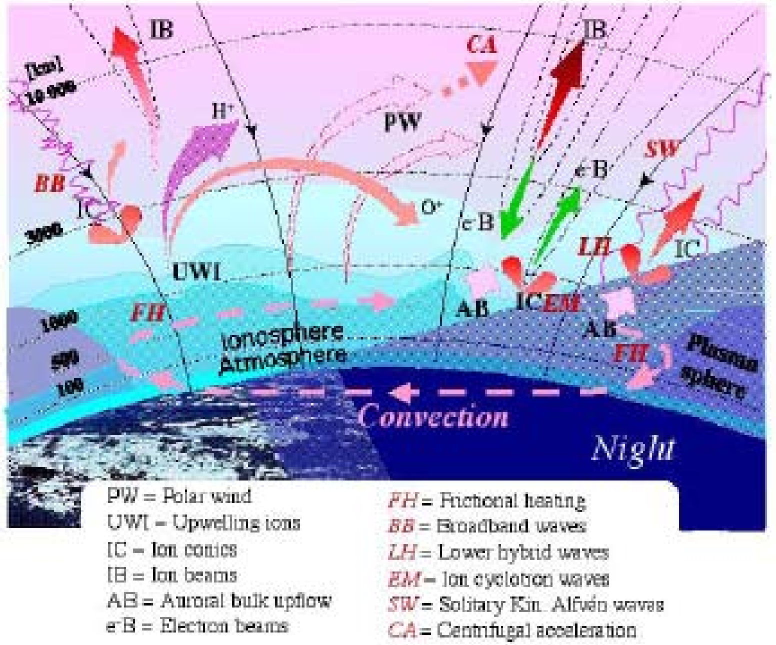



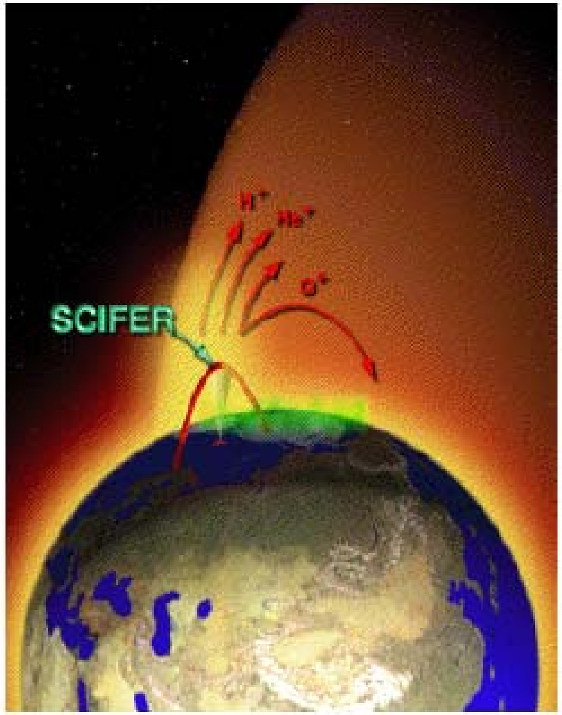
# Radar image ionospheric plasma vertical flow

Application: Ion outflow events

Observe O+, He+, H+ ions

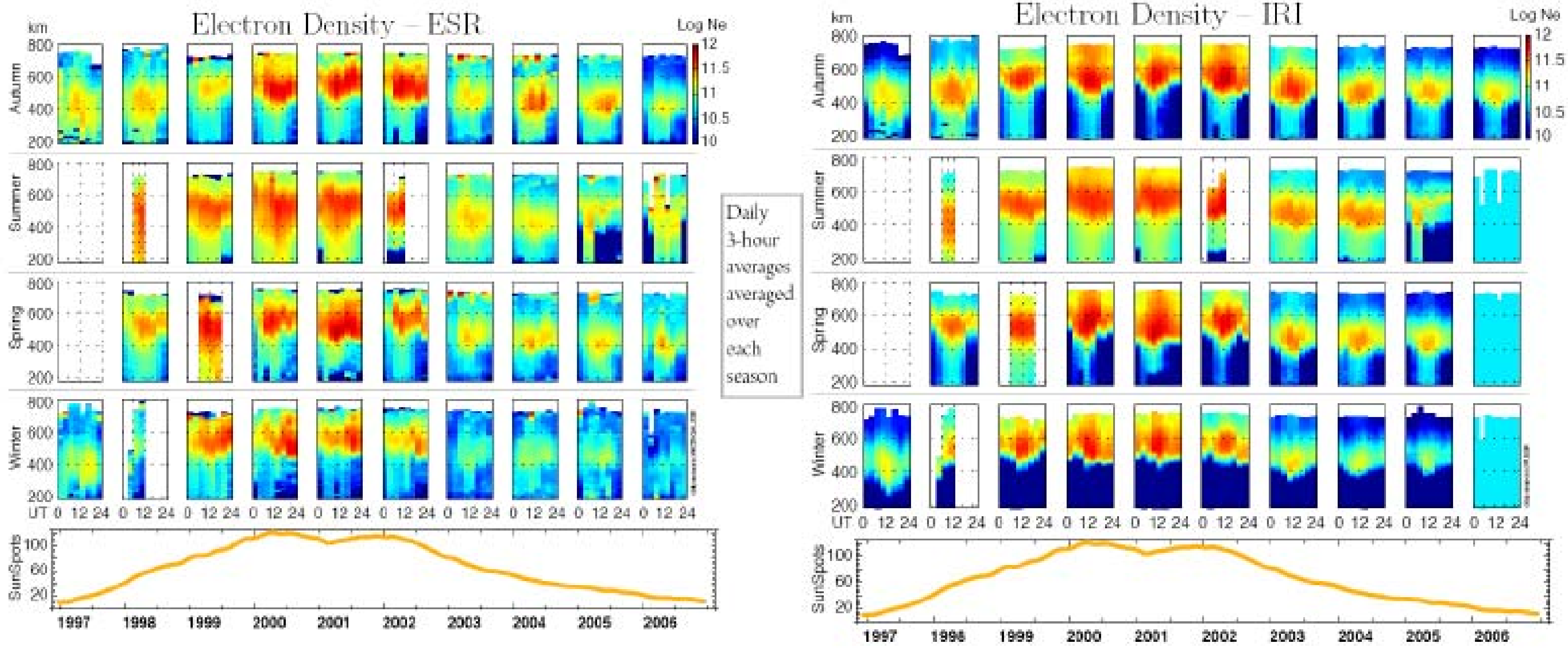
Search for signatures of field-aligned potential drops



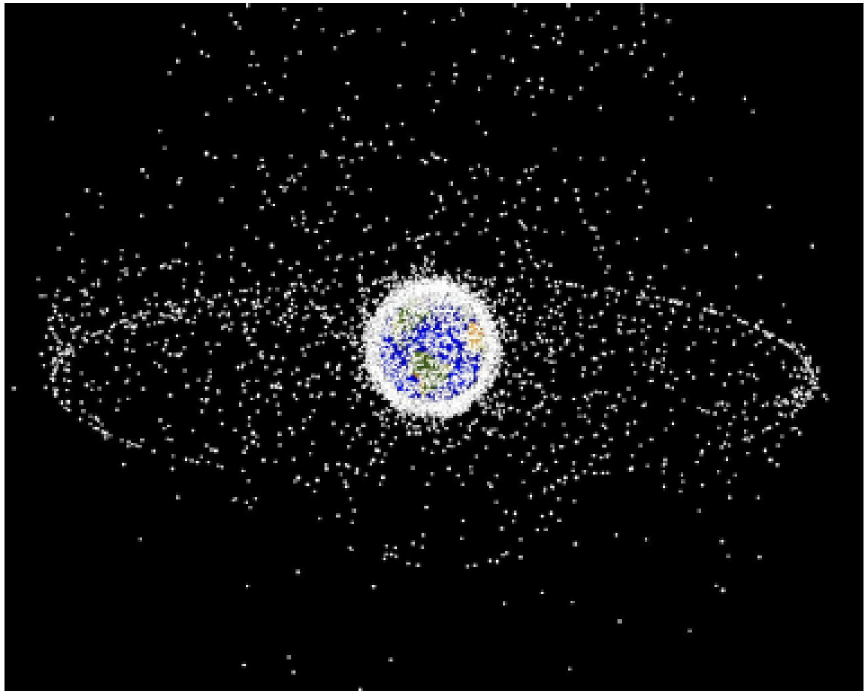
# Continuous (low power) ionospheric monitoring

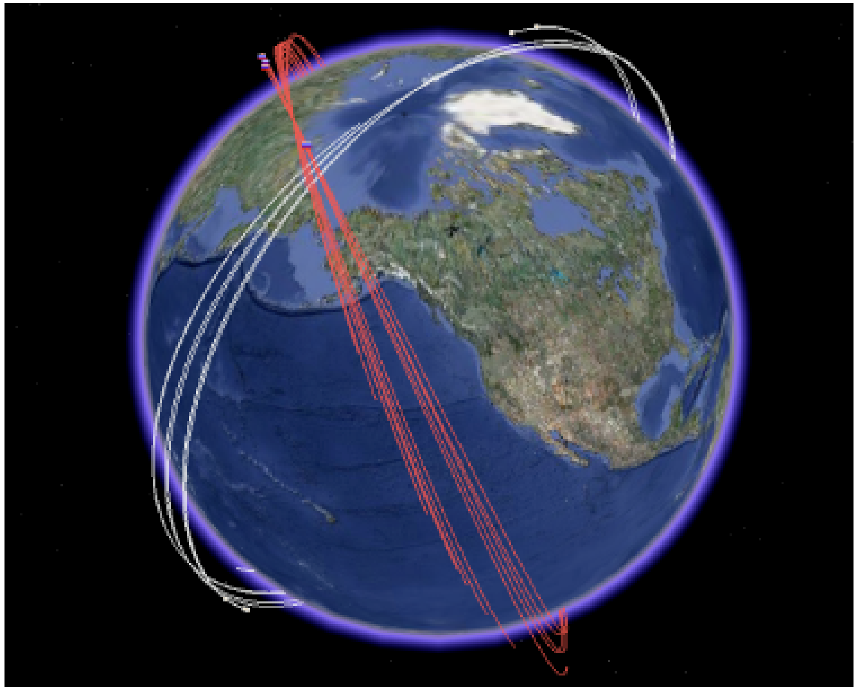
## Application: Modelling for climate change




ESR IPY 2007 run

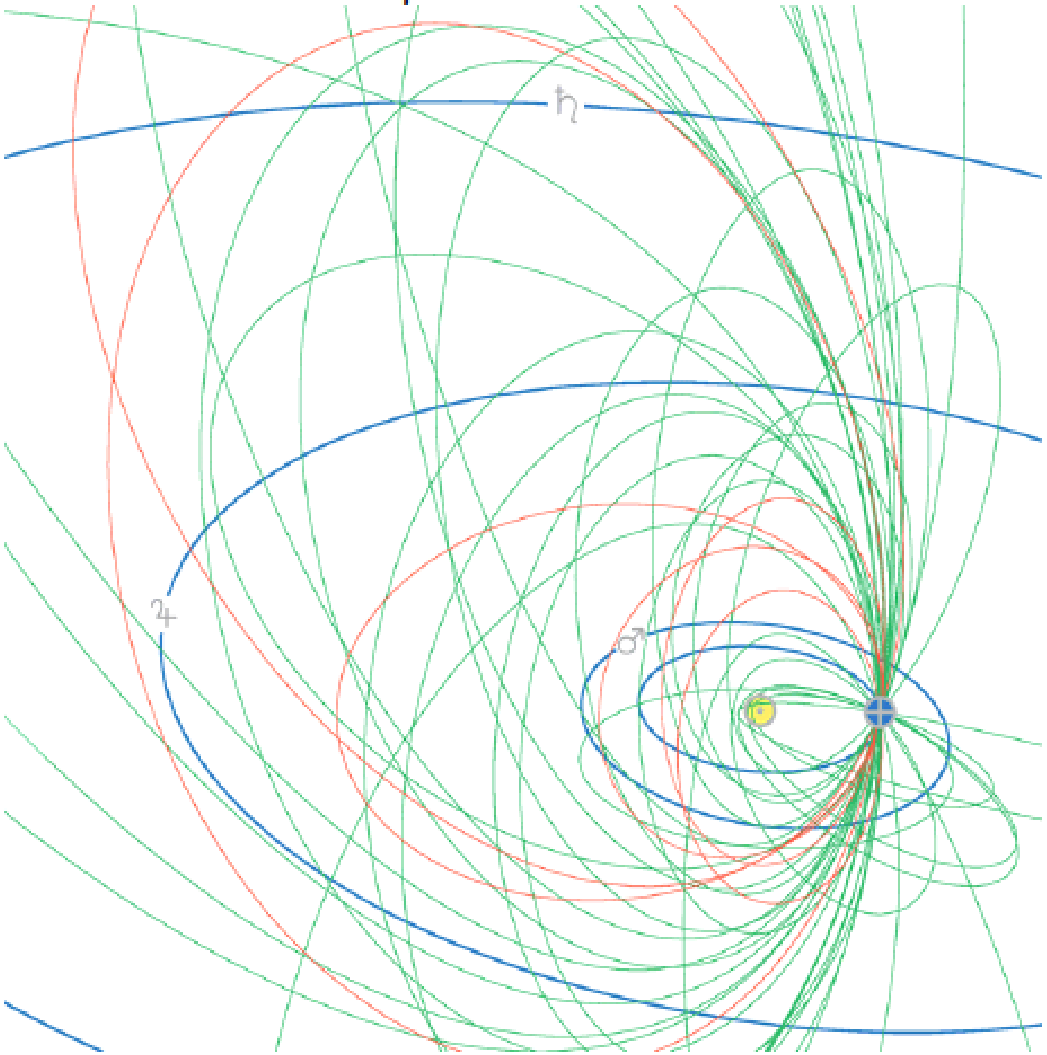
# Track space debris



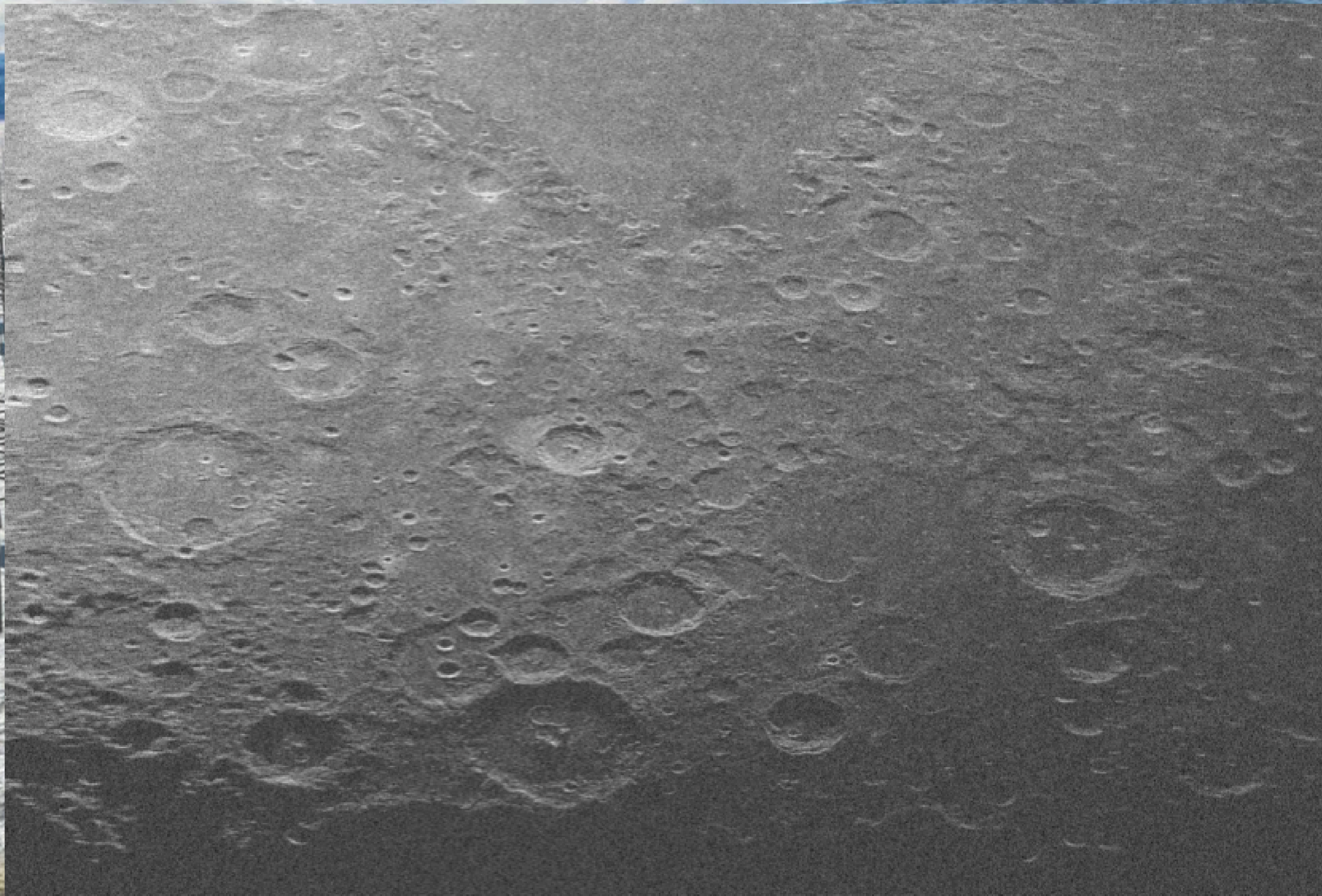


# Uniquely determine the orbits of near-Earth objects

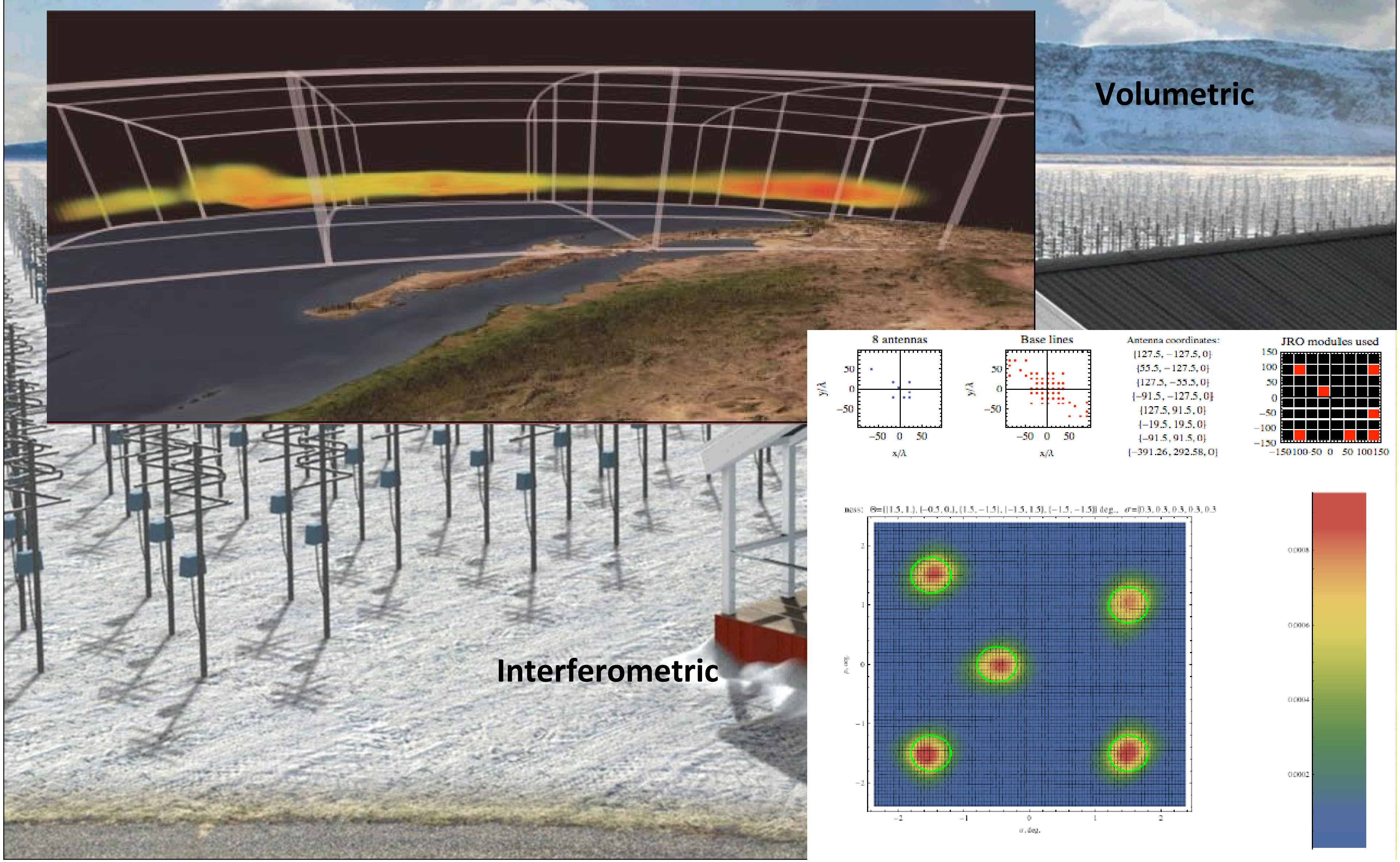
Application: Meteoroids, and their interactions with other planets such as Jupiter and Saturn



# Radar reflectivity map of the Moon



# Two Kinds of Imaging



# Status and Timeline

Original discussions in 2002

Application for FP6 Design Study funding 2004

FP6 Design Study 2005-2009 (2.8 ME)

Added to ESFRI Roadmap December 2008

Preparing Preparatory Phase Application

National Funding Decisions Autumn 2009

Submission of FP7 Application December 2009

Preparatory Phase 2010-2013

Construction 2014-2015

Operations 2015-2045

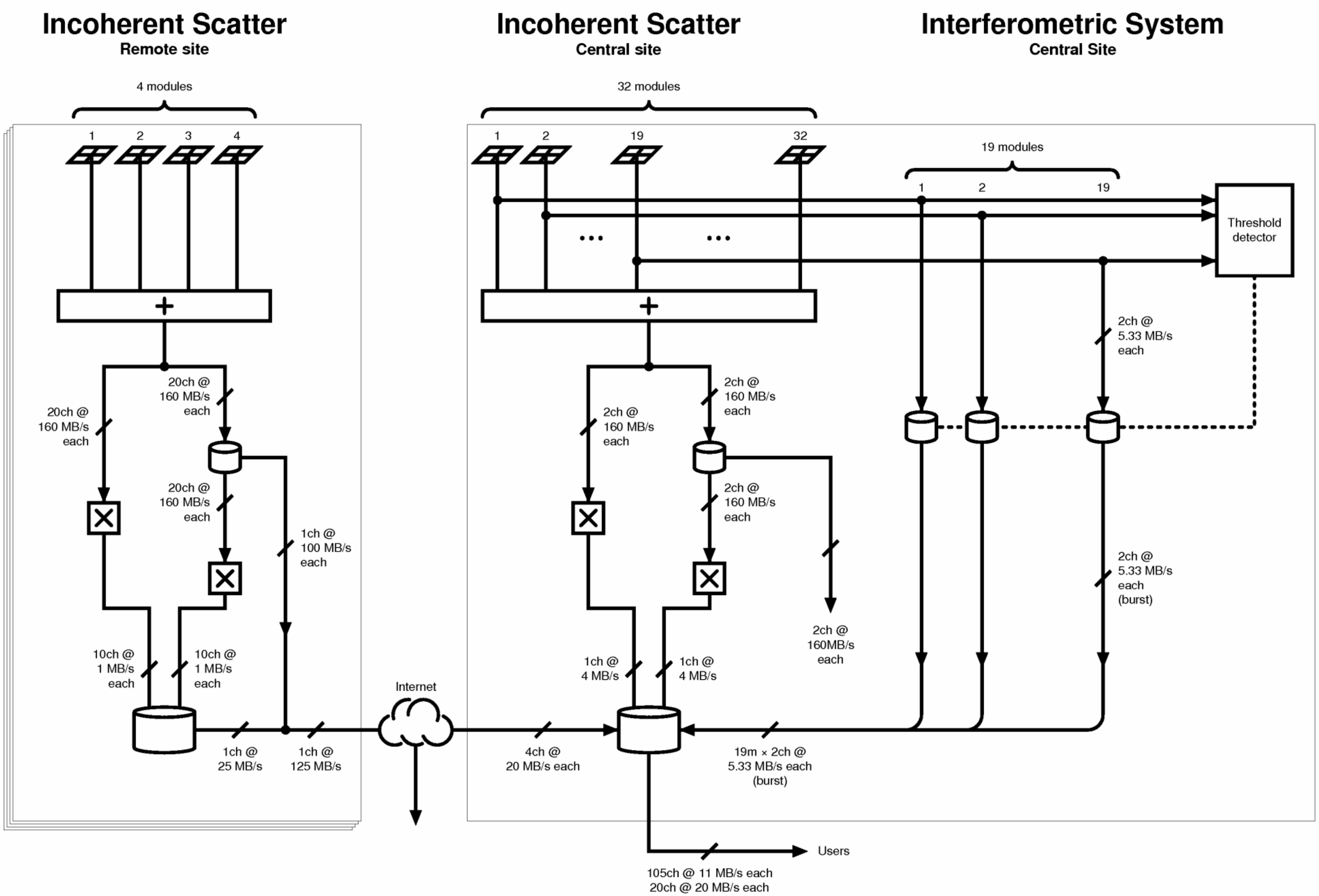
# Principles

- EISCAT-3D is very different to EISCAT
  - Much more low-level data
  - Continuous operation, unattended remotes
  - Interferometry as well as standard IS
  - Lots of supporting instruments
- Store data at the lowest practical level
  - Analysis can be done direct from samples
  - Any pre-processing reduces flexibility
  - A wide range of appliations and techniques
- Data volumes are very large
  - Can't store lowest level data forever
  - Keep them until they are "optimally processed"
  - Keep a set of correlated data forever (as now)

# Types of Data

- Incoherent Scatter
  - Continuous, complex, amplitude-domain data
  - Two orthogonal polarisation streams
  - 80 MHz sampling at 16 bits
  - Bandpassing, but limit set by modulation bandwidth
- Interferometry
  - Continuous on limited number of baselines
  - Don't record if nothing happening….but need ability to "backspace" and "run on".
  - Save data until optimum brightness function is made and transferred to archive
- Supporting Instruments
  - EISCAT-3D will attract many supporting instruments, using same data system
  - Some data sets big (e.g. imagers) but not always interesting
  - Suitable for mixture of short-term buffer and permanent archive

# EISCAT-3D Data System

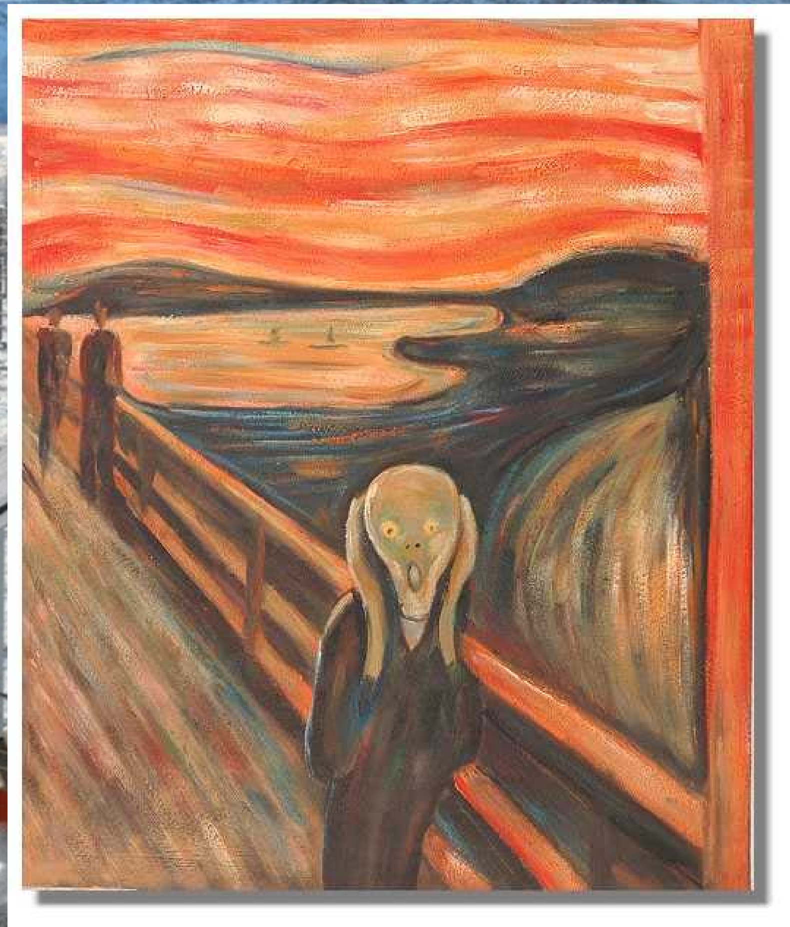


# Types of Archive

- Ring Buffer
  - High volume (~100 TB) short duration (hours to days)
  - Data accumulate constantly – oldest data over-written
  - Records IS data and interferometry when events detected
  - Needs to record latent archive data in event of network outage
- Interferometry System
  - Small storage area (~100 GB), holds only the past few minutes of data
  - Data accumulate constantly, and tested against threshold
  - If event detected, divert data flow (and backscpacing) otherwise delete
- Permanent Archive
  - Large capacity (~1PB) permanent archive
  - Mid and high-level data @ 200 TB/year
  - Tiered storage, connected to multi-user computing facility

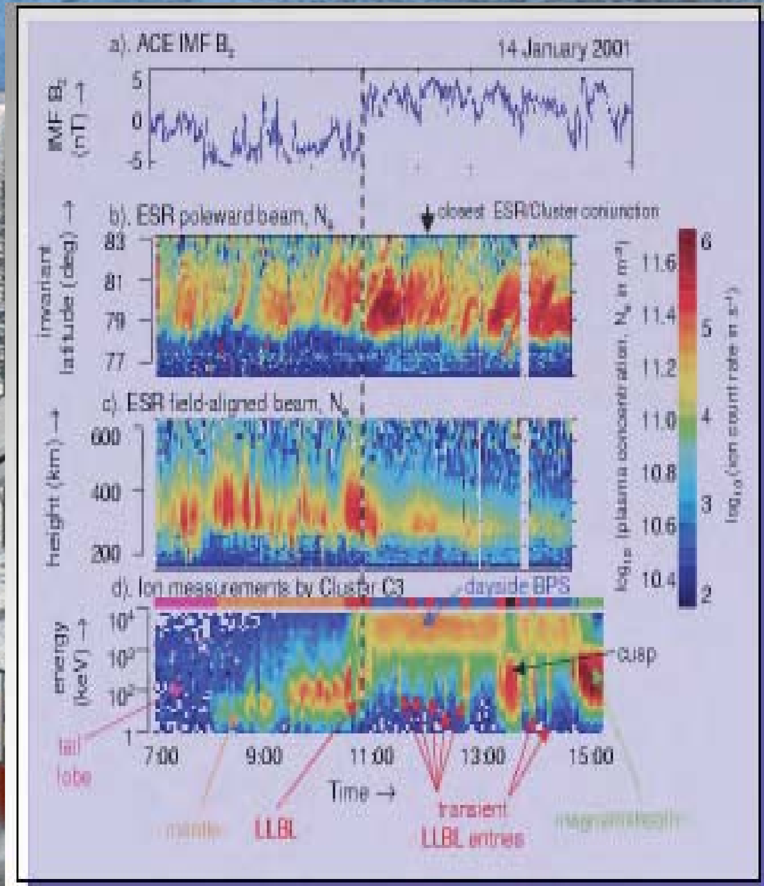
# Low-Level Data

- Voltage data (lowest level)
  - 80 MHz sampling, 16 bits
  - 2.56 Gb/s/element means $4 \times 10^{13}$ b/s (!)
  - Combine by group (49 antennas)
  - Then into <10 beams
  - Each beam ~ 25 TB/day
- Beam-formed data: Central site
  - Only one (fast scanning) signal beam
  - Small volume calibration beam(s)
  - Approx 1 TB/hour (320 MB/s)
  - Voltage data, not band limited
- Beam-formed data: Remote sites
  - 5-10 beams, but intersection limited
  - Same order as central site
  - Identical short-term storage at all sites



# Higher-Level Data

- **Interferometry Data**
  - 19 modules in use (202 MB/s, 17 TB/day)
  - But keep only 5% of samples above threshold
  - Lead-in and follow-on data (tens of GB)
- **Supporting Instruments**
  - Common data network for other diagnostics
  - Optical instruments, other radars
  - Estimated at 150 GB/day at central site
  - 30 GB/day for each remote station
- **Highest-Level Data**
  - Analysed data products (small)
  - Correlation functions ~200 TB/year
  - Maybe not needed...



# Supporting Instruments

- Data rates from variety of instruments
  - Other radars (coherent scatter, meteor)
  - Lidars and advanced sounders
  - Passive optical (high-resolution imagers)
  - Radio instruments (riometers, VLF, GPS)
  - Magnetometers
- Advanced instruments at central site only
  - Remote sites unattended, therefore
  - No instruments needing manual intervention
  - No huge data sets allowed
- Data volumes can still be large
  - High-resolution cameras can produce 100s of GB/day
  - But not all of the data are interesting….
  - Design for 150 GB/day at central site, 30 GB/day at remotes.

# Archiving Requirements

**Ring Buffer**

High volume (~100 TB) short duration (hours/days)

Data accumulate constantly , oldest over-written

Records interferometry when events detected

Latent archive data in event of network outage

**Interferometry System**

Small area (~100 GB), few minutes of data

Data accumulate constantly, threshold tested

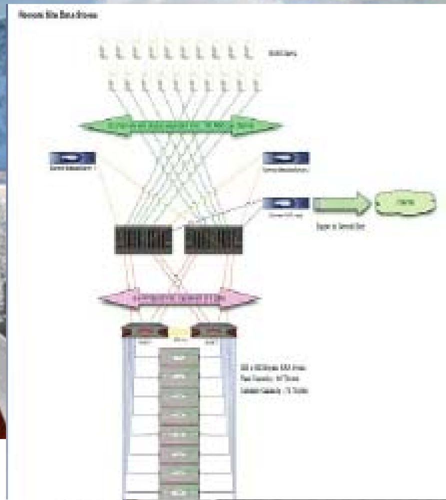
If event detected, divert data flow, otherwise delete

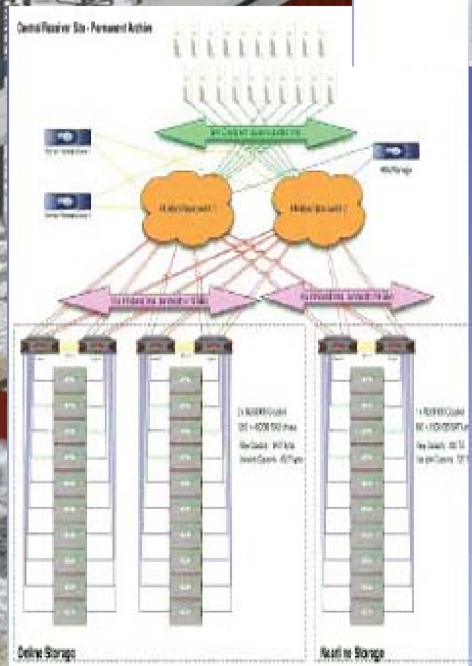
**Permanent Archive**

Large capacity (~1PB) permanent archive

Mid and high-level data @ 200 TB/year

Tiered storage, connected to multi-user computing





# Specifications: Ring Buffer

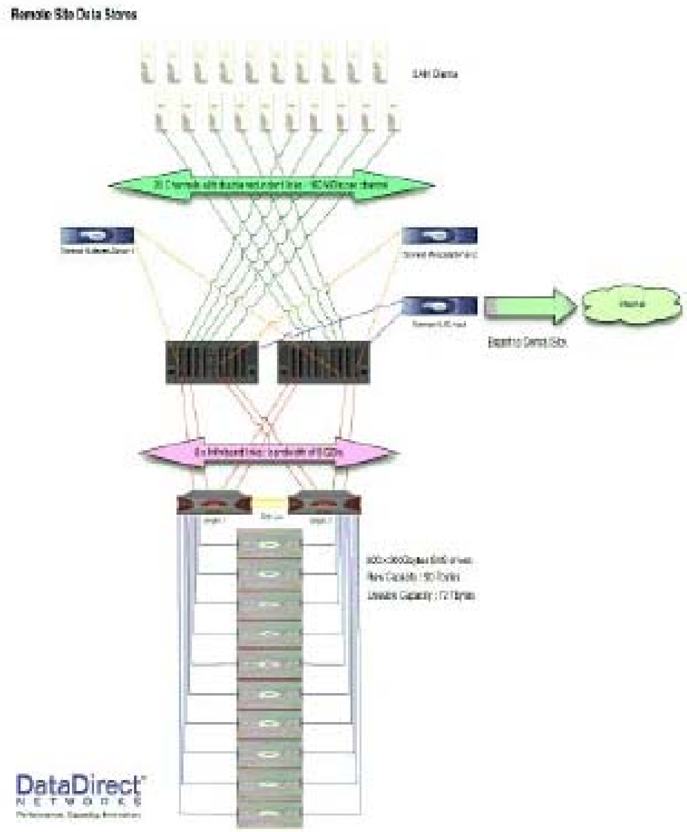
- Minimum of 56 TB short-term storage
  - IS and interferometry both produce ~ 1 TB/hour
  - ~2 days of full-bandwidth ISR data
  - ~2 weeks of bandpassed data
  - Several months of high-level data (weather latency)
- 4 input, 8 output channels @ 160 MB/s
  - Somebody needs to read these data !!
- 38 input, 38 output channels @ 6 MB/s
  - Less demanding things, including monitoring
- Identical systems at central site and remotes
- Power draw < 300 kW
- System management, monitoring tools, warranties

# Specifications: Central Archive

- 1 PB of usable initial storage
  - Initially a five year archive
  - 400 TB on line
  - 600 TB "near on-line" e.g. tape library
  - Extensible at 200 TB/year
- Input 300 MB/s over all channels
  - > 20 TB/day – allows fast filling
- Output 1 TB/s over all channels
  - 100 output channels
  - Assume we have lots of simultaneous users
  - 2 high-volume output channels
- Power draw <300 kW
- System management, monitoring tools, warranties

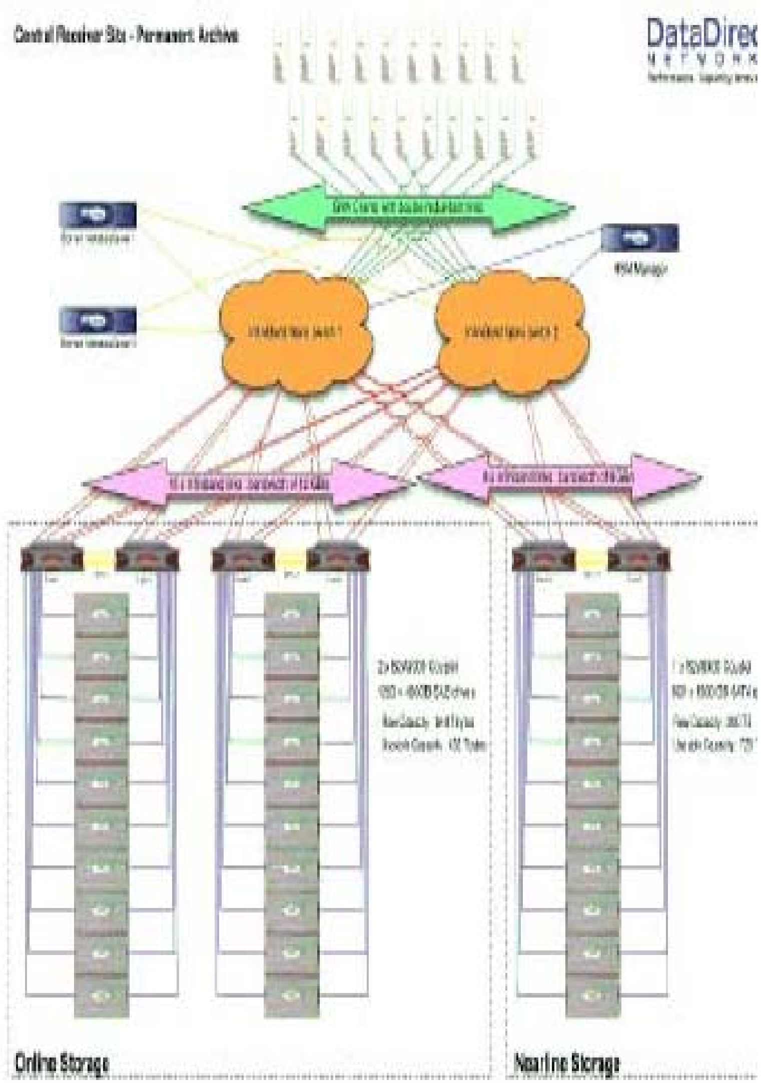
# Solutions: Ring Buffer

- Two solutions for multiple input channels
  - Each channel separate, lots of channels
  - Multiplex into a few high-rate channels
  - Second solution probably better
  - e.g. 20 channels, multiplexed into 8 links of 6 GB/s.
- Multiple drives, multiple enclosures
  - 10 drive enclosures
  - Each enclosure 50% filled (300 x 300 GB SAS drives)
  - Resulting capacity 90 TB (72 TB directly usable)
- Expansion and degradation
  - Half-filled cabinets allow expansion
  - Multiple disks allow graceful degradation
  - Power draw and temperature range within spec.



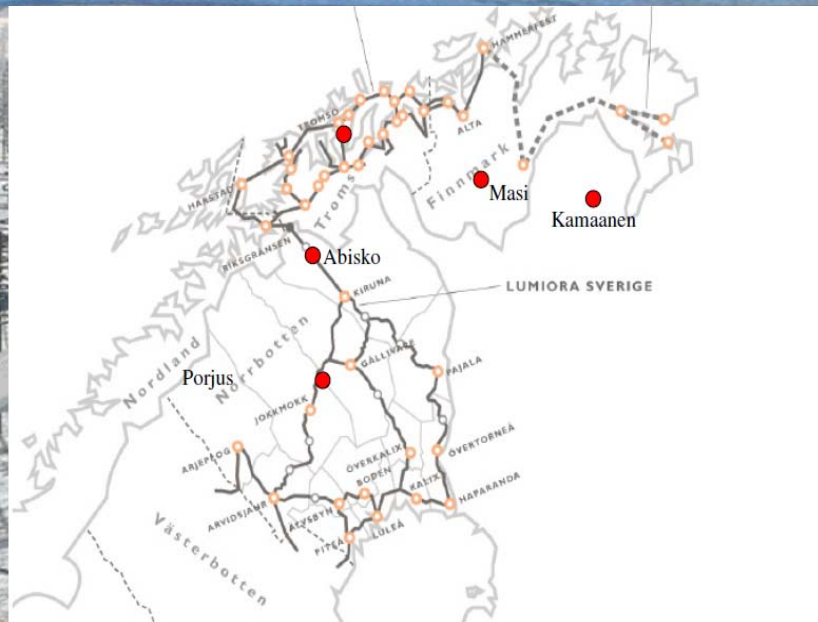
# Solutions: Central Archive

- Central site only
  - Can be a staffed system, easier maintenance
  - Mix of on-line and near-on-line
  - User access immediate, even for historic data
- MAID – Massive Array of Idle Disks
  - Large disk arrays with "sleep mode"
  - Spin down if unused for given time (5-330 mins)
- Example system: 1.2 PB archive
  - 24 GB/s bandwidth over 20 channels, 20 TB/hour bac
  - RAID 6 graceful degradation, modular "hot swap" components
  - Single system supports 1200 disk drives



# Network Requirements

- Data transfer from the remotes
  - 1 beam is 320 MB/s, remotes have multiple beams
  - Supporting instruments add ~30% overhead
- Recover from interrupts quickly
  - Otherwise we may never catch up
  - Interrupts might last days/weeks
- Fast links already practical
  - Protocols for 10 GB/s links exist already
  - How should we factor network costs into our plan?
- Back-up if the network fails
  - Something to tell us if the site is alive
  - …and how cold it is……
  - Mobile phone, satellite, microwave link




*Lumiora Fibre Network*

# Get involved !

- FP7 proposal to be submitted at beginning of December

- Plan includes a work package to look at data handling, including the possible role of data centres.

- There is still (just) time to get involved with our consortium.

- Contacts

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