How is Earth Atmosphere Coupled to Space?

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EISCAT Scientific Association

Kiruna

Sweden

How is Earth Atmosphere Coupled to Space?

EISCAT Overview
EISCAT_3D Project
e – infrastructure needs
solutions & planning

EISCAT_3D is
RI for the Environment on
ESFRI Roadmap

ESFRI Roadmap 2008
FP6 Design Phase Project 2005-2009
FP7 Preparatory Phase Project 2010-2014

Expected:
Start of construction: 2015/2016
Start of operation: 2019/2022

Investment:
76 M€* (stage 1**)
Operation:
6.2 M€/yr (stage 1**)

International RI located in Europe
Number of Partners: 6 Associates and 3 Affiliates

(*) numbers depend on exchange rate
(**) Stage 1: three radar sites out of five

European Strategy Forum
on Research Infrastructures

ESFRI

EUROPEAN ROADMAP
FOR RESEARCH
INFRASTRUCTURES

Roadmap 2008

UPDATE 2008

Science Case: *www.eiscat.se*

EISCAT = **E**uropean **I**ncoherent **Scat**ter Facility

location

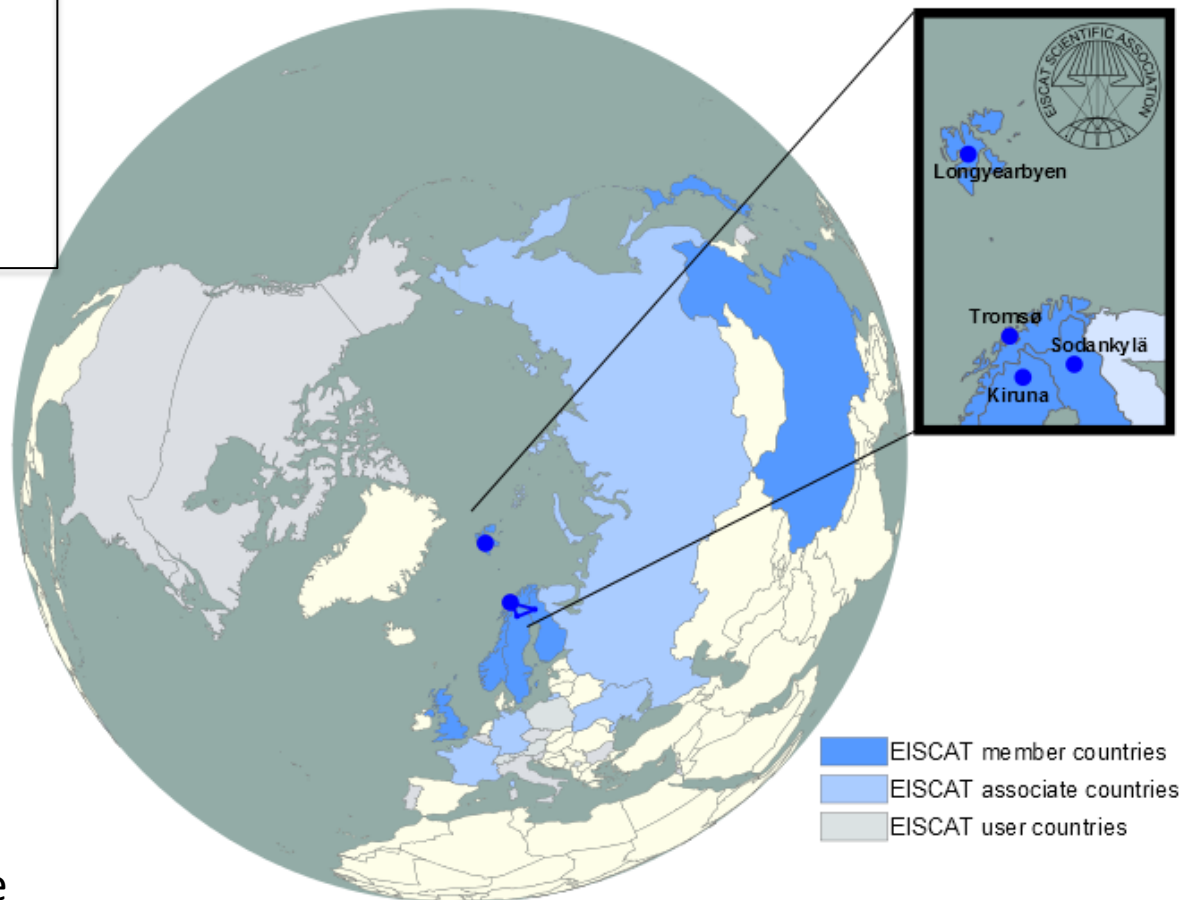**method** to observe charged constituents within the Earth atmosphere with high power radio waves

Observations 2500 hrs/yr
EISCAT participates in:
global radar observations,
rocket & satellite campaigns

Members:

🇨🇳 China

🇫🇮 Finland

🇯🇵 Japan

🇳🇴 Norway

🇸🇪 Sweden

🇬🇧 United Kingdom

affiliated: Russia, Ukrane, France

Longyearbyen

Tromsø

Sodankylä

Kiruna

EISCAT member countries
EISCAT associate countries
EISCAT user countries

Earth – Space Transition at Polar Atmosphere

How is the Earth atmosphere coupled to space?

Space

EISCAT studies **polar** ionosphere
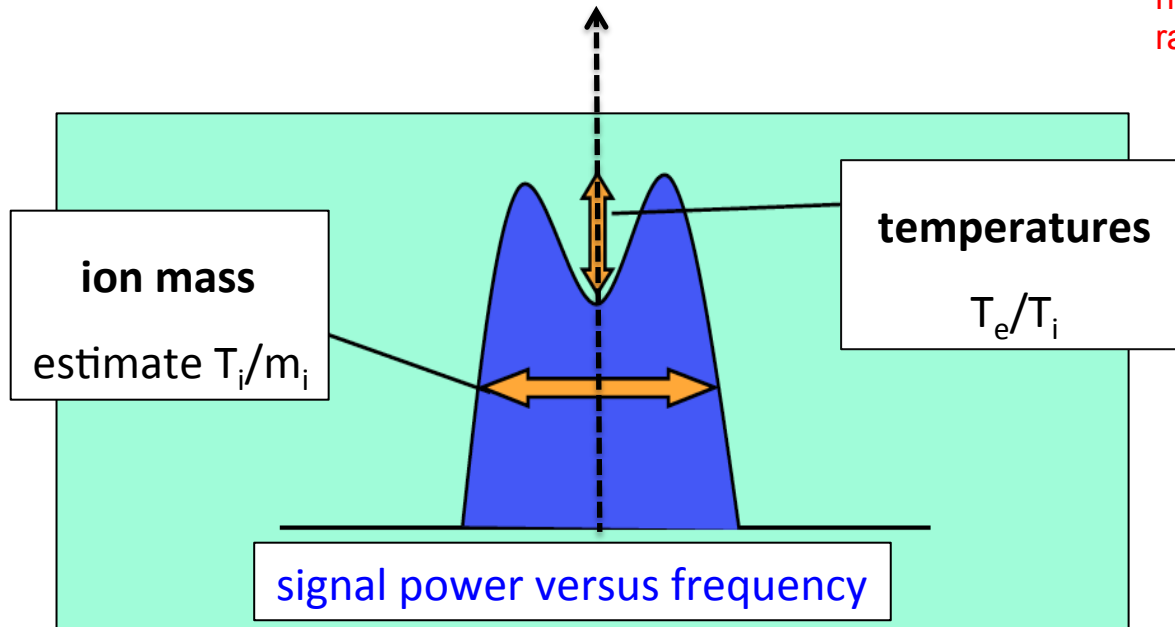$\approx 60 - 1200$ km
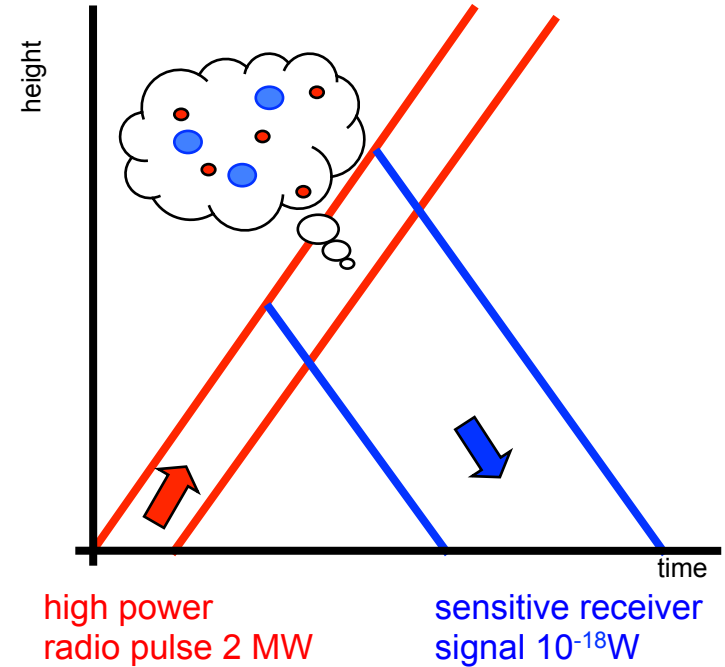
Neutral Atmosphere

altitude
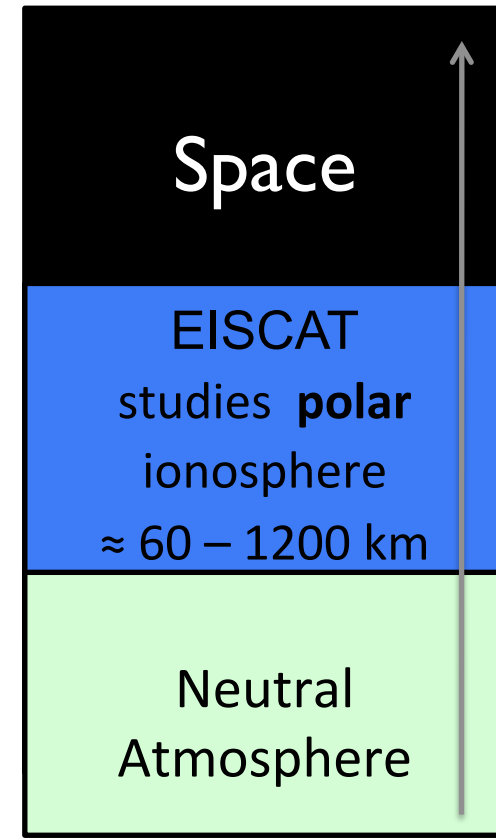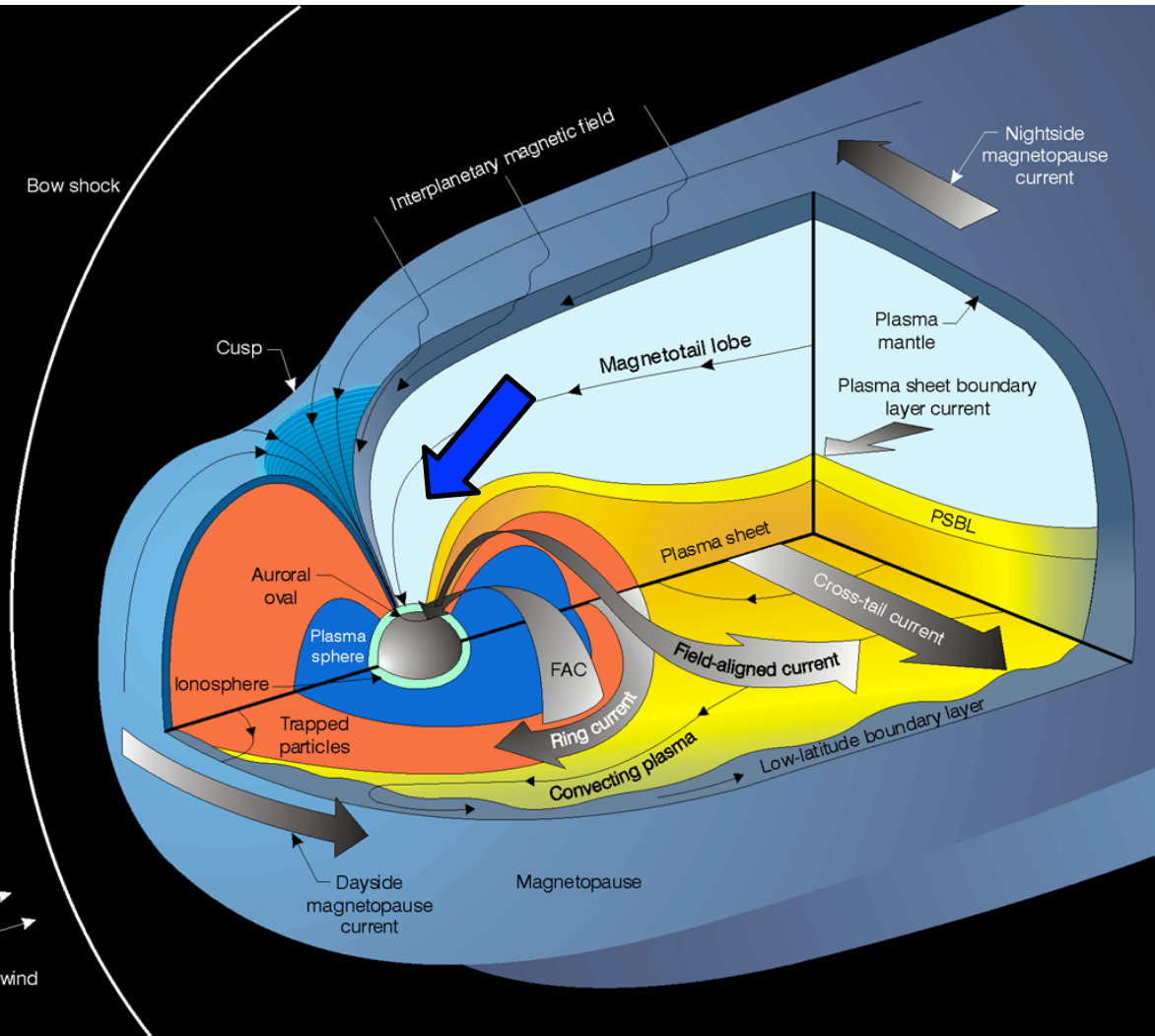
unique location

Incoherent Scatter

ions and electrons are coupled through plasma waves

derive standard parameters density, temperature, (…..) for ions and electrons

Electrons scatter the radio wave:

high power
radio pulse 2 MW

sensitive receiver
signal 10^{-18}W

space – time ambiguity

ion mass

estimate T_i/m_i

temperatures

T_e/T_i

signal power versus frequency

Measurements during 11 year solar cycle

EISCAT Svalbard Radar (ESR) electron density observations:

Daily 3-hour averages averaged over each season

time series data!
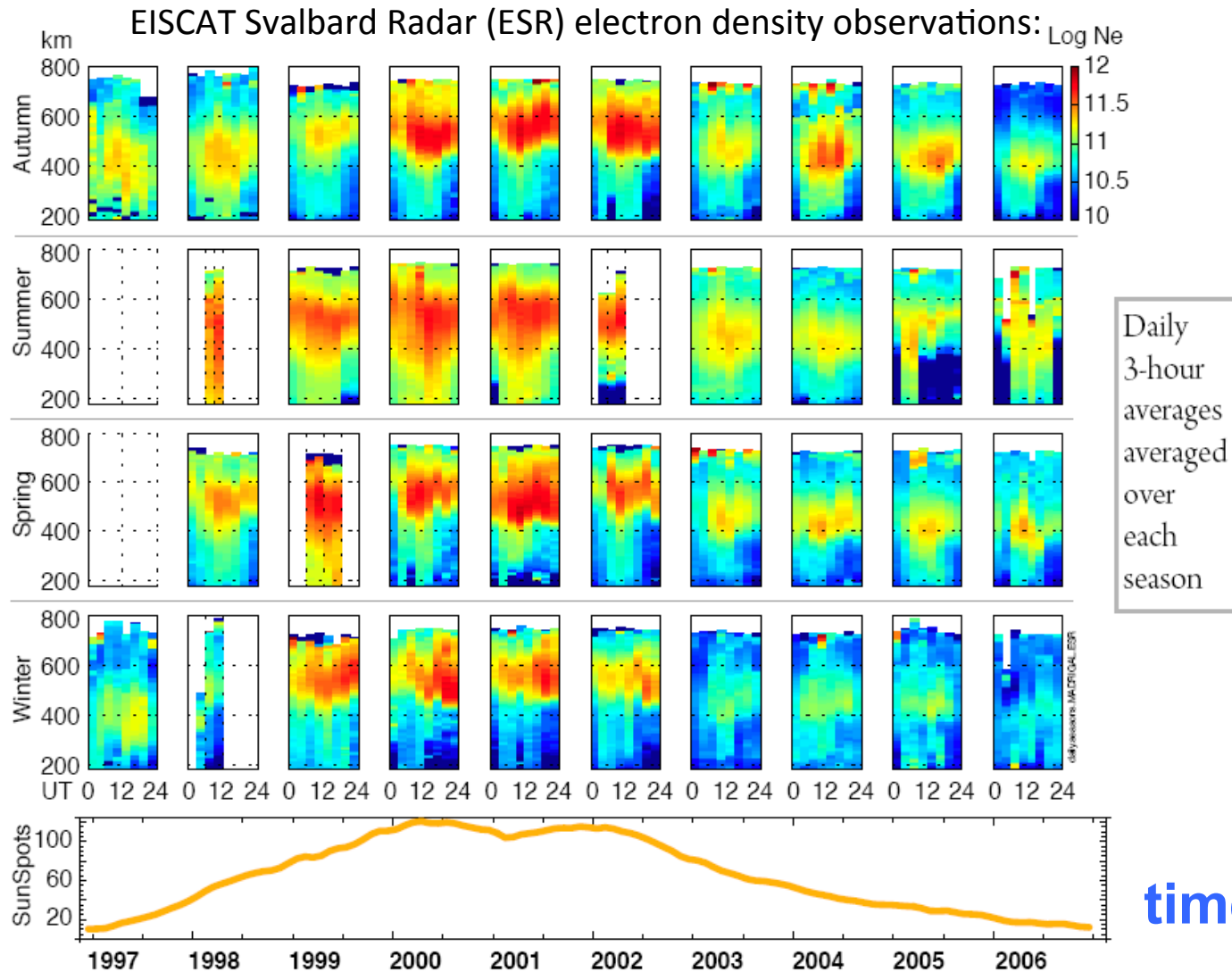
Incoherent Scatter

Observe complex plasma &
dusty plasma phenomena
≠ thermal equilibrium

0449:30 - 0449:40 UT   0449:40 - 0449:50 UT

Naturally Enhanced Ion Acoustic Lines (NEIALs)

ion mass

estimate T_i/m_i

temperatures

T_e/T_i

signal power versus frequency
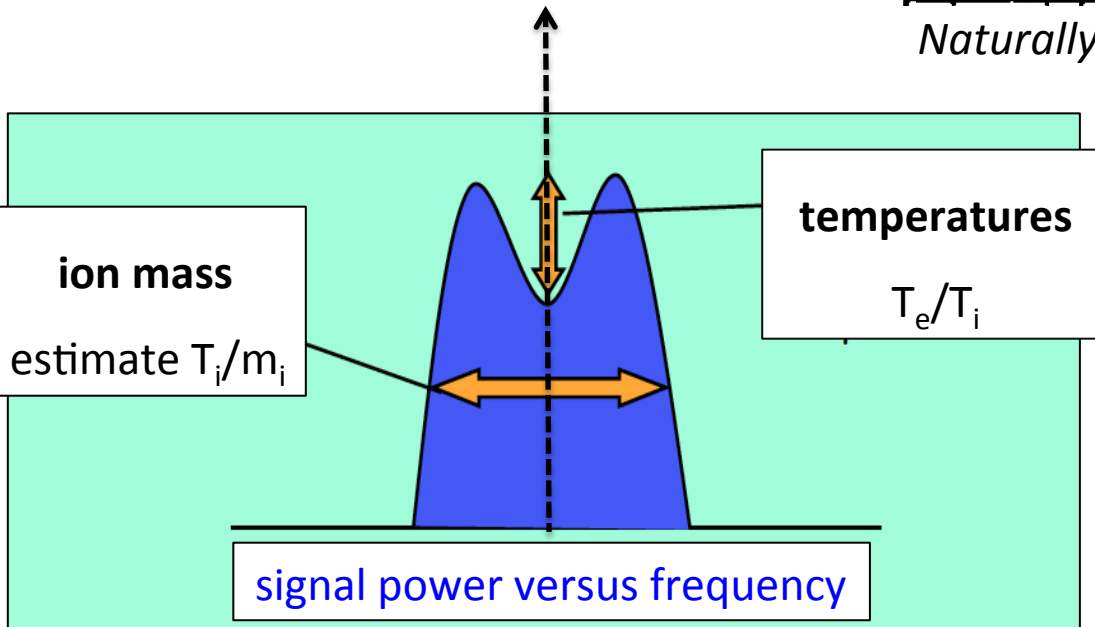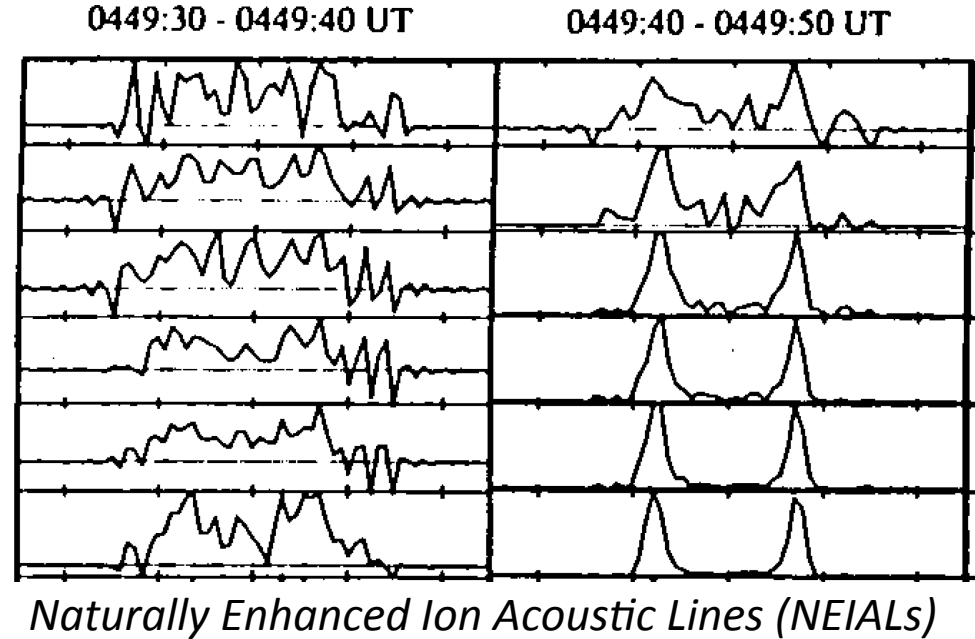
**non – standard
data products!**

EISCAT today

Tromsø, Norway

Sodankylä, Finland

EISCAT & its user community developed plans for EISCAT_3D
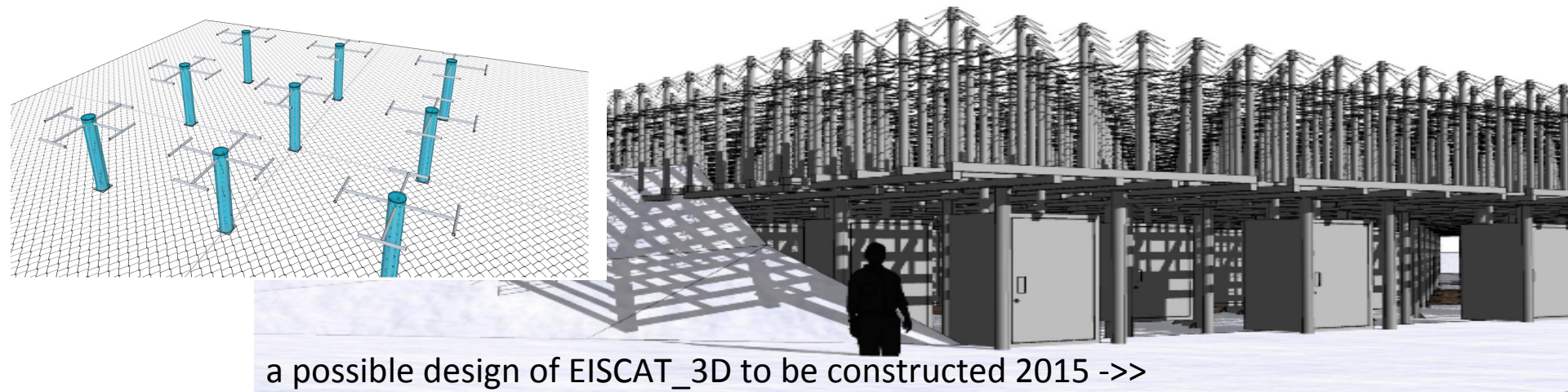

Kiruna, Sweden

Longyearbyen, Svalbard

EISCAT_3D
multi-static phased array

apply digital processing for

- beam steering

- volumetric imaging

(resolve time - space ambiguity)

a possible design of EISCAT_3D to be constructed 2015 ->>
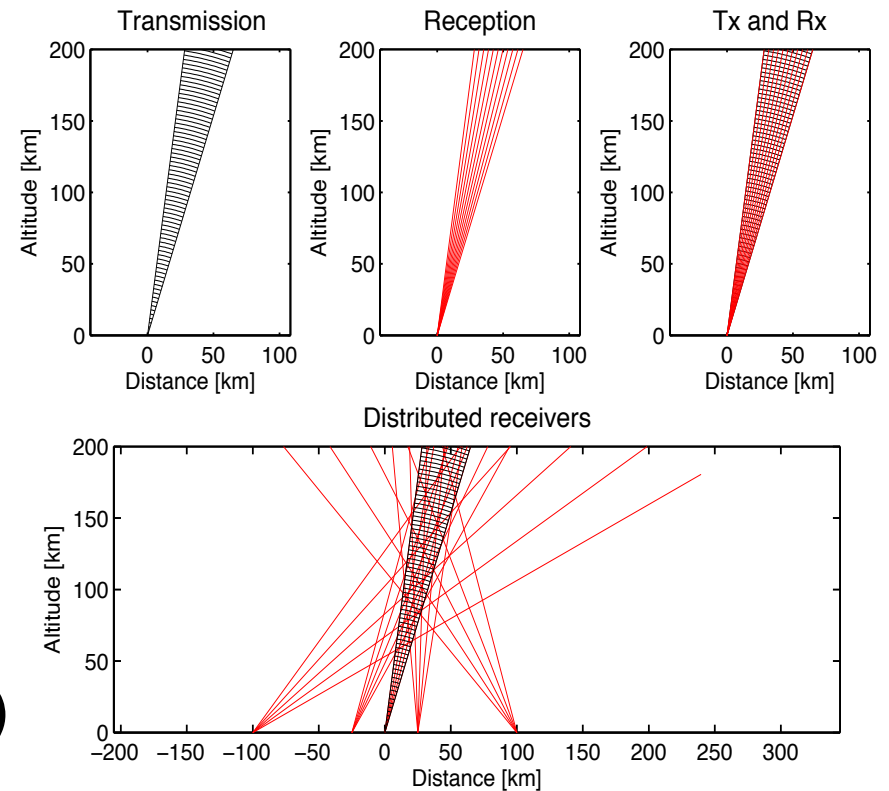
10.000 Antennas per site!

Array = 109 Sub-Arrays: **3**

antenna element
2 polarizations   **1**

support structure
& ground plane

3 Ø power

10GE

instrument
container

Sub-Array = 91 antenna elements: **2**

1

antenna element & ground plane

3D EISCAT

System Overview

on-site

3D EISCAT

digital control

analogue & antenna

digital processing

1. EISCAT_3D Radar Array

109 Sub-arrays
91 Antenna elements/Sub-array
Dual polarization, crossed dipoles
182 dipoles / Sub-array

Sub-array

Support structure

x 182

4. Transmit unit

Exciter — SSPA — T/R — Ant

DC

Power supply

2. Front end unit

Rx

RF in
Fc = 233,3 MHz

LNA

Anti-aliasing

RF 233,3 +/- 15 MHz

7. Time and Frequency

WR Slave — WR — * White Rabbit Master — Frequency std

Clk

Clock & trig gen.

Clk

x 109

WR

*network timing protocol

5. Pulse & Steering Control

Start

Ctrl.

Radar Contr. — CPU

Ctrl.

9. Network

VPN — Ethernet

8.5 Gbit/s (BW 5 MHz)
18 Gbit/s (BW 30 MHz)

Ethernet

operation centre

Operations center
20 PB storage
500 Tflop/s

USER Request

Archive
2 PB disk
2 x 10 PB tape
50 Tflop/s

data centre

3. Sub-array Beam former (BW 30 MHz)

ADC 16 bit — 60 Ms/s

x 182

Subarray Beam Former 5.4 Tflop/s

6. Status and Control

I/O

I/O Parallel — CPU

I/O

Serial

8. Computing System (BW 5 MHz)

Process computer 55 Tflop/s — Ring Buffer 86 TB RAM

64 Gbit/s — 700 Gbit/s

Overall Beam Former 22 Tflop/s

x 109

Portal

10. National e-Infrastructures

specialized computing & on-site networks

6.3 Gbit/s (BW 5 MHz)
38 Gbit/s (BW 30 MHz)

USER

generic high-level computing & networks

e – infrastructure distribution
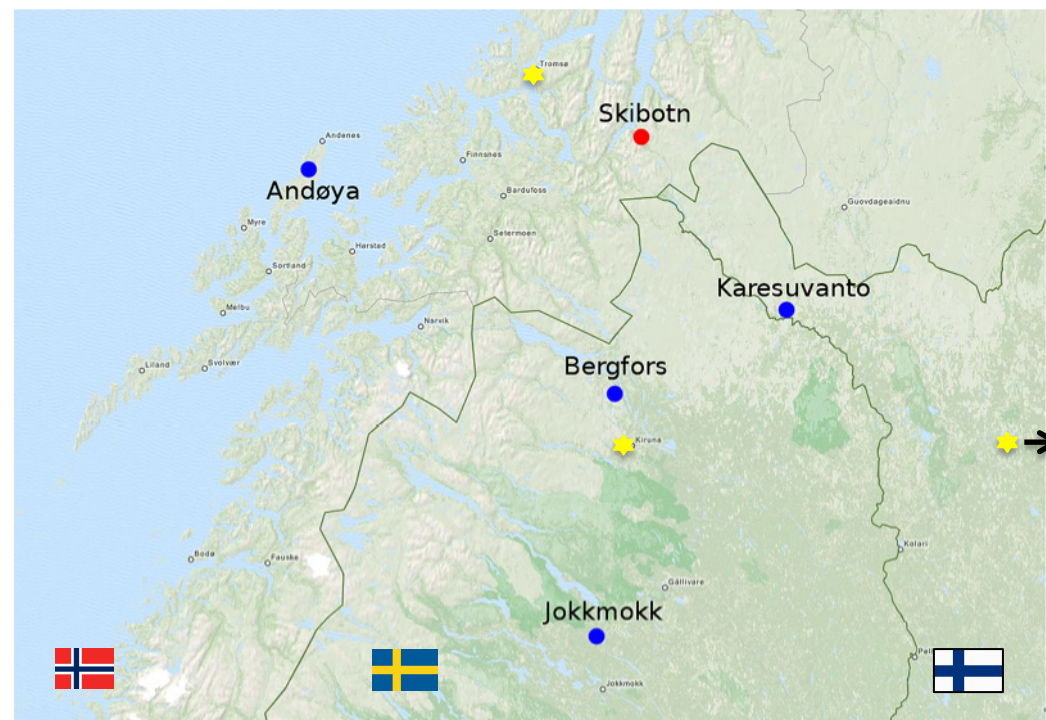
● ● radar sites

⭐ academic host institutions in Tromsø, Kiruna, Sodankylä

Operations on 5 Sites	Operation Centre	Data Centre
Beam-forming	Operation	Storage
Correlated products	Generate multistatic products	Search engines
Fitting of plasma parameters	Produce metadata	User-defined analysis
Generate specialized products	Data validation	Visualization

EISCAT e - infrastructure   national e - infrastructure

EISCAT_3D e-infrastructure overview
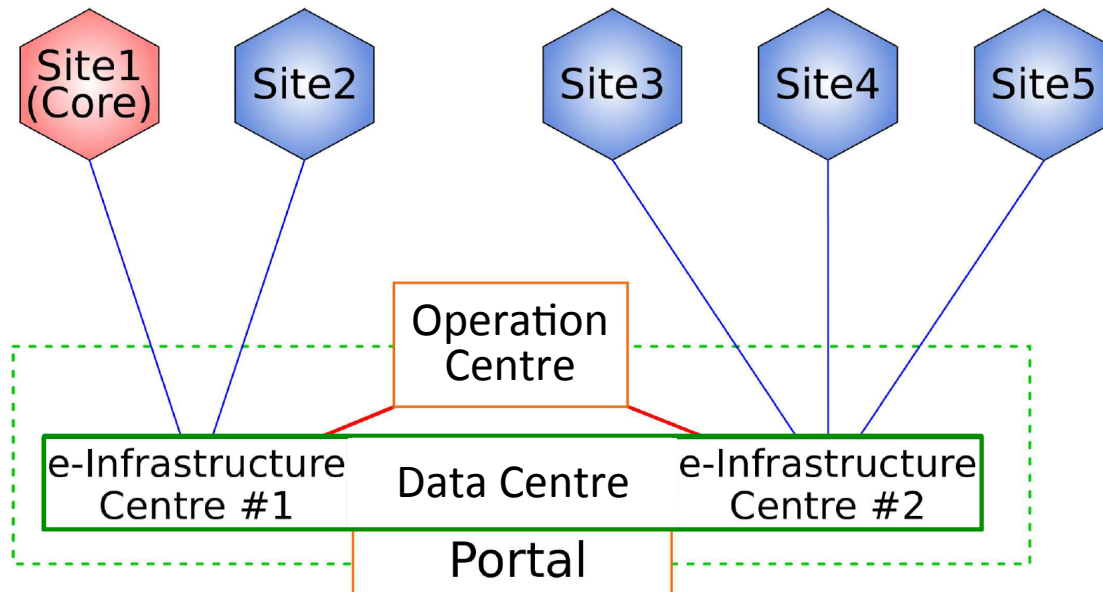
Establish data centre within existing national e-infrastructures

Store archived data redundantly at 2 centres

Establish single floating portal for the entire data centre

Co-locate operation centre with existing e-Infrastructure site

Establish mirror archive for geographically remote users

Low-Level Data Challenge - one antenna becomes many……

single antenna data rate:

    30 MHz x 16 bits x 2 polarisations x 2 = 2Gb/s

    makes ~ 20 TB/day

EISCAT_3D array data rate

    multiply by 10,000* = 20 Tb/s/site

    makes ~ 200 PB/day

Strategy:

    reduce on-site

    use ring-buffer

    wait for cheaper storage

the lowest-level data never exist as a single data set…

EISCAT_3D computing year 1 - 5

	Sites (per site)	Operation Centre	Data Centre	
	Real-time	Post-processing	User Access & Archive	
Storage	86 TB RAM 1 PB Disk	20 PB Disk	2 PB Disk	2 x 10 PB Tape (2 PB per year of operation)
Computing	590 Tflops/s (FPGA) 77 Tflops/s (other)	500 Tflops/s	50 Tflops/s	

2 PB/year permits storing of:

- basic ionospheric parameters with full 3D resolution
- selected raw data streams
- integrated lag profiles (altitude resolution x 4)
- additional data products

e – Infrastructure needs

for implementation

    develop specialized on-site computing

    establish network connection to sites

    plan & negotiate archiving & data centre

    recruit IT experts for commissioning phase

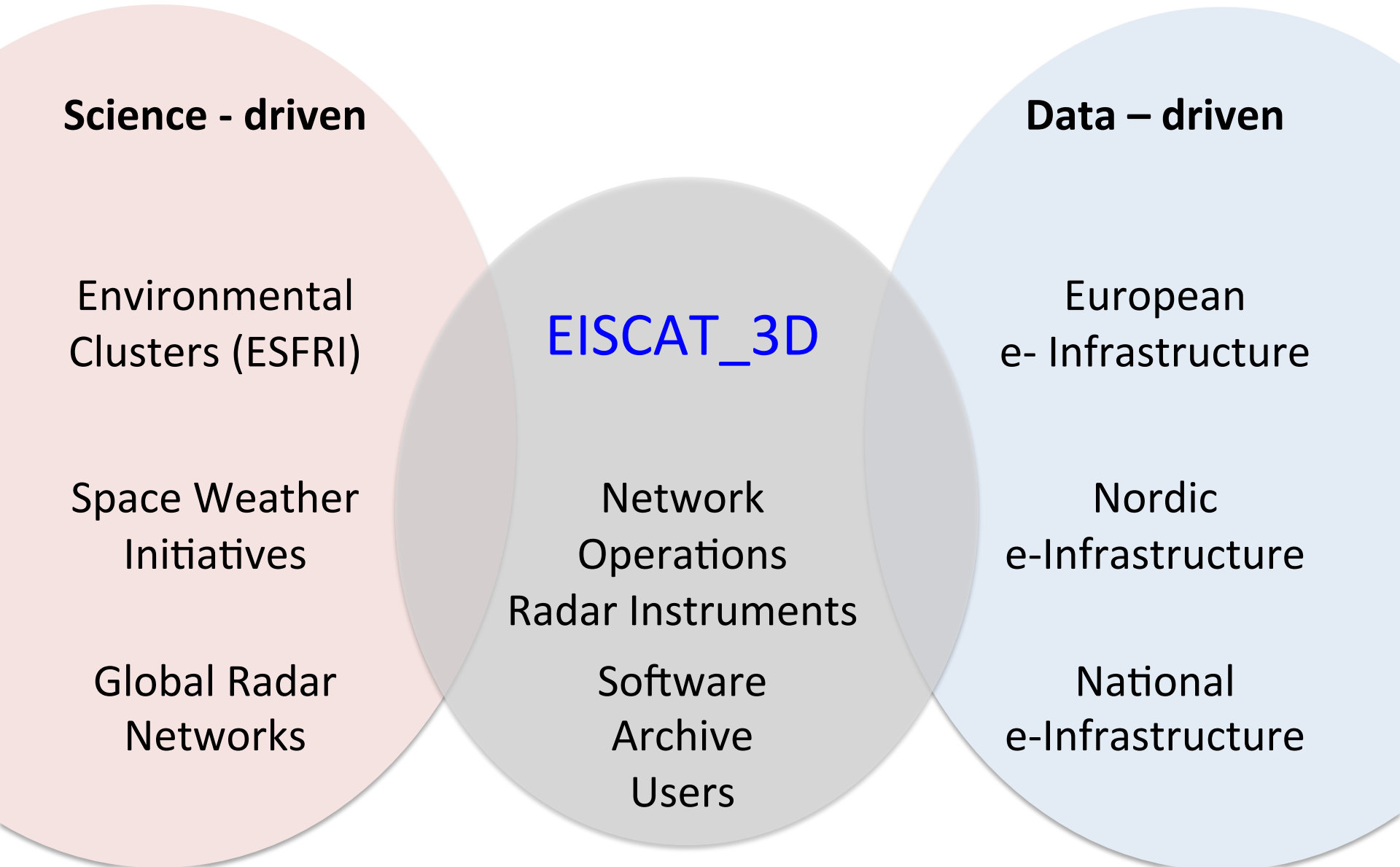for operation

    flexible response to developing research questions

    long-term archiving & easy access to time series data

    combine scientific & data handling competence

Links to e-Science & e-Infrastructure

Science - driven

Environmental
Clusters (ESFRI)

Space Weather
Initiatives

Global Radar
Networks

EISCAT_3D

Network
Operations
Radar Instruments

Software
Archive
Users

Data – driven

European
e- Infrastructure

Nordic
e-Infrastructure

National
e-Infrastructure

Links to e-Science & e-Infrastructure

Science - driven

Environmental
Clusters (ESFRI)

Space Weather
Initiatives

Global Radar
Networks

H2020 / submitted

CooPlus

Collaboration on environmental data
(EU, US, Canada, Australia & Brazil)

ENVRI$_{plus}$

Common solutions to shared challenges
for ESFRI infrastructures

FP7

CoopEUS EU-US

Collaboration on environmental data

ESPAS

e-infrastructure for **near-Earth space data**

Links to e-Science & e-Infrastructure

Submitted proposals H2020

DPINFRA

Data **preservation** infrastructure

EGI-Engage

Data **storage** in federated cloud

VLDATA

Handle & distribute **very large datasets**

NordForsk/NeIC*

Support EISCAT_3D

computing, storage & archive **solutions**
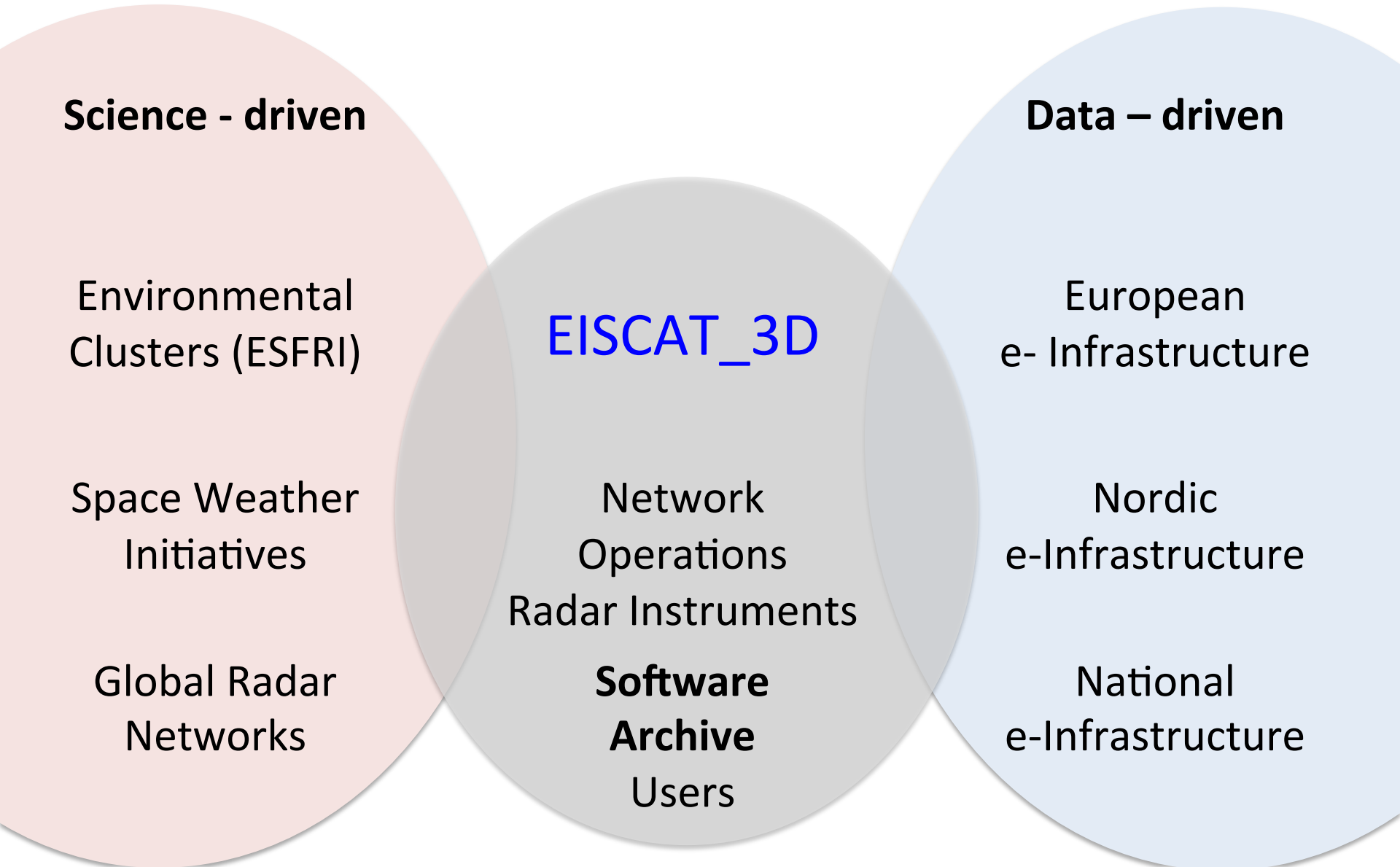
(*NeIC: Nordic e-Infrastructure Collaboration)

Data – driven

European
e- Infrastructure

Nordic
e-Infrastructure

National
e-Infrastructure

Links to e-Science & e-Infrastructure

Science - driven

Environmental Clusters (ESFRI)

Space Weather Initiatives

Global Radar Networks

EISCAT_3D

Network Operations Radar Instruments

Software Archive Users

Data – driven

European e- Infrastructure

Nordic e-Infrastructure

National e-Infrastructure

Support EISCAT_3D Project

Find workable and cost-efficient solutions for the EISCAT_3D computing, storage and archive

Facilitate an effective dialogue on the implementation of EISCAT_3D with the stakeholders in the host countries

Make best use of the existing expertise in the host countries for implementing EISCAT_3D

Nordic e-Infrastructure Collaboration / Nordforsk (3 years)

Open Position for Support EISCAT_3D Project

Applications should be submitted to neic@nordforsk.org by *20 November*

Questions may be directed to Gudmund Høst, phone +47 95816846

see neic.nordforsk.org

NordForsk is an organisation under the Nordic Council of Ministers that provides funding for Nordic research cooperation as well as advice and input on Nordic research policy. The organisation plays a key role in enhancing the value of existing research activities in the five Nordic countries, Finland, Sweden, Norway, Denmark and Iceland, as well as the autonomous territories of the Faroe Islands, Greenland and the Aaland Islands. NordForsk has a basic allocation of NOK 121 million in 2014. The organisation's head office is located in central Oslo. For further information, see www.nordforsk.org.

The Nordic e-Infrastructure Collaboration (NeIC) is seeking:

Project manager/e-infrastructure specialist for the Supporting EISCAT_3D project

NordForsk is coordinating and hosting the Nordic e-Infrastructure Collaboration (NeIC) since January 2012. The organisation is financed by or via the national research agencies. In 2014, the new organisation has an annual budget of 3 million Euros which covers a director and as of October 2014 a staff of 20 persons dispersed within the Nordic countries.

NeIC supports the Nordic research community by:

Supporting collaboration on e-infrastructure in the Nordic region.

Providing added value to researchers and national funders.

Contributing to more cost-efficient development and deployment of e-infrastructure services.

Supporting the national e-infrastructure providers in terms of competence building, task sharing and joint operation of services.

neic.nordforsk.org

The vision of NeIC is to facilitate the development and operation of high quality e-infrastructure solutions in areas of joint Nordic interest.

In that functional role, NeIC was approached by the EISCAT Scientific Association with an updated Letter of Interest (https://wiki.neic.no/wiki/Letters_of_interest) in order to initiate a new collaborative activity (Supporting EISCAT_3D) to support preparing for the implementation of the EISCAT_3D project.
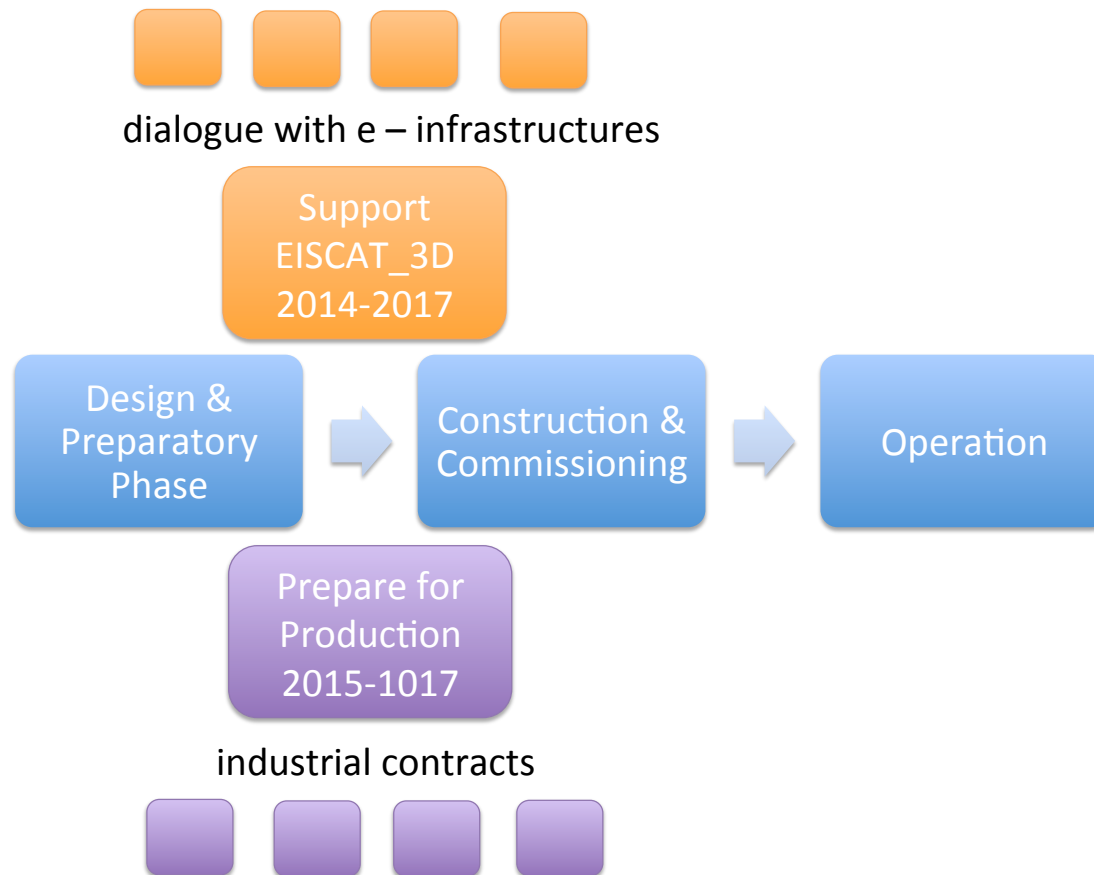
EISCAT_3D is an environmental research infrastructure on the European ESFRI roadmap. It is proposed as an international research infrastructure using the incoherent scatter technique to study the upper atmosphere above the Arctic in order to investigate how the Earth's atmosphere is coupled to space. EISCAT_3D is a multi-static phased array radar system that will be installed at remote locations in the most Northern parts of the Scandinavian peninsula. The system will be operated by and be an integral part of the EISCAT Scientific Association.

Today the EISCAT Scientific Association operates and maintains three incoherent scatter radar systems and an ionospheric heater on Svalbard and on the Scandinavian mainland and can look back to over 30 years of successful operation for basic research. Current EISCAT associates are China, Finland, Japan, Norway, Sweden, and the United Kingdom.

The EISCAT_3D baseline design consists of a core site that will be located close to the intersection of the Swedish, Norwegian and Finnish borders and four receiving sites located within approximately 50 to 250 km from the core. The implementation is planned in four stages with the initial stage 1 consisting of three full-sized antenna arrays: the core and two receive sites. Its construction can start 2016, first operations in 2018 and full science operation in 2021.

Next Step
EISCAT_3D Implementation

dialogue with e – infrastructures

Support EISCAT_3D 2014-2017

Design & Preparatory Phase → **Construction & Commissioning** → **Operation**

Prepare for Production 2015-1017

industrial contracts

e- infrastructure?

use common solutions where & when practical
a good start but need to keep the momentum

how to keep flexibility & reach sustainability of operation ?
who pays for time series data?

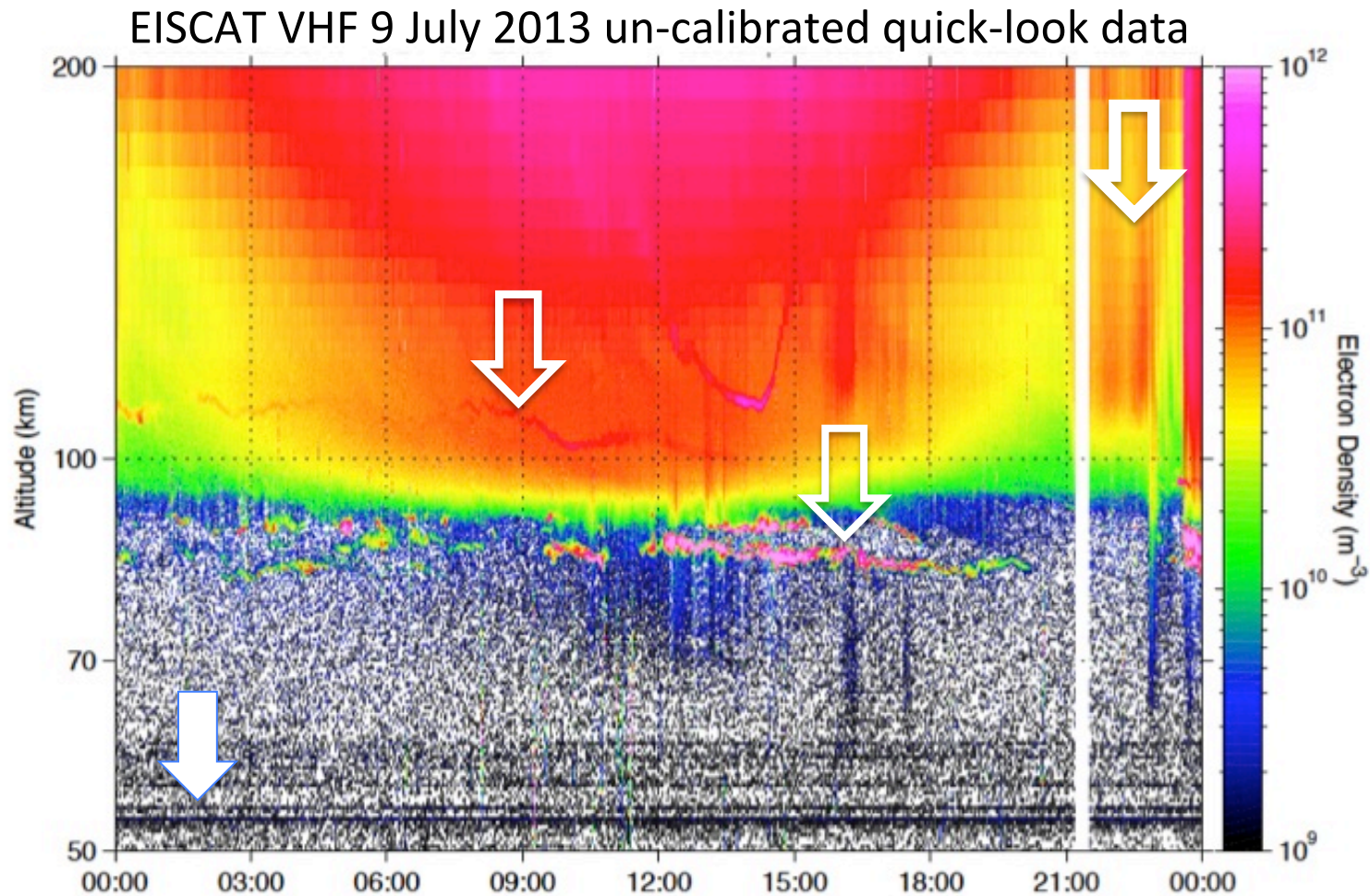how to facilitate close link between research & data handling?

How is Earth Atmosphere Coupled to Space?

Thank you!

Standard Analysis of one day of observations:

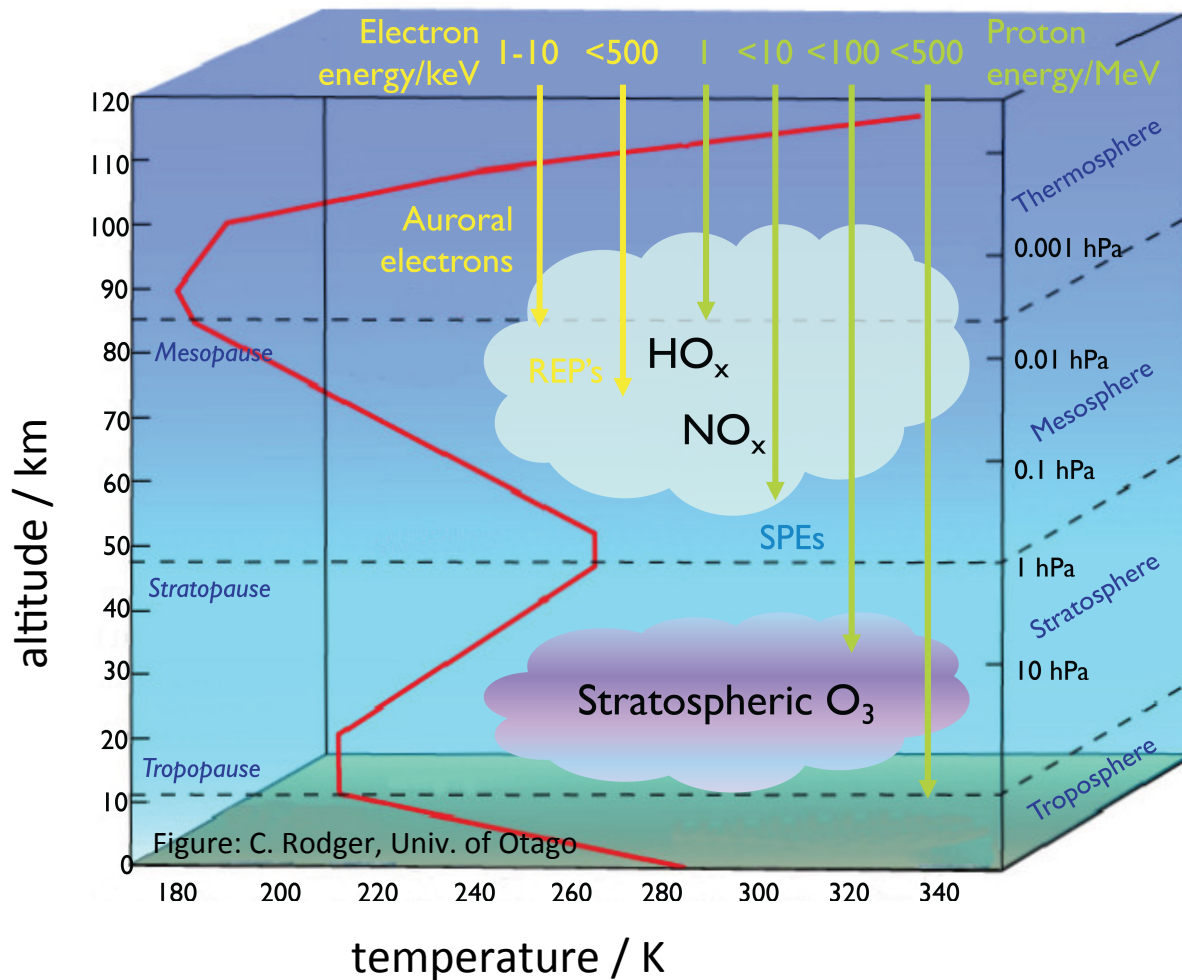EISCAT VHF 9 July 2013 un-calibrated quick-look data

Electron densities above 100 km - Sporadic E-layers (metallic ions)
Precipitation events of high energy protons - Polar Mesospheric Summer Echoes (PMSE)
Radar reflections at the ground (¨ground clutter¨)

Why study aurora?

Figure: C. Rodger, Univ. of Otago

(adapted from E. Turunen & colleagues SGO, Sodankylä)