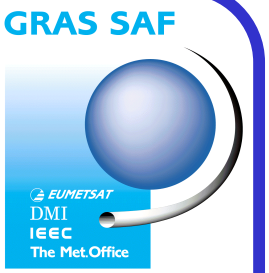

The GRAS SAF Project

- an Operational Radio Occultation System

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The Met Office (UK)

GRAS SAF

Global navigation satellite system
Receiver for
Atmospheric
Sounding
Satellite
Application
Facility

- a EUMETSAT Project ***www.dmi.dk/pub/GRAS_SAF***

Host Institute: Danish Meteorological Institute (Denmark)
Partners: Institute d'Estudis Espacials de Catalunya (Spain)
The Met Office (UK)

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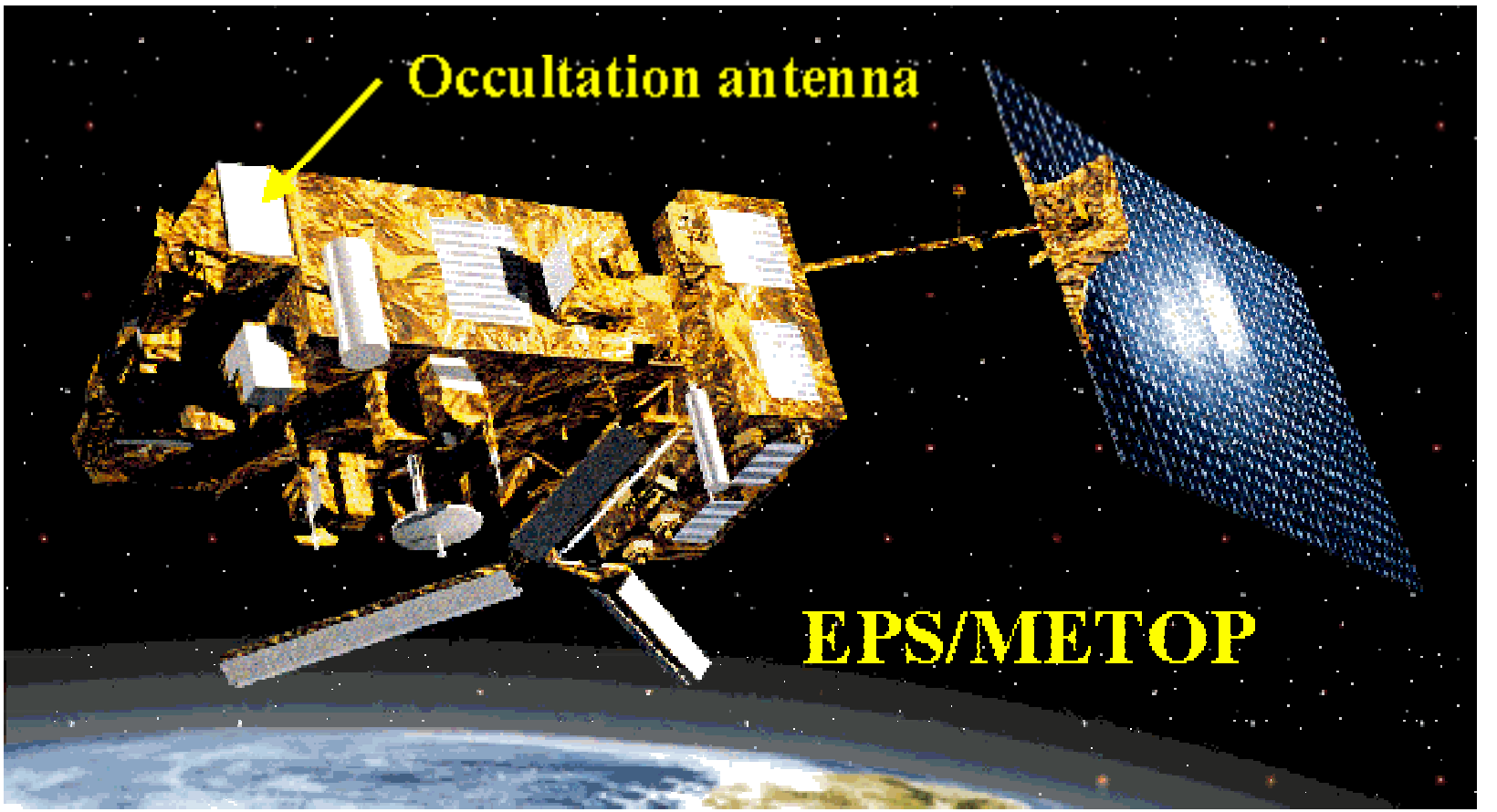
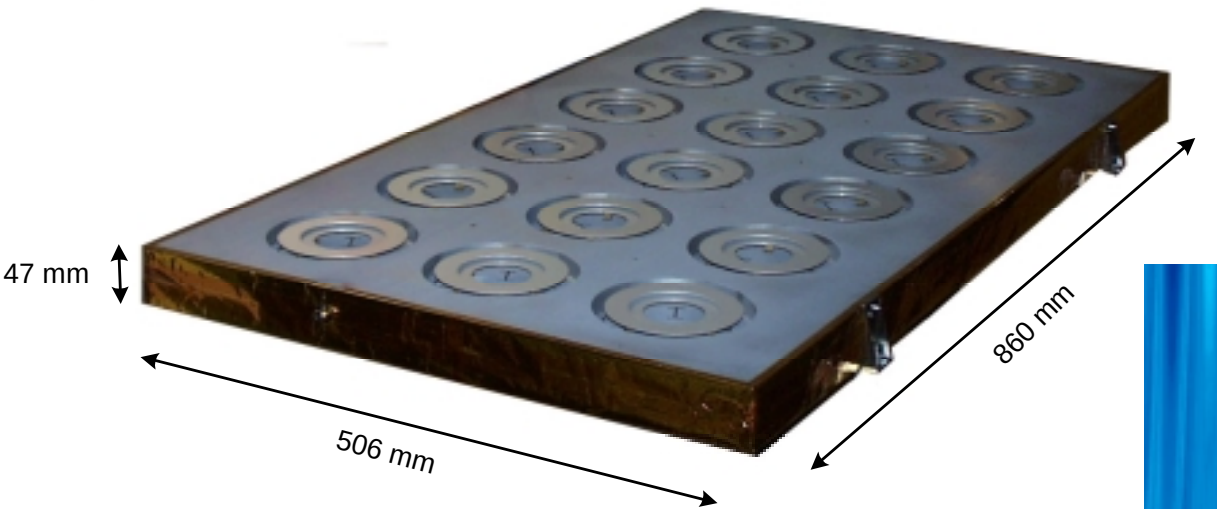
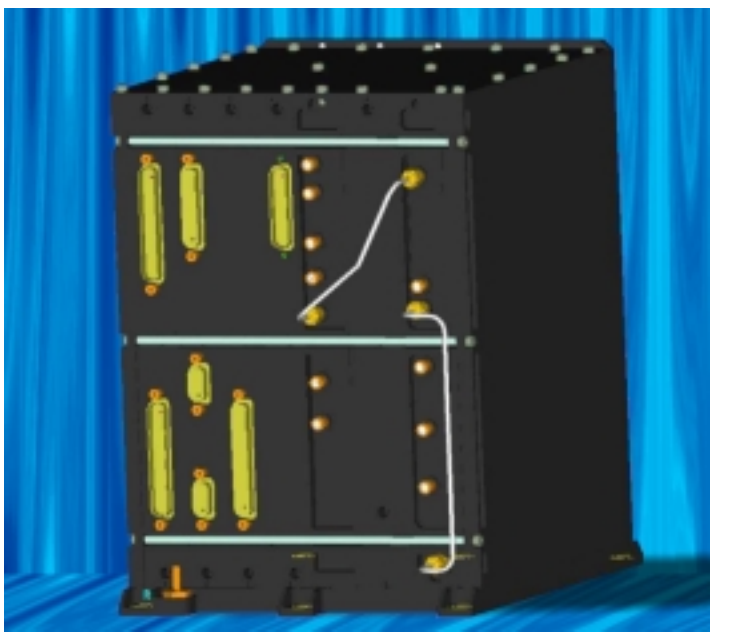
EUMETSATs EPS/Metop Satellite



GRAS Antenna and Receiver





Initial Joint Polar System (IJPS)
(EPS + NPOESS Program)

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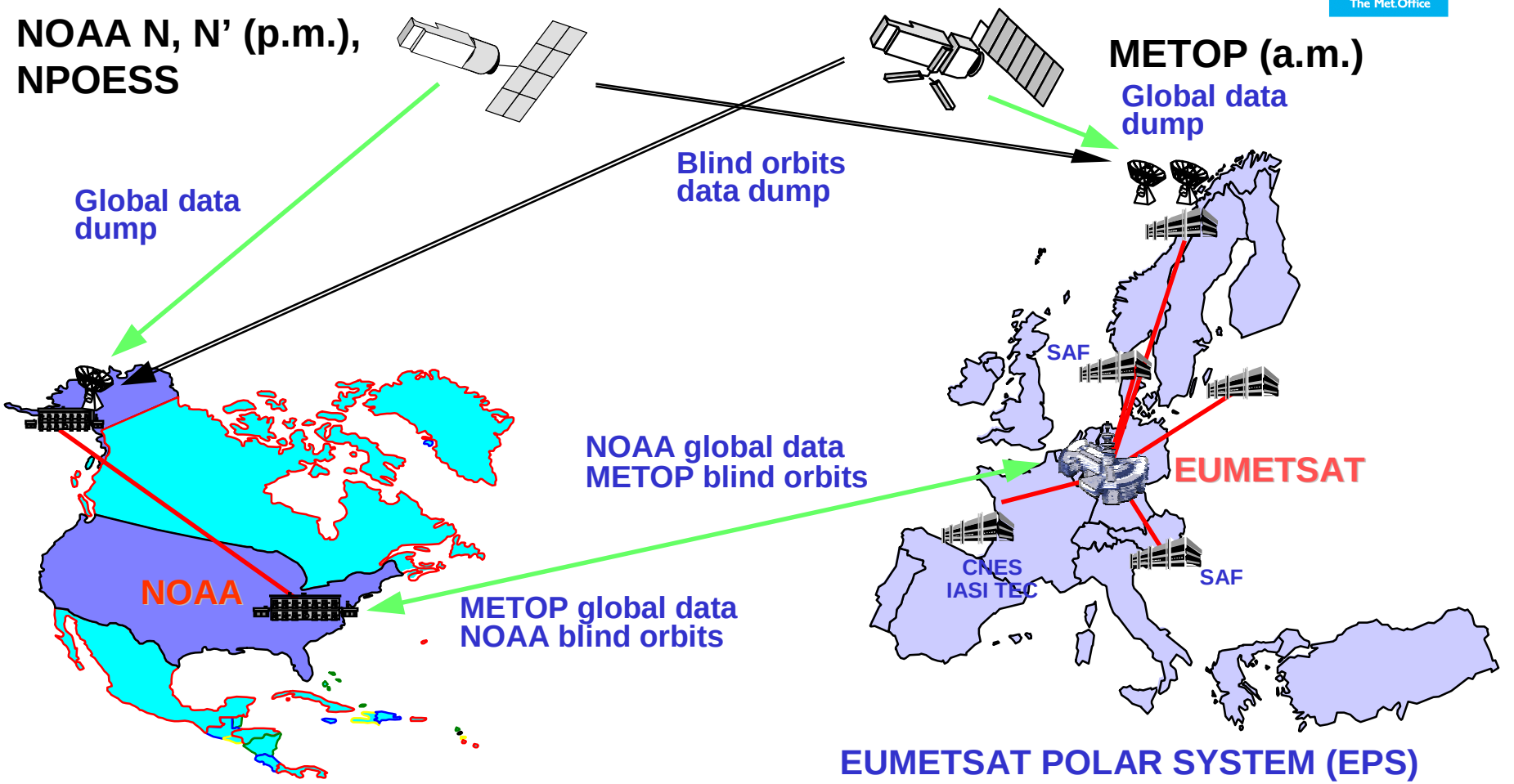
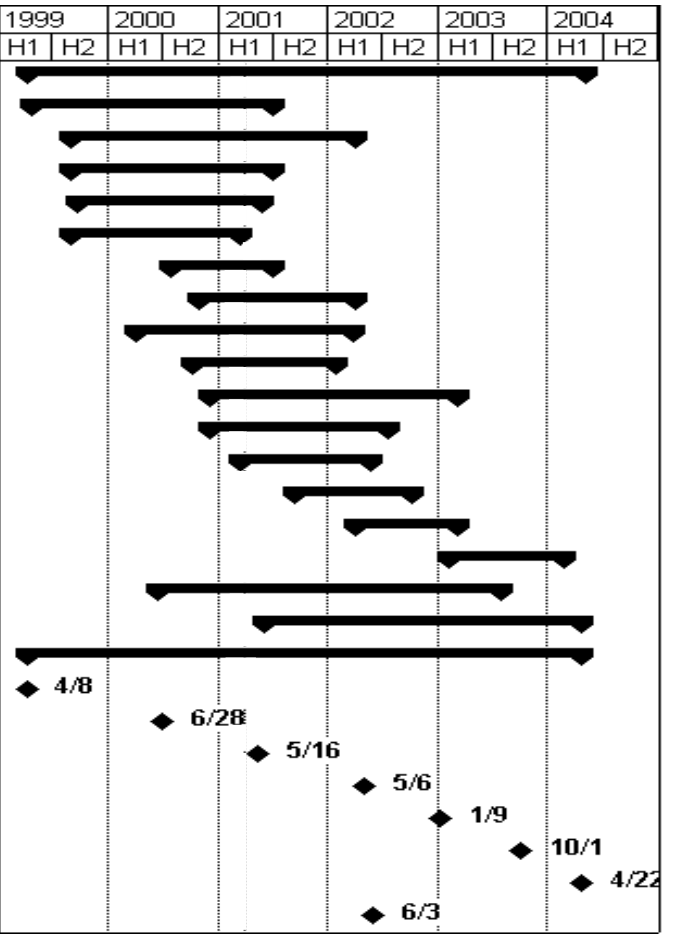
The Met.Office

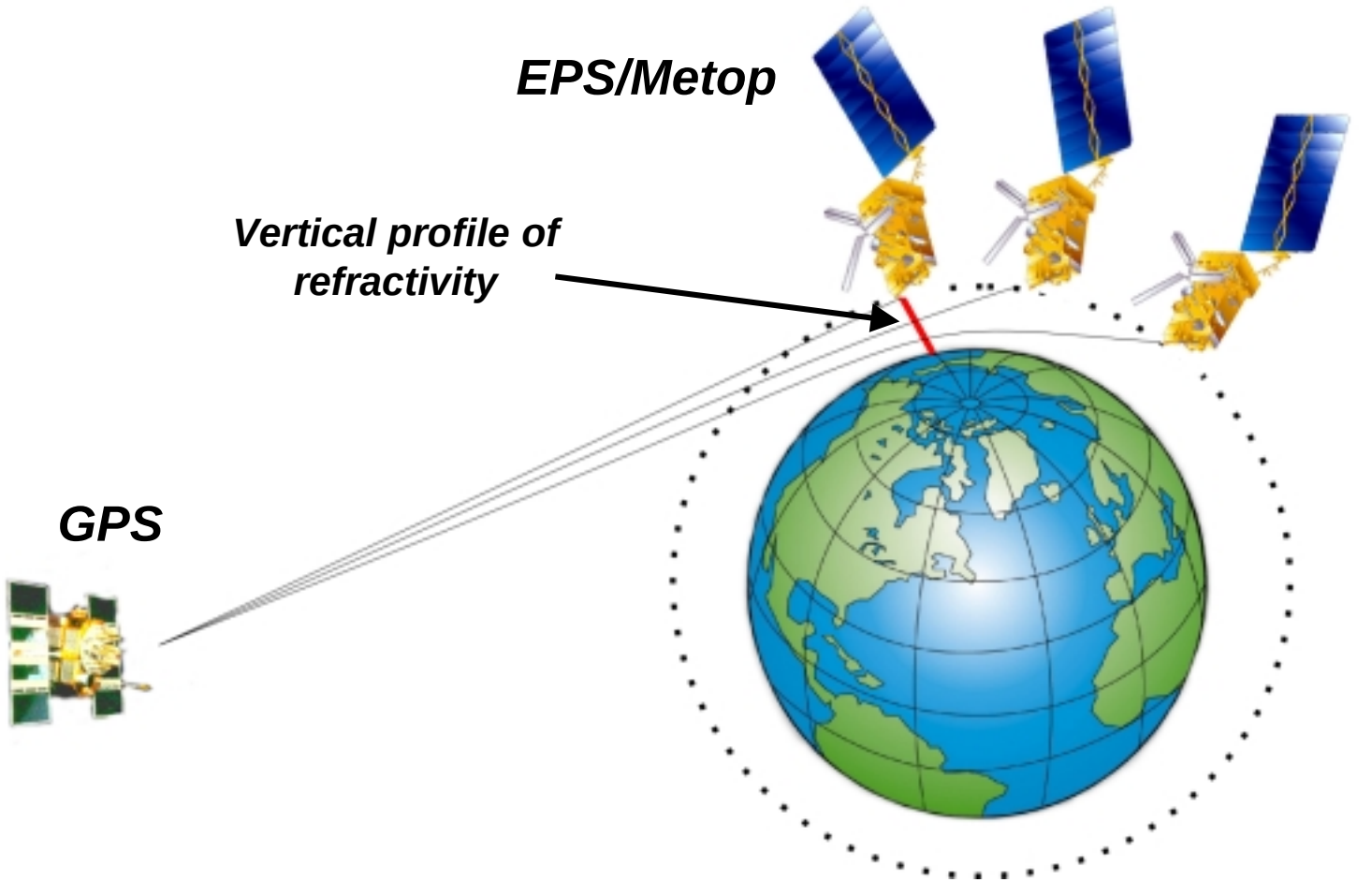


Project Schedule

ID	Task Name
1	**WP10000 Coodination and management**
17	**Preparatory phase**
23	**WP20000 Research and Development**
24	**WP22000 Data product retrieval algorithms**
25	**WP22100Sounding Products**
32	**WP22200 Refractivity products**
35	**WP22300 Atmosphere products**
39	**WP23000 Development of assimilation software**
42	**WP24000 Error analysis**
47	**WP25000 Geophysical scenarios**
53	**WP30000 Development of the software and processing chain**
54	**WP31000 Sounding products**
59	**WP32000 Refractivity products**
63	**WP33000 Atmosphere products**
67	**WP34000 Assimilation processing software**
72	**WP40000 Development of validation products and software**
77	**WP50000 Design, development and integration of data manager**
95	**WP60000 Intgration and testing in the overall EPS ground segme**
101	**Reviews**
102	Kick-Off
103	RADR-RR
104	RADR-DR
105	Mid-Term Review (MTR)
106	Integration Readiness Review (IRR)
107	System Integration Verification and Validation Review (SIVVR)
108	Operational Readiness Review (ORR)
109	Preliminary Proposal for the Operational Phase (POP)



EPS/Metop Radio Occultation from GPS



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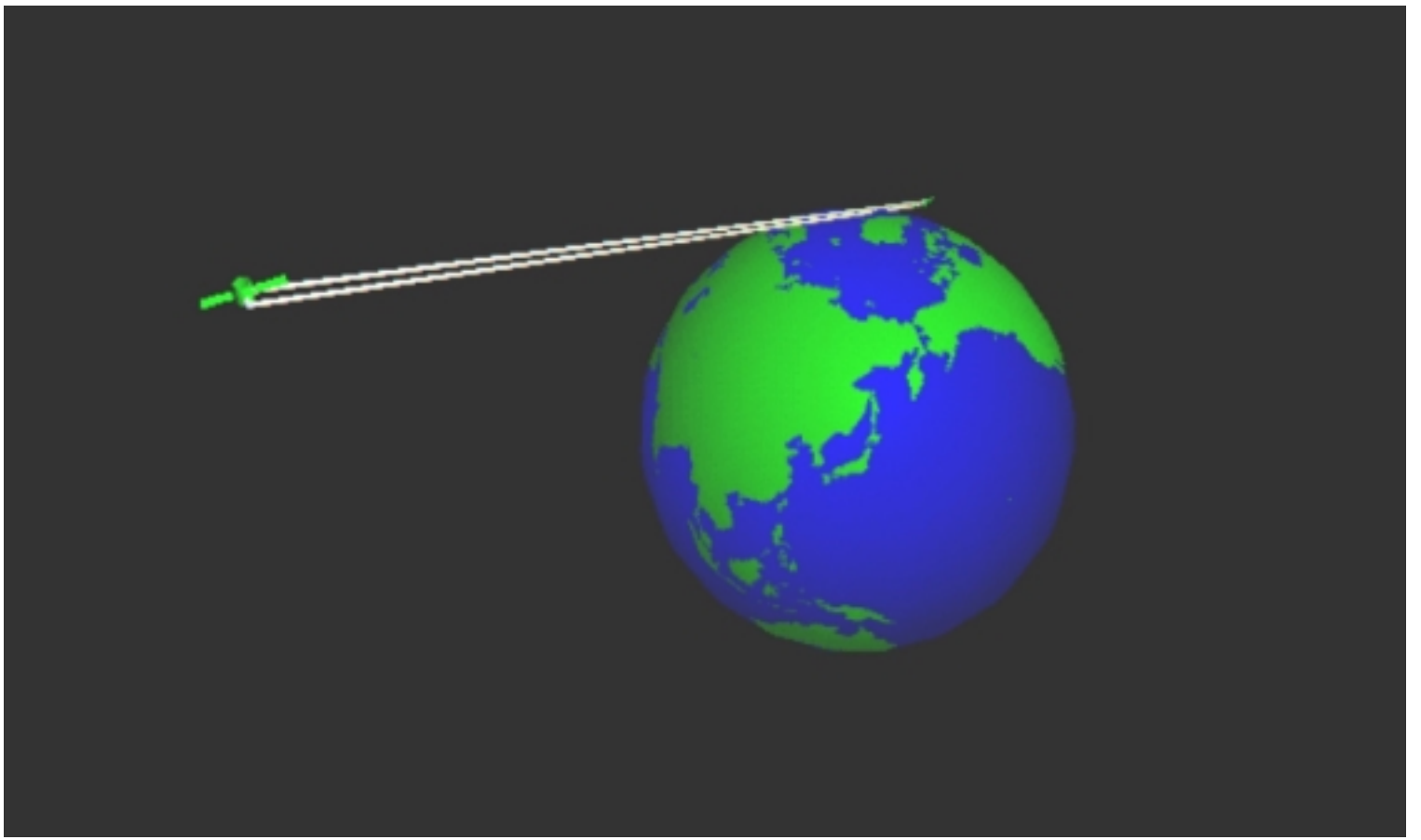
Occultation seen in Perspective



General Principle of Radio Occultation Data Processing

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Bending angle: Obtained from the measured phases (of the radio signals traversing the media from the GPS to the EPS/Metop satellite) and the position and velocities of the two satellites

Ionospheric corrected bending angle: Obtained by linearily combining the bending angles ($\alpha 1$ and $\alpha 2$) corresponding to the two radio frequencies (L1 and L2)

Refractivity: Calculated from the bending angle as a function of height using the Abel Transform inversion scheme or other methods

"Dry" temperature and pressure: Obtained using the ideal gas law and assumption of hydrostatic equilibrium

Water vapor (specific humidity) and "wet" pressure: Obtained using an ancillary temperature source and an iterative algorithm

Retreived Temperature (Dry) Profile from Ørsted

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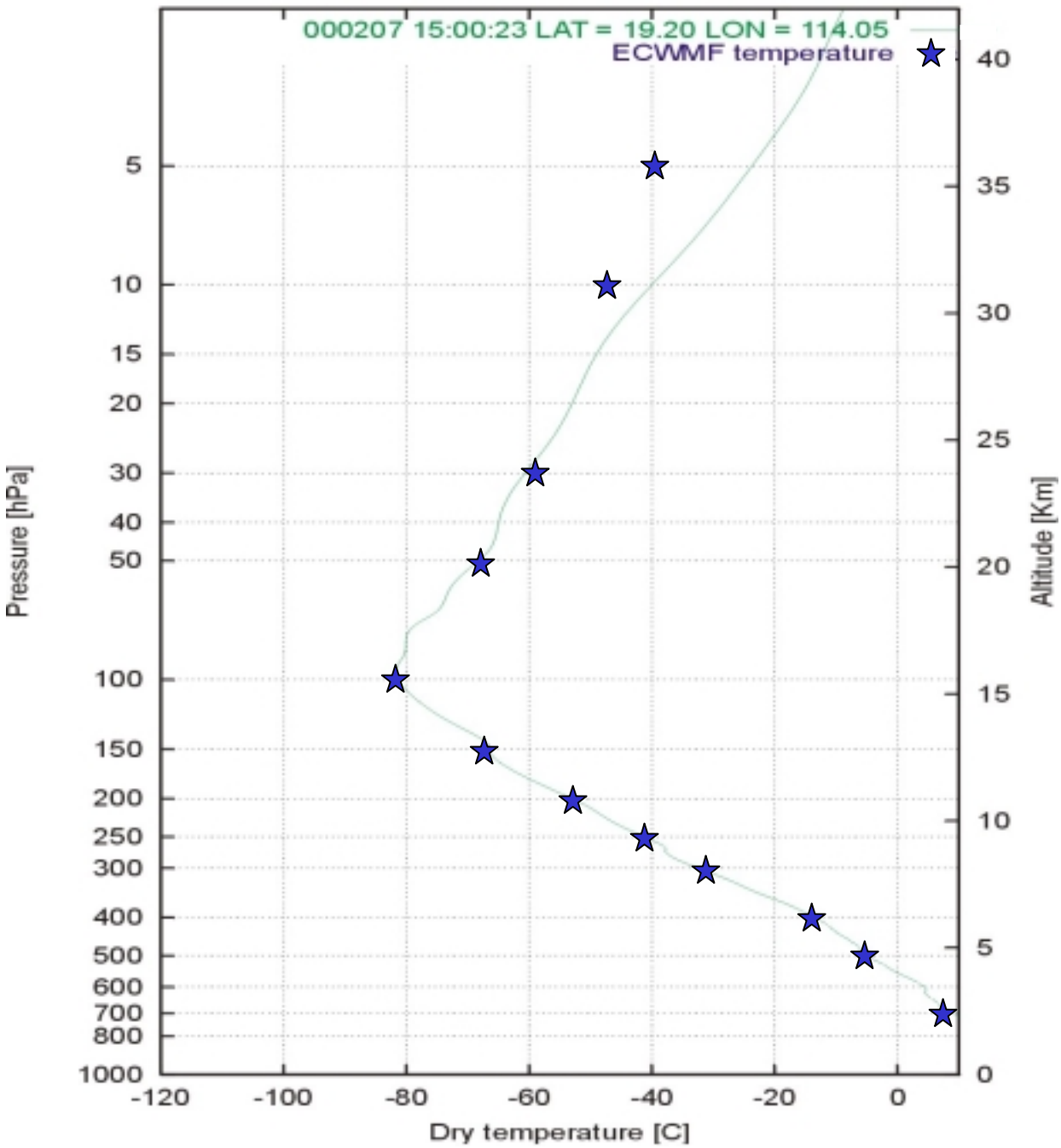

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Advantages of Radio Occultations

Absolute measurement

The technique needs no calibration. The basics of the observation is a measurement of time.

Global coverage

The geometry of the observation leads for one satellite to evenly distributed data on a 24-hour interval. Observations over seas and oceans (covering 70% of the Earth) minimize the major error source in accuracy of weather forecast and climate models.

High vertical resolution

The vertical resolution limited by the Fresnel zone of the observation leads to information of atmosphere phenomena with scale sizes less than 0.5 km.

Insensitive to clouds and precipitation

The wavelengths applied makes the measurement transparent to clouds and rain hampering other space techniques.

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Radio Sonde Station Distribution

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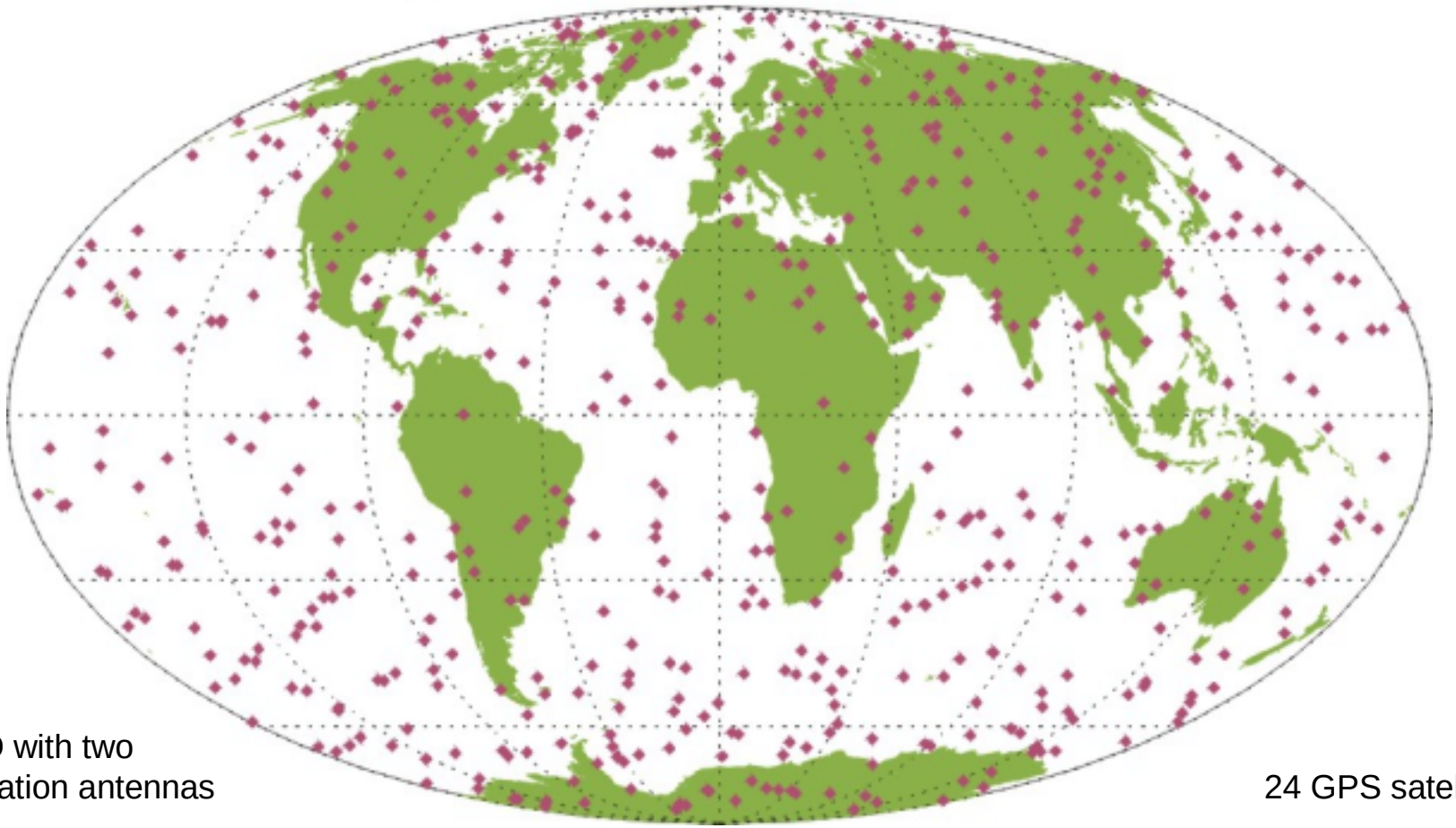
Typical 24-hour EPS/Metop Radio Occultation Distribution



1 LEO with two occultation antennas

24 GPS satellites

GRAS SAF Products

Data Product	*Characteristics*
Refractivity Profile	**Neutral Refractivity as a function of height and location of the occultation**
Observation Characteristics	**Error profile and covariance matrices of the observables. Time information for the occultation data. Latitude, longitude and radial position of the occultation products in geodetic coordinates.**
Temperature Profile	**Temperature and error estimate as a function of height and location of the occultation**
Specific Humidity Profile	**Specific humidity (water vapor) and error estimate as a function of height and location of the occultation**
Pressure Profile	**Pressure and error estimate as a function of height and location of the occultation, including surface pressure**

GRAS SAF Assimilation S/W Products

Statistically optimal 1D-Var refractivity retrieval code

Forward models for 4D-Var:

- **Direct assimilation of refractivity profiles into an NWP model**
- **Plane-averaged refractivity forward model for assimilation into an NWP model**
- **Direct assimilation of bending angle as a function of impact parameter into an NWP model**

GRAS SAF Products Time Requirements

Near-Real Time Products:

To be delivered less than 3 hours after measurement, using RMDCN (Regional Meteorological Data Communication Network), GTS, a.o.
Mainly for NWP use.

Offline Products:

Improved products re-processed using precise satellite orbits, additional NWP input, etc.
To be delivered less than 30 days after measurement, using FTP, DVD/CD-ROM, WWW download, a.o.
Mainly for climate research use.

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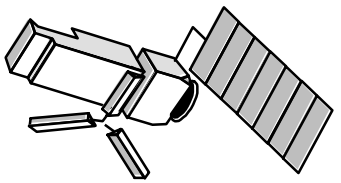
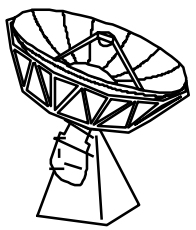
Data Levels and Processing

EPS/Metop
Measurement

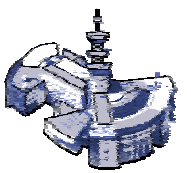


Raw Data Downlink



High-latitude Downlink Site
Demultiplexing, Quality check

Level 0 Data:
Phase and Amplitude Data, Tracking and Ancillary Data, Ground Site Data, ...



EPS Core Ground Segment
Level 0 -> Level 1a Processing
Level 1a -> Level 1b Processing

Level 1a Data:
Phase Delays, Doppler Shifts, SNR, Earth Location Data, ...

Level 1b Data:
Bending Angles, Impact Parameters, Auxiliary Data, ...

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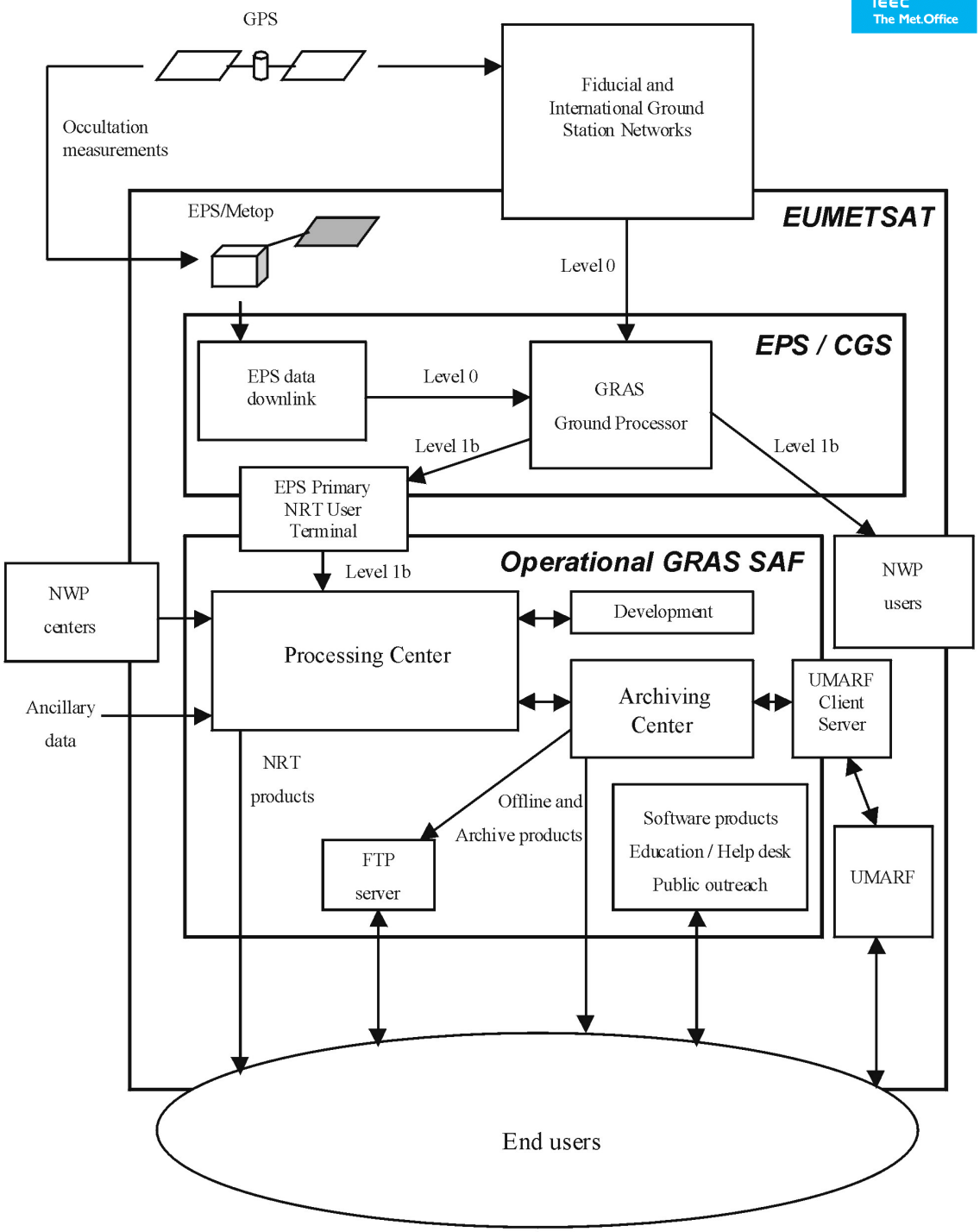
Level 1b -> Level 2 Processing, Dissemination, Archiving, ...

Level 2 Data:
Refractivity, pressure, temperature, and humidity profiles, Validation Data ...

End Users

GRAS SAF Data Flow Model



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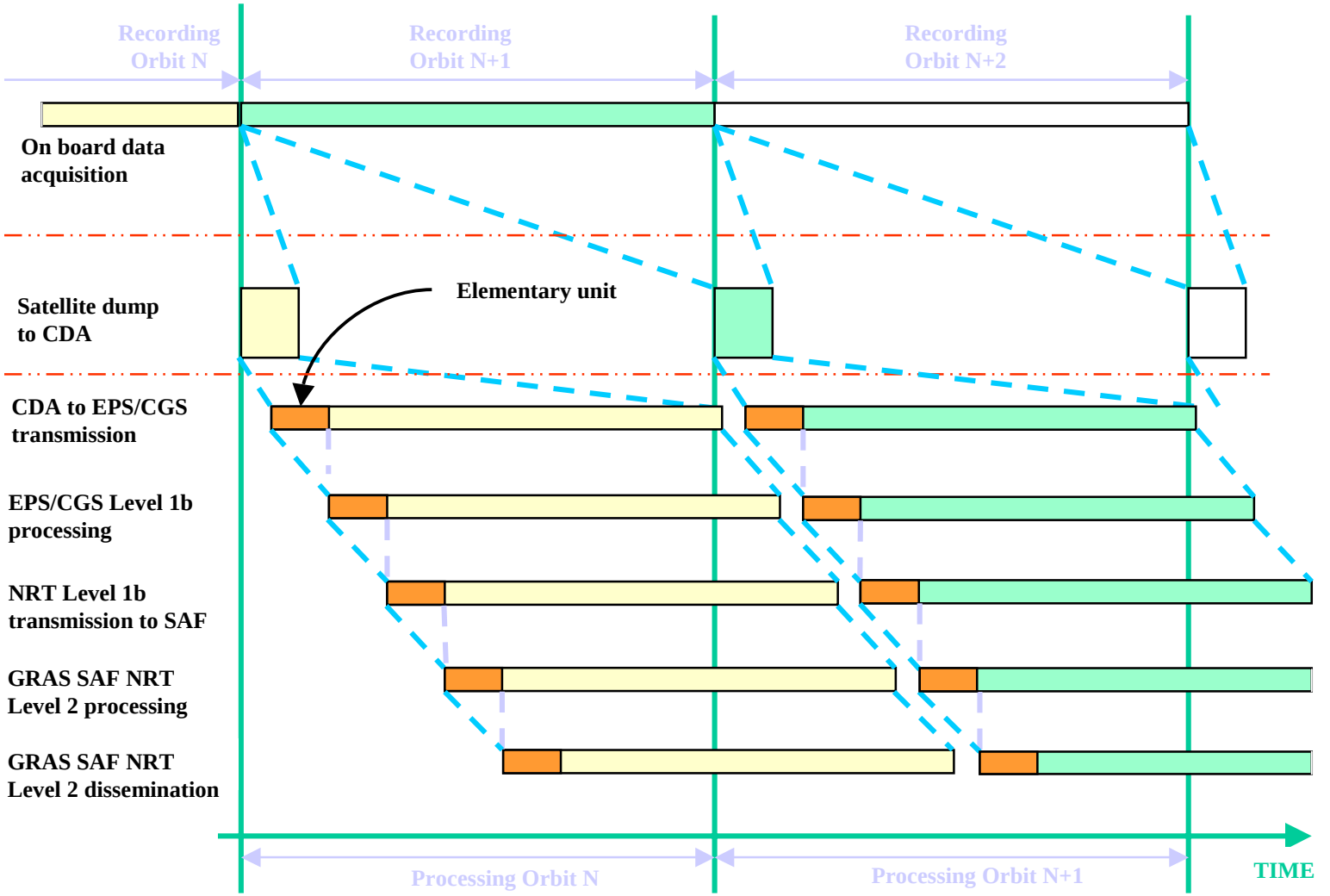
Data Flow as a Function of Time



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User Requirements for NWP

		Temperature	Specific Humidity	Surface Pressure	Refractivity	Bending Angle
Horizontal Domain		Global	Global	Global	Global	Global
Horizontal Sampling		100–2000km	100 – 2000km	100–2000km	100–2000km	100–2000km
Vertical Domain		Sfc–1 hPa	Sfc–100 hPa	Sfc (msl)	Sfc–1 hPa	Sfc–80 km
Vertical Sampling	**LT**	0.3–3km	0.4–2 km	–	0.3–3 km	2–5 Hz
	HT	1–3 km	1–3 km	–	1–3 km	
	LS	1–3 km	–	–	1–3 km	
	HS	1–3 km	–	–	1–3 km	
Time Window		1–12 hrs	1–12 hrs	1–12 hrs	1–12 hrs	1–12 hrs
RMS Accuracy	**LT**	0.5–3 K	0.25–1 g/kg	0.5–2 hPa	0.1–0.5%	1 µrad or 0.4%
	HT	0.5–3 K	0.05–0.2g/kg	–	0.1–0.2%	
	LS	0.5–3 K	–	–	0.1–0.2%	
	HS	0.5–5 K	–	–	0.2–2%	
Timeliness		1-3 hrs	1–3 hrs	1–3 hrs	1–3 hrs	1–3 hrs

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User Requirements for Climate Research

		Temperature	Specific Humidity
Horizontal Domain		Global	Global
Horizontal Sampling		100–1000 km	100–1000 km
Vertical Domain		Surface to 1 hPa	Surface to 1 hPa
Vertical Resolution	**LT**	0.3–3 km	0.5–2 km
	HT	1–3 km	0.5–2 km
	LS	1–3 km	0.5–2 km
	HS	5–10 km	1–3 km
Time Resolution		3–24 hrs	3–24 hrs
RMS Accuracy	**LT**	0.5–3 K	0.25–1 g/kg
	HT	0.5–3 K	0.05–0.2 g/kg
	LS	0.5–3 K	–
	HS	1–3K	–
Timeliness		30–60 days	30–60 days
Time Domain		> 10 years	> 10 years
Long-term Stability		< 0.1 K/decade	< 2% RH/decade
No. of profiles/ grid box/month		> 10	> 10

GRAS SAF Outlook

- First EPS/Metop satellite to be launched in 2005 (target)
- GRAS SAF will supply continuous, operational radio occultation data for weather forecasts and climate research
- Growth potential: Inclusion of GALILEO reception capability on future EPS/Metop satellites, inclusion of occultation data from other satellites in GRAS SAF processing

More information about the project:

www.dmi.dk/pub/GRAS_SAF

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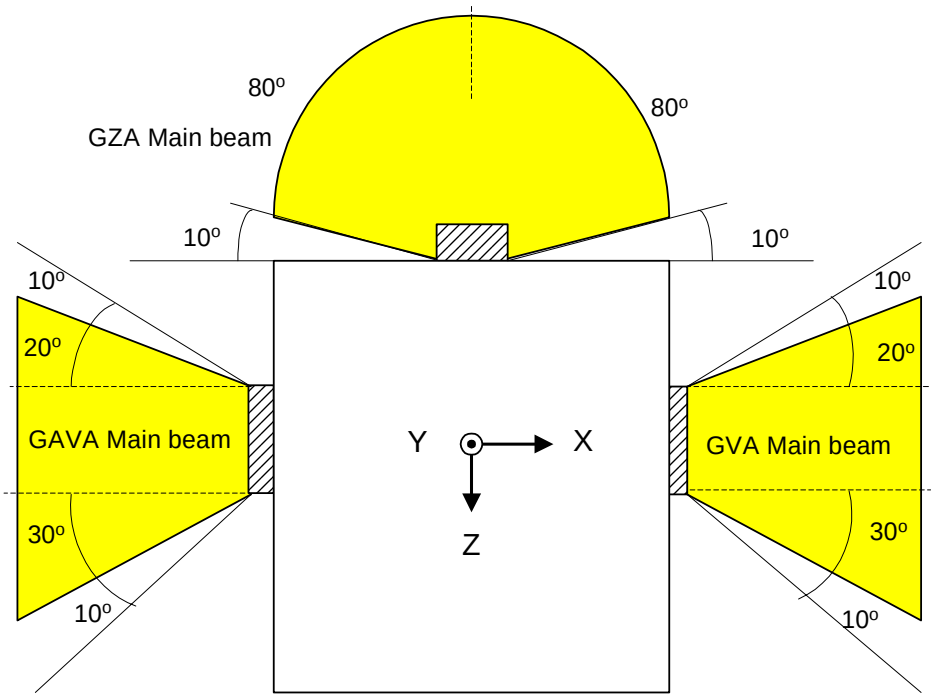
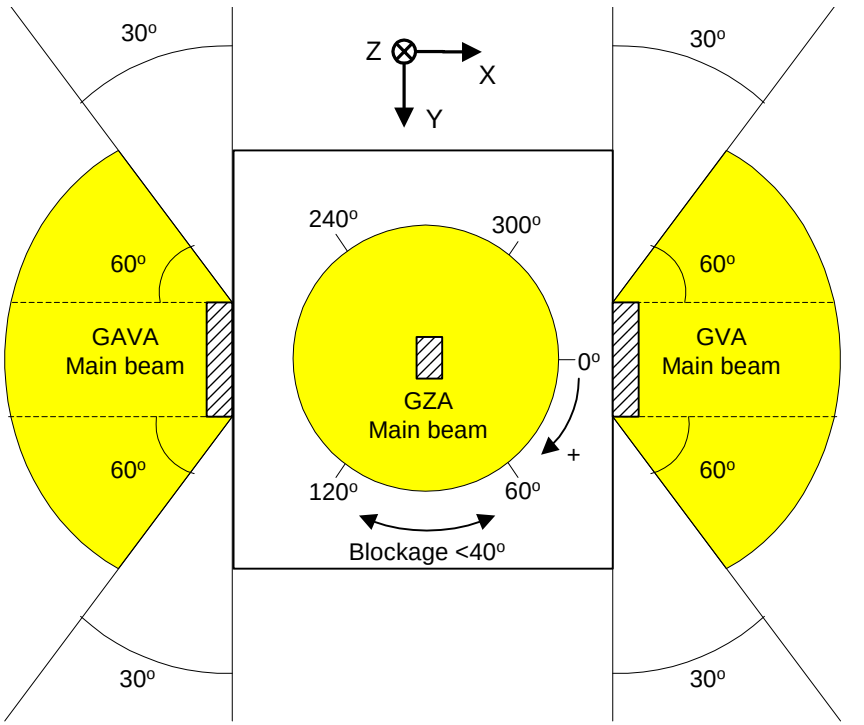
(The following slides are for optional use during the question session only)

Antenna Field of View

Side view

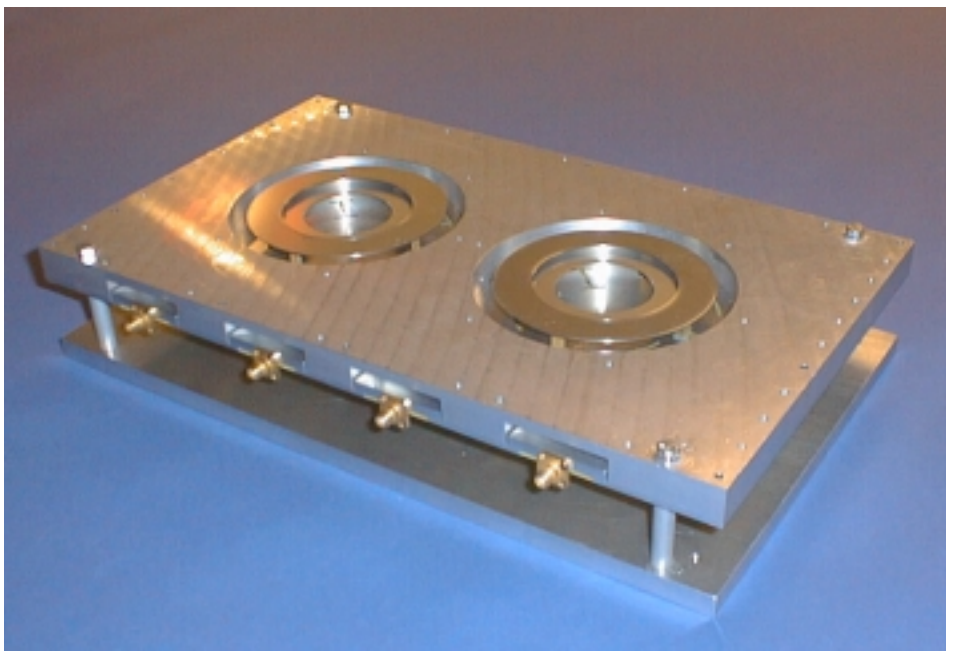


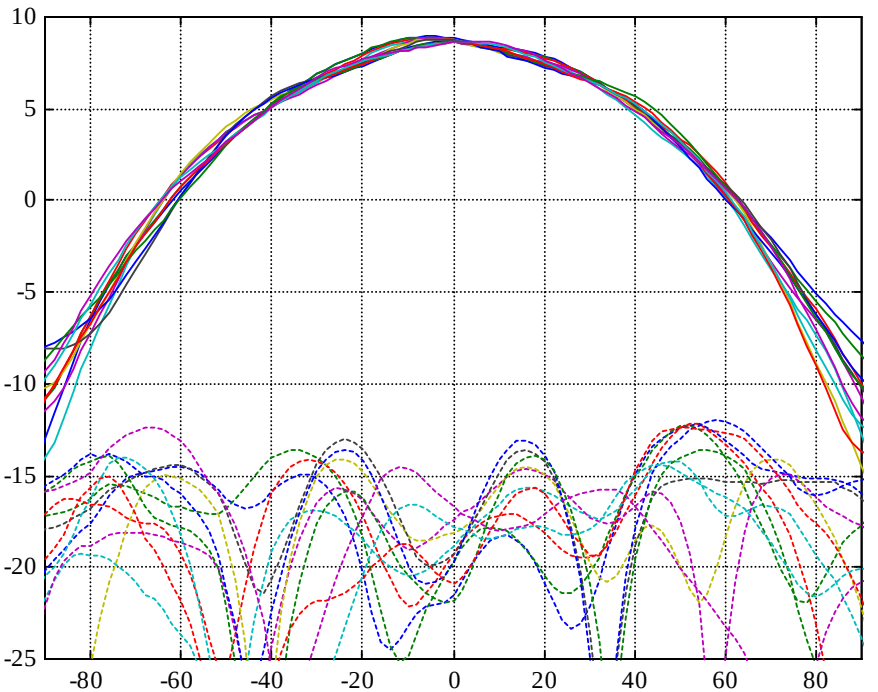
Top view



GRAS Zenith Antenna GZA

Two element antenna, L1 and L2





GAVA/GVA Performance