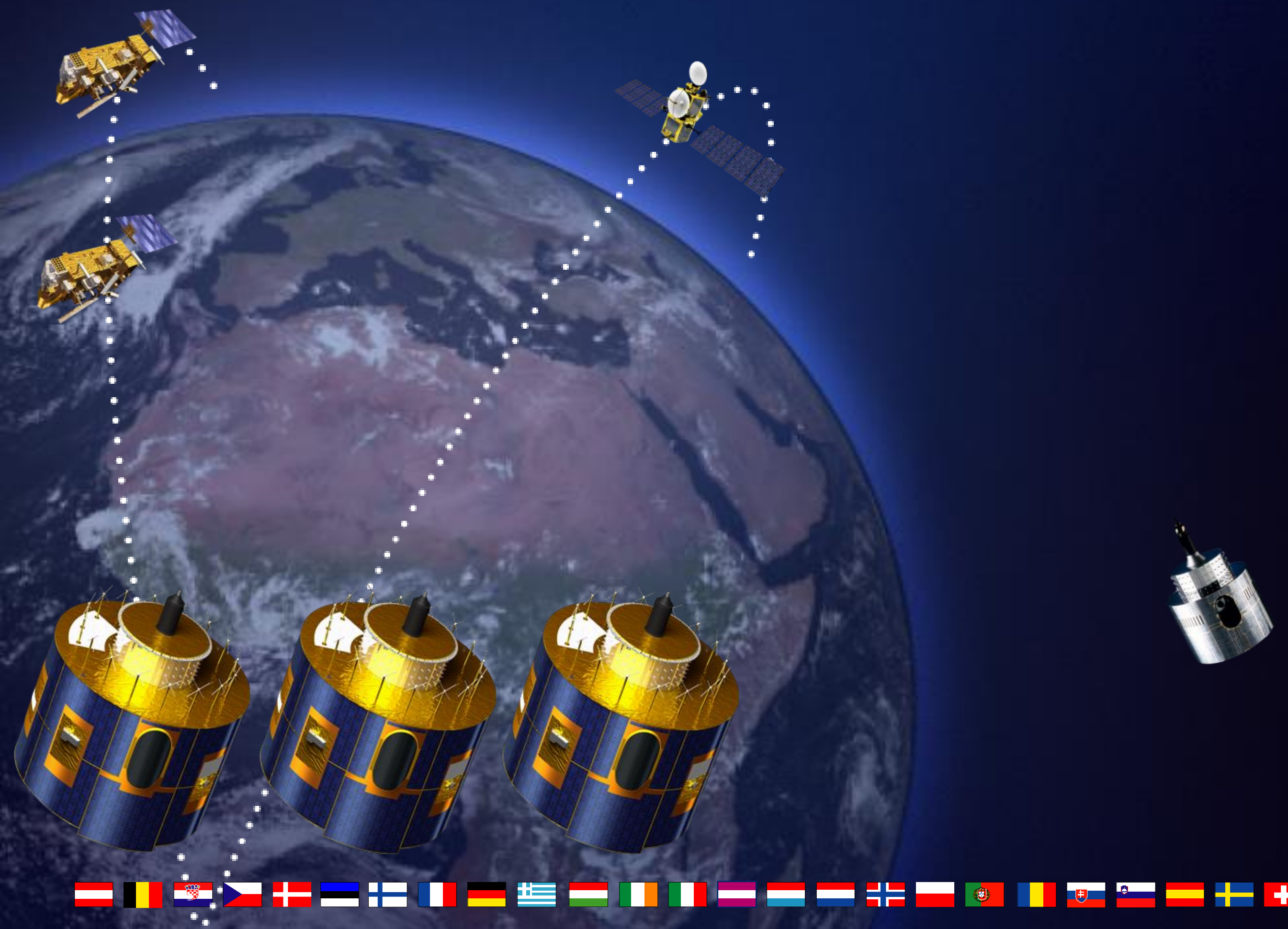
TECHNIQUES AND PROCESSES FOR PRE-LAUNCH CHARACTERISATION OF NEW INSTRUMENTS

EUMETSAT



Dieter Klaes
EUMETSAT

OUTLINE

1. Introduction
2. Identification of requirements
3. Development activities
4. Operations preparation and testing
5. Commissioning activities
6. Summary and Conclusion

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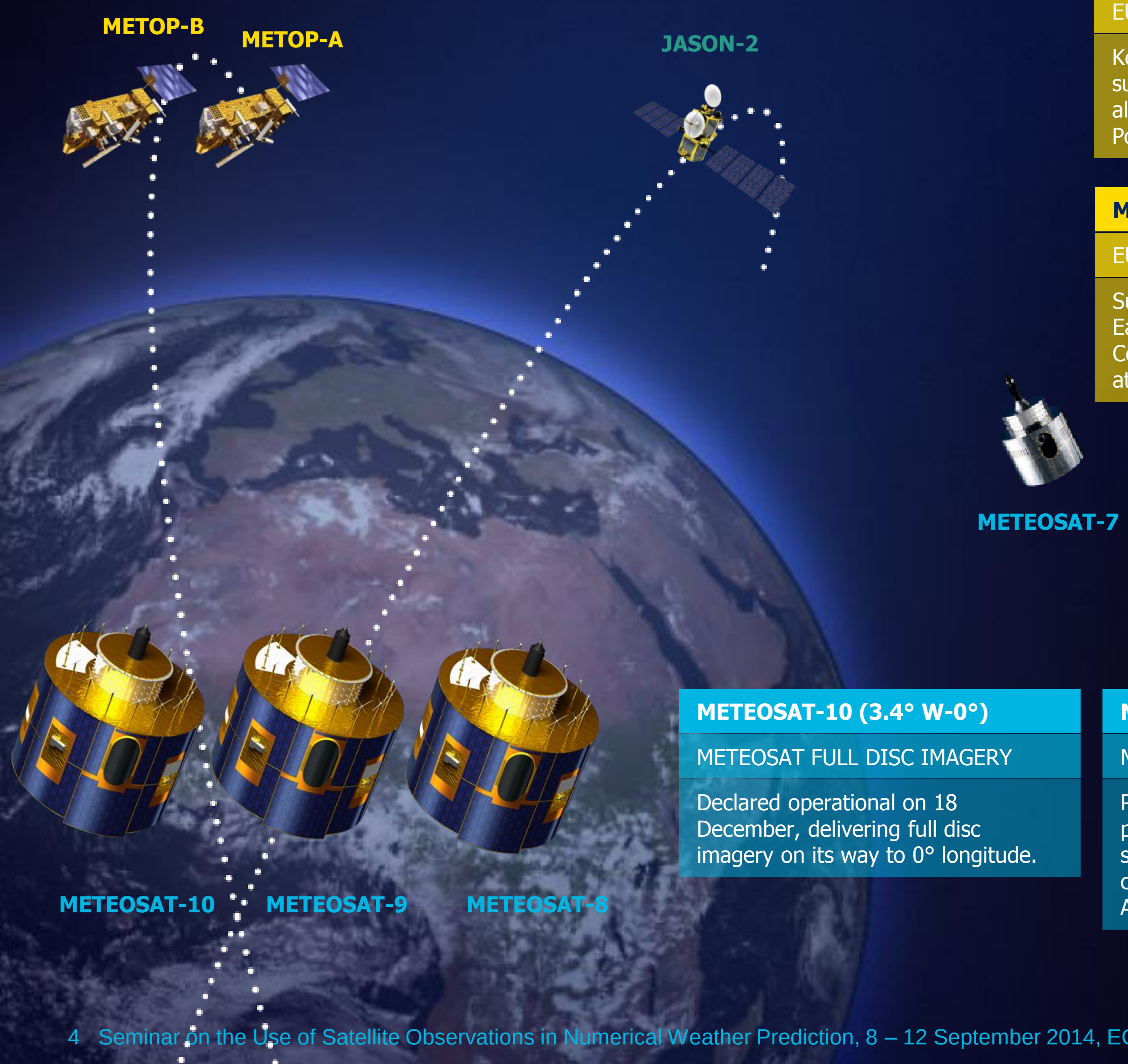
Current EUMETSAT satellites



METOP-A (98.7° incl.)

EUMETSAT POLAR SYSTEM

Kept in its nominal mid-morning sun synchronous orbit at 817km altitude as part of the EUMETSAT Polar System (EPS)

JASON-2 (66° incl.)

OCEAN SURFACE TOPOGRAPHY

Kept in its nominal non-synchronous low Earth orbit at 1,336km altitude, in support of the Ocean Surface Topography Mission.

METOP-B (98.7° incl.)

EUMETSAT POLAR SYSTEM

Successfully launched into low Earth orbit on 17 September. Commissioning activities ongoing at the end of 2012.

METEOSAT-7 (57.5° EAST)

INDIAN OCEAN DATA COVERAGE

Operated in support of the Indian Ocean Data Coverage (IODC) mission, bridging an observational gap in this region

METEOSAT-10 (3.4° W-0°)

METEOSAT FULL DISC IMAGERY

Declared operational on 18 December, delivering full disc imagery on its way to 0° longitude.

METEOSAT-9 (0°)

METEOSAT FULL DISC IMAGERY

Positioned at 0° in support of the prime Meteosat full disc imagery service over the European continent, Africa and parts of the Atlantic and Indian oceans.

METEOSAT-8 (9.5° EAST)

RAPID SCANNING SERVICE (RSS)

Positioned at 9.5° East delivering the Rapid Scanning Service (RSS) over Europe and adjacent seas.

EUMETSAT

Benefit areas of weather forecasting

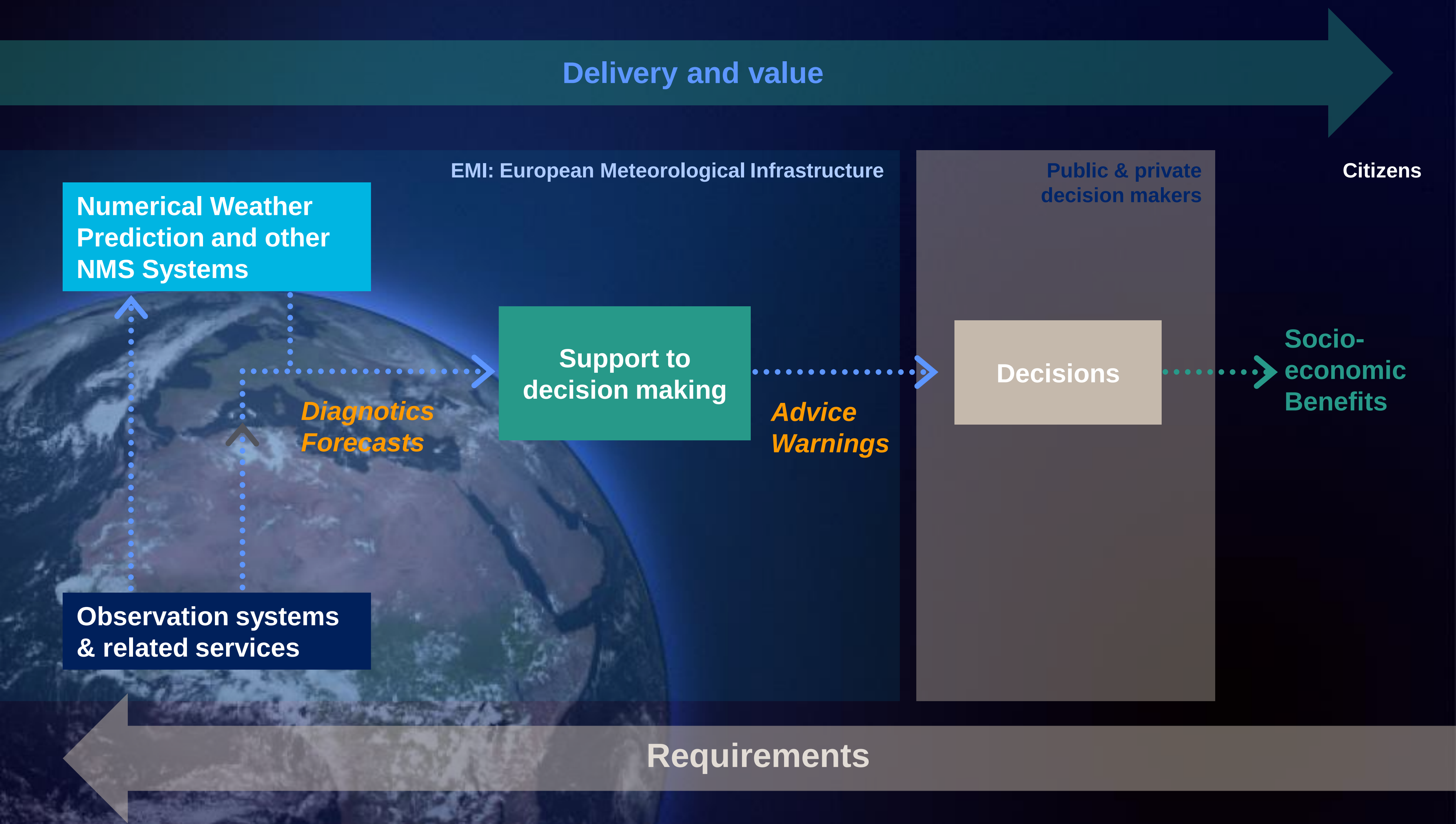
Safety of life, property and infrastructure…

Transport …

….Energy, agriculture, tourism….

…Climate policy and environment protection

From observation to decision making: EUMETSAT's role in the value adding chain



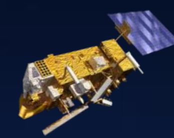
How we deliver programmes

REQUIREMENTS

European National Meteorological Services (NMS)

Satellite developement & procurement
esa

Operational Agency
EUMETSAT



Satellite R&D agency

European Space Industry

- Interface with users and definition of user and system level requirements
- Overall system design and development
- Procurement of ground segment & launch services
- Operation of full satellite systems & ground infrastructure
- Delivery of data, products and support services to users

Private Enterprises, Value-Added Services, End-Users

Design and manufacturing

DELIVERY

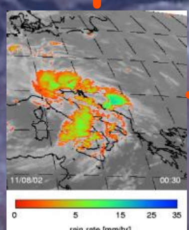
ESA-EUMETSAT cooperation model

EUMETSAT council
Customer authority

Operational
service provider

Users

Management of interactions
with users



System operations, maintenance & upgrades
Delivery of agreed products and services

Procurement of rec. Spacecraft
Support to launch campaign

Manufacturing
and support

Customer
EUMETSAT
ESA
Industry

This is a long process

- Project phases
  - In a space project there are several phases which proceed the project towards operational implementation
  - Phase 0 – Mission Analysis/Needs Identification
  - Phase A – Feasibility
  - Phase B – Preliminary Definition
  - Phase C – Detailed Definition
  - Phase D – Production/Ground Qualification Testing
  - Phase E – Utilisation
  - Phase F – Disposal
- ECSS Standard (European Cooperation for Space Standards)

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Identification of Requirements: Long term aspect

- Long term preparation: Think of new programmes before the actual one has been launched its satellites
- That means: need to know
  - Applications in the future
  - Possible Improvements
  - Extended and New Applications
  - Possible Technological Developments
  - Limits

Identification of Requirements: Unknown Terrain

- Projection of the future
- Adaptation of observations to the applications e.g.
  - Model grid size
  - New parameters
  - Timeliness
  - Performances to get an improvement
  - Knowledge of available requirements
  - What is possible?

Identification of Requirements

- What are the applications?
- Who are the Users? Are there Users?
- What parameters will be needed?
- What are the observation requirements?
- Which missions can satisfy the requirements?
- Where are gaps?
- Which other developments are there?

Assess available information

Find and Assess Sources of Information

- Heritage
- WMO data bases
  - RRR
  - OSCAR
- CEOS
- Gap analysis for GCOS
- Others

User Consultation process

- Involve Users
- Involve Experts in the field
- Stakeholders
- Bring them together
  - Application Expert Groups – by themes
  - Users – from "Customers" related to applications
  - Experts for measurement systems
  - Other experts

Establish the requirements

- Mission requirements
- Observation Requirements
- User Requirements
- Proposal/Payload requirements
- -> Candidate missions
- -> Selected missions

- Illustrated at the example of EPS-SG

User Requirements Definition Steps (1/5)

Step 1

Initial formulation of potential user requirements in terms of

- List of objective and threshold requirements,
  - Objective: Observation goal
  - Threshold: Minimum level for usefulness
- Accuracy
- Spatial sampling
- Temporal sampling
- Reporting delay
- Breakthrough level: Expected to make a delta improvement in the targeted service
- Priority

Basis for AEG discussion and subsequent user consultation

User Requirements Definition Steps (2/5)

Step 2

Initial assessment of suitable observation techniques

For each potential user requirement:

- Broad identification of observation techniques
- Identification of precursor instruments/missions
- Estimation of performance against threshold-objective range

User Requirements Definition Steps (3/5)

Step 3 Generation of Mission Requirements

- Grouping of user requirements in candidate missions
- Definition of data levels
  (raw, calibrated, resampled at satellite radiances, level 2 data, ...)
- Derivation of observation requirements
  (spatial, spectral resolution, radiometric accuracy, ...)
- Identification of non-observation requirements / user services

Step 4 Technical Requirements (ESA)

- Derivation of technical requirements for sensor/system studies
  (e.g. MTF, spectral response, pointing accuracy, ...)

User Requirements Definition Steps (4/5)

User Consultation

1. Initial Formulation

Remote Sensing Experts Assessment

2. Observation Techniques

Requirements and Mission Analysis
Scientific/Technical Studies

Delegate Bodies Decisions

3. Mission Requirements

Sensor/System/Mission Analysis
Technical Studies

4. Technical Requirements

User Requirements Definition Steps (5/5)

from Phase 0 → to Phase A

(mission definition) → *(feasibility)*

↓ *Requirements and Mission Analysis*
Scientific/Technical Studies

Mission Requirements → **End-User Requirements**

↓ *Sensor/System/Mission Analysis*
Technical Studies

Technical Requirements → **System Requirements**

} *Programme Proposal (Phase B)*

Initial Scope of Tentative Missions

Initial scope of tentative missions given by requirements based on

- EUMETSAT (MTG) User Consultation - NWC, NWP position papers
- WMO database of requirements
- GCOS
- IGOS Themes
  - Ocean
  - Atmospheric Chemistry
  - Carbon Cycle
  - Water Cycle
- GOOS
- GMES Themes
  - Ocean
  - Land
  - Atmospheric Chemistry

Application Experts Groups – Example EPS-SG

- Support of EUMETSAT user consultation towards EPS-SG

- Analysing the needs of EUMETSAT users in the 2020+ timeframe
  - Starting with MTG Position Papers
    - Global numerical weather prediction
    - Regional numerical weather prediction
    - Now-casting
  - Analysing the evolution of those applications
  - Taking account of further applications:
    - Operational oceanography
    - Atmospheric chemistry and carbon cycle (protocol monitoring and air quality)
    - Land surface analysis at large scale
    - Climate monitoring

- Formulation of EUMETSAT user needs: **Position Papers**

Requirements from NWP and Climate Monitoring

- Numerical Weather Prediction:
  - Most substantial improvement in global and regional NWP is expected from use of more detailed 3D observations of horizontal wind vector
  - Wind vector measurements over Europe are currently obtained from radiosonde and aircraft ascent/descent
  - Strong need to extend the observation network to oceans, tropics, and polar regions
  - Dynamical aspects of the atmosphere will increasingly require observation of small-scale phenomena in wind fields
- Climate Monitoring
  - Assessment of eventual decadal to century scale changes
  - Essential to determine causes of change (natural or anthropogenic)

Initial list of instruments identified (1/2)

- Atmospheric Sounding
  - Hyper-spectral infrared sounder
  - Microwave radiometer
  - Radio occultation sounding
  - Differential Absorption lidar
- Wind Profiling
  - Doppler wind lidar
- Cloud, precipitation, and land surface imaging
  - Optical high-resolution imager
  - Microwave imager
  - Cloud/precipitation radar

Initial list of instruments identified (1/2)

- Ocean imaging
  - Optical high-resolution imager
  - Microwave imager
  - Scatterometer

- Ocean topography
  - Altimeter

- Atmospheric chemistry
  - High-resolution infrared sounding
  - Nadir-viewing UV-SWIR spectrometer
  - Limb-viewing IR sounder
  - Limb-viewing mm-wave sounder

Identification of Missions

- Heritage instrument, mission continuity
- Mission continuity, but also improvements and new requirements, challenging technology
- Complementary mission contributions by partners

EPS-SG payload complement and targeted applications

EPS-SG Satellite-A missions	Instrument (and provider)	Predecessor on Metop	Applications benefitting						
			Atmospheric Chemistry	Climate Monitoring	Hydrology	Nowcasting (NWC) at high latitudes	Numerical Weather Prediction (NWP)	Oceanography	Land
INFRARED ATMOSPHERIC SOUNDING (IAS)	IASI-NG (CNES)	IASI (CNES)	■	■		■	■	■	
MICROWAVE SOUNDING (MWS)	MWS (ESA)	AMSU-A (NOAA) MHS (EUMETSAT)		■		■	■		
VISIBLE-INFRARED IMAGING (VII)	METIMAGE (DLR)	AVHRR (NOAA)		■	■	■	■	■	■
RADIO OCCULTATION (RO)	RO (ESA)	GRAS (ESA)		■			■		
UV/VIS/NIR/SWIR SOUNDING (UVNS)	SENTINEL-5 (COPERNICUS, ESA)	GOME-2 (ESA)	■	■			■		
MULTI-VIEWING, -CHANNEL, -POLARISATION IMAGING (3MI)	3MI (ESA)	-/-	■	■		■			■

EPS-SG Satellite-B missions	Instrument (and provider)	Predecessor on Metop	Applications benefitting						
			Atmospheric Chemistry	Climate Monitoring	Hydrology	Nowcasting (NWC) at high latitudes	Numerical Weather Prediction (NWP)	Oceanography	Land
SCATTEROMETER (SCA)	SCA (ESA)	ASCAT (ESA)		■	■	■	■	■	■
RADIO OCCULTATION (RO)	RO #2 (ESA)	GRAS (ESA)		■			■		
MICROWAVE IMAGING FOR PRECIPITATION (MWI)	MWI (ESA)	-/-		■	■	■	■	■	
ICE CLOUD IMAGER (ICI)	ICI (ESA)	-/-		■	■	■	■		
ADVANCED DATA COLLECTION SYSTEM (ADCS)	ARGOS-4 (CNES)	A-DCS (CNES)		■				■	

- Atmospheric Chemistry
- Climate Monitoring
- Hydrology
- Land
- Nowcasting (NWC) at high latitudes
- Numerical Weather Prediction (NWP)
- Oceanography

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EPS-SG: Joint EUMETSAT-ESA planning

End User Requirements

- EURD (End User Requirements Document), owned by Council
  - Basis for the development
  - Derived: SRD (System requirements), GSRD (Ground Segment Requirements) etc.
  - Specifications for processors
- Instrument development as part of satellite development (see co-operation model)
- Instruments provided from Partners

Development activities and milestones

- System approach
- Baseline documents, cooperation industry – partners – EUMETSAT
- SDP – System Development Plan
- Specially for processors
  - ATBD – Algorithm Theoretical Basis Document
  - PGS / PFS / ADS
    - Product Generation Specification
    - Product Format Specification
    - Auxiliary Data Specification
  - Prototype Processors

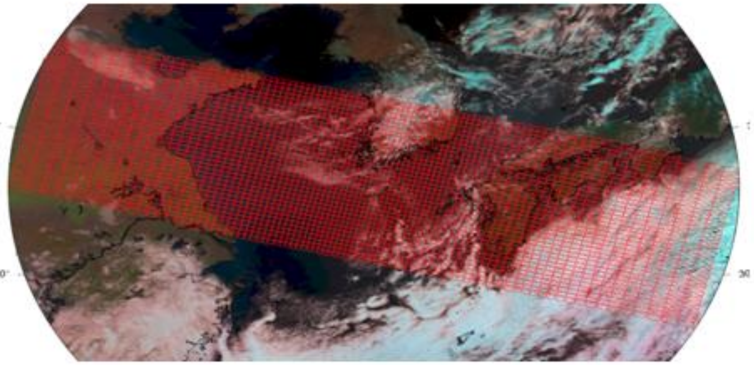
Development activities and milestones

- Instrument Development
  - IRS – Instrument Requirements Specifications
  - PDS – Payload Data Simulator
  - GPP – Ground Processor Prototype
- Instrument and product TEST data
  - Testing the System
  - Testing the Throughput
  - Testing the Performance

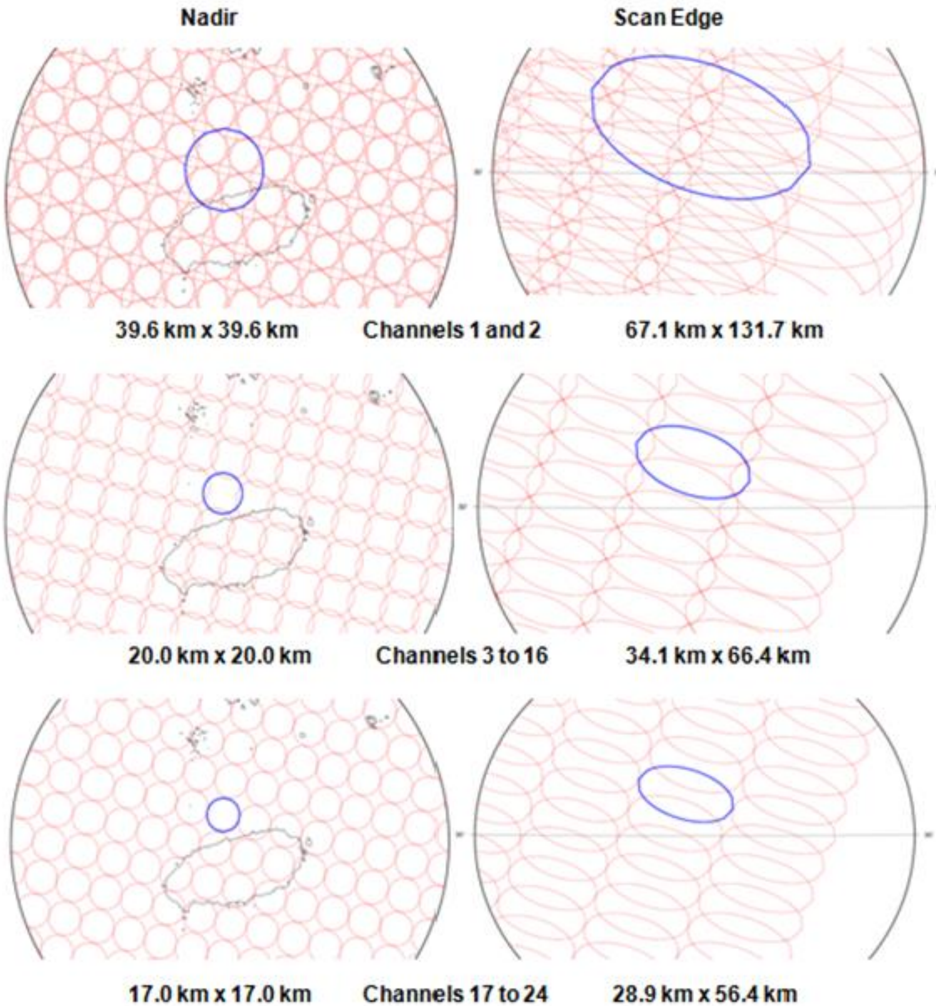
Atmospheric Profiling

Microwave and IR Sounding - selected highlights

Example from the MWS PT: Preliminary MWS Sampling Properties Based on End-User Requirements



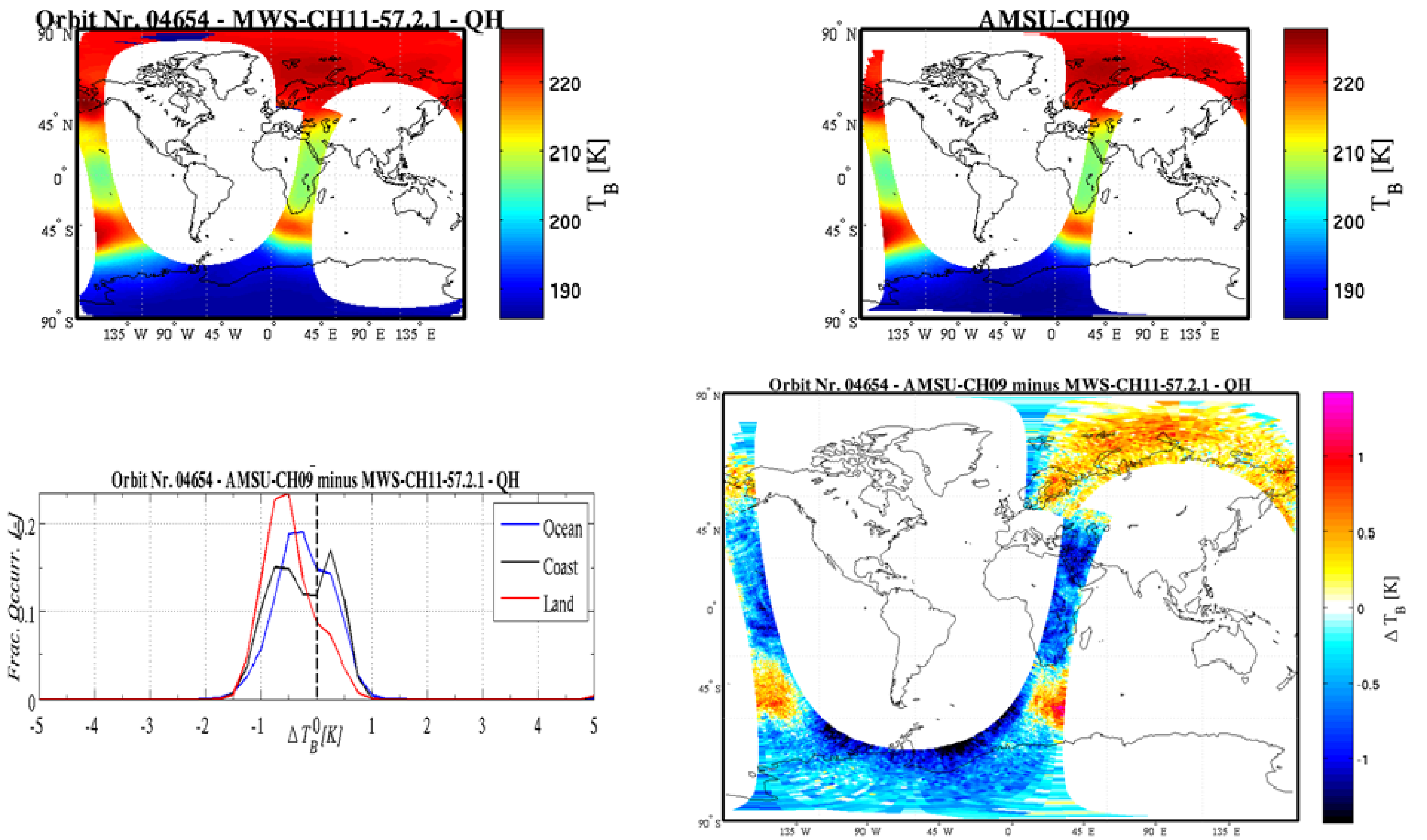
- 87 pixels per scan line
- 2.55 seconds scan duration
- 49.25° maximum scanning angle
- 2202 km swath width



Atmospheric Profiling
Microwave and IR Sounding - selected highlights

Status of MWS Test Data: Validation of Test Data from an External Study (Informus)

Temperature Sounding Channel

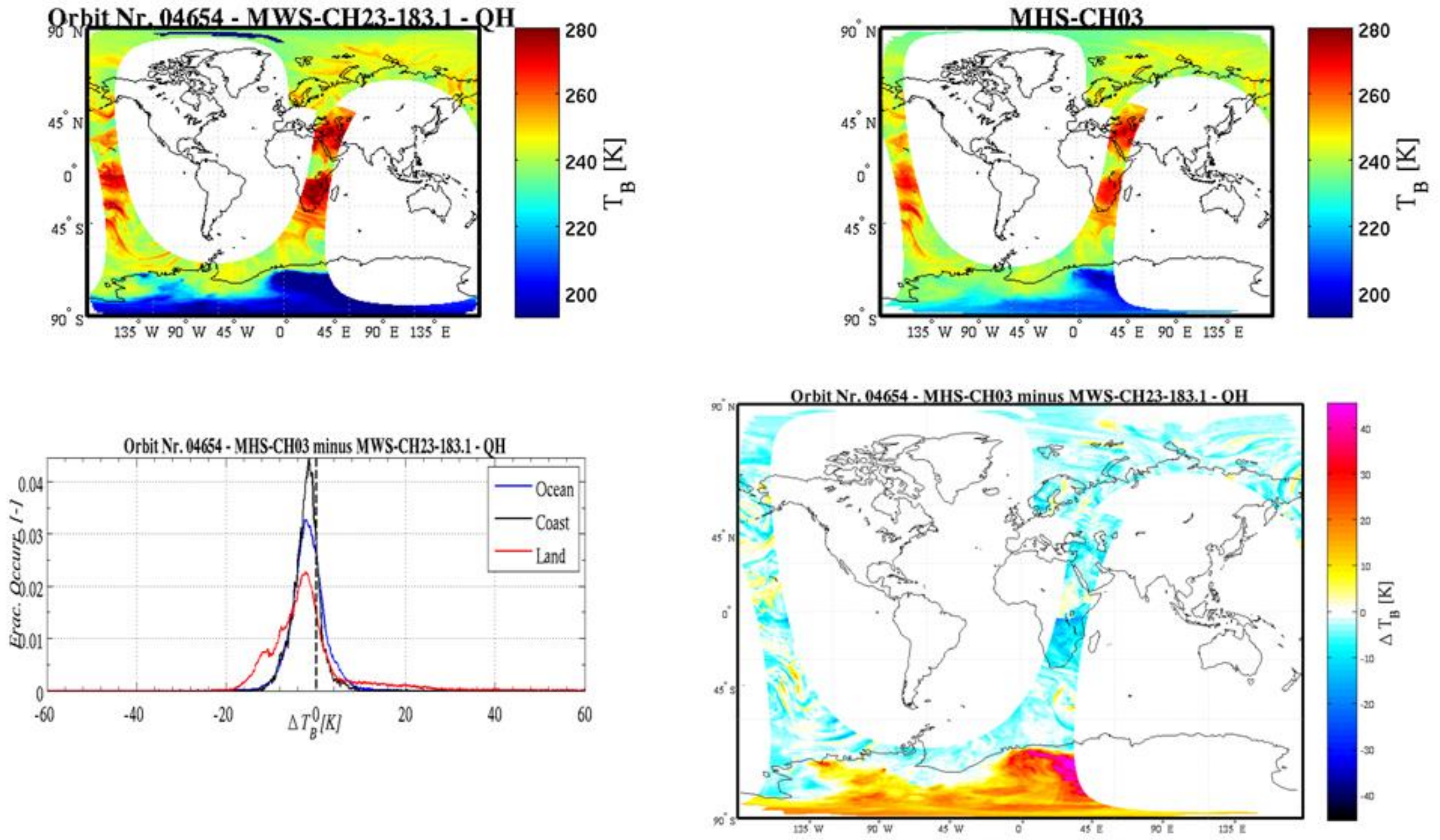


Atmospheric Profiling

Microwave and IR Sounding - selected highlights

Status of MWS Test Data: Validation of Test Data from an External Study (Informus)

Water Vapour Channel



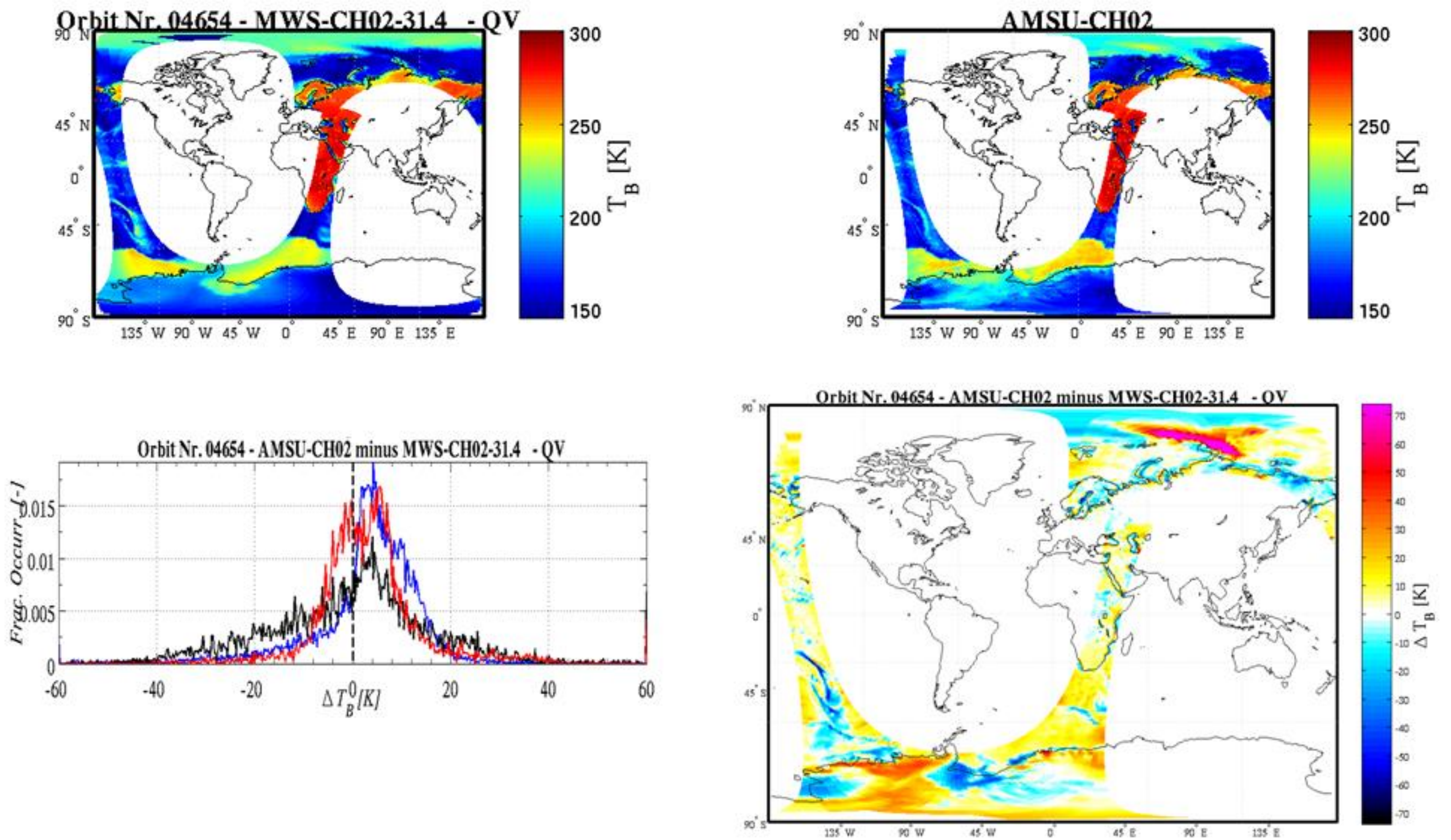
EUMETSAT

Atmospheric Profiling

Microwave and IR Sounding - selected highlights

Status of MWS Test Data: Validation of Test Data from an External Study (Informus)

Surface/Water Vapour Channel

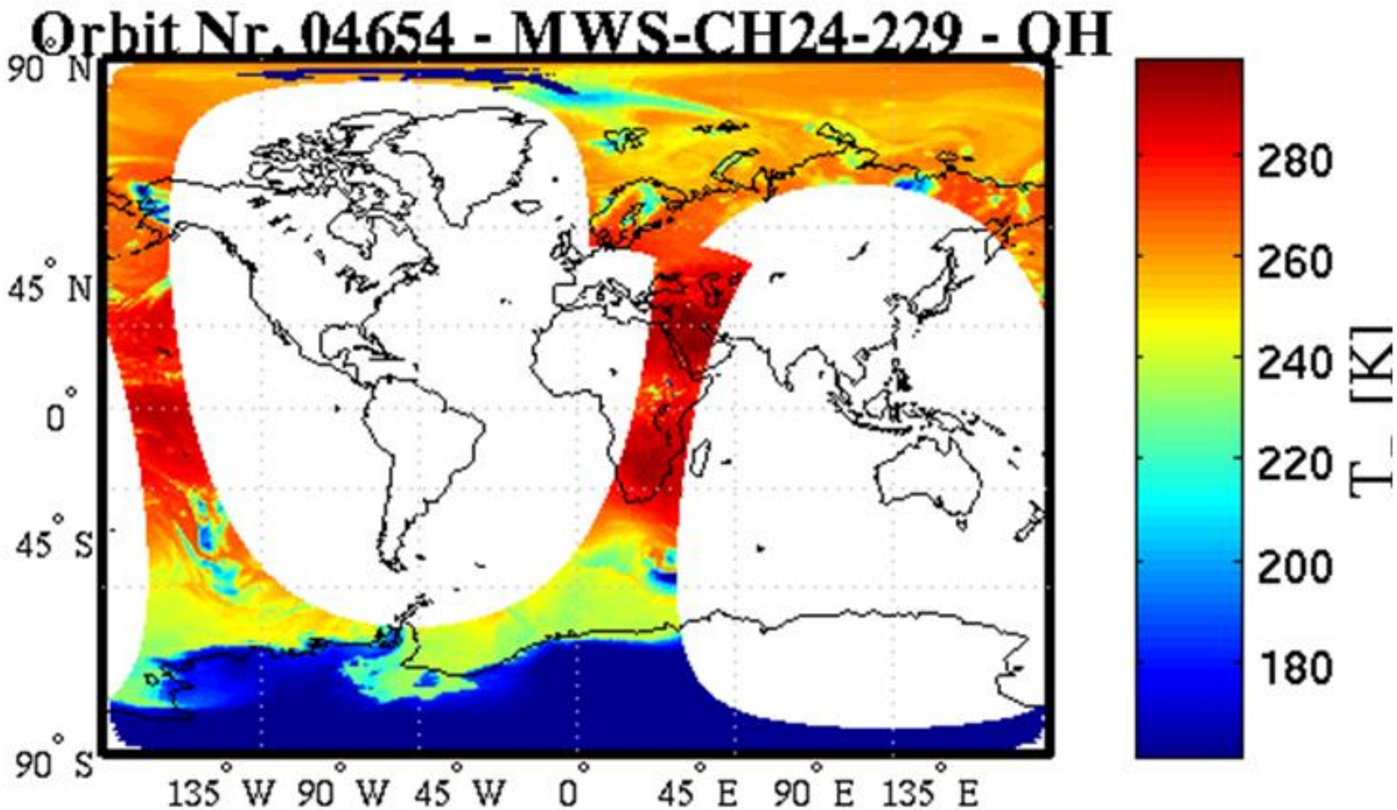


Atmospheric Profiling

Microwave and IR Sounding - selected highlights

Status of MWS Test Data: Validation of Test Data from an External Study (Informus)

229 GHz Channel for Thin Cirrus Cloud Detection



Development activities

- Industrial development supported by
  - Simulations (test data etc.)
  - SAG, MAG (Science-, Mission Advisory Groups)
  - ISSWG (IASI Sounding Science Working Group
  - IFCT (Instrument Functional Chain Teams)
  - MIST (MTG IRS Science Team)
  - LIST (Lightning Imager Science Team)
  - Task forces

Development activities

- Instrument construction
- Interaction with programmes, SAG, experts
- Instrument characterisation and tests
- Documented in Calibration Handbook (Calibration Log book)
- Contains all activities and measurements of the instrument

Calibration Handbook

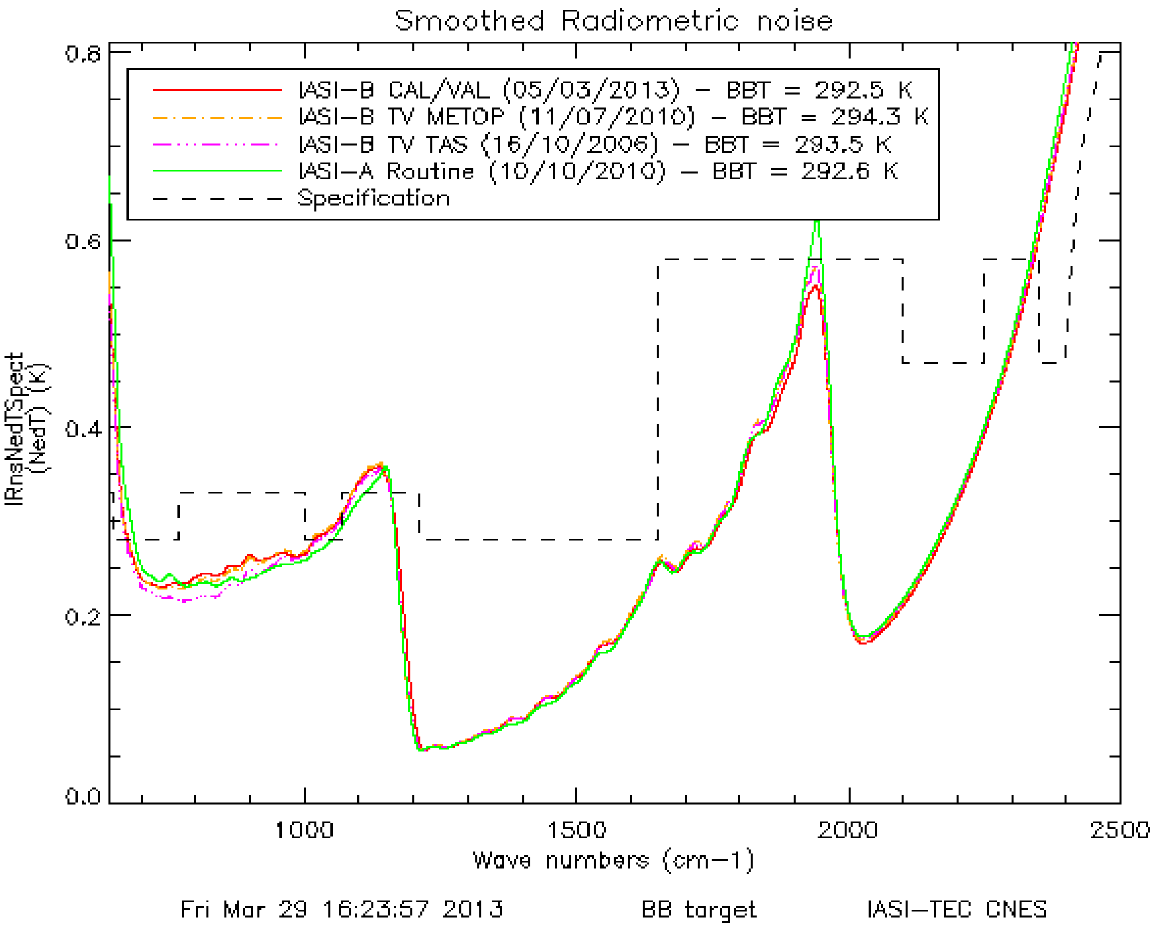
- Highlights from a Calibration Log book (example AMSU-A1)
  - PRT Sensor and Circuit Calibration for in Flight Warm Calibration Targets and AMSU components
  - Error Analysis of In-Flight Warm Calibration Target brightness Temperatures
  - Error Analysis of Primary Blackbody Calibration Standard Target Brightness Temperature
  - Thermal Vacuum Measurement Error Budget
  - Non-linearity of the Channels
  - Antenna Position data
  - Antenna Alignment data
  - Antenna Patterns
  - In-flight Cold Calibration
    - Antenna Side Lobe Interference/Earth and Spacecraft Radiation Analysis
    - Cosmic Background Temperature Via Planck's Radiation law
    - Bias and Random Errors for the in-flight cold calibration
  - Thermal vacuum Radiometric Performance and Calibration
    - Calibration of In-flight Warm Calibration target
    - Radiometer Transfer Function (84K to 330K Thermal/vacuum Measurements)
    - Recommended In-flight Transfer Function (3K to 330K)
    - Calibration Algorithm Least Squares Linear Fit
    - Calibration Curves of Housekeeping Analog Voltages and Temperature Sensors
  - Allowable Temperature Ranges
  - Channel Frequency and Bandwidth Characteristics
  - Radiometric Counts Limits

Instrument deliveries

- Instrument
- Documentation
- Calibration algorithms
- Calibration parameters
- Thermal vac data
- Laboratory characterisation
- External calibration

Example IASI
Sounder radiometric noise

- L0 NEDT



- IASI-A and IASI-B noise level have the same order of magnitude IASI-B slightly lower than IASI-A (except between 850 and 1150 cm^{-1})

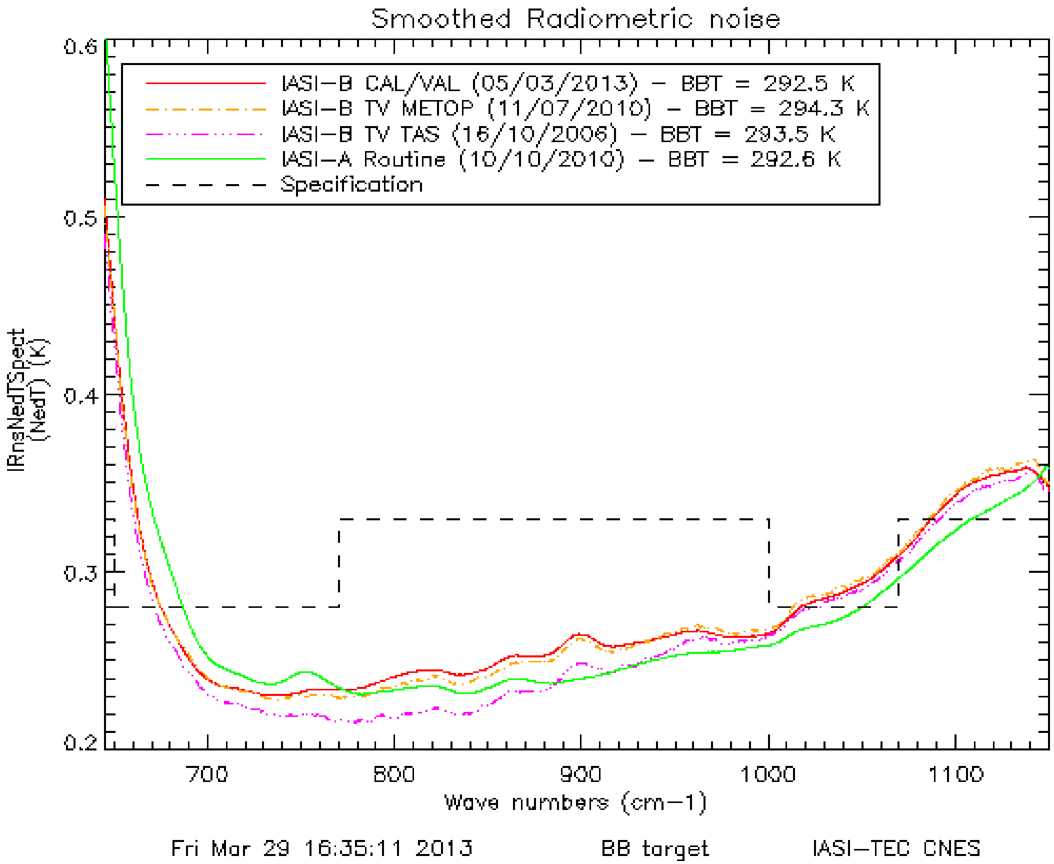
- Good agreement between IASI-B noise measured on ground and in flight

Credit CNES: Jordi Chinaud et al., 2013

EUMETSAT

Example IASI
Sounder radiometric noise

- L0 NEDT (zoom B1)

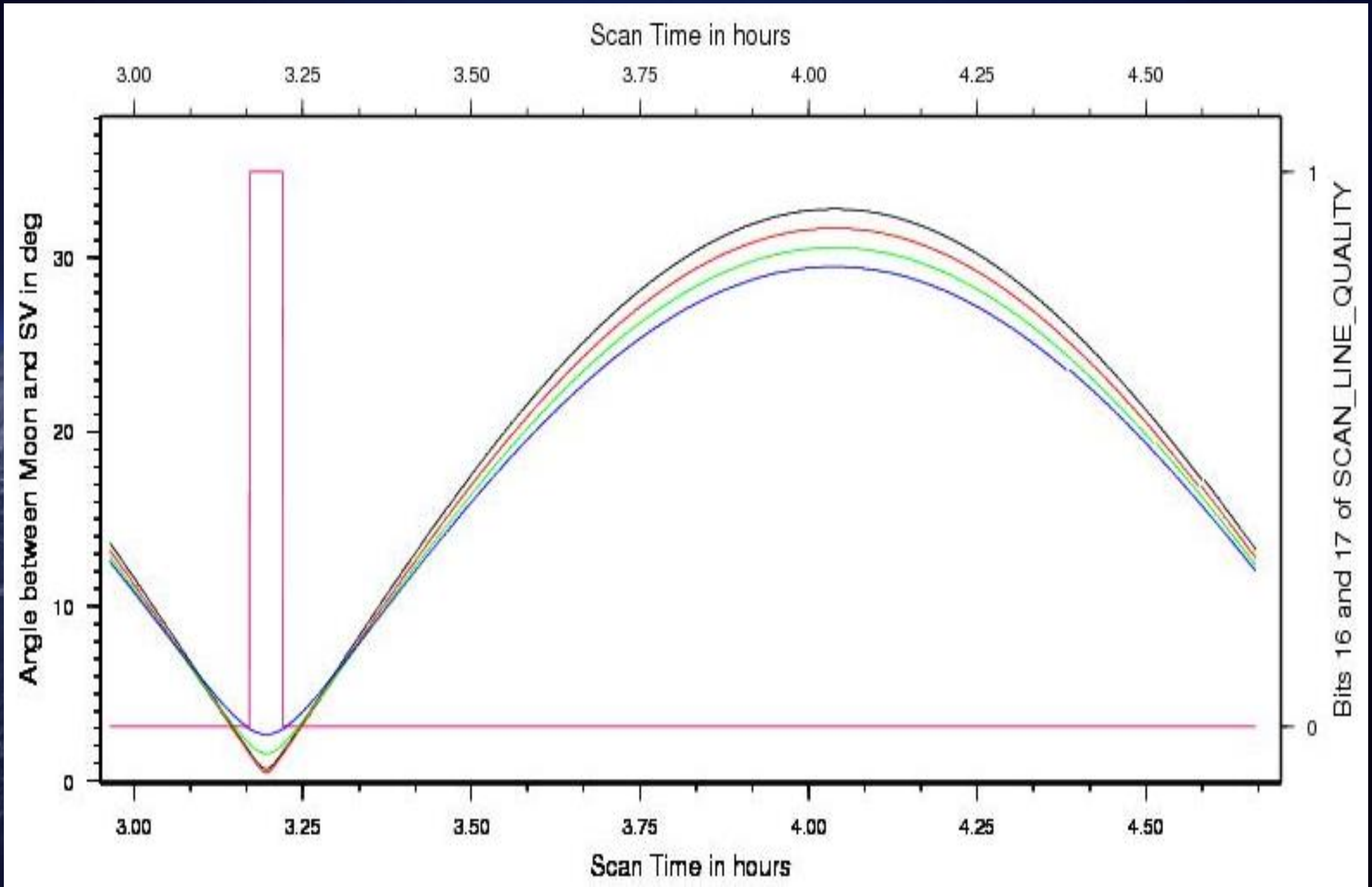


Credit CNES: Jordi Chinaud et al., 2013

Instrument delivery

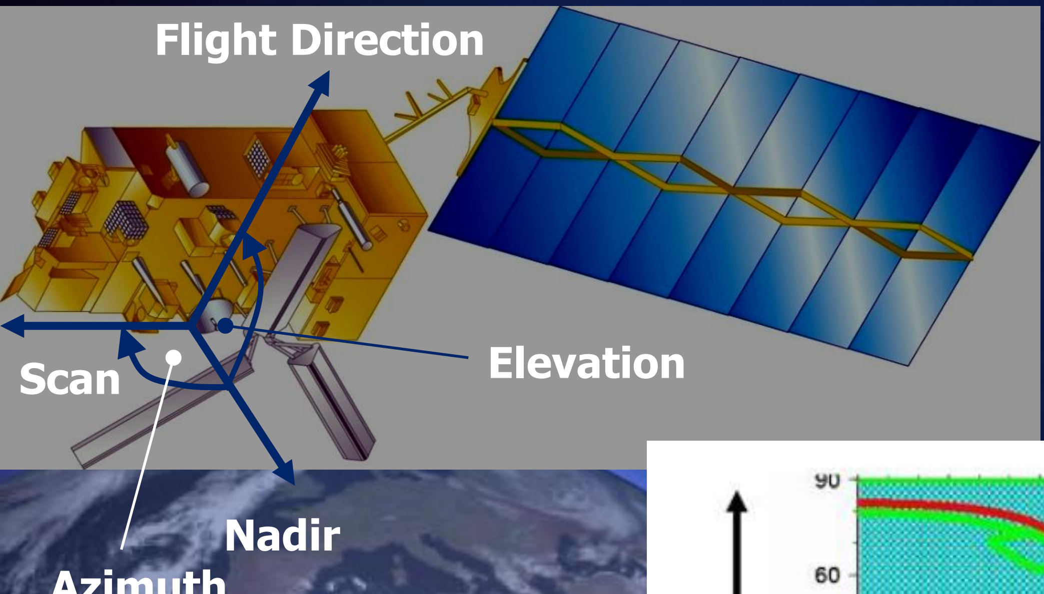
- End item data pack (EIDP)
  - Delivered with instrument
  - Contains all documents including
    - Charactrisation data, e.g. Antenna patterns, antenna corrections
    - Calibration handbook
    - Thermal vac data from the satellite
    - Drawings
    - etc.

Metop-A MHS Data Processing - example



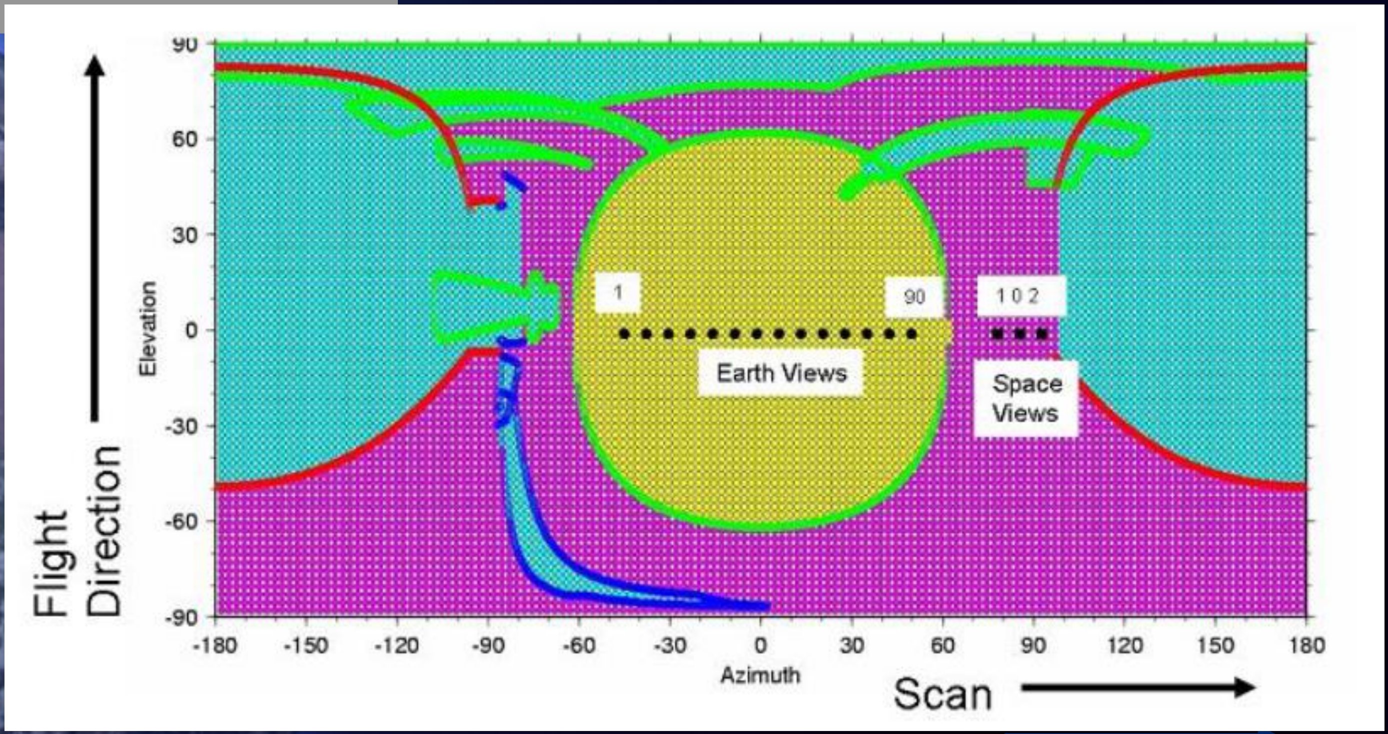
⇒**Lunar contamination is flagged for angles smaller than 4°**

Metop MHS Antenna Correction



MHS Signal Simulation

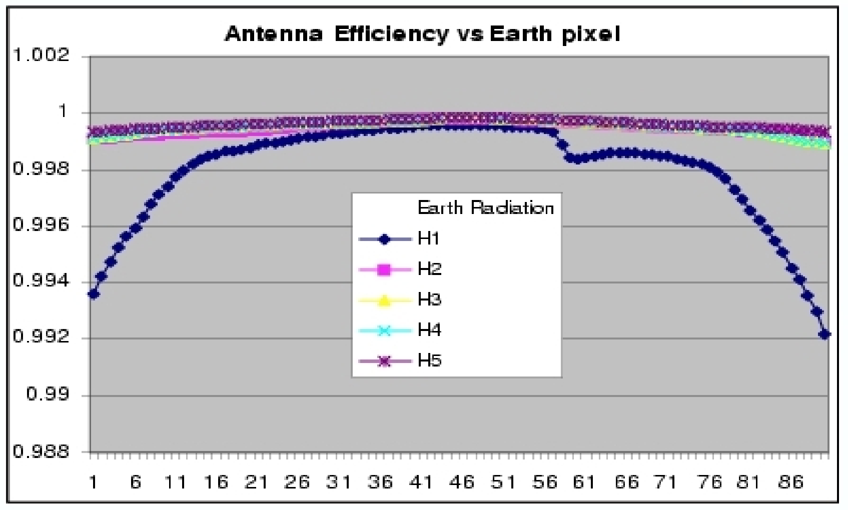
Input: * Antenna pattern
* Geometrical model of emitting and reflecting bodies in the MHS views

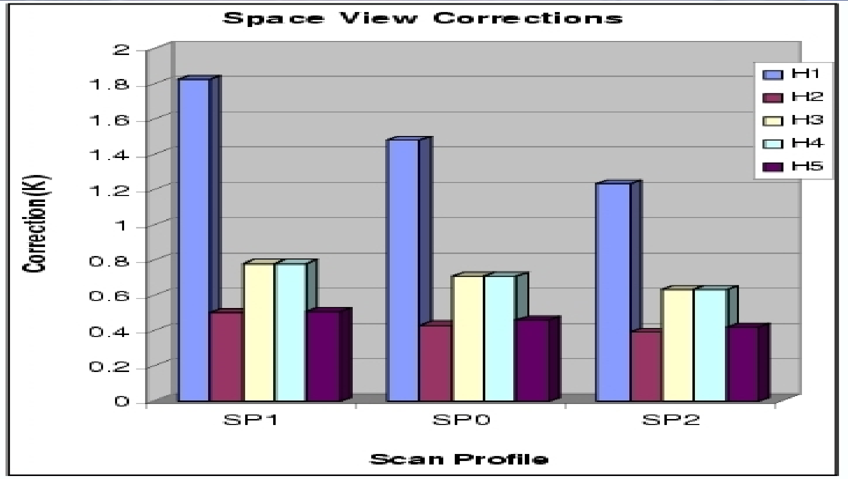


Metop-A MHS Antenna Correction

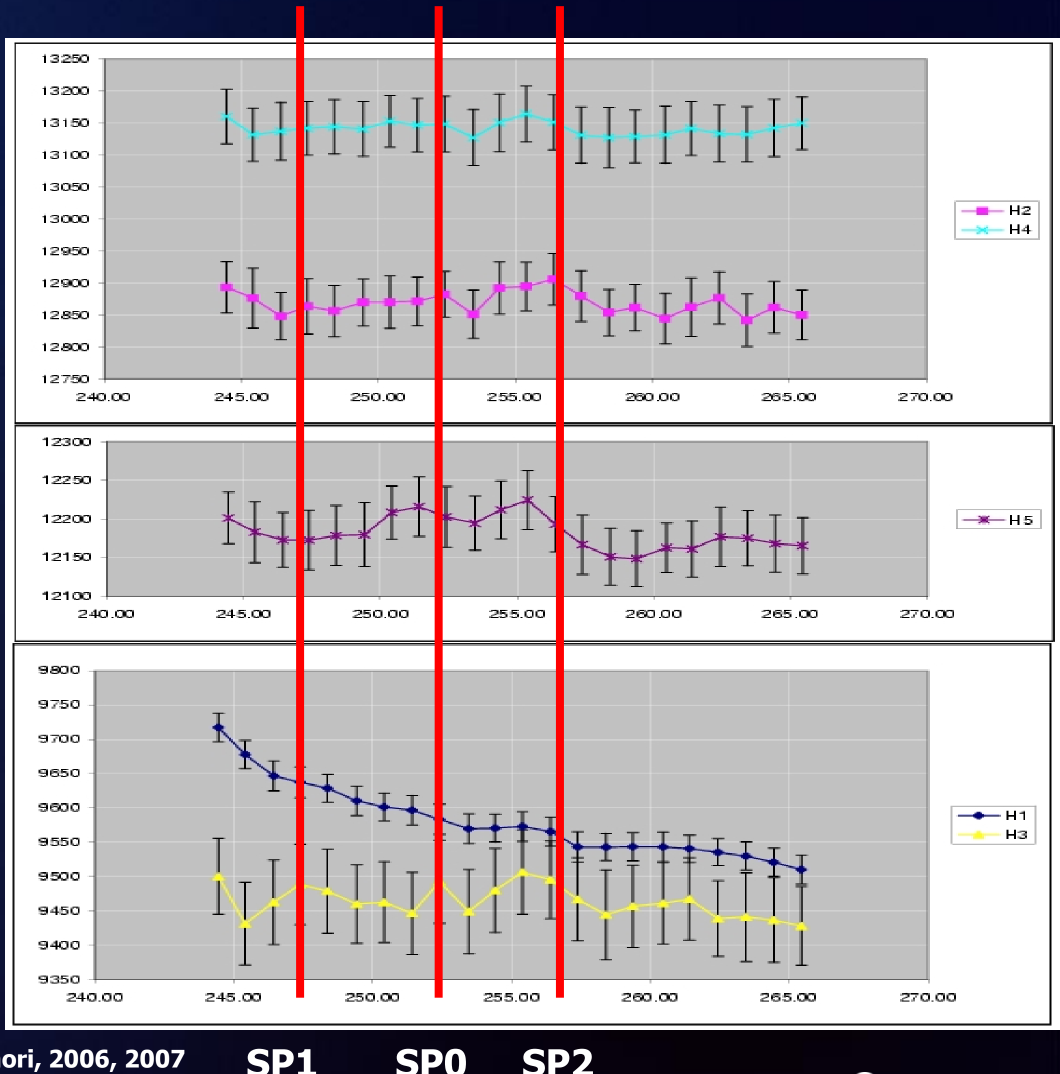
MHS Signal Simulation

Output: * Antenna correction





In-Orbit Verification Results



Bonsignori, 2006, 2007

SP1 SP0 SP2

EUMETSAT

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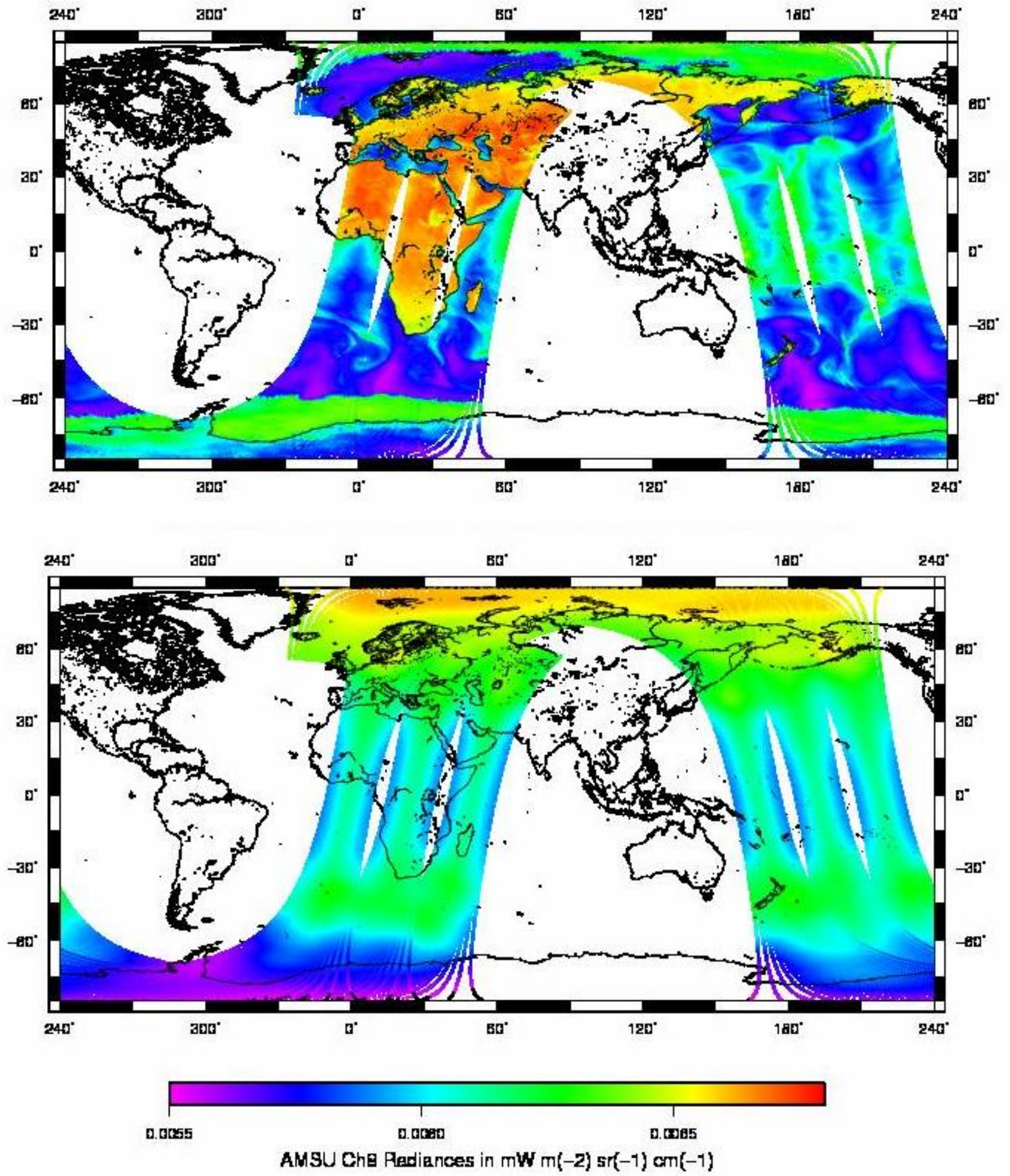
Highlights

- Acceptance and testing
- Testing the system
- Rehearsals
- Availability of parameters to Users
- Early availability of specifications
- Availability of test data
- Availability of readers
- Global/Local processing

Rehearsals for Cal/Val in June 2012

- Metop-B data were simulated by Metop-A data
- Corresponding Metop-B processing nodes in GS-2 have been configured to simulate a true Metop-B processing as close as possible.
  - This means that the incoming Metop-A Level 0 data stream is processed with the specifications of the Metop-B instrument suite
- Validation was done as in the Commissioning Phase
- The simulated data cover three orbits starting at about 5:51, 7:33, and 9:15 UTC, respectively, on 25. June 2012.
- Validation was done as in the Commissioning Phase
- Example for ATOVS/AVHRR:
  - Calibrated Erath View Radiances
  - Geolocation
  - Satellite and Solar Azimuth and Elevation
  - Surface Type (for AMSU, MHS, and HIRS only)
  - Surface Altitude (for AMSU, MHS, and HIRS only)

ATOVS – AMSU-A from rehearsal



- Geolocated Earth View Radiances
  - Channel 1 (top)
  - Channel 8 (bottom)
- Values for all channels (1-15) in the expected ranges
- Validation against reference prototype
  - Very small differences in all channels
  - Differences due to handling of PRTs and are below noise level
  - Issue of PRTs is being investigated
- Geolocation is well within all limits
- All angles are in good agreement
- Surface height and surface type as well as land/sea mask have been visually inspected and seem reasonable

* Channel 7 cannot be simulated as it was out of spec on Metop-A

Potential partners for support to Metop-B Cal/Val and candidates for (early) data access

Partner	Subject of support	POC	Status
ECMWF	Monitoring and assimilation - IASI - ATOVS - ASCAT - GRAS - (GOME) - Polar winds	Jean-Noel Thépaut Stephen English Sean Healy	Agreed **POC: Steve English**
MetOffice UK	Monitoring and assimilation - IASI - ATOVS - GRAS - Polar winds	Fiona Hilton	agreement expected
MetOffice UK	JAIVEx2 (together with NASA/NOAA)	Jonathan Taylor	**Contacted** **No replies received by MetOfficefrom the US side** **NO JAIVex in 2012**
Météo-France	Monitoring and assimilation - IASI - ATOVS - GRAS ConcordIASI	Vincent Guidard Lydie Lavanant Florence Rabier	Agreement expected
NWP SAF Météo-France MetOffice UK	Direct Readout with HRPT - AAPP - IASI OPS	Pascal Brunel Nigel Atkinson	Agreement expected

Contacts established
Agreements and POC being received

Potential partners for support to Metop-B Cal/Val and candidates for (early) data access

Partner	Subject of support	POC	Status
OSI SAF	ASCAT winds	Ad Stoffelen	agreed
O3MSAF	GOME L2 products	DLR	Agreed **POC: Diego Loyola (DLR)** **POC: Olaf Tuinder (KNMI)**
U Bremen	GOME L2 products	A Richter	Agreed **POC: Andreas Richter**
H-SAF	Soil Moisture	W Wagner	Agreed **POC: Sebastian Hahn**
GRAS SAF	GRAS L2 products	Ken Lauritsen (DMI)	Agreed **POC: Hallgeir Wilhelmsen** **Kristian Rune Larsen**
NWC SAF	Direct readout products	Adam Dybbroe	Agreed **POC: Adam Dybbroe**
NOAA	All instruments		Agreement assumed as main partner, contacts ongoing
ISSWG Members	IASI L1/L2	According to list	Agreed **POC: Daniel Hurtmans (ULB)** **POC: Cathy Boonne and Juliette Hadji-Lazaro (LATMOS/IPSL)**

Contacts established
Agreements and POC being received

Early product delivery (according to the schedule from launch date L)

Slide from LORR

• AMSU-A1,A2	< L+ 2 wk
• AVHRR/3 VIS	< L+ 2 wk
• MHS	< L+ 3 wk
• ASCAT	< L+ 5 wk
• AVHRR/3 IR	< L+ 4 wk
• HIRS/4	< L+ 4 wk
• GRAS	< L+ 5 wk
• GOME-2	< L+16 wk
• IASI first interferogramme	< L+ 5 wk
• IASI Early Level 1 spectra	< L+16 wk

Coordination with Partners

Example:

- Coordination with NOAA on Calibration Coefficients for ATOVS/AVHRR
- Also relevant for AAPP (NWP SAF)
- Publication of coefficients as early as possible on web-page
- Participation in respective Cal/Val activities (ATOVS/AVHRR is processed in both NOAA and EUMETSAT Ground Segements)
- Assuring coherence of calibration in both ground segments and also coherence with locally processed data (relevant for EARS)

Examples from CPIDS and Antenna Correction files

```
################################################################
###                                                          ###
###     AMSU Calibration Parameters for A1-108 and A2-106    ###
###                Onboard Metop-B                           ###
###                                                          ###
###     version 03 Author: Joerg Ackermann, EUMETSAT         ###
###                                                          ###
################################################################
03   ; version number (cal parameter id in 1B dataset)
2011 ; year of the version
259  ; day of year of the version.
## Values for Fundamental Constants ##
## Speed of light m/s ##
299792458
## Planck constant J s ##
6.6260755e-34
## Boltzmann constant J/K ##
1.380658e-23
## First & second radiation constants mW/(sqm.ster.cm^-4) & K/cm^-1 ##
 1.191044e-05,1.438769
## Brightness temperature of space at AMSU frequencies degK ##
2.73
## 15 Central wavenumbers ##
0.793897,1.047421,1.677830,1.761235,1.787785,1.814590,1.832608,1.851295
1.911001,1.911001,1.911001,1.911001,1.911001,1.911001,2.968887
## Band Correction Coefficients a,b for each channel --
## used to modify TW to give an effective temperature T'W for use
## in the Planck function.
0,1
0,1
0,1
0,1
0,1
0,1
0,1
0,1
0,1
0,1
0,1
0,1
0,1
0,1
0,1
## Nominal space & internal target viewing angles
-83.333,180.0
-81.667,180.0
-80.000,180.0
-76.667,180.0
# lunaflag for turning on(1)/off(0) moon
 1
# threshold angle for moon contamination in degrees * 100
 390
##############################################################################
## AMSU-A1 DATA S/N 108 (METOPB) ##
## ID of instrument
29
# Selected position of space view for calibration 0->3 (will be selected during IOV)#
0
# Slope and offset for counts to antenna posn in deg, A1-1 and A1-2 (adapted to Tab. 10.0.1 values)#
-0.021973, 51.36
-0.021973, 46.06
# Antenna Pos error allowed in deg for cal and Earth views, A1-1 and A1-2 #
1.3,0.33
1.3,0.33
# IWT PRT count to temperature in degK conversion coefficients (best fit of data in Tab. 4.1.1)#
 254.8997   1.6486870E-03   5.9915850E-09   3.0658910E-14
 254.7430   1.6523180E-03   6.0197870E-09   2.9858890E-14
 254.6643   1.6539240E-03   5.9841080E-09   2.9776300E-14
 254.8877   1.6574190E-03   5.9341200E-09   3.1709220E-14
 254.1918   1.6465040E-03   6.0760720E-09   2.8224180E-14
 255.6000   1.6162670E-03   6.1592160E-09   3.7101130E-14
 254.7424   1.6486220E-03   5.9308110E-09   3.0390770E-14
 255.5381   1.6180470E-03   6.1058810E-09   3.6427240E-14
 255.4768   1.6296350E-03   6.2061300E-09   3.8552680E-14
 254.4784   1.6470340E-03   5.9518710E-09   2.9568630E-14
# Weight coefficients for each PRT, A1-1 and A1-2 #
1,1,1,1,1
1,1,1,1,1
# Reasonable PRT temp limits in degK (min,max), A1-1 and A1-2 #
258.15.313.15
```

```
##########################################################################################

 Antenna Correction Coefficients for the following instruments onboard Metop-B:
 AMSU-A2 S/N 106  (Channels  1 and 2)
 AMSU-A1 S/N 108  (Channels  3 to 15)
 MHS_FM5          (Channels 16 to 20)

 The ordering for each channel is:

 * Channel Number
 * Earth view efficiencies starting with earth view position 1 and ending with
   Earth view position 30 (AMSU) or 90 (MHS)
 * Platform efficiencies starting with earth view position 1 and ending with
   Earth view position 30 (AMSU) or 90 (MHS)
 * Space view efficiencies starting with earth view position 1 and ending with
   Earth view position 30 (AMSU) or 90 (MHS)

  AMSU-A1 and AMSU-A2 data were generated and made available by Tsan Mo, NOAA/NESDIS
  MHS data were computed by Joerg Ackermann, EUMETSAT

  This is Version 1.1 (14 September 2011)

##########################################################################################

 1
0.9825350.9830100.9833300.9838800.9843930.9847490.9851400.9854100.9855790.985880
0.9861380.9862130.9862490.9862810.9861940.9862750.9863520.9868040.9870670.986909
0.9868800.9867950.9863760.9859340.9858220.9859560.9859270.9859610.9857970.985656
0.0101010.0098080.0094800.0093020.0090980.0088900.0087340.0085550.0082700.007781
0.0076040.0074220.0072140.0071320.0070730.0067080.0063610.0058550.0053820.005080
0.0047570.0046210.0044210.0042860.0041460.0038910.0035760.0034360.0035510.003629
0.0073650.0071830.0071890.0068180.0065090.0063610.0061260.0060360.0061510.006339
0.0062590.0063640.0065370.0065870.0067330.0070170.0072870.0073410.0075500.008011
0.0083630.0085850.0092030.0097800.0100320.0101530.0104960.0106030.0106520.010715
 2
0.9944900.9947170.9949450.9950940.9952370.9953120.9953960.9955530.9956220.995764
0.9958320.9958400.9958400.9958380.9958000.9957480.9957650.9958010.9957970.995761
0.9956330.9954280.9952900.9952460.9952320.9951880.9950960.9950450.9949060.994844
0.0030950.0029960.0029430.0029080.0028560.0028190.0027370.0026820.0026010.002550
0.0025020.0024420.0023940.0022830.0022220.0020920.0020050.0019290.0018350.001727
0.0016420.0015340.0014760.0014790.0014610.0014600.0014710.0014950.0015920.001735
0.0024150.0022870.0021120.0019980.0019070.0018700.0018670.0017650.0017780.001686
0.0016660.0017170.0017660.0018790.0019770.0021600.0022300.0022710.0023680.002513
0.0027250.0030380.0032340.0032750.0033070.0033520.0034330.0034600.0035020.003421
 3
0.9902190.9907520.9913440.9920130.9928000.9934090.9937190.9940140.9941930.994227
0.9942630.9941860.9941730.9940910.9939800.9939130.9939760.9941320.9941450.993908
0.9932600.9929620.9925820.9923290.9919440.9914560.9905460.9897090.9889160.988287
0.0035740.0035030.0033700.0032620.0031510.0031050.0030440.0028910.0027860.002725
0.0027090.0026940.0026670.0026080.0024450.0022320.0020940.0020150.0020100.002073
0.0021590.0022270.0023100.0024730.0026620.0027720.0028850.0031050.0037660.004093
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 4
0.9911760.9917780.9924420.9932870.9941150.9947700.9949820.9950750.9950480.995038
0.9950150.9949180.9948490.9947160.9945420.9943820.9942040.9939940.9938370.993620
0.9931440.9927970.9925700.9922720.9919040.9909570.9897430.9887960.9879700.987408
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0.0060800.0055210.0048910.0040490.0032240.0025360.0022980.0021790.0021630.002130
0.0020990.0021300.0021300.0022210.0023120.0024220.0025910.0027680.0028850.003036
```


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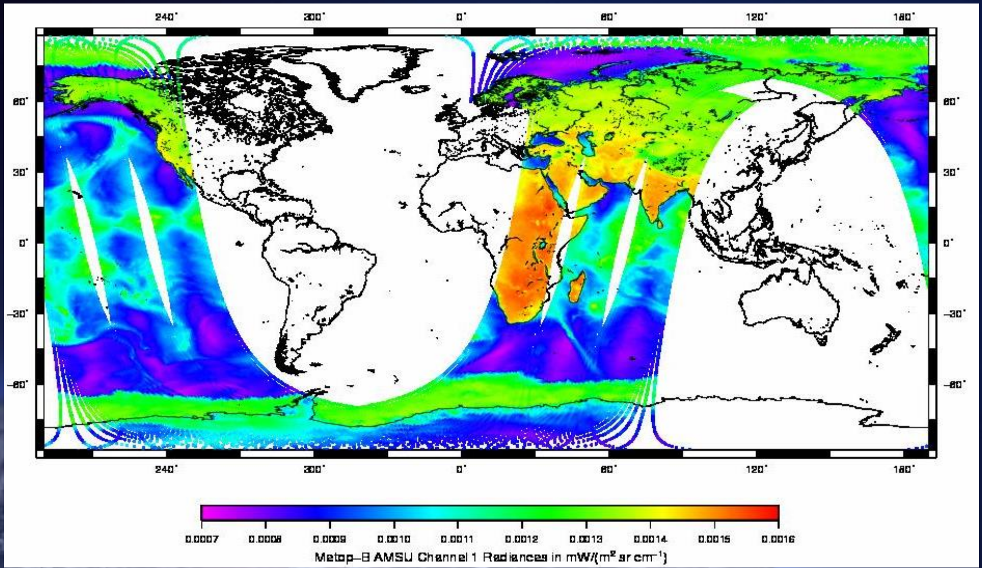
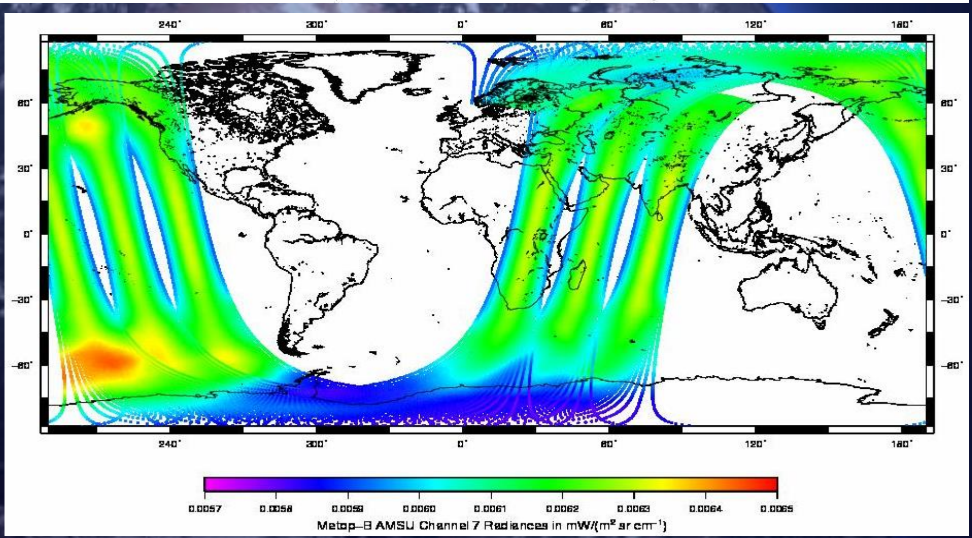
TECHNIQUES AND PROCESSES FOR PRE-LAUNCH CHARACTERISATION OF NEW INSTRUMENTS

1. Introduction
2. Identification of requirements
3. Development activities
4. Operations preparation and testing
5. Commissioning activities
6. Summary and Conclusion

- SIOV (Satellite in Orbit Verification) and Cal/Val (Calibration/Validation)
- All stakeholders involved
- User participation
- Provide data as early as possible
- Obtain feedback
- Operational as early as possible
- Each step (data release) with a review

ATOVS – AMSU-A on Metop-B in Commissioning





- Geolocated Earth View Radiances
  - Channel 1 (top)
  - Channel 7 (bottom)
- Values for all channels (1-15) in the expected ranges
- Validation against reference prototype
  - Very small differences in all channels
  - Differences due to handling of PRTs and are below noise level
  - Issue of PRTs is being investigated
- Geolocation is between 0 and 900m (due to different orbit propagator handling), well within all limits
- All angles are in good agreement
- Surface height and surface type as well as land/sea mask have been visually inspected and seem reasonable

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Commissioning Summary Metop-B as example

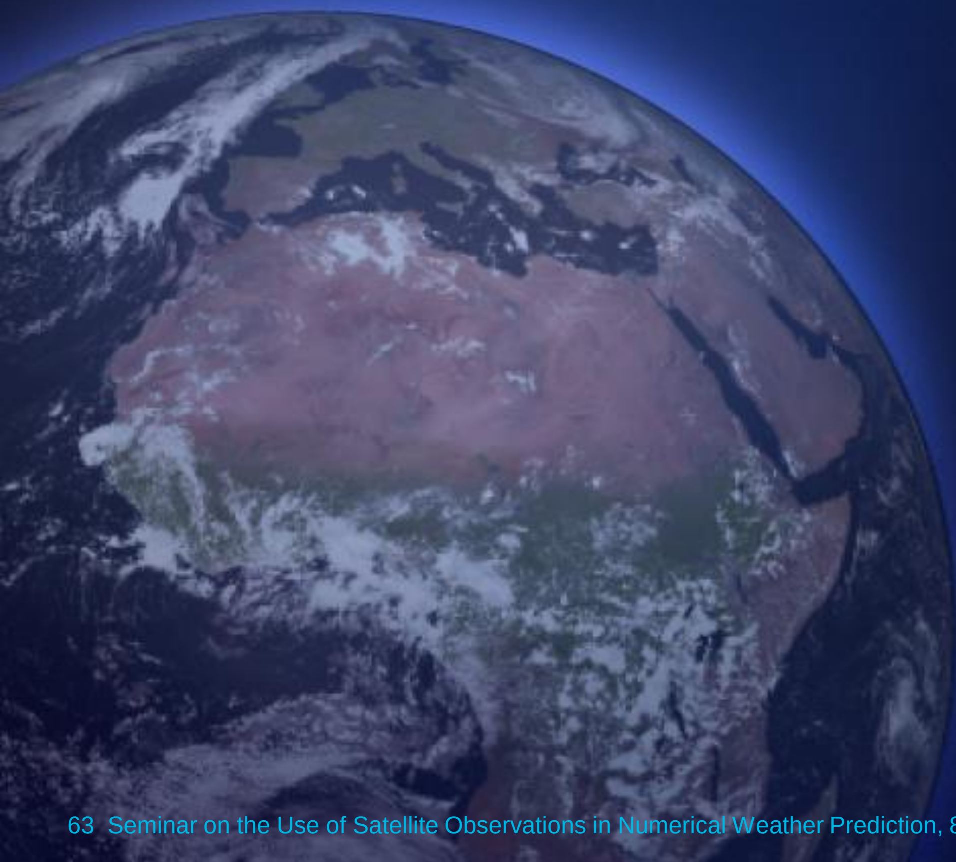
- **Metop-B successfully** launched **17 September 2012** from Baikonur Cosmodrome
- **LEOP – 3 days** by ESOC
- **SIOV – 6 weeks**, SIOV **Handover end October 2012**
- **Cal/Val Phase** in parallel, as status allowed,
- **First products** to users **4 days** after launch
- Phase 1 until Commissioning Handover Review
- **Commissioning Handover** 29 January 2013 **successful**
- **Cal/Val Phase 2** (included remaining IASI (L1 by CNES, L2 in house) ATOVS L2 and GOME-2 activities)
- Metop-B prime satellite **24 April 2013**
- **End of commissioning 31 July 2013**

Commissioning Results: Products Status Metop-B end of July 2013

		Special Trial Dissemination	Pre-Op Dissemination	End of Cal / Val
AMSU-A	L1	28/09/12 <L+2w	11/12/12	07/12/12
AVHRR	L1	05/10/12 <L+3w	11/12/12	07/12/12
HIRS	L1	26/10/12* <L+6w	11/12/12*	07/12/12*
MHS	L1	02/10/12 <L+2w	11/12/12	07/12/12
ASCAT	L1	23/10/12 <L+5w	04/12/12	15/03/13
GOME	L1	12/12/12 <L+12w	13/02/13	06/05/13
GRAS	L1	01/10/12 <L+2w	15/11/12	26/10/12
IASI	L1	22/01/13 <L+17w	20/02/13	17/04/13
IASI	L2	07/03/13 <L+6m	26/06/13	18/07/13
AVHRR Winds	L2	18/03/13 <L+6m	26/06/13	26/06/13
ATOVS	L2	n/a	04/06/13	19/07/13
ASCAT SOMO	L2	13/11/12 <L+2m	11/12/12	15/03/13

***noise degradation since January 2013**

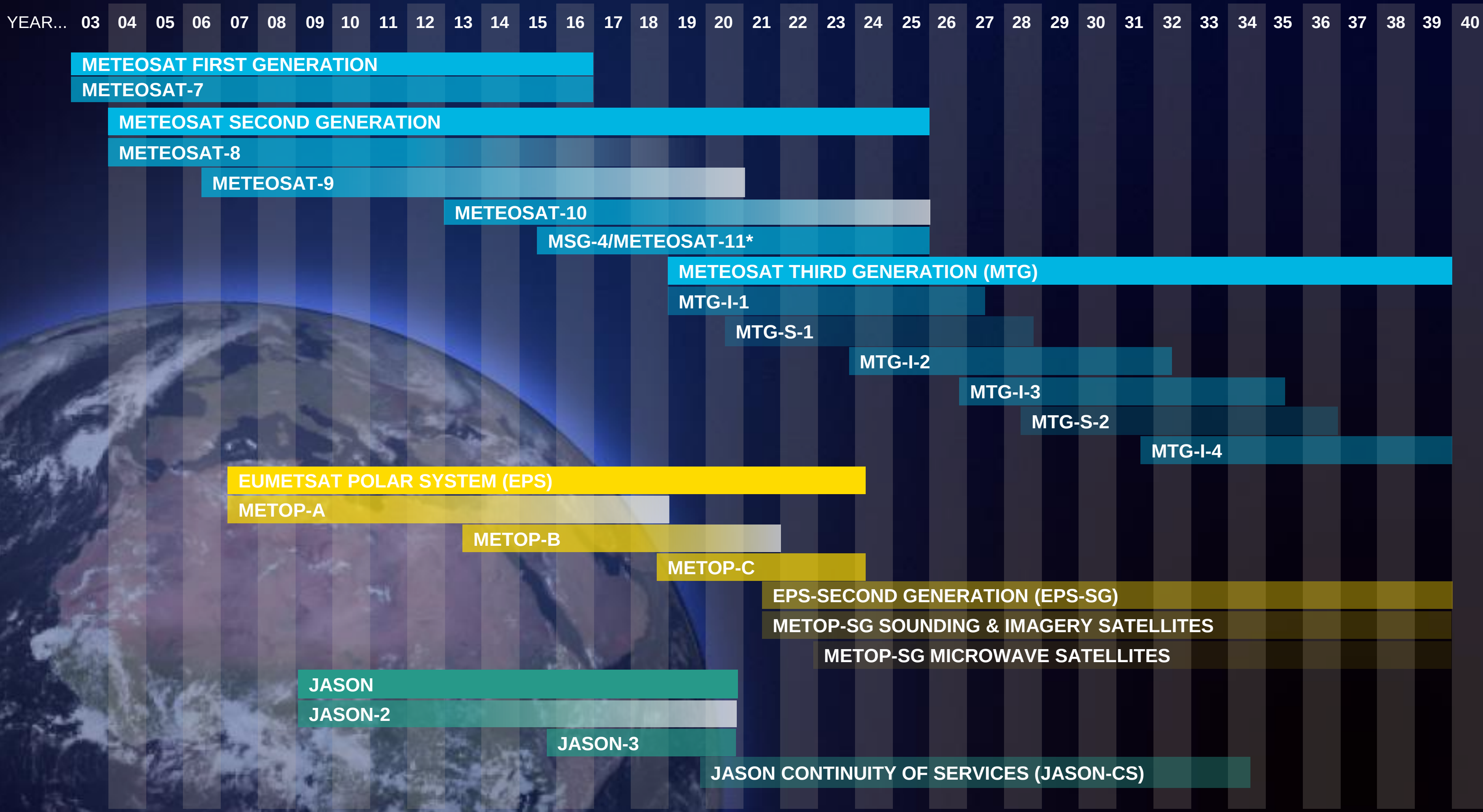
6 SUMMARY & CONCLUSIONS



Concluding Remarks

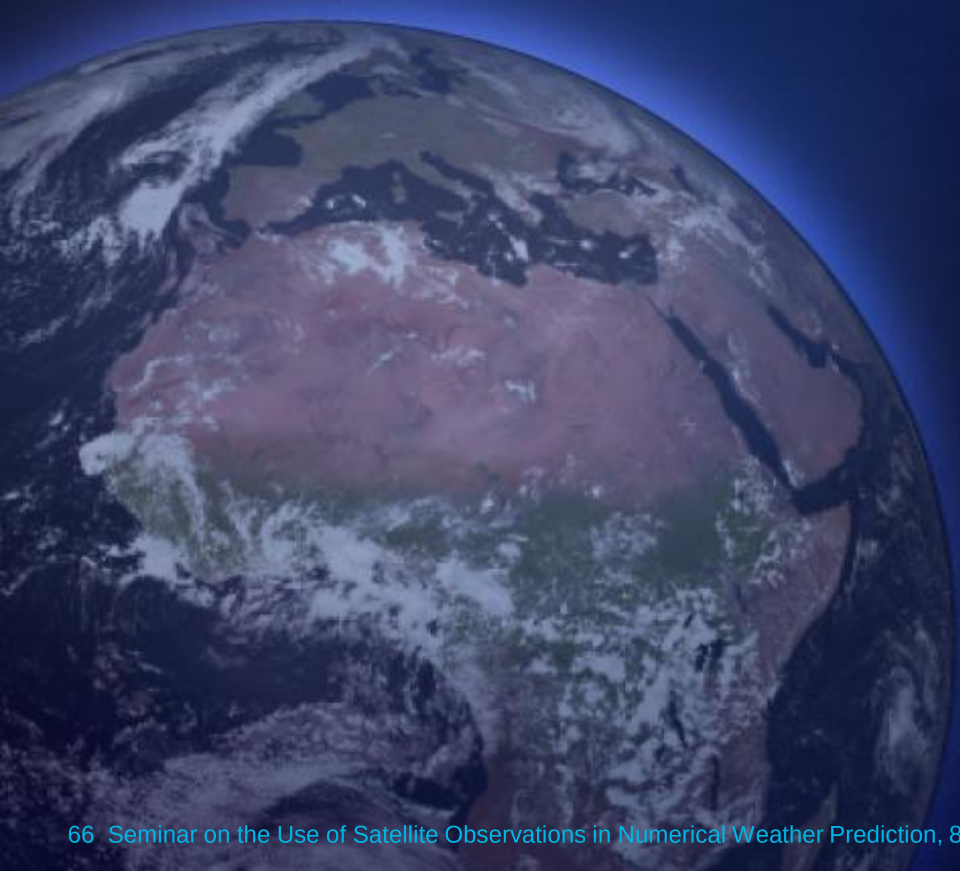
- Long process
- Thorough preparation
- Instrument development with specialists
- Baseline
- User involvement – Mission Expert Teams
- SAGs
- Data as early as possible to Users
- Lessons learnt applied

EUMETSAT mission planning...



Only the full operational phase of each mission is represented, excluding commissioning.
*** MSG-4/Meteosat-11 will be stored in orbit, before replacing Meteosat-10**

Thank you for your attention !



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RESERVE SLIDES

User Consultation:
Example from EPS-SG in 2006, then called Post-EPS

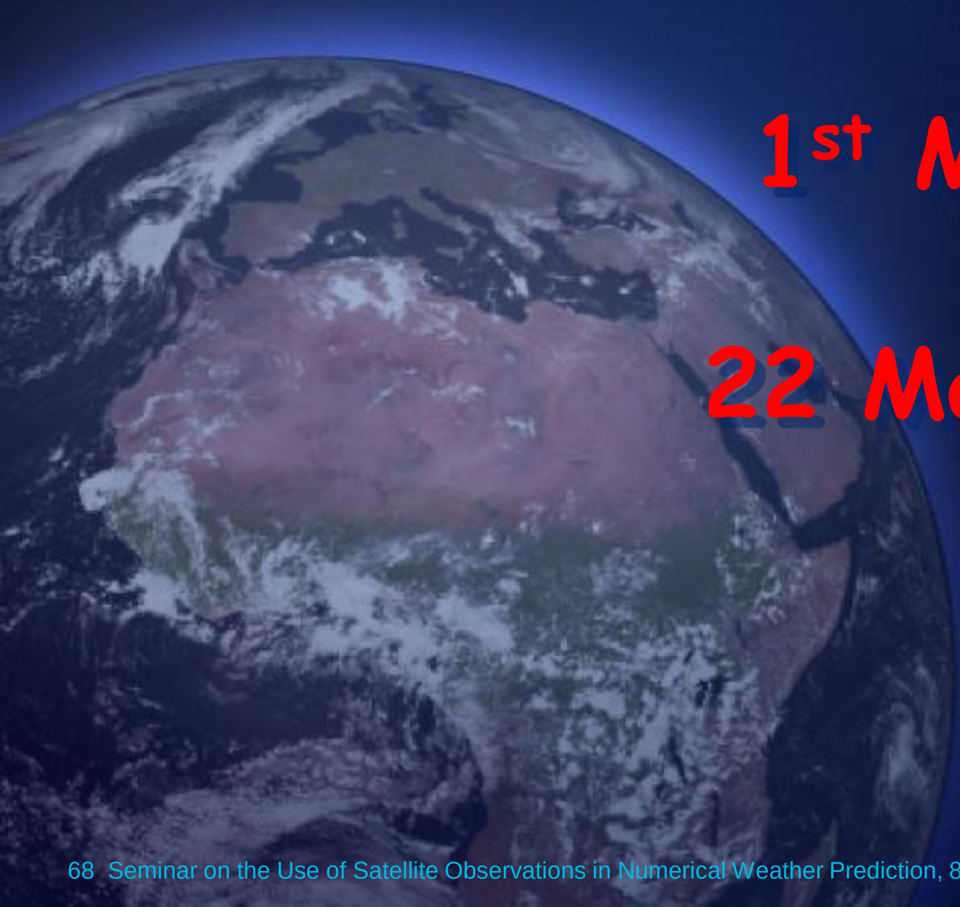
Post-EPS

Mission Experts Team

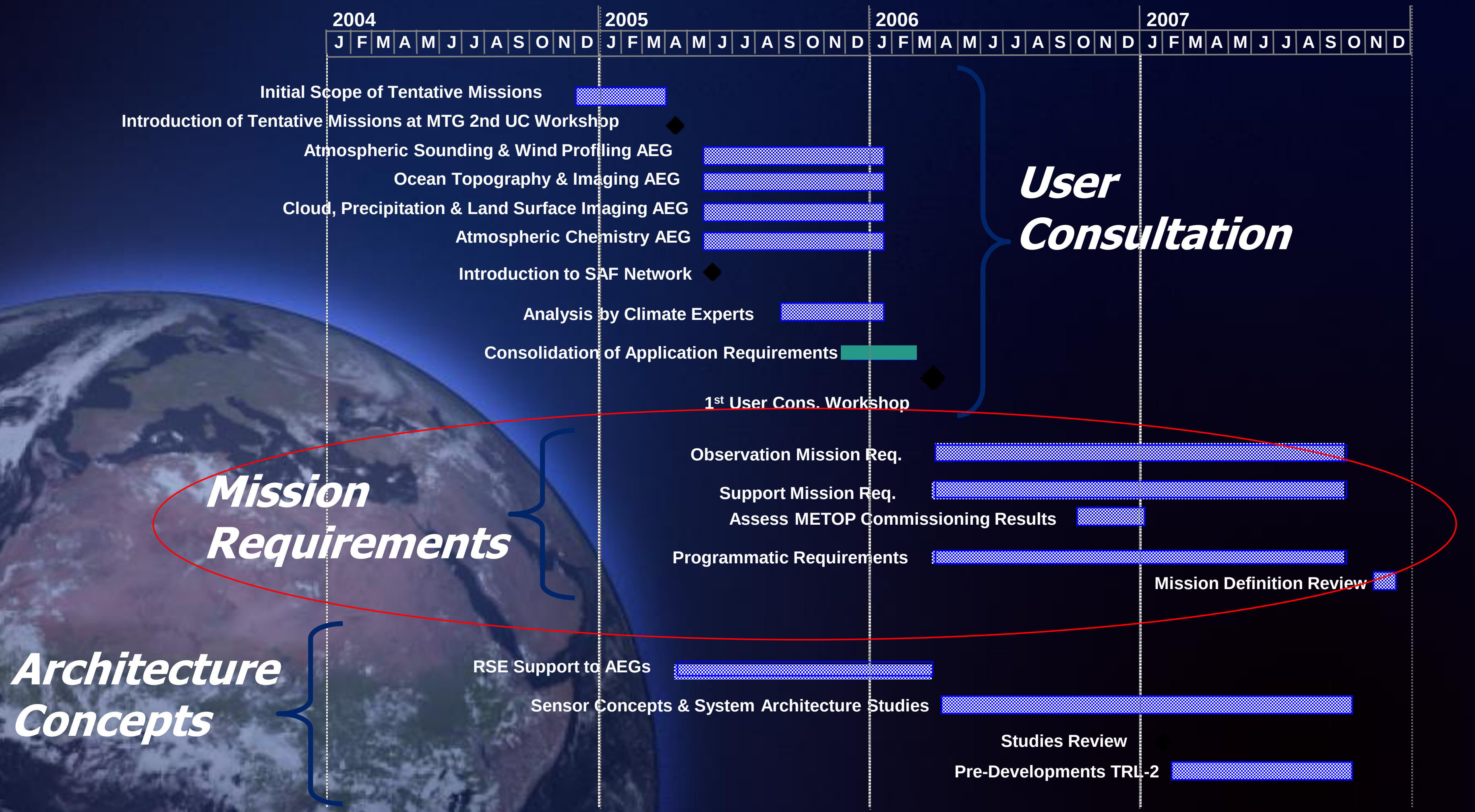
PMET

1st Meeting

22 May 2006



Post-EPS Planning



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Mission Requirements Document

- Mission Requirements will be derived from the User Requirements as expressed in the Post-EPS Position Papers

- Mission requirements will address candidate observation missions related to the geophysical parameters specified in the Position Papers

- The requirements will be documented in a Mission Requirements Document (MRD)
  - The MRD be the basis for industrial studies led by ESA on sensor and system architecture concepts
  - The industrial studies will provide feedback from a technological viewpoint
  - The MRD will be updated iteratively aiming at confirmation and validation of requirements in view of remote sensing capabilities in the 2020 time frame

- Validation of requirements against programmatic requirements and constraints such as affordability are out of the scope of the present Phase 0

Post-EPS Mission Experts Group (1/2)

- Analysis of Position Papers towards possible observation missions
- Identification of observation missions
  - Basis are user needs and their priorities
  - Aim at maximising fulfilment of user needs while minimising diversity of solutions, risks, and cost
  - No exclusion of missions on sole cost basis
  - Solutions must have sufficient level of maturity for an operational mission
- Identify scientific/technical areas that need to be analysed in support of the definition of mission requirements

Post-EPS Mission Experts Group (2/2)

- Provision of guidance and support to the definition of mission requirements for the identified missions and review of relevant issues

- Review of study results
  - Assessment of compliance with mission requirements
  - Assessment of impact on target service in case of incompliance
  - Advice on acceptable relaxations and trade-offs

- Response to queries on technical issues raised by EUMETSAT, ESA or industrial studies

- Support of meetings, reviews, and workshops

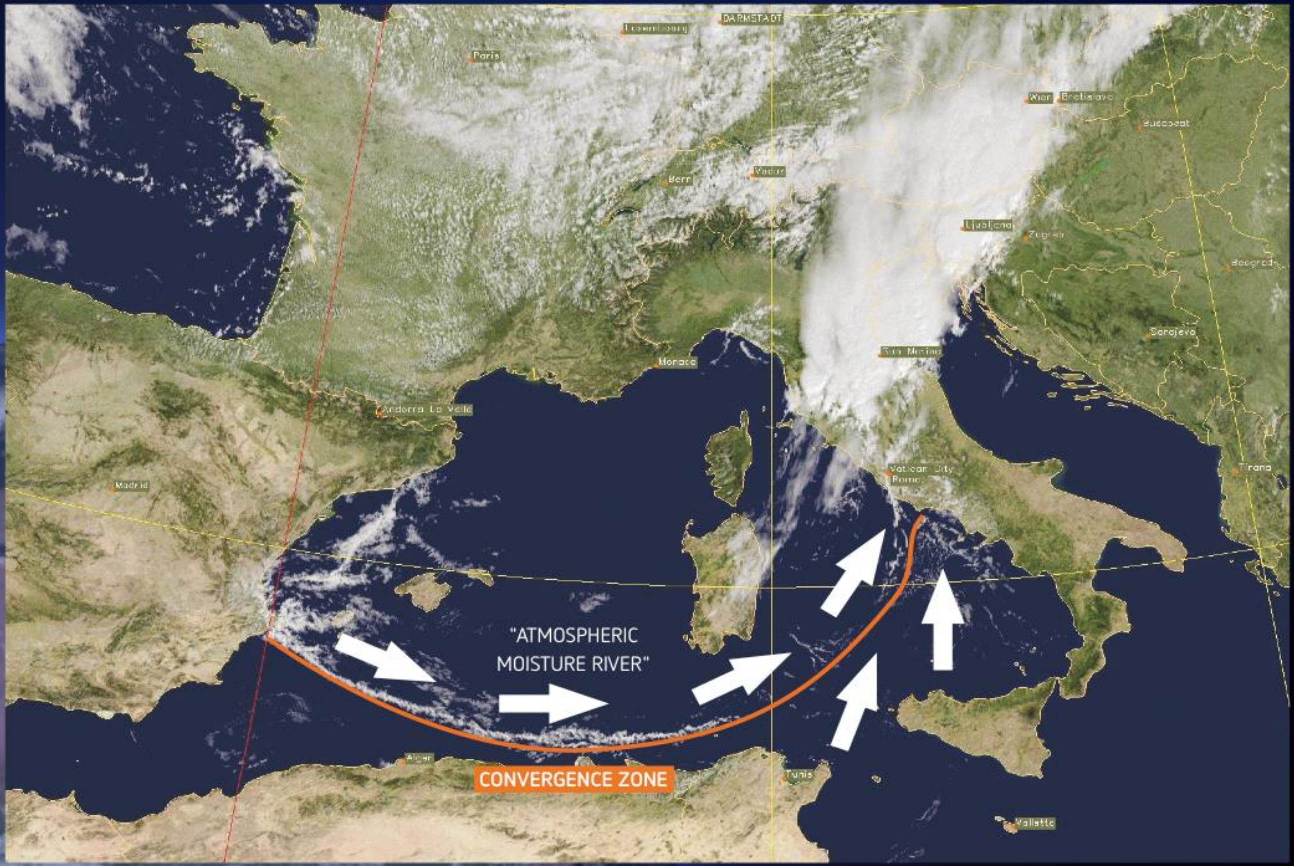
- PMET shall not participate to industrial studies in other frame than foreseen under the TOR

Schedule (in 2006)

- April/May 2006: Identification of candidate missions
- Autumn 2006: Review of technical documentation input to ESA led industrial studies on sensor/system concepts
- Mid 2007: Review of output from industrial studies at their mid-term review

Reserve slides: Benefits of satellite data and products

Diagnosing moist air flow



On 26 August 2012, 09:30 UTC, the high resolution visible (HRV) channel of Meteosat-8 observed the cold front that terminated the heat wave over Italy. Forecasters could diagnose from imagery the moist air flow ahead of it ("atmospheric moisture river"), which can, under certain conditions, lead to heavy rainfall and flash-floods.

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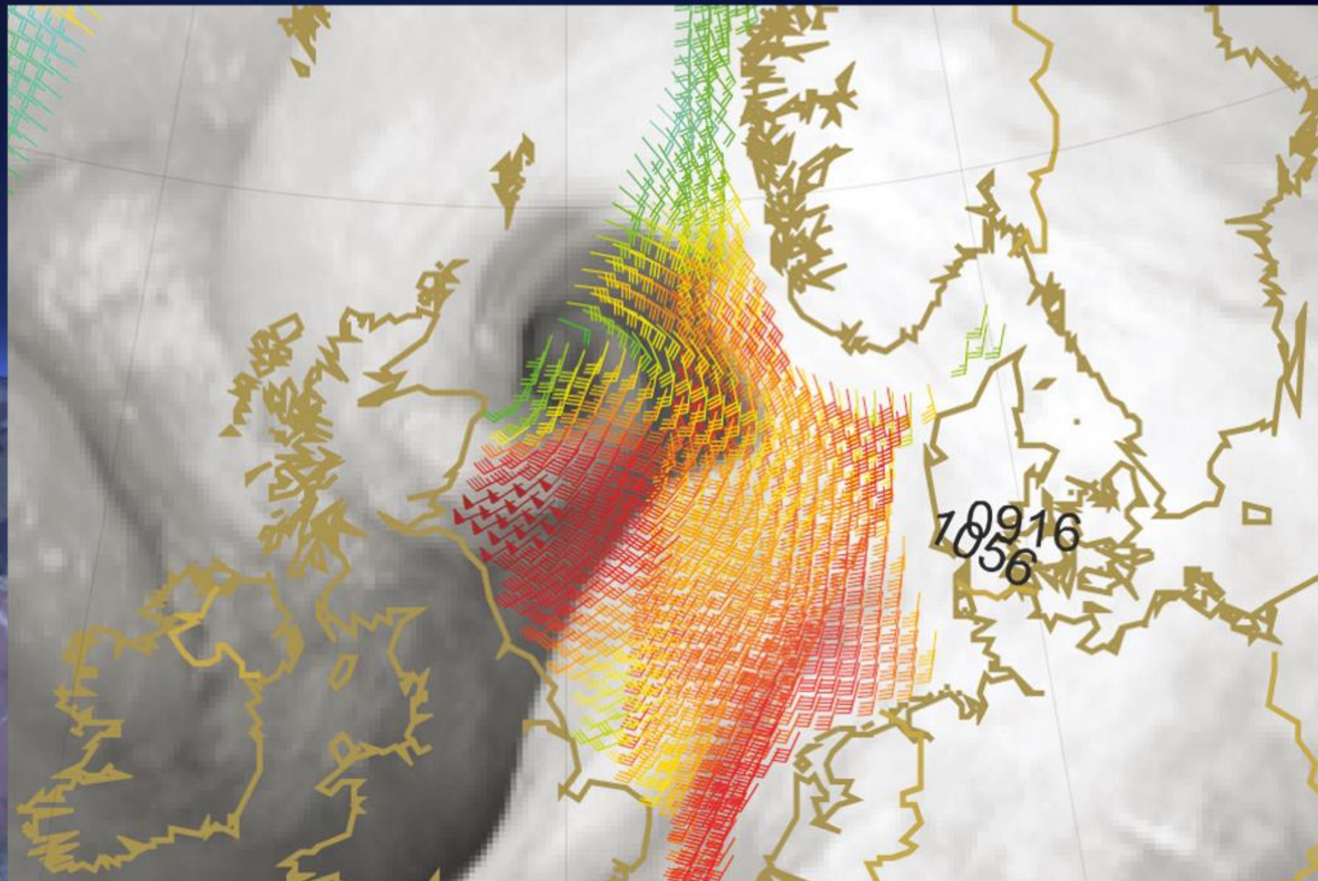
Storm Ulli



Structure of Storm Ulli as observed on 3 January 2012, by Meteosat-9 (12:00 UTC, water vapour channel), and Metop-A ASCAT (winds) as it was centred over the North Sea between the British Isles and Norway. Wind gusts were recorded in Glasgow (78 knots at 08:20 UTC), Edinburgh (70 knots at 08:50 UTC) and in excess of 87 knots in other locations.

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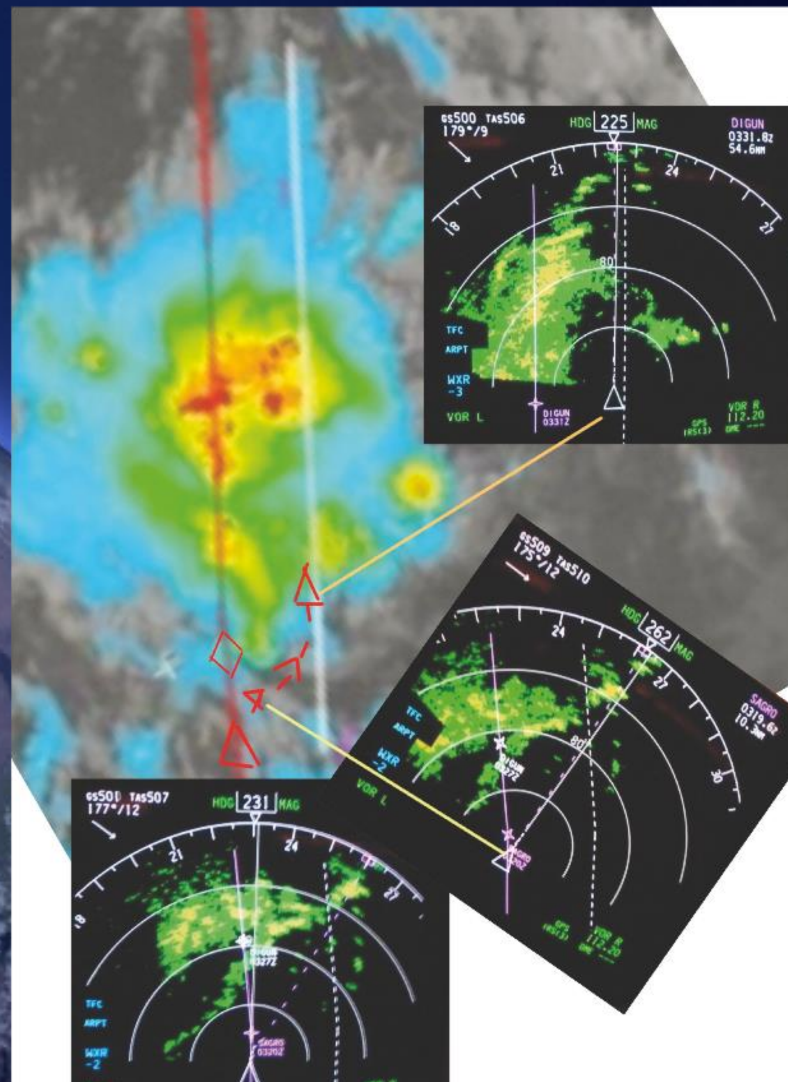
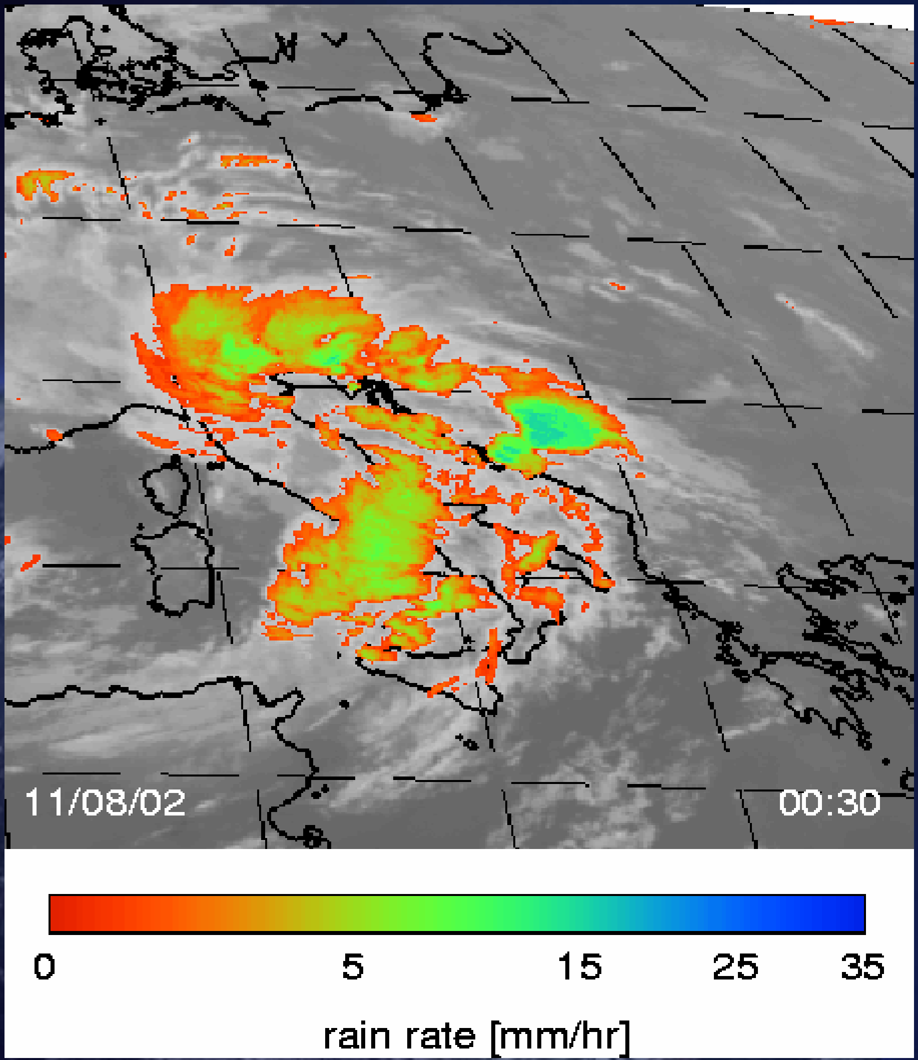
Comparison of Meteosat products and aircraft radar

EUMETSAT imagery compared with successive aircraft radar scopes during flight changes (about 60 nautical miles) decided by the pilot to avoid severe convection.



Meteosat-7 observes disastrous rainfall: 11 - 13 Aug. 2002, Elbe flood



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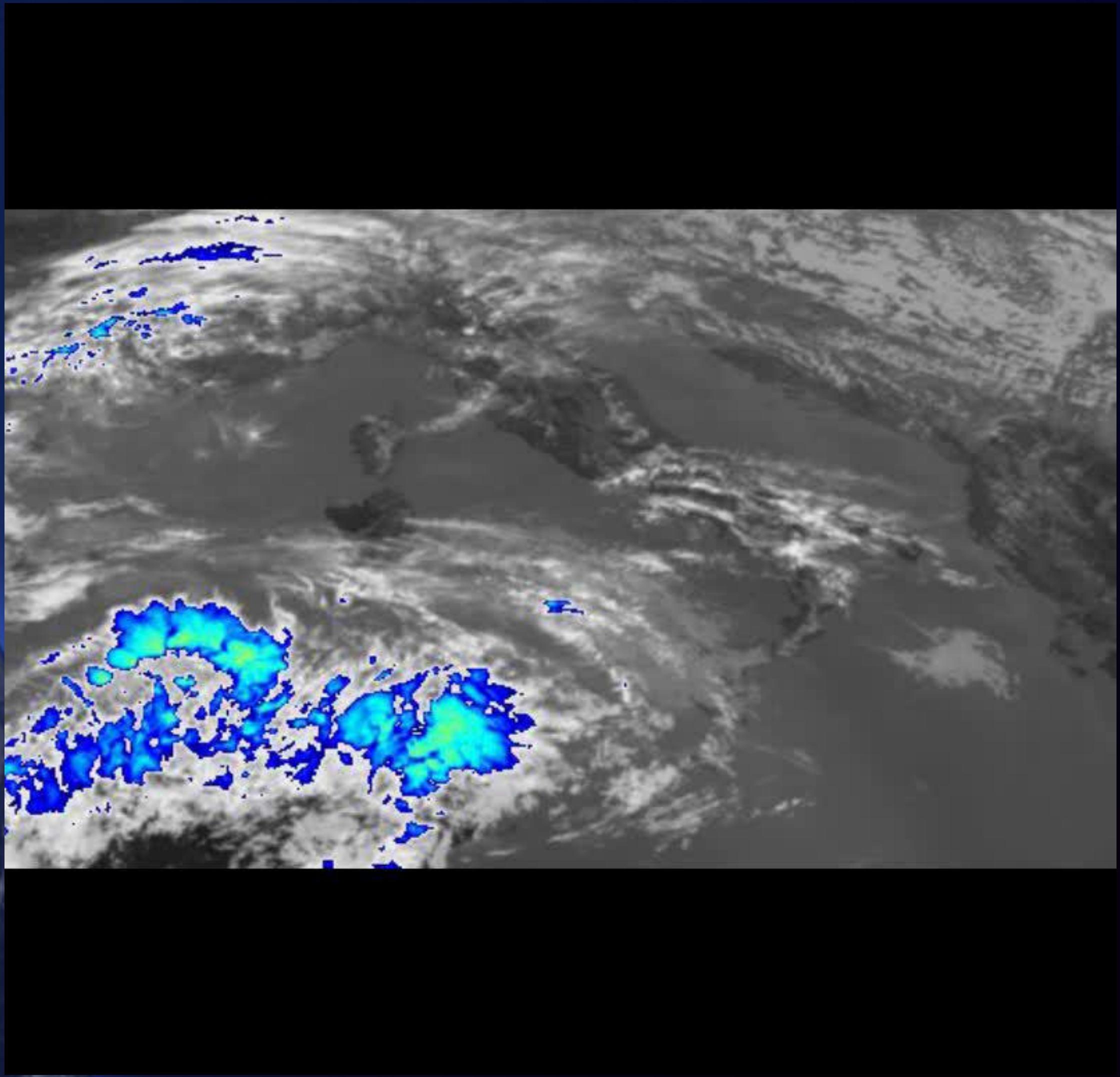
Cold U-shaped storms over Southern Italy

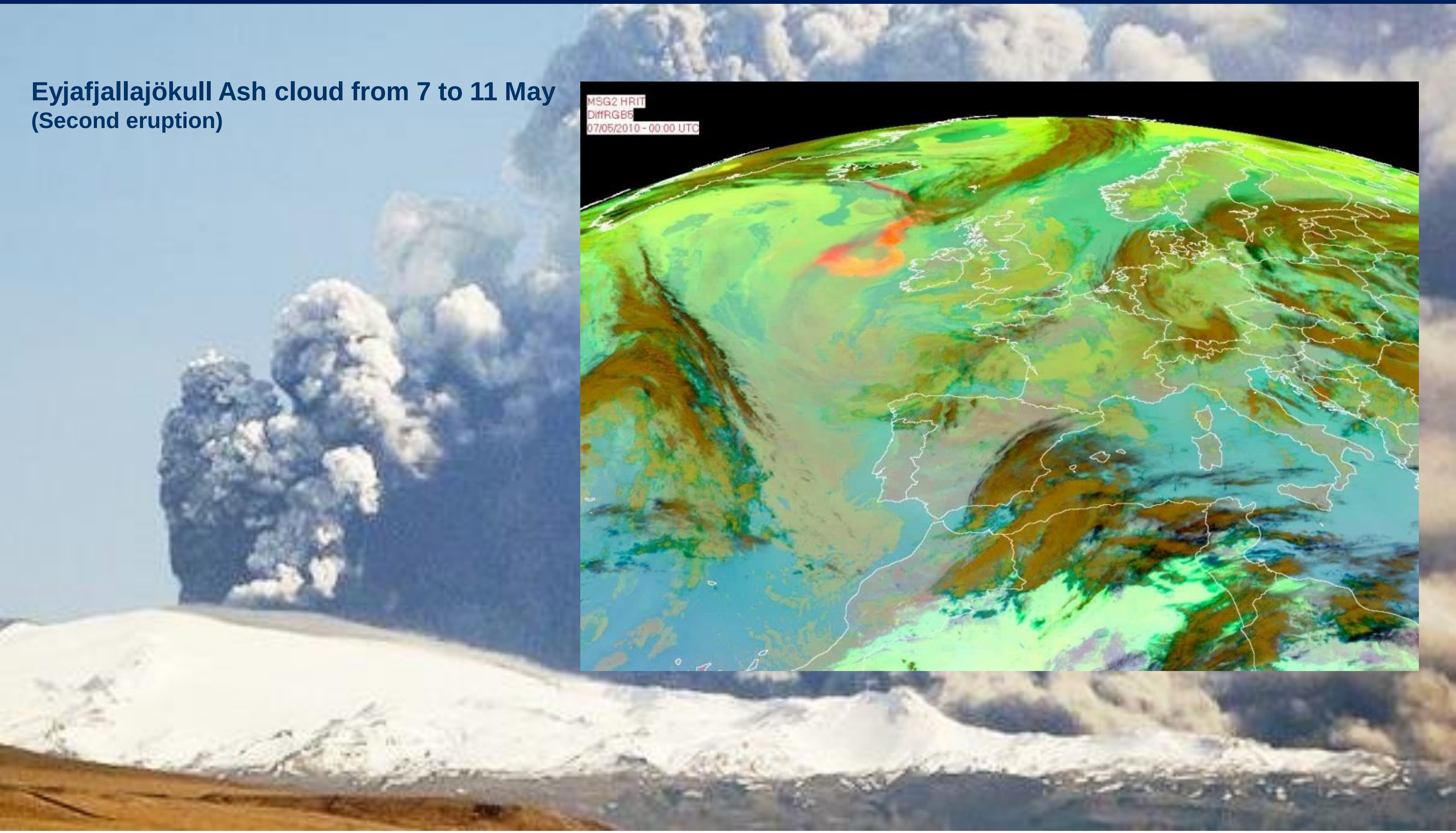
Typically associated with severe weather such as heavy rain, hail and damaging winds

(Meteosat-8 IR10.8 BT RSS - 02/09/10 13:30 - 03/09/10 07:00 UTC)



Weather-related dispersion of volcanic ash

Eyjafjallajökull Ash cloud from 7 to 11 May
(Second eruption)



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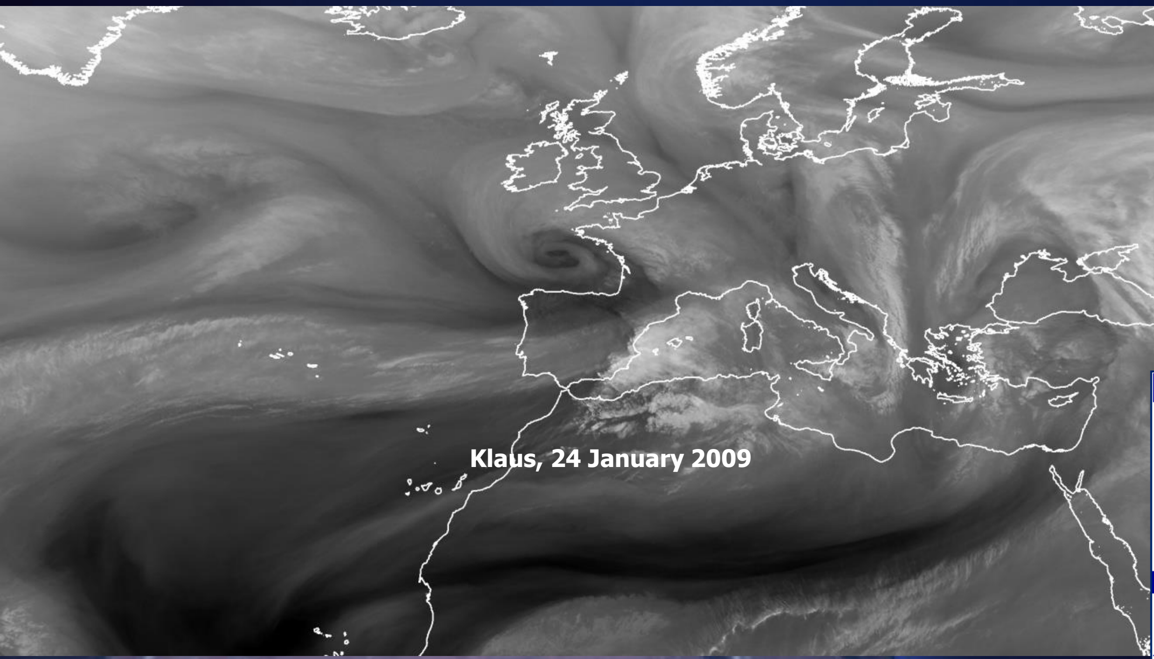
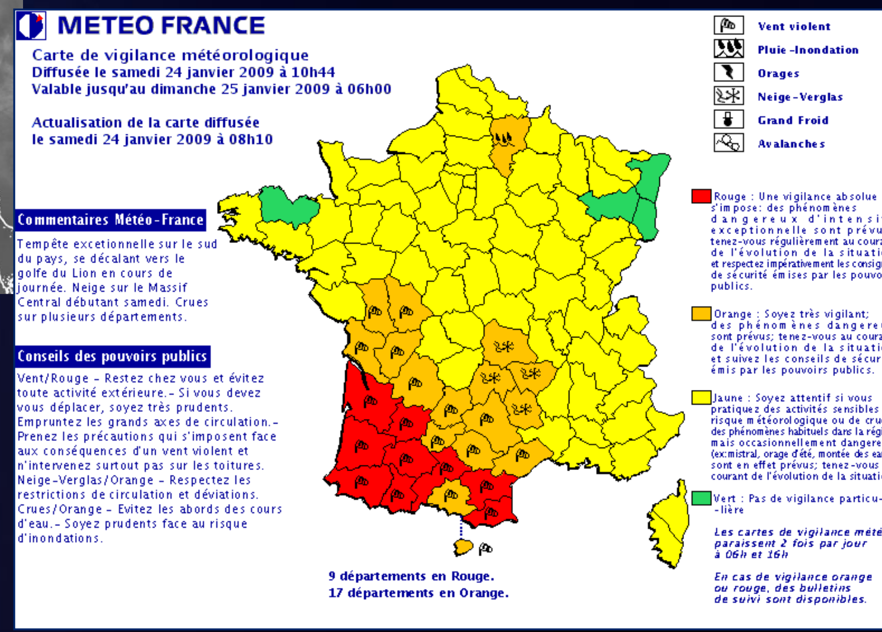
Severe storm warning: Klaus, 24 January 2009 (MSG water vapour channel)





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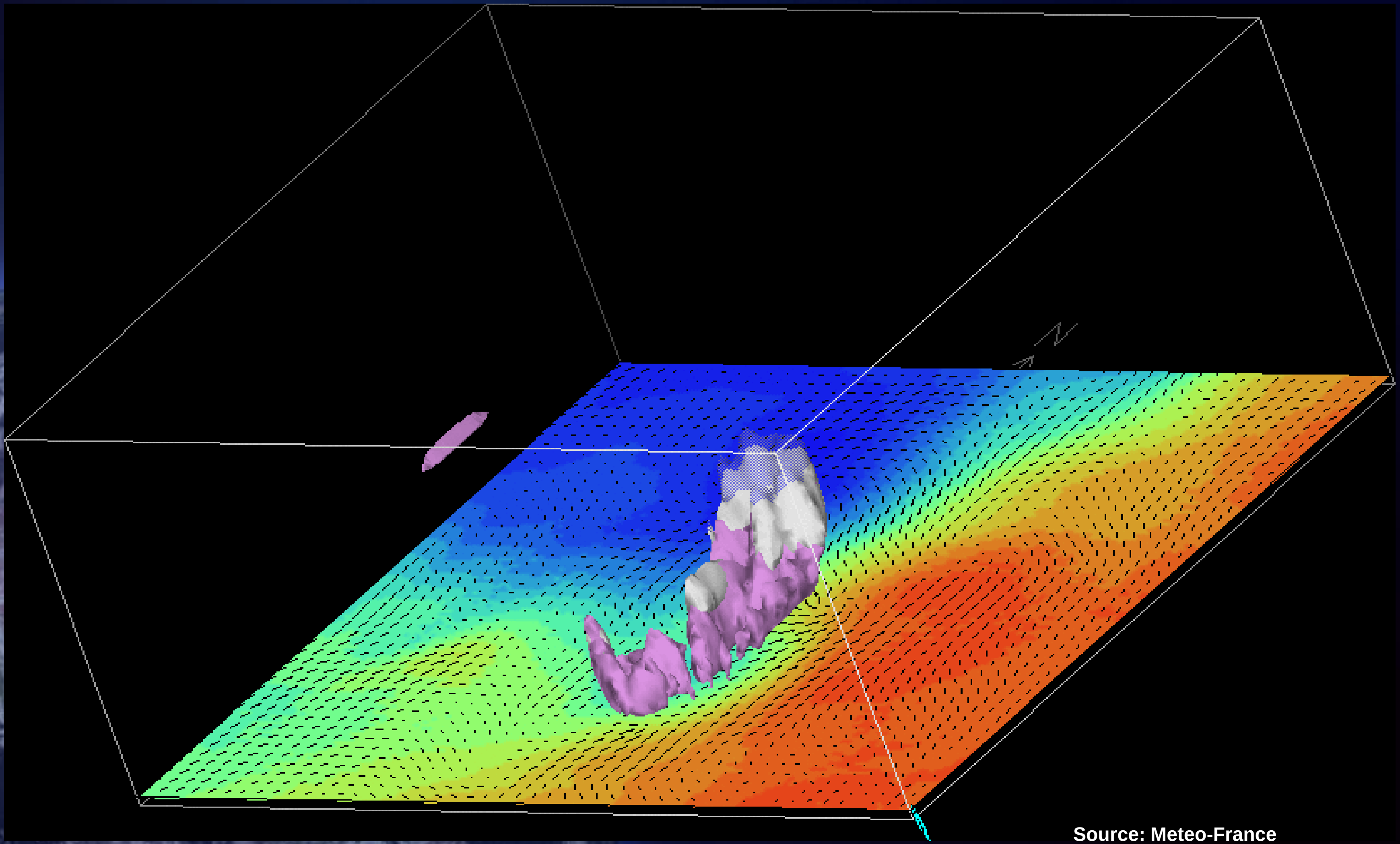
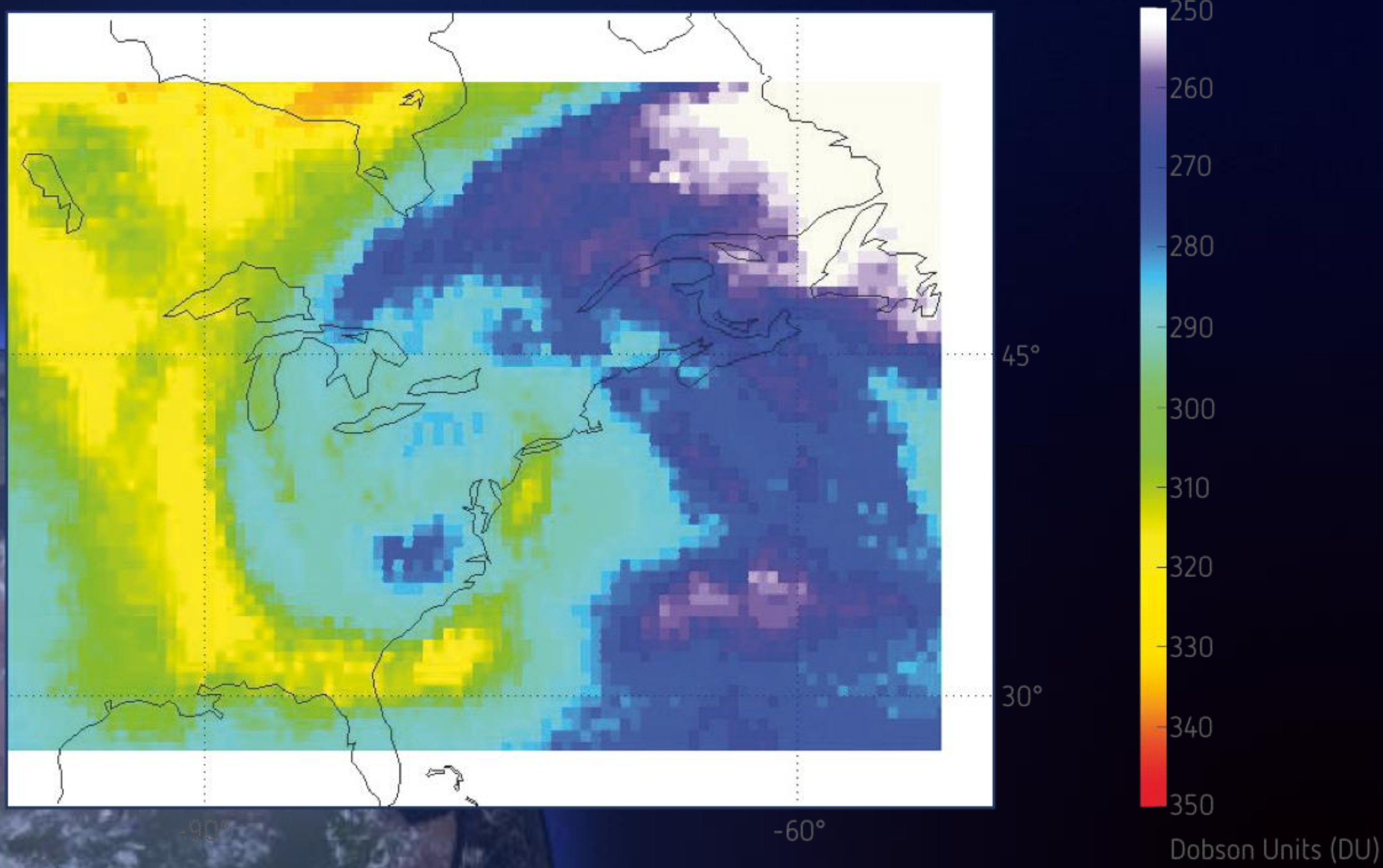
Generalisation of convection-resolving models for short range forecasts and support to nowcasting



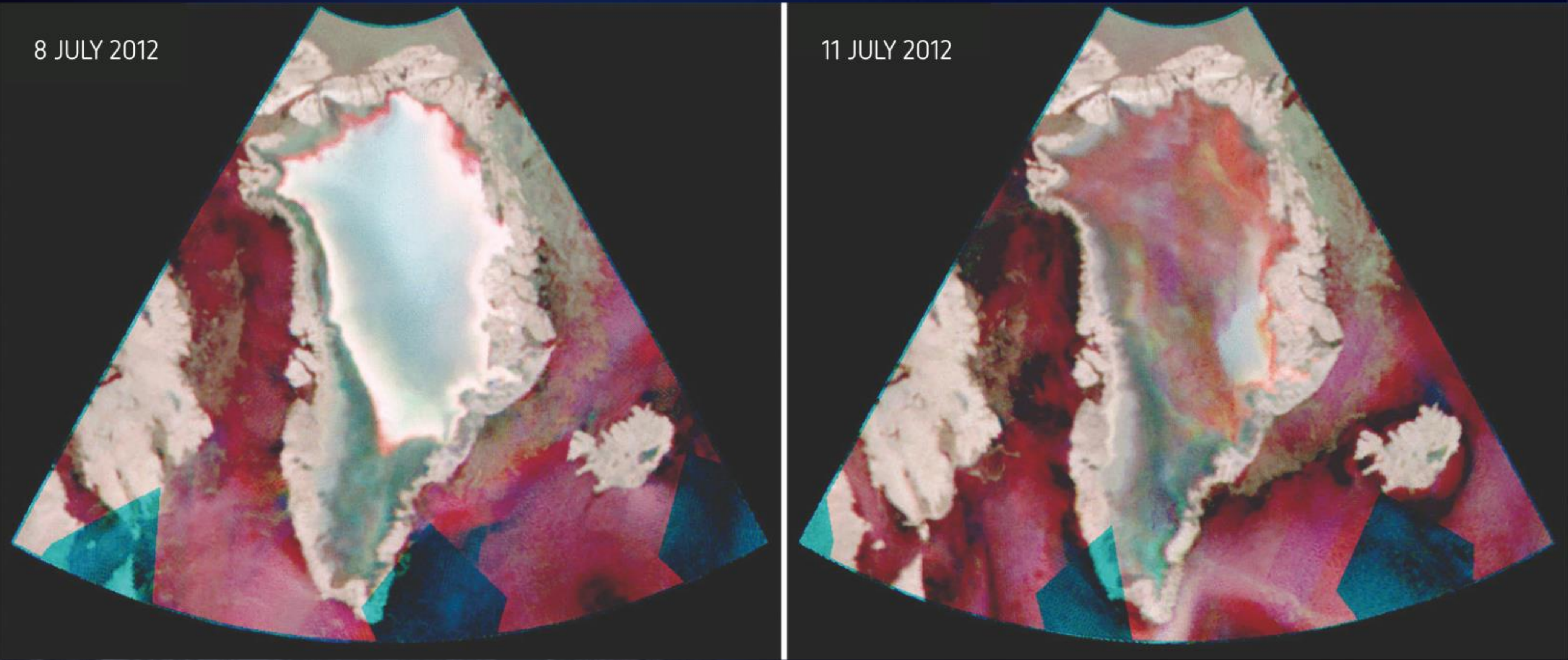
Source: Meteo-France

The benefit of two Metop satellites in orbit



Impact of hurricane Sandy on total ozone, as observed by the GOME-2 instruments of Metop-A and Metop-B, on 30 October 2012. Only the combination of both instruments can map the full region impacted by the storm.

Extreme Greenland ice sheet melt



Metop-A ASCAT backscatter over Greenland changing dramatically from 8 and 11 July 2012. Imagery discriminates land (grey), summer melt (dark green), fast surface melt (red), refrozen melt (bright white) and non-melted (dark grey/blue). This event was likely due to extreme air surface temperature during those days.

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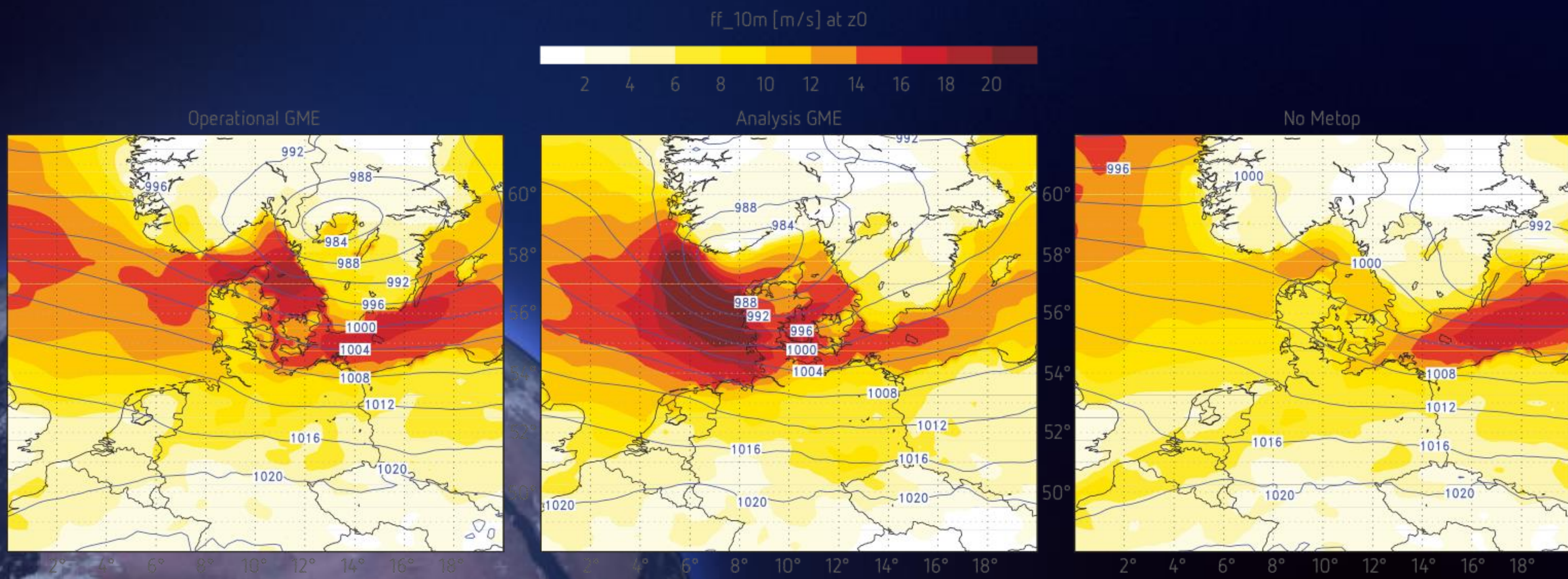
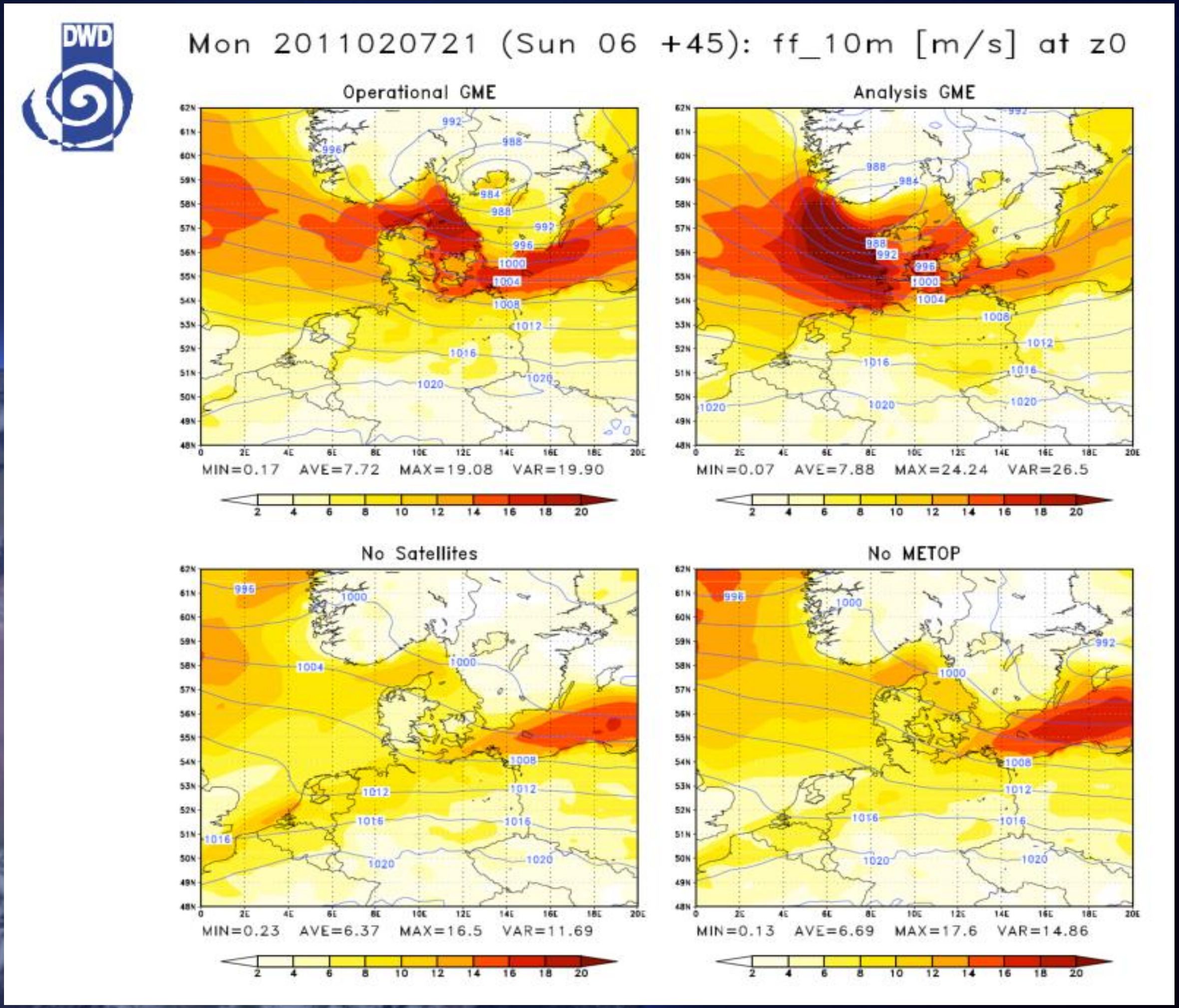
Winter storm Nicolas



Winter storm "Nicolas": DWD 45-hour forecasts of surface pressure (contour lines) and surface wind speed (shaded areas - units m/s) for 7 February 2011, 21:00 UTC with (left) and without (right) Metop observations, compared to operational analysis (best approximation of ground truth, centre)

Failing to forecast major storms without Metop-A



Winter storm "Nicolas": 45 hour forecasts and operational analysis (best approximation of ground truth) of surface pressure (contour lines) and 10m wind speed (shaded areas – units M/S) for 7 February 2011

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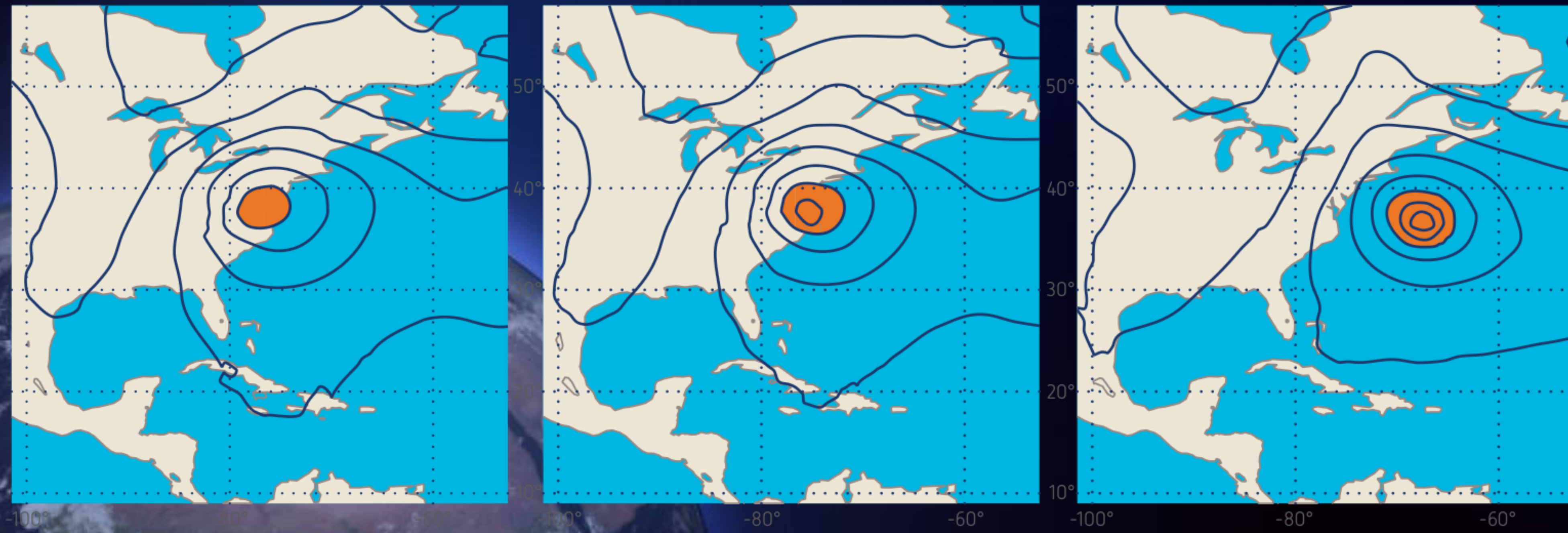
Hurricane Sandy



Five-day forecast of cyclone Sandy landfall on the US coast by the ECMWF global model, with (left) and without (right) ingestion of observations from polar orbiting satellites, compared to the operational analysis (best approximation of ground truth, centre)

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