INTO THE FUTURE
AN OVERVIEW OF THE EUMETSAT SATELLITE PROGRAMMES

Kenneth Holmlund
EUMETSAT
And many other contributors from EUMETSAT and its partners
METOP -A and -B
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)
EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

JASON-2
(LOW-EARTH, 63° INCL. NON SYNCHRONOUS ORBIT)
OCEAN SURFACE TOPOGRAPHY MISSION

METEOSAT SECOND GENERATION -8.-9.-10, MSG-4 (-11)
(GEOSTATIONARY ORBIT)
TWO-SATELLITE SYSTEM:
- MSG-4 (METEOSAT-11) under commissioning
- METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)
- METEOSAT-9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)
- METEOSAT- 8: BACK UP AT 3.5°E

METEOSAT – 7 (1st GENERATION)
(GEOSTATIONARY ORBIT)
INDIAN OCEAN DATA COVERAGE MISSION
AT 57°5 E (UNTIL END 2016)
Future programmes shape the 2018 – 2040 timeframe

MTG: Approved, under development
Sentinel-4 approved (funded by Copernicus)

Jason-CS/Sentinel-6:
Approval process ongoing

EPS-SG: Approved, under development
Sentinel-5 approved (funded by Copernicus)
Process for user requirements elaboration

User Needs

Should drive

User Requirements
Process for user requirements elaboration

Users

Can't always formulate

User Needs

Should drive

User Requirements

Are not always aware of
Process for user requirements elaboration

User Needs

User Requirements

Technological Capabilities

Trigger / justify evolution

Open possibilities

Constrain the fulfilment

Are not always aware of

Can't always formulate

Should drive

Users
Process for user requirements elaboration

Users → Can’t always formulate

User Needs → Should drive

User Requirements

Trigger / justify evolution → Open possibilities

Constrain the fulfilment

Experts

Know / translate

Experts → Formulate

Experts → Consider

User Requirements → Technological Capabilities

Are not always aware of

Experts

Experts
Process for user requirements elaboration

1. Users
   - Can't always formulate
   - Are not always aware of

2. User Workshop
   - Discuss / endorse
   - Guide

3. User Needs
   - Should drive

4. User Requirements
   - Formulate
   - Constrain the fulfilment
   - Open possibilities
   - Trigger / justify evolution

5. Technological Capabilities
   - Consider

6. Experts
   - Know / translate
Process for user requirements elaboration

1. **User Needs**
   - Discuss / endorse
   - Approves
   - Formulate
   - Open possibilities
   - Constrain the fulfilment
   - User Requirements
   - Trigger / justify evolution
   - Technological Capabilities
   - User Workshop

2. **Experts**
   - Approves user list
   - Know / translate

3. **Users**
   - Are not always aware of User Needs
   - User Requirements
   - Should drive
   - Consider
   - Discuss / endorse
   - Guide

4. **Approves user list**
   - User Workshop
Process for user requirements elaboration

User Needs

- Should drive
- Open possibilities
- Constrain the fulfilment

User Requirements

Technological Capabilities

User Workshop

- Guide
- Discuss / endorse

Experts

- Know / translate
- Approves user list

Users

- Approves
- Can’t always formulate

EUMETSAT

Are not always aware of
MTG user requirements for NWC

MTG user requirements for NWP regional

MTG user requirements for NWP global

Δt > 1 hour

Other user requirements (WMO, IGOS + others)

Post-EPS Application Experts Groups

AEG expertise

AEG Sounding & Wind

AEG Clouds, Precip, Land

AEG Oceanography

AEG Climate monitoring

AEG Atmosph. Chemistry

Global

Coastal

Post-EPS user requirements

Composition-climate

Ozone & UV

Air quality

INPUT TO AEGs
Meteosat-7 is the last
Located over
- Indian Ocean
Operational
- until end of 2016
MSG-4 (Meteosat-11)
- is the last
- in-orbit storage 2.5 y
Indian Ocean Data
- coverage is considered using Meteosat-8
Operational programme
- until 2025 (TBC)
From MVIRI through SEVIRI to FCI on MTG
Visual Analysis: Monitoring Stages of Convection

23. September 2009
Mediterranean Sea

[Images of satellite maps and data analysis]
Visual Analysis: Monitoring Stages of Convection

“Sandwich Product”

BT 240 K | 200 K
Met-8 super-rapid scans 2.5 min experiment
Meteosat Third Generation: Mission overview

- Imagery mission implemented by a two-satellite MTG-I system:
  1. Full disk imagery every 10 minutes in 16 spectral bands
  2. Fast imaging of European weather every 2.5 minutes
  3. Lightning Imager (LI)

- Hyperspectral Infrared (IRS) Sounding mission:
  4. 3D mapping of water vapour, temperature, O3 every 1 hour
  5. Air quality monitoring and atmospheric chemistry in synergy with Sentinel-4 Ultraviolet Visible

- Start of operations in 2019 and 2021
- Operational exploitation: 2019–2040
“Accumulated flash area” product, integrated over 15 minutes and updated every 30 seconds
Date: 20 June 2013.
MTG Mission: InfraRed Sounder (IRS)

MTG-IRS will deliver unprecedented information on horizontal and vertical gradients of moisture, wind and temperature from the geostationary orbit:

- Full Disk Sounding;
- Repeat Cycle = 60 min;
- spatial resolution of 4 km,
- hyperspectral soundings at 0.625 cm\(^{-1}\) spectral sampling in two bands:
  - Long-Wave-IR (LWIR: 700 – 1210 cm\(^{-1}\) ~820 spectral samples)
  - Mid-Wave-IR (MWIR: 1600 – 2175 cm\(^{-1}\) ~920 spectral samples)
MTG Mission: hosting GMES Sentinel-4

- The GMES Sentinel-4 sounding mission is achieved through the Ultraviolet, Visible & Near-infrared (UVN) Instrument accommodated on the MTG-S satellites
  - covering Europe every hour
  - taking measurements in three spectral bands (UV: 305 - 400 nm; VIS: 400 - 500 nm, NIR: 750 - 775 nm)
  - with a resolution around 8km.

- The primary data products are O3, NO2, SO2, HCHO and aerosol optical depth.

Synergies of missions flying on MTG

GMES S4-UVN

- O3, CO, NO2
- SO2, VOC(H2CO, CHOCHO), Aerosol/PM

MTG-IRS

MTG-LI

MTG-FCI
Metop-A launched in 2006
- Metop-B launched in 2012
- Metop-C launch scheduled for 2019
- Sun Synchronous orbit
- 820 km, 9h30 LST, 100 min
- Sole source of mid-morning orbit data
- 11 Instruments
- Soyuz Launcher Service (Baikonur/Kourou)
- ESOC LEOP Service (Darmstadt)
- Central & distributed Ground Segment components
- 14+ years of operations

8 Meteorological Themes
The EUMETSAT polar system as part of the initial joint polar system shared with the US

- Coordinated programmes
- Exchange of instruments
- Coordinated operations, data and services
- Only Metop provides mid-morning service
- And now China has committed to the early morning orbit
Current Capabilities - EUMETSAT Polar System

- **AVHRR**: Advanced Very High Resolution Radiometer
- **HIRS/4**: High-resolution Infrared Radiation Sounder
- **IASI**: Infrared Atmospheric Sounding Interferometer
- **AMSU-A1**: Advanced Microwave Sounding Unit-A1
- **MHS**: Microwave Humidity Sounder
- **GRAS**: GPS Receiver for Atmospheric Sounding
- **GOME-2**: Global Ozone Monitoring Experiment
- **AMSU-A2**: Advanced Microwave Sounding Unit-A2
- **ASCAT**: Advanced SCATterometer
Aerosol: PMAp (GOME-2 + AVHRR)
Metop A & B combined

Ocean = Operational retrieval
Land = test retrieval in development
Metop-B is in the same orbital plane as Metop-A

Morning Orbit

Equator crossing time: 09:30 LST
Orbit phasing: 48.93 min.
Dual Metop winds: Global coverage and quality improvement in polar regions

Global dual Metop winds

Metop winds over South Pole (QI > 80)

One Metop

Dual Metop
EUMETSAT dual Metop winds: Global coverage

AVHR_AMV_2D_20140815
platforms M01 and M02

Wind speed
(QI > 60)

Bin size = 80x80 km²
EPS Second Generation

- Primary mission: further improve observational inputs to Numerical Weather Prediction models

- Significant contributions to other real time applications:
  - Nowcasting at high latitudes
  - Marine meteorology and operational oceanography
  - Operational hydrology
  - Air quality monitoring

- Climate monitoring: expand by 20+ years the climate data records initiated in 2006 with EPS
EPS Second Generation

- Continuation and enhancement of service from mid morning polar orbit in 2021 – 2040

- Twin satellite in-orbit configuration:
  - **Metop-SG A**: optical imagery and sounding mission
    - Flies the Copernicus Sentinel-5 instrument
  - **Metop-SG B**: microwave imaging mission

- Two series of 3 successive satellites for 21 years of operations

- European contribution to the Joint Polar System (JPS) shared with the US/NOAA
EPS Second Generation

Satellites at a glance

- **METOP-SG-B**
  - Launch mass = 3.79 tons
  - Mean power consumption = 2.7 kW
  - Data rate = 14 / 14 / 17 Mbps
  - Launcher: Soyuz in Kourou / Falcon 9 / Ariane 5
  - Orbit: MetOp Sun Synchronous Orbit 817 km, 9h30 Local Time at Descending Node
  - Controlled re-entry into the South Pacific Ocean Uninhabited Area

- **METOP-SG-A**
  - Launch mass = 4.08 tons
  - Mean power consumption = 3.4 kW
  - Data rate = 60 / 22 / 77 Mbps
EPS Second Generation Instruments’ Overview

Distribution of Instruments per Satellite

<table>
<thead>
<tr>
<th>Customer Furnished Instruments</th>
<th>Contractor Provided Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>IASI-NG</td>
<td>3MI</td>
</tr>
<tr>
<td>METimage</td>
<td>RO</td>
</tr>
<tr>
<td>Sentinel-5</td>
<td>MWS</td>
</tr>
<tr>
<td>ADCS-4</td>
<td>RO</td>
</tr>
<tr>
<td></td>
<td>MWI</td>
</tr>
<tr>
<td></td>
<td>ICI</td>
</tr>
<tr>
<td></td>
<td>SCA</td>
</tr>
</tbody>
</table>

IASI-NG: Temperature & Humidity Profiles at High Vertical & Medium Spatial Resolutions

METimage: High Resolution Cloud Products

Sentinel-5: Ozone & Other Atmospheric Gases Profile & Column, Aerosols Optical Depth

ADCS-4: Advanced Data Collection System

3MI: Aerosols Optical Thickness, Particle Characterisation, Volcanic Ashes

MWS: Temperature & Humidity Profiles in Clear & Cloudy Air, Cloud Liquid Water Total Column

RO: Temperature, Pressure & Humidity Profiles Electrons Contents in Ionosphere

MWI: Precipitation & Cloud Products, Water Vapour Profiles & Imagery, Sea-Ice

ICI: Cloud Products (in Particular Ice Clouds), Snowfall Detection & Quantification

SCA: Ocean Surface Wind Vectors and Soil Moisture

CPI:
EPS-SG Current Status

- Achieved approval of the scope and contents of the EPS-SG Programme Proposal which includes the draft cooperation agreements with ESA, CNES, DLR and NOAA

- Achieved in June 2015 approval of full EPS-SG programme from January 2016 onwards

  - System Preliminary Design Review (PDR) successfully completed in June 2015
  - ESA: Prime contractors for the Metop-SG A and B satellites selected and Phase B2 kicked off in June 2014, PDR planned for September 2015
  - CNES: IASI-NG PDR successfully completed in May 2015
  - CNES: The first flight model of A-DCS4 for EPS-SG is under assembly
  - DLR: METimage instrument PDR successfully completed in July 2015
  - EUM: Overall Ground Segment PDR planned for September 2015
MONITORING THE OCEAN IN SUPPORT OF COPERNICUS
Sentinel-3 Satellite and Payload

- **SLSTR**: Sea and Land Surface Temperature Radiometer
- **SRAL**: Synthetic Aperture Radar Altimeter
- **OLCI**: Ocean and Land Colour Instrument
- **MWR**: Micro-Wave Radiometer
- **LRR**: Laser Retro-Reflector
- **DORIS**: Doppler Orbitography and Radiopositioning Integrated by Satellite
- **STM**: Surface Topography Mission = SRAL + MWR
Sentinel-3 Marine product contents

**Level 1B:** SLTSR (radiance, BT at TOA) and OLCI (radiance at TOA) and SRAL (waveforms) (ESA and EUMETSAT)

**Level 2 OLCI:**
- Normalised water surface reflectance
- Algal pigment concentration for open and for coastal waters
- Total suspended matter concentration
- Diffuse attenuation coefficient
- Coloured dissolved matter absorption
- Photosynthetically active radiation
- Integrated water vapour
- Aerosol optical depth
- Aerosol Angström exponent

**Level 2 SLTSR:**
- Sea surface temperature (L2P GHRSSST standard)

**Level 2 SRAL:**
- Sea/coastal zone surface height
- Significant wave height
- Wind speed
- Backscatter coefficient $\sigma_0$
- Sea ice height, freeboard
- Total water, liquid water (from MWR)
Combining Sentinel-3 & Jason altimetry for operational oceanography and climate change monitoring

(Courtesy CNES/CLS/ESA)
From Jason-2 to Jason-3, Jason-CS: Global sea level rise

IPCC projections: Uncertainties

Observational evidence: Unique Climate Data Record

Global mean sea level during the altimetry era has risen at a nearly constant rate since 1993 (+- 3 mm/year).

Relatively consistent despite large regional interannual variations and accelerations in the melting of land ice.
Mean sea level trends: regional differences

- Why has the western Pacific risen 3 times faster?
- Why has sea level dropped near the U.S. West Coast?
- How will regional sea level change in the future?
PRODUCT STATUS AND SCIENCE MATURITY
## Product Status

<table>
<thead>
<tr>
<th>STATUS</th>
<th>DEMONSTRATIONAL</th>
<th>PRE-OPERATIONAL</th>
<th>OPERATIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRODUCT QUALITY</strong></td>
<td>First version of the Product</td>
<td>Quality approaching to expected levels</td>
<td>Expected Quality (as per Requirements)</td>
</tr>
<tr>
<td><strong>STATUS OF VALIDATION PROCESS</strong></td>
<td>Limited Validation performed</td>
<td>Validation almost completed (if not completed), with documented limitations</td>
<td>Validation performed and fully documented</td>
</tr>
<tr>
<td><strong>PRODUCT LIMITATIONS</strong></td>
<td>Potentially unknown or Major</td>
<td>Known &amp; Not Major or None</td>
<td>None or Known limitations agreed with Users</td>
</tr>
<tr>
<td><strong>PRODUCT DOCUMENTATION</strong></td>
<td>Product Validation report &amp; User manual Not Available</td>
<td>Product Validation report &amp; User manual (mainly) completed</td>
<td>All completed, published and available</td>
</tr>
<tr>
<td><strong>AUDIENCE</strong></td>
<td>Internal Users + Investigators</td>
<td>Varying from ‘limited set of Users’ to ‘All Registered Users’</td>
<td>Usually ‘All Registered Users’ (unless exceptions)</td>
</tr>
<tr>
<td><strong>ACCESS BY EXTERNAL USERS</strong></td>
<td>No Access to the Documentation</td>
<td>Documentation on the WEB</td>
<td>Documentation on the WEB</td>
</tr>
<tr>
<td>Maturity</td>
<td>Software Readiness</td>
<td>Metadata</td>
<td>CDR Name Here</td>
</tr>
<tr>
<td>----------</td>
<td>---------------------</td>
<td>----------</td>
<td>---------------</td>
</tr>
<tr>
<td>1</td>
<td>Conceptual development</td>
<td>Little or none</td>
<td>Draft Climate Algorithm Theoretical Basis Document (C-ATBD); paper on algorithm submitted</td>
</tr>
<tr>
<td>2</td>
<td>Significant code changes expected</td>
<td>Research grade</td>
<td>C-ATBD Version 1+; paper on algorithm reviewed</td>
</tr>
<tr>
<td>3</td>
<td>Moderate code changes expected</td>
<td>Research grade; Meets int'l standards: ISO or FGDC for collection; netCDF for file</td>
<td>Public C-ATBD; Peer-reviewed publication on algorithm</td>
</tr>
<tr>
<td>4</td>
<td>Some code changes expected</td>
<td>Exists at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset</td>
<td>Public C-ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed publication on algorithm; paper on product submitted</td>
</tr>
<tr>
<td>5</td>
<td>Minimal code changes expected; Stable, portable and reproducible</td>
<td>Complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset</td>
<td>Public C-ATBD, Review version of OAD, Peer-reviewed publications on algorithm and product</td>
</tr>
<tr>
<td>6</td>
<td>No code changes expected; Stable and reproducible; portable and operationally efficient</td>
<td>Updated and complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets current international standards for dataset</td>
<td>Public C-ATBD and OAD; Multiple peer-reviewed publications on algorithm and product</td>
</tr>
<tr>
<td>Maturity</td>
<td>PRODUCT VALIDATION</td>
<td>Independent validation</td>
<td>Uncertainty (for TCDRs)</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------</td>
<td>------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Little or None</td>
<td>Incomplete</td>
<td>Little or no information on biases and errors</td>
</tr>
<tr>
<td>2</td>
<td>Minimal</td>
<td>Comparison to training set, test dataset, or previous product</td>
<td>Limited information on biases and errors</td>
</tr>
<tr>
<td>3</td>
<td>Uncertainty estimated for select locations/times</td>
<td>At least 1 comparison to models, in-situ data, or other independent products as available and appropriate to particular CDR</td>
<td>Biases and errors identified and documented</td>
</tr>
<tr>
<td>4</td>
<td>Uncertainty estimated over widely distributed times/location by multiple investigators; Differences understood.</td>
<td>At least 2 comparisons to models, in-situ data, or other independent products as available and appropriate to particular CDR; differences in results understood</td>
<td>Biases and errors quantified</td>
</tr>
<tr>
<td>5</td>
<td>Consistent uncertainties estimated over most environmental conditions by multiple investigators</td>
<td>At least 5 comparisons to models, in-situ data, or other independent products as available and appropriate to particular CDR; differences in results understood</td>
<td>Biases and errors minimized</td>
</tr>
<tr>
<td>6</td>
<td>Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation; quantified errors</td>
<td>At least 10 comparisons to models, in-situ data, or other independent products as available and appropriate to particular CDR; observation strategy designed to reveal systematic errors through independent cross checks, open inspection, and continuous interrogation</td>
<td>Biases and errors minimized</td>
</tr>
<tr>
<td>Maturity</td>
<td>Software Readiness</td>
<td>Metadata</td>
<td>Documentation</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------</td>
<td>----------</td>
<td>---------------</td>
</tr>
<tr>
<td>1</td>
<td>Conceptual development</td>
<td>Little or none</td>
<td>Draft Climate Algorithm Theoretical Basis Document (C-ATBD); paper on algorithm submitted</td>
</tr>
<tr>
<td>2</td>
<td>Significant code changes expected</td>
<td>Research grade</td>
<td>C-ATBD Version 1+ ; paper on algorithm reviewed</td>
</tr>
<tr>
<td>3</td>
<td>Moderate code changes expected</td>
<td>Research grade; Meets int'l standards: ISO or FGDC for collection; netCDF for file</td>
<td>Public C-ATBD; Peer-reviewed publication on algorithm</td>
</tr>
<tr>
<td>4</td>
<td>Some code changes expected</td>
<td>Exists at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset</td>
<td>Public C-ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed publication on algorithm; paper on product submitted</td>
</tr>
<tr>
<td>5</td>
<td>Minimal code changes expected; Stable, portable and reproducible</td>
<td>Complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset</td>
<td>Public C-ATBD, Review version of OAD, Peer-reviewed publications on algorithm and product</td>
</tr>
<tr>
<td>6</td>
<td>No code changes expected; Stable and reproducible; portable and operationally efficient</td>
<td>Updated and complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets current international standards for dataset</td>
<td>Public C-ATBD and OAD; Multiple peer-reviewed publications on algorithm and product</td>
</tr>
</tbody>
</table>

5.083333 4.5 2

46 JPSS Science Team Meeting 2015
FP7 CORE-CLIMAX
Establishing Common Practices for Climate Observations

System Maturity Matrix

- Where can products be found?
- What original observations were used?
- What methods were used?
- How do we ensure authenticity?

Let’s define a Maturity Matrix (1=low, 6=high) that sets expectations and assesses progress.

<table>
<thead>
<tr>
<th>Software</th>
<th>Metadata</th>
<th>Documents</th>
<th>Uncertainties</th>
<th>Access</th>
<th>Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are to codes compliant with standards, stable, portable and reproducible?</td>
<td>Do the metadata meet int. standards, and allow provenance tracking?</td>
<td>Are the formal documents and peer-reviewed papers up-to-date and public?</td>
<td>Are the uncertainties assessed systematically in a standard manner?</td>
<td>Are the data, source code, and documents publicly available?</td>
<td>Are the data widely used in the scientific, decision and policy making communities?</td>
</tr>
</tbody>
</table>

Application Performance Matrix

- Does the coverage of the record suffice?
- Is there sufficient level of detail?
- Are the obs./derived products of adequate quality?
- How does the quality vary in time?

Application Performance Matrix (1=low, 6=high) that characterises the applicability of the data record.

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Sampling</th>
<th>Uncertainty</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the record length and spatial coverage meeting the application’s requirements?</td>
<td>Does the spatial and temporal sampling meet the applications requirements?</td>
<td>Does the random and systematic uncertainties meet the requirements?</td>
<td>Does the temporal stability meet the requirements?</td>
</tr>
</tbody>
</table>

Courtesy: John Bates (NOAA)
Beta level
- Products intended to enable users to gain familiarity with the parameters and the data formats

Provisional
- Product was defined to facilitate data exploration and process studies that do not require rigorous validation. These data are partially validated and improvements are continuing

Validated
- Stage 1-4 validated
**Stage 1 Validation:** Product accuracy is estimated using a small number of independent measurements obtained from selected locations and time periods and ground-truth/field program efforts.

**Stage 2 Validation:** Product accuracy is estimated over a significant set of locations and time periods by comparison with reference in situ or other suitable reference data. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and time periods. Results are published in the peer-reviewed literature.

**Stage 3 Validation:** Product accuracy has been assessed. Uncertainties in the product and its associated structure are well quantified from comparison with reference in situ or other suitable reference data. Uncertainties are characterized in a statistically robust way over multiple locations and time periods representing global conditions. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and periods. Results are published in the peer-reviewed literature.

**Stage 4 Validation:** Validation results for stage 3 are systematically updated when new product versions are released and as the time-series expands.
Science Maturity Index (1/2)

- Initiated by concepts developed for Climate data record Generation - (see e.g. Bates and Privette 2012)

- However, there are also significant technical aspects in the CDR maturity model, whereas here we are trying to assess the scientific maturity of the centrally derived products

- The proposed index is based on four major maturity categories:
  - Scientific Understanding
  - Modelling of the physical principals
  - Instrument capability and characterisation
  - Validation

- All categories receive an estimate:
  - 3 = Highest achievable status, 2 = medium maturity and 1 = initial/immature

- The Scientific Maturity Index =
  - Sum of the estimates per category (Max = 12, Min = 4)
Science Maturity Index (2/2)

- The purpose of the Index is to provide guidance on where efforts should be invested for future development.
- It is considered a useful complementary dimension based on an agreed assessment methodology.
- However, it is only one aspect that has to be considered.
- In addition the utility of the product for scientific application and exploitation has to be considered.
- Should also aid setting the overall priorities wrt to available resources.
An example for Metop Level-1 data

<table>
<thead>
<tr>
<th>Product Processing Facility (PPF)</th>
<th>Metop-A Status</th>
<th>Metop-B Status</th>
<th>Maturity Total (SU, M, ICC, VAL)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVHRR Level 1</td>
<td>Operational</td>
<td>Operational</td>
<td>12 (3,3,3,3)</td>
<td></td>
</tr>
<tr>
<td>AMSU-A Level 1</td>
<td>Operational</td>
<td>Operational</td>
<td>11 (3,3,2,3)</td>
<td>Some channel out of spec / failed</td>
</tr>
<tr>
<td>HIRS/4 Level 1</td>
<td>Operational</td>
<td>Operational</td>
<td>11 (3,3,2,3)</td>
<td>Some channels on Metop-B are at times out of specification</td>
</tr>
<tr>
<td>MHS Level 1</td>
<td>Operational</td>
<td>Operational</td>
<td>12 (3,3,3,3)</td>
<td></td>
</tr>
<tr>
<td>IASI Level 1</td>
<td>Operational</td>
<td>Operational</td>
<td>12 (3,3,3,3)</td>
<td></td>
</tr>
<tr>
<td>IASI L1 PCC</td>
<td>Operational</td>
<td>Operational</td>
<td>9 (3,2,2,2)</td>
<td></td>
</tr>
<tr>
<td>ASCAT Level 1</td>
<td>Operational</td>
<td>Operational</td>
<td>10 (3,2,2,3)</td>
<td></td>
</tr>
<tr>
<td>GOME-2 Level 1</td>
<td>Operational</td>
<td>Operational</td>
<td>11 (3,3,2,3)</td>
<td>Metop-A operating in 960km and Metop-B in 1920km swath mode.</td>
</tr>
<tr>
<td>GRAS Level 1</td>
<td>Operational</td>
<td>Operational</td>
<td>9 (3,2,2,2)</td>
<td>GO</td>
</tr>
<tr>
<td>PPF</td>
<td>Product Status</td>
<td>Maturity Total (SU, M, ICC, VAL)</td>
<td>Remarks</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>--------------------</td>
<td>----------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>IASI temperature and humidity retrieval</td>
<td>Operational</td>
<td>11 (3,2,3,3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IASI Ozone total column</td>
<td>Operational</td>
<td>11 (3,3,3,2)</td>
<td>Validation on-going with O3M SAF</td>
<td></td>
</tr>
<tr>
<td>IASI CO profiles</td>
<td>Operational</td>
<td>10 (3,2,3,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IASI trace gases (ozone profiles, N₂O, CH₄, CO₂)</td>
<td>Demonstrational</td>
<td>7 (2,2,2,1)</td>
<td>Development started for CH₄</td>
<td></td>
</tr>
<tr>
<td>IASI surface emissivity</td>
<td>Pre-operational</td>
<td>7 (2,2,2,1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IASI Cloud Parameters</td>
<td>Operational</td>
<td>11 (3,3,2,3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IASI SST L2Pcore</td>
<td>Operational</td>
<td>11 (3,3,3,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATOVS Level 2</td>
<td>Operational</td>
<td>12 (3,3,2,3)</td>
<td>Some degradation for Metop-A due to noisy or missing AMSU-A channels</td>
<td></td>
</tr>
<tr>
<td>ASCAT Soil Moisture</td>
<td>Operational</td>
<td>8 (2,2,2,2)</td>
<td>H-SAF product operated</td>
<td></td>
</tr>
<tr>
<td>Polar Cap Winds from AVHRR</td>
<td>Operational</td>
<td>9 (3,2,2,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global AVHRR Winds</td>
<td>Operational</td>
<td>7 (3,2,1,1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triplet AVHRR Winds</td>
<td>Pre-operational</td>
<td>7 (3,2,1,1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polar Multi-sensor Aerosol properties over sea</td>
<td>Operational</td>
<td>9 (3,2,2,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polar Multi-sensor Aerosol (v2) including land</td>
<td>Pre-operational</td>
<td>8 (3,2,2,1)</td>
<td>Validation on-going</td>
<td></td>
</tr>
<tr>
<td>SRL</td>
<td>Name</td>
<td>Associated documents</td>
<td>Theory / Model</td>
<td>Observation</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------------------</td>
<td>----------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Scientific Idea</td>
<td></td>
<td>Scientific idea</td>
<td>Non</td>
</tr>
<tr>
<td>2</td>
<td>Conceptual Technique</td>
<td></td>
<td>Conceptual model, physical principal is clearly defined (no software is needed)</td>
<td>Gap analysis; complementary in observation system; uniqueness</td>
</tr>
<tr>
<td>3</td>
<td>Scientific / Observation Requirements</td>
<td>Mission proposal</td>
<td>Forward model is available (i.e. RTM simulation of measur.)</td>
<td>Initial capability assessment (Info content anal.)</td>
</tr>
<tr>
<td>4</td>
<td>Proof of concept</td>
<td>MRD</td>
<td>Consolidated approach 1st sim. obs are available</td>
<td>Simulated measurements</td>
</tr>
<tr>
<td>5</td>
<td>End-to-end performance simulations</td>
<td>Stable MRD, E2E (End-to-end simulator)</td>
<td>Consolidated retrieval and draft ATBD (+ prototype) are available</td>
<td>Demonstrator (e.g. airborne instr) “real data”</td>
</tr>
<tr>
<td>6</td>
<td>Consolidated science and products (end: launch of sat)</td>
<td>ATBD’s</td>
<td>Final ATBD and operational processor / implementation</td>
<td>Pre-launch</td>
</tr>
<tr>
<td>7</td>
<td>Demonstrated science (commissioning phase)</td>
<td></td>
<td>In orbit characterisations; perf vs. spec (EURD)</td>
<td>CAL/VAL conducted,; Early release of data; beta /demo data ava.</td>
</tr>
<tr>
<td>8</td>
<td>Validated and matured science (sat declared op)</td>
<td>Science feedback</td>
<td></td>
<td>Full validation</td>
</tr>
<tr>
<td>9</td>
<td>Science Impact quantification</td>
<td></td>
<td>Advancement in scientific understanding</td>
<td></td>
</tr>
</tbody>
</table>
Thank You
Questions?