UPDATE ON EUMETSAT’S PROGRAMMES & CALIBRATION ACTIVITIES

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EUMETSAT
Outline

• EUMETSAT Objectives

• EUMETSAT Programmes
  • Present
  • Future

• Calibration Activities
  • Vicarious Calibration
  • Inter-Calibration (through GSICS)
  • Other
EUMETSAT’s Objectives and Vision

EUMETSAT’s objectives:
1. To establish, maintain and exploit European systems of operational meteorological satellites
2. To contribute to the operational monitoring of the climate & the detection of global climatic changes
3. Furthermore, other environment monitoring issues are considered when interactions with the atmosphere or the ocean are involved

EUMETSAT’s vision:
- Be the leading user-governed operational agency for European Earth Observation satellite programmes that are consistent with the objectives of the EUMETSAT Convention and,
- Be a trusted global partner for the provision of satellite data from GEO and LEO orbits.
EUMETSAT’s strategy – Eight objectives

1. Deliver satellite programmes which meet the needs of EUMETSAT Member States;

2. Provide services based on cost-effective ground and space segment infrastructures which respond to evolving user requirements;

3. Meet additional needs of EUMETSAT Member States for global space-based observations through international cooperation;

4. Secure new opportunities in areas that are complementary to EUMETSAT’s programmes and meet Member States’ requirements;

5. Extend the user base for EUMETSAT data, products and service in EUMETSAT Member/Cooperating States and for WMO Members;

6. Be an active partner in European and Global initiatives of relevance to space-based weather, climate and environmental monitoring;

7. Deliver continuously improved management processes;

8. Recruit and maintain a core resource of talented and engaged people with relevant skills.
Geostationary satellites

Meteosat Second Generation (MSG)

• 4 geostationary weather satellites, operations at least until 2018 (MTG)

• Full disk imagery: Imaging European weather, every 15 minutes with 12 spectral bands (currently Meteosat-10)

• Rapid Scan Service (RSS) every 5 minutes (currently Meteosat-9): detection of rapid, local development of convective systems

• Data collection for environmental monitoring
EUMETSAT’s geostationary satellite coverage

- Meteosat-10 (0° Longitude)
- Meteosat-9 (9.5° E) (RSS)
- Meteosat-8 (3.5° E) (Back-up)
- Meteosat-7 (57.5° E)
Meteosat-8 12-hour “super rapid scan” experiments
(shown: 20 June 2013)

- Four days: 17 May, 17, 20 June, 29 July
- Enables research on convection and preparation for Meteosat Third Generation

[Map of Europe with weather conditions]

[Images of satellite images with time stamps: 2.5 Minutes, 5 Minutes, 15 Minutes]
Meteosat Third Generation (MTG)

- 4 MTG-I imaging and
- 2 MTG-S sounding satellites
  - both 3-axis stabilised

- Start of operations in 2018 and 2019,
  - for 15-20 years

- Imaging mission
  - Imaging Full Disc/European weather
    - every 10/2.5 minutes
    - with 16 spectral bands
  - new Lightning Imager

- Sounding mission (IR and UV)
  - Hyperspectral infrared sounder (IRS)
    - high-resolution soundings of
      - water vapour, temperature, O3 in 4D
  - Ultra-violet, Visible and NIR Sounder (UVN):
    - atmospheric chemistry and air quality monitoring
    - Copernicus Sentinel 4 Instrument
MTG Programme Status

• MTG-I Satellite:
  • schedule is stable with FAR (Flight Acceptance Review) in July 2018.
  • PDR of the LI is on-going.

• MTG-S Satellite
  • Most probable date for the MTG-S FAR is January 2021
  • Closure of the MTG-S PDR : October 2013
  • Closure of the S-4 PDR : November 2013
Current Polar-orbiting satellites: EUMETSAT Polar System

Dual operation of Metop-A and Metop-B

Metop-A launched in 2006: 21:30 Asc
Metop-B launched in 2012: +48 min

Metop-B prime satellite since April 2013

Metop-C launch planned for 2018

Part of Initial Joint Polar System shared with NOAA

Missions and Payload
• Imagery (VIS, IR), sounding (IR, MW, UV, GPS occultation), radar (ASCAT)
• direct broadcasting and data collection capabilities

Applications
• Numerical Weather Prediction and Nowcasting at high latitudes
• Marine meteorology and oceanography
• Air quality, atmospheric chemistry
## EPS-SG (Second Generation) Payload

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<th>Satellite-A Missions</th>
<th>Instrument (and Provider)</th>
<th>Predecessor on Metop</th>
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<tr>
<td>Infrared Atmospheric Sounding (IAS)</td>
<td>IASI-NG (CNES)</td>
<td>IASI (CNES)</td>
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<tr>
<td>Microwave Sounding (MWS)</td>
<td>MWS (ESA)</td>
<td>AMSU-A (NOAA)</td>
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<td></td>
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<td>MHS (EUM)</td>
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<td>Visible-infrared Imaging (VI)</td>
<td>METImage (DLR)</td>
<td>AVHRR (NOAA)</td>
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<tr>
<td>Radio Occultation (RO)</td>
<td>RO (ESA)</td>
<td>GRAS (ESA)</td>
</tr>
<tr>
<td>UV/VIS/NIR/SWIR Sounding (UVNS)</td>
<td>Sentinel-5 (Copernicus, ESA)</td>
<td>GOME-2 (ESA)</td>
</tr>
<tr>
<td>Multi-viewing, -channel, -polarisation Imaging (3MI)</td>
<td>3MI (ESA)</td>
<td>-/-</td>
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<table>
<thead>
<tr>
<th>Satellite-B Missions</th>
<th>Instrument (and Provider)</th>
<th>Predecessor on Metop</th>
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<tr>
<td>Scatterometer (SCA)</td>
<td>SCA (ESA)</td>
<td>ASCAT</td>
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<tr>
<td>Radio Occultation (RO)</td>
<td>RO (ESA)</td>
<td>GRAS (ESA)</td>
</tr>
<tr>
<td>Microwave Imaging for Precipitation (MWI)</td>
<td>MWI (ESA)</td>
<td>-/-</td>
</tr>
<tr>
<td>Ice Cloud Imager (ICI )</td>
<td>ICI (ESA)</td>
<td>-/-</td>
</tr>
<tr>
<td>Advanced Data Collection System (ADCS)</td>
<td>Argos-4 (CNES)</td>
<td>A-DCS</td>
</tr>
</tbody>
</table>
EPS-Second Generation (next generation of Metop satellites)

- Metop-SG Programme was approved by ESA Council
  - Approval of contract proposals for phases B2/C/D expected in April 2014
  - Phase B2 to be kicked off in July 2014

- EPS-SG End User Requirements Document was approved by Council as baseline for Phase B
  - Nine observation missions to be implemented with a two-satellite system serving 21 years of operation, first launch foreseen in 2021

- EPS-SG full programme approval expected in 2014
  - Cooperation with NOAA on JPS, signed in 2013
  - ESA as main development agency for the space segment
  - Provision of IASI-NG (Next Generation) by CNES
  - Provision of future imager METimage by DLR
Monitoring the oceans and climate in partnership

High precision altimetry

**Jason-2**
- launched in June 2008
- EUMETSAT’s first optional programme (new convention)
- Applications: marine meteorology, operational oceanography, seasonal prediction and climate monitoring

**Jason-3**
- under development, to provide continuity with Jason-2
- launch scheduled in April 2014

**Jason-CS**
- future programme under discussion with ESA, EC, NOAA in the context of Copernicus
- to provide continuity after Jason-3
Monitoring the oceans within Copernicus: Sentinel 3

EUMETSAT will operate the Sentinel-3 satellite for the European Copernicus programme

- Further response to the operational needs of the European marine (and climate) community,

Data provision with near-real-time and off-line products includes:
- sea-surface topography (radar altimetry);
- sea-surface temperature (advanced visible/thermal radiometer);
- ocean-surface colour (visible spectrometer).

*ultimately under ESA responsibility*
Calibration Activities at EUMETSAT

• On-board calibration monitoring
  • Gain, noise, stats, ...

• Vicarious Calibration using Pseudo Invariant Targets
  • Deserts
  • Rayleigh scattering
  • Deep Convective Clouds
  • Moon
    } MSG, MFG, MTG-FCI

• Inter-calibration – through GSICS
  • Pseudo Invariant Targets
    - As above wrt MODIS
  • Collocated Observations
    - IR: MSG, MFG, HIRS, MTG

• Support for Climate Services
  • Reprocessing & Recalibration based on above
  • Generation of Fundamental Climate Data Records
Inter-Calibration

- Inter-Calibration Corrections
  - Developed within GSICS

- GEO-LEO IR
  - Collocated observation (SNO)
  - Meteosat/SEVIRI-Metop/IASI
  - Pre-Operational
  - Including Uncertainty Analysis
  - Bias Monitoring
  - Used to support commissioning
  - Analysis of ice contamination
  - Developing Delta Correction to migrate references

- GEO-LEO VIS
  - Pseudo-Invariant Targets
  - In Development
  - for Meteosat/SEVIRI– Aqua/MODIS:
    - Deep Convective Cloud
    - Lunar

Example of EUMETSAT’s Bias Monitoring of Meteosat-9 for GSICS
Time series of standard bias in infrared channels of Meteosat-10/SEVIRI relative to Metop-B/IASI, expressed in brightness temperature [K].
- These comparisons used to generate inter-calibration corrections.
- Allow monitoring of instrument anomalies.
- The trend lines show steady degradation of the 13.4 μm channel’s calibration and sudden recoveries, following the spacecraft decontamination procedures.
- Validated model of how the ice contamination.
- Other channels (not shown) have small, stable biases.
Lunar calibration – EUMETSAT achievements

- Developed automatic lunar imagery extraction tool
- Extensive and unique archive of lunar images acquired by Meteosat-7, -8, -9 and -10
  - (for SEVIRI only, about 1030 images at low resolution and about 170 for HRVIS).
- EUMETSAT implementation of USGS ROLO model
  - (fully validated and tested with USGS)

➡ Enhanced monitoring and inter-calibration capabilities for reflective solar bands.
- Through collaboration with USGS and CNES
  - phase angle dependence was identified
  - Issue for GEO imagers (no choice on illumination)
  - should be corrected

\[ \Delta \text{Irradiance vs. } g \text{ for the MSG2/NIR1.6 channel} \]
Lunar calibration – EUMETSAT achievements

- Bias in irradiance = monitoring of the combined system instrument/calibration
- Gain on ROLO scale = monitoring of the instrument drift

Combining analysis = powerful monitoring tool

BUT phase angle dependence should be characterized and removed

**Annual Average Rate of Calibration Gain Drift**

*Bold = Moon results. In small italic = SSCC drift from all available runs.*

<table>
<thead>
<tr>
<th></th>
<th>VIS0.6</th>
<th>VIS0.8</th>
<th>NIR1.6</th>
<th>HRVIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meteosat-8</td>
<td>0.483 ± 0.014</td>
<td>0.444 ± 0.013</td>
<td>-0.013 ± 0.018</td>
<td>0.493 ± 0.059</td>
</tr>
<tr>
<td></td>
<td>(0.358 ± 0.228)</td>
<td>(0.367 ± 0.193)</td>
<td>(0.031 ± 0.180)</td>
<td>(0.398 ± 0.222)</td>
</tr>
<tr>
<td>Meteosat-9</td>
<td>0.475 ± 0.022</td>
<td>0.468 ± 0.020</td>
<td>0.033 ± 0.025</td>
<td>0.550 ± 0.062</td>
</tr>
<tr>
<td></td>
<td>(0.359 ± 0.255)</td>
<td>(0.467 ± 0.249)</td>
<td>(-0.051 ± 0.220)</td>
<td>(0.510 ± 0.285)</td>
</tr>
<tr>
<td>Meteosat-10</td>
<td>-0.841 ± 0.293</td>
<td>-0.665 ± 0.203</td>
<td>-0.365 ± 0.634</td>
<td>N.A.</td>
</tr>
<tr>
<td></td>
<td>(-0.590 ± 2.756)</td>
<td>(-0.318 ± 2.990)</td>
<td>(0.128 ± 2.222)</td>
<td>(-0.653 ± 2.752)</td>
</tr>
</tbody>
</table>

All SEVIRI within specifications for long-term drift
GSICS - Inter-calibration with MODIS – DCC

Implementation of the GSICS ATBD

• Deep Convective Clouds
  • inter-calibration transfer targets
• No need for simultaneous observations (DCC stability over time)
• Inter-calibration between all GEOs possible due to DCC global distribution (common calibration reference)

After BRDF correction to overhead sun

Monthly PDFs of DCC reference radiances (MODIS Aqua)

Monthly PDFs of DCC target counts (geostationary satellites [Meteosat])

\[
Gain_{Met9} = \frac{Aqua^{\text{Equiv.Nadir}}}{K_{\text{Met9}}} \cdot \frac{SBAF_{\text{MET9}/Aqua}}{K_{\text{Met9}} - K_0}
\]
Combining results

Example of the VI S06 band on MSG2/SEVI RI.
Grey/black big dots: SSCC gains.
Black small dots: gains as available in Level 1.5 image headers (derived from SSCC).
Blue dots: lunar calibration.
Magenta: DCC gains

Development of Multi-Mission Integrated Calibration Monitoring System
Summary

• **Calibration is key to ensuring EUMETSAT achieves its objectives:**
  1. To establish, maintain and exploit European systems of operational meteorological satellites
  2. To contribute to the operational monitoring of the climate & the detection of global climatic changes
  3. Furthermore, other environment monitoring issues are considered when interactions with the atmosphere or the ocean are involved

• **EUMETSAT continues to develop new calibration capabilities**
  • For real-time operations
  • and in support of climate reanalysis
  • In international cooperation, including
    • Global Space-based Inter-Calibration System
    • WGCV
Thank you