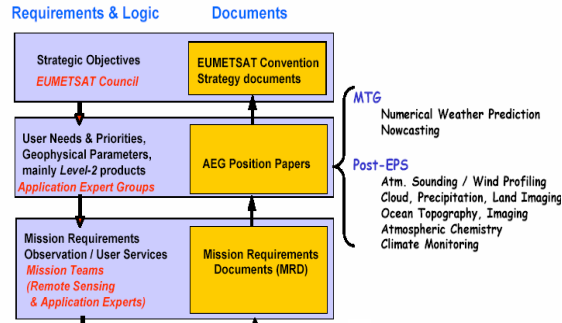
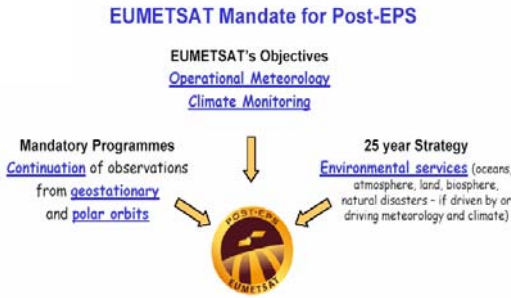


Definition of Mission Requirements for Clouds, Precipitation, Aerosol and Earth Radiation Budget for the follow-on EUMETSAT Polar System

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The Cloud, Precipitation and Large Scale Land Surface Imaging (CPL) Position Paper (Rizzi et al, 2005) defines technology free user requirements for cloud, precipitation, aerosols, Earth radiation budget, snow, soil moisture, vegetation and fire in the Post-EPS timeframe.

The Post-EPS Mission Requirements Document (MRD) defines a set of 18 missions aimed at meeting these user requirements. Expertise from Remote Sensing Scientists, the Post-EPS Mission Experts Team (PMET) and heritage observations has been drawn upon. The following missions are relevant to observations of clouds, precipitation, aerosol and Earth radiation budget:

- Visible/Infrared Imager (VII)
- Microwave Imager (MWI)
- Cloud and Precipitation Profiling Radar (CPR)
- Radiant Energy Radiometer (RER)
- Aerosol Profiling Lidar (APL)
- Multi-channel, multi-viewing, multi-polarisation imager (3MI).

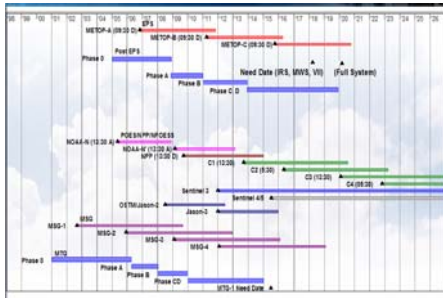
All position papers are available for download at www.eumetsat.int.

The Aerosol Profiling Lidar (APL)

- The sole source of the instrument requirements adopted for the APL is the ATLID concept outlined in the ESA Earth Explorer mission EarthCARE.
- The driving observations are
 - Aerosol optical thickness profile,
 - Optically thin cloud optical thickness profile,
 - Particle shape,
 - Altitude of cloud boundaries.
- In addition it will discriminate the molecular backscatter ("Rayleigh") from the aerosol and cloud particle returns ("Mie") using the High-Spectral Resolution (HSR) technique in order to determine the highly variable aerosol extinction to backscatter ratio.
- A single 355 nm wavelength lidar with a High Spectral Resolution (HSR) receiver separating Rayleigh and Mie backscatter returns is required.

The Radiant Energy Radiometer (RER)

- The Radiant Energy Radiometry mission (RER) measures radiance leaving the Earth's atmosphere for improving the understanding of the radiation budget and monitoring its effects on the Earth's climate.
- The major products to be derived from the Radiant Energy Radiometer are:
 - Solar radiation reflected to space from the Earth-atmosphere system.
 - Terrestrial radiation emitted to space from the Earth-atmosphere system.
- Spectral and radiometric requirements are given in tables 4 and 5.
- The RER is similar to the EarthCARE BBR but with an extra (lower priority) band, RER-3, for cloud radiative effects in the frame of process studies. The accuracy requirements for the RER are also more demanding coming from the Earth radiation budget monitoring community.



Channel number	Central Wavelength (µm)	FWHM (µm)	Primary Use	Priority
VII-4	0.443	0.01	Aerosol, 'true colour imagery' (blue channel)	1
VII-5	0.47	0.02	Aerosol, surface albedo, cloud reflectance, cloud optical depth, vegetation	2
VII-8	0.555	0.02	Clouds, vegetation, 'true colour imagery' (green channel)	1
VII-9	0.565	0.01	Cloud characterisation	2
VII-12	0.67	0.02	Clouds, vegetation, 'true colour imagery' (red channel)	1
VII-15	0.763	0.01	Cloud top height assignment	2
VII-16	0.763	0.04		2
VII-17	0.865	0.015	Vegetation, aerosol, clouds, surface features	1
VII-19	0.936	0.01	Water vapour	2
VII-20	0.94	0.05		1
VII-22	1.24	0.02	Cloud optical thickness, particle size distribution, vegetation, aerosol	2
VII-23	1.375	0.03	High level aerosol, cirrus clouds, water vapour imagery	1
VII-24	1.64	0.02	Cloud phase, snow, vegetation, aerosol, fire	1
VII-25	2.13	0.05	Cloud microphysics at cloud top, vegetation, fire (effects)	1
VII-26	3.75	0.18	Cloud parameters, cloud microphysics at cloud top, absorbing aerosol, SST, LST, fire, sea and land ice	1
VII-28	3.959	0.06	SST, LST, fire	2
VII-30	4.05	0.05	SST, LST, fire	2
VII-33	6.715	0.36	Water vapour imagery (including wind in polar regions), water vapour profile (coarse vertical resolution)	1
VII-34	7.325	0.3		1
VII-35	8.55	0.3	Cirrus clouds, cloud emissivity	1
VII-36	9.73	0.3	Total ozone	1
VII-37	10.8	1	Cloud parameters including cirrus detection, surface temperatures and other radiative parameters, surface imagery (snow, ice etc)	1
VII-38	11.03	0.3		2
VII-39	12.02	0.5		1
VII-40	13.335	0.3	CO ₂ slicing for accurate cloud top height, Temperature profile (coarse vertical resolution)	1

Table 1: The VII spectral characteristics and channel priorities

Channel name	Frequency (GHz)	Bandwidth (MHz)	Stability (MHz)	Primary Utilisation (secondary utilisation in brackets)	Priority
MW-3	6.9	350	50	SST, (LST, soil moisture)	2
MW-4	10.65	100	50	Sea surface wind, SST, (surface roughness correction for SST)	2
MW-5	18.7	200	50	Sea-surface wind, sea-ice, precipitation, surface correction for water vapour	1
MW-6	23.8	400	50	Total column water vapour over sea, precipitation	1
MW-7	31.4 or 36.5	1000	50	Sea-surface wind, sea-ice & snow, cloud liquid water, precipitation	1
MW-8	50.3	200	10	Precipitation over sea and land, drizzle, snowfall, temperature in cloudy areas	2
MW-9	52.61 or 52.80	400	100	Sea-ice & snow imagery, cloud liquid water, precipitation	1
MW-12	89.0	4000	TBC	Clouds and precipitation over sea and land	2
MW-13	100.49	TBC	TBC		2
MW-19	183.31±8.4	3000	100	Water vapour profile and snowfall	2
MW-20	183.31±6.1	1500	100		2
MW-22	183.31±3.4	1500	100		2

Table 2: The MWI spectral characteristics and channel priorities

Channel name	Frequency (GHz)	NE ΔF (K) (T/B/O)	Bias (K)	Polarisation (%)	IPST Size at 3dB (km) (T/B/O)
MW-3	6.9	0.35/0.3/0.25	0.25	V, H	50/40/30
MW-4	10.65	0.5/0.44/0.4	0.5	V, H	30/20/15
MW-5	18.7	0.6/0.5/0.44	0.5	V, H	20/15/10
MW-6	23.8	0.3/0.45/0.6	0.5	V, H	20/15/10
MW-7	36.5 or 31.4	0.6/0.5/0.42	0.5	V, H	20/15/10
MW-8	50.3	0.3/0.2/0.1	0.5	V, H	15/10/8
MW-9	52.61 or 52.80	0.3/0.2/0.1	0.5	V, H	15/10/8
MW-12	89.0	1.0/0.8/0.5	1.0	V, H	15/10/8
MW-13	100.49	TBC	TBC	V, H	15/10/8
MW-19	183.31±8.4	0.8/0.6/0.5	1.0	V, H	15/10/8
MW-20	183.31±6.1	1.0/0.75/0.5	1.0	V, H	15/10/8
MW-22	183.31±3.4	1.0/0.75/0.5	1.0	V, H	15/10/8

Table 3: The MWI radiometric requirements

Mission BAND	Central Wavelength (µm)	FWHM (µm)	Polarization	Primary Use	Priority
3MI-1	0.342	0.06 (TBC)	Y	Absorbing aerosol	2
3MI-2	0.388	0.06 (TBC)	Y		2
3MI-3	0.443	0.02	Y	Aerosol absorption and height indicators (TBC)	1
3MI-4	0.490	0.02	Y	Aerosol, surface albedo, cloud reflectance, cloud optical depth	1
3MI-5	0.555	0.02	Y	Surface albedo	3
3MI-6	0.670	0.02	Y	Aerosol properties	1
3MI-7	0.763	0.01	Y	Cloud height	2
3MI-8	0.765	0.04	Y	Cloud height	2
3MI-9	0.865	0.04	Y	Vegetation, aerosol, clouds, surface features	1
3MI-10	1.370	0.04	Y	Cirrus clouds, water vapour imagery,	1
3MI-11	1.650	0.04	Y	Ground characterisation for aerosol inversion	1
3MI-12	2.130	0.04	Y	Cloud microphysics at cloud top, Vegetation, fire (effects) Ground characterisation for aerosol inversion	1

Table 6: The 3MI radiometric requirements

The Visible/Infrared Imager VII

- The PEPS VIS/IR Imaging Mission (VII) is a cross-purpose medium resolution, multi-spectral optical imaging serving operational meteorology, oceanography and climate applications.
- Driving observations are clouds, aerosol and large scale land surface imagery.
- Spectral characteristics for priority 1 and 2 channels are given in table 1.
- Refinement of spectral and radiometric requirements will occur in frame of a multivariate analysis study.
- Spatial resolution at nadir is 500m for all channels with relaxation up to 1 km allowed for non-priority 1 channels. 250m resolution at nadir is preferred for the 670 and 865 nm channels.

The Microwave Imager (MWI)

- The primary objective of the Microwave Imaging mission is to support Numerical Weather Prediction at regional and global scales, through the provision of:
 - Cloud and precipitation products including bulk microphysical parameters
 - Total column water vapour, temperature and water vapour profiles (complementary to MWS)
 - All weather sea surface temperature (SST) and ocean salinity
 - Sea ice coverage (and type)
 - All weather snow (coverage, depth and water equivalent), and soil moisture products
 - All weather sea surface temperature and salinity
 - Water vapour imagery and total column water vapour
 - Sea surface winds (complementary to the scatterometer)
- To fulfil these observations, channels ranging 1.4 GHz to 664 GHz are required. This cannot be fulfilled with a single instrument so separate requirements have been defined for the following applications in order to assist mission subdivision and provide traceability to the applications:
 - Ocean and Land (1-4 GHz – 89 GHz)
 - Precipitation (10.65 – 183 GHz)
 - Cloud (36.5 – 664 GHz)

•A baseline configuration has been defined, based on AMSR-E heritage with additional channels for clouds and precipitation identified in a recent information content study [Bauer and Di Michele, 2007]. Spectral and radiometric requirements are given in tables 2 and 3.

The Cloud and Precipitation Profiling Radar (CPR)

The primary products to be derived from the CPR mission include:

- Precipitation profile (solid and liquid, including drizzle)
 - Freezing level height and melting layer depth in clouds
 - Cloud cover profile
 - Cloud liquid and ice water profile
 - Cloud top height and cloud base height
 - Cloud liquid and ice water total column
 - Secondary products include microphysical observations such as particle and drop size distributions (DSD).
- Specification is relatively immature. Preliminary specifications are given in tables 7-9.
- Possibilities for a baseline configuration include:
- Electronically scanning 35 GHz radar (sensitivity will not meet cloud requirements).
 - 35/94 GHz nadir dual frequency radar (better for cloud and DSD but no swath).
- Trade-off studies needed to optimise swath and sensitivity.

Band	Swath [km]/(T/B/O)
Ku	Nadir-only ≥200
Ka	Nadir-only ≥100
W	Nadir-only ≥50(TBC)

Table 7: The CPR swath width requirements

Approx. Frequency	Band	Use	Priority
14 GHz	Ku	Heavy precipitation profile	1
		Weak rain and snowfall profile	2
		Cloud liquid water and ice profile	3
35 GHz	Ka	Heavy precipitation profile	2
		Weak rain and snowfall profile	1
		Cloud liquid water and ice profile	2
94 GHz	W	Heavy precipitation profile	3
		Weak rain and snowfall profile	2
		Cloud liquid water and ice profile	1

Table 8: The CPR spectral characteristics and priorities

Band	Rainfall rate range near the surface (mm/h)	Max radar reflectivity cloud top (dBZ)	Radar sensitivity (dBZ)	Accuracy = $\frac{\text{Iabs error (mm/h)}}{\text{Iref error (mm/h)}}$				
				Threshold (mm/h)	Beamthrough (mm/h)	Objective (mm/h)	Objective (%)	
Ku	0.5-50	45	16	0.5	50	0.2	0.1	10
Ka	0.2-10	45	12	0.2	50	0.2	0.1	10
W	0.05-2.0 (or rain rates up to 2.0 mm/h)	30	-30	100%	50%		20%	

Table 9: The CPR radiometric requirements

Channel	Bandwidth	Purpose
RER-1	0.2 – 4.0 µm	Total solar radiation at TOA
RER-2	0.2 – 200 µm	Total radiance energy at TOA
RER-3	8 – 12 µm	Emitted radiance energy (TOA) in the main IR window region

Table 4: The RER radiometric requirements

Channel	Dynamic Range	Radiometric Noise	Absolute Accuracy/B.T
RER-1	0 – 350 W m ⁻² sr ⁻¹	0.3 W m ⁻² sr ⁻¹	0.5/0.8 W m ⁻² sr ⁻¹ @R<100 W m ⁻² sr ⁻¹ , else 0.5%/1%
RER-2	0 – 500 W m ⁻² sr ⁻¹	0.3 W m ⁻² sr ⁻¹	0.5/0.6 W m ⁻² sr ⁻¹ @R<100 W m ⁻² sr ⁻¹ , else 0.3%/0.5%
RER-3	0 – 30 W m ⁻² sr ⁻¹	0.3 W m ⁻² sr ⁻¹	0.3/0.5 W m ⁻² sr ⁻¹

Table 5: The RER spectral characteristics

The Multi-channel, Multi-viewing, Multi-polarisation Imager (3MI)

- The primary objective of the 3MI mission is to provide high quality imagery of aerosol parameters for climate records, etc. through the provision of:
 - Aerosol optical depths for accumulation, coarse and total modes at high horizontal resolution
 - Aerosol particle size for accumulation, coarse and total modes.
 - Aerosol type through Angstrom exponent, refractive index, non sphericity index.
 - Aerosol height index
- The current baseline specification of the mission is based on the heritage instrument POLDIER on board PARASOL, with the addition of channels in the UV for aerosol height inference (see table 6 for spectral characteristics).
- A second implementation of this mission, the 3MI', additionally considers aerosol and cirrus absorption by the inclusion of channels in the thermal infrared. The 3MI' concept also offers an opportunity to accommodate broad band radiometry channels on board. In this sense the 3MI' overlaps with the VII and RER. Pre-phase A studies will further explore the optimal instrument concept.

Next Steps

•ESA and EUMETSAT are commencing pre-phase A studies at instrument and system levels with the support of industry and representatives of the user and science communities. Studies are planned for completion in 2008 and aim at defining and trading off possible mission and system concepts.

•2nd user consultation workshop is scheduled for 2008.

Acknowledgments

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