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Abstract— ESA is currently running two parallel, competitive phase A/B1 studies for MetOp Second Generation (MetOp-SG). MetOp-SG is the space segment of EUMETSAT Polar System (EPS-SG) consisting of the satellites and instruments. The Phase A/B1 studies will be completed in the first quarter of 2013. The final implementation phases (B2/C/D) are planned to start 2013. ESA is responsible for instrument design of five missions, namely Microwave Sounding Mission (MWS), Scatterometer mission (SCA), Radio Occultation mission (RO), Microwave Imaging mission (MWI), Ice Cloud Imaging (ICI) mission, and Multi-viewing, Multi-channel, Multi-polarization imaging mission (3MI). This paper will present the instrument main design elements of the 3MI mission, primarily aimed at providing aerosol characterization for climate monitoring, Numerical Weather Prediction (NWP), atmospheric chemistry and air quality. The 3MI instrument is a passive radiometer measuring the polarized radiances reflected by the Earth under different viewing geometries and across several spectral bands spanning the visible and short-wave infrared spectrum. The paper will present the main performances of the instrument and will concentrate mainly on the performance improvements with respect to its heritage derived by the POLDER instrument. The engineering of some key performance requirements (multi-viewing, polarization sensitivity, etc.) will also be discussed.

Multi-viewing, Multi-channel, Multi-polarisation imaging mission (3MI), polarimetry, POLDER, BRDF, Aerosols

I. INTRODUCTION

Since 2006, the European contribution to operational meteorological observations from polar orbit has been provided by the first generation of Meteorological Operational (MetOp) satellites. The MetOp Second Generation (MetOp-SG) series of satellites will provide continuity and enhancement of these observations in the timeframe of 2020 to 2040.

The MetOp-SG programme is being implemented in collaboration with EUMETSAT. ESA develops the prototype MetOp-SG satellites (including associated instruments) and procures, on behalf of EUMETSAT, the recurrent satellites (and associated instruments). EUMETSAT is responsible for the overall mission, funds the recurrent satellites, develops the ground segment, procures the launch and LEOP services and performs the satellites operations. The corresponding

EUMETSAT Programme is termed the EUMETSAT Polar System – Second Generation or EPS-SG.

The payload of the MetOp-SG satellites consists of the following instruments:

The visible and infrared imager (METImage), to provide information on clouds, cloud cover, land surface properties, sea, ice and land surface temperatures, etc.; the Infrared Atmospheric Sounding Interferometer–New Generation (IASI-NG), to provide atmospheric temperature and humidity profiles, as well as monitor ozone and various trace gases; the MicroWave Sounder (MWS), to provide atmospheric temperature and humidity profiles; the SCATTERometer (SCA), to provide ocean surface wind vectors and land surface soil moisture; the Radio Occultation sounder (RO), to provide atmospheric temperature and humidity profiles, as well as information about the ionosphere, the Sentinel-5 (S-5) instrument, to monitor various trace gases, air quality and support climate monitoring; the MicroWave Imager (MWI), to provide precipitation monitoring as well as sea ice extent information; the Ice and Cloud Imager (ICI), to measure cloud ice water path, properties and altitude; the Multi-viewing, Multi-channel, Multi-polarization Imager (3MI), to provide information on atmospheric aerosols; and the Data Collection System Argos-4, for the collection and transmission of observations and data from surface, buoy, ship, balloon or airborne data collection platforms.

From the above, the MWS, SCA, RO, MWI, ICI and 3MI instruments are developed under the ESA MetOp-SG Programme, while the Sentinel-5 instrument is developed by ESA under the GMES Space Component (GSC) Programme. The other instruments are provided through EUMETSAT under cooperation agreements with its partners DLR and CNES, and will be provided as Customer Furnished Items to the MetOp-SG contractor.

Targeting an operational system of 21 years of operations, the current baseline foresees the implementation of the above payload complement in a two parallel series of satellites (designated as ‘Satellite A’ and ‘Satellite B’) in a three units per series (so-called “3+3” configuration).

The currently on-going parallel Phase A/B1 studies will be completed in the first quarter of 2013, while the final implementation phases (B2/C/D) are planned to start in 2013.

II. THE 3MI MISSION OBJECTIVES AND BENEFITS

The 3MI mission is primarily aimed at providing aerosol characterization for climate monitoring, Numerical Weather Prediction (NWP), atmospheric chemistry and air quality. High quality aerosol imagery delivered by the 3MI mission will facilitate the measurement of all essential aerosol parameters for climate records, such as aerosol optical depths, particle types and sizes, refractive index, sphericity and height index. When used as constrains to the models, these products will be used to provide improved Air Quality Index and Aerosol Load Masses for different particles sizes.

Secondary mission objectives include the measurement of surface albedo as well as improved cloud characterization. More specifically, the mission will facilitate the measurement of surface albedo via the observation of the surface BRDF, made possible by the unique multi-angular measurement concept adopted. Similarly, while METimage will provide information on most cloud properties, the multi-viewing and multi-polarization measurements delivered by the 3MI mission will allow for accurate characterization of the extension, optical depth, particle size as well as asphericity factor and crystal orientation of cirrus clouds. While currently, aerosol and cirrus parameters are mostly used in General Circulation Models for climate simulation and prediction, utilization of these parameters is becoming increasingly important in operational NWP as the representation of radiative processes in the atmosphere is a recognized area of deficiency. Hence, the 3MI mission is expected to be of great benefit to both real-time and non-real-time user communities.

The mission will also contribute to artifact correction on other sensors (e.g. Infrared Atmospheric Sounding Sensor – IASING, the VIS/IR Imager – METimage, and the Ultra-Violet /Visible/Near Infrared/Short Wave Infrared spectrometer – UVNS/S5).

III. HISTORICAL PERSPECTIVE

The measurements from several optical passive satellite instruments are currently used for aerosol retrieval. Most rely on measurements of the reflected signal from the Earth-atmosphere system at several wavelengths but only one viewing angle. With this type of instruments it is possible to derive Aerosol Optical Thickness (AOT) as well as some quantitative aerosol microphysical properties, however, these retrievals heavily depend on the underlying aerosol model assumed. The MODerate resolution Imaging Spectroradiometer (MODIS) on Aqua and Terra satellites (NASA), the MEdium Resolution Imaging Spectrometer (MERIS) on board Envisat satellite (ESA) and the Advanced Very High Resolution Radiometer (AVHRR) on board Metop satellite (EUMETSAT) are typical examples. Some instruments do offer multi-view capability, such as the Multiangle Imaging SpectroRadiometer (MISR) on board Terra satellite (NASA) or the Advance Along Track Scattering Radiometer (AATSR) on

board Envisat satellite, nevertheless they lack multi-polarisation capability.

Aerosol properties can only be unambiguously determined by instruments that can measure both intensity and polarisation at several viewing angles. The only instrument designed specifically to do exactly that is the POLDER instrument [1]. Developed by CNES, POLDER-1 and POLDER-2, respectively launched in 1996 and 2002 on board the Japanese satellites ADEOS (ADvanced Earth Observation Satellite) and ADOES-2 [2], were short-lived. POLDER-3 [3] followed in 2004 on board the PARASOL satellite (A-train) and still delivers its measurements today, having the highest aerosol retrieval capability of all other passive instruments currently in space. The Aerosol Polarimetric Sensor (APS), which was designed to provide even higher polarimetric accuracy and a larger number of viewing angles [4], unfortunately failed during launch of the Glory satellite in March 2011.

3MI is an evolution of the POLDER-3 / PARASOL instrument. It will therefore provide similar type of measurements (multi-angle, multi-wavelength and multi-polarisation) nevertheless with an improved spatial resolution (4 km at nadir) and coverage, and over an extended spectral range (400 to 2100 nm). In what follows, these improvements with respect to POLDER will be explicitly described.

IV. THE 3MI MEASUREMENT CONCEPT

The 3MI instrument collects accurate observations of the polarised and directional solar radiation reflected by the Earth-atmosphere system, by sampling the polarised BRDF of all targets within the swath of the instrument at several spectral channels and polarisations. In order to facilitate the ‘multi-viewing’ type of measurements, 3MI adopts a similar to the POLDER instrument concept, upon which overlapping 2D images on the surface of Earth are recorded consecutively at regular points along the orbit (called along-track (ALT) acquisition points) thus providing the means to sense the Top of Atmosphere (TOA) radiance at different Observation Zenith Angles (OZAs) for each target. This is schematically shown in the next figure (Fig. 1).

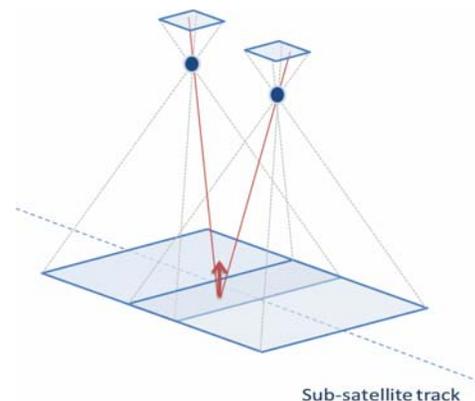


Figure 1. The 3MI measurement concept – This examples shows two images recorded in two along-track acquisition points

The multi-wavelength and multi-polarisation measurement capability is facilitated by means of a continuously rotating filter wheel. The 3MI instrument is providing a number of spectral channels spanning over an extended (compared to that of POLDER) spectral range, from 410 nm to 2130 nm. To achieve this, 3MI features two optical modules (VNIR and SWIR), each made of a dedicated telescope and focal plane assembly, both sharing a single filter wheel hosting all necessary spectral filters and polarisers. All spectral channels within each module are thus recorded sequentially, while, for the polarised ones, three consecutive polarisation measurements are taken with a linear polarizer oriented at +60, 0, and -60 degrees respectively, mounted in series with the corresponding spectral bandpass filters on the filter wheel.

The proximity of the consecutive ALT acquisition points determines the number and the angular spacing of the acquired views for each target on ground, while the rotation speed of the filter wheel determines the temporal and angular co-registration of the various spectral channels of the instrument in each view. Typically, the filter wheel rotates several times between two consecutive ALT acquisitions even though measurements are acquired during only one (typical) of those.

In 3MI, all channels are acquired (in any given ALT acquisition) in less than 7 sec during a single filter wheel rotation, while the distance between two consecutive ALT acquisitions is in the order of 22 sec. In the current instrument baseline, the two modules feature different ALT FOVs which has an impact both on the number of OZAs acquired per target and also on the OZA sampling range achieved for the two different groups of channels. The VNIR module features a FOV of $\pm 50.2^\circ \times \pm 50.2^\circ$ (ACT x ALT respectively), while the 3MI SWIR module features a FOV of $\pm 50.2^\circ \times \pm 30^\circ$ (ACT x ALT respectively). Due to this difference and given the timings mentioned earlier, this leads to approximately 14 and 6 OZAs views for each target within the swath of the instrument for the VNIR and SWIR groups respectively. The angular sampling range will also vary accordingly between the two modules (see following sections). It is possible however to increase the number of angular samples in the SWIR module by implementing the so-called angular ‘oversampling’, whereby additional images are obtained, only for the SWIR channels, using one of the extra rotations of the filter wheel in-between the two nominal ALT acquisitions (during which the instrument would otherwise remain idle). These extra samples, however, cannot be co-registered with the VNIR ones.

One direct consequence of the adopted measurement concept is that, during any given pass of the satellite, a set of views is collected, which are nevertheless different for different targets on Earth. Fig. 2 demonstrates this, reporting the OZAs recorded for various targets on the sub-satellite track (from the VNIR module), between two sub-satellite points corresponding to two consecutive ALT acquisition points. The horizontal axis reports the normalised distance of a given target between those two points. It can also be seen from this figure that the angular sampling interval among the different angular samples collected for each target is not constant either (varies from about 5 deg to approximately 12 deg) and also different for different targets. Still, this irregular sampling is thought to

facilitate improved accuracy of the aerosol specific retrieval algorithms.

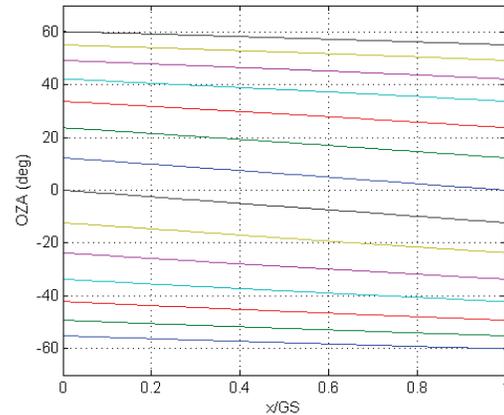


Figure 2. OZA sampling for targets on the sub-satellite track of 3MI (assumed ALT FOV = 50.2°)

Fig.3 shows the 3MI (VNIR) footprint when the satellite crosses the equator indicating the range of different OZAs recorded by the instrument for the different targets on Earth in a single image acquisition.

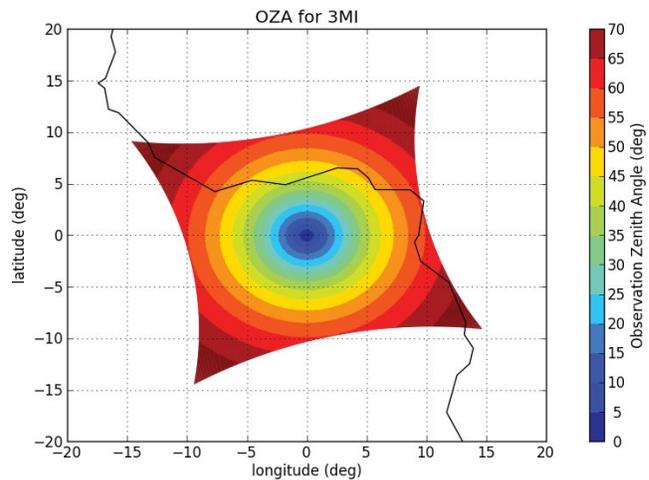


Figure 3. Footprint of 3MI VNIR channels

V. 3MI INSTRUMENT CHARACTERISTICS AND KEY PERFORMANCES

A. 3MI Swath and Coverage

3MI features a minimum swath of 2200 km. This compares with the 1366 km of the POLDER3/PARASOL instrument. The swath of 3MI is much larger due to both the higher altitude of the MetOp-SG orbit (see Table I) as compared with that of Parosol/A-train (705 km) as well as the increased ACT FOV of the instrument ($\pm 50.2^\circ$ of 3MI compares with $\pm 42.6^\circ$ of POLDER3). Fig. 4 shows the footprints of the two instruments in same scale for cross-comparison (only the VNIR is shown for the 3MI in this figure).

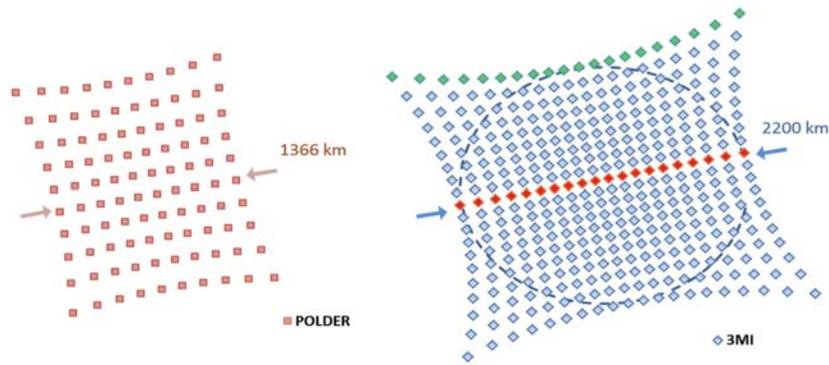


Figure 4. Comparison of the 3MI (right) and POLDER3 (left) footprints and swaths. Shown number of samples is only for visualisation.

It is noted that the swath of the instrument is driven by the projection of the central detector line of the instrument on the Earth's surface (otherwise called the *nadir view* of the instrument and shown in red in Fig. 4). Assuming a rectangular detector is used, the other views (off-nadir) will typically cover an even larger swath and the corresponding area on Earth will include that covered by the nadir view swath. This is demonstrated schematically in Fig. 5 showing the swath scanned by the nadir-view and the extreme off-nadir view (50° off-nadir – shown in green in Fig. 4) of the instrument (yaw steering control is assumed to be on).

TABLE I. METOP-SG VS. PARASOL ORBIT

Orbital elements	MetOp-SG	PARASOL
Semi-major axis (km)	7195.605	7083.137
Eccentricity	0.001165	0.0012
Argument of perigee (deg)	90	90
Inclination (deg)	98.701	98.2
LTAN	21:30	13:30

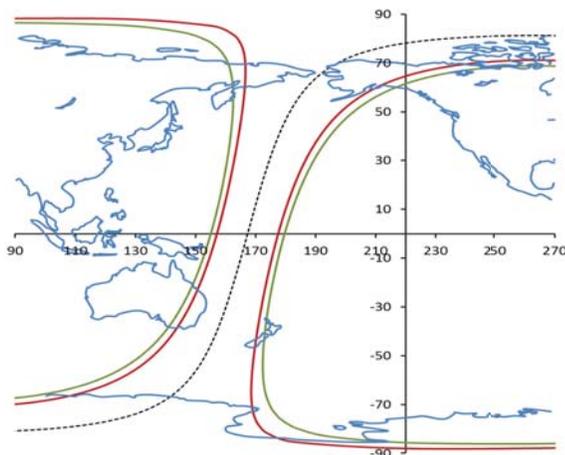


Figure 5. Yaw steering ensures that the area scanned by the nadir view of the instrument is also covered by the other (off-nadir) views. The dark dotted line is the sub-satellite track.

Finally, Fig.6 gives the variation of the swath of the instrument together with the variation of the altitude in the actual MetOp-SG orbit (the orbital elements of Table I have been assumed).

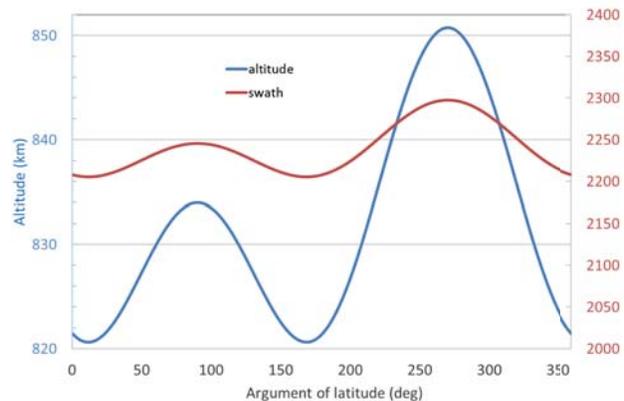


Figure 6. Variation of altitude and swath of 3MI along the MetOp-SG orbit

B. Illumination Geometry

The illumination geometry of the 3MI mission is obviously of great interest for the retrieval accuracy of the final products. For aerosol properties retrieval, both the sun illumination angle, described by the Sun Zenith Angle (SZA), as well as the Scattering Angle (SCA), defined as the π supplement of the angle formed by the direction of sun illumination and the satellite viewing direction in the target reference frame, is of particular importance. In Fig. 7 & Fig.8, we provide respectively the SZA and SCA angles (only the SCA angles achieved by the nadir view of the instrument is shown for simplicity), for both the 3MI and POLDER-3. Their difference is obviously due to the different orbits of the two instruments. It is worth noting that, for 3MI and for a larger part of its swath (compared to that of POLDER3), scattering angles closer to 90° are achieved.

C. Spatial Sampling

The spatial sampling distance (SSD) of 3MI in both the along track and across track directions at nadir is less than 4km square over the full MetOp-SG orbit.

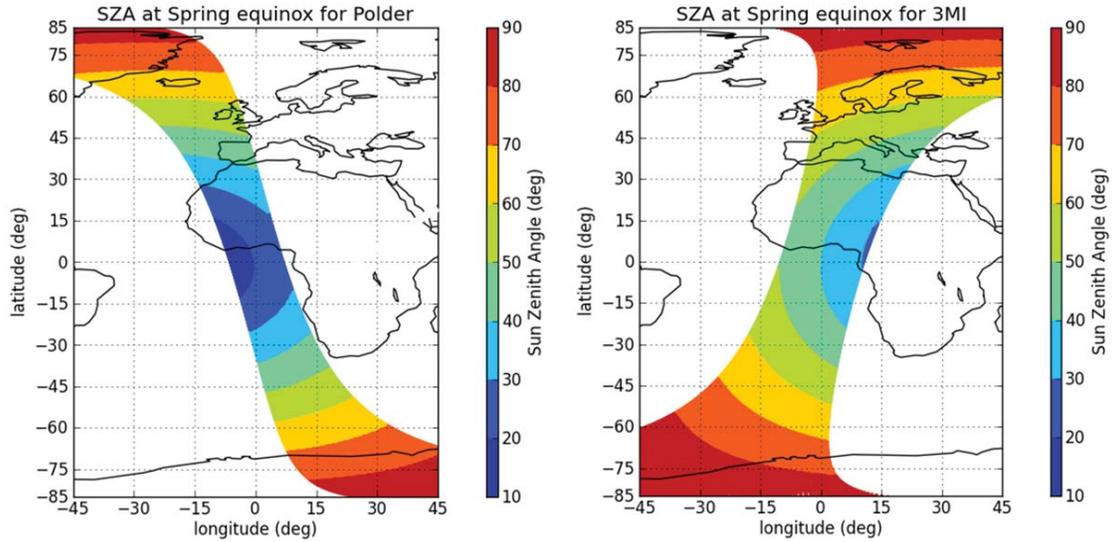


Figure 7. Sun Zenith Angle for POLDER-3 and 3MI

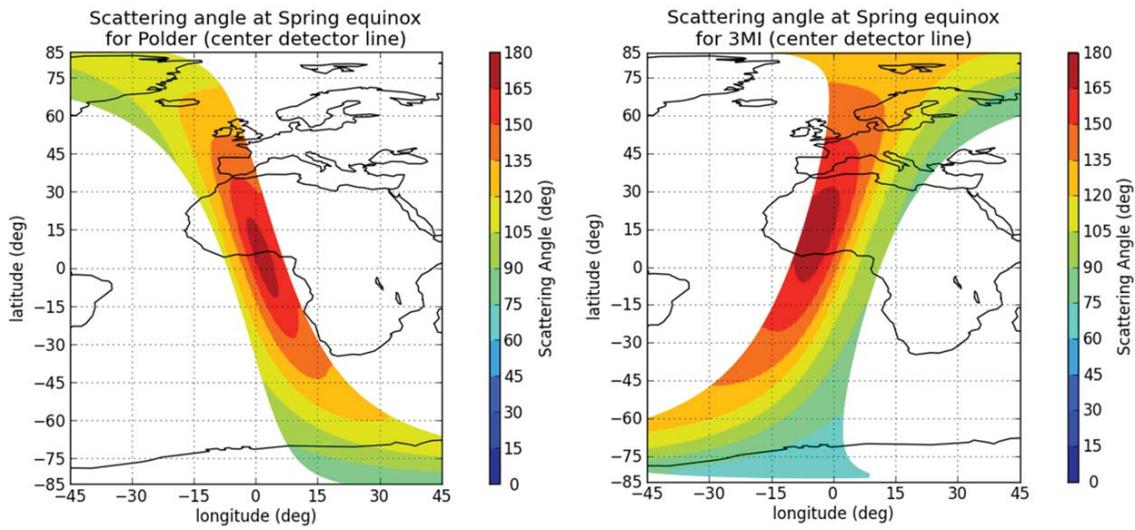


Figure 8. Scattering Angle for POLDER-3 and 3MI (only the nadir view of the instruments is shown)

This compares with approximately 6 km of POLDER-3. The focal length of the VNIR and SWIR modules is adjusted accordingly to match this performance given the pixel size at detector level and considering the variation of the altitude during mission. Currently, both detector planes feature square detector pixels and a pixel size in the order of 25-30 μm . It is stressed that the aforementioned spatial sampling distance (4 km) is applicable only for the nadir point of the instrument. It will naturally increase as we move off-nadir, due to the combination of the mapping law of the instrument (for 3MI this is an $f\text{-tan}(\text{THETA})$ law) and the curvature of the Earth. The way the SSD of 3MI varies across its FOV is depicted in Fig. 9 for an image acquisition performed over the equator. Shown are samples collected by the instrument nadir view (central detector raw) and samples collected by the extreme off-nadir view (red and green set of samples in Fig. 4 respectively).

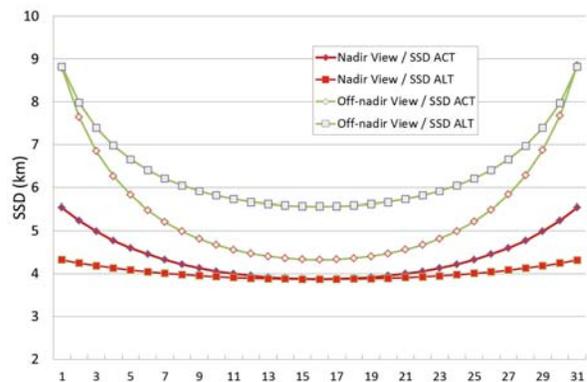


Figure 9. Spatial sampling distance variation across the filed of view of 3MI (red and green colours as of Fig. 4)

TABLE II. 3MI SPECTRAL BANDS

	PARASOL POLDER				3MI - Start of Phase A				3MI - End of Phase A		
	Central Wavelength (nm)	Bandwidth (nm)	Polarisation		Central Wavelength (nm)	Bandwidth (nm)	Polarisation		Central Wavelength (nm)	Bandwidth (nm)	Polarisation
VIS-NIR				354	10	Y		410	20	Y	
				388	20	Y					
		443	20	N	443	20	Y	443	20	Y	
		490	20	Y	490	20	Y	490	20	Y	
		565	20	N	555	20	Y[G]/N[R]	555	20	Y	
		670	20	Y	670	20	Y	670	20	Y	
		763	10	N	763	10	N	763	10	N	
		765	40	N	754[G] / 765[R]	20[G] / 40[R]	N	754	20	N	
		865	40	Y	865	40	Y	865	40	Y	
		910	20	N	910	20	N	910	20	N	
	1020	20	N								
SWIR				1370	40	Y	1370	40	Y		
				1650	40	Y[G]/N[R]	1650	40	Y		
				2130	40	Y	2130	40	Y		

D. Spectral Bands

The 3MI spectral bands are shown in Table II. For comparison this table contains also the POLDER-3 spectral bands as well as the bands of 3MI at the beginning and the end of the Phase A studies. This last table is the current 3MI baseline. Red color is used to indicate the main differences. The extension of the spectral coverage of 3MI towards both sides of the spectrum is evident from this table. Channels 354 nm and 388 nm, were originally considered for 3MI, however, they were finally replaced by the channel at 410 nm, in order to reduce risk and maintain affordability of the instrument. Another significant improvement with respect to POLDER-3 is also the increase of the number of polarized channels now baselined for 3MI (9 as compared to 3 of POLDER3). [G] and [R] symbols in the table, stand for ‘Goal’ and ‘Threshold’ values as used during the execution of the Phase A trade-off studies. In this Table, one can also see how the various 3MI channels are shared between the two instrument modules. It is noted however that a duplicate of the 910 nm channel is also included in the SWIR module in the current baseline for spatial co-registration purposes.

E. Angular Sampling Range

The aforementioned differences in the ALT FOV between the two 3MI modules (VNIR & SWIR) in the current baseline, result in a reduced angular sampling range between the two groups of channels accordingly. Table III summarizes the predicted performances.

TABLE III. 3MI ANGULAR SAMPLING PERFORMANCES

	VNIR channels	SWIR channels
Number of views	≥ 14	≥ 12 ^a
OZA sampling range ^b	≥ 110°	≥ 50°

a. 6 of 12 are not co-registered with VNIR channels
b. Refers to targets on the sub-satellite track

F. Polarisation Sensitivity

Assuming measurement of a stable, spatially uniform and linearly polarised scene, the polarisation sensitivity of the instrument is defined as $PS = (S_{max} - S_{min}) / (S_{max} + S_{min})$, where S_{max} and S_{min} are the maximum and minimum sample values respectively obtained when the polarisation is gradually rotated over 180 deg. Being one of the key performances of the 3MI instrument, a lot of effort has been dedicated during the Phase A studies to correctly predict this performance and tailor the design of the instrument to meet the relevant specifications. Our studies have shown that the polarisation sensitivity is mainly degraded at increasing off-axis angles mainly due to the introduction of ellipticity to the input linear polarisation at these incidence angles from the anti-reflection (AR) coatings of the camera lens. Table IV shows the predicted performances of the 3MI current baseline for samples acquired with an $OZA \leq 60^\circ$ and for samples acquired with an $OZA > 60^\circ$. Fig. 10 gives a typical example of the behavior of polarisation sensitivity across the FOV of the instrument, for both a polarised and a non-polarised channel.

TABLE IV. 3MI POLARISATION SENSITIVITY PERFORMANCES

3MI channel	Polarisation Sensitivity	
	OZA ≤ 60°	OZA > 60°
All 3MI polarised channels (except 410 nm)	> 0.96	> 0.94
410 nm channel	> 0.93	> 0.91
All 3MI non-polarised channels	< 0.05	< 0.07

G. Radiometric Accuracy and Resolution

Similarly to the POLDER instrument, 3MI does not feature an on-board calibration system. Its absolute radiometric calibration cannot be subsequently guaranteed at instrument level, but will be subject to the accuracy of the vicarious

calibration campaigns to be performed during the lifetime of the instrument. As a result, the output product of 3MI at instrument level (conventionally noted as Level 1b1), will be subject to absolute radiometric scaling and correction during the actual operations.

The radiometric resolution on the other hand will be guaranteed at instrument level for the full lifetime of the mission. A signal-to-noise ratio (SNR) of 200 is specified for a range of Top-of-Atmosphere radiances between L_{ref} and L_{max} , where the ratio of L_{max}/L_{ref} is approximately 11 for all spectral bands.

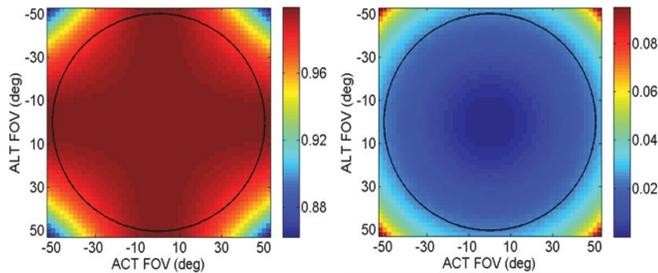


Figure 10. Typical example of polarisation sensitivity performances for a polarised (left) and a non-polarised (right) 3MI channel

VI. THE 3MI INSTRUMENT DESIGN

The two parallel AB1 studies are currently on-going. The 3MI instrument concept which was adopted following the feasibility phase (Phase A) is a very similar one to the one proposed at the end of the previous Phase 0 studies, and, as already mentioned, draws largely on the design heritage of the POLDER instrument. Fig. 11 depicts this concept.

A. 3MI Structure

The main structural element of 3MI is the optical bench used to sustain the two optical modules (camera optics + housing + baffling) as well as the filter wheel assembly consisting of the filter wheel mechanism and the filter wheel itself. This structure is then isostatically mounted on a baseplate, this being the mechanical interface with the platform. Thermal hardware and proximity electronic are also

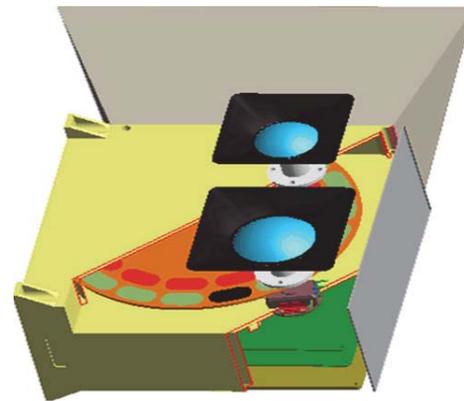
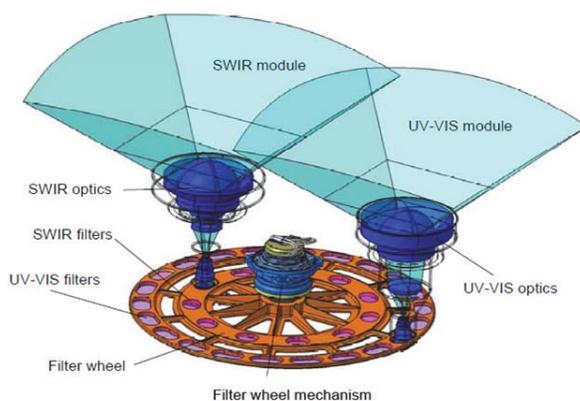


Figure 11. The 3MI instrument design concept (figures are from the Phase 0 studies)

mounted on the baseplate. Focal plane assemblies can be then either mounted on the optical bench or on the baseplate itself.

B. Number of modules

Currently two modules are foreseen for 3MI. The two modules are similar in form and function and are meant to cover respectively the two different specified spectral domains of the instrument (VNIR & SWIR). Channel 3MI-9a (910 nm) is to be included in both modules.

C. Telescope design / per module

Each module features a wide FOV dioptric telescope (minimum $\pm 57^\circ$ diagonal). The optical design is telecentric and deploys several optical elements, some of which including aspheric surfaces. High performance / low polarization anti-reflection (AR) coatings are deployed on all surfaces to meet the stringent straylight and polarization sensitivity requirements of the instrument. All optical heads feature a minimum ACT FOV of $\pm 50.2^\circ$. From the MetOp-SG orbit this offers a swath of 2200 km and a full daily coverage of the globe with small gaps at equator. The ALT FOV of the VNIR module is also approximately $\pm 50^\circ$, while for the SWIR module a reduced ALT FOV (approximately $\pm 30^\circ$) is adopted to align it with the selection of the SWIR detector.

D. Spectral separation

Measurement of the different spectral channels and polarizations is performed sequentially in time and facilitated by a rotating filter wheel performing one revolution in less than 7s each time and which is placed between the optical heads and the focal plane assemblies. The wheel features two concentric rings each accommodating the filter slots for the VNIR and SWIR modules respectively. Filter elements are typically a combination of Fabry-Perot (all dielectric) and blocking substrates (coloured glass). Neutral density filters are also used to regulate the input intensity to manageable levels. One filter wheel is used to serve both modules.

E. Focal Plane assembly (FPA) and Thermal Control

Two-dimensional large format detectors are used on all modules. Charged Coupled Devices (CCD) and photovoltaic HgCdTe detectors hybridized on top of a CMOS Read-Out Integrated Circuit (ROIC) are proposed for the VNIR and SWIR modules respectively. In order to reduce the dark current, the SWIR FPA is cooled down to 180K-190K via means of passive cooling (radiator), and its temperature stabilized using controlled heater circuits.

VII. CONCLUSIONS

The 3MI mission will form part of the MetOp-SG programme being implemented in collaboration with EUMETSAT and targeting an operational system of 21 years of operations. The 3MI measurements will allow for the retrieval of the properties of atmospheric aerosols with an accuracy better than any current optical mission. In this paper we presented the main performance and design characteristics of the instrument as it is currently baselined following the on-going feasibility studies.

REFERENCES

- [1] P. Deschamps, F. Bréon, M. Leroy, A. Podaire, A. Bricaud, J. Buriez, and G. Sèze, "The POLDER mission: Instrument Characteristics and Scientific Objectives," *IEEE Transactions On Geoscience and Remote Sensing*. 32(3), 1994, pp.598-615.
- [2] <http://smc.cnes.fr/POLDER/index.htm>
- [3] <http://smc.cnes.fr/PARASOL/>
- [4] <http://glory.gsfc.nasa.gov/overview-aps.html>