Ocean Colour Radiometry – Virtual Constellation (OCR-VC)
Implementation Strategy and Plan
Phase I (2008- ca. 2012)

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Submitted to SIT on behalf of the OCR-VC Leadership by
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Background

The OCR Virtual Constellation (OCR-VC) will provide calibrated ocean-colour radiances (OCR) at key wavelength bands. Ocean colour radiance is the wavelength-dependent solar energy captured by an optical sensor looking at the sea surface. Water-leaving radiances contain latent information on the optical constituents of sea water, in particular the pigments (primarily chlorophyll-a) contained in the phytoplankton. Less than 10% of the OCR signal backscattered from seawater reaches satellite sensors owing to absorption and scattering by atmospheric molecules and aerosols aerosols, and thus correcting for the atmospheric contribution is an absolute requirement to product calibrated OCR from satellite altitudes.

The key space segment capabilities are the current and future polar-orbiting global OCR satellite missions (see figure 1). Of specific interest are SeaWiFS, MERIS on Envisat, MODIS-Aqua, OCM on Oceansat-2, OLCI on Sentinel 3A and 3B, SGLI on GCOM-C, VIIRS on NPOESS-C1, possibly VIIRS on NPP, and future NASA and CNES instruments under consideration. Other instruments such as China's COCTS (HY-1B) and Korea's planned GOCI are also of interest but are not collecting global data.

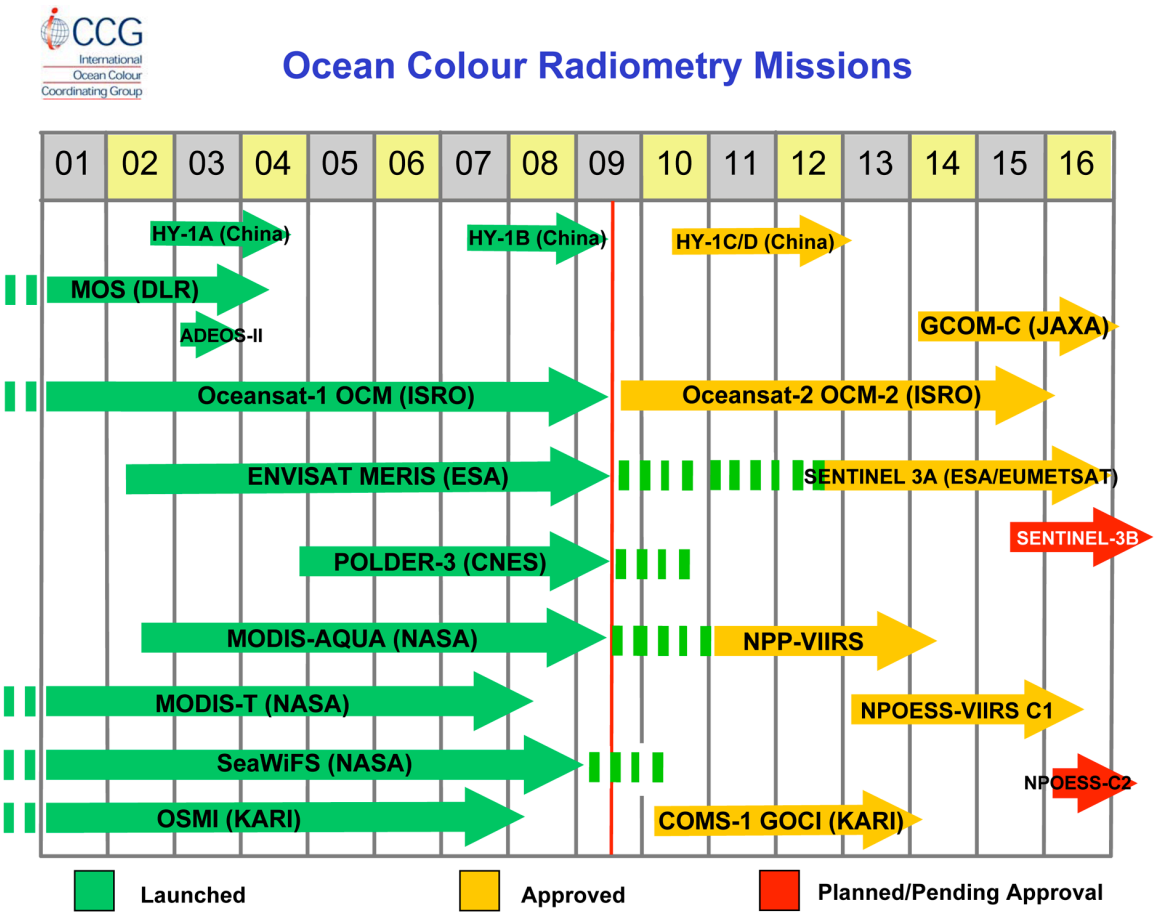

Figure 1. *Past, current and planned ocean-colour radiometry missions.*

Cross-calibrated OCR data from multiple satellites will be merged to provide an Essential Climate Variable (ECV) (or Fundamental Climate Data Record, FCDR) of water-leaving radiances from which scientific data products related to marine ecosystems and ocean biogeochemistry for near-surface global ocean and coastal waters are calculated. Wavelengths centered at 412, 443, 490, 510, 531, 555, 620, 670, 681 and 709 nm are the most useful for deriving OCR data products (see next paragraph). To accurately calculate the effect of the atmosphere on the water-leaving radiance reaching satellite altitudes requires additional measurements in the near-infrared.

The most important OCR data products currently in use are phytoplankton chlorophyll-a concentration, coloured organic matter (COM), particulate organic carbon, and suspended sediments. Other products are in development. OCR data products are the only measurements related to biological and biogeochemical processes in the ocean that can be routinely obtained at ocean basin and global ocean scales.

The Global Climate Observing System (GCOS) requirements for OCR provide a concise summary statement as to the value of OCR data (GCOS-107, WMO/TD No. 1338, September 2006): "The primary benefits of OCR to GCOS are climate monitoring; chlorophyll-a linked to carbon-cycling including between the ocean and the atmosphere;

and ocean particulate carbon estimated from ocean colour. Other applications include essential information for natural living-resource management and monitoring of the health of coastal seas." **Most of the tasks identified in this document under Objectives 1-3 are directly related to these GCOS requirements. Specific GEO Tasks are also associated with objectives and sub-objectives.**

The OCR-VC also has important responsibilities for promoting and encouraging data inter-operability. Specific goals are to seek agreement on data product specification/definition and inter-traceable calibration/validation to ensure that multiple sensor data will contribute to societal benefit areas and to research leading to new products and applications. Capacity building is an important activity, so that data can be effectively shared and used by all collaborating organizations.

Space agency representatives to the IOCCG make up the leadership of the OCR-VC. Two OCR-VC co-chairs from this group (currently JAXA's Hiroshi Murakami and JRC's Mark Dowell) perform the coordinating function and are supported by the IOCCG Chair (currently James Yoder) and IOCCG Executive Scientist (Venetia Stuart). The leadership group propose new activities, track timelines and deliverables, report updates and deliverables to CEOS-SIT including to the appropriate CEOS website, and point out any gaps and deficiencies in implementation. The latter is particularly important as the discussion at CEOS-SIT meetings can result in offers of help to resolve issues and challenges from those attending (and those attending CEOS meetings generally control resources in their respective agencies).

The OCR-VC Implementation Plan will be developed in two phases: Phase 1: 2008 through the launch of Sentinel-3 (late 2012) (this document). Phase 2: Post-launch of Sentinel-3 and also including VIIRS on NPOESS, GCOM-C and overlap with sensors still operating from Phase 1 (e.g. OCM-2).

Science Requirements For OCR Measurements, Technical Specifications for Cross – Calibration, Calibration Practices and Data Inter-Operability Issues.

SeaWiFS radiometric specifications (Table 1) are a good baseline for minimum specifications for an OCR instrument in the OCR-VC. The preferred Equatorial crossing time is local noon but crossing times ranging from 1030 to 1330 are acceptable. Both ascending and descending sun-synchronous orbits are acceptable. The ability for a sensor to tilt so that it can observe the ocean looking away from the sun, and thus minimize sun glint, is preferred but nadir-viewing instruments are acceptable. There is a large and growing scientific literature on the subject of OCR calibration and related activities including 43 volumes of pre-launch and 29 volumes of post-launch technical reports for SeaWiFS alone, many of which deal with calibration, characterization and validation issues (see http://oceancolor.gsfc.nasa.gov/SeaWiFS/BACKGROUND/), plus many publications in scientific journals. MERIS calibration practices are summarized by Delwart (MERIS and AATSR User Workshop, ESRIN, 22 September 2008).

Table 1. Major instrument parameters and characteristics of the SeaWiFS ocean colour sensor.

Instrument Bands				
Band	Wavelength FWHM nm	Saturation Radiance mW cm^{-2} μm^{-1} sr^{-1}	Input Radiance mW cm^{-2} μm^{-1} sr^{-1}	SNR[1]
1	402-422	13.63	9.10	499
2	433-453	13.25	8.41	674
3	480-500	10.50	6.56	667
4	500-520	9.08	5.64	640
5	545-565	7.44	4.57	596
6	660-680	4.20	2.46	442
7	745-785	3.00	1.61	455
8	845-885	2.13	1.09	467
Sensor Accuracy				
Radiance Accuracy:	<5% absolute each band			
Relative Precision:	<1% linearity			
Between Band Precision:	< 5% relative band-to-band (over 0.5-0.9 full scale)			
Polarization:	<2% sensitivity (all angles)			
Nadir Resolution:	1.1 km LAC; 4.5 km GAC			
Mission Characteristics				
Orbit Type:	Sun synchronous at 705 km			
Equator Crossing:	Noon ± 20 min., descending			
Saturation Recovery:	<10 samples			
Modulation Transfer Function	≥0.3 at Nyquist			
Swath Width (at equator):	2,801 km LAC (±58.3°)			
	1,502 km GAC (±45.0°)			
Scan Plane Tilt:	±20°, 0°, -20°			
Digitization:	10 bits			

1. Minimum values measured at input radiances

The goal of all calibration activities is to produce water-leaving radiances (reflectance) with an uncertainty of 5% in clear, open ocean waters. This requires that calibration data collected by field instruments have a calibration and measurement capability on the order of 1% (Hooker, S.B . and McClain, C.R. 2000. Prog. Oceanogr. 45: 427-465). The required components and accepted practices for an OCR calibration program include: accurate pre-launch calibration and characterization of the sensor; a procedure for vicarious calibration using data from the NASA/NOAA Marine Optical Buoy (MOBY) or ESA's MERMAID data base (http://hermes.acri.fr/mermaid/home/home.php); clearly defined measurement protocols; a process for field and calibration equipment traceable to national standards; highly accurate atmospheric correction procedures; and processes for monitoring in-orbit instrument stability (e.g. by routine viewing of the moon).

Objectives of the OCR-VC Implementation Plan (and agency points of contact)

Objective 1: Ensuring OCR continuity (Supporting GCOS requirement for an Ocean Colour ECV).

- Activities to improve VIIRS, with launch of NPP-VIIRS anticipated in 2011 and NPOESS C-1 no earlier than 2013. NPOESS Program has mitigated cross-talk issues with improved filter construction for VIIRS on C1, and that also provides better spectral out of band performance. Extensive sensor polarization and spectral characterizations were performed on NPP-VIIRS, but benefits of those characterizations are still under study. Improved spectral characterization is being planned but has not yet been implemented. VIIRS ocean cal/val program plan is now in the execution phase. (DiGiacomo, NOAA).

- GCOM-C and SGLI instrument is in development for launch in Q1 of 2014. Proposals responding to research announcement were submitted in Q1 2009, and the science team, including international participation, was selected in Q3 of 2009. International collaboration for the mission is currently under discussion (Murakami, JAXA).

- OCM-2: Launch of ISRO's OCM-2 is anticipated for Q3 of 2009. ISRO will provide online access of Level 1-B to international research users at no cost. NASA will put OCM-2 data processing capability into SeaDAS (Navulgund, ISRO; Bontempi, NASA; and others).

- KORDI, CNES, NASA, NOAA, ISRO and others are evaluating geostationary or geosynchronous orbits for OCR sensors. KORDI will launch GOCI (first OCR sensor in geo orbit) in Q1 2010.

- IOCCG Working Group is evaluating user requirements as well as new capabilities for OCR measurements that will be provided by OCR sensors on geostationary/geosynchronous platforms (WG Chair is David Antoine).

- Pre-launch cooperative activities for Sentinel-3A and B (which carries OLCI - the MERIS follow-on instrument) are underway. Both the Sentinel-3A and 3B missions are now approved (Regner, ESA; Bonekamp, Eumetsat).

- Brazil and Argentina plan to launch a two-sensor, OCR mission with instruments for both global and regional coastal coverage. Mission specifications will be completed in Q4 of 2009 (Kampel, INPE).

Objective 2: Provide high quality data sets (Supporting GCOS requirement for an Ocean Colour ECV).

- Continue support for the MOBY bio-optical buoy which is used to provide high quality data for vicarious calibration of OCR sensors. All MOBY data is now available on-line for any user. MOBY-continuation (MOBY-C) will insure continuity of vicarious calibration across past, present and future ocean colour sensors. NOAA's goal is to get MOBY-C, new optics only to start using the existing infrastructure, into the water before the end of 2011. (DiGiacomo, NOAA).

- Continue support for vicarious calibration activities using the BOUSSOLE buoy (Thouvenot, CNES).

- NASA will initiate first end to end update of processing methodology to reprocess MODIS-Terra, MODIS-Aqua, SeaWiFS, OCTS and CZCS to be completed by September 2009.

  NASA will sponsor an HPLC round-robin experiment to improve quality of HPLC measurements of phytoplankton chlorophyll and other pigments for the SeaBAS archive and establish HPLC measurement protocols. Final report of the round-robin will be submitted Q3 of 2009 (Bontempi, NASA).

- Continue interaction between NASA and ESA related to MERIS calibration and characterization and extend to pre-launch Sentinel-3 activities (Bontempi, NASA and Regner, ESA).

- MERIS will be reprocessed for third time by Dec 2009 using the same vicarious adjustment approach as used by NASA for SeaWiFS (Regner, ESA).

- MERMAID (MERis Matchup Insitu Database) is a centralized data base of *in situ* bio-optical data measurements concurrent with MERIS data extraction. The database currently contains data from sources such as AAOT (Venice tower), BOUSSOLE, and MOBY and shall support and sustain Cal/Val activities including vicarious adjustment and algorithm development and validations. Further data are being acquired from a broader range of PIs through an invitation to contribute to this central tool in the MERIS validation strategy. MERMAID will be one of the tools for validating the next MERIS reprocessing (Regner, ESA).

- GEO Task EC-09-01c: Regional Networks for Ecosystems. ChloroGIN - promotes *in situ* measurement of chlorophyll in combination with satellite derived estimates. Approach is a network of regional networks with active networks in Canada, Africa, South America (Antares), Indian Ocean, and Europe. China (contact is Xianqiang He of SOED/SIO/SOA) expressed interest in establishing a network for Chinese regional waters (Dowell and Hoepffner, JRC).

- ESA's GlobColour project demonstrated the benefits of multiple sensor data merger as an important step towards an ocean colour Essential Climate Variable

(ECV) for global products and has produced a 10-yr global data set based on MERIS, SeaWiFS and MODIS at 4.6 km resolution imagery. Spatial coverage is improved, e.g. what could be achieved in 8-days with SeaWiFS can be accomplished in 4-days by merging data from all 3 sensors. Data are freely available. Completed Q1 of 2009 (Regner, ESA). GlobColour products will continue as part of the EC GMES Marine Core Service, i.e. MyOcean.

- ESA is currently planning CoastColour for several coastal study areas using MERIS 300-m data. Proposals were due April 30, and Decision on "Champion Users" expected in Q4 2009 (Regner, ESA)

- NASA to lead an IOCCG working group on Level-1 requirements for ocean colour sensors. Pre-launch and on-orbit requirements will be addressed, including vicarious calibration and on-orbit calibration (Bontempi, NASA).

Objective 3: Data harmonization (Supporting GCOS requirement for an Ocean Colour ECV).

- MERIS Quality Working Group (QWG) includes members of SeaWiFS and MODIS teams with the most recent meeting held i27-29 April, 2009 at ESRIN. QWG meetings will continue in the future (Regner, ESA).

- IOCCG WG is evaluating requirements and applications for bio-optical sensors on ARGO floats for calibration and validation and to add vertical dimension for satellite OCR observations (WG Chair: Claustre, Laboratoire d'Oceanographie de Villefranche). Development activities are underway and pilot studies are under consideration (Thouvenot, CNES and Bontempi, NASA).

- IOCCG Working Group (WG) Geostationary OCR Sensors (WG Chair: D. Antoine, Laboratoire d' Oceanographie de Villefranche). A specific question for the Geostationary WG is how can one relate the data from geostationary platforms for regional coverage (related to regional climate impacts as well as regional GEOSS tasks) to polar orbiting instruments (Ahn, KORDI).

- IOCCG and OCR need better representation on Global Climate Observing System (GCOS) committees, as OCR is poorly represented now. For example, IOCCG should have a representative on the Ocean Observations Panel for Climate (OOPC). JRC organized an interdisciplinary GCOS discussion workshop in June 2009. The workshop was be cross-panel i.e. AOPC, TOPC and OOPC and will look at global biosphere production estimates and related ECVs (including of course OCR).

Objective 4: Facilitate timely and easy access to data (user interface)

- GEO Task AG-06-02: Data Utilization in Fisheries and Aquaculture. The Societal Applications in Fisheries and Aquaculture using Remotely-Sensed

Imagery (SAFARI) project was created to accelerate the assimilation of Earth observation data into fisheries research and ecosystem-based fisheries management on a world scale. SAFARI is bringing together an international forum of leading experts to facilitate the application of rapidly-evolving satellite technology to fisheries management questions through collaboration and networking. This initiative, primarily funded by the Canadian Space Agency, is developed under the framework of the Group on Earth Observations. It also involves the participation of Canadian Department of Fisheries and Oceans and the IOCCG. SAFARI will support the OCR-VC by identifying opportunities for the enhanced utilization of Earth observations in fisheries and aquaculture, and by providing a framework for consulting with experts from fisheries, aquaculture, coastal zone management and Earth observation communities at regional and international levels. An IOCCG monograph on this topic will be printed by Q4 2009. SAFARI brochure was published in Q1 2009 and was translated into French. An international SAFARI symposium on remote sensing and fisheries will be held in Kochi, India, 15-17 February 2010. Proposal for a Phase 2 of SAFARI, perhaps to be combined with ChloroGIN, is under consideration. Decision expected Q1 2010. (Platt, IOCCG; Crevier, CSA).

- In response to an expression of interest articulated by Canadian Ocean stakeholders, the Canadian Space Agency (CSA) is upgrading ground infrastructure at the Canada Centre for Remote Sensing (CCRS) for the reception and processing of full resolution (300-m) MERIS data. The station mask covers most of the Canadian Artic, Pacific and Atlantic coasts. This initiative, established in collaboration with the European Space Agency and the support of the CCRS, will provide access to all recent MERIS Full Resolution (FR) Level 1 products (MER_FRS_1P) and Level 2 products (MER_FRS_2P) covering North America. The project started about 1 year ago with data currently processed in Europe. Beginning in Q4 2009, data will be processed in Canada rather than in Europe. Access is available to Canadian Govt. users or to ESA-approved users from any country (Crevier, CSA).

- NOAA is developing an OceanWatch portal for VIIRS and possibly international sensors that will provide access to space-based observations of the global ocean for operations and climate applications (DiGiacomo, NOAA).

- GEO Task WA-08-01g: Global Water Quality Monitoring. A GEO inland and coastal water quality remote sensing algorithm international workshop was held 19-21 May 2009 in D.C. (NASA supported). Report expected in Q4 2009. The workshop was related to GEO task WA-08-01g (Digiacomo, NOAA).

- INPE in cooperation with CSA will process MERIS FSR data for South American waters starting Q4, 2009 (Kampel, INPE).

Objective 5: Capacity building and Outreach (GEO Task CB-09-03b: Establishing Regional Capacity Building Networks).

- Training course on "*Methods and Applications of Ocean Colour Remote Sensing in African Coastal and Regional Seas*". Principle sponsors are JRC and Institute of Marine Sciences, University of Dar-es-Salaam, Tanzania. It will take place from 12 - 23 October 2009 at the University of Dar-es-Salaam, Stone Town, Zanzibar, Tanzania. Co-sponsors include IOCCG and other organisations, (Hoepffner, JRC).

- GEO Task ST-09-02: Promoting Awareness and Benefits of GEO. The organizers of the OceanObs'09 conference accepted a proposal from the OCR-VC leads for a white paper describing the OCR-VC. The conference is in Venice, Italy starting September 21, 2009, and is a major conference related to ocean observations and will have many attendees. Prof. James Yoder (IOCCG) will present a paper on the OCR-VC in the plenary sessions. See http://www.oceanobs09.net/index.php

- GMES Africa will include remote sensing of marine and coastal areas. Implementation plan by early 2010 (Hoepffner, JRC).

- The GKSS Research Centre, Geesthacht, Germany, in cooperation with the IOCCG, held an advanced training course/workshop for 15 participants on: *Inversion Procedures in Ocean-Colour Remote Sensing*: 10-14 August 2009, in Hamburg Germany The course was organized by Dr. Roland Doerffer (GKSS) and addressed the issues of complex waters with different optical components. The workshop provided participants with an overview of inversion methods and models, to prepare bio-optical models and training data sets for inversion methods, and to taught participants how to use various inversion techniques. The course brought together scientists or advanced graduate students working with ocean-colour data in coastal waters.