The GOES-R Coastal Waters Imager: Monitoring the Coastal Ocean

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GOES-R Coastal Waters Imager*

- CW will *would have* provided the first ocean color capability from geo orbit
  - Can make measurements in constant tidal conditions
- CW enables more frequent views of U.S. coastal ocean
  - Necessary to resolve rapid changes due to tides and coastal currents
- CW provides more opportunities for cloud-free viewing
  - Better detect/monitor/track rapidly changing phenomena such as Harmful Algal Blooms, sediment plumes, and chaotic coastal zone currents magnitude that could be underestimated due to diurnal behavior
- CW offers higher spatial resolution (300 meters)
  - Fisheries researchers are limited by spatial resolution of current systems—better than 1 km needed to improve measurement and modeling of small scale phenomena such as migration pathways for salmon fisheries

*Note: CW was part of the Hyperspectral Environmental Suite (HES) which was removed from GOES-R in October 2006.

NOAA HES-CW Applications

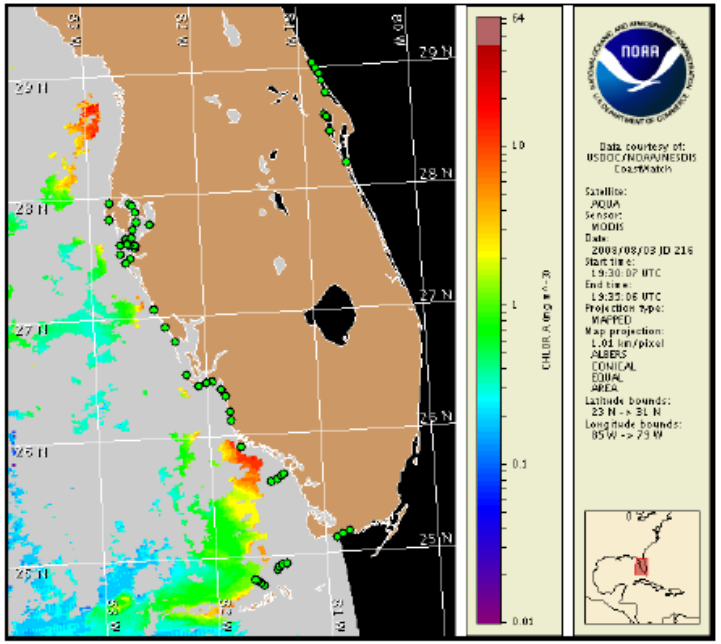
- Water quality monitoring
- Coastal hazard assessment
- Natural resource management in coastal and estuarine areas (*supports integrated ecosystem assessments et al.*)
- Human and ecosystem health awareness
- Climate variability prediction (e.g., carbon cycle)
- Landscape changes
- Navigation safety
- Coral reef detection and health appraisal

Harmful Algal Blooms – Operational Monitoring and Forecasting

Gulf of Mexico: South Florida

Gulf of Mexico Harmful Algal Bloom Bulletin

Region: South Florida
4 August 2008
NOAA Ocean Service
NOAA Satellites and Information Service
Last bulletin: July 28, 2008



Satellite chlorophyll image with possible HAB areas shown by red polygon(s). Cell concentration sampling data from July 25 to 31 shown as red (high), orange (medium), yellow (low b), brown (low a), blue(very low b), purple (very low a), pink (present), and green (not present). For a list of cell count data providers and a key to the cell concentration categories, please see the HABFS bulletin guide:
http://www.csc.noaa.gov/crs/habf/habfs_bulletin_guide.pdf

Please note the following restrictions on all SeaWiFS imagery derived from CoastWatch.

1. Data are restricted to civil marine applications only; i.e. federal, state, and local government use/distribution is permitted.
2. Image products may be published in newspapers. Any other publishing arrangements must receive GeoEye approval via the CoastWatch Program.

Conditions Report

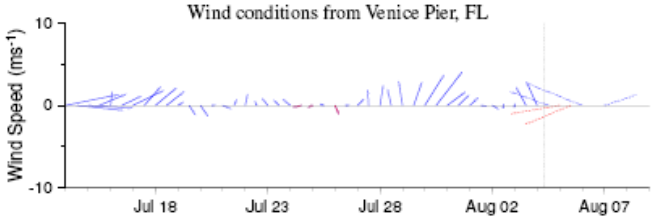
There is currently no indication of a harmful algal bloom at the coast in southwest Florida. No impacts are expected alongshore southwest Florida today through Sunday, August 10.

Analysis

There is currently no indication of a harmful algal bloom at the coast in southwest Florida. No *Karenia brevis* was found in samples collected last week between Pinellas County and the Florida Keys (FWRI, MML, SCHD; 7/30-8/1). Cloud cover has obscured recent satellite imagery, limiting analysis. Imagery from July 31 continued to show patches of elevated to high chlorophyll alongshore SW Florida due to confirmed non-harmful algae. Dead fish have been reported in the upper Tampa Bay, but are not due to *K. brevis* (FWRI, 08/01). Upwelling conditions are possible through Wednesday, August 6, however bloom formation alongshore is unlikely. No impacts are expected along the coast through Sunday, August 10.

Please note that SeaWiFS imagery is temporarily unavailable for display on this bulletin due to technical difficulties; MODIS imagery is shown on pages 1 and 2 of this bulletin.

"Fenstermacher, Fisher



Wind speed and direction are averaged over 12 hours from buoy measurements. Length of line indicates speed; angle indicates direction. Red indicates that the wind direction favors upwelling near the coast. Values to the left of the dotted vertical line are measured values; values to the right are forecasts.

Wind Analysis

SW Florida: Southeast to easterly winds today through Wednesday, with onshore winds in the afternoon (5-10 kns; 3-5 m/s). Southwesterlies Thursday and Friday (5-10 kns; 3-5 m/s)

To see previous bulletins and forecasts for other Harmful Algal Bloom Bulletin regions, visit the NOAA CoastWatch bulletin archive: http://coastwatch.noaa.gov/hab/bulletins_ns.htm

NOAA/NOS - http://coastwatch.noaa.gov/hab/bulletins_ms.htm

Products

- Chlorophyll
- Reflectance
- Turbidity
- Particulate absorption
- Dissolved absorption
- Diffuse attenuation
- Backscatter
- Fluorescence
- TSM
- POC
- Other?

HES-CW Operational Channel Specifications (April 2006)

Nominal Threshold Channel Center Wavelength (um)	Nominal Threshold Resolution (um)	Nominal Threshold Signal to Noise	Nominal GOAL Channel Center Wavelength (um)	Nominal GOAL Resolution (um)	Nominal Goal Signal to Noise
0.412	0.02	300 to 1 all channels	0.345	0.02	900 to 1 all channels
0.443	0.02		0.38	0.02	
0.49	0.02		0.407 through 0.987	0.01	
0.51	0.02		0.57	0.01	
0.555	0.02		0.72	0.02	
0.58	0.02		1.24	0.04	
0.61	0.02		1.38	0.03	
0.645	0.01		1.61	0.06	
0.667	0.01		2.26	0.05	
0.678	0.01		11.2 (2 km)	0.8	
0.709	0.02		12.3 (2 km)	1	
0.75	0.02	Nominal Threshold Horiz. Resolution			Nominal Goal Horiz. Resolution
0.865	0.02	300-meters (at Equator)			150-meters (at Equator) except for LW IR channels

White text represents the new MRD Baseline of nine channels on GOES-R. Yellow text represents additional requirements above the MRD Threshold design. All requirements were approved and endorsed by the members of the Coastal Ocean Applications and Science Team (COAST).

NOAA Operational Specifications for Satellite Ocean Color Measurement

Nominal Threshold Channel Center Wavelength (um)	Nominal Threshold Resolution (um)	Nominal Threshold Signal to Noise	Nominal GOAL Channel Center Wavelength (um)	Nominal GOAL Resolution (um)	Nominal Goal Signal to Noise
0.412	0.02	300 to 1 all channels	0.345	0.02	900 to 1 all channels
0.443	0.02		0.380	0.02	
0.490	0.02		0.407 through 0.987	0.01	
0.510	0.02		0.570	0.05	
0.555	0.02		1.000	0.04	
0.580	0.02		1.240	0.03	
0.610	0.02		1.380	0.03	
0.645	0.01		1.640	0.03	
0.667	0.01		2.130	0.05	
0.678	0.01		11.200 (2 km)	0.8	
0.709	0.01		12.300 (2 km)	1	
0.750	0.02	Nominal Threshold Horiz. Resolution: 300 m; 3 hr refresh rate			Nominal Goal Horiz. Res: 150 m except for LW IR channels 1 hr refresh rate
0.865	0.02				
1.240	0.03				
1.640	0.03				
2.130	0.05				

Based on threshold and objective requirements for coastal ocean color as documented in NATIONAL OCEAN SERVICE Environmental Satellite Requirements DRAFT February 8, 2005, with later review and endorsement by members of the Coastal Ocean Applications and Science Team (COAST). Some updates made August 2008, including adding SWIR bands to threshold.

Utility of SWIR Bands in Turbid Coastal Waters

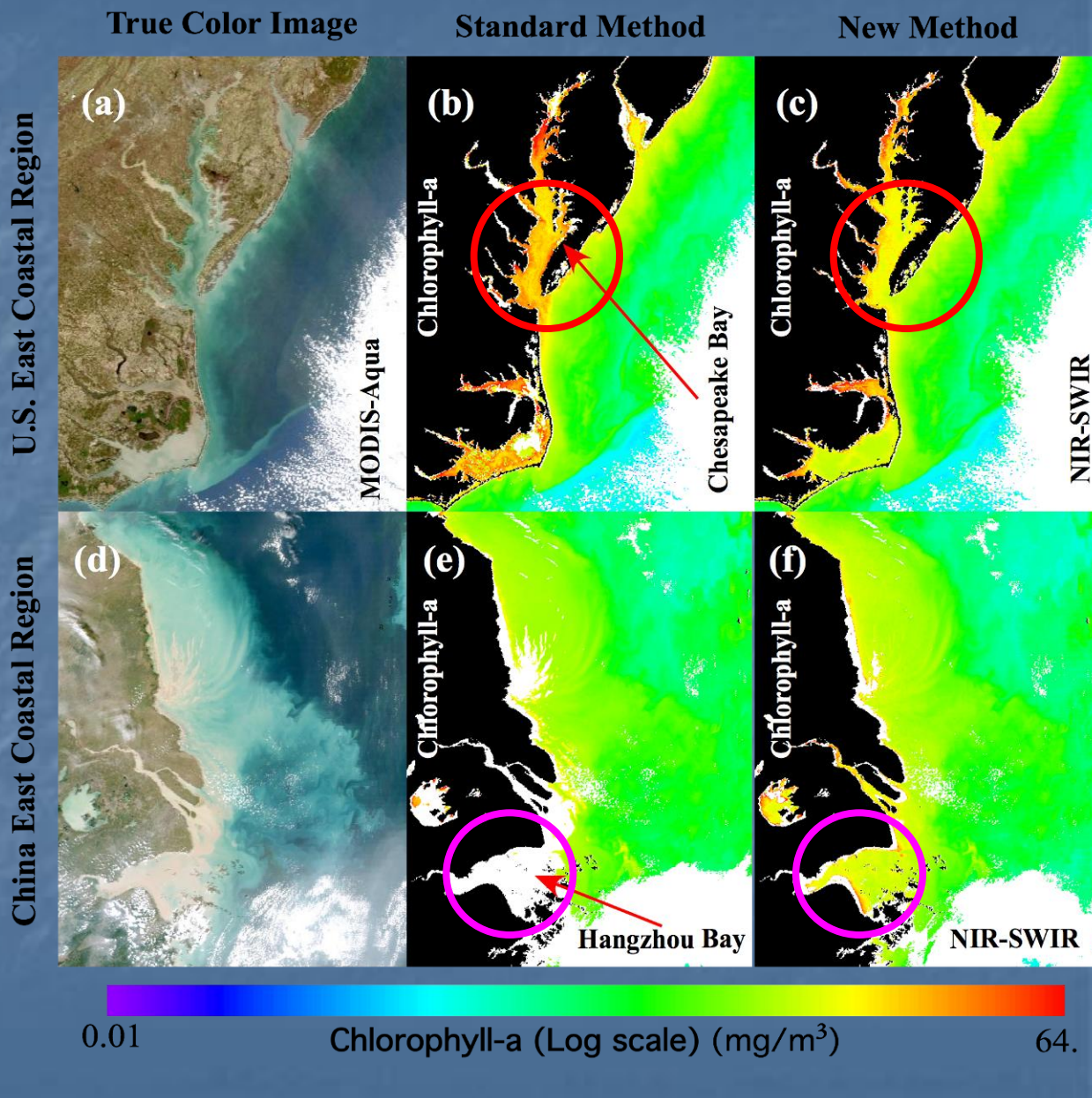
Comparison:

MODIS-derived chl-a using existing standard as well as new method using NIR-SWIR algorithm (Wang & Shi, 2007)

US East Coast (panels a-c)
China East Coast (panels d-f)

Significance: MODIS-derived chlorophyll-a data are significantly improved using the new atmospheric correction techniques for turbid coastal waters, e.g. Chesapeake & Hanzhou Bays.

Also see Wang, 2007; Wang et al., 2007 et al.



Sampling Frequency & other Requirements

- Sampling Frequency:
  - *Threshold* requirement is to sample the entire U.S. coastal waters once every three hours during daylight (except Alaska which is not imaged); *Goal* is hourly
  - Additional sampling for selected regions at higher frequency
  - May be adjusted for cloud cover; use Advanced Baseline Imager (ABI) to select cloud free areas for imaging
  - Additional goal requirement of Open Ocean (OO) sampling

    - Is this a priority, or is MODIS, VIIRS etc. adequate?

    - Should “we” recommend selected areas, such as the Caribbean, Bahamas, South American Coast, etc.?

- Many other requirements for simultaneity, stability, jitter, etc.

- Multi-spectral vs hyperspectral: Given the option to add something, “we” should go for hyperspectral in the VNIR

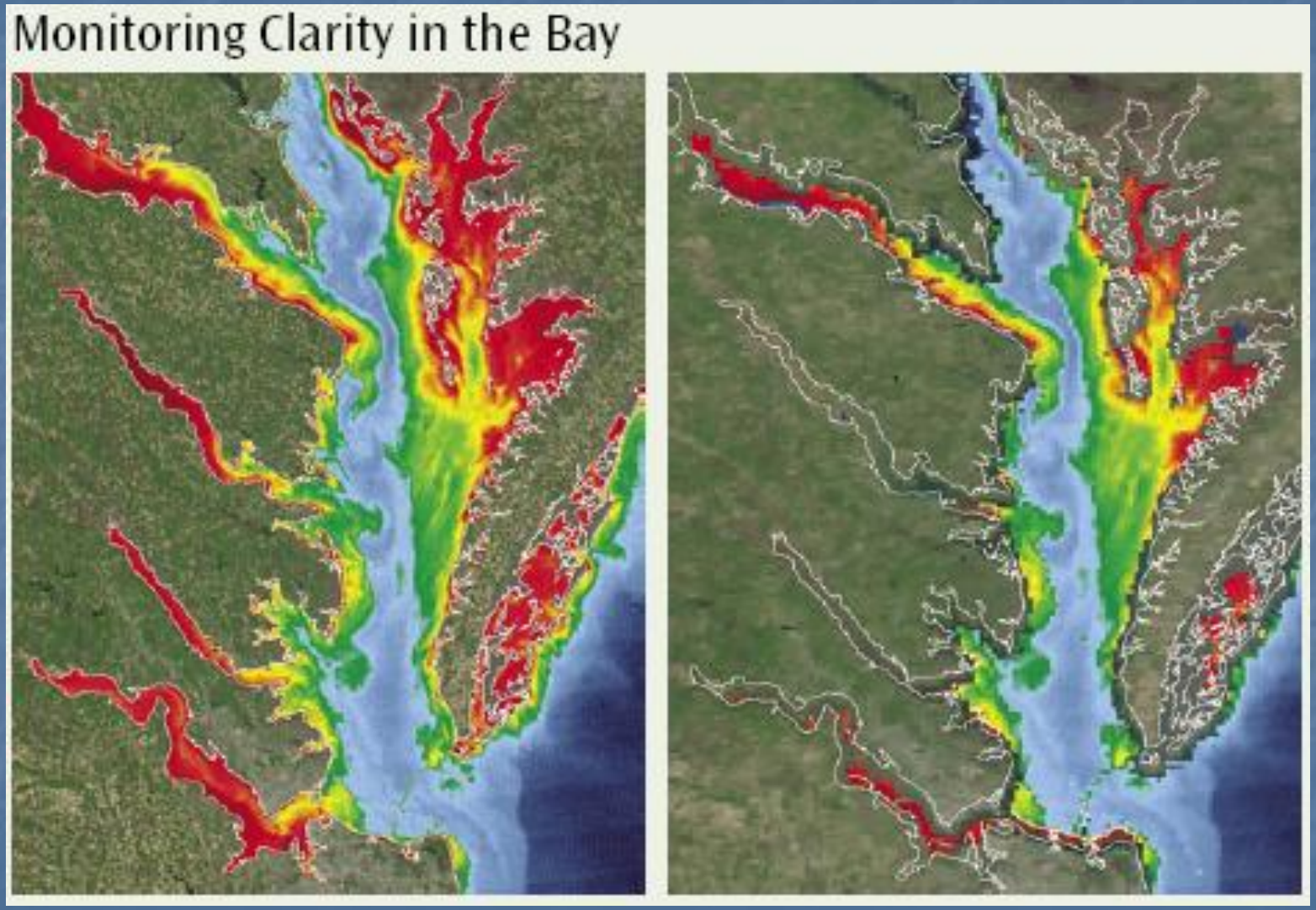
Signal-to-Noise Ratio (SNR)

- Threshold requirement is 300:1 for ocean radiances
  - Initial requirement for SeaWiFS; but SeaWiFS performance exceeded this (more like 450:1)
- *Goal requirement is 900:1 for ocean radiances*
  - Exceeds MODIS SNR
  - Difficult and costly to achieve
  - SNR goes up as the square root of the signal
    - The main noise source is shot noise
- Do we need more than the threshold 300:1? If so are "we" happy with 400:1?, 500:1?
- Is the threshold ok for some channels, but not others? If so which channels do we need more SNR?

Spatial Resolution

- The spatial resolution is at Nadir (over the Equator) so it degrades by latitude in U. S. coastal waters.
- The threshold requirement is 300 m at nadir; order 400-450 m in U. S. Coastal waters.
  - Is this adequate?
- The goal requirement is 150 m (200 m over U. S.). It will be very expensive to achieve this higher resolution.
  - Cost goes as the square of the spatial resolution improvement
  - May not be possible for our SNR, etc.
  - Will compete with frequency of coverage, SNR, and number of bands.

Higher spatial resolution crucial for monitoring of complex coastal waters



MODIS (250 m)

MODIS (1 km)

Courtesy Bob Arnone, NRL

Prioritizing Goal Requirements

- HES-CW built to the threshold requirements will meet the basic needs and provide a dramatic improvement over present capabilities for coastal imaging.
- Goal requirements compete with each other, e.g. higher spatial resolution makes it harder to increase sampling frequency or SNR.
- Top priority goals are:
  - Higher frequency of sampling
  - Hyperspectral instead of multispectral
  - Higher SNR
  - Additional channels for atmospheric correction (SWIR, UV)

OCAPI: "Ocean Color Advanced Permanent Imager"

- A consortium of French labs and industry submitted a proposal to CNES in April 2008, as an answer to the "call for ideas" that CNES issued in preparation of its prospective exercise (proposal led by "Laboratoire d'Océanographie de Villefranche", optics & remote sensing group; PI D. Antoine)
- The proposal was examined in June 2008 by the CNES scientific committee (Ocean group of the "TOSCA" scientific committee)
- March 2009 : CNES meeting to discuss the prospective in Earth observation for the next decade. Geostationary observations, in particular for ocean color, were recognized as one of the priorities for satellite oceanography.
- Technical studies were carried out in parallel, in 2008-2009 :
  - "LEO/GEO trade off", showing that the GEO orbit is probably the best solution if the main criterion is to obtain observations with a high revisit (< 1 hour).
  - Instrument specifications and design, based on existing designs & incorporating new technologies
- A "phase A" study should start in 2010
- A science mission group is being formed (will be opened to members from the international community)
- The project presently looks for international collaboration (science & technical aspects)
- Open points (still numerous):
  - Local *versus* Earth disk, Geostationary *versus* Geosynchronous (better observation of high latitudes), number and location of spectral bands, spatial resolution, revisit frequency, type of platform (dedicated of piggy bagging), ….
- Possible time frame : 2013-2015

OCAPI: "Ocean Color Advanced Permanent Imager"

- Science focus (not exhaustive)
  - Biological-physical coupling at meso and sub meso-scales
  - Diurnal cycle of ocean properties
  - Data assimilation into biological-physical coupled models & operational oceanography
  - Phytoplankton functional type and biogeochemical models
  - Sediment transport in river plumes and carbon sequestration in ocean margins
  - Aerosol transport
  - Operational services for the coastal environment (HABs, eutrophication, front detection,…)

- Mission (still open to many changes)
  - In a regional logic : European waters, Mediterranean Sea
  - In a more "global" logic: as above + Northeast Atlantic, Southeast Atlantic
  - Revisit ~30 min

- Instrument (still open to many changes)
  - Could derive from the GOCI design, with improved coverage (Earth disk?) and spectral range (400-900 nm) /resolution (MERIS like?)
  - Radiometric requirements are those of OC in general
  - Spatial resolution ~300 m.
  - Onboard calibration
  - Moon observations for long-term stability? (feasible)

All these points are still open; they are precisely the subject of the future work of the mission science group, which is being formed

Motivations for setting up this WG

• Several mission proposals were submitted to agencies in the past decade (to ESA, NASA, CNES, …), including (non-exhaustively):

- Special event imager (NASA / NOAA), W.E. Esaias & C. Brown PIs
- COCOA proposal to NASA, J.W. Campbell PI
- NASA's "Hyperspectral Environmental Suite" (HES)
- BIOGEOSAT (ESA / CNES), D. Antoine PI
- "Advanced Baseline Imager" (ABI) on GOES-R or –S (only 2 large bands in the VIS)
- ….

• Others are under examination

- Geo-CAPE proposal to NASA ("Coastal and Air Pollution Events"; Maninno & Campbell)
- OCAPI proposal to CNES ("Ocean Color Advanced Permanent Imager"), D. Antoine PI
- …

• One is now planned for launch (GOCI on COMS-1, from Korea, before the end of 2009)

• The interest for such observations is growing, which means that other missions might be decided within the next years

• So, it's typically where IOCCG can enter into play, in order to set up requirements, advocate for coordination, foster collaborations etc…

IOCCG Working group "Ocean colour from the geostationary orbit"

International Ocean-Colour Coordinating Group

Terms of references for the working group

✓ Why the GEO orbit is of interest for ocean color science and operational uses of ocean color observations? (advantages of the GEO orbit, examples of possible uses & applications…)

✓ What is the situation "today" (2009-2010) in terms of mission plans in space Agencies?

✓ What could be the complementarity between the GEO and LEO orbits (scenarios)

✓ What could be the complementarity with the other observations which are also possible from the GEO orbit.

✓ What an ocean color sensor on a GEO orbit can do for other research and operational communities?

✓ What are the specific requirements of ocean color observations from the GEO orbit?

✓ What would be the "target" of such GEO ocean color sensors? (regional *versus* Earth disk)

✓ How can we build international cooperation with sensors looking at "fixed" positions?

Working group membership

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IOCCG Working group "Ocean colour from the geostationary orbit"

International Ocean-Colour Coordinating Group

Working group activities / schedule

See at http://www.ioccg.org/groups/geostn.html

Past:

✓ WG Proposal to IOCCG	February 2008, Paris, 13th committee meeting
✓ Final TORs and membership	August 15, 2008
✓ First meeting in Korea	November 1st, 2008
✓ Report of the 1st meeting	November 14, 2008
✓ Collection of contributions	First set of contributions is available since January 2009

Present / near future:

✓ Collection of revised contributions	Will continue until the end of September 2009
✓ Draft report	Should be available before the end of 2009
✓ Submission to IOCCG	January 2010 (tentatively)