SAR-Africa

Workshop Report

Cape Town, November 2008

http://www.afro-sea.org.za/mrsu/sarAfrica

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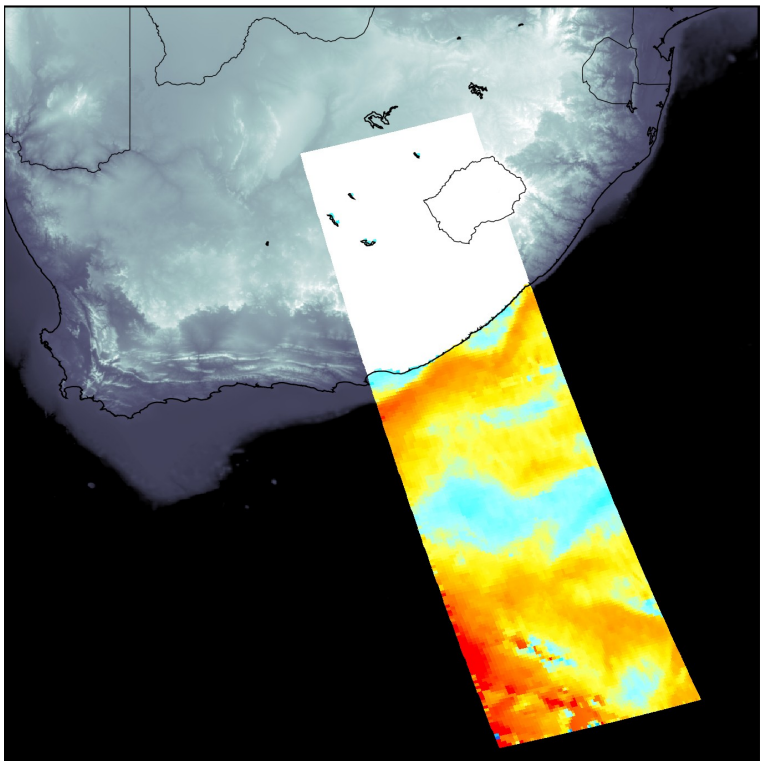

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1. Executive summary

SAR-Africa or Synthetic Aperture Radar for Africa, is an initiative led by the Marine Remote Sensing Unit (MRSU). The SAR-Africa project aims to develop a sustainable research and operational capacity for marine Synthetic Aperture Radar applications in Southern Africa. Synthetic aperture radars are the only instruments in space that can simultaneously provide measurements of current, wave and wind fields. SAR products are also used operationally to detect ships, oil spills or track ice motions. At present, there exists no facility in Southern Africa for processing or disseminating SAR products to the marine community.

In November 2008, the MRSU held its first SAR-Africa workshop at the University of Cape Town, in South Africa. The list of workshop participants and the agenda are included in the Appendix. The SAR-Africa workshop was the starting point for a South African / Norwegian collaboration on Synthetic Aperture Radar developments and research, with the South African partners being the Council for Scientific and Industrial Research (CSIR) and the University of Cape Town (UCT) and the Norwegian partners being the Nansen Environmental and Remote Sensing Center (NERSC) and the Northern Research Institute NORUT. The workshop was well attended, with 12 institutions from 4 countries being represented. Scientists from French, Norwegian and the European Space Agency (ESA) institutes were present as well as South African representatives from UCT, CSIR, IMT, SAEON, SAWS, CHPC and MCM (See Appendix for further reference). Financial support for the workshop was provided by SARCURE (a South African / Norwegian bilateral agreement) funded by the Research Council of Norway (RCN), and by the Council for Scientific and Industrial Research (CSIR).

Within the workshop, SAR applications, data processing, data availability, limitations and validation needs were reviewed, providing a broad overview and an introduction to the new possibilities of using SAR products in the marine environment. A number of presentations were dedicated to highlighting the variable and energetic processes and dynamics that make the coast and shelf seas of southern Africa an ideal test area for application and further development of SAR products. Future activities toward the development of a SAR expertise in South Africa were planned in the context of the other research initiatives occuring both in southern Africa and abroad.

2. Scientific context

Since July 2007, the Agulhas Current has become a region of systematic data

acquisition for high resolution Envisat Advanced Synthetic Aperture Radar (ASAR) data products under the ESA funded SAR ocean wind-wave-current project (Collard et al., 2007). All acquisitions are then systematically processed in Near Real Time using the latest scientific understanding of electromagnetic wave interaction with the sea surface to retrieve wind, wave and surface current, still subject to proper validation. The resulting geophysical products are then accessible to the scientific community via a demonstration web site (http://soprano.boost-technologies.com). In particular the current product is a completely new type of information brought to the scientific community. This presents South African researchers with an unique opportunity to increase their knowledge of the Agulhas Current system and to further their understanding of the processes occuring along the south eastern shores of Africa.

2.1.The Agulhas Current system:

The eastern shores of South Africa support a high degree of biodiversity and endemism and a range of eco-sensitive environments such as mangroves or coral reefs. Major economic activities along the continental shelf of the Agulhas Current include fishing, oil and mineral exploration as well as an intense ship traffic, with the transport of crude oil from the Middle East to Europe (http://www.eoearth.org/article/Agulhas_Current_large_marine_ecosystem). The Agulhas Current, which flows along the continental shelf of southern Africa, is the most intense western boundary current of the southern hemisphere. It transports large volumes of warm water southwards and has an average transport of 70 SV, with typical current velocities reaching up to and even exceeding 2 m/sec. The Agulhas Current is an important component of the global thermohaline circulation (Gordon, 1985) and has a significant impact on the overlying atmosphere (Lee-Thorpe et al, 1999; Jury et al, 1997; Rouault et al, 1999). The Agulhas Current is affected by a wide range of meso and sub-mesoscale processes such as rings, eddies, filaments or plumes (Lutjeharms, 2006). The highly variable and complex circulation associated with the Agulhas Current provides an ideal natural laboratory for testing and developing remote sensing products.

2.2.Remote sensing of the Agulhas Current:

In South Africa, past efforts in marine remote sensing developments have focused on providing ocean colour and sea surface temperature (SST) data to the marine community. These data, while extremely useful, are often limited by the ubiquitous presence of clouds in the region. Satellite altimetry products have also been used extensively in the Agulhas Current region to characterise the mesoscale variability of

the Agulhas Current system and to study wave / current interactions (Grundlingh, 1995). However, the use of altimetry in the coastal regions poses serious challenges and often results in the loss of data near the shore (Stansfield et al, 2008). Synthetic aperture radars are the only instruments that can simulatenously sample the wave, current and wind fields from space. SAR instruments are not affected by atmospheric conditions, night and day variations, and are able to sample from the open ocean to the coast at a very high resolution (order 30-100 m). At present, there exists no facility in Southern Africa for processing or disseminating SAR products to the marine community. Developing such a capability in South Africa would compliment current and past remote sensing developments, bringing a whole new range of data products specifically suited to monitoring the physical environment.

3. Possible applications of SAR products in Southern Africa

Synthetic aperture radars measure the ocean's sea surface roughness. By recording the amplitude and phase of the backscattered signal from the sea surface roughness, synthetic aperture radars are able to provide information on wind, waves, currents, surface film (oil/ biological matter) or sea ice. High resolution current, wind and wave data derived from SAR could be used in synergy with numerical models, for both model validation and as data assimilation sources.

3.1.Research applications:

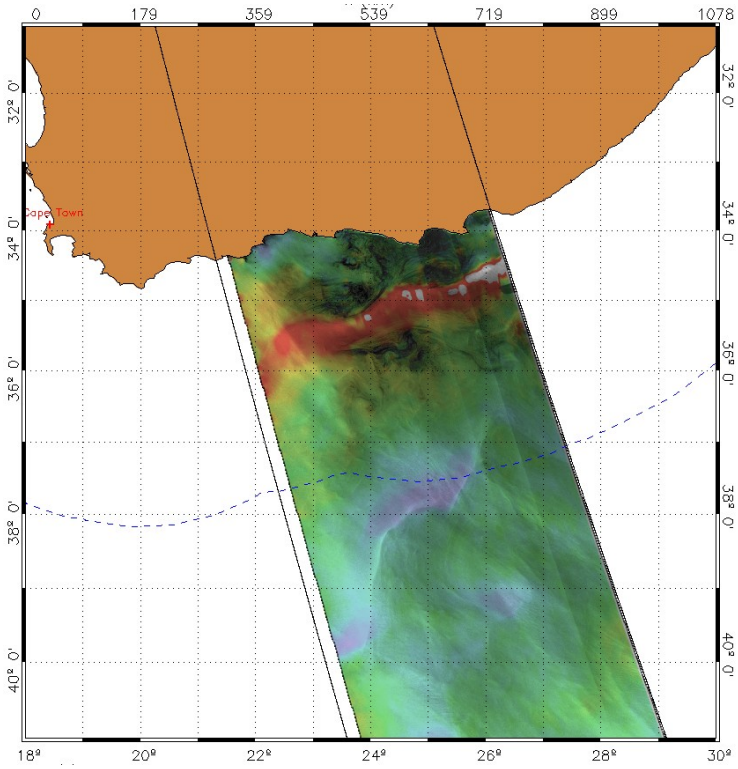
Ocean / atmosphere interaction:

High resolution wind fields (order of 1km) can be derived from SAR data products. Those high resolution wind datasets could be used for the study of local atmospheric systems such as coastal lows, and their impact on the oceanic and coastal regions. The availability of high resolution synoptic winds in South Africa is very important, as winds are a major driving mechanism for many of the coastal systems in the region. These high resolution wind field datasets are also capturing the impact of stratifiation changes on atmospheric boundary layer turbulence and near surface wind as one crosses from cold-to-warmer (or visa-versa) water associated with the boundary of the Agulhas Current.

Dynamics of the Agulhas Current:

The mapping of current speed from space is a completely new technology and a significant breakthrough for oceanographers. The technique was pioneered by Dr Chapron et al (2003, 2005) and has since been successfully applied using the Envisat ASAR data by Dr Collard (CLS) and his colleagues. It was also recently reported in GRL

by Johannessen et al (2008). This product, while still in need of further validation, could bring new insights to the dynamic structure of meso-scale variability in the Agulhas Current.



Surface radial velocity in the Agulhas Current region.
Credits: CLS radar division

Wave / Current interactions:

The Agulhas Current is known for the destructive effect of its giant waves on passing ships. The capacity of SAR instruments to produce concurrent estimations of surface current, wind and wave fields could help further our understanding of wave / current interaction processes.

Photo of a rogue wave taken off Durban in South Africa in 1980
Credits: Philippe Lijour

SAR product validations:

The Agulhas Current is a natural laboratory for testing new remote sensing products. Together with the Gulf Stream, and coastal areas off the northwest coast of France and Norway, the Agulhas Current has become a region for systematic data acquisition for high resolution ASAR data. This provides researchers with a unique opportunity to test and improve their products under the persistent and intense dynamics and mesoscale variability of the Agulhas Current. Product validation and algorithms improvement will be one of the major focus of the research within the SAR-Africa project. Significant progress could be made by combining the knowledge of African researchers and their regional datasets, to the international expertise on SAR products.

3.2.Operational applications:

Oil spill detection:

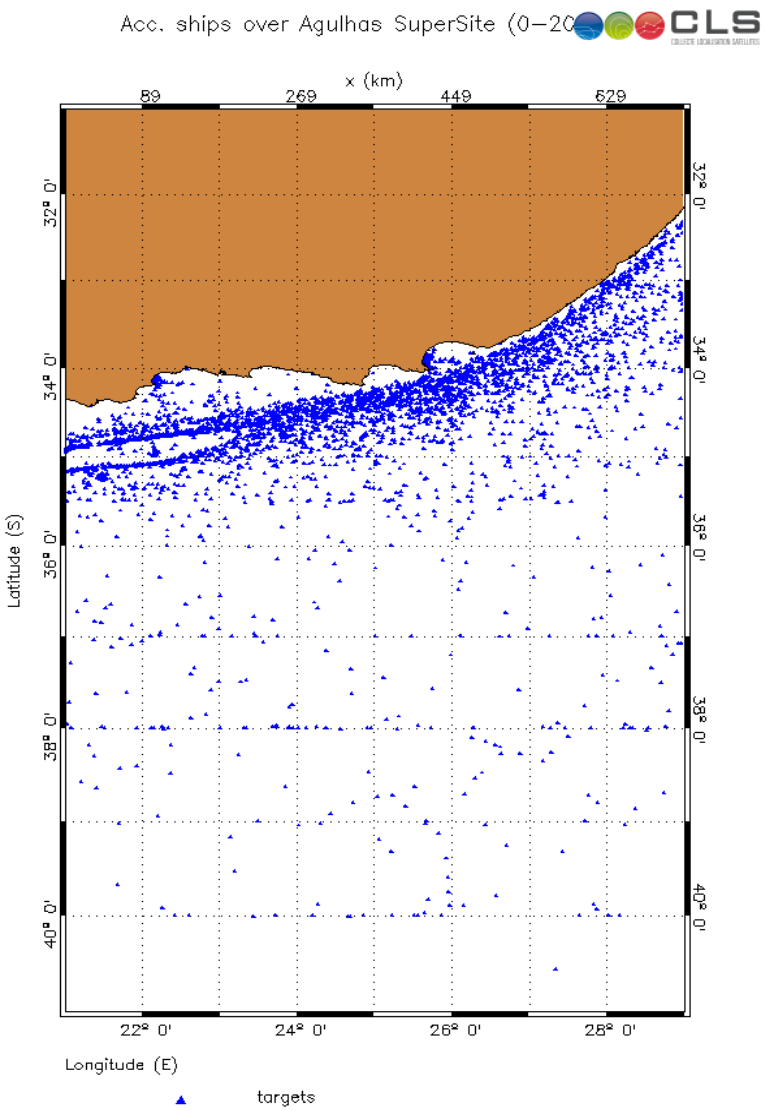
The Agulhas current lies on an important shipping route for the transport of crude oil from the Middle East to Europe and the Americas. Oil tankers navigating around Cape Agulhas can be exposed to extreme weather and sea conditions, which greatly increases the risk of major marine pollution. Oil spills, wether accidental or illegal, can cause significant damage to the environment. SAR products are routinely used around the world to detect and map oils spills (eg. EMSA, http://cleanseanet.emsa.europa.eu). Spills at sea cause a dampening of the sea surface roughness and are detected as

black patches areas in SAR images. In the SAR image below, an example of oil spill pollution caused by oil rigs in the North Sea is illustrated. Oil rigs appear as small bright dots while dark tones indicate the areas affected by the oil.

Oil slicks from oil rigs in the North Sea.
Credits: Johannessen et al., 1994

Ship surveillance and maritime traffic monitoring:

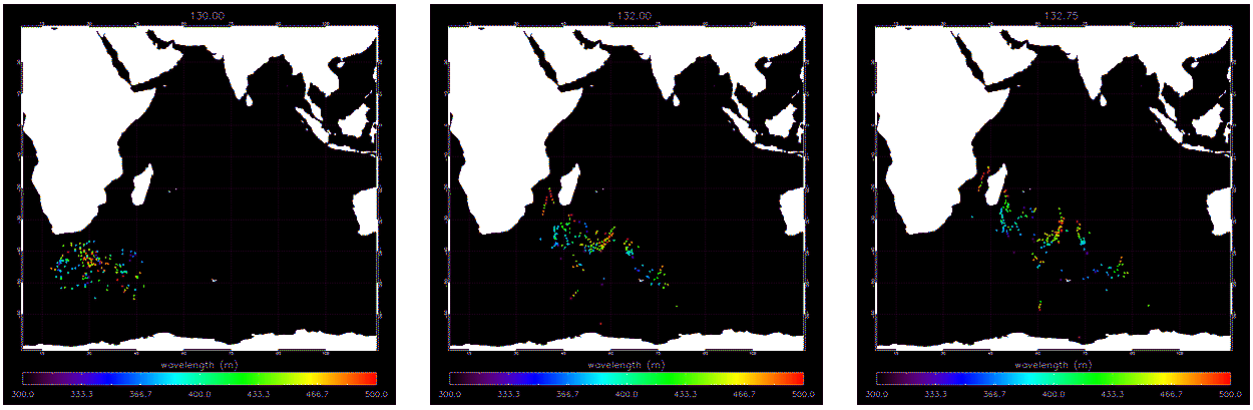
Ships are highly reflective and appear as very bright spots in SAR images. SAR data can be used to detect ships in the ocean, irrespective of weather conditions, day or night. Coupled with vessel monitoring systems, SAR's capacity to detect vessels at sea could be used effectively to take action against illegal fishing, illegal oil damping or to monitor traffic at sea and ensure the safety of sea routes. The figure overleaf shows ships detected in the Agulhas Current region using 1 year of SAR imagery. Such imaging capacity could be used to help define safer shipping routes in order to avoid extreme events such as rogue waves, which often occur on the landward border of the Agulhas Current (Lujeharms, 2006).



Ships detected in the Agulhas Current region over a period of a year using Envisat ASAR data.
Credits: CLS radar division.

Sea-state monitoring and storm predictions:

The ability of SAR instruments to simulatenously map wind, wave and current wind fields can be extremely useful for the provision of accurate sea state bulletins. Recently, SAR wave measurements have also been used to track the origin and the path of large wave storms (http://www.scientificblogging.com). An example of Envisat ASAR data capacity to track the path of storms is given in the figure overleaf.



Consecutive images of a storm tracked from the south of Cape Town and across the Indian Ocean in May 2007. Colours indicate the wavelength of the waves from short (blue) to long (red).
Credits: IFREMER - BOOST Technologies

4. Development strategy

4.1.Collaborations and Partners:

The SAR-Africa initiative will draw momentum from its collaborations with world leaders in the development of SAR products for the oceanic and coastal regions. The SAR-Africa workshop was used as a mean of formalising and consolidating the international partnerships with the following institutes:

- Nansen Environmental and Remote Sensing Center (NERSC, Norway)
- Northern Research Institute (NORUT IT, Norway)
- Collecte Localisation Satellites (CLS, France)
- Centre ERS d'Archivage et de Traitement (CERSAT, France)

Through its collaborations, SAR-Africa has already been granted the use, for research purposes, of the Envisat ASAR and ERS data by the European Space Agency (ESA).

4.2.Scientific synergies:

SAR-Africa will work in synergy with stakeholders and Large Marine Ecosystems (LME) and will develop links with the variety of institutions with an interest in the project.

The SAR-Africa efforts are concurrent with the Aticore-Africa project, which aims to develop coastal altimetry products for the coastal environment (Stansfield et al, 2008). Synergy will also be maximised with existing remote sensing capabilities such as sea surface temperature (SST) and ocean colour radiometry.

Several oceanographic programs are currently underway in the Agulhas Current region. SAR-Africa will benefit from the output of the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) project, a program which is expected to provide "*new and important information on ocean currents and how they interact with and influence the climate, biodiversity and economies of the western Indian Ocean region*" (http://www.asclme.org/). SAR-Africa will take advantage of data streams coming from the CSIR funded River Influenced Bights and Bays (RIBBS), and the African Coelocanth Ecosystem Project (ACEP) projects to validate and demonstrate SAR products.

4.3.Capacity building:

Sustainable capacity development is a vital component of the project, and this will be achieved through streamlining with the GOOS-Africa development strategy. Technology exchange through collaborative post-graduate projects, training, and workshops are some of the primary mechanisms. There will be a focus on capacity building using South Africa mechanisms initially, with a view to developing other African users through GOOS-Africa.

One PhD project (Marjolaine Rouault, CSIR), starting in 2009 will directly feed into SAR-Africa through the retrieval and validation of ASAR radial surface current velocities in the Agulhas Current region based on the Doppler frequency anomaly estimation. In addition, funding has been obtained for an MSc student to undertake a study of wave / current interactions in 2009. This MSc will benefit both the SAR-Africa and Alticore-Africa initiatives.

4.4.Validation:

The validation of SAR remote sensing products (consistent wind, wave and current) is essential to providing correct estimates of the ocean properties both for research and operational purposes. Within SAR-Africa, priority will therefore be given to research activities which include the validation of SAR products.

SAR-Africa, through its CSIR and UCT representatives, is actively engaging with local and international scientists to benefit from current and future field measurements in the Agulhas Current region. It is planned that the extensive ACEP measurement program (from 2009 to 2011), will form part of the SAR-Africa validation exercise. Synergies with the ASCLME program or the MCM and SAEON driven measurement campaigns are also currently being explored.

5. Recommendations

Financial support for the development of SAR products should be actively sought, prioritising research through collaborative PhD - and post-graduate projects.

There are considerable incentives to use SAR products on an operational basis for monitoring and surveillance purposes. Assessing the requirements for operational activities could pave the way for the future implementations of an operational capacity to monitor South Africa's fleet, detect and monitor oil spills as well as provide iceberg tracking support in the southern ocean.

The validation of SAR products against in situ observations is essential for the successful implementation of a SAR research and operational capacity. In addition to exploring potential synergies with existing or future measurement campaigns, efforts should be made to put in place a dedicated SAR field validation campaign. Such a campaign could also serve also the needs of future SAR missions such as the ESA Sentinel 1 C-band SAR mission.

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7. Appendix

7.1.Participants:

Name	Affiliation
Backeberg, Bjorn	University of Cape Town (UCT)
Bernard, Stewart	Council for Scientific and Industrial Research (CSIR)
Chang, Nicolette	Council for Scientific and Industrial Research (CSIR)
Dagestad, Knut-Frode	Nansen Environmental and Remote Sensing Center (NERSC)
Davidson, Malcom	European Space Agency (ESA)
Diedericks, Gerhardus	Council for Scientific and Industrial Research (CSIR)
Goshen, Wayne	South African Environmental Observation Network (SAEON)
Hermes, Juliet	Nansen Environmental and Remote Sensing Center (NERSC)
Hunter, Ian	South African Weather Services (SAWS)
Inggs, Michael	Centre for High Performance Computing (CHPC)
Johannessen, Johnny	Nansen Environmental and Remote Sensing Center (NERSC)
Johnsen, Harald	Northern Research Institute (NORUT IT)
Manyilizu, Majuto	University of Cape Town (UCT)
Mouche, Alexis	Collecte Localisation Satellites (CLS)
Piollé, Jean-François	Centre ERS d'Archivage et de Traitement (CERSAT)
Pitcher, Grant	Marine and Coastal Management (MCM)
Reason, Chris	University of Cape Town (UCT)
Roberts, Mike	Marine and Coastal Management (MCM)
Roman, Raymond	University of Cape Town (UCT)
Rossow, Marius	Council for Scientific and Industrial Research (CSIR)
Rouault, Marjolaine	Council for Scientific and Industrial Research (CSIR)
Swart, Sebastian	University of Cape Town (UCT)
Shillington, Frank	University of Cape Town (UCT)
Veitch, Jennifer	University of Cape Town (UCT)
Wainman, Carl	Institute for Maritime Technology (IMT)
Whittle, Christo	University of Cape Town (UCT)

7.2.Agenda

Day 1:

09:00 - 09:15	Welcome and introduction to the workshop
09:15 - 10:00	SAR wave field retrievals (Harald Johnsen)
10:00 - 10:45	SAR swell tracking system (Alexis Mouche)
10:45 - 11:15	Coffee and Tea
11:15 - 12:00	SAR and wind field retrievals (Knut-Frode Dagestad)
12:00 - 12:45	SAR Doppler wind estimation (Alexis Mouche)
12:45 - 13:45	Lunch
13:45 - 14:45	SAR surface velocity measurements in Agulhas (Johnny A. Johannessen)
14:45 - 15:30	Using the Agulhas as a natural laboratory for satellite synergy (Johnny A. Johannessen)
15:30 - 16:00	Coffee and Tea
16:00 - 16:45	Sentinel 1 SAR system overview (M. Davidson or Marcus Engdahl, European Space Agency)
16:45 - 17:30	Summary and Discussion

Day 2:

09:15 - 10:00	A review of the physical oceanography around Southern Africa (Frank Shillington)
10:00 - 10:45	Overview of in situ measurement programs in the Agulhas Current System (Mike Roberts)
10:45 - 11:15	Coffee and tea
11:15 - 11:45	Numerical modelling of the Agulhas Current with Roms (Nicolette Chang)
11:45 - 12:15	Developing HYCOM for eddy-resolving modelling of the Agulhas Current (Bjorn Backeberg)
12:15 - 12:45	Operational activities of the South African Weather Services (Ian Hunter)
12:45 - 13:45	Lunch
13:45 - 14:15	Review of remote sensing activities at the MRSU (Stewart Bernard)
14:15 - 14:45	Developing capacity for altimetry and SAR in South Africa (Marjolaine Rouault)
14:45 - 15:30	Radio wave sensors developments and possible applications to40 oceanography (Michael Inggs)
15:30 - 16:00	Coffee and Tea
16:00 - 16:45	Remote sensing data and dissemination tools at CERSAT (J. F Piolle)
16:45 - 17:30	Summary and discussion of possible field validation campaigns

Day 3:

Morning	Summary of findings, synergies with ongoing research, relevance for GOOS Africa, etc.
12:45 - 13:45	Lunch
Afternoon	- Identification of joint SA-France-Norway projects, possibility for field validation campaigns, students to lead SAR - Africa developments - Outline of workshop report - Tentative dates for next workshop in Norway in 2009