

**Mission Of Scatterometer and Along-Track Interferometer for  
Ocean Current and Vector Wind Applications  
(MOSAIC)**

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## *Executive Summary*

*MOSAIC* is a satellite mission concept that combines scatterometry and along-track interferometry (ATI) into a single Ku-band instrument to acquire high-resolution measurements of both ocean surface current and vector wind. The mission will be the first satellite demonstration of ocean surface current measurements, and will make ocean vector wind measurements that will yield a five-fold or better improvement in spatial resolutions from the current state-of-the-art scatterometer satellite. The simultaneous wind measurements provide critical data that significantly improve the current measurements. The continuous and global view from space of these two fundamental ocean measurements, especially surface currents that are only sparsely measured by *in situ* sensors, will be of significant value for both scientific research and practical applications. *MOSAIC* will provide the key missing pieces for the Integrated Ocean Observing System (IOOS) and the global Earth observing system. In addition to Weather and Climate, *MOSAIC* will play a major role in Earth Science Applications and Societal Needs, Ecosystem Dynamics, and Human Health and Security.

### **1. *MOSAIC Science and Applications***

#### **1.1 *MOSAIC Measurement Frontier: First Satellite Measurement of Ocean Surface Current and a Five-Fold Improvement in Mapping Ocean Vector Winds***

*MOSAIC* will demonstrate that accurate and useful ocean surface current measurements can be made from space. Ocean surface current is a poorly known yet important variable that is not routinely mapped by any other satellite. Ocean surface current has been repeatedly identified as a critical variable, contributing to many of the NASA Earth Observing System goals. It is also listed as a high priority parameter for the Integrated Ocean Observing System (IOOS). Ocean surface current is presently a missing dynamic variable within space-based ocean observation that, along with satellites that measure other ocean variables, such as surface topography (TOPEX/Poseidon and Jason), vector winds (QuikSCAT), sea surface temperature (AVHRR and MODIS) and salinity (Aquarius), and color (SeaWiFS and MODIS) measurements, will form a complete suite of surface observations for both scientific research and practical applications.

Ocean surface currents can be considered as indicators of the deeper circulation and, in some cases, are controlling the 3-dimensional ocean circulation. The surface is also where human contact with the ocean is greatest and where air-sea interactions are responsible for the primary momentum and thermal forcing of ocean currents, and thus information about it can provide important understanding regarding Earth system processes and societal issues.

The measurement of surface currents has been conducted, historically, using a variety of techniques. Most recent direct measurement techniques involve satellite-tracked drifting buoys with much increased accuracy and resolutions (Niiler et al., 1987). Every two subsequent point measurements of their locations and the elapsed time can be used to estimate the ocean surface current. Today, there are on the order of one thousand drifting buoys over the world ocean that are continuously tracked by satellites. Although the drifting buoys can travel to those regions that are difficult to deploy moored buoys or seldom transited by ships, many areas of interest over the world ocean still remain unexplored. *MOSAIC* will provide the first global map of surface current and update it continuously.

In addition to the novel measurement of ocean surface current, *MOSAIC* will also provide simultaneous measurements of ocean vector winds with a five-fold or more increase in spatial resolution over the current state-of-the-art scatterometer instruments (e.g., SeaWinds on QuikSCAT). Furthermore, the simultaneous measurements of ocean surface current and vector winds will enable synergistic investigations at the interface between the ocean and atmosphere.

## 1.2 *MOSAIC* Science and Application Objectives

The *MOSAIC* science and application objectives are:

- To measure the ocean surface current and vector winds simultaneously with the required accuracy and resolution, and
- To make significant contributions to five of the seven NRC Panel themes:
  - Earth Science Applications and Societal Needs
  - Land-Use Change, Ecosystem Dynamics and Biodiversity
  - Weather
  - Climate Variability and Change
  - Human Health and Security

### 1.2.1 *Earth Science Applications and Societal Needs*

**Oil Spill Response.** Ocean surface current and vector winds are the key parameters to monitor and predict oil spill trajectories. Under the National Contingency Plan, NOAA is designated to provide the Scientific Support Coordinator (SSC) to the United States Coast Guard, which serves as the Federal On Scene Coordinator for oil spill response. NOAA's decision-support tool for oil spill response during real-time operations is the General NOAA Oil Modeling Environment (GNOME). GNOME forecasts spill trajectories based upon the best wind and ocean current information available at the time of the response.

Accurate current and wind estimates and forecasts are the key to a realistic forecast of future oil spill trajectories. During the 1989 Exxon Valdez oil spill, there was virtually no information about the local ocean surface current, therefore limiting the skill of predicting the oil spill trajectories and thus limiting evaluation of the impact to wildlife and the coastal community (Figure 1). *MOSAIC* will provide these two key parameters. Data from *MOSAIC* and other complementary *in situ* and satellite observations, once assimilated into the NOAA real-time operational forecast model (e.g., GNOME), can improve the forecast of oil spill trajectories.

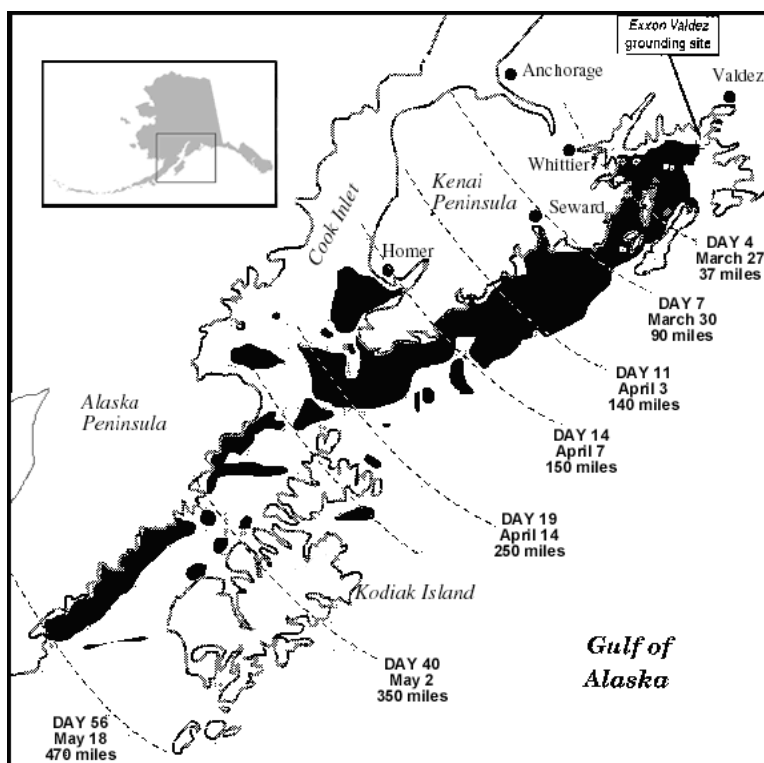


Figure 1. Oil spill trajectories after the 1989 Exxon Valdez oil spill in the Prince William Sound, Alaska. It should be pointed out that the oil spill patterns follow closely to the Alaska coastal current that can be directly measured by the proposed *MOSAIC* mission. (see <http://www.evostc.state.ak.us/facts/spillmap.html> for more details)

### 1.2.2 Land-Use Change, Ecosystem Dynamics and Biodiversity

**Ecosystem and Fishery Management.** Many decisions related to ecosystem and fishery management rely on the information of the ocean surface current. Ocean surface current can be used to derive trajectory statistics for estimating pathways of connectivity for coastal marine communities, dominant flow patterns for fisheries stock assessments, and locating/monitoring marine protected areas. For example, a salmon hatchery manager needs to know the optimal conditions to release salmon fry. The longer the salmon fry are held in pens awaiting optimal conditions for release, the more food they require and the greater expense incurred by the hatcheries. The ocean surface current and vector winds can be directly used to determine the local oceanographic conditions near the time of fry release and identify optimum release conditions.

### 1.2.3 Weather

**Marine Weather.** The existing ocean vector wind measurements from the QuikSCAT satellite have shown a significant impact on global weather forecasts. Over the oceans, the 25-km QuikSCAT vector wind data can extend the skill of weather forecasts to be able to predict as much as 6~12 hours earlier. Currently, the satellite wind observations are operationally used at the National Centers for Environmental Prediction (NCEP), a branch of the National Weather Service, Washington, and the European Centre for Medium-Range Weather Forecasts (ECMWF), Reading, England. The improvements in weather forecasts are particularly evident over the Southern Hemisphere and in the upper atmosphere where less *in situ* measurements are collected.

With a five-fold or more increase in spatial resolution, the proposed *MOSAIC* satellite mission will further impact weather research and forecasts. The 5-km wind observations will realistically resolve tropical cyclones and impact the hurricane forecasts. *MOSAIC* will also break new ground in the area of **Marine Weather** prediction and impact marine safety. For example, small aircraft accidents contribute significantly to the search and rescue operations by the United States Coast Guard. *MOSAIC* can contribute to reducing these accidents by improving marine weather prediction, thus allowing pilots to be more prepared for flight conditions. There is particular concern for the safety of those in coastal areas where ocean conditions play an important role in the weather forecast. It is expected that *MOSAIC* will provide much needed high-resolution vector wind measurements for expanded and improved marine safety and aviation forecasts.

#### ***1.2.4 Climate Variability and Change***

The measurements taken by the *MOSAIC* mission represent two key global scale observational data sets in the Earth climate system. The first global map of ocean surface current will resolve unknown patterns and variations of the world ocean circulation, and will serve as a new and effective type of reference data set for model validations. Because of the lack of data, there are many unknowns in the dynamical structure of the upper ocean circulation, especially regarding temporal and finer-scale spatial variability. *MOSAIC* will enable the study of air-sea interactions on the 10~100 km scales corresponding to mesoscale eddies and coastal upwelling centers. Furthermore, *MOSAIC* will also contribute to the interdisciplinary science area of studying the interaction between the physics and biogeochemistry of the ocean.

In addition to the global drifter programs, there are currently close to 2000 subsurface floats deployed over the world ocean as part of the international Argo program. These global measurements, when assimilated into 3-dimensional numerical models such as those coordinated by the Global Ocean Data Assimilation Experiment (GODAE), will form a truly integrated ocean observing system.

#### ***1.2.5 Human Health and Security***

**Water quality.** Urban coastal ocean areas have significant socio-economical value due to their intense recreational and commercial utilization. Assessing short-term water quality and determining long-term compliance with water quality regulations are the top two responsibilities for coastal managers. Clean beaches and coastal waters are central to the local economy and community lifestyle. Sources of marine pollution are numerous: sewage outfalls and spills; runoff from rivers and storm drains; industrial waste; offshore dumpsites; and discharge or spills from vessels (Figure 2). These coastal pollution hazards have significant ramifications for human and ecosystem health and productivity.

*MOSAIC* will provide the key data set to address these water quality issues. When the *MOSAIC* data and other existing *in situ* and satellite observations are assimilated into a predictive ocean model, we will be able to monitor and more importantly predict the time evolution and fate of ocean discharges from point sources. This will assist in developing permit requirements and enforcement. We will be able to determine flushing rates to quantify pollutant residence time as it affects beach closure times and assess the regional capacity of coastal waters to accept increasing discharges and the associated ecological impacts. We will be able to provide water quality managers and policy makers with a better scientific basis for evaluating the effectiveness of management strategies and prioritizing water quality infrastructure improvements.



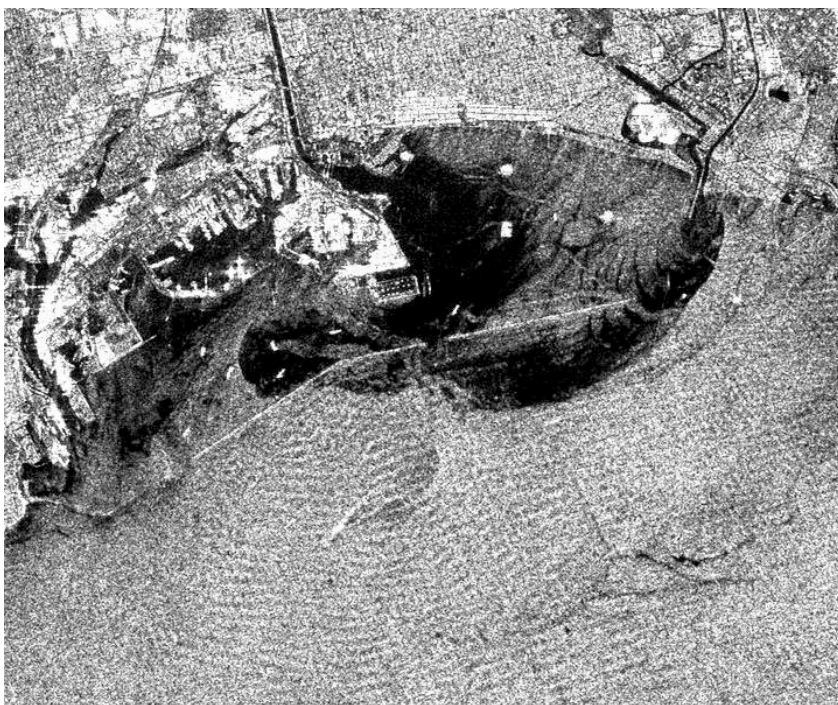


Figure 2. Radar image of storm-water runoff plumes from Los Angeles and San Gabriel Rivers into the Los Angeles and Long Beach Harbors as derived from the European Remote Sensing (ERS-1) satellite. (after DiGiacomo et al., 2004)

### **1.3 Relevance to Earth Science/Applications and Operational Capabilities**

NASA Earth science and applications call for breakthrough missions over the coming decades with either new measurement concepts or orders of magnitude improvements over the current state-of-the-art satellite missions. The proposed *MOSAIC* mission concept satisfies both of these challenges: it performs the first satellite measurement of ocean surface current and provides the capability for a five-fold or better improvement in mapping ocean vector winds. Further, the *MOSAIC* data, once implemented in real-time operations and integrated with prediction models, can be used for a variety of practical applications such as oil spill response and management of ecosystem and water quality.

The ocean surface current has been previously identified as a high priority parameter to be measured from space as part of the Earth Observing System. It is also listed as a key parameter within the IOOS and Global Earth Observing System of Systems (GEOSS). Specifically, the *MOSAIC* data products will be integrated into the application decision support tool (see Figure 3 for an example of oil spill response) along with other complementary *in situ* and satellite observations providing information for application users and policy decision makers.

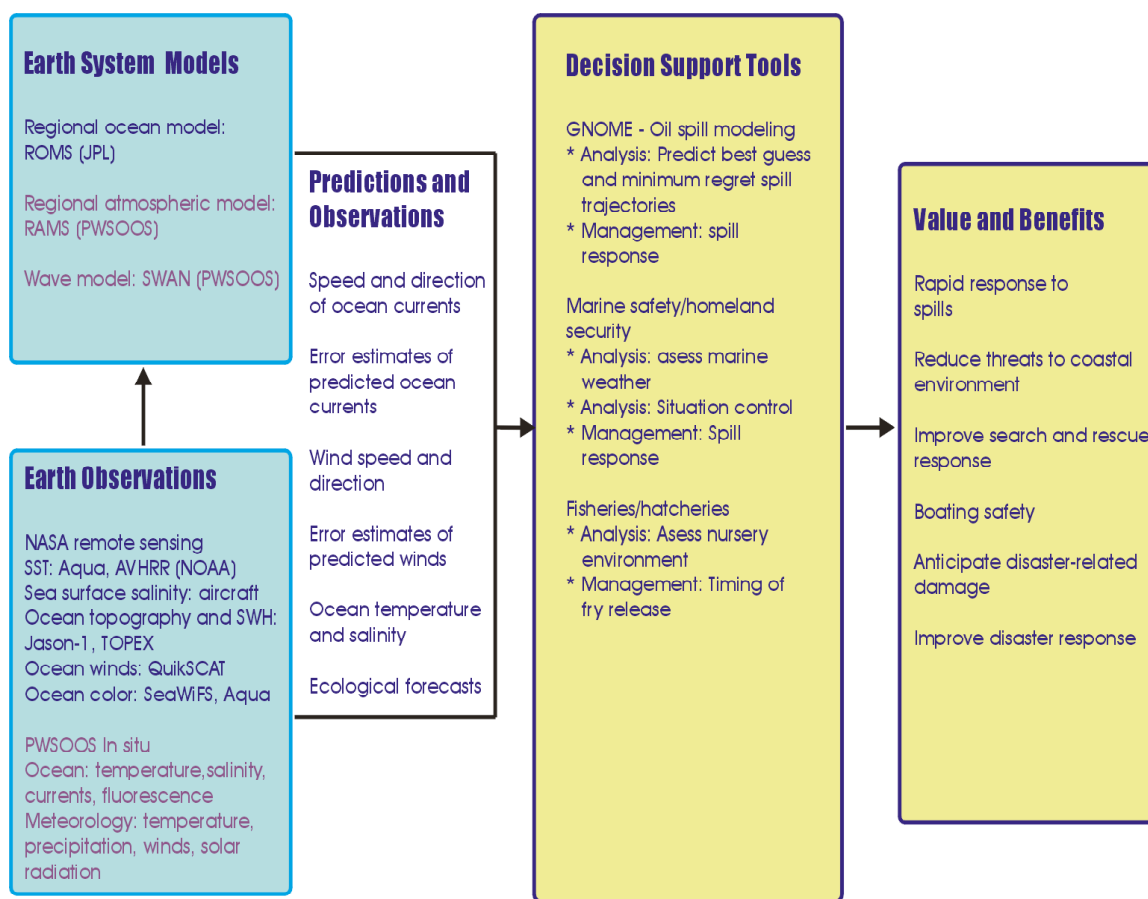


Figure 3. An example of operational applications of how *MOSAIC* satellite data and other complementary observations can be used in a decision support tool (e.g., NOAA's GNOME) for oil spill trajectory predictions.

#### 1.4 Synergy with other National and International Programs

Many ocean surface parameters are routinely measured from space, including sea surface temperature, sea surface height, ocean vector winds, and ocean color. Once the *Aquarius* satellite is launched in 2009 as an Earth System Science Pathfinder (ESSP) mission to measure the ocean surface salinity, the ocean surface current will be the only ocean surface parameter that is not directly measured from space. This is another compelling reason that *MOSAIC* should be integrated into the global Earth observing systems at the earliest opportunity.

The proposed *MOSAIC* mission to measure the ocean surface current on a global scale will complement the national Surface Current Mapping Initiative (SCMI) currently being planned (<http://www.ocean.us/oceanusInitiative.jsp>). SCMI proposes to implement a surface current mapping system for the U.S. continental shelf regions (U.S. coastal waters or EEZ, and possibly out to ranges of ~200 km from shore) established on the land-based high frequency (HF) radar backscatter instruments (Paduan and Graber, 1997). Imaging of land will contaminate the first few footprints away from the coastline. A combination of open-ocean *MOSAIC* satellite observations and coastal radar measurements will therefore form a truly global observing system of ocean surface current.

The global surface current measurements from the proposed *MOSAIC* mission will also complement the Ocean Research Interactive Observatory Networks (ORION)



program currently planned for a FY 2007 start by the National Science Foundation (NSF). ORION focuses the science, technology, education and outreach of an emerging network of science driven ocean observing systems (<http://www.orionprogram.org/>). By combining the ORION *in situ* measurements with the satellite-based observations on the global scale (such as the proposed MOSAIC), we will discover new processes that directly impact human society, our climate and the ecosystem.

## 2. MOSAIC Measurements and Instruments

### 2.1 Surface Current Measurement: Along-Track Interferometry

The technique of measuring surface currents using coastal HF radars (Paduan et al., 2004) cannot be implemented from space due to the low radio frequencies used. An alternate method, which can be implemented in space-borne applications, was introduced by Goldstein et al. (1989) and is generally called Along-Track Interferometry (ATI).

Conceptually, the ATI measurement is straightforward: the same scene is imaged twice, with a short temporal separation  $\tau$  between measurements (Figure 4). If the scatters in the imaged pixel have moved in the interval, the radar phase difference between the two observations will be  $\delta\Phi = 2k v_r \tau$ , where  $k$  is the electromagnetic wavenumber and  $v_r$  is the velocity of the scatterer in the direction from the radar to the scatterer. In practice, the temporal separation is accomplished by flying two radar antennas displaced along the direction of flight, so that after a time  $\tau = B/V$  ( $B$  is the antenna separation and  $V$  is the platform velocity), the second antenna will occupy the same position as the first. This configuration results in a radial or line-of-sight velocity component.

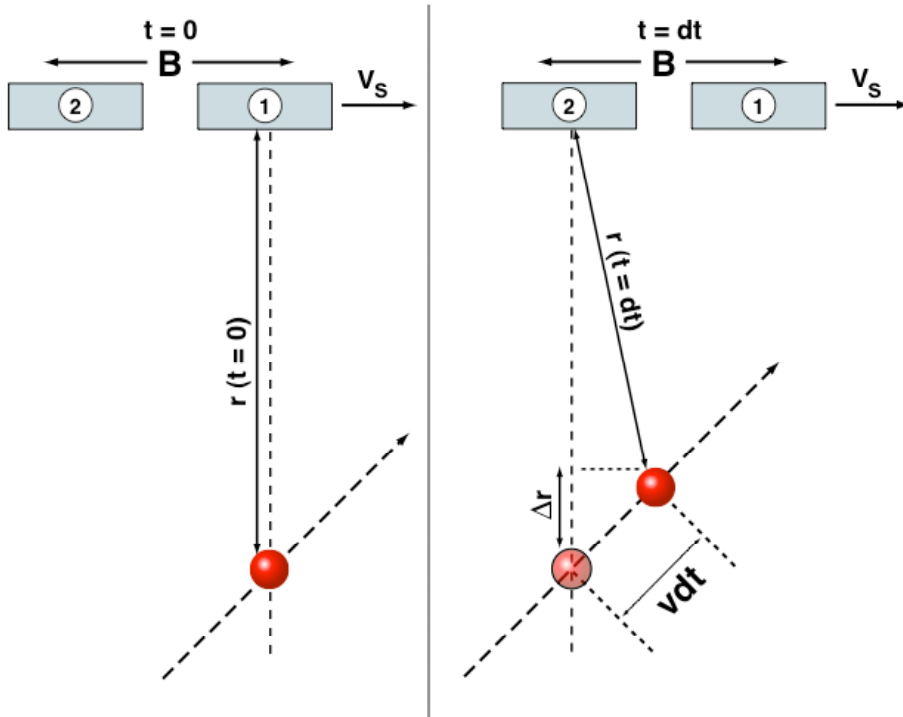


Figure 4: ATI measurement concept. At  $t=0$ , antenna 1 measures the phase of the signal scattered from the target ( $\Phi=2kr(t=0)$ ). A short time later, the same target is measured by antenna 2. A change in the propagation phase will correspond to a displacement  $\Delta r$ , which can be attributed to a radial velocity  $v$  such that  $\Delta r = v dt$ .

To perform a vector velocity measurement, one must measure the radial velocity from two different azimuth angles, as proposed by Frasier and Camps (2001). For ocean surfaces and moderate incidence angles, the bulk of the scattering will be from Bragg resonant waves in the gravity-capillary regime (Plant, 2003). The ATI measured velocity will consist of several components: the intrinsic velocity of the scatters, the modulation of their velocity by large scale wave orbital velocity (Thompson and Jensen, 1993), surface drift due to Stokes drift and wind drift currents (Weber, 2003), and the surface current below the wind drift current. In addition, electromagnetic scattering effects may bias the velocity measurement due to modulation of the small wave amplitude and slope by the large waves (Moller et al., 1998).

The measured velocity can be written as  $U_{\text{total}} = U_{\text{current}} + U_{\text{bragg}} + U_{\text{orbital}} + U_{\text{EM}} + U_{\text{wind-drift}}$ . The separation of all of these velocities requires additional knowledge about the wind and wave conditions. The Bragg contribution ( $U_{\text{bragg}}$ ) can be removed if the wind direction is known (Thompson and Jensen, 1993; Frasier and Camp, 2001; Moller et al., 1998). In our proposed concept, the wind direction would be obtained through the combination of an ATI instrument and a radar scatterometer. The bulk of the orbital velocity contribution ( $U_{\text{orbital}}$ ) will average out if the spatial averaging scale of the measurement is much longer than the dominant wavelength. In our proposed concept, the averaging scale would be between 1 km and 5 km, which is much greater than the scale of dominant ocean waves. The EM bias effects ( $U_{\text{EM}}$ ) can be removed through knowledge of the wind speed (obtained by the scatterometer) and wave spectral information derived from a wave model (e.g., Wave Model or WAM). The wind drift contribution ( $U_{\text{wind-drift}}$ ) can be estimated from knowledge of the wind speed and direction (Weber, 2003), which are derived from the scatterometer.

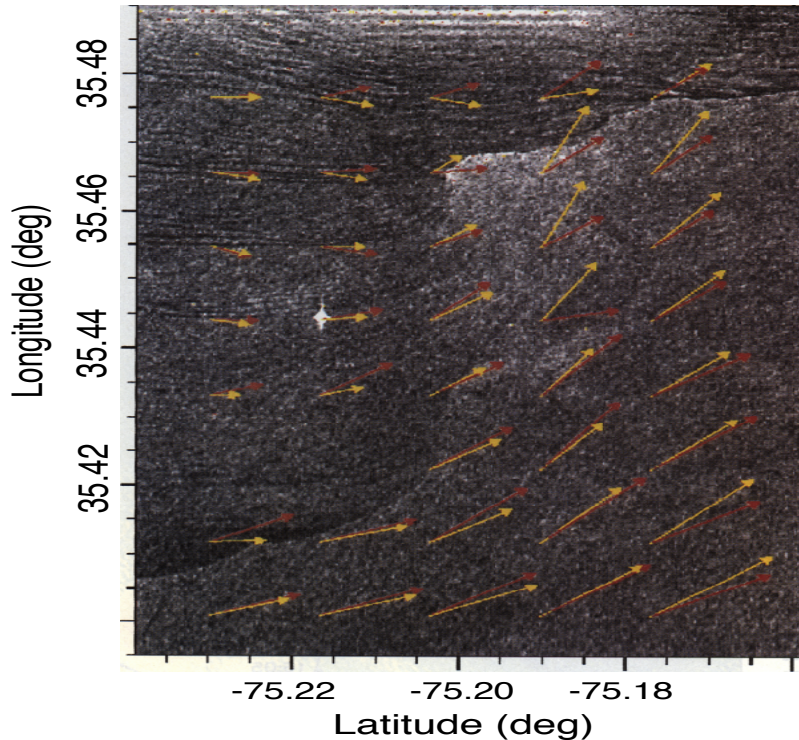


Figure 5: Comparison of the full surface current vectors (yellow arrows) constructed using AIRSAR in L-band ATI configuration using two separate perpendicular passes with HF coastal radar estimates (red arrows) for ocean currents off Cape Hatteras (from Graber et al., 1996).

As an example of how all of these components can be integrated, we present in Figure 5 results of a comparison between ATI derived vector currents and those obtained by HF coastal radars (Graber et al., 1996). The relative root mean squared accuracy between the two measurements varied between 5 cm/s to 11 cm/s, depending on which component of the vector velocity was being imaged. Recently, Romeiser (personal communication, 2005) has demonstrated the inversion of radial velocities from the space-borne SRTM interferometer, although a detailed validation of the data has not yet been published.

The retrieval of surface currents is limited by the knowledge of the local wind direction for Bragg wave removal. This limitation applies even more strongly to the use of Doppler centroid, another technique demonstrated with RADARSAT and Envisat SAR imagery for measuring radial currents, which can be implemented with conventional SARs but that has been found to result in coarser resolution currents. The instrument we propose combines the mature Ku-band vector wind scatterometry technique (demonstrated in NSCAT and QuikSCAT) and an additional set of antennas for along-track interferometry. The use of Ku-band is based on the maturity of the wind vector scatterometry technique at this frequency, coupled with available mature components. At lower frequencies, the wind speed model function is not as sensitive to wind direction, while higher frequencies have yet to be explored.

## **2.2 Simultaneous Surface Current and Vector Wind Measurement: Combined Scatterometry and ATI**

The second parameter measured by the proposed *MOSAIC* mission is the ocean surface wind vector. Radar wind scatterometry is a proven technique to obtain wind speed and direction over the sea surface, and has been demonstrated on several past missions. Scatterometers have been flown at Ku-Band on SEASAT, NSCAT/ADEOS-I, and SeaWinds/QuikSCAT. Unlike ATI where the determination of changing phase is the primary objective, a scatterometer makes a precise measurement of the surface backscatter cross-section. By measuring the backscatter from multiple azimuth angles, both the surface wind speed and direction can be determined. Because measurements at multiple azimuths (or “squints”) is a requirement for the ATI current velocity as well, it is a natural fit to make these two different measurements simultaneously.

## **2.3 Science Traceability Matrix**

The proposed *MOSAIC* mission concept is based on the relationship between the scientific objectives and the data to be returned, and this determines the instrument payload design requirements in the science traceability matrix shown below. *MOSAIC* science objectives are oriented toward high-resolution measurements for real-time operations. These will be achieved with a 5-km spatial resolution and the best possible measurement accuracy.

The Science Traceability Matrix defines the instrument and mission requirements to meet the science goals			
<i>Science Goals</i>	<i>Measurement Requirements</i>	<i>Instrument Requirements</i>	<i>Mission Requirements</i>
<ul style="list-style-type: none"> <li>* Earth Science Applications and Societal Needs</li> <li>* Ecosystem Dynamics</li> <li>* Weather</li> <li>* Climate Variability and Change</li> <li>* Human Health and Security</li> </ul>	Global map Intraseasonal variability Annual cycle Interannual variability	Measure ocean surface current and vector winds with Ku-band radar scatterometer with 15-m baseline ATI	Polar orbit 3-year mission life with a minimal mission of 1-year
	Spatial resolution: Coastal: 1~5 km Open-ocean: 10~100 km	3m by 0.5 m antenna.	Low-Earth orbit @650-km altitude
	Temporal repeat: 1~3 day	Maps 50% of the world in 1 day, 80% in two days, and 100% in three days	~800-km swath
	<ul style="list-style-type: none"> <li>* Current Accuracy: Coastal: 5~10 cm/sec; Open-ocean: 1~5 cm/s; Direction: 6° at 1 m/sec &amp; 11° at 50 cm/sec</li> <li>* Wind Accuracy: 1 m/sec; 10°</li> </ul>	0.1 degree rms phase accuracy measurements after spatial averaging. 0.1 dB cross section accuracy. 2 azimuth angles.	Major error sources/corrections need to be well understood

It should be pointed out that both tidal and inertial motions, which have periods that are diurnal or shorter, cannot be Nyquist sampled by our radar system by itself. This potential aliasing problem due to the limited temporal repeat of the satellite is not particularly new for satellite remote sensing. For satellite altimetry, one needed to make the sea level correction from a very accurate tidal model in addition to many other geophysical corrections such as sea level pressure, wave-state bias (both EM and physical), and tropospheric water vapor. The proposed *MOSAIC* data retrieval will have to follow the same methodology to solve the problems of sufficiently accurate tidal, inertial, and Stokes-drift (wave) currents in order to subtract them from the desired current. Using the QuikSCAT orbit, we have conducted a preliminary study of the potential aliasing of inertial currents. The preliminary study suggests that a Kalman filter approach assuming that the period is known and fixed with varying amplitude and phase as in Gaspar and Wunsch (1989) may be effective in removing inertial currents.

Rather than viewing our proposed measurements in isolation, we propose, following the paradigm shown in Figure 3, that our proposed *MOSAIC* mission be considered as a key component in an integrated system consisting of available *in situ* data, such as drifters and coastal HF radars, and dynamic models which would assimilate all available data, including our instrument data. The constraints imposed by the dynamics, the *in situ* observations, and our data can then be used to study phenomena that are not sampled by any one component alone.

## 2.4 Baseline Mission Concept Description

The key to the *MOSAIC* mission concept is the combination of, and synergy between, the ATI surface current measurement and the scatterometry vector wind measurement. The instrument concept extends a conventional Ku-Band radar scatterometer, based on an NSCAT-like paradigm, with an along-track baseline. At each end of this baseline are a series of four fore and aft squinted antennae, enabling the vector ATI and coincident wind measurements.

The ATI instrument can achieve open-ocean 5-km pixel measurements of both vector surface currents and wind velocities – a five-fold increase in previously attained wind measurement resolutions and the first space-borne demonstration of vector surface current measurements. The instrument attains a nominal current accuracy of 10 cm/s over the entire swath at moderate to high wind-speeds, allowing higher accuracy (e.g., 1 cm/s) when averaged to a larger spatial scale (e.g., 100 km). The simultaneous wind accuracy can be 1 m/s for speed and  $10^\circ$  for direction. It is feasible to operate the instruments over a selected region with higher spatial resolutions (e.g., 1-km) with reduced swath width synthesizing a short aperture. Because of this, the *MOSAIC* mission can be specially designed to resolve certain regional phenomena with a smaller spatial scale.

In order to achieve a substantial swath we observe on both sides on the spacecraft, illuminating two strips spanning incidence angles of approximately  $20\text{--}47^\circ$ . (Such angles are within the Bragg scattering regime.) The result is two 400-km wide swaths in each squinted viewing direction, with a nadir gap of 400-km. Elevation scanning is required to maintain this swath and have sufficient antenna gain to meet our required measurement precisions. For the special mode of operations with 1-km resolutions, the swath is reduced to 250-km through synthesis of short unfocused apertures.

Our nominal mission orbit scenario has a  $60^\circ$  inclination and a 650-km altitude for near-global coverage. After 2 days, at squint angles of  $45^\circ$ , this orbit results in full coverage at high latitudes, and 70% coverage at equatorial latitudes. A near global coverage can be achieved within 3 days.

Key driving parameters for the *MOSAIC* instrument design are the baseline length, the transmit power and the data rate. The baseline is a trade between the measurement precision, the ocean decorrelation time, physical constraints and the unambiguous velocity. Balancing these trades we are currently considering a 15-m baseline. The peak power for sufficient backscattered signal strength is approximately 500W/side and requires one or more tube amplifiers. The data rate is dictated by the transmitted bandwidth – a trade of resolution, number of independent samples and signal to noise ratio – and may necessitate on-board processing if it is too high for current downlink and storage capacities.

## 3. *MOSAIC Mission Implementation*

### 3.1 Mission Cost Estimate

The proposed *MOSAIC* mission will be a medium-size mission with a cost ranging from \$300 to \$400M. In order to obtain an order of magnitude cost estimate for the *MOSAIC* mission, it is assumed that the instrument is on a single, dedicated “free-flying” spacecraft placed in low-Earth orbit. The cost estimation includes the instrument, spacecraft, launch vehicle, mission operations, science data system, as well as the accompanying project management, system engineering, and mission assurance activities



and healthy project reserves. Although detailed costing must await a more detailed system definition, and is therefore beyond the scope of this white paper, it is possible to obtain a reasonable cost estimate by comparison to two similar systems that have recently undergone rigorous cost exercises.

The two systems selected for cost comparison purposes are the Ocean Vector Winds Mission (OVWM) and the Wide Swath Ocean Altimeter (WSOA). OVWM has been studied as a follow-on mission to SeaWinds. The specific OVWM implementation considered for cost comparison is the “MEOScat” concept, which includes a two-channel Ku-Band scatterometer, a large deployable structure for supporting a 4.5 meter diameter parabolic reflector antenna, a spacecraft bus, Delta-II launch vehicle, and a ground system for a minimum three-year mission. The WSOA is an instrument concept which includes a two channel interferometric Ku-Band radar, two deployable Ku-Band reflector array antennas and accompanying deployable mast structures to form the baseline, and a ground data processing system. Taking the relevant element costs from each mission and scaling the numbers up where appropriate (e.g., eight antennas instead of two for WSOA), we arrived at a ROM cost for an ATI/Scat mission of between \$300~\$400M FY 2005 dollars. The ability to approach the lower end of this range depends largely on the ability to utilize a launch vehicle significantly less expensive than a Delta-II (e.g., Taurus or Mintotaur-IV).

### 3.2 Degree of Maturity and Readiness

The proposed *MOSAIC* mission relies heavily on the technology heritage developed for several previous satellite missions. The *MOSAIC* instrument design carries significant heritage in technique, processing and instrument technology. Basing the design on an NSCAT type of configuration, including the use of slotted waveguide antennas and a real-aperture configuration (in open-ocean mode) substantially reduces risk. The physical baseline follows that of SRTM and WSOA, which had booms of 60-m and 6.4-m respectively. The *MOSAIC* transmitter has heritage in the Cassini and WSOA systems, and similar on-board processing capabilities were addressed by WSOA and numerous non-flight programs.

The following table shows high heritage technologies, including the Ku-Band radar receiver electronics, fan-beam antennas, and the deployable mast structure necessary to form the baseline and support the antennas. Two areas that may require additional development are the use of higher power transmitters, and phase calibration techniques. Higher power transmitters may be obtained by combining lower power tubes with heritage, or by the direct development of high power devices. Phase calibration is perhaps the most critical area requiring additional study. Phase calibration involves the combined use of high stability (electrical and mechanical) components, as well as methods to directly calibrate the relative phase of the antenna/electronics combinations at either end of the baseline.

Key Mission Element	Heritage Comments
Ku-Band Radar Transmitters, TWTA	120 W TWTA developed for NSCAT, SeaWinds, WSOA, OVWM. Higher power (500 W) may be necessary for ATI/Scat. Combination of multiple high heritage tubes, or development of new high power device.
Ku-Band Receiver Electronics	High heritage from SeaWinds, WSOA.
Elevation scanned, fan-	Slotted waveguide antennas used on NSCAT and ERS-1,2,



beam antennas	ASCAT. Ferrite phase shifters for scanning high heritage.
Deployable support for baseline	60 meter deployable mast structure (ADAM) used on SRTM. Prototype mast for WSOA 6 meter baseline developed and demonstrated.
Interferometric Calibration	SRTM & WSOA.

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