Modular Aerial Sensing System (MASS) measurements during SOCAL2013

Luc Lenain, W. Kendall Melville, Laurent Grare, Peter Sutherland & Nick Statom

Scripps Institution of Oceanography, University of California, San Diego 9500 Gilman Dr., La Jolla, CA

Measurement platforms used during SoCal2013 experiment. Left panel shows the Partenavia aircraft making a low pass over R/P FLIP. Right panel shows a wave glider (yellow object in foreground) navigating between R/V Melville and R/P FLIP.

Overall Goals

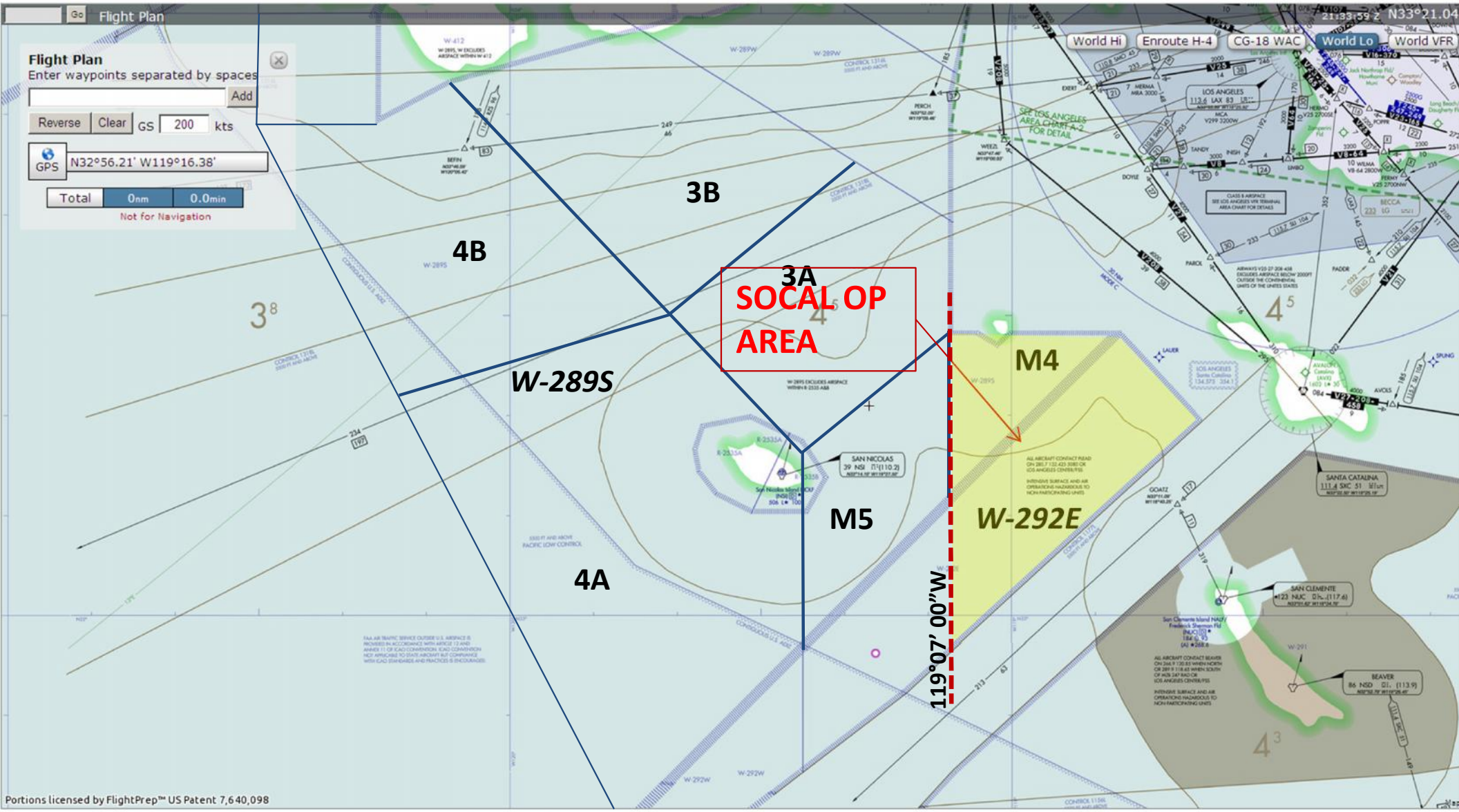
Following the ONR HIRES DRI program, our objectives were to conduct spatio-temporal measurements of the wave field, underlying subsurface conditions and coincident MABL characterization using aircraft, research platform, USVs and a research vessel over a greater mix of swell and wind waves and better instrumentation.

- **How well can marine radar systems represent the ocean surface wave field?**
- **Explore the remote (IR, hyperspectral) measurement of Langmuir turbulence and the vortex force term (Stokes drift and vertical vorticity)**
- **Wave-current interaction**
- **Can wave breaking characteristics be measured and quantified?**
- **How does the wave state affect fluxes in MABL, especially drag?**
- **What are appropriate ways to observe, predict & parameterize lower MABL over waves?**

FLIP was moored approximately between San Nicholas, San Clemente, and Santa Catalina Islands in the Southern California Bight from November 6 to November 22 2014. The wave gliders were set to navigate within approximately 2 km of FLIP in order to give broader spatial coverage of sub-surface measurements, allowing comparison with airborne remote sensing data.

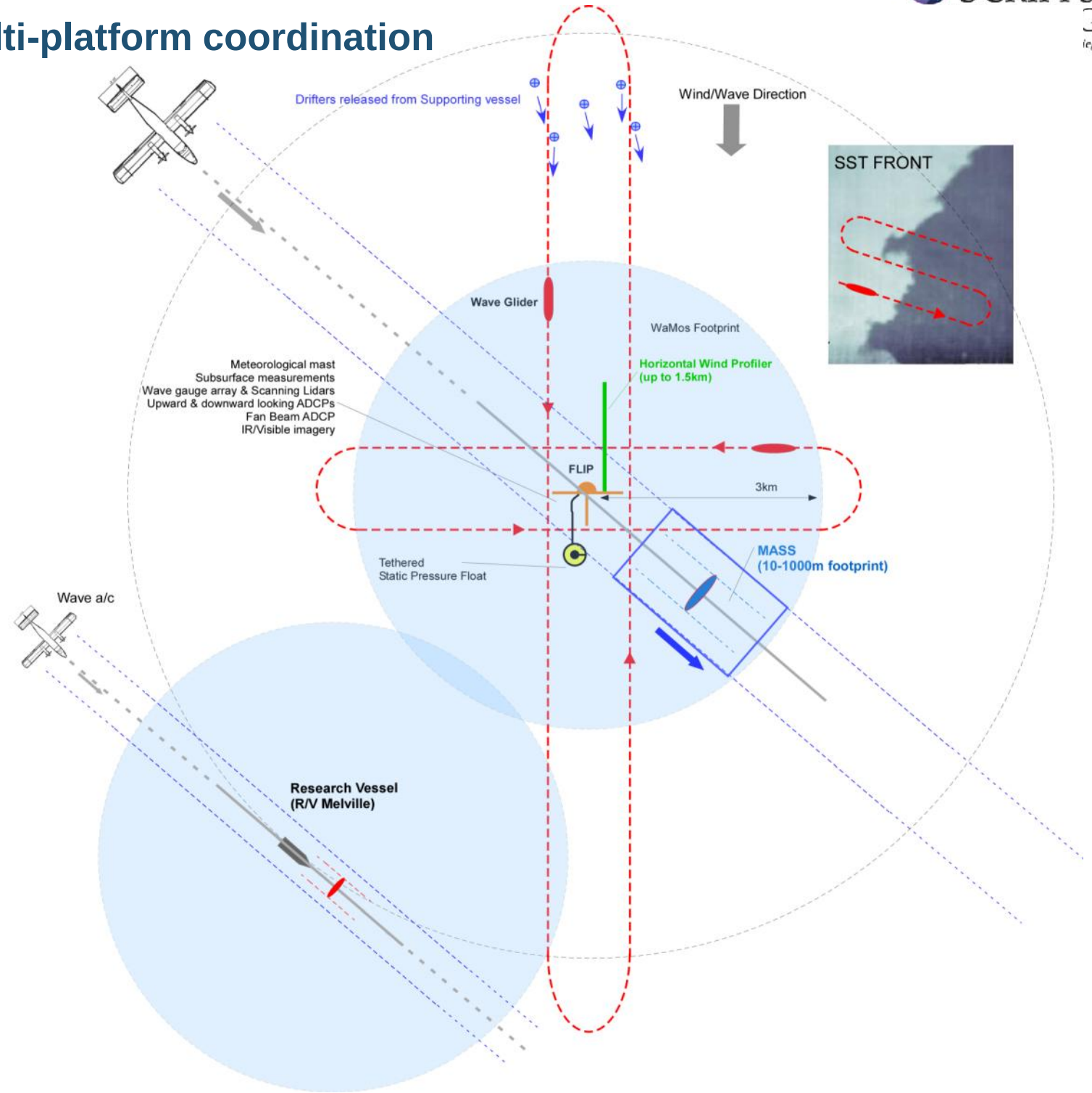
R/V Melville also operated in the direct vicinity of FLIP.

Air & Water spaces coordination

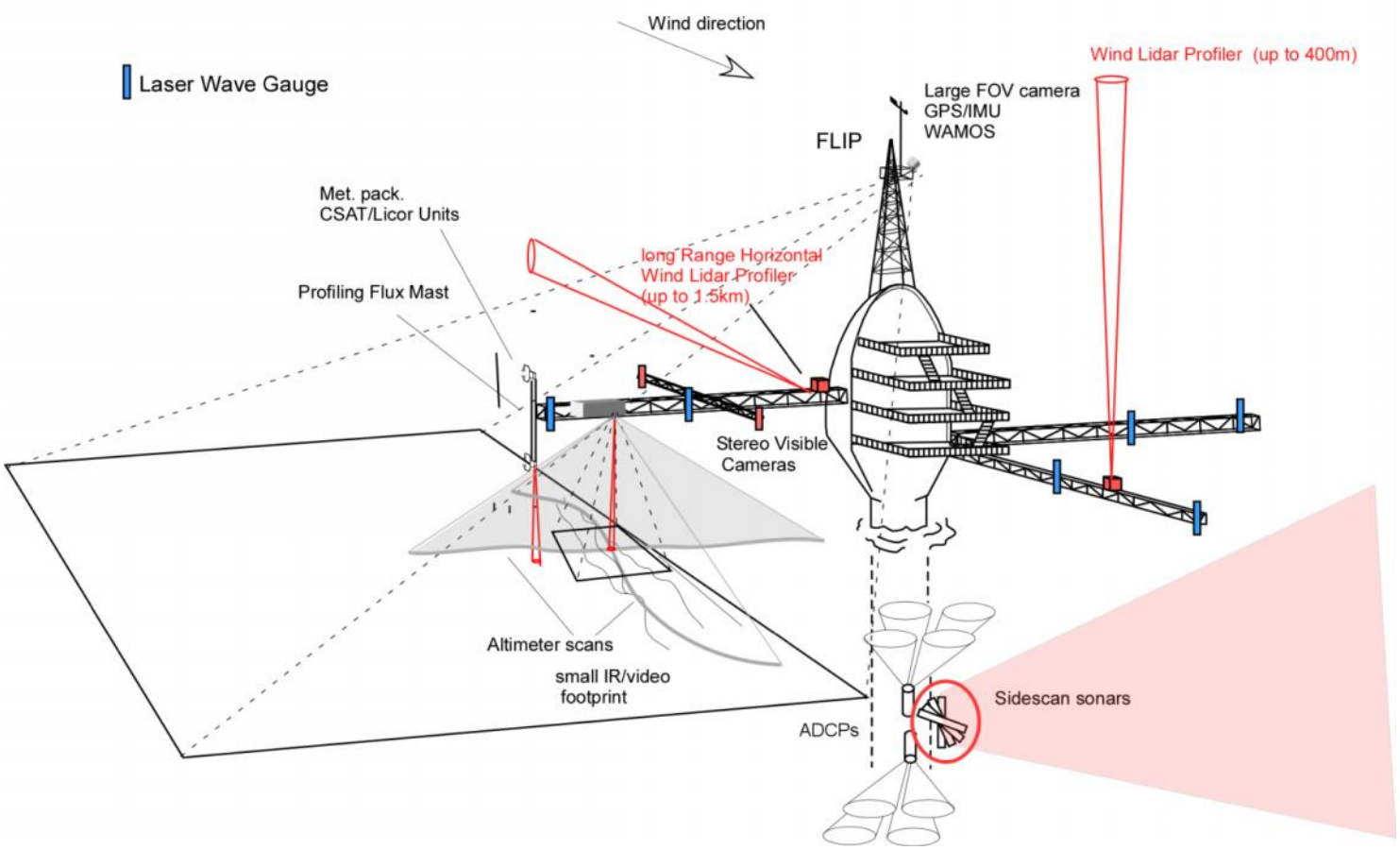


Deployment of R/P FLIP (moored), R/V Melville, MASS-instrumented aircraft (Partenavia P68) and Wave Gliders in November 2013.

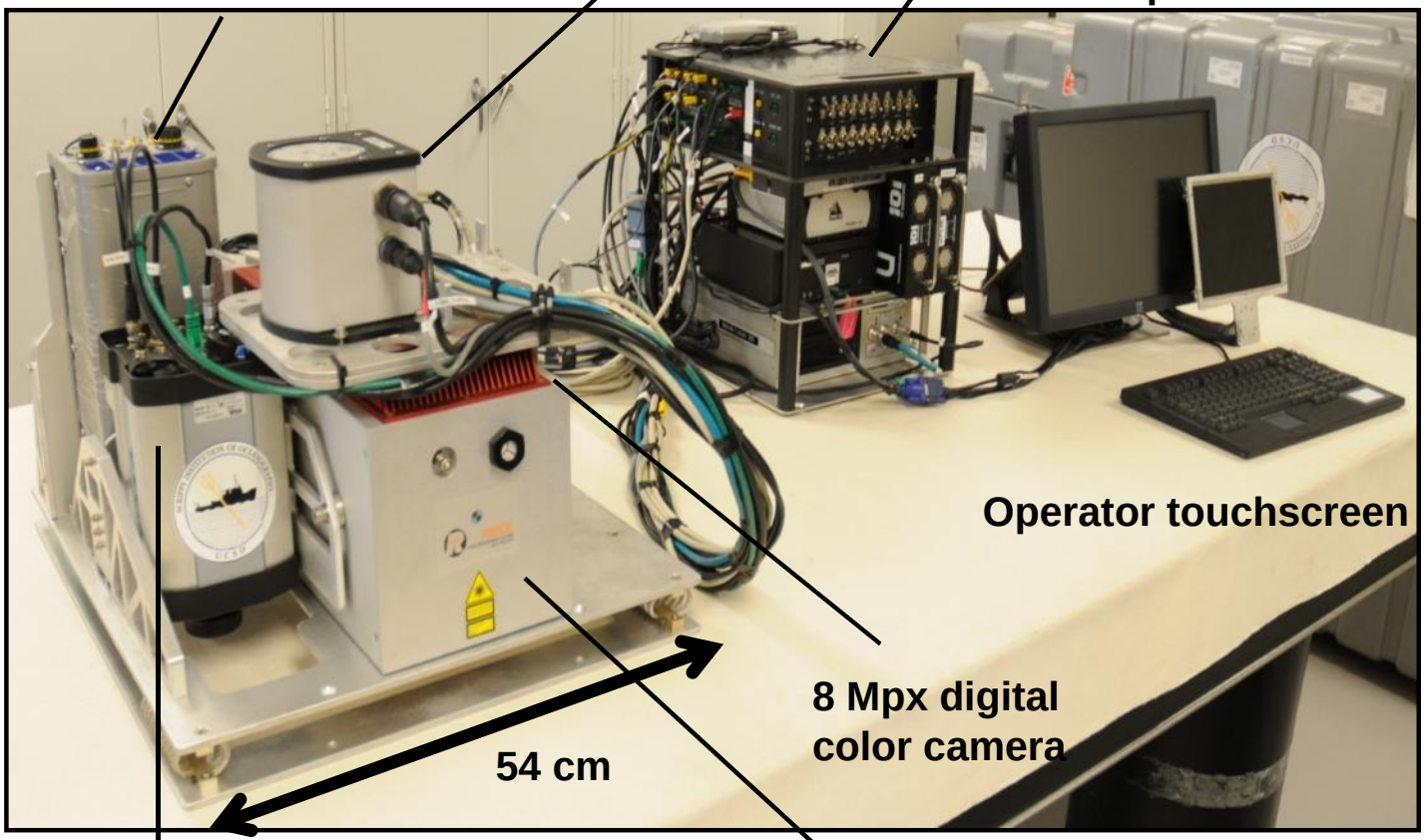
Overview & multi-platform coordination



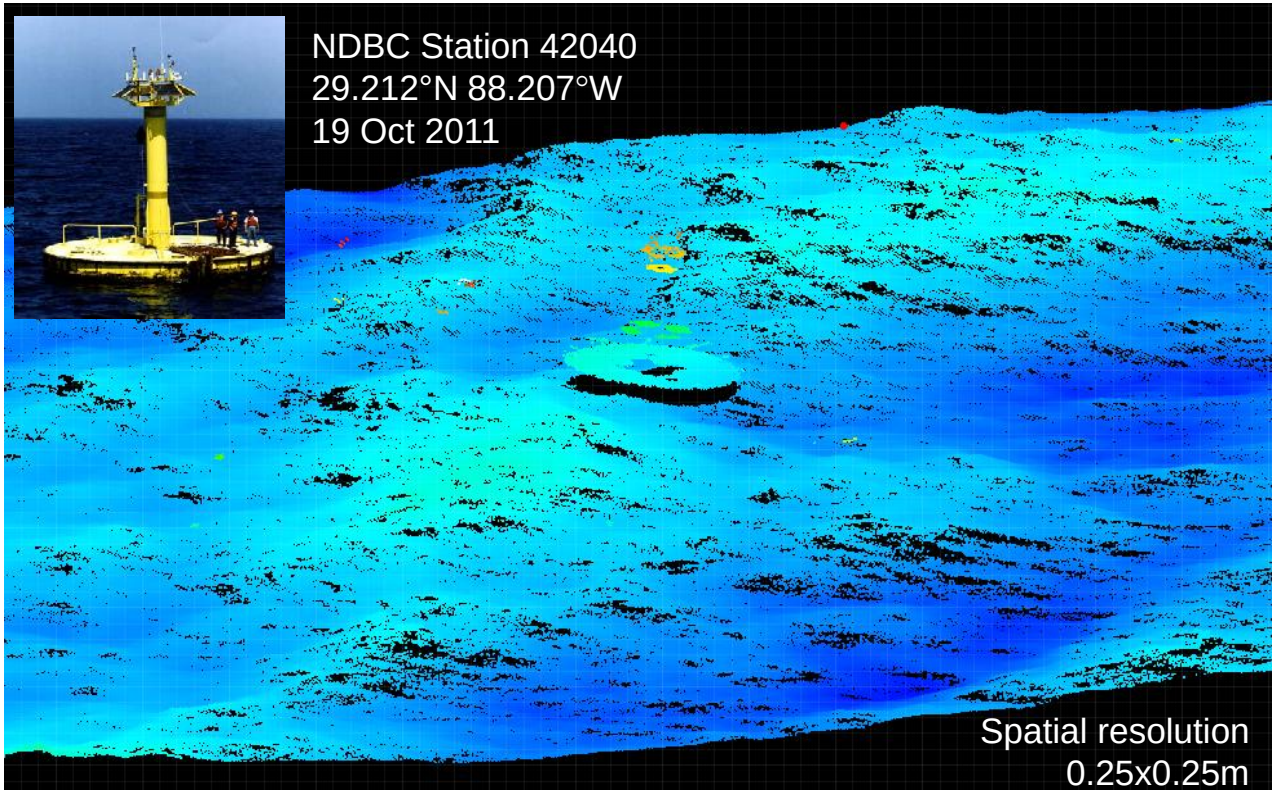
R/P FLIP


Wind direction
Laser Wave Gauge
Wind Lidar Profiler (up to 400m)
Large FOV camera
GPS/IMU
WAMOS
FLIP
Met. pack.
CSAT/Licor Units
long Range Horizontal
Wind Lidar Profiler
(up to 1.5km)
Profiling Flux Mast
Stereo Visible
Cameras
Altimeter scans
small IR/video
footprint
ADCPs
Sidescan sonars

SIO Modular Aerial Sensing System (MASS)



SIO Modular Aerial Sensing System (MASS)



Example of surface elevation as measured from the MASS during a recent experiment in the Gulf of Mexico, flying above NDBC buoy #42040. (wind~12m/s, Hs = 3.1m)

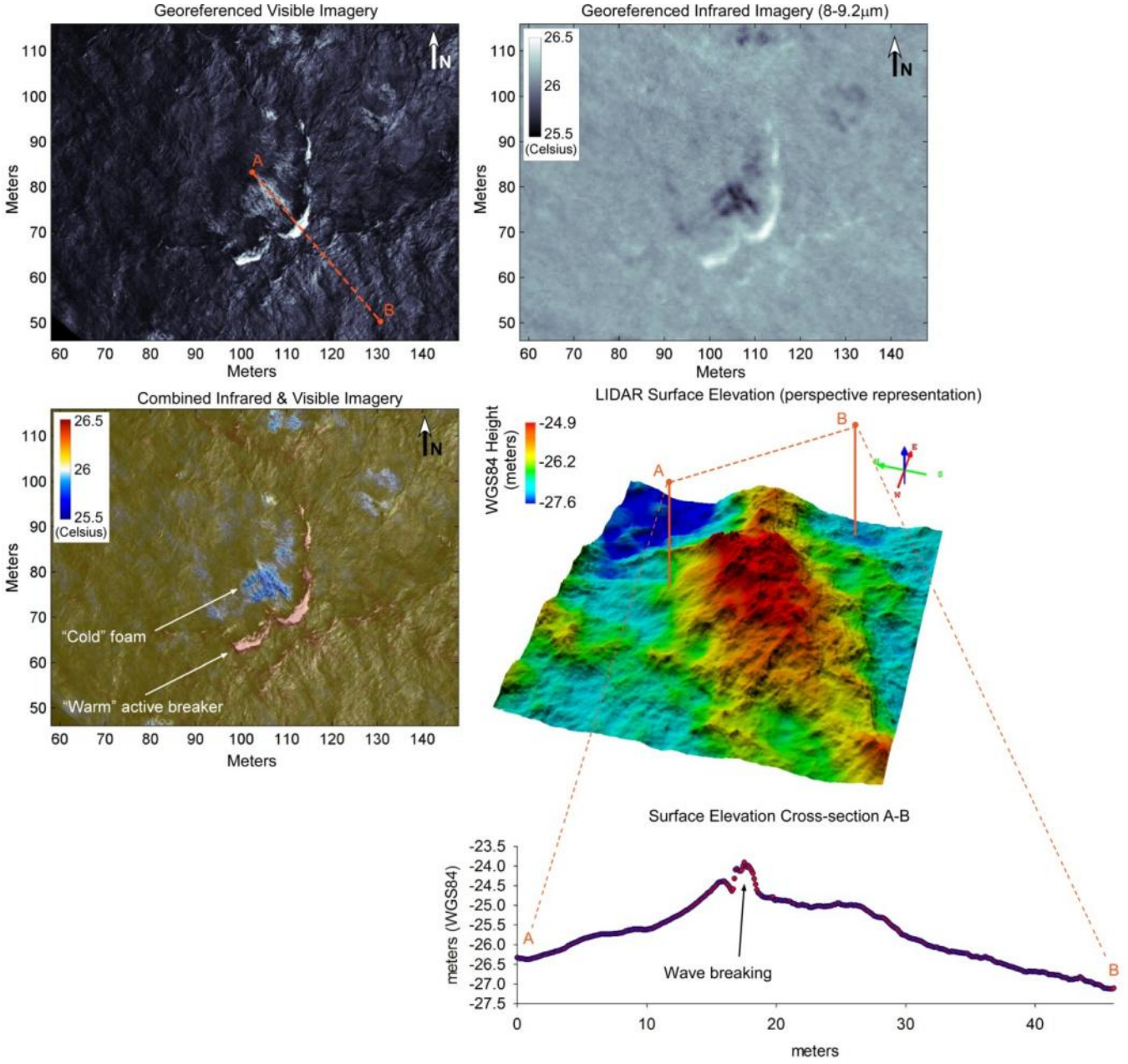
Rapid processing capability

Instrumentation		**Measurement**
Scanning Waveform Lidar	Riegl Q680i	Surface wave, surface slope, directional wave spectra (vert. accuracy ~2-3cm)
Long-wave IR Camera	FLIR SC6000 (QWIP)	Ocean surface processes, wave kinematics and breaking, frontal processes
High-Resolution Video	JaiPulnix AB-800CL	Ocean surface processes, wave kinematics and breaking, frontal processes
Hyperspectral Camera	Specim EagleAISA	Ocean surface and biogeochemical processes
GPS/IMU	Novatel SPAN-LN200	Georeferencing, trajectory

MASS – Example of High-Resolution Measurements of Breaking Waves (IR & Visible)

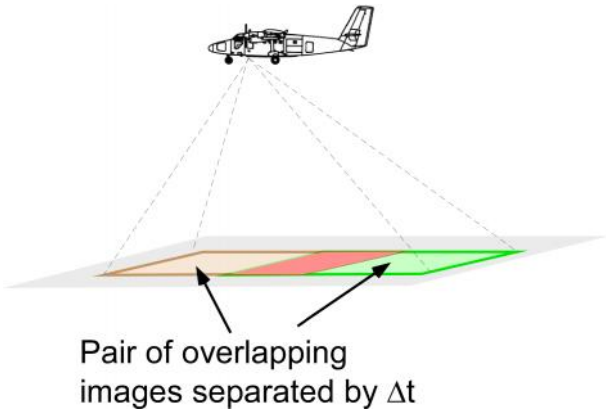
Sample georeferenced images of a breaking wave in the visible and infrared (8-9.2μm) bands during a recent experiment in the Gulf of Mexico. Note that the foam is colder (blue) due to rapid cooling (T_{water} - T_{atm} ≈ 8°C) while the active breaker is warmer (red), disrupting the surface skin layer and bringing warmer water from below.

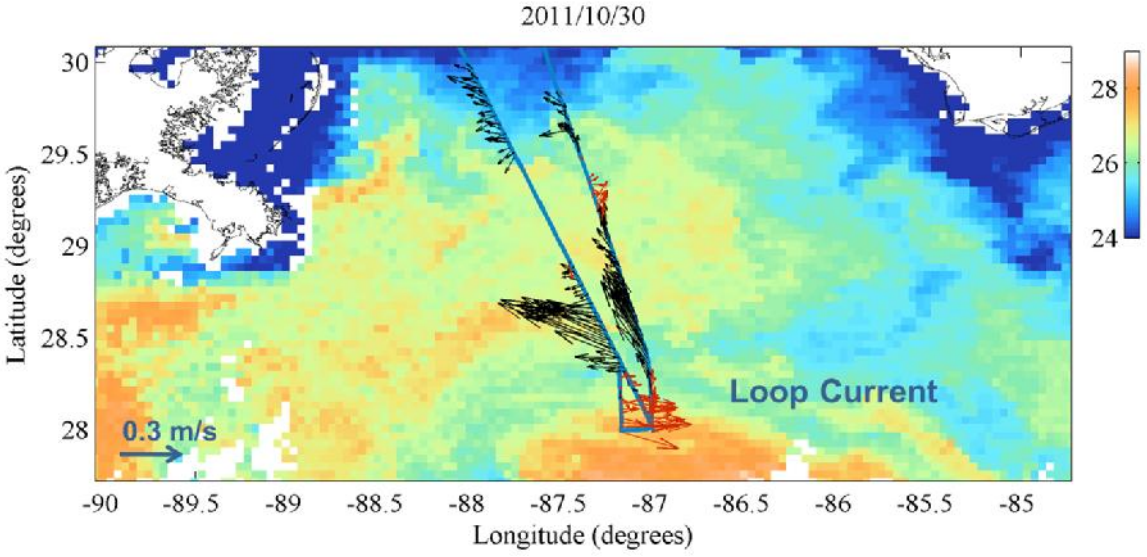
Also shown is a perspective view of the sea surface elevation for the same breaking wave color coded for WGS84 height (World Geodetic System 1984 datum). The lower panel shows the profile of the transect A-B marked in the georeferenced visible image.



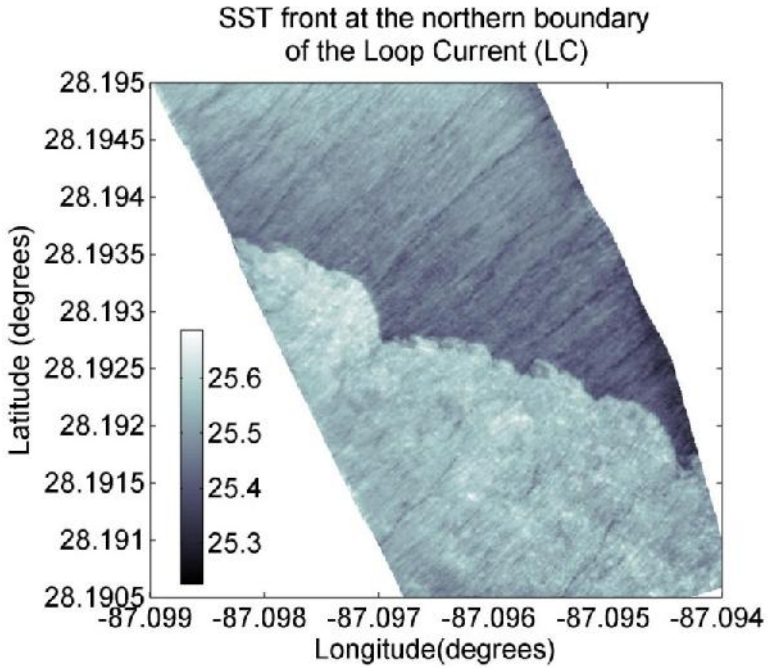
Another MASS application – Characterization of surface kinematics from airborne thermal imagery

An image processing technique was developed to characterize sea surface kinematics from thermal imagery of the ocean surface.
Thermal structures (e.g. Langmuir circulations) are tracked in space and time using **cross-correlation techniques** between a pair of images referenced to an earth coordinate frame, separated by a Δt ranging from 3 to 7 sec (depending on flight altitude). The obtained surface velocity maps are then averaged over a 5km long swath to remove wave effects.



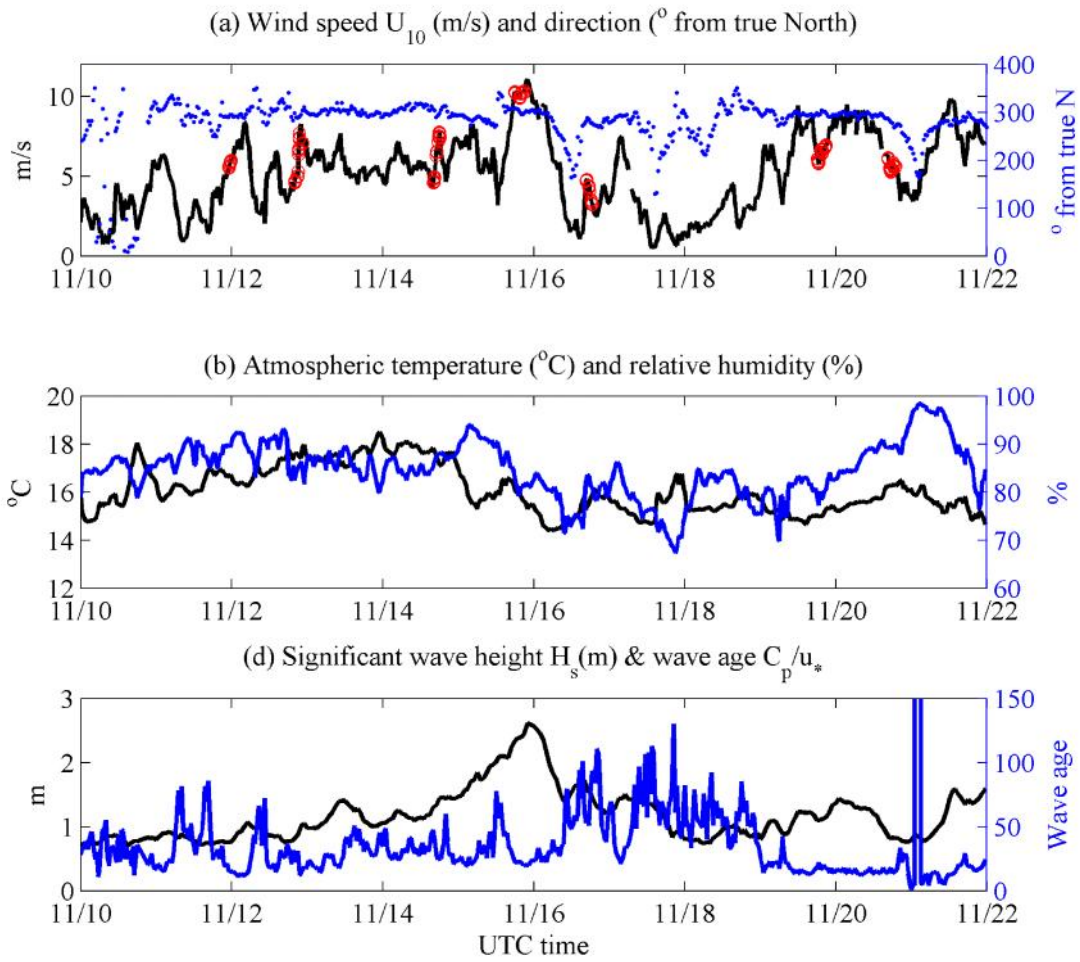


Sea surface temperature estimated from TERRA level 3 daily product (°C) on October 30, 2011, 10hr prior to the airborne survey conducted the same day. The flight track is shown in blue. The average surface velocities derived from the thermal imagery are shown as vectors along the flight track (red, positive easterly velocity, black, positive westerly velocity). Note the sharp change in surface velocities as the aircraft went across the LC.



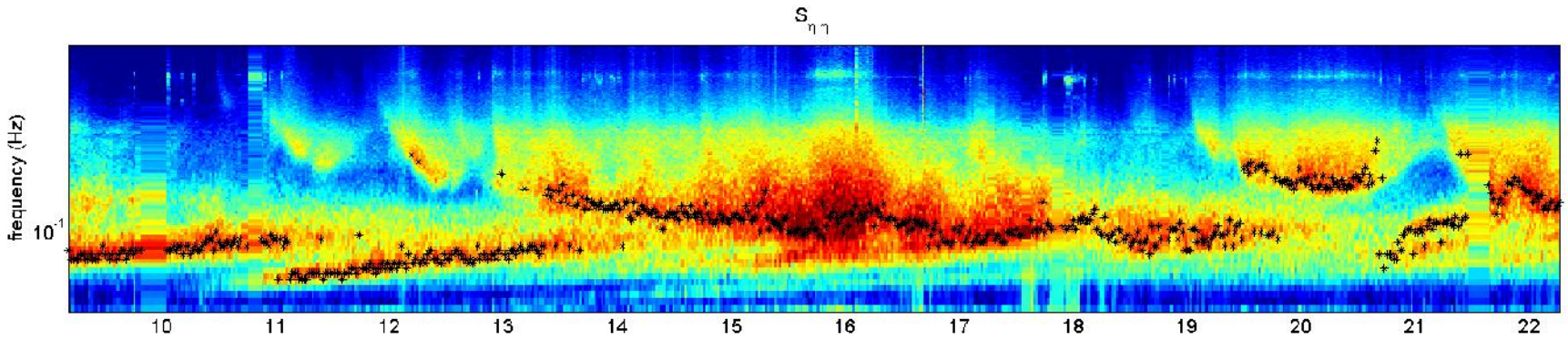
Environmental conditions during SOCAL2013

Red dots in upper panel represent MASS overflight time

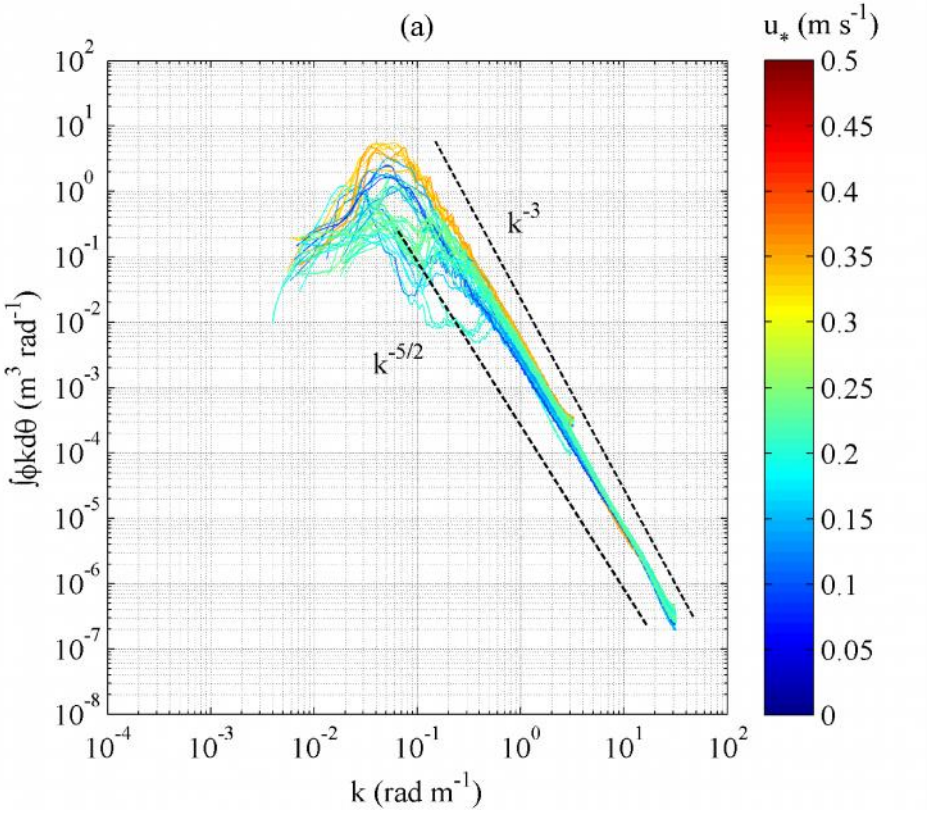


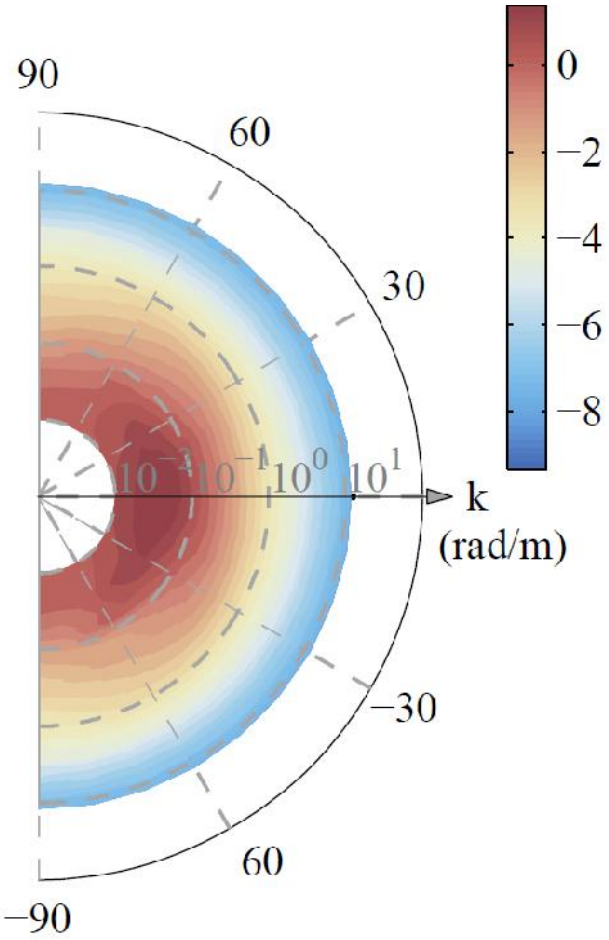
Winds ranged from 0 to 11 m/s, typically from the north west, and significant wave heights ranged from 0.7 to 2.7.

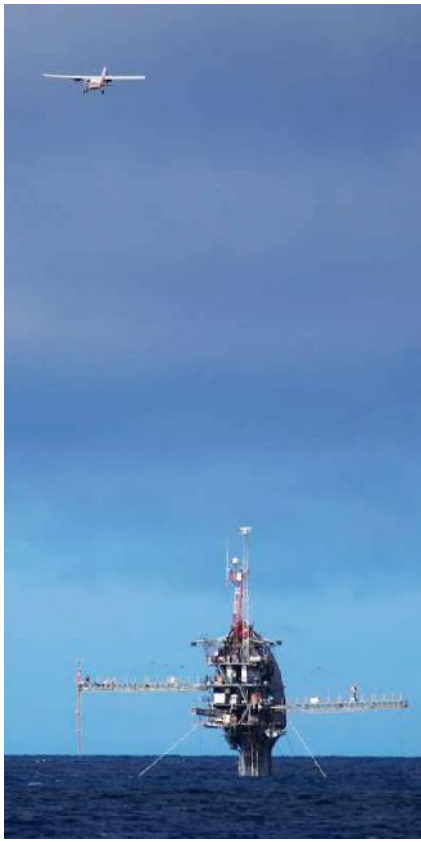
Two major wind events, on the 15th, and one peaking on the 20th. In addition to the wind waves associated with these events, wave fields also included multiple swell components.



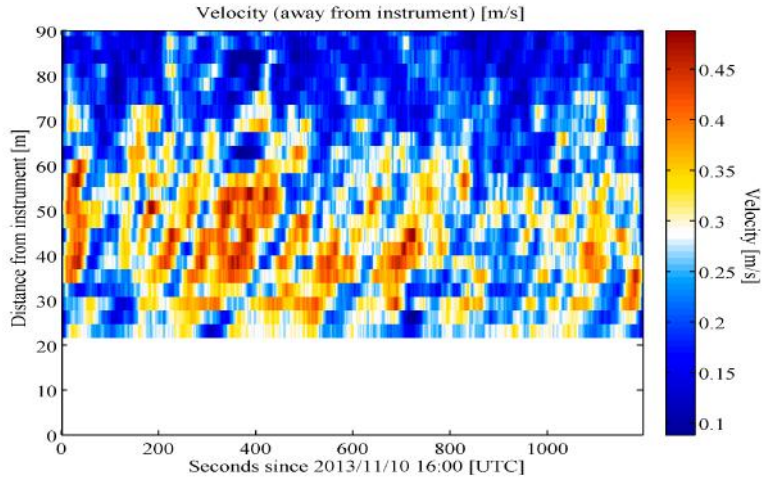
MASS - Wave Observations down to wavelengths of <0.6m during SOCAL2013







Coincident airborne and platform/vessel measurements (preliminary)



Airborne IR imagery

Observations of along-wind streak structures. Top panel shows cross-wind near-surface current velocity measured using a fan-beam ADCP mounted on FLIP's hull. The bottom panel is a (contrast enhanced) image taken by the video camera mounted on FLIP's crows nest showing streak structures at the surface. The regions of convergence in the ADCP data are thought to correspond to the streak structures seen in the visible imagery. Righ panel shows the IR imagery recorded around the same time from the MASS

Summary

Over the past two years, we have integrated a novel, portable, high-resolution airborne topographic lidar with video and hyperspectral imaging systems.

The scanning waveform lidar is coupled to a highly accurate GPS/inertial measurement unit permitting airborne measurements of the sea surface elevation and whitecap coverage with swath widths of up to 800 m under the aircraft track over water, and horizontal spatial resolution as low as 0.1m.

High-resolution, phase-resolved measurements of wind, waves, surface kinematics were conducted using the MASS coincidently with the Wave Glider, R/P FLIP and R/V Melville . Analysis underway.

In the process of setting up a recharge facility to make this capability available to the broader Community.