S-MODE Field Experiment Report 2021-05-07

Summary: Today we had the first demonstration of simultaneous data collection by four instruments that play a key role in future S-MODE campaigns: DopplerScatt (JPL) measured winds and currents; MASS (SIO) measured directional waves, surface kinematics, surface temperature and hyperspectral bands; MOSES (UCLA) measured wide-swath surface temperature; 3 instrumented wave gliders (SIO) provided in situ observations of current profiles, upper ocean and surface waves properties, and meteorological information. The experiment leveraged the site and *in situ* data collection from an ongoing ONR TFO deployment 200 miles from shore, which collected additional site characterization data (e.g. wirewalkers, drifting T-chains). One of the goals of this initial S-MODE deployment is to collect data over many different ocean conditions to characterize measurement performance across the instrument suite. The weather on May 7th certainly satisfied the exploration of the outer ranges of conditions: the area was under gale warning and experienced mean winds of about 13 m/s with wind gusts around 20 m/s. The significant wave height was in the range of 4-5 m. Luckily, although there were scattered clouds, MASS was able to collect below the clouds and MOSES between the gaps. The crew and pilots for the NASA 801 and the TOI Twin Otter put in extremely long hours, collecting data from about 2 pm to about 5:50 pm, which implied that the operators started at 7 am and ended back home around 10 pm. The data collections went well and the team will be busy looking at data over the weekend.

Experiment Site Conditions

The ONR TFO experiment was located about 325 km from shore, in the California Current. Figure 1 below shows the experiment location, together with B200 tracks and *in situ* asset locations. *In situ* measurements included 3 SIO wave gliders (which will participate in future S-MODE deployments) and data collected by the SIO-operated UNOLS R/V Roger Revelle.

Figure 2 shows the Navy NCOM model forecast for our day of data collection: 1/30th of a degree grid sampling (2 nm) currents were forecast to be relatively weak (< 25 cm/s) for our collection times. Similar current magnitudes, but somewhat different mesoscale circulation are also present in the Navy's HYCOM model (not shown). However, low resolution models like this cannot capture smaller scale phenomena, such as the internal wave and frontal activity recorded in the area by ESA's Sentinel 1 SAR imagery, shown in Figure 3. One of the motivations behind S-MODE is to be able to fill in these smaller energetic scales not captured by the models.

The environmental conditions during the data collections were extreme: a gale warning was in effect and forecasts showed extreme winds and wind gusts (Figure 4) and high seas (Figure 5). The day started cloudy, cleared up, but then scattered clouds

and hazier conditions developed later in the afternoon (see Figure 6 for the *in situ* wind and wave conditions). MASS dropped altitude to below 1200 ft to work below the cloud deck. MOSES was affected by clouds and haze.

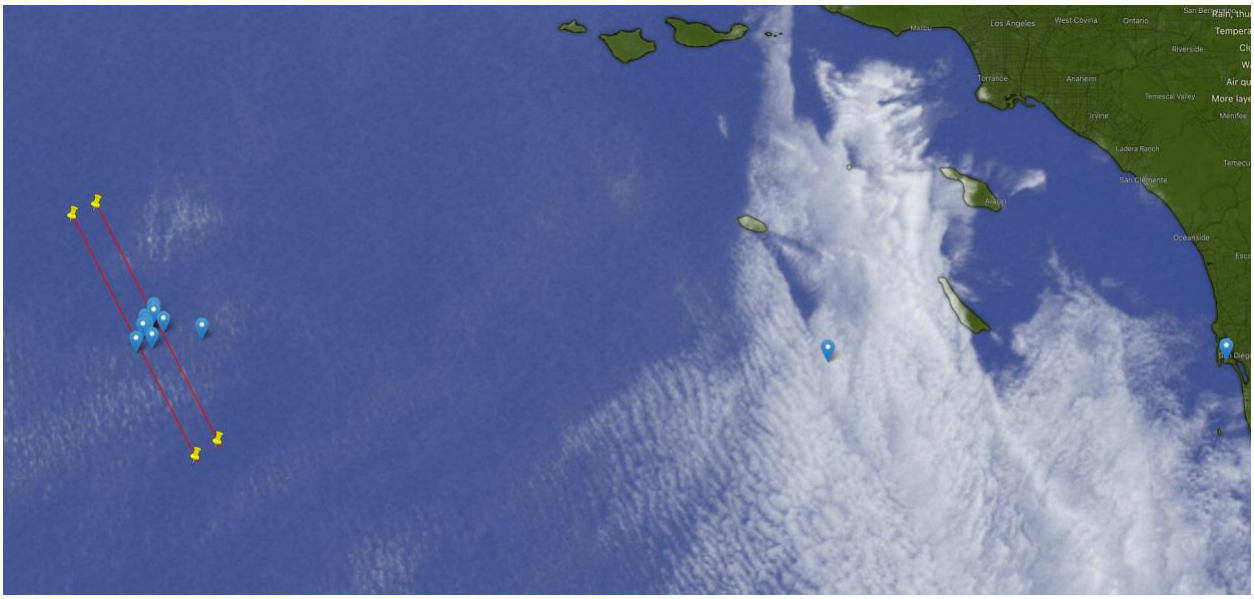


Fig 1: Location of the TFO experiment with GOES satellite cloud conditions during the S-MODE data collections. The red lines show the B200 racetrack pattern and the waypoints show the locations of the ONR TFO *in situ* assets. (Image by windy.com)

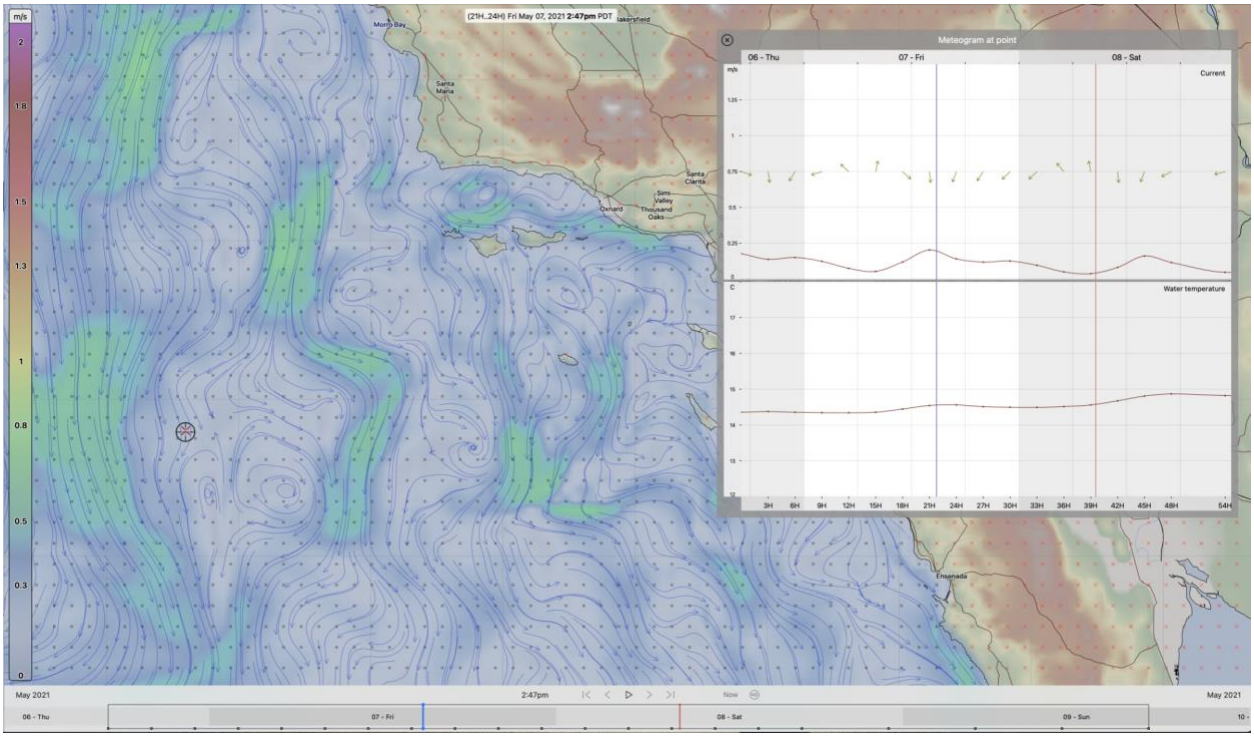


Fig 2: Surface currents from the U.S. Navy NCOM model (1/30 deg resolution) for 2021-05-07. The model surface current at the site is relatively weak (< 25 cm/s) during the airborne data collection, with some temporal variability. (Image by LuckGrib)

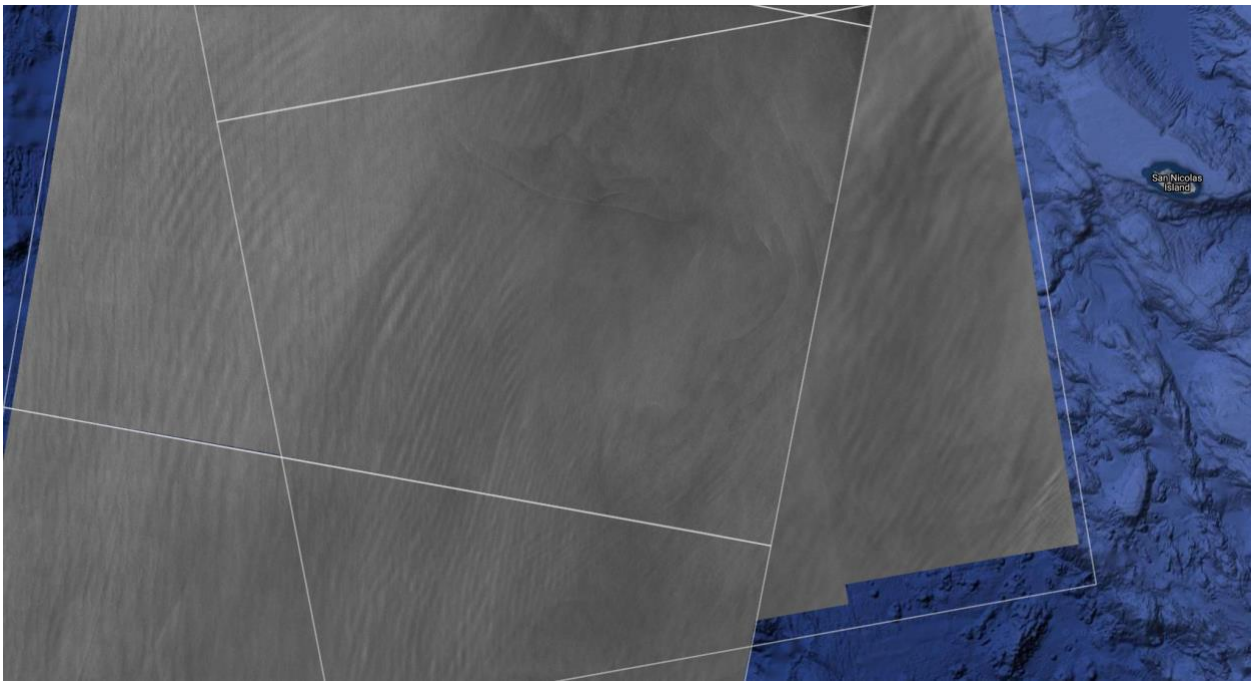


Fig 3: ESA Sentinel 1 SAR imagery collected on May 4 (see San Nicolas Island for location reference). These images capture strong internal wave and frontal activity not resolved by lower resolution models. (Courtesy of Copernicus, served by OceanDataLab)

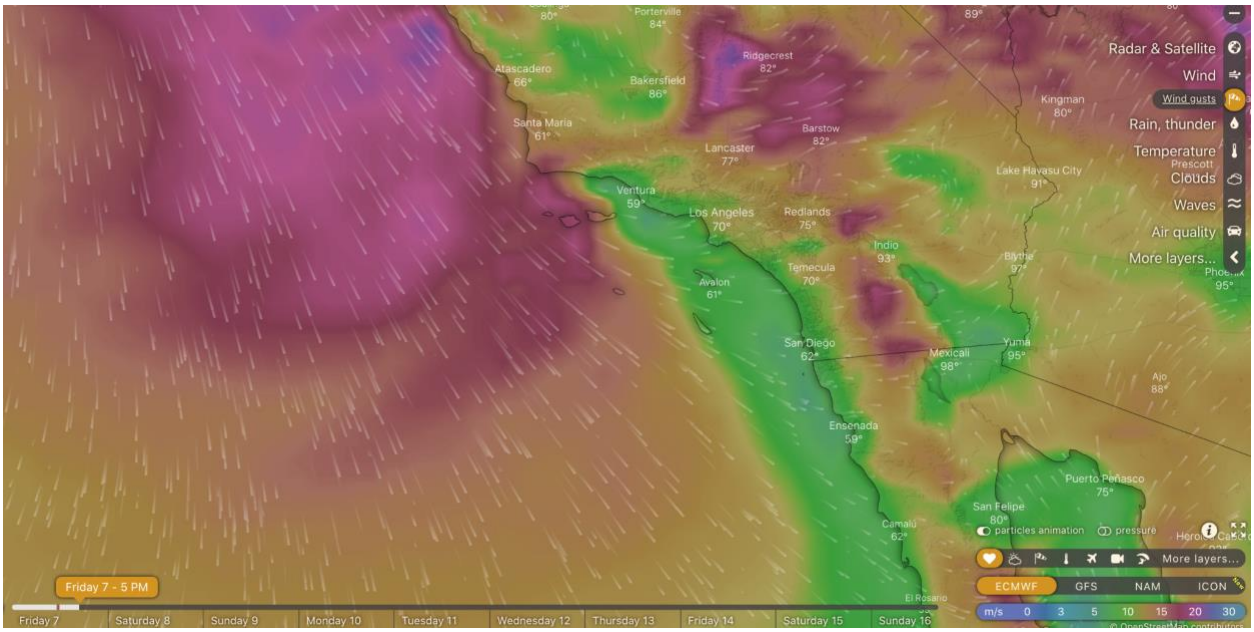


Fig 4: ECMWF wind gust forecast during the data collection: wind gusts neared 20 m/s. (Image by windy.com)

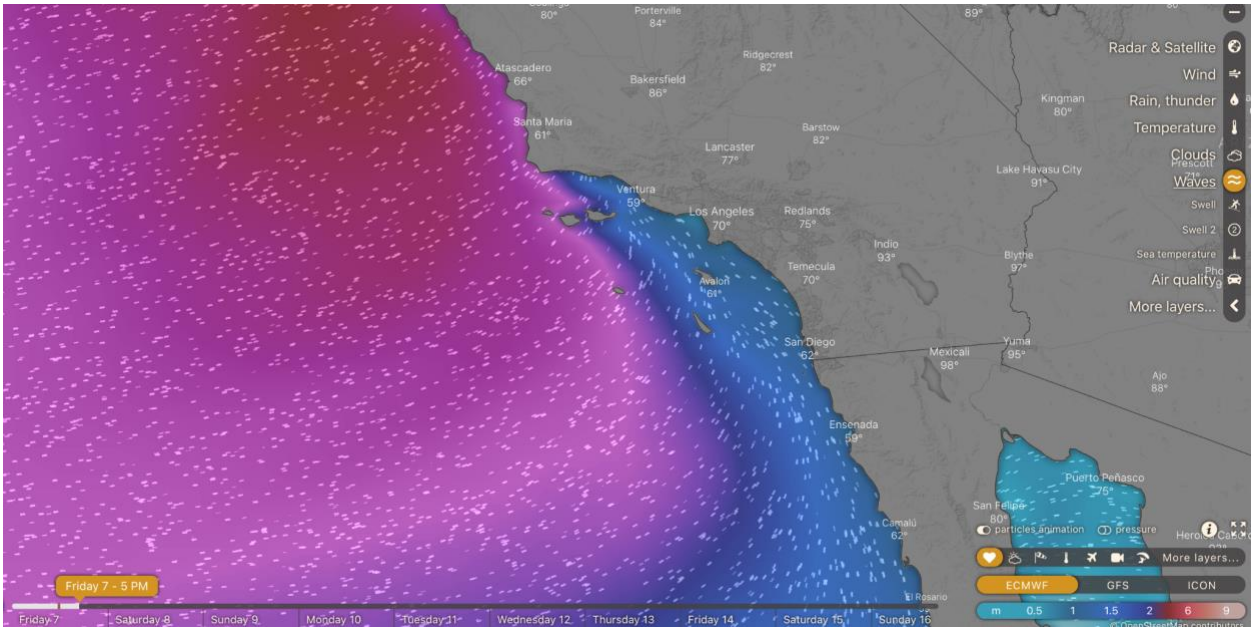


Fig 5: ECMWF significant wave height forecast during the data collection: SWH was in the 4m to 6m range (Image by windy.com)

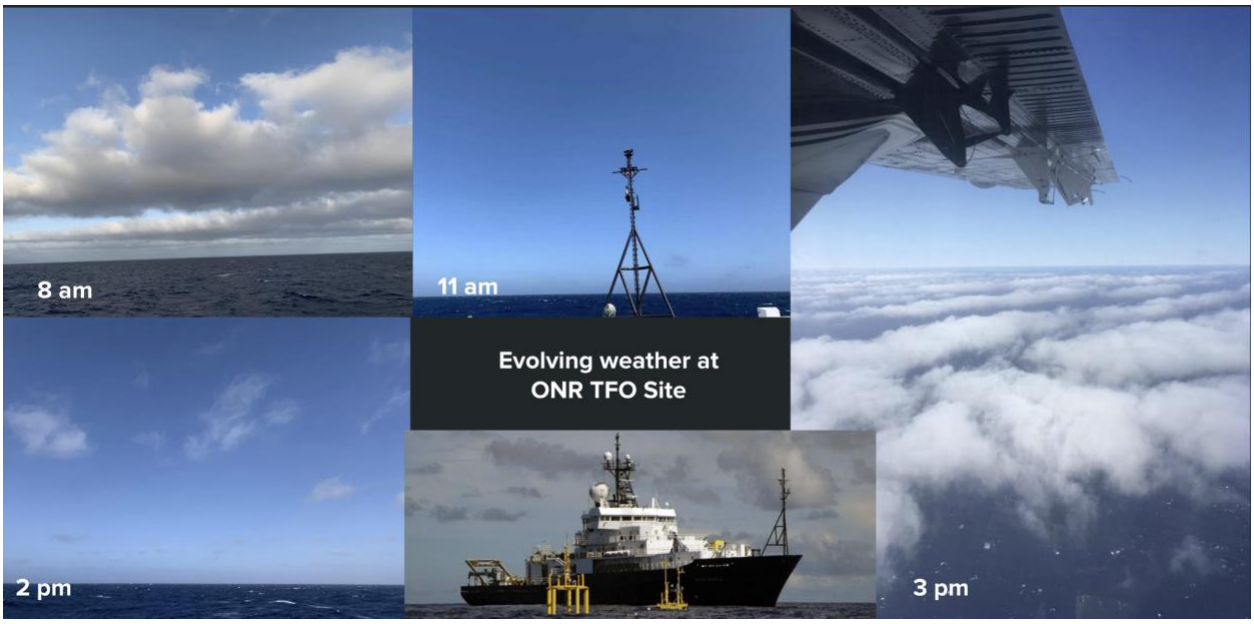


Fig 6: Evolving weather conditions at the ONR TFO site by the (pictured) R/V Roger Revelle (8 am, 11 am, 2 pm) and the MASS team (3 pm). After initial clearing, some scattered clouds formed in the late afternoon and the atmosphere was hazy. Note the wave breaking seen in the pictures, indicating strong winds and waves.

(Preliminary) Data Collection Report

The DopplerScatt and MOSES data were collected by the AFRC NASA 801 King Air B200, piloted by James Less and Mike Stewart (see Figure 7). DopplerScatt was operated by Federica Polverari (JPL) and MOSES was operated by Jeroen Molemaker (UCLA) (also in Figure 7). The data collection strategy is pictured and described in Figure 8. It was designed to have coincident sampling between airborne instruments with a temporal separation of less than 15 minutes. The flight direction was along the wind and wave direction.

All of the instruments seemed to operate nominally during the data collection. Figures 9 and 10 show and describe the MASS and DopplerScatt instruments in operation during the flight.

Fig 7: Pilots James Less and Mike Stewart and instrument investigators Jeroen Molemaker and Federica Polverari before take-off. (Photo J. Piotrowski, AFRC)

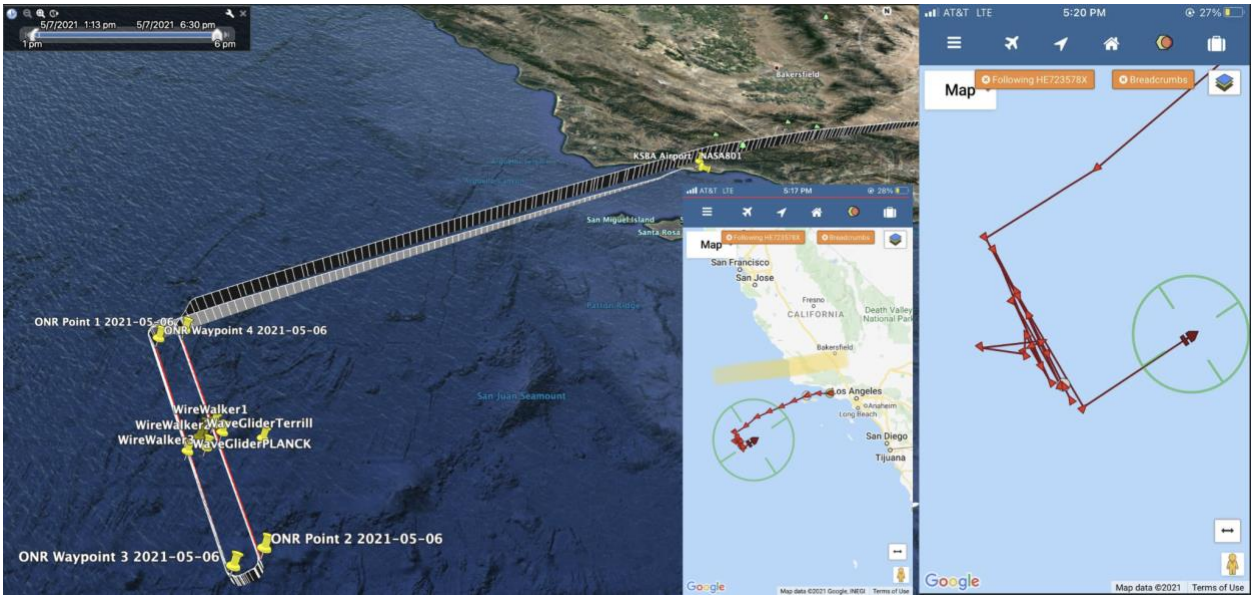
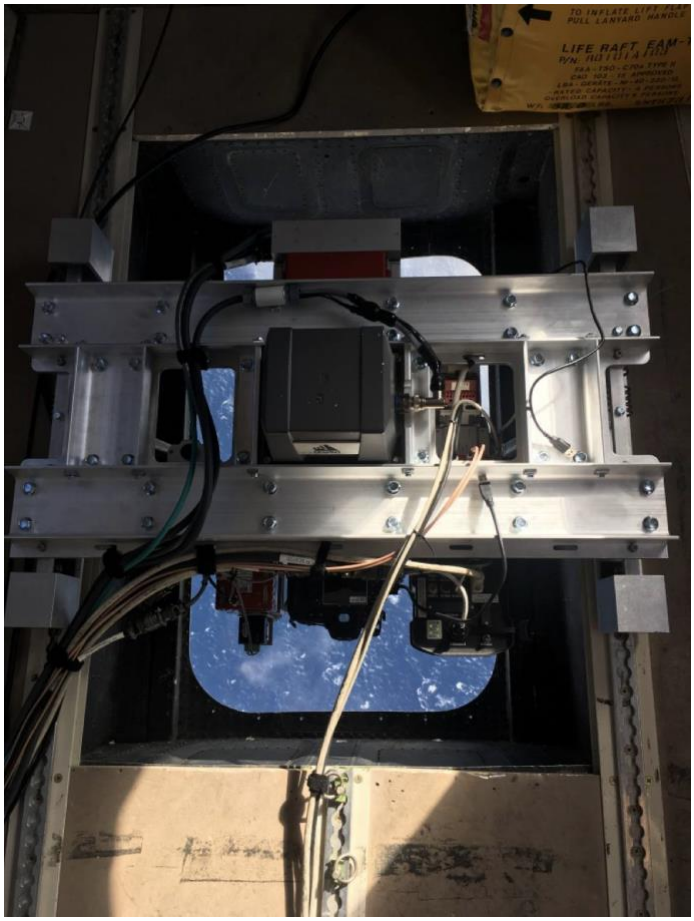


Fig 8: Flight pattern for the NASA 801 with *in situ* assets (left). Overview of TOI Twin Otter carrying MASS (inset and right). The B200 flew a 100 km racetrack pattern for 5 laps centered on the *in situ* instruments and along the wind/wave direction. MASS collected a 50 km lawnmower pattern that mapped the space between the B200 tracks and was imaged by DopplerScatt and MOSES (note that, due to infrequent updates, the pattern is very distorted in the right panel).

Fig 9: SIO MASS looking down on breaking ocean waves. MASS operates very close to the ocean surface (1200 ft here) to obtain very high resolution data with a smaller swath (~1 km) compared to the other instruments. It can measure wave heights and spectra, sea surface height, sea surface temperature, and collect hyperspectral imagery. It is mounted on a Twin Otter International airplane that has extended flight duration



capabilities to reach far-off locations, like the TFO site, with a smaller plane. (Photo, MASS operator Nick Statom, SIO)

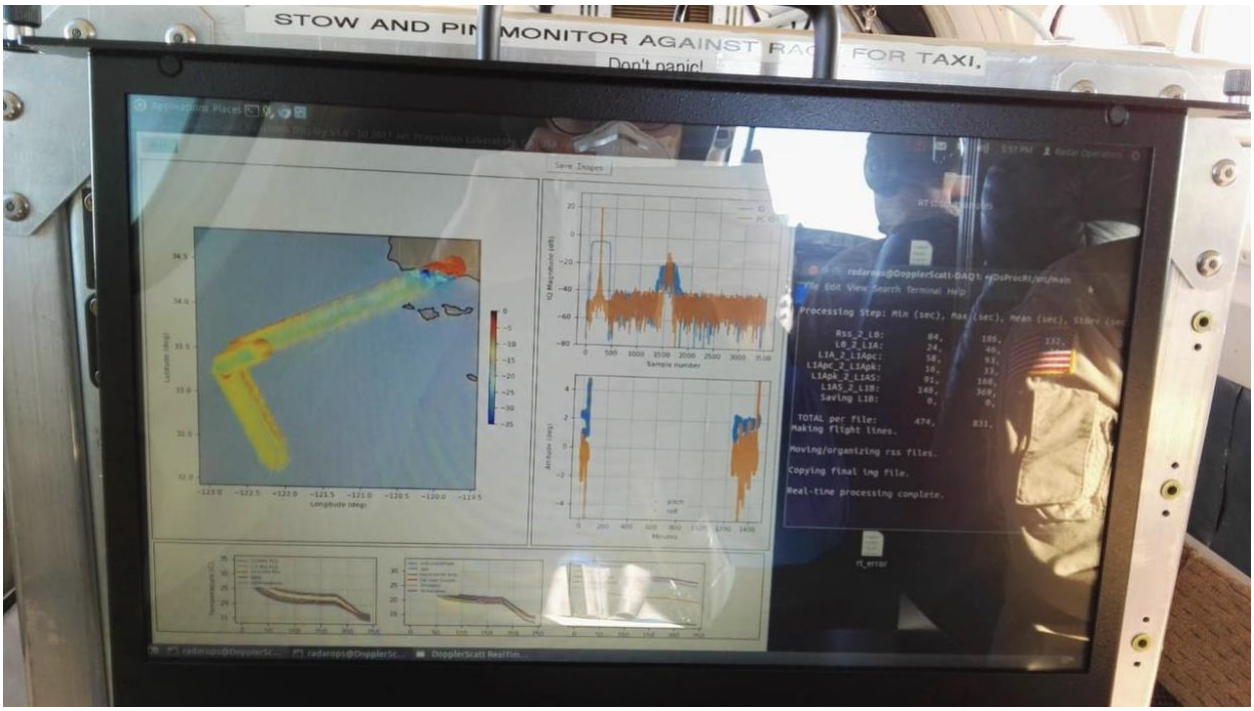


Fig 10: DopplerScatt real-time display showing normalized radar cross section that can be related to surface wind speed. The yellow and red colors indicate wind speeds in excess of 10 m/s. (Photo, DopplerScatt operator, Federica Polverari (JPL))