Response of upper ocean currents to Typhoon Fanapi

Verena Hormann, SIO/UCSD
vhormann@ucsd.edu

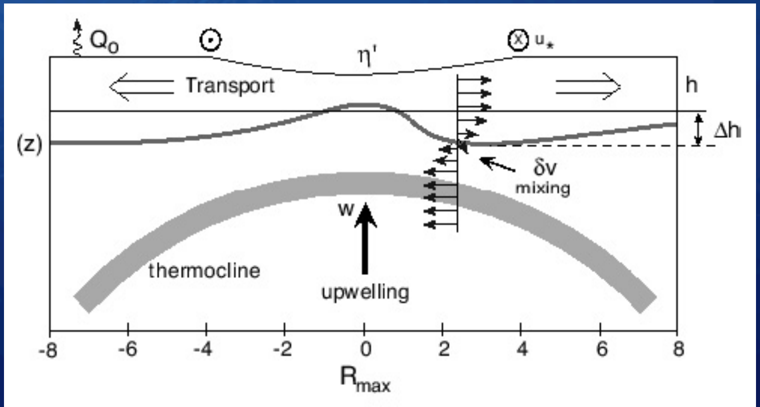
Luca R. Centurioni, Luc Rainville,
Craig M. Lee, and Lancelot J. Braasch

DBCP-30 Scientific and Technical Workshop, 27 Oct. 2014, Weihai, China

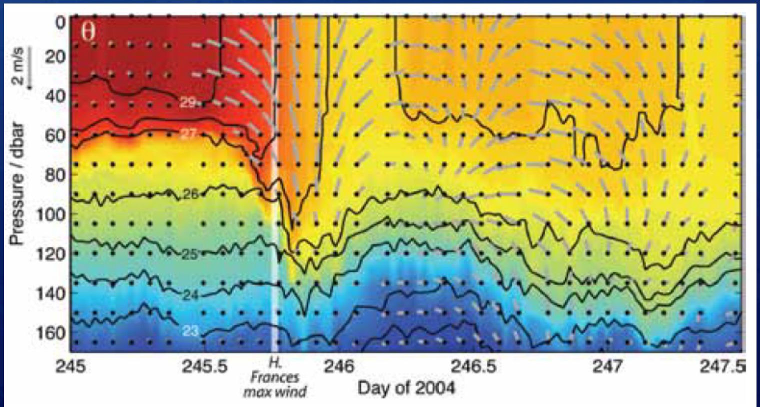
Ocean response to tropical cyclones

- Tropical cyclones (TCs) draw their energy from the warm ocean, changing it in a broad swath around their tracks by direct cooling and the action of TC-generated waves and currents [e.g., Leipper, 1967; Shay, 2010], which affects TC evolution [e.g., D’Asaro et al., 2011 & 2014]

- Rare direct observations of storm-induced currents provide an important reference for coupled ocean-atmosphere forecast models

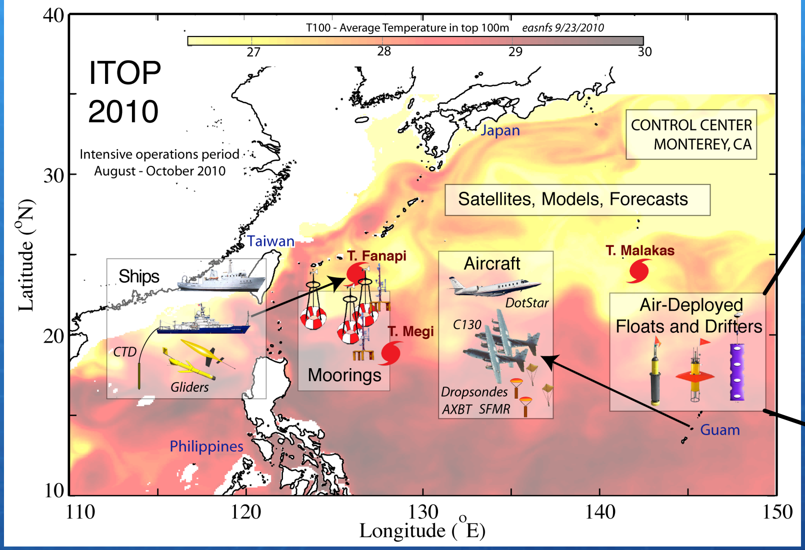


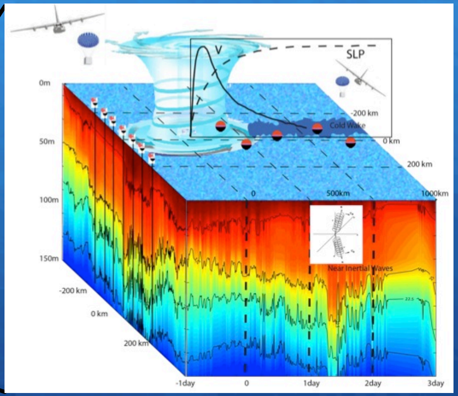
Shay, 2010



D’Asaro et al., 2011

ITOP program



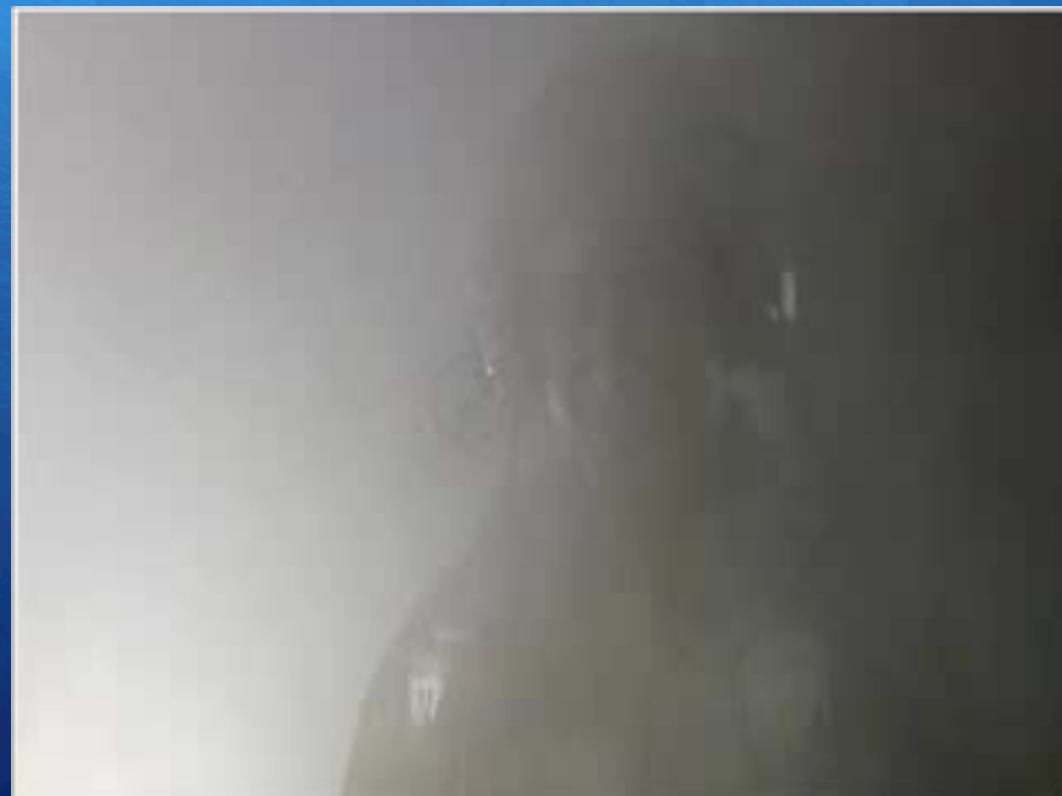


Conceptual schematic of drifter deployments

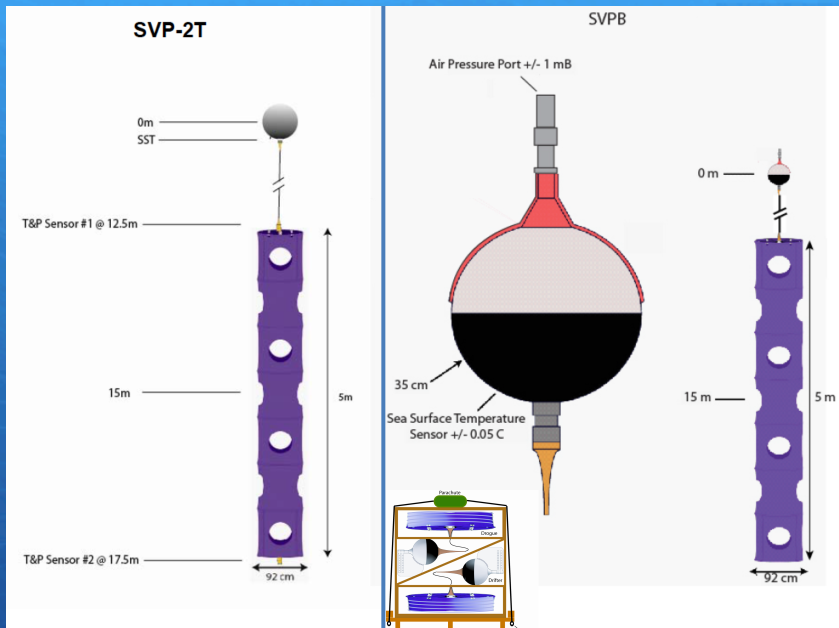
- ITOP (Impact of Typhoons on the Ocean in the Pacific) program combined intensive meteorological and oceanographic observations of TCs in the western North Pacific to study typhoon interactions with both the atmosphere and upper ocean

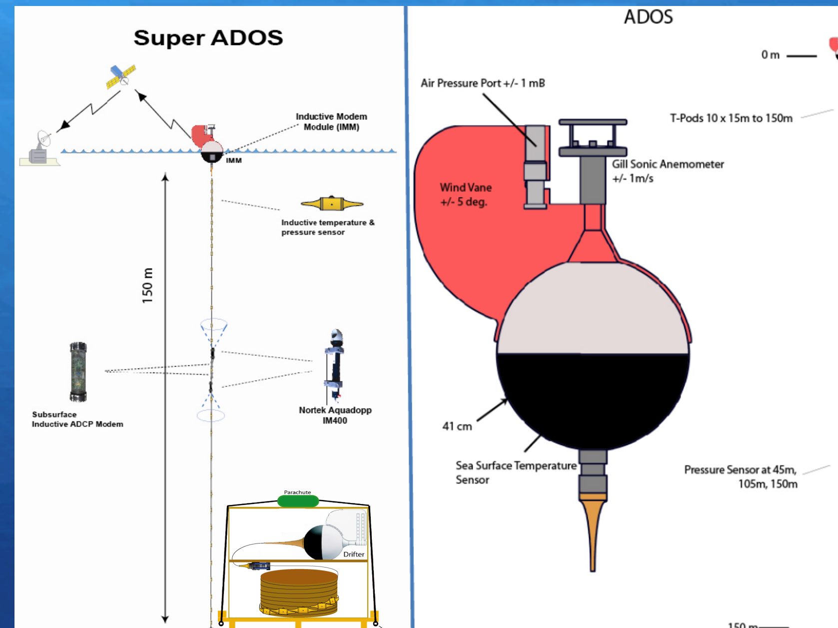
D'Asaro et al., 2014

Air-deployment by "Hurricane Hunters"



SVP & ADOS drifters



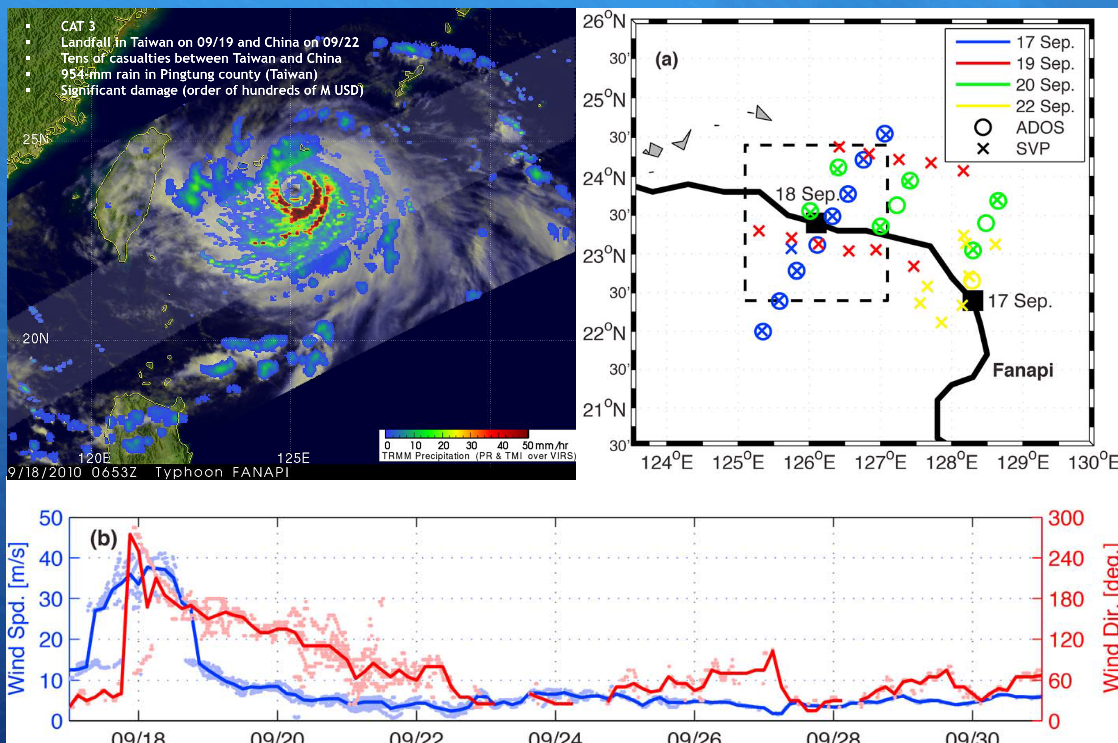


Sensor accuracy

- Barometer: ± 0.4 mb
- Thermistor: ± 0.05°C
- Wind direction: ± 2°
- Wind speed: ± 2% @ 12 m/s

- ADCP: 1% ± 0.5 cm/s
- Sampling: every 15 min
- Averaging: 160 sec
- Data per day: ~ 85% of 24 hr
- Battery life: ~ 5 months

Typhoon Fanapi

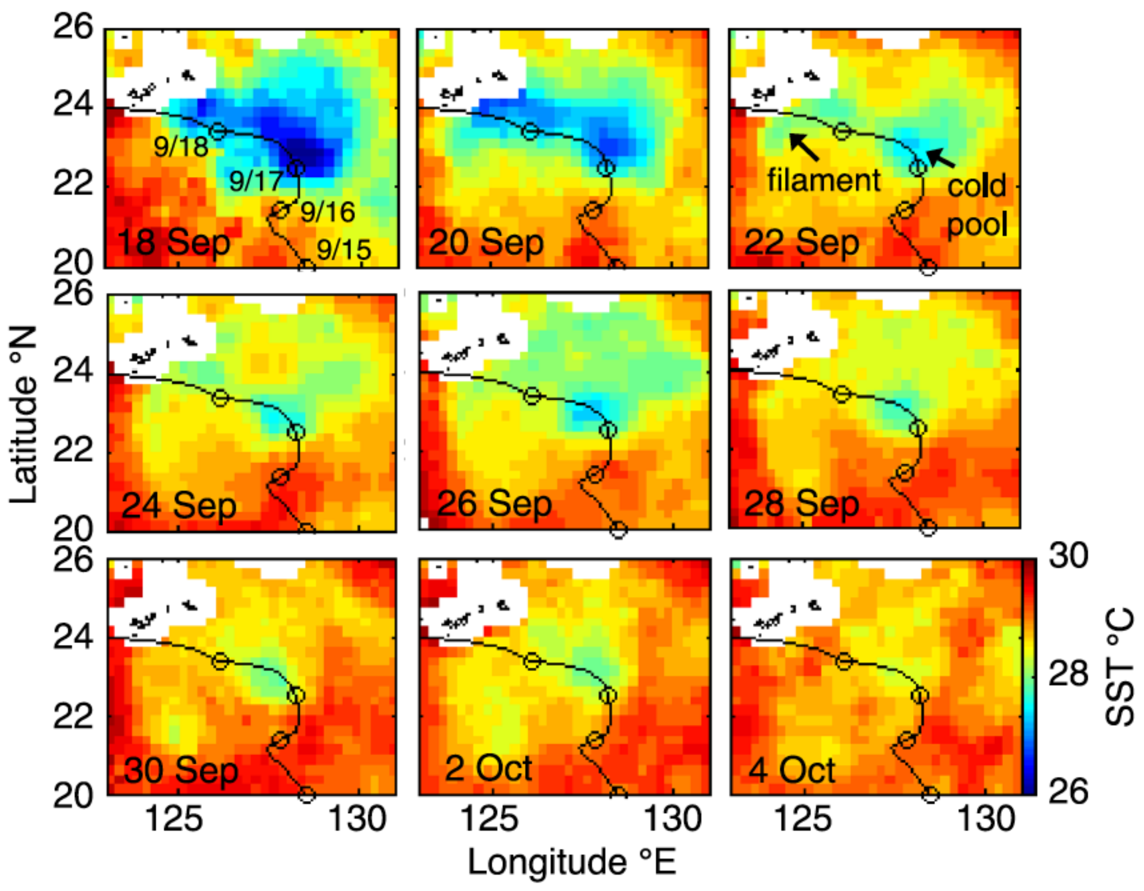


Maximum strength on 18 Sep. 2010 (~40 m/s)

- Air-deployment of extensive drifter array in front of Typhoon Fanapi and into its wake
- Separation of the observations into sub- and near-inertial motions using low- and band-pass filters

Hormann et al., 2014

Evolution of the cold wake

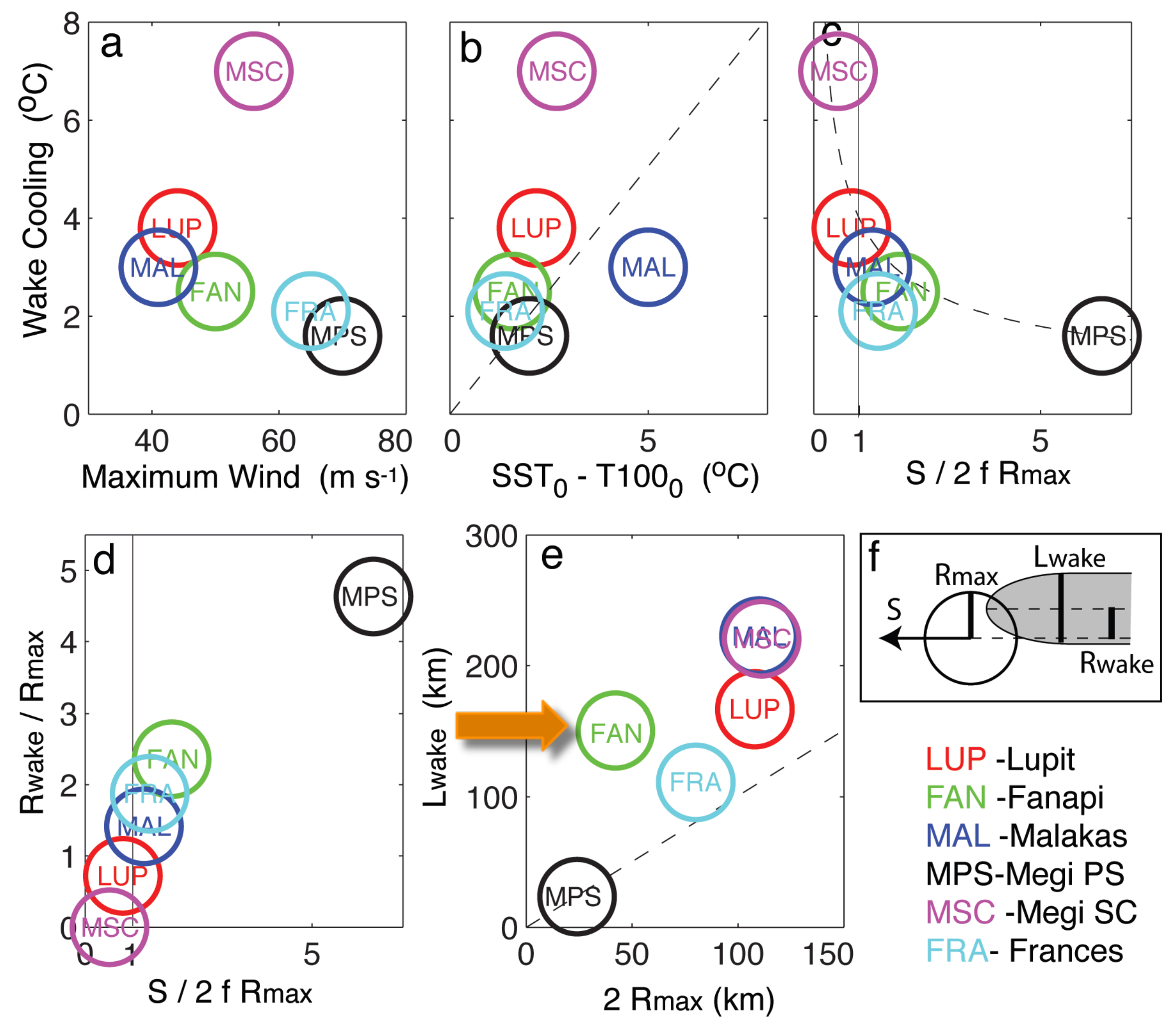


Spatially non-uniform cold wake

- Passage of Typhoon Fanapi associated with formation of a cold wake
- Mesoscale eddy field played an important role in the evolution of the cold wake

Mrvaljevic et al., 2013

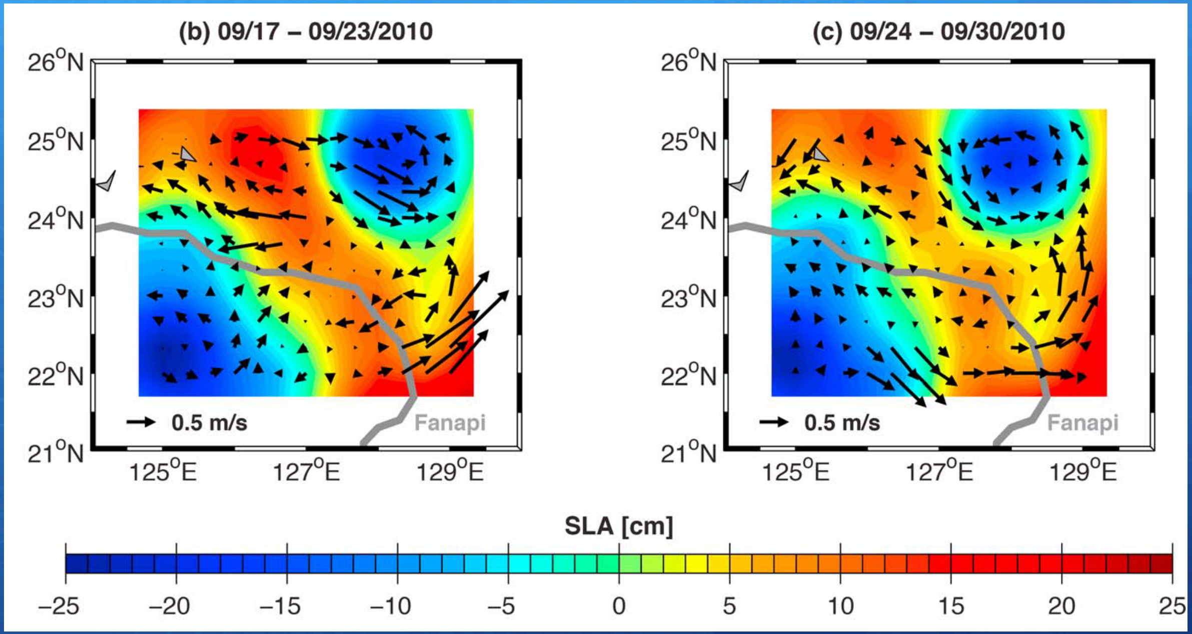
Wake properties



- Comparison of Typhoon Fanapi's cold wake (width L_{wake} = 150 km, offset from track R_{wake} = 49 km) with other ITOP storms and Hurricane Frances

D'Asaro et al., 2014

Sub-inertial currents

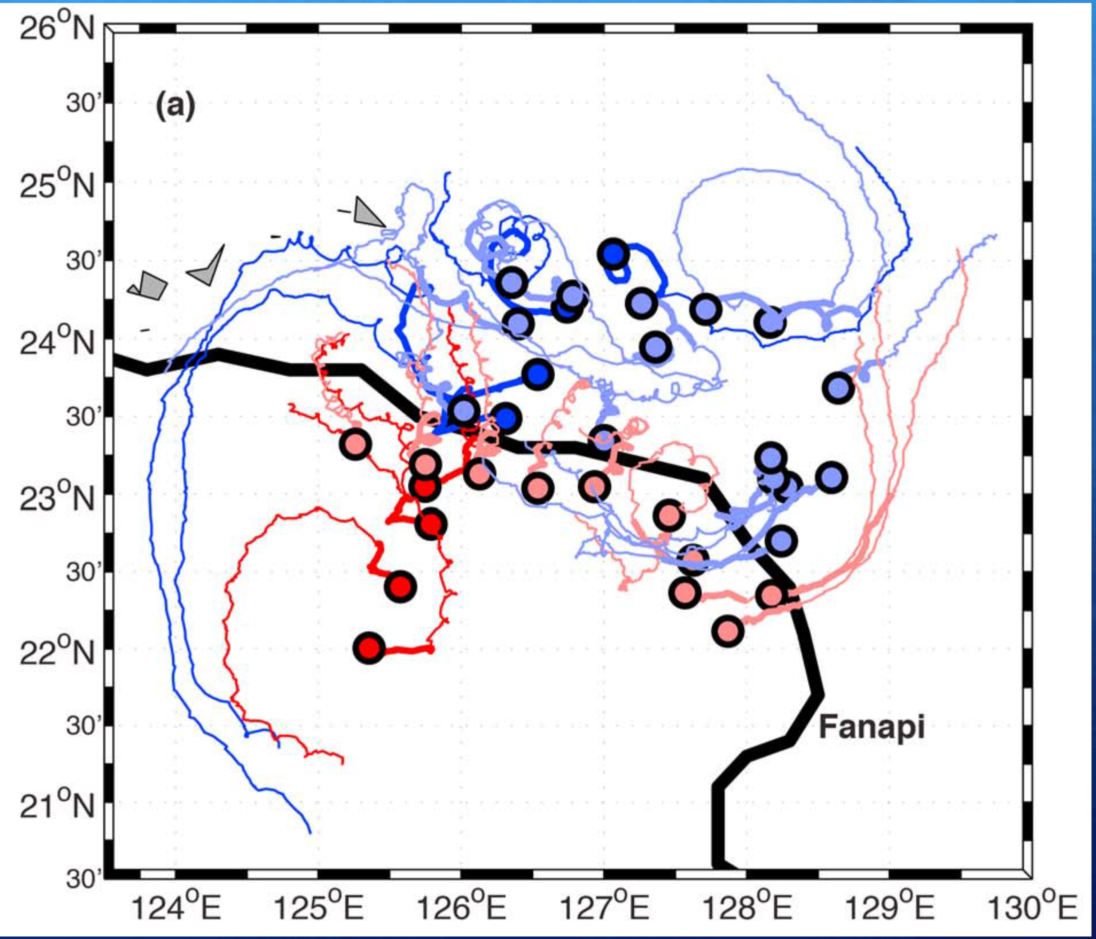


Mesoscale eddy field highlighted by AVISO sea level anomalies (e.g., ~24.5°N, 128.5°E)

- Importance of strong advection in the region affected by Typhoon Fanapi quantified by derived sub-inertial circulation
- Strong northeastward currents around 22.5°N, 129°E during 17-23 Sep. 2010 (~1 m/s) possibly related to Typhoon Fanapi

Hormann et al., 2014

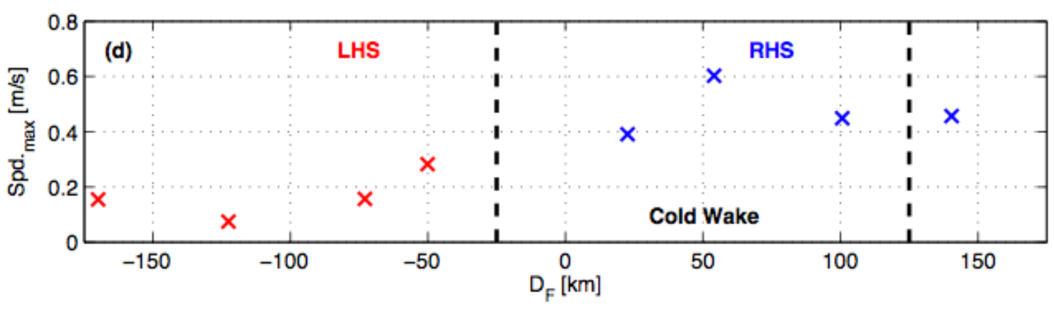
Near-inertial motions

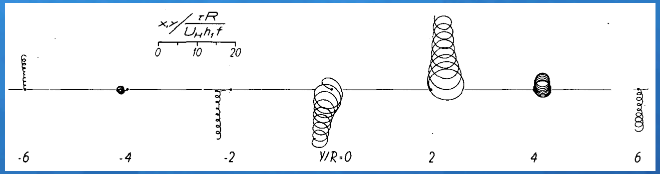


- Characteristic cycloidal drifter tracks indicate excitation of strong near-inertial motions by Typhoon Fanapi
- Partition of the observations into right (blue) and left-hand side (red) deployments

Hormann et al., 2014

Near-inertial speed



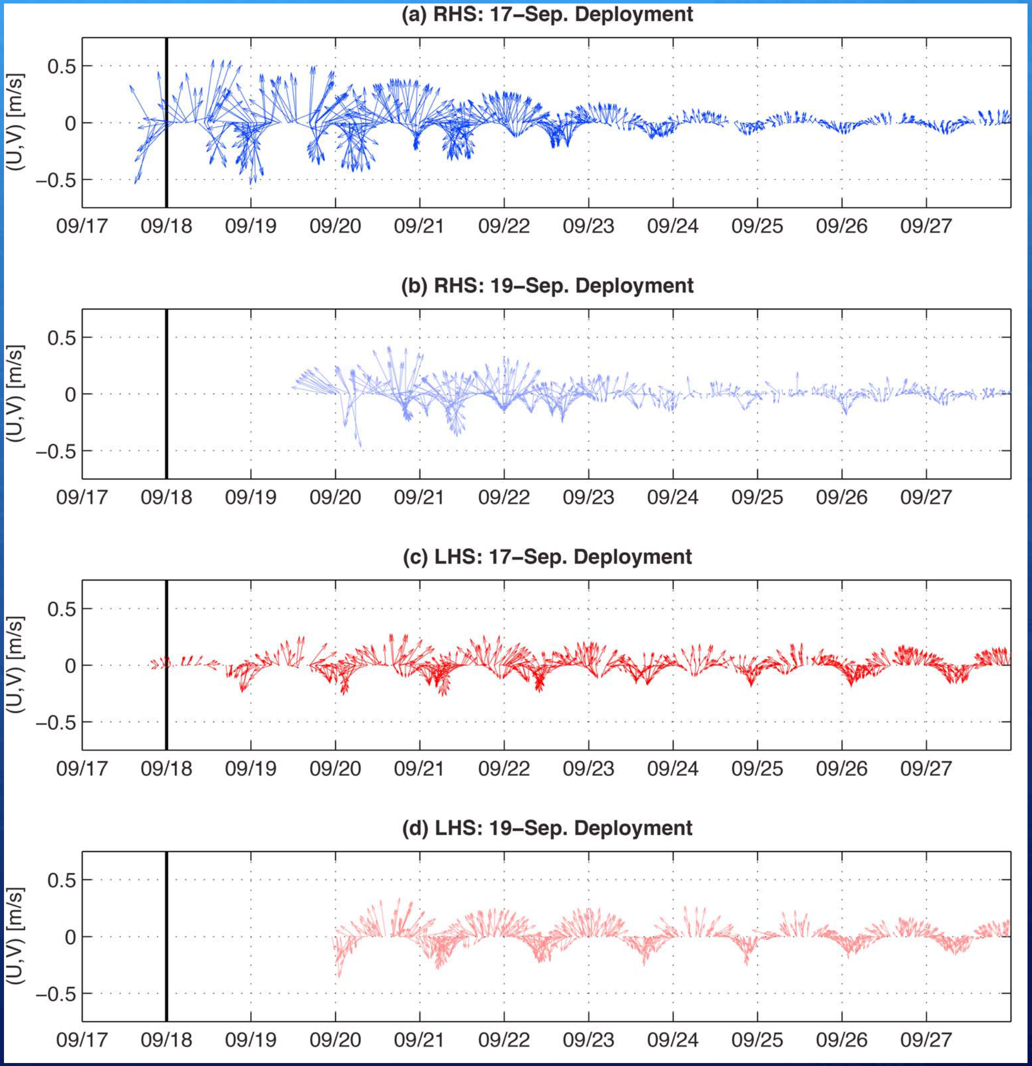


Price, 1983

- Strongest near-inertial motions on the right-hand side near the center of Typhoon Fanapi's cold wake
- Far smaller maximum speeds outside the range of the cold wake (~0.15 m/s)
- Distribution of the near-inertial speeds consistent with simulated particle tracks in the mixed layer of a storm wake

Hormann et al., 2014

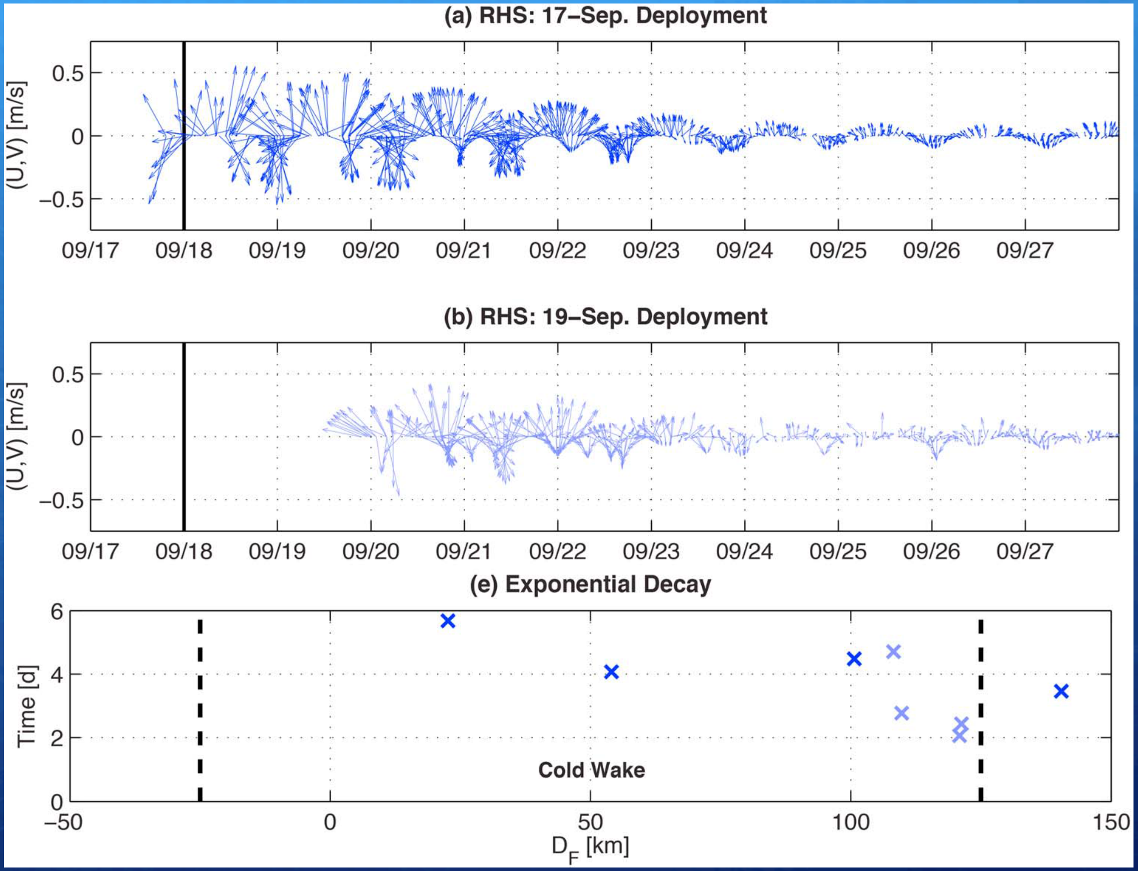
Near-inertial currents



- Much stronger near-inertial currents to the right of Typhoon Fanapi's track in the first 2-3 days
- Maximum velocities appear to occur 1-2 days earlier on the right as compared to the left

Hormann et al., 2014

Near-inertial decay

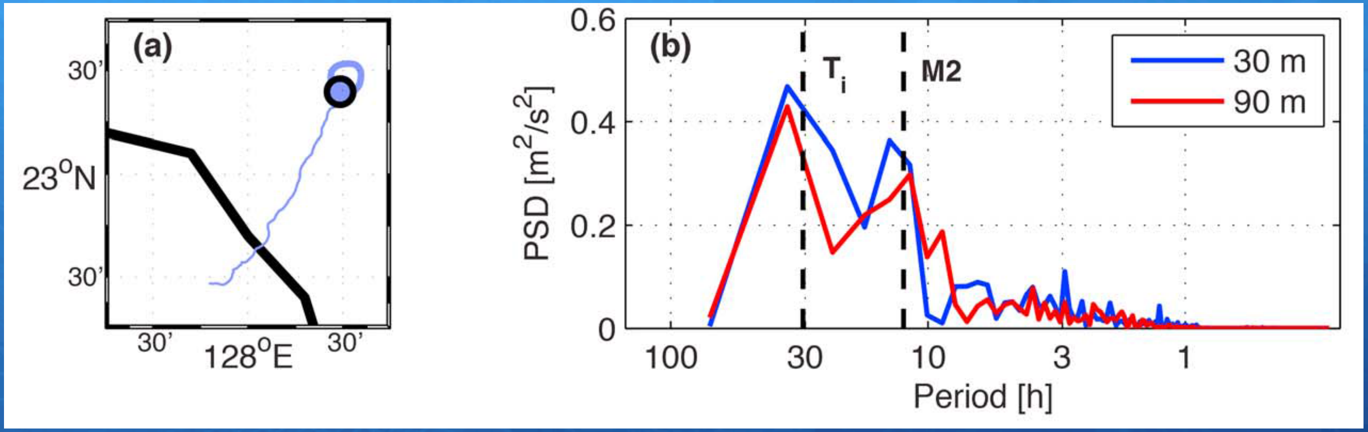


Exponential fits explain overall about 85% of the variance

- Exponential decay determined by fits to the individual drifter speeds on Typhoon Fanapi's right-hand side
- *e*-folding time generally on the order of 4 days within the range of the cold wake

Hormann et al., 2014

Frequency shifts



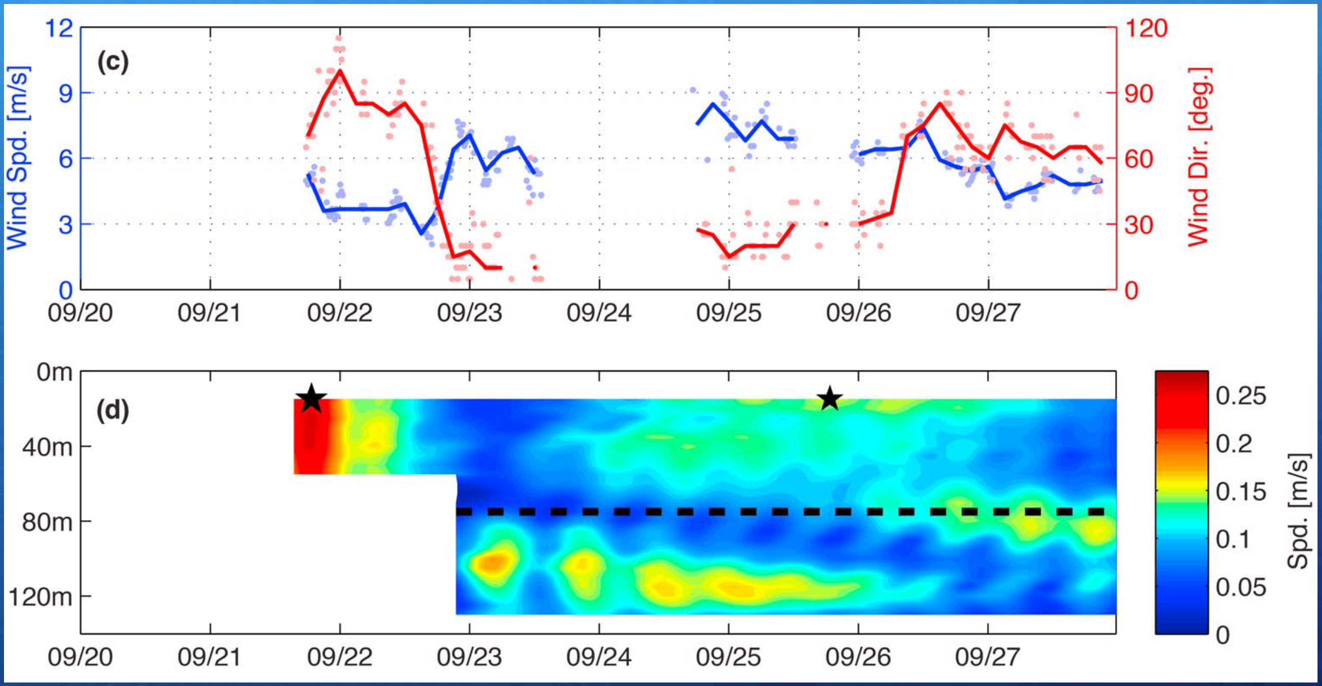
T_i: local inertial period

M2: lunar semi-diurnal tide

- Besides a prominent M2 tide, enhanced spectral energy slightly above the local inertial period T_i
- Dominant frequency commonly found to shift above the local inertial frequency, in proportion to one half the mixed-layer Burger number [e.g., Price, 1983; Shay et al., 1998]

Hormann et al., 2014

Super ADOS observations



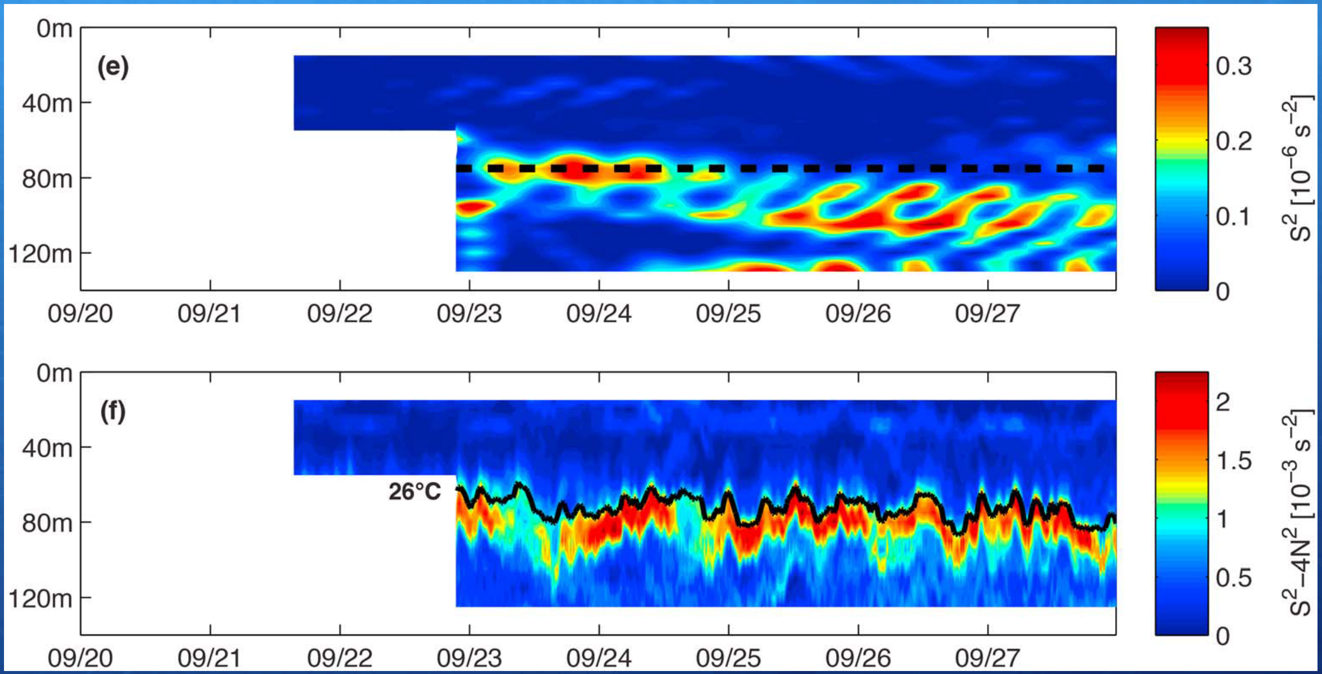
Changes in wind field starting on 23 Sep. 2010

Largest near-inertial speed on 21 Sep. 2010

- Two downward propagating near-inertial waves, with the first directly related to Typhoon Fanapi

Hormann et al., 2014

Shear instabilities



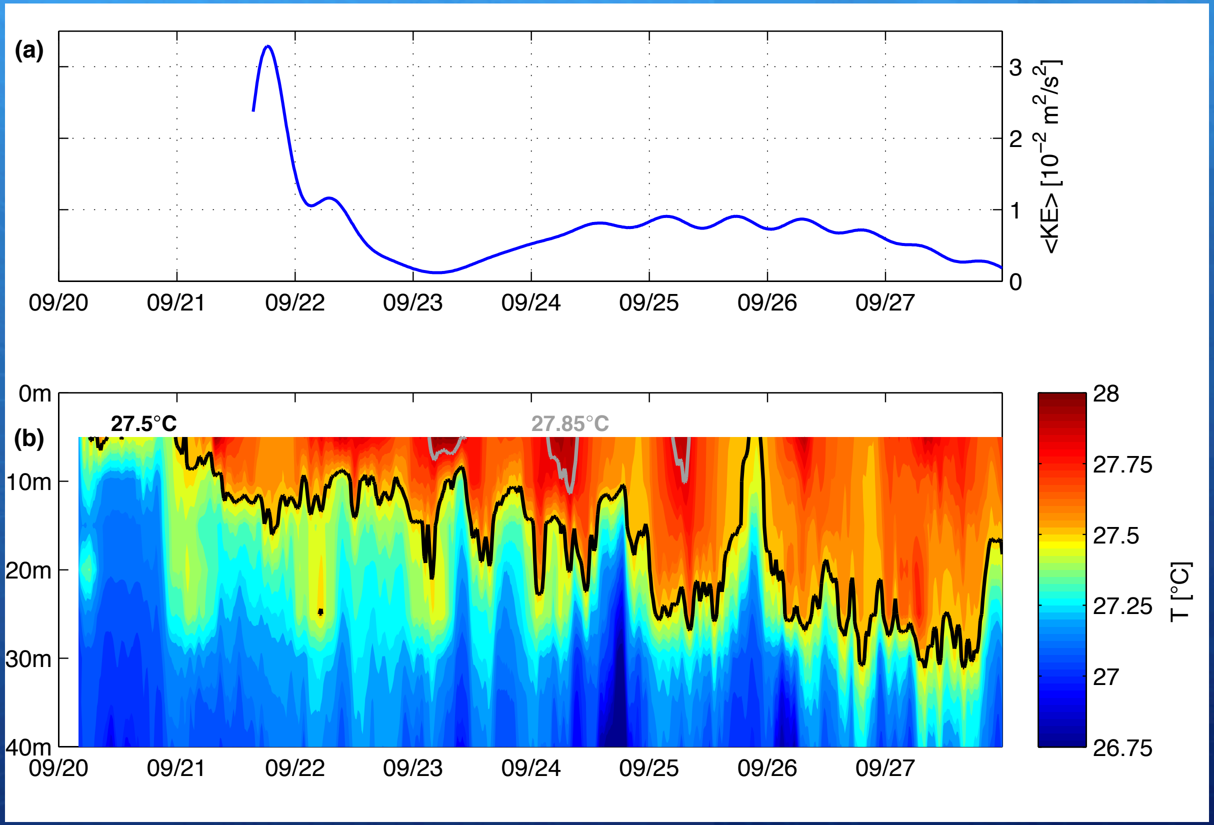
75 m: ADCP deployment depth

26°C isotherm: mixed-layer base

- Potentially unstable mixed-layer base in Typhoon Fanapi's cold wake due to shear flow instabilities

Hormann et al., 2014

Diurnal cycle



- Noticeably reduced diurnal cycle of subsurface temperatures when near-inertial kinetic energy was largest

Heat flux variations of importance for cold wake warming [Price et al., 2008]

Hormann et al., 2014

Conclusions

- Advection by the sub-inertial circulation of importance for the evolution of Typhoon Fanapi’s cold wake
- Rightward bias of near-inertial currents, with peak magnitudes of up to 0.6 m/s and an *e*-folding time of about 4 days within the cold wake
- Near-inertial shear instabilities across the base of the mixed layer in Typhoon Fanapi’s cold wake
- Diurnal temperature cycle noticeably reduced when near-inertial motions were strongest