Direct observations of ocean surface waves and currents within the context of air-sea interaction and momentum transfer

F. J. Ocampo-Torres, P. Osuna, N. Rascle, R. Durazo*, H. García-Nava*, G. Díaz, B. Esquivel-Trava*, A. Moulin, D. Peláez-Zapata, C. F. Herrera, D. Larios
-Department of Physical Oceanography, CICESE
*University of Baja California

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Contents

Motivation.

Background:The INTOA Experiment, relevant results.

New opportunity: air-sea interaction measurements.

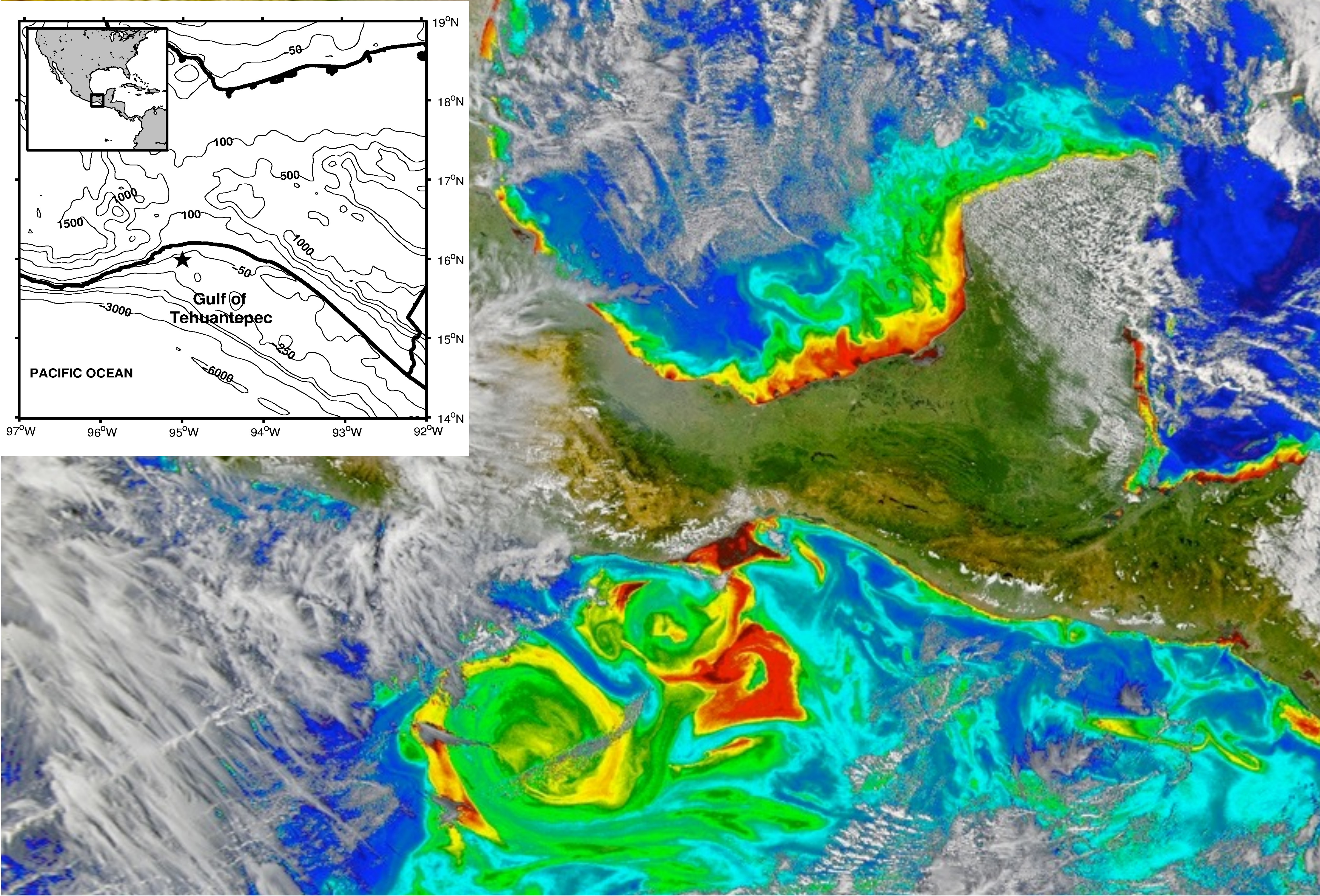
CIGoM a CONACYT-SENER initiative.

Preliminary results from pilot experiments offshore Ensenada, work still under progress.

Next steps.

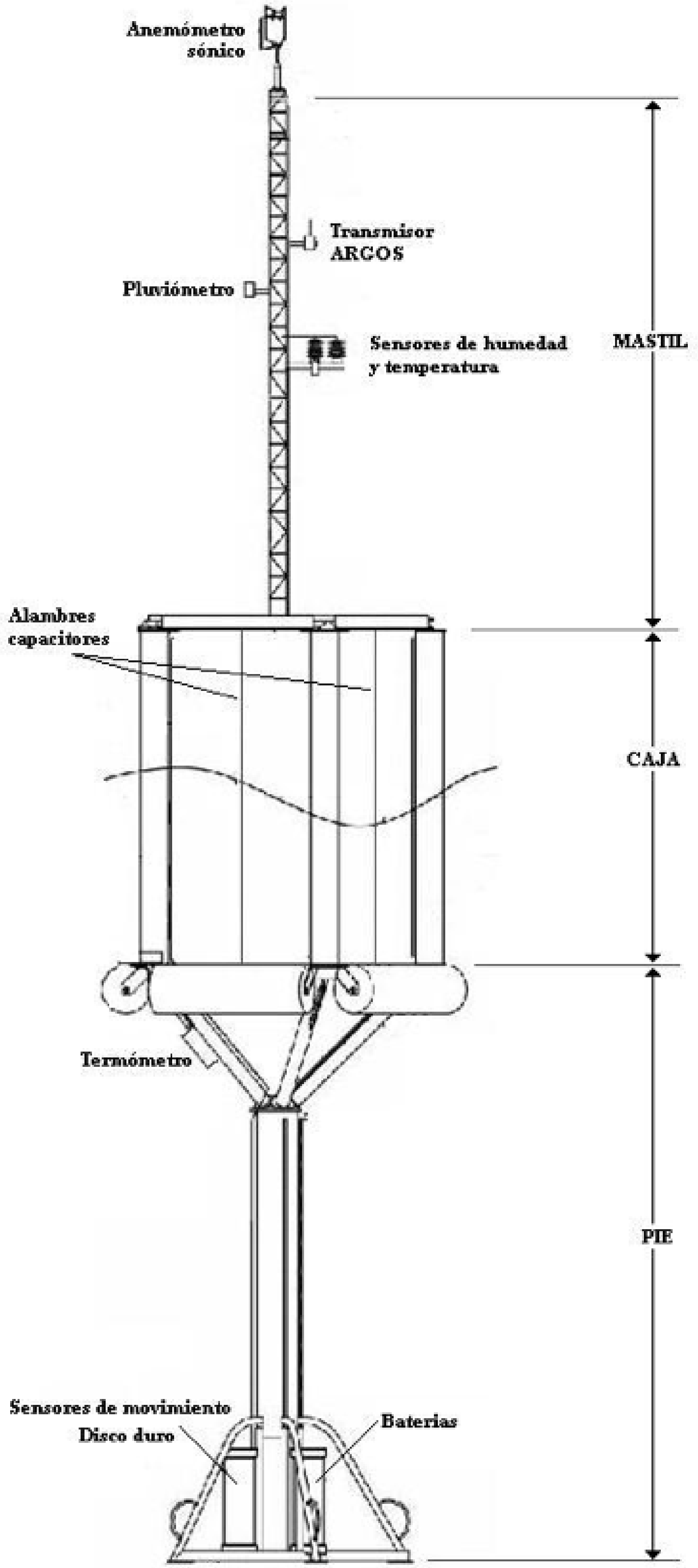
Motivation

Research interest in The Waves Group at CICESE.
Recognising the relevance of ocean surface waves.
Air-sea interaction processes: fundamental aspect of many present challenges.
Weather; Climate and its changes; Maritime applications; Energy; etc.
Interlink: lower atmosphere, waves, momentum transfer,
upper ocean currents, and turbulence.
Better knowledge is desired, it is needed.
Great opportunity to measure from space.
Ground truth is always needed and welcome.

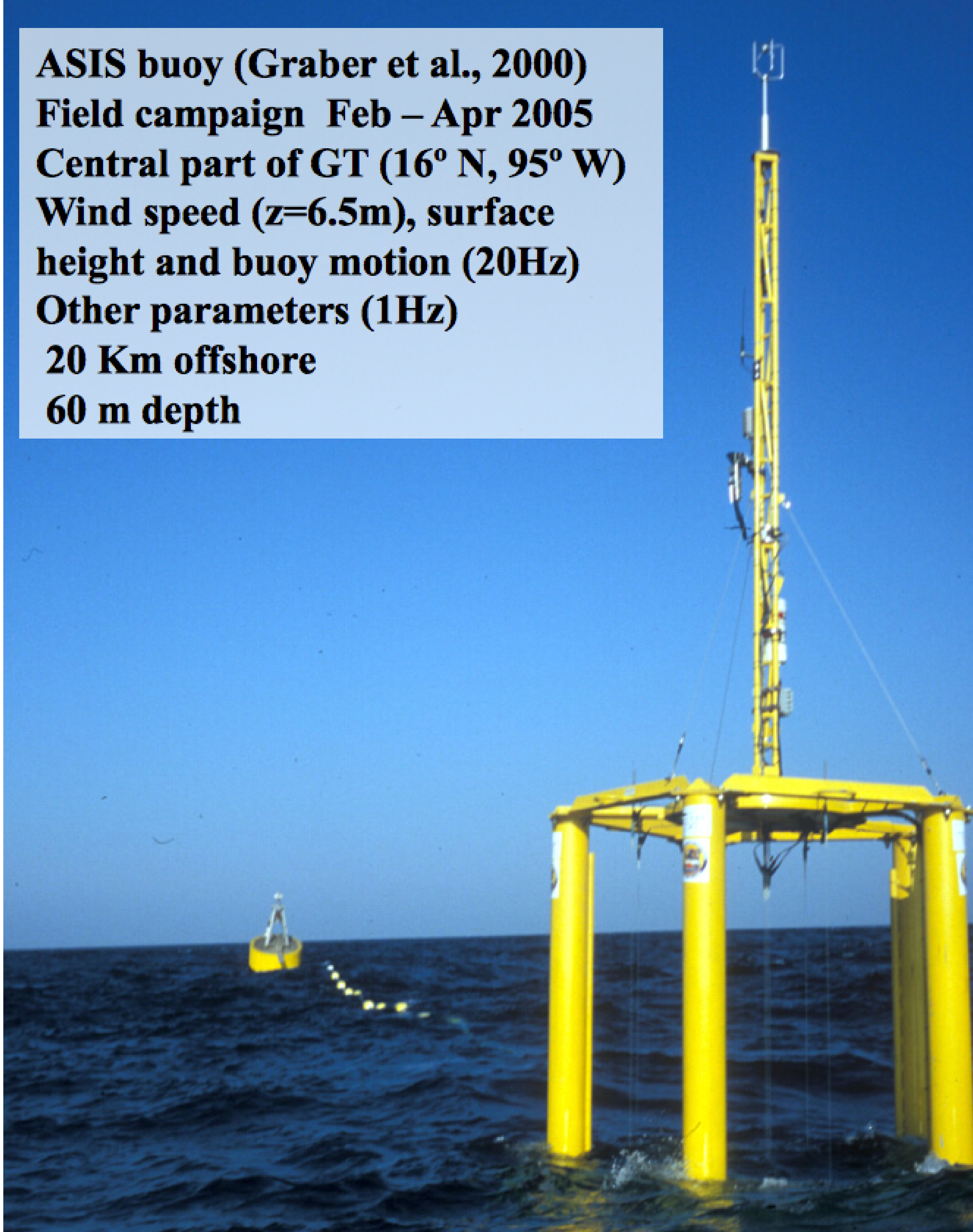


The Air-Sea Interaction Experiment in the Gulf of Tehuantepec

Offshore wind jets impose a characteristic dynamics **(Ocampo-Torres et al., 2011, B-LM)**



ASIS buoy (Graber et al., 2000)
Field campaign Feb – Apr 2005
Central part of GT (16º N, 95º W)
Wind speed (z=6.5m), surface height and buoy motion (20Hz)
Other parameters (1Hz)
20 Km offshore
60 m depth



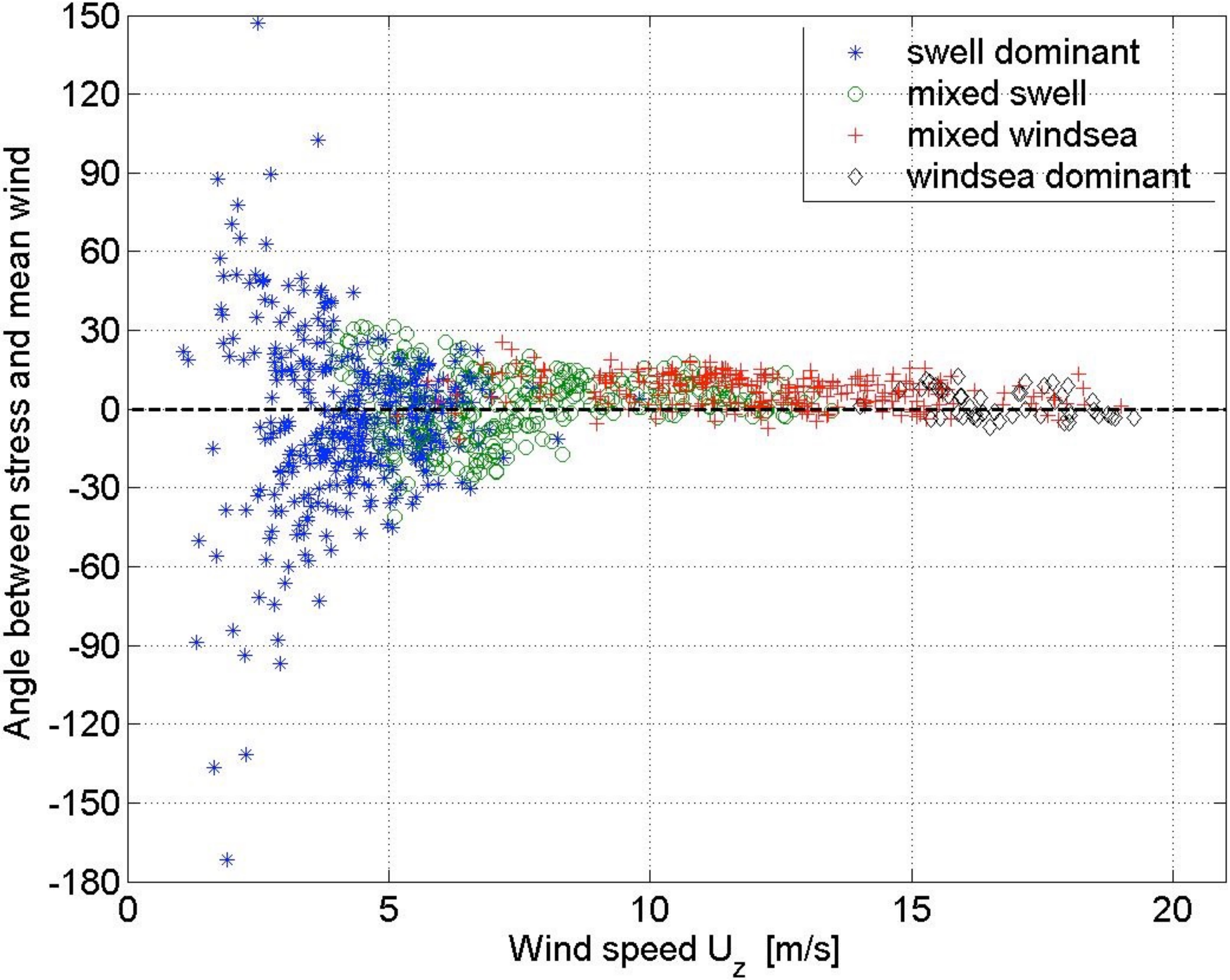
Basic Data Processing

30 min runs

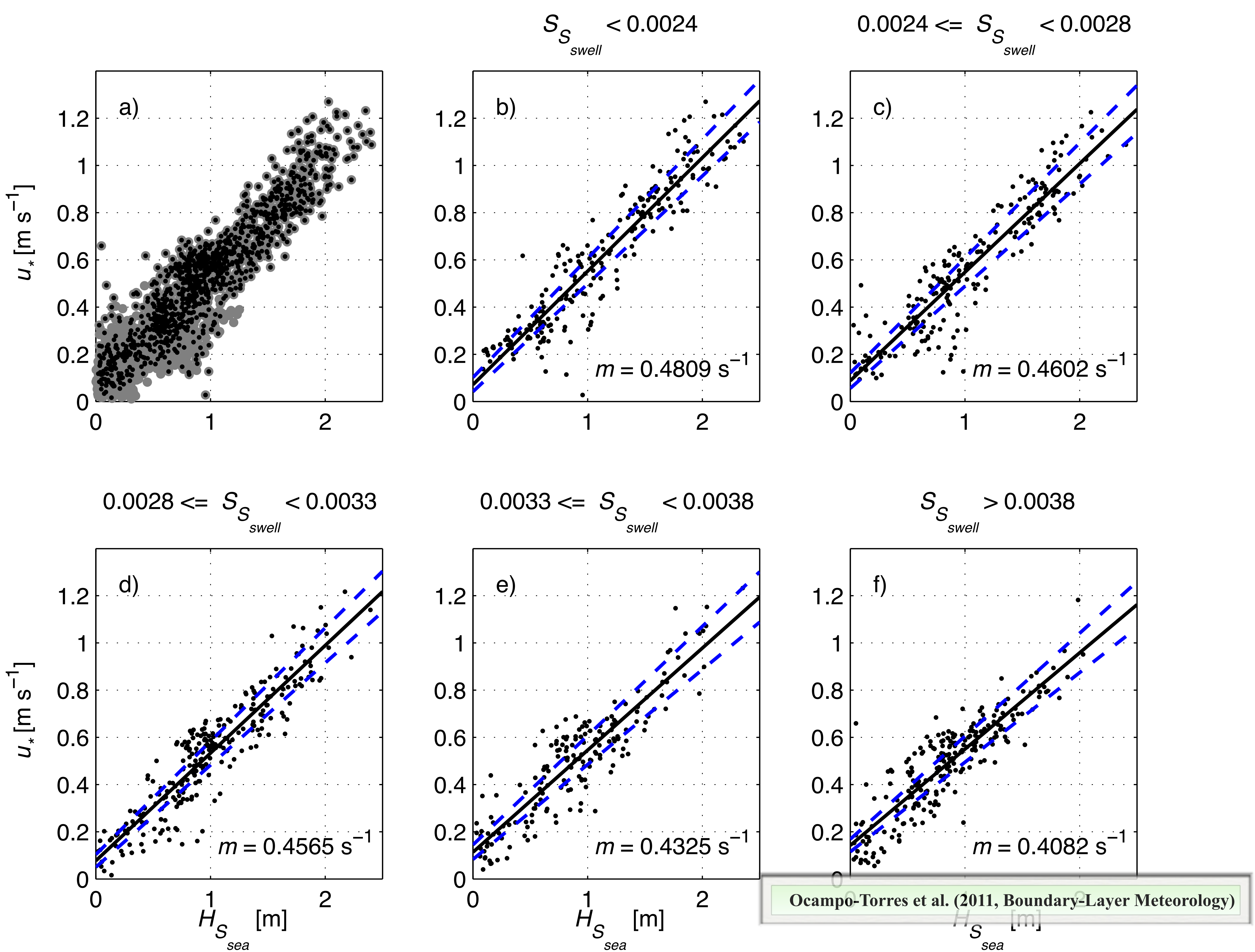
- Motion correction
- Wind velocity, surface height
- Wave frequency and directional spectra
- Wind stress (Eddy Correlation method)

$$\boldsymbol{\tau} = -\rho(\overline{u'w'}\hat{\boldsymbol{i}} + \overline{v'w'}\hat{\boldsymbol{j}})$$

- Mean atmosphere and ocean conditions
- [Wind, temperature (air, water), humidity, atmospheric pressure]



Angle between stress and mean wind
Wind speed U_z [m/s]
swell dominant
mixed swell
mixed windsea
windsea dominant
150
120
90
60
30
0
-30
-60
-90
-120
-150
-180
0
5
10
15
20

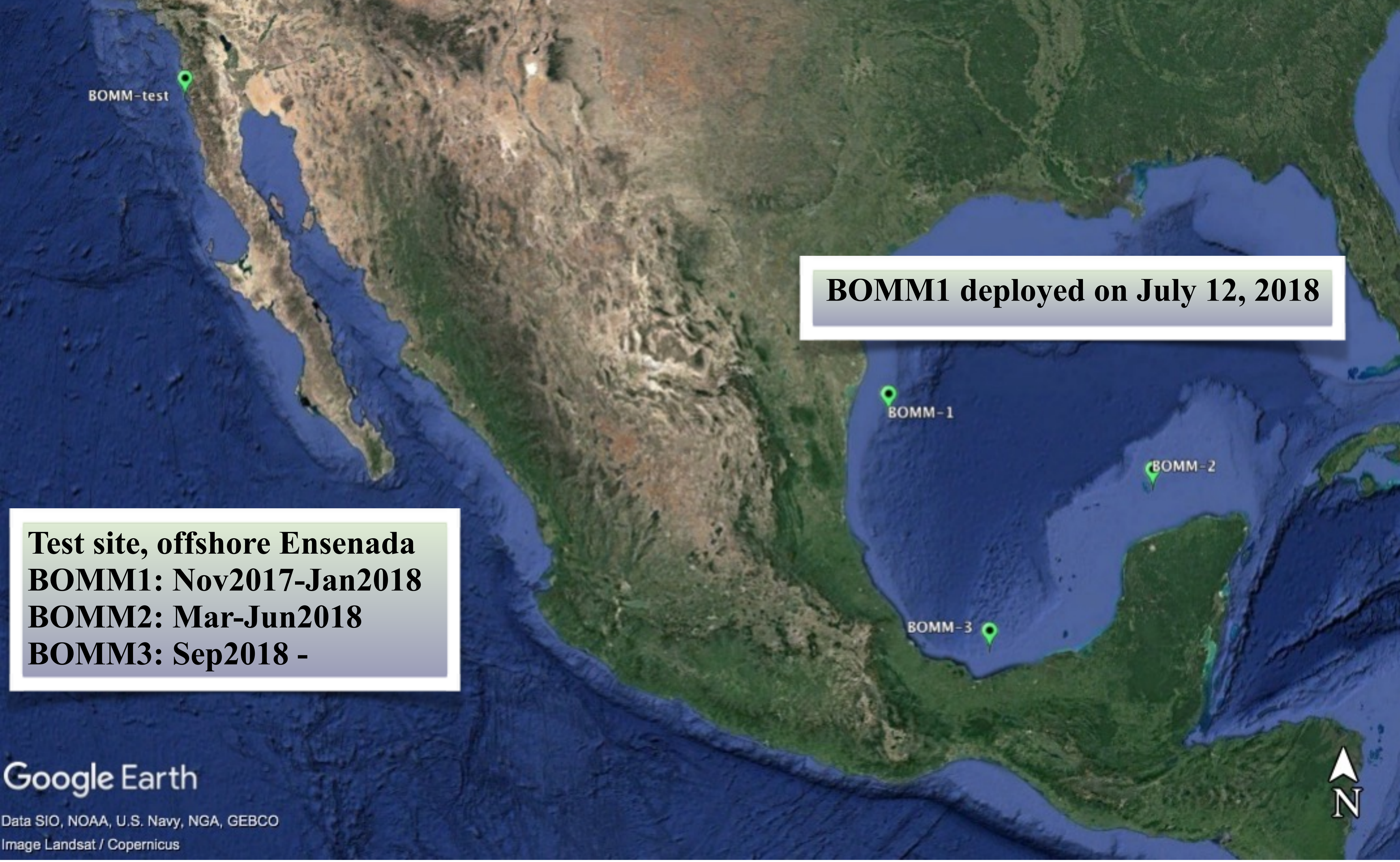


Ocampo-Torres et al. (2011, Boundary-Layer Meteorology)

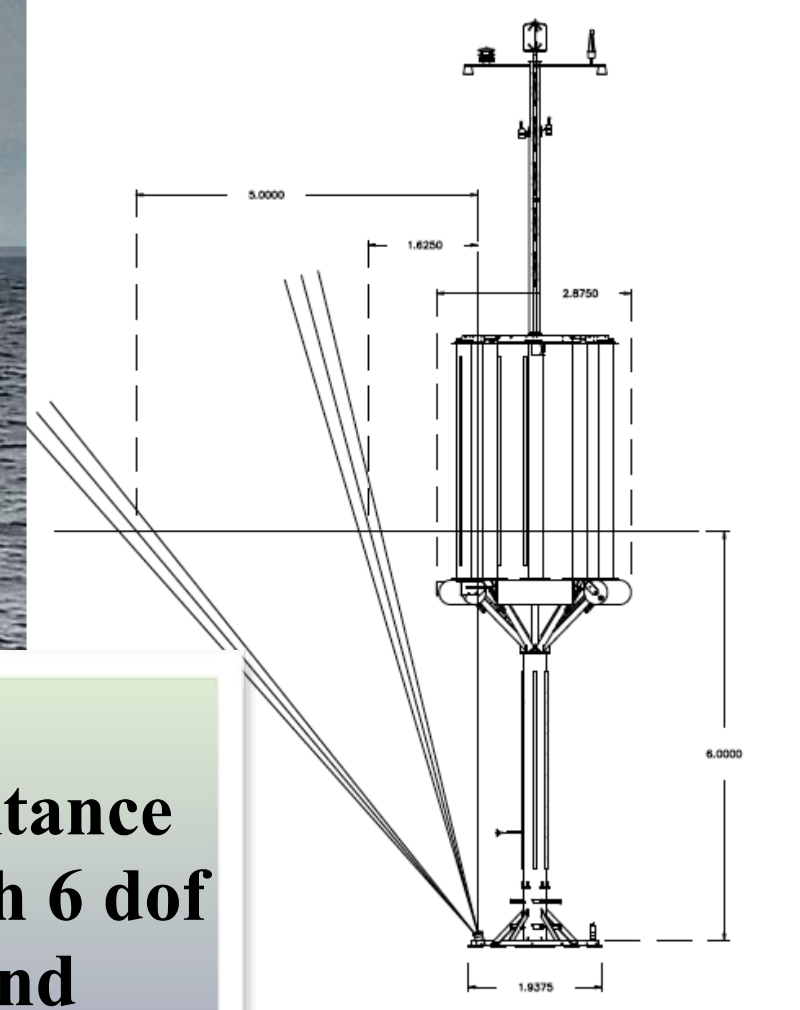
H. García-Nava, F. J. Ocampo-Torres, P. Osuna, and M. A. Donelan (2009) JGR
P. A. Hwang, H. García-Nava, F. J. Ocampo-Torres (2011) JPO
H. García-Nava, F. J. Ocampo-Torres, P. A. Hwang (2015) B-LM

Main issues we agree upon:
Wide range of wind speed and important variability.
Unique conditions of wind-sea opposing swell.

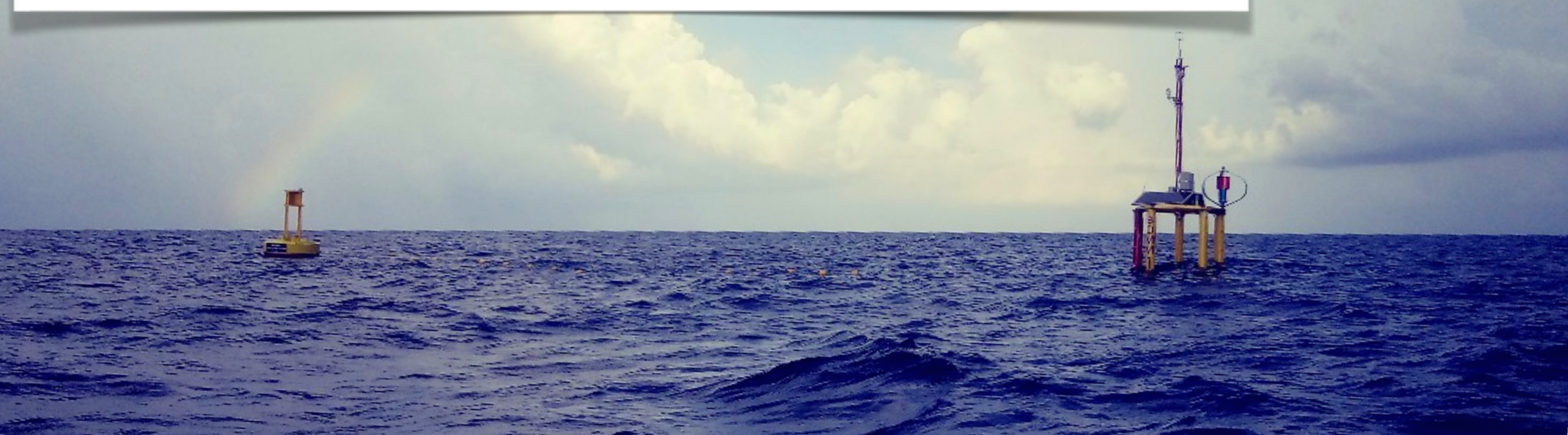
-Limited swell steepness.
-Exploring other relevant processes.



Network for oceanographic observations (physical, geo-chemical, ecological) to generate scenarios upon exploration and production activities of offshore oil in the Gulf of Mexico, 201441 project funded by SENER-CONACyT



Enhanced spar buoys: electronics, more sensors.
Sonic anemometer, Met station, air & water CO2, 6 capacitance wave staff, CTD(O2, pH), ADCP, ADV, electronics unit with 6 dof motion sensor, solid state drives, rechargeable batteries, wind generator and solar panels [LiCor CO2 sensor, 2 video cameras].

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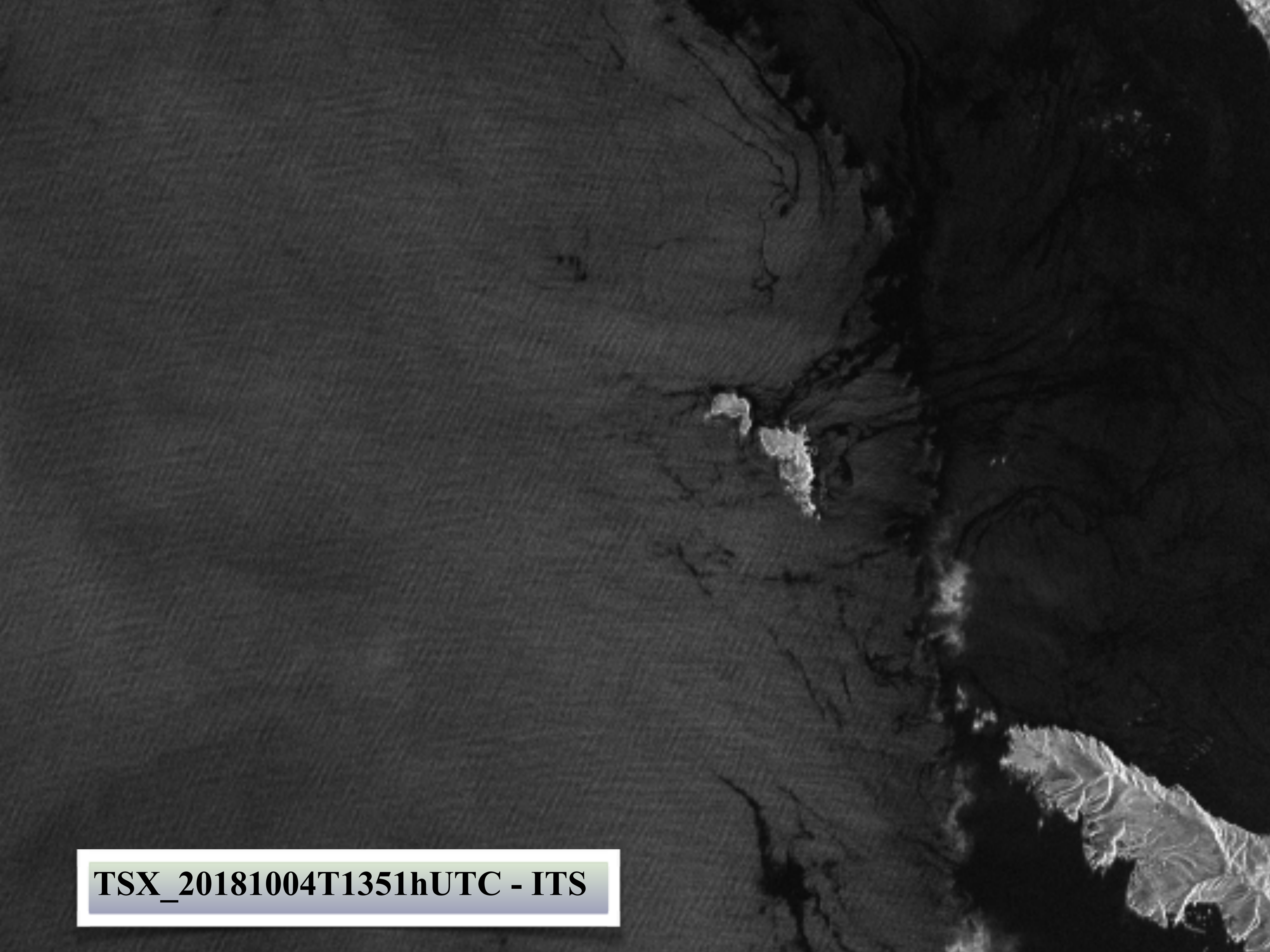
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Hopefully under a variety of surface waves conditions.
Relationship between wave spectra and the TKE dissipation rate.

Dissipation rate of TKE in the upper ocean

$$\frac{Dq}{Dt} = -\overline{\mathbf{u}'w'} \cdot \frac{\partial \mathbf{u}}{\partial z} - \overline{\mathbf{u}'w'} \cdot \frac{\partial \mathbf{u}_S}{\partial z} - \frac{\partial}{\partial z}\left(\overline{w'q} + \frac{1}{\rho_0}\overline{w'p'}\right) + \overline{w'b'} - \varepsilon$$

- Law of the wall

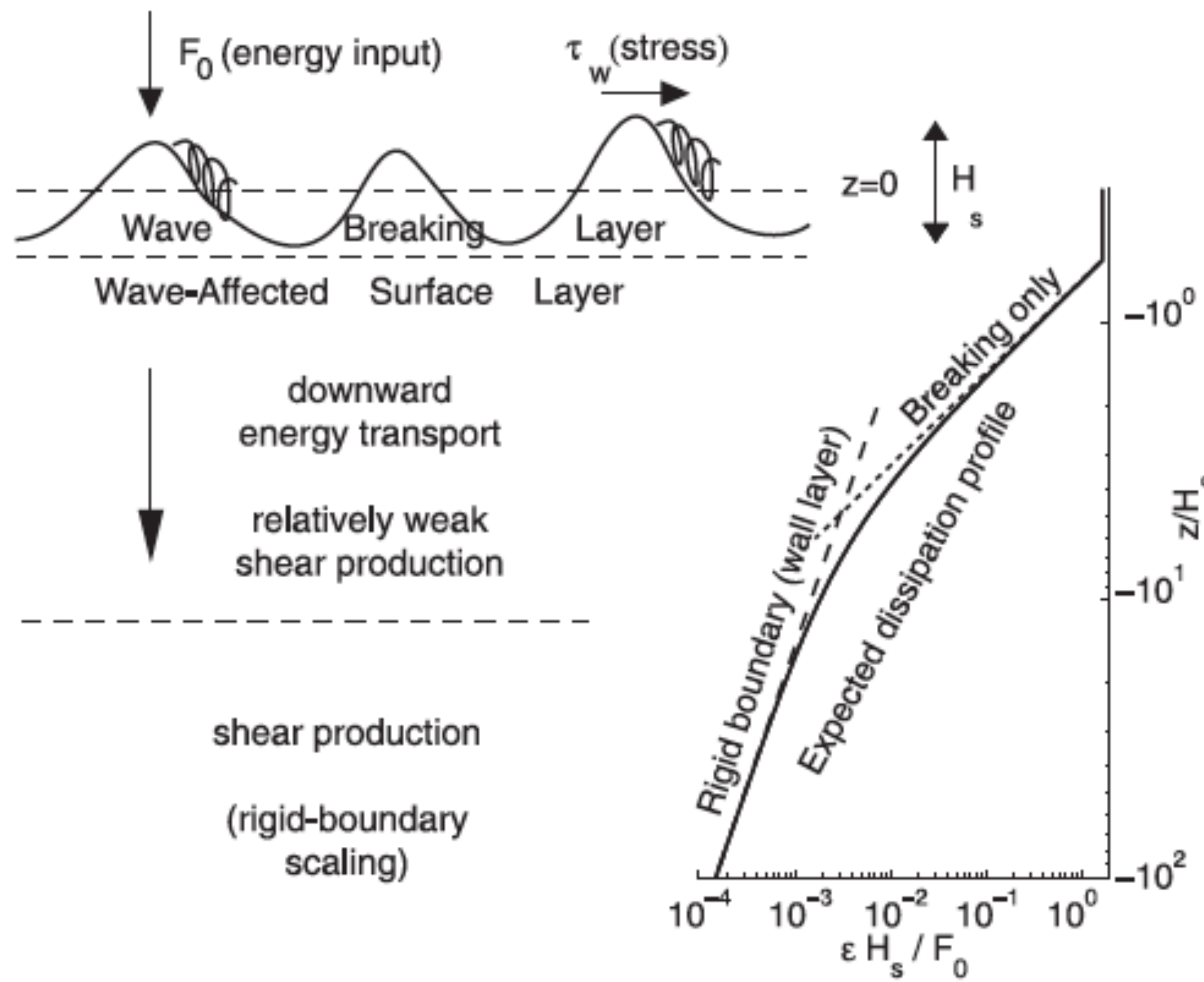
$$\varepsilon = \frac{u_{\star w}^3}{\kappa z}$$

- Total momentum flux from the atmosphere:

$$\tau = \rho_a \overline{\mathbf{u}'w'}$$

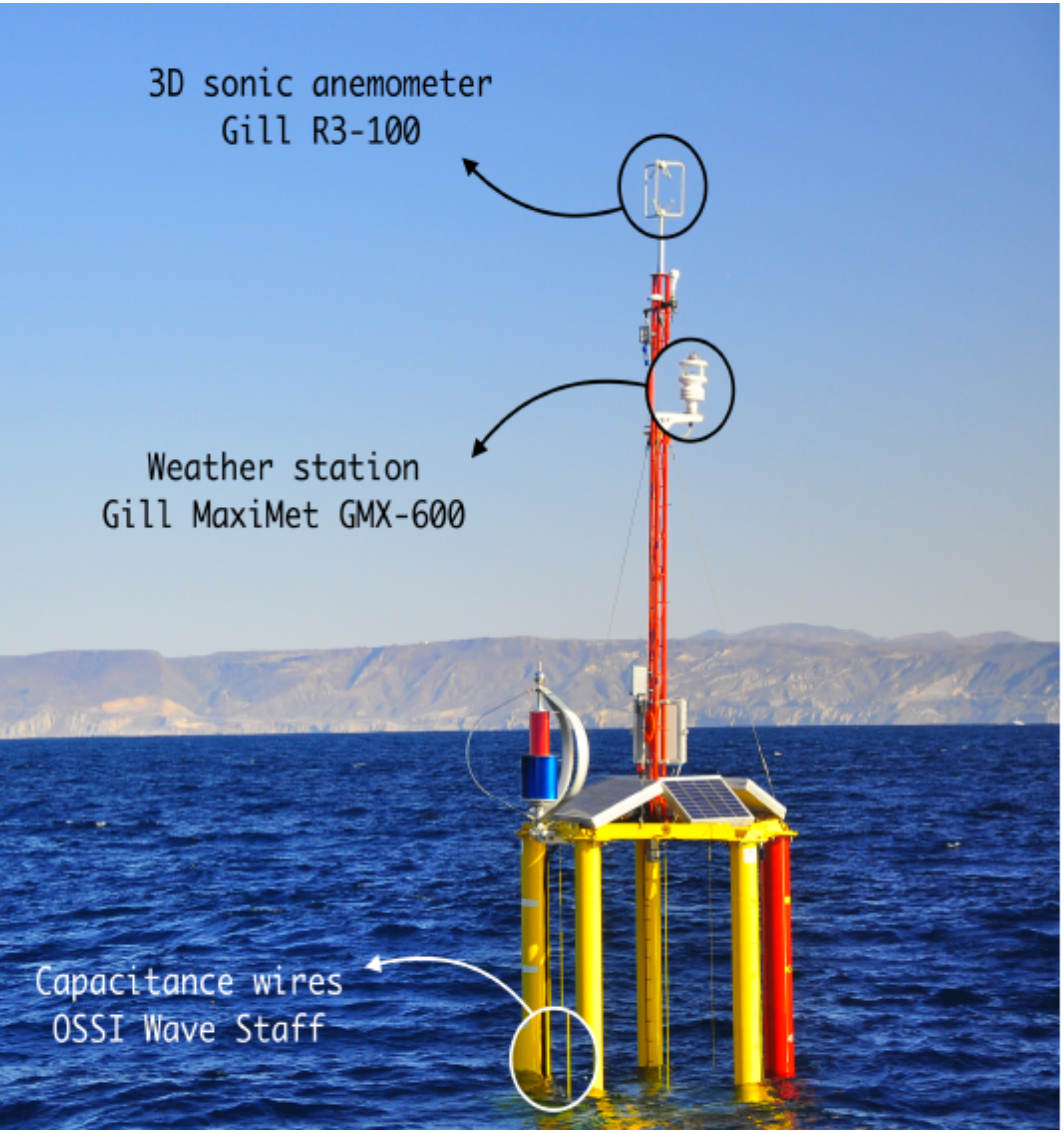
- Energy flux from the waves to the ocean:

$$F_0 = -\rho_w g \iint S_{\mathrm{ds}}(f,\theta)\mathrm{d}f\mathrm{d}\theta$$



Taken from Gerbi *et al.* (2009)

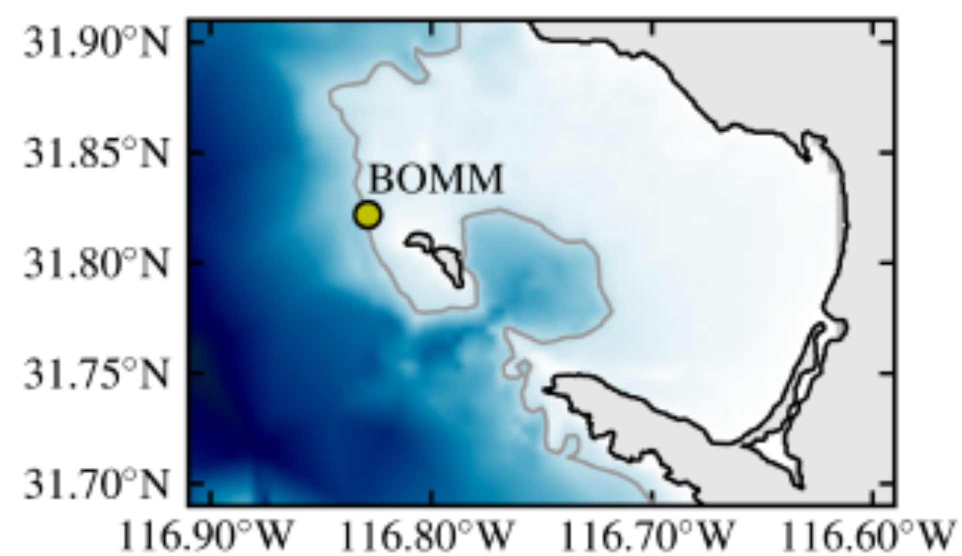
Daniel Peláez MSc thesis



Observations in the air-sea interface

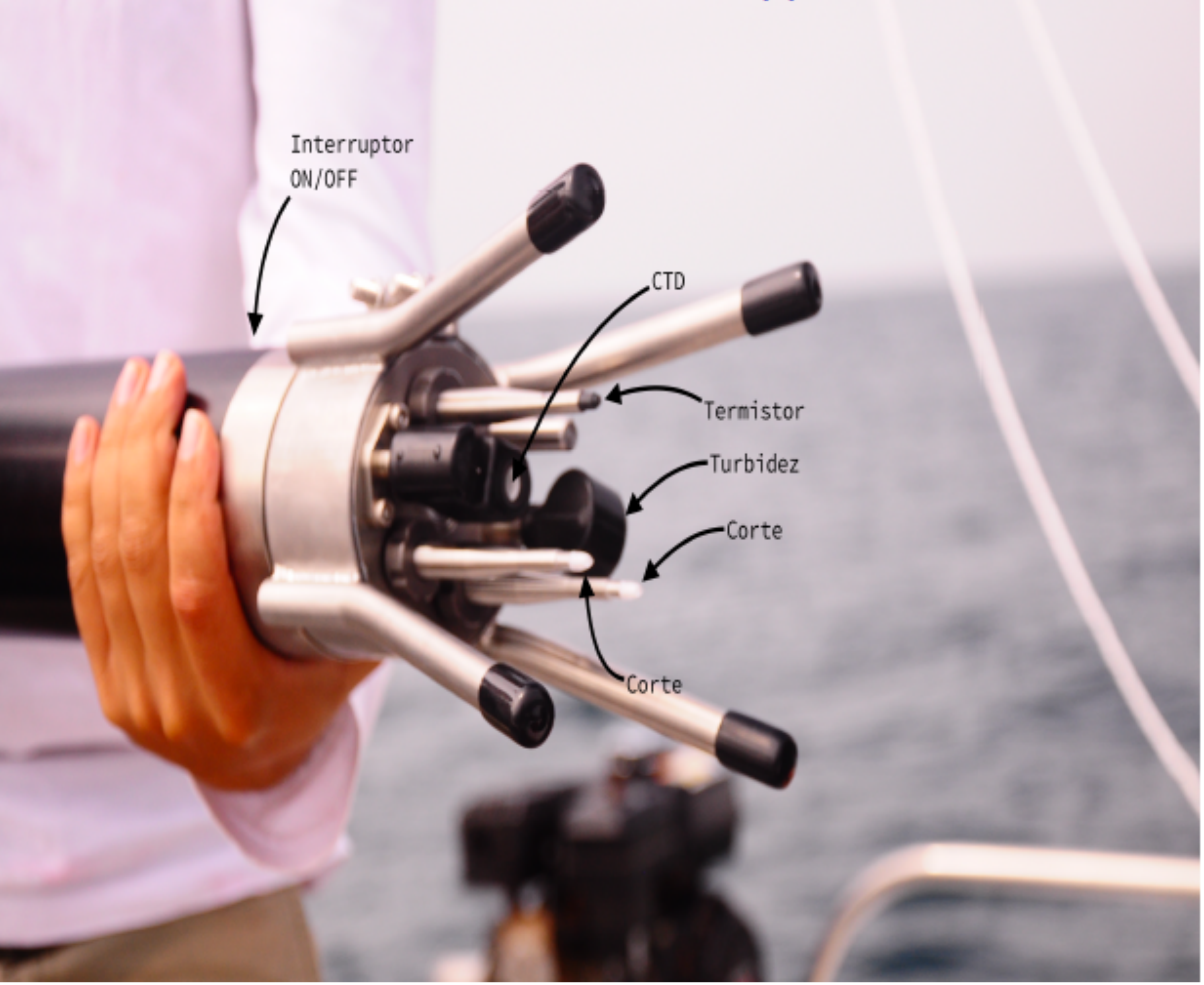
Oceanographic and Marine Meteorology Buoy (BOMM)

- Weather station.
- 3D sonic anemometer.
- Capacitance wires array.
- Inertial Motion Unit (Accelerometers + Gyros).



Measurement period:
Nov, 2017 to Feb, 2018.

Microstructure observations in the upper ocean



Rockland VMP-250 profiler:

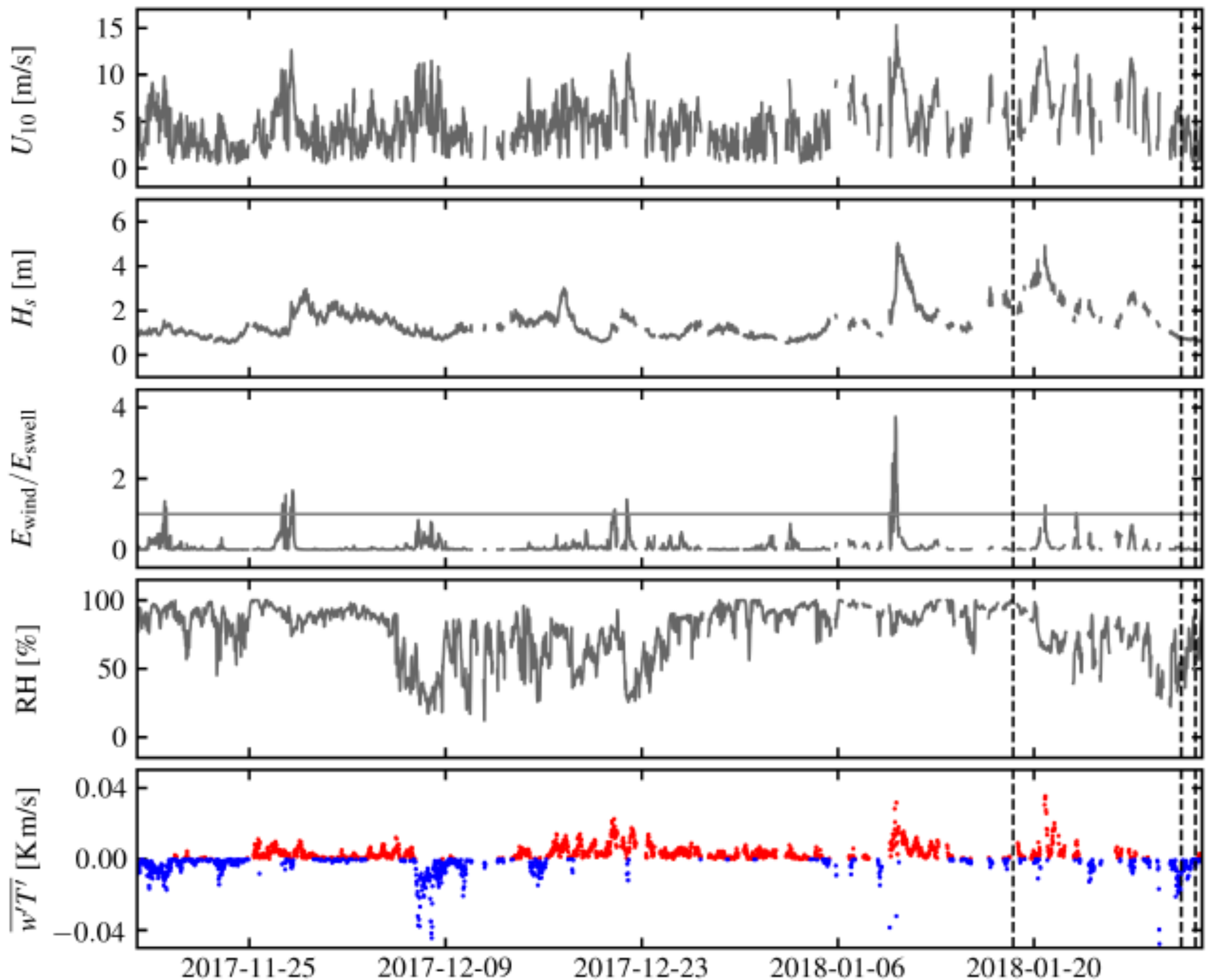
- Velocity shear probes (2).
- High-response thermistor.
- Pressure gauge.
- Standard CT sensor.

Field campaigns:

- July 4, 2017
- **January 18, 2018**
- January 23, 2018
- **January 30, 2018**
- **January 31, 2018**

512 Hz

Meteorological and sea-state conditions



Estimation of the dissipation rate of TKE

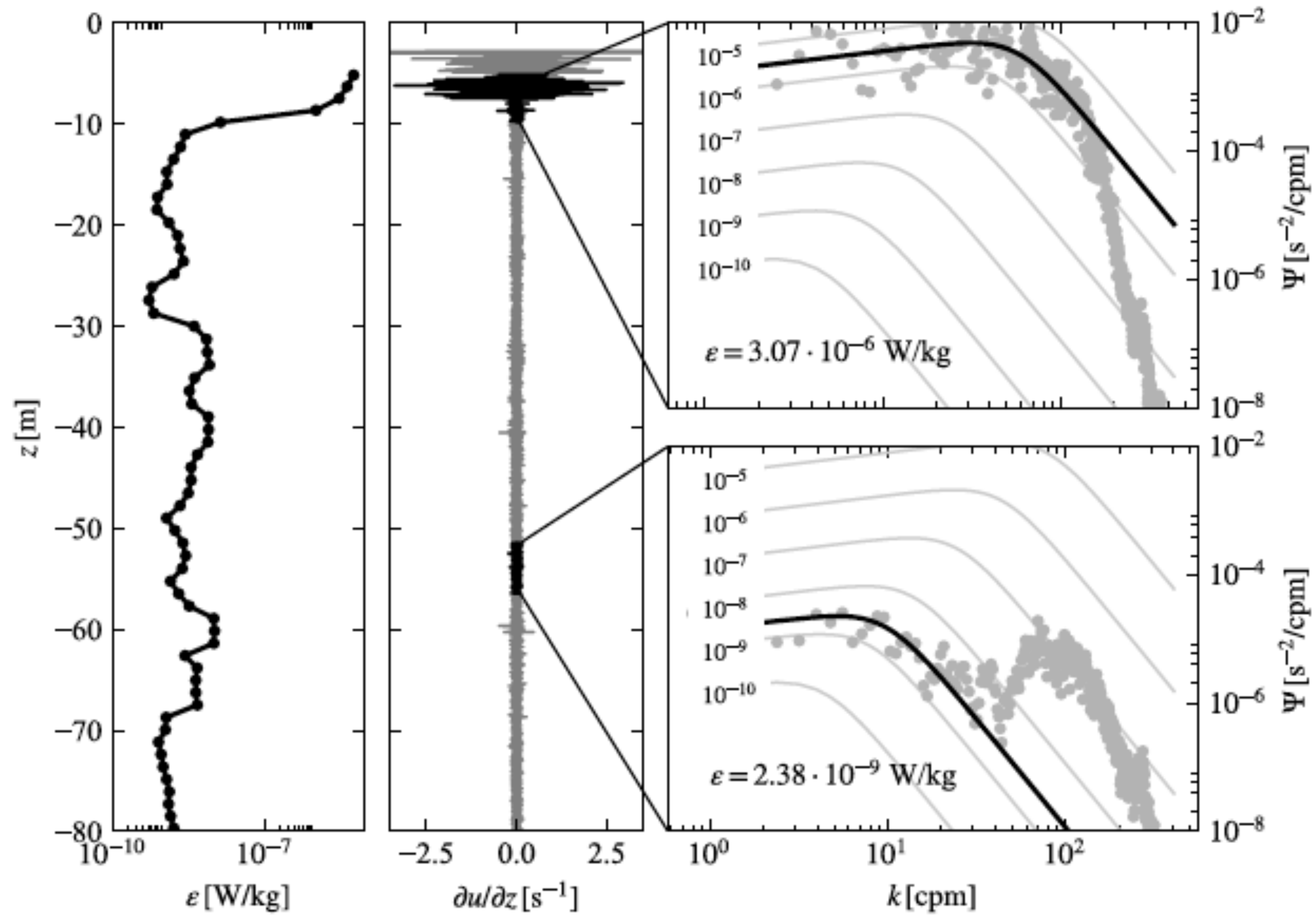
Data processing:

1. "Despiking" and "high-pass" filter.
2. Correction due to instrument vibrations.
3. Segments of 2^{12} length ($8\,\mathrm{s} \sim 5\,\mathrm{m}$).
4. Fourier transform and Hanning, 50% overlapped.
5. Fitting to a Nasmyth universal spectrum (Lueck, 2013).

$$\Psi_N(\tilde{k}) = \left(\frac{\varepsilon^3}{\nu}\right) \frac{8.05\tilde{k}^{1/3}}{1 + (20.6\tilde{k})^{3.715}}$$

6. Compute dissipation rate of TKE:

$$\varepsilon = \frac{15}{2}\nu\overline{\left(\frac{\partial u}{\partial z}\right)^2} = \frac{15}{2}\nu\int_0^{k_c}\Psi(k)\mathrm{d}k$$



Scaling of the dissipation rate of TKE

For different wave conditions

Production/Dissipation: Law of the wall

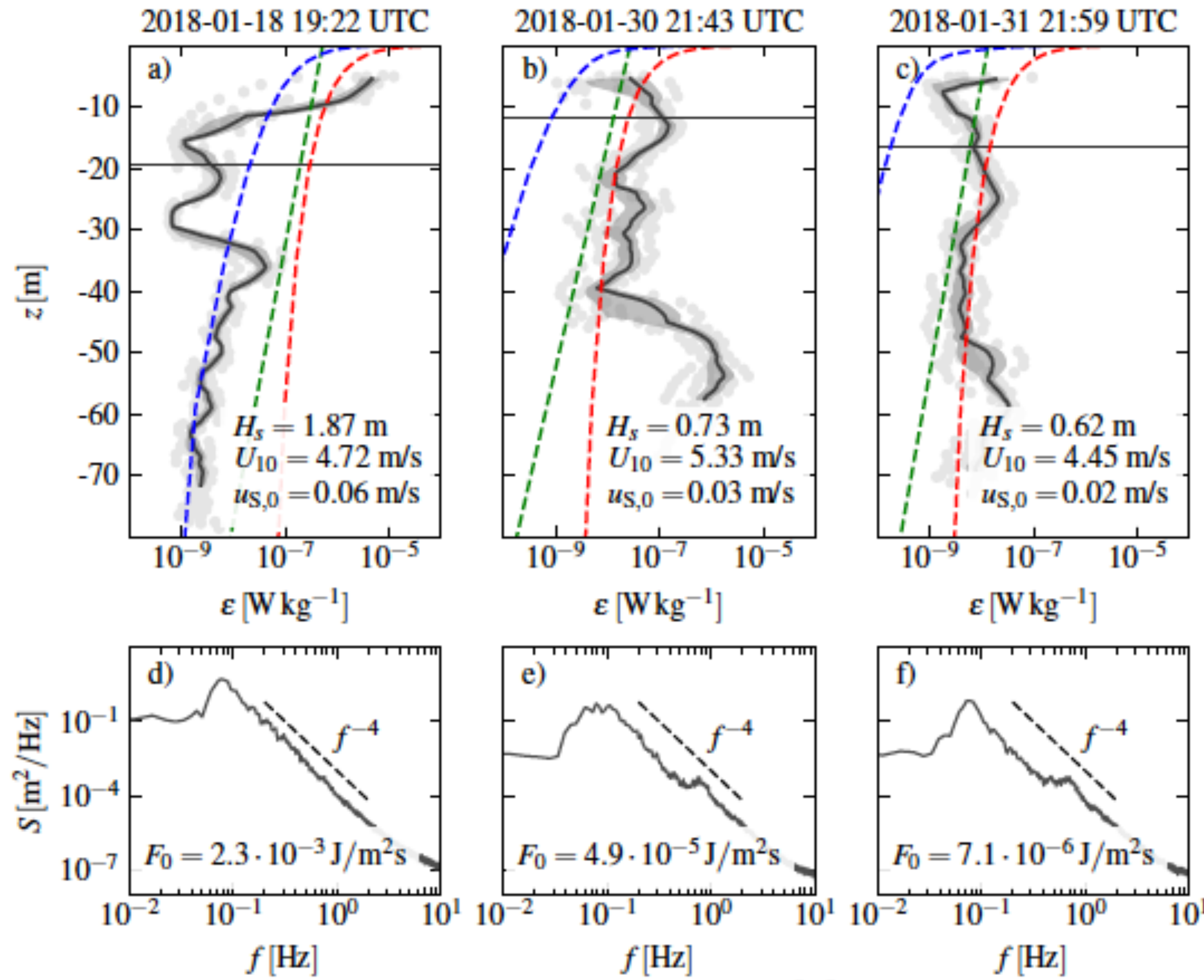
$$\varepsilon = \frac{u_{\star w}^3}{\kappa z}$$

Production/Dissipation: Stokes drift

$$\varepsilon = a_1 u_{\star w}^2 \frac{\partial u_S}{\partial z}; \quad a_1 = 3.75\beta\sqrt{\frac{H_s}{\lambda}}$$

Huang y Qiao (2010) parameterization

$$\varepsilon = 148\beta\sqrt{\delta}\frac{u_{S,0}u_{\star w}^2}{\lambda}e^{2kz}; \quad \delta = \frac{H_s}{\lambda}$$



Energy dissipated $\Rightarrow F_0 = -\rho_w g \iint S_{ds}(f,\theta)\mathrm{d}f\mathrm{d}\theta$

Scaling of the dissipation rate of TKE

For high wave conditions

Production/Dissipation: Law of the wall

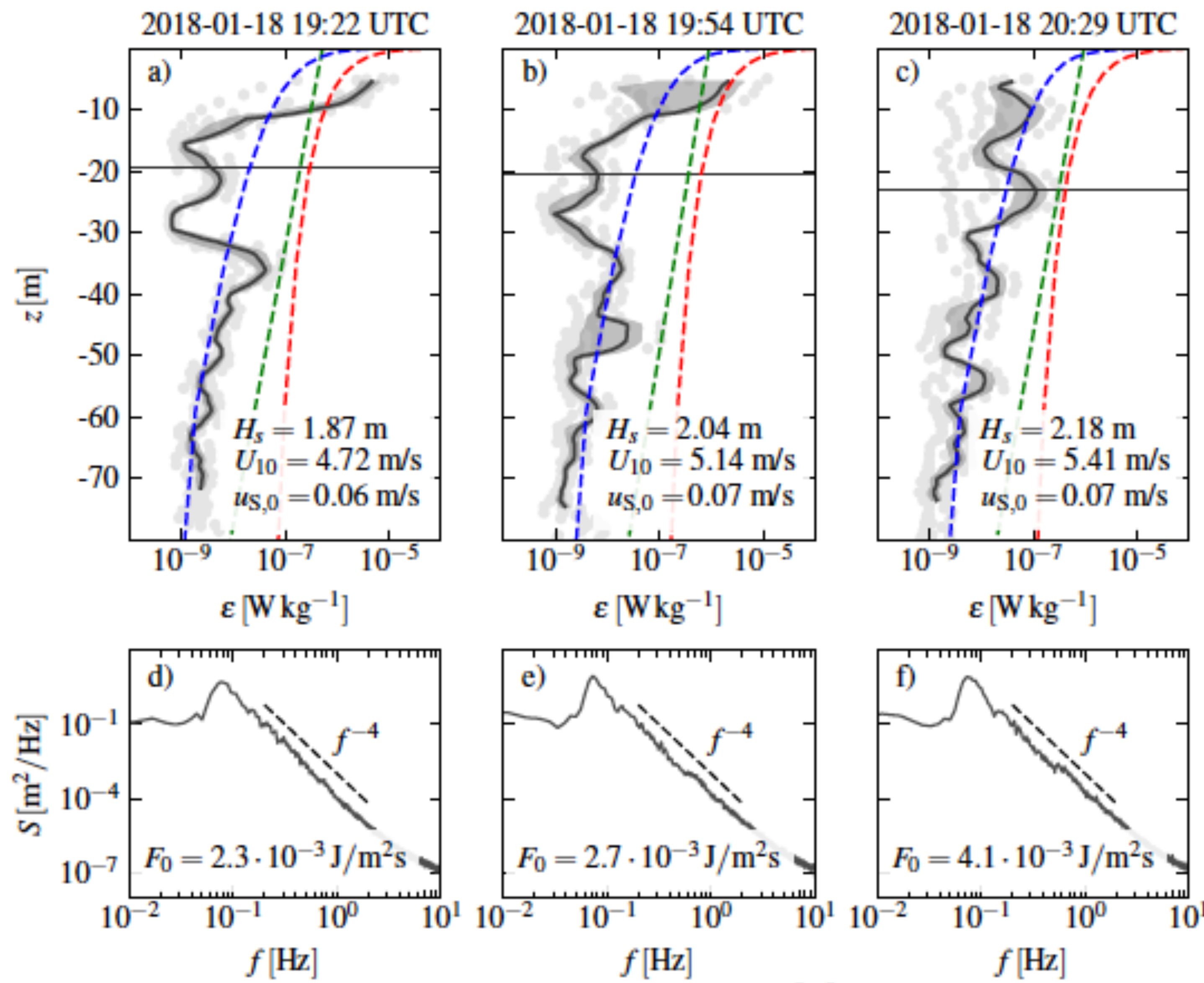
$$\varepsilon = \frac{u_{*w}^3}{\kappa z}$$

Production/Dissipation: Stokes drift

$$\varepsilon = a_1 u_{\star w}^2 \frac{\partial u_S}{\partial z}; \quad a_1 = 3.75\beta\sqrt{\frac{H_s}{\lambda}}$$

Huang y Qiao (2010) parameterization

$$\varepsilon = 148\beta\sqrt{\delta}\frac{u_{S,0}u_{\star w}^2}{\lambda}e^{2kz}; \quad \delta = \frac{H_s}{\lambda}$$



Energy dissipated $\Rightarrow F_0 = -\rho_w g \iint S_{\text{ds}}(f,\theta)\mathrm{d}f\mathrm{d}\theta$

Final remarks and next steps

Work still under progress and results under further analysis.
Currents measurements still under processing.

Needs to perform detailed direct measurements.
We are preparing for cal/val activities.
Plans to deploy our spar buoys in Mexican waters.
Air-sea interaction, momentum fluxes, directional waves, currents in the uppermost part of water column.

Thanks