UCI DataBase, Wave Spectra, and FLIP Motion

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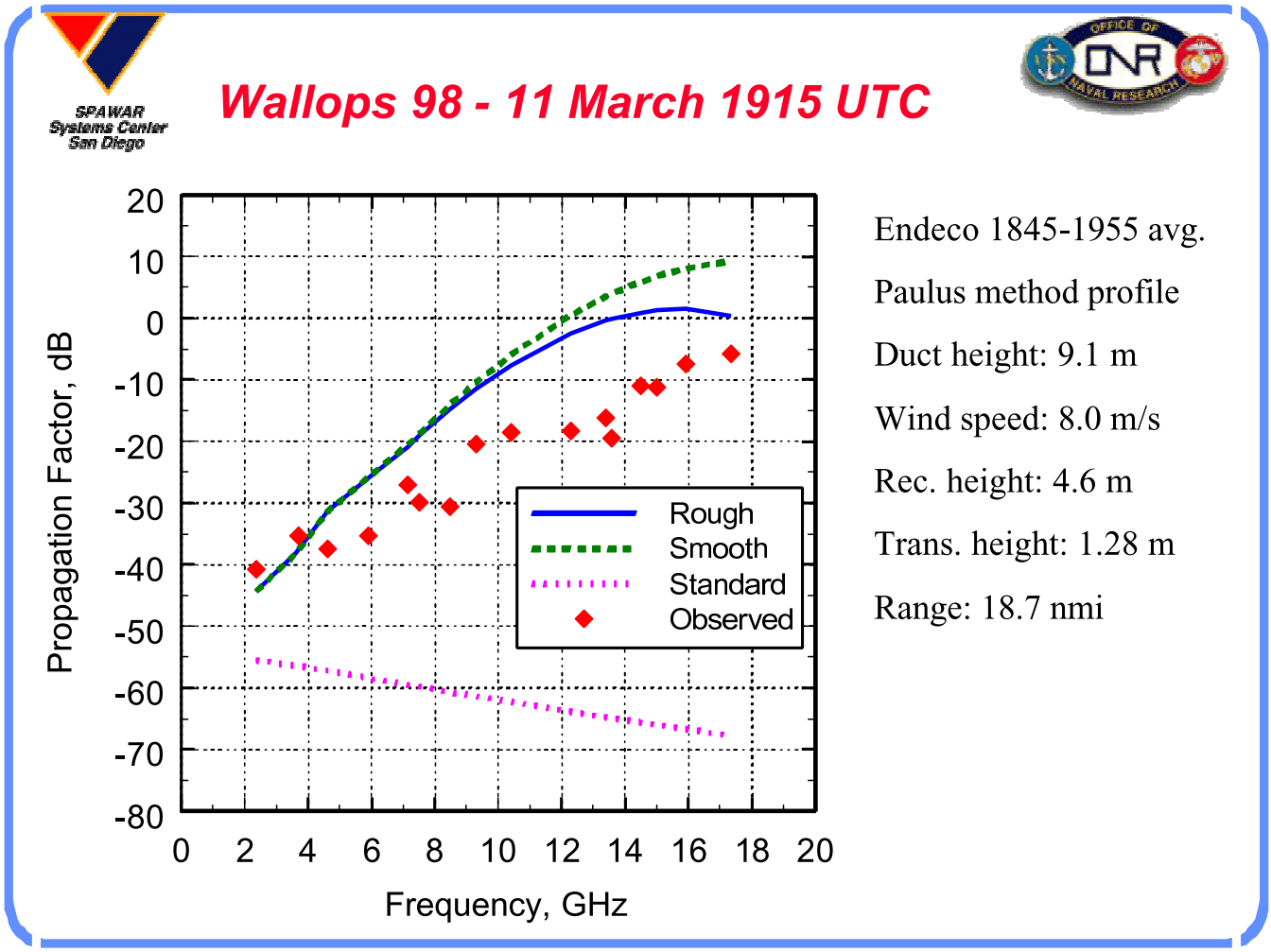


SPAWAR's measurements have indicated that normal modes models for propagation in ducting conditions

$$\left(\frac{\mathrm{d}^2}{\mathrm{d}z^2} + k_0^2\varepsilon(z) - \kappa^2\right)\psi(\kappa, z) = 0$$

overestimate the signal's intensity.

Random refraction

The EM signal is scattered by the inhomogeneities of the air's refractivity

$$N = (n-1) \times 10^6 \approx K_1 \frac{P_d}{T} + K_3 \frac{e}{T^2}$$

Propagation of the EM field moments:

$$\left[2\mathrm{i}k \frac{\partial}{\partial x} + (\Delta_1 + \cdots + \Delta_n - \Delta_1' - \cdots - \Delta_m') + \frac{\mathrm{i}k^3}{4} F_{nm} \right] \Gamma_{nm} = 0,$$

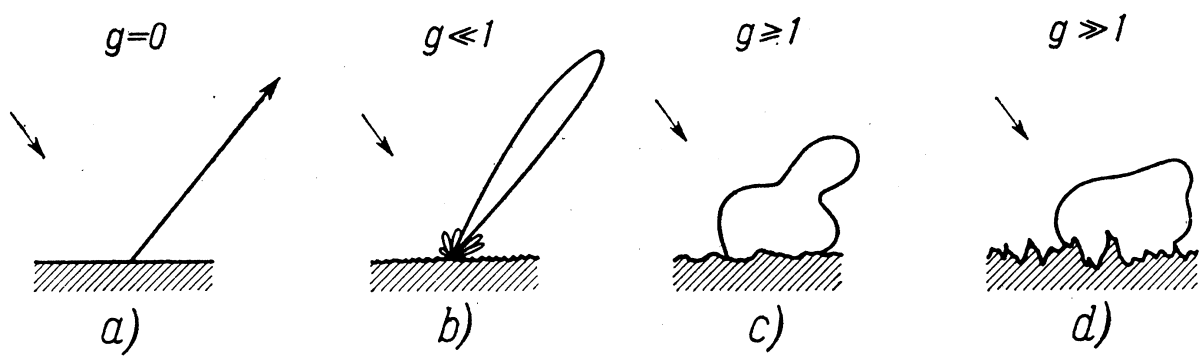
where

$$\Gamma_{nm} = \langle E(x, \boldsymbol{\rho}_1) \cdots E(x, \boldsymbol{\rho}_n) E^*(x, \boldsymbol{\rho}_1') \cdots E^*(x, \boldsymbol{\rho}_m') \rangle$$

$$F_{nm} = \sum_{k=1}^{n} \sum_{l=1}^{n} A(\boldsymbol{\rho}_k - \boldsymbol{\rho}_l) - 2 \sum_{k=1}^{n} \sum_{l=1}^{m} A(\boldsymbol{\rho}_k - \boldsymbol{\rho}_l') + \sum_{k=1}^{m} \sum_{l=1}^{m} A(\boldsymbol{\rho}_k' - \boldsymbol{\rho}_l'),$$

$$A(\boldsymbol{\rho}_k - \boldsymbol{\rho}_l) = \int \langle n(\boldsymbol{\rho}_k) n(\boldsymbol{\rho}_l) \rangle \mathrm{d}\zeta, \qquad \zeta = z_k - z_l.$$

Scattering from a rough surface



The power of the scattered field

$$\langle EE^* \rangle \propto \begin{cases} \langle e^{\mathrm{i}(q_{z1}\eta_1 + q_{z2}\eta_2)} \rangle & \text{for diffusive scattering} \\ \langle e^{\mathrm{i}q_z \eta} \rangle & \text{for coherent scattering} \end{cases}$$

The nonlinear wave-wave interaction modifies the probablity distributions (e.g. elevation, slope) of the sea surface and therefore the averages, e.g. $\langle e^{\mathrm{i}q_z \eta} \rangle$.

RED's Hypotheses

1. Inaccurate information about the duct's strength and structure brings uncertainty in modeling results.
2. The atmospheric random refraction and scattering from the rough ocean surface further degrade beam's energy and contract the coherence radius.
3. The surface waves can influence the pattern of EM propagation by:
   (a) Rough surface scattering,
   (b) Inducing semi-periodic fluctuations of the refractvity which contribute to the random refraction,
   (c) Reorganizing MABL. The waves modify the fluxes of momentum and kinetic energy and the profiles in MABL.

Measurements of Humidity

- Edge Tech Chilled Mirror Hygrometer (5 instruments, Analog)
- Lyman-α Hygrometer (3 instruments, Analog)
- Krypton Hygrometer (2 instruments, Analog)

Measurements of Temperature

- Ultrasonic Thermometers (2 Gill, 4 Campbell Scientific, Analog)
- Hart Scientific (8 thermistor channels, 2 display boxes, RS-232)
- Infrared thermometer for sea surface temperature (Analog)

Measurements of Wind Velocity

- Ultrasonic Anemometers (2 Gill, 4 Campbell Scientific, Analog)

Wave Measurements

- NOBSKA MAVS3 Acoustic Current Meter (2 instruments, RS-485)
- Wave-wire under the instruments mast (Analog).

Pressure Measurements

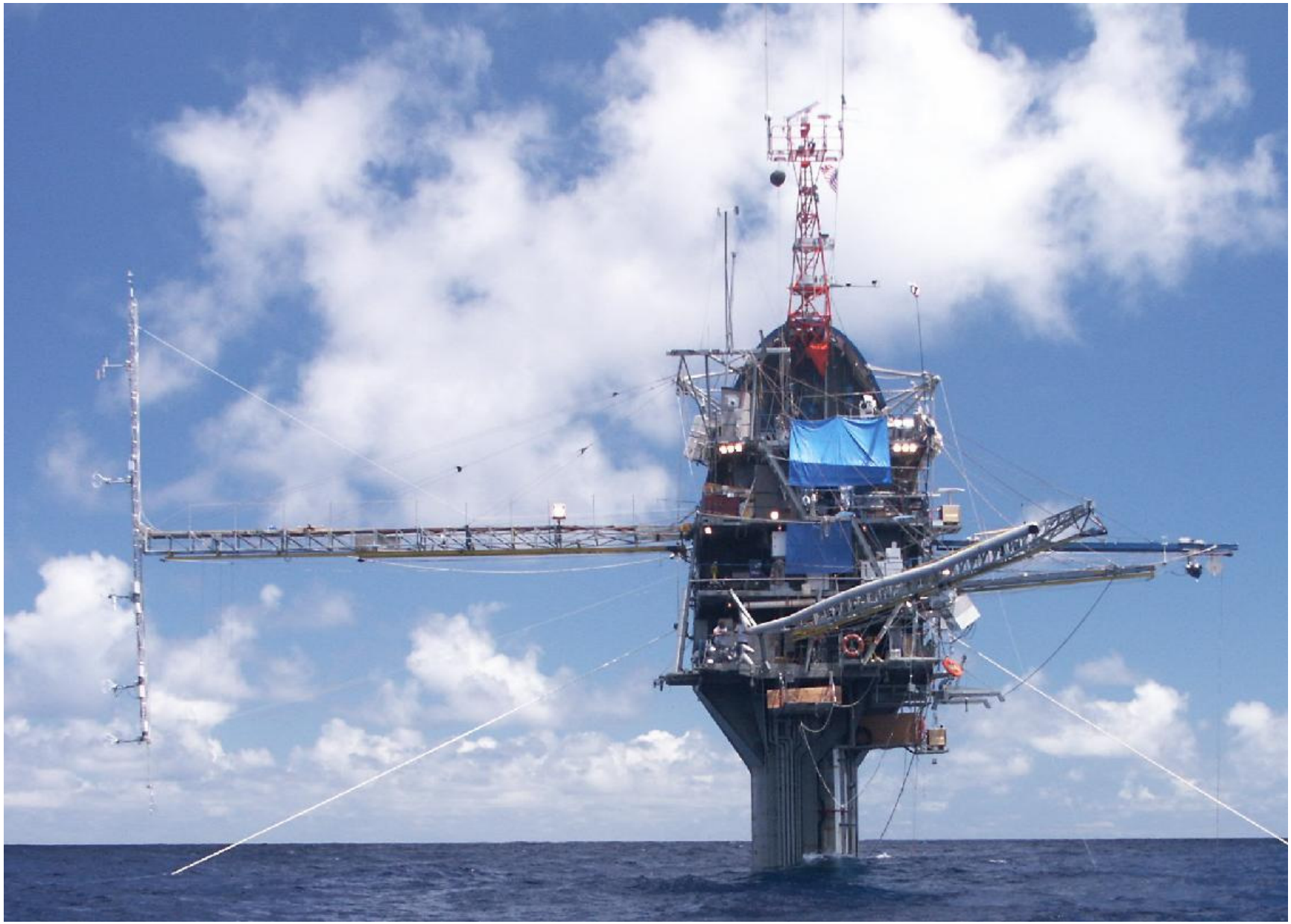
- Paroscientific 202BG Diff. Pressure Transducer (2 instruments, RS-232)
- Paroscientific Met3A Barometer (2 instruments, RS-232)

Motion, Inertial Navigation and GPS

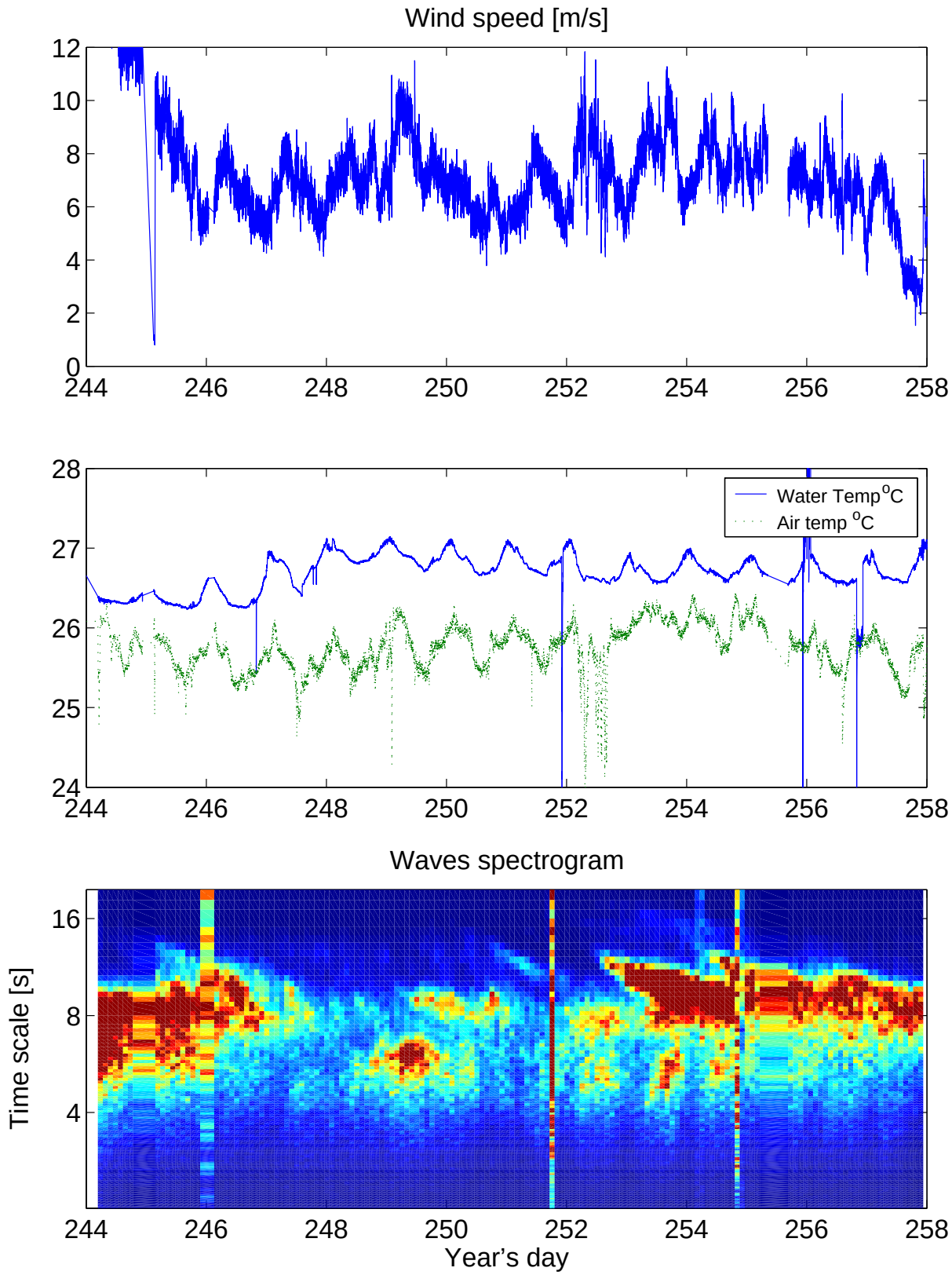
- Systron Donner MotionPak (3 accelerations and 3 angular rates, Analog)
- BOEING C-MIGITS II (3 Velocities, 3 angles, GPS, RS-232)
- Flip Gyroscope (Heading, Analog)

Data Acquisition System National Instruments PXI-1010:

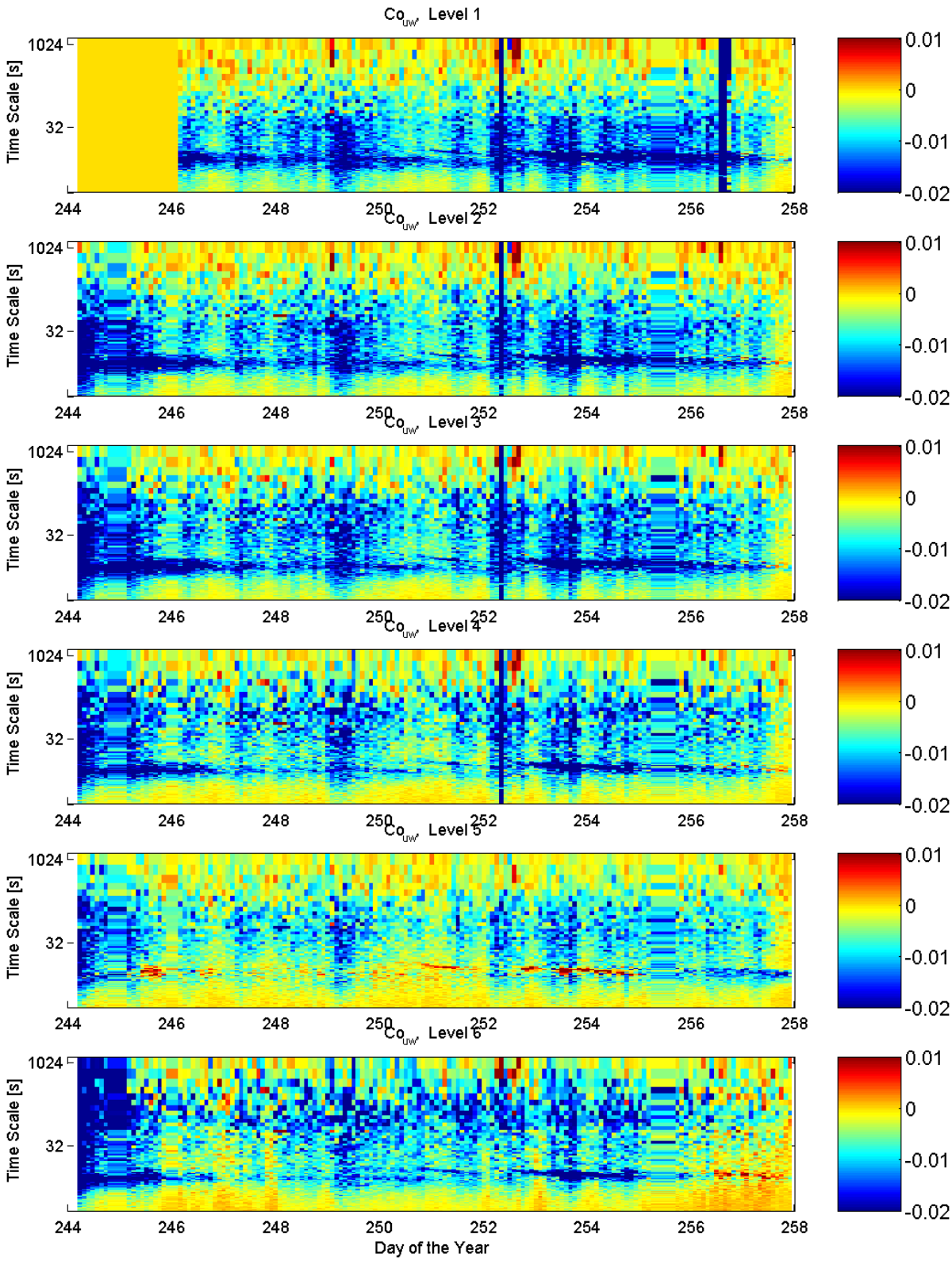
- Controller PXI-8170 (Ethernet, SCSI, USB)
- 6031E 16 bit ADC board, 8 Port RS-232 boards, 8 Port RS-485 board.
- SCXI-1001 signal conditioning chassis, anti-aliasing filters, multiplexing.



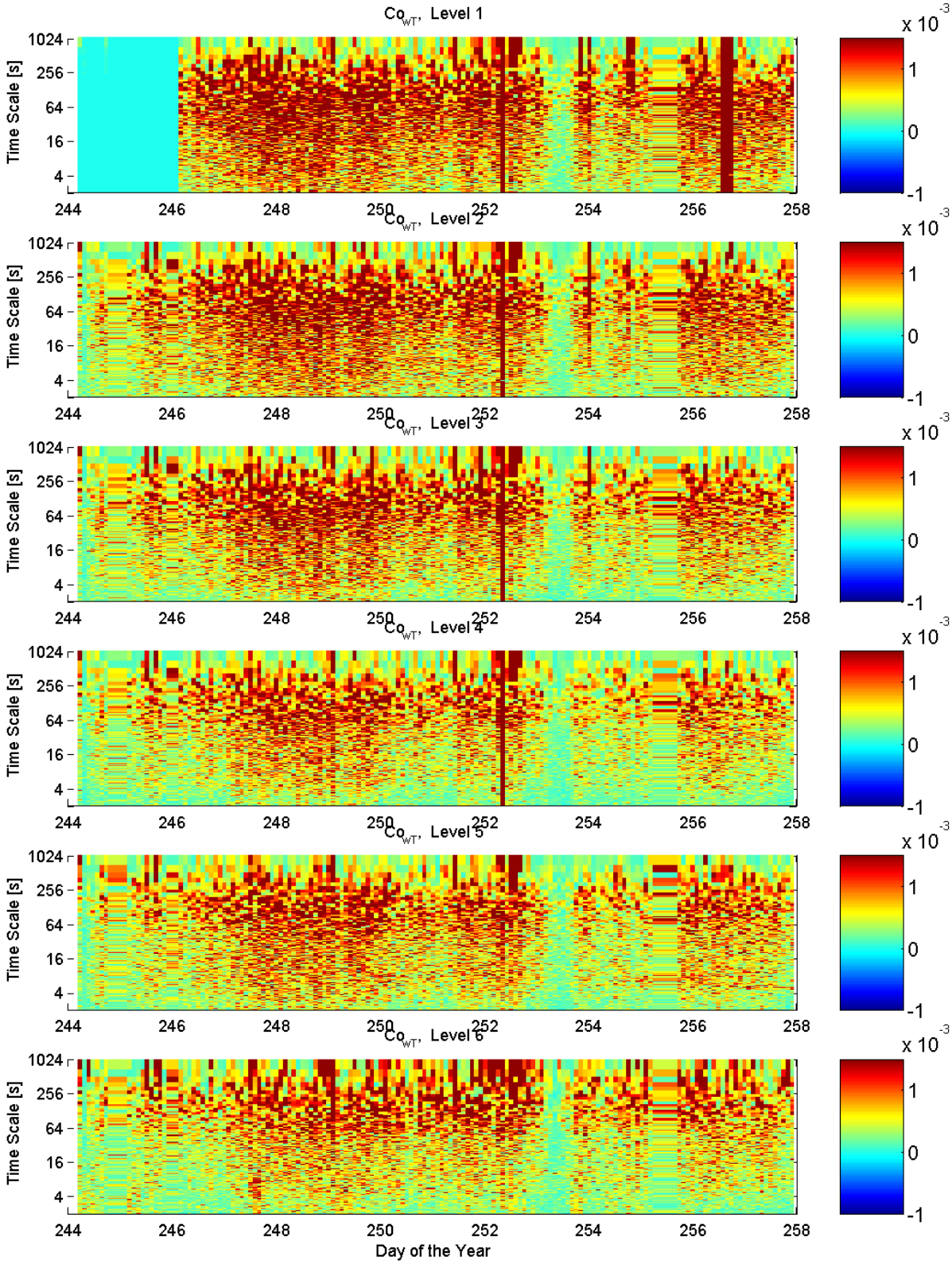
Wind Speed, Temperatures, Wave Spectra



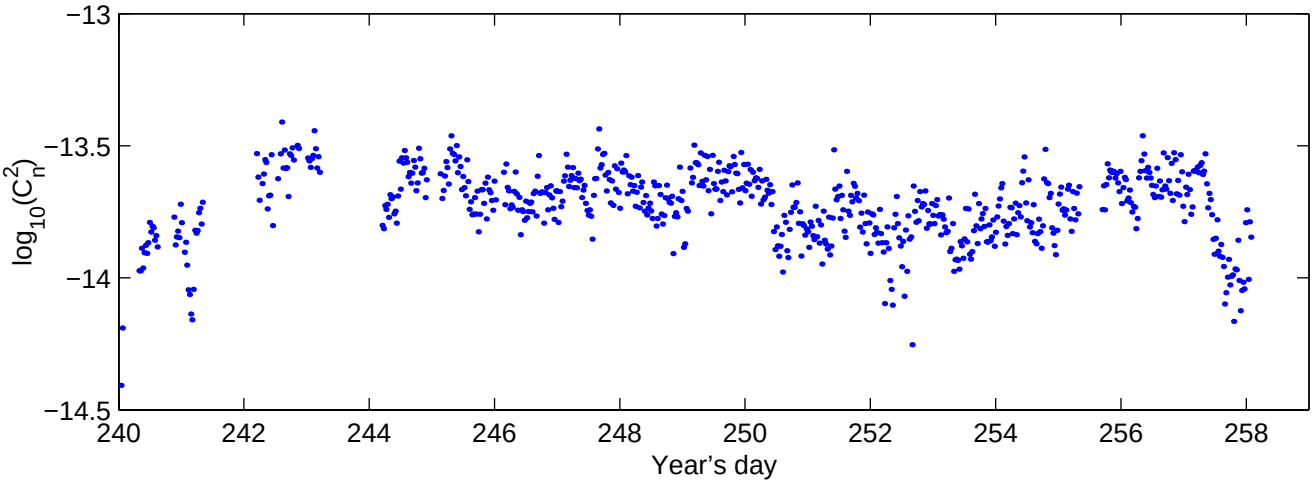
Momentum Flux Spectrograms

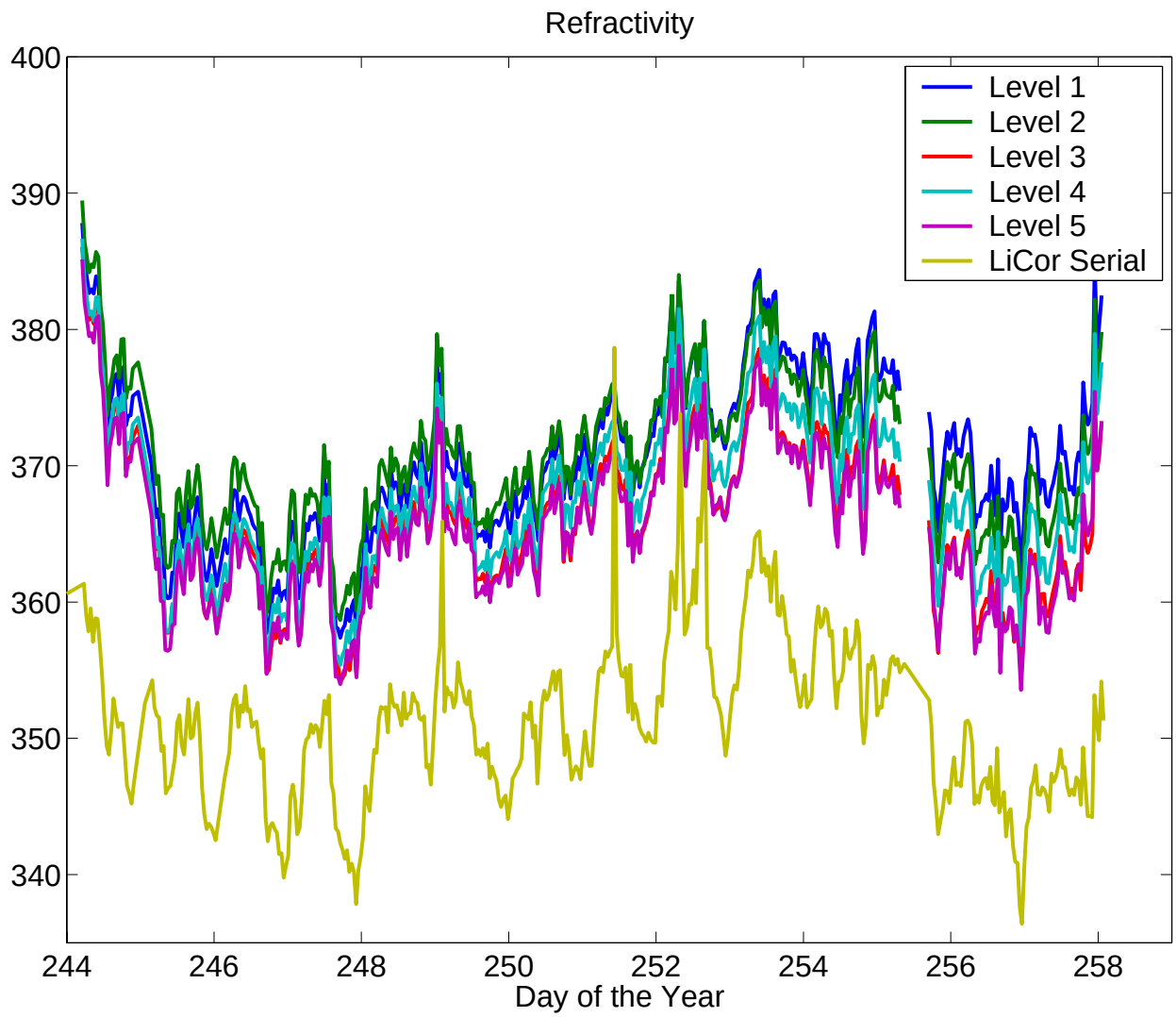


Heat Flux Spectrograms

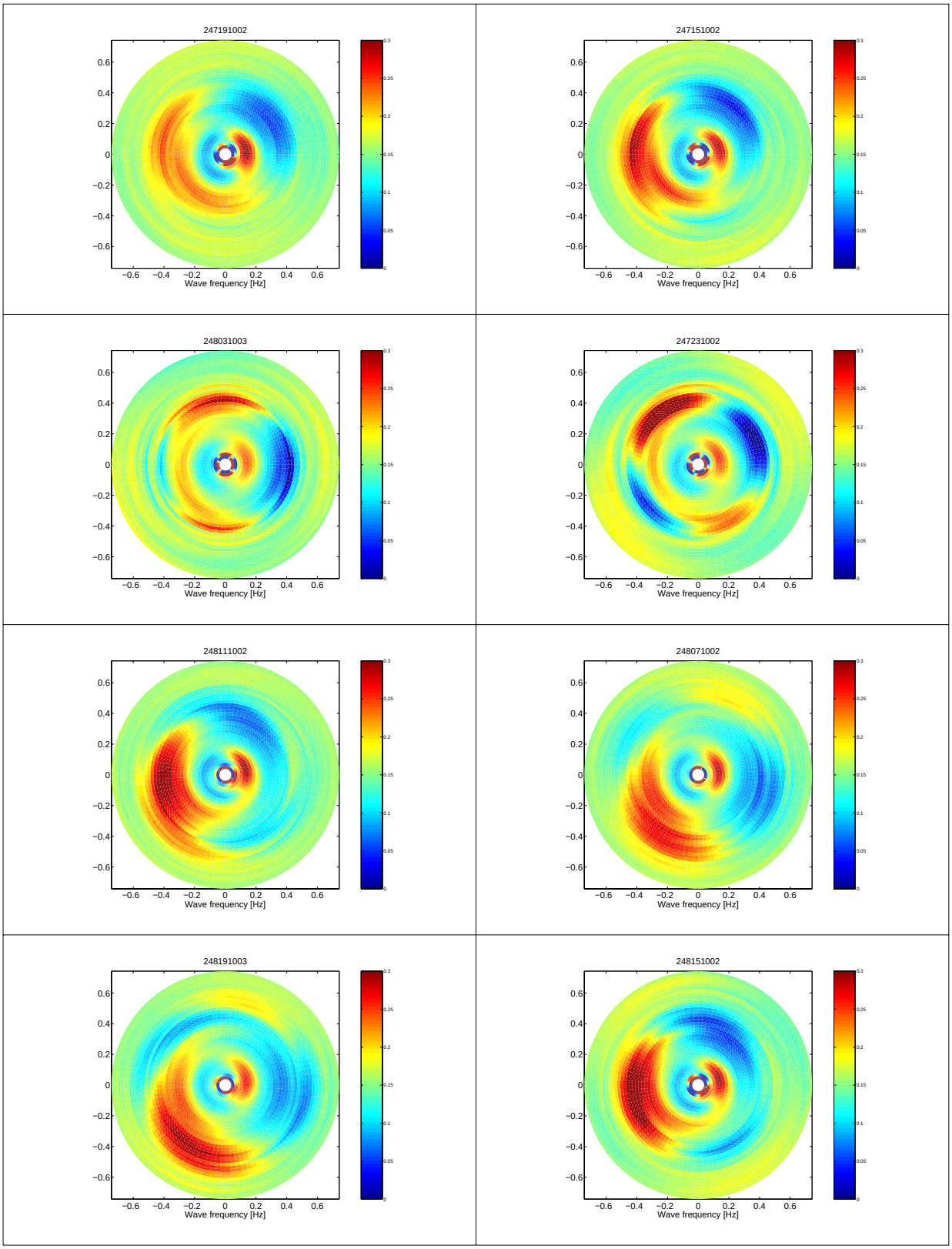


Structure Parameter and Refractivity





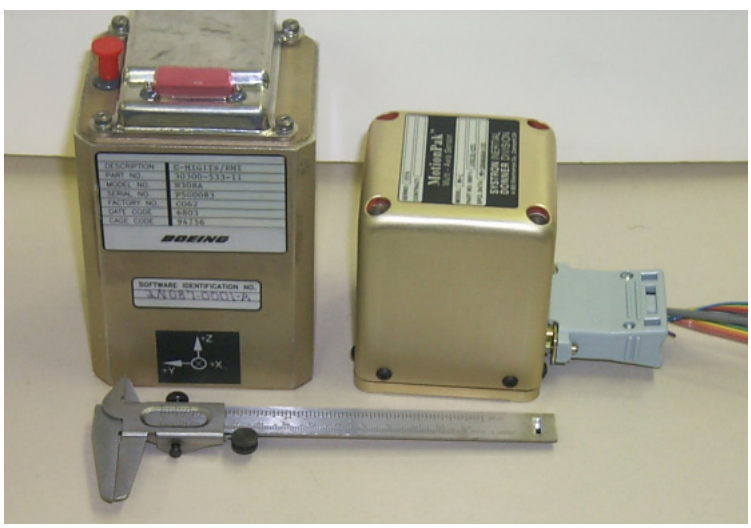
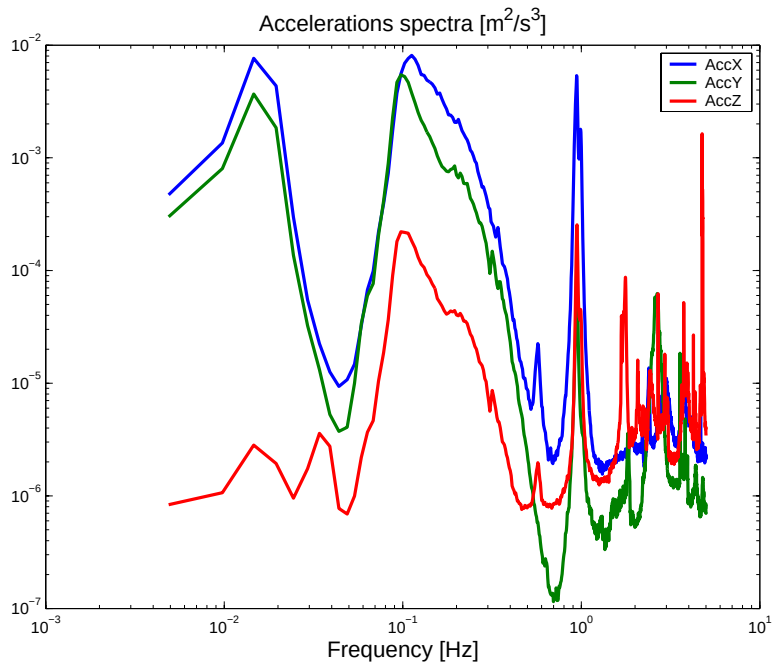
Waves Directional Spread Function



Technical Tasks

- **Data Synchronization**
- **Signal compensation** Correction for instrument's response.
- **FLIP Motion Corrections**

$$\boldsymbol{u} = \boldsymbol{T}^{-1}\boldsymbol{u}_m + \int \left(\boldsymbol{T}^{-1}\boldsymbol{a}_m - \boldsymbol{g}\right) \mathrm{dt} + \boldsymbol{T}^{-1}\left(\boldsymbol{\Omega}_m \times \boldsymbol{r}_m\right),$$

Euler angle rates and the body-referenced rates are related as:

$$\begin{bmatrix} \dot{\varphi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} 1 & \sin\varphi\tan\theta & \cos\phi\tan\theta \\ 0 & \cos\varphi & -\sin\varphi \\ 0 & \sin\varphi/\cos\theta & \cos\varphi/\cos\theta \end{bmatrix} \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \end{bmatrix}$$