**Summary**

Background: Atmospheric cold fronts have along-frontal scales of many 1000s km, but much shorter cross-frontal scales of 10-100s km. At the sea surface, the high winds near the fronts generate strongly coupled short wind-waves, while the abrupt shift in wind direction across the front, combined with the rapid translation of the frontal system, produces a large area of misaligned surface waves behind the cold fronts.

Objectives: To characterize the sea state associated with the misaligned waves and evaluate their impacts on surface drag, air-sea momentum fluxes, and wind profiles.

Results: Misaligned waves increase the surface drag and wind stress, reducing wind speed in the MABL. The misaligned waves are continuously generated/disappear as the fronts translate eastward.

**Wind and waves under atmospheric cold fronts: Case study**

- **Surface wind (m/s)**
- **Wave-wind angle (θ)**
- **Wind stress (N/m²)

Measurements indicate a passage of a cold front around Dec 6, with abrupt shifts in wind direction, a rapid drop in air temperature, and an increase in Hs. The strongly misaligned young waves lasted, in this case, for ~24 hours after the passage of the cold front.

The misaligned young waves after the front are also well captured. The peak (mean) wave direction produces more abrupt (gradual) shifts in the wave direction. The mean wave direction agrees better with the Pioneer array data (though it uses peak wave direction). The misaligned young waves are captured.

**Simulated wind and wave conditions**

- **Wind direction, mean wave direction**
- **Wave direction, peak wave direction**

The strongly misaligned young waves are captured. The peak (mean) wave direction produces more abrupt (gradual) shifts in the wave direction. The mean wave direction agrees better with the Pioneer array data (though it uses peak wave direction).

**Wind and waves observed at the Pioneer Array**

Measurements indicate a passage of a cold front around Dec 6, with abrupt shifts in wind direction, a rapid drop in air temperature, and an increase in Hs. The strongly misaligned young waves lasted, in this case, for ~24 hours after the passage of the cold front.

The misaligned young waves after the front are also well captured. The peak (mean) wave direction produces more abrupt (gradual) shifts in the wave direction. The mean wave direction agrees better with the Pioneer array data (though it uses peak wave direction).

**Effects on air-sea fluxes and MABL winds**

Including the misaligned wave effect in the bulk formula increases the stress by up to 30%, and decreases wind speeds by up to 10% over a large area behind the cold front. Before the cold front, the wind profiles were identical between the two runs.

As the cold front passed, the increased stress due to misaligned waves in WBF6 produced distinctly weaker wind. The strongest differences are found at the surface, but the systematic (although it’s small) wind speed reduction in WBF8 is found throughout the MABL.