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A Diagnostic Diagram to Understand the Marine Atmospheric Boundary Layer at High Wind Speeds

Anthony Kettle
Geophysical Institute, University of Bergen, Norway (ajkettle1@hotmail.com)

Long time series of offshore meteorological measurements in the lower marine atmospheric boundary layer show dynamical regimes and variability that are forced partly by interaction with the underlying sea surface and partly by the passage of cloud systems overhead. At low wind speeds, the dynamics and stability structure of the surface layer depend mainly on the air-sea temperature difference and the measured wind speed at a standard height. The physical processes are mostly understood and the quantified through Monin-Obukhov (MO) similarity theory. At high wind speeds different dynamical regimes become dominant. Breaking waves contribute to the atmospheric loading of sea spray and water vapor and modify the character of air-sea interaction. Downdrafts and boundary layer rolls associated with clouds at the top of the boundary layer impact vertical heat and momentum fluxes. Data from offshore meteorological monitoring sites will typically show different behavior and the regime shifts depending on the local winds and synoptic conditions. However, the regular methods to interpret time series through spectral analysis give only a partial view of dynamics in the atmospheric boundary layer. Also, the spectral methods have limited use for boundary layer and mesoscale modellers whose geophysical diagnostics are mostly anchored in directly measurable quantities: wind speed, temperature, precipitation, pressure, and radiation. Of these, wind speed and the air-sea temperature difference are the most important factors that characterize the dynamics of the lower atmospheric boundary layer and they provide a dynamical and thermodynamic constraint to frame observed processes, especially at high wind speeds. This was recognized in the early interpretation of the Froya database of gale force coastal winds from mid-Norway (Andersen, O.J. and J. Lovseth, Gale force maritime wind. The Froya data base. Part 1: Sites and instrumentation. Review of the data base, Journal of Wind Engineering and Industrial Aerodynamics, 57, 97-100, 1995). In the Froya study, plots on axes of wind speed and air-sea temperature difference provided an effective method to ‘fingerprint’ atmospheric conditions and summarize large segments of the data. The increasing numbers of offshore meteorological masts associated with the offshore wind industry are amenable to a similar approach to understand the main characteristics of the boundary layer. In this presentation, the Froya diagnostic figure is used interpret data from the FINO1 platform in the North Sea and understand boundary layer dynamics at high wind speeds.