Diurnal variations of coupled atmosphere – ocean conditions across an air-sea interface, including atmospheric temperature, moisture and winds profiles, and upper ocean temperature, are fundamental features of the Earth climate system with substantial implications for ecosystems. Our societies increasingly depend on reliable data on near-surface conditions. Among others, wind speed determines the potential for energy production from off-shore renewable sources,. Therefore, robust monitoring and forecasting of meteorological conditions become increasingly important. At the same time, weather models struggle with the realistic representation of diurnal variations in these conditions.

Forecasting weather conditions near Earth's surface may seem like a relatively simple task. However, evolution of near-surface conditions involves interactions between surface, planetary boundary layer – the lowest part of the atmosphere directly affected by surface and higher layers of the atmosphere. A prime example of such interactions are cumulus clouds, which form and evolve due to both local and large-scale processes, couple the free atmosphere to the surface processes, and impact local near-surface energy budget and wind profile.

Therefore, near-surface meteorological conditions, and reliable prediction of thereof, are important, but the reliability of their forecasts is sub-optimal due to lacks in understanding of underlying processes. Furthermore, weather forecasts require data that describe the initial state of the atmosphere. Collocated measurements of atmosphere and ocean, across an air-sea interface, are rare and difficult. This data gap contributes to the lower quality of weather forecasts, especially in maritime and coastal regions.

Here, we propose to take advantage novel capacity of atmospheric measurements offered by the uncrewed aircraft systems (drones) to collect high-quality data and analyze feedback between the diurnal evolution sea surface temperature, variability in atmospheric properties and development, evolution and organization of a cloud fields. Assessment of those interactions requires frequent observations across an air-sea interface, both in the top layer of the ocean and within the lowest part of the atmosphere. We will utilize multi-rotor uncrewed aircraft systems, which are relatively easy to control and integrate with measurement devices, and allow measurements within a single column of the air in a range up to the top of the planetary boundary layer. Measurements will be merged with satellite and weather modeling data in order to assess interactions between diurnal evolution within the planetary boundary layer, convective clouds (local processes), and large-scale conditions in various regions. As a result, the importance of coupled processes across an air-sea interface on evolution of clouds will be analyzed.

In order to fulfill those research objectives, frequent in-situ near-surface observations (temperature, humidity, wind, pressure, solar radiation) and profiles within the planetary boundary layer (temperature, humidity, and wind) and oceanic warm layers (temperature) will be conducted with uncrewed aircraft systems in various locations, including coastal zones, islands as well as from research vessels. Data will be gathered during several measurement campaigns. During each campaign, near-surface meteorological conditions will be continuously observed and several measurement flights per day will be conducted to collect collocated profiles across an air-sea interface. As a result, a comprehensive observational dataset will be created and used to advance understanding of local atmosphere – ocean feedbacks on diurnal time scale as well as to provide benchmark assessment of weather forecasts.

The proposed research program has the potential to improve monitoring techniques and advance the understanding of near-surface meteorological processes on a diurnal time scale, which is a requirement for reliable forecasts. The use of uncrewed aircraft systems for atmospheric research has been endorsed by the World Meteorological Organization, which organizes "Global Demonstration Project on Uncrewed Aircraft Systems Use in Operational Meteorology" (2024). This project will directly contribute to these efforts.