Evaluation of global reanalysis strengths and weakness using surface observations

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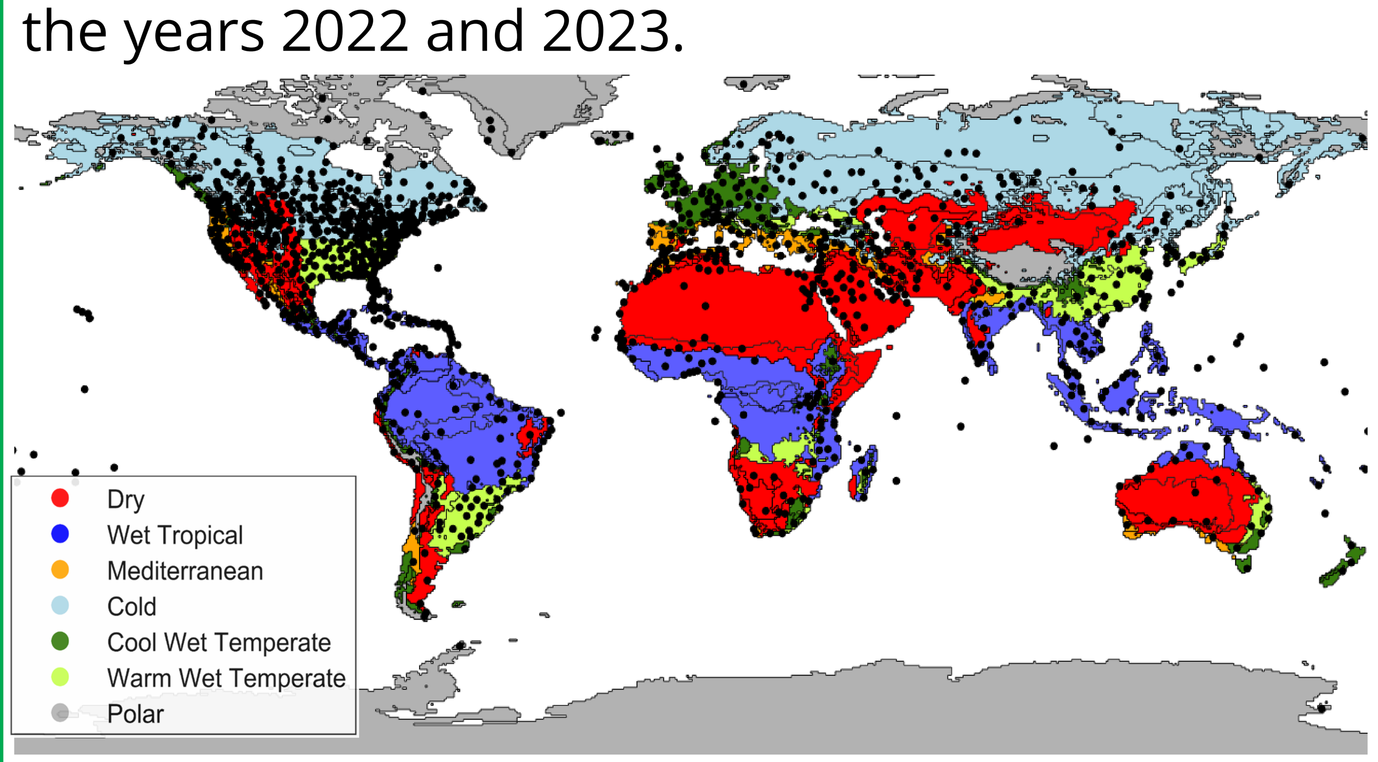
Motivation

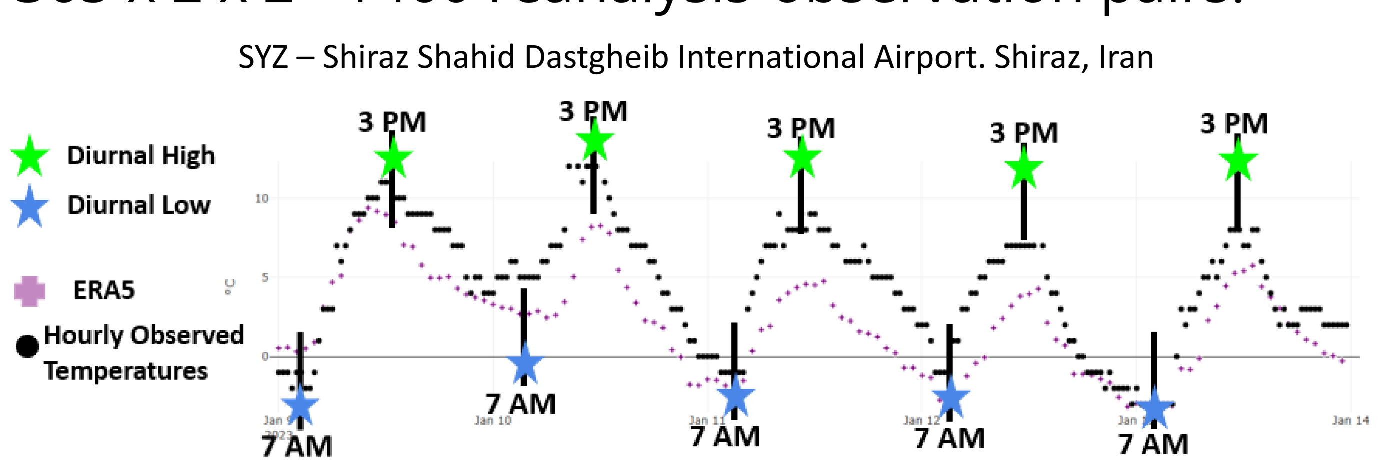
Reanalysis products which blend weather model output with observations are commonly used but their quality is not expected to be uniform everywhere and in all conditions. Our goal is to assess the strengths and weaknesses of global reanalysis products compared to actual observations across diverse climate zones, seasonal and diurnal cycles, and weather conditions. This information will be useful to users to assess adequacy for purpose for their specific applications.

Data and Methods

We compare temperature and dew point from ECMWF ERA5 reanalysis to surface observations at 1144 airport weather stations. We subset to the data into simplified Köppen-Geiger climate zones and aggregate biases for the years 2022 and 2023.

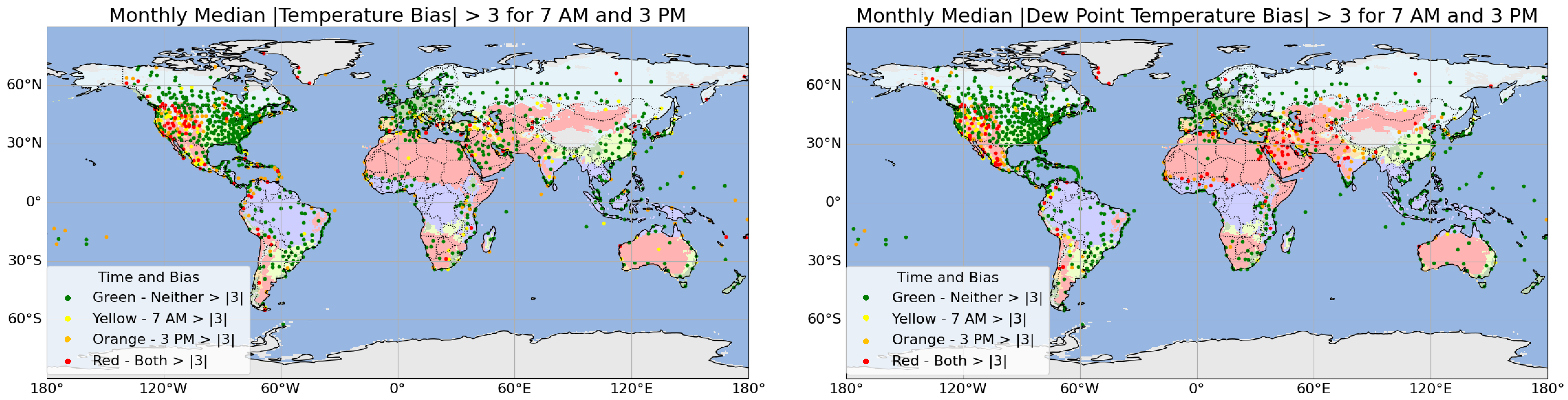


To capture the diurnal cycle, we focus on 7 AM local time (near daily minimum temperature) and 3 PM local time (near daily maximum temperature). If there are no missing observations, a station has 365 x 2 x 2 =1460 reanalysis-observation pairs.

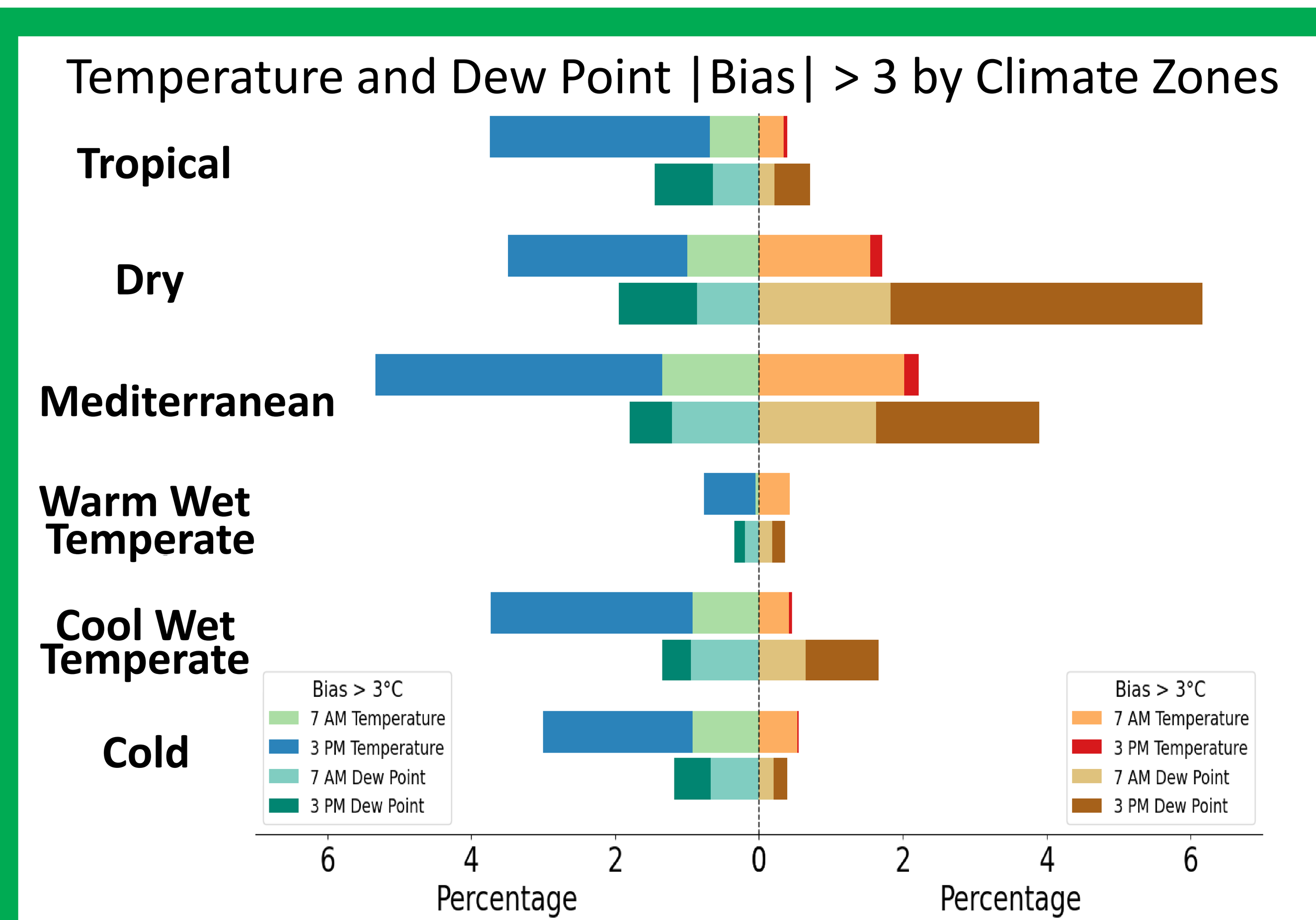


Time series plots showing reanalysis and observed temperature data in relation to our daily maximum (3 PM) and minimum (7 AM) time estimate

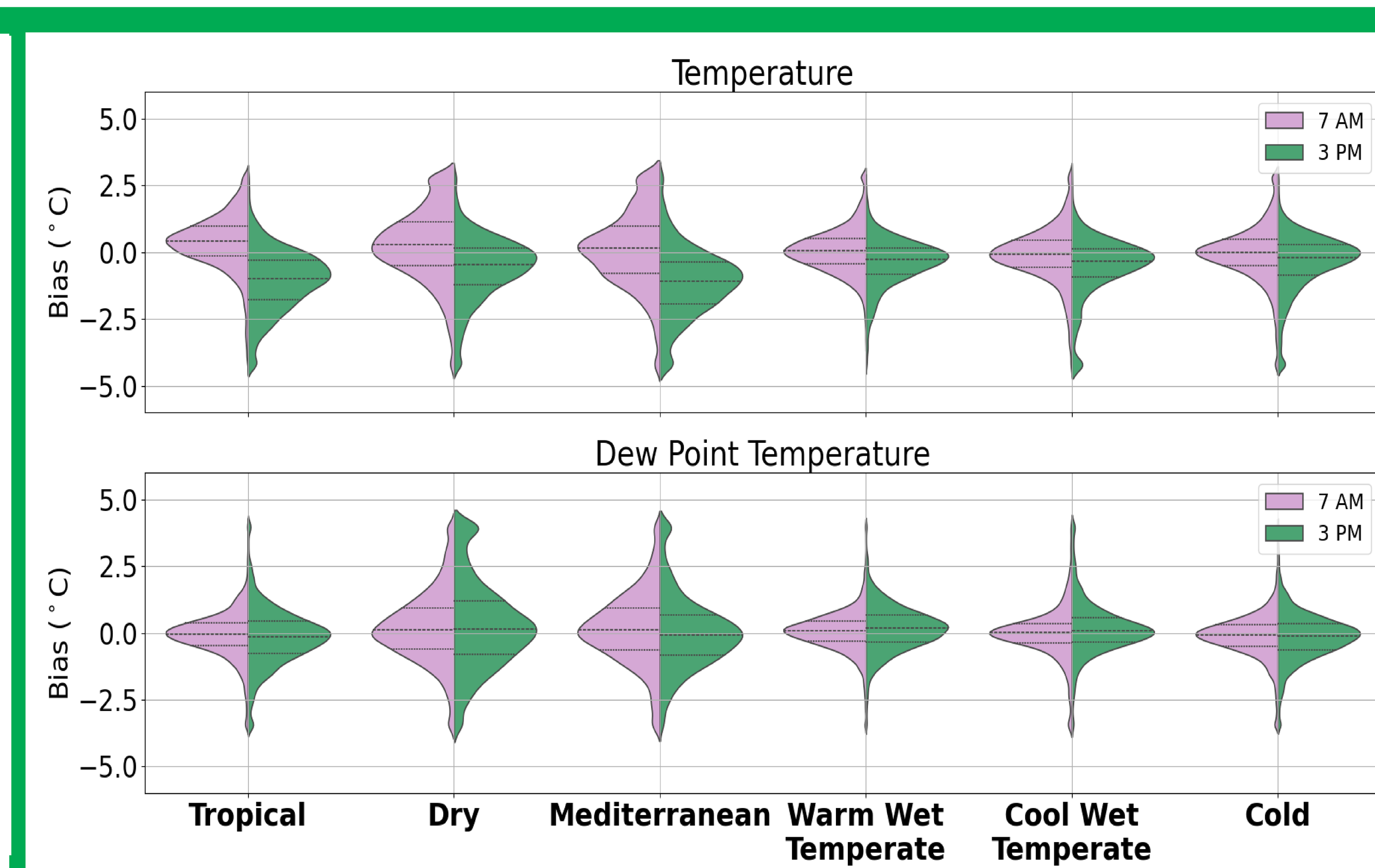
We also show some initial comparisons of vertical profiles from upper-air soundings versus ERA5.



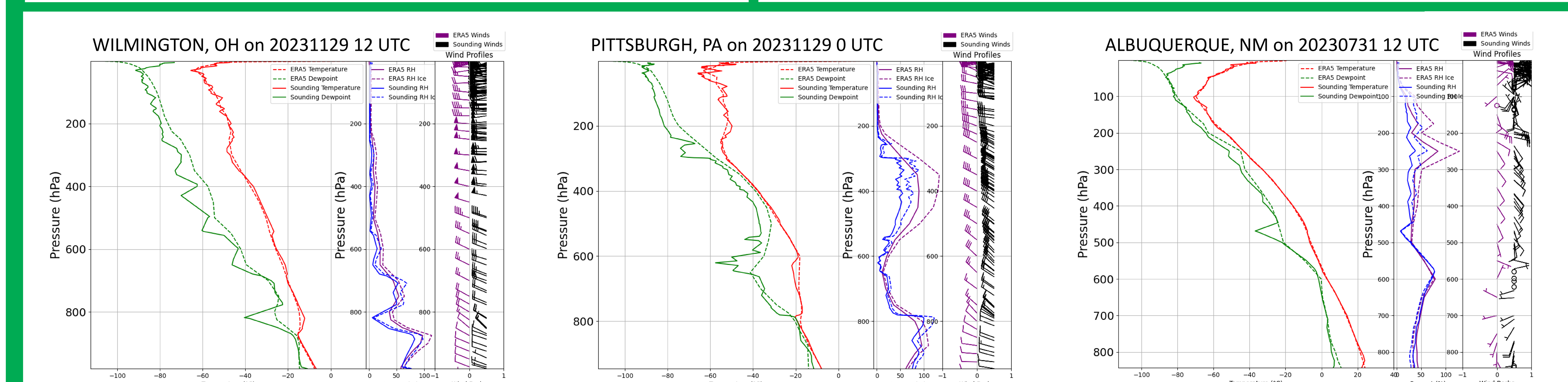
Global maps showing locations with ERA5 Temperature and Dew Point Temperature with smaller and larger biases for 2022- 2023 with climate zones color-coded. Bias = reanalysis – observations. Stations are color-coded based on their median bias over the 2 year data set. Most stations (green) have smaller biases (|bias| ≤ 3℃), but dryer zones are more problematic with larger biases (|bias| > 3℃) at either 7 AM, 3 PM or both.



Frequency of large temperature or dewpoint biases at 7 AM and 3 PM local time by climate zone. For temperature (top bar of each pair), the Mediterranean zone has ~5% of times with large cold biases. For dew point (bottom bar of each pair), large dry biases are present in the Dry (~6%) and Mediterranean Zones (~4%).



Violin plots showing distributions of ERA5 Temperature and Dew Point Temperature biases at 7 AM and 3 PM for each climate zone. Dashed lines within indicate 75^{th}, 50^{th}, and 25^{th} percentiles. Bias distributions are widest for the Dry and Mediterranean zones.



Example vertical profiles comparing ERA5 temperature, dewpoint, relative humidity with respect to water and to ice, and wind profiles versus upper air soundings. ERA5 captures general profile trends correctly given its coarser vertical resolution compared to observations. Dew point and RH are less accurate than temperature. When observed wind speeds are < 5 kts, observed wind direction is often not reliable.

Summary and Future Work

Based on the 2 years of data examined so far, overall ERA5 does best in representing local 7 AM and 3 PM temperatures and dewpoints in Temperate zones. It performs less well in the Dry and Mediterranean zones. Next steps will address performance in conditions outside of the 10^{th} and 90^{th} percentiles of the observed long-term climatology for each station. Additionally, we will extend the analysis period back to 1980, and examine other reanalysis products including MERRA2, NCEP, and NAV-GEM. We will expand our analysis to other meteorological variables, incorporate vertical profile analysis, and include available buoy data.

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