Numerical Weather Forecast Biases by Region and Climate Zones

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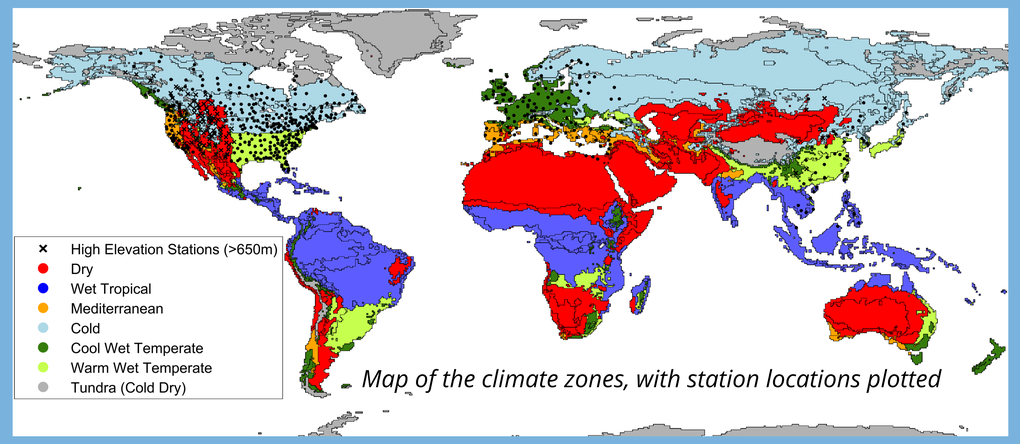
Motivation

Our goal is to assess where weather forecasts are more and less reliable by climate zones and geographic regions. Information on weather forecast model strengths and weaknesses is helpful to both forecast users and model developers.



Map of the climate zones, with station locations plotted

Temperature Median Biases

Temperature (˚C)	Summer 7AM		Summer 3PM		Winter 7AM		Winter 3PM	
Climate Zone	GFS	COAMPS	GFS	COAMPS	GFS	COAMPS	GFS	COAMPS
Cold	-0.48	-0.05	-0.63	-0.84	-0.33	-1.08	-0.22	-0.49
Sample Size	214	201	214	201	196	202	196	202
Cold High Elevation	0.46	-0.11	-0.61	-0.99	-2.18	-2.47	-1.72	-1.15
Sample Size	38	13	38	13	38	13	38	13
Dry	0.28	0.27	-0.05	0.31	1.77	0.61	-0.6	-0.62
Sample Size	16	10	16	10	10	10	10	10
Dry High Elevation	1.09	-0.14	-0.28	-2.28	1.19	0.7	-1.18	-1.09
Sample Size	46	8	46	8	43	7	43	7
Cool Wet Temperate	-0.72	-0.34	-0.74	-1.42	0	-0.05	-1.05	-0.26
Sample Size	66	66	66	66	9	64	9	64
Mediterranean	-0.26	0	-0.95	-0.83	-0.39	0.15	-1.61	-1.26
Sample Size	65	64	65	64	31	63	31	63
Warm Wet Temperate	-0.58	0.6	0.18	0.19	0.44	1.03	-0.83	-0.93
Sample Size	126	134	126	134	118	134	118	134
Tropical	-0.6	0.76	-0.93	-0.07	-0.45	0.42	-1.45	-0.91
Sample Size	16	14	16	14	16	14	16	14

During the winter season of 11/2022 to 02/2023 across all climate zones, both COAMPS and GFS temperature forecasts tended to be too cool at 3 pm local time. The GFS and COAMPS especially struggled in the cold high elevation zones.

During the summer season of 5/2023-9/2023, for a given climate zone median temperature errors in both models were usually smaller than in winter.

Dew Point Median Biases

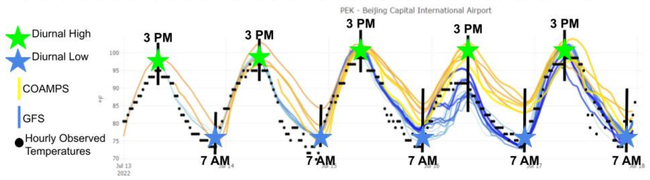
Dew Point (˚C)	Summer 7AM		Summer 3PM		Winter 7AM		Winter 3PM	
Climate Zone	GFS	COAMPS	GFS	COAMPS	GFS	COAMPS	GFS	COAMPS
Cold	-1.12	0.44	-1.06	1.14	-0.14	0.27	0.72	1.79
Sample Size	214	201	214	201	196	202	196	202
Cold High Elevation	-1.27	0.12	-1.33	0.88	-1.32	-1	0.6	1.06
Sample Size	38	13	38	13	38	13	38	13
Dry	-2.07	-0.45	-3.02	-1.01	-1.13	-0.18	-1.43	-0.67
Sample Size	16	10	16	10	10	10	10	10
Dry High Elevation	-1.38	-0.86	-1.89	-0.73	-0.33	0.63	0.15	1.38
Sample Size	46	8	46	8	43	7	43	7
Cool Wet Temperate	-1.03	-0.01	-0.96	0.55	-1.27	0.19	-0.73	0.21
Sample Size	66	66	66	66	9	64	9	64
Mediterranean	-1.6	-0.26	-2.27	0.11	-1.26	-0.56	-1.24	-0.7
Sample Size	65	64	65	64	31	63	31	63
Warm Wet Temperate	-1.51	-0.1	-1.89	-0.43	-0.12	1.27	-0.15	1.32
Sample Size	126	134	126	134	118	134	118	134
Tropical	-1.69	-0.15	-2.1	-0.45	-1.23	0.03	-1.45	0.06
Sample Size	16	14	16	14	16	14	16	14

GFS dewpoints overall tend to be too dry in the summer season (5/2023-9/2023), especially in dry and mediterranean zones at 3 pm. COAMPS dewpoint biases in summer at 7 am are all less than -1 ˚C.

In winter (11/2022-2/2023), COAMPS forecast dew points are often too moist at 3 pm in the cold and warm wet temperate zones. For GFS for a given climate zone, dew point biases were usually lower than in summer.

Methods

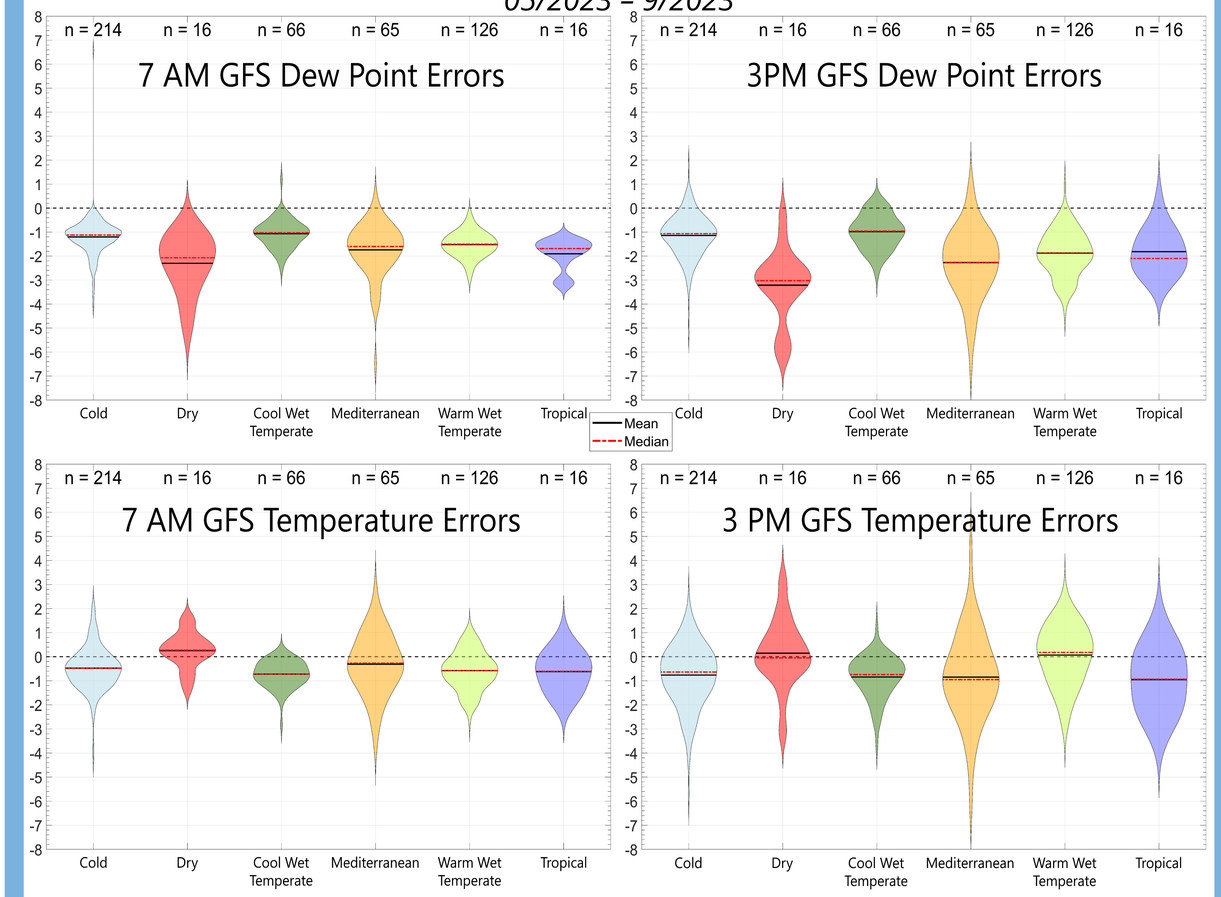
We compare temperature and dew point forecasts from two operational weather forecast models, the U.S Navy's Regional Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) and NOAA's Global Forecasting System (GFS) to surface observations at airport weather stations. Focus is on the winter and summer seasons at 7 AM local time (near daily minimum temperature) and 3 PM local time (near daily maximum temperature). Model 48-hour lead time forecasts are matched with observations at the forecast's valid time.

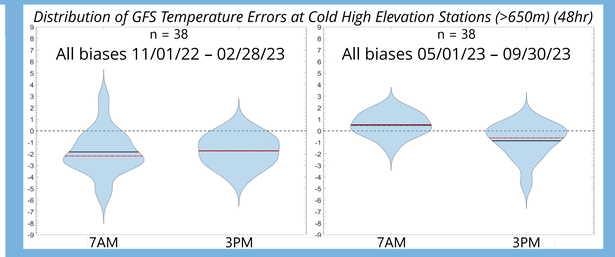


Time series plots showing temperature data as it relates to forecast daily maximum and minimum time estimate

The airport weather stations are subset into six groups based on simplified Koeppen-Geiger climate zones : 'Cold', 'Dry', 'Cool Wet Temperate', 'Mediterranean', 'Warm Wet Temperate', and 'Wet Tropical'. Data from stations across North America, Europe, and East Asia correspond to the three regions for operational COAMPS forecasts. For context, we compare biases in COAMPS to GFS.

Error distributions across the six climate regions for GFS 48-hour lead time forecasts 05/2023 – 9/2023





Summary (~48-h lead time forecast evaluation)

- Despite using older physical parameterizations, the COAMPS regional model often performs similar to or better than GFS at 7 AM and 3 PM for a given climate zone.
- GFS has an overall dry dew point bias in summer in all climate zones. Largest biases are in dry and mediterranean zones which have lower mean dew points.
- Temperature biases tend to be larger at cold high elevation stations likely associated in part with grids (COAMPS ~15.5 km, GFS ~27 km) that do not resolve fine scale features in terrain.
- Future work will include weather stations in Africa, South America, Oceania, and the rest of Asia for comparison to global models and examine longer time periods.

Acknowledgements

Thank you to McKenzie Sevier, Logan McLaurin, and Jordan Fritz for their feedback and guidance. This work is supported by ONR N00014-21-1-2116.