MAC-MAQ Conference
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Davis, CA

Diagnosing Errors in Boundary Layer Structure

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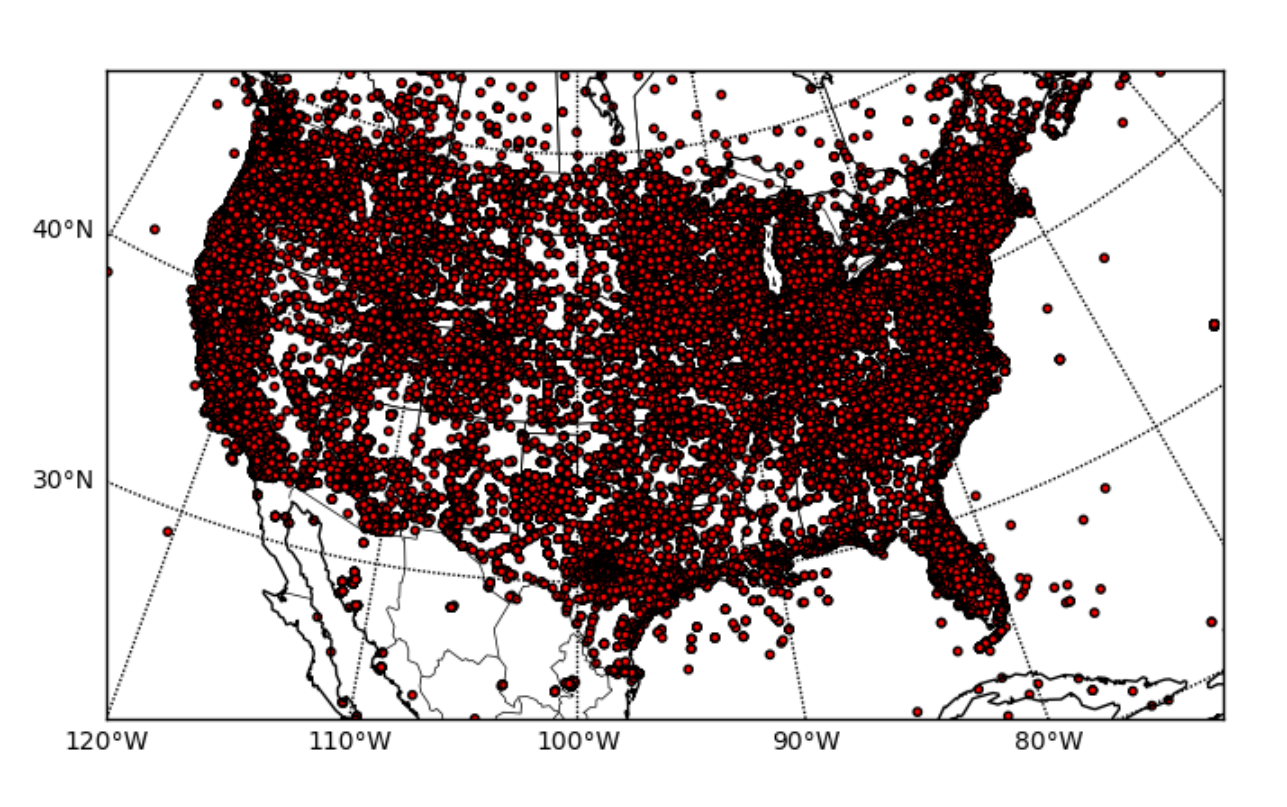
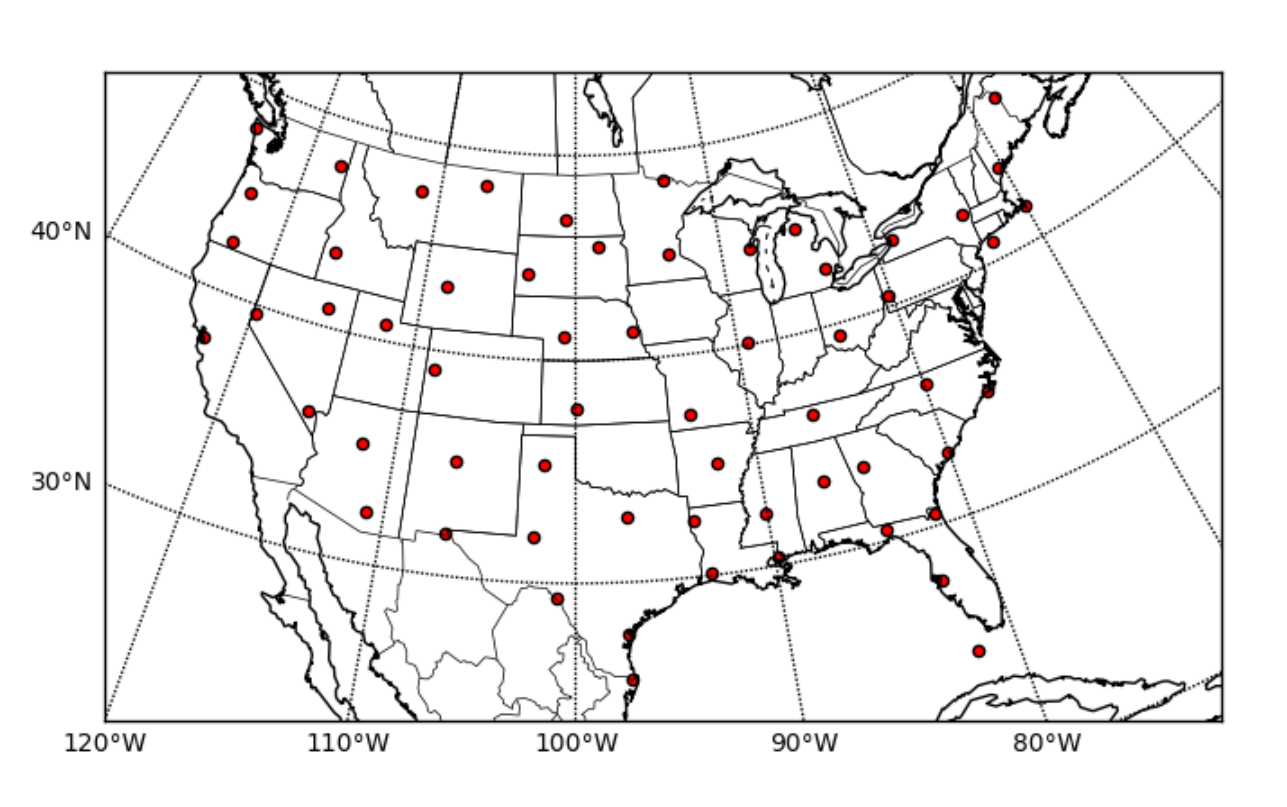
Available surface stations



Includes low quality stations (cf. Fovell and Gallagher 2018)

From MADIS, 6 March 2016 at 00Z

Available high-frequency radiosondes



N = 60

Much fewer observations

Only twice per day

Much more difficult to handle

Archive is degrading

Some stations do not report to the NCEI archive

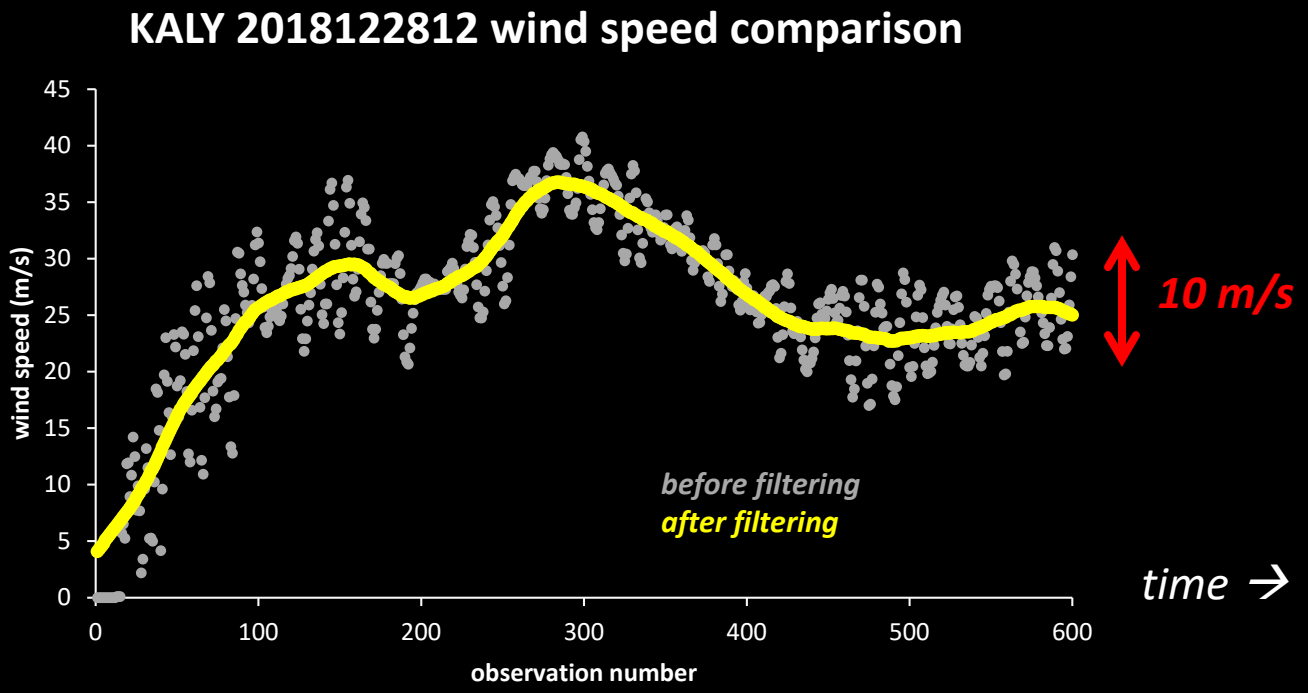
Analysis

- Operational HRRR analyses and forecasts on native model levels (NCEP) ["better"]
- High-frequency radiosonde observations (NCEI)
  - 1-second obs ~ O(10 m) Δz
  - Archive incomplete and degrading
- Interpolated obs to HRRR model levels @ each site and time, then averaged over both
- Focus: first 24 h from 00Z and 12Z model runs
- Some results for April to June 2019

Challenges (partial list)

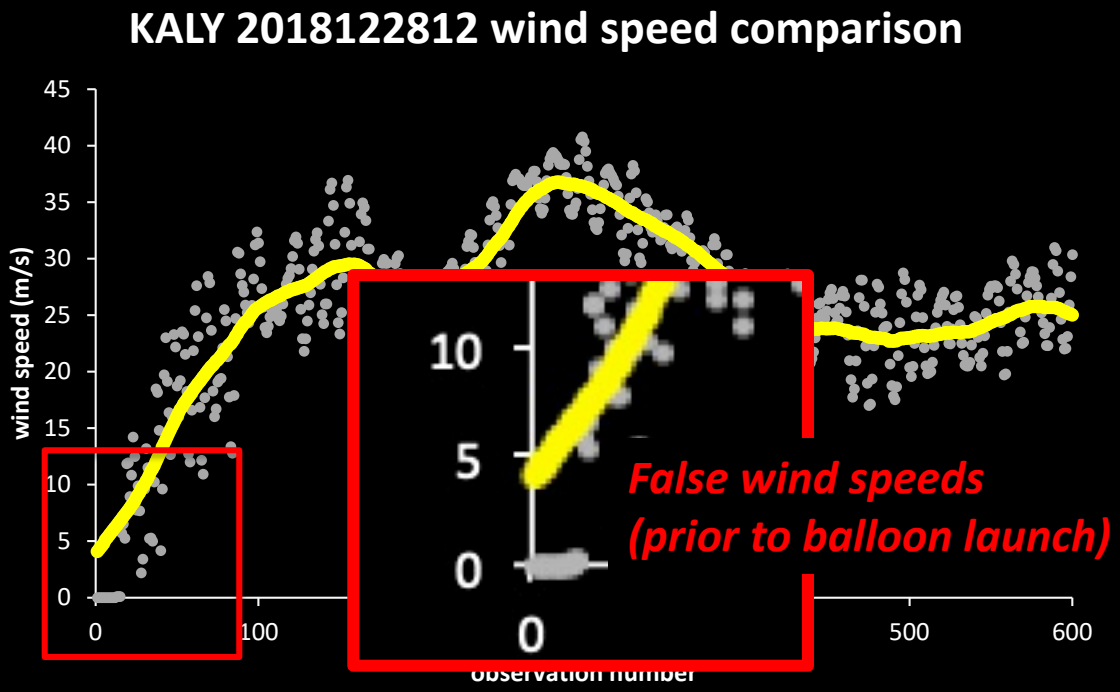
- Station ground height AGL needs to be determined
- Discrepancies exist between actual and HRRR elevations
- Non-standard release and barometer placement heights (worst offender: Albany, NY)
- Pressure- and GPS-derived heights MSL do not agree
- Pendular motion necessitates filtering
- Pre-launch data need to be removed
- 80% of launches ≥50 min prior to nominal times (00Z, 12Z) [Coniglio et al. 2013; Evans et al. 2018]
  - Compare to 24 h *and* 23 h forecasts

Raw vs. filtered wind speeds - example



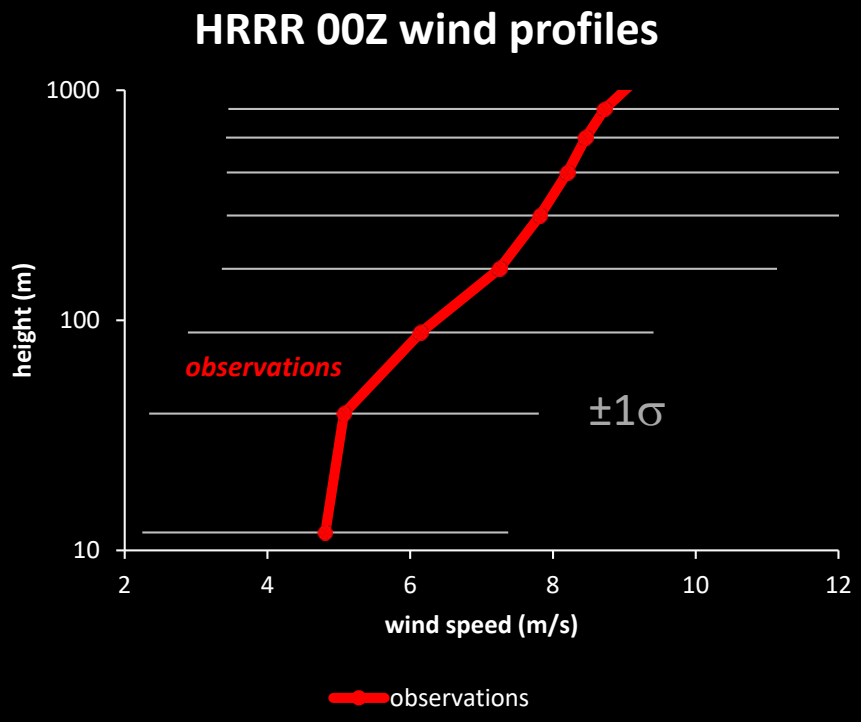
Expectation:
All of these issues will average themselves out over space and time

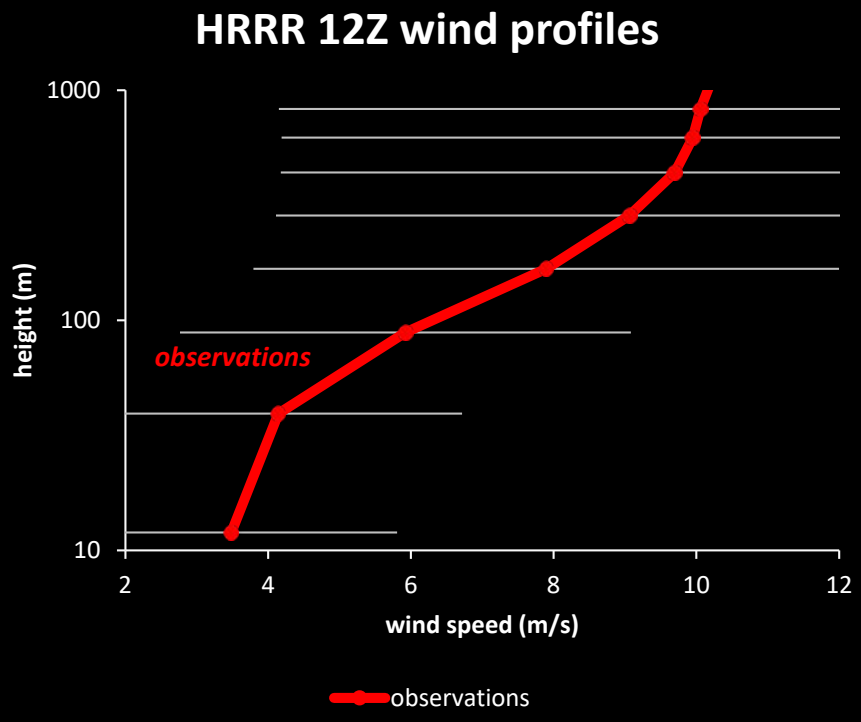
Raw vs. filtered wind speeds - example



Need to identify and remove pre-launch data

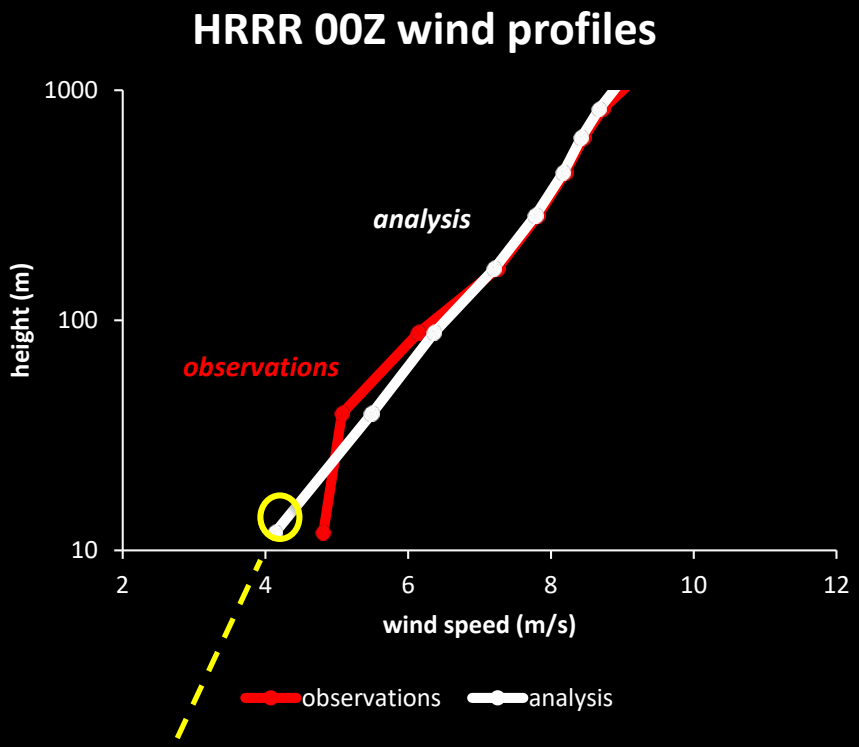
Vertical profile of wind at 60 radiosonde sites: April 2019

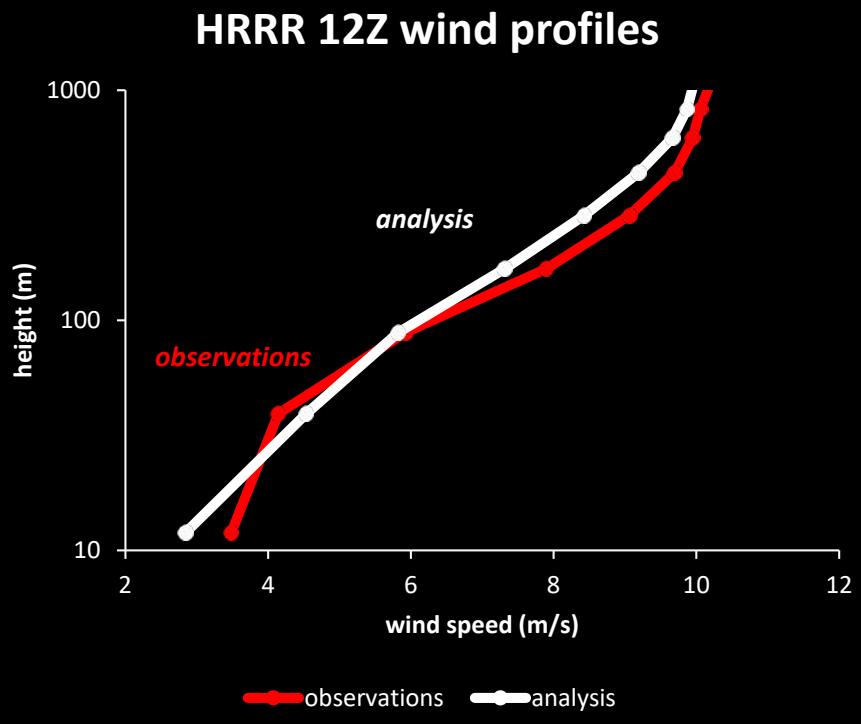




"Kink" in observations is very persistent but may be artifact

Vertical profile of wind at 60 radiosonde sites: April 2019



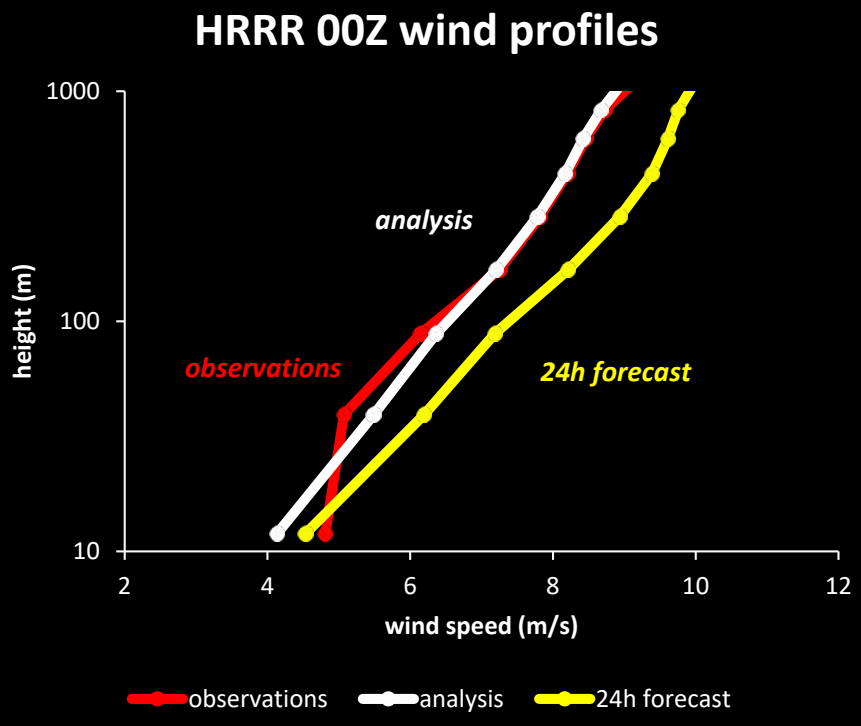


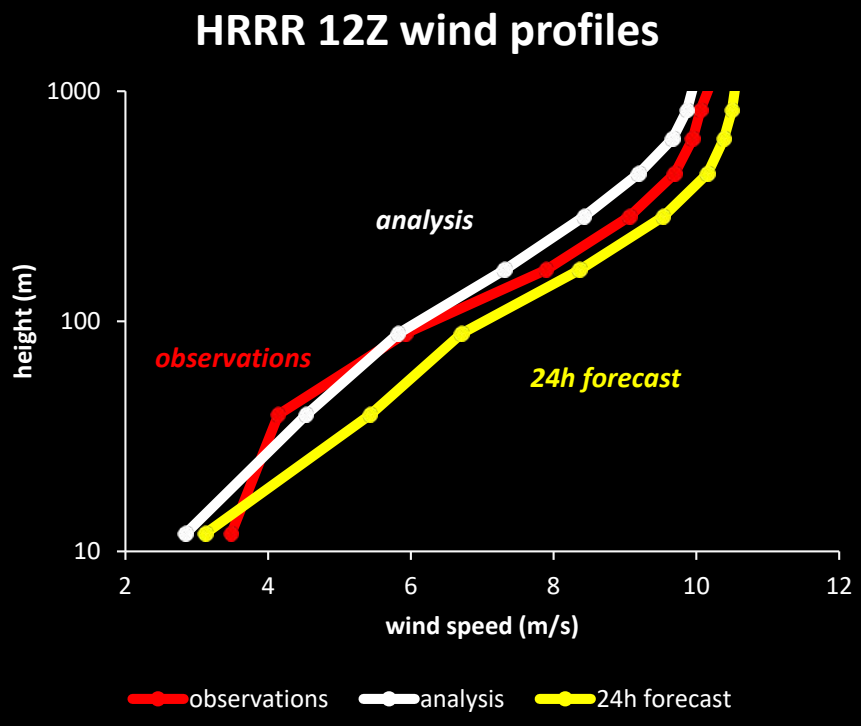
"Kink" in observations is very persistent but may be artifact

Analysis time wind bias is "small"

[and incorporates these data]

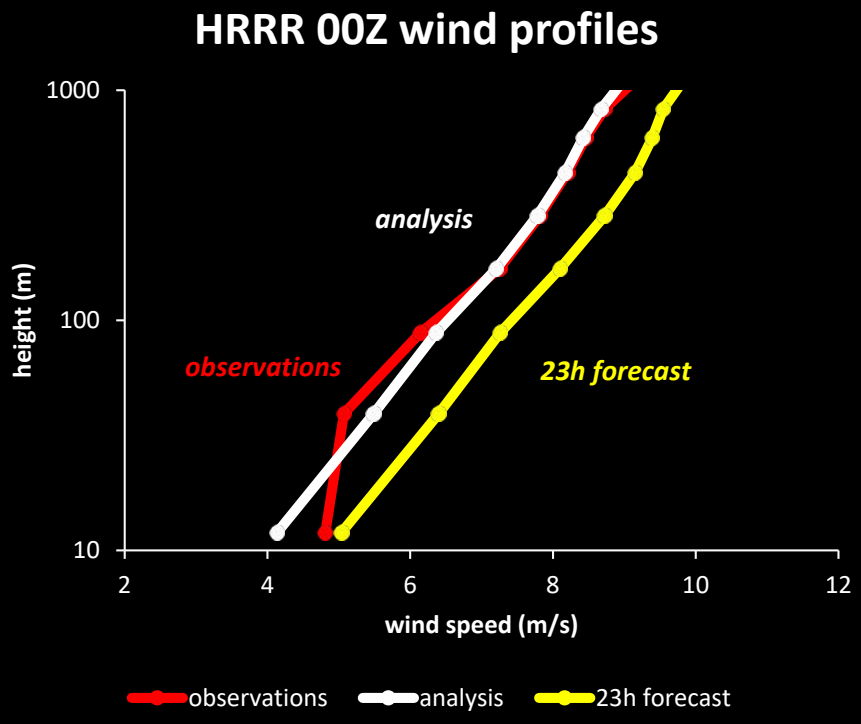
Vertical profile of wind at 60 radiosonde sites: April 2019

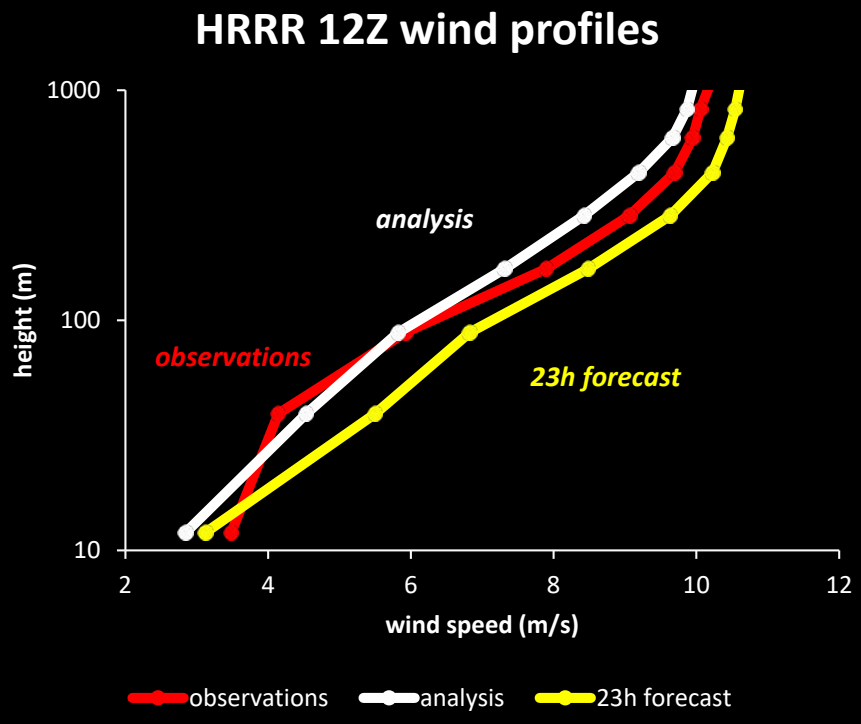




Compare to 24 h forecasts

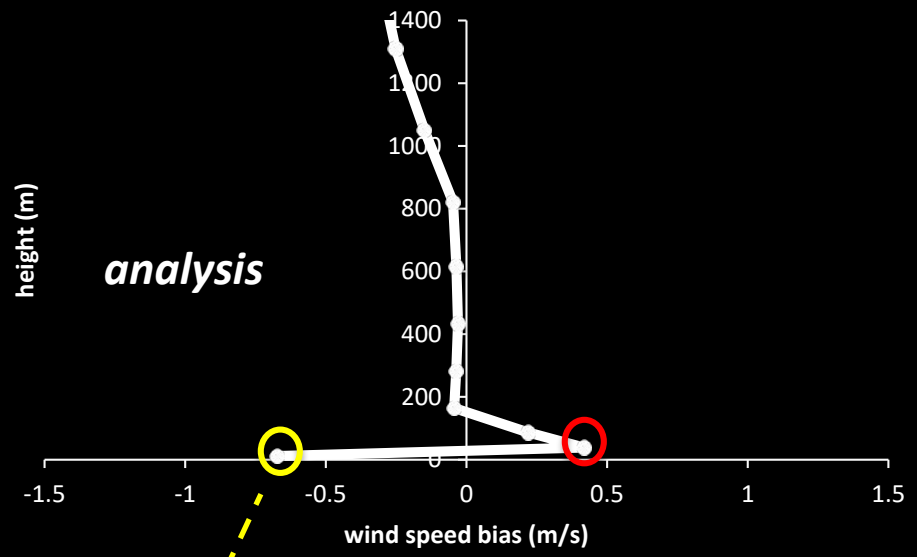
Vertical profile of wind at 60 radiosonde sites: April 2019





Compare to 23 h forecasts

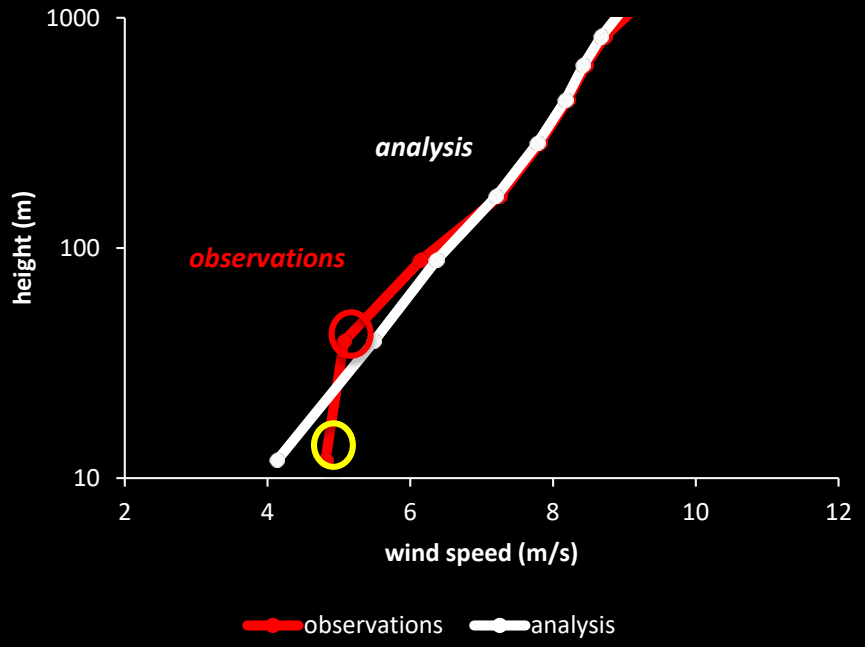
Wind speed bias 00Z



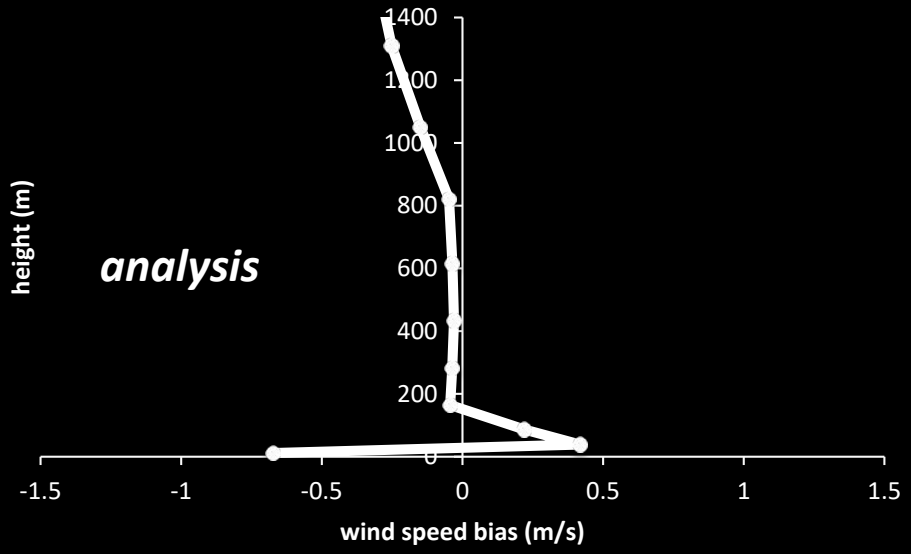
Consistent with ASOS 10m wind bias

Forecast bias vs. height
April 2019

HRRR 00Z wind profiles

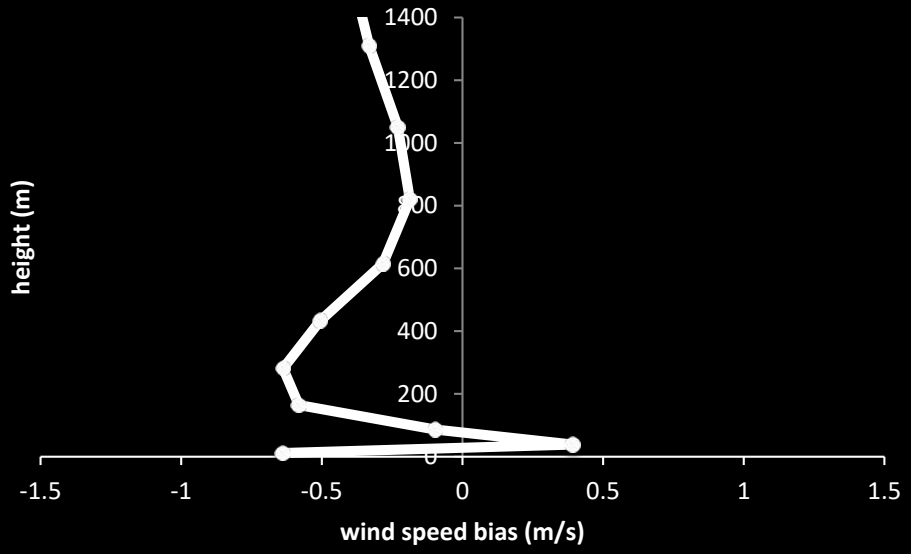


Wind speed bias 00Z

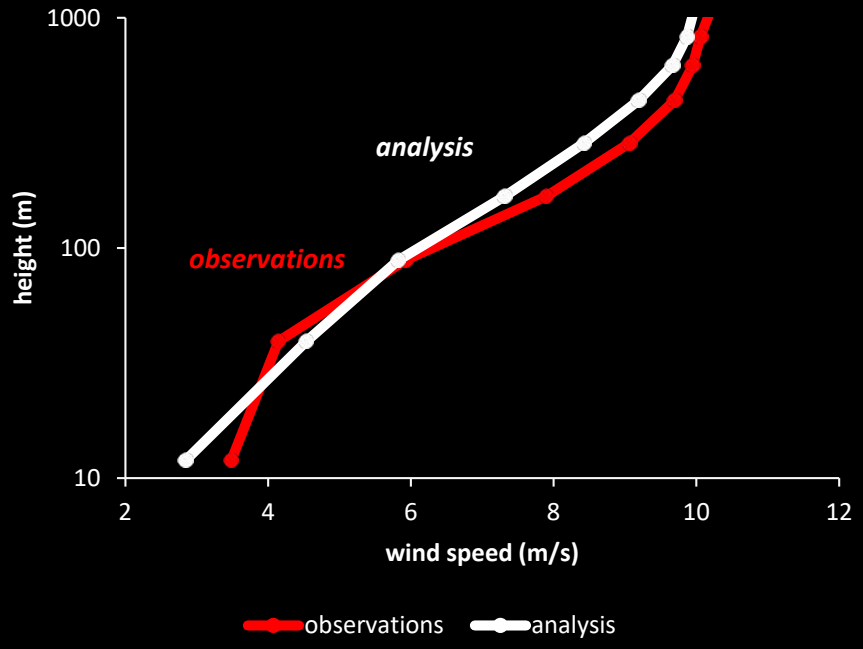


Forecast bias vs. height
April 2019

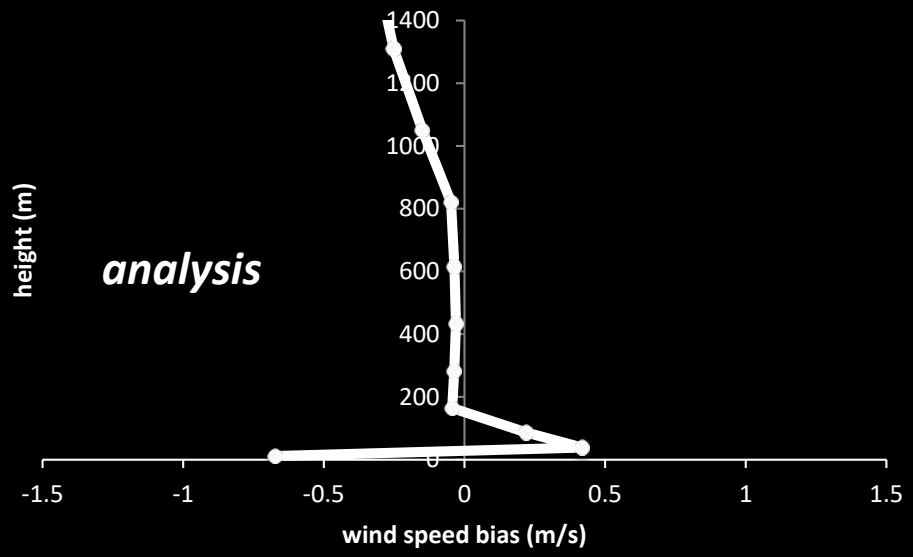
Wind speed bias 12Z



HRRR 12Z wind profiles

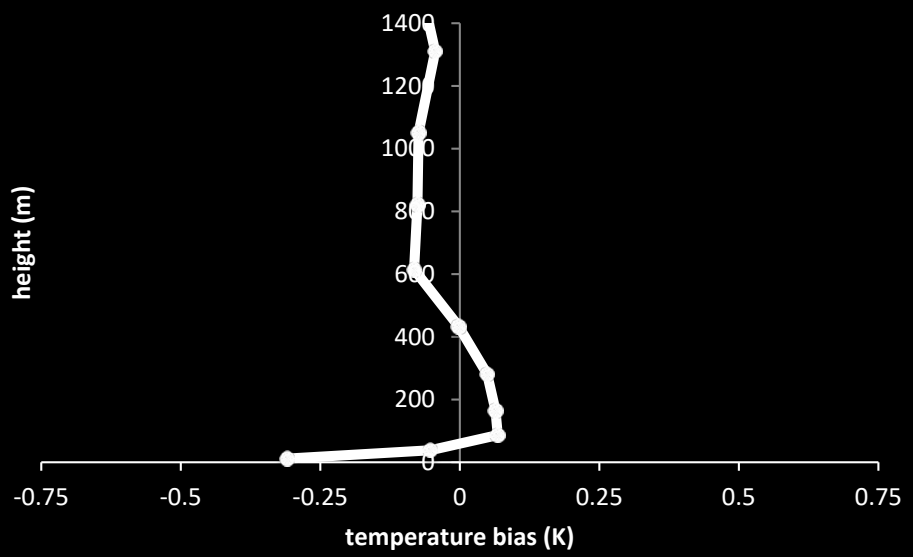


Wind speed bias 00Z

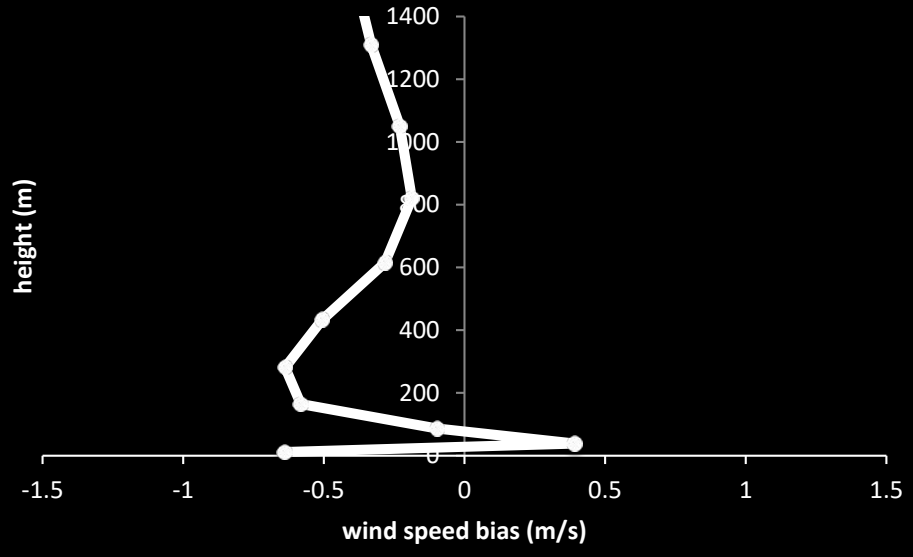


analysis

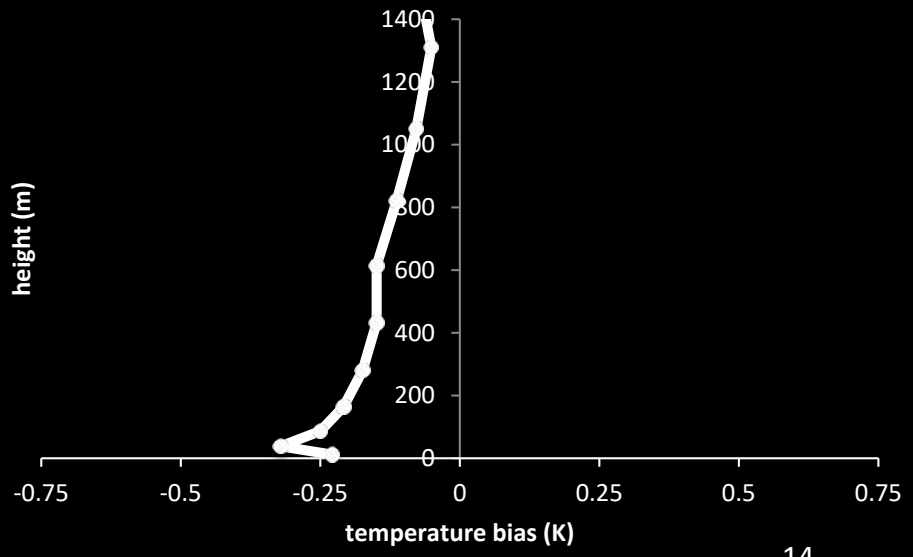
Temperature bias 00Z



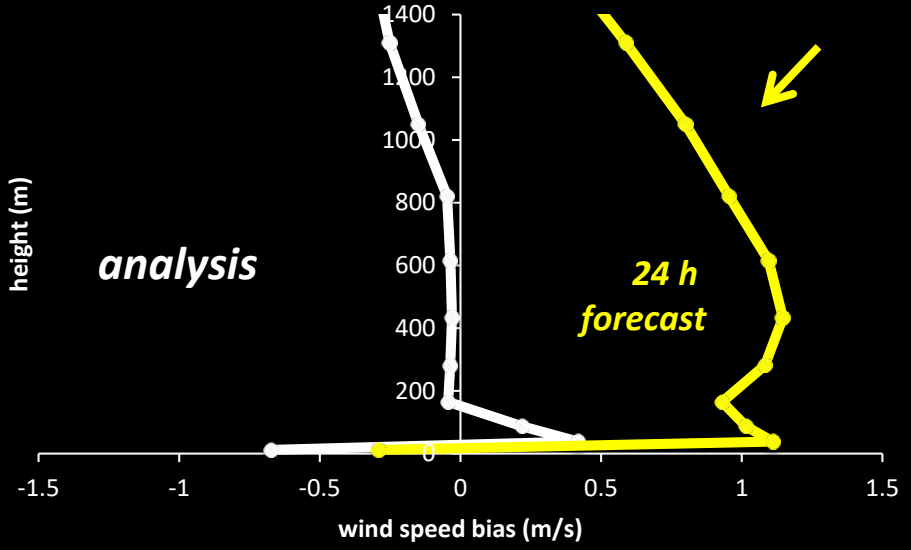
Wind speed bias 12Z



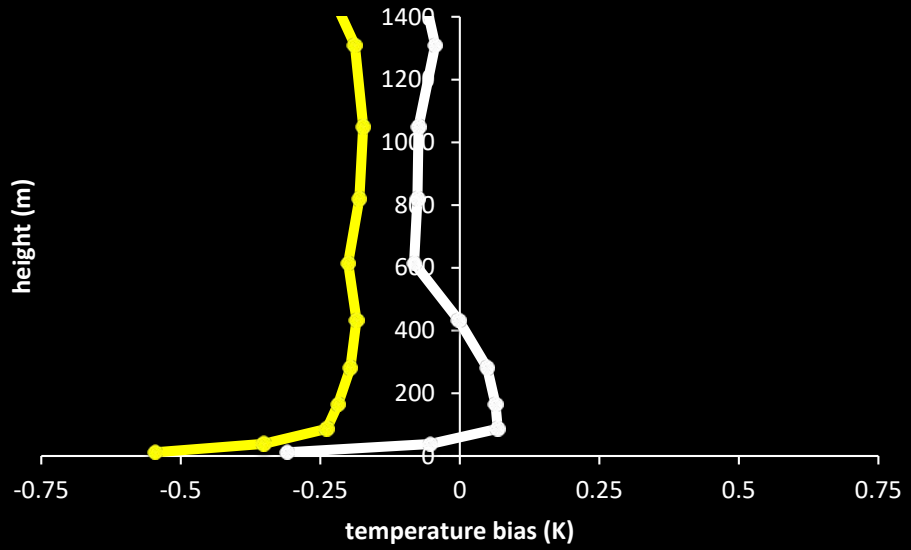
Temperature bias 12Z



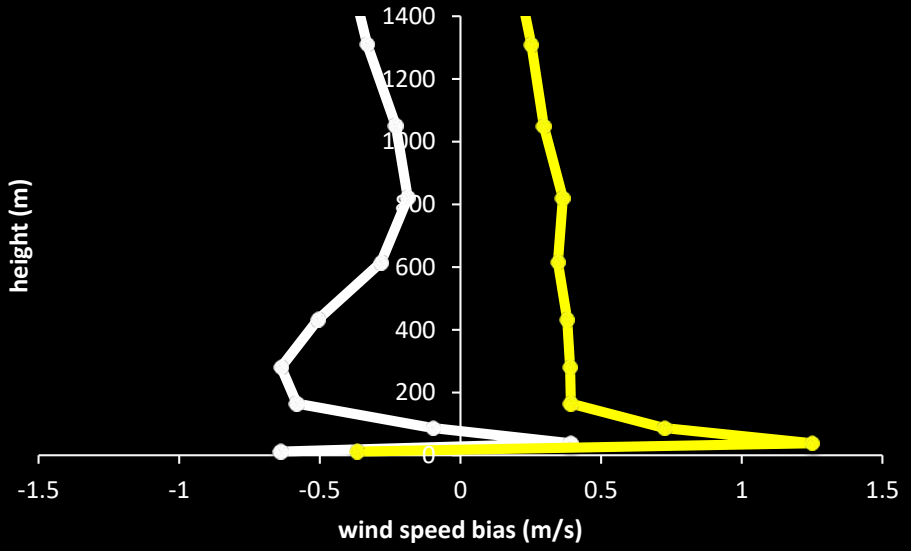
Wind speed bias 00Z



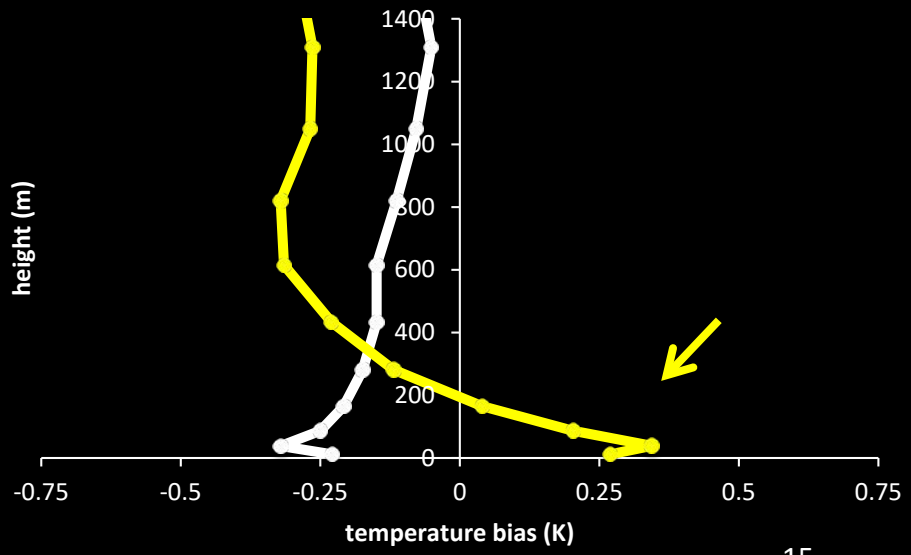
Temperature bias 00Z



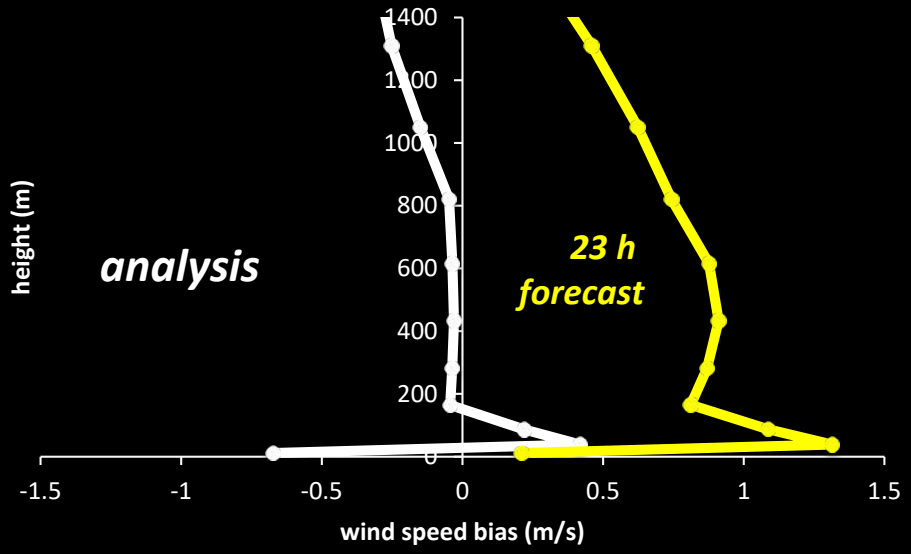
Wind speed bias 12Z



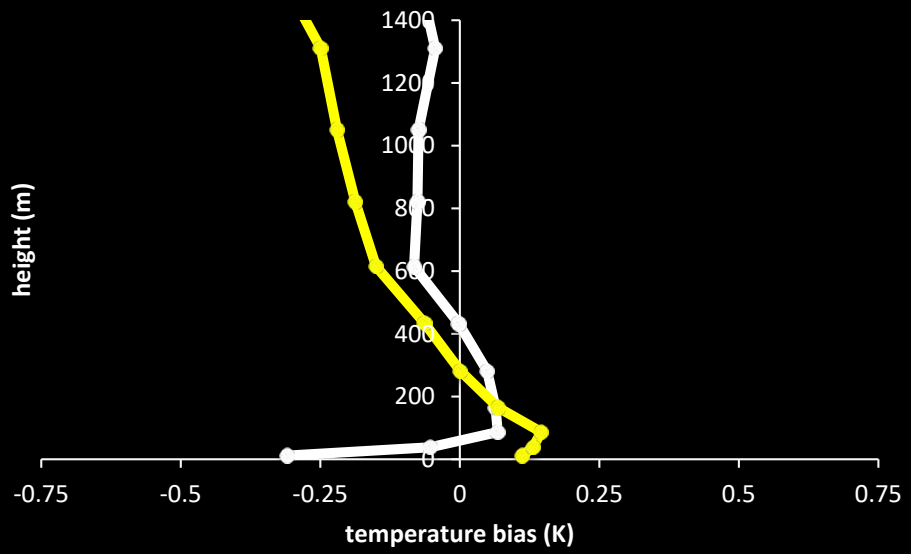
Temperature bias 12Z



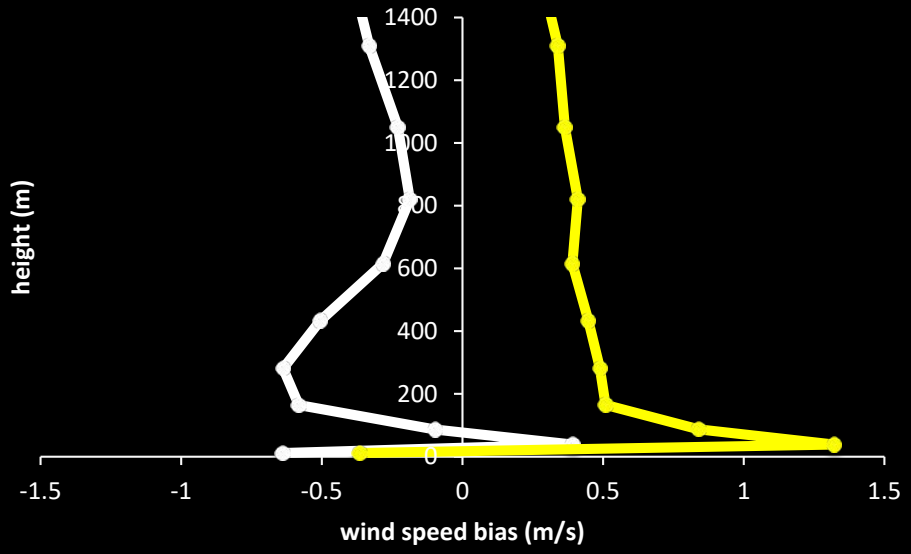
Wind speed bias 00Z



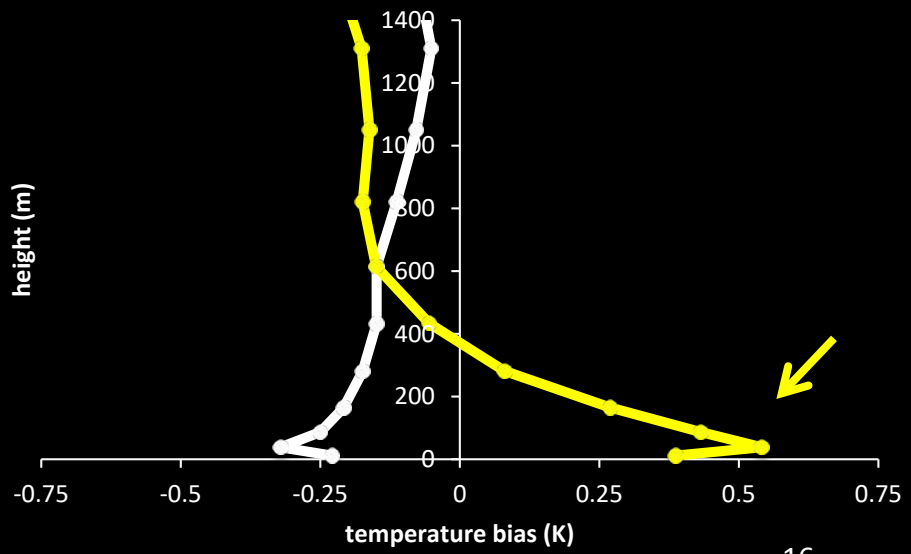
Temperature bias 00Z



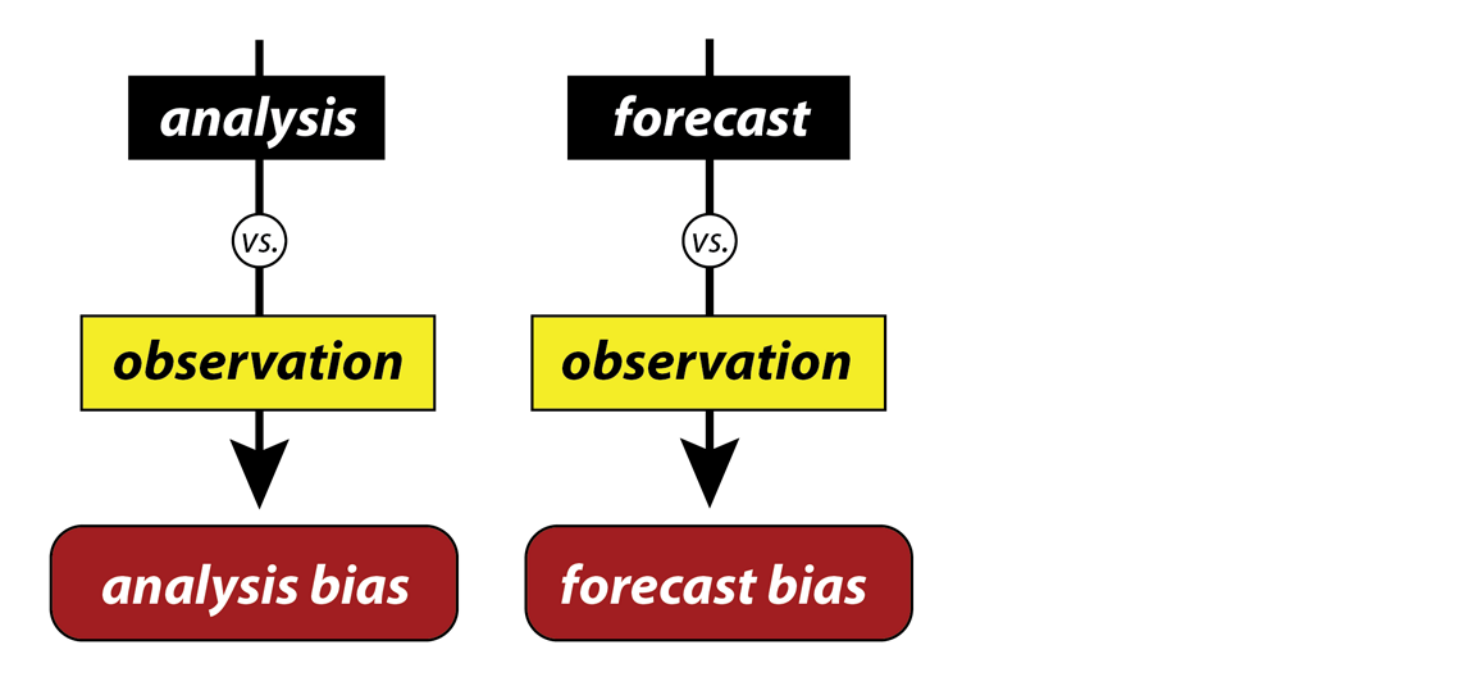
Wind speed bias 00Z



Temperature bias 12Z

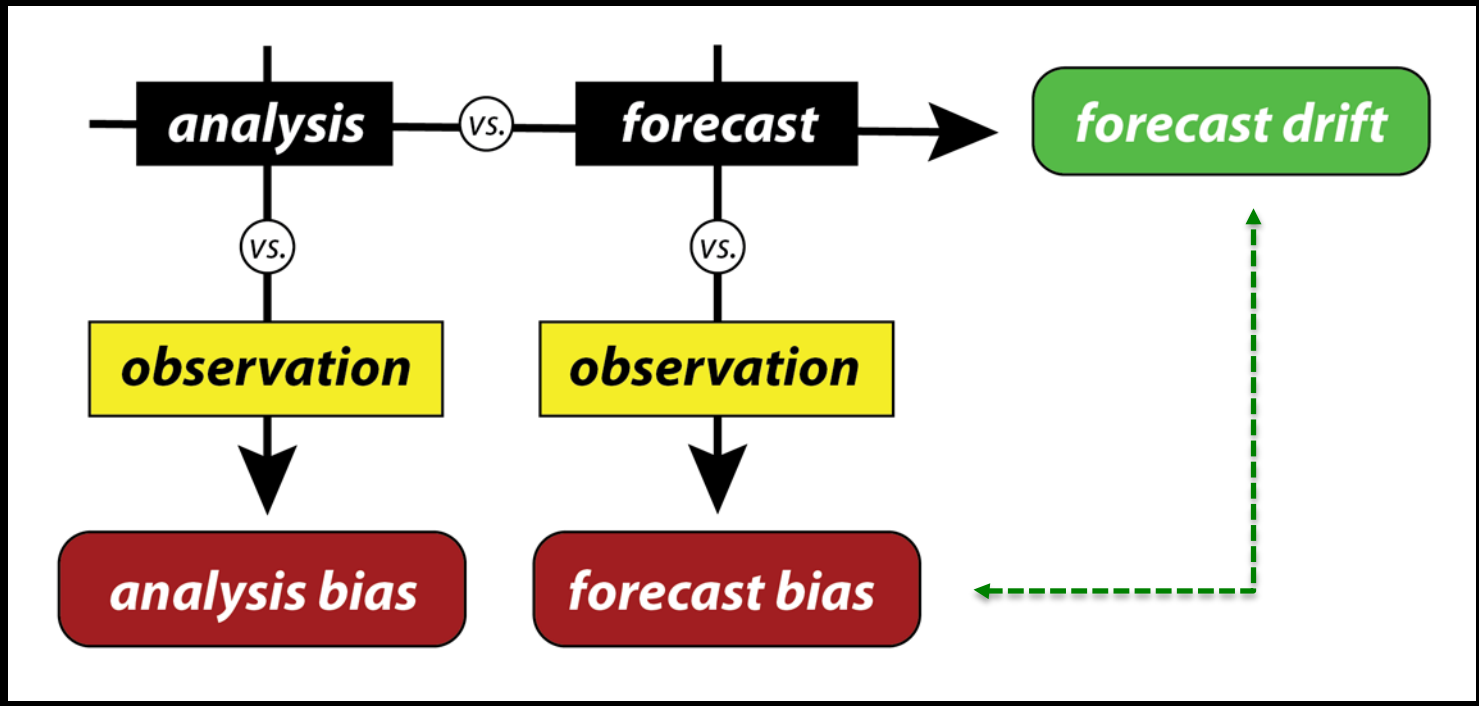


Forecast *bias*: the goal



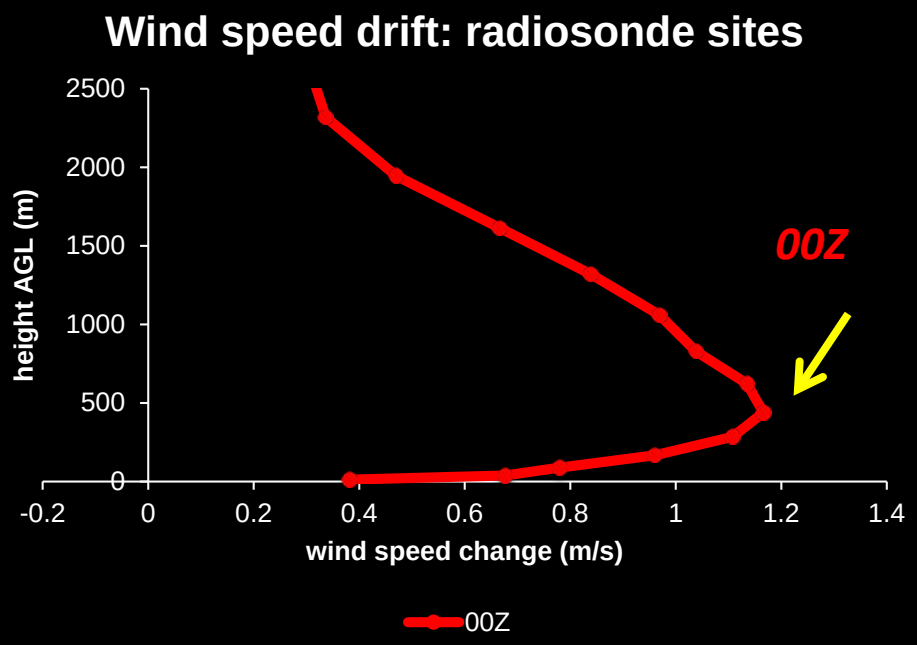
"small" "not small"

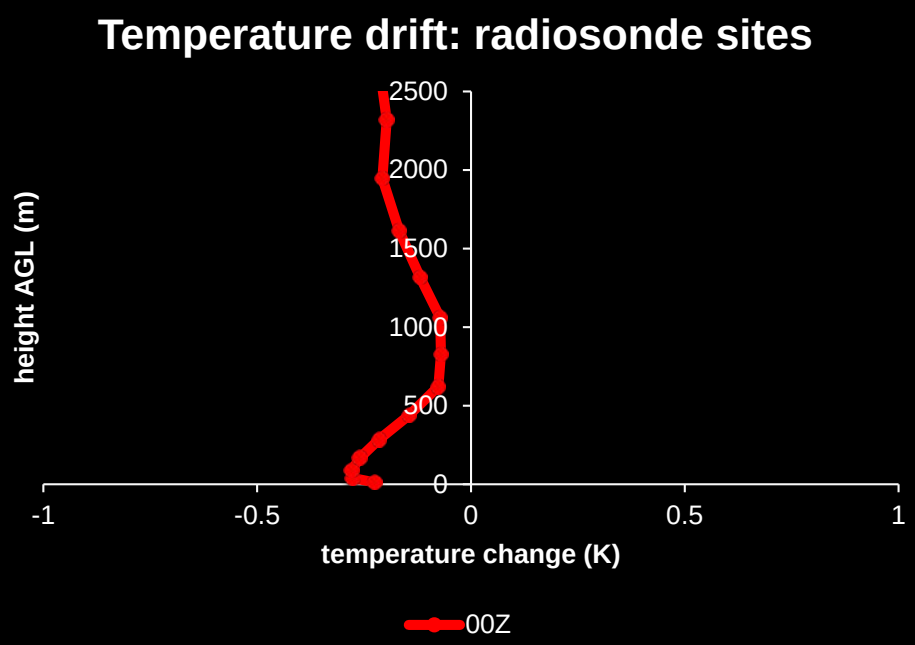
Forecast *drift*: the shortcut



"small" "not small"

April 2019 24-h forecast drift (60 radiosonde sites)

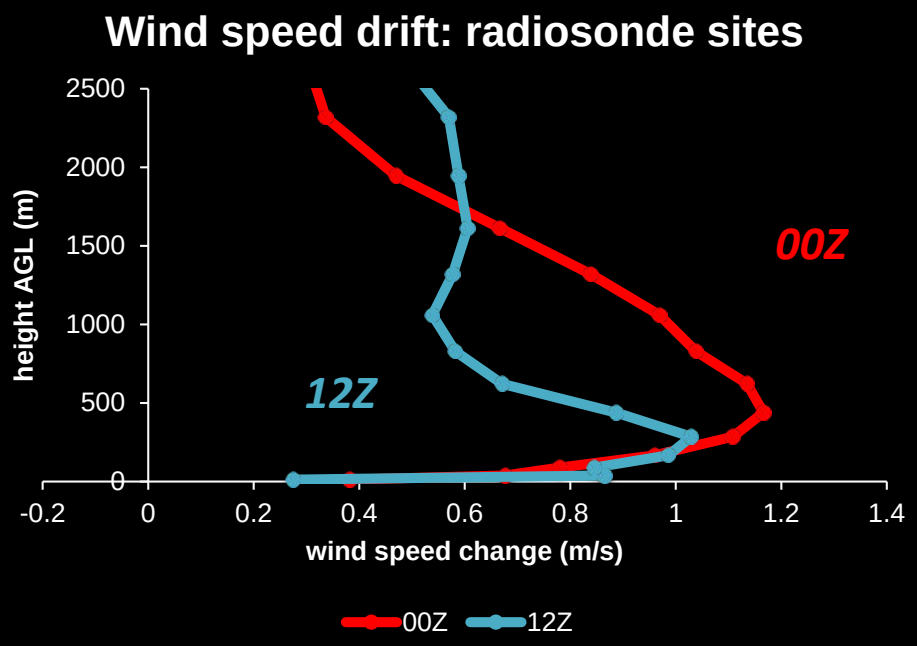


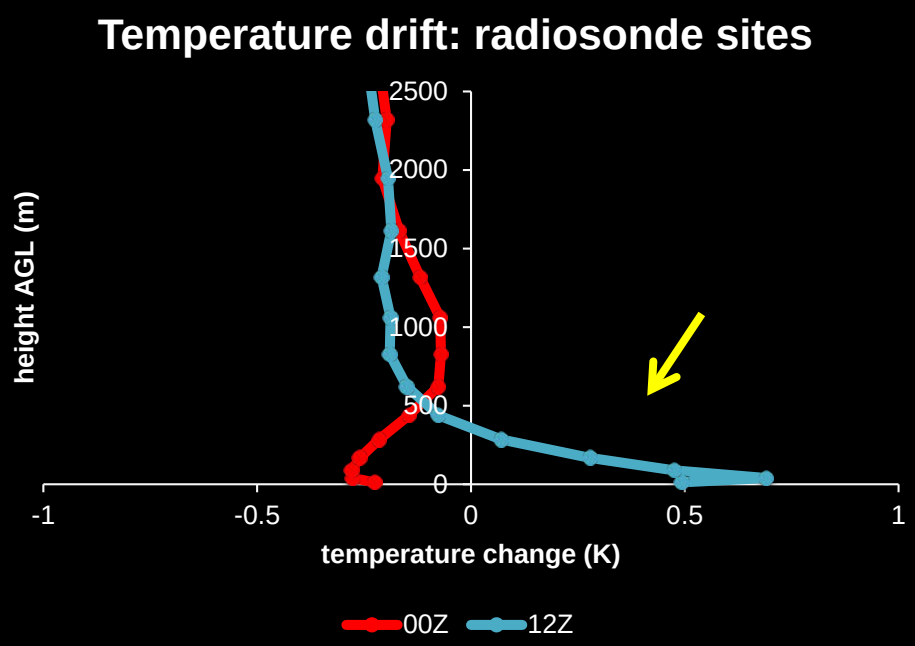


NO OBSERVATIONS DIRECTLY INVOLVED

Height coordinate = average model height AGL

April 2019 24-h forecast drift (60 radiosonde sites)



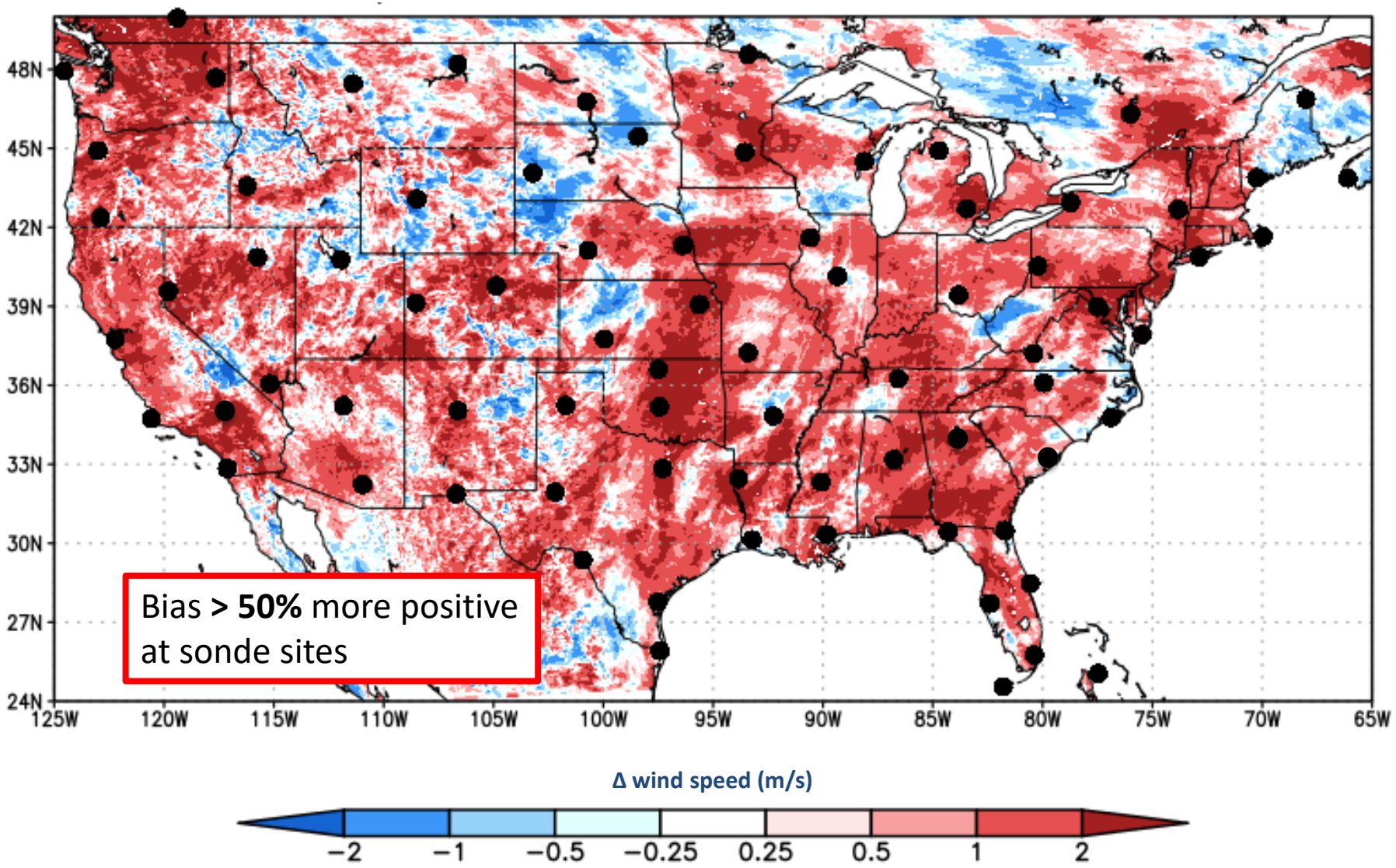


NO OBSERVATIONS DIRECTLY INVOLVED

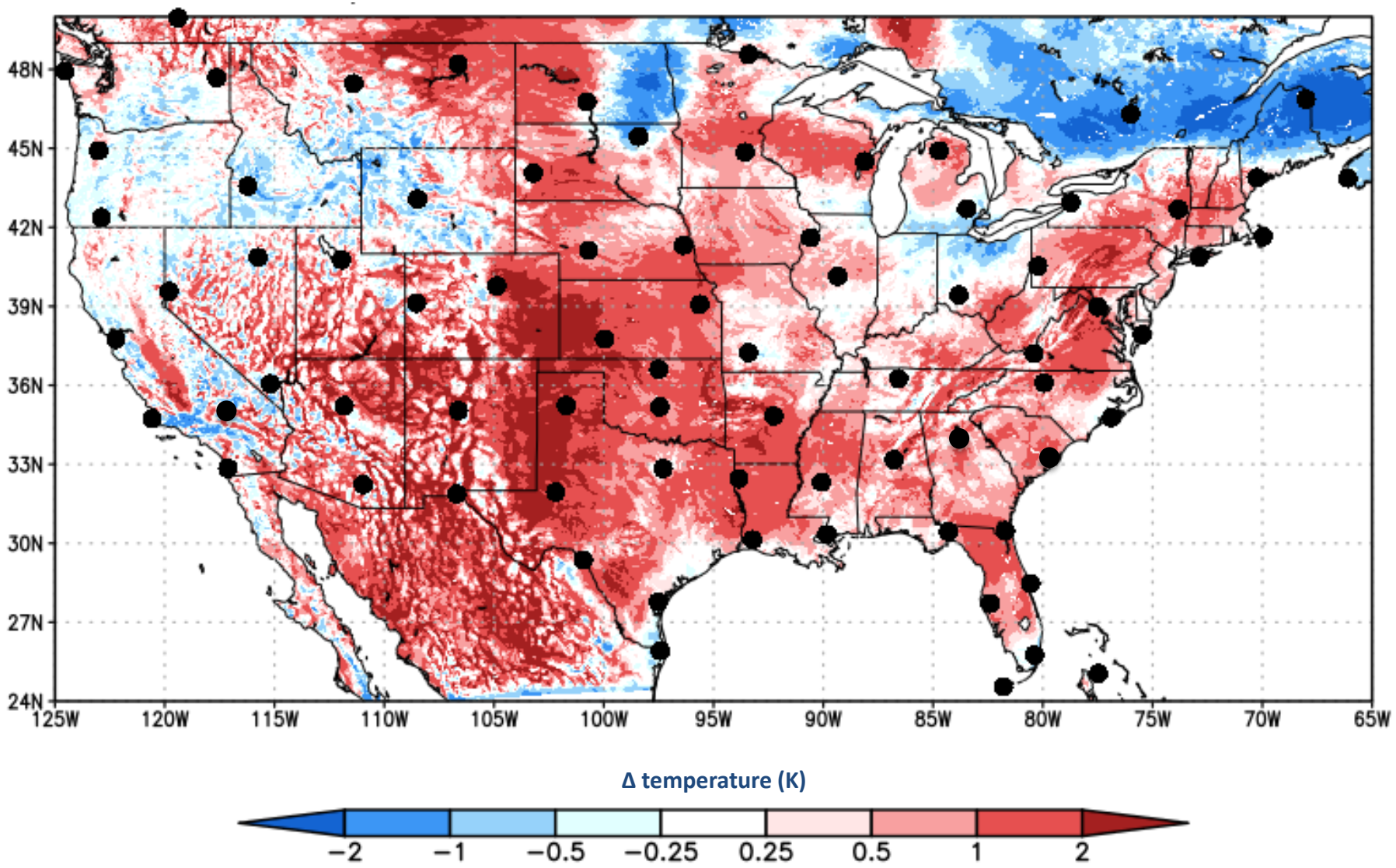
Height coordinate = average model height AGL

All sondes shown

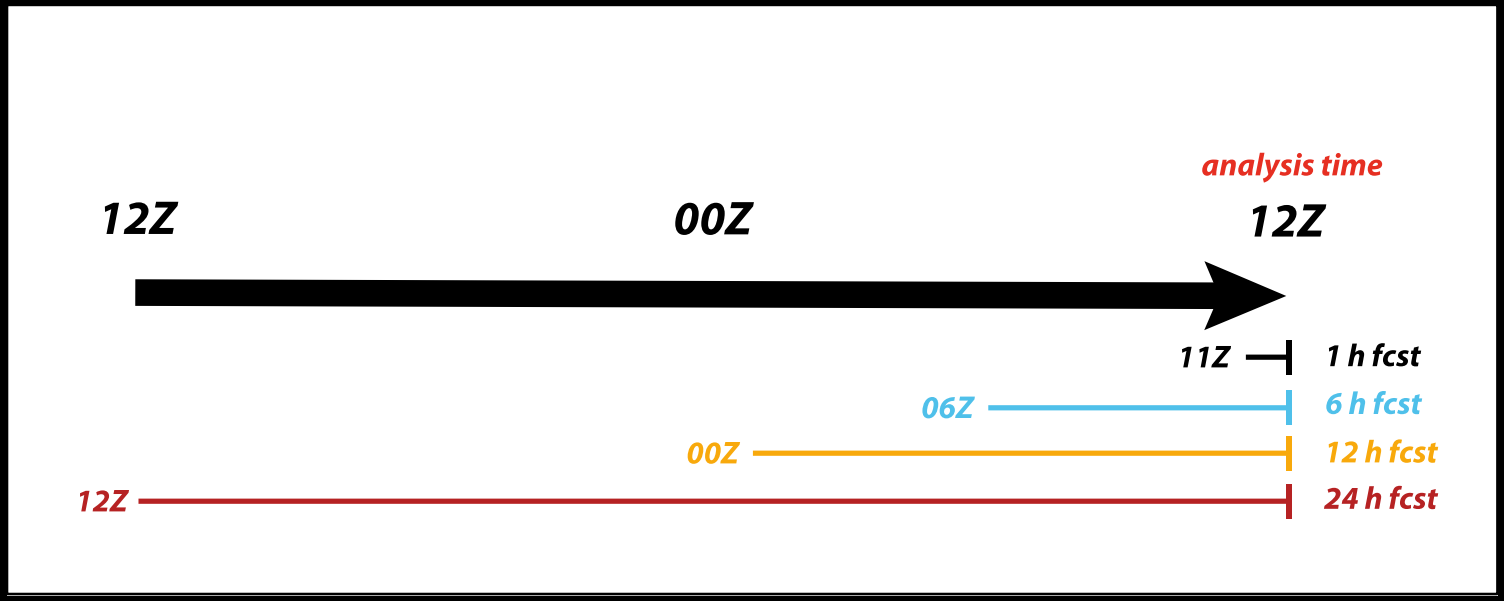
April 2019 ~ 00Z
24-h wind speed forecast drift: model level 6 (~430 m AGL)



April 2019 ~ 12Z
24-h temperature forecast drift: model level 2 (~39 m AGL)

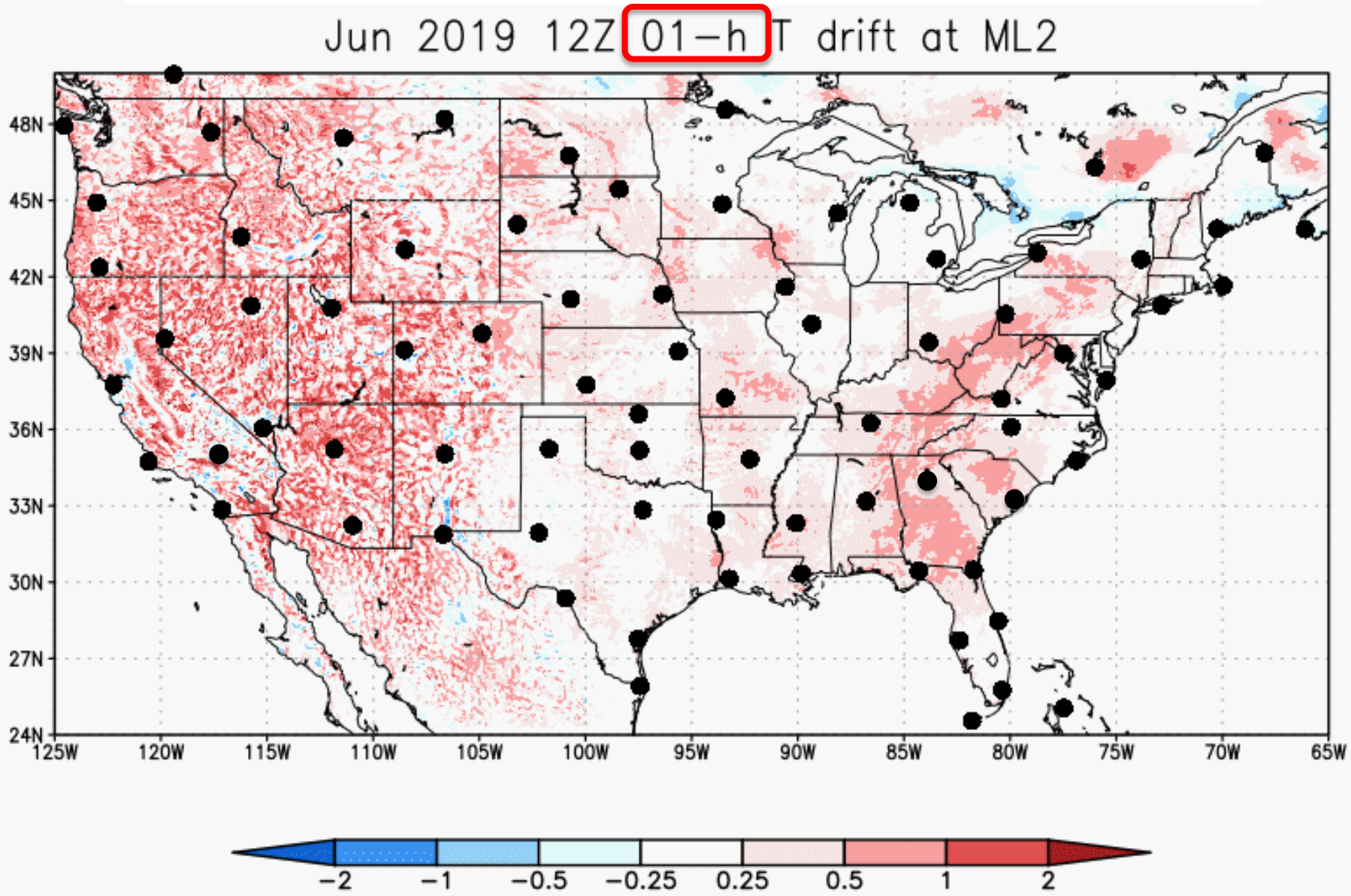


Evolution of forecast drift

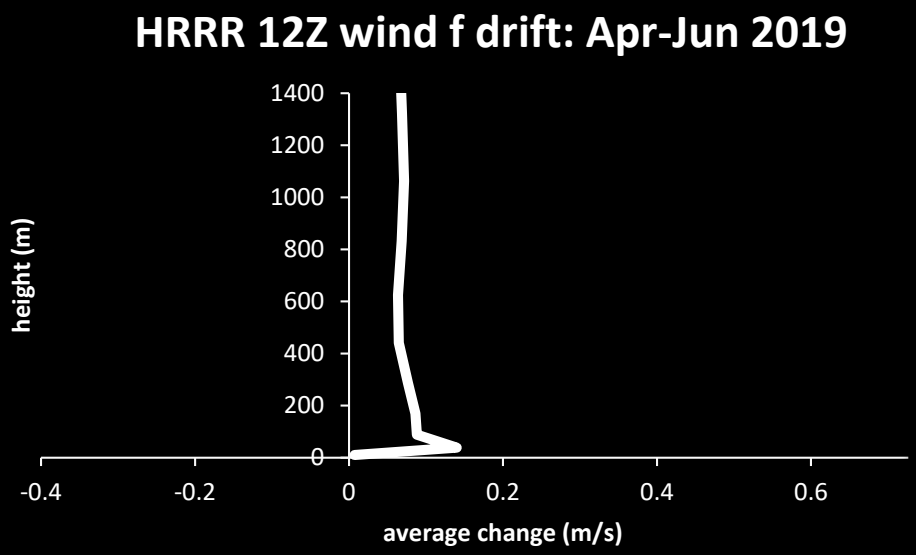


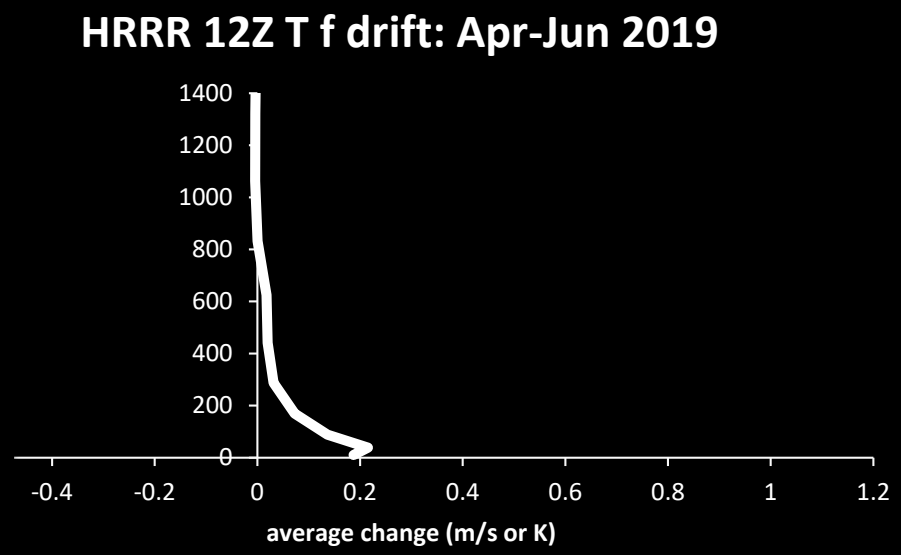
Analysis for all land areas in HRRR (including outside of CONUS)

June 2019 ~ 12Z
Temperature forecast drift: model level 2 (~39 m AGL)



12Z forecast drift evolution [April to June 2019]





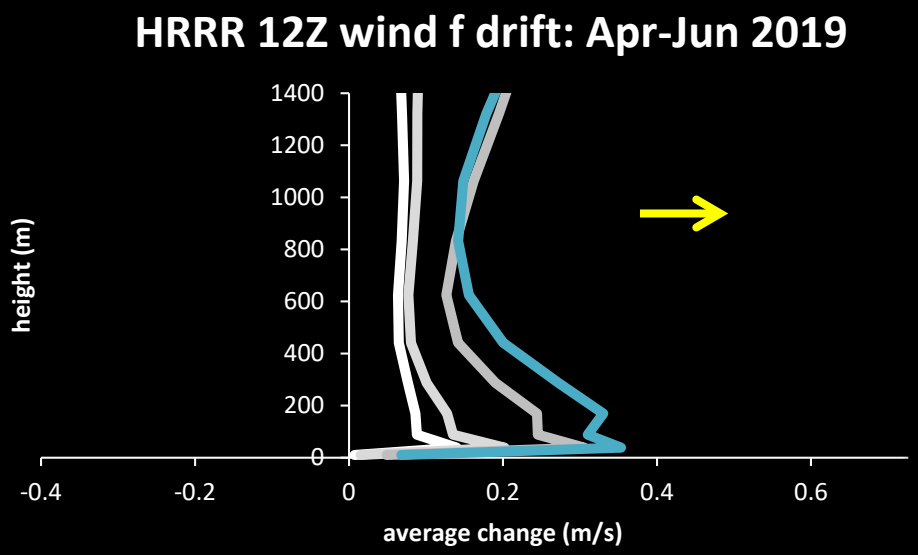
1-h drift

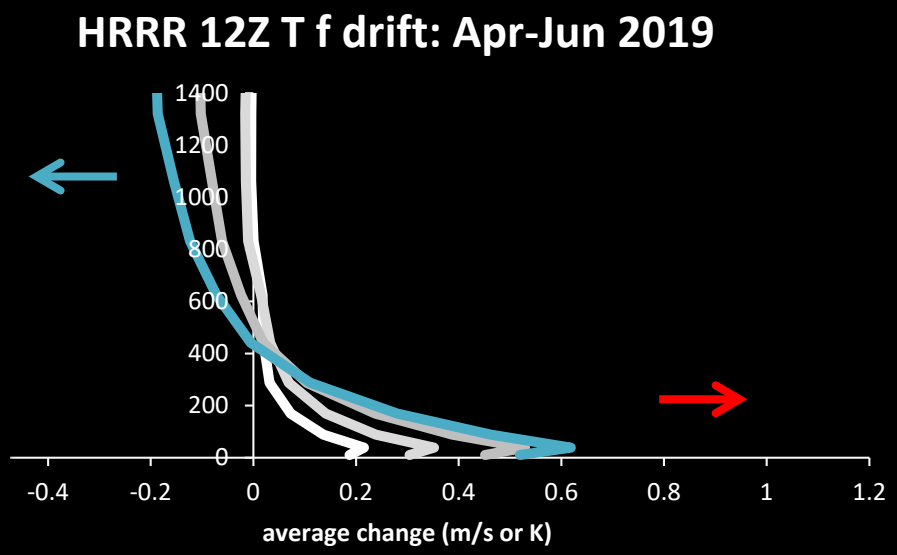
From 11Z to 12Z

Over all HRRR land areas

NO OBSERVATIONS DIRECTLY INVOLVED

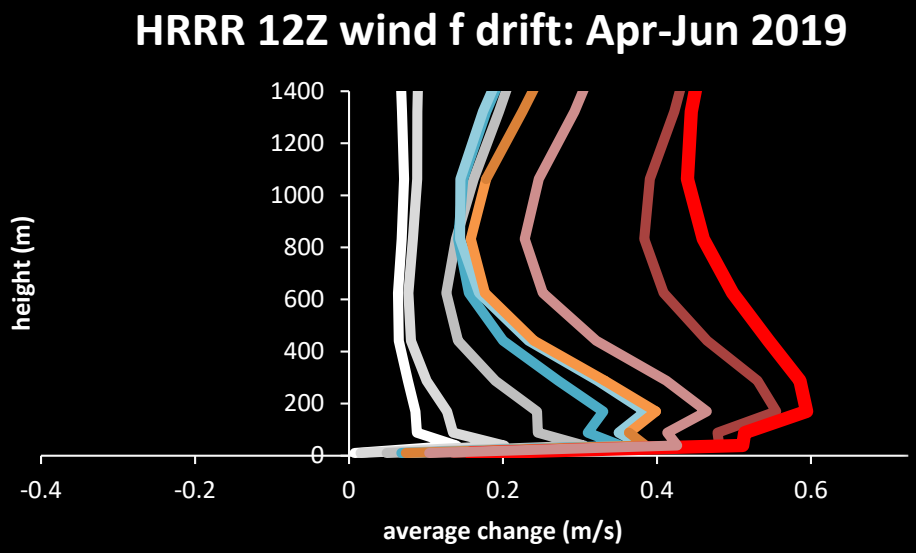
12Z forecast drift evolution [April to June 2019]

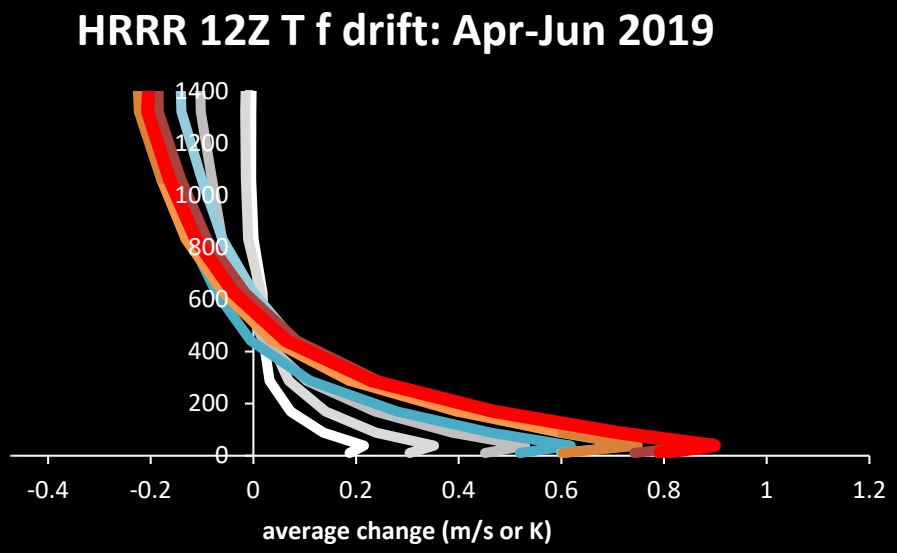




Up to 6h prior to 12Z

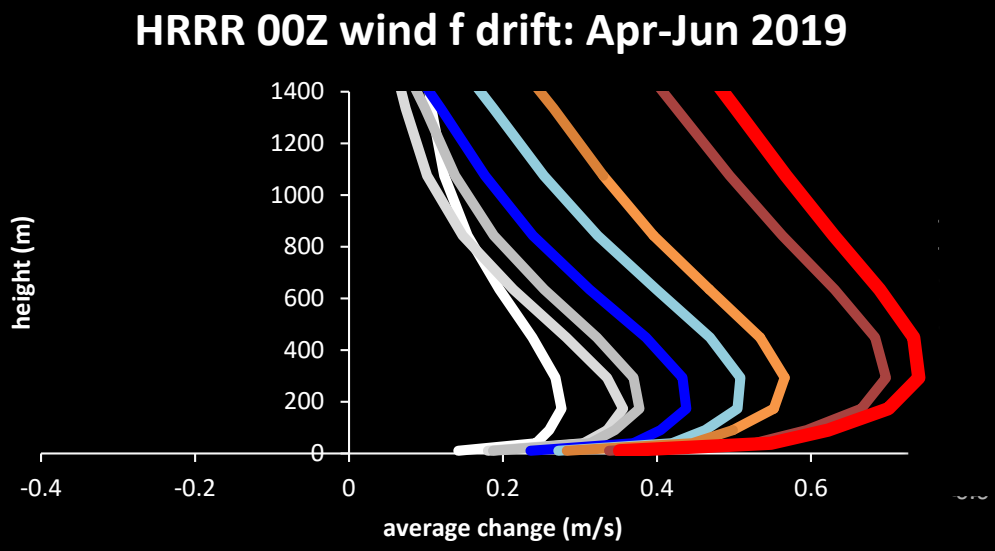
12Z forecast drift evolution [April to June 2019]

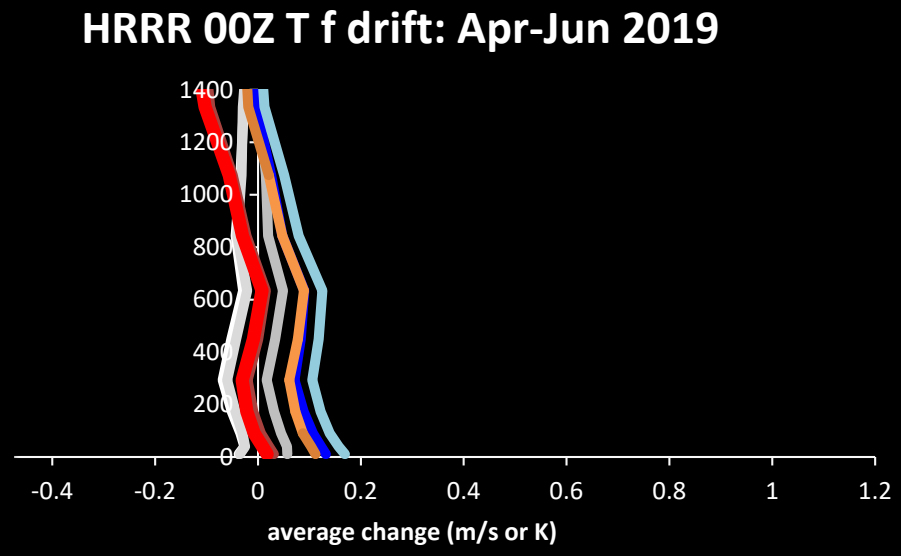




Up to 24h prior to 12Z

00Z forecast drift evolution [April to June 2019]





Temperature drift not as pronounced
Wind drift is worse

Summary

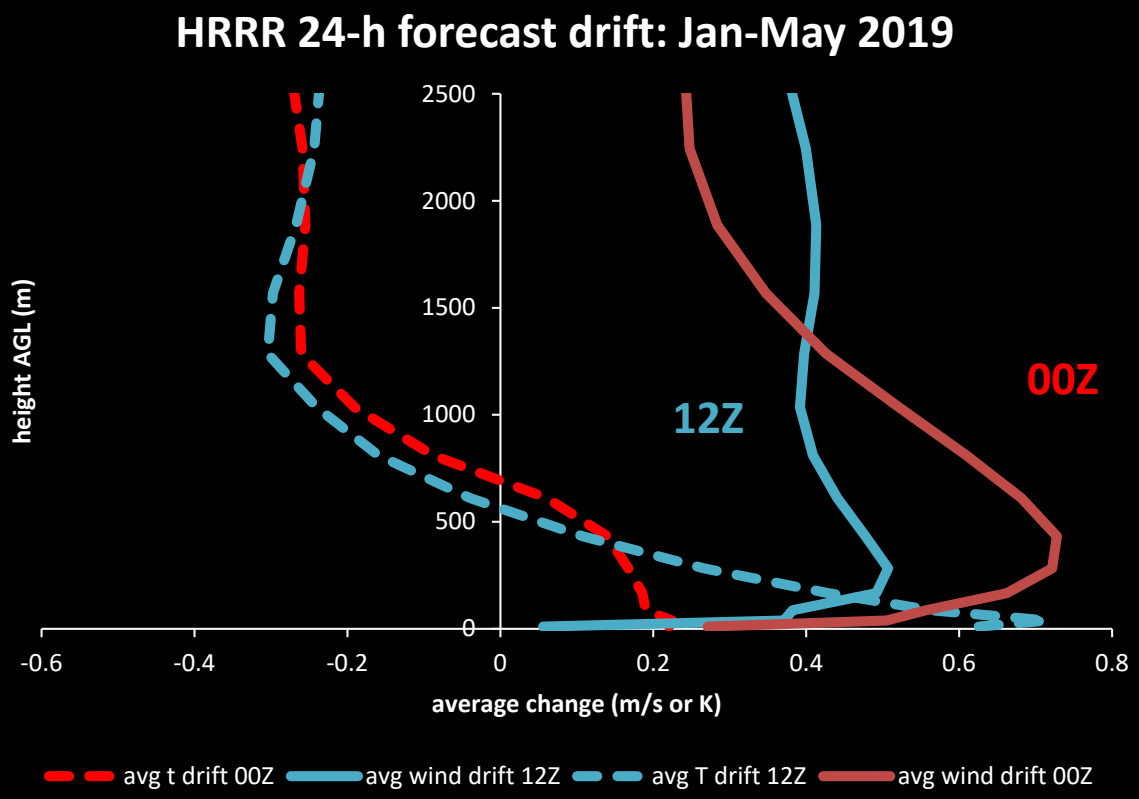
- Boundary layer winds are crucial to many applications but not nearly as well verified
- HRRR 00Z and 12Z analysis have relatively small bias
  - Of course, analyses include radiosonde observations
- Therefore, forecast *drift* reveals information about forecast *bias*, at much lower effort
- Systematic positive wind biases at most heights in the boundary layer
  - Larger at 00Z than 12Z
  - Appear quickly with time
  - Suggestion that radiosonde information not retained long
- Systematic warm biases quickly emerge near surface at 12Z
- Analysis should lead to improvements in boundary layer, surface layer, and land surface parameterizations, among others

[end]

Summary

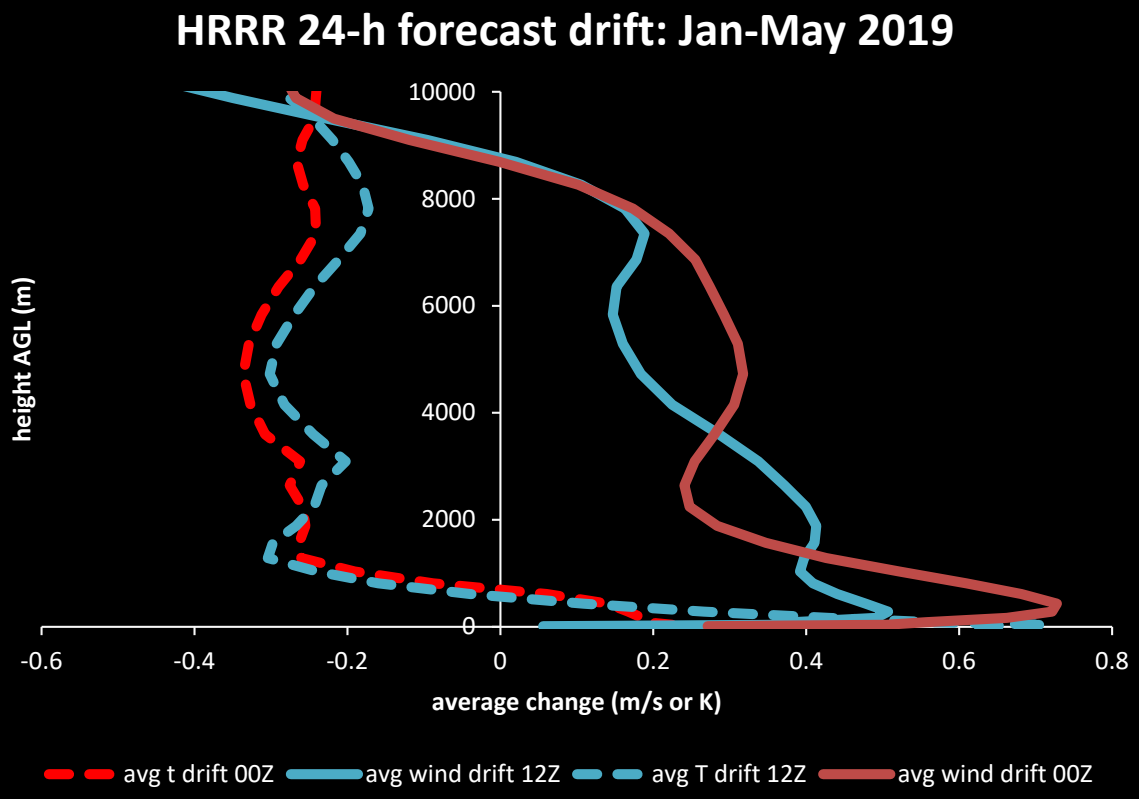
- 24-h forecast drift April 2019:
  - Wind speed increases both day and night (robust)
  - Nocturnal stability decreases near surface
- Radiosonde comparison indicates analysis possesses less bias
- Further analysis suggests fast wind bias emerges quickly & occurs in other months
- Sources of errors/differences: PBL mixing magnitude and depth, surface layer, land surface model, microphysics, clouds & radiation, and larger-scale contributions etc..

HRRR forecast drift: Jan-May 2019



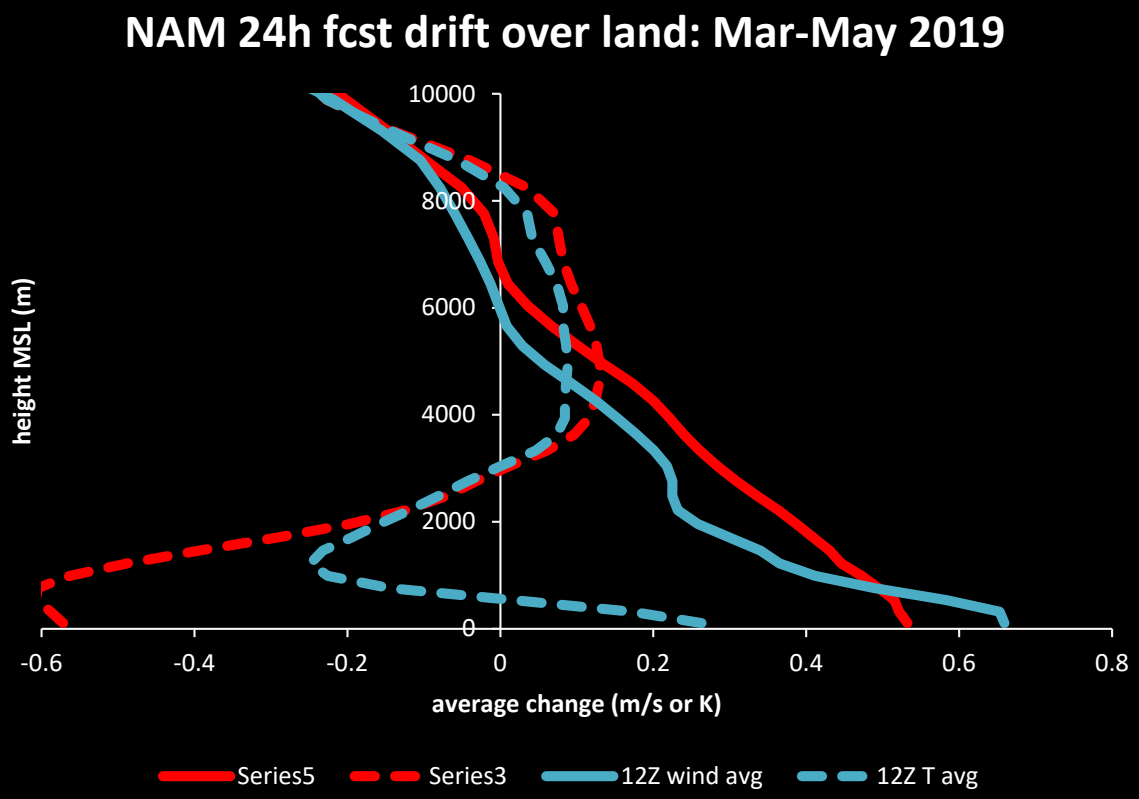
NO OBSERVATIONS DIRECTLY INVOLVED
but analysis bias < forecast bias

HRRR forecast drift: Jan-May 2019 [over all land areas in model]



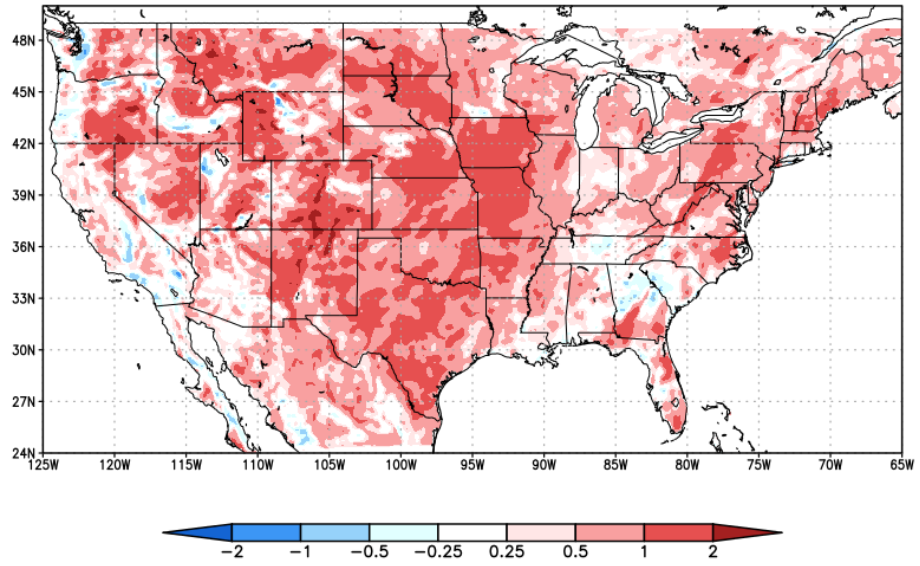
NO OBSERVATIONS DIRECTLY INVOLVED
but analysis bias < forecast bias

NAM forecast drift: Mar-May 2019



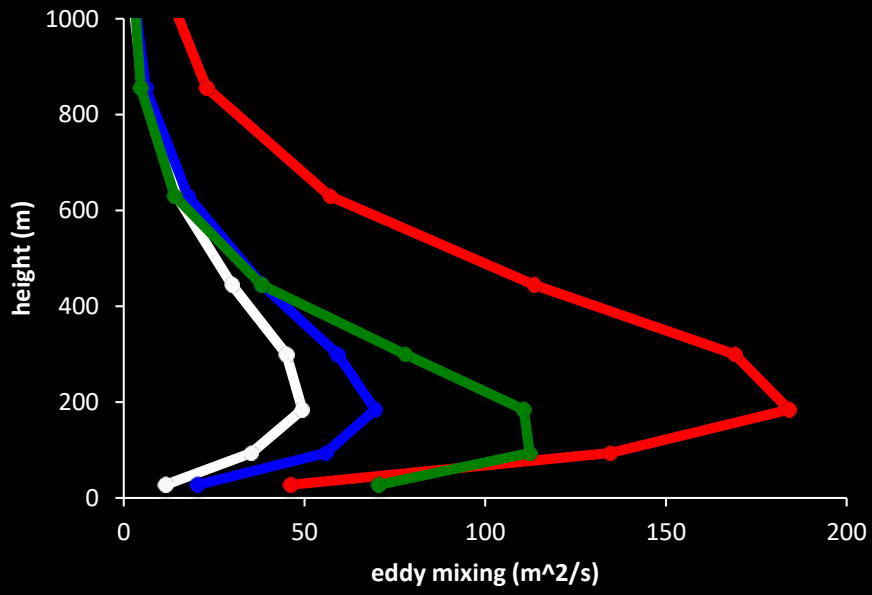
NAM data on pressure levels;
Heights are MSL

Near-surface wind speed difference @ 18Z

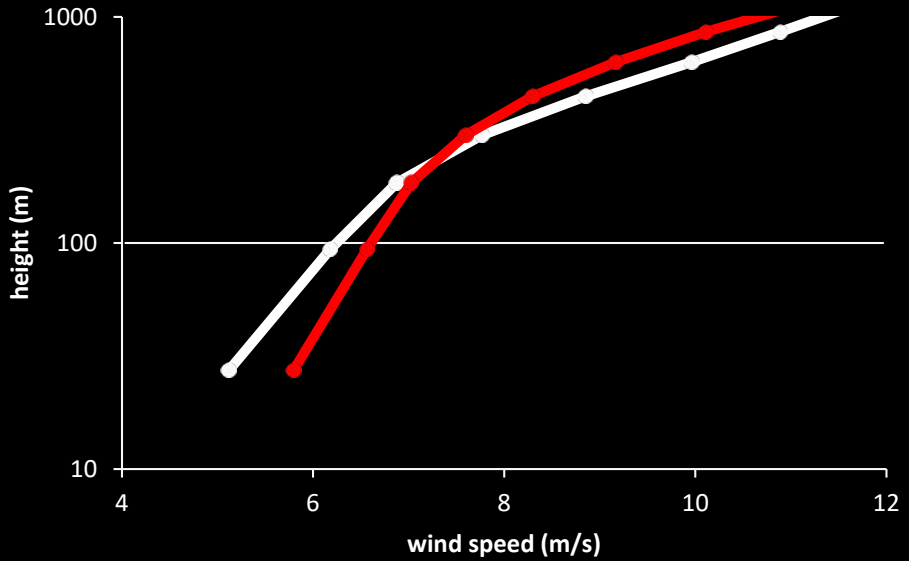


Limited non-HRRR PBL experiment

Average mixing over land at 18Z

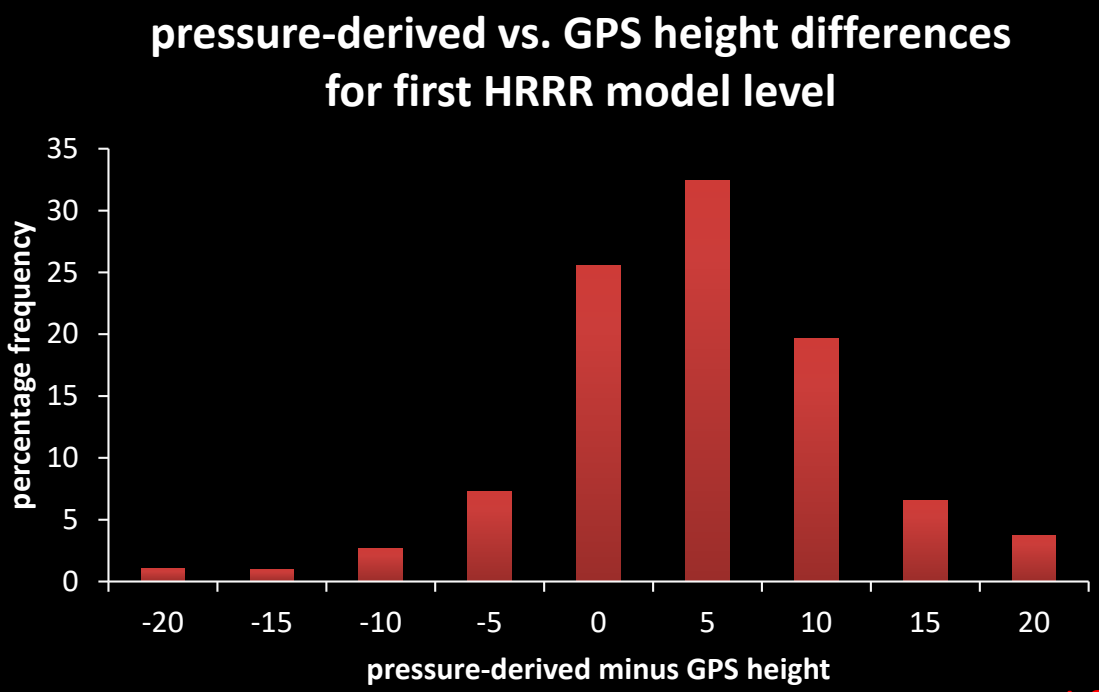


18Z average wind profiles



PBL positive wind bias probably not mixing since it is so deep

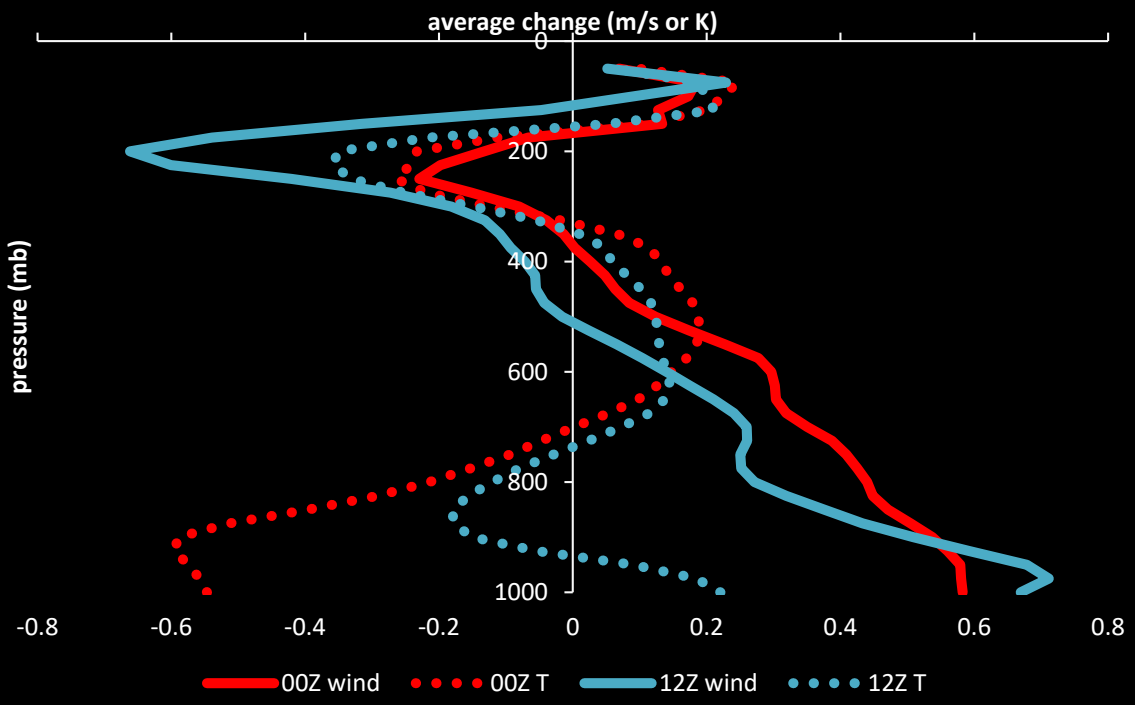
Observation height discrepancies



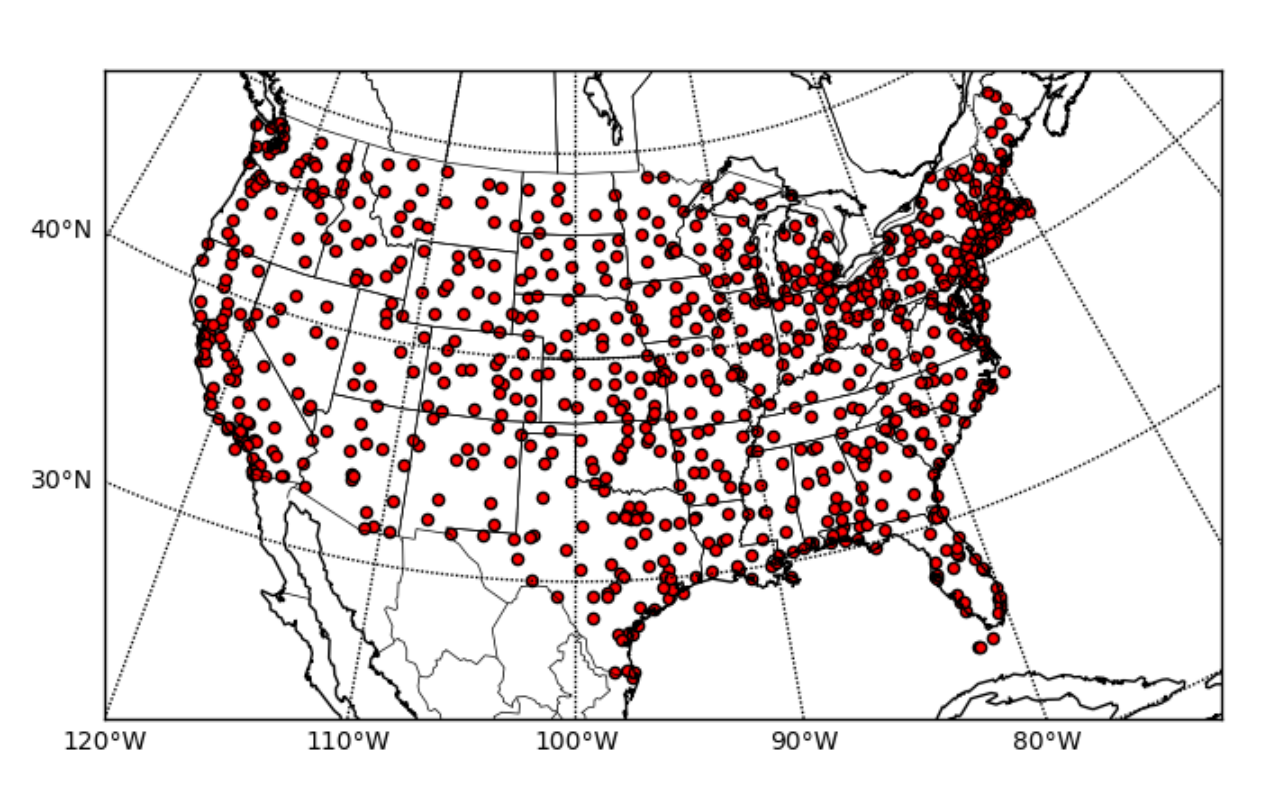
Mean difference ~2 m

GPS instrument generally gives
lower height estimate

NAM 24h forecast drift over land: May 2019

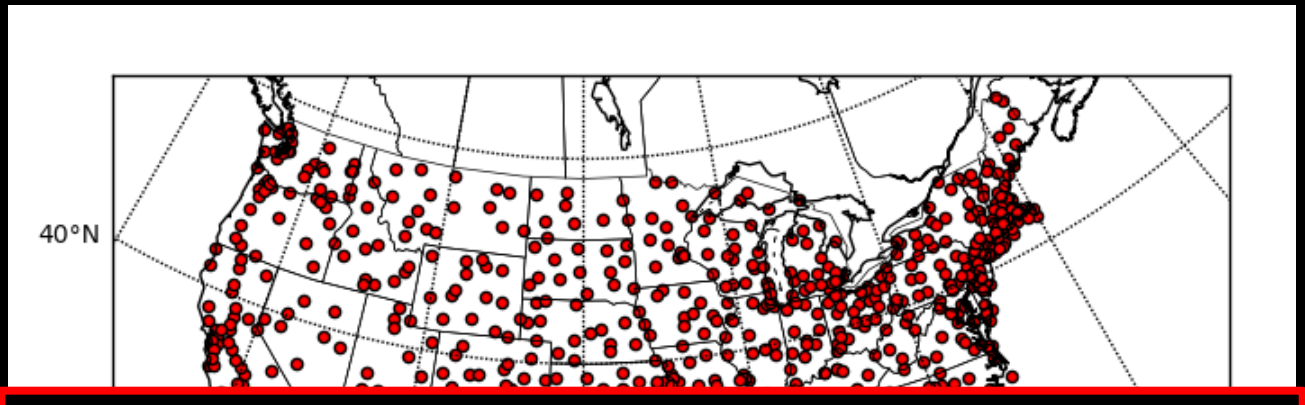


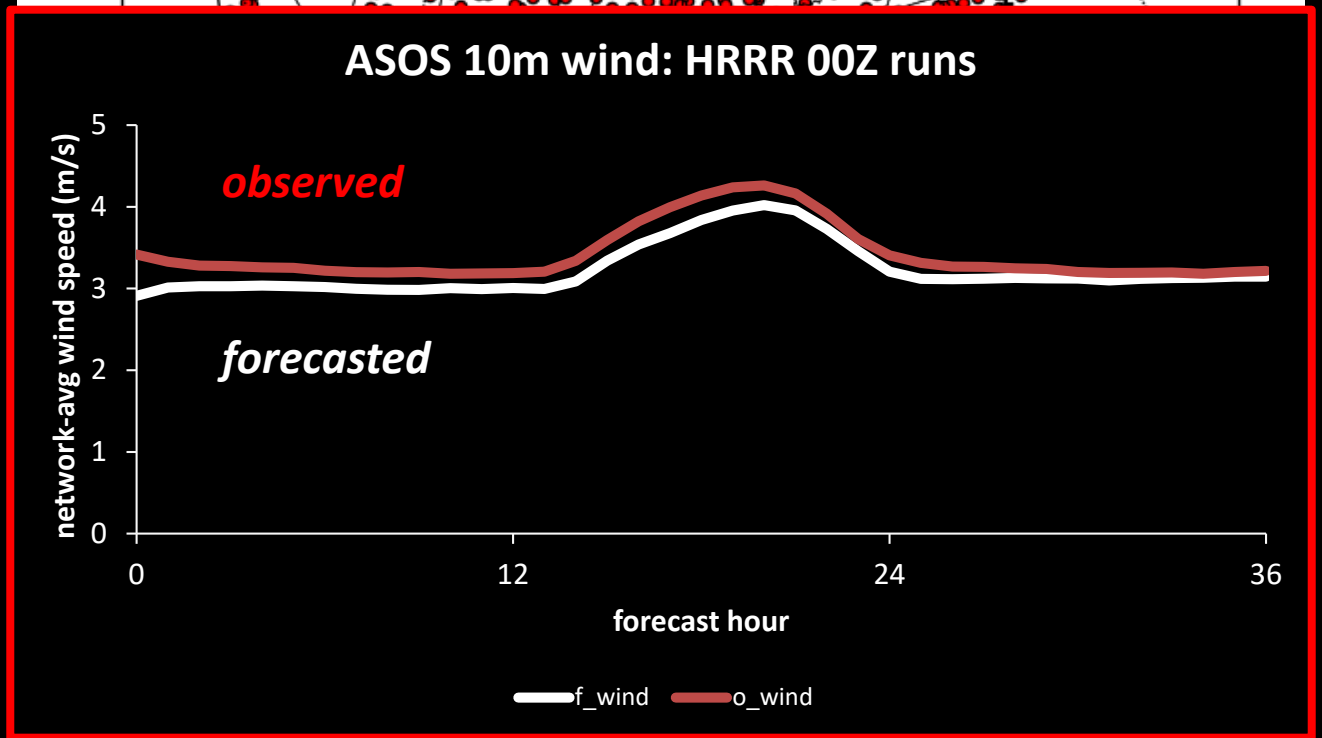
Available ASOS stations



N > 800

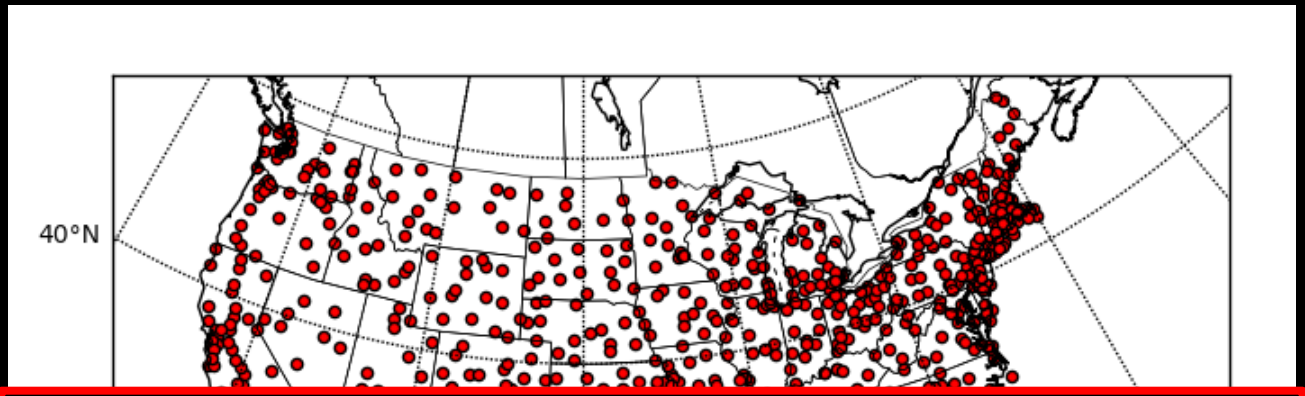
Available ASOS stations

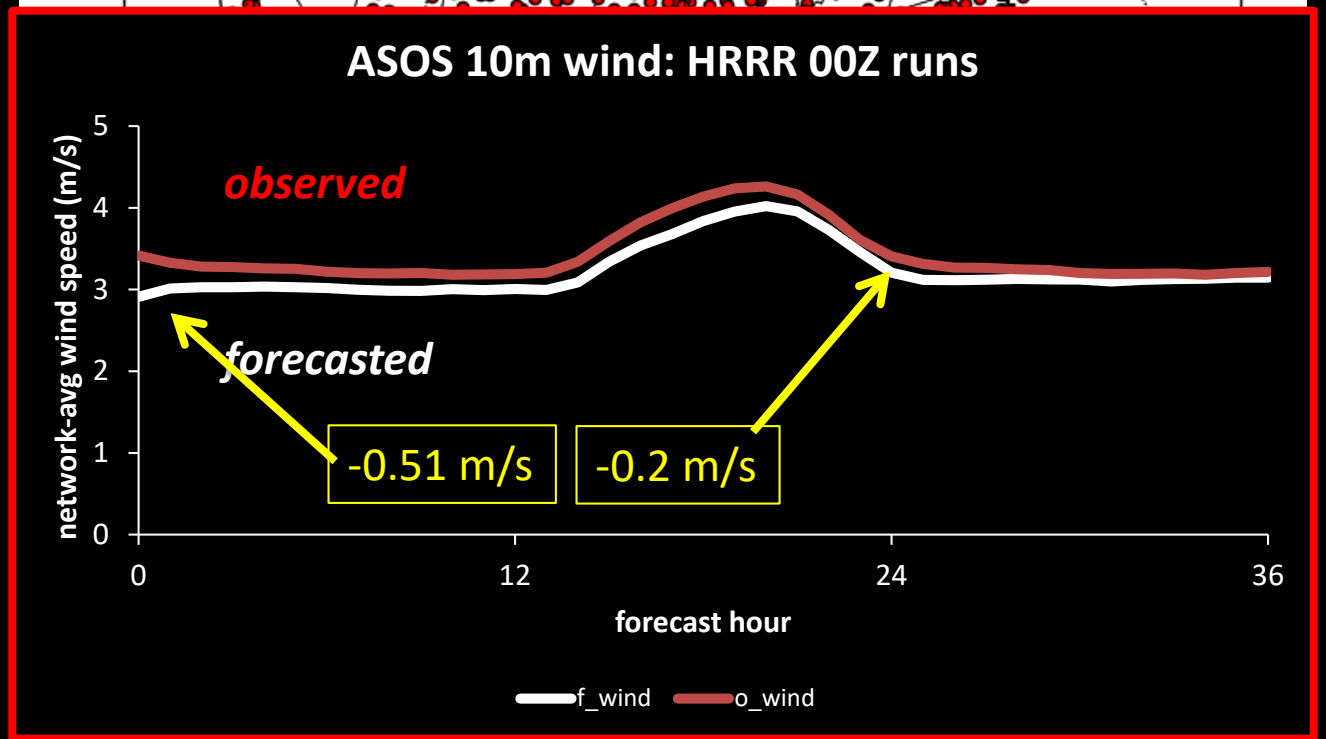




2-month average

Available ASOS stations





Forecast bias = forecast – observation