Arctic near surface air temperature is warmer in CESM2, is this a good thing?

Elin McIlhattan and Tristan L'Ecuyer

University of Wisconsin – Madison

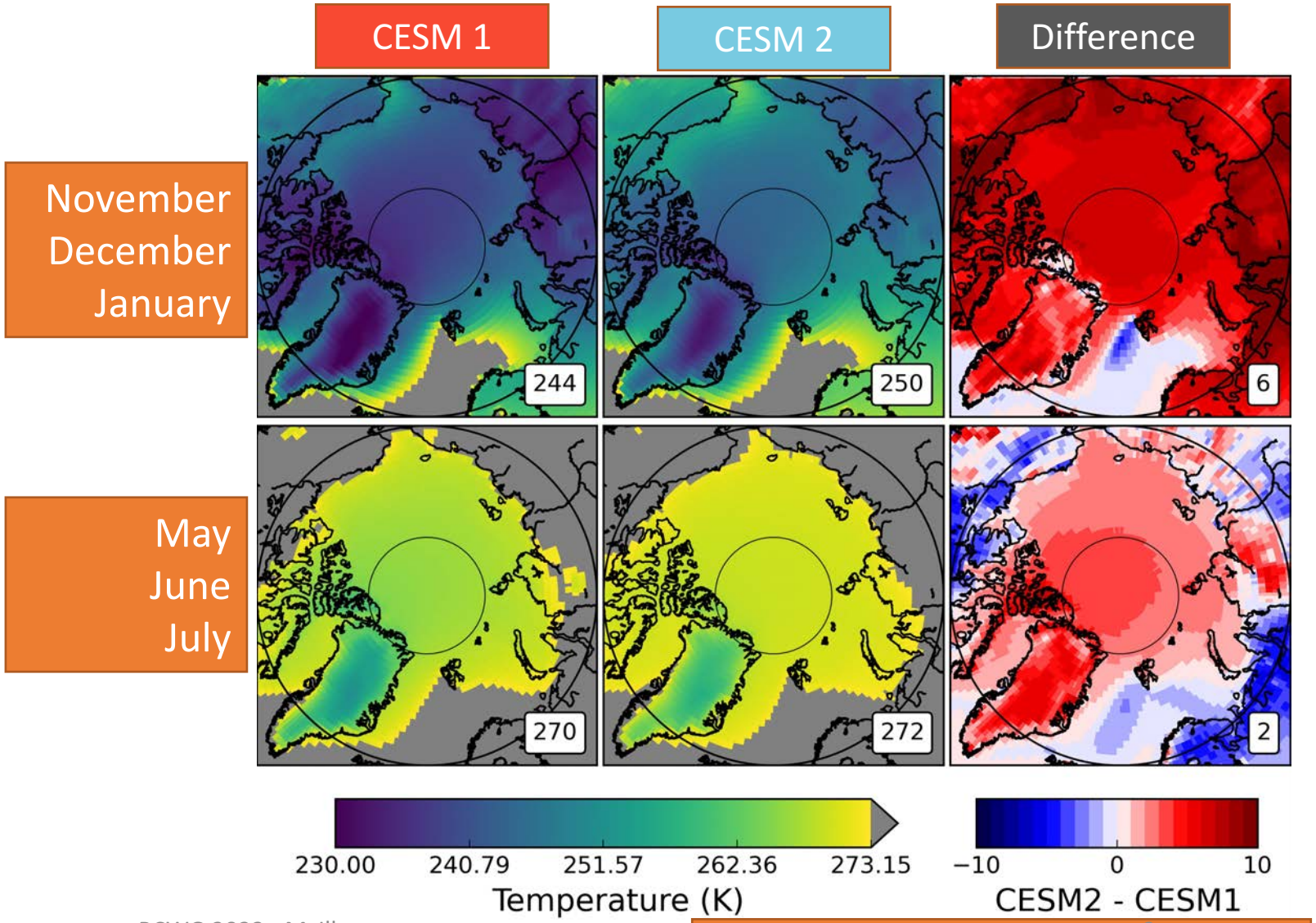
Presentation for the Polar Climate Working Group winter meeting 2023

WISCONSIN

UNIVERSITY OF WISCONSIN–MADISON

Motivation: New Arctic Mean State in CESM2

- Compared the **pre-industrial control runs** of the **CESM1** and **CESM2** large ensembles
- **CESM2**'s Arctic is cloudier, warmer, and rainier
- Arctic surface (and near surface) temperature is 3K warmer annually

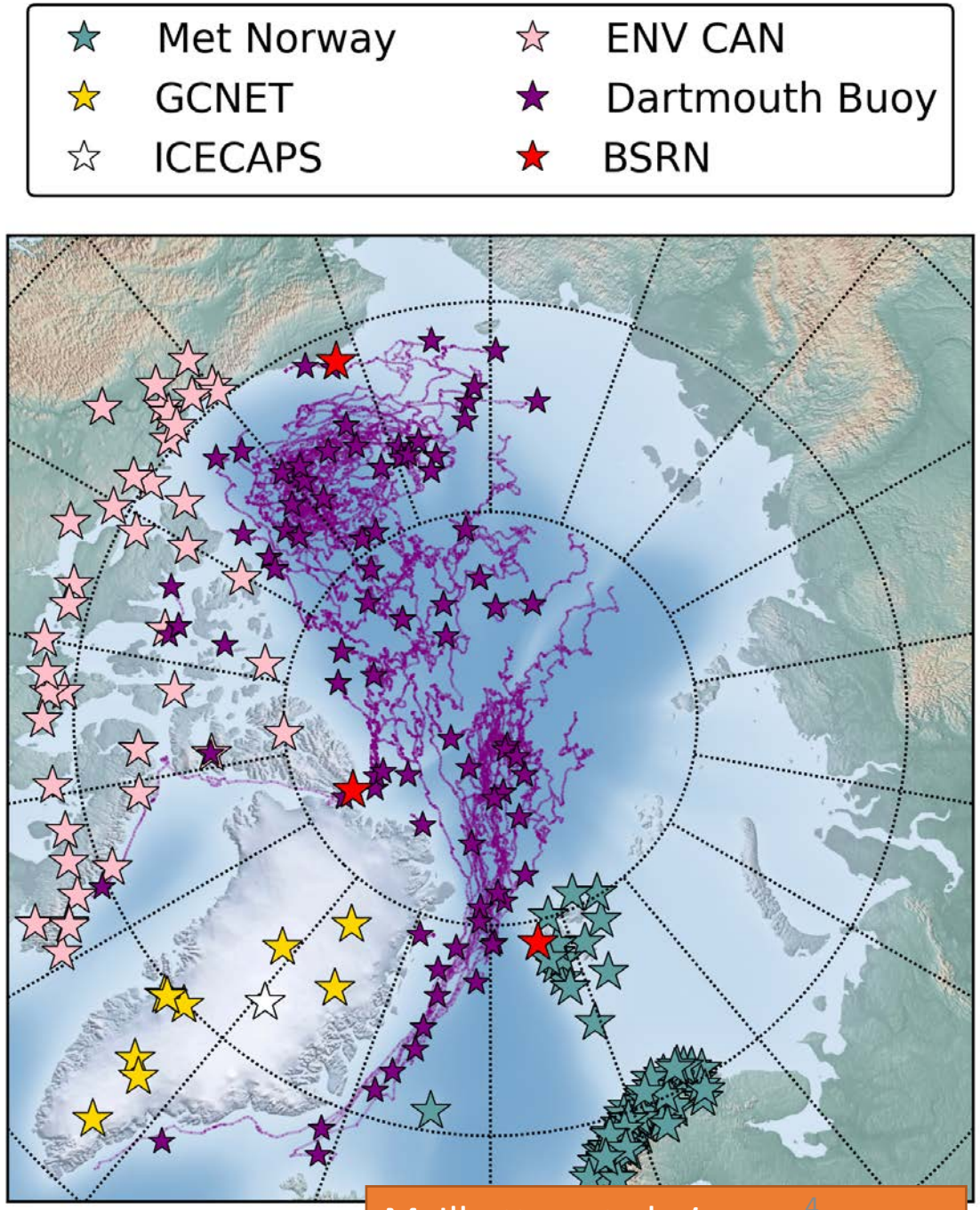


McIlhattan et al., JGR-Atm, 2020

Question: Is the warmer Arctic in CESM2 more realistic?

Near Surface Air Temperature Observations

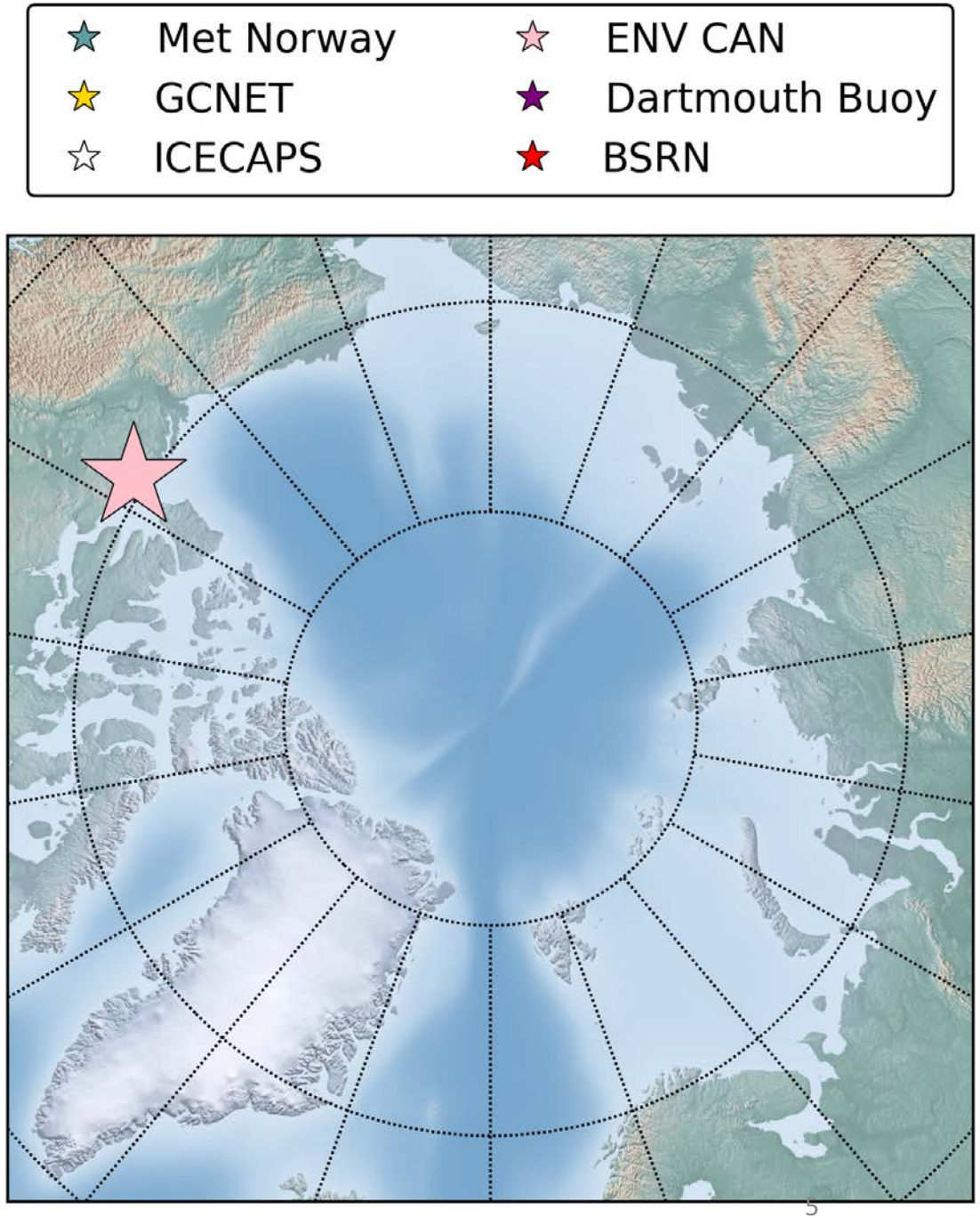
- 147 Ground-Based Stations (so far)
  - Met Norway
  - Greenland Climate Network (GCNET)
  - Environment Canada
  - Baseline Surface Radiation Network (BSRN)
  - Summit Station (ICECAPS)
- 85 Arctic Buoys
  - CRREL-Dartmouth Mass Balance Buoy Program



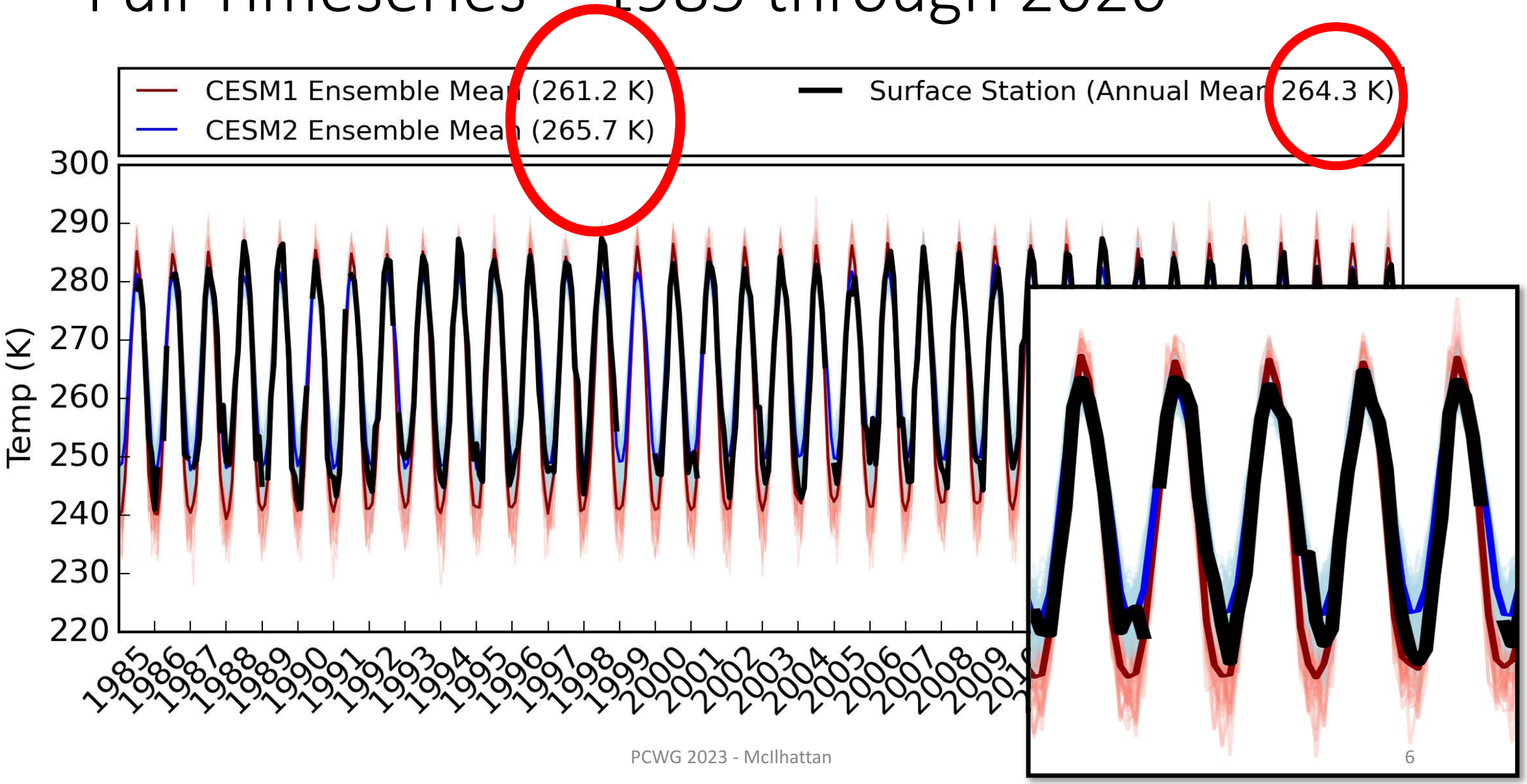
McIlhattan et al., *in prep*

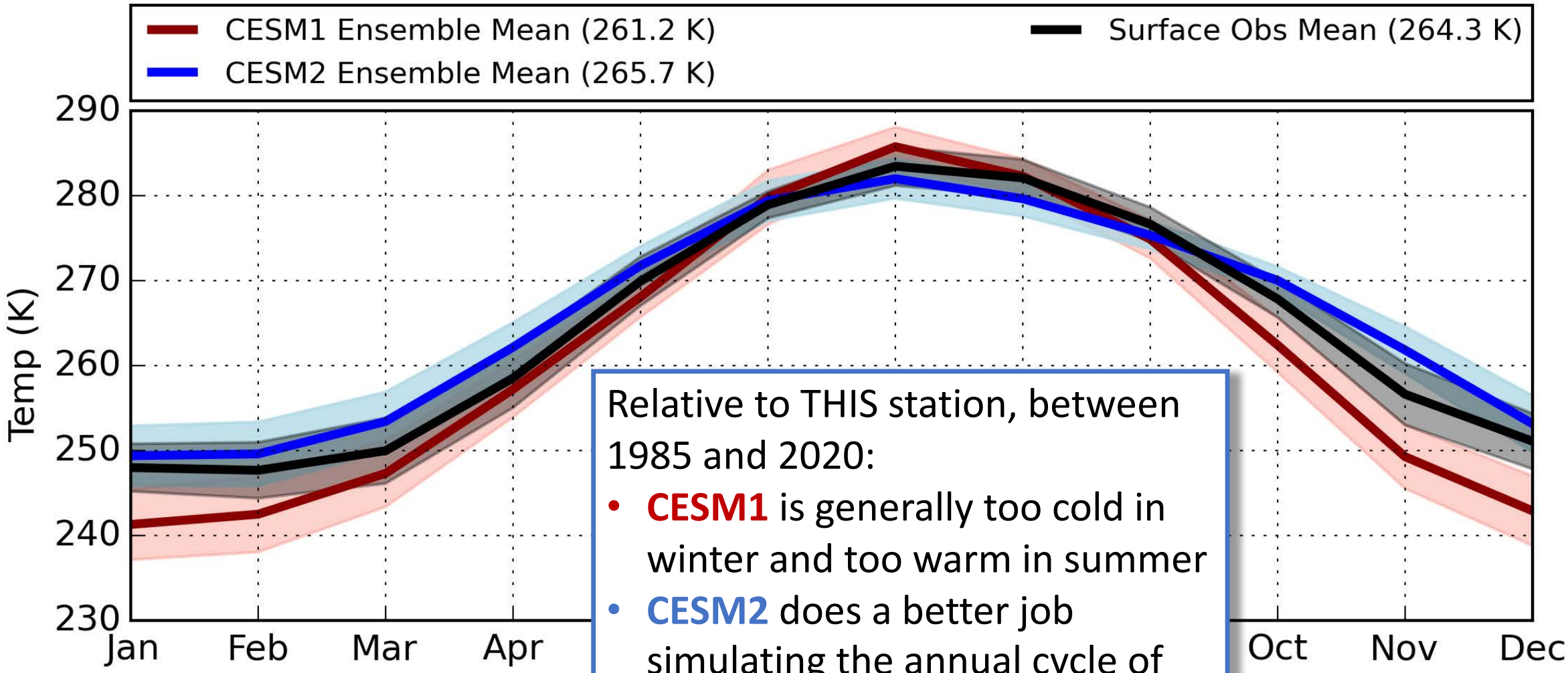
A sample ground-based station – **2203058**

- Observations:
  - Require a minimum of 5 years of data
  - Use monthly mean near surface air temperature for the lifetime of the station
- Model:
  - We take those corresponding years from each member of the CESM1 and CESM2 large ensembles



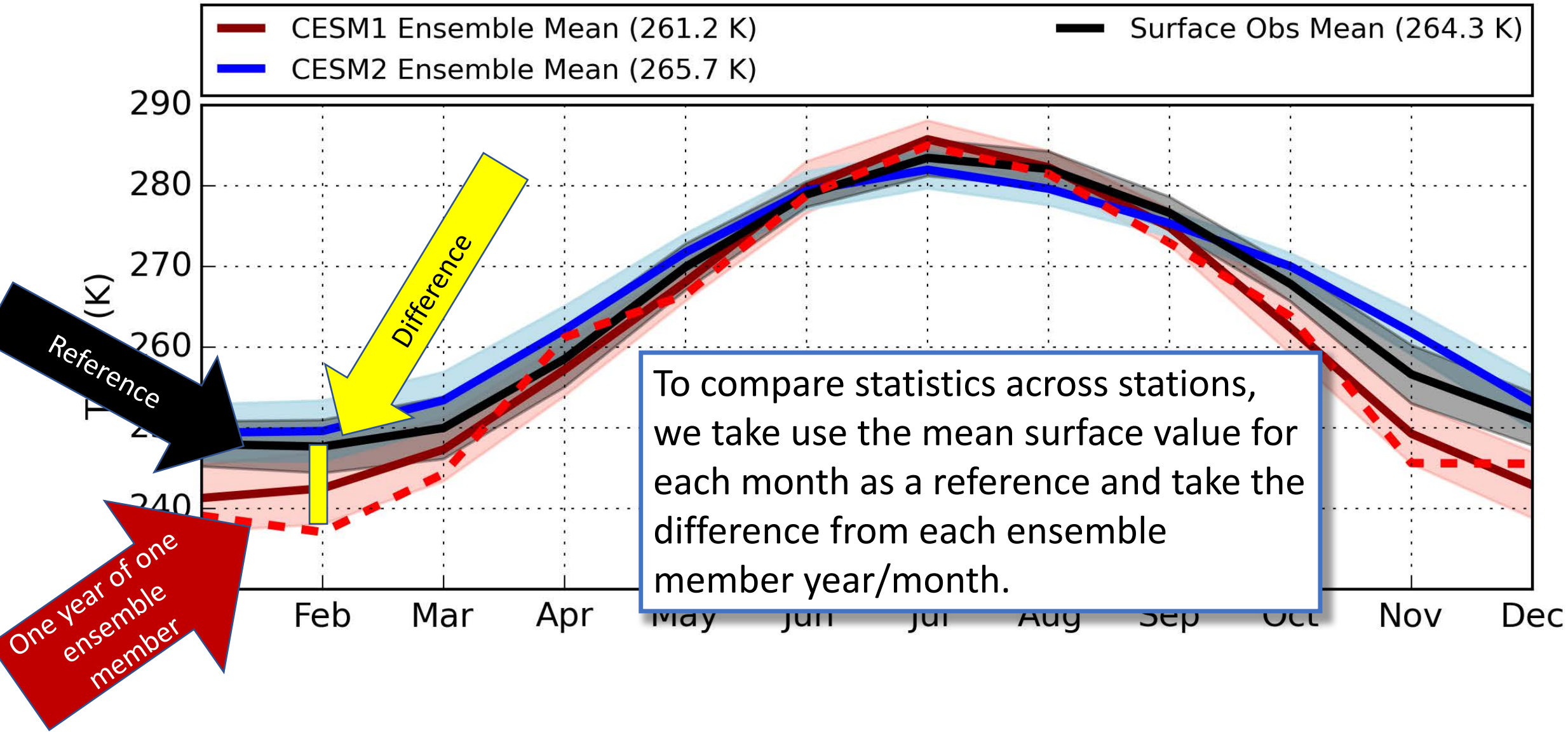
Full Timeseries – 1985 through 2020



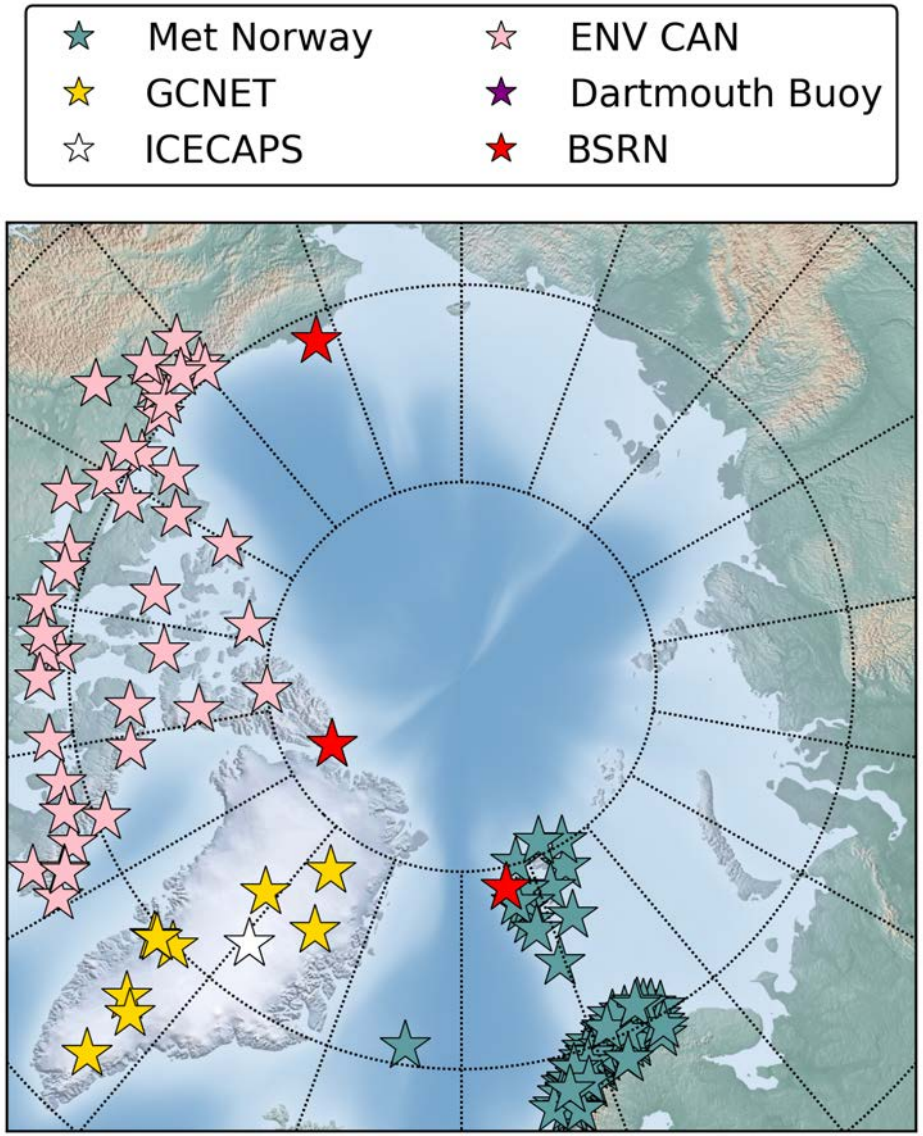


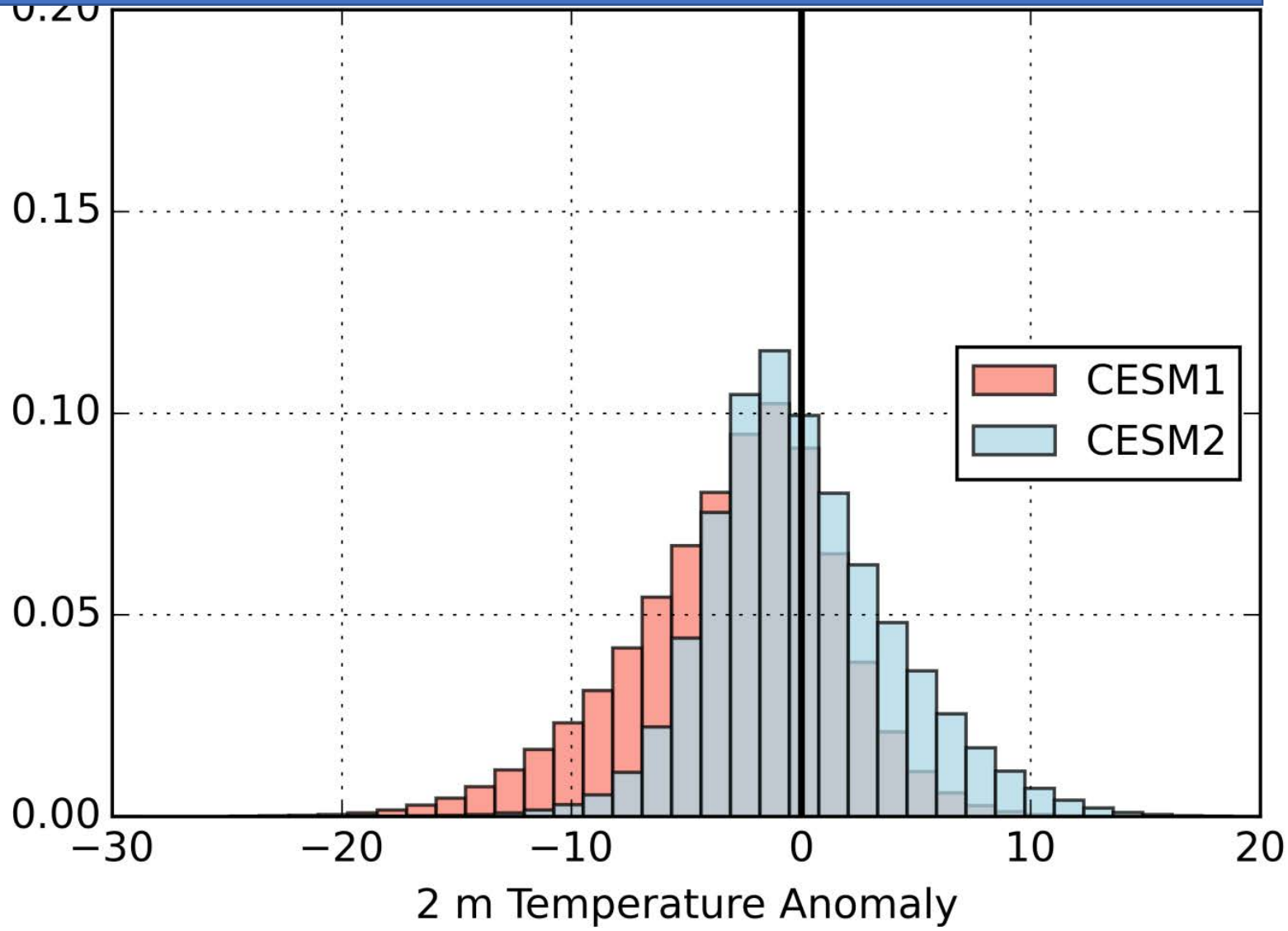
Relative to THIS station, between 1985 and 2020:

- **CESM1** is generally too cold in winter and too warm in summer
- **CESM2** does a better job simulating the annual cycle of near surface air temperature


Station 2203058 Lon/Lat:-124.08, 69.35
Annual Cycle from 5-1985 to 12-2020
CESM1 Ensemble Mean (261.2 K)
CESM2 Ensemble Mean (265.7 K)
Surface Obs Mean (264.3 K)
290
280
270
260
240
(K)
Feb
Mar
Apr
Nov
Dec
Reference
Difference
One year of one ensemble member
To compare statistics across stations, we take use the mean surface value for each month as a reference and take the difference from each ensemble member year/month.

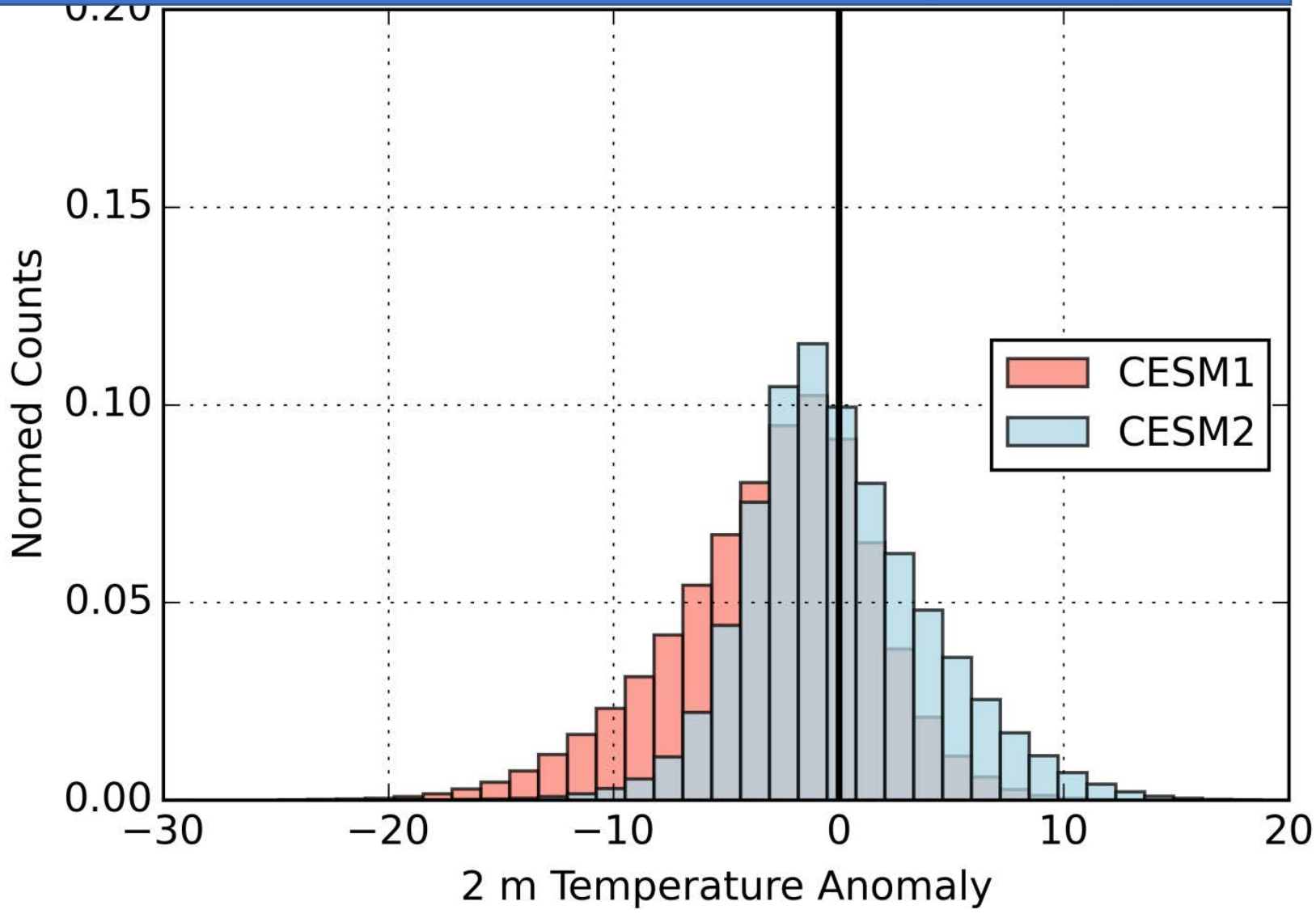
Ground Based Stations (147) – All months (42,764)





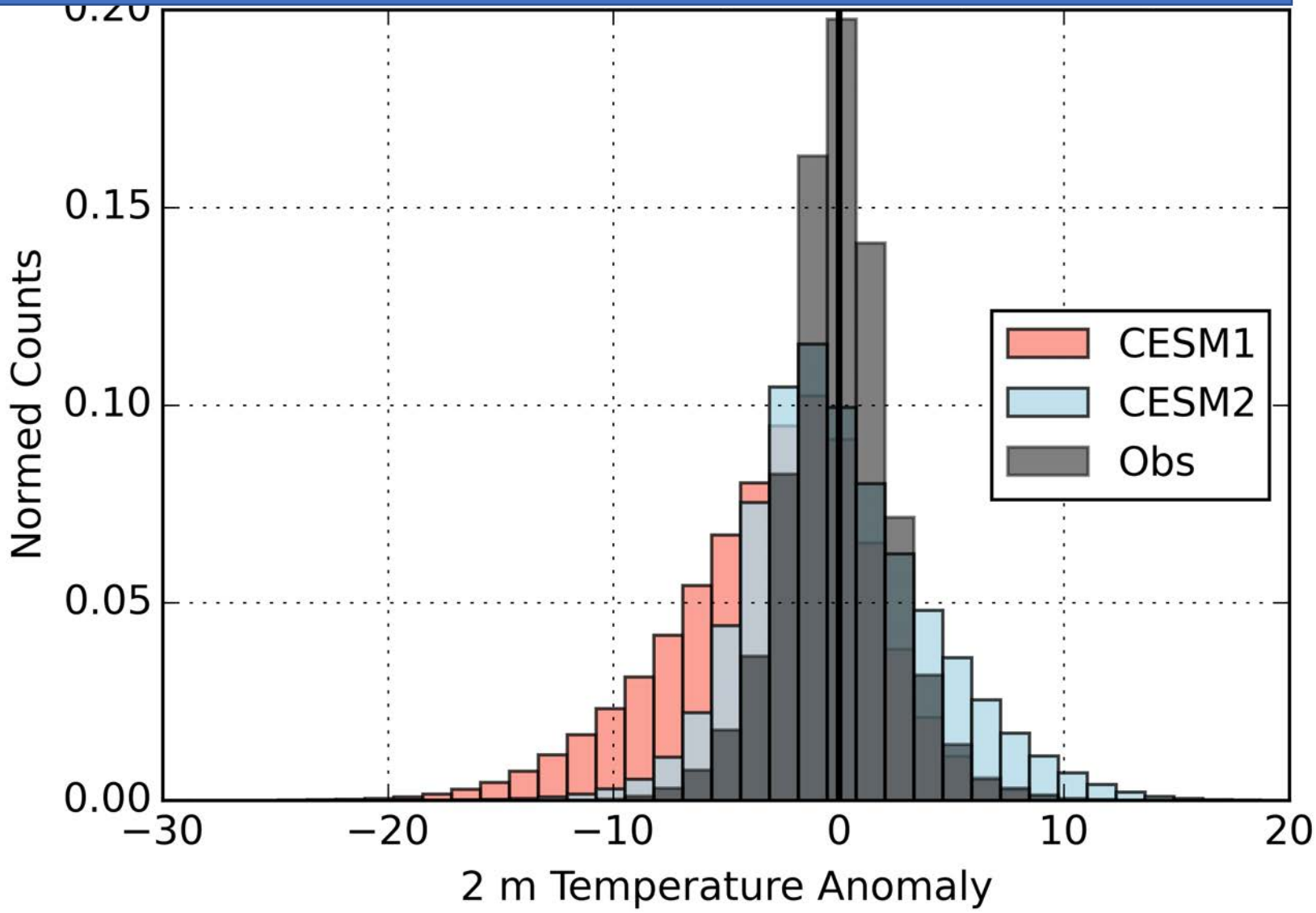
Ground Based Stations (147) – All Months

- All ensemble members for all available station data (~1.4 million CESM1 values and ~3.7 million CESM2 values)
- **CESM2** anomalies are centered around zero
- **CESM1** anomalies are skewed cold relative to station data



Ground Based Stations (147) – All Months

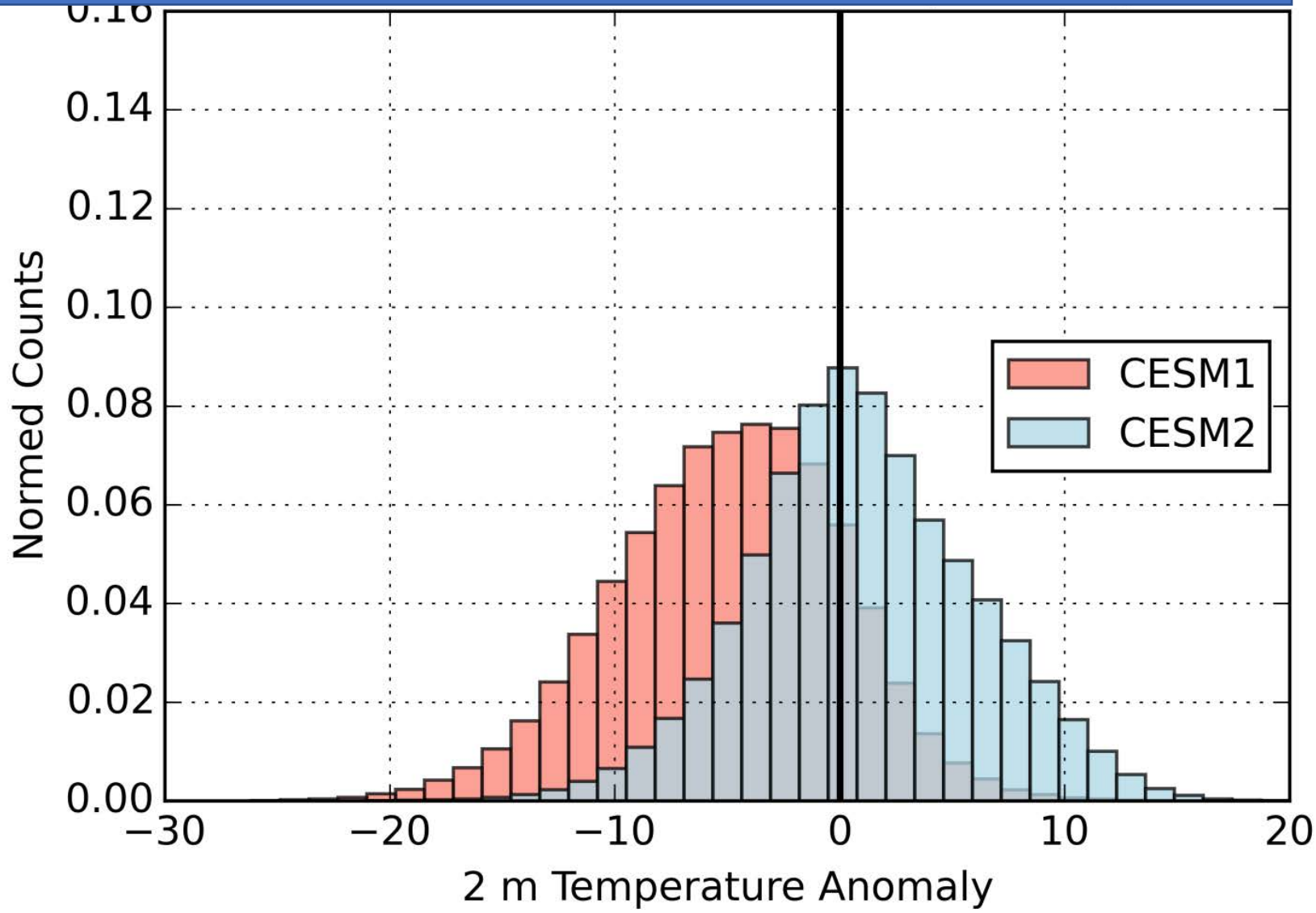
- All years of station data (~43 thousand values)
- Histogram of observed values has a narrower distribution (expected)
- **CESM2** does a better job capturing the character of the observed distribution



Recall: Winter (NDJ) saw the largest temperature increase in the Arctic mean state

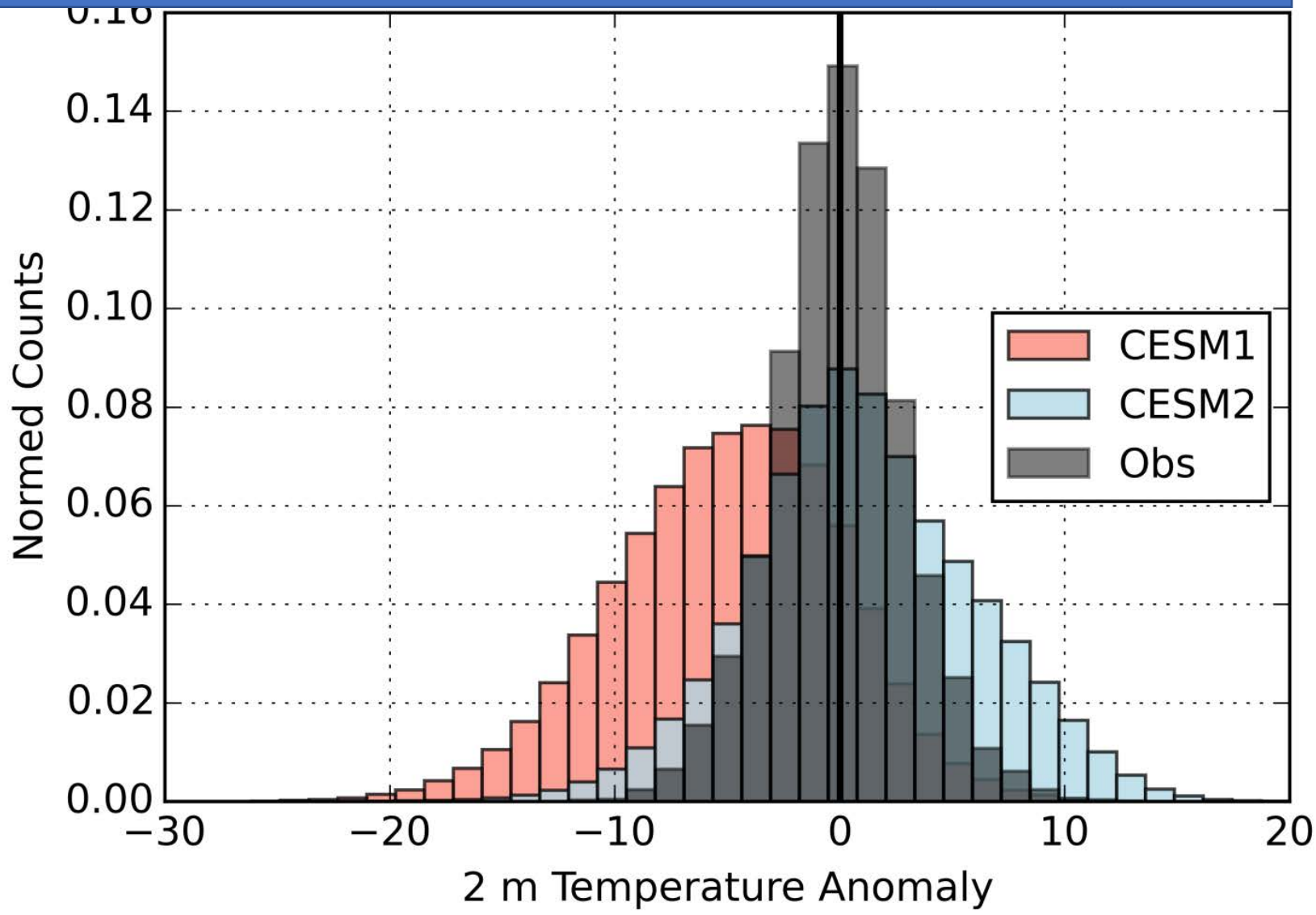
Ground Based Stations (147) – Winter Only (NDJ)

- **CESM1** winter values are biased colder
- **CESM2** winter anomalies peak at zero

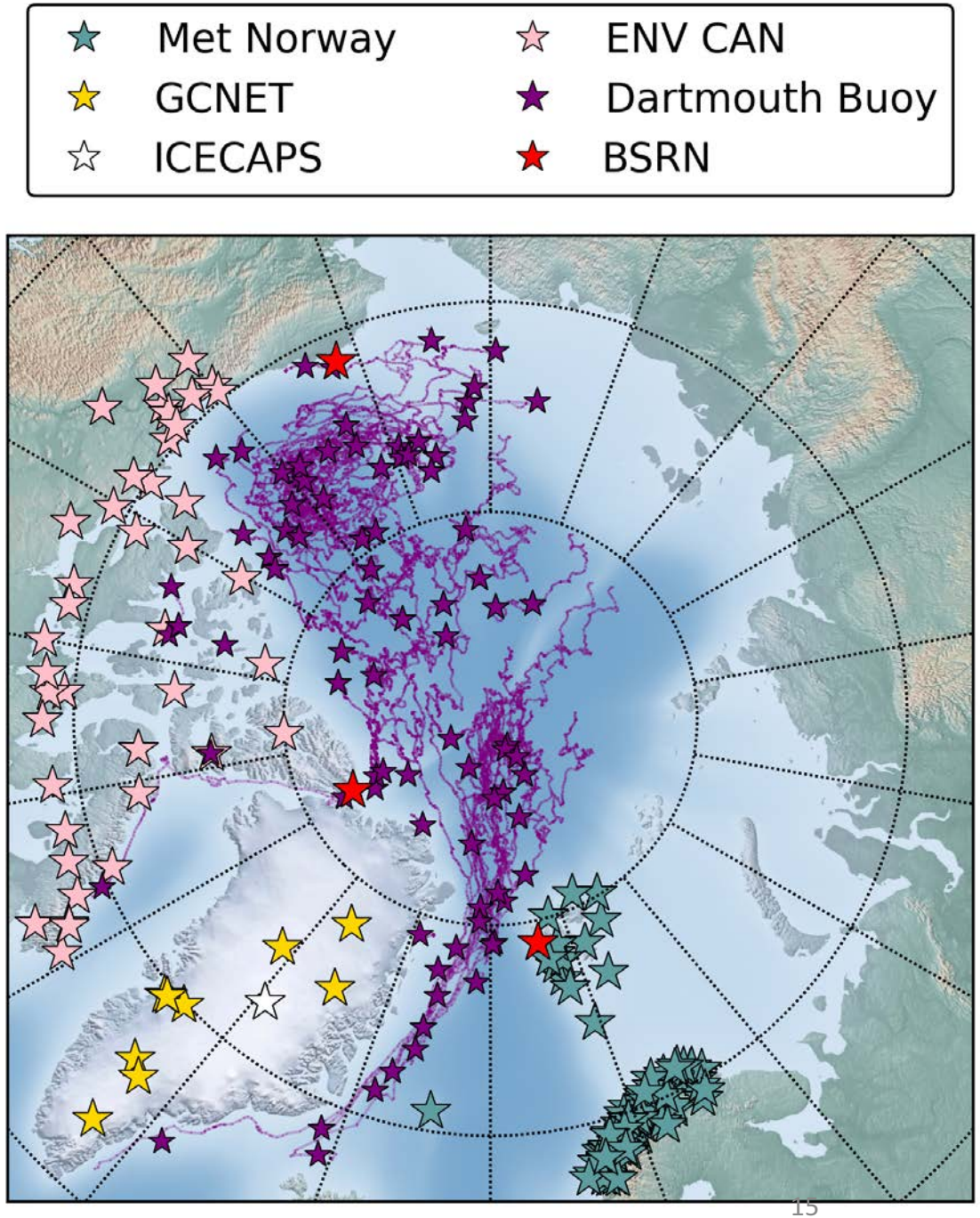


Ground Based Stations (147) – Winter Only (NDJ)

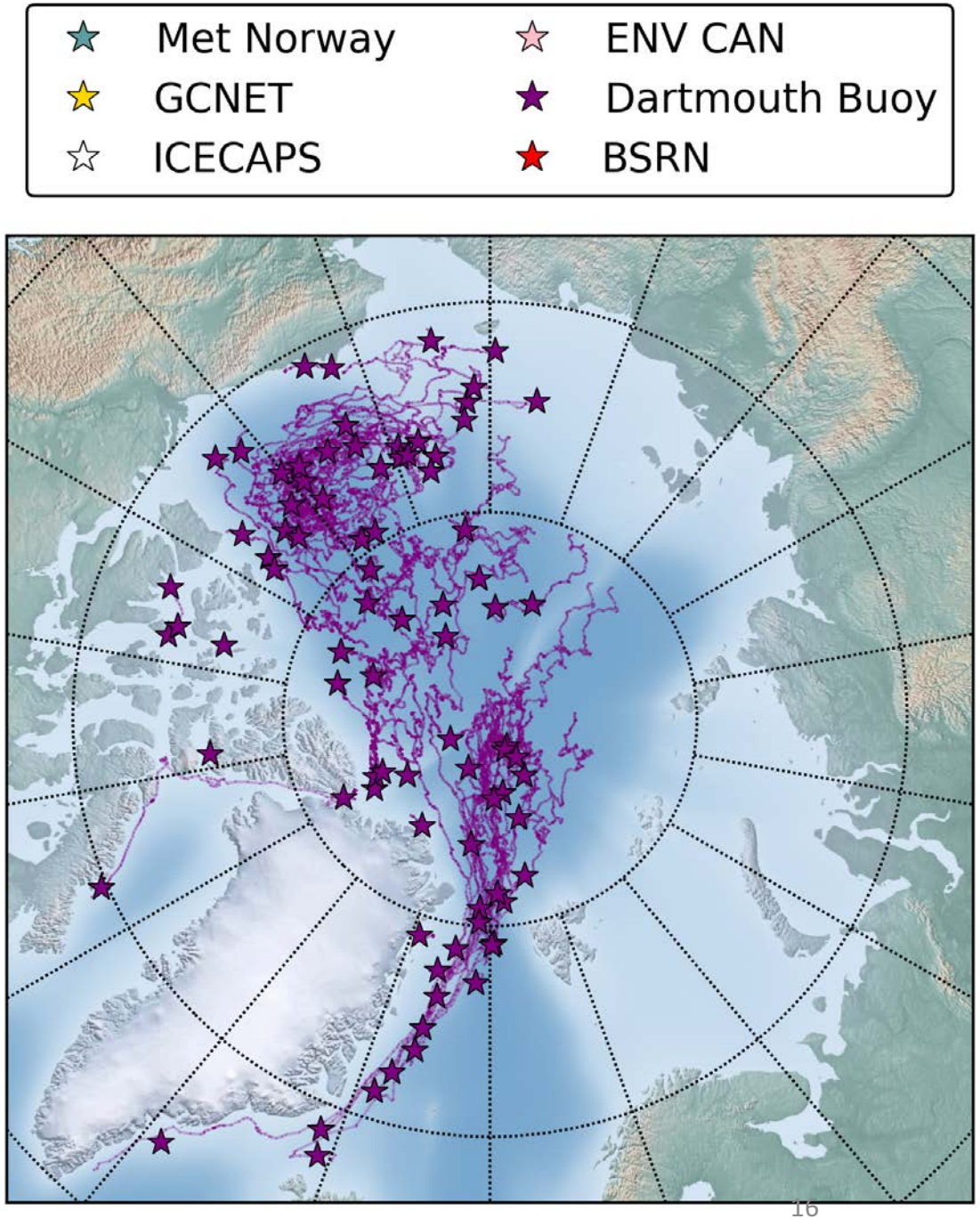
- Observations show **CESM2** may be skewed slightly too warm in winter
- However **CESM2**'s representation of 2m air temperature is much closer to observed (*for these 147 stations*)



Great! But how does it CESM2 do over the sea ice?

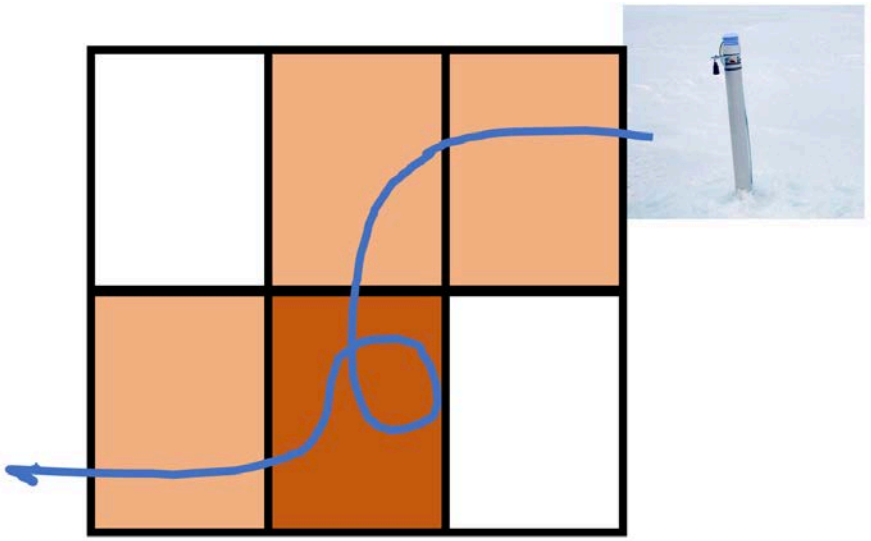


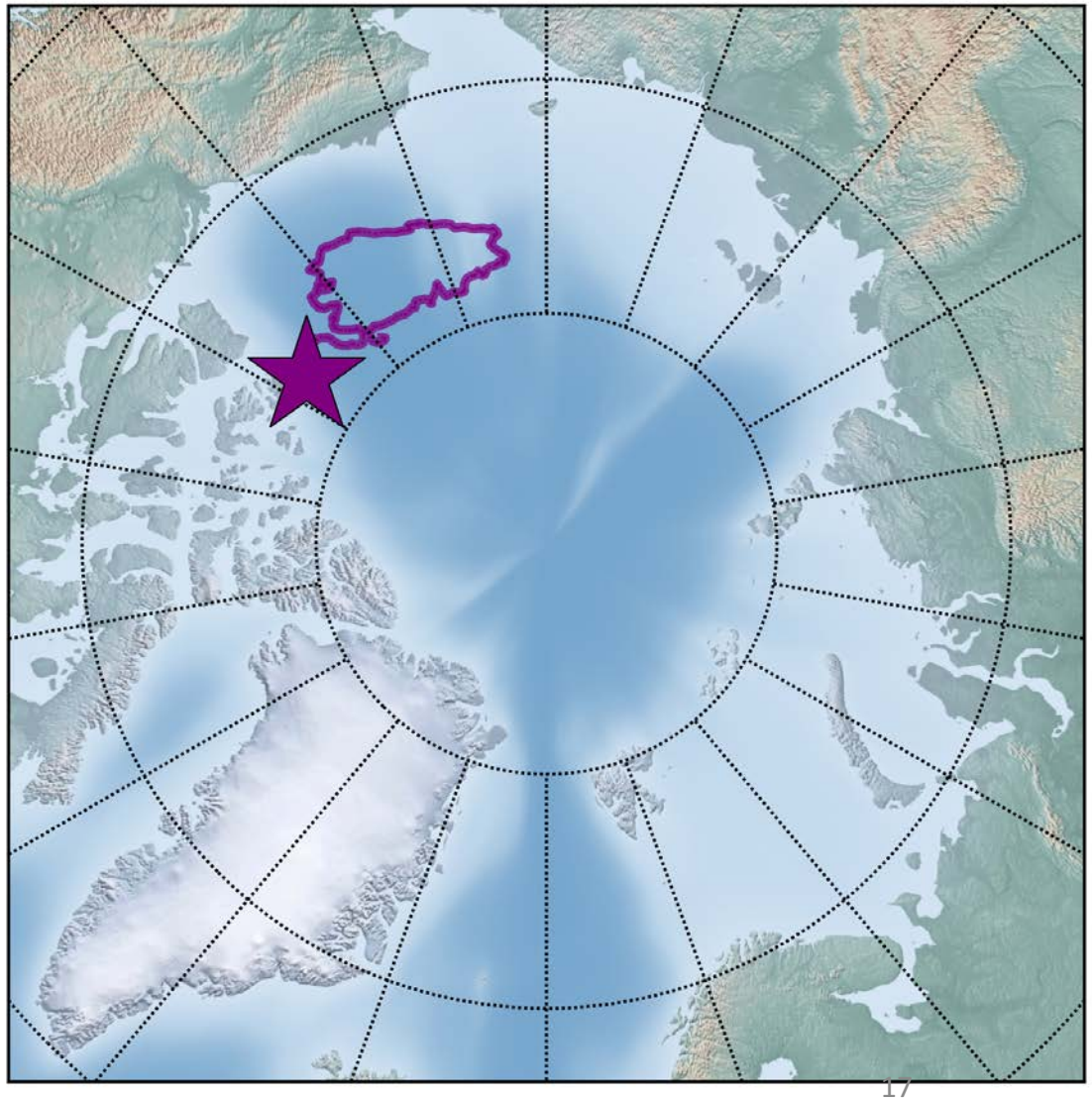
- Total: 85 buoys with a minimum of 2 months of usable data (>15 days in the month)
  - 764 months
- 58 buoys with a minimum of 6 months of data
  - 659 months
- 19 buoys with 12 months or more of data



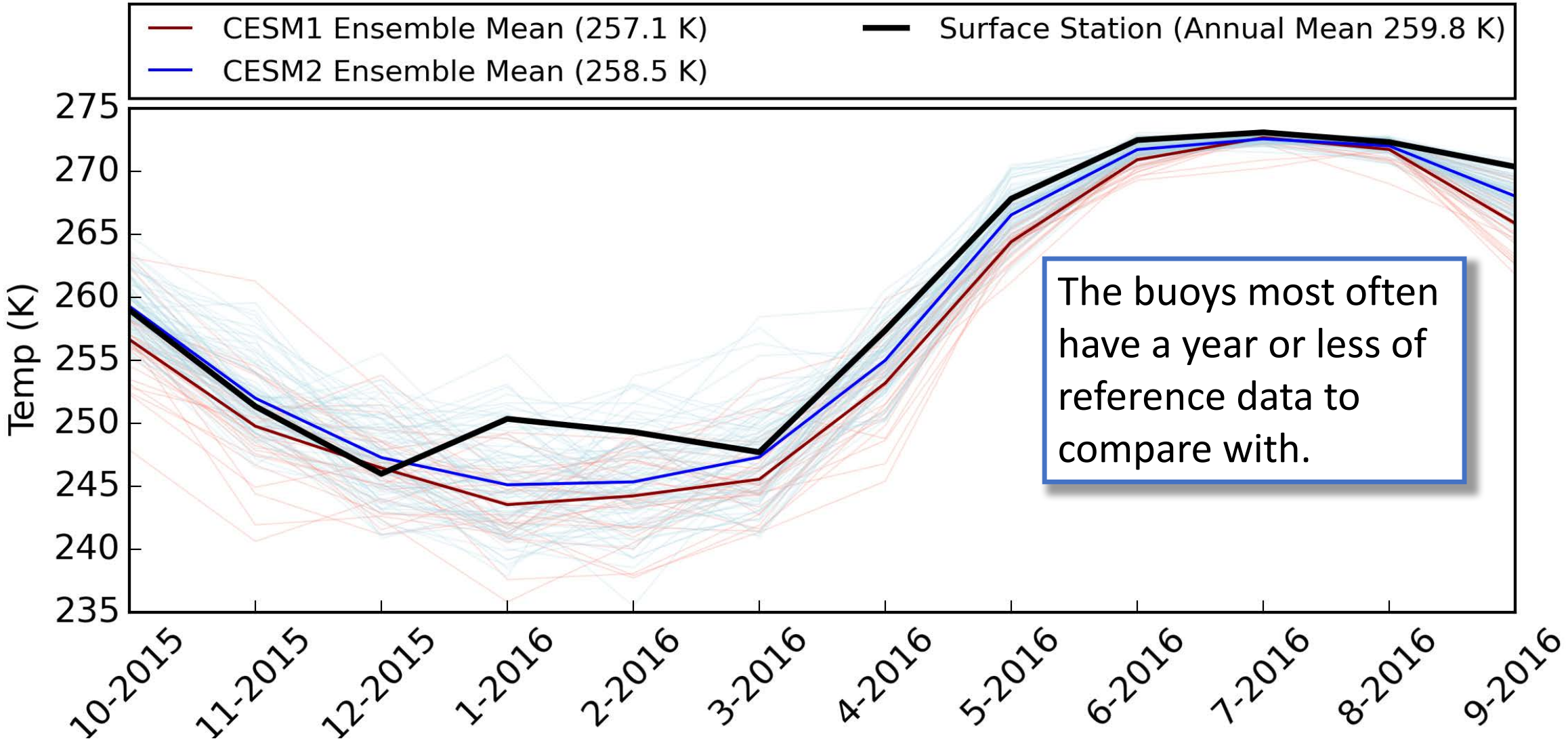
Buoy Example – 2015J

- Monthly CESM values are a mean of all grid boxes the buoy travelled through, weighted by the number of days spent in each box

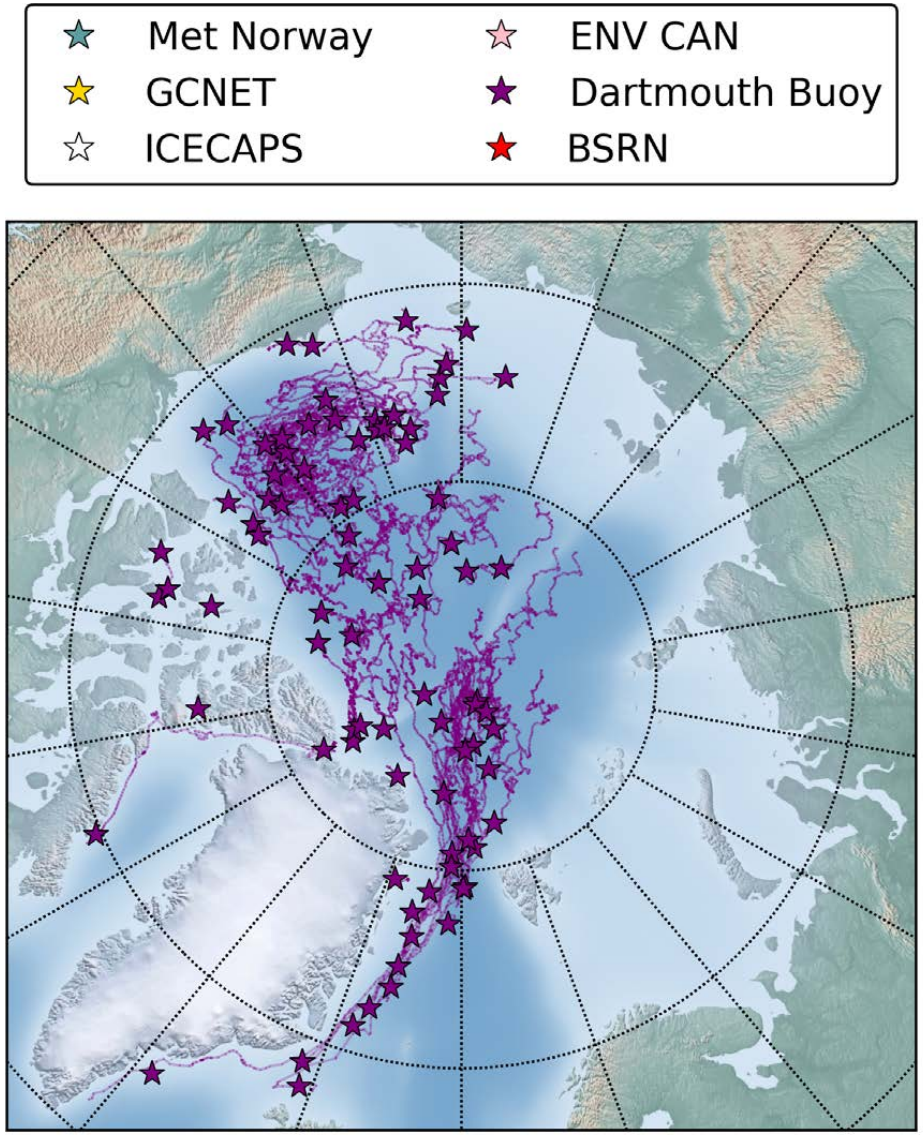


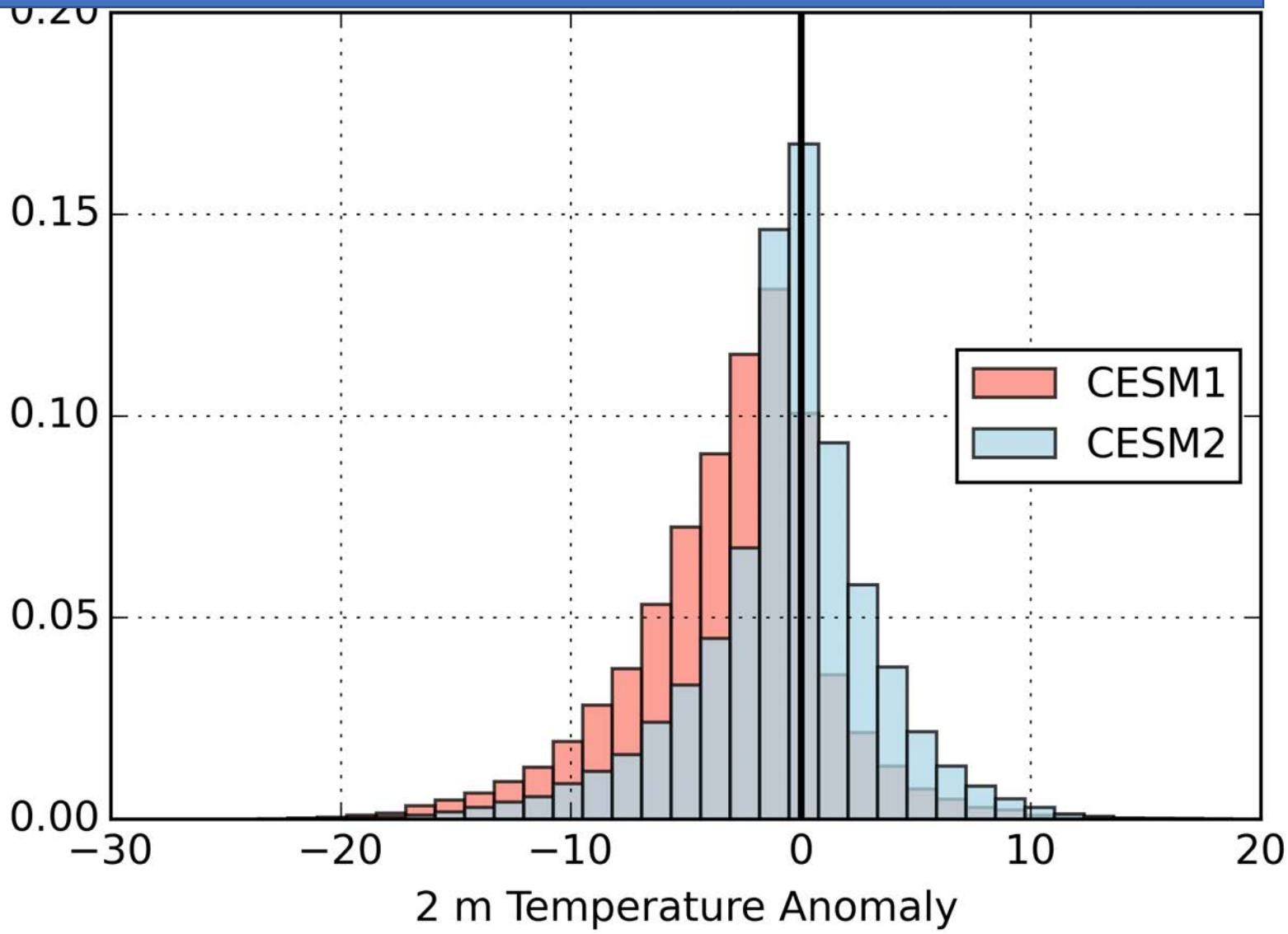


Buoy 2015J Lon/Lat:-124.82, 77.35



Buoys (85) – All months (764)



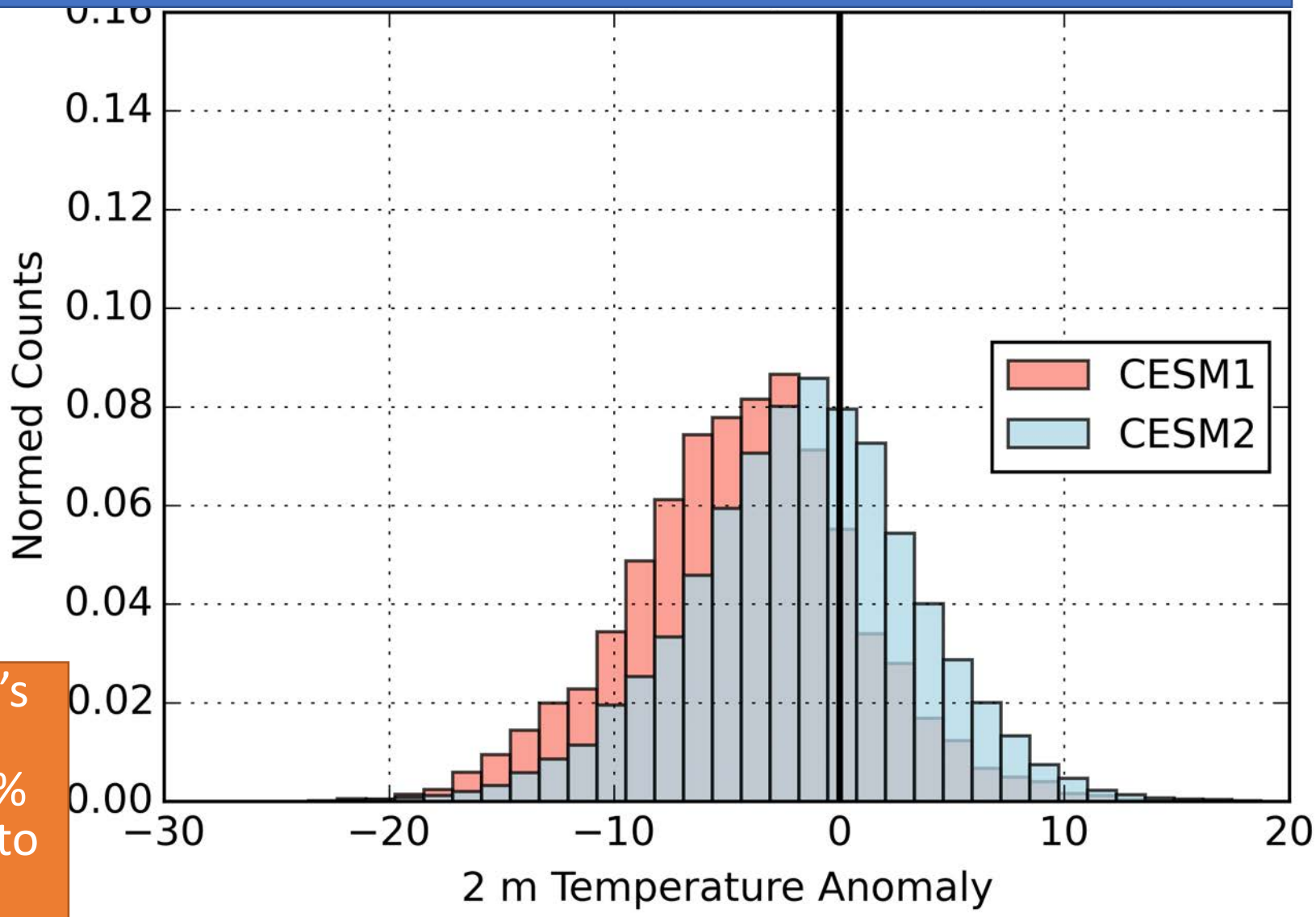


Buoys (85) – Winter Only (NDJ)

- The buoys show a consistent story with the ground-based stations:

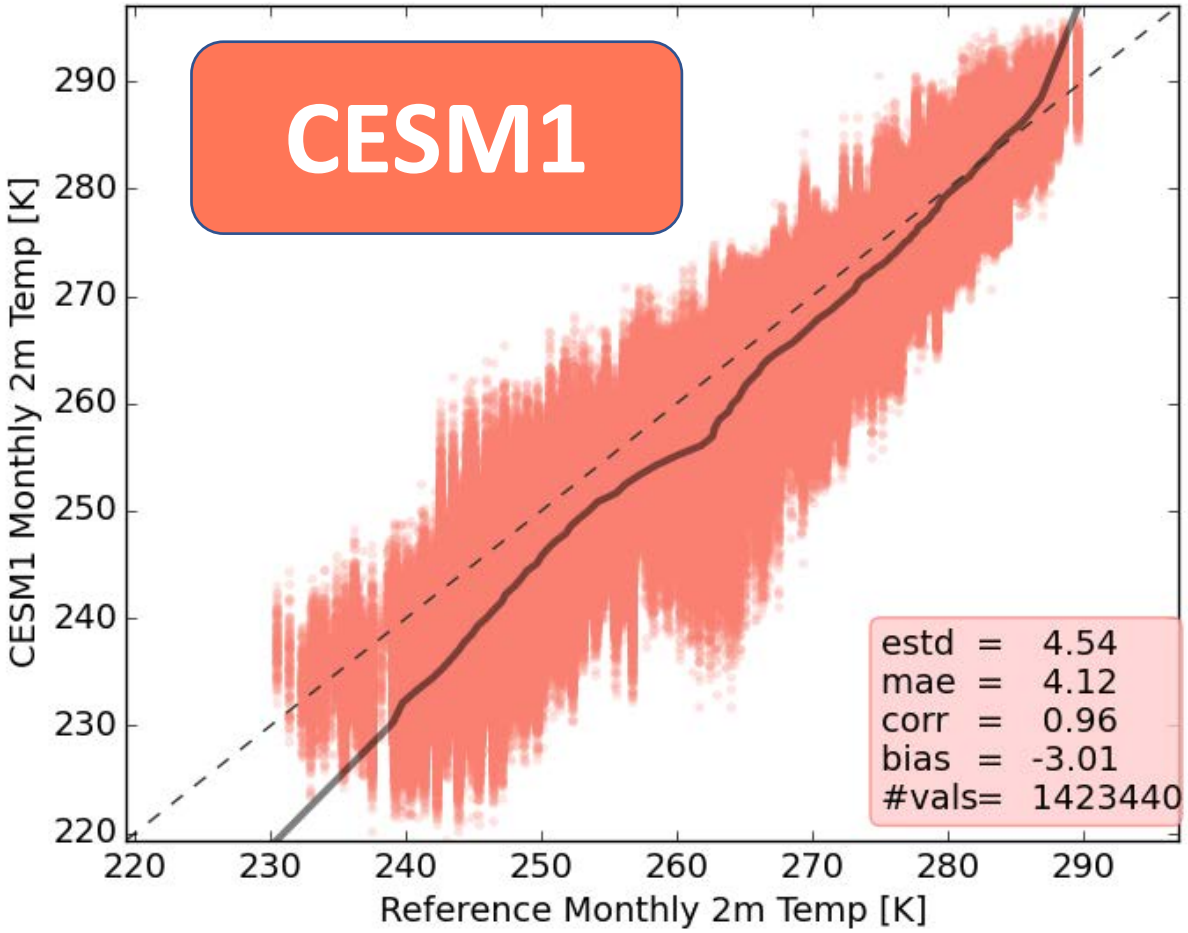
  CESM2's representation of Arctic monthly 2m air temperature is much closer to observed

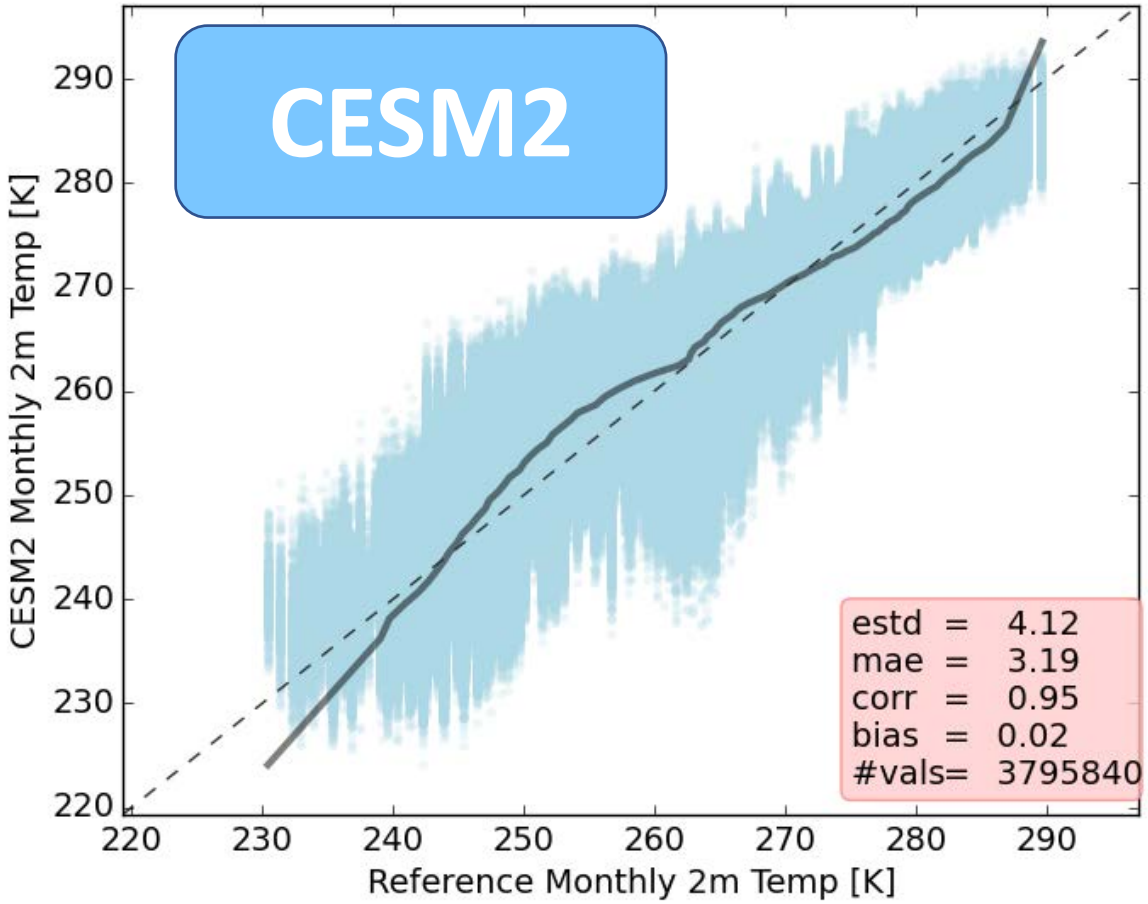
NOTE: For monthly statistics, it's important to look at the buoys alone because they are only ~2% of the data points when added to the station data.



A few more quantitative statistics

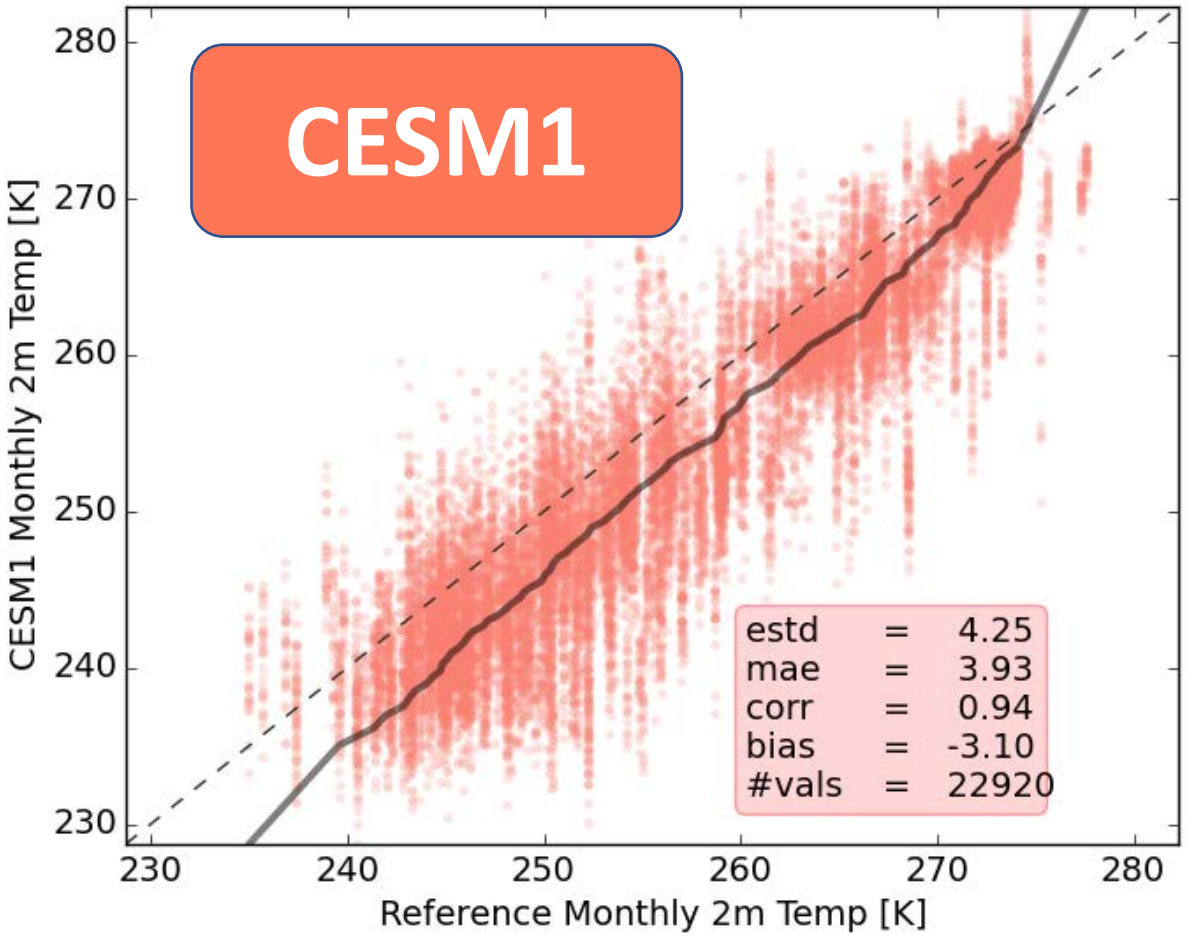
Ground Based Stations (147) – no buoys

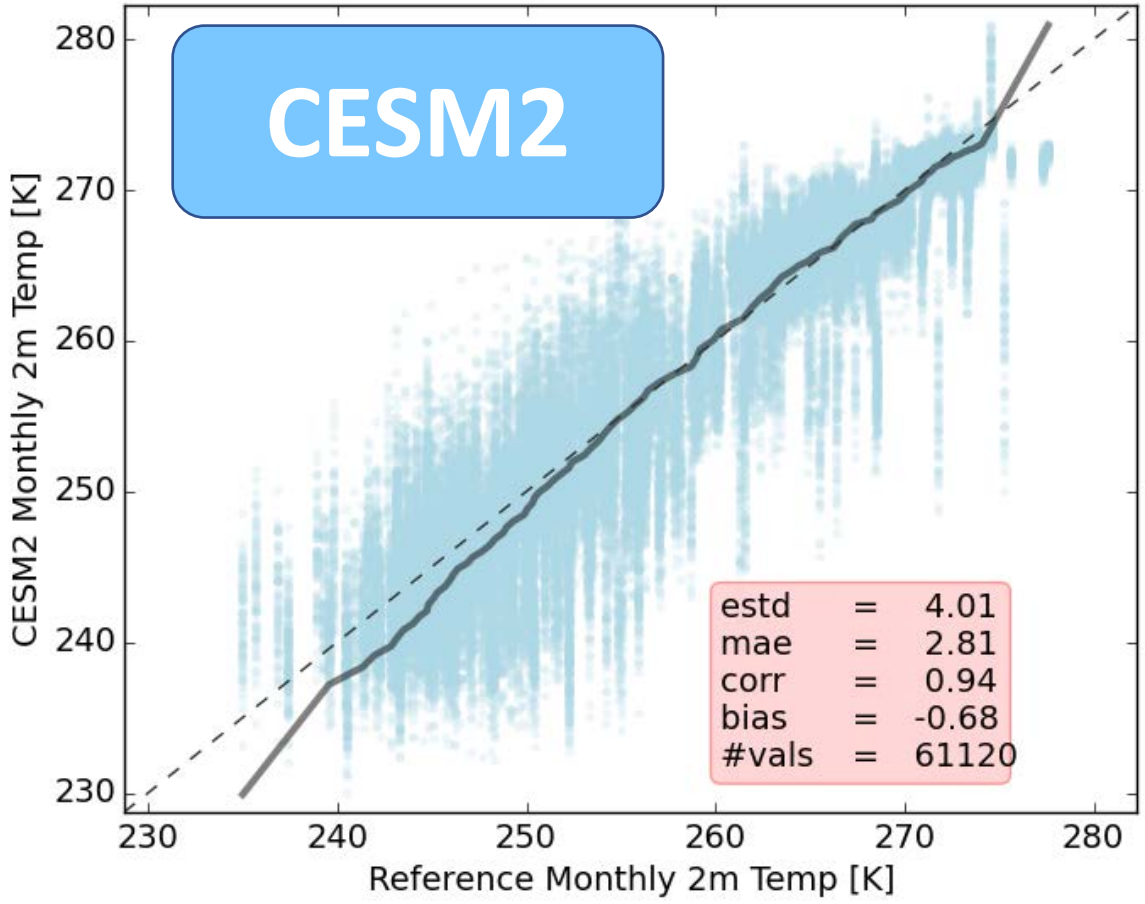




- **CESM1** does worse at colder temperatures – fitting with winter
- **CESM2** has eliminated the -3K cold bias

Only Buoys (85)



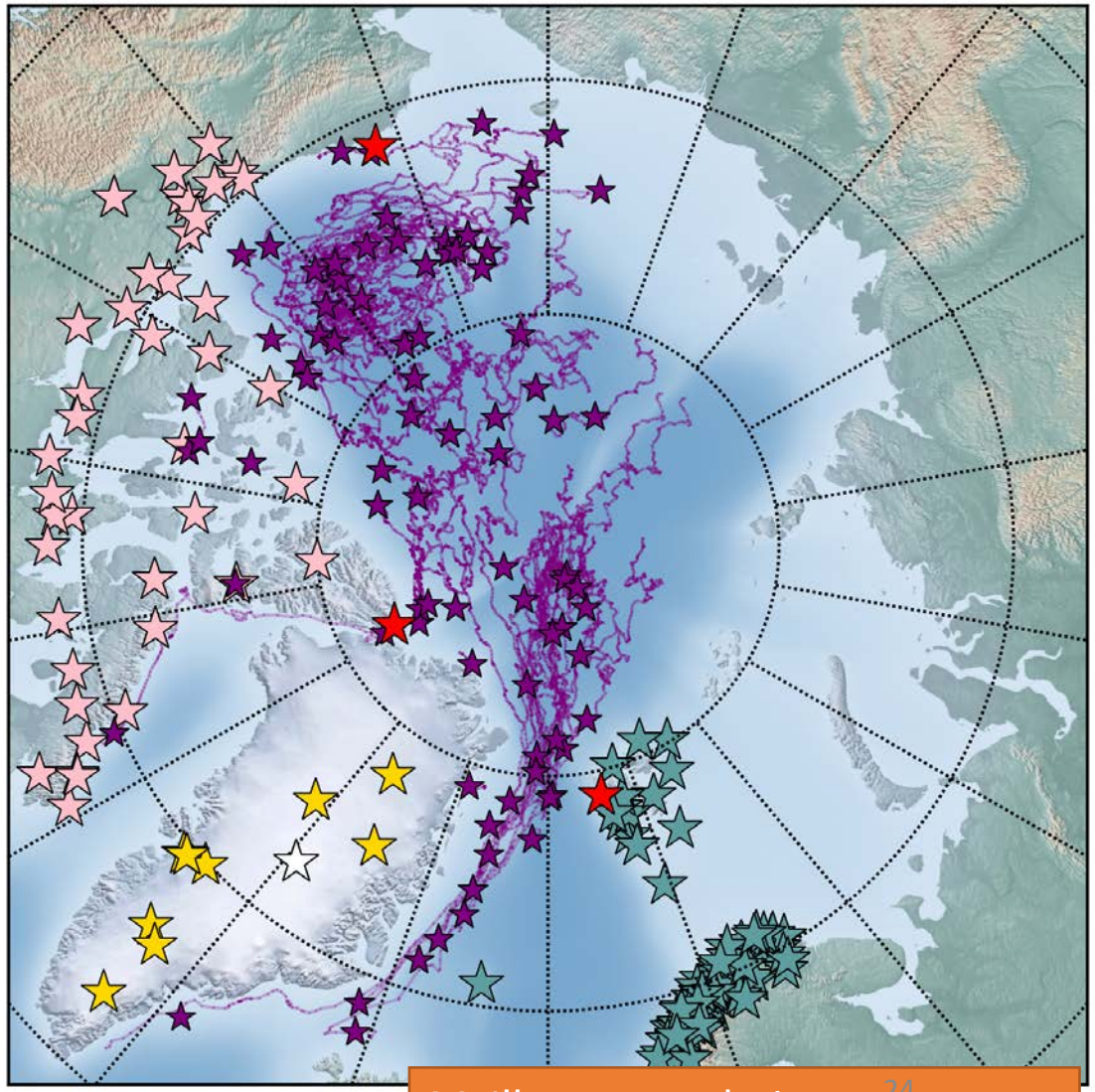


- **CESM2** has reduced the cold bias to -0.68K

Conclusions – Future Work

- The warmer temperatures seem to be an improvement! *(Based on the stations and buoys we have looked at so far)*

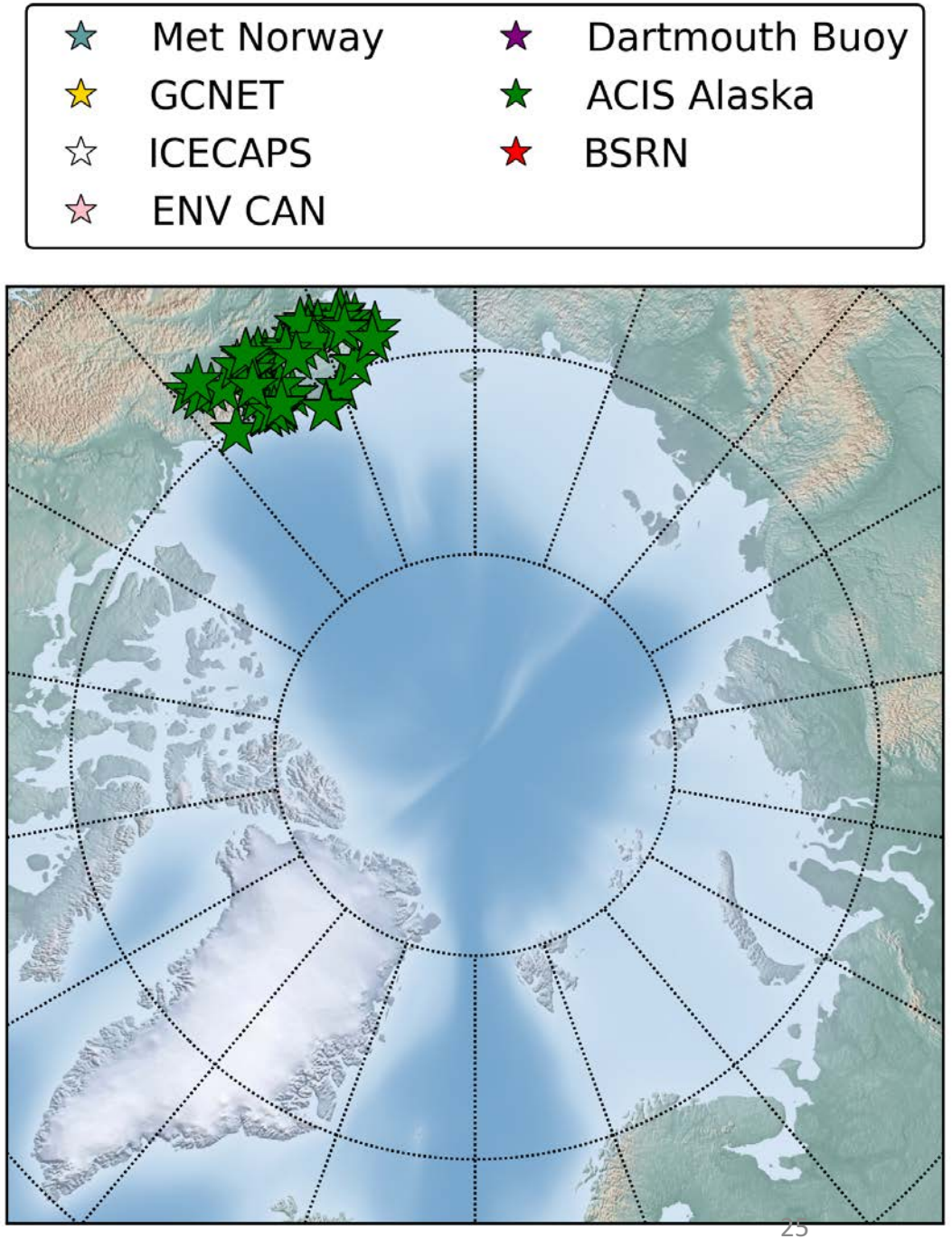
- Up next:
  - Add stations in Alaska (see next slide)
  - Add PROMICE Greenland stations
  - Thin Norway stations
  - *Does anyone know of available Russian temperature data?*



McIlhattan et al., *in prep*

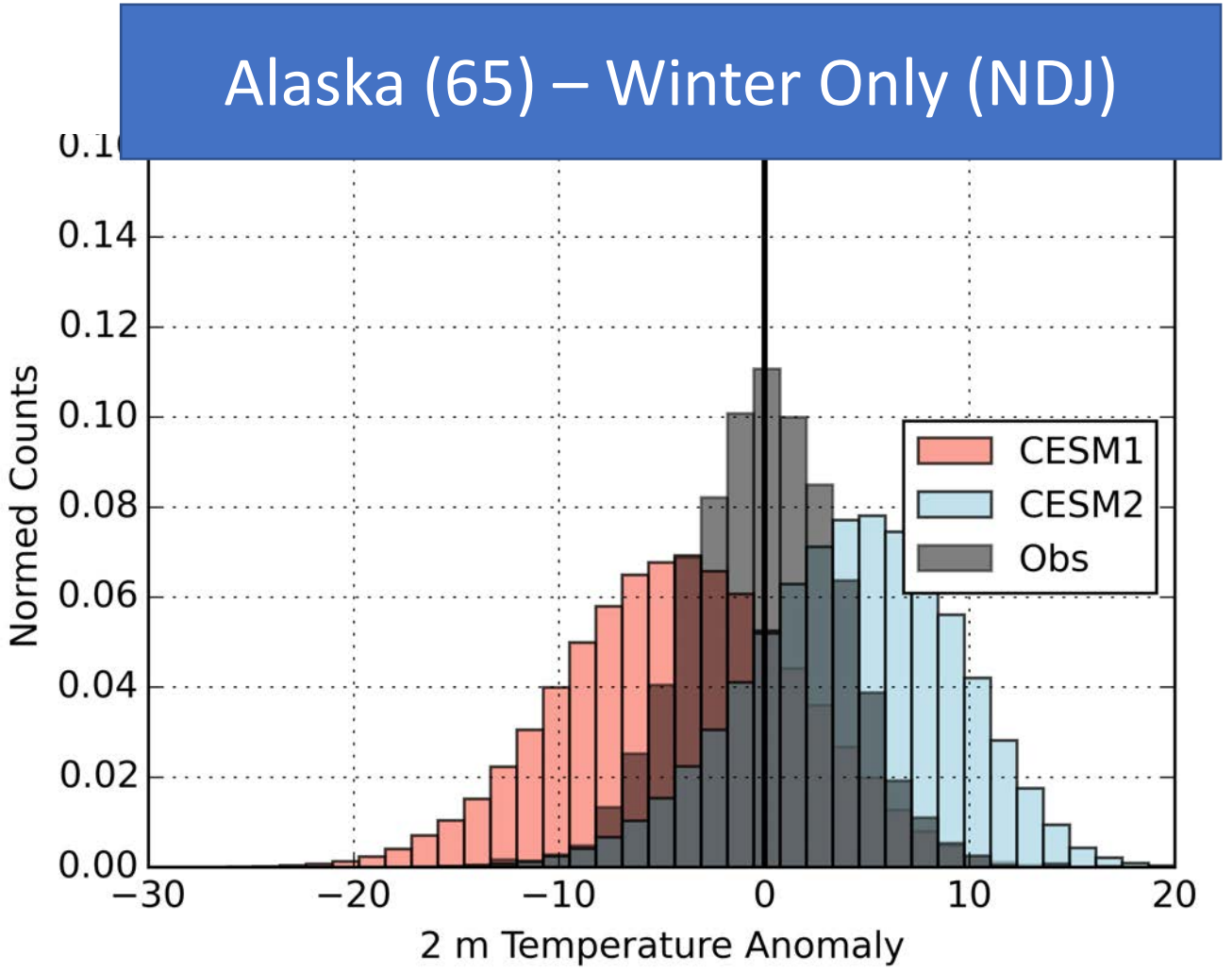
Fresh Results (and a puzzle): Alaska

- 65 ground-based stations in northern Alaska obtained from Applied Climate Information System (ACIS)



Fresh Results (and a puzzle): Alaska

- **CESM1** still too cold relative to observations, but **CESM2** is distinctly warmer in winter.
- Not related to absorbed SW
- The increase in downwelling LW is not larger than elsewhere in the Arctic
- **Are there surface/circulation changes unique to northern Alaska that anyone is aware of?**



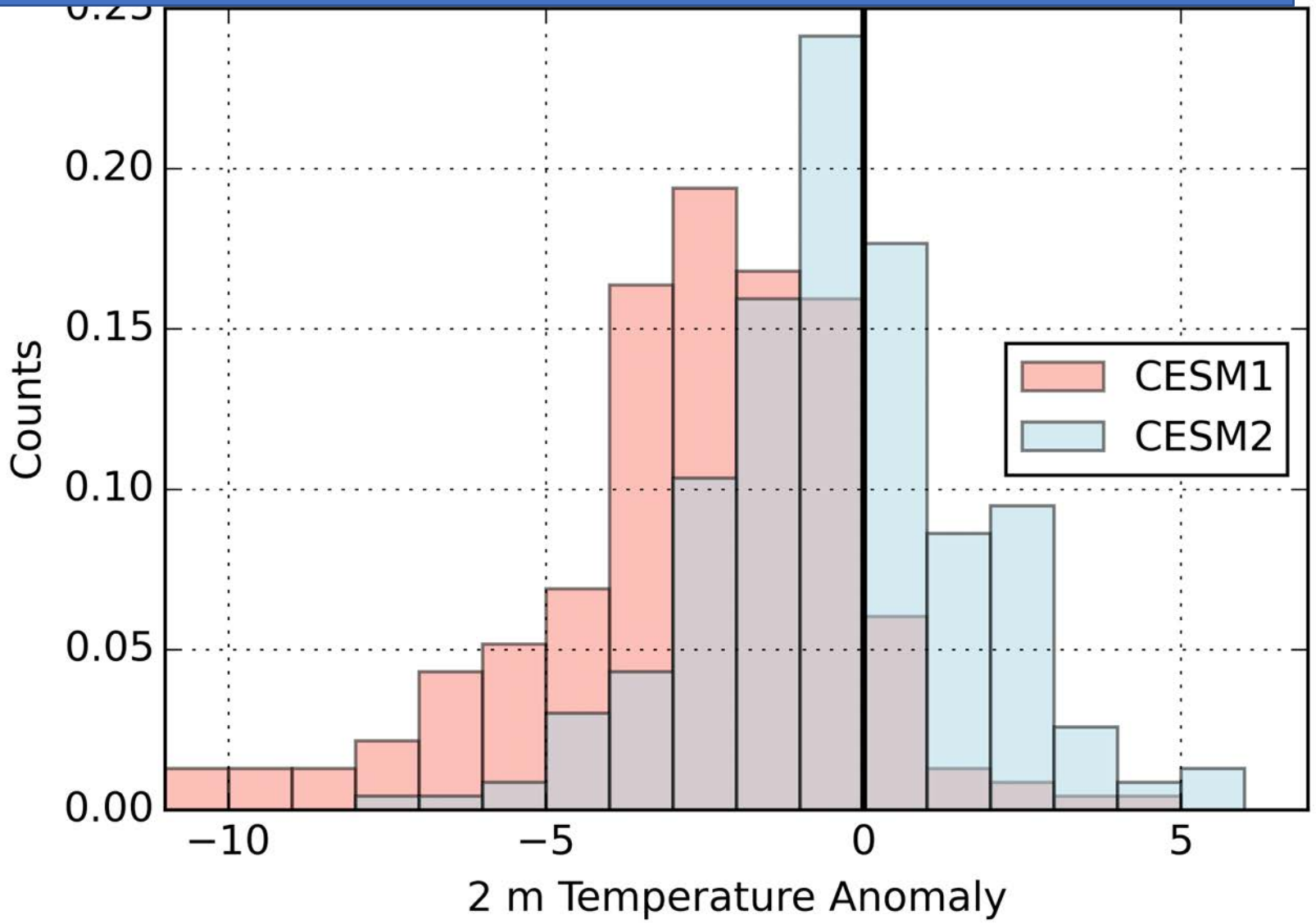
Thank you!
Questions?

mcilhattan@wisc.edu

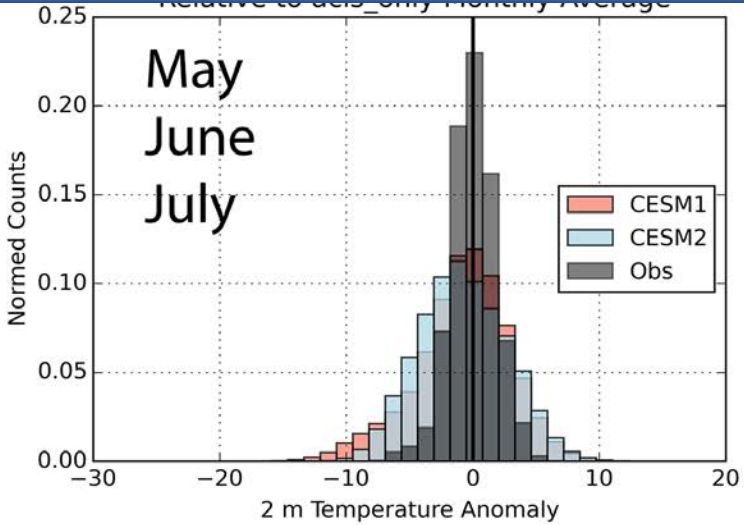
Extra Slides

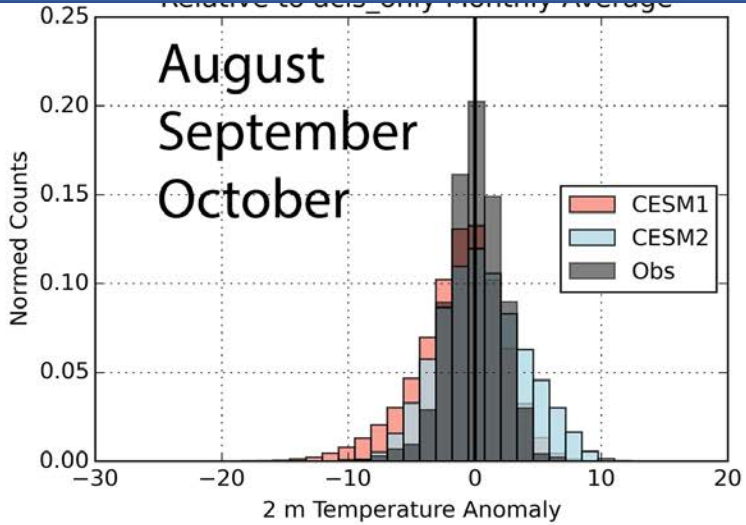
Buoys and Ground Based Stations (232) – Lifetime Average

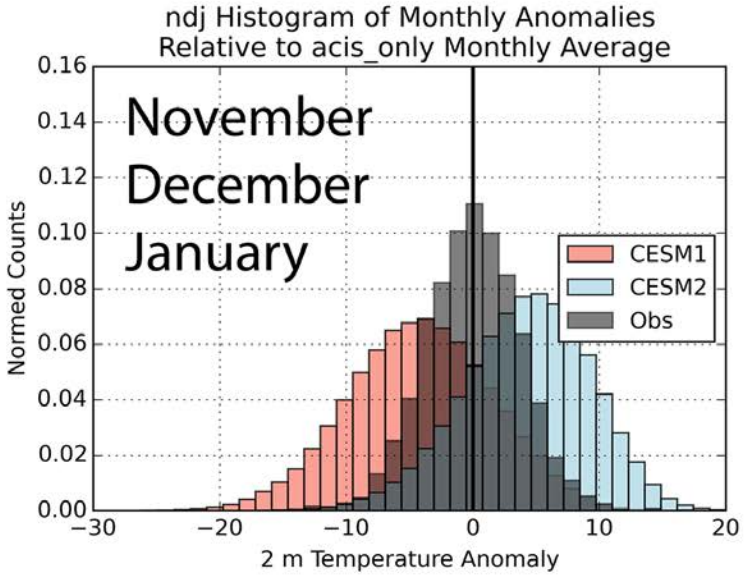
- When taking only a single average temperature from the station and each version of CESM
- **CESM2**'s representation of Arctic monthly 2m air temperature is much closer to observed

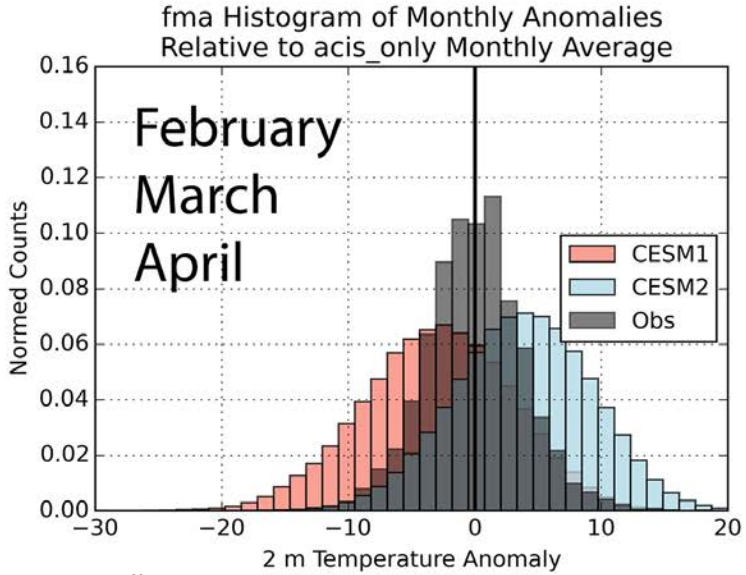


Alaska Stations - Seasonal

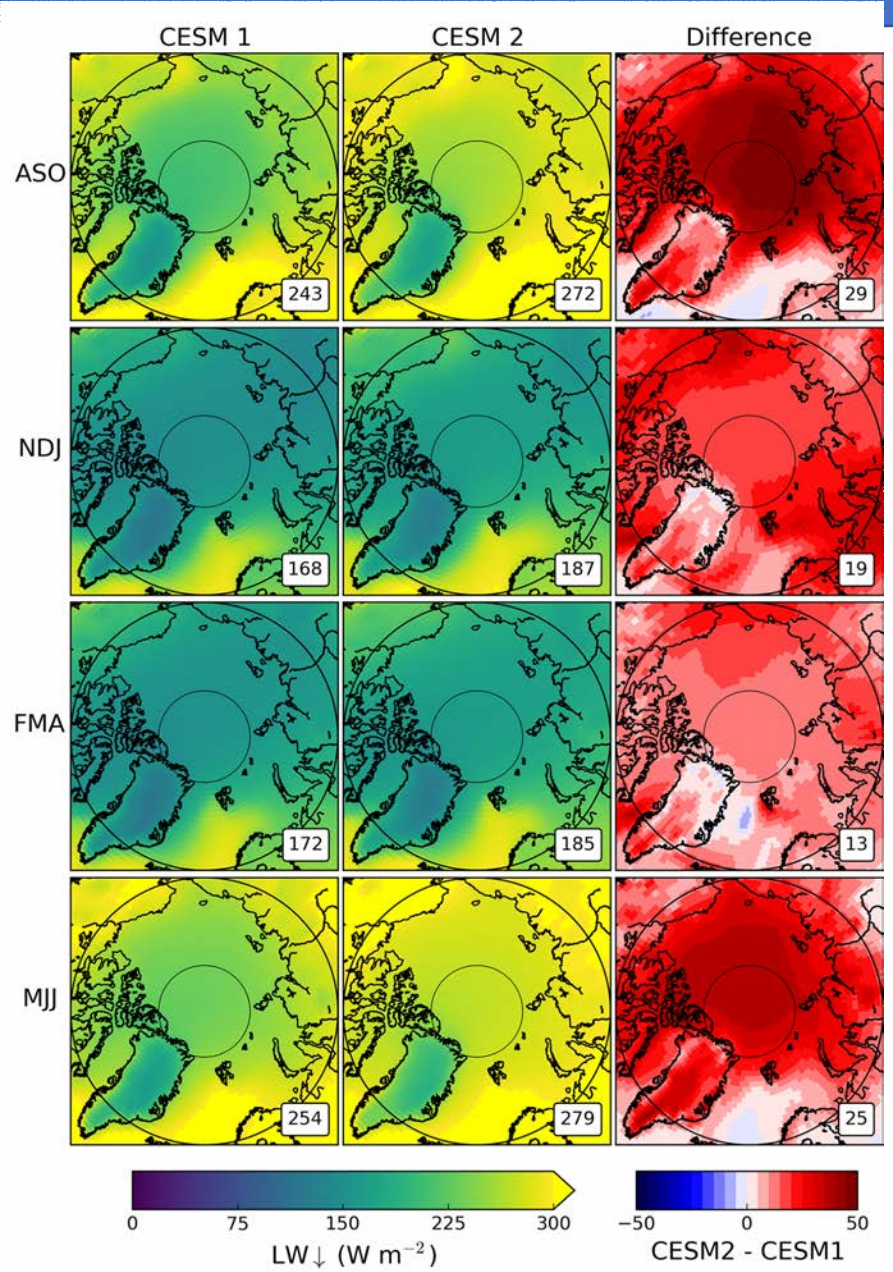


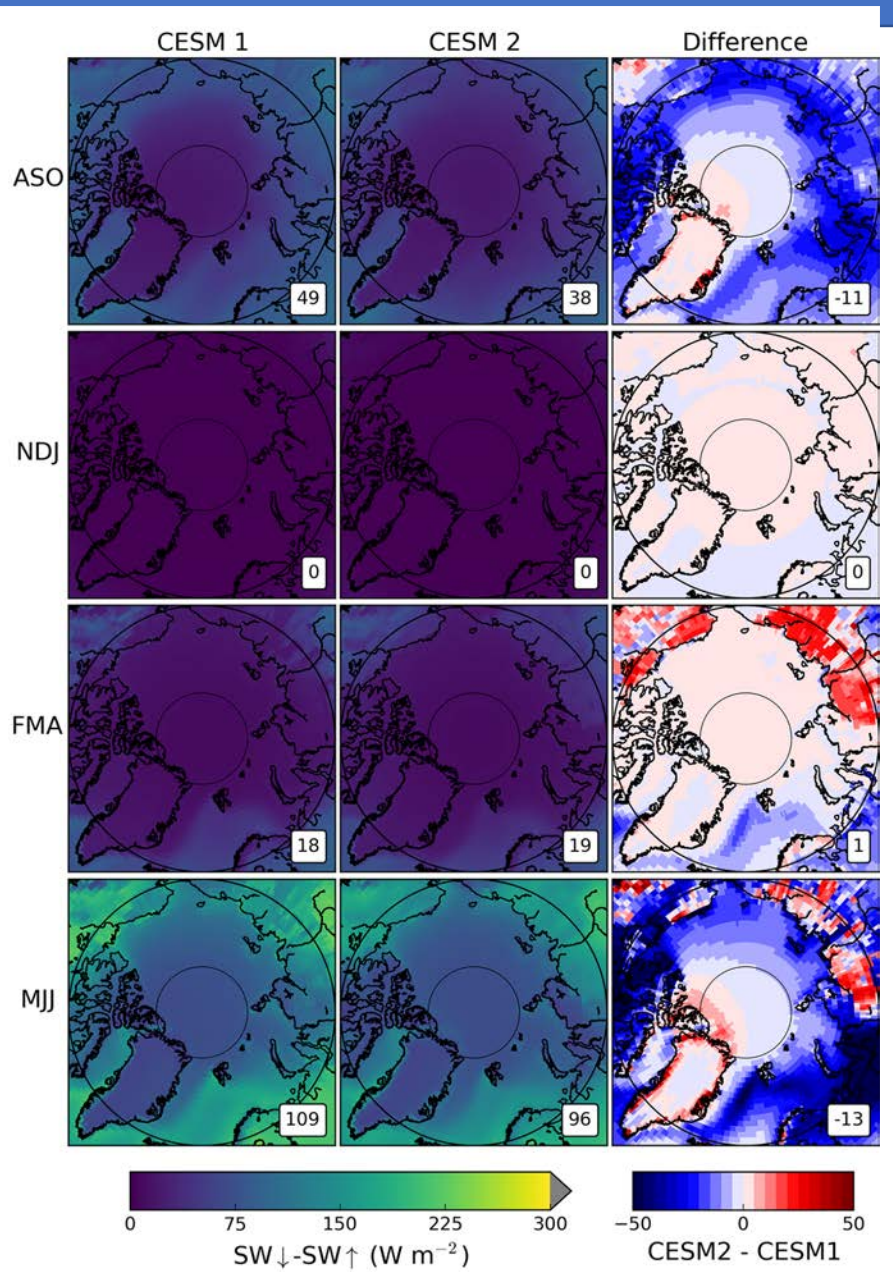






Downwelling LW and Absorbed SW Radiation





Skin Temperature and Near Surface Air Temperature