Sixty Years of Widespread Warming in the Southern Mid- and High-Latitudes (1957-2016)

Megan E. Jones[1], David H. Bromwich[1], Julien P. Nicolas[1], and Jorge Carrasco[2]

[1]Polar Meteorology Group, Byrd Polar and Climate Research Center, The Ohio State University, Columbus, OH, USA

[2]Centro de Investigación GAIA Antártica, Universidad de Magallanes, Punta Arenas, Chile

Objectives

- Put temperature changes in West Antarctica and the Antarctic Peninsula into a **larger temporal and spatial perspective** (1957-2016)
- Expand on previous studies by using more station data and multiple time periods
- **Prioritize using observational data** over reanalyses before 1979
- Also consider sea surface temperatures, atmospheric circulation patterns, and indices of climate modes to determine temperature drivers

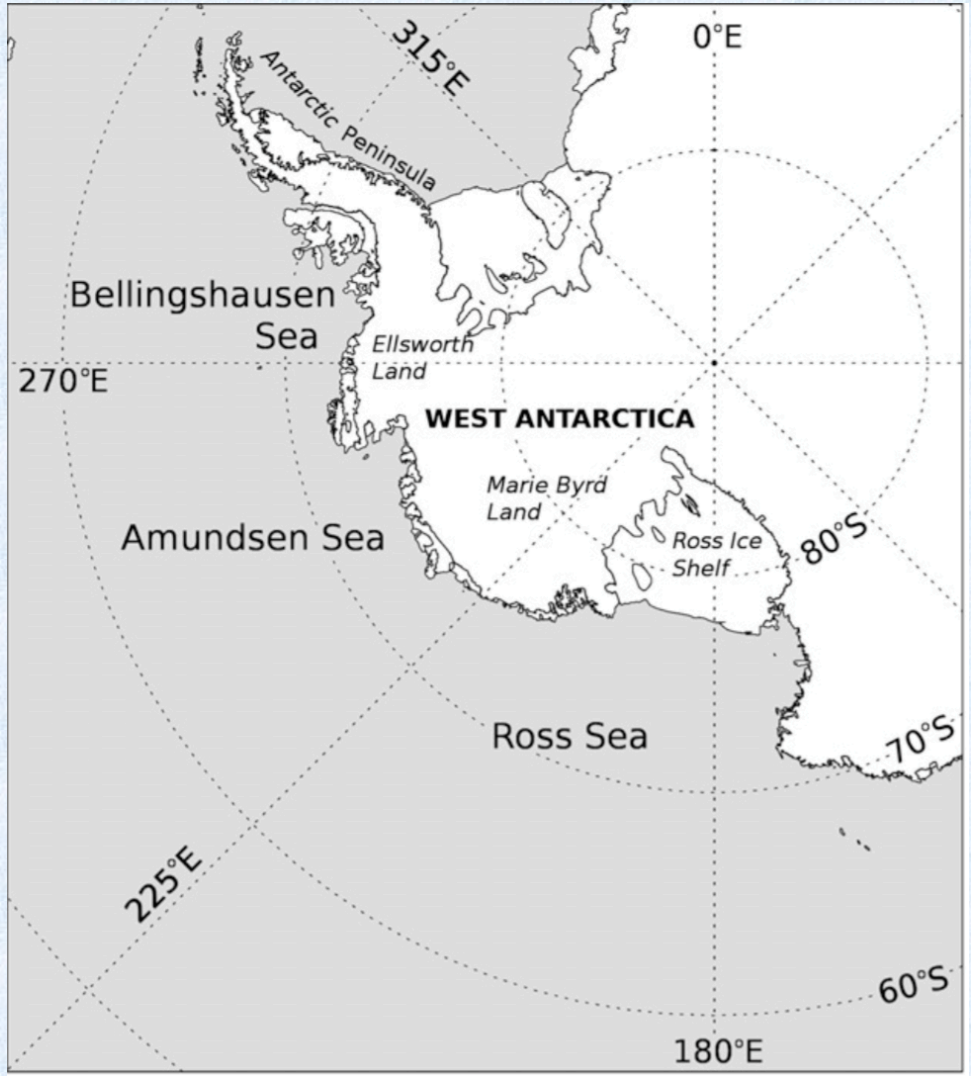
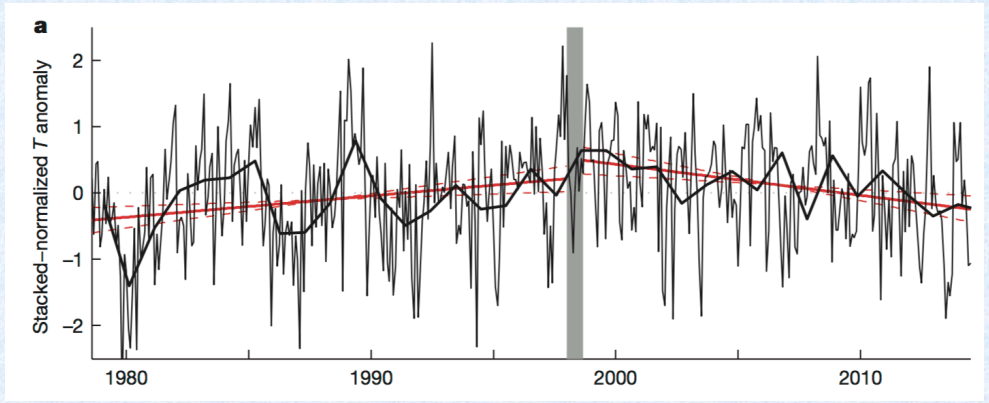
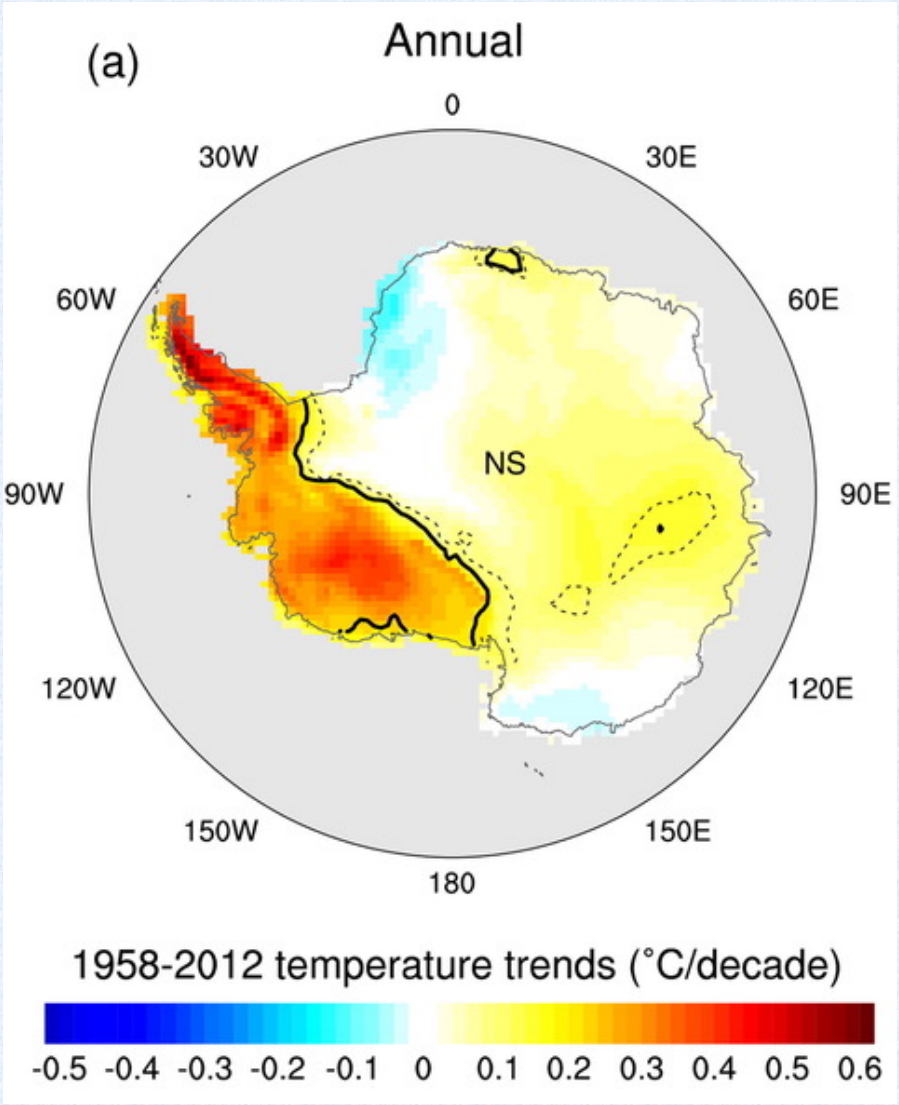


Figure from Hosking et al. 2013

Background

- Trends since the late 1950s typically reveal **warming on the Peninsula and West Antarctica**, with East Antarctica relatively stable
- Recent studies have shown strong cooling in the Antarctic Peninsula region during austral summer of the past 17 years



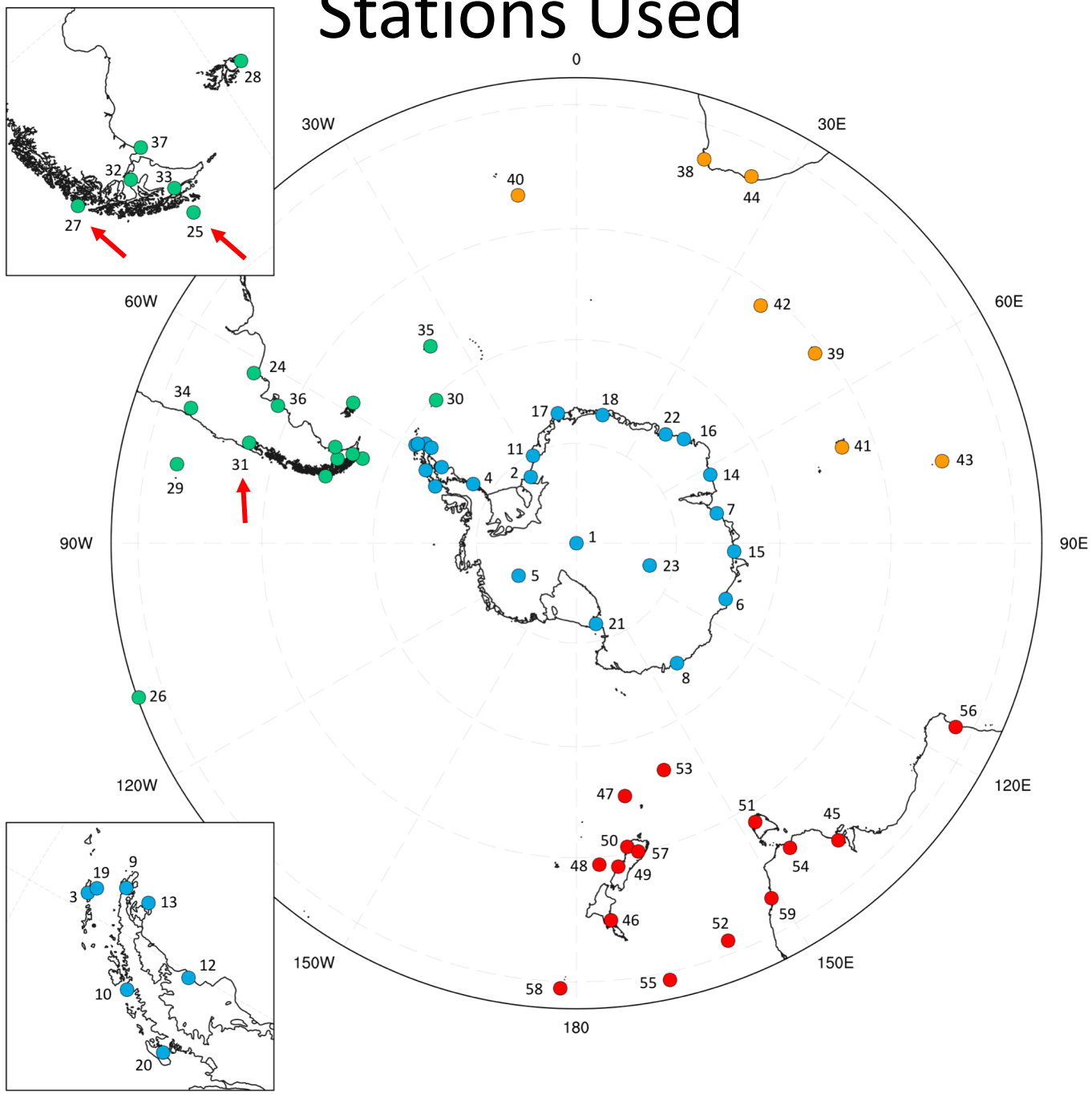


Left: from Turner et al. 2016; Above: from Nicolas and Bromwich 2014

Data

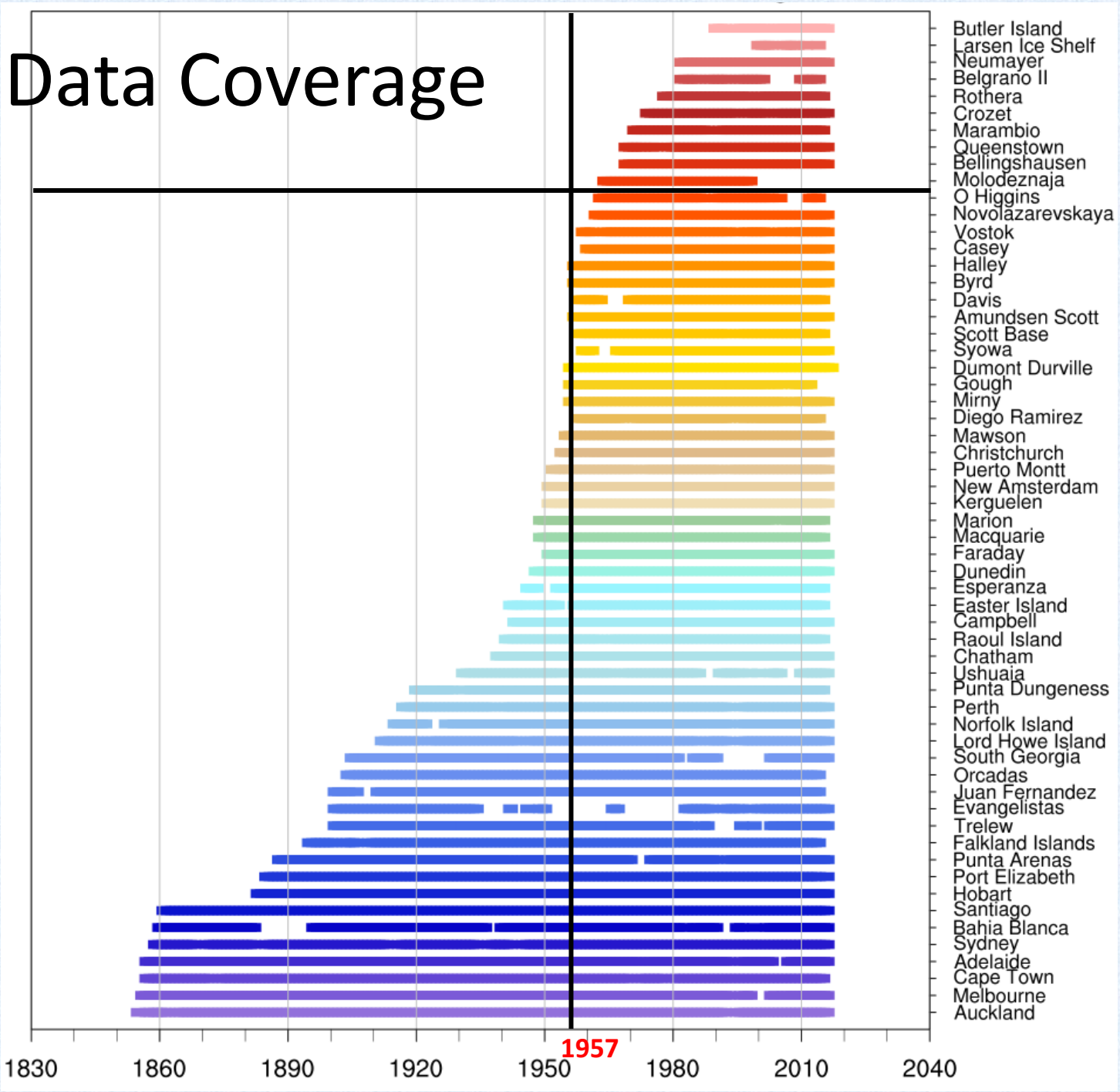
- 2-meter monthly air temperature from station observations (1957-2016)
  - READER archive, NCAR RDA ds 570.0, NOAA NCEI, New Zealand National Climate Database, Meteo-France, Global Historical Climatology Network, Navy Weather Service of Chile, Nicolas and Bromwich 2014, Lister and Jones 2015
- MSLP and 500 Geopotential Heights from ERA-Interim reanalysis (1979-2016)
- SST data from HadISST1 observation dataset (1957-2016)
- Southern Annular Mode Index from Marshall et al. 2003 (1957-2016)
- Indices for the El Niño Southern Oscillation and Pacific Decadal Oscillation from CPC (1957-2016)

Stations Used

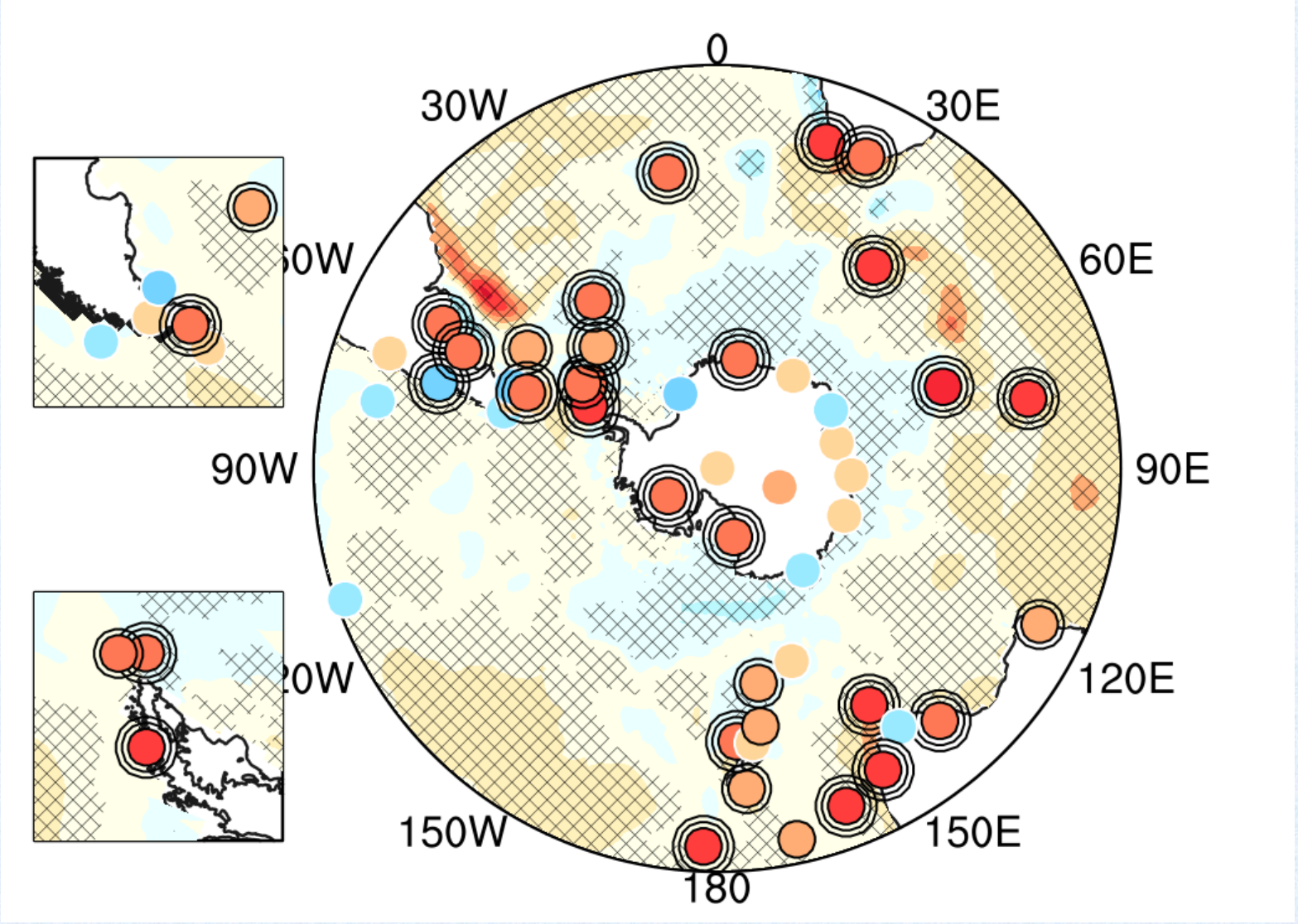


1. Amundsen-Scott
2. Belgrano II
3. Bellingshausen
4. Butler Island
5. Byrd
6. Casey
7. Davis
8. Dumont D'Urville
9. Esperanza
10. Faraday/Vernadsky
11. Halley
12. Larsen Ice Shelf
13. Marambio
14. Mawson
15. Mirny
16. Molodeznaja
17. Neumayer
18. Novolazarevskaya
19. O'Higgins
20. Rothera
21. Scott Base
22. Syowa
23. Vostok
24. Bahia Blanca
25. Diego Ramirez
26. Easter Island
27. Evangelistas
28. Falkland Island
29. Juan Fernandez
30. Orcadas
31. Puerto Montt
32. Punta Arenas
33. Punta Dungeness
34. Santiago
35. South Georgia
36. Trelew
37. Ushuaia
38. Cape Town
39. Crozet
40. Gough
41. Kerguelen
42. Marion
43. New Amsterdam
44. Port Elizabeth
45. Adelaide
46. Auckland
47. Campbell
48. Chatham
49. Christchurch
50. Dunedin
51. Hobart
52. Lord Howe Island
53. Macquarie
54. Melbourne
55. Norfolk Island
56. Perth
57. Queenstown
58. Raoul Island
59. Sydney

Annual Station Data Coverage



1957-2016 Annual Temperature Trends



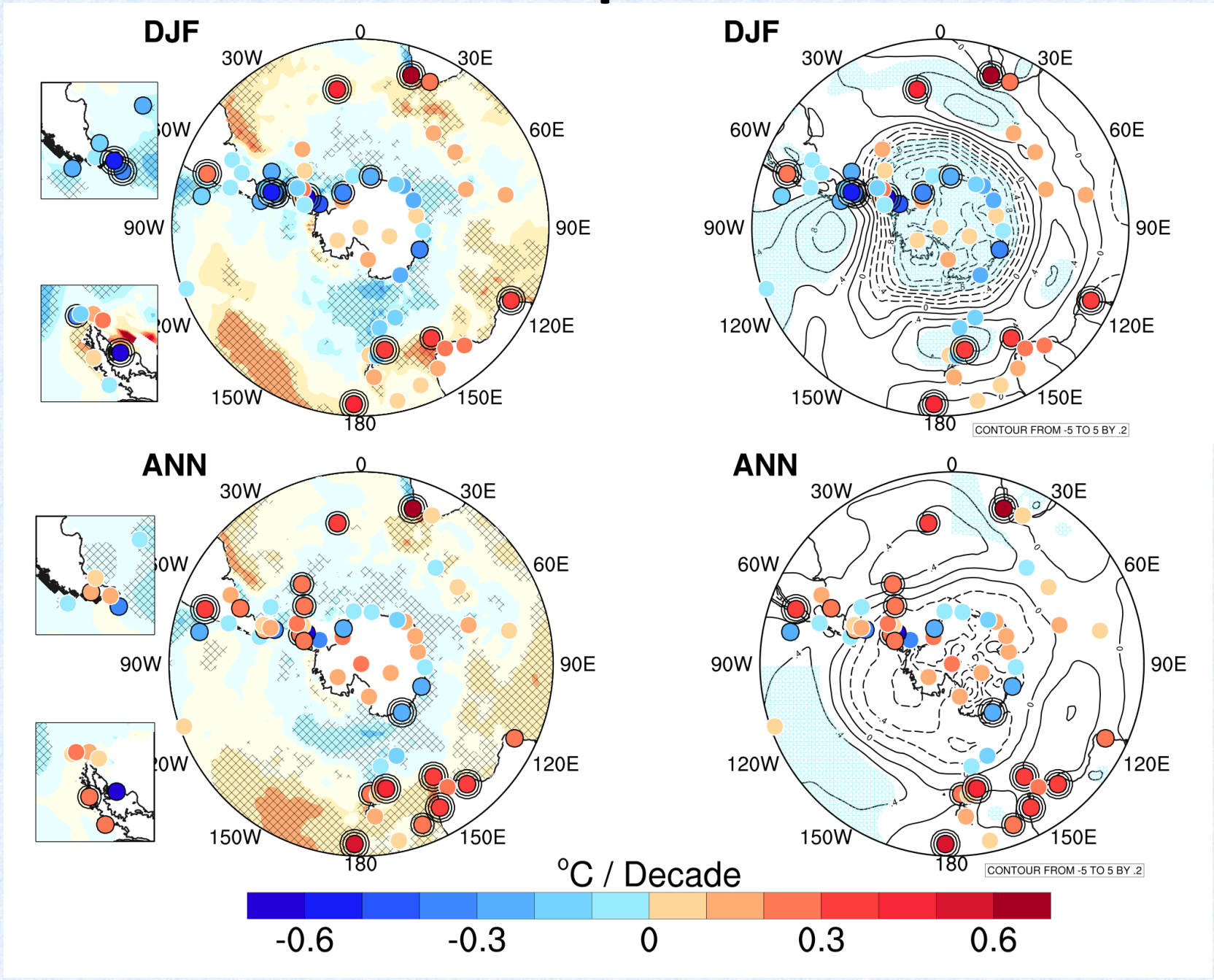
Widespread, statistically significant warming across the mid-latitudes

Antarctic Peninsula and West Antarctica are both warming at ~0.3 °C/decade

East Antarctica has overall weaker warming/cooling

SSTs warming in midlatitudes, low confidence in high latitudes

1979-2016 Temperature Trends

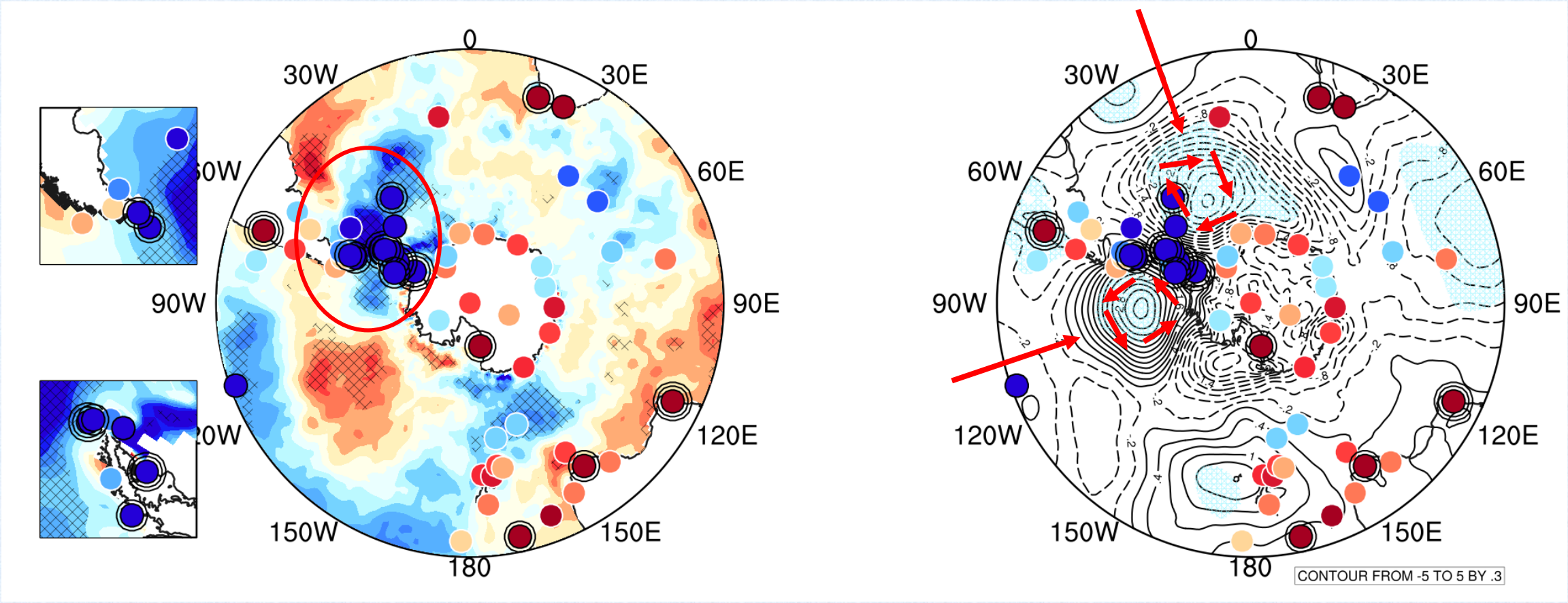


Warming is weaker overall, with less statistical significance

SAM pattern visible in DJF MSLP trends

SSTs warming in midlatitudes and cooling directly around Antarctica

1999-2016 Summer Temperature Trends

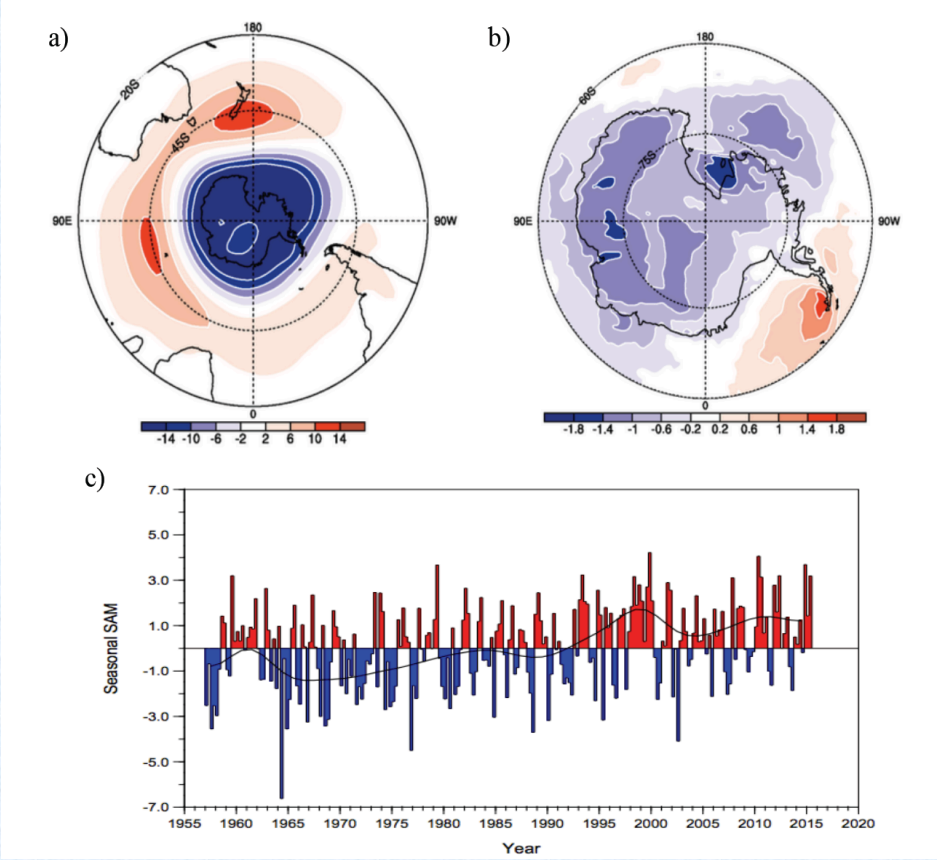


°C / Decade

-0.6 -0.3 0 0.3 0.6

Climate Modes and Features

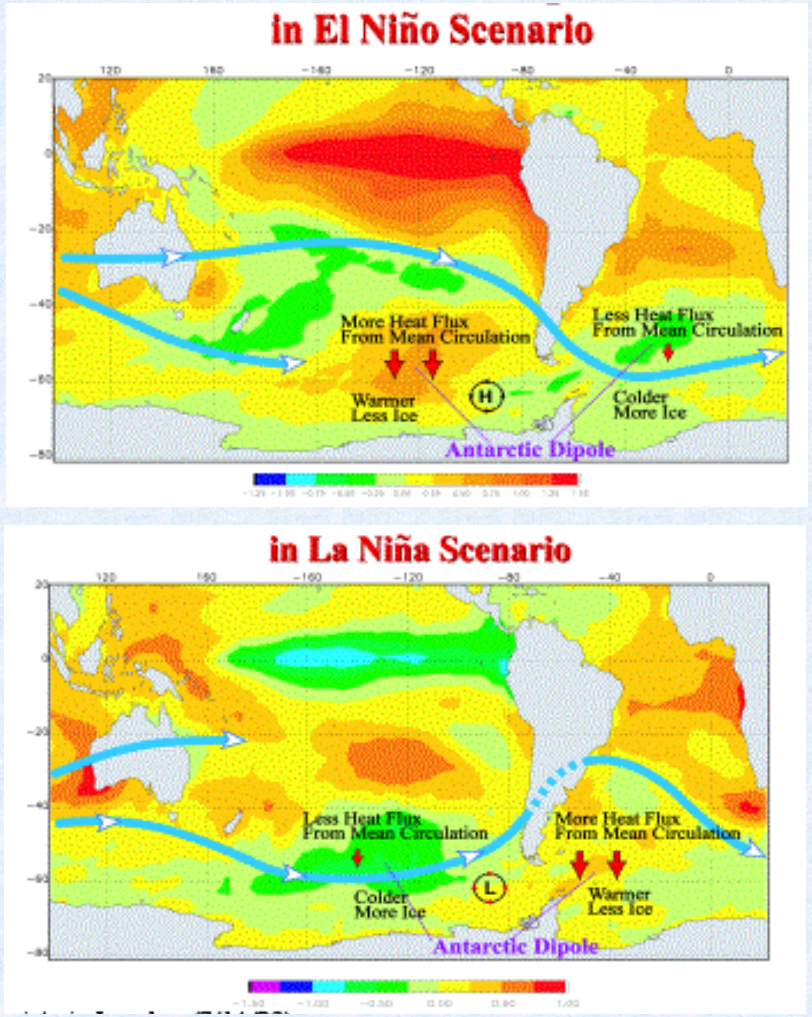
The Southern Annular Mode (SAM)



From the 2013 IPCC Report

Positive phase = cooler temperatures over Antarctica, warmer temperatures in the midlatitudes

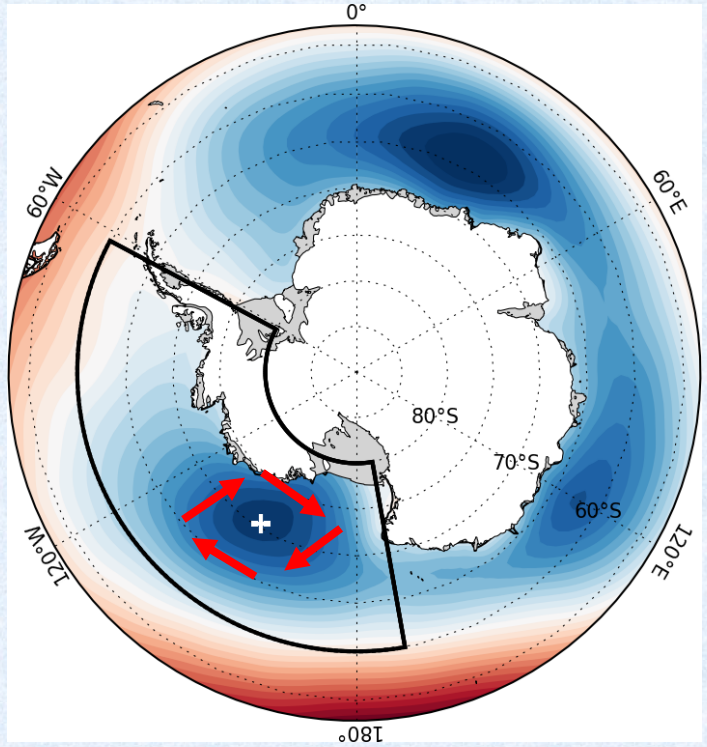
The El Niño Southern Oscillation (ENSO)



From Columbia University

La Niña = East Antarctic cooling

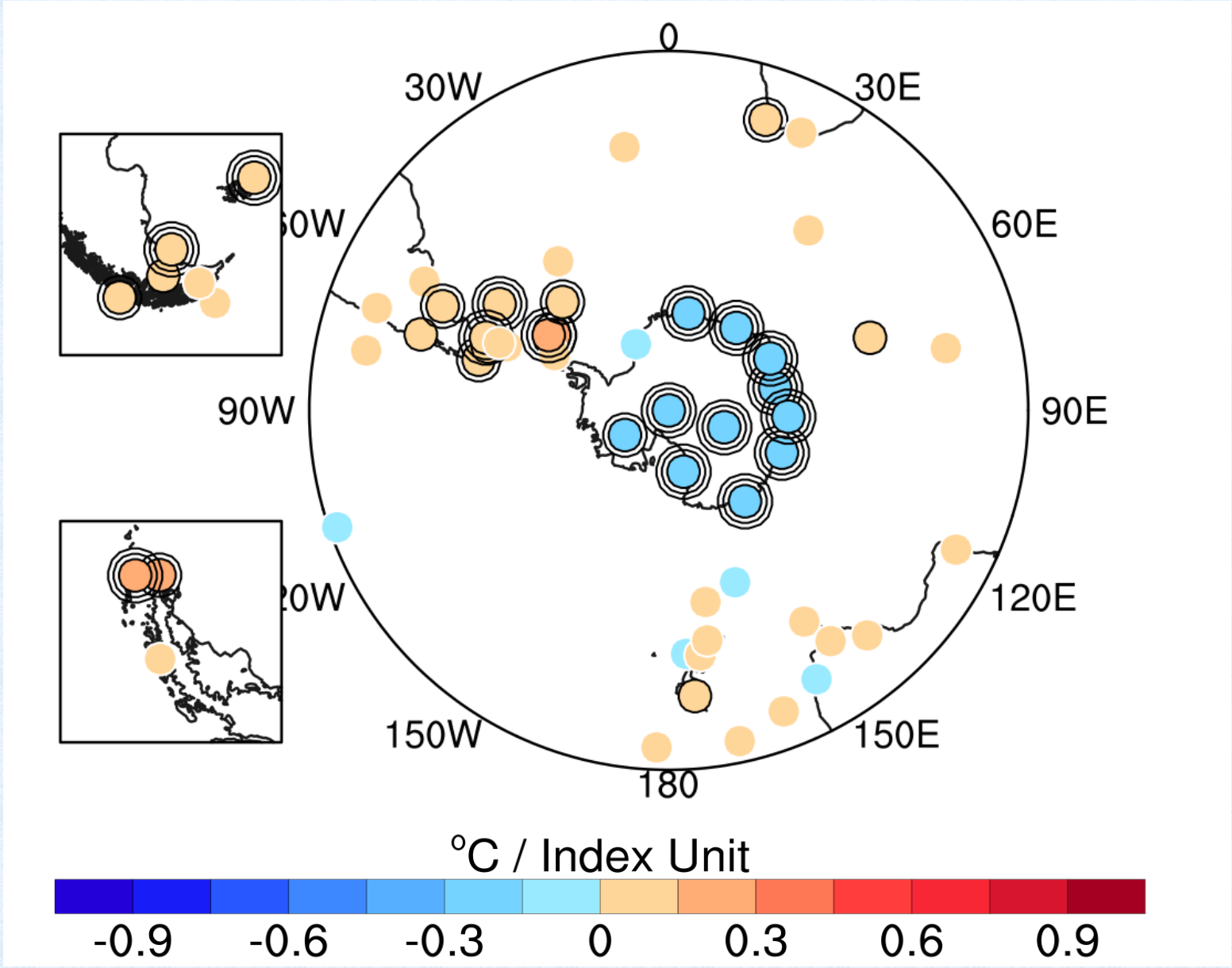
The Amundsen Sea Low (ASL)



From the UCAR Climate Data Guide

Negative height trends = clockwise spin and warm air advection onto Antarctica; enhanced by positive SAM, La Niña, and GHG increases

1957-2016 Annual Surface Temperature and SAM Index Regression Coefficients



Similar to correlations except include magnitude

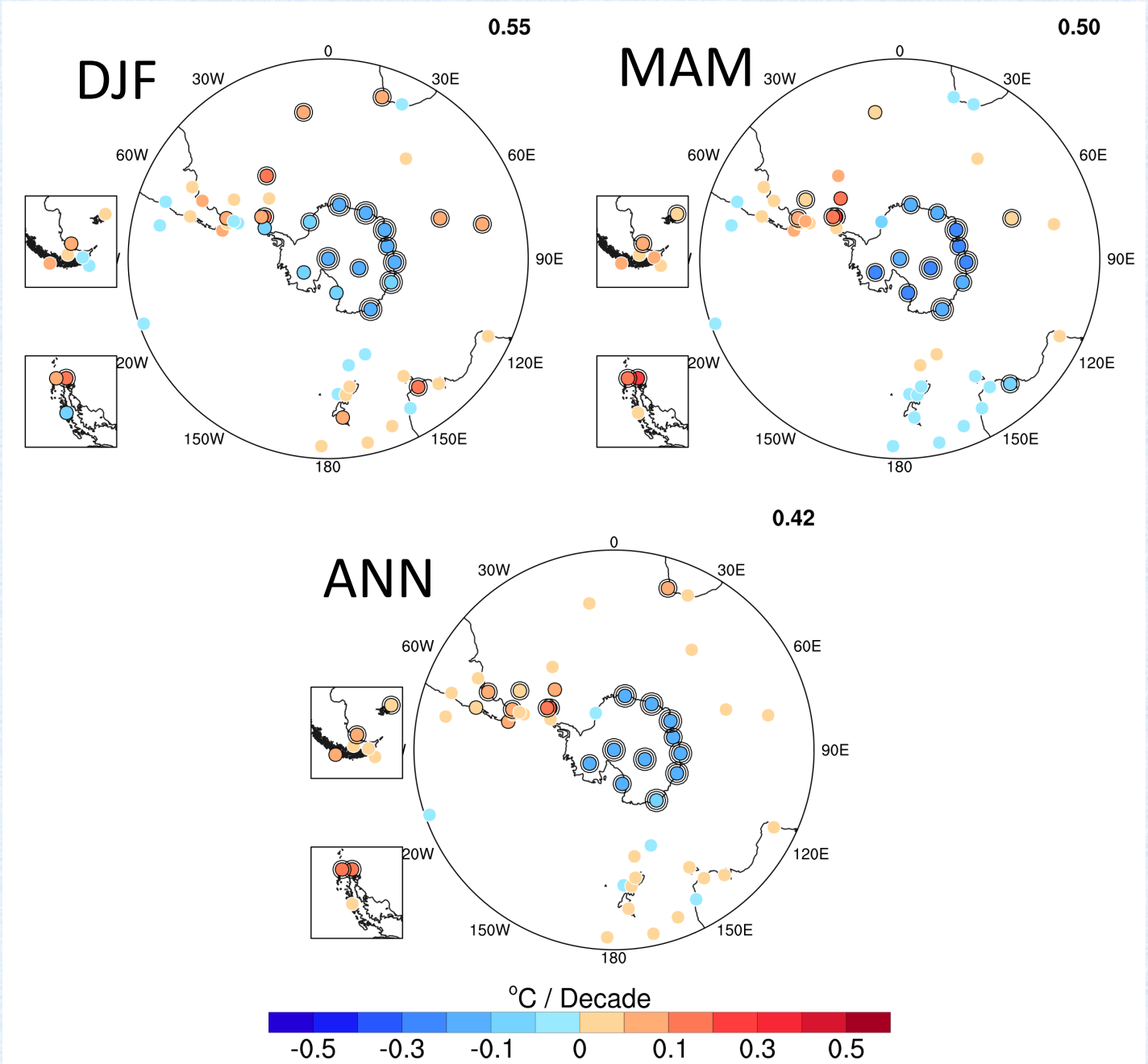
Cooling over East and West Antarctica in a positive SAM phase

Warming over Peninsula region in a positive SAM phase

Summary

- **Widespread warming** across mid-latitudes and focus area in the longest time period (1957-2016)
- **SAM is most influential climate mode** with ENSO secondary
  - Positive SAM trend caused by stratospheric ozone depletion and GHG increase
  - Consistent cooling trend over continental Antarctica
- Congruence Analysis
  - **Determine the portion of the temperature trend at each station associated with the SAM** (SAM-congruent trend)
  - Remove this trend from overall temperatures to reveal background trends
  - Only applicable to periods with a statistically significant SAM trend

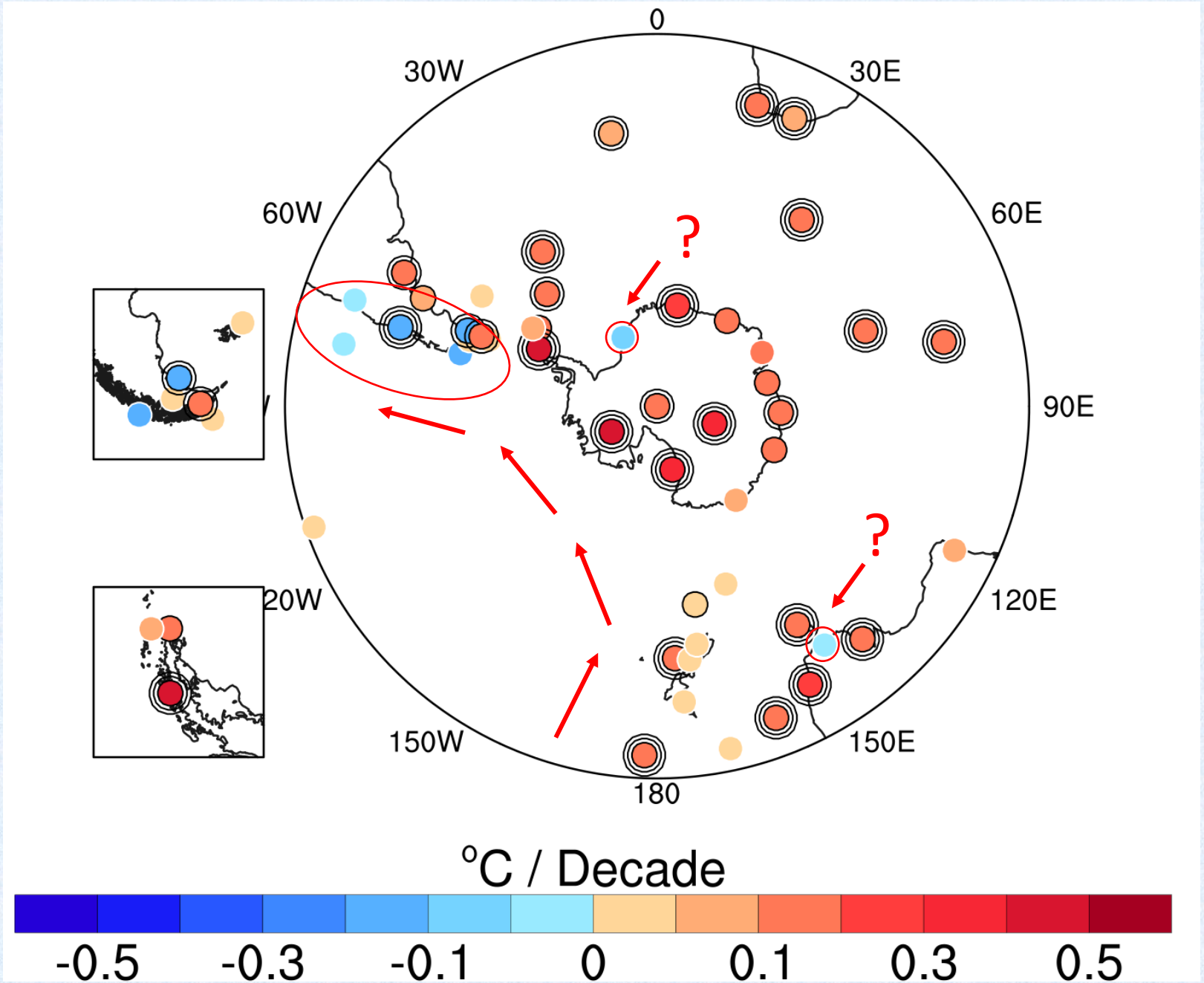
1957-2016 SAM-Congruent Temperature Trends



Reflects pattern seen in regression coefficients

Positive trend in SAM leads to cooling over continental Antarctica, warming on the Peninsula

1957-2016 Annual Background Temperature Trends

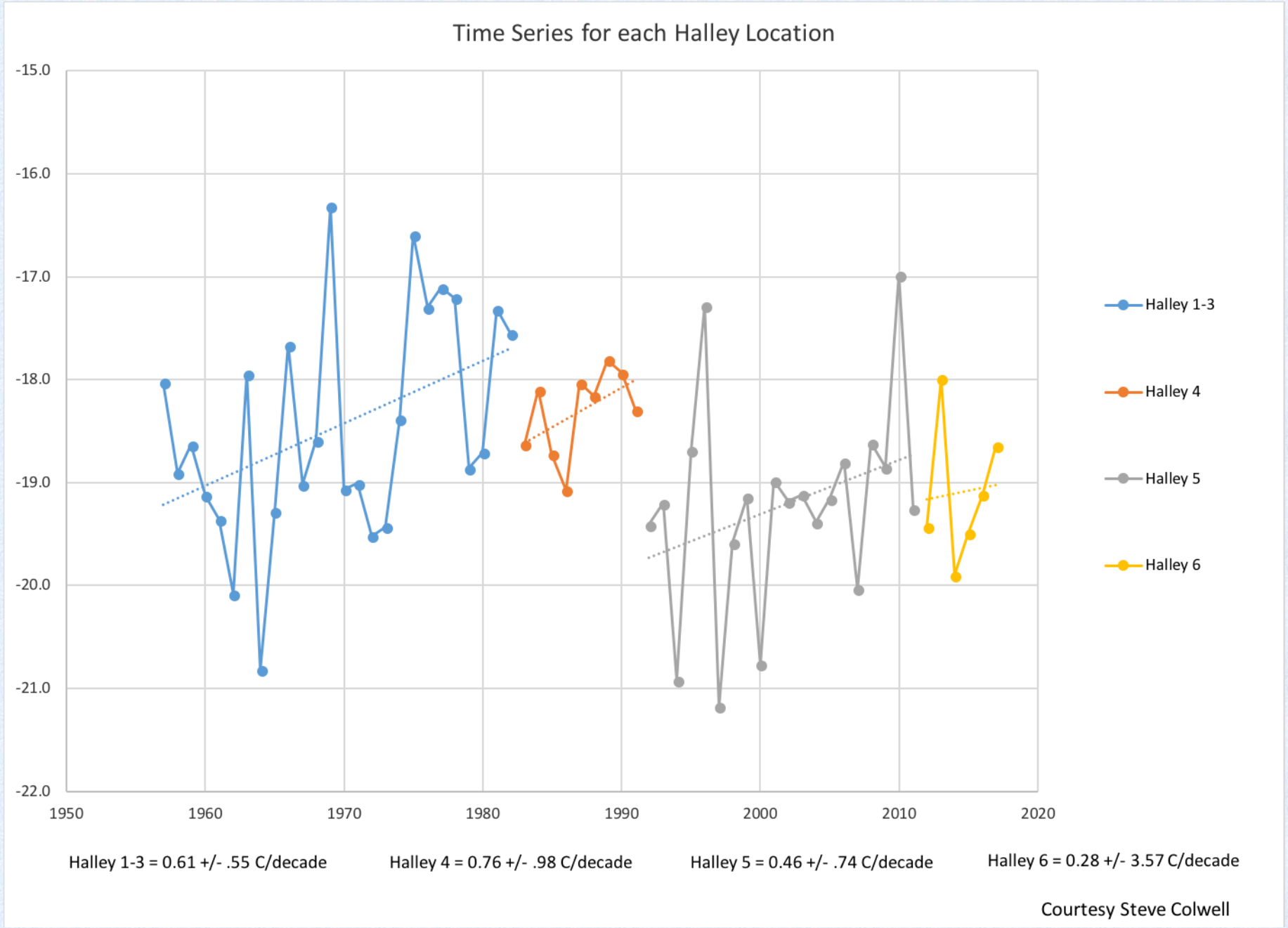


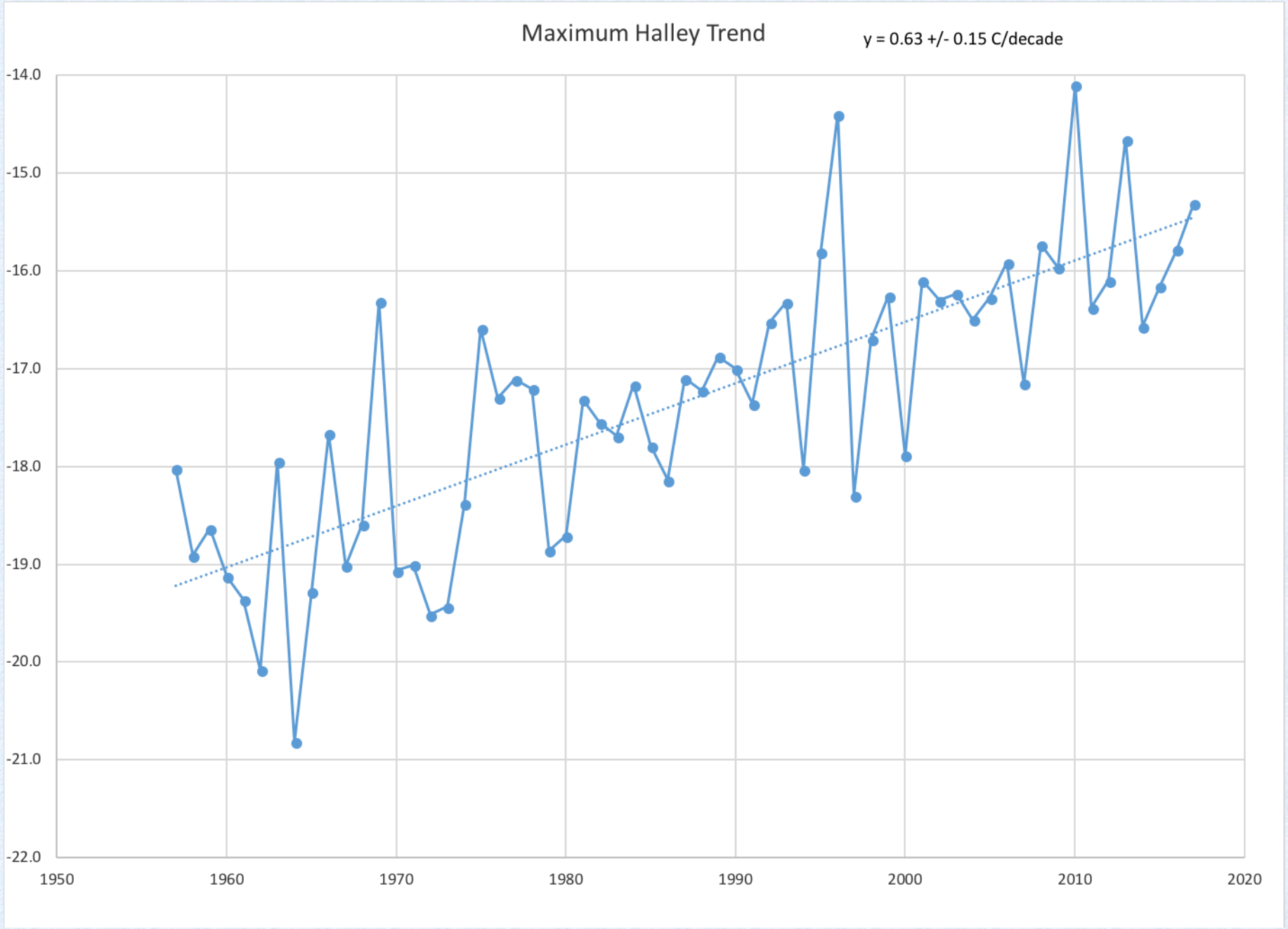
Warming becomes much more prevalent when SAM cooling trends are removed

Very few areas of cooling across all 49 stations – location changes and South Pacific Gyre

Conclusions

- Observational temperature trends show warming across much of the extratropical Southern Hemisphere over the past 60 years
- The short-term cooling trend in the Antarctic Peninsula and West Antarctica (1999-2016) disappears in long-term trends (1957-2016)
- Multiple analyses confirm the Southern Annular Mode has the most influence on temperature variability across Antarctica
- SAM has been trending toward its positive phase, which is characterized by cooling over continental Antarctica and warming over the Peninsula
- Removing the influence of the SAM reveals even stronger warming, including East Antarctica
- Widespread warming reflects the impact of anthropogenic climate change seen throughout the rest of the planet


Time Series for each Halley Location
-15.0
-16.0
-17.0
-18.0
-19.0
-20.0
-21.0
-22.0
1950
1960
1970
1980
1990
2000
2010
2020
Halley 1-3
Halley 4
Halley 5
Halley 6
Halley 1-3 = 0.61 +/- .55 C/decade
Halley 4 = 0.76 +/- .98 C/decade
Halley 5 = 0.46 +/- .74 C/decade
Halley 6 = 0.28 +/- 3.57 C/decade
Courtesy Steve Colwell


Maximum Halley Trend
y = 0.63 +/- 0.15 C/decade
-14.0
-15.0
-16.0
-17.0
-18.0
-19.0
-20.0
-21.0
-22.0
1950
1960
1970
1980
1990
2000
2010
2020

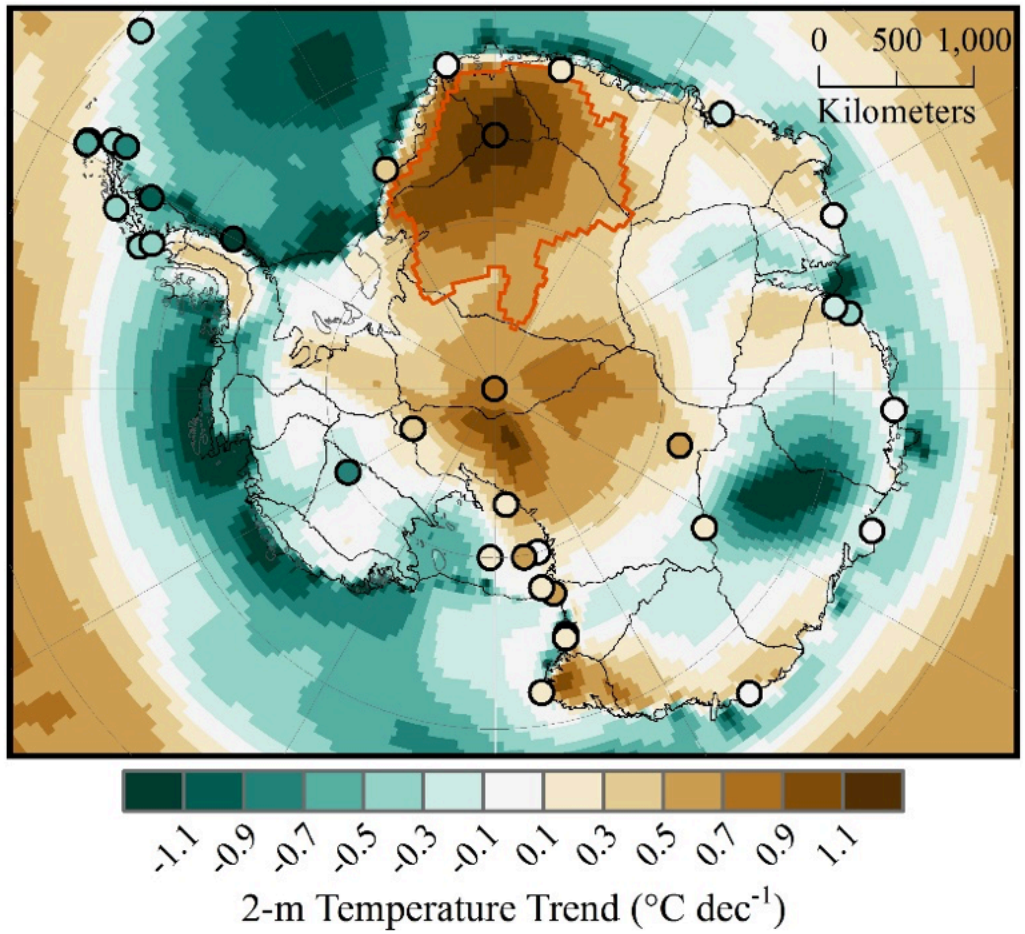
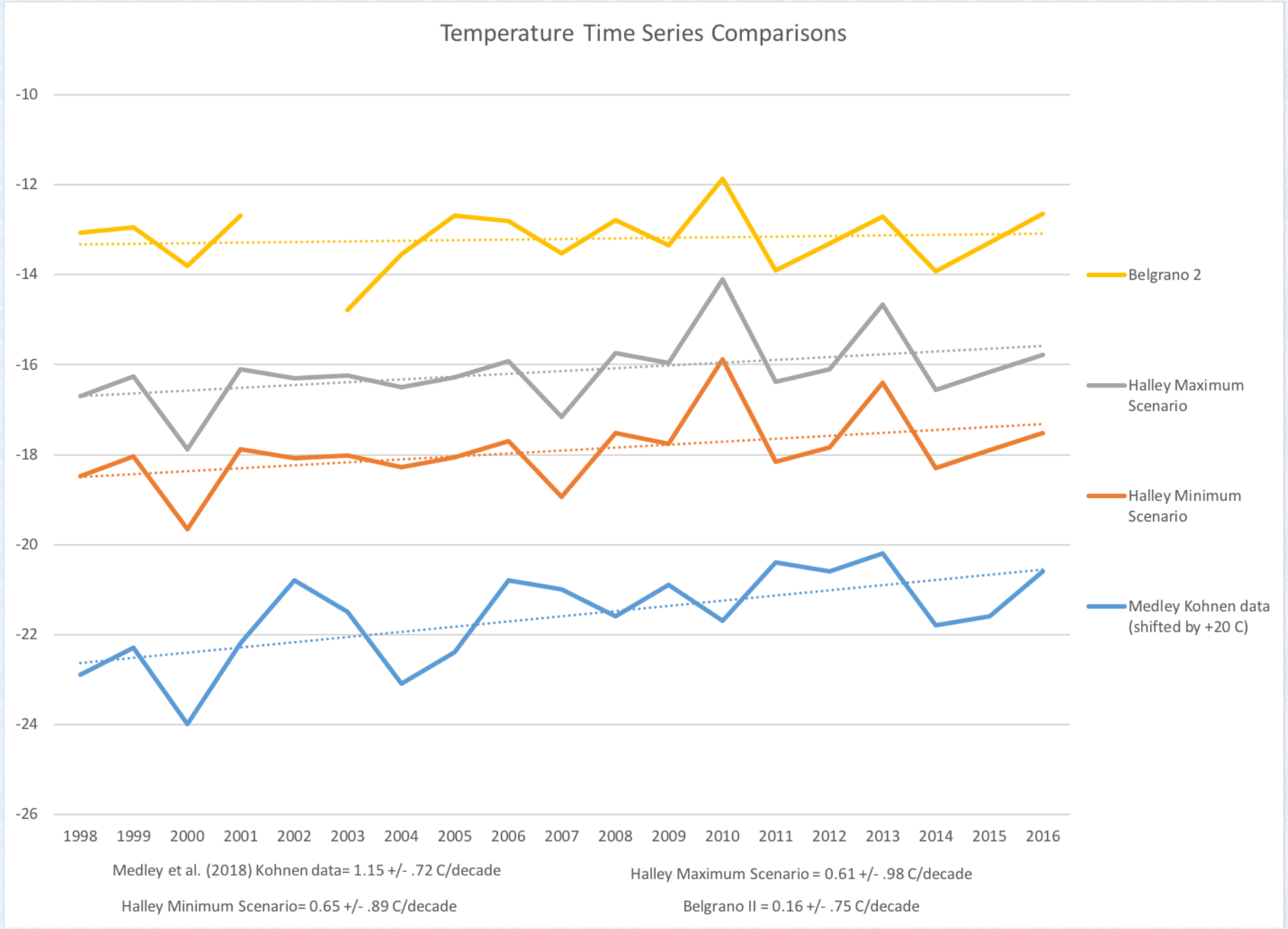


Figure S3. Bias corrected MERRA-2 trends based on comparison with the MET-READER database (see Fig. S2). Colored circles show the observed AWS trends from the MET-READER database. The region of influence for the Kohnen AWS is outlined in red. This confirms that warming is likely occurring within the red bounds, but that it is likely not as strong as the AWS at Kohnen since the warming is strongest there.

For 1998-2016, From Medley et al. (2018)


Temperature Time Series Comparisons
-10
-12
-14
-16
-18
-20
-22
-24
-26
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Belgrano 2
Halley Maximum Scenario
Halley Minimum Scenario
Medley Kohnen data (shifted by +20 C)
Medley et al. (2018) Kohnen data= 1.15 +/- .72 C/decade
Halley Minimum Scenario= 0.65 +/- .89 C/decade
Halley Maximum Scenario = 0.61 +/- .98 C/decade
Belgrano II = 0.16 +/- .75 C/decade

Questions?

Jones.5837@osu.edu

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