An Assessment of Contemporary Global Reanalyses in the Polar Regions

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Overview

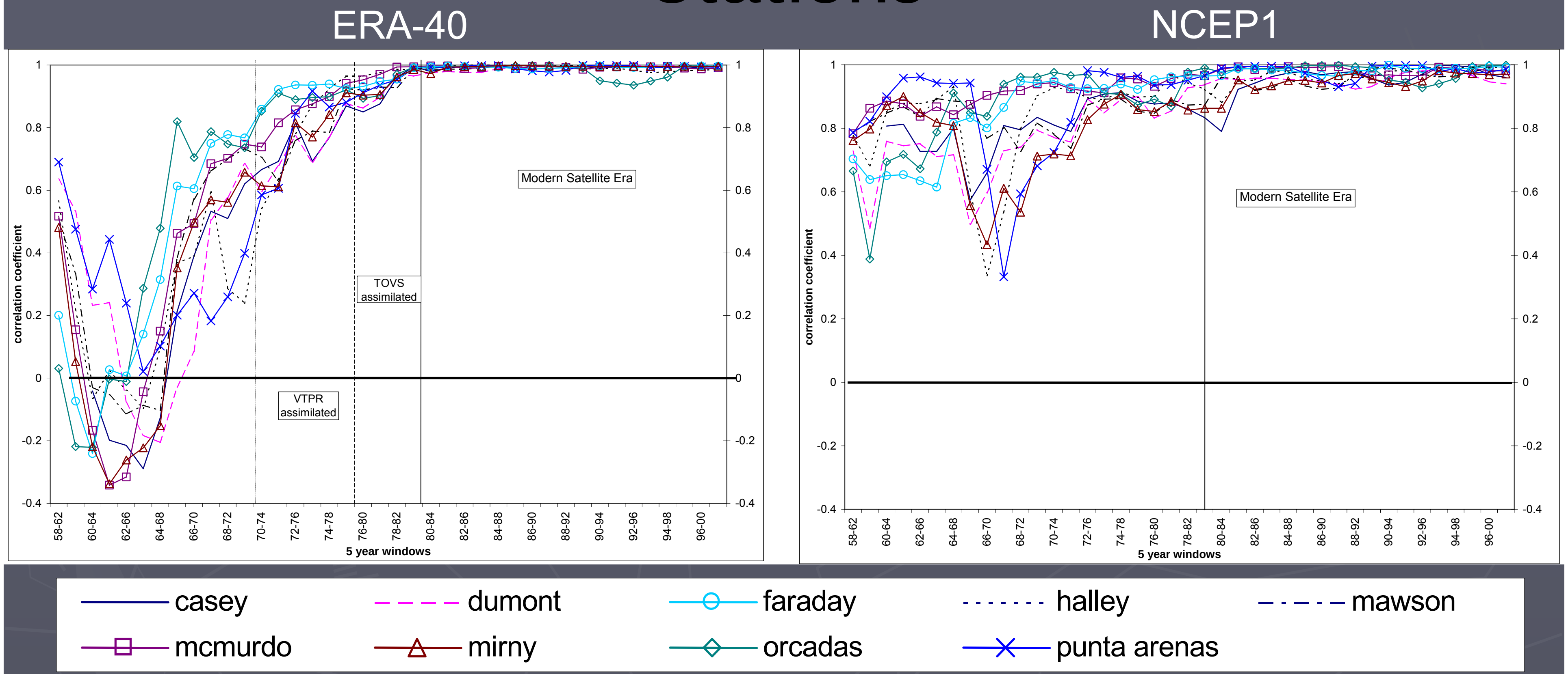
- This presentation summarizes the findings of the "Workshop on High Latitude Reanalyses" funded by the Scientific Committee on Antarctic Research (SCAR)
- Workshop held 10-12 April, 2006 at the British Antarctic Survey (BAS) in Cambridge, with a one-day visit to ECMWF
- A publication is in preparation which details the status of the global reanalyses in the polar regions based on the information presented at this workshop

Reanalysis Performance in Polar Regions

- There is a sharp change in skill in the reanalyses from 1958-1978 to 1979-2001 in the Southern Ocean and Antarctica, particularly in ERA-40
- The skill in the Arctic region is much better throughout the whole period
- Smaller yet significant differences between the reanalyses still exist during the modern satellite era in both regions

Pre-satellite Era (1958-1978) vs. Modern Satellite Era (1979-2001) Comparisons

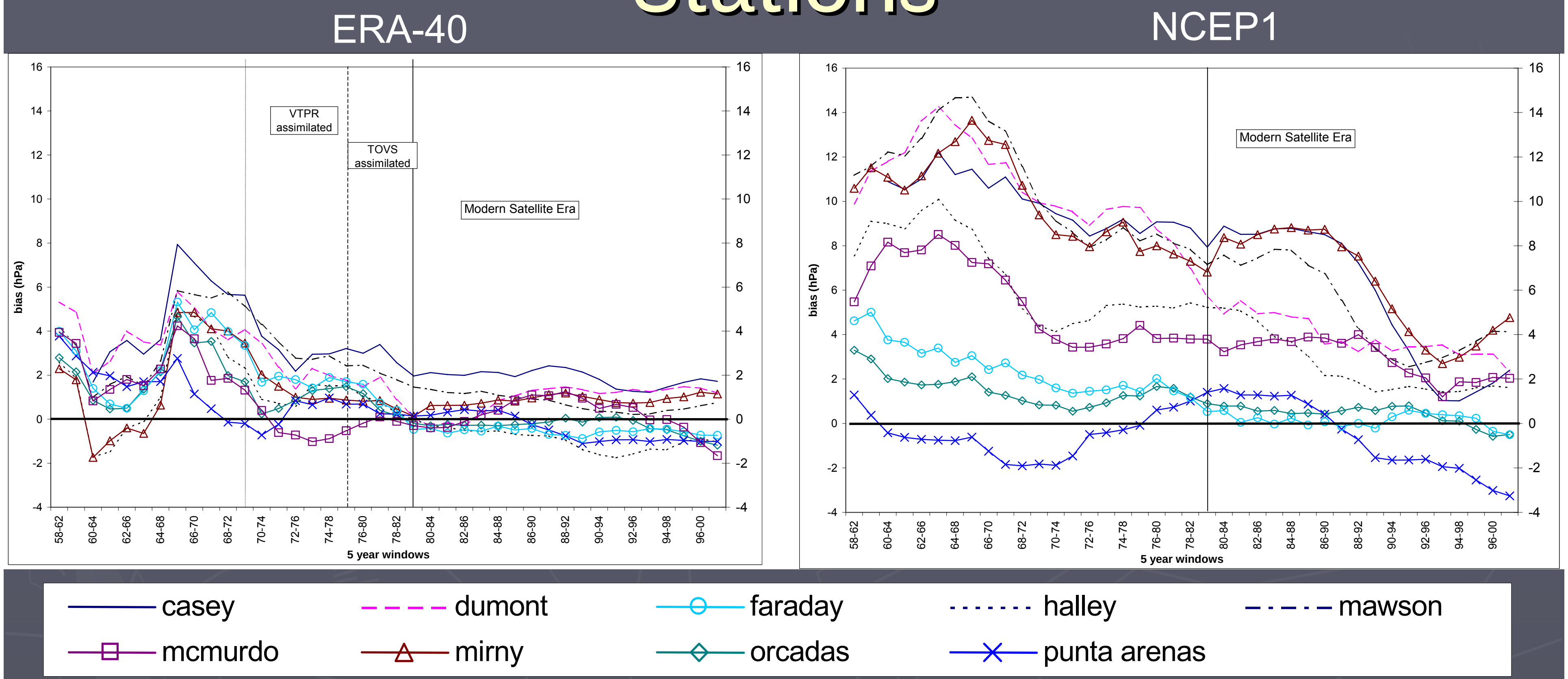
Winter MSLP Correlations, Antarctic Stations



ERA-40 correlations with the MSLP at several Antarctic Stations are low and even negative in the 1958-1972 period. Significant trends in skill can be seen in conjunction with the assimilation of satellite data, with near perfect correlations occurring during the modern satellite era, 1979-2001. NCEP1 shows more consistencies in the correlations with time.

From Bromwich and Fogt (2004) *J. Climate*, **17**, 4603-4619

Winter MSLP Biases, Antarctic Stations

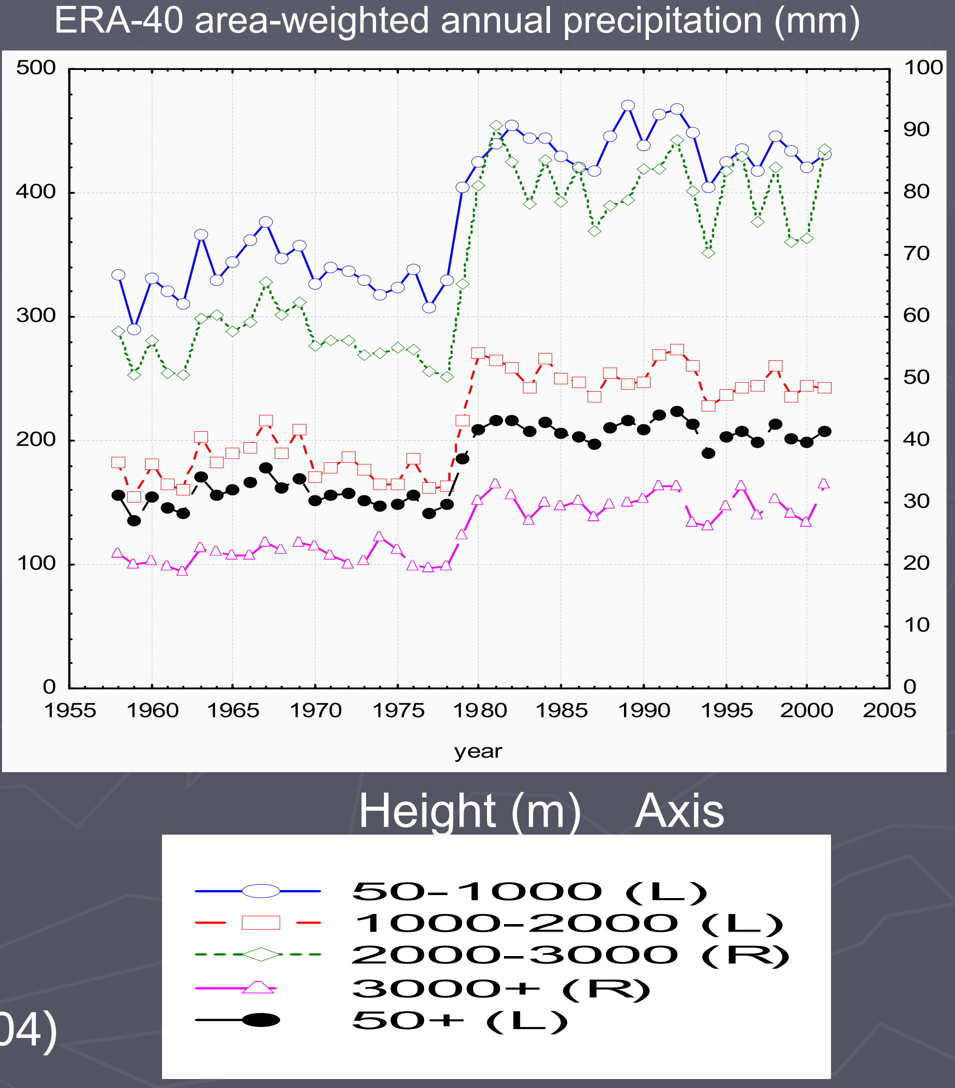


ERA-40 MSLP biases at many high latitude stations, however, are much lower than those in NCEP1, which has a known artificial trend in MSLP (e.g., Hines et al. 2000; Marshall and Harangozo 2000). The biases (at times > 12 hPa) in the East Antarctic stations persist until the mid-1990s.

From Bromwich and Fogt (2004)

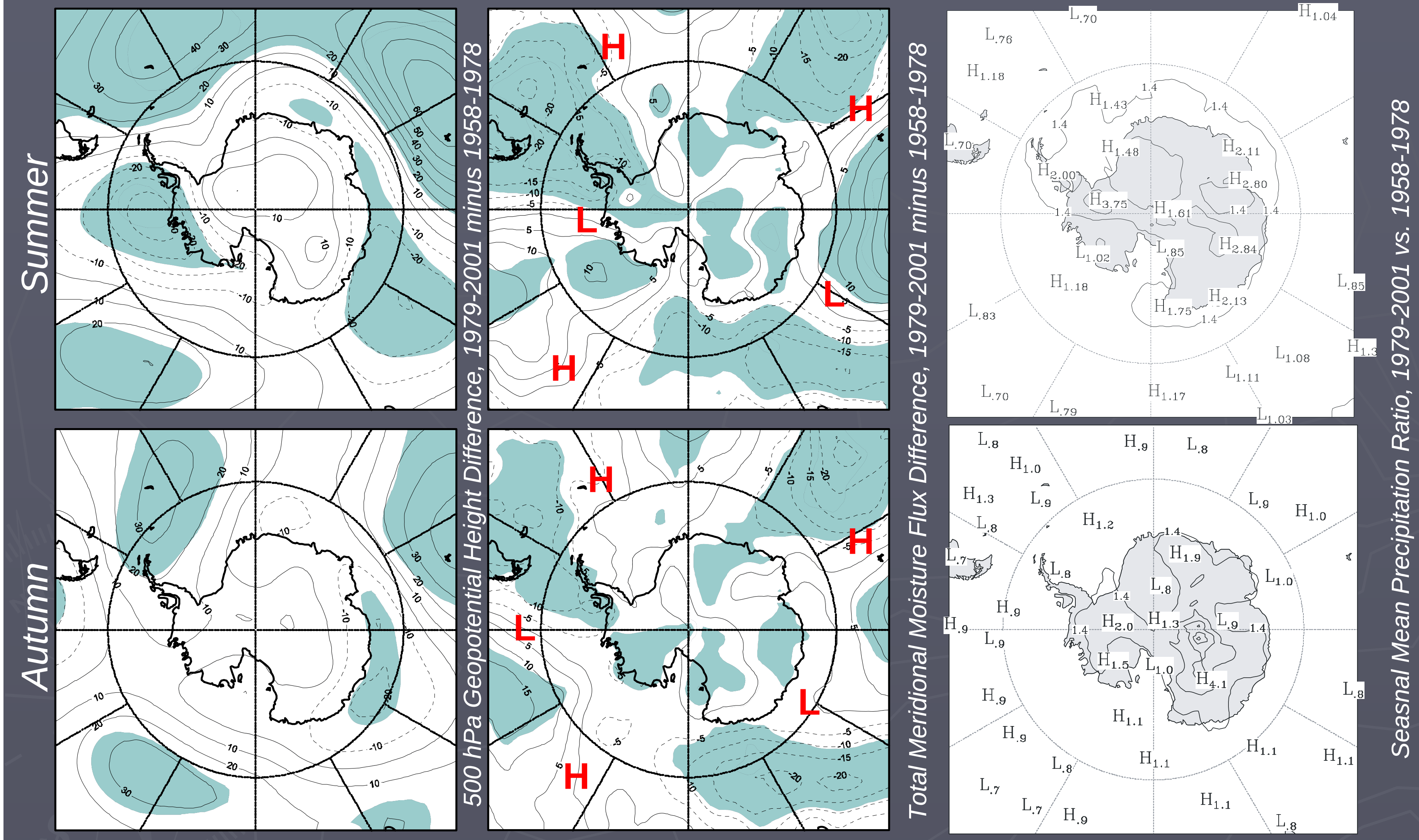
ERA-40 Total Annual Antarctic Precipitation Problem at the Start of the Modern Satellite Era

- The large increase in data from satellite soundings starting at 1979 creates a discontinuity in the total Antarctic precipitation fields.



Adapted from van den Berg et al. (2004)

ERA-40 Seasonal Changes across 1979



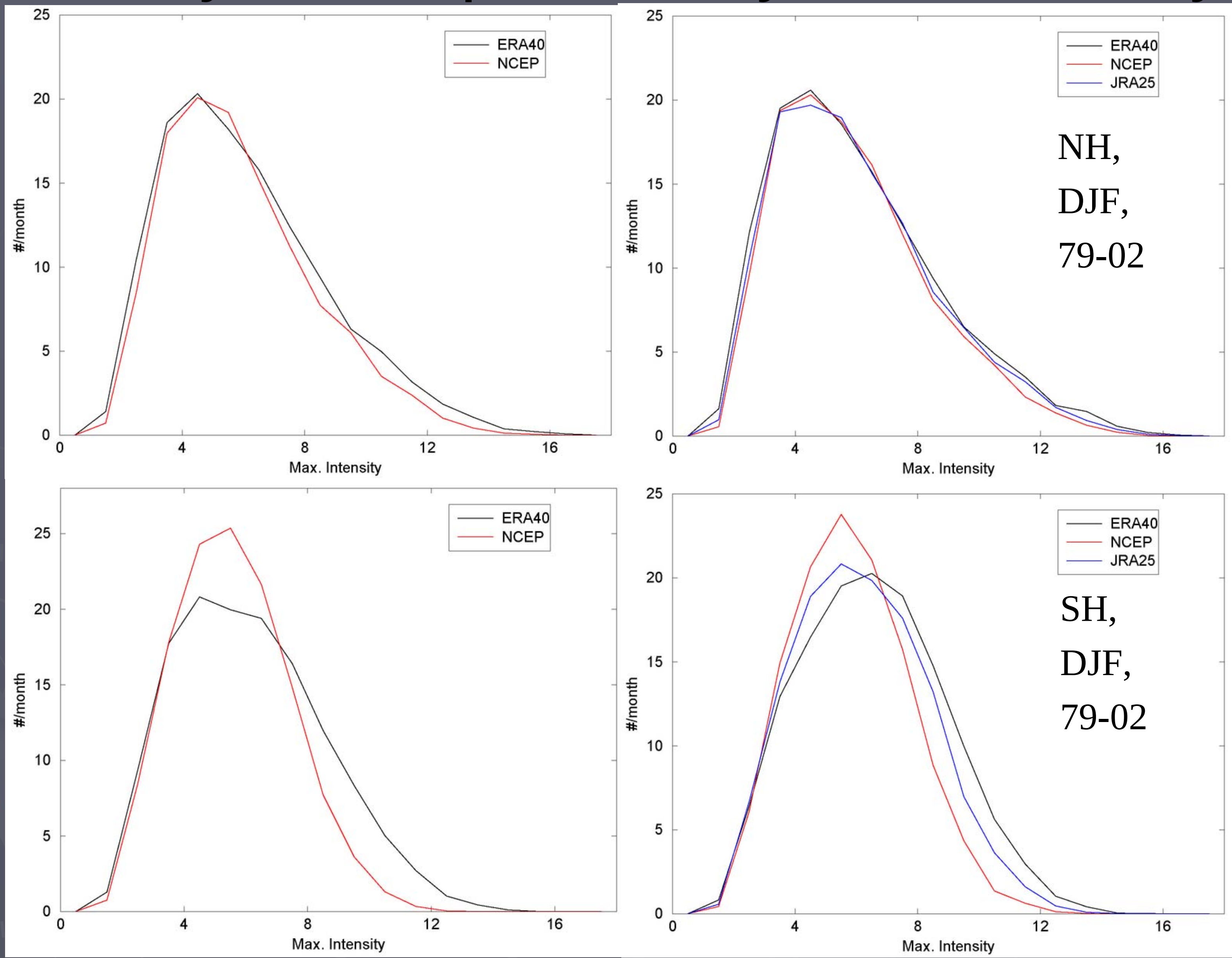
Shaded regions are significant (two-tailed) at the p<0.05 level

- ERA-40 demonstrates significant shifts in the longwave pattern entering the modern satellite era that explain the changes in the moisture flux , and the corresponding changes in the precipitation

Reanalysis Comparison, Cyclone Intensity

NH,
DJF,
58-78

SH,
DJF,
58-78

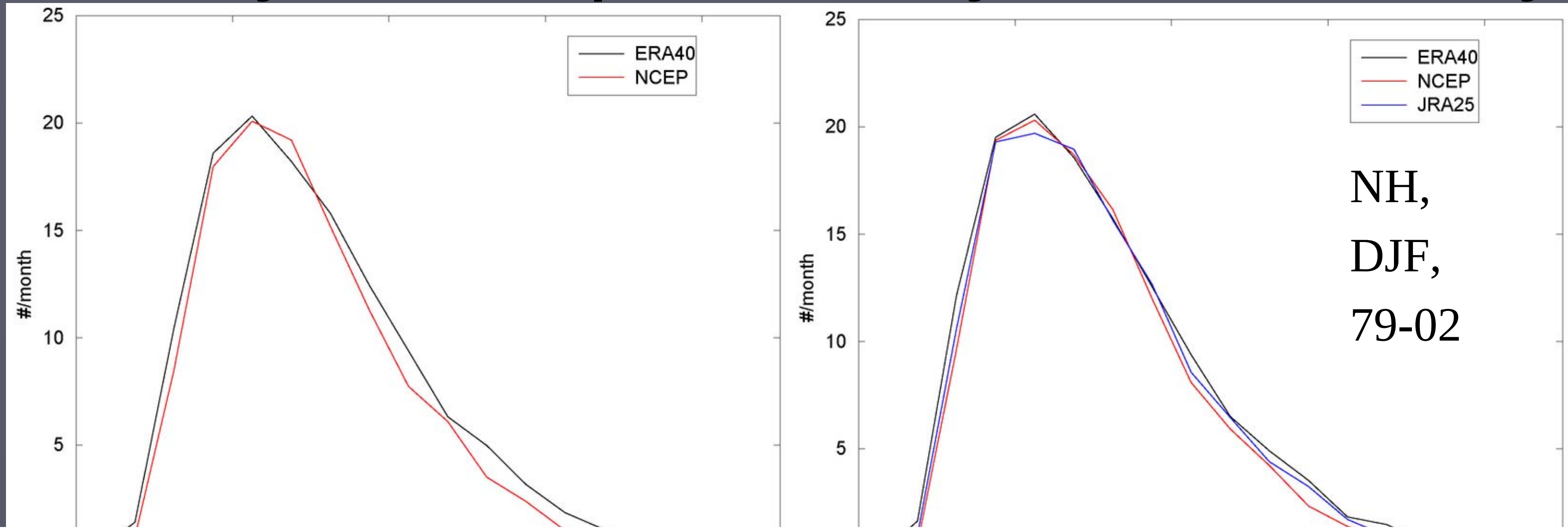


Results are obtained using the 850 hPa relative vorticity and the cyclone tracking algorithm employed by Hoskins and Hodges (2002)

Figure provided by Kevin Hodges, U Reading

Reanalysis Comparison, Cyclone Intensity

NH, DJF, 58-78



Conclusion: Very little change is observed in the NH from 1958-2002. Larger changes are seen in the SH, where differences exist between the reanalyses even during the modern satellite era

SH, DJF, 58-78

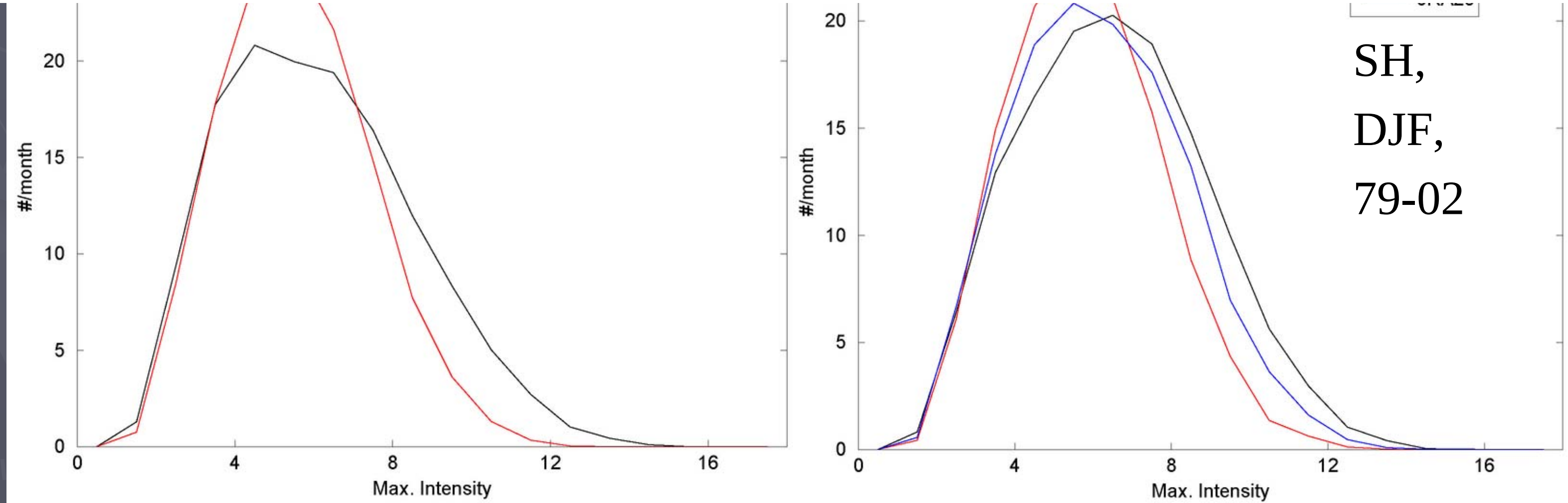


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Figure provided by Kevin Hodges, U Reading

Winter Cyclone Matching, ERA-40 & NCEP1

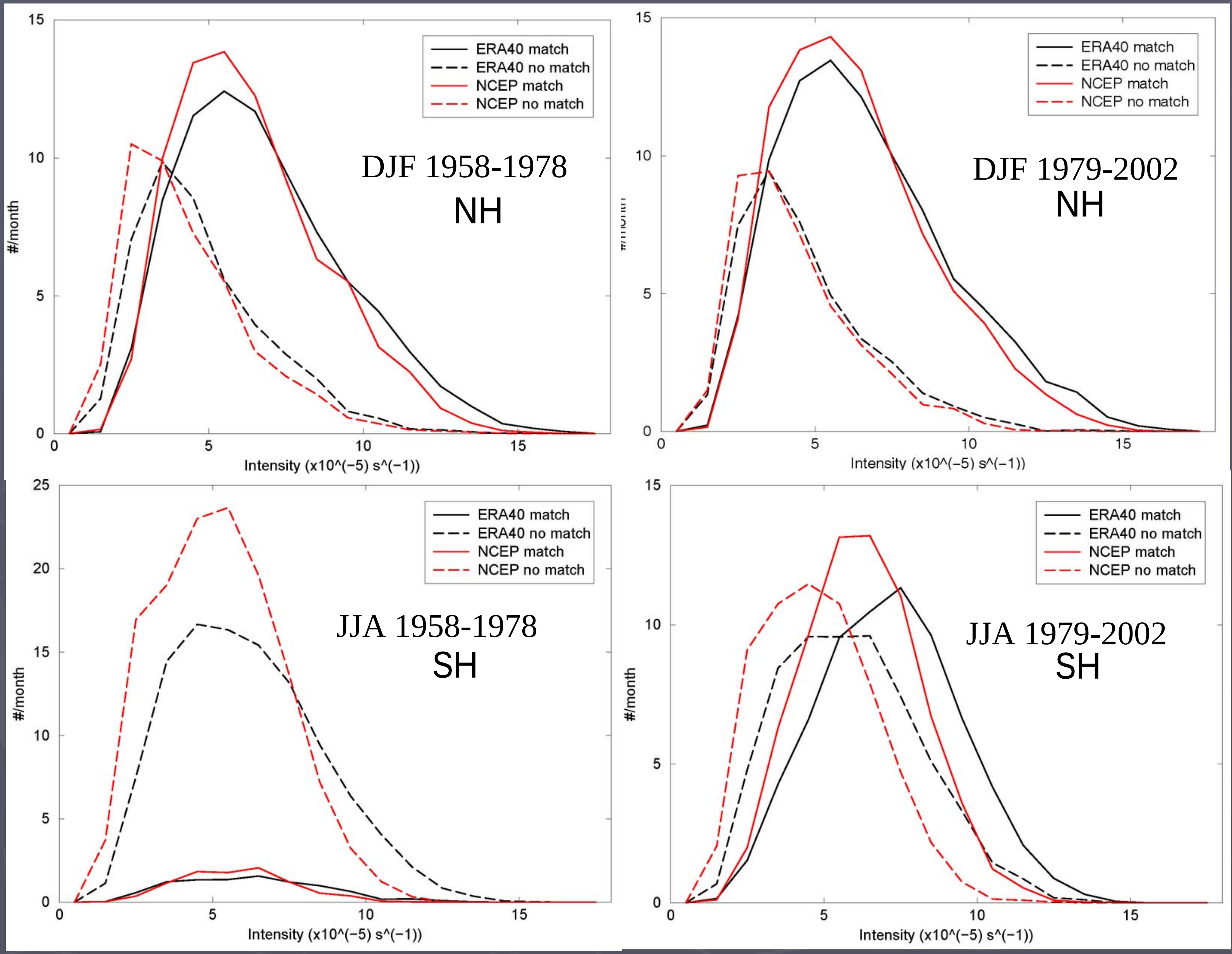
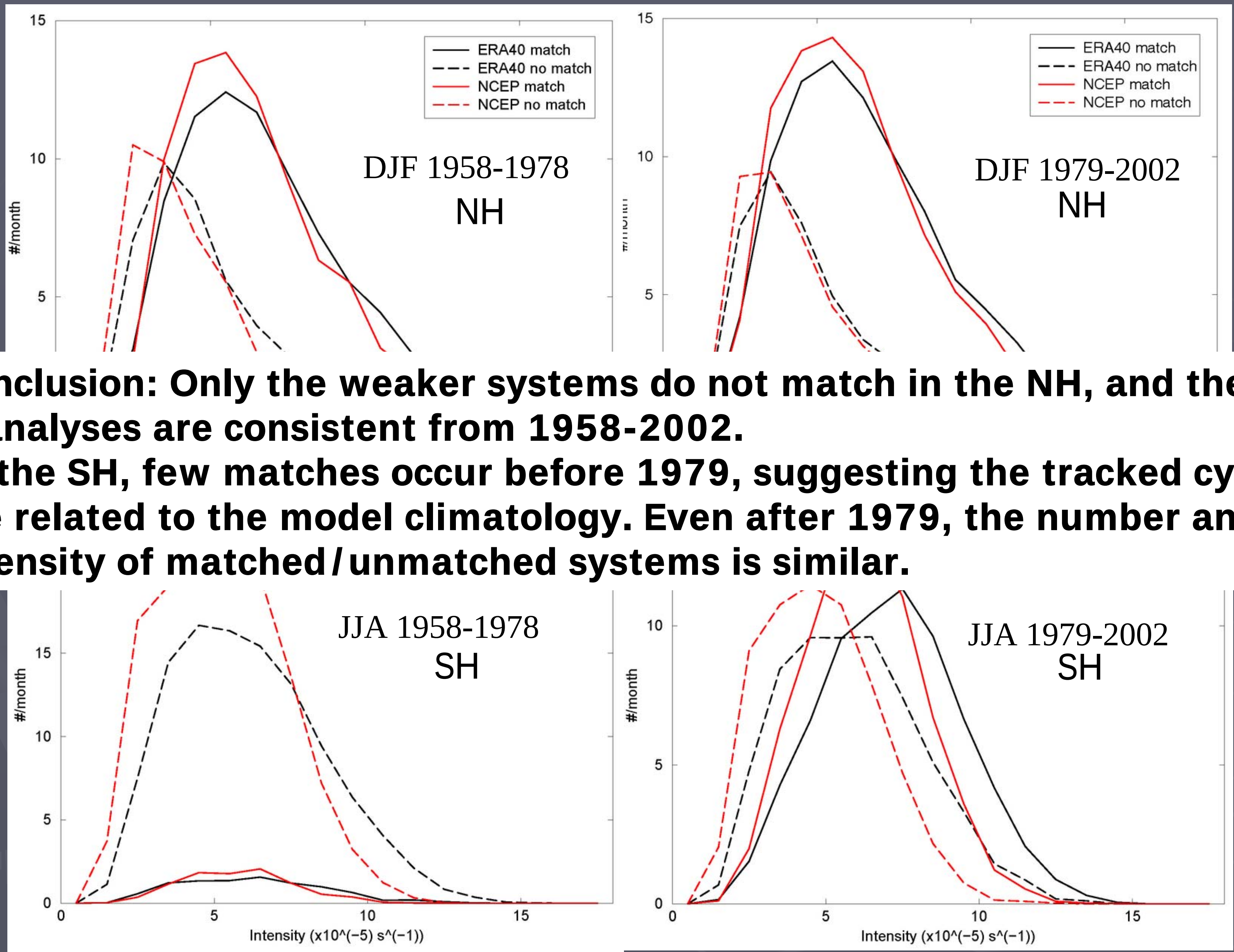


Figure provided by Kevin Hodges, U Reading

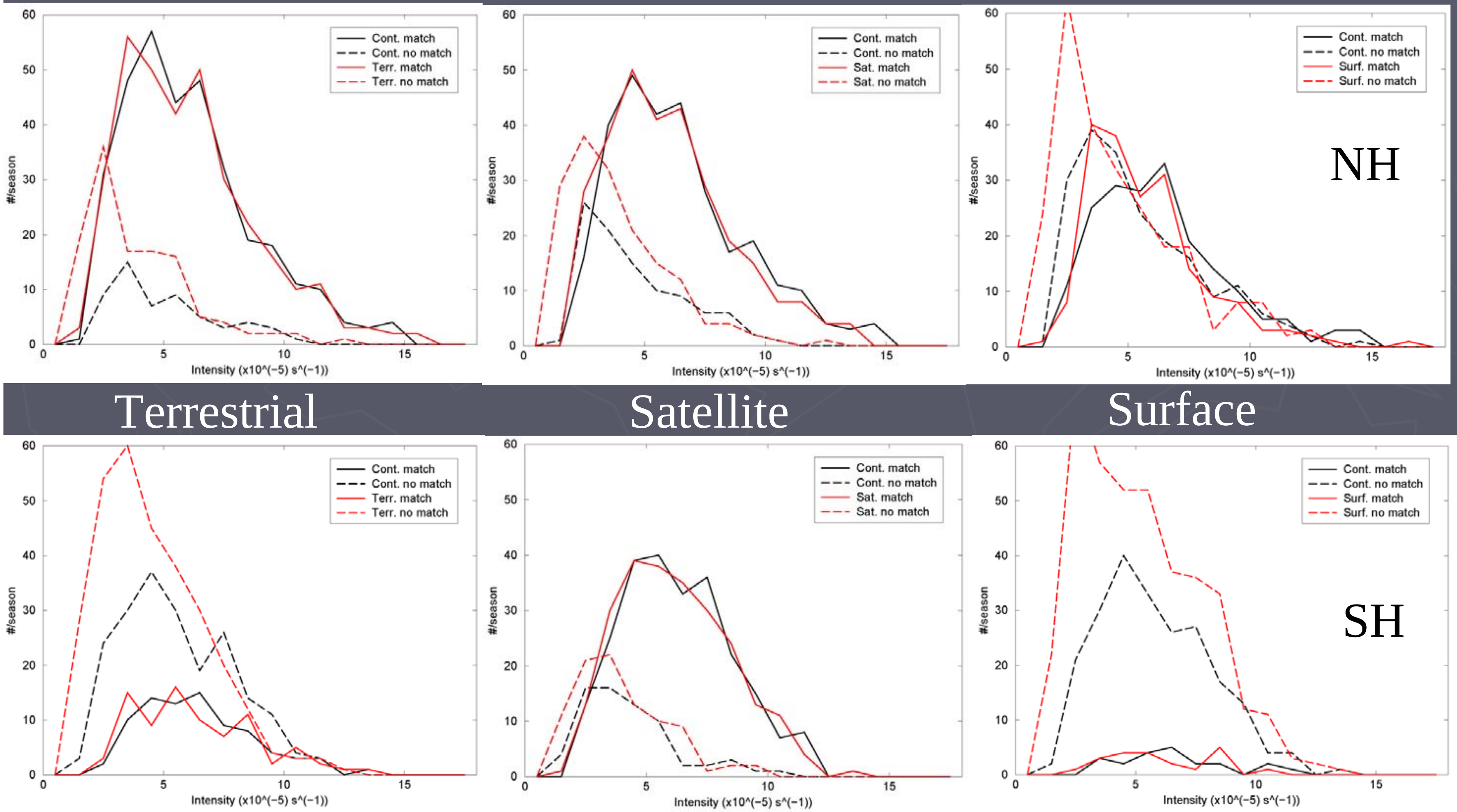
Winter Cyclone Matching, ERA-40 & NCEP1



Conclusion: Only the weaker systems do not match in the NH, and the reanalyses are consistent from 1958-2002.

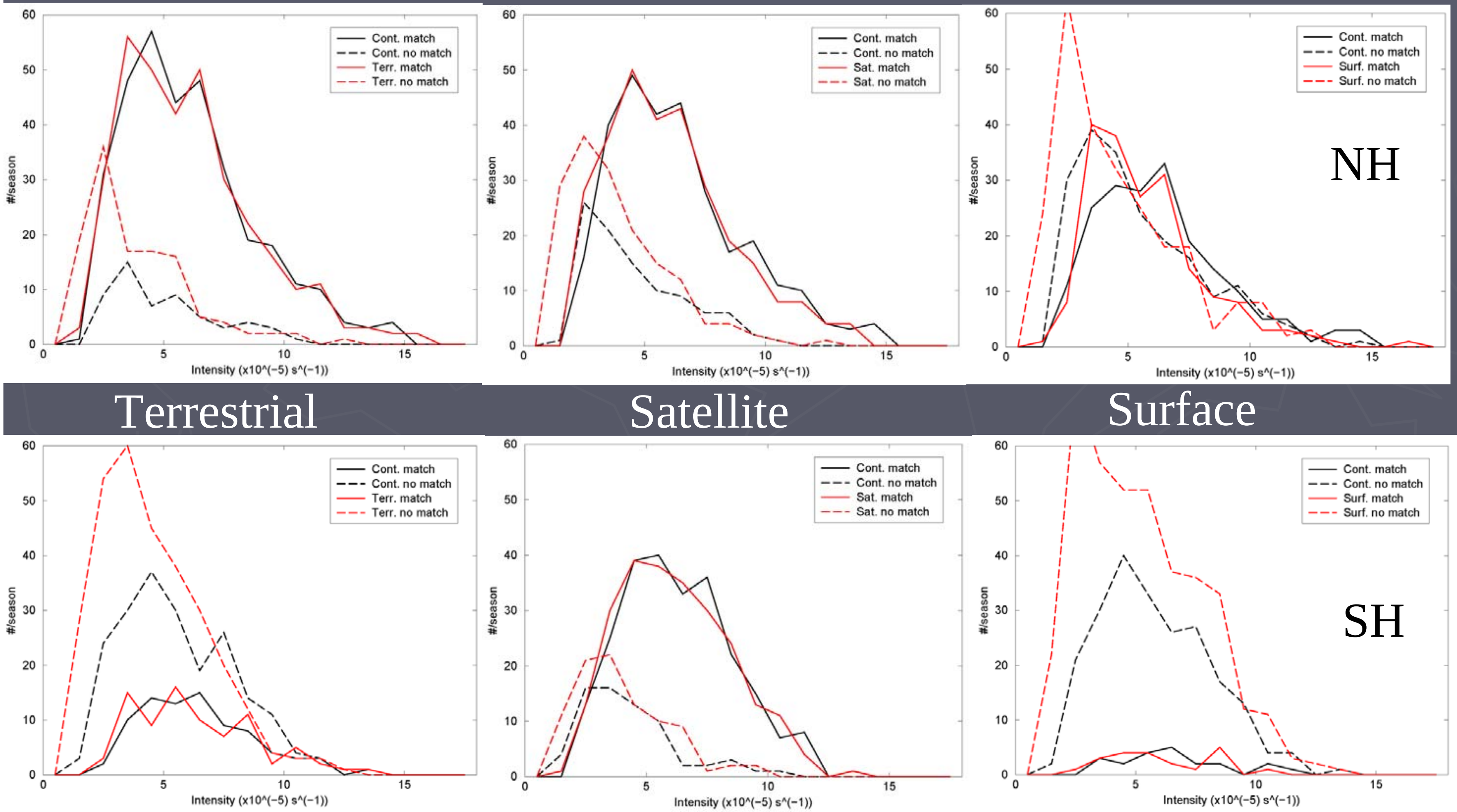
In the SH, few matches occur before 1979, suggesting the tracked cyclones are related to the model climatology. Even after 1979, the number and intensity of matched/unmatched systems is similar.

Observing System Sensitivity (90/91)



Adapted from Bengsston et al. (2004)

Observing System Sensitivity (90/91)



Conclusion: The satellite data are very important in the SH, and less important in the NH.

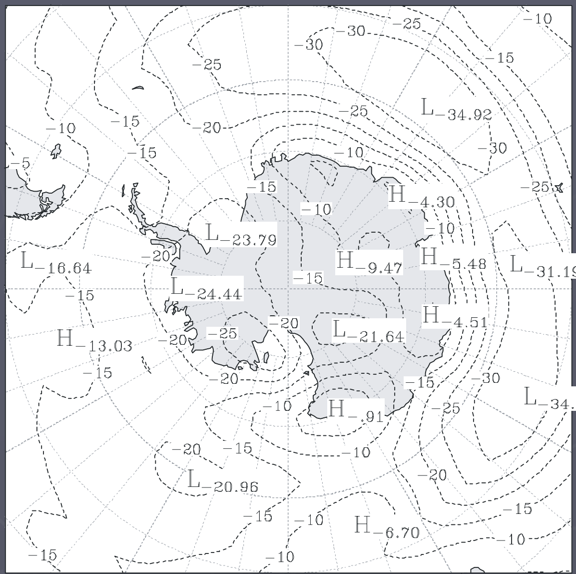
Comparison 1958-1978 vs. 1979-2001 Summary

- Little change is observed in the Northern Hemisphere skill from 1958-2002; it remains reliable throughout the period
- The changes in the Southern Hemisphere mean circulation are large, and in turn affect precipitation (the jump) and cyclonic variability
- The Southern Hemisphere performance is strongly guided by the quantity of satellite data

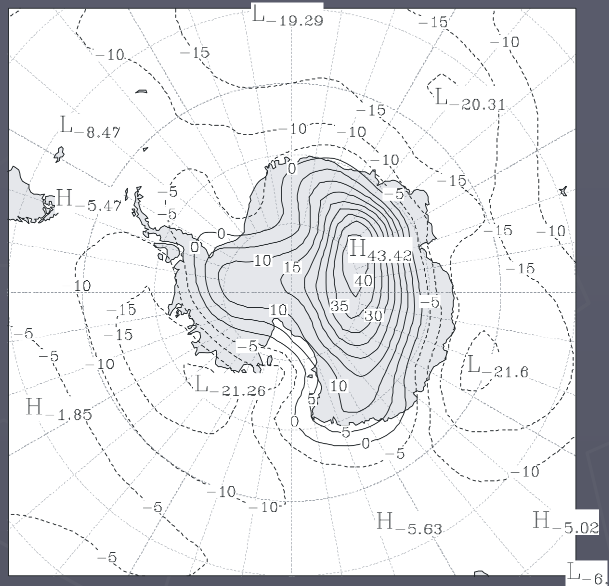
Reanalyses Comparisons During the Modern Satellite Era, 1979-2002

The Antarctic

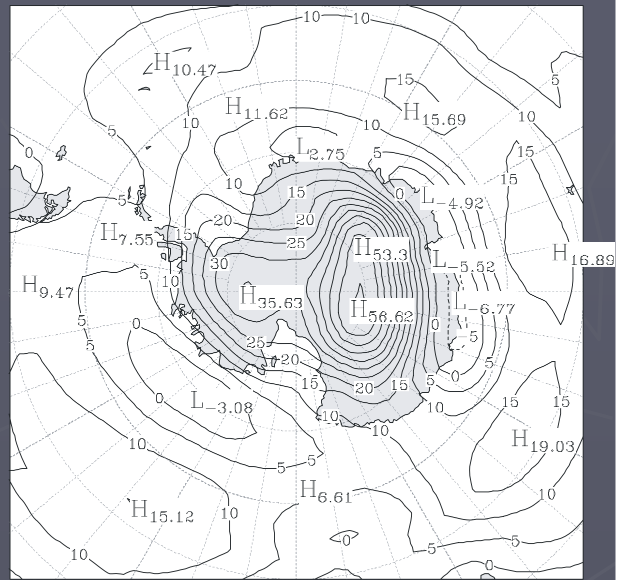
500 hPa Geopotential Height Differences from the Reanalyses, 1979-2001, Southern Hemisphere



E40 - JRA 500z



E40 – NCEP2 500z

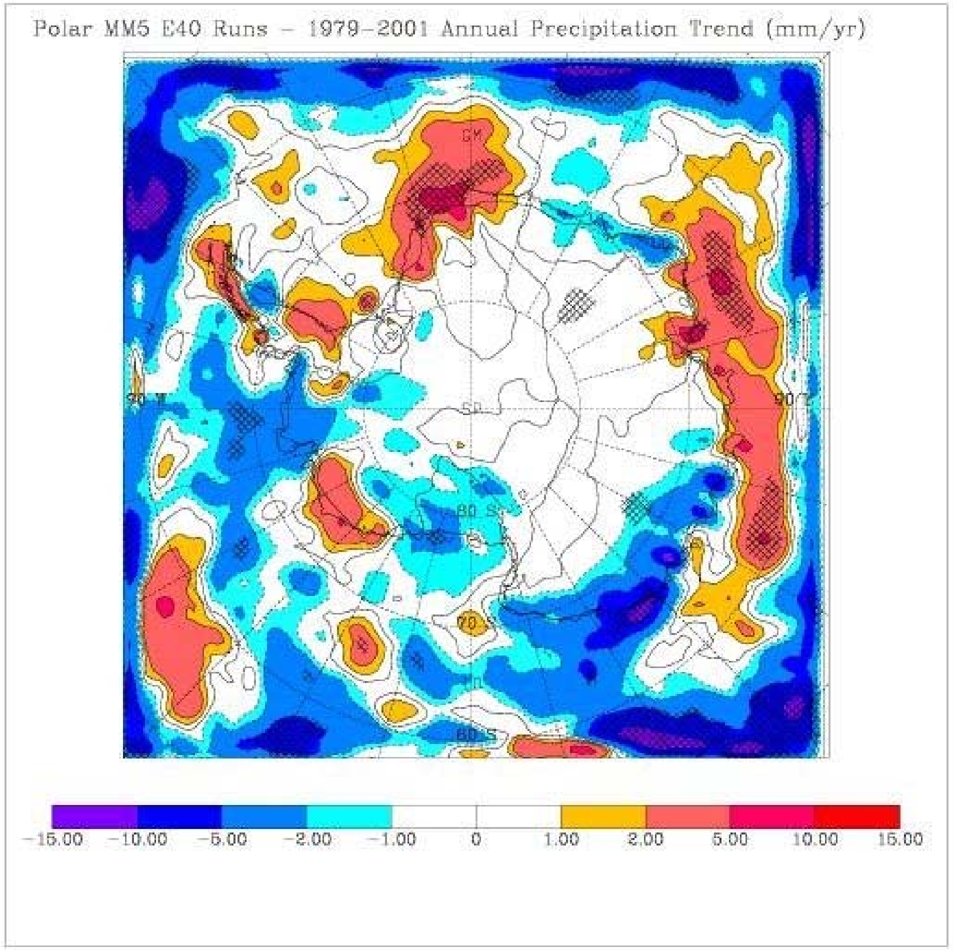


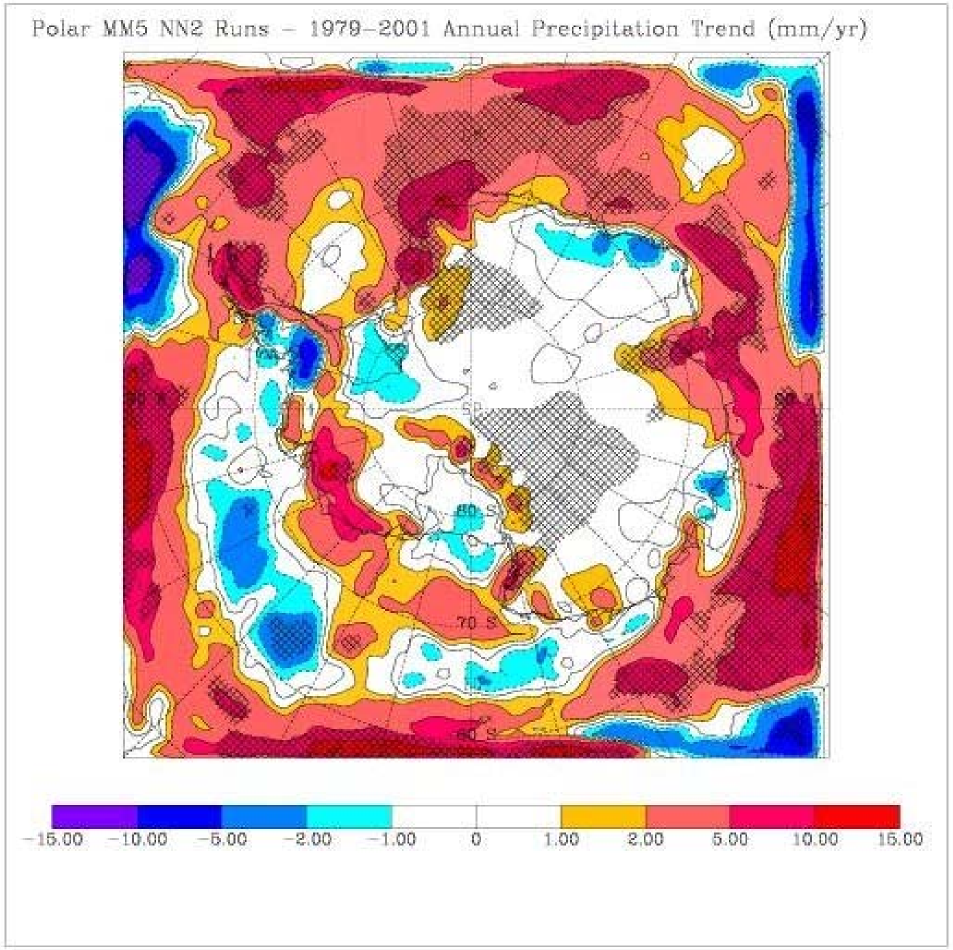
JRA – NCEP2 500z

- During the modern satellite era, there are still mean circulation differences in the various reanalyses.
- Two key regions can be seen: the interior of the continent and in the Southern Ocean off the East Antarctic coast.

From Bromwich and Fogt, in preparation

PMM5 Antarctic Precipitation Trends, 1979-2001, Driven by the Reanalyses





PMM5 E40

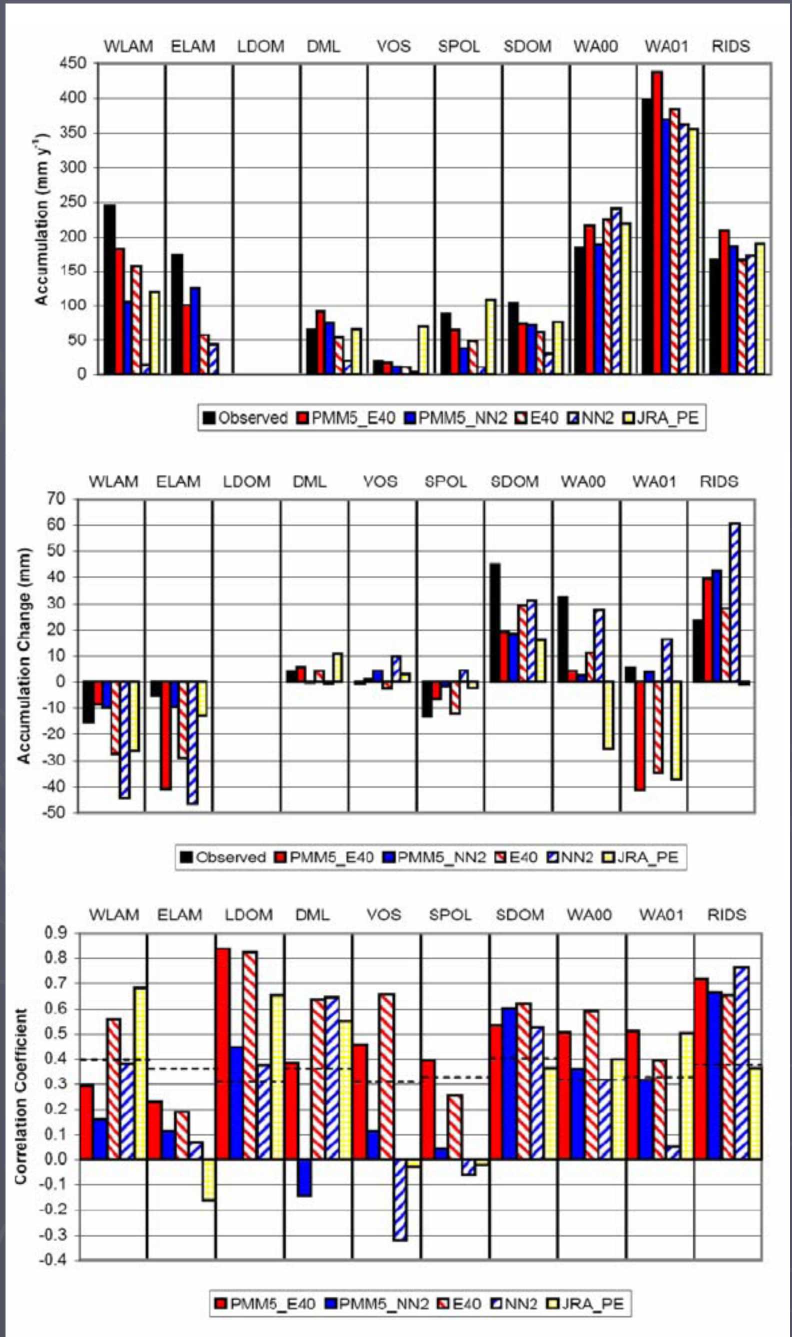
Continental Average:
Mean= 209 mm y^{-1}
Trend= **-0.32** mm y^{-2}

PMM5 NN2

Continental Average:
Mean= 182 mm y^{-1}
Trend= **+0.72** mm y^{-2}

Conclusion: The trends are opposite in sign and magnitude

Figure provided by Andrew Monaghan, BPRC



Reanalysis Comparisons with Antarctic Ice Core Data, 1985-2001

- Comparing the accumulation records from the model and the reanalyses reveals large differences
- Here, ERA-40 shows the most resemblance to observations, and is the first reanalysis to accurately capture Antarctic precipitation trends post 1985
- JRA-25 produces substantially more precipitation over the high Antarctic interior than observations

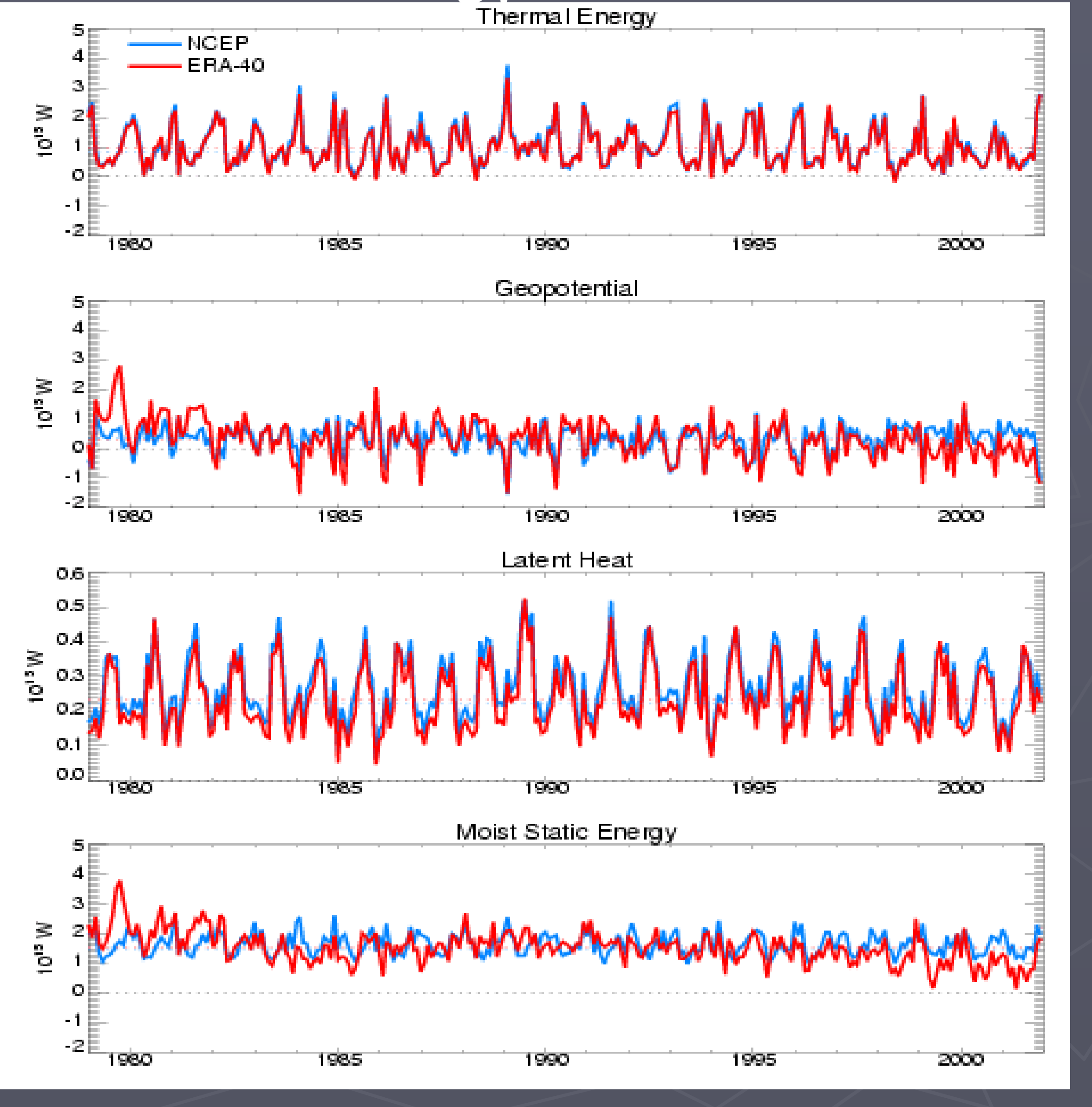
Adapted from Monaghan et al. (2006)

Antarctic Differences 1979-2002

- Differences exist in the mean circulation during the modern satellite era
- Precipitation trends simulated by a regional mesoscale model with boundary and initial conditions provided by the reanalyses are of opposite sign and magnitude for 1979-2001
- There are differences in the accumulation from the reanalyses when compared to ice core data, 1985-2001
- ERA-40 provides the best representation of Antarctic precipitation from 1985-2001

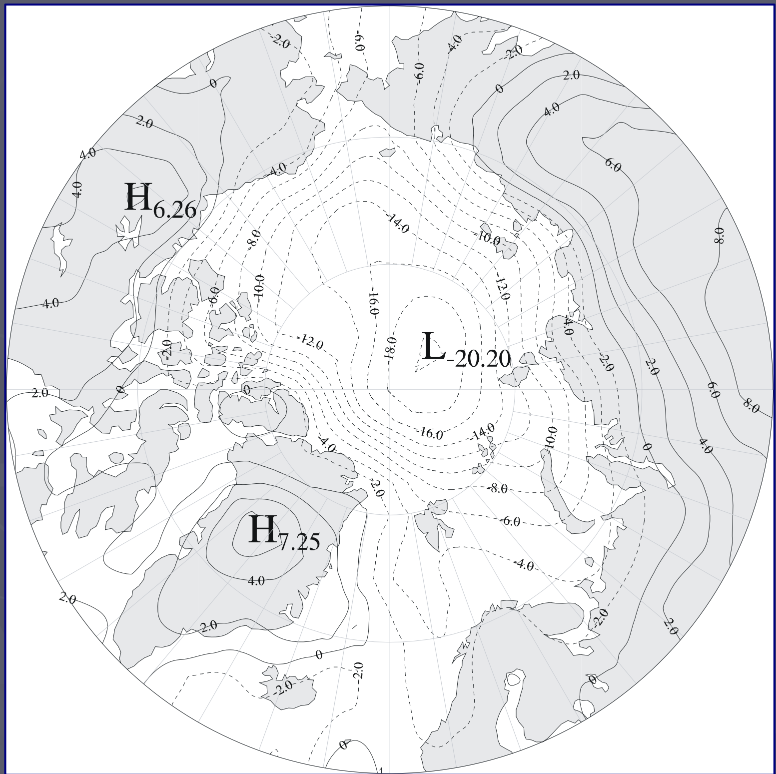
The Arctic

Mass Corrected Energy Fluxes Across 70 deg. N

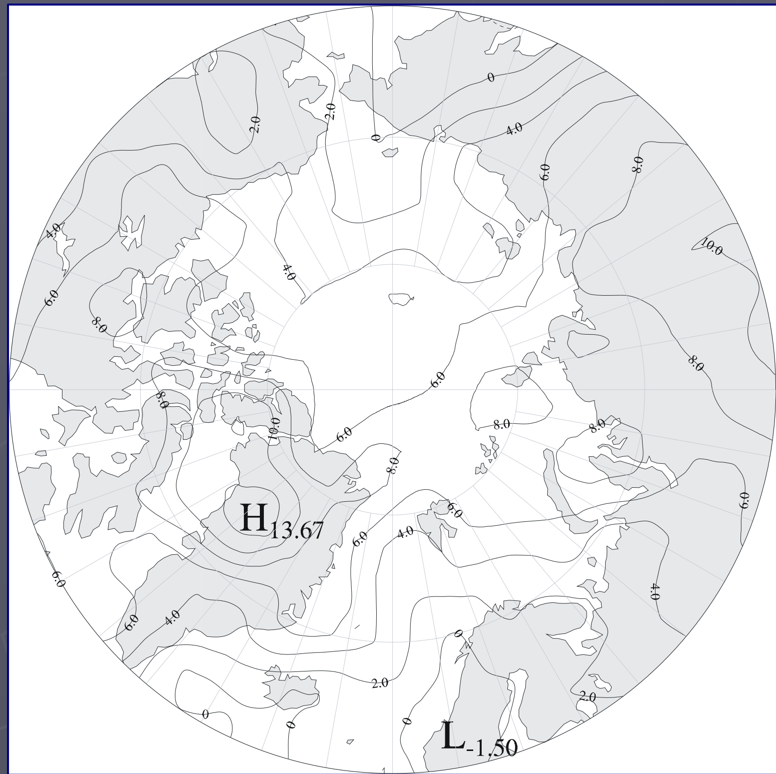


Differences in the energy fluxes are small across 70° N
From Serreze et al. (2006)

Arctic Ocean Cold Bias
500 hPa height difference (ERA40-NNR) (gpm)



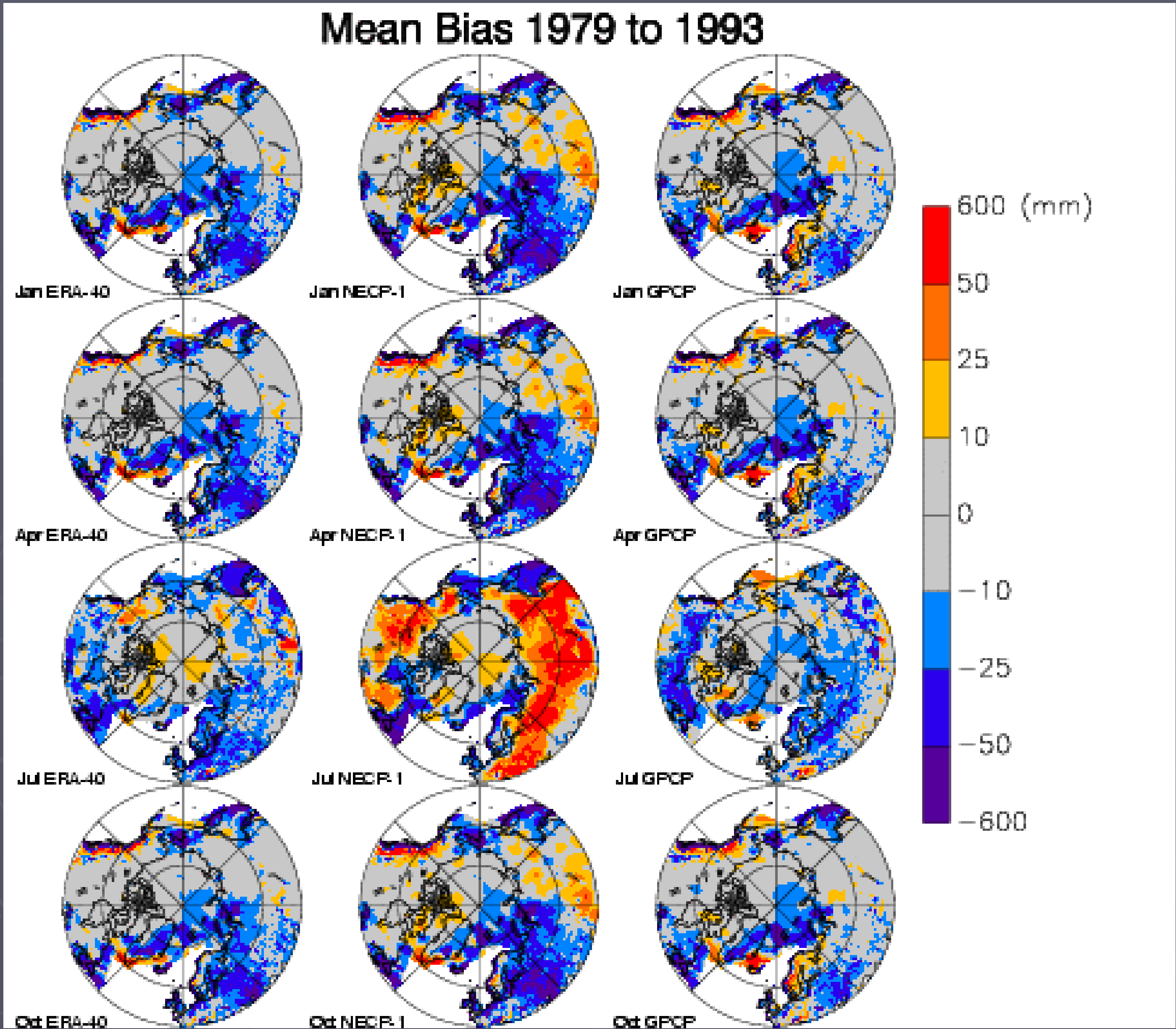
1996 annual average difference, just before HIRS assimilation (HA) change.



1997 annual average difference, right after HA change.

From Bromwich and Wang (2005)

Precipitation Biases: ERA-40, NCEP-1 and GPCP vs. blended gauge archive



Adapted from Serreze et al. (2005)

Radiation and Cloud Differences in the Arctic

↓ solar and cloud fraction at Barrow (June 2001): ERA40 (red) vs ARM/NSA (black)

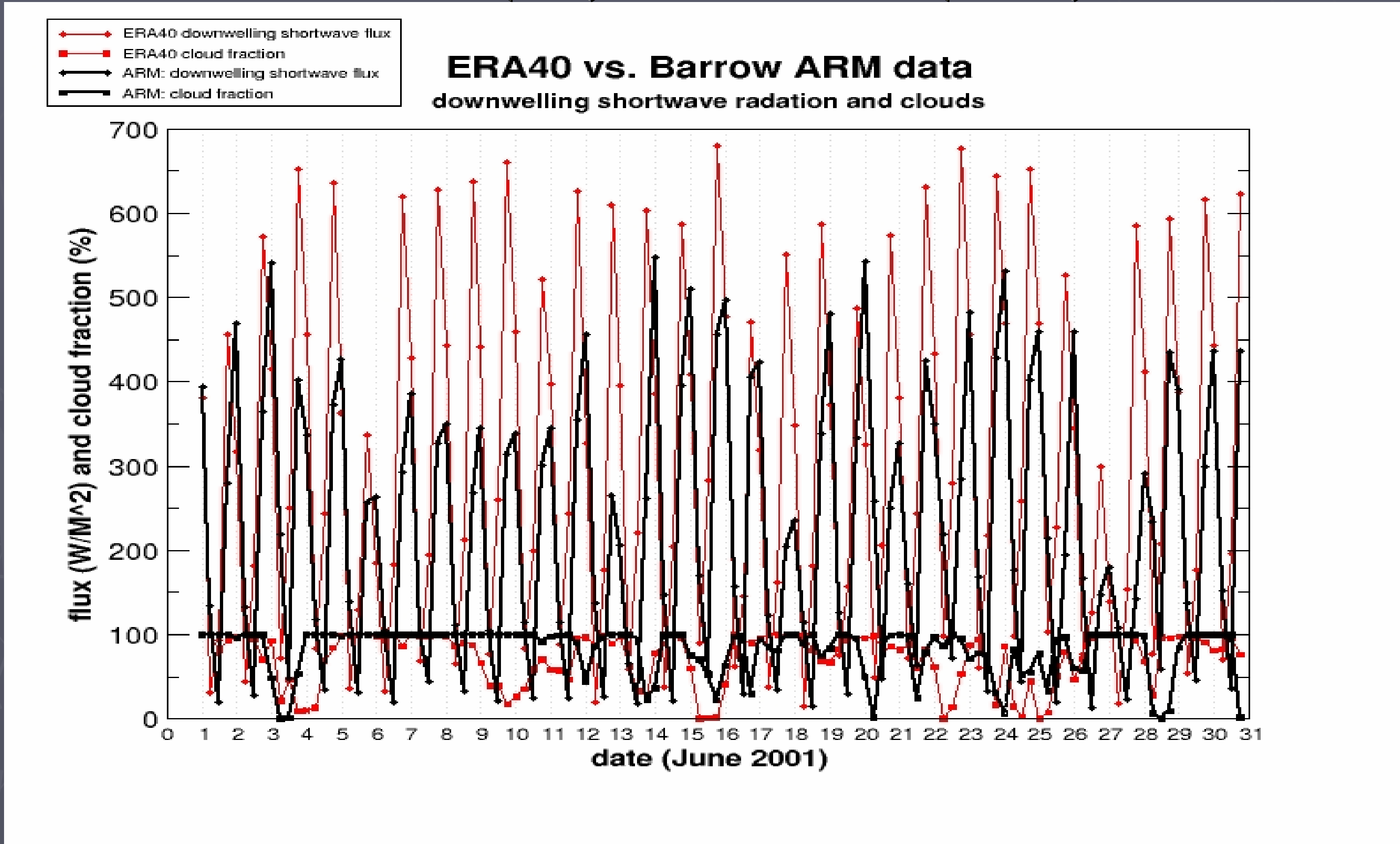


Figure provided by John Walsh, U Alaska Fairbanks

Radiation and Cloud Differences in the Arctic

↓ solar and cloud fraction at Barrow (June 2001): NCEP (blue) vs ARM/NSA (black)

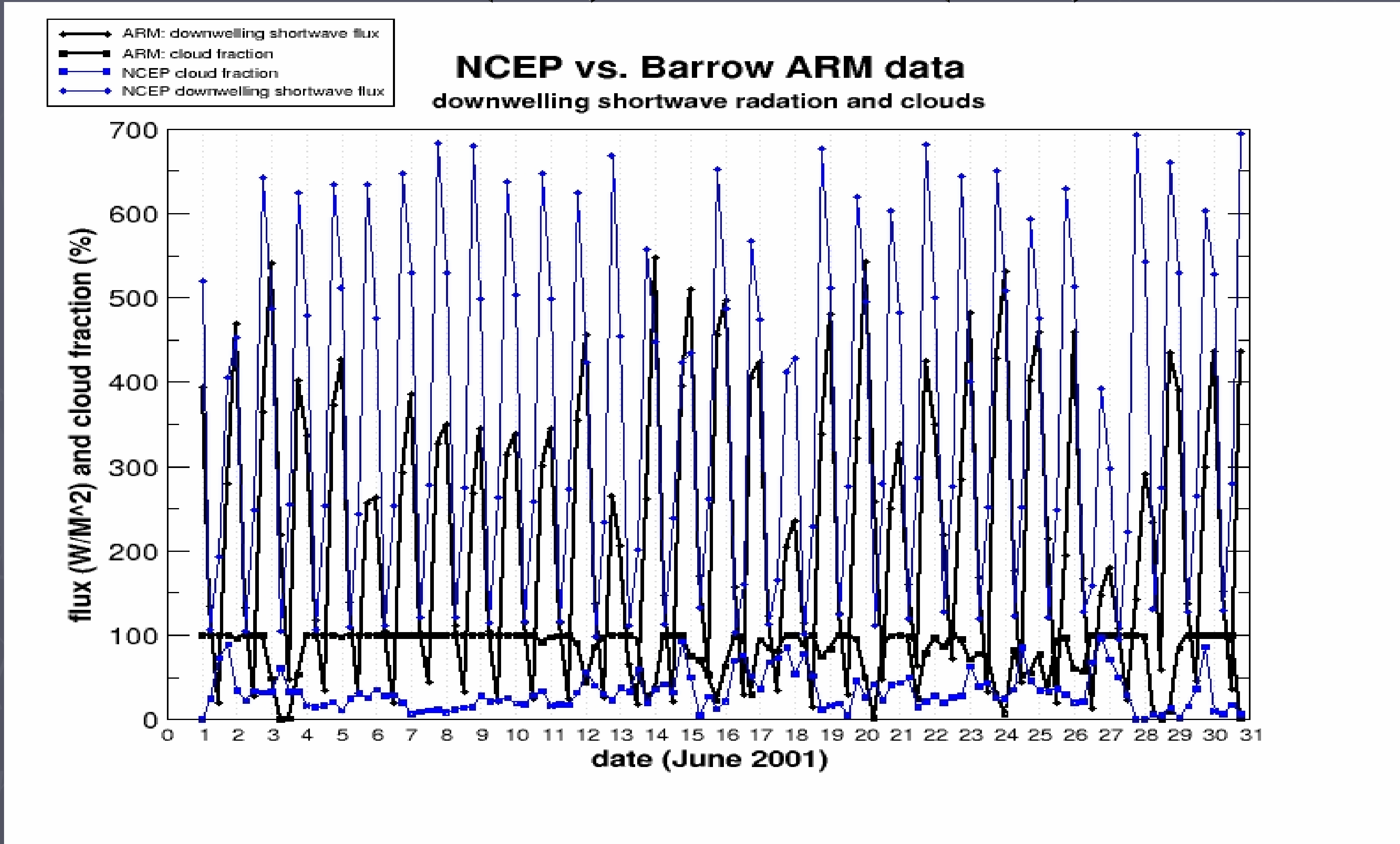
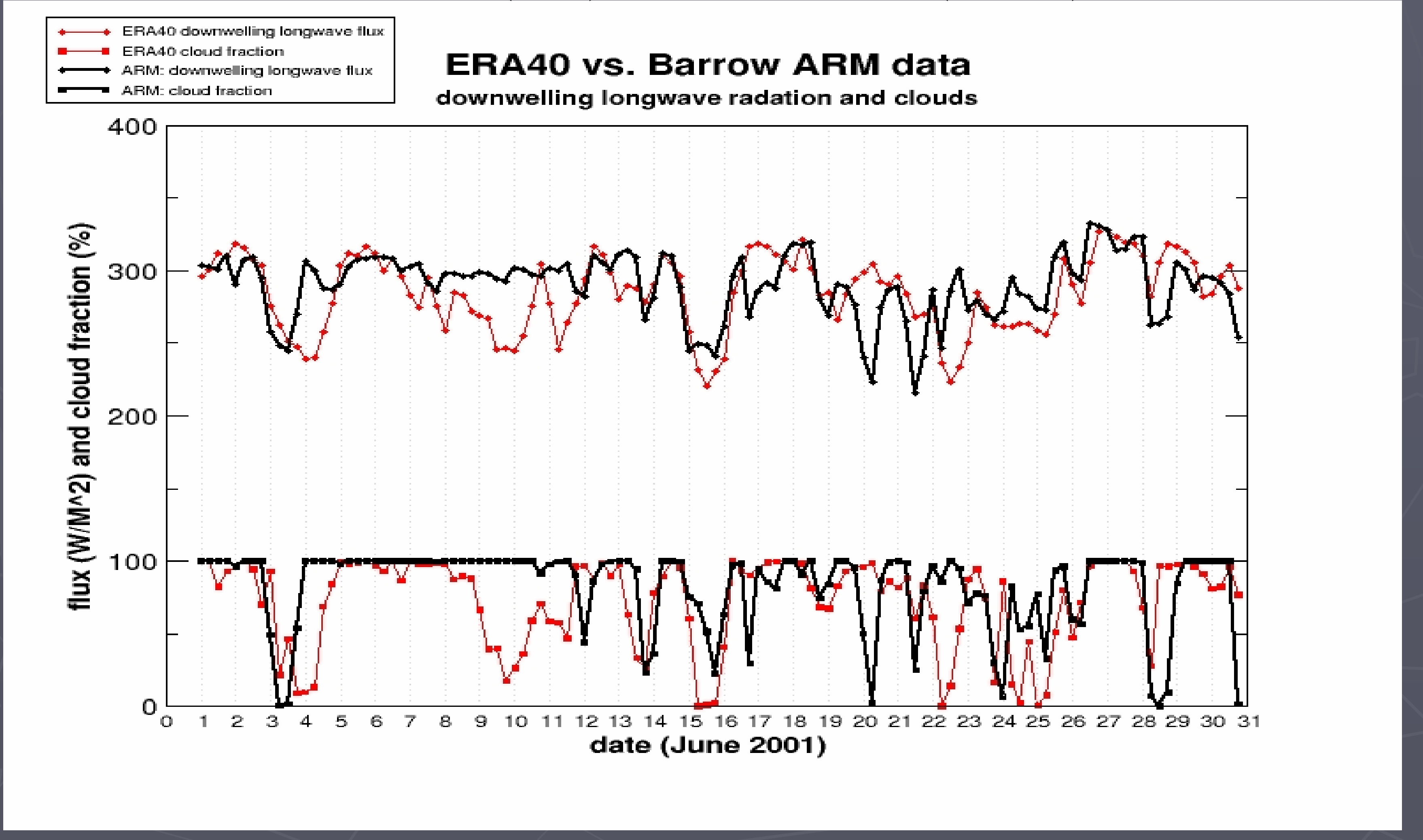


Figure provided by John Walsh, U Alaska Fairbanks

Radiation and Cloud Differences in the Arctic

↓ longwave and cloud fraction at Barrow (June 2001): ERA40 (red) vs ARM/NSA (black)



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Radiation and Cloud Differences in the Arctic

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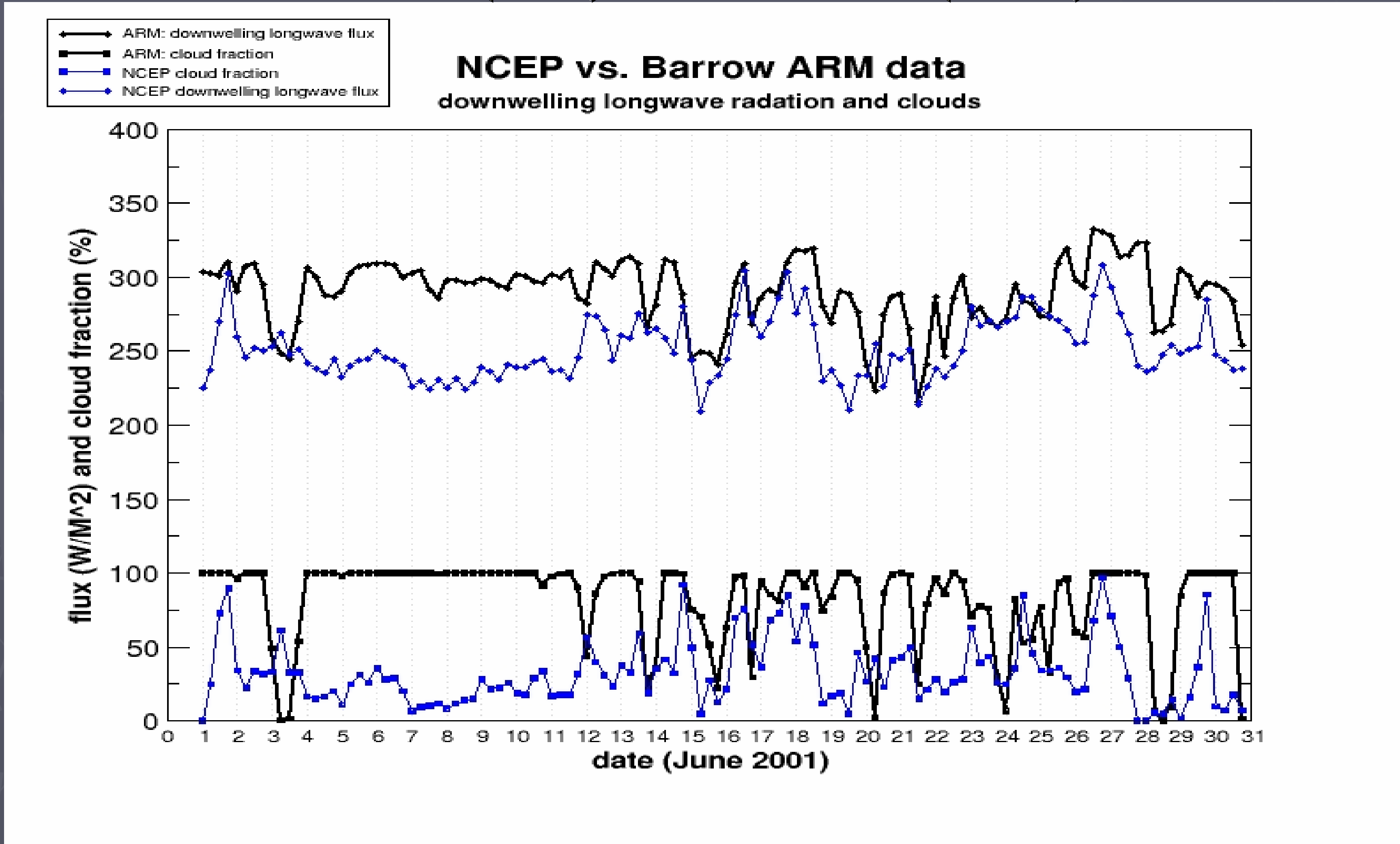


Figure provided by John Walsh, U Alaska Fairbanks

Arctic Differences 1979-2002

- Performance in Arctic is superior to that in the Antarctic
- Good agreement of mass corrected energy fluxes across 70^{o}N between ERA-40 and NCEP
- There is a cold bias in the central Arctic in ERA-40 related to the assimilation of HIRS radiances
- Other errors relate to fields commonly problematic in forecasting models:
  - Precipitation (NCEP too excessive over Arctic land surfaces in summer)
  - Clouds & Radiation
    - ERA-40 [NCEP] has good [deficient] cloud variability but insufficient [good] impact on the downwelling shortwave radiation from the cloud cover
    - However, there is good agreement between the skill of cloud prediction and downwelling longwave radiation in both ERA-40 and NCEP

Improving Future Reanalyses in the Polar Regions

Suggestions for Future Reanalyses in the Polar Regions

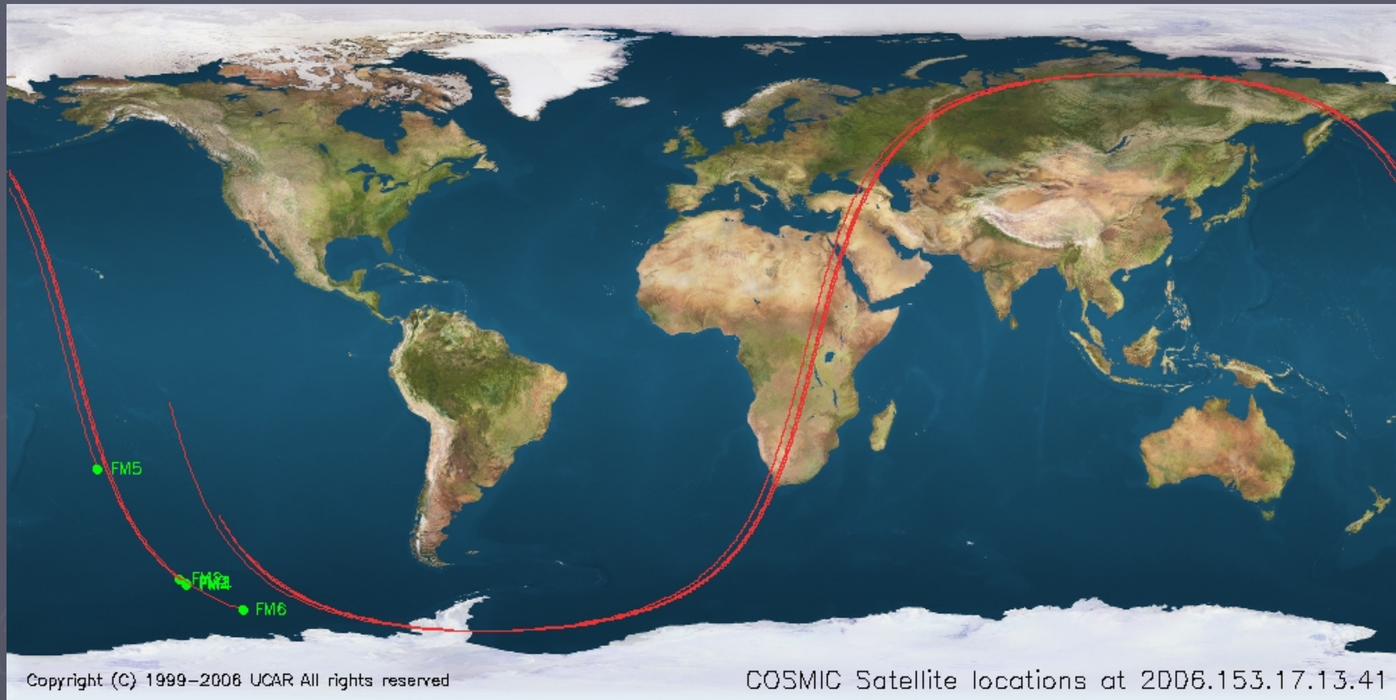
- Clearly improvements must be made in the Southern Hemisphere prior to 1979:
  - Increase the amount of data assimilated in data sparse regions
  - Different assimilation schemes may be necessary for before and after 1979 to help reduce the shock caused by the vast quantity of data entering at the start of the modern satellite era

Additional Data and Methods to Consider to Improve Quality in Southern Hemisphere before 1979

- Data from Pibals (winds only)
  - coverage in southern South America and Peninsula region as early as 1949, coastal Antarctica at IGY
- Early satellite sounding data (SIRS and SRC), available from as early as 1969
- Use some “bogus” SLP and 500 hPa observations, 1950-1969
- The use of 4-D Var with a long time window

Data information provided by Roy Jenne, NCAR

Additional Current Data for Reanalyses in both Polar Regions: COSMIC Radio Occultation (RO) Soundings



- COSMIC satellites are going through a validation phase now:
  - All six satellites are healthy
  - All payload working as expected
  - Begin orbit raising for one satellite last week
- Mass production of GPS RO sounding is expected to begin in late June 2006.

Information and figure provided by Bill Kuo, UCAR

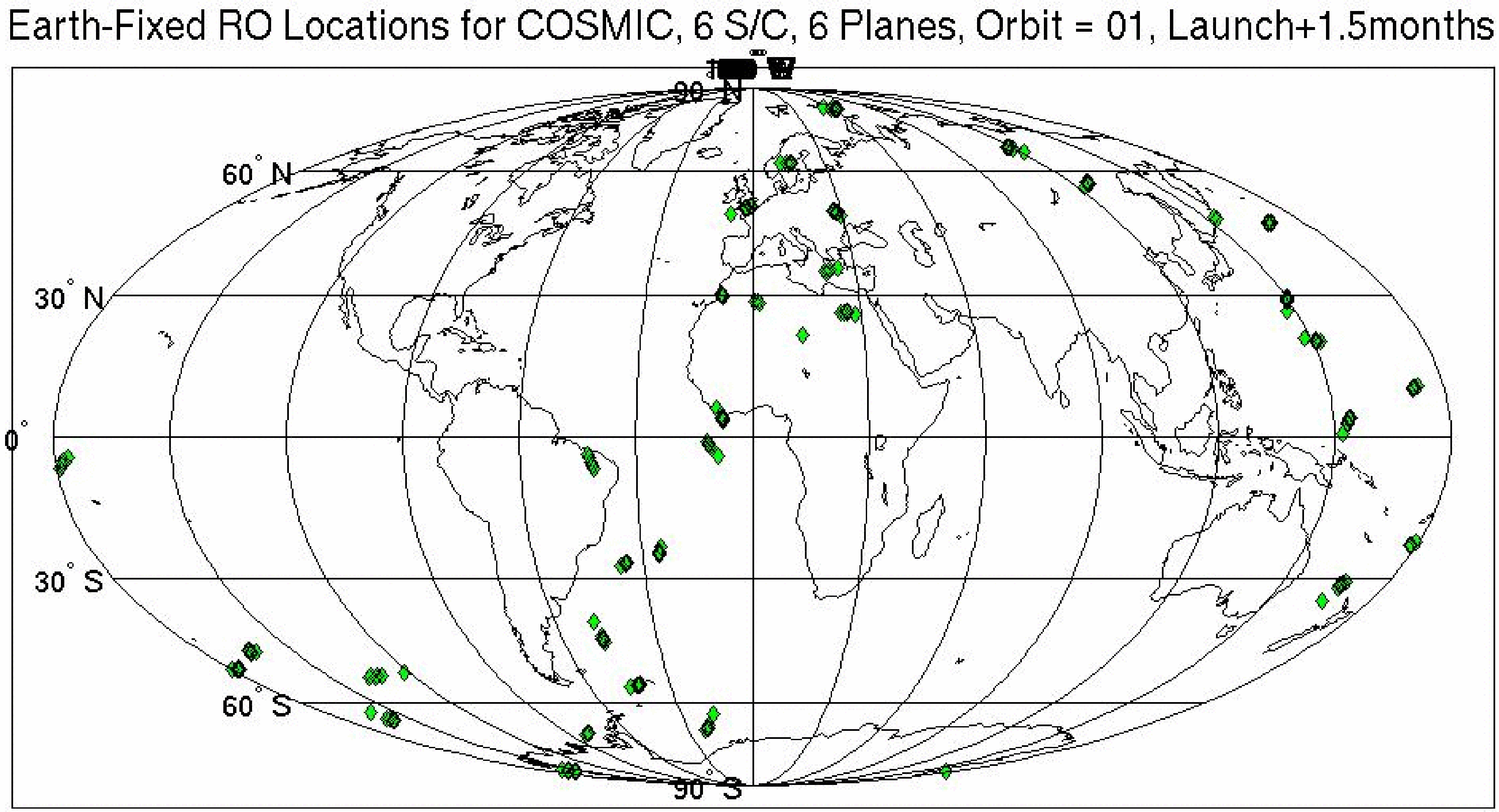


Figure provided by Bill Kuo, UCAR

COSMIC Sounding Distribution in a Day (at maturity)

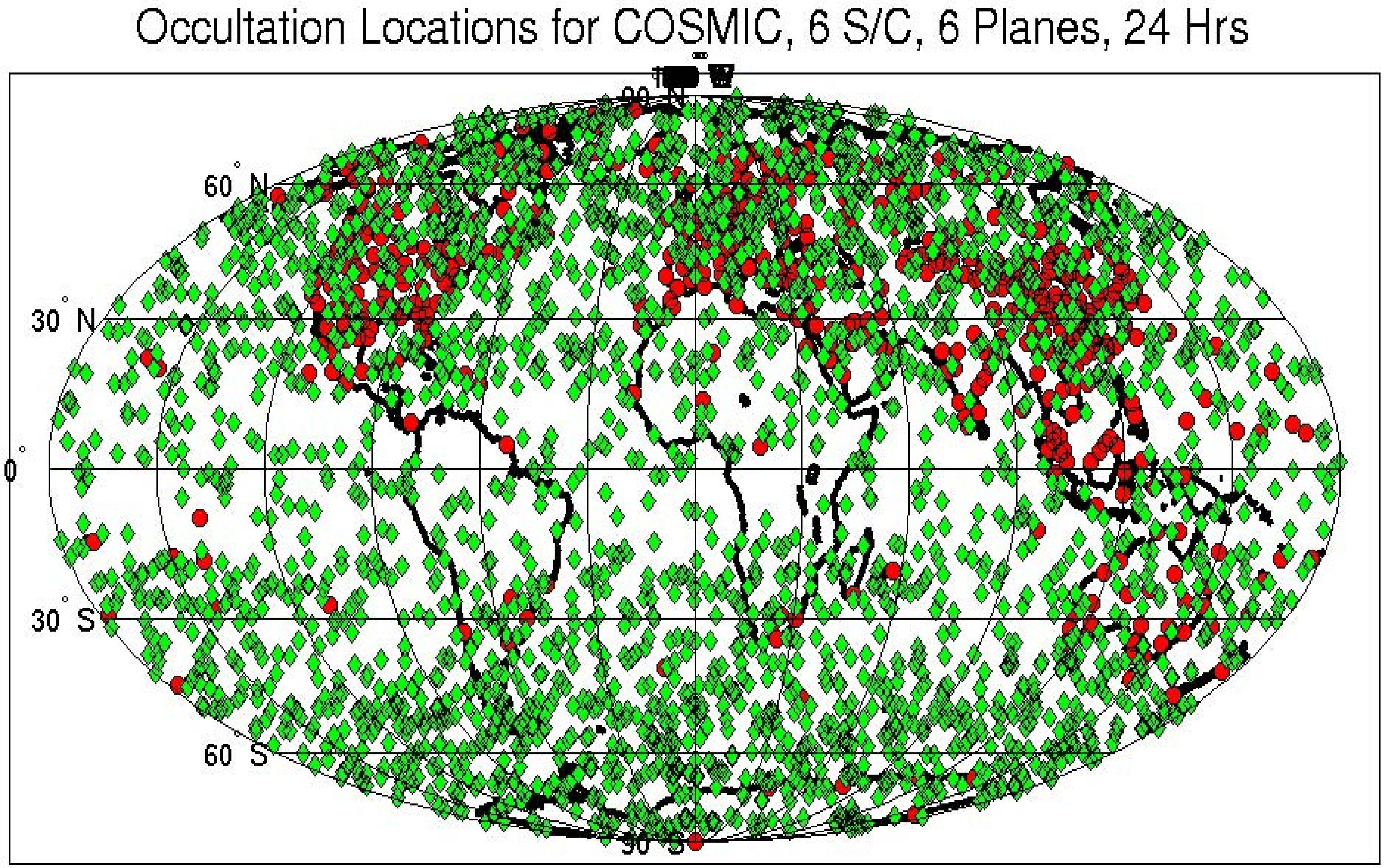


Figure provided by Bill Kuo, UCAR

Total COSMIC GPS RO Soundings in a Day in the Southern Hemisphere

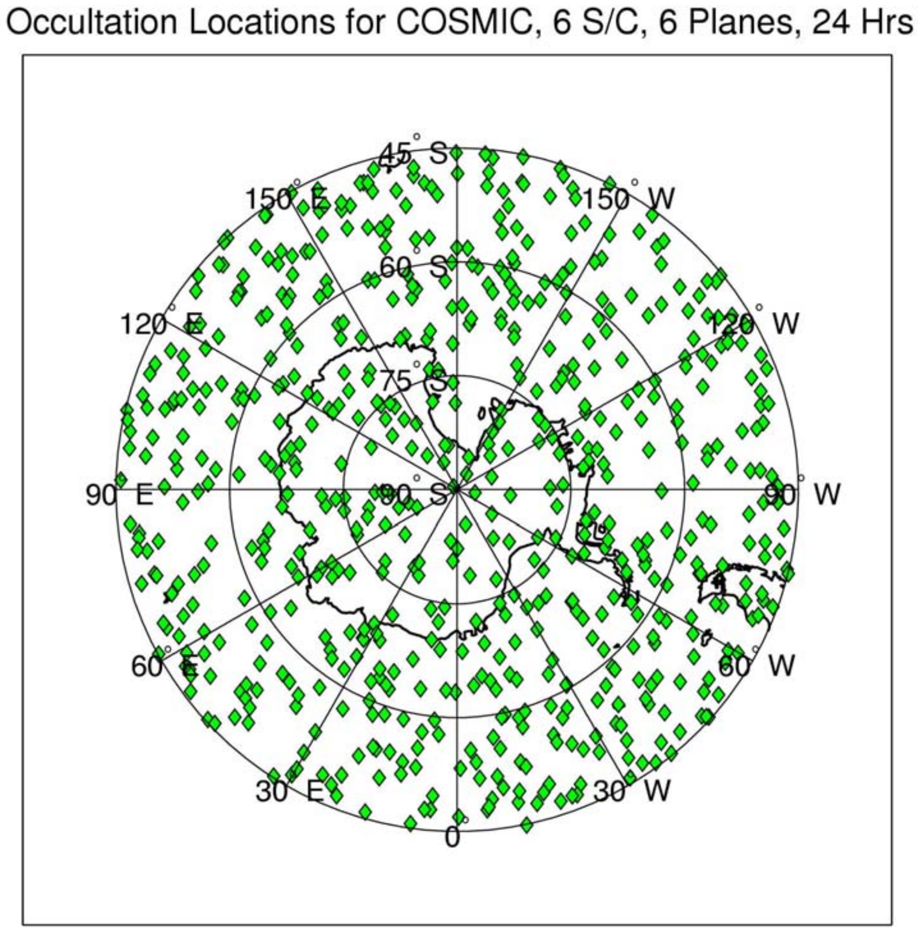


Figure provided by Bill Kuo, UCAR

Talk Summary

- Currently, the reanalyses in the middle and high latitudes of the Southern Hemisphere are only useful in the summer months from 1979- onwards
  - The lack of agreement prior to 1979 in the SH between observations and the reanalyses, and between the reanalyses themselves, suggests that there is little reflection of reality in the reanalyses, but rather a reflection of their own model climatology
- Smaller differences after 1979 are found in:
  - Precipitation in both polar regions, both trends and magnitude
  - Mean atmospheric circulation in the Antarctic interior and Southern Ocean
  - Cloud and associated radiation variability in the Arctic

Talk Summary, Con't

- To produce a more reliable reanalysis from 40°-90°S prior to the modern satellite era, the use of all available data is required, including early satellite soundings
- Data assimilation schemes need to be tuned to work better in data sparse regions
  - May require the use of different assimilation schemes for 1958-1978 and 1979-2001 in order to reduce the shock arising from the vast quantity of data available at the start of the modern satellite era