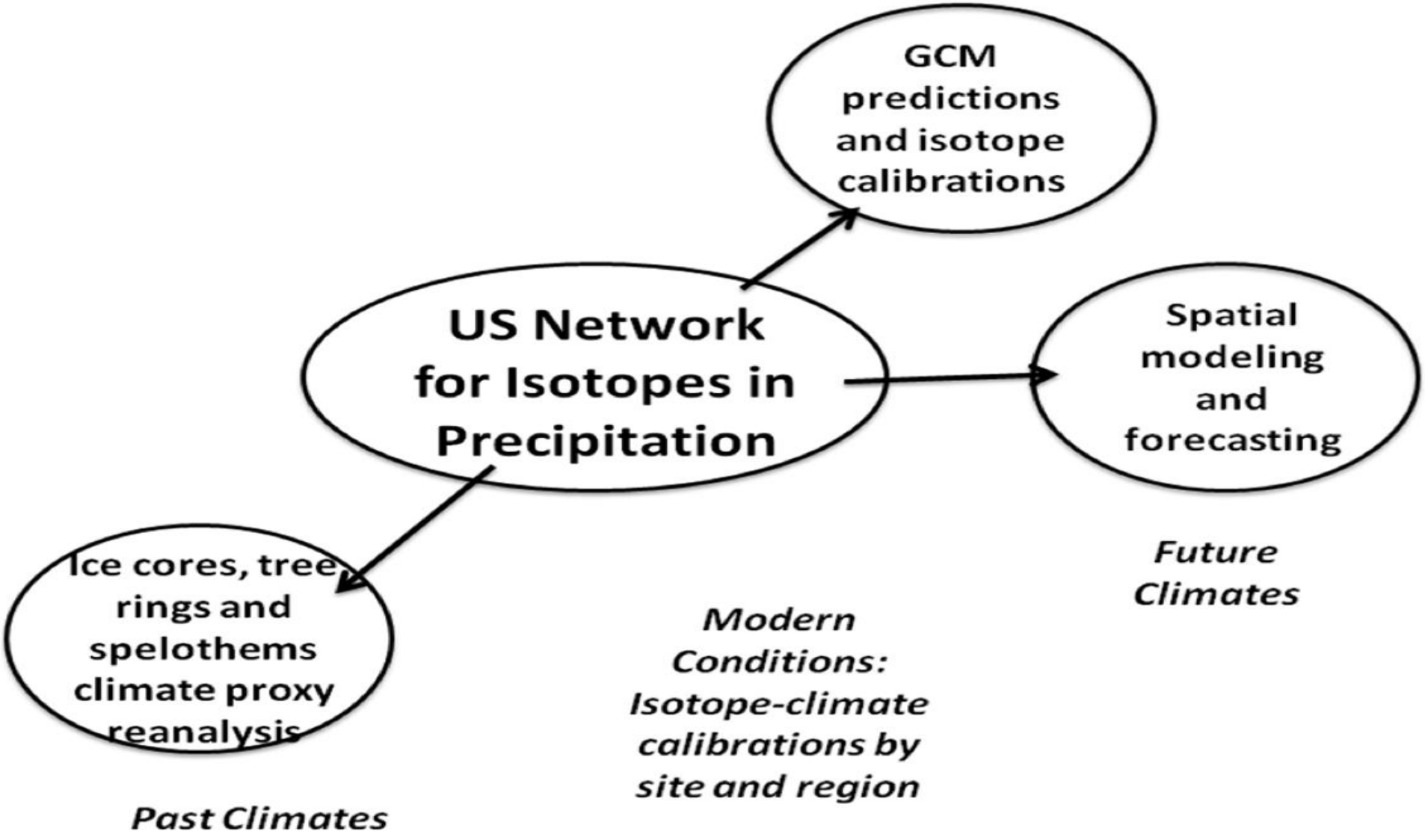
US Network for Isotopes in Precipitation: Recent Findings and the Research Trajectories

Jeff Welker and colleagues
Environment and Natural Resources Institute
University of Alaska Anchorage

NW Greenland-Welker-NSF Research Site

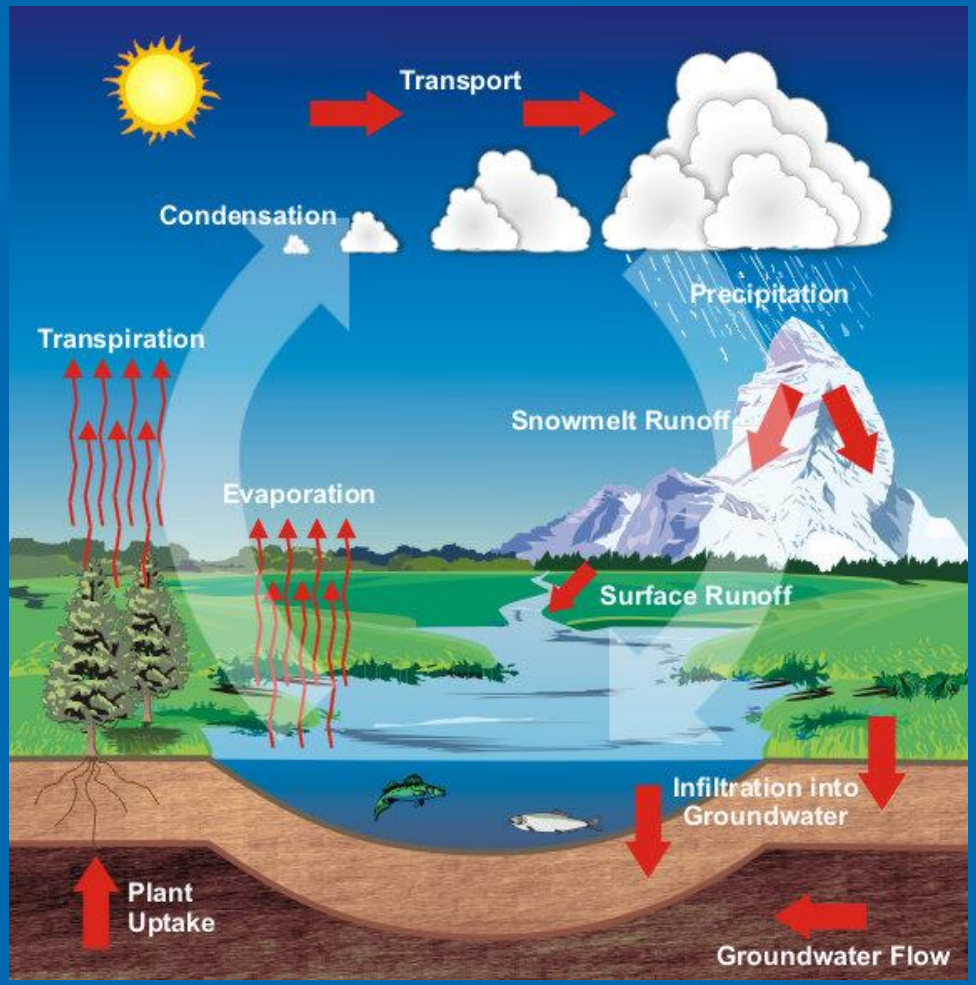
OVERVIEW

- Background
- USNIP
- Early Findings
- Recent Discoveries
- Next Generation of Research
  - Time series
  - Climate Oscillations
  - Climate reconstructions-reanalysis
  - NEON



Collaborations with NADP since 1994 examining the patterns and processes of precipitation isotope geochemistry at the continental scale

Hydrological Cycle



Precipitation is the foundation of the hydrologic cycle and has applications to all aspects of water resource use, it's geochemistry is recorded in climate proxies and it controls in large part the C and N cycles

Multiple processes define the hydrological cycle and several processes are temperature dependent-evaporation, condensation and precipitation

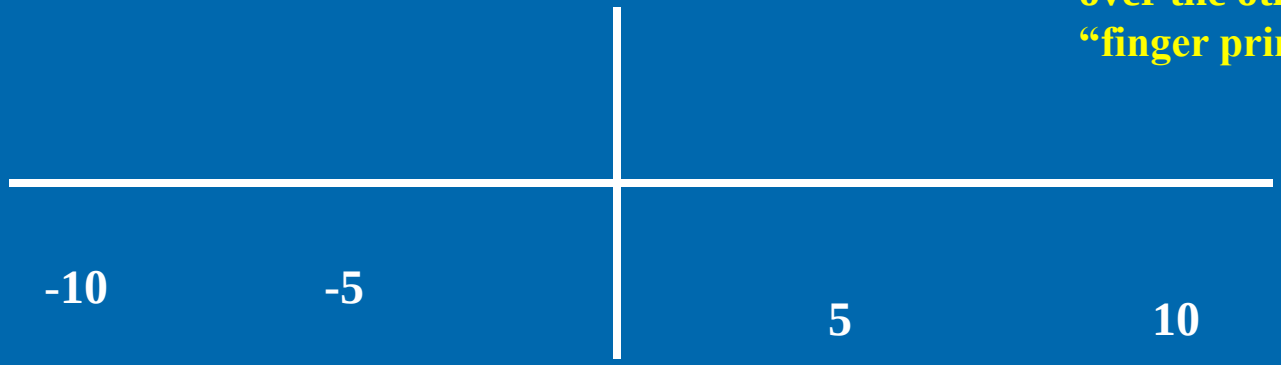
Applications of stable isotopes in precipitation

- Understanding modern drivers of isotope geochemistry
  - Temperature, storm tracks, recycling
- Site and region specific climate reconstructions using proxy records
  - Ice cores, tree rings, speleothems, lake vares
- Migratory bird forensics
  - Wintering locations of Alaskan geese, tundra swans
- Long-term monitoring of Ecohydrologic Processes-NEON-contributions
- General Circulation Models
  - Hydrological calibrations

Isotopes-Elements with atoms that have different numbers of neutrons

Isotope jargon

Heavy and light isotopes behave slightly differently and thus some processes (condensation-evaporation-precipitation) favor one over the other, leaving a "finger print"



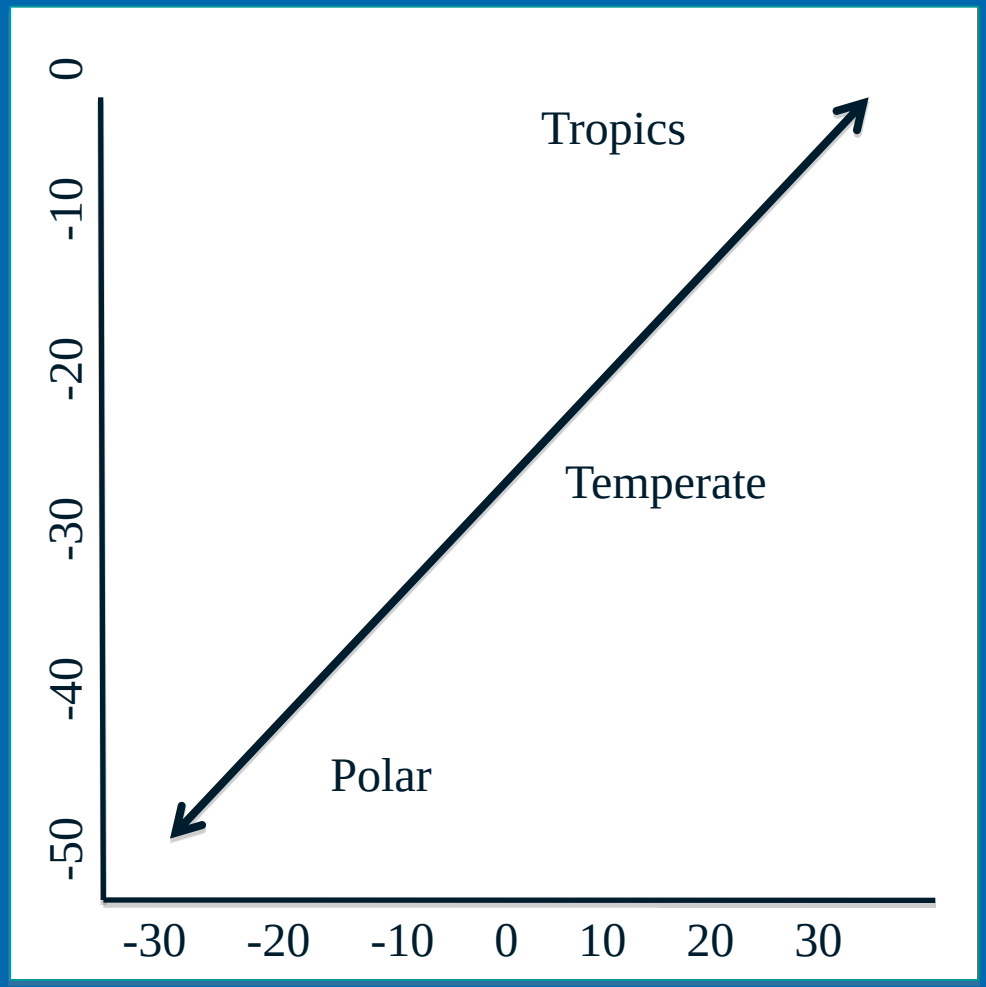
Depleted *compared to the standard*

Enriched *compared to the standard*

δ=0

SMOW

($^{18}O/^{16}O$, $^{2}H/^{1}H$)



Classic Danssgard study in 1964 depicting temperature controls on the $\delta^{18}O$ values of precipitation. However, it was a space for temperature substitution- low temperatures from the Arctic and Antarctic, warm places-tropics. Not a record of interannual variation at one site, where confounding variables could be accounted for in the analysis.

Global Network for Isotopes in Precipitation-IAEA (International Atomic Energy Agency)

. 3. Geographical distribution of the IAEA/WMO network stations for which a minimum of one complete year of stable isotope re
vailable.

weighted mean annual $\delta^{18}O$

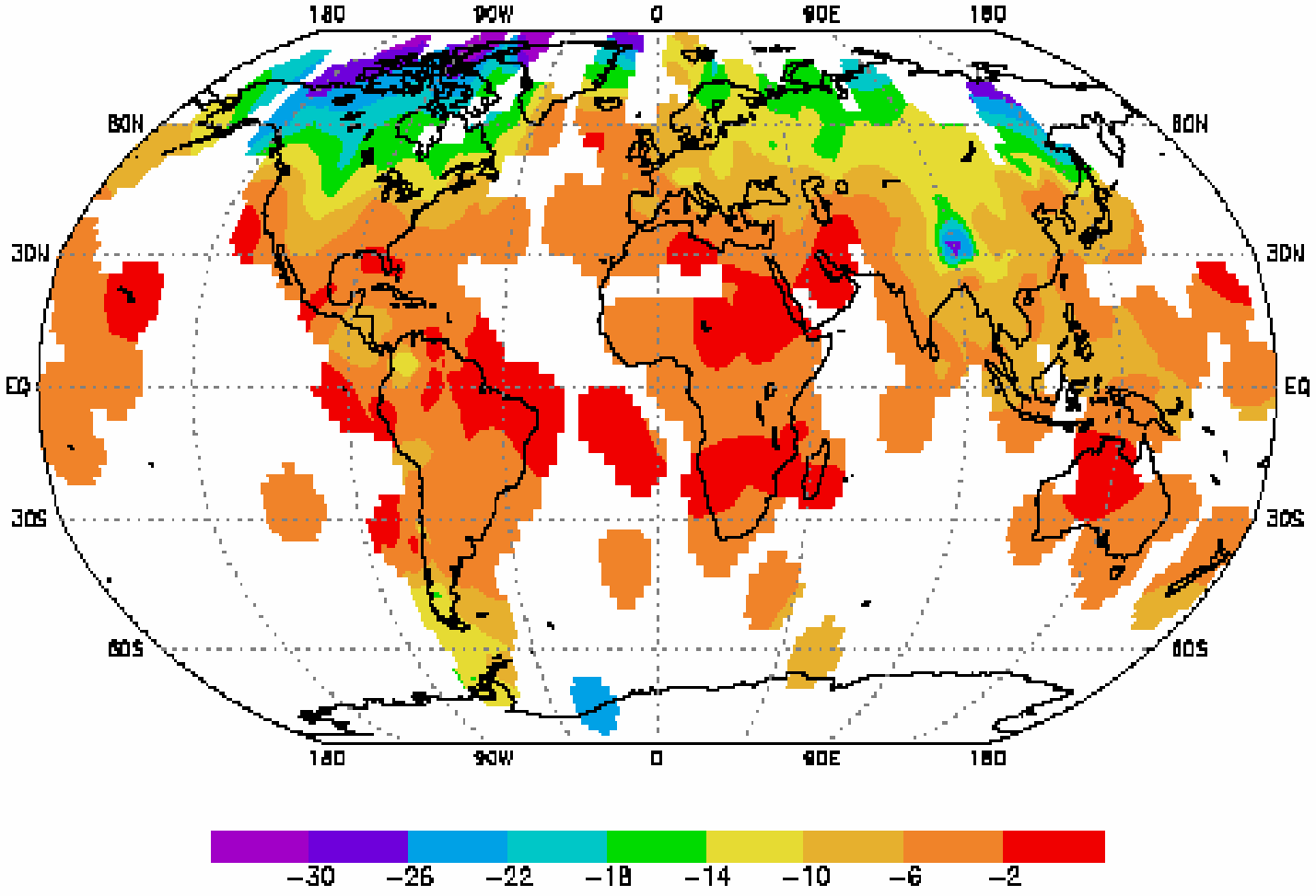


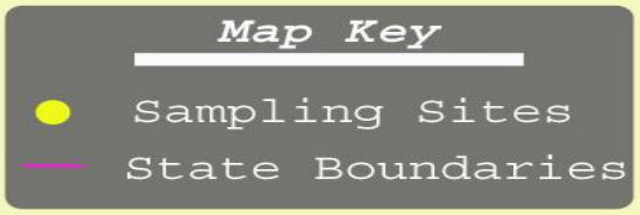
FIG. 5 Contour map of amount-weighted mean annual $\delta^{18}O$ in precipitation derived from the GNIP database, for stations reporting as of 1997 (see [1]).

A

US Network for Isotopes in Precipitation (USNIP) *Welker et al.*

NADP sample analysis beginning in 1989

B



C

Welker 2000

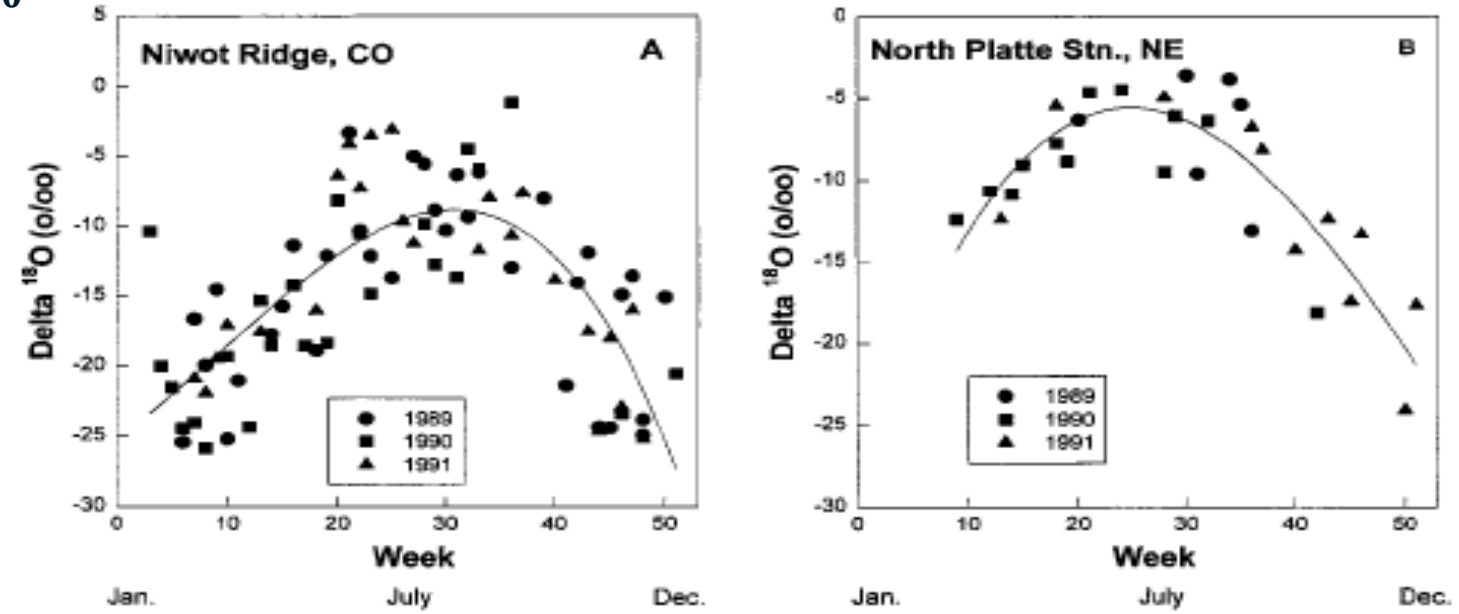


Figure 7. The $\delta^{18}O$ values of precipitation (‰) collected at weekly intervals (1–52) for the site at Niwot Ridge, Colorado during 1989, 1990 and 1991 (A) and for the site at North Platte, Nebraska (B). Precipitation samples were not available for all weeks

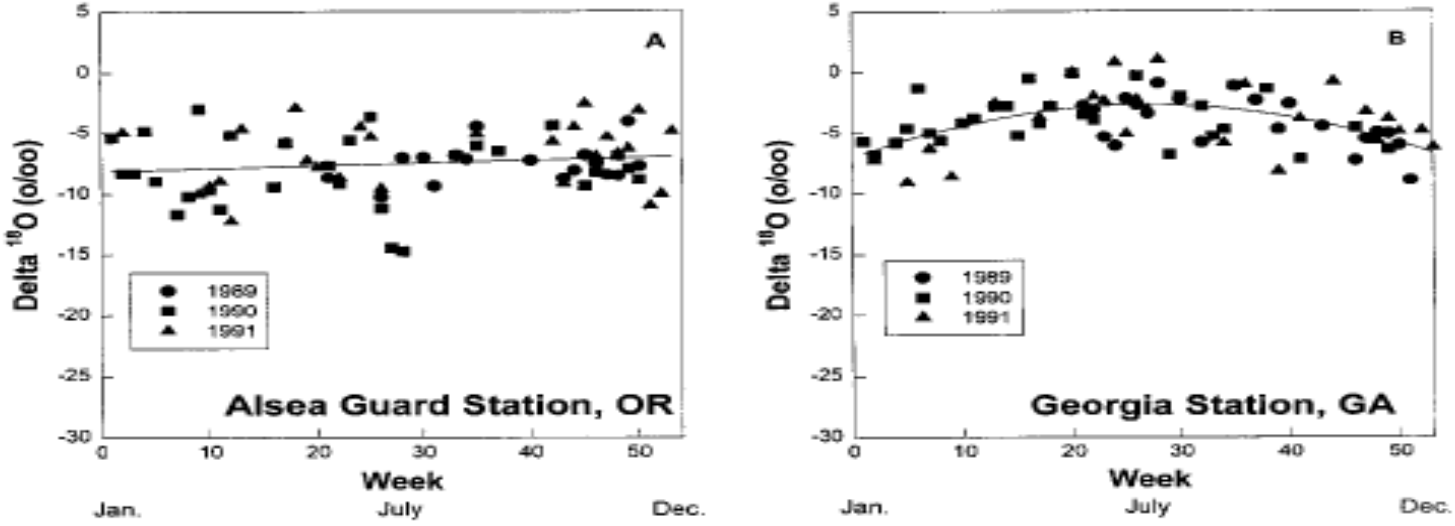
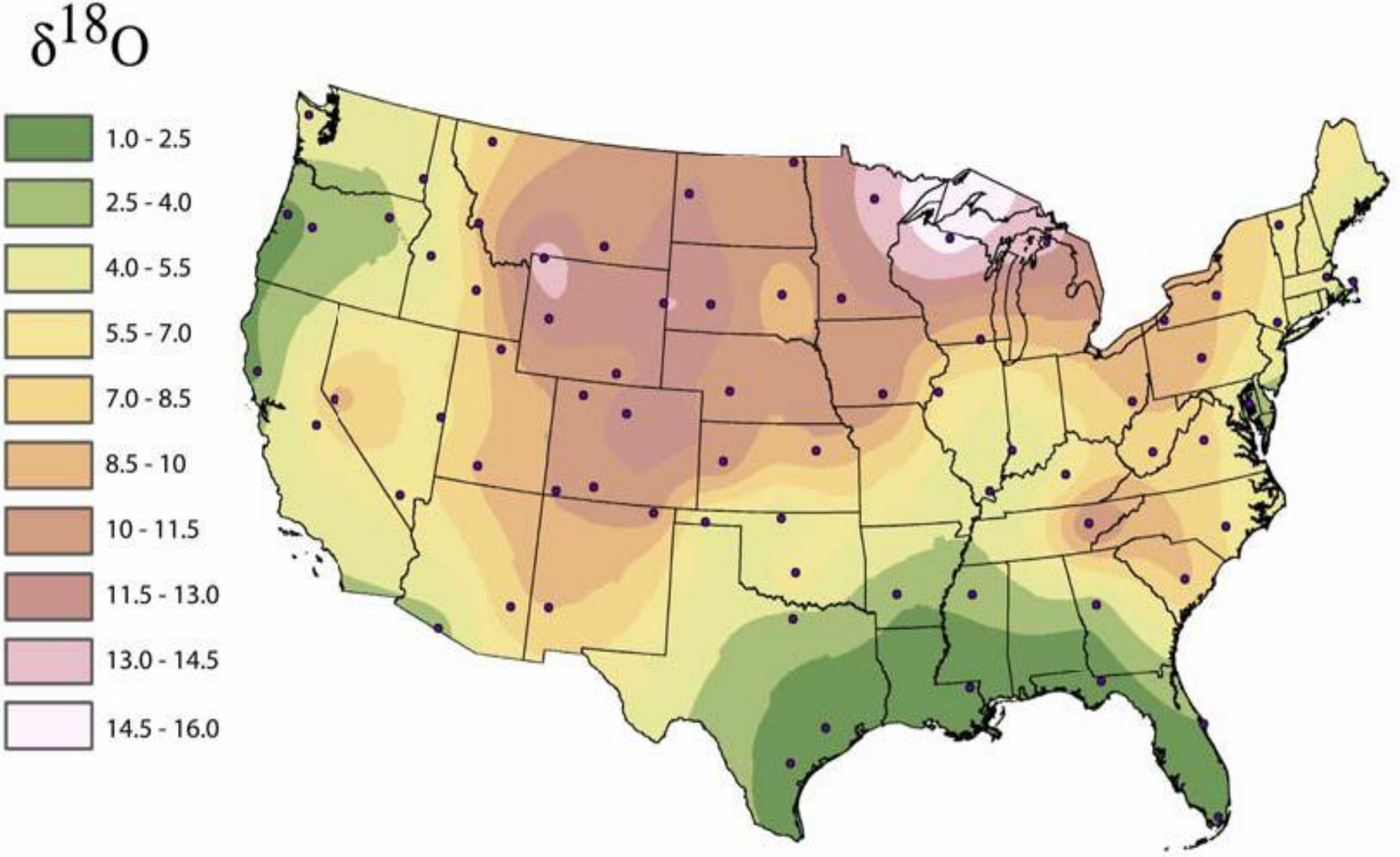


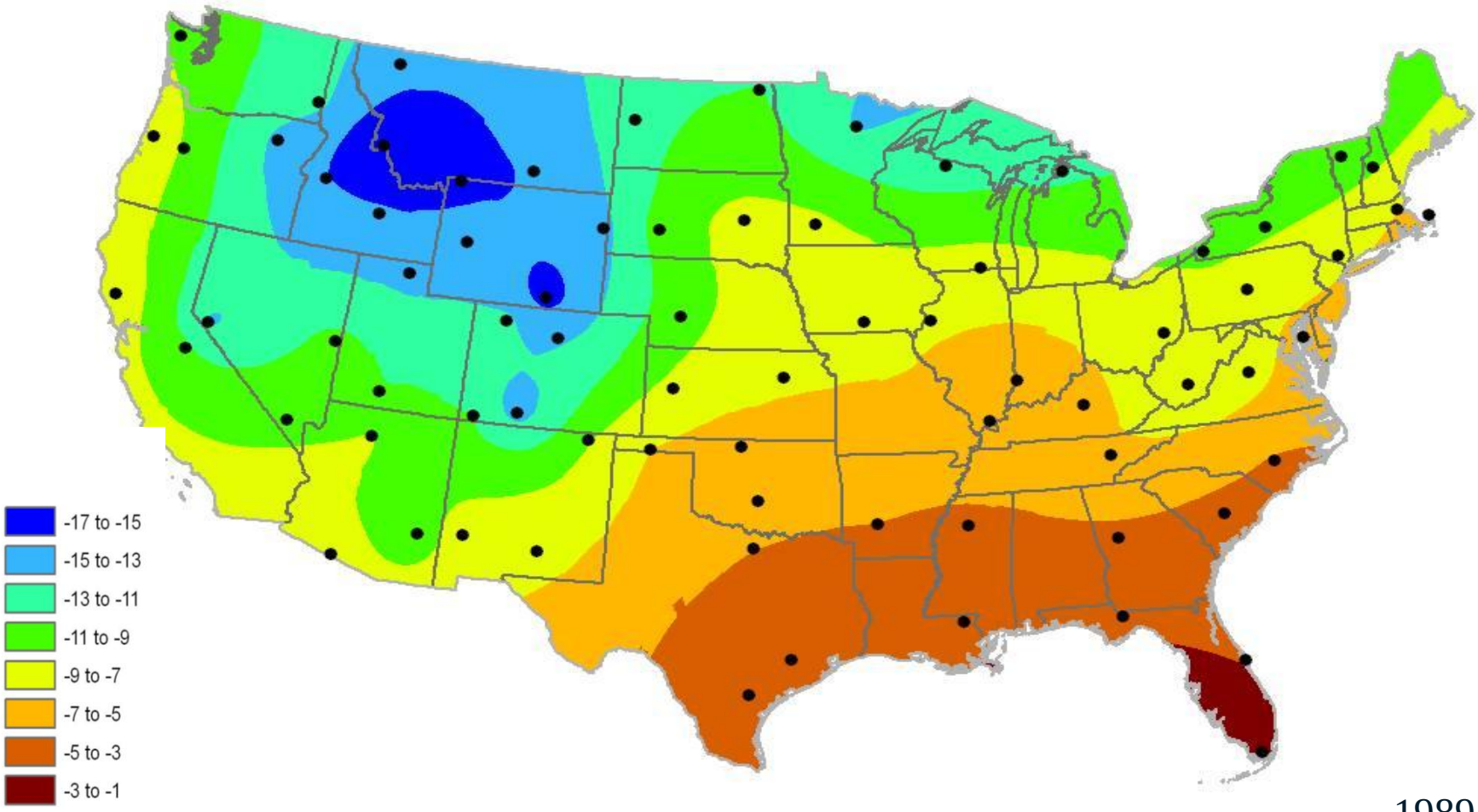
Figure 8. The $\delta^{18}O$ values of precipitation (‰) collected at weekly intervals (1–52) for the site at Alsea Guard Station, Oregon during 1989, 1990 and 1991 (A) and for the site at Georgia Station, GA (B). Precipitation samples were not available for all weeks

$\delta^{18}O$ Seasonal Range

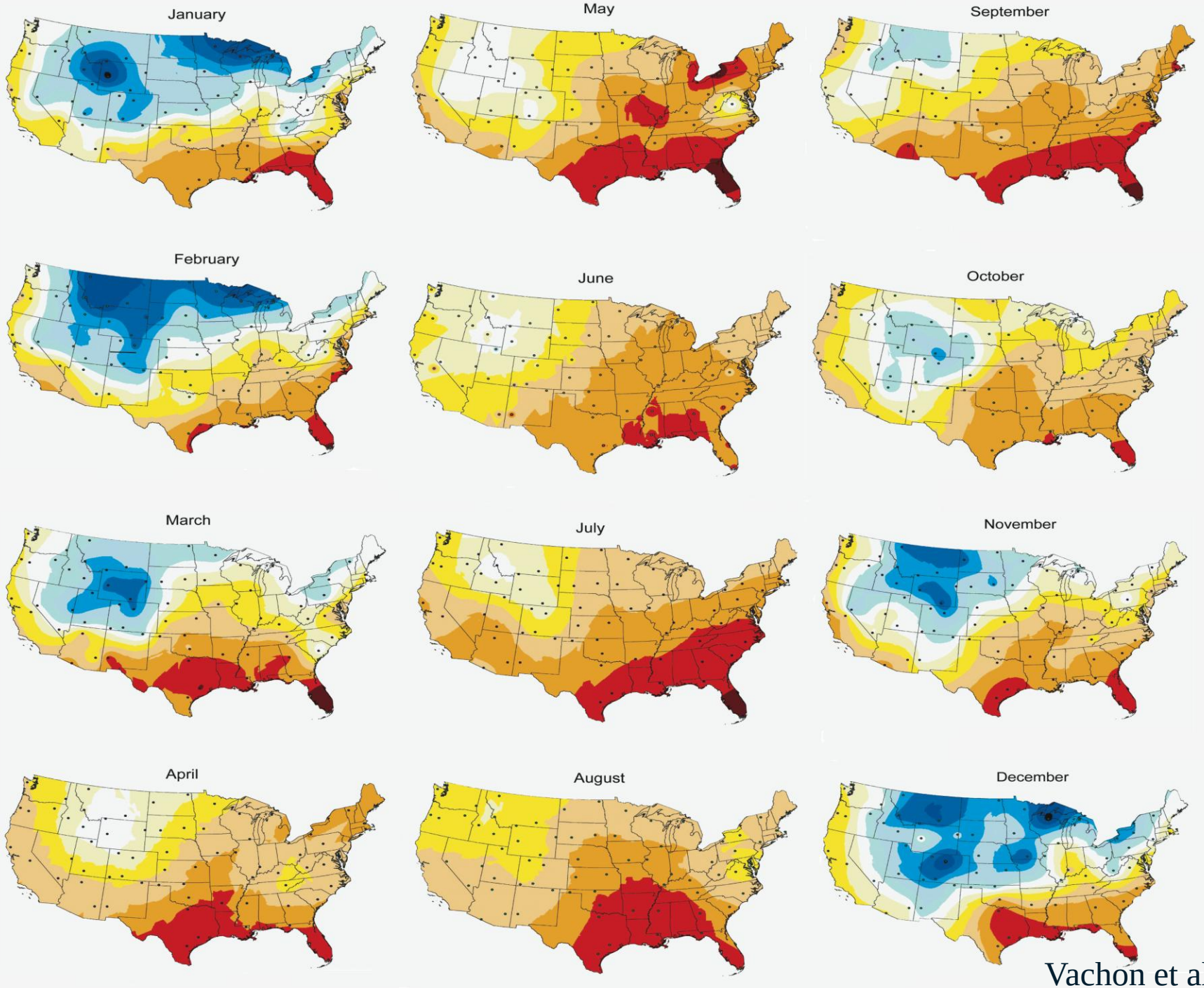


Vachon et al. 2007

Average

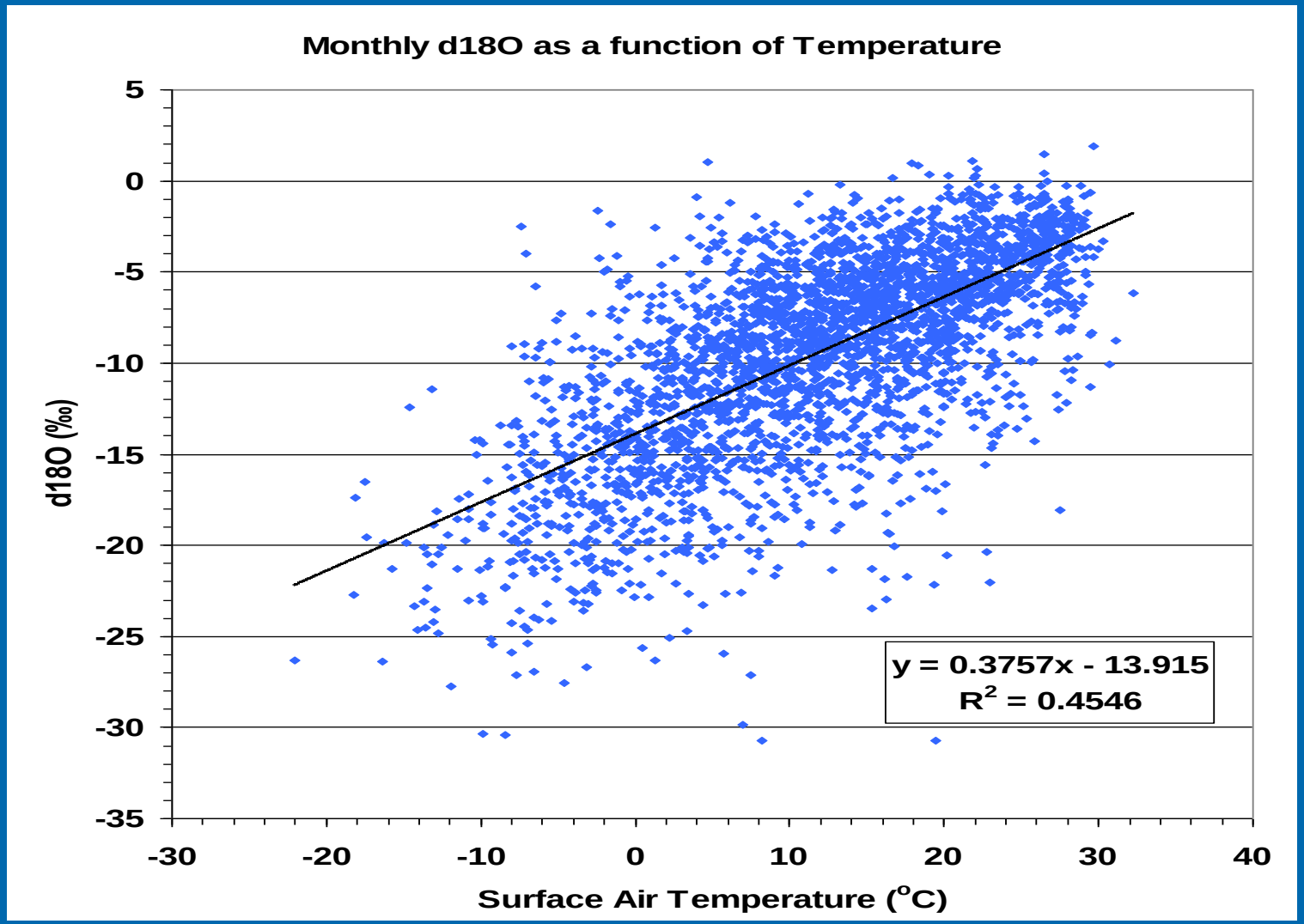


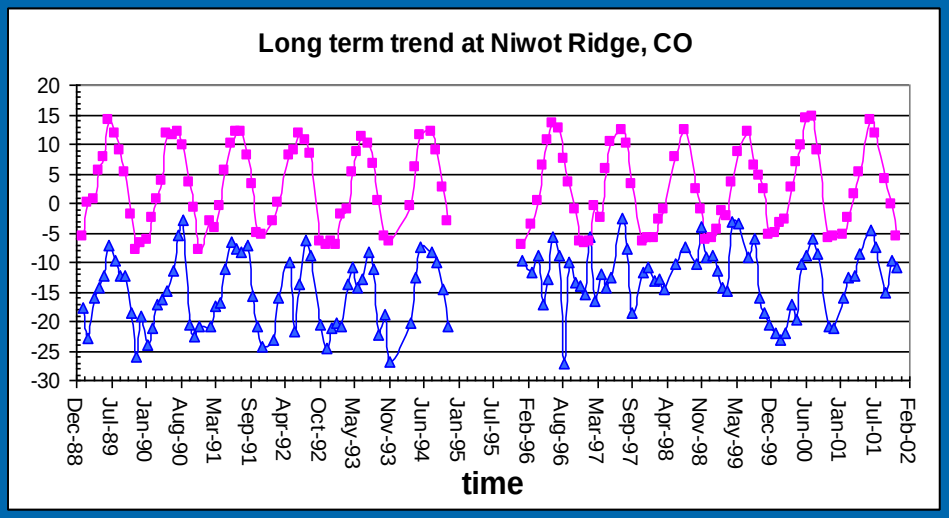
1989-1996

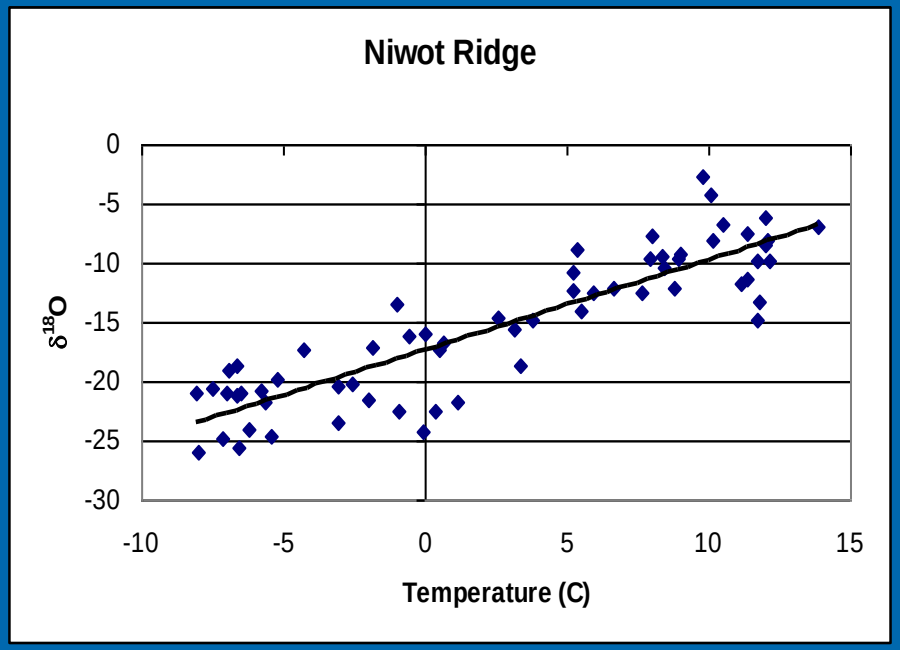


Vachon et al. 2010

Effect of Physical Processes

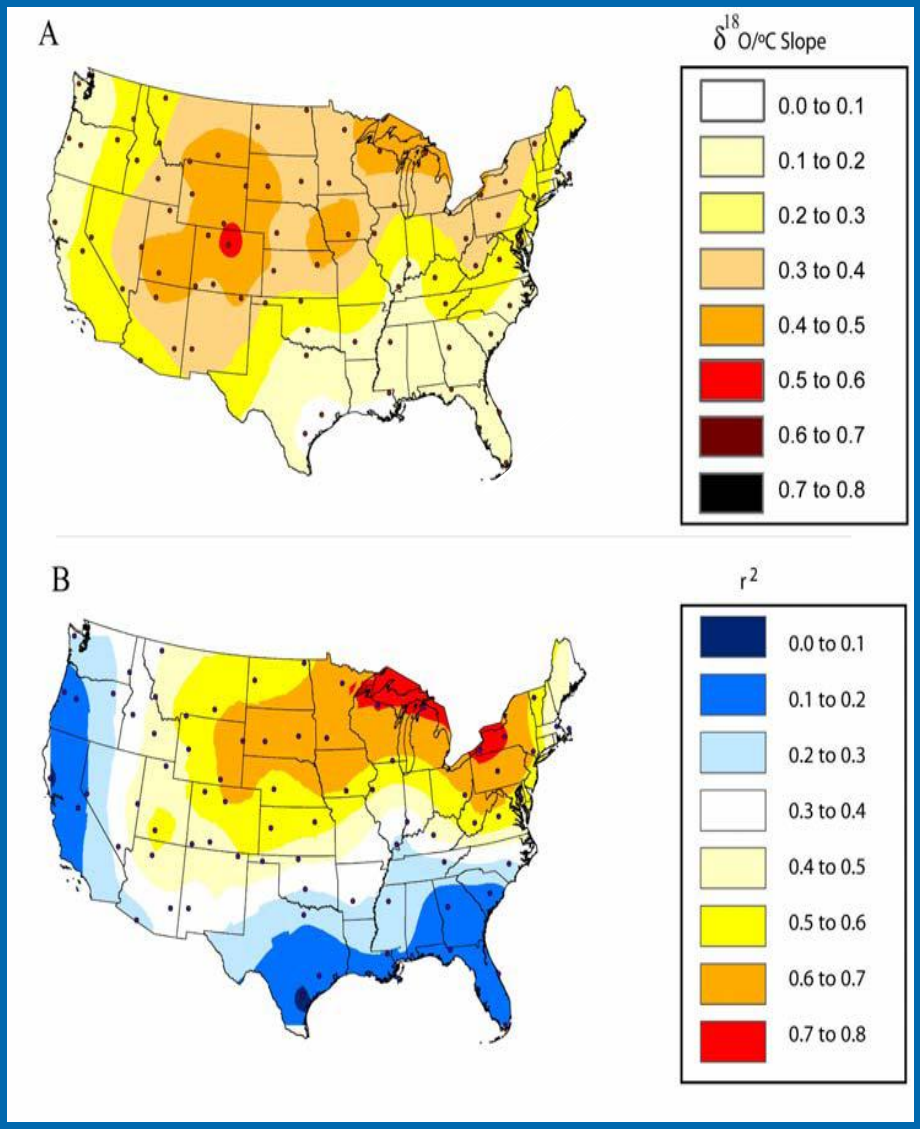




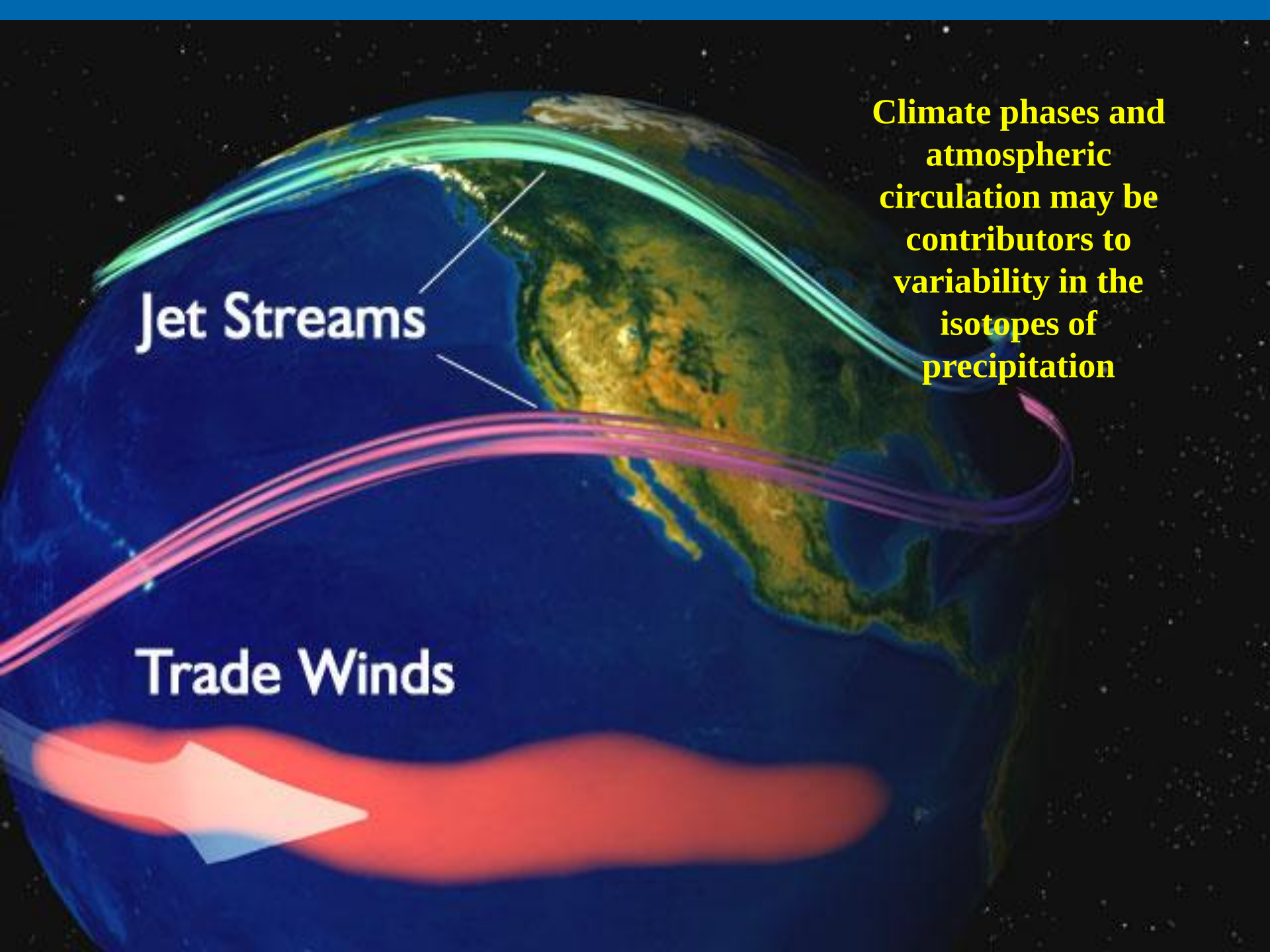


0.6 ‰ $^{18}O/^{o}C$

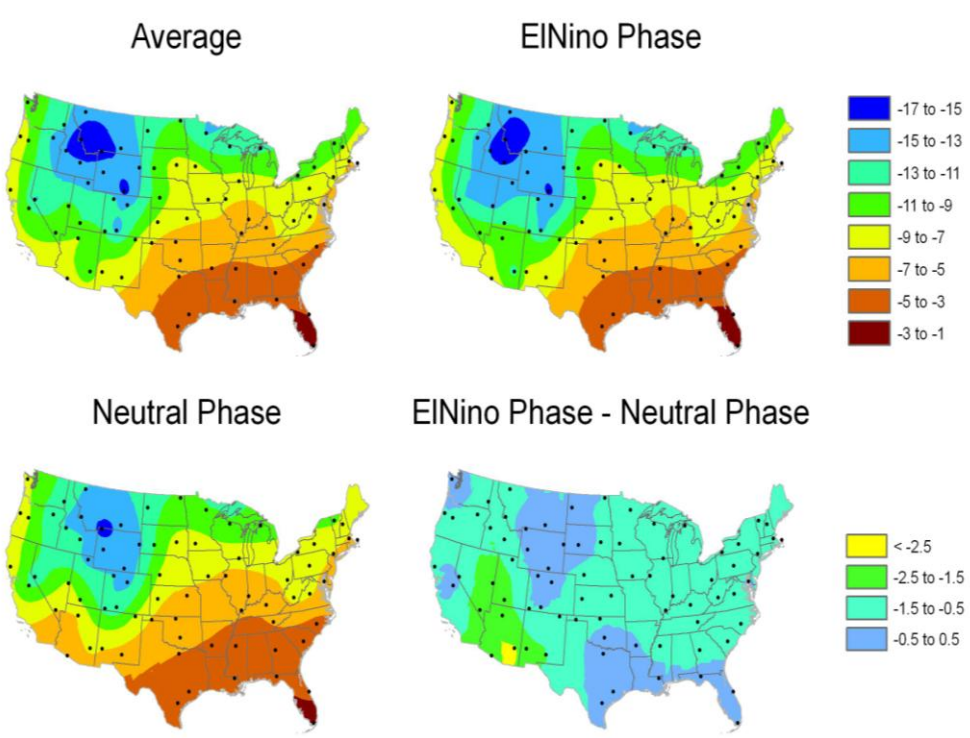
Precipitation Isotopes track temperature in the US with high confidence, but seldom in coastal regions

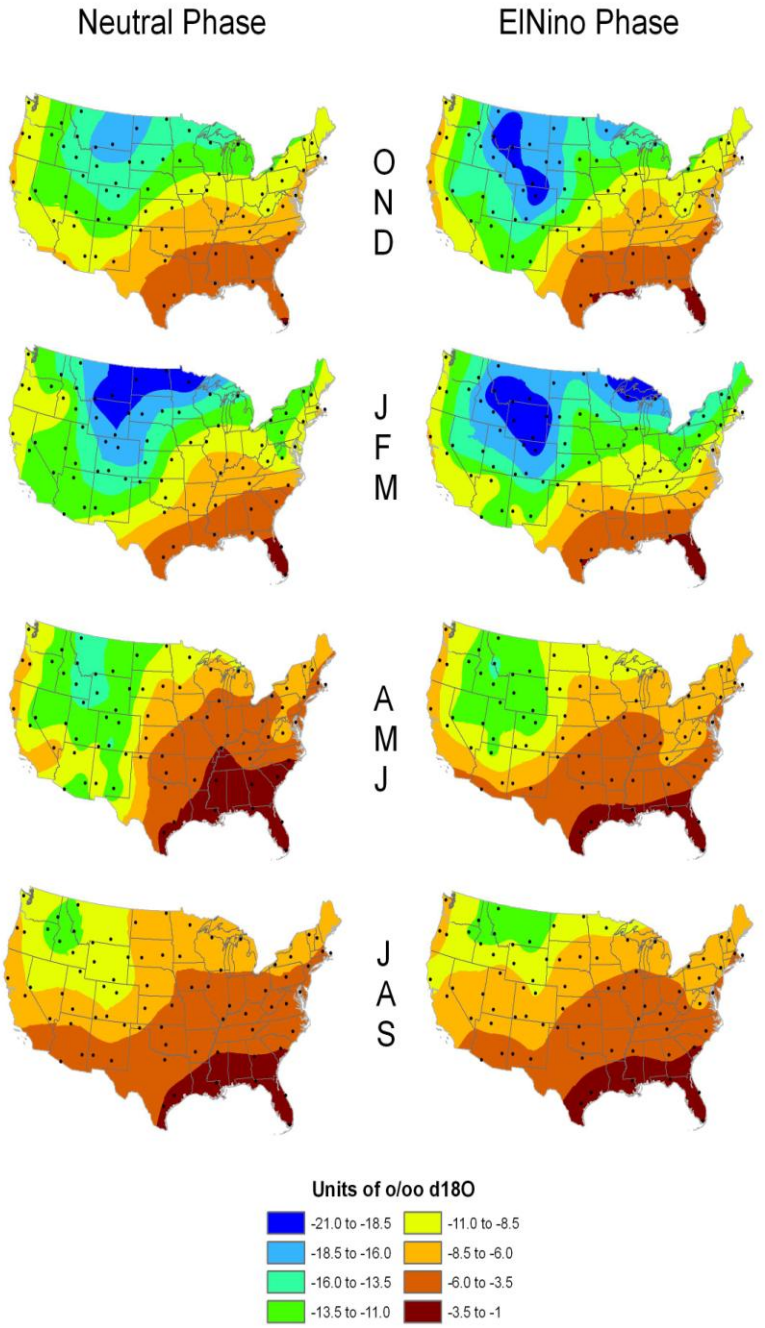



How might climate phases such as ENSO, and PDO effect the spatial patterns of isotopes in precipitation



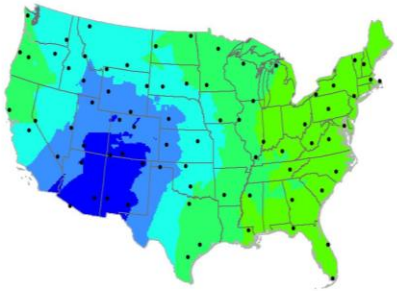
Climate phases and atmospheric circulation may be contributors to variability in the isotopes of precipitation



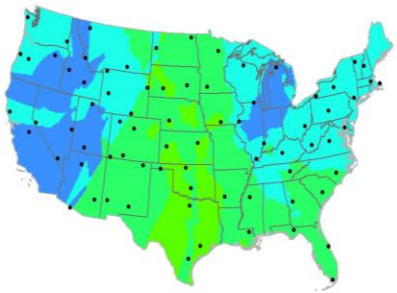


$\delta^{18}O$ values of precipitation during Neutral (1989 & 1995) and El Nino (1990-1994) climate phases

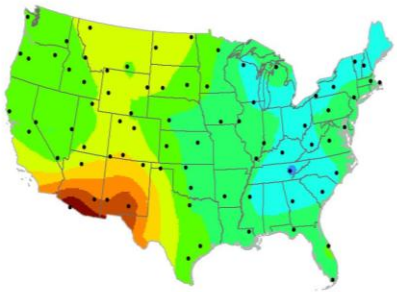
ElNino Phase - Neutral Phase



O
N
D



J
F
M

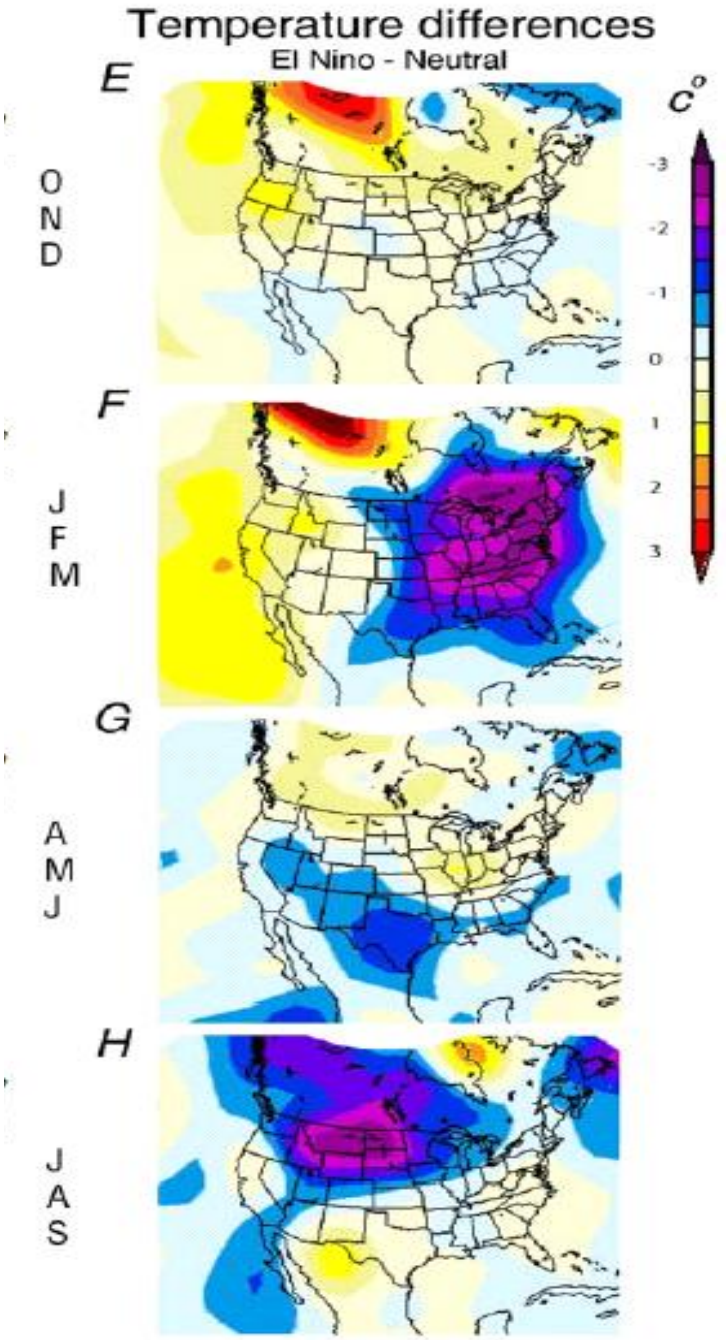


A
M
J

J
A
S

Units of o/oo d18O

-4 to -3	1 to 2
-3 to -2	2 to 3
-2 to -1	3 to 4
-1 to 0	4 to 5
0 to 1	5 to 6



Northern Foothills of AK, Toolik Lake Field Station

AIRMoN Studies of Storm Tracks

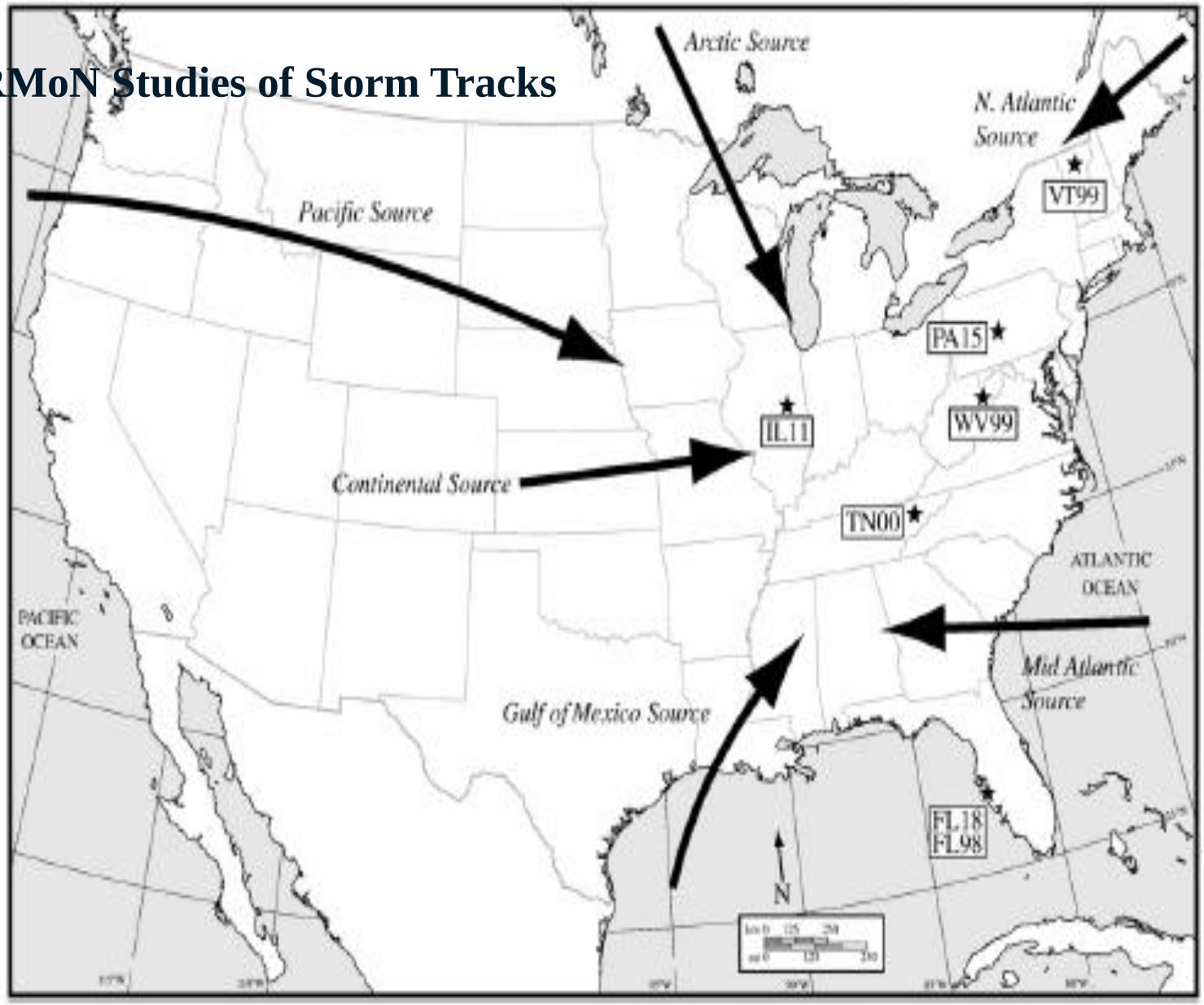
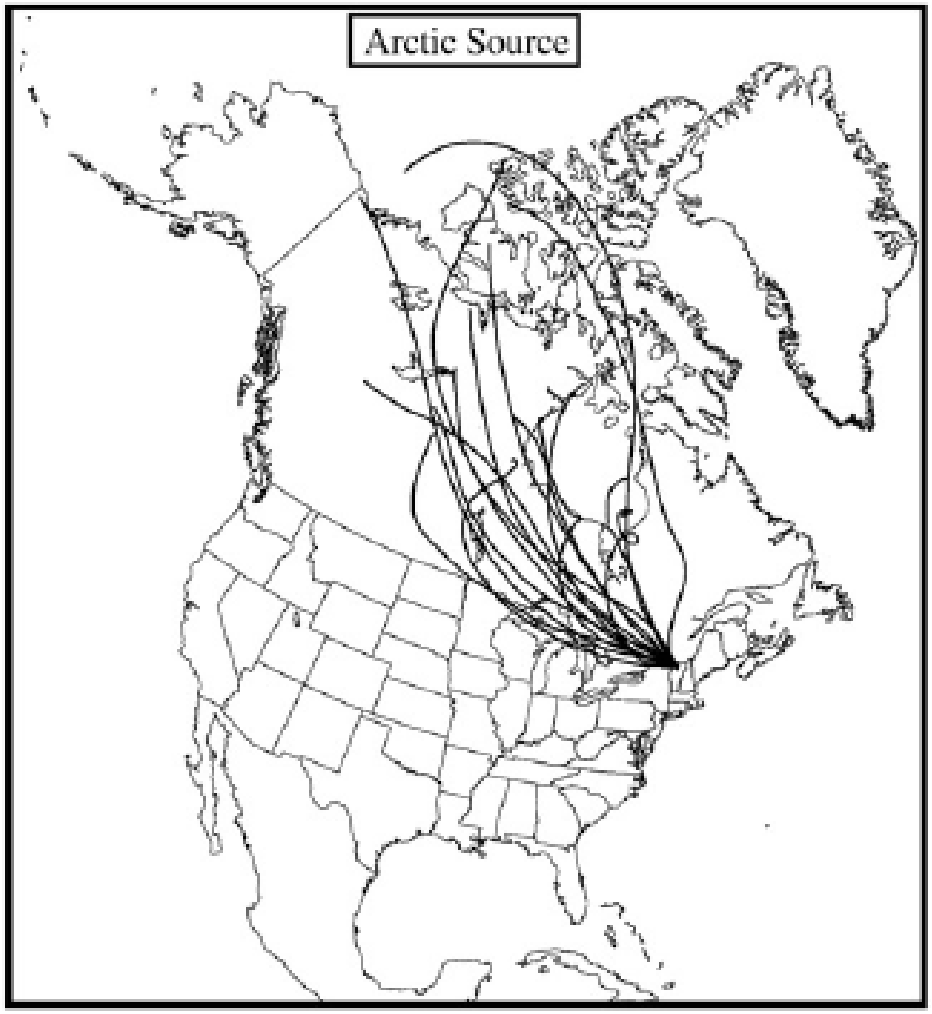
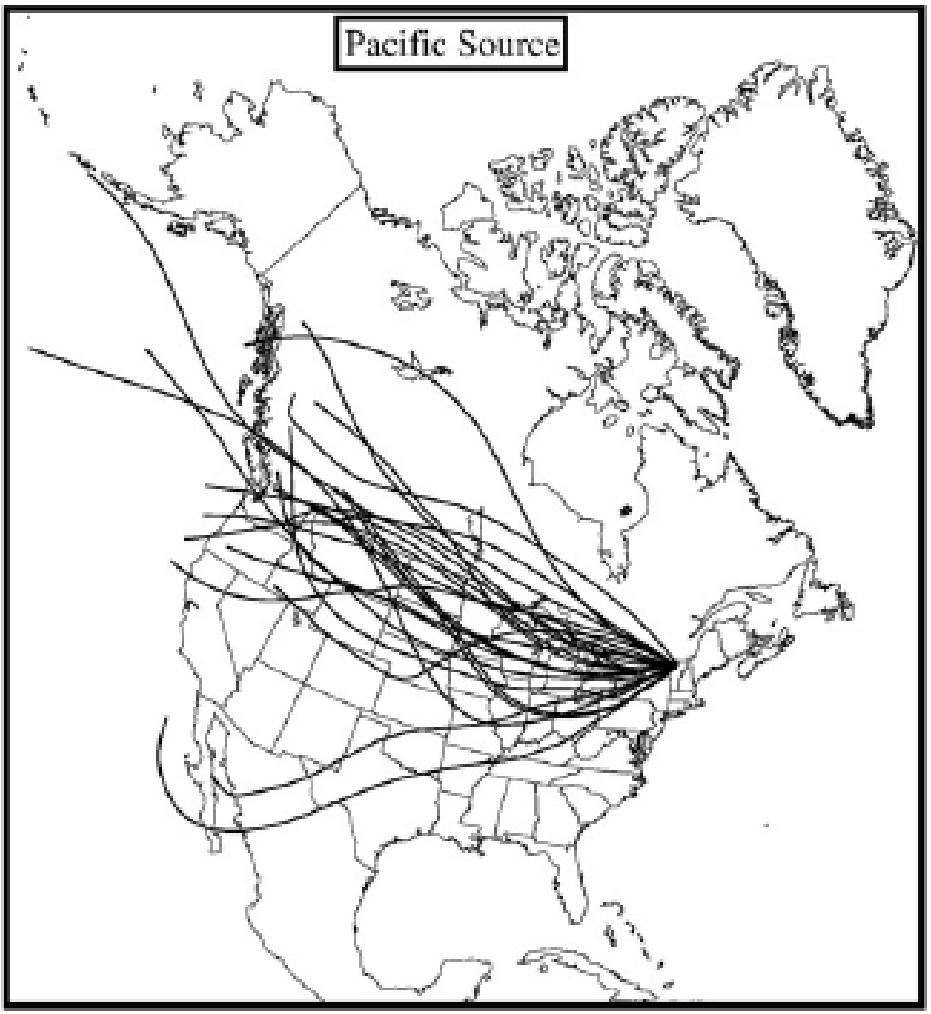


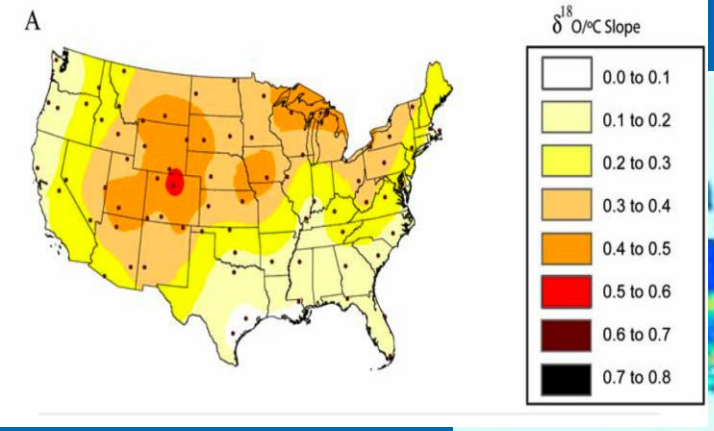
Fig. 1. Location map of the six AIRMoN sample sites in the eastern US at which precipitation samples were collected. The approximate locations of the six precipitation sources are indicated by the arrows. The actual airmass trajectories are highly variable for all six of the source categories (see Fig. 3).

Sjostrom and Welker 2009

Northern Vermont Precipitation is derived from a multitude of sources including moisture transported from the Northern and Southern Pacific



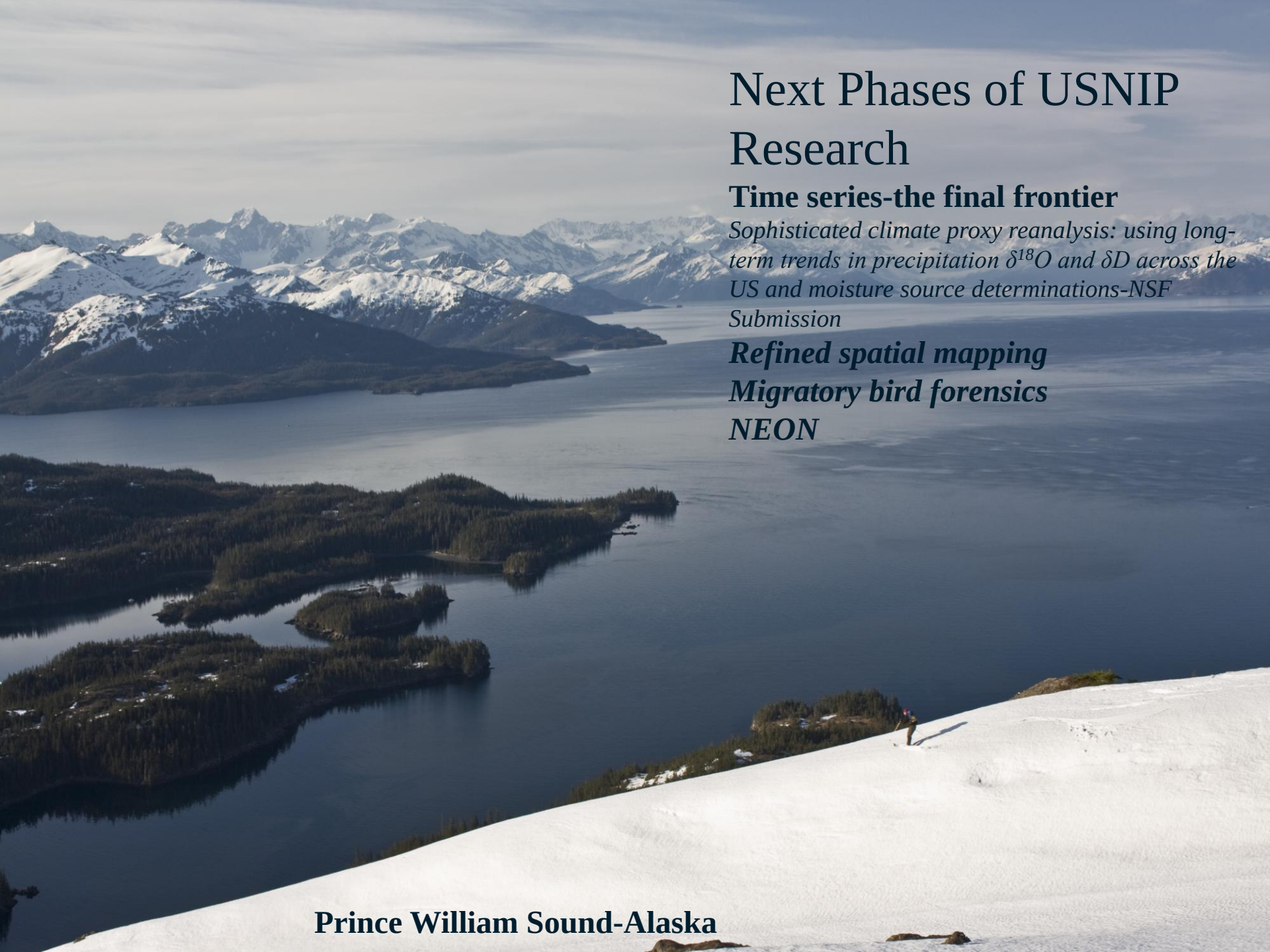




Shifting moisture sources may be a principle component to accounting for the spatial and seasonal variation in the isotopes in precipitation across the US, especially in coastal regions

Winter
Summer
Summer
Winter
Winter
Summer

Vachon et al. 2010b



Next Phases of USNIP Research

Time series-the final frontier

Sophisticated climate proxy reanalysis: using long-term trends in precipitation $\delta^{18}O$ and δD across the US and moisture source determinations-NSF Submission

Refined spatial mapping

Migratory bird forensics

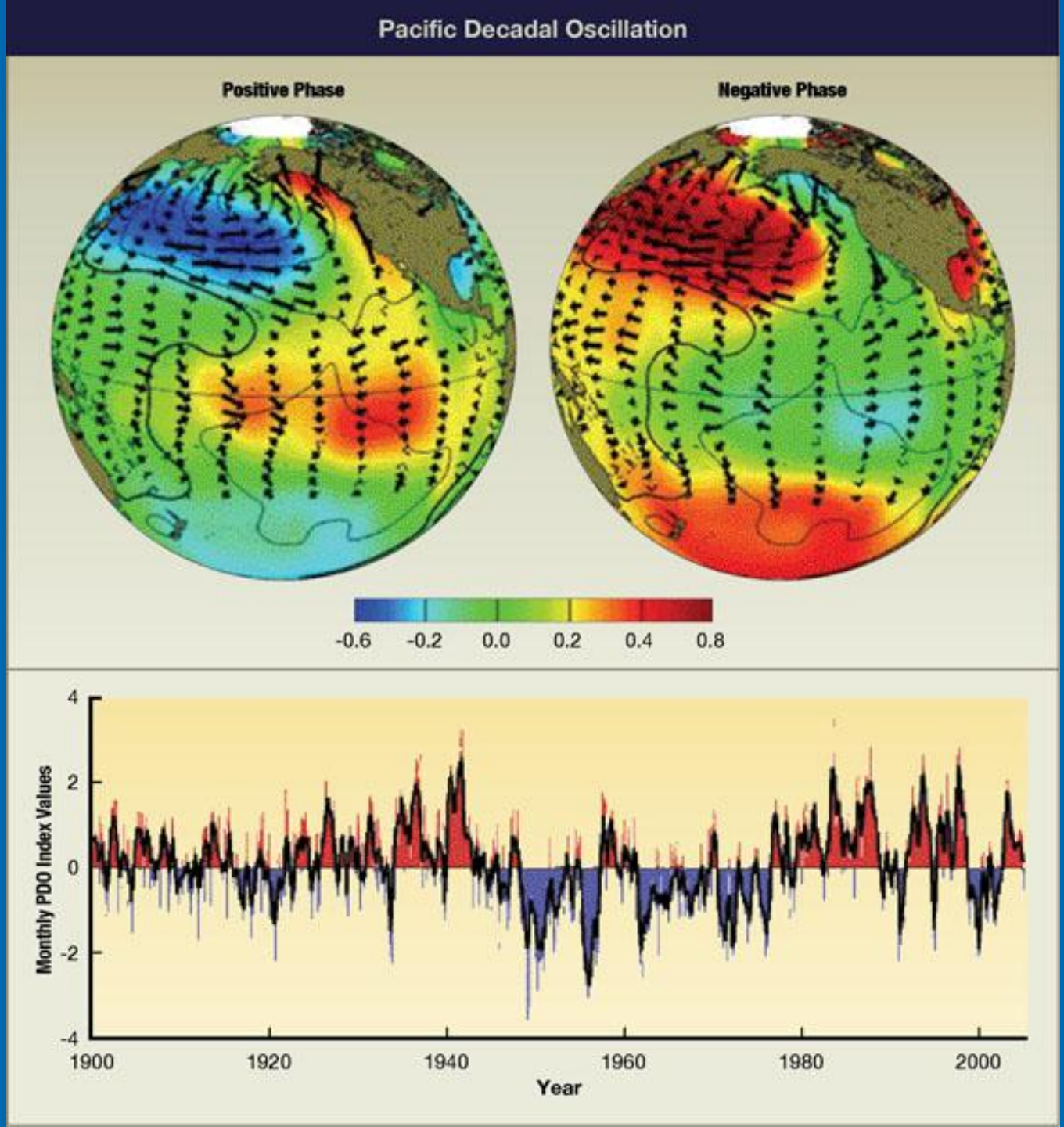
NEON

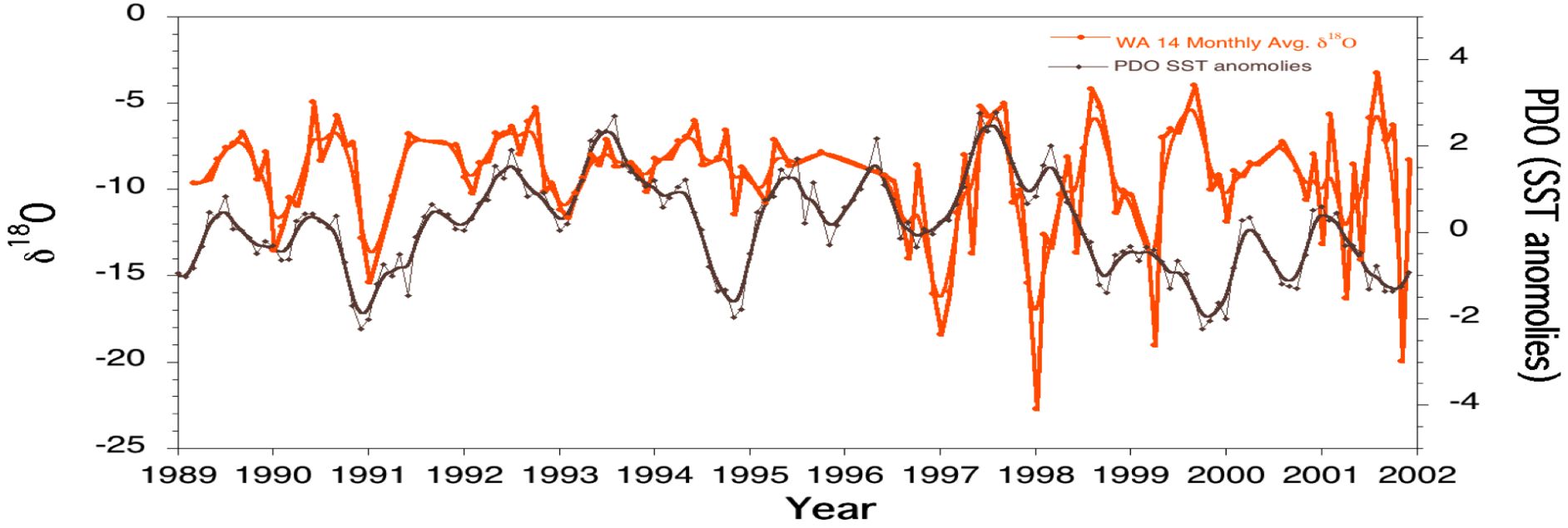
Prince William Sound-Alaska

Stable Isotope Laboratory-Environment and Natural Resources Institute-*University of Alaska Anchorage*

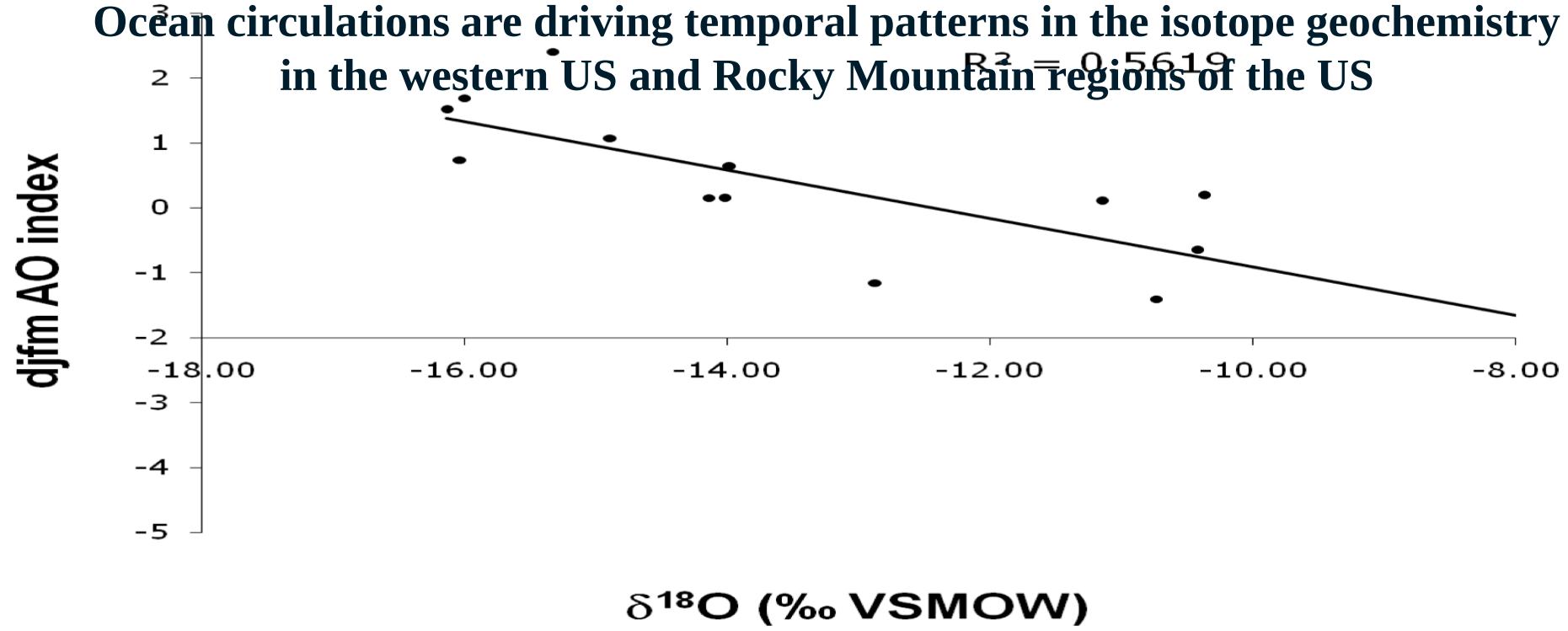
Supported in part by NSF-Major Research Instrumentation Program

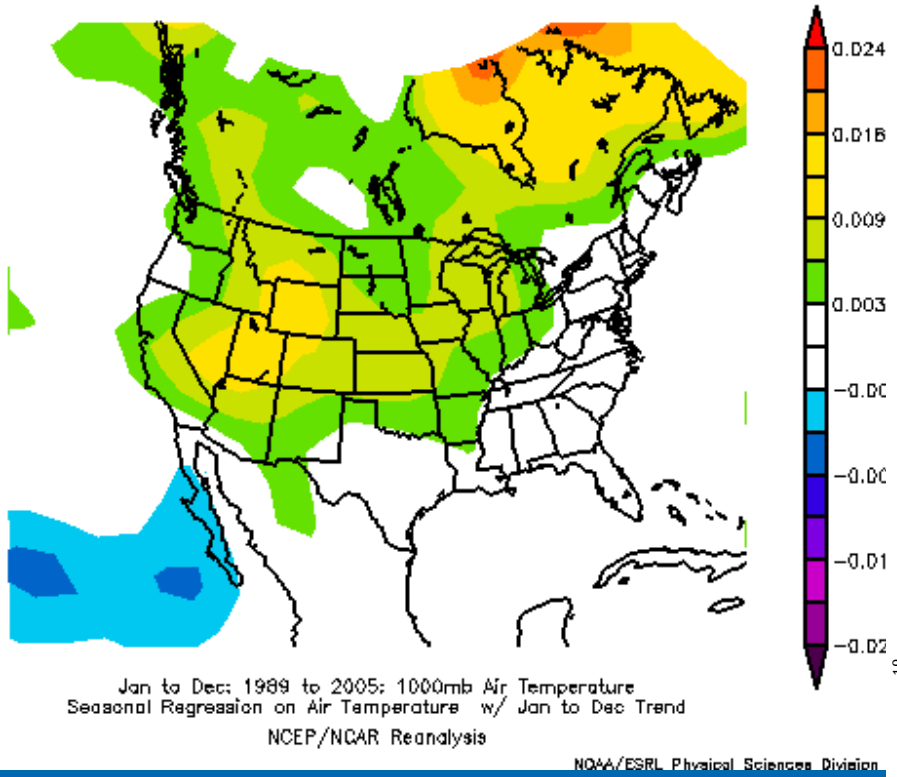
Pacific Ocean currents change patterns on decadal time periods which shifts the sources of moisture for the US and the temperatures of those moisture sources. Collectively these oscillations may explain in part the long-term patterns in the isotopes in precipitation in the US. And, subsequent variation in isotopes in climate proxies-ice cores, tree rings, stalagmites may reflect this variation

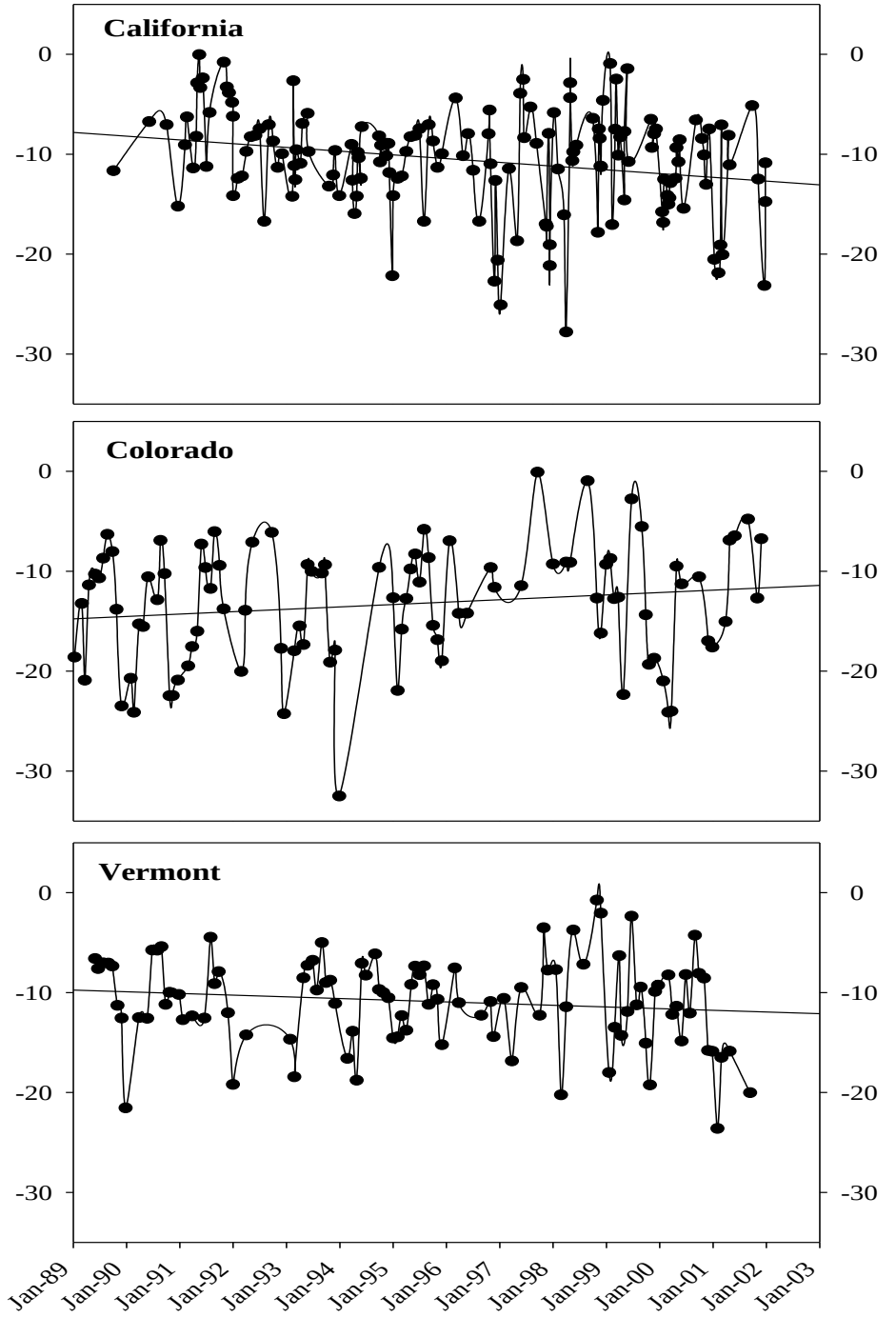




Ocean circulations are driving temporal patterns in the isotope geochemistry in the western US and Rocky Mountain regions of the US







***Are USNIP sites recording the differential degrees of annual climate warming across the US?*-Maybe-**

NEON linkages and Climate Change Monitoring at the Continental Scale

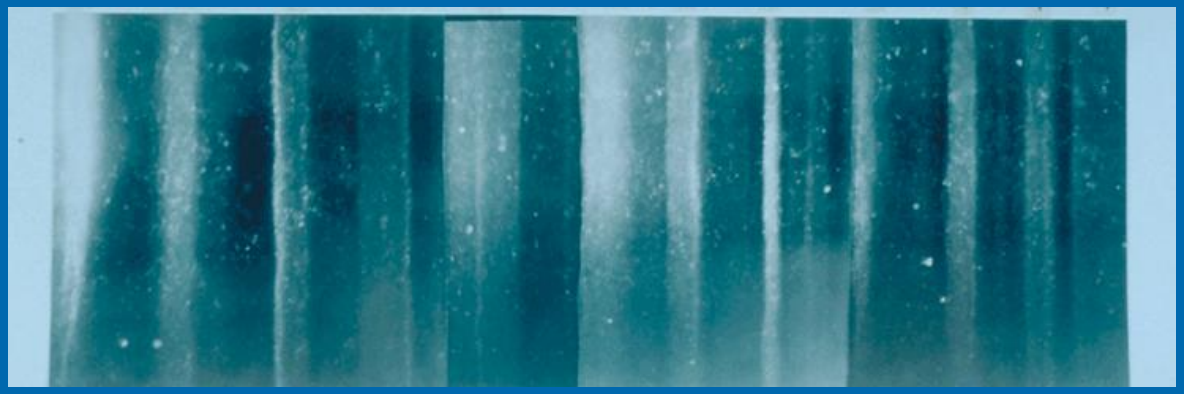
Proxy records of climate!

Tree-Rings

Desert Southwest

Speleothems

Wind Cave NP



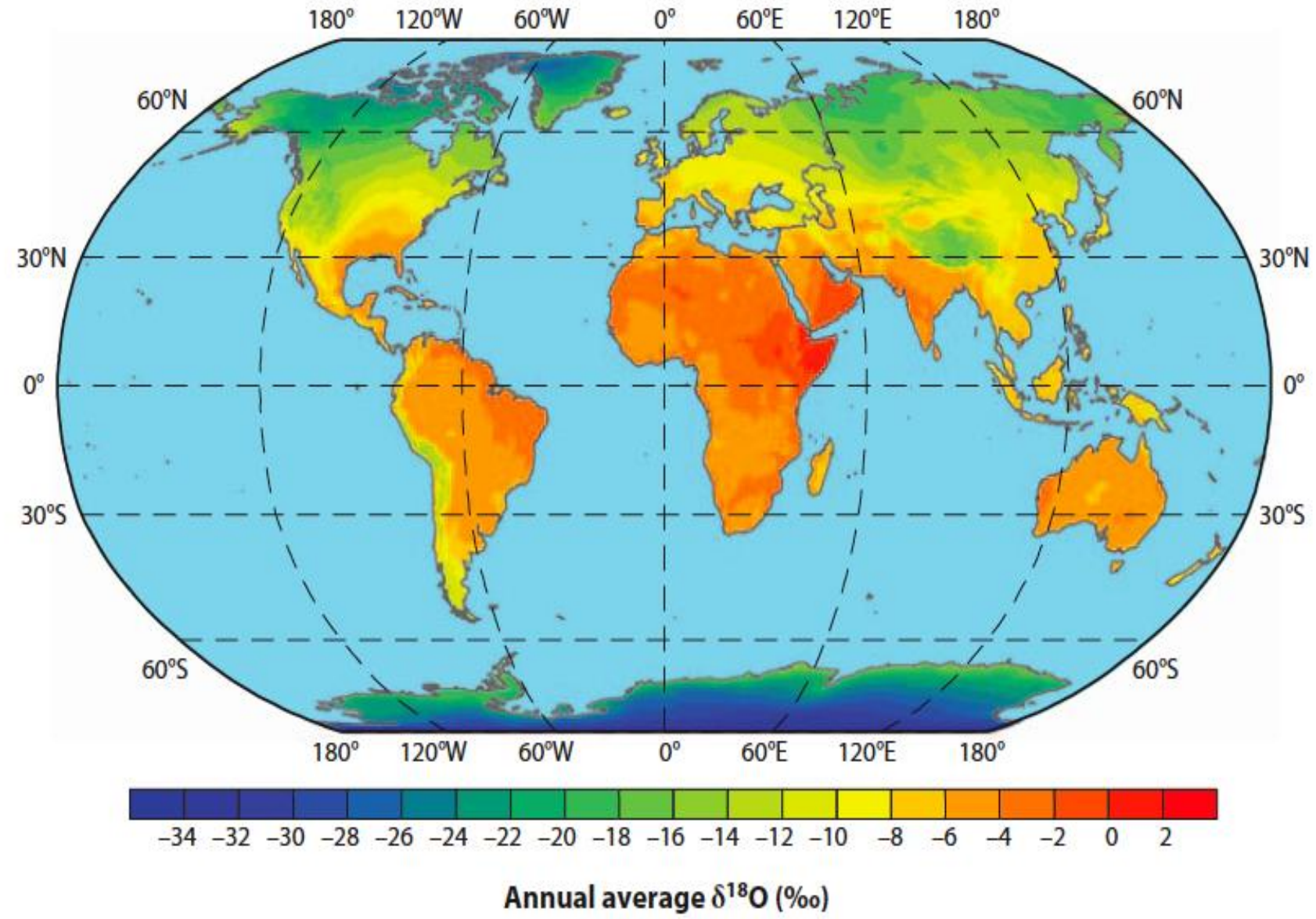
Ice Cores-Fremont Glacier-WY

Site/region specific $\delta^{18}O$& δD-climate relations will be used to reanalyze climate records.

-higher resolution as opposed to using global averages

-greater consideration of storm tracks and climate oscillations

-reinterpretation of past climates will allow improved forecasting of future climates


a
180° 120°W 60°W 0° 60°E 120°E 180°
60°N
30°N
0°
30°S
60°S
–34 –32 –30 –28 –26 –24 –22 –20 –18 –16 –14 –12 –10 –8 –6 –4 –2 0 2
Annual average δ18O (‰)

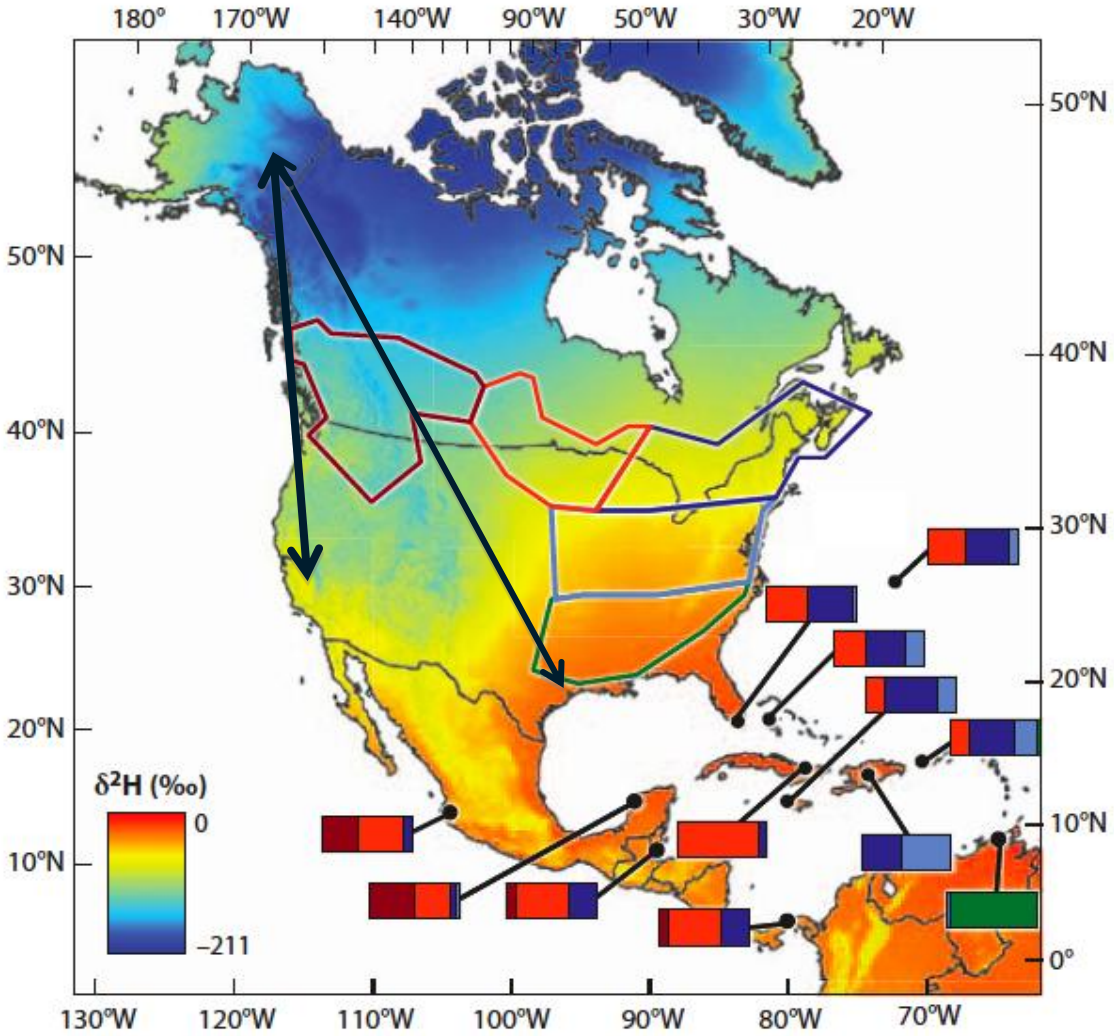


Figure 10

Probabilistic assignment of American Redstart individuals to breeding areas based on the H isotopic composition of feathers grown at breeding sites and collected on the wintering grounds. Horizontal bars show the fraction of individuals collected at each wintering site (*dots*) assigned to each breeding range (*colored polygons*) based on feather isotopic composition and an isoscape predicting compositions of locally grown feathers (*background color field*). This example shows a pattern of chain migration, wherein birds breeding in the northern part of the breeding range, for example, tend to migrate to the northern part of the wintering range. Figure reprinted from Bowen et al. (2009b); data from Norris et al. (2006).

Summary:

The continental patterns of isotope in precipitation are now well defined

The controls, however are just being uncovered and involved both temperature and moisture source processes

Time series and the role of climate oscillations will be the focus of the program in the future along with reanalysis of climate proxies and the meaning of their records

Linkages with NEON will be important for long-term climate monitoring

Acknowledgements

NADP and all the site operators
Central Analytical Lab
Chris Lehmann and Brenda Riney

Mount Blackburn-Wrangle-Saint Elias Range, Alaska

USNIP Supported Publications

1. Stevenson B. A., Kelly, E., McDonald, E., Busacca. A., and Welker, J. M. 2010.
2. Vachon, R., Welker, J. M., White, J. and Vaughn, B. 2010a
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