Projected increase in Precipitation

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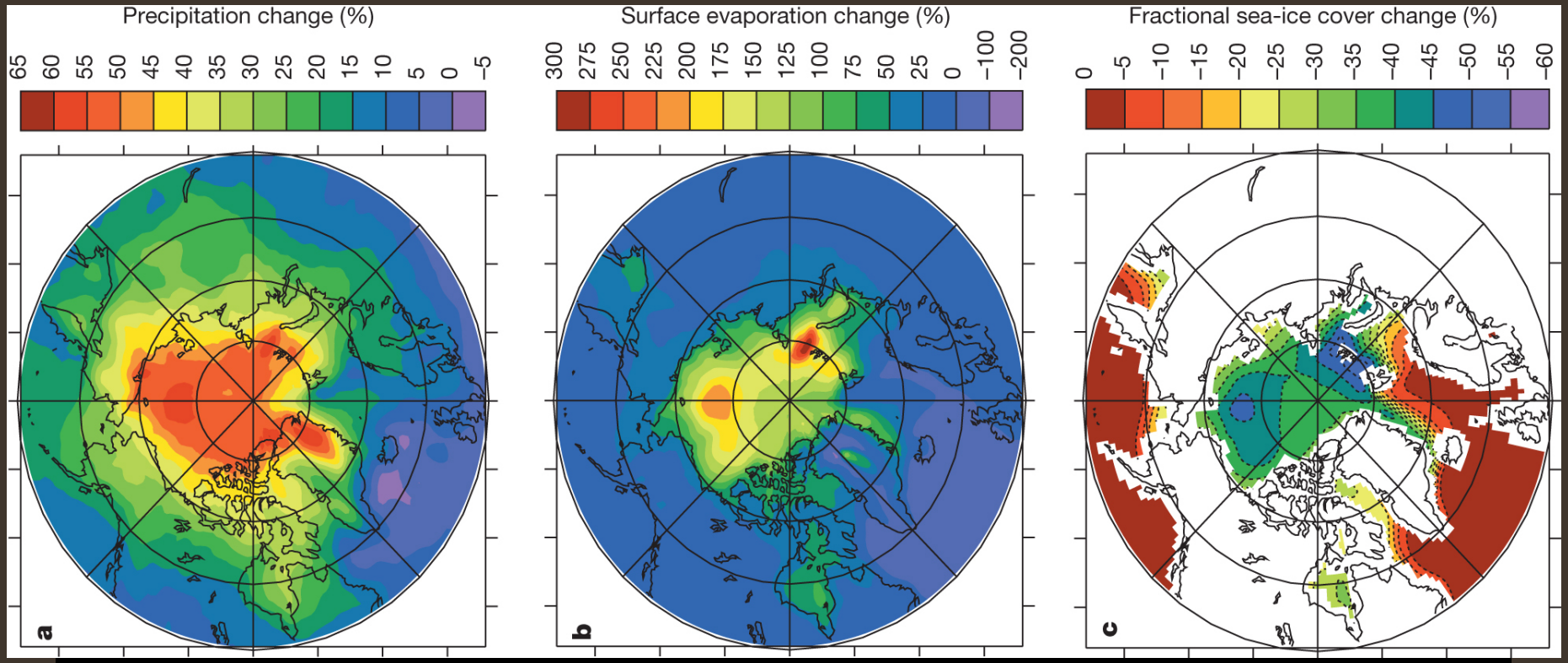

CMIP models. RCP 8.6

Bintanja and Selten, Nature 2014

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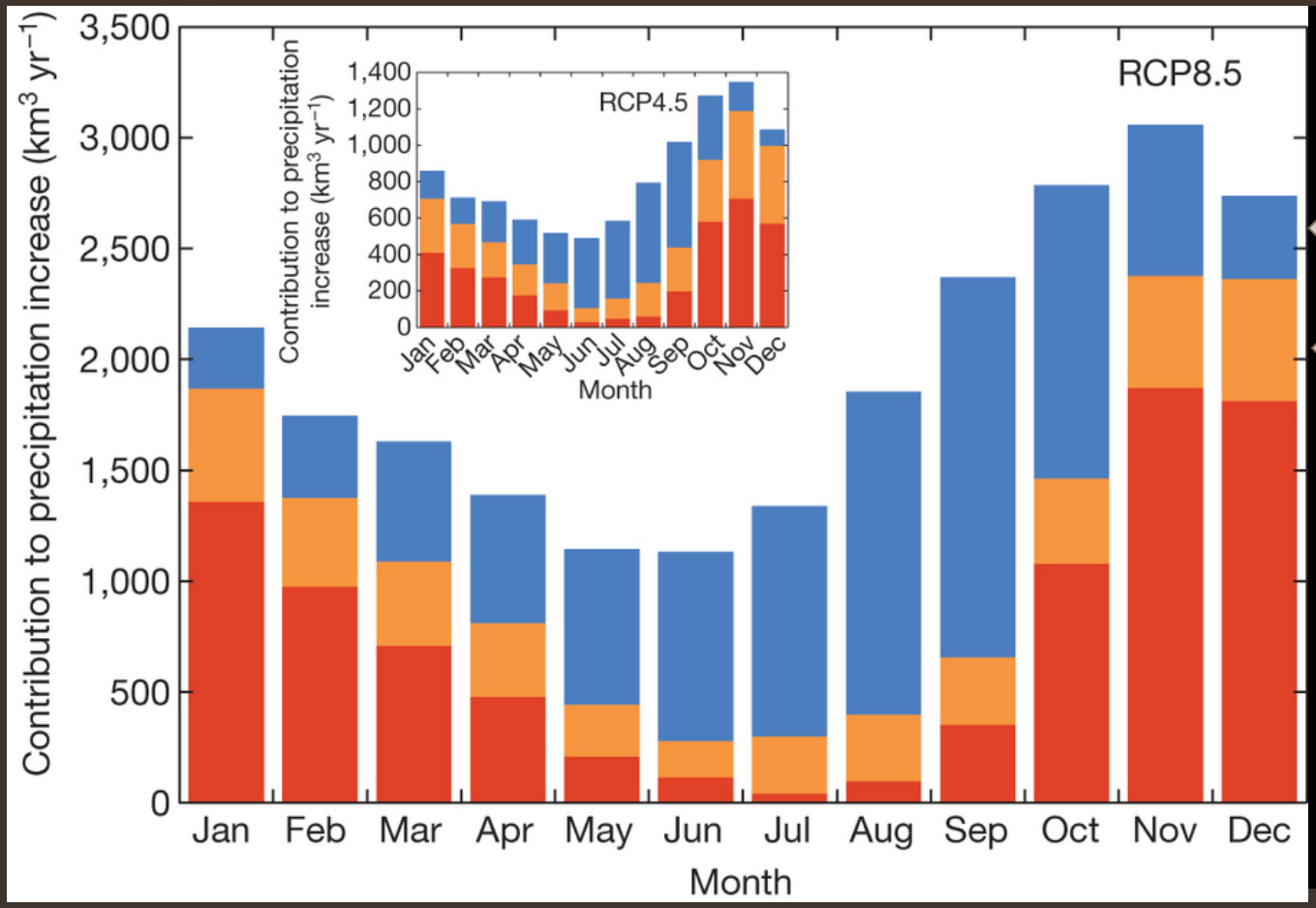
Consequences

… increases in Arctic precipitation are firmly linked to Arctic warming and sea-ice decline.

… seasonally varying increase in Arctic precipitation is likely to increase river discharge and snowfall over ice sheets,

and could … affect global climate through freshening of the Arctic Ocean and subsequent modulations of the Atlantic meridional overturning circulation

Origin of precipitation trend



Transport

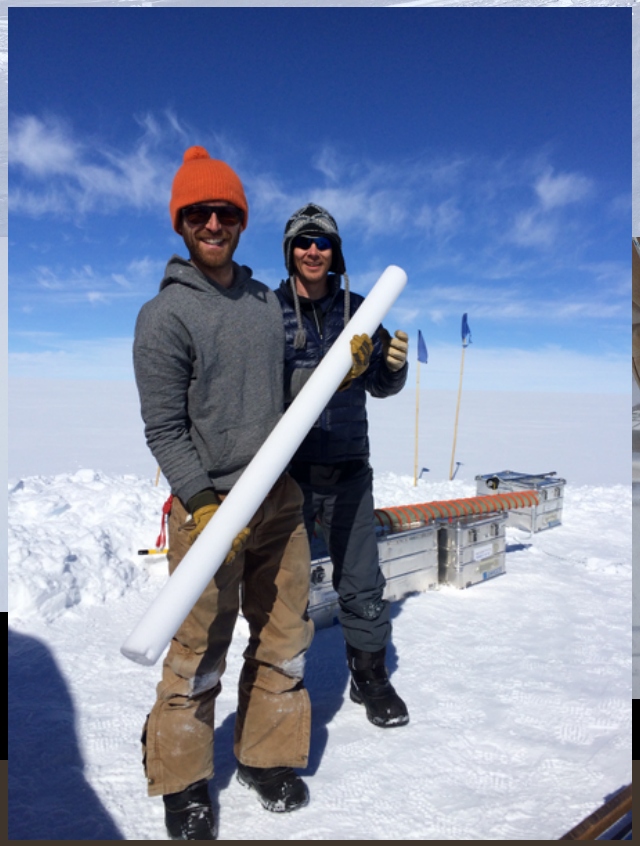
Evaporation unrelated to sea ice

Evaporation due to sea ice decline

Bintanja and Selten, Nature 2014

- Regional hydrological change
- Increased precipitation – why?
  (Can be deduced from models…. Observations?)

- Mores suggest locally increases evaporation rates
  (more open water, less frozen landscape/snow)
- *Implies increases in wetlands with biogeochemical impacts*



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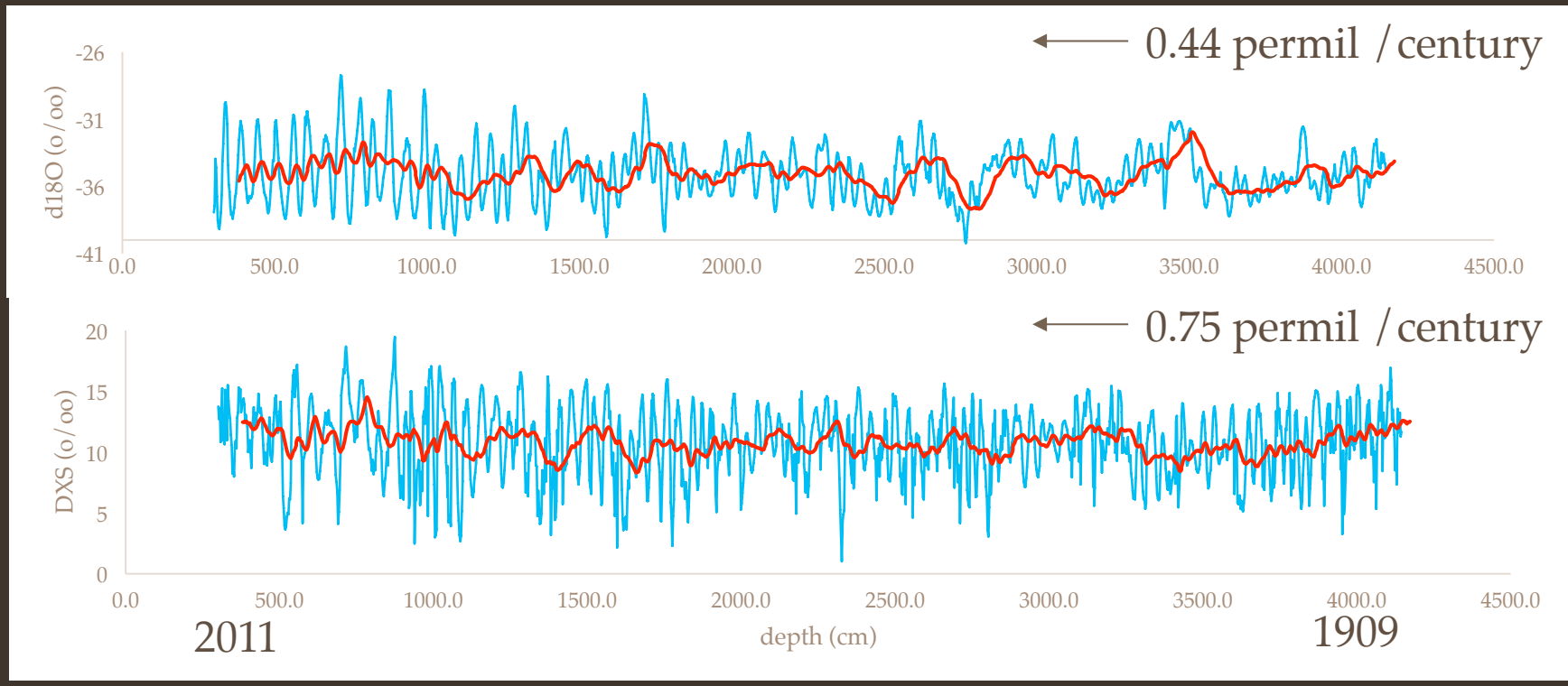
Isotope ratios



- Amplitude decreases with age ($d^{18}O$, not DXS…)
  (vapor exchange / diffusion)
- Low frequency variability
  (which depends on diffusion length)

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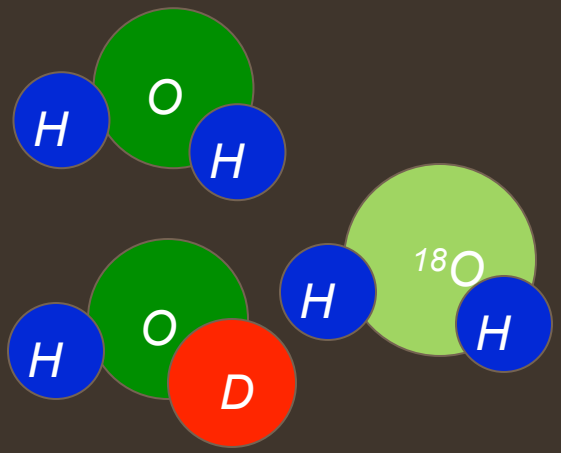
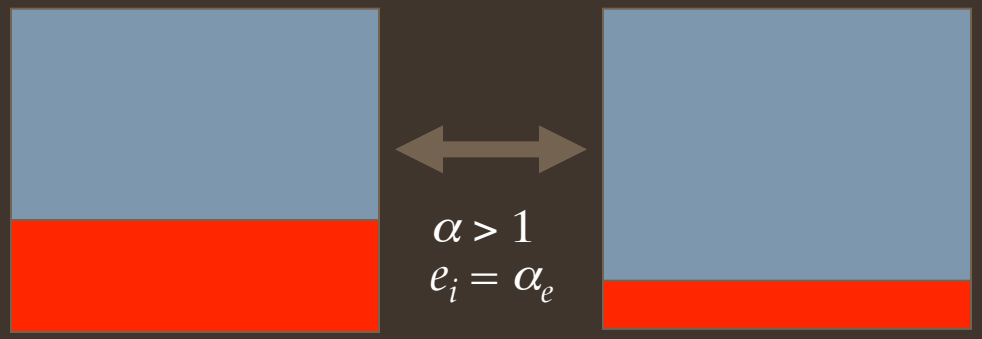
Equilibrium fractionation





liquid
(e.g., ocean)

vapor
(e.g., atmosphere)

Two isotope exchanges…

Condensation

Vapor becomes depleted as heavy removed preferentially

Evaporation

Restores toward ocean/land ratios, or vapor toward ratios of condensate

On earth, conditions under which condensation occurs is different from the conditions when evaporation occurs

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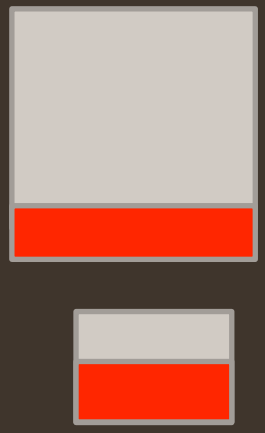
Water vapor

R_0

Water vapor

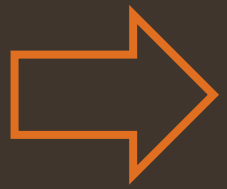


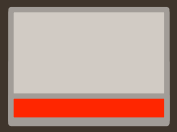
$R_{vapor} < R_0$

$R_{condensate} > R_0$

Condensate
(e.g., rain drops)

Isotopic fractionation: $R_c = \alpha R_v$



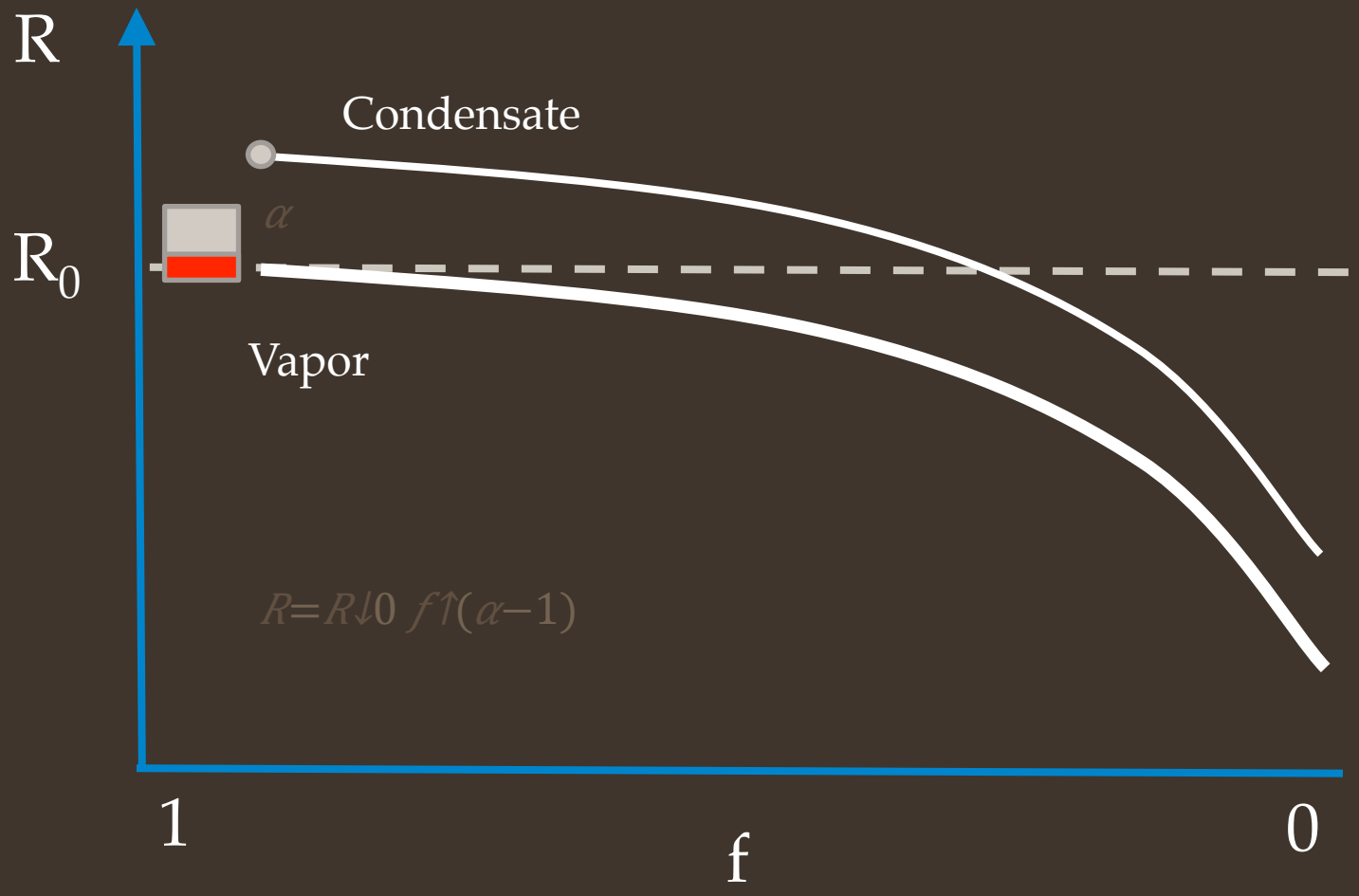


Water vapor

$R_{vapor} \ll R_0$

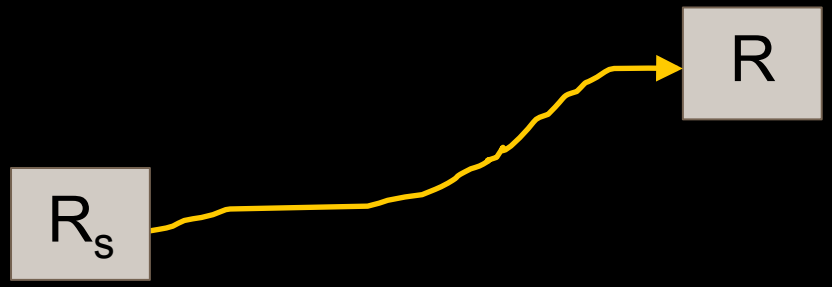
$R_{condensate} < R_0$

More condensate (e.g., rain drops)


R
Condensate
α
R0
Vapor
R=R↓0 f↑(α−1)
1
f
0

Rayleigh framework

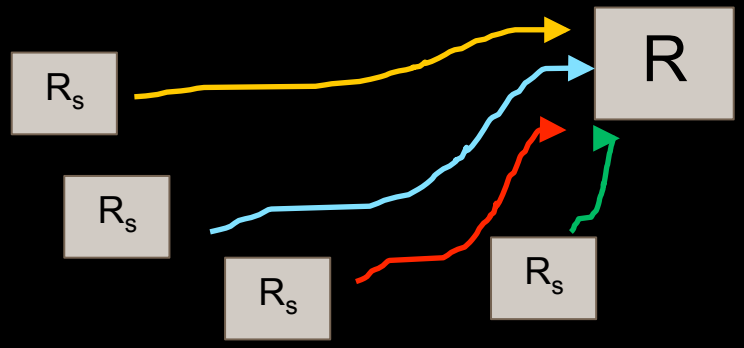
$$R = R_s F^{\alpha - 1}$$



Final isotope ratio depends on source, R_s, and fraction of moisture remaining, F

But not a single source….

$$R = \sum_i f_i R_{s,i} F_i^{\alpha_i - 1}$$



Superposition describes mixing
(Also, F, is relate to temperature)

High latitude moisture sources

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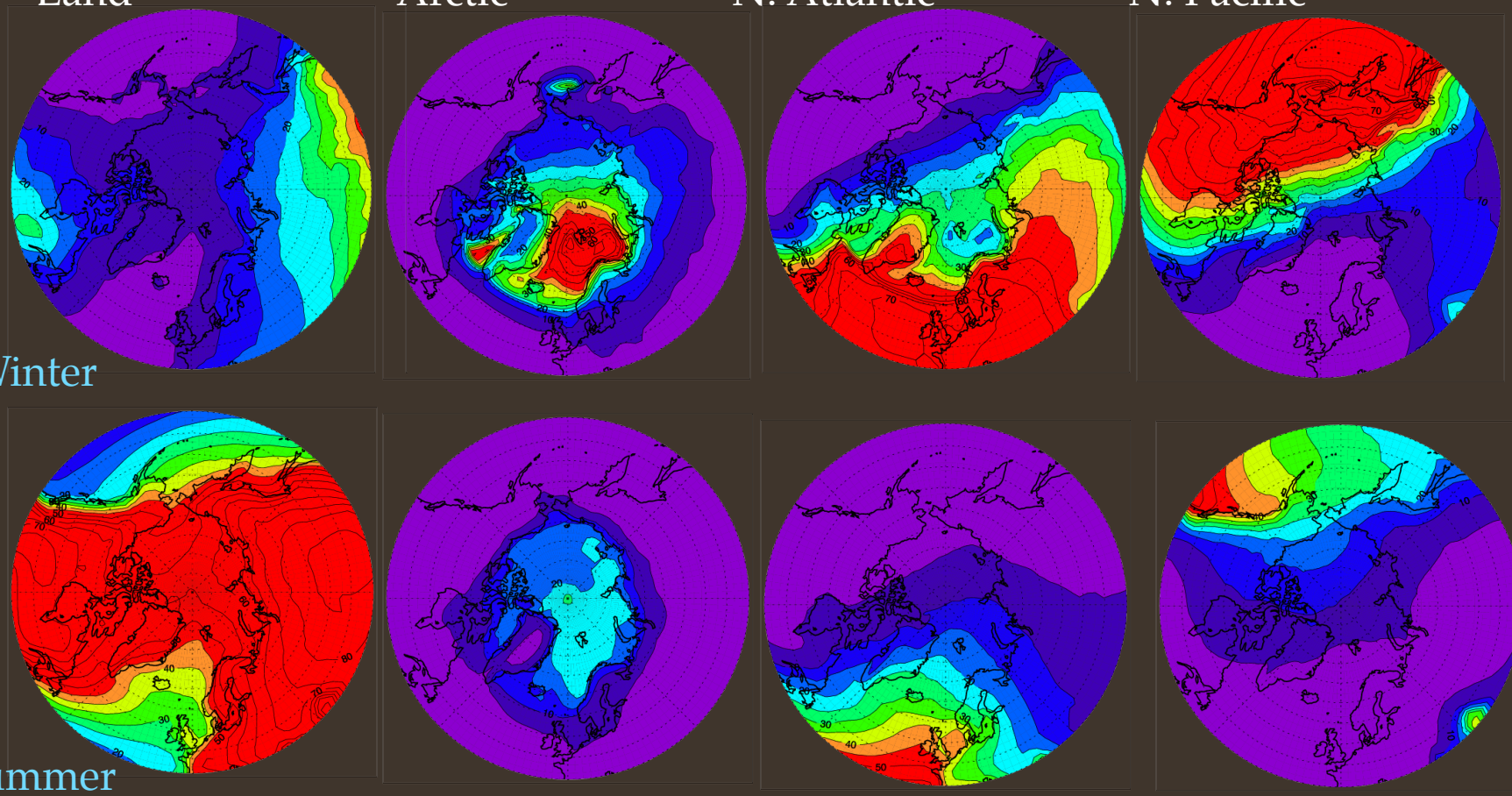

Red > 50%

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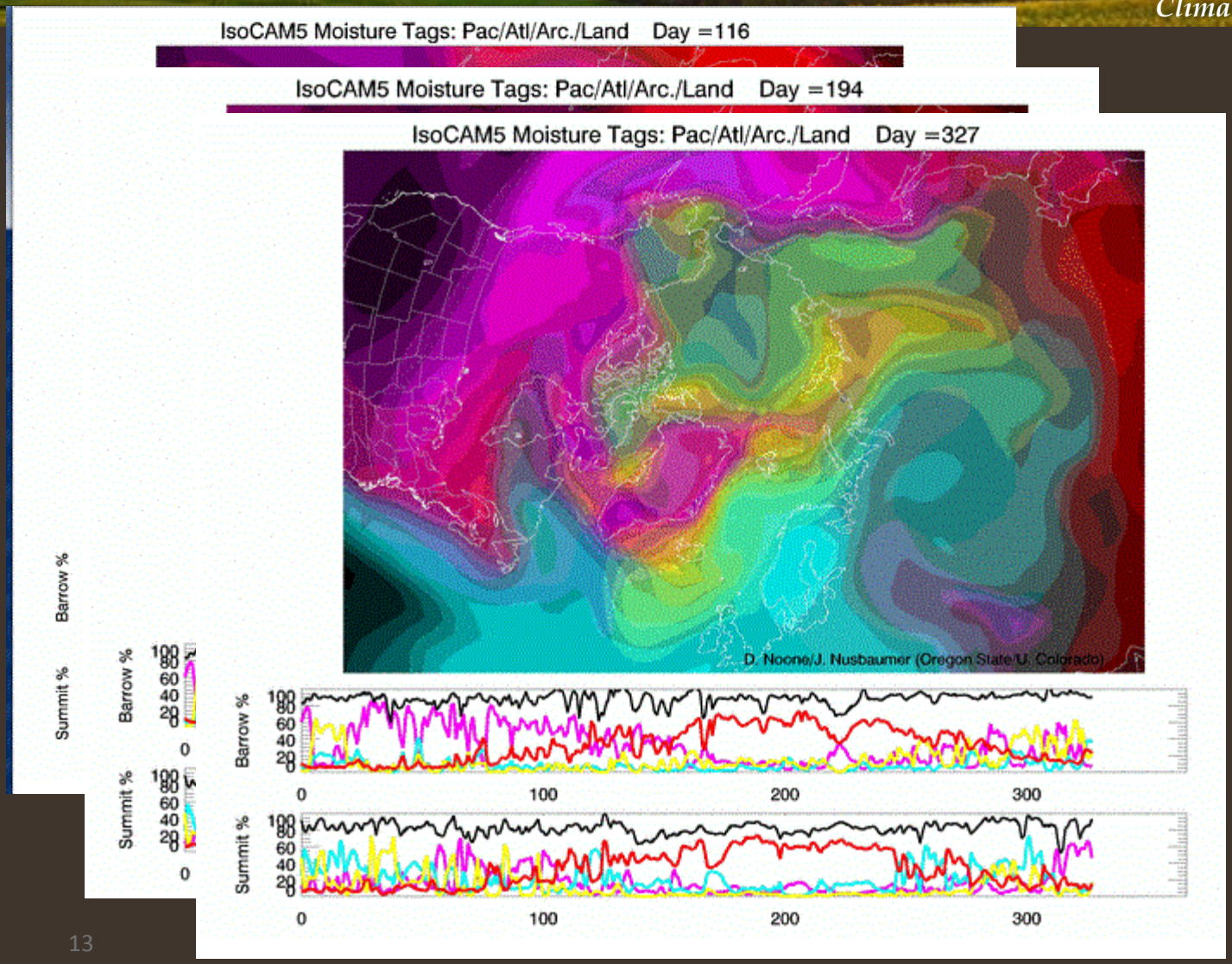

Pacific

Arctic Ocean

Land

Atlantic

Mixing structure quantifiable with grouping of several trace gases

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Summit isotopes correlated with source regions

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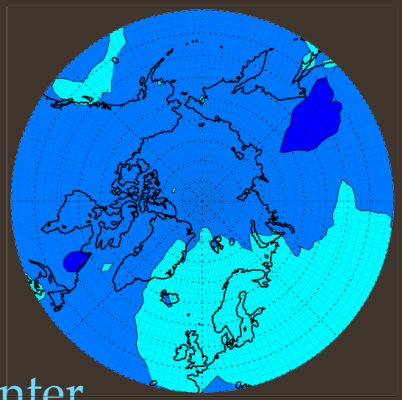
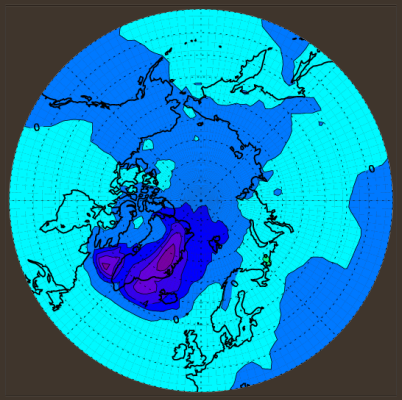
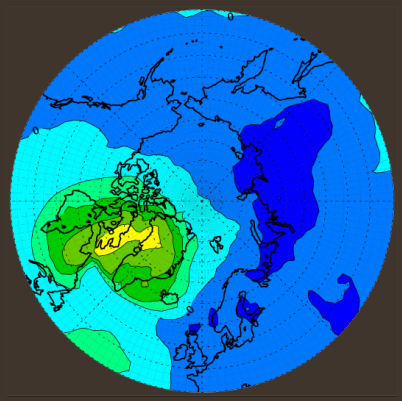
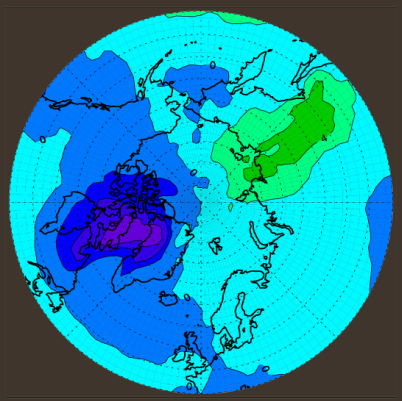
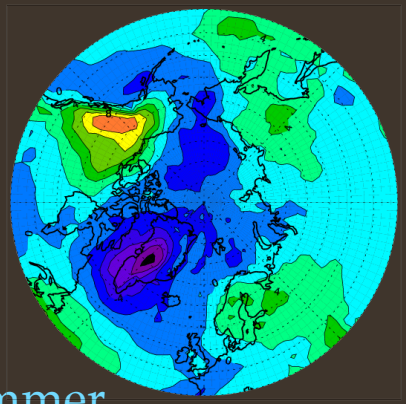
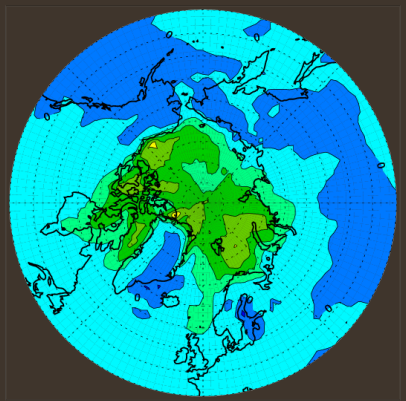
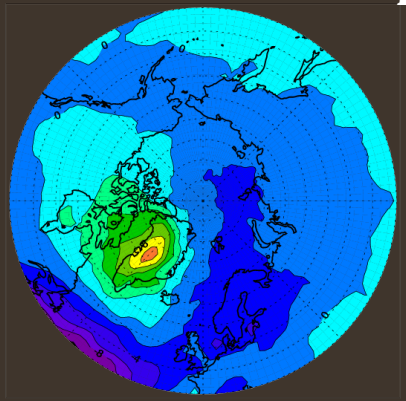
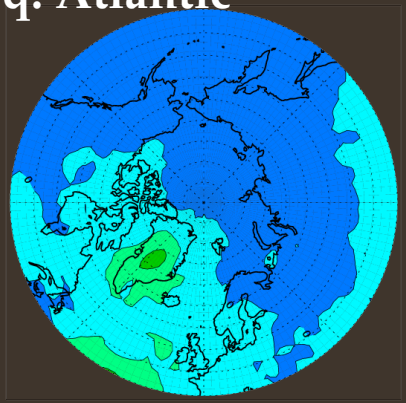
Land | Arctic | N. Atlantic | N. Pacific

Winter

Eq. Atlantic

Summer

N. Pacific has trivial influence in Summer

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100 year trend in precipitation isotope ratios

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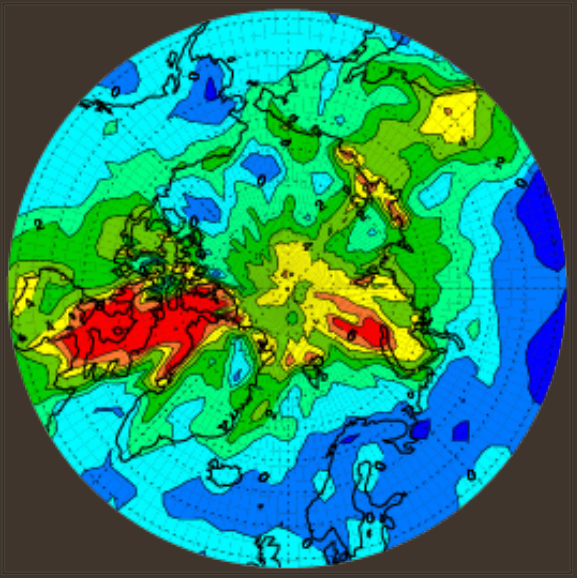
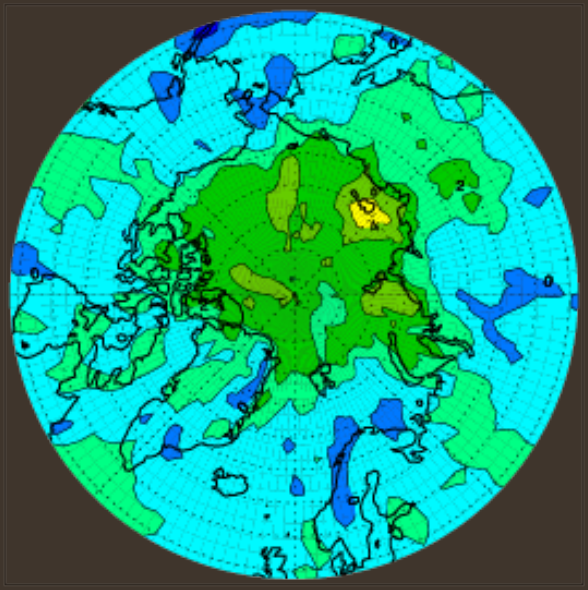
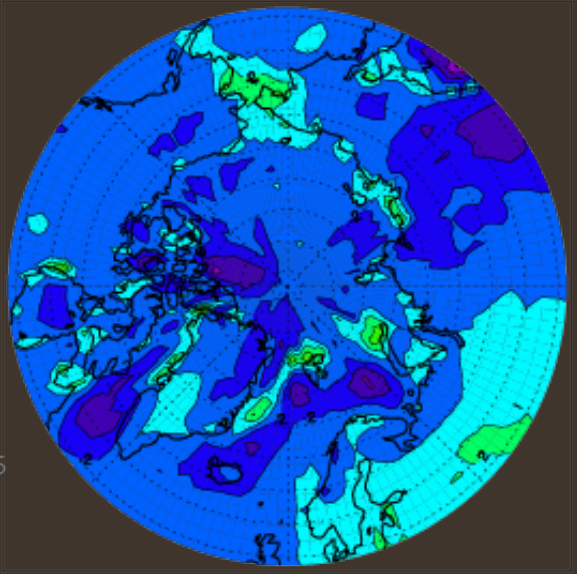
d18O Winter

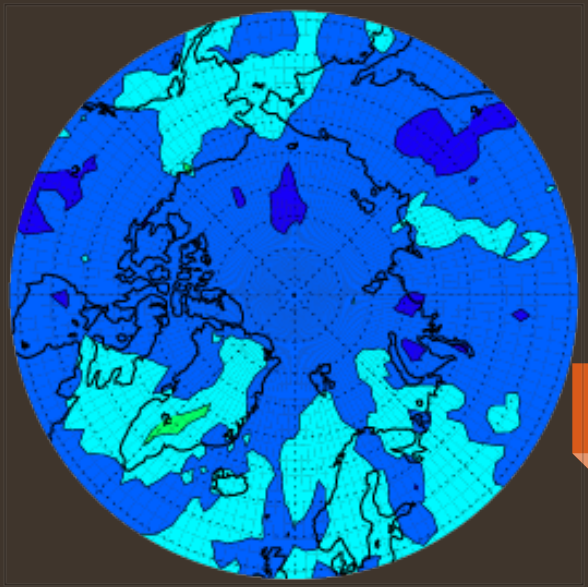




d18O Summer

DXS Winter





DXS Summer

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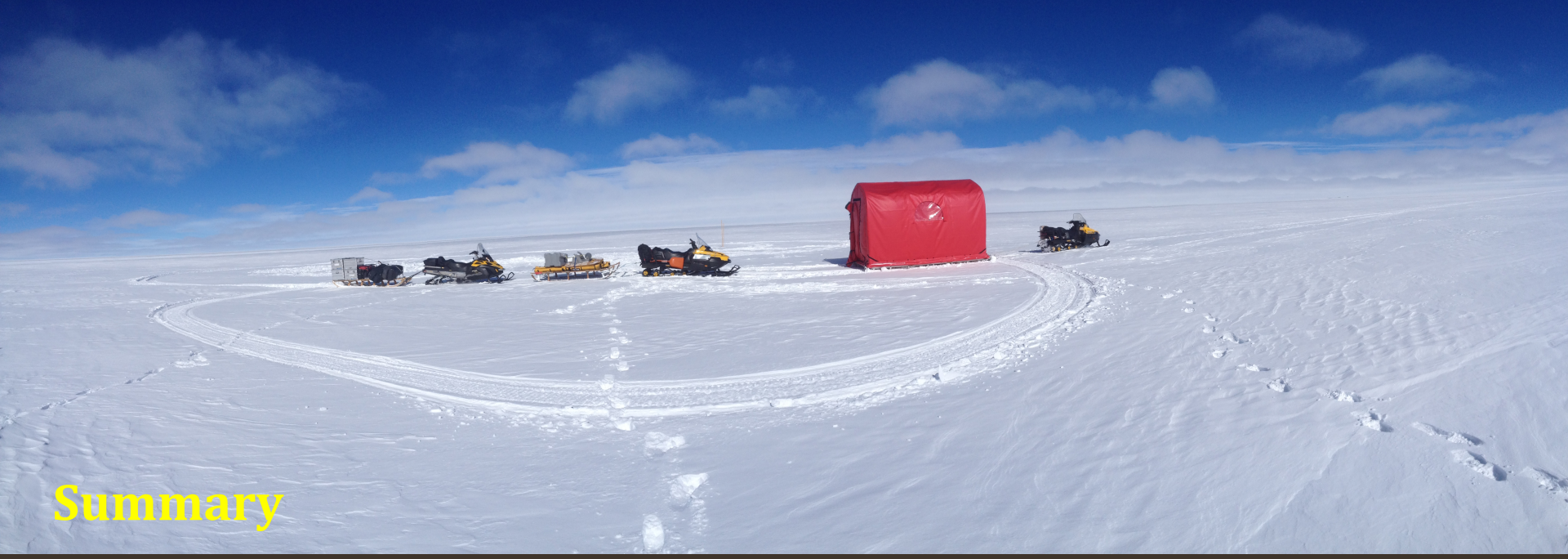

Summary

1. Stable isotope ratios of water vapor, and precipitation, reflect origin of water (i.e., and ***OBSERVABLE*** quantity similar to a budget decomposition)

2. Isotope ratios more sensitive indicator because
   they integrate hydrological history

3. Summit results contradict existing findings – i.e., not sea ice controlled
   In summer, ***less*** Arctic (more N. Atlantic).
   In winter, less land moisture (more N. Atlantic)

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