C and H_2O Cycle Measurements and Observations in the High and Low Arctic: Experiments & Monitoring

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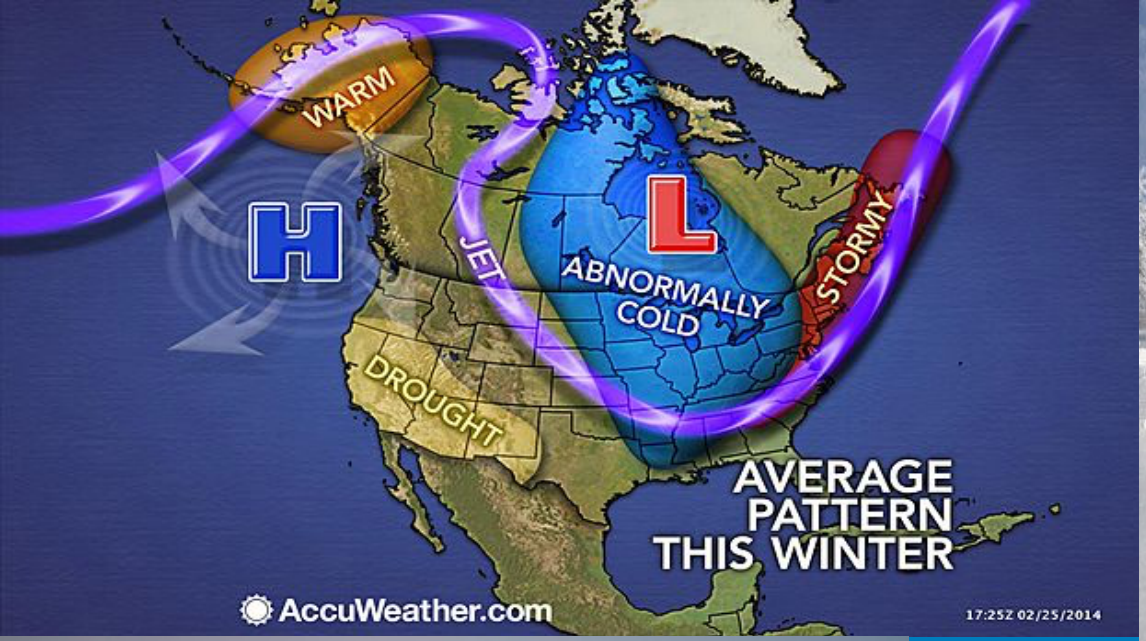
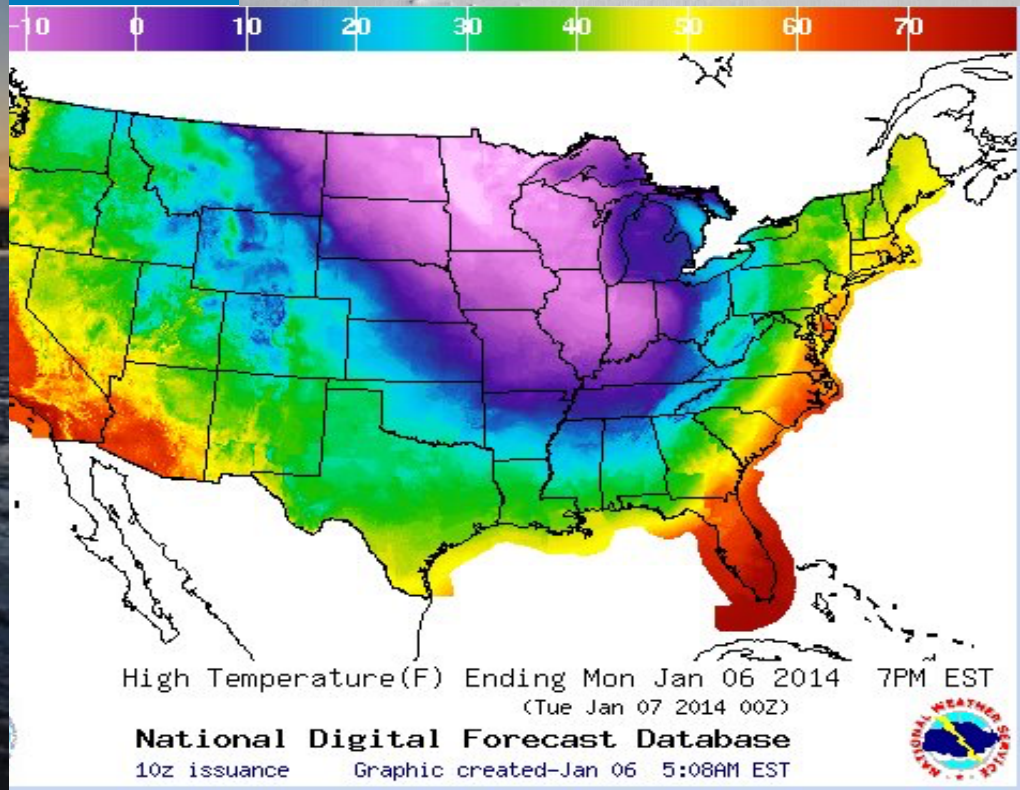
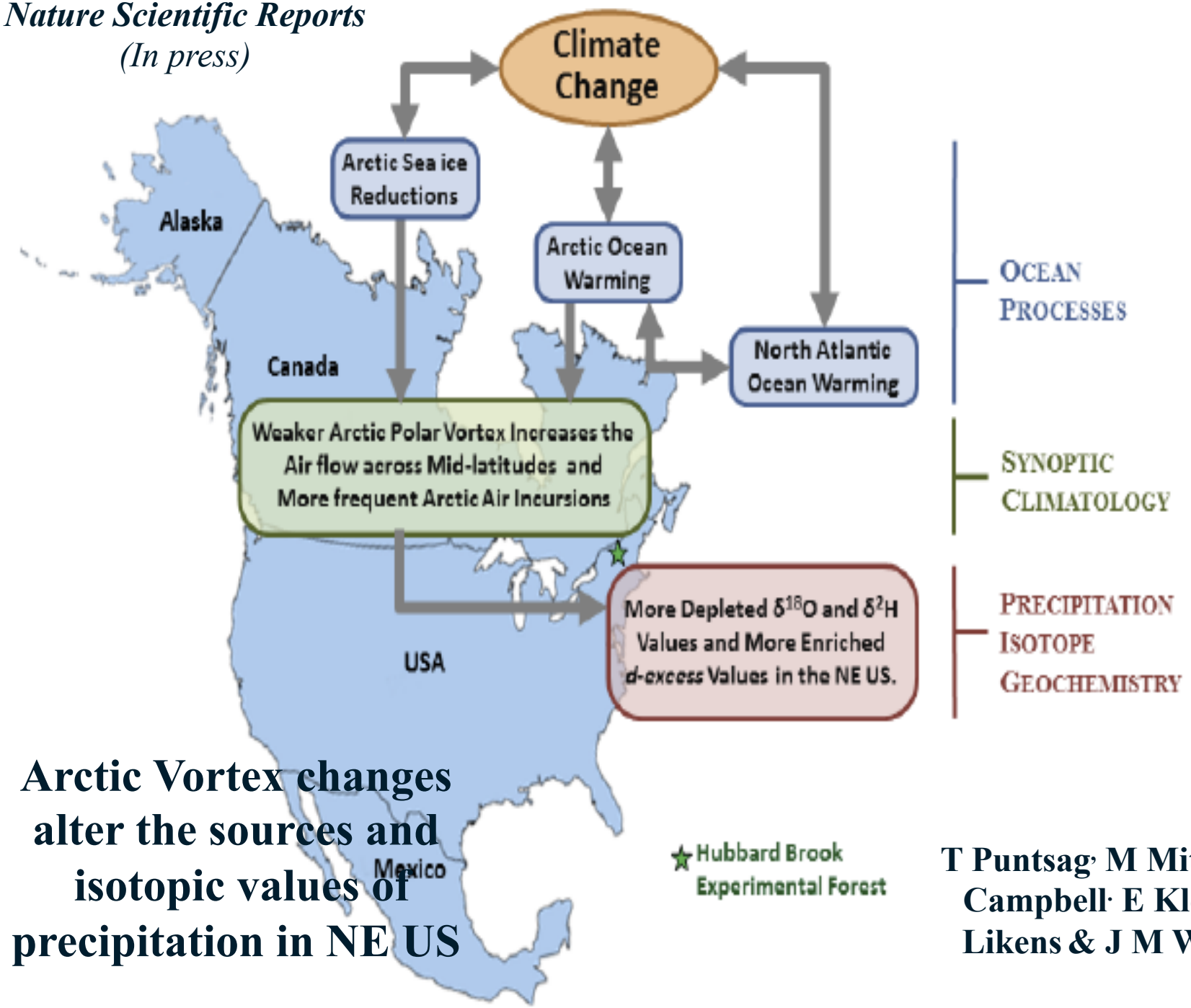
AON
ARCTIC OBSERVING NETWORK


WARM
H
L
JET
ABNORMALLY COLD
STORMY
DROUGHT
AVERAGE PATTERN THIS WINTER
AccuWeather.com
17:25Z 02/25/2014


-10
0
10
20
30
40
50
60
70
High Temperature(F) Ending Mon Jan 06 2014 7PM EST
(Tue Jan 07 2014 00Z)
National Digital Forecast Database
10z issuance
Graphic created-Jan 06 5:08AM EST

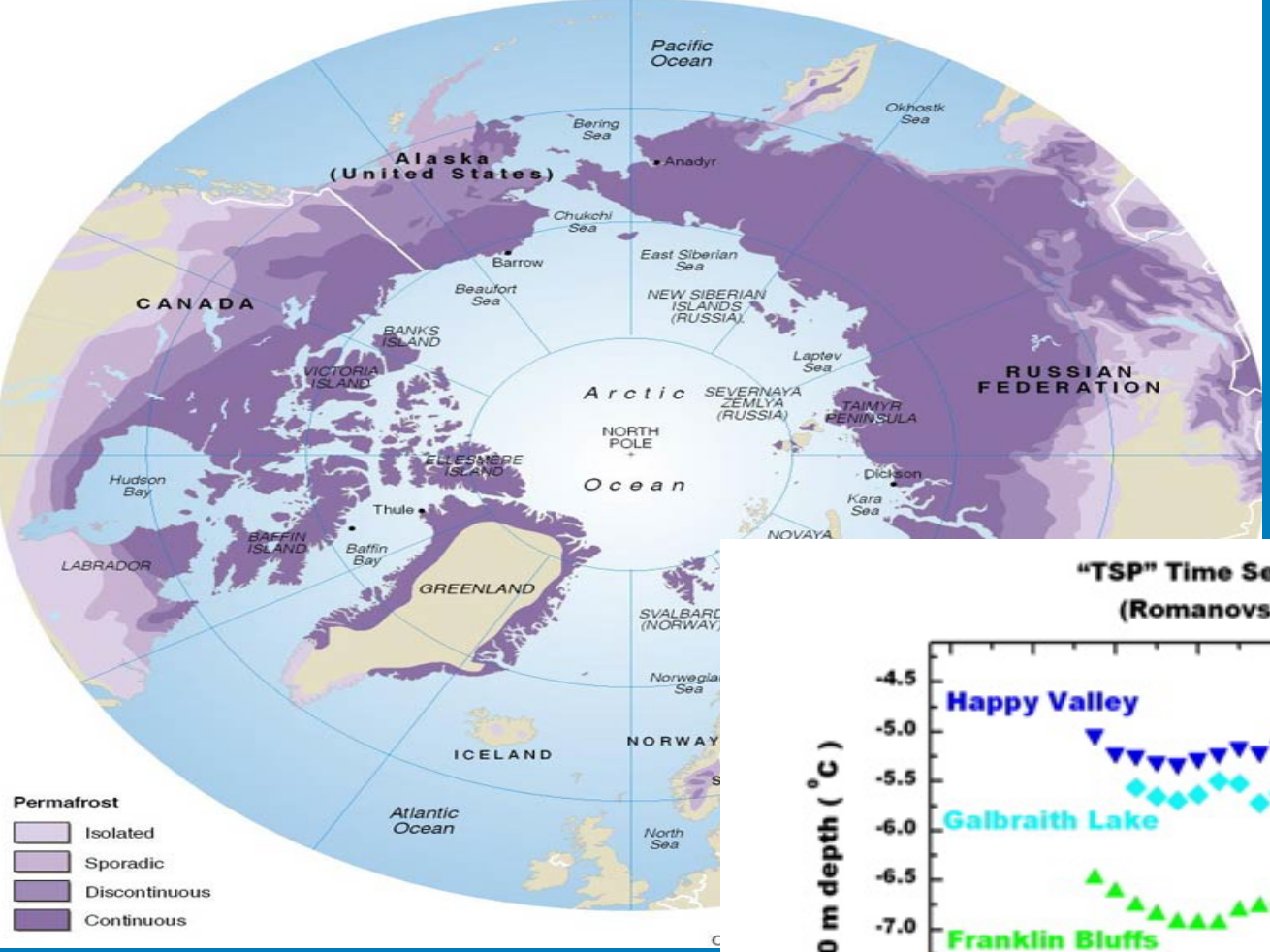
Nature Scientific Reports
(In press)



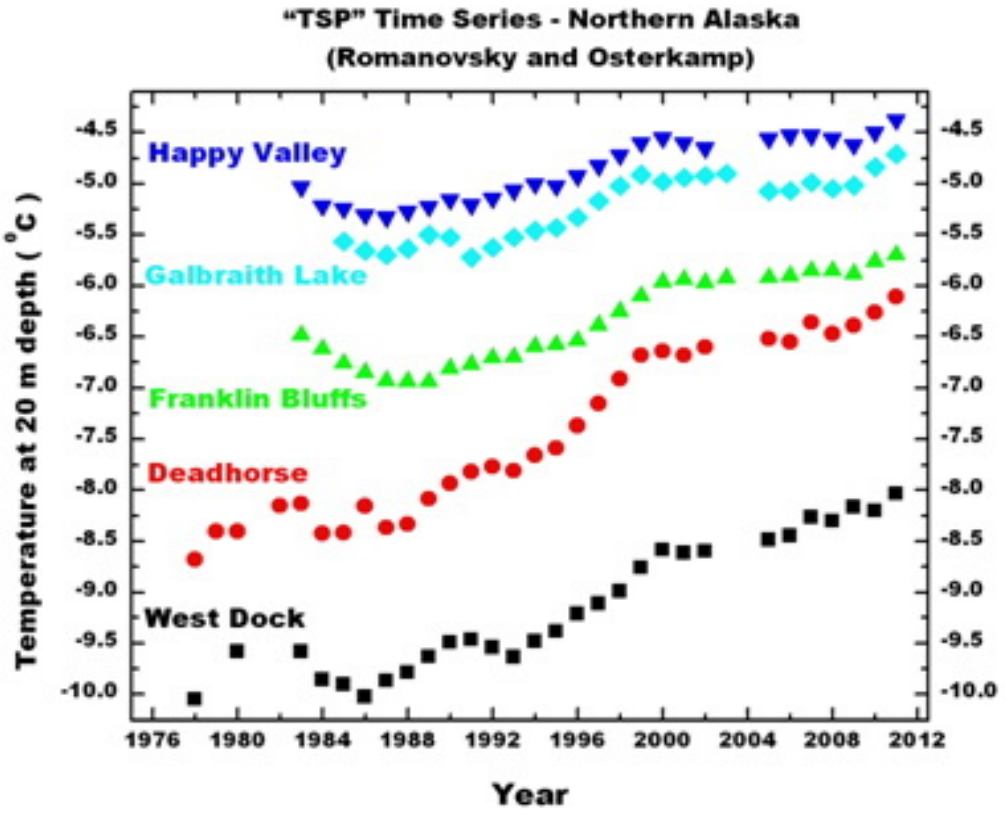
Arctic Vortex changes alter the sources and isotopic values of precipitation in NE US

T Puntsag, M Mitchell, J Campbell, E Klein, G Likens & J M Welker

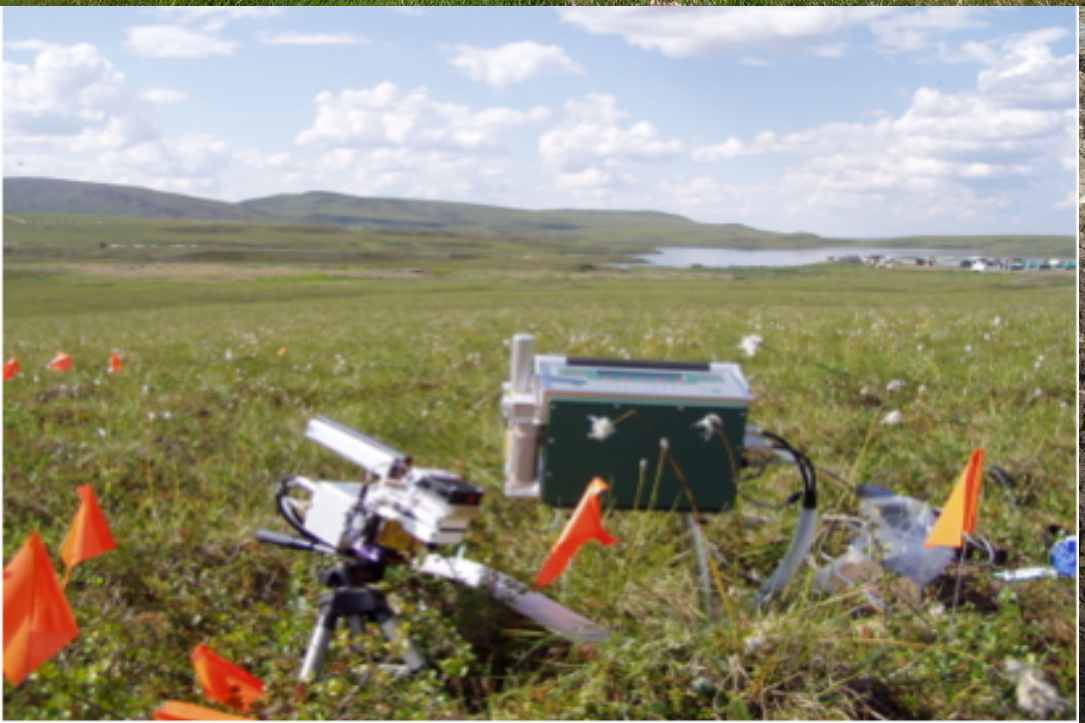
CO_2 and CH_4 fluxes and sources as permafrost thaws and precipitation changes



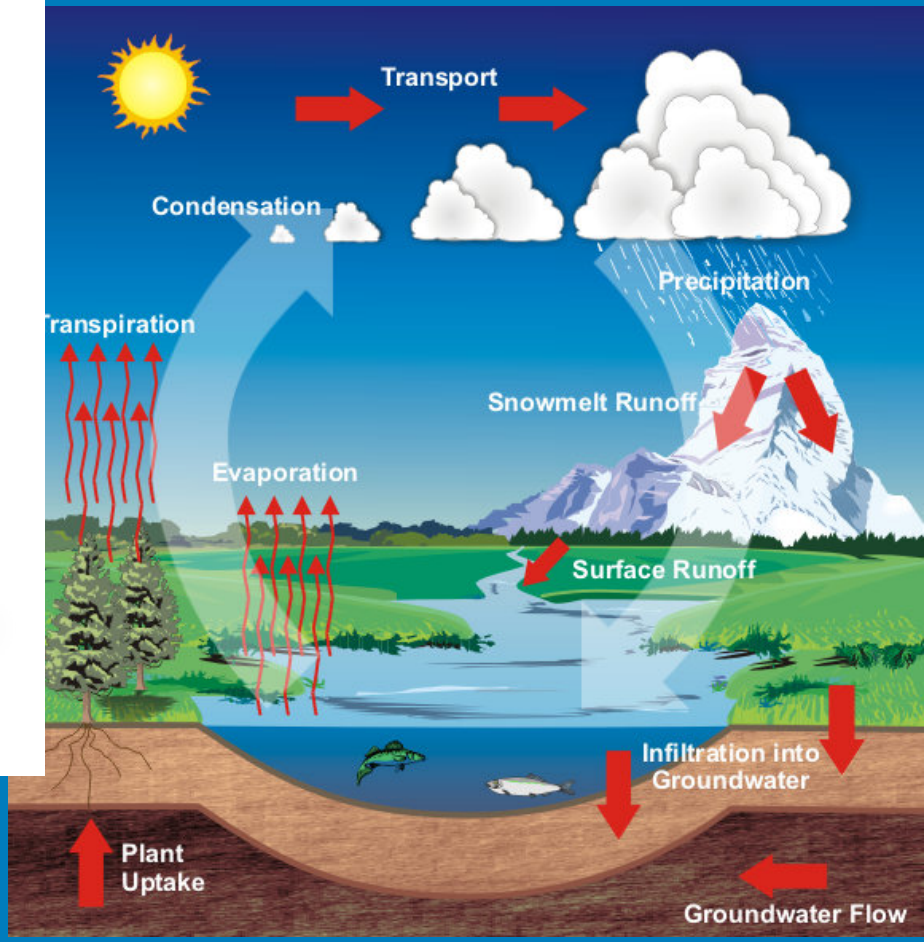
Modern and Ancient C mixing during summer and winter as ecosystem respiration



Permafrost dominated polar stripe landscapes in the High Arctic of NW Greenland

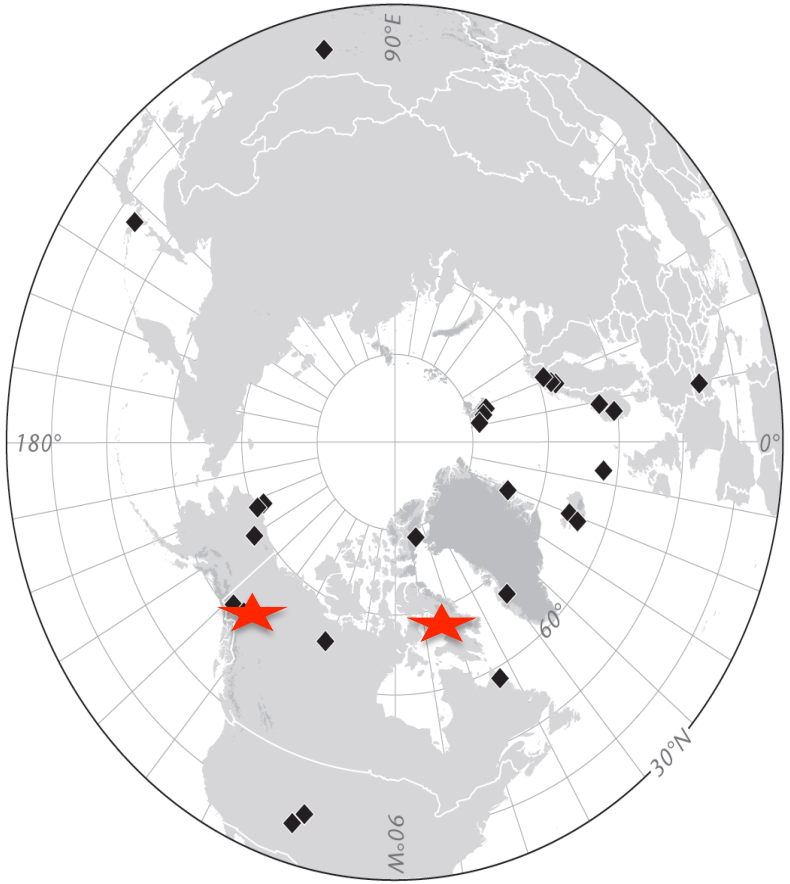


Hydrological Cycle



Multiple processes and attributes define the cryosphere and the hydrological cycle are at the core of a changing Arctic

Winter focused research was initiated in 1994 as part of a NSF OPP project “The International Tundra Experiment” ITEX-how do coupled changes in winter and summer climates effect moist and dry tundra function, structures and feedbacks



ITEX: International Tundra Experiment

A Pan Arctic, cross-site study of tundra changes using observations and long term experiments

Observations: interannual variations in phenology, C&H_2O relations, synoptic weather and drivers of ecohydrology
Experiments: summer warming and or winter increases and decreases in snow depth

1. Thule, NW Greenland-76ºN
2. Toolik Lake, AK, 68ºN

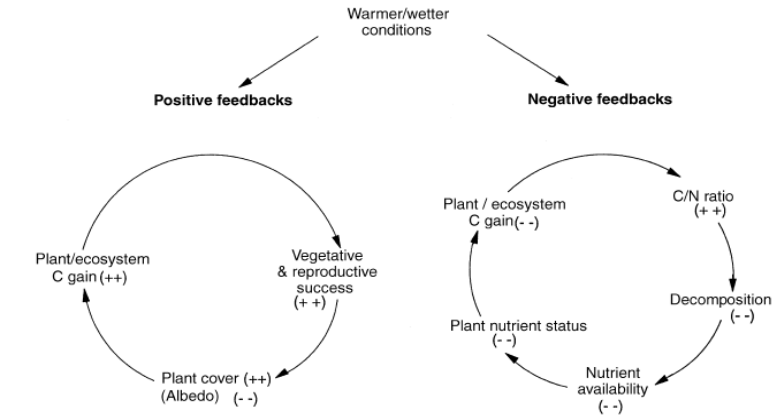
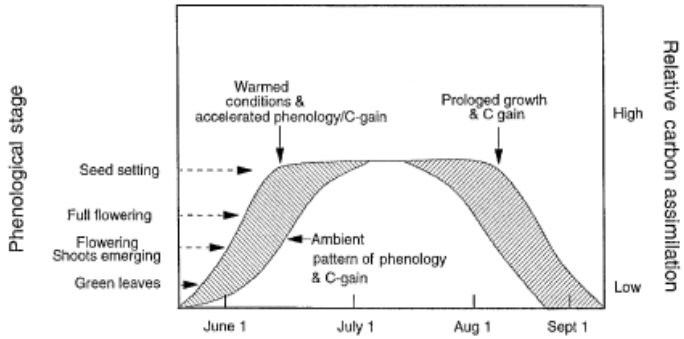


Fig. 14 A model of the extent to which the direct responses of *Dryas octopetala* plants and ecosystems to changes in environmental conditions may have both positive and negative feedback effects on the functional attributes of these habitats.



, **13** A simplified conceptual diagram depicting the extent to which changes in environmental conditions may accelerate phenological velopment, growth and carbon gain in *Dryas octopetala* plants and ecosystems early in the growing season, and how changes in ditions may prolong phenology, growth and carbon gain late in the growing season.

Responses of Dryas octopetla to ITEX environmental manipulations: a synthesis with circumpolar comparisions: 1997: Welker et al. GCB


NW Greenland


Brooks Range, N Alaska


High Arctic of NW Greenland

Key Observational Discoveries

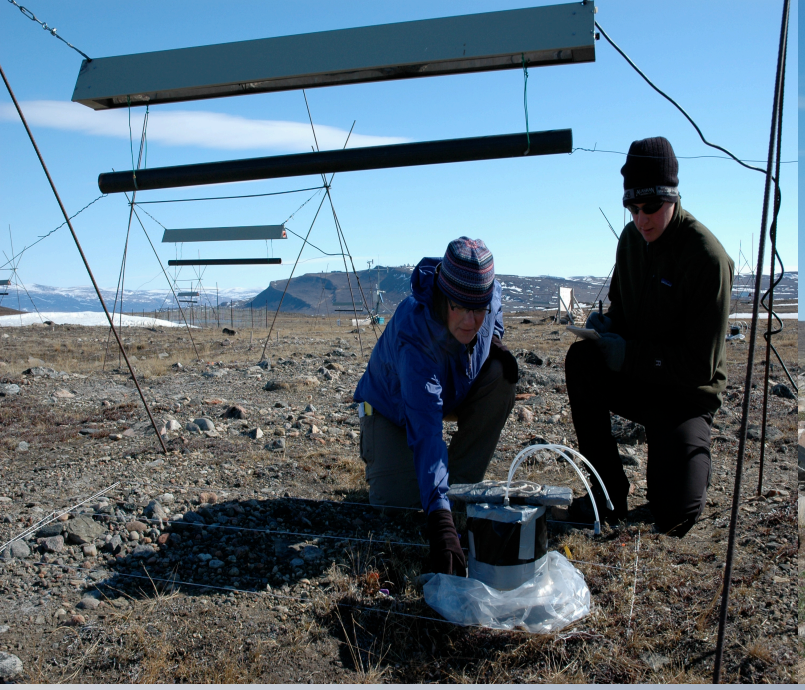
C pools are ~10 x greater then previously estimated and Ancient C (>25k bp) is present within the top 1 m of the soil- *Horwath et al. 2008-JGR*

Ancient C is leaking into the modern atmosphere as CO_2- *Czimczik and Welker 2010-AAAR*

Greenland Ice Sheet derived rivers are transporting ancient C as DOC and POC into N Baffin Bay- *Csank, Welker and Czimczik 2015 JGR*

Lake drying will lead to greater CO_2 and CH_4 emissions as aquatic systems become wet sedge but will switch to C sinks as the communities transition to moist and dry tundra-*McKnight et al. 2015-AGU*

Inglefield Land-NW Greenland, 78°N




Warming, watering and snow addition
experimental site in NW Greenland
5

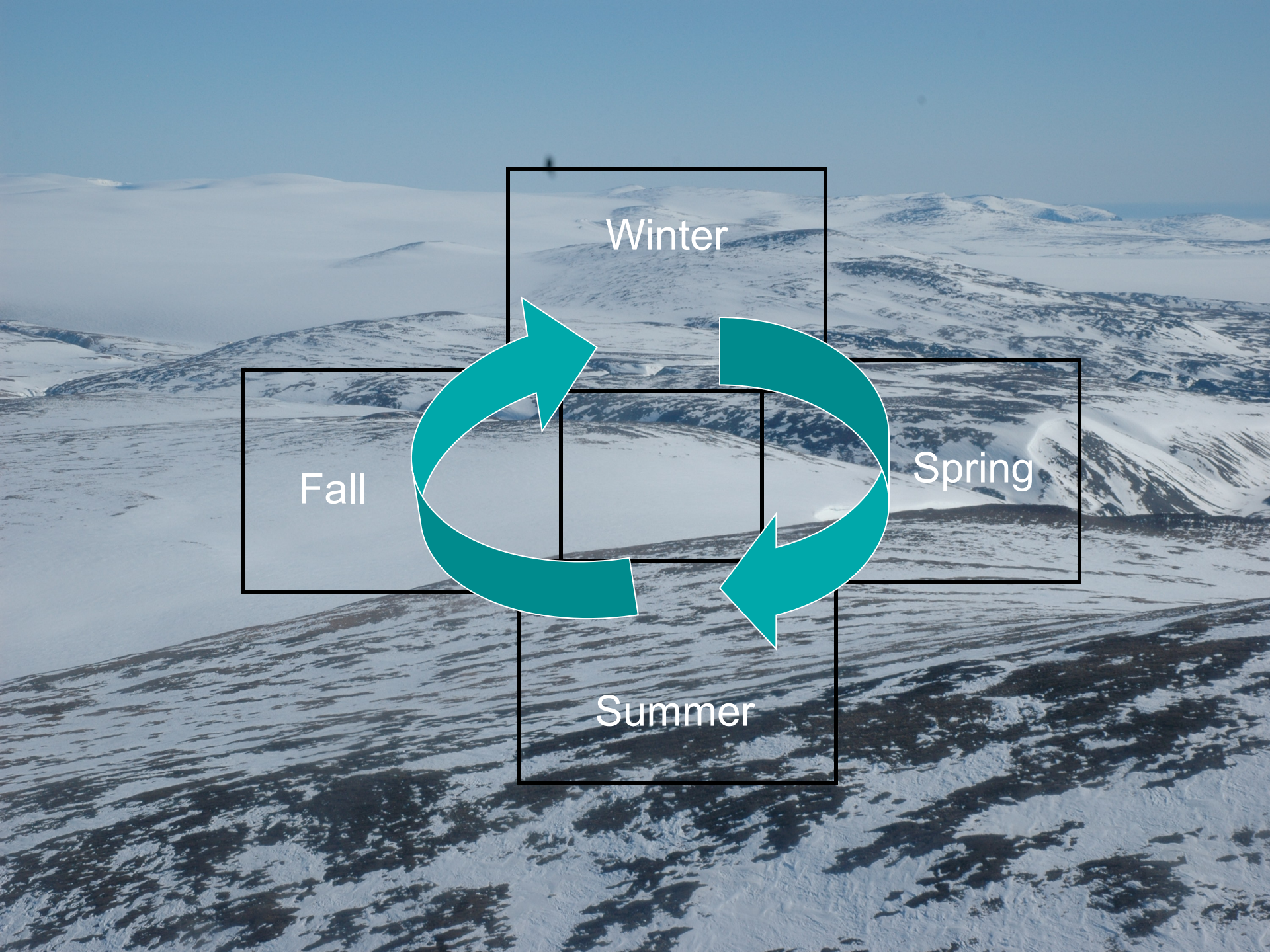
Experimental Observations

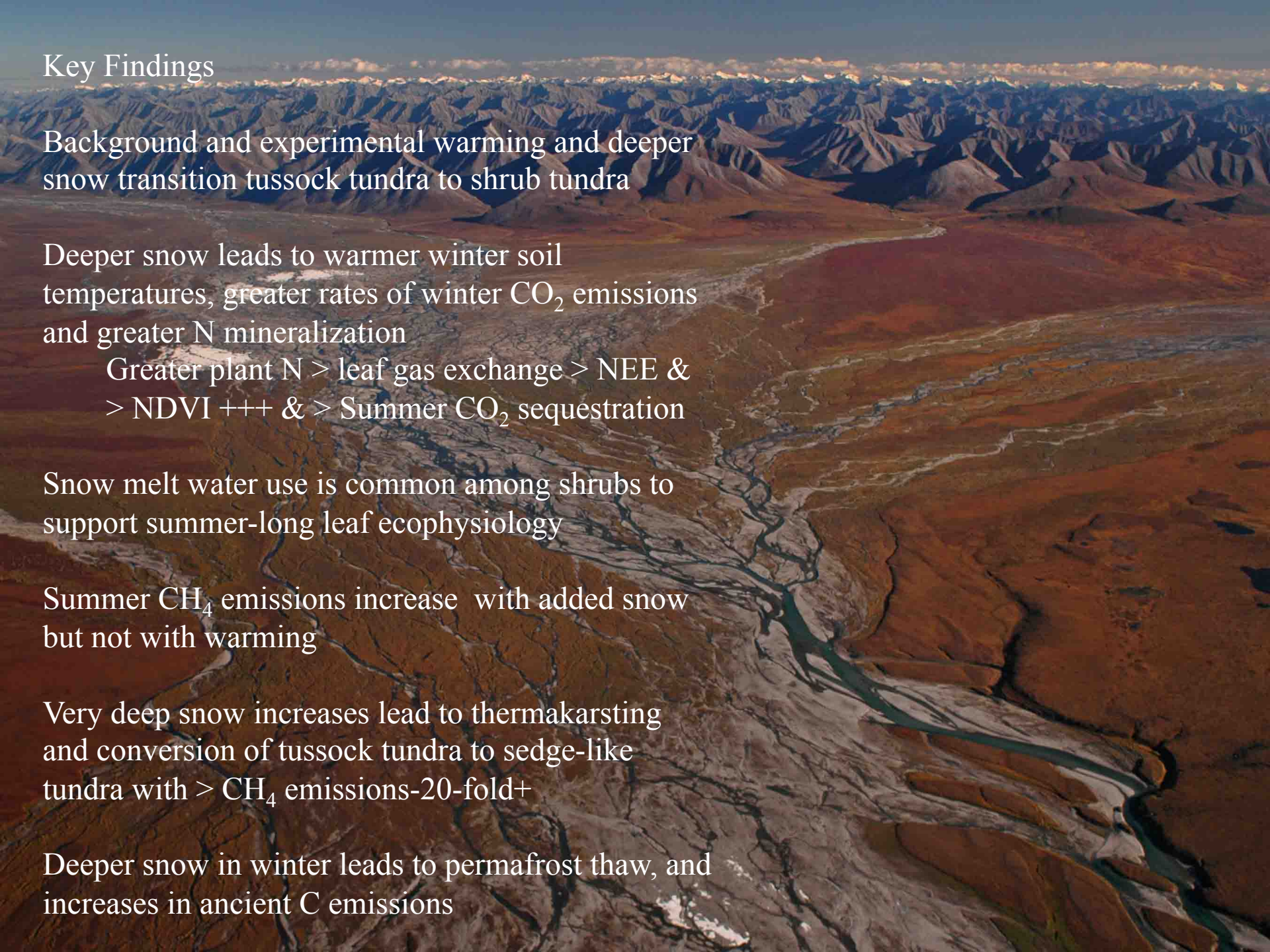
Ancient C contributions to polar semi-desert emissions is regulated by ecohydrology-precipitation regimes-*Lupascu, Cziimczik & Welker et al. 2013 & 2014-Nature Climate Change*

Net C sequestration responses of polar semi-deserts to warming are not linear and are predicated on summer precipitation regimes-*Sharpe, Sullivan & Welker, 2013, GCB*

Deeper snow in winter leads to greater emissions over the 250+ winter period and C sequestration is greatest in the subsequent summers where snow was deep, but not excessive (seasonality effect)-*Rogers, Sullivan & Welker 2011, AAAR*

Snow melt water drives soil and plant N processes more than water relations which stimulates GPP-*ERL 2013 Leffler & Welker*


Winter
Fall
Spring
Summer



Key Findings

Background and experimental warming and deeper snow transition tussock tundra to shrub tundra

Deeper snow leads to warmer winter soil temperatures, greater rates of winter CO_2 emissions and greater N mineralization

Greater plant N > leaf gas exchange > NEE & > NDVI +++ & > Summer CO_2 sequestration

Snow melt water use is common among shrubs to support summer-long leaf ecophysiology

Summer CH_4 emissions increase with added snow but not with warming

Very deep snow increases lead to thermakarsting and conversion of tussock tundra to sedge-like tundra with > CH_4 emissions-20-fold+

Deeper snow in winter leads to permafrost thaw, and increases in ancient C emissions

Climate warming (Figure 2)

+ GPP/NDVI

Shrub density (Figure 1)

Snow depth (Figure 5a)

Soil temperature (Figures 4a, 4b and 5b)

Microbial activity (Figures 6a, 6b, and 7a)

Nutrient availability (Figure 7b)

Snow Biogeochemical Feedbacks

High rates and prolonged leaf gas exchange

Snow Ecohydrologic Feedbacks

Snow Melt water supply

Future Trajectories and Approaches

How do future Arctic landscapes interact with a changing climate and do transitions into a new vegetation assemblages have stronger or weaker feedback effects via C, N and water cycles?

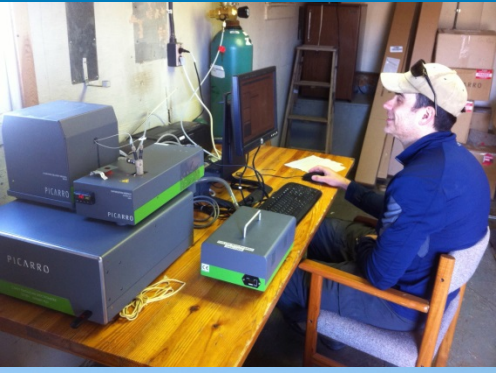
Are there differences in the interactions between the C-N-water cycles in the High vs. Low Arctic and how is the coupling of these cycles effected by accelerated summer warming & drying with more or less winter snow in the prior winters

How are changes in the fundamental basis of Arctic climate and moisture sources manifested in tundra ecohydrology and how are these changes reflected in local records of climate and past landscape processes

Nature Scientific Reports-2015

Arctic cyclone water vapor isotopes support past sea ice retreat recorded in Greenland Ice

E Klein and J Welker et al.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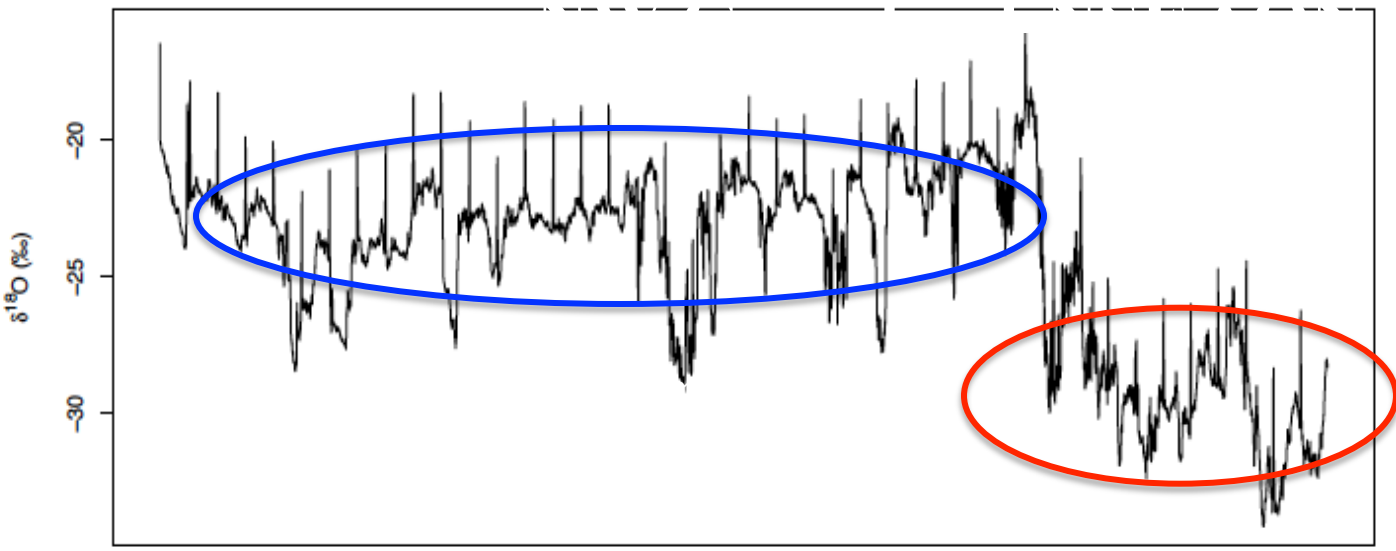
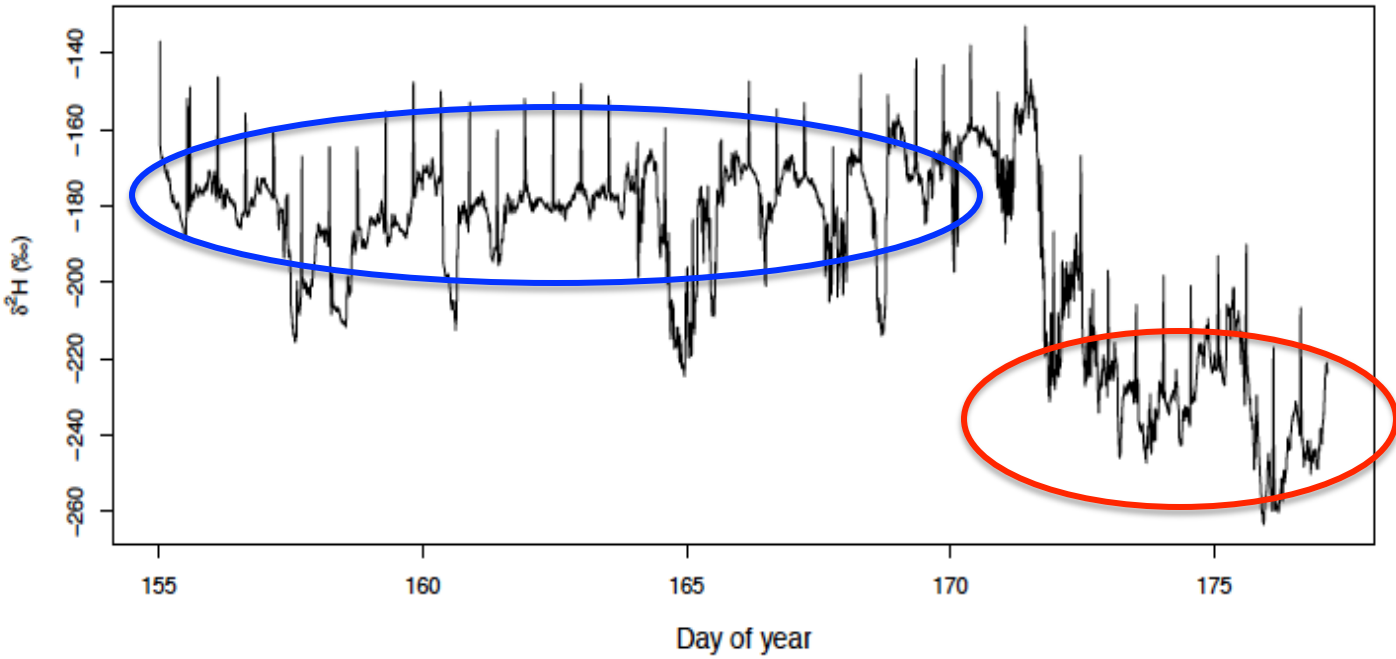
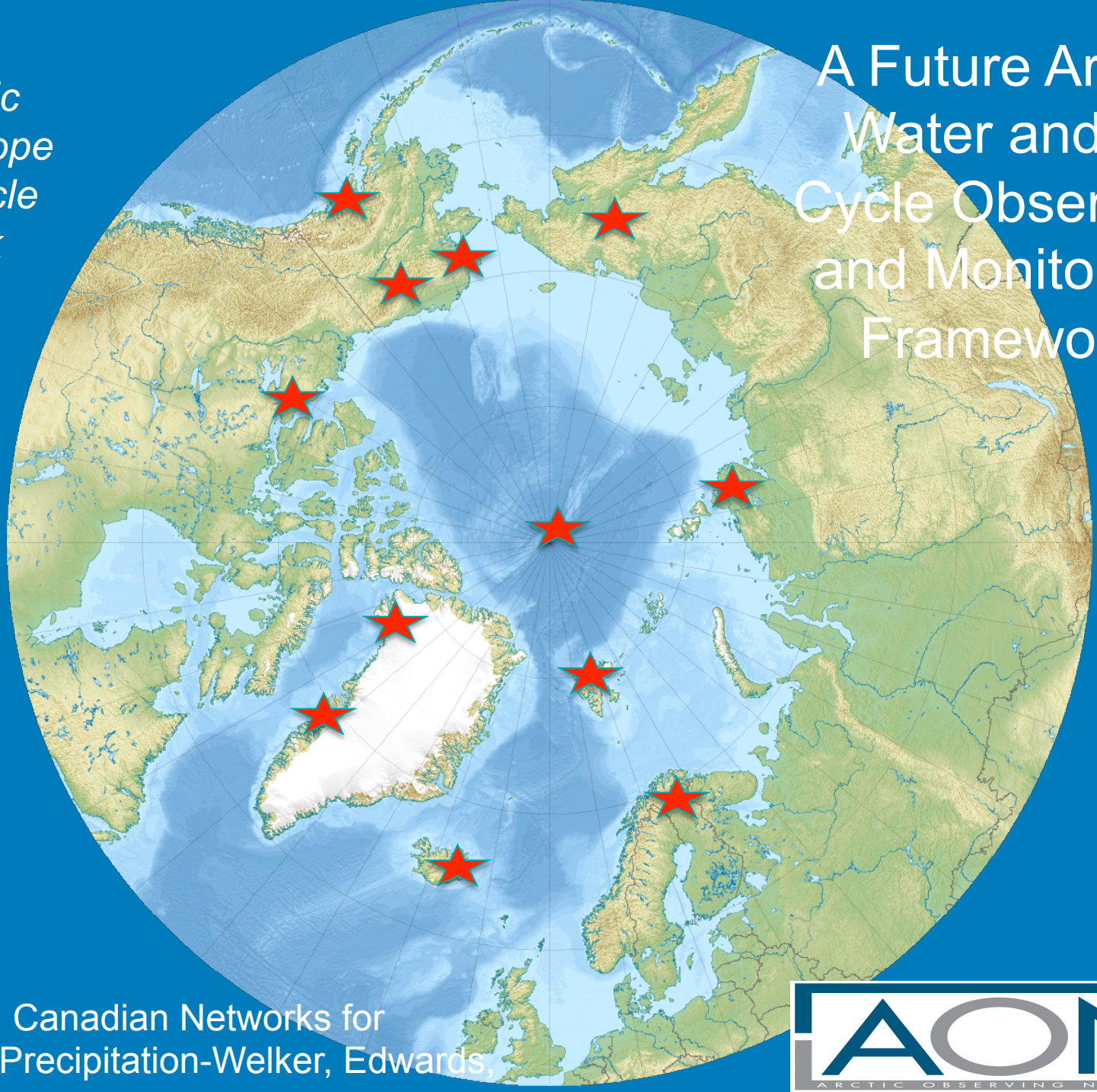

δ18O (‰)
-20
-25
-30


δ2H (‰)
-140
-160
-180
-200
-220
-240
-260
155
160
165
170
175
Day of year

Pan Arctic Water Isotope and C Cycle Network

A Future Arctic Water and C Cycle Observing and Monitoring Framework



AKWIN and Canadian Networks for Isotopes in Precipitation-Welker, Edwards,

Moist Acidic Tundra, Toolik