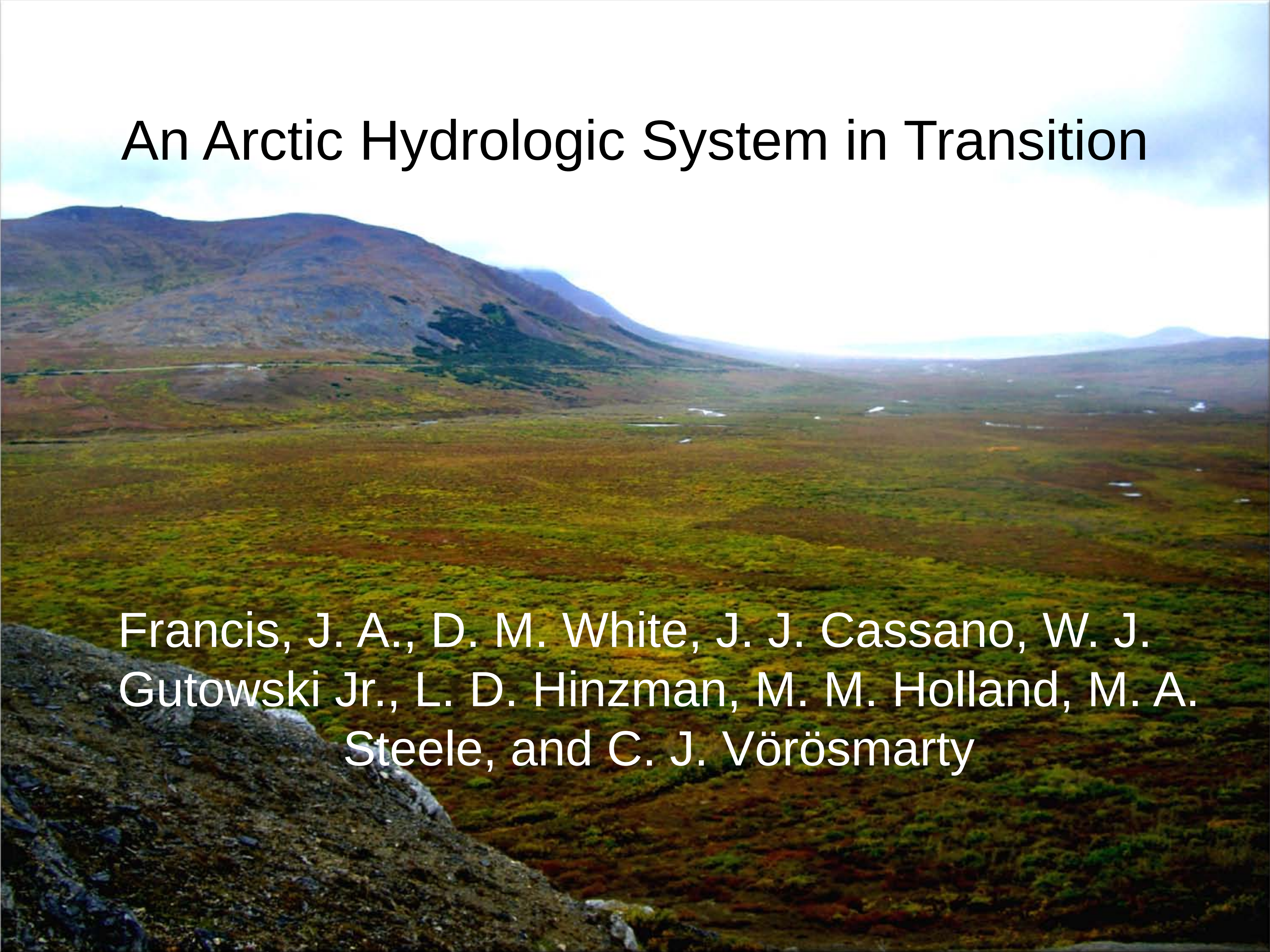
An Arctic Hydrologic System in Transition



Francis, J. A., D. M. White, J. J. Cassano, W. J. Gutowski Jr., L. D. Hinzman, M. M. Holland, M. A. Steele, and C. J. Vörösmarty

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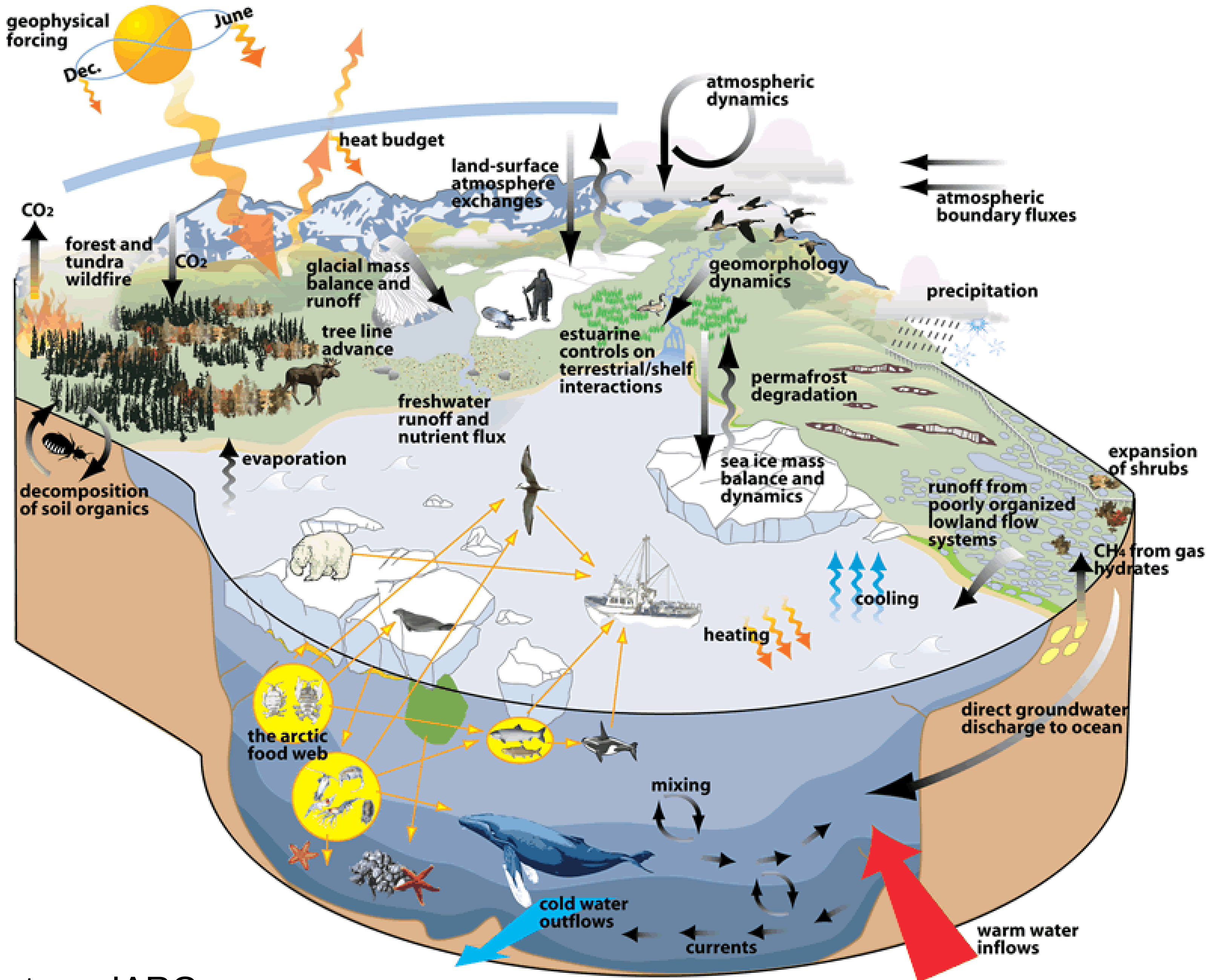
FWI Synthesis Activities - Working Groups

“Budgeteers” WG (Mark Serreze, Richard Lammers, Craig Lee, and Dick Moritz)

“CAWG” (Changes, Attributions, Impacts and Implications) WG (Marika Holland, Jennifer Francis, Craig Lee, Max Holmes, Dan White, Larry Hinzman)

“Intensifiers” WG (Michael Rawlins, lead) formed at 2006

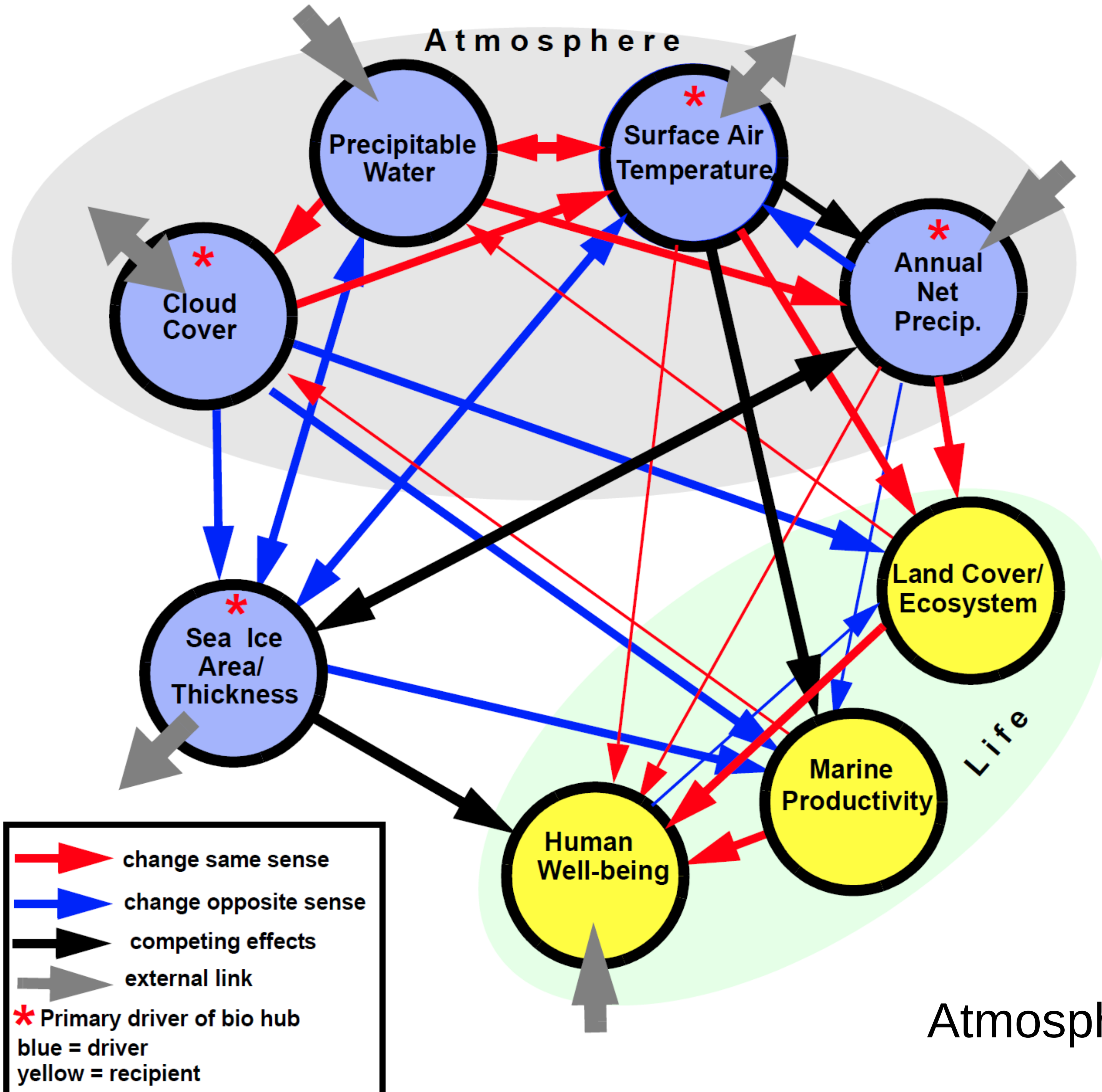


Courtesy: IARC

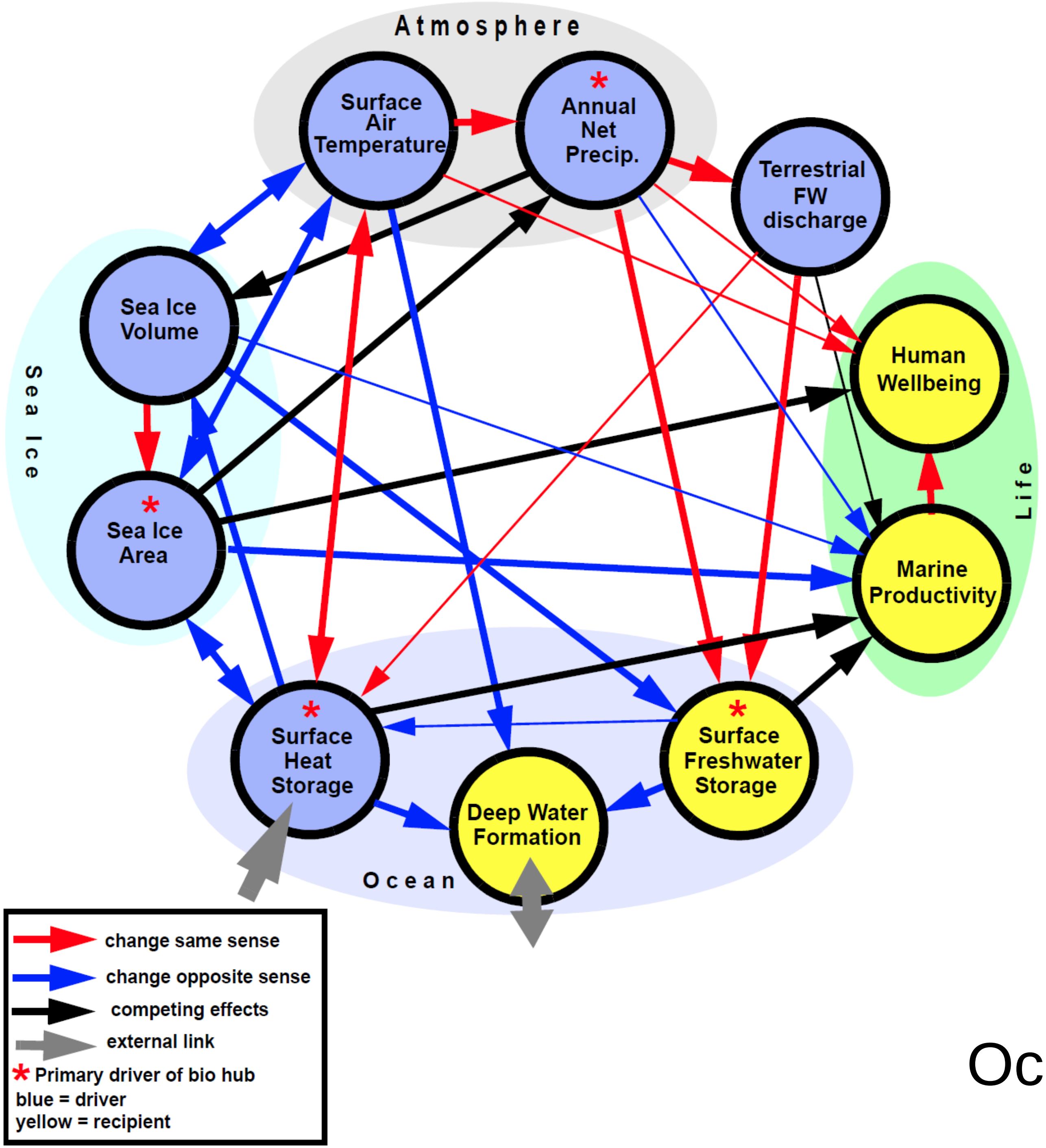
EOS
EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

Arctic System on Trajectory to New, Seasonally Ice-Free State

Overpeck, J. T. M. Sturm, J. A. Francis, D. K. Perovich, M. C. Serreze, R. Benner, E. C. Carmack, F. S. Chapin III, S. C. Gerlach, L. C. Hamilton, L. D. Hinzman, M. Holland, H. P. Huntington, J. R. Key, A. H. Lloyd, G. M. MacDonald, J. McFadden, D. Noone, T. D. Prowse, P. Schlosser, and C. Vörösmarty. 2005. Arctic System on Trajectory to New, Seasonally Ice-Free State. 86(34): 309, 312-313. 23 August 2005.


Atmosphere
Precipitable Water
*
Surface Air Temperature
*
Cloud Cover
*
Annual Net Precip.
*
Sea Ice Area/ Thickness
Land Cover/ Ecosystem
Marine Productivity
Human Well-being
Life
change same sense
change opposite sense
competing effects
external link
* Primary driver of bio hub
blue = driver
yellow = recipient

Atmosphere


Atmosphere
Surface Air Temperature
*
Annual Net Precip.
Terrestrial FW discharge
Sea Ice
Sea Ice Volume
*
Sea Ice Area
Life
Human Wellbeing
Marine Productivity
*
Surface Heat Storage
Deep Water Formation
*
Surface Freshwater Storage
Ocean
change same sense
change opposite sense
competing effects
external link
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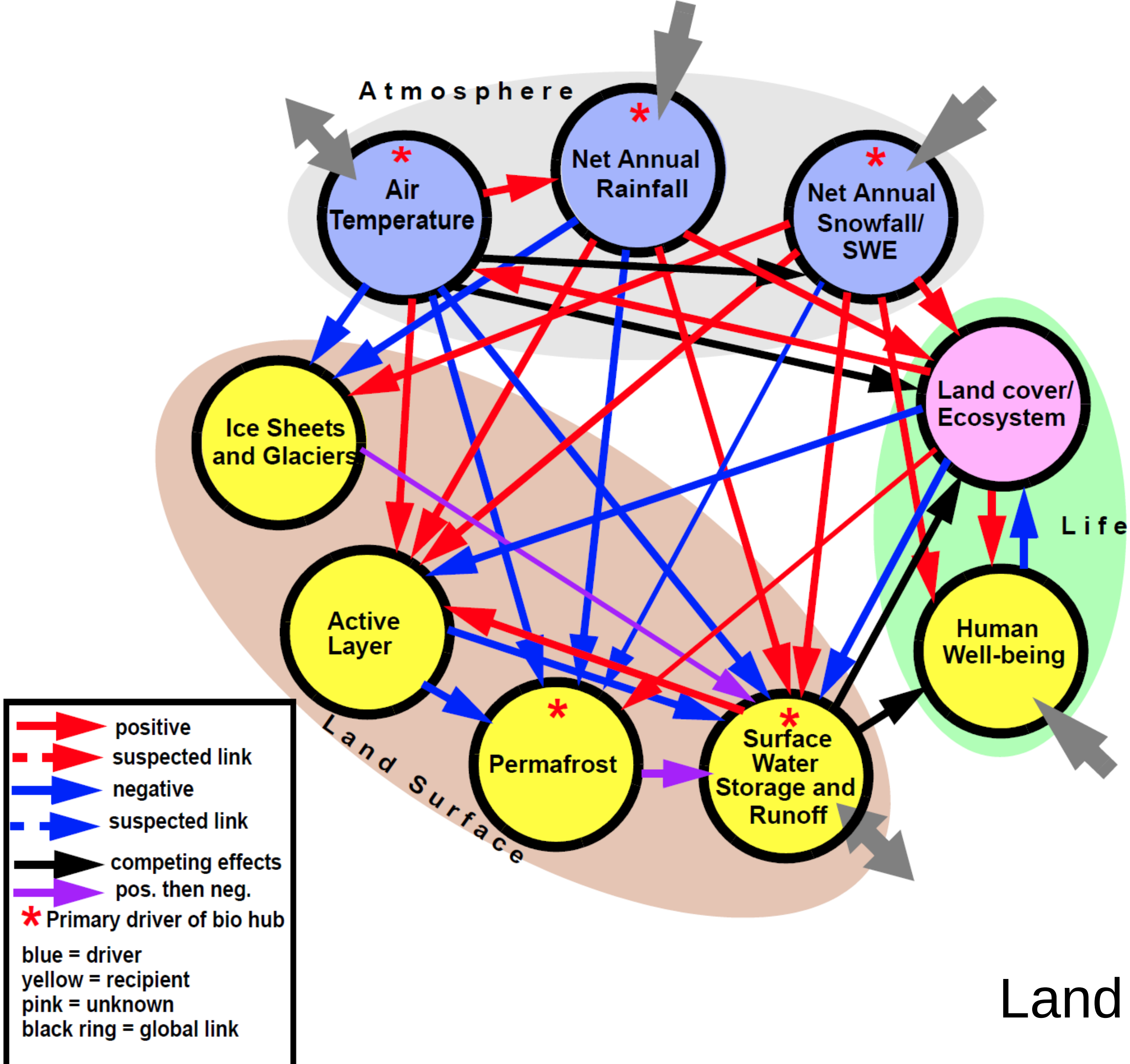
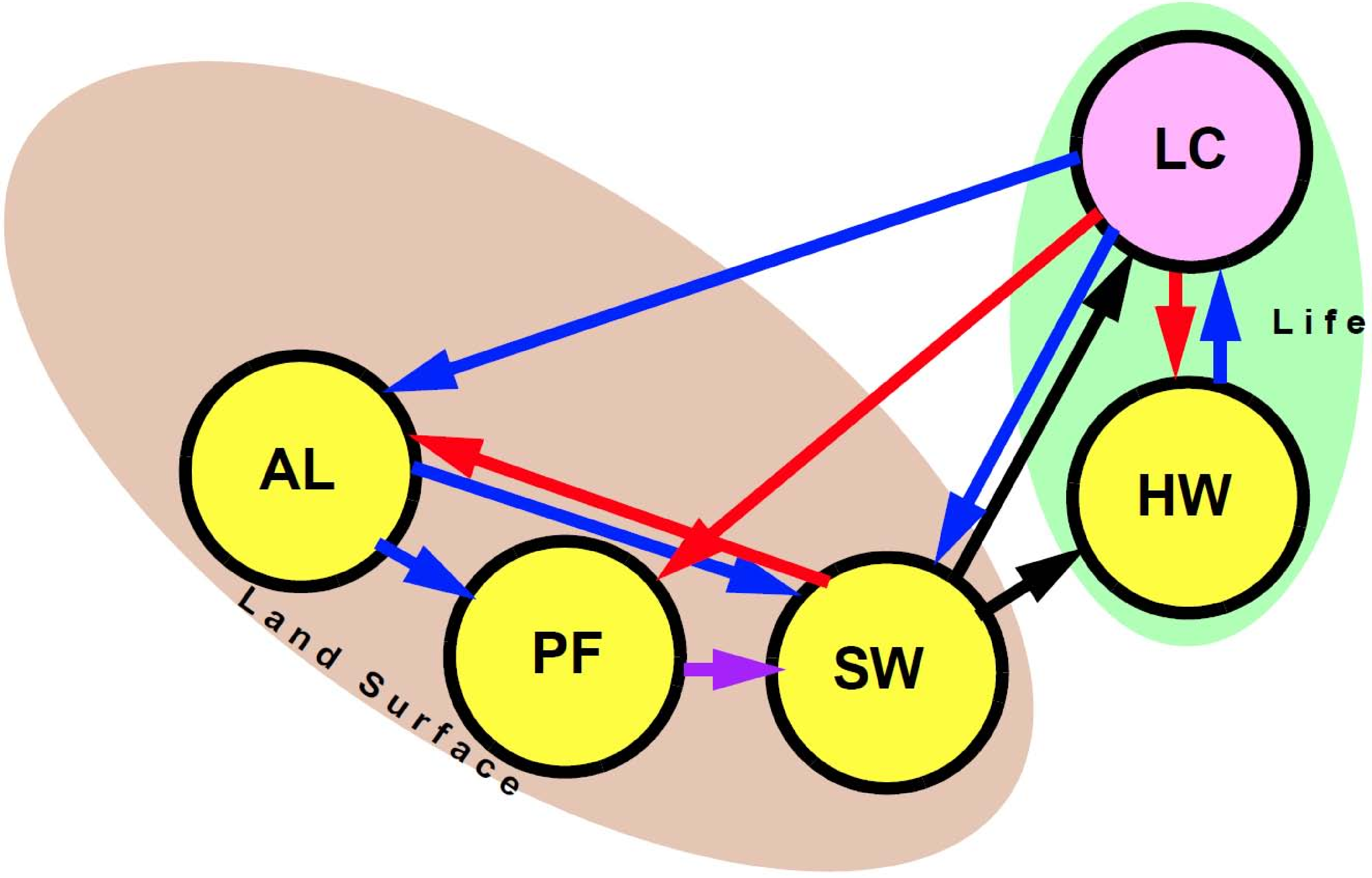
Ocean


Atmosphere
Air Temperature
Net Annual Rainfall
Net Annual Snowfall/ SWE
Land cover/ Ecosystem
Life
Human Well-being
Ice Sheets and Glaciers
Active Layer
Permafrost
Surface Water Storage and Runoff
Land Surface
positive
suspected link
negative
suspected link
competing effects
pos. then neg.
Primary driver of bio hub
blue = driver
yellow = recipient
pink = unknown
black ring = global link

Land

Feedbacks and verifications


LC
AL
PF
SW
HW
Life
Land Surface

Feedbacks and verifications

Impacts on the “life hubs”

Lessons learned

1. The atmospheric hubs in each subsystem were net drivers. The life hubs in each subsystem were net recipients.

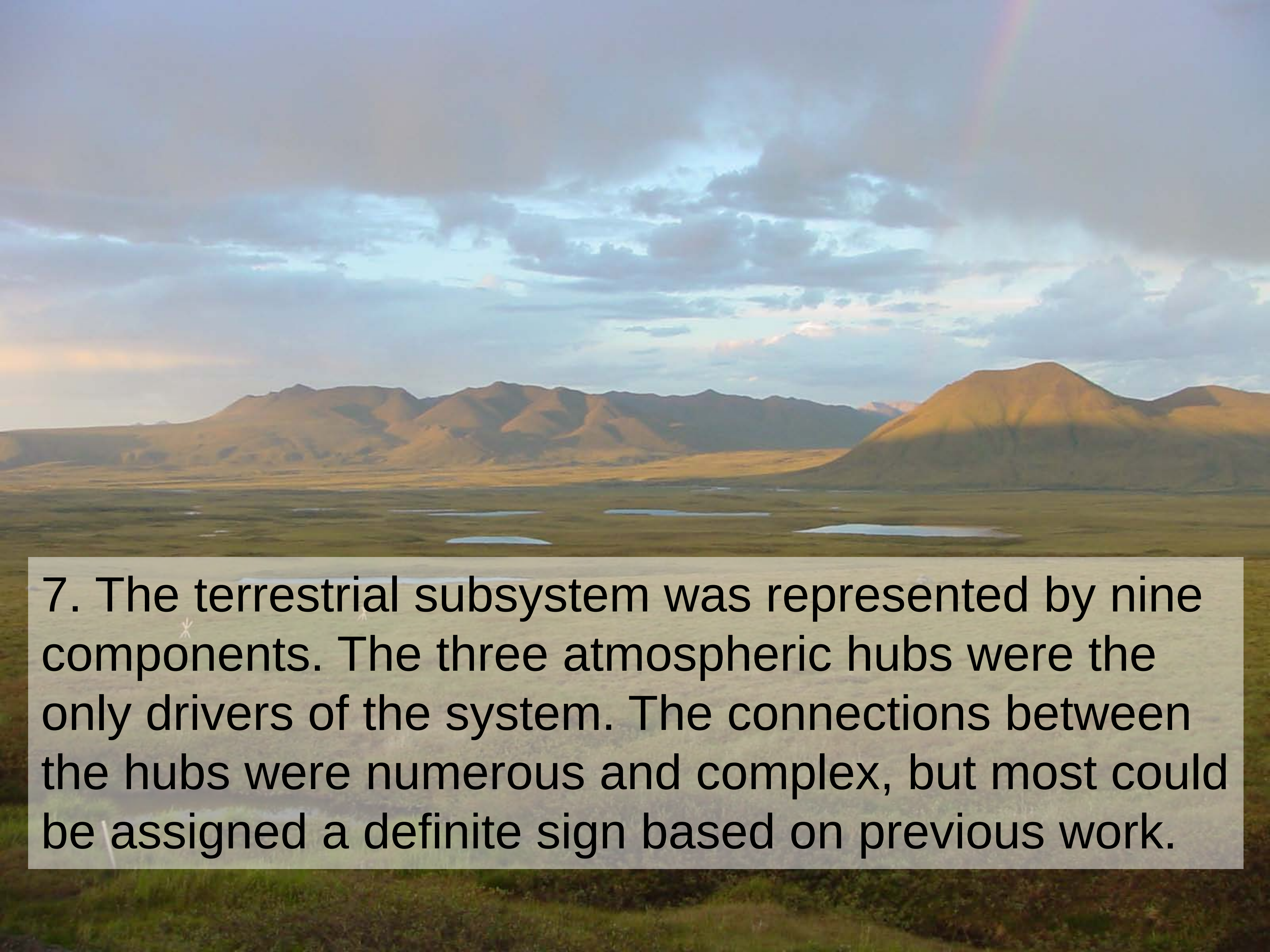
2. The atmospheric subsystem consisted of 5 hubs; all were drivers, all directly linked with the global climate system, and all but one interacted directly with life hubs.

3. Seven feedbacks were in the atmospheric subsystem: four positive, one negative, two uncertain. All but two feedbacks involved sea ice. The effects of the feedbacks on the biological components were varying and often competing.

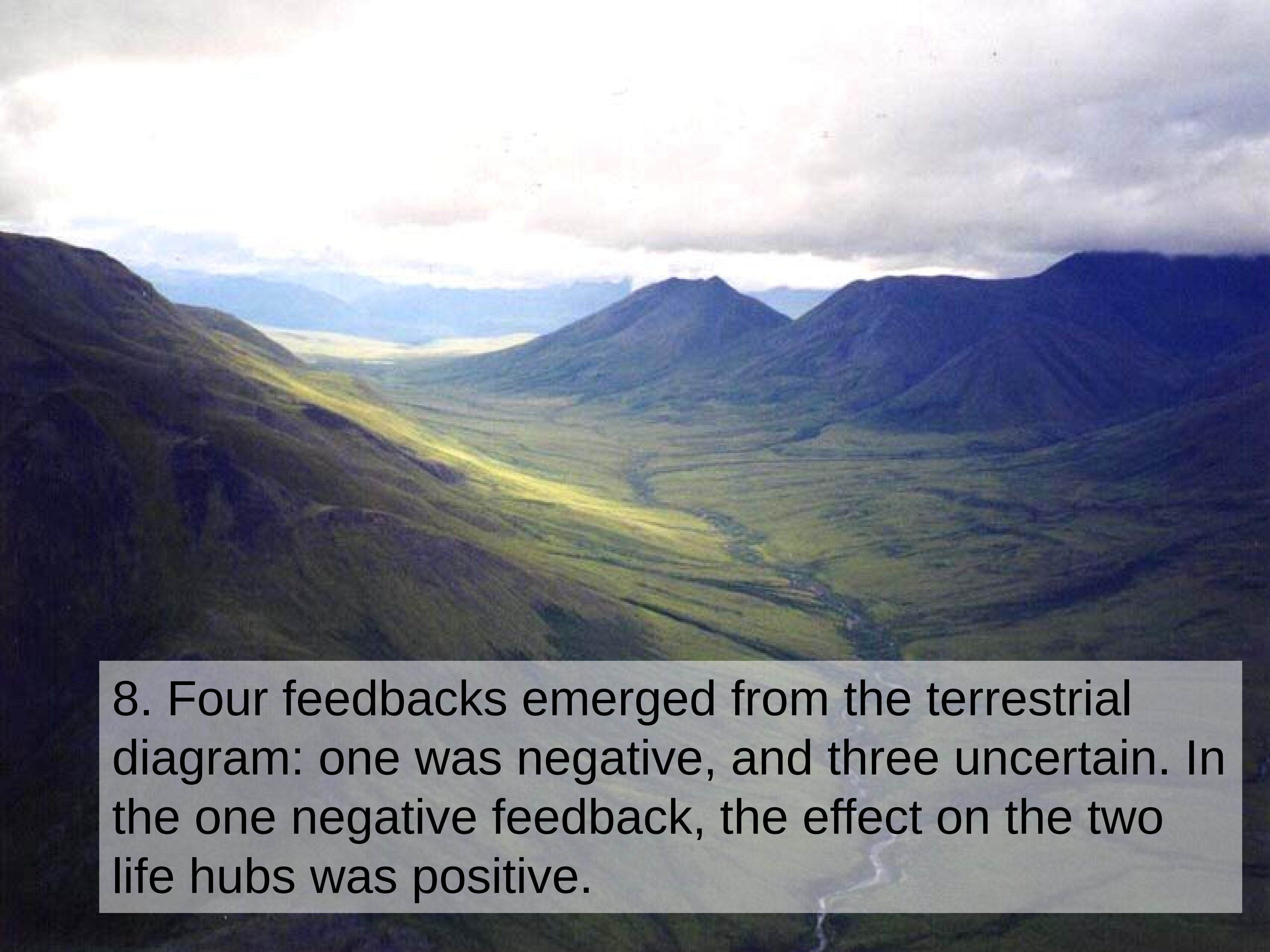
4. The oceanic subsystem consisted of ten hubs, half of which were drivers: two were atmospheric, two represented sea ice, and one was terrestrial freshwater discharge. All three of the “wet ocean” hubs were recipients, as were the two life hubs.

5. Five feedback loops were identified in the oceanic subsystem: one was positive, one was negative, and three were uncertain as to their signs.

6. All of the feedbacks in the oceanic system involved sea ice. The influence of these feedbacks on the life hubs was highly uncertain re: competing factors in the relationships between changes in the physical system and the wellbeing of marine organisms and human society.

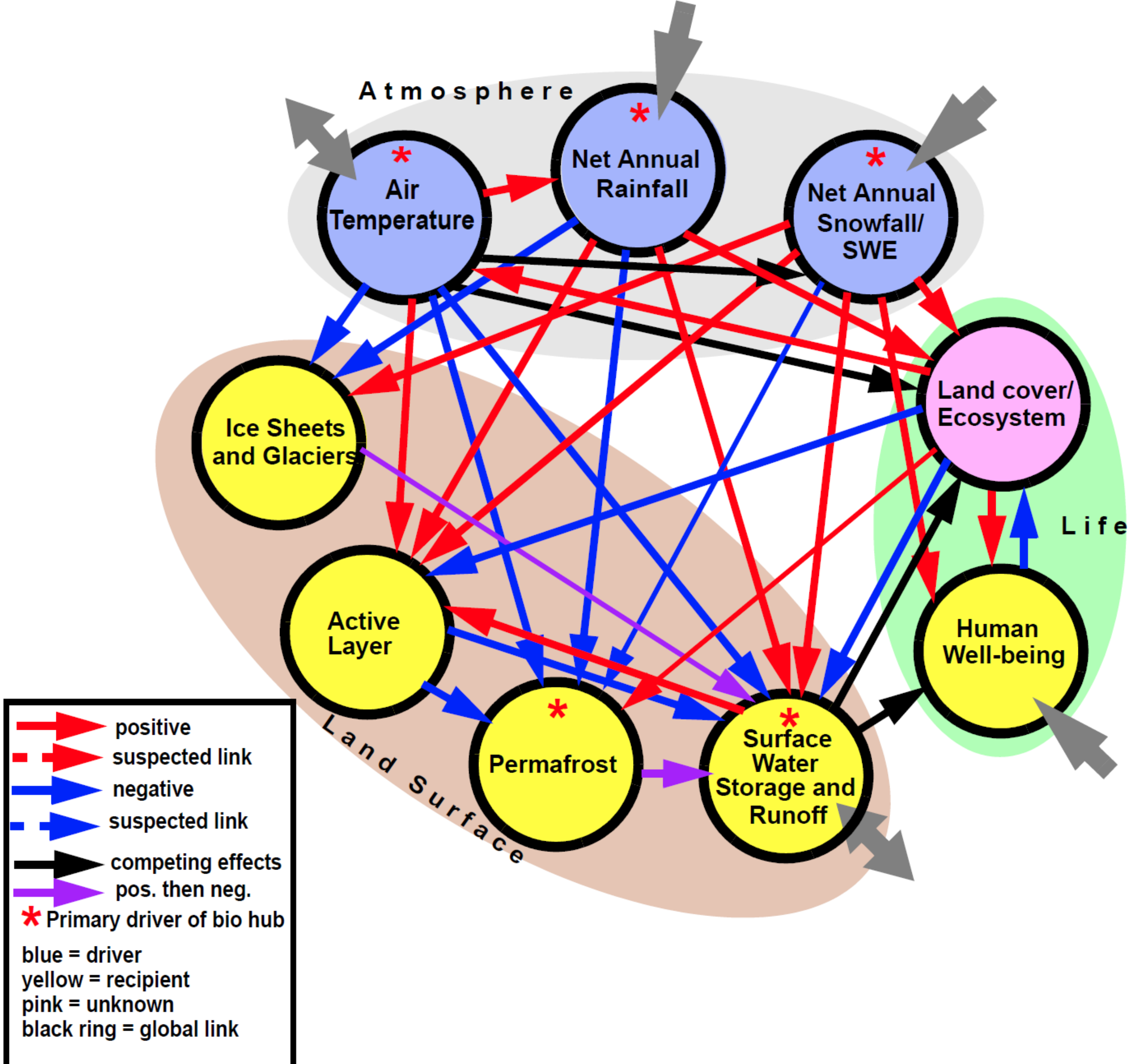


7. The terrestrial subsystem was represented by nine components. The three atmospheric hubs were the only drivers of the system. The connections between the hubs were numerous and complex, but most could be assigned a definite sign based on previous work.



8. Four feedbacks emerged from the terrestrial diagram: one was negative, and three uncertain. In the one negative feedback, the effect on the two life hubs was positive.

9. Surprisingly, all four of the terrestrial subsystem feedbacks included the land cover/ecosystem/vegetation hub, underscoring the essential role played by the changing tundra in the arctic hydrologic system.



Atmosphere
*
Air Temperature
*
Net Annual Rainfall
*
Net Annual Snowfall/ SWE
Land cover/ Ecosystem
Ice Sheets and Glaciers
Life
Active Layer
Human Well-being
*
Permafrost
*
Surface Water Storage and Runoff
Land Surface
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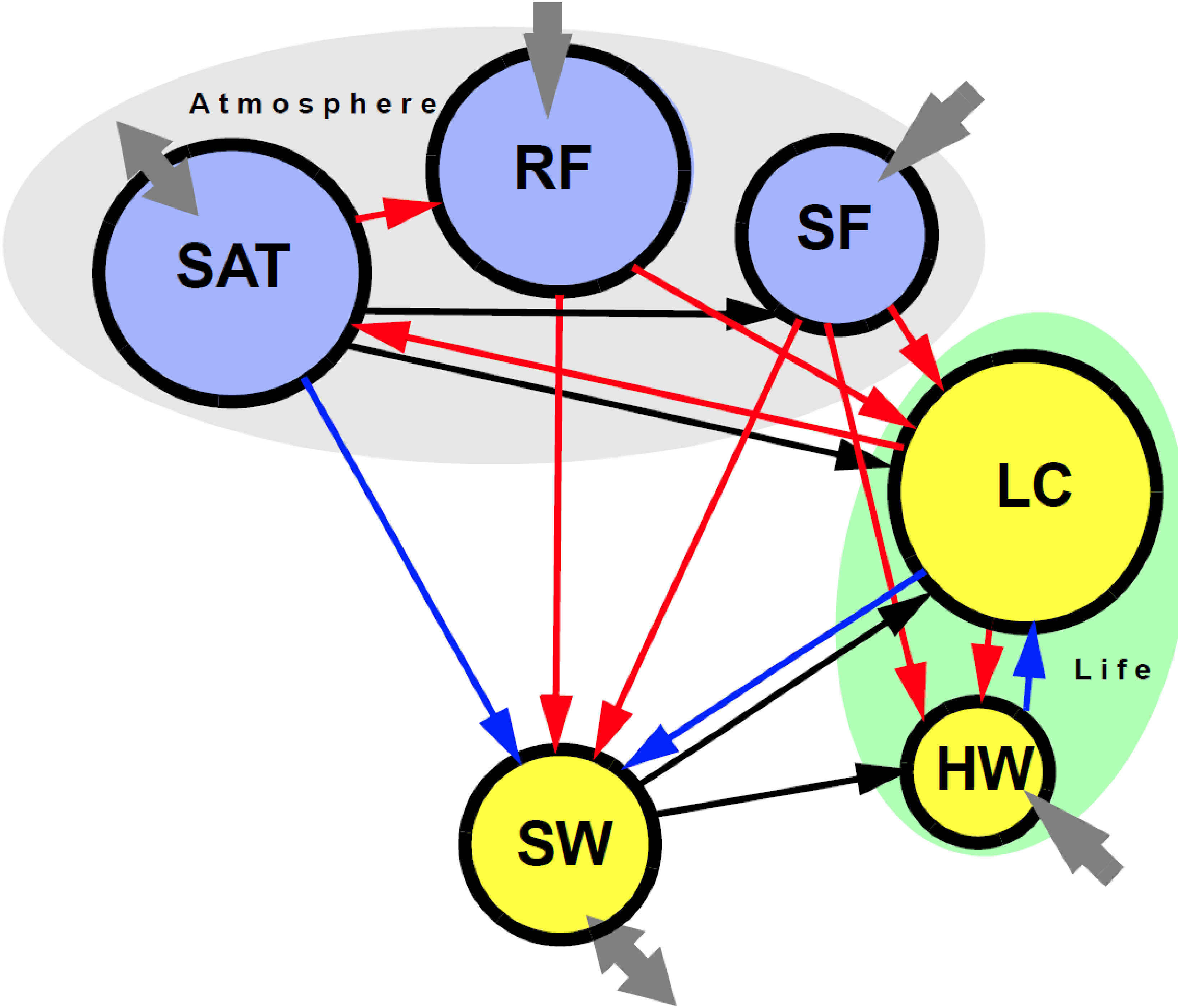
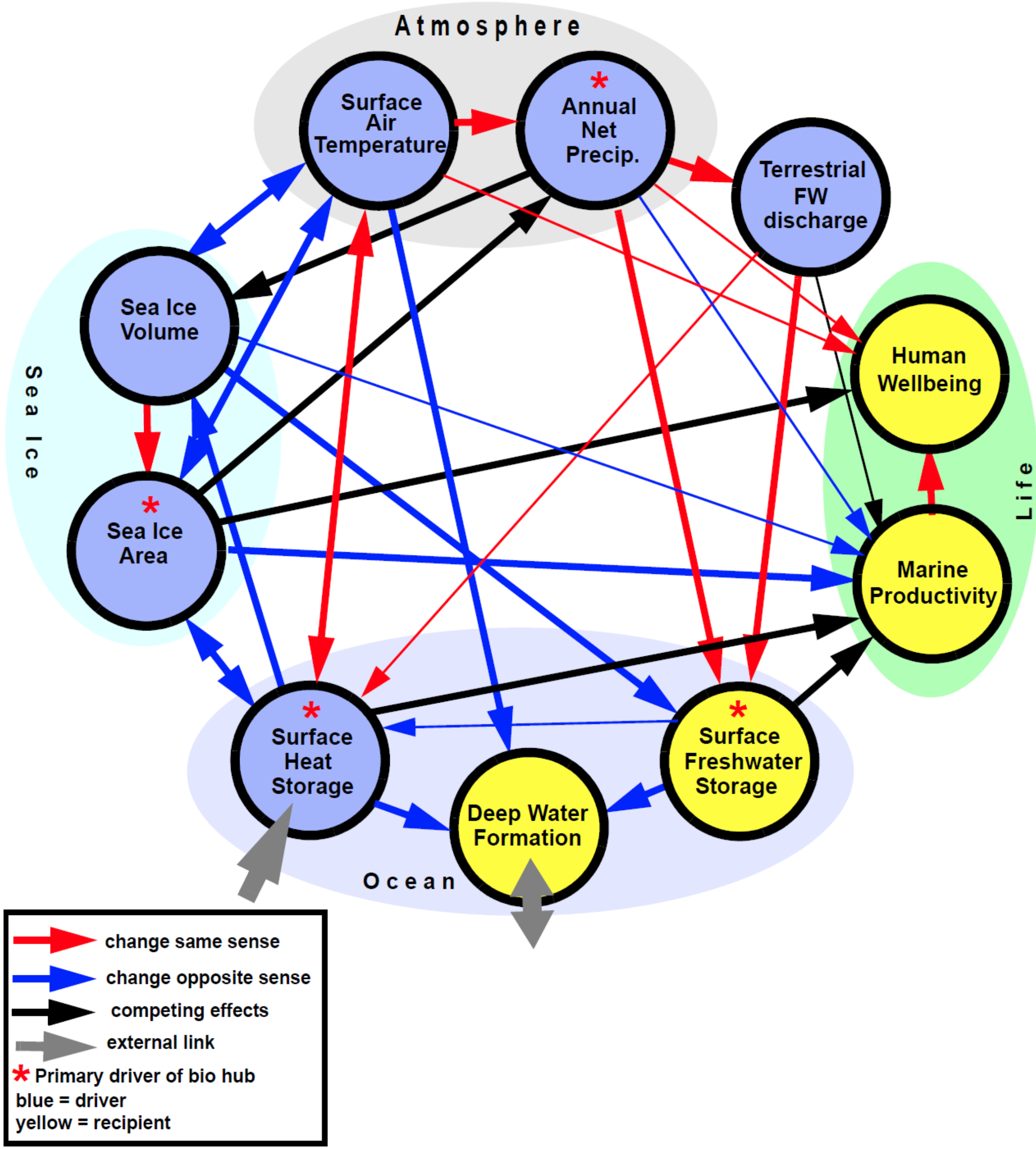


Atmosphere
RF
SF
SAT
LC
Life
HW
SW


Atmosphere
Surface Air Temperature
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Annual Net Precip.
Terrestrial FW discharge
Sea Ice Volume
Sea Ice
*
Sea Ice Area
Human Wellbeing
Marine Productivity
Life
*
Surface Heat Storage
Deep Water Formation
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Surface Freshwater Storage
Ocean
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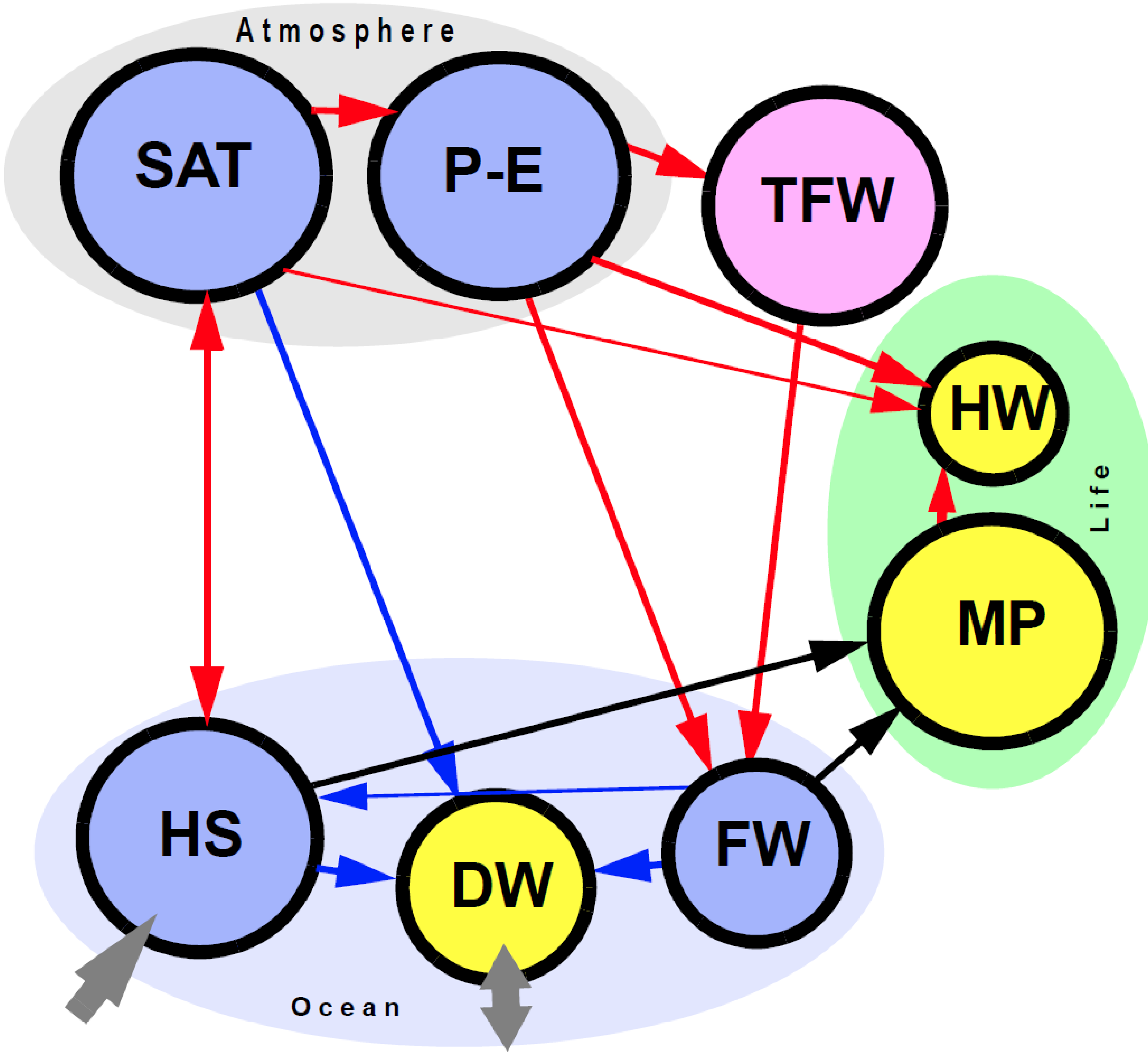
Atmosphere
SAT
P-E
TFW
HW
Life
MP
HS
DW
FW
Ocean

1. In the seasonally ice-free scenario, the diagram for the atmospheric subsystem was much simpler. All the components except human well-being increased. Of the seven feedbacks in the present-day system, only two remained. Prosperity may increase, however, as new economic opportunities emerge in a seasonally ice-free Arctic Ocean. Dependents on sea-ice mammals may suffer.

2. The future oceanic system minus its two sea-ice hubs was greatly simplified. Half of the interactions represented by arrows disappeared, and all five of the feedback loops were gone. All of the hubs except human well-being and deepwater formation increased in a seasonally ice-free scenario.

3. The terrestrial subsystem lost three hubs in the depiction of the future: permafrost, glaciers/ice sheets, and the active layer. All remaining components increased except for human well-being, and the number of interactions among hubs drops from 32 to 14.

As the landscape becomes more midlatitude-like in terms of its hydrologic cycle, the traditional way of life for arctic peoples will likely become more difficult to preserve. Again, however, there may be many more economic opportunities in the warmer Arctic.

Thank you

This work was funded by the National Science Foundation as part of the Freshwater Integration Study.