Initiative Proposal – Advancing Integrated, Cross-cutting Practices for Arctic Flux Observations

Detailed observations of energetic, hydrological and chemical fluxes at the surface-atmosphere interface are necessary to understand and model coupling within the Arctic climate system (Figure 1). Global and regional models may represent Arctic state variables with relative accuracy, but it has been observed that they consistently fail to represent the observed magnitude and direction of energetic fluxes within the Arctic system (Jones, 2014; Aas et al, in press). Some results of this failure are highly uncertain projections about the future state of the Arctic cryosphere and biosphere (McGuire et al., 2013) and high uncertainty about the fate of cryospheric carbon in the global atmosphere (McGuire et al., 2012; Belshe et al., 2013; Hayes et al. 2014; Christensen, 2014).

To address these poorly constrained processes, coupling between the Arctic atmosphere, land surface and subsurface must be evaluated as an integrated system of energy, moisture and chemical exchange – each with unique observational challenges and process complexities in extreme Arctic environments. For example, closing the terms of the surface energy balance (SEB) requires sustained, high quality observations of key physical parameters (radiation, turbulence, and storage), which are hampered by frost accumulation on sensors and instrument detection limits at extreme low temperatures (Figure 2). In-situ observations of moisture, carbon and other trace gas fluxes in the Arctic are equally challenging and must consider cold-shifted calibrations and conditions unique to frozen ground and permafrost soils (e.g. calibration of soil moisture sensors in permafrost soils). Interpreting seasonal and inter-annual variability in all of these terms requires well characterized land surface and subsurface properties and processes, including for example, vegetation description (Figure 3), soil carbon quantity and quality, permafrost depth and temperature, and active layer depth interpretation; these require a geographically extensive pan-Arctic approach to sample the vast diversity of landscapes and regional atmospheric forcing regimes. The ability to up-scale surface-based in situ observations enables data to be comparable with global gridded data products, including from satellites, reanalyses, and climate models. This will foster critically needed mutually beneficial information exchange between disparate scientific communities, and is thus of paramount importance.

A host of initiatives, organizations and disciplines share an interest in these topics (Figure 4), yet no one organization has the expertise or mandate to tackle the integrated, pan-Arctic challenge. In recognition of this, it is proposed to develop an International Arctic Science Committee (IASC) cross-cutting initiative to bring together the expertise and resources of IASC member science communities. A starting point for developing collaborative research objectives and refining community interest would be an open workshop in 2016 in association with the Fairbanks ASSW. A series of formal and informal discussions[1] and previous terrestrial flux workshops[2] have identified the following topics where progress could be made:

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[1] IASOA hosted brownbag at AGU 2013 Fall meeting; 4 IASOA Atmosphere-surface working group meetings (2014-2015) – See Appendix

[2] Two workshops hosted for a group of ~15 national and international participants in Edmonton in 2009 and Woods Hole in 2008, sponsored by the NSF Arctic Observatory Network (AON) project 'Collaborative Research on Carbon, Water, and Energy Balance of the Arctic Landscape at Flagship Observatories in Alaska and Siberia'

1. Frame pan-Arctic synthesis science questions to address as an interdisciplinary community considering in particular what can be done with the existing set of observations.
2. Identify inter-operable data products (and the collaboration infrastructure that will support their development) that could address these questions; focusing across the current pan-Arctic infrastructure of Arctic flux observations; considering Arctic-specific constraints; involving the relevant range of disciplines as well as the modeling and satellite community in data product design. Develop strategies for data product design that promotes data sharing, but also facilitates spatial-temporal scaling. Address how data will be documented and accessed.
3. Develop consistent practices for site (land surface and subsurface) characterization across the current locations where flux measurements are made; consider consistent practices for up-scaling.
4. Identify and champion expansion of observational capacity of terrestrial cryosphere, ecosystems and atmosphere in under-sampled processes and regions.

Appendix

Needs Identified at AGU, 2013

To gather input and identify other experts and coordinating bodies in the Arctic flux measurement community, IASOA called an informal round-table discussion at the Fall 2013 American Geophysical Union (AGU) meeting. More than 40 people attended. Common interests included:

- Need to identify high-latitude/high-elevation best practices and related these back to Ameriflux, NEON, etc. so that they can be sure to take these into account for their sites in high-latitude regions (extreme cold temperature operations not part of Ameriflux, Fluxnet, NEON, ICOS, etc.)
- Need to improve cold-weather instrument performance (note: Campbell Scientific was present and interested in working with community, e.g. test sites)
- Need to improve low temperature gas sampling/analysis (e.g. cold-shifted calibrations)
- Need to improve up-scaling and integration
- Need to improve year-round operations: site communications; system power (specifically at stand-alone sites and considering Arctic-specific demands like de-icing)
- Need to identify sites, parameters, datasets around the Arctic
- Need to identify modeling & remote sensing communities interested in observations
- Need to develop stronger interdisciplinary efforts, in particular, leverage the large stations as sites for multi-disciplinary integration

Needs Identified by IASOA Atmosphere-Surface Exchange Group (http://www.esrl.noaa.gov/psd/iasoa/node/76)

The IASOA working group (on-going since spring of 2014) has refined the above objectives to 3 foci – with an emphasis on working with modelers:

- Comparative analysis of Flux methodologies for Arctic-specific conditions – choose target site for multi-approach analysis and comparison (BRW or TIK both good candidates)
- Review of land surface characterization methodologies across the major observatories; opportunities for addressing scale with e.g. UAV's
- Networking with other disciplines to explore year-round "closure" experiments at the major observatories.

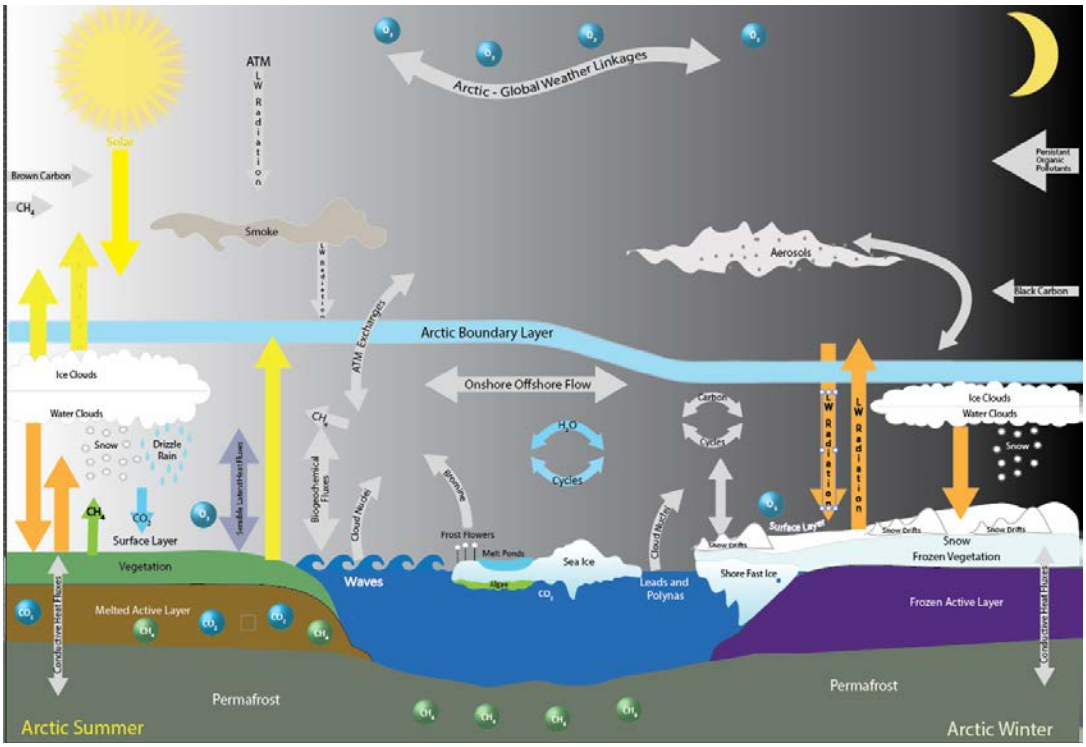

Figure 1. Energetic, hydrological and chemical exchanges within in the Arctic climate system are tightly coupled and must be understood through system-wide observations (courtesy T. Uttal).

Figure 2. Observations of the radiation and turbulent parameters of the surface energy balance at Arctic stations must be carefully evaluated and corrected to account for frost and other environmental impacts.

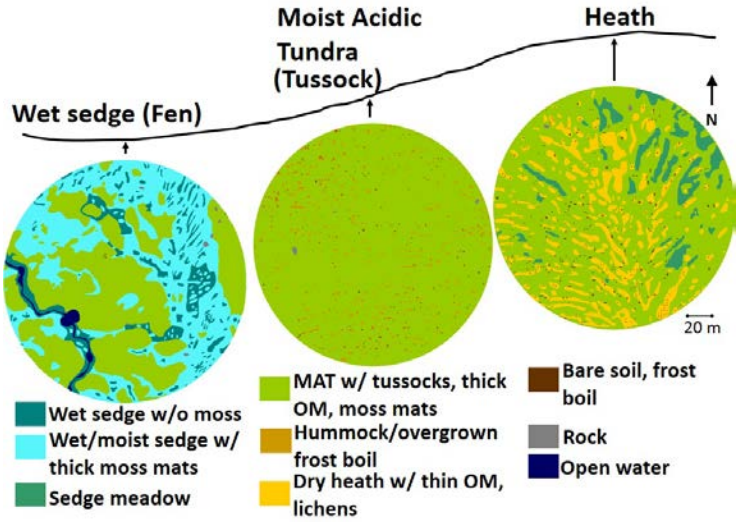

Figure 3. Characterization of the vegetation surrounding three flux towers, wet sedge tundra, moist acidic tussock tundra, and heath tundra, at the Imnavait Watershed in northern Alaska. Description of the highly heterogeneous tundra vegetation is essential to interpreting fluxes. Reproduced from Kade, A., M.S. Bret-Harte, E.S. Euskirchen, C. Edgar, R Fulweber. 2012. Seasonal variations in CO_2 flux among various tundra plant communities in Arctic Alaska. *Journal of Geophysical Research – Biogeosciences,* 117, G04007, doi:10.1029/2012JG002065

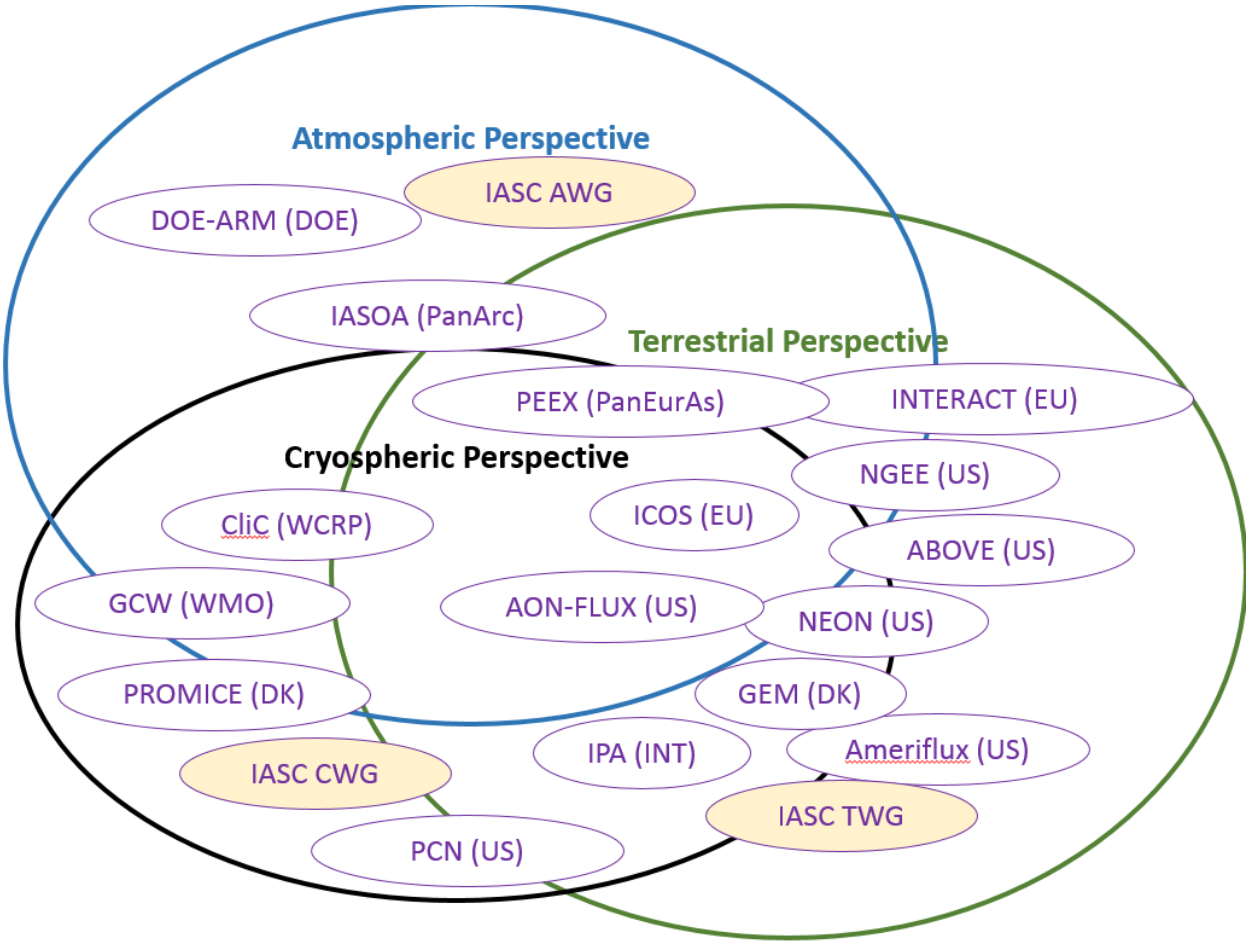

Figure 4. Direct observations of the coupled Atmospheric-Terrestrial-Cryospheric System create overlapping interests among many activities. How can these groups come together to share practices and work towards shared objectives (improved observations, improved understanding) for the coupled Arctic Atmos-Cryo-Terrestrial System?

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