Preview of Award 1263854 - final Project Report

Federal Agency and Organization Element to Which Report is Submitted:
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Federal Grant or Other Identifying Number Assigned by Agency:
1263854
Project Title:
Cumulative Effects of Arctic Oil Development - planning and designing for sustainability
PD/PI Name:

- Donald A Walker, Principal Investigator
- Gary P Kofinas, Co-Principal Investigator
- Yuri L Shur, Co-Principal Investigator

Recipient Organization:
University of Alaska Fairbanks Campus
Project/Grant Period:
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Reporting Period:
09/01/2020 - 08/31/2021
Submitting Official (if other than PD\PI):

- Donald A Walker
- Principal Investigator

Submission Date:
11/20/2021
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)
Donald A Walker

Accomplishments

* What are the major goals of the project?

Cumulative Effects of Arctic Oil Development -- Planning and Designing for Sustainability

Developing Arctic oil & gas resources requires extensive networks of roads, pipelines and other forms of infrastructure. The cumulative environmental and social effects of expanding developments are difficult to assess — especially in the face of rapid climate change and unpredictable politics, oil markets, and social and economic changes. Previous analyses of the cumulative effects (CE) of oil and gas development in northern Alaska have recommended comprehensive adaptive planning approaches to 1) minimize the spread of infrastructure across land that is used by indigenous people for subsistence, and 2) reduce the indirect effects of infrastructure that result in the thawing of ice-rich permafrost. A sustainable approach to CE requires collaboration between indigenous people, industry, and scientists from a broad spectrum of disciplines to address these infrastructure-related concerns. This project had four inter-related goals:

Goals with high intellectural merit:

1. Hierarchical case study of the cumulative effects of industrial infrastructure at Prudhoe Bay, Alaska. This goal focuses on the combined infrastructure-related effects associated with gravel mines, roads and other areas of gravel placement, and climate-related changes to ecosystems. The study is developing a process-based understanding of infrastructure-related permafrost, landform, and vegetation change in terrain undergoing thermokarst formation (the development of highly eroded landforms that result from the thawing of ice-rich permafrost). The project includes an examination of infrastructure and landscape change at multiple scales in the Prudhoe Bay Oilfield (PBO) and field studies of change along roads. The study helped answer the questions “How have these landscapes changed over the history of development?” "What direction will changes take in future years?" and “Can adaptive management methods address the complex issues related to placement, usage and decommissioning of infrastructure in Northern Alaska?”

Goals with mainly broader impacts:

2. Social-ecological implications and adaptive management of climate change and thawing permafrost. As the Arctic’s ecosystems and infrastructure networks change, so do its peoples. Most residents of the Arctic make their homes in small to medium sized communities, often in remote regions where they rely heavily on climate-sensitive livelihoods. This research was undertaken to explore the current and potential influences of thawing permafrost and other climate changes on important aspects of community life in Iñupiaq villages and also how the issue of cumulative impacts are preceived in villages and by the oil industry.

3. An international Arctic Infrastructure action group: Rapid Arctic Transitions due to Infrastructure and Climate (RATIC). The goal of RATIC is to bring cumulative-effects-of-infrastructure issues to greater prominence within the international Arctic research community and encourage research on the joint effects of climate change and expanding infrastructure in the Arctic.

4. Education/outreach component. A new field course is training students in arctic system science and introducing them to the issues of industrial development and adaptive management approaches. The 21-day course includes a 16-day expedition along the Elliott and Dalton highways in Alaska. The course includes a visit to Minto, an Athabascan village on the Tolovana River; Wiseman, an old mining community along the Dalton Highway; and the Prudhoe Bay Oilfield, where they learn firsthand about the issues with oilfield infrastructure, its impacts and the oil industry's ecological monitoring and vegetation rehabilitation practices.

* What was accomplished under these goals and objectives (you must provide information for at least one of the 4 categories below)?

Major Activities:

We requested and received a no-cost extension to complete work on the following aspects of the project:

- Completion of Component I, a hierarchical case study of cumulative effects of industrial infrastructure in the Prudhoe Bay Oilfield.
- Completion of Component II, social-ecological implications and adaptive management of climate change and thawing permafrost
- Conversion of a portion of our data management system from a locally developed system using gLynx to an open-source cataloging system called Comprehensive Kerbal Archive Network (CKAN). T

Major activities during Sep 2020 to Sep 2021 included:

- Continued monitoring of the road effects sites at Prudhoe Bay, AK during 2021 field season.
- Completion, submittal, and revision of two synthesis papers regarding permafrost and vegetation impacts of a road in ice-wedge polygons (Kanevskiy et al. 2021 in review. and Walker et al. 2021 in review)
- Completion of several papers related to the human dimensions aspects of the project.
- Continued development of Infrastructure Action Group as part of theT-MOSAiC initiative.
- Continued progress on Woodward Ph.D. thesis.
- Completion of the conversion of our data management system (Alaska Arctic Geoecological Atlas, AAGA (https://arcticatlas.geobotany.org) from gLynx to CKAN (Comprehensive Kerbal Archive Network).

Specific Objectives:

Component I activities. Hierarchical case study of the cumulative effects of industrial infrastructure at Prudhoe Bay, Alaska.

Ia. Ground-based plot-level studies of infrastructure- and climate-related change to permafrost, landforms, and vegetation. Continued work at two intensive study sites in the heavily-impacted Deadhorse area of the PBO region with the objective of completing two synthesis publications for submittal to the Special Issue of the journal *Arctic Science "*Terrestrial Geosystems, Ecosystems, and Human Systems in the Fast-Changing Arctic (T-MOSAiC)"

Ib. Analysis of the impacts of infrastructure, road dust, and flooding on vegetation using remote sensing. We contributed to an new pan-Arctic infrastructure map made by Prof. Annett Bartsch, University of Vienna and funded by the European Space Agency. Arc-SEES funds were used to partially fund Dr. Helena Bergstedt, a post-doc working with Dr. Ben Jones and Prof. Walker, utilized information from the pan-Arctic infrastructure map with the objective of analyzing of the the spatial and temporal influence of infrastructure on road-dust distribution, seasonal snow melt timing, and their influence on vegetation productivity and early season surface water cover in the Prudhoe Bay Oilfield.

Component II activities. Social-ecological implication and adaptive management of climate change and thawing permafrost

IIa. The study of information gaps and informal institutions in Wainwright, Alaska's adaptation to climate change. ARCSEES partially funded the PhD of Tracie Curry.

IIb.The study of cumulative effects management on the North Slope of Alaska. Research conducted by Kofinas, Johnson, Curry, and Woodward). We evaluated the practice of assessing and managing for cumulative effects (CEs) on the North Slope of Alaska.

***IIc.* Comparative Study of thawing permafrost in two rural arctic communities and its implications to sustainability** (PhD dissertation of Allison Woodward - anticipated date of defense 12/2021).

***IId. The IPCC* Special Report on Oceans and the Cryosphere -** Gary Kofinas served as a lead author in " Polar Systems" (Chapter 3) of the report, and several other chapters (Chapters 1, 4, CB9).

***IIe. Special Issue of the journal* Ecology and Society on Resilience and Change in Arctic Alaska** - ARCSEES support of Kofinas contributed to his work as special issue editor of Resilience and Change in E&S.

IIf. International Arctic infrastructure action group: Rapid Arctic Transitions due to Infrastructure and Climate (RATIC). The initial goal of RATIC was to bring cumulative-effects-of-infrastructure issues to greater prominence within the international

Arctic research community and encourage research on the joint effects of climatechange and expanding infrastructure in the Arctic. During the last funding cycle several online RATIC meetings occurred.

Data management activities:

Conversion of our data management system from gLynx to CKAN. A major objectiv eo the NCE was to complete conversion of our plot and mapping database in the Alaska Arctic Geoecological Atlas from gLynx to CKAN.

Significant Results:

Key publications and conclusions for components with high intellectual merit:

Component I. Ground-based plot-level studies of infrastructure- and climate related change.

Key publications:

Kanevskiy, M. et al., 2021 (accepted for publication). Vulnerability of Ice Wedges and Reversible Nature of Ice-Wedge Thermokarst in Areas Affected by Road Infrastructure, Prudhoe Bay Oilfield, Alaska. *Arctic Science.*

Walker, D.A. et al., 2021 (in review). Long-term vegetation and environmental effects of and road in an ice-wedge polygon landscape, Prudhoe Bay Oilfield, Alaska. Arctic Science.

Key conclusions:

1. Vulnerability of ice wedges strongly depends on the structure and thickness of soil layers above ice wedges, including the active, transient, and intermediate layers. In comparison with the undisturbed area, sites adjacent to the roads had smaller average thicknesses of the protective intermediate layer (4 cm vs 9 cm), and this layer was absent above almost 60% of ice wedges (vs ~45% in undisturbed areas). Despite the strong influence of infrastructure, ice-wedge degradation is a reversible process. Deepening of troughs during ice-wedge degradation leads to a substantial increase in mean annual ground temperatures but not in thaw depths. Thus, stabilization of ice wedges in the areas of cold continuous permafrost can occur despite accumulation of snow and water in the troughs. Although thermokarst is usually more severe in flooded areas, higher plant productivity, more litter, and mineral material (including road dust) accumulating in the troughs contribute to formation of the intermediate layer, which protects ice wedges from further melting.
2. Environmental impact assessments for new Arctic infrastructure do not adequately consider the likely long-term cumulative effects of climate change and infrastructure in areas with ice-rich permafrost. This is due in part to the lack of

long-term environmental studies that monitor changes after infrastructure was built. This case study in the Prudhoe Bay Oilfield examined climate- and road-related changes in a network of low-centered ice-wedge polygons from 1949 to 2020. We studied four trajectories of change related to thermokarst, road dust, and flooding along a heavily traveled road and a site relatively remote from roads. Climate-related impacts influenced the number and size of thermokarst ponds and resulted in changes to ice-wedge-polygon morphology, thaw depths, snow depths, dominant vegetation types, and shrub abundance. Road dust caused large reductions in species richness particularly small forbs, mosses, and lichens. Flooding increased permafrost degradation, polygon center-trough elevation contrasts, and vegetation productivity. While it was not possible to isolate the influence of any one factor, the combined datasets provide unique insights into the rate and extent of ecological disturbances associated with infrastructure-affected landscapes under decades of climate warming. We conclude with recommendations for future cumulative impact assessments in areas with ice-rich permafrost.

Component II. Social-ecological implication and adaptive management of climate change and thawing permafrost

1. **The study of information gaps and informal institutions in Wainwright, Alaska's adaptation to climate change.** Environmental governance in the context of climate change adaptation brings together diverse actors and stakeholders to develop and enact policies across a broad range of scales. However, local needs and priorities are often mismatched with those pursued by entities at different levels of decision-making. This mismatch is perpetuated in part by the dominating influence of the Western worldview in knowledge processes involving the creation, sharing, and use of environmental knowledge. Persistent biases that favor Western science and technical information while marginalizing other important sources like local and Indigenous knowledge create blind spots that may adversely affect adaptation outcomes. In this research, a case study of the Native Village of Wainwright, Alaska is used to explore the topic of information blind spots in environmental governance resulting from 1) low resolution tools employed within broad scale adaptation initiatives; 2) preferences for easily quantifiable information; and 3) the challenge of communicating context-rich details to outside decision makers given disciplinary biases and organizational conventions. The research resulted in a Tracie Curry's PhD dissertation that comprises manuscripts based on three studies undertaken to address the above blind spots in specific areas of adaptation planning.

   Key publication: Tracie Curry, Chanda Meek & Matthew Berman (2021) Informal institutions and adaptation: patterns and pathways of influence in a remote Arctic community, *Local Environment*, 26:9, 1070-1091, DOI: 10.1080/13549839.2021.1962828

2. **The study of cumulative effects management on the North Slope of Alaska** We evaluated the practice of assessing and managing for cumulative

effects (CEs) on the North Slope of Alaska. In this research we conducted 50 interviews about CEs with employees of industry, state and federal agencies, non-profits and Indigenous organizations who are involved in oil and gas activities on the North Slope. From the interviews we uncovered a state of deep confusion regarding definitions for and management of cumulative effects. Participants in interviews reported different definitions of cumulative effects and cited the absence of a unified evaluated framework, weak collaboration, and problems with sharing of information, which are creating significant challenges evaluating CEs on a project by project basis. They noted that without a coordinated effort to share identified reasonably foreseeable effects, each evaluation of cumulative effects essentially starts from scratch. None of the participants indicated the need to consider the impact of proposed projects on climate change in their assessment of cumulative effects. These findings are in line with previous studies on the challenges of implementing CE assessments and management programs, and underscore the need for a unified and systematic approach for evaluating and mitigating CEs.

Key publication: The findings of this research will be submitted for publication in a special issue on Resilience and Change in Arctic Alaska in the journal *Ecology and Society*.

3. **Comparative Study of thawing permafrost in two rural arctic communities and its implications to sustainability.** Climate change is currently resulting in the thawing of permafrost across the North, with implications to the well-being of arctic Indigenous communities. We examined the impacts and community responses to thawing permafrost (TPF) in two arctic villages of Alaska and the utility of incremental adaptation and transformation in different local conditions. Based on research conducted in *Anaktuvuk* and Seliwick Alaska, we evaluated how thawing permafrost is affecting critical dimensions of community well-being, including residents' livelihoods, cultural traditions, health and overall sustainability. Of particular interest are village infrastructure, subsistence harvesting, transportation, and water supplies. Sources of evidence included thaw depth transects, interviews with local residents, and available reports and other literature. The study illustrates the heterogeneity of climate change impacts in arctic communities and the need to undertake place-based assessments with strong community involvement to determine how best to respond to TPF.   A framework for assessing the implications of TPF on local arctic communities is proposed for use by decision makers to consider pathways for building community resilience.

   Key publication: PhD dissertation of Allison Woodward - anticipated date of defense 12/2021.

Key outcomes or Other achievements:

Other achievements:

1. ***Quantifying the spatial and temporal influence of infrastructure on seasonal snowpack, snow-melt timing and vegetation productivity.***

   Key publications:

   Bartsch A, Pointner G, Ingeman-Nielsen T, Lu W. Towards Circumpolar Mapping of Arctic Settlements and Infrastructure Based on Sentinel-1 and Sentinel-2. Remote Sensing. Multidisciplinary Digital Publishing Institute; 2020;12(15):2368.

   Bergstedt H, Jones B, Walker D, Pierce J, Bartsch A, Pointner G. Quantifying the spatial and temporal influence of infrastructure on seasonal snow melt timing and its influence on vegetation productivity and early season surface water cover in the Prudhoe Bay Oilfields. 2021. Paper presented at the EGU General Assmbly 2021. pp. EGU21–10296. https://doi.org/10.5194/egusphere-egu21-10296.

   Key conclusions:

   Infrastructure expands rapidly in the Arctic due to industrial development. At the sametime, climate change impacts are pronounced in the Arctic. Ground temperatures are, for example, increasing as well as coastal erosion. A consistent account of the current human footprint is needed in order to evaluate the impact on the environments as well as risk for infrastructure. Identification of roads and settlements with satellite data is challenging due to the size of single features and low density of clusters. Spatial resolution and spectral characteristics of satellite data are the main issuesm regarding their separation. The Copernicus Sentinel-1 and -2 missions recently provided good spatial coverage and at the same time comparably high pixel spacing starting with 10 m for modes available across the entire Arctic. The purpose of this study was to assess the capabilities of both, Sentinel-1 C-band Synthetic Aperture Radar (SAR) and the Sentinel-2 multispectral information for Arctic focused mapping. Settings differ across the Arctic (historic settlements versus industrial, locations on bedrock versus tundra landscapes) and reference data are scarce and inconsistent. The type of features and data scarcity demand specific classification approaches. The machine learning approaches Gradient Boosting Machines (GBM) and deep learning (DL)-based semantic segmentation have been tested. Records for the Alaskan North Slope,Western Greenland, and Svalbard in addition to high-resolution satellite data have been used for validation and calibration. Deep learning is superior to GBM with respect to users accuracy. GBM therefore requires comprehensive postprocessing. SAR provides added value in case of GBM. VV is of benefit for road identification and HH fordetection of buildings. Unfortunately, the Sentinel-1 acquisition strategy is varying across the Arctic. The majority is covered in VV+VH only. DL is of benefit for road and building detection but misses large proportions of other human-impacted areas, such as gravel pads which are typical for gas and oil fields. A combination of results from both GBM (Sentinel-1 and -2 combined) and DL (Sentinel-2; Sentinel-1 optional) is therefore suggested for circumpolar mapping.

2. **The IPCC *Special Report on Oceans and the Cryosphere* -** Dr. Kofinas' contribution in Chapter 3 was focused on human responses to climate change in various sectors of polar systems, and included an evaluation of options for resilience pathways in the face of climate change (pages 3-77 to 3-99). Tables 3.4 and 3.5 summarized findings of the chapter's section on Human Responses to Climate Change)

3. **Special Issue of the journal *Ecology and Society* on Resilience and Change in Arctic Alaska.** ARCSEES support of Kofinas also contributed to his work as special issue editor of Resilience and Change in E&S.

4. ***International Arctic infrastructure action group: Rapid Arctic Transitions due to Infrastructure and Climate (RATIC).*** In 2020, RATIC assumed the role of the T-MOSAiC Infrastructure Action Group during the 2019–2021 MOSAiC Arctic Drift Expedition. Dr. Walker and Peter Schweitzer (U. of Vienna) are co-chairs of the AG, and Jana Peirce is the Coordinator. The action group is collaborating with T-MOSAiC to identify and promote activities and synergies that lead toward sustainable Arctic infrastructure, including those that: Monitor the consequences to natural terrestrial systems of unusual climate sea-ice, atmosphere, and ocean changes during the MOSAiC ice-drift expedition. Observe and monitor consequences to the built environment, including, roads, runways, railways, pipelines, and indigenous, village, and urban infrastructure. Examine the consequences of climate and infrastructure changes to Arctic social systems. Begin developing an Arctic infrastructure observing network, with a focus on coastal and near-coastal social-ecological systems in ice-rich-permafrost environments. RATIC was born with the goal of promoting sustainable Arctic infrastructure as a key research theme requiring a collaborative multidisciplinary approach involving scientists, local communities, governments and industry.

* What opportunities for training and professional development has the project provided?

Education/ outreach

1. Funds from the project were used to partially fund completion of Alison Woodward's Ph.D. work.

2. Funds were also used to partially fund publication of Tracie Curry's Ph.D.

3. Plans were made for conducting the summer field course *Arctic Alaska Vegetation, Permafrost, & Ecosystems*. This field course was conducted in 2014, 2015, 2016, and 2018. It was cancelled in 2020 and 2021 due to the COVID situation in Alaska, which prevented foreign students entering Alaska and greatly reduced travel on the Dalton Highway.

* Have the results been disseminated to communities of interest? If so, please provide details.

See the previous section, Item 4, International Arctic Infrastructure action group.

Products

Books

Book Chapters

- Gary Kofinas, Shauna BurnSilver and Andrey N. Petrov (2020). Methodological Challenges and Innovations in Arctic Community Sustainability Research. *Arctic Sustainability, Key Methodologies and Knowledge Domains* Jessica K. Graybill, Andrey N. Petrov. Routledge Taylor & Francis Group. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; ISBN: ISBN 9780367228194.
- Meredith, M., M. Sommerkorn, S. Cassotta, C. Derksen, A. Ekaykin, A. Hollowed, G. Kofinas, A. Mackintosh, J. Melbourne-Thomas, M.M.C. Muelbert, G. Ottersen, H. Pritchard, and E.A.G. Schuur (2019). Polar Regions. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer. Intergovernmental Panel on Climate Change. . Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes

Inventions

Journals or Juried Conference Papers

- Bergstedt H, Jones B, Walker D, Pierce J, Bartsch A, Pointner G. (2021). Quantifying the spatial and temporal influence of infrastructure on seasonal snow melt timing and its influence on vegetation productivity and early season surface water cover in the Prudhoe Bay oilfields. *EGU21*. 10296. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi.org/10.5194/egusphere-egu21-10296
- Berman, M. D., J. I. Schmidt, and G. Kofinas (2021). Comparing adaptive capacity of Arctic communities responding to environmental change. *Ecology and Society*. 26 (3), 22. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: /doi.org/10.5751/ES-12304-260322
- Bhatt, U. S., D. A. Walker, M. K. Raynolds, J. E. Walsh, P. A. Bieniek, L. Cai, J. C. Comiso E. Epstein, G. V. Frost, R. Gersten, A. S. Hendricks, J. E. Pinzon, L. Stock, and C. J. Tucker (2021). Climate drivers of Arctic tundra variability and change using an indicators framework. *Environmental Research Letters*. 16 (5), 055019. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi.org/10.1088/1748-9326/abe676
- Blair, B and G Kofinas (2020). Cross-scale risk perception: differences between tribal leaders and resource managers in Arctic Alaska. *Ecology and Society*. 25 (3), 9. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: /doi.org/10.5751/ES-11776-250409

- Epstein, H.E., D.A. Walker, G.V. Frost, M.K. Raynolds, U.S. Bhatt, R. Daanen, B. Forbes, J. Geml, E. Kaärlejarvi, O. Khitun, A. Khomutov, P. Kuss, M. Leibman, G. Matyshak, N. Moskalenko, P. Orekhov, V.E. Romanovsky, I. Timling (2021). Spatial patterns of arctic tundra vegetation properties on different soils along the Eurasia Arctic Transect, and insights for a changing Arctic. *Environmental Research Letters*. 16 01400. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi.org/10.1088/1748-9326/abe676
- Kanevskiy, M., Y. Shur, D. A. Walker, M. T. Jorgenson, B. M. Jones, M. Buchhorn, G. Matyshak, H. Bergstedt, A. L. Breen, B. Connor, R. Daanen, A. K. Liljedahl, V. E. Romanovsky, and E. Watson-Cook (2021). Vulnerability of ice wedges and reversible nature of ice-wedge thermokarst in areas affected by road infrastructure, Prudhoe Bay Oilfield, Alaska. *Arctic Science*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Povoroznyuk, O., Vincent, W.F., Schweitzer, P., Laptander, R., Bennett, M., Calmels, F., Sergeev, D. Arp, C., Forbes, B., Roy-Léveillée, P., and Walker, D.A. (2021). Roads and Railways: Environmental and Social Consequences of Transport Infrastructure in the Circumpolar North. *Arctic Science*. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Schneider von Deimling, H. Lee, H, T. Ingeman-Nielsen, S. Westermann, V. Romanovsky, S. Lamoureaux, D.A. Walker, S. Chadburn, L. Cai, E. Trochim, J. Nitzbon, S Jacobi, M. Langer. (2020). Consequences of permafrost degradation for Arctic infrastructure - bridging the model gap between regional and engineering scales. *The Cryosphere*. 15 (5), 2451. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi.org/10.5194/tc-15-2451-2021
- Walker, D. A., M. K. Raynolds, M. Z. Kanevskiy, Y. Shur, V. E. Romanovsky, B. M. Jones, M. Buchhorn, M. T. Jorgenson, J. Šibík, A. L. Breen, A. Kade, E. Watson-Cook, H. Bergstedt, A. K. Liljedahl, R. Daanen, B. Connor, D. J. Nicolsky, and J. L. Peirce (2021). Cumulative impacts of a gravel road and climate change in an ice-wedge polygon landscape, Prudhoe Bay, Alaska. *Arctic Science*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Licenses

Other Conference Presentations / Papers

Other Products

- *NOAA Website.*

  Frost, G. V., U. S. Bhatt, H. E. Epstein, I. Myers-Smith, G. K. Phoenix, L. T. Berner, J. W. Bjerke, B. C. Forbes, M. J. Macander, S. J. Goetz, J. T. Kerby, T. Park, M. K. Raynolds, H. Tommervik, and **D. A. Walker.** (2020). Tundra greenness. *Arctic Report Card* 2020, J. Richter-Menge, M. L. Druckenmiller, and M. Jeffries (Eds.). DOI: 10.25923/46m-0w23.

  NOAA Arctic Report Card Website

Other Publications

Patent Applications

Technologies or Techniques

Thesis/Dissertations

Websites or Other Internet Sites

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Walker, Donald	PD/PI	0
Kofinas, Gary	Co PD/PI	1
Shur, Yuri	Co PD/PI	0
Raynolds, Martha	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Peirce, Jana	Other Professional	0
Woodward, Allison	Graduate Student (research assistant)	6

Full details of individuals who have worked on the project:

Donald A Walker
Email: dawalker@alaska.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 0

Contribution to the Project: PI

Funding Support: NSF NNA AWARD 1263854

Change in active other support: No

International Collaboration: No
International Travel: No

Gary P Kofinas
Email: gary.kofinas@alaska.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Co-PI

Funding Support: This award

Change in active other support: No

International Collaboration: No
International Travel: No

Yuri L Shur
Email: yshur@alaska.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 0

Contribution to the Project: co-PI

Funding Support: this award

Change in active other support: No

International Collaboration: No
International Travel: No

Martha K Raynolds
Email: mkraynolds@alaska.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 0

Contribution to the Project: Field research, mapping, wrote 2 publications

Funding Support: This project

International Collaboration: No
International Travel: No

Jana L. Peirce
Email: jlpeirce@alaska.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 0

Contribution to the Project: Coordination of project. Writing and editing reports, field work, data analysis

Funding Support: this grant

International Collaboration: No
International Travel: No

Allison Woodward
Email: allison.woodward@alaska.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 6

Contribution to the Project: Ph.D. thesis on effects of climate and permafrost change to local communities

Funding Support: Partial support from this project and EPSCoR grant

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Earth Cryosphere Institute	Other Organizations (foreign or domestic)	Tyumen, Russia
University of Eastern Finland	Academic Institution	Finland

Full details of organizations that have been involved as partners:

Earth Cryosphere Institute

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Tyumen, Russia

Partner's Contribution to the Project:
Financial support
In-Kind Support
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Helping with RATIC workshop and Russian case study

University of Eastern Finland

Organization Type: Academic Institution
Organization Location: Finland

Partner's Contribution to the Project:
Financial support
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Helping with the RATIC workshop and Russian case study

Were other collaborators or contacts involved? If so, please provide details.

Nothing to report

Impacts

What is the impact on the development of the principal discipline(s) of the project?

The ArcSEES initiative has had a major impact to the amount of funding and emphasis regarding infrastructure in the Arctic. This project has had especially large effect, both through the scientific quantitative analysis of cumulative effects of infrastructure and climate change and at the international level through RATIC Action Group.

Prior to the ArcSEES project, there was virtually no emphasis on Arctic Infrastructure within NSF. ArcSEES and this project served as a model for the NSF Navigating the New Arctic (NNA) initiative. A similar pattern occurred at the international level where the RATIC initiative became the core of IASC T-MOSAiC Infrastructure Action Group, which is observing and monitoring consequences to the built environment to Arctic social ecological systems and developing an Arctic infrastructure observing network for the pan-Arctic region.

What is the impact on other disciplines?

1. The impact to society as a whole is perhaps best illustrated by Dr. Kofinas' contribution in Chapter 3 of the IPCC Special Report on Oceans and the Cryosphere focused on human responses to climate change in various sectors of polar systems, and is an important summary of the options for resilience pathways in the face of climate change.

2. The cross disciplinary activities are best illustrated by the Rapid Arctic Transitions due to Infrastructure and Climate (RATIC) project, which involved numerous investigators from IASC Terrestrial, Social and Human, Cryosphere Working groups and includes permafrost scientists, climatologists, hydrologists, vegetation and soil scientists, ecologists, remote sensing scientists, and social scientists. This group wrote a white paper (Walker, D.A., & J.L. Peirce (eds.) 2015. Rapid Arctic Transitions due to Infrastructure and Climate (RATIC): A contribution to ICARP III. Alaska Geobotany Center Publication AGC15-02. University of Alaska Fairbanks, Fairbanks, Alaska, 58 pp.) that served as a template for the project during the past six years. Monthly Zoom seminars for this group continue to be well attended by participants from all these disciplines from around the Arctic.

What is the impact on the development of human resources?

There has been a major shift during the period of the grant from in the Arctic community exmining cumulative impacts of infrastructure from projects mainly focused on the environment and climate change to project focused more on communities and adaptation to change. This shift has occurred at the project, NNA level, and at the international level.

What was the impact on teaching and educational experiences?

The field course developed for this project is still unique in its emphasis on cumulative impacts of infrastructure and climate change. The course did not draw heavily on Alaska students because of conflicts with summer jobs and cost of the course, but it draw well for mature students and international students who saw this as a unique opportunity to receive training across a wide range of Arctic disciplines, and wide swath of Arctic environments.

What is the impact on physical resources that form infrastructure?

Nothing to report.

What is the impact on institutional resources that form infrastructure?

Nothing to report.

What is the impact on information resources that form infrastructure?

Our Circumpolar Arctic Vegetation Map (CAVM), and Arctic Vegetation Archive (AVA), Arctic Vegetation Classification (AVC) has made a very large impact on accessibility and application of vegation data to a wide variety of analyses at the pan-Arctic scale.

What is the impact on technology transfer?

Nothing to report.

What is the impact on society beyond science and technology?

The human-dimension publications from this project are having an impact on policy and decisions of agencies addressing the cumulative impacts in the Arctic. For example, according the National Resources Defense Council, our paper regarding the likely cumulative landscape impacts of 3D-seismic impacts in the Arctic National Wildlife Refuge (Raynolds et al. 2019) played a major role in DOI's decision to suspend all activities related to oil and gas leasing in the ANWR pending a more thorough cumulative impacts assessment (DOI 2021).

What percentage of the award's budget was spent in a foreign country?

No funds were spent in foreign countries.

Changes/Problems

Changes in approach and reason for change

The project has continued to have difficult personnel issues related to completion of some aspects of the human dimensions aspect of the project. Alison Woodward continues to have severe depression related to the death of her husband, and was unable to complete her thesis within the timeline of the project. However, she is very close and Gary Kofinas is helping her get across the finish line and anticipates completion in Spring Semester 2022.

We also had further problems completing the transfer of our datamanagement system to a CKAN cataloging system, because the Geographic Information Network of Alaska (GINA, UAF), which houses our Alaska Arctic Geoecological Atlas, experienced further staff reductions and we lost our primary data manager, Lisa Druckenmiller. However, we were finally able to achieve transfer of all the files and stablilize our data management by expanding the duties of our lab coordinator, Jana Pierce, to include data management. Jana has excellent skills and deep experience and had already been largely responsible for our data reports and archiving data with Arctic Data Center. This will help Jana by increasing her salary and time commitment to the AGC and will make the data catalog and user interface more stable, and accessible through our web site, and more portable for long-term security of the data.

Actual or Anticipated problems or delays and actions or plans to resolve them

We completed all of the analysis associated with the project despite difficult work schedules, project communication, and administration of the grant during the COVID-19 and Delta variant crises. The latter was very severe in Alaska during 2021. It and the general budget crisis at UAF caused greatly reduced UAF administrative staff, general unavailability of many people in our lab. It occurred during summer and fall 2021 and greatly affected our summer field operations. However, we did have a successful field season and in the end accomplished all of our objectives. However, the crises did delay completion of several publications. The two major synthesis publications (Walker et al. 2021, and Kanevskiy et al. 2021) are still in revision. The PI (Walker) contracted COVID-19 in March 2020, and still suffers long-term COVID systems and continues to work at a reduced pace. The good news is that both publications are near to final acceptance.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.

Change in primary performance site location

I have returned to working full days at my office at UAF.

Our project and lab coordinator, Jana Peirce, continues to work primarily from home and comes in for part days 2-3 days per week.

Special Requirements

Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.