Final Report for Period: 09/2011 - 08/2012
Submitted on: 09/25/2012
Principal Investigator: Bhatt, Uma S.
Award ID: 0902175
Organization: U of Alaska Fairbanks
Submitted By:
Bhatt, Uma - Principal Investigator
Title:
Collaborative Research: Seasonality of circumpolar tundra - ocean and atmosphere controls and effects on energy and carbon budgets

Project Participants

Senior Personnel

Name: Bhatt, Uma
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Walker, Donald
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Name: Raynolds, Martha
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Raynolds is a plant ecologist who provided her expertise in the analysis and interpretation of NDVI and temperature data. She has had experience with remote sensing data and understands issues that arise in the Arctic in remotely sensed data.

Graduate Student

Name: Bieniek, Peter
Worked for more than 160 Hours: No
Contribution to Project:
Mr. Bieniek began work on this project on Aug 1, 2010 and we expect he will defend his PhD in Spring 2012.

Name: Tran, Huy
Worked for more than 160 Hours: No
Contribution to Project:
Mr. Tran is a Ph.D. student in our department whose research employs the WRF model. During the summer of 2012 he was partially supported on this project to conduct WRF simulations to test hypotheses developed from an analysis of observational data by Ph.D. student Bieniek and the project team.

Undergraduate Student

Technician, Programmer

Name: Barbour, Edith
Worked for more than 160 Hours: Yes
Contribution to Project:
Edith Barbour contributed to various project support activities (poster preparation and printing, figure preparation) and is responsible for the final data archiving with ACADIS.

Other Participant

Research Experience for Undergraduates

Organizational Partners

UNIVERSITY OF VIRGINIA
H.E. Epstein, Dept. Env. Sci, UVA is the primary PI of this project through this collaborative proposal.

University of Washington
M. Steele of APL works with us on this collaborative proposal.

NASA/GODDARD SPACE FLIGHT CENTER
J. Comiso, J. Pinzon, and C.J. Tucker have actively worked with us in this project. Drs. Pinzon and Tucker continue to improve the AVHRR NDVI data set for Arctic regions. Dr. Comiso provides expertise on the AVHRR sea ice concentration and surface temperature data sets. These are the longest available data sets and their length make a climate study possible.

University of Texas at El Paso
C. Tweedie has provided ground truth data in the High Canadian Arctic and provides expertise on Arctic plant ecology.

Michigan State University
Dr. Pat Webber has provided ground truth for vegetation changes in the High Canadian Arctic and provides arctic plant expertise.

Chinese Academy of Sciences
Dr. G. Jia provides expertise in the interpretation of NDVI analysis.

NOAA National Weather Service Operation Support Facility
Mr. R. Thoman of Fairbanks office of the National Weather Service, provided weather expertise for Ph.D. student Bieniek's component of our study. Mr. Thoman is an expert on Alaska climate and is a weather forecaster for the NWS in Fairbanks. He contributed substantially to the study and is a co-author on Bieniek's publication.

Centre National de la Recherche Scientifique Francaise
Walker and Bhatt co-authored and contributed to a publication on vegetation changes in Greenland by Dr. Valerie Masson-Delmotte of CNRS.

Alfred Wegner Institute
Mr. Marcel Buchhorn, Alfred Wegner Institute in Potsdam, Germany visited with Dr. Walker during summer 2012. Mr. Buchhorn and his supervisor Dr. B. Heim are experts on remote sensing and vegetation in the Arctic. Meetings and discussions with their team have been ongoing for some time.

University of Wisconsin-Madison
Dr. Yinghui Liu of SSEC at UW-Madison has been working with us regarding remote sensing cloud observations in the Arctic, which likely explain some of the recent temperature trends.

Other Collaborators or Contacts

Dr. R. Gens (Alaska SAR Facility, University of Alaska) has provided remote sensing data expertise.
Drs. D. Robinson (Rutgers University), A. Frei (Hunter College, NY) and C. Derksen (Climate Research Division, Environment Canada) have provided snow data expertise for our project.

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:

This project is training a Ph.D. level graduate student and a postdoc on climate variability research and in particular is building their skills to better conduct interdisciplinary Arctic climate research. They have gained experience by interacting with faculty and researchers from the areas of plant biology, climate variability, oceanography, and remote sensing.

Outreach Activities:

The following activities have taken place during the time of this grant.

1)UAF Summer Sessions evening Monday Marvels public lecture by Bhatt on 2 August 2010 titled ?Climate Variability and Change In Alaska?, included results from this project about vegetation, sea ice and temperature changes over Alaskan tundra.

2) Bhatt presented an invited talk titled ?Seasonality shifts in circumpolar Arctic tundra vegetation, land temperatures, and coastal sea ice? on October 1, 2010 at the annual meeting of the Society for Advancement of Chicanos and Native Americans in Science in the Shifting Polar Environments Create Uncertain Futures session.

3) UAF Museum visualization of Arctic greening is serving to communicate our results to the general public. In addition to graphics, the PIs of the visualization project have developed text in consultation with us to go with the movie. They have added a video of scientists discussing their research that is being displayed with the graphics. This multi-media presentation is currently being displayed at the University of Alaska Museum.

4) We have incorporated findings from this work into Osher Lifelong Learning (http://www.uaf.edu/olli/) courses taught by Bhatt and Raynolds at the University of Alaska Fairbanks.

Journal Publications

U.S. Bhatt, D.A. Walker, M.K. Raynolds, J.C. Comiso, H.E. Epstein, G.Jia, R. Gens, J.E. Pinzon, C.J. Tucker, C.E. Tweedie, and P.J. Webber, "Circumpolar Arctic tundra vegetation change is linked to sea-ice decline, Earth Interactions", Earth Interactions, p. , vol. , (2010). Published, doi: 10.1175/2010EI315.1

Raynolds, M.K., F. Huettmann, D.A. Walker, and D. Verbyla, "Modeling environmental controls on Arctic NDVI and effects of predicted changes in climate", Remote Sensing of Environment, p. , vol. , (2011). Submitted,

Walker, D.A, U.S. Bhatt, M.K. Raynolds, J.E. Comiso, H.E. Epstein and G.J. Jia, "Land: Vegetation, in State of the Climate in 2009", Bulletin of the American Meteorological Society, p. , vol. , (2010). Published,

Pinzon, J.E., M.K. Raynolds, E.W. Pak, U.S. Bhatt, D.A. Walker, and C.J. Tucker, "NDVI3g: a consistent long term vegetation index data set optimized for polar trend analysis", Remote Sensing Open Access Journa, p. , vol. , (2012). in preparation,

Walker, D.A.; Bhatt, U.S.; Callaghan, T.V.; J.C. Comiso; H.E. Epstein; B.C. Forbes; M. Gill; W.A. Gould; G.H.R. Henry; G.J. Jia; S.V. Kokelj; T.C. Lantz; S.F Oberbauer; J.E. Pinzon; M.K. Raynolds; G.R. Shaver; C.J. Tucker; C.E. Tweedie, "The Arctic: Land: Vegetation", Bulletin of the American Meteorological Society, p. , vol. , (2011). Accepted,

Raynolds M. K., Walker D. A., Epstein H. E., Pinzon J. E. and Tucker C. J., "A new estimate of tundra-biome phytomass from trans-Arctic field data and AVHRR NDVI", Remote Sensing Letters, p. , vol. 3, (2012). Published, doi:10.1080/01431161.2011.609188

Epstein, H.E., Raynolds, M.K., Walker, D.A., Bhatt, U.S., Tucker, C.J., Pinzon, J.E., "Dynamics of aboveground phytomass of the circumpolar arctic tundra during the past three deca", Environmental Research Letters, p. , vol. 7:12, (2012). Published,

Walker, D.A., Epstein, H.E., Raynolds, M.K., Kuss, P., Kopecky, M.A., Frost, G.V., Dani??ls, F.J.A., Leibman, M.O., Moskalenko, N.G., Matyshak, G.V., Khitun, O.V., Khomutov, A.V., Forbes, B.C., Bhatt, U.S., Kade, A.N., Vonlanthen, C.M., Tichy, L., "Environment, vegetation and greenness (NDVI) along the North America and Eurasia Arctic transects", Environmental Research Letters, p. , vol. 7:1, (2012). Published,

Yu, Q., Epstein, H.E., Walker, D.A., Frost, G.V., Forbes, "Modeling dynamics of tundra plant communities on the Yamal Peninsula, Russia, in response to climate change and grazing pressure", Environmental Research Letters, p. , vol. 6:(4), (2011). Published,

Walker, D.A., Kuss, H.P., Epstein, H.E., Kade, A.N., Vonlanthen, C., Raynolds, M.K., Dani??ls, F.J.A, "Vegetation of zonal patterned-ground ecosystems along the North American Arctic Transect", Applied Vegetation Science, p. 440, vol. 14, (2011). Published,

Masson-Delmotte, V., Swingedouw, D., Landais, A., Seidenkrantz, M.-S., Gauthier, E., Bichet, V., Massa, C., Perren, B., Jomelli, V., Adalgeirsdottir, G., Hesselbjerg Christensen, J., Arneborg, J., Bhatt, U., Walker, D. A., Elberling, B., Gillet-Chaulet, F, "Greenland climate change: from the past to the future", WIREs Climate Change, p. 427, vol. 3, (2012). Published, doi: 10.1002/wcc.186

J. Overland, U. Bhatt, J. Key, Y. Liu, J. Walsh, and M. Wang, "[The Arctic] Air temperature, atmospheric circulation, and clouds??? [in "State of the Climate in 2011"]", Bull. Amer. Meteor. Soc, p. S127, vol. 93, (2012). Published,

D.A. Walker, U.S. Bhatt, H.E. Epstein, P. Bieniek, J. Comiso, G.V. Frost, J. Pinzon, M.K Raynolds, and C.J. Tucker, "[The Arctic] Changing Arctic Tundra Vegetation Biomass and Greenness??? [in "State of the Climate in 2011"].", Bull. Amer. Meteor. Soc., p. S138, vol. 93(7), (2012). Published,

Bieniek P., U. Bhatt, D. Walker, M. Raynolds, J. Comiso, H. Epstein, J. Pinzon, C. Tucker, R. Thoman, H. Trang, N. M??lders, W. Ermold, J. Zhang, and M. Steele, "Alaska coastal tundra vegetation links to climate", Earth Interactions, p. , vol. , (2012). in preparation,

Walker et al., "Diverging tundra productivity patterns in continental vs. oceanic portions of the Arctic", Environmental Research Letters, p. , vol. , (2012). in preparation,

Bhatt et al., "Drivers of Recent Pan-Arctic Tundra Vegetation Variability and Change", Earth Interactions, p. , vol. , (2012). in preparation,

Books or Other One-time Publications

U.S. Bhatt (Poster), D.A. Walker, M.K. Raynolds, H.E. Epstein, G. Jia, J.C. Comiso, J.E. Pinzon, C.J. Tucker, "Climatology and variability of the ice-ocean-atmosphere-terrestrial system on the Yamal", (2010). Poster Presentation, Not applicable
Bibliography: LCLUC Science Team Meeting, Bethesda, MD, 20-22 April 2010

U.S. Bhatt, D.A. Walker, M.K. Raynolds, H.E. Epstein, G. Jia, J.C. Comiso, J.E. Pinzon, C.J. Tucker, "Seasonality of the atmosphere-ocean-ice-terrestrial environment of Arctic tundra", (2010). Conference Poster Presentation, Presented
Collection: State of the Arctic, Miami, FL, March 2010
Bibliography: Section 1.2. Understanding the Linkages and Feedbacks Between the Arctic System Components.

U.S. Bhatt (Talk), D.A. Walker, M.K. Raynolds, H.E. Epstein, G. Jia, J.C. Comiso, R Gens, J.E. Pinzon, C.J. Tucker, C.E. Tweedie, P.J. Webber, "Circumpolar Arctic tundra Vegetation Change is Linked to Sea-Ice Decline", (2010). Oral Presentation, Presented
Collection: State of the Arctic, 16 March 2010, Miami, FL
Bibliography: http://soa.arcus.org/abstracts/circumpolar-arctic-tundra-vegetation-change-linked-sea-ice-decline

U.S. Bhatt, D.A. Walker, M.K. Raynolds, H.E. Epstein, G. Jia, J.C. Comiso, J.E. Pinzon, C.J. Tucker, "Climatology and Seasonality of the ice-ocean-atmosphere-terrestrial system on the Yamal", (2010). Oral Presentation, Presented
Collection: Second Yamal Land-Cover Land-Use Change Workshop, Rovaniemi Finland 8 March 2010
Bibliography: http://www.geobotany.uaf.edu/yamal/ptText.php?queryID=188

H.E. Epstein (Talk), D.A. Walker, M.K. Raynolds, A.M. Kelley, G.J. Jia, C.L. Ping, G.J. Michaelson, M.O. Liebman, E. Kaarlej?rvi , A.V. Khomutov , P. Kuss , N.G. Moskalenko, P. Orekhov, G. Matyshak, B.C. Forbes, and Q. Yu, "Vegetation biomass, leaf area index, and NDVI patterns and relationships along two latitudinal transects in arctic tundra", (2010). Oral Presentation, Presented

Collection: Second Yamal Land-Cover Land-Use Change Workshop, Rovaniemi, Finland, 8-10 March 2010
Bibliography: http://www.geobotany.uaf.edu/yamal/ptText.php?queryID=166

J. C. Comiso, "State of the Cryosphere in the Arctic", (2010). Oral Presentation, Presented
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Bibliography: http://www.geobotany.uaf.edu/yamal/ptText.php?queryID=164

J.E. Pinzon and C.J. Tucker, "GIMMS 3g NDVI set and global NDVI trends", (2010). Oral Presentation, Presented
Collection: Second Yamal Land-Cover Land-Use Change Workshop, Rovaniemi, Finland, 8-10 March 2010
Bibliography: http://www.geobotany.uaf.edu/yamal/ptText.php?queryID=168

M.K. Raynolds, D.A. Walker, U.S. Bhatt, J.E. Pinzon, J.C. Comiso, "NDVI trends 1981-2008 in the circumpolar Arctic and Yamal", (2010). Oral Presentation, Presented
Collection: Second Yamal Land-Cover Land-Use Change Workshop, Rovaniemi, Finland, 8-10 March 2010
Bibliography: http://www.geobotany.uaf.edu/yamal/ptText.php?queryID=184

U.S. Bhatt, D.A. Walker, M.K. Raynolds, J.C. Comiso, H.E. Epstein, G. Jia, R. Gens, J.E. Pinzon, C.J. Tucker, C.E. Tweedie, and P.J. Webber., "Circumpolar Arctic Tundra Vegetation Change is Linked to Sea-Ice Decline", (2010). Poster Presentation, Presented
Collection: Second Yamal Land-Cover Land-Use Change Workshop, Rovaniemi, Finland, 8-10 March 2010
Bibliography: http://www.geobotany.uaf.edu/yamal/

U.S. Bhatt, D.A. Walker, M.K. Raynolds, M. Steele, H.E. Epstein, G. Jia, J.C. Comiso, J.E. Pinzon, C.J. Tucker, "Seasonality of the air-sea-ice-land environment of Arctic tundra in Northern Eurasia and North America", (2009). Poster Presentation, Presented
Collection: 2009 AGU Fall Meeting, Poster GC31A-0701, San Francisco, CA, Wednesday 16 December 2009
Bibliography: www.agu.org

U.S. Bhatt, D.A. Walker, M.K. Raynolds, M. Steele, H.E. Epstein, G. Jia, J.C. Comiso, J.E. Pinzon, C.J. Tucker, "Seasonality of the air-sea-ice-land environment of Arctic tundra in Northern Eurasia and North America", (2009). Oral Presentation, Presented
Collection: Dept. Atmospheric Sciences Informal Seminar, Wed. 18 Nov 2009, Fairbanks, AK
Bibliography: http://www.gi.alaska.edu/~molders/zeitplan_fall2009.htm

D.A. Walker, H.E. Epstein, U.S. Bhatt, M.O. Liebman, B.C. Forbes, M.K. Raynolds, G.J. Jia, G.V. Frost, A.V. Khomutov, P. Orekhov, P.J. Webber, C.E. Tweedie, W.A. Gould, J. Mercado, C.A. Munger, H.A. Maeir, J.C. Comiso, J.E. Pinzon, J.C. Tucker, "Greening of the Arctic: A "planet to plant" analysis of vegetation change in the Arctic", (2010). Oral Presentation, Presented
Collection: IPY Oslo Science Conference, 2010 8-12 June
Bibliography: http://ipy-osc.no/abstract/418955

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al., "Understanding drivers of recent Arctic tundra vegetation changes.", (2010). Oral Presentation, http://www.geobotany.org/library/talks/BhattUS2010_agu_tal101217.pdf
Bibliography: Abstract GC43B-08, presented at Fall Meeting, AGU, San Francisco, CA, 13-17 December.

Bieniek, P.A., Bhatt, U.S., Walker, D.A., et al., "Alaska tundra vegetation trends and their links to the large-scale climate", (2010). Poster presentation, http://www.geobotany.org/library/posters/BieniekPA2010_agu_pos20101213.pdf
Bibliography: Abstract GC43B-0976, presented at Fall Meeting, AGU, San Francisco, CA, 13-17 December.

Raynolds, M.K., Walker, D.A., Verbyla, D., Munger, C.A., "Changes in tundra vegetation over 25 years as measured by Landsat NDVI in the Upper Kuparuk River Basin, North Slope Alaska, 1985-2009.", (2010). Oral Presentation, http://www.geobotany.org/library/posters/RaynoldsMK2010_agu_pos20101213.pdf
Bibliography: Abstract GC43B-0984, presented at Fall Meeting, AGU, San Francisco, CA, 13-17 December.

Walker, D.A., "Greening of the Arctic: Spatial and temporal (1982-2009) variation of circumpolar tundra NDVI and aboveground biomass", (2010). Oral Presentation, http://www.geobotany.org/library/talks/WalkerDA2010_agu_tal20101213.pdf
Bibliography: Abstract GC53B-01, presented at Fall Meeting, AGU, San Francisco, CA, 13-17 December.

Bhatt, U.S., Walker, D.A., Raynolds, M.K., et al., "Seasonal changes of the ice-ocean-atmosphere-terrestrial system on the Yamal.", (2011). Poster presentation, http://www.geobotany.org/library/posters/BhattUS2011_lcluc_110328.pdf
Bibliography: LCLUC Science Team Meeting Adelphi, MD March 28-30.

Walker, D.A., "Greening of the Arctic: Climate change and circumpolar Arctic vegetation.", (2011). Oral Presentation, Published
Bibliography: Presented at: Fulbright Lecture, Cesko Budovice University Cesko Budovice, Czech Republic April 27.

Walker, D.A., "Socio-ecological effects of oil and gas development in the Arctic: Comparison of the Prudhoe Bay, Alaska and Bovanenkova, Russia regions.", (2011). Oral Presentation, Published
Bibliography: Presented at: Earth Day, 20th Celebration of the Czech Fulbright Commission American Center, Prague, Czech Republic April 21.

Walker, D.A., "Arctic vegetation along two long bioclimatic transects in North America and Russia.", (2011). Oral Presentation, Published
Bibliography: Presented at: Fulbright Lecture, Botany Dept., Masarysk University Brno, Czech Republic March 10.

Walker, D.A., Kuss, H.P., Kopecky, M., et al., "The North American and Eurasia Arctic transects: Using phytosociology and remote sensing to detect vegetation pattern and change.", (2011). Oral Presentation, http://www.geobotany.org/library/talks/WalkerDA2011_eva_tal110406.pdf
Bibliography: Presented at: European Vegetation Survey 20th Workshop Rome, Italy April 6-9.

Walker, D.A., Raynolds, M.K., Epstein, H.E., et al., "Greening of the Arctic: Spatial variation of biomass and NDVI along two Arctic transects and the Circumpolar Arctic.", (2011). Oral Presentation, http://www.geobotany.org/library/posters/WalkerDA2011_lcluc_110328.pdf
Bibliography: Presented at: LCLUC Science Team Meeting Adelphi, MD March 28-30.

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, "Seasonality of climate parameters that characterize Arctic tundra vegetation", (2011). Oral Presentation, Published
Bibliography: Presented in: Session 5 Cryosphere and Terrestrial Processes, Wednesday 4 May 2011, Polar AMS, Boston, MA

Raynolds, M. K., "Searching for the response of northern vegetation to climate change", (2011). Oral Presentation, talk given
Bibliography: Presented to the Iceland Institute of Natural History (6 April 2011) and the University of Akureyri (28 April 2011)

Raynolds, M.K., Walker, D.A., Kofinas, G.P., Ambrosius, K.J., "Sixty years of landscape change within an Artic Oilfield, Prudhoe Bay, Alaska", (2012). oral presentation, Oral presentation given
Bibliography: Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20

Walker, D.A., "Summary of the Greening of the Arctic Project", (2012). Oral presentation, oral presentation given
Bibliography: Third Yamal Land-Cover Land-Use Change Workshop. Rovaniemi, Finland May 19-20

Walker, D.A., Webber, P.J., Brown, J., Raynolds, M.K., Streever, W., Ambrosius, K., "The evolution of the Integrated Geobotanical and Historical Change Mapping (IGHCM) approach for documenting landscape change (1949-2010), Prudhoe Bay oil field, AK, USA", (2012). Oral presentation, oral presentation given
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Epstein, H.E., Raynolds, M.K., Walker, D.A., Bhatt, U.S., Tucker, C.J., Pinzon, J.E., Frost, G.V., Yu, Q., Jia, G.J., Zeng, H., "Recent dynamics of arctic tundra vegetation: Remote sensing, field observations, and modeling", (2012). oral presentation, oral presentation
Bibliography: IPY 2012 From Knowledge to Action. Montreal, Quebec April 22-27

Epstein, H.E., Yu, Q., Frost, G.V., Raynolds, M.K., Walker, D.A., Bhatt, U.S., Tucker, C.J., Pinzon, J.E., "Climate and grazing influences on circumpolar dynamics of arctic tundra vegetation", (2012). Oral presentation, oral presentation given
Bibliography: 12th International Circumpolar Remote Sensing Symposium. Levi, Finland May 14-18.

Yu, Q., Epstein, H.E., Walker, D.A., Forbes, B.C., "Dynamics of Circum-Arctic Tundra Plant Communities in Response to Climate Warming and Grazing Pressure", (2012). Oral presentation, oral presentation given
Bibliography: IPY 2012 From Knowledge to Action. Montreal, Canada April 22-27

Walker, D.A., Epstein, H.E., Bhatt, U.S., and coauthors, "Greening of the Arctic Project (IPY-GOA, project ID 569)", (2012). Oral presentation, oral presentation given
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Bibliography: IPY 2012 From Knowledge to Action. Montreal, Quebec April 22-27

Bhatt U.S. and coauthors, "The role of seasonality and large-scale climate drivers in recent Pan-Arctic tundra vegetation variability and change", (2011). Poster Presentation, presented
Bibliography: Abstract GC51F-1075, presented at AGU Fall Meeting. San Francisco, CA, December 5-9.

Bieniek, P.A., Bhatt, U.S., Walker, D.A., Raynolds, M.K., Comiso, J.C., "Alaska tundra vegetation trends and their links to the large-scale climate", (2011). Oral presentation, presented
Bibliography: Impacts of Changing Seasonality on Arctic Systems and an Arctic in Rapid Transition II. Abstract GC32A-04, presented at AGU Fall Meeting. San Francisco, CA, December 5-9.

Walker, D.A., Bhatt, U.S., Raynolds, M.K., Bieniek, P.A., Epstein, H.E., Frost, G.V., Leibman, M.O., Forbes, B.C., Comiso, J.C., Tucker, C.J., Pinzon, J., "Satellite and land-based observations of environment, vegetation and NDVI along two Arctic Transects: Partial results from the IPY Greening of the Arctic Project.", (2011). Poster Presentation, presented
Bibliography: Abstract GC51F-1072, presented at AGU Fall Meeting. San Francisco, CA, December 5-9

Bhatt, US, DA Walker, MK Raynolds, PA Bieniek (poster), H E Epstein, JC Comiso, JE Pinzon, CJ Tucker, "Understanding Recent Arctic Tundra Vegetation Changes", (2011). Poster Presentation, presented
Bibliography: Session C11: The Role of the Cryosphere in Climate, World Climate Research Programme Open Science Conference 2011, Denver, CO, Monday October 24, 2011.

Bieniek P., "Assessing River Ice Breakup Date, Coastal Tundra Vegetation and Climate Divisions in the Context of Alaska Climate Variability", (2012). Thesis, Published
Bibliography: Ph.D. thesis University of Alaska Fairbanks. available on-line at:
http://ffden-2.phys.uaf.edu/atm/atm/graduates.html_files/Bieniek_P_PhD2012Thesis.pdf

Web/Internet Site

URL(s):

http://www.geobotany.uaf.edu/seasonality/index

Description:

This web site outlines the project and lists presentations/publications associated with this grant.

Other Specific Products

Product Type:

Audio or video products

Product Description:

Topp, R. 2012. The Changing Arctic. UA Museum of the North (movie).

We worked with the University of Alaska Fairbanks Museum on a visual public display that is currently being shown at the museum on a Magic Planet Display. We provided data and graphics of sea ice concentration, NDVI (over Arctic tundra), surface temperatures (over Arctic Tundra). This device is about 30 inches in diameter and will project graphics onto a sphere (from the inside) for public outreach and educational purposes. The museum project was funded by NASA and it partners with the Imaginarium Discovery Center at the Anchorage Museum and the Challenger Learning Center in Kenai. There is also a traveling projection device, so our tundra greening story will be presented throughout Alaska in outreach and educational events.

Sharing Information:

This product is playing at the UAF Museum and a flat projection is available on the web at:
http://www.geobotany.org/library/media/tca_ver6_ece/Resources/tca_ver6_ece.mov

Contributions

Contributions within Discipline:

One of our key findings that impacts Arctic climate understanding is that sea ice decline is linked to the nearby coastal warming in the observations. This has implications for interpretation of mechanisms of polar amplification. In addition, this is an important mechanism to consider in the development of earth system models as we try to project what will happen in the future.

Contributions to Other Disciplines:

I think our process of effectively conducting interdisciplinary research across various Arctic environmental disciplines has led to a better understanding of how arctic tundra vegetation is linked to the large-scale and local climate.

Contributions to Human Resource Development:

We have mentored a PhD student to completion and Postdoc in doing climate research. We have developed their skills on how to engage in interdisciplinary research, which will better prepare them for future research opportunities.

Contributions to Resources for Research and Education:

Our results have been discussed in various courses taught at the University of Alaska Fairbanks. ATM 656 Climate and Climate Change was taught by Bhatt in Fall 2009. This is a graduate level climate class taken by students from various disciplines (e.g. engineering, hydrology, a professional journalist, and atmospheric sciences). In Fall 2011, Bhatt co-taught the graduate climate course with a faculty member from the UAF Geography Department. The students were from both departments and were able to share the strengths of each discipline with the other (ATM:technical/physical/mathematical, GEO: multi-disciplinary/big-picture). They were particularly interested in this project.

Walker taught graduate courses in the Biology department at UAF that incorporated material from this research.

Contributions Beyond Science and Engineering:

While this connection is in an early stage, the foundation has been laid on how to discuss these results with members of the community that depend on tundra resources for their livelihood. This community is particularly interested in the links between climate/weather and tundra vegetation productivity.

Conference Proceedings

Categories for which nothing is reported:

Any Conference

Key Findings

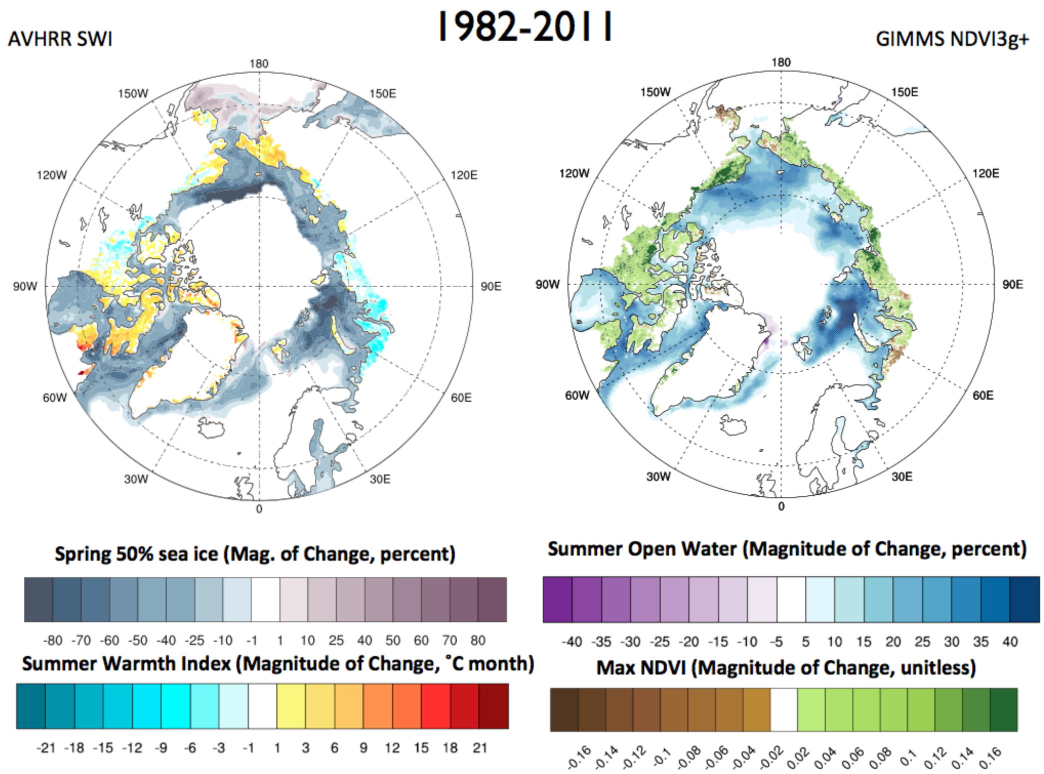

Figure 1. Magnitude of 1982-2011 trends in spring sea ice (left panel), SWI (left panel), summer open water (right panel), and MaxNDVI (right panel). Figure in Walker (2012a) and updated from Bhatt (2010).

PART I) Highlights are summarized below from an analysis of seasonal summer warmth index (SWI), sea ice concentration, time integrated normalized difference vegetation index (TI-NDVI), and MaxNDVI in the 50-km and full tundra coastal zones.

<u>Trends</u>

An analysis of trends for 1982-2008 demonstrates that in most of the Treshnikov-based tundra divisions (see Figure 2 in Bhatt et al. 2010 for division boundaries) decreases in sea ice correspond with increases in SWI, TI-NDVI, and MaxNDVI (see Figures 3-4 in Bhatt et al. 2010). When the analysis was extended to 1982-2011 there are several notable differences from the earlier period (Figure 1) particularly for land surface temperatures. There is a larger area of cooling over western Eurasia and there is cooling over the southern tundra areas in North America, which had been warming in the earlier period.

SWI and NDVI have generally increased over the Arctic tundra domain from 1982-2011, however there are several areas where NDVI (e.g. SW Alaska, Chutoka, and Coastal West Kara Sea) and SWI (e.g. parts of central Asia between 60-120E) have decreased. Open water (sum of weekly open water in % from May-Aug) during summer has increased everywhere in the coastal Arctic with the largest increases in Beringia and Kara-Barents Sea (Figure 1).

The land warming and MaxNDVI increase is larger over North America than Eurasia (Figures 2-3). SWI has flattened out over the past decade in North America and is actually showing cooling over Eurasia (Figure 3). Coastal sea ice decreases have been larger over Eurasia than North America (Figure 3) for the full period. Trends are diverging in NDVI between North

America and Eurasia after 2001 (Figure 2) (Walker et al. 2012c).

Variability

Linearly detrended correlation analysis for 1982-2008 shows that SWI (sum of the degree months above freezing during the growing season), sea ice concentration and TI-NDVI (sum of biweekly MaxNDVI values over the growing season) are significantly correlated in most of the Arctic (Table 1). The relationship is as follows: if sea ice is below average, then TI-NDVI and SWI tend to be above average. This has remained generally true over the 1982-2011 period though the correlations have weakened in some regions.

* The above findings are documented in the following publications: Bhatt et al. (2010), Walker et al (2012a), and Walker et al. (2012c).

Table 1. Correlations between linearly de-trended sea ice, SWI and TI-NDVI time series from 1982-2008, for different Pan-arctic regions in the 50 km coastal land and ocean domains. Correlations between sea ice within 50 km of the coast and the full tundra domain is shown in parenthesis. Significance at the **95**% (*90%*) or greater level is indicated in **bold** (*italic*). Table is taken from Bhatt et al. 2010.

	Avg. 50% ice conc.	sea ice & SWI	SWI & TI-NDVI	sea ice & TI-NDVI
N. Hemis.	16-22Jul	**-0.49** (-0.32)	**0.64** **(0.57)**	**-0.56** **(-0.55)**
N. America	23-29Jul	**-0.56** **(-0.40)**	**0.60** **(0.57)**	**-0.53** **(-0.50)**
Eurasia	9-15Jul	**-0.58** **(-0.40)**	**0.67** **(0.65)**	**-0.51** **(-0.41)**
E. Bering	30Apr-6May	-0.12 (-0.04)	**0.57** **(0.48)**	**-0.47** **(-0.47)**
E.Chukchi	11-17Jul	-0.13 (-0.02)	**0.55** **(0.51)**	**-0.41** (-0.37)
Beaufort	9-15Jul	*-0.37* (-0.31)	**0.50** (0.31)	-0.20 (-0.17)
Can. Arch.	6-12Aug	**-0.77** **(-0.66)**	**0.78** **(0.76)**	**-0.64** **(-0.65)**
Baffin Bay	2-8Jul	**-0.38** **(-0.46)**	**0.55** **(0.44)**	*-0.35* *(-0.37)*
Davis Str.	21-27May	0.05 (-0.19)	*0.35* *(0.35)*	-0.27 (-0.26)
Grnlnd Sea	30Jul-5Aug	**-0.46** **(-0.54)**	0.29 (0.12)	-0.17 (-0.16)
Barents	21-27May	**-0.50** **(-0.44)**	**0.65** **(0.45)**	*-0.34* *(-0.33)*
W. Kara	16-22Jul	**-0.41** (-0.36)	**0.56** **(0.54)**	-0.28 (-0.24)
E. Kara	13-19Aug	**-0.41** (-0.30)	**0.78** **(0.74)**	**-0.46** **(-0.43)**
Laptev	23-29Jul	**-0.68** **(-0.59)**	**0.74** **(0.76)**	**-0.69** **(-0.61)**
E. Siberian	23-29Jul	**-0.62** **(-0.53)**	**0.60** **(0.62)**	**-0.64** **(-0.63)**
W. Chukchi	2-8Jul	**-0.54** **(-0.49)**	**0.52** **(0.45)**	*-0.36* *(-0.32)*
W. Bering	14-20May	-0.09 (-0.05)	**0.39** (0.13)	0.16 (0.14)

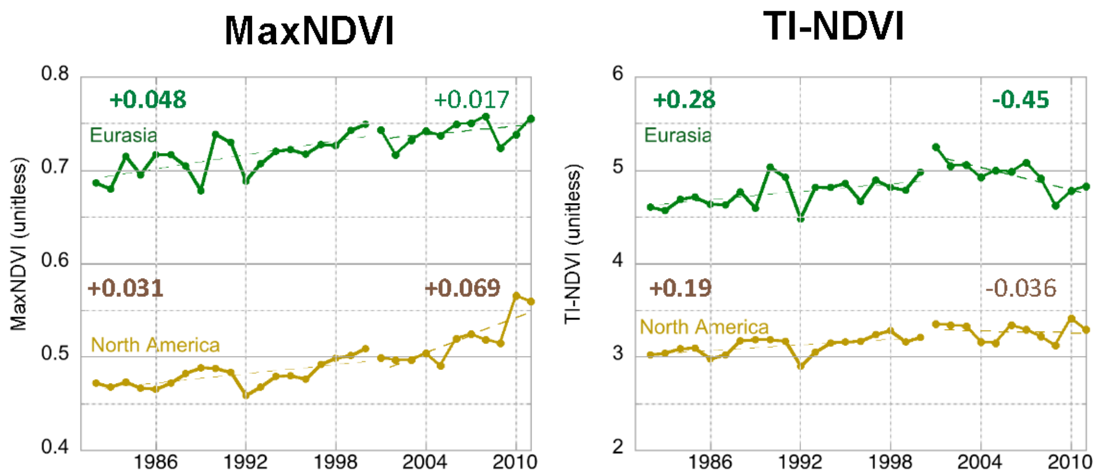

Figure 2. MaxNDVI (left) and TI-NDVI (right) during summer from 1982 to 2011 over the full tundra domains. Trends are largest for North America while the mean is larger in Eurasia. The trends are not constant over time and change after 2001. Trend magnitudes are shown above each line segment for the period over which the trend was calculated. Updated from Bhatt et al. (2010) and presented in Bhatt et al. (2012b).

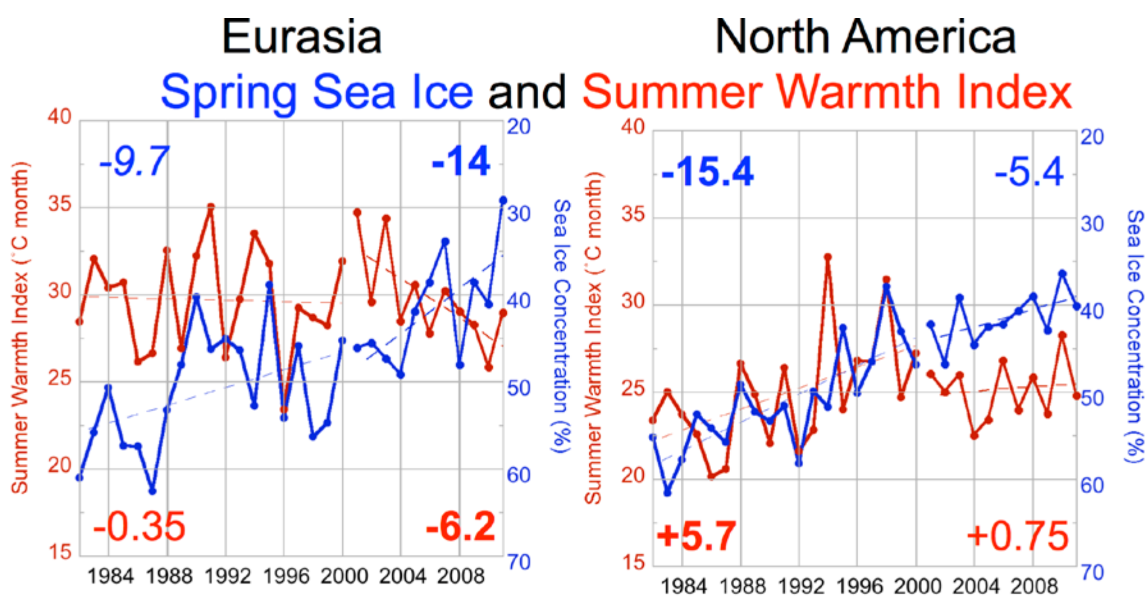

Figure 3. Spring sea ice (blue) and SWI (red) for Eurasia (left) and North America (right) from 1982 to 2011 over the full tundra domains. The trends are not constant over time and change after 2001. Trend magnitudes are shown above each line segment for the period over which the trend was calculated. Updated from Bhatt et al. (2010) and presented in Bhatt et al. (2012b).

PART II) Highlights are summarized below from an analysis of biweekly MaxNDVI, weekly sea ice concentration and weekly surface temperature during the summer from 1982-2011.

Decadal curves of the seasonal cycle of biweekly MaxNDVI show that the largest increases from the 90's to the 00's are during spring over Eurasia but during peak season over North America (Figure 4). The hemispheric differences are consistent with the individual Treshnikov regions in each hemisphere. This suggests that likely different processes are operating in Eurasia and North America.

Weekly trend analysis of sea ice in the 100-km coastal zone shows that the largest declines are during spring and fall when the break up is early or delayed, respectively. The timing of breakup and freeze-up are earlier in the Beaufort than the W. Kara highlighting a shift in the summer ice-free season. This will likely impact the moisture available for precipitation during spring and fall and would in turn impact the vegetation.

Weekly trend analysis of land surface temperatures reveals differences between North America and Eurasia. North America displays large year-round warming while Eurasia displays the largest warming in fall/winter. Many parts of Eurasian tundra have been cooling during the summer (Figure 1). The most intriguing result of the weekly temperature trend analysis is a midsummer cooling that was found in most regions aside from the high Arctic (Example for North America shown in Figure 5). Fifteen-year running trends for N. America (Figure 5, bottom panel) highlights the changing magnitudes and sign of the trends during in all parts of the growing season. Until 2002, North America was warming during all parts of the growing season, but in the last decade there has been cooling during spring and summer. Mechanisms for this midsummer cooling are being explored for the Beaufort domain using Weather Research and Forecasting (WRF) model and more details are provided below.

* The above findings are documented in the following publications: Bhatt et al. (2012a), Bhatt et al. (2012b), Walker et al. (2011), Walker et al. (2010), and Bieniek (2012).

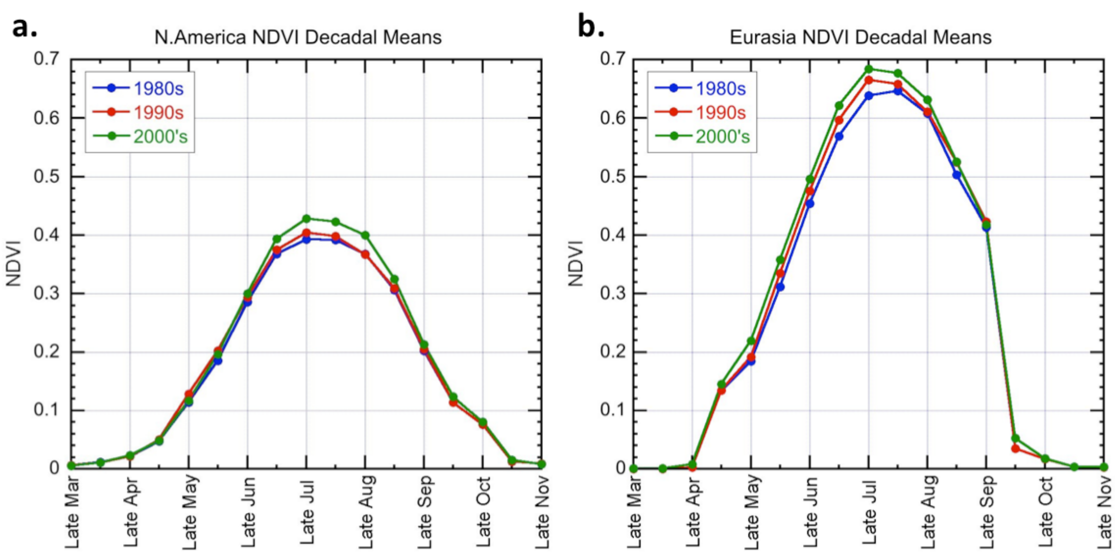

Figure 4. Decadal changes in NDVI-derived phenology in (a) Eurasia and (b) North America.

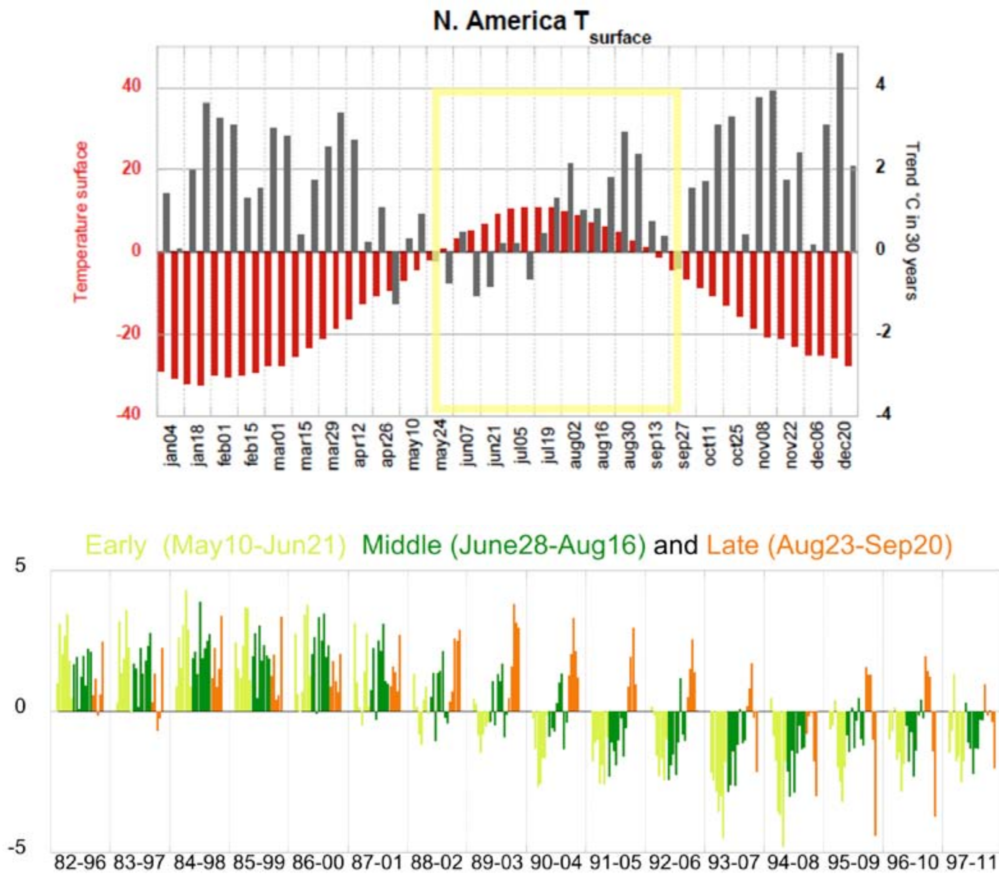

Figure 5. North America full tundra region weekly surface temperature climatology (red bars in top panel), trends (grey bars in top panel) and 15-year running surface temperature trends during the early (light green), middle (green) and late (orange) growing season (bottom panel).

PART III) Highlights are summarized below from an analysis of vegetation-climate links over Alaska.

In the tundra of northern Alaska, significant increases have been documented in seasonal MaxNDVI along the Beaufort and Chukchi Sea coasts. In contrast, maxNDVI has declined over coastal tundra areas in southwest Alaska along the Bering Sea (Figure 6) (Bhatt et al. 2010; Bieniek 2012; Bieniek et al. 2012). Increasing land surface temperatures have been documented in the Chukchi, Beaufort and Bering Sea tundra regions during the summer, but temperatures have declined in midsummer.

In the Beaufort and East Chukchi regions, the strength of the Beaufort High was correlated with NDVI, however the sign of the relationship depends on the summer month indicating a complex relationship. The maxNDVI is above average when the June Beaufort High (BH) is stronger, however, a weaker BH in July is also linked with increased TI-NDVI (time-integrated over the season). The following sequence of events is hypothesized to occur. A stronger BH can suppress cloudiness and increase solar insolation, which would lead to warming in June. Wind speed analysis (station and Reanalysis data) is consistent with warmer June temperatures and a strengthening of the local sea breeze circulation. The decline in the July BH may be due to a weakening of the sea breeze circulation that occurs from land surface cooling that reduces the land-sea contrast. The cooling over land is hypothesized to occur from increased convection and increased cloud cover, which reduces solar insolation and cools the surface (Bieniek 2012; Bieniek et al. 2012).

Idealized WRF simulations were conducted to explore the impact on sea-breeze circulations of a land surface temperatures on the North Slope and to test the mechanism outlined above. Warmer and cooler than average land surface temperatures were specified in a set of WRF model sensitivity experiments. The control simulation and the sensitivity experiments were driven by the large-scale weather conditions from the summer of 2010. Analysis of the WRF simulations is in progress but preliminary results suggest that there is an impact on the circulation of land surface temperature anomalies. The WRF results will be included in Bieniek et al. 2012.

The decline of NDVI in the East Bering region is consistent with later snowmelt due to late season snowfall that delays the onset of the growing season. The delay in snowmelt may be linked to an increase in occurrences of the positive phase of the West Pacific Pattern. Winter snow water equivalent in the East Bering tundra region is positively correlated with maxNDVI, where reduced maxNDVI tends to occur with reduced winter snowfall.

* The above results are documented in the following publications: Bieniek (2012) and Bieniek et al. (2012).

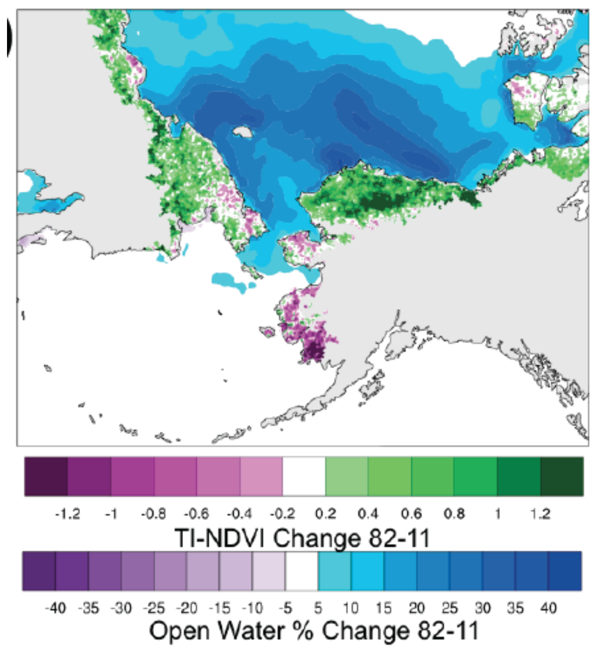

Figure 6. Linear trend magnitude from 1982-2011 of (a) time integrated NDVI (TI-NDVI) and May-August open water (percent).

Part IV) Highlights are summarized below from the evaluation of remote sensing NDVI data.

In order to have confidence in satellite measurements, it is important to link ground measurements of biomass to remotely sensed measures of vegetation productivity. In Raynolds et al. (2012), above ground biomass measurements in two transects (North American Arctic Transect and Eurasian Arctic Transect) which traverse the north-south bioclimate gradient were compared to satellite NDVI values at the nearest pixel. The relationship between Eurasian and North American biomass measurements turned out to be nearly the same, which allows NDVI to be equated with aboveground biomass in a global relationship (Figure 7) (Raynolds et al. 2012). The mean biomass in Eurasia is larger for a given bioclimate subzone and is likely due to climatic, soil, and other factors. This result supports comparing NDVI in North America and Eurasia.

The collaboration of our climate analysis group with J. Pinzon and C. J. Tucker of NASA led to the reprocessing of AVHRR NDVI data and this has permitted the first circumpolar analysis over tundra of NDVI changes in the High Arctic north of 72N. Our seasonality analysis of NDVI,

which revealed new intra-seasonal biases related to cloud masking, has led to a subsequent reprocessing of the AVHRR NDVI by Drs. Pinzon and Tucker. The latest data set NDVI3g (October 2010) has been corrected for most of the intra-seasonal biases, however there is an issue that is still currently under consideration (Pinzon et al. 2012).
* The above results are supported by the following publications: Raynolds et al. (2012), Walker et al. (2012b), and Pinzon et al. (2012).

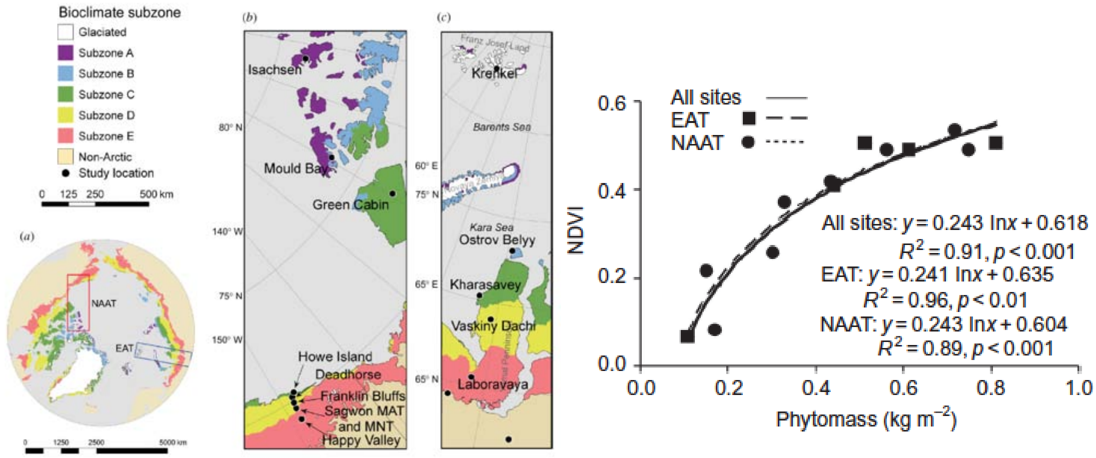

Figure 7. Left panel shows the North American Arctic Transect (NAAT) and the Eurasian Transect (ET) that traverses the north-south bioclimate gradient. The stations with ground measurements of biomass are shown in center panels. The right panel shows above ground biomass on the horizontal axis and NDVI on the vertical axis. Relationship between MaxNDVI and aboveground biomass similar for both transects. Figure appears in Raynolds et al. (2012).

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Research and Educational Activities

Overview

The major research goal of this project is to characterize the seasonal linkages between land surface greenness and a suite of land, atmosphere and ocean measures in the context of Arctic tundra vegetation. We have analyzed the seasonality of Arctic sea ice concentrations, land surface temperatures and NDVI and how they have changed over the satellite record. We have included additional remote sensing data (e.g. snow), climate data (e.g. Reanalysis Data), and ocean assimilation (heat content) information to advance our understanding of how and why the tundra is changing. Specific activities are described below.

Educational Activities

1) P. Bieniek successfully defended and received his Ph.D. degree in August 2012. His research focused on the three tundra regions in Alaska and he analyzed them in the context of weather and climate. His analysis suggested that terrestrial-air interactions could be altering local sea breeze circulations, particularly on the North Slope of Alaska. This idea was tested by running of a set of WRF model simulations (by Mr. H. Tran, a PhD student in Dept. of Atmos. Sci.) that imposed anomalous warming and cooling of the coastal land surface in the Beaufort tundra region.

2) We have incorporated findings from this work in the Dept. of Atmospheric Sciences climate discussion seminar ('Climate Journal Club') for graduate students, postdocs, and faculty, during Spring 2010 and Spring 2011 semesters. We have also incorporated material from this work into Osher Lifelong Learning (http://www.uaf.edu/olli/) courses taught by Bhatt and Raynolds at the University of Alaska Fairbanks.

Research Activities

1) We updated our findings based on 1982-2008 from the Bhatt et al. (2010, Earth Interactions) paper with analysis for the period 1982-2011.

2) We fine-tuned the analysis of regional trends and variability on a seasonal time scale for sea ice concentration, surface temperature and updated NDVI data. These results appeared in our 2010 Earth Interactions paper and when the analysis was extended to the 1982-2011 period, the response appears to be a more heterogeneous.

3) We analyzed weekly climatology, variance and trends for sea ice concentration and surface temperature for the 19 Arctic regions (regions were revised in January 2011). The same analysis was conducted for biweekly NDVI. We have analyzed decadal average seasonal curves for open water, biweekly NDVI and weekly land temperatures.

4) We have analyzed our parameters by bioclimate subzone (zonal divisions based on available warmth and plant type).

5) Bieniek has implemented a curve fitting method for the biweekly NDVI to provide daily NDVI values. The dates of greenup and how that has changed can be determined using these results.

Other Activities that Enhance Research and Education

1) We held weekly meetings for the UAF team throughout the project to discuss project progress, exchange scientific ideas, and to plan future activities.

2) We have conducted meetings with collaborators on this project to discuss results and plan activities at 2009 Fall AGU, 2010 State of the Arctic, and 2010 Fall AGU meetings. Telecons and emails have been used as necessary to communicate among the collaborators.

3) We have worked and continue to work with J. Pinzon and C.J. Tucker to identify NDVI biases so they can be corrected through reprocessing the biweekly NDVI. We received a corrected version of the data in October 2010, the NDVI3g, which has been corrected for errors due to clouds. The NDVI currently has some regional errors, which have been partially addressed.

4) We have concluded after analysis of numerous snow data sets that we will include results from both GLOBSNOW and passive microwave (SSMR) snow water equivalent in our publications. We have performed extensive analysis using the passive microwave snow water equivalent data and feel confident in these results due to their consistency with trends in the NDVI data. There are some differences between GLOBSNOW and the SSMR product.

5) We have contributed plots and text based on results from this project for the Bulletin of the American Meteorological Society 'State of the Climate' report on Arctic high latitude vegetation for 2009, 2010, and

2011. We have contributed to the vegetation section of the 'State of the Arctic' report in 2010, 2011, and will do so for 2012 also. We have contributed a figure with four panels containing NDVI, SWI and sea ice trends over the tundra to a paper on polar amplification by Serreze et al. (2011 in Global and Planetary Change).

6) We have presented results at various meetings (e.g. 2009 Fall AGU, State of the Arctic, IPY Oslo Science Conference, 2010 Fall AGU, 2011 Polar AMS, 2011 Fall AGU, and 2012 IPY Montreal Conference). A complete list is provided under one-time publications section of this report.

7) We worked with the University of Alaska Fairbanks Museum on a visual public display that is currently being shown at the museum on a Magic Planet Display. We provided data and graphics of sea ice concentration, NDVI (over Arctic tundra), surface temperatures (over Arctic Tundra). This device is about 30 inches in diameter and will project graphics onto a sphere (from the inside) for public outreach and educational purposes. The museum project was funded by NASA and it partners with the Imaginarium Discovery Center at the Anchorage Museum and the Challenger Learning Center in Kenai. There is also a traveling projection device, so our tundra greening story will be presented throughout Alaska in outreach and educational events.

8) In January 2011, Uma Bhatt and Peter Bieniek attended a 1-day workshop in Anchorage for an NSF funded project for Dr. Ann Riordan, who is working with Calista Elders in SW Alaska. We presented several slides of our remotely sensed greening (actually browning) trends for our E. Bering domain and listened to Elders discuss what they observe at the ground. Their ground level observations helped us target our climate data analysis on snow variability. In January 2012, Bhatt and Bieniek joined Dr. Riordan in Bethel Alaska for a subsequent 3-day meeting with the Calista Elders where we presented a follow-up analysis for E. Bering region based on our previous discussions. The January 2012 discussions have prompted us to examine wind patterns in this area using station data and gridded reanalysis winds. Snow and wind will likely be an important part of the E. Bering story.

9) The final regional time series of MaxNDVI, sea ice concentration, and land surface temperatures for each of the 50-km, 100-km and full tundra Treshnikov land and ocean divisions will be archived at ACADIS.