Circumpolar Arctic Tundra Vegetation Change is Linked to Sea-Ice Decline

Uma Bhatt[1], Donald A. Walker[2], Martha K. Raynolds[2], Howard E. Epstein[4], Gensuo Jia[5], Josefino C. Comiso[6] Jorge E Pinzon[6], Compton J. Tucker[6]

[1] Geophysical Institute & Dept. Atmospheric Sciences at U. Alaska Fairbanks (UAF), [2] Institute of Arctic Biology at UAF, [4]Dept. of Env. Sci. at University of VA, [5]CAS, Beijing China, [6]NASA Goddard Space Flight Center

NASA/NEESPI Workshop Rovaniemi Finland March 2010

Main Results

- **Demonstrates linkages between diminishing Arctic sea ice and changes in Arctic terrestrial ecosystems**
- **Early-summer ice break up declined an average of 25% while land warming has been more pronounced in North America (+30%) than in Eurasia (16%)**
- **NDVI has increased across most of the Arctic (exceptions in the Bering and W. Chukchi Seas)**

Motivation and Methods

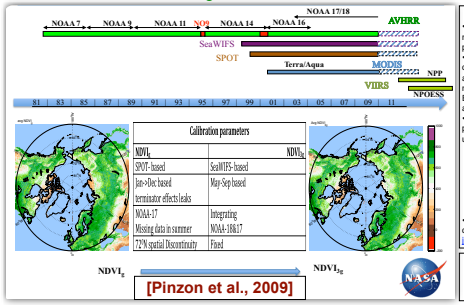
Goal: Document trends in tundra productivity
Document tundra-climate relationships

Data: Use 25 km resolution SSMI passive microwave Bootstrap Sea Ice Concentration (SIC), AVHRR Surface Temperature (T_s), and new GIMMS $NDVI_{3g}$ for the Arctic over the 1982-2008 period.

Methods: Standard climate trend and correlation analysis techniques applied to regional (Modified Treshnikov basins) time series of Maximum NDVI, Time Integrated NDVI, Summer Warmth Index, and sea ice concentration constructed using data within 50-km of Arctic coastlines (ocean & land) .

Map delineating regions used in this research.

New GIMMS-$NDVI_{3g}$ for the Arctic



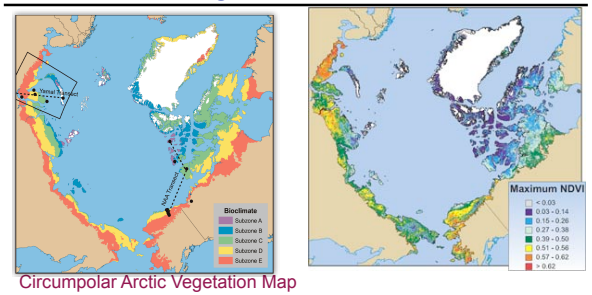
[Pinzon et al., 2009]

Technical Information

- The GIMMS data set uses a histogram matching approach with periodogram parameter regularization
- To ensure spatial coherence, temporal consistency among the AVHRR NDVI record and ensure continuity for the coming missions: National Polar Orbiting Operational Environmental Satellite System (NPOESS) and Preparatory project (NPP).
- An apparent 72N spatial discontinuity in the previous GIMMS-NDVIg product was fixed by using histogram matching from:
  - SeaWIFS instead of SPOT which doesn't collect data above 720N
  - May-September instead of January-December to avoid terminator effects leaking into the parameters.
  - An integration of NOAA-18 and NOAA-17 NDVI data.
- **$NDVI_{3g}$** is ready for distribution for all continents (for more information contact jorge.e.pinzon@nasa.gov).

NDVI = (NIR-R)/(NIR+R) NIR: spectral reflectance in near-infrared band (0.725-1.1 μm) & R: red chlorophyll absorbing portion of spectrum (0.58-0.68 μm)

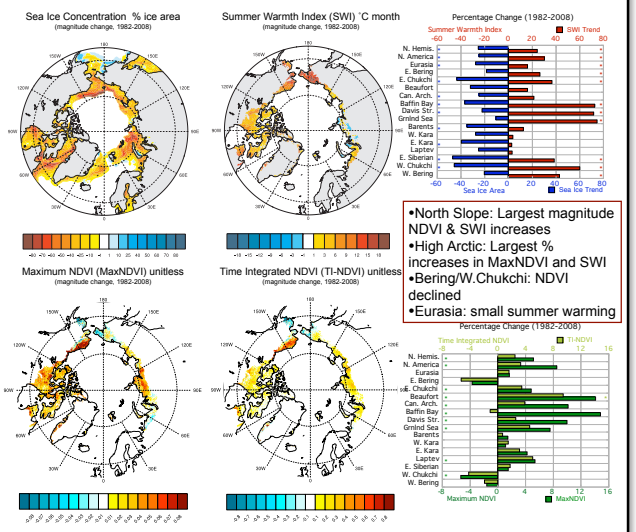
Mean Tundra Vegetation is Linked with Climatological Position of Sea Ice



Circumpolar Arctic Vegetation Map

- 80% of the Arctic tundra (3.2 million km²) < 100 km from ocean Subzone A (mosses) to Subzone E (low shrubs)

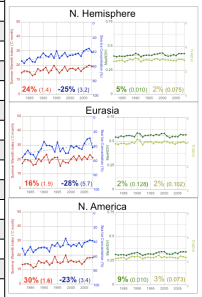
Trends: Ice is Declining while NDVIs & SWI Increasing



- North Slope: Largest magnitude NDVI & SWI increases
- High Arctic: Largest % increases in MaxNDVI and SWI
- Bering/W.Chukchi: NDVI declined
- Eurasia: small summer warming

Significant Co-variability between NDVI, SWI & Sea Ice

	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)

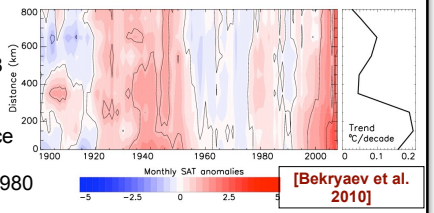


Linearly Detrended Correlations (Bold >95%, Italic >90% Significance)

- Correlations larger in 50-km coastal zone than over the full tundra zone suggesting strongest connection is in the near coastal zone.
- North American Warming Larger & Eurasian Variability Larger

Sea ice declines are driving vegetation increases

- Modeling evidence (Fixed ice GCM)
  - Lawrence et al. 2008
  - Bhatt et al. 2008
  - Deser et al. 2010
- Observational Evidence
  - Rouse 1991
  - Haugen and Brown 1980
  - Mean NDVI map
  - Bekryaev et al. 2010 (accepted to J. Climate) Largest warming on land is close to the coast when ice declines (MDV). Ice increases result in cooling but magnitude is smaller.
  - Alternate Theory: Is the forcing from comes from the south?



[Bekryaev et al. 2010]

46 years of Vegetation Change: Baffin Island

- Repeat photos of Lewis Glacier after 46 year show increases in vegetation in recently deglaciated areas (500 years).
- Retreating glaciers may help explain large NDVI trends in Greenland Sea, Baffin Bay & Davis Strait.

[Bhatt et al., 2010]

Final Comments

- Corrected NDVI data north of 72˚N permitted us to also document ecologically important percentage changes of NDVI in the High Arctic where there are few or no shrubs.
- What are the causes of the heterogeneity of Arctic vegetation response?
- Areas marginal to perennial sea-ice (Subzone A) and the margins of the large glaciers will see the most rapid percentage changes if the perennial ice vanishes.

References

- Pinzon, J. E., E. Pak, C.J. Tucker, 2009 (submitted), A revised AVHRR 8-km NDVI Data Set - Compatibility with MODIS and SPOT Vegetation NDVI Data, American Geophysical Union EOS Transactions.
- 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, 2010 (in revision): Circumpolar Arctic tundra vegetation change is linked to sea-ice decline, Earth Interactions.

Acknowledgements

This study was supported by grants NSF ARC-0531180, NASA NNG6NE00A, NSF ANS-0732885, NSF ARC-0902175, NASA Land Cover Land Use Change on the Yamal Peninsula.