Climate Variations and Alaska Tundra Vegetation Productivity Declines in Spring

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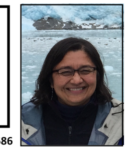

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Main Findings

- NDVI varies considerably from year-to-year and has been declining in recent years particularly during spring.
- NDVI declines occur for all bioclimate subzones in Eurasia and in subzones C and D in North America.
- Southeast Alaska has been browning over the 1982-2014 record, but shows greening from 2010-2015.

Motivation and Methods

Question: Why is tundra vegetation productivity declining over past few years, particularly in spring?

Data: 1) 25 km passive microwave Bootstrap Sea Ice Concentration (SIC)
2) AVHRR Surface Temperature (T_s)
3) GIMMS $NDVI_{3g}$ for the Arctic [Pinzon et al. 2014]

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)

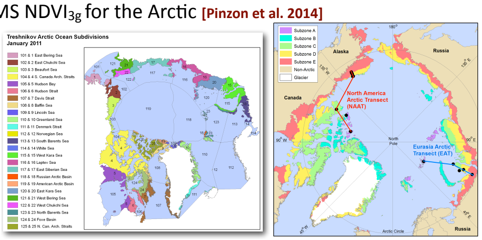

Figure 1. Updated Treshnikov divisions [Bhatt et al. 2013] (left) and Bioclimate subzones [Walker et al. 2005](right).

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 100-km of Arctic coastlines (ocean & land). **Study period 1982-2014**.

Overall, summer sea ice declining, land surface warming and vegetation greenness increasing.

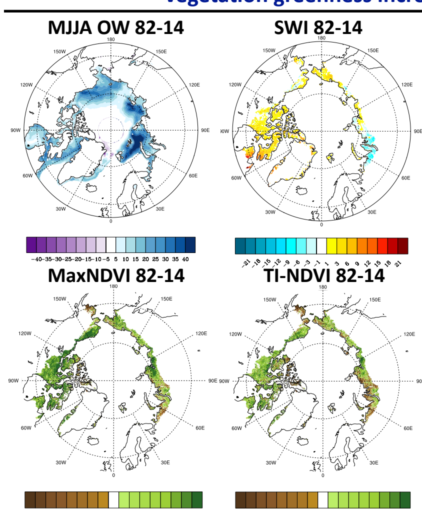

Figure 2. Updated trends of summer open water (OW) (top left), Summer Warmth Index (SWI: sum of the degree months above 0C) (top right), Maximum NDVI (bottom left), and TI-NDVI (bottom right). OW and SWI are shown as an total trend over the 33 year period (1982-2014) while NDVI are shown as percent change since 1982. Updated from [Bhatt et al. 2010].

- **Summer OW is increasing**
- **SWI is increasing overall except in W. Eurasia, but trends have weakened compared to earlier period**
- **MaxNDVI increasing except in SW Alaska, W. Eurasia, and N. Cananda**
- **TI-NDVI increasing but has more declining trends than MaxNDVI**

MaxNDVI and TI-NDVI have decreased in last 5 years

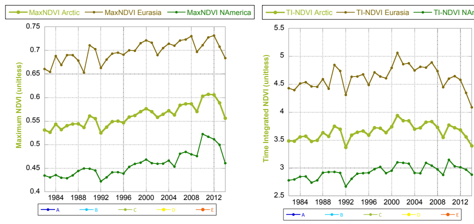

Figure 3. Time series of MaxNDVI (left panel) and TI-NDVI (right panel) for Arctic, North America and Eurasia tundra regions.

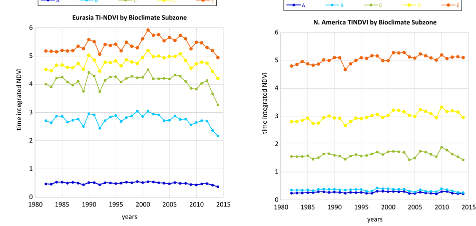

Figure 4. Time series of Ti-NDVI for Eurasia (left panel) and North America (right panel) for Bioclimate subzones A (coldest) to E (warmest).

[Epstein et al. 2014 and 2015]

- **MaxNDVI shows overall increase but declines over last 4-5 years.**
- **TI-NDVI shows declines since 2001 in Eurasia for all bioclimate subzones.**
- **TI-NDVI shows declines since 2010 for N. America for subpoena C and D.**

Mechanism: More Spring Snow, Delayed Snowmelt, and later Greenup

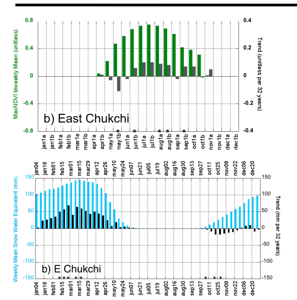

Figure 5. East Chukchi biweekly NDVI climatology (green) and trend (grey) in top panel for 1982-2013. East Chukchi weekly Globsnow SWE climatology (blue) and trend (grey) in bottom panel . From Bieniek et al. [2016].

More snow is expected in a warmer climate as the hydrological cycle strengthens.

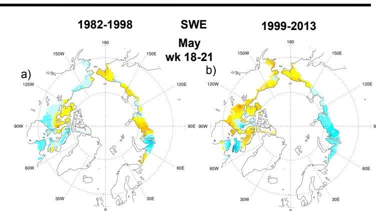

Figure 6. Globsnow SWE trend over 1982-1998 and 1999-2013. North America shows an increase of SWE in late spring in the past 15 years. From Bhatt et al. [2015].

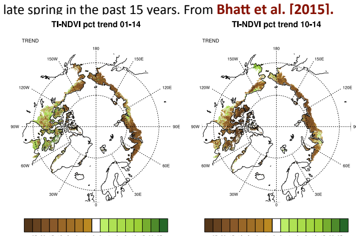

Figure 7. TI-NDVI trend is fairly widespread in recent years.

Mechanism: Midwinter Thaw; Early Greenup followed by Freeze

'Skip' Walker testimonial: In Spring 2015 large areas of northern Alaska experienced a severe frost after an early snow melt. This caused widespread browning of the leaves of several shrub species including *Vaccinium uliginosum* seen in these photos in the Brooks Range, taken in mid June 2015 during our Arctic Alaska Environmental Change summer field course. We also noted widespread dieback of this year's leaves on other shrubs such as *Betula nana* and *Salix* spp. in the Toolik Lake area.

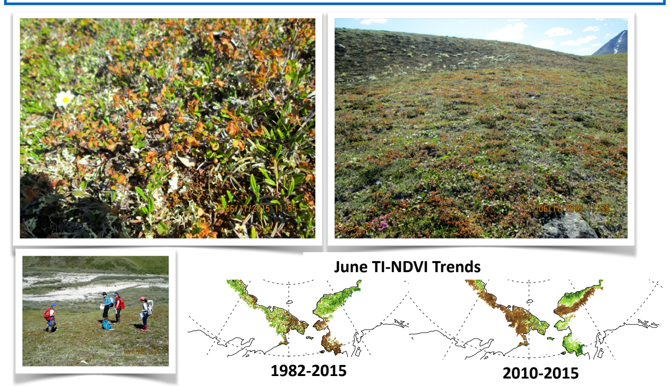

Figure 8. Mid June 2015, North Slope Alaska brown frosted blueberry leaves (*Vaccinium uliginosum)* (top left and right). Students puzzle over what is going on at the ground (bottom left). Jun NDVI trends (bottom right).

Summary & Thoughts

- **NDVI declines are largest in spring particularly over the last 5-10 years.**
- **Two proposed meteorological mechanisms for NDVI declines: 1) increased spring snow fall, later melt and later greenup and 2) winter snow melt followed by a freeze which damages plants [Bjerke et al. 2013].**
- **It is likely that both mechanisms (plus others) are important causes of NDVI declines.**
- **A climate mechanism is more consistent with large-scale NDVI trends.**

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Acknowledgements

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