

Winter frozen season effects on vegetation canopy growth in northern high latitudes

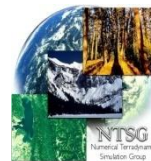
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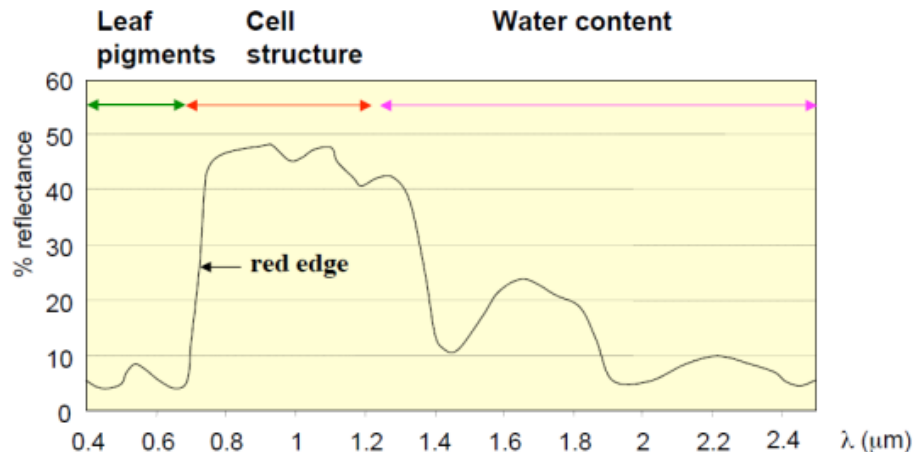


Introduction

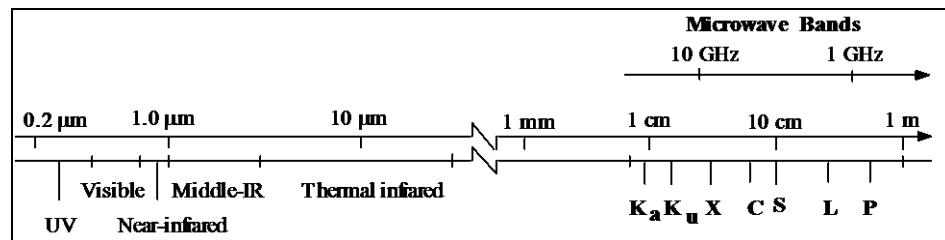
- Frozen temperatures are a major constraint to northern high latitude (NHL) growing seasons.
- Winter frozen season strongly influences vegetation dormancy & productivity.
- Abrupt near 0°C, the landscape freeze/thaw (FT) state transition is a natural analog to a hydrologic & biospheric on/off switch.
- The FT signal from satellite microwave remote sensing is closely linked to frozen temperature constraints to vegetation phenology & productivity, land-atmosphere trace gas exchange (e.g., CO₂) & surface water mobility.
- Spring thaw signal coincides with growing season initiation & influences atmospheric CO₂ source/sink strength.
- Recent evidence of increasing vegetation stress & water limitations to productivity with continued warming & longer non-frozen season.
- Negative factors may increasingly outweigh positive effects to plant growth, reducing productivity & C sink strength.

Remote Sensing Utility

Vegetation index:



Electromagnetic spectrum:



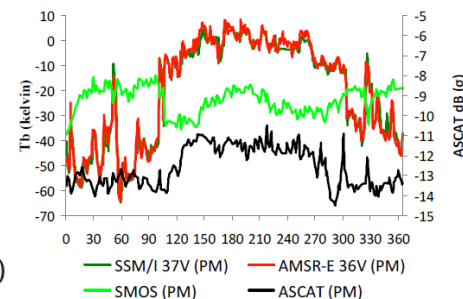
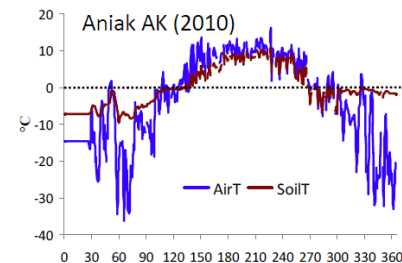
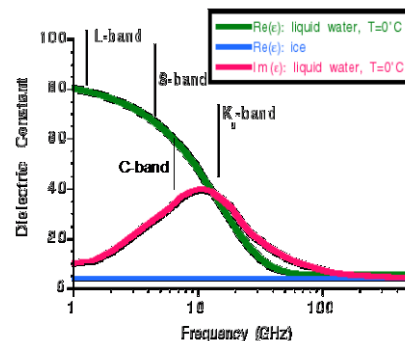
Microwave signal is less sensitive to atmospheric cloud/aerosol contamination & solar illumination effects than optical/NIR reflectance.

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}$$

$$EVI \text{ or } EVI2 = G \times \frac{\rho_{NIR} - \rho_{Red}}{L + \rho_{NIR} + C_1 \times \rho_{Red} - C_2 \times \rho_{Blue}}$$

Vegetation Indices (VI) are optical measures of vegetation canopy **greenness**

FT detection theory:



Seasonal Threshold Approach:

$$\Delta Tb = \frac{(Tb(x,t) - \text{FrozRef}(x,t))}{(\text{ThawRef}(x,t) - \text{FrozRef}(x,t))}$$

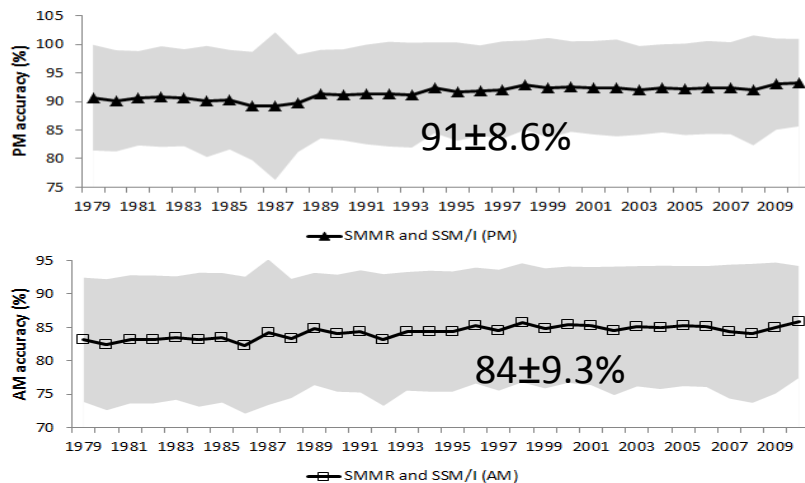
$$\Delta Tb(x,t) > T_{\text{thawed}}(x,t), \Delta Tb(x,t) \leq T_{\text{frozen}}(x,t)$$

The FT Earth System Data Record (FT-ESDR)

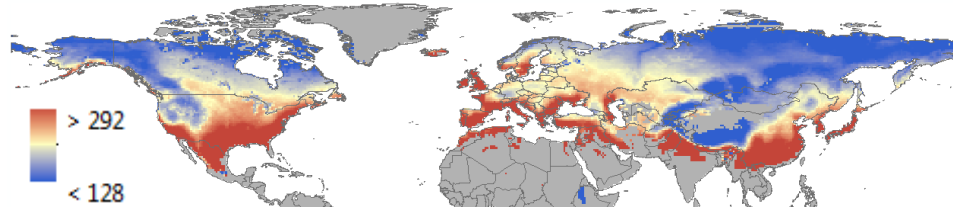
Approach:

- Domain: Global vegetated land areas where frozen temperature constrain annual productivity;
- Integration of satellite microwave 37V GHz T_b records from SMMR & SSM/I;
- Temporal change classification of daily (AM & PM overpass) T_b series using seasonal FT reference states on a grid cell-wise basis;
- 4 discrete classification levels: F (AM&PM), NF, TR (AM frozen, PM non-frozen) & INV-TR;
- Continuous daily record (AM, PM, CO)

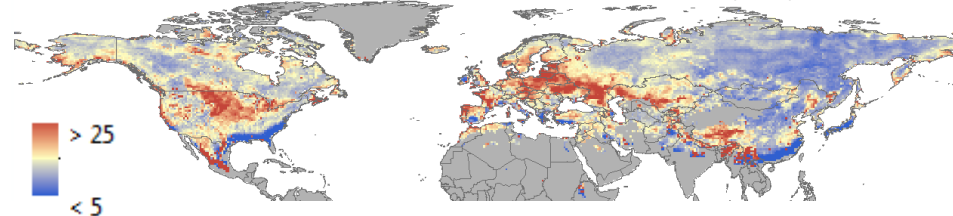
FT-ESDR QC:



Mean Non-frozen season (days), 1979-2010



Non-frozen season variation (SD, days yr⁻¹)



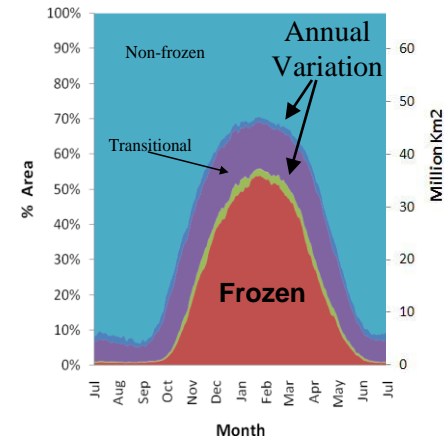
Formats:

- HDF-5, binary & Geotiff

Status:

- 2010: Initial (V.1) data release (20 yr record);
- 2012: V.2 data release (32 yr record);
- FT-ESDR publicly available (NSIDC DAAC);
- Additional updates & data releases planned.

Global FT Climatology



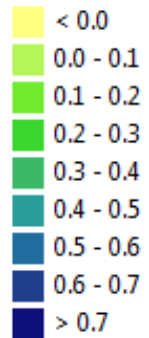
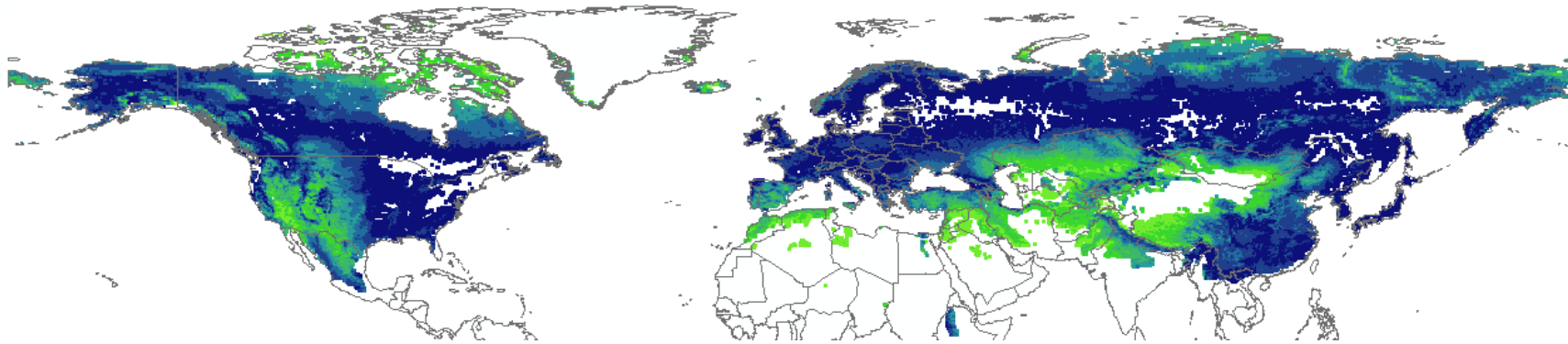
Kim et al. 2011. TGARS

VIP ESDR Vegetation Index

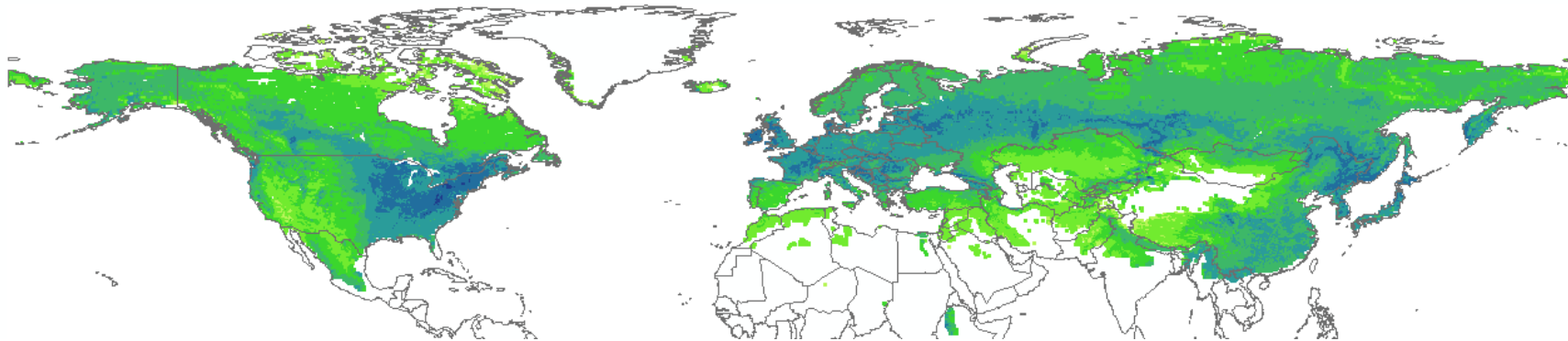
Datasets:

- NDVI & EVI2, 1982 to 2010, 0.05 degrees (5.6 km), bi-monthly product.
- Continuity Top-down Data (P4) & Good Quality Pixel.
- Re-projection to 25 x 25 km global EASE-Grid.

Summer
NDVI

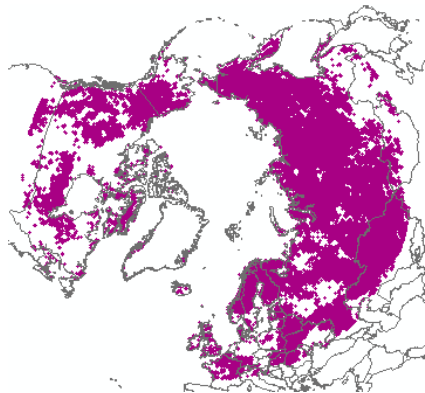
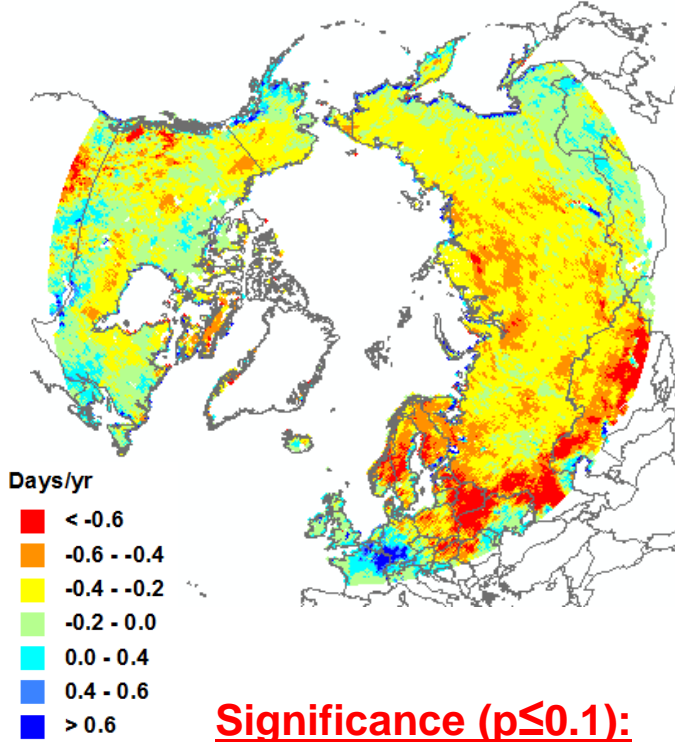


Summer
EVI2

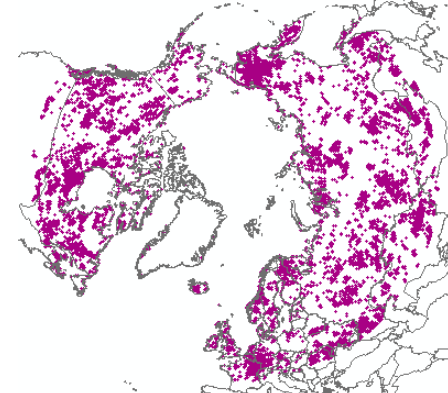
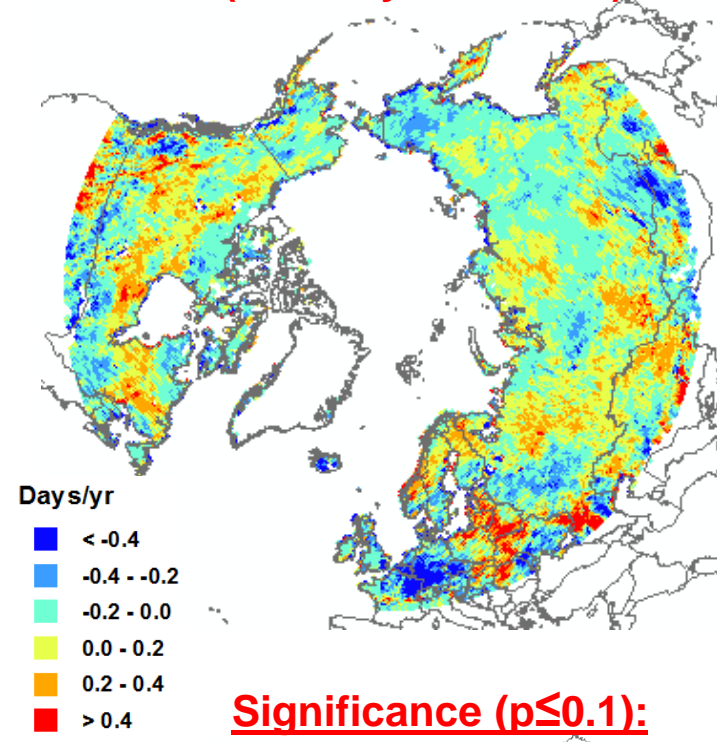


FT-ESDR NHL Annual Variability and Trends (1979-2010)

FR (JaAu) Frozen Season Trend
(-2.8 days decade⁻¹; p<0.01)

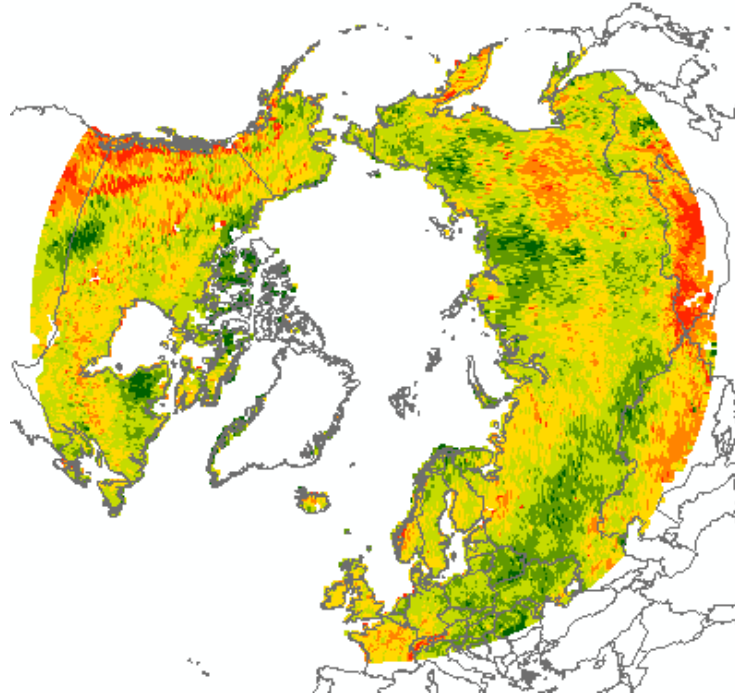


TR (JaAu) Frost Days
(0.09 days decade⁻¹)

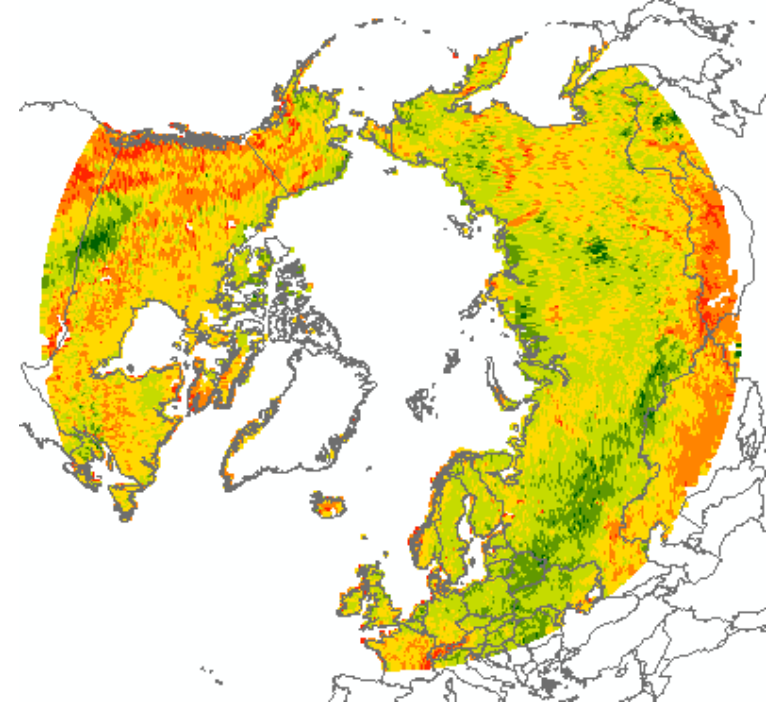


NHL Trends in VIP ESDR Vegetation index

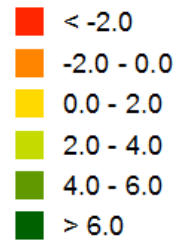
Summer NDVI Trend
(2.3 % decade⁻¹; p<0.1):



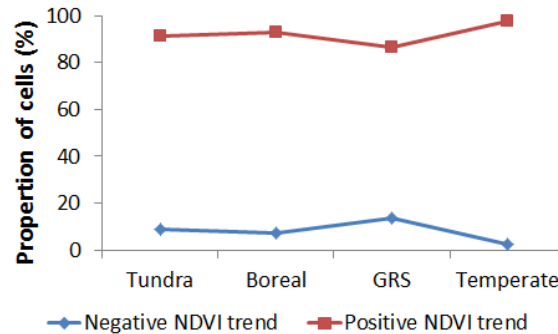
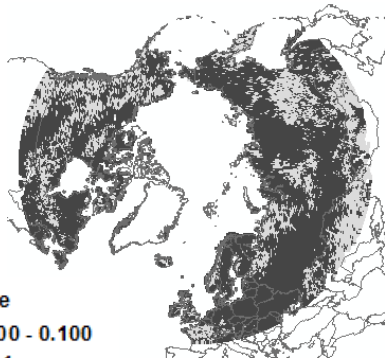
Summer EVI2 Trend
(1.8 % decade⁻¹; p<0.1):



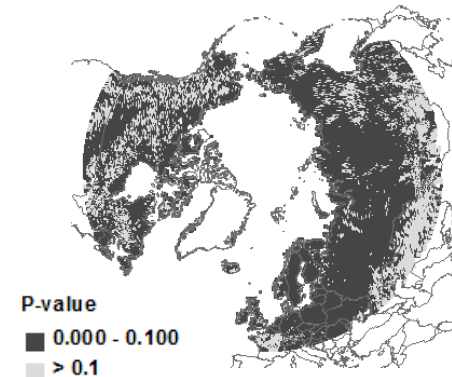
% decade⁻¹



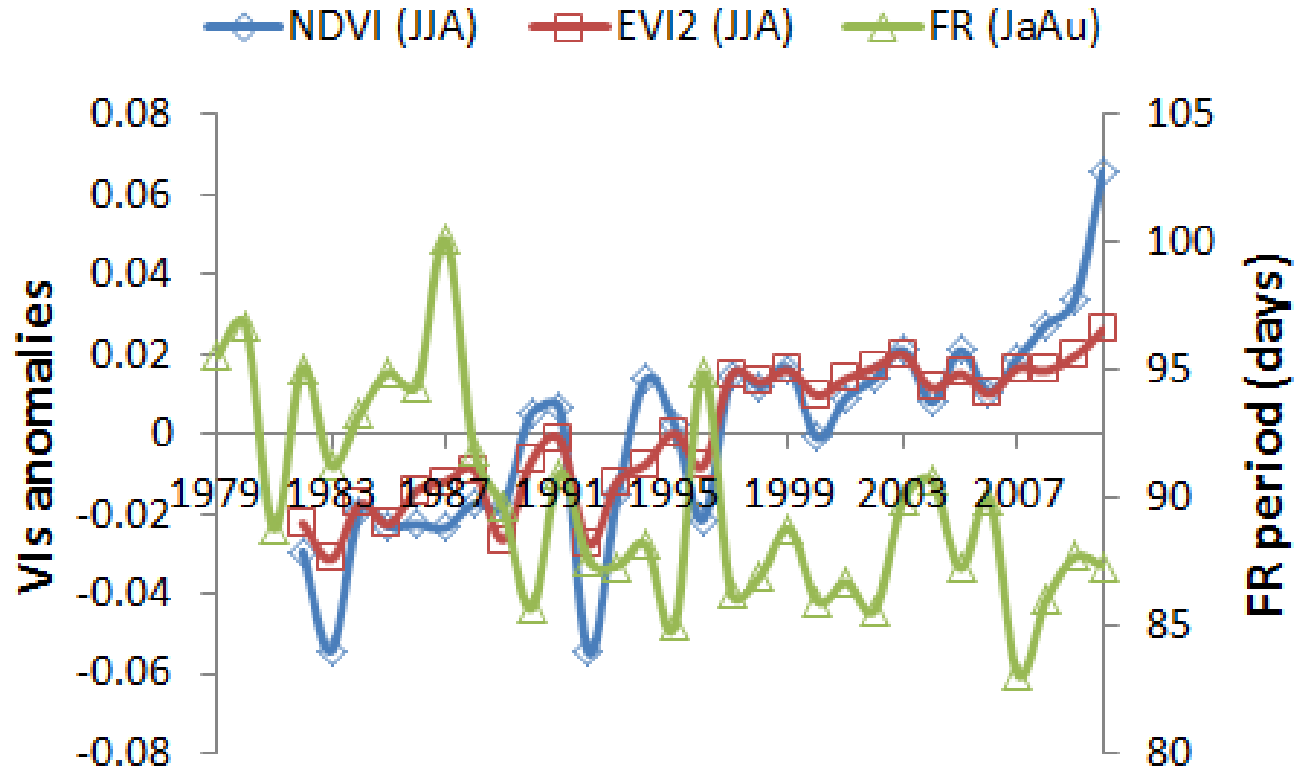
Significance (p≤0.1):



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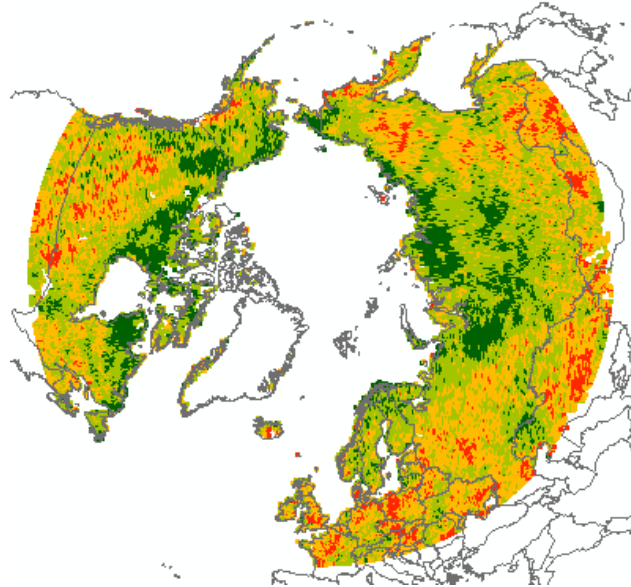
Mean Annual NHL VI and FR (JaAu) Season Variability



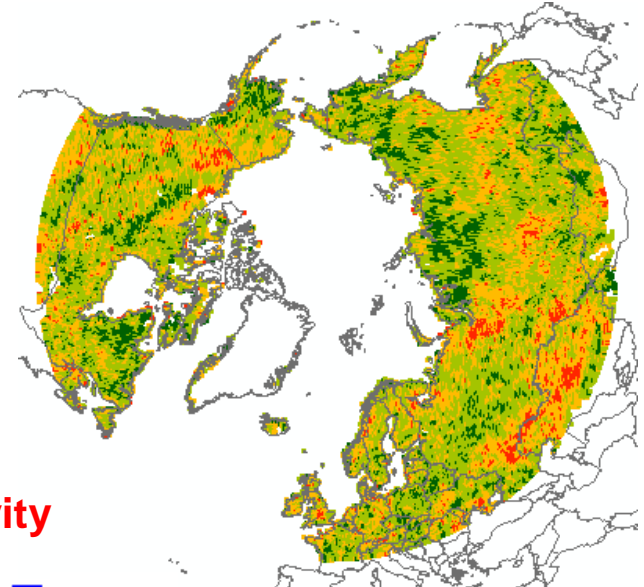
Vegetation Response to FT-ESDR Frozen Season Changes

- Negative relationships between FT-ESDR frozen season variability & VIP NDVI for energy constraint regions; FT effects reduced or reversed in more water limited areas;
- Regional increases in TR frost days negatively impact NDVI summer growth for ~61% of the domain.

NDVI vs FR Season



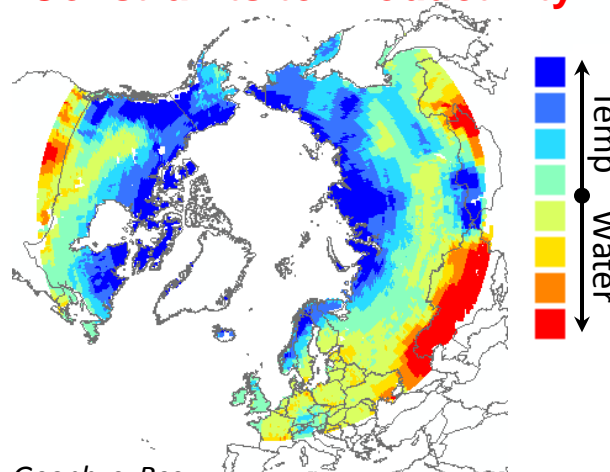
NDVI vs TR Frost Days



Correlation (r)

- Strong negative
- Negative
- Positive
- Strong positive

Estimated Climate Constraints to Productivity



Conclusions

- The FT record shows that the FR season is significantly decreasing for 50.2% of the NHL domain & 1979-2010 period;
- The NDVI & EVI2 trends indicate that NHL vegetation is predominantly greening, coincident with a declining FR season (warming);
- Weak annual correspondence between the VIs & FR season variability reflects opposing FR impacts on vegetation growth between energy & water constrained portions of the domain;
- A declining FR season is generally promoting vegetation growth in NHL cold temperature constrained areas, while these effects are weaker or reversed in more water constrained areas; potential benefits of a shorter FR season are offset by apparent negative productivity effects of an increasing trend in TR frost days in some areas.

Research Team

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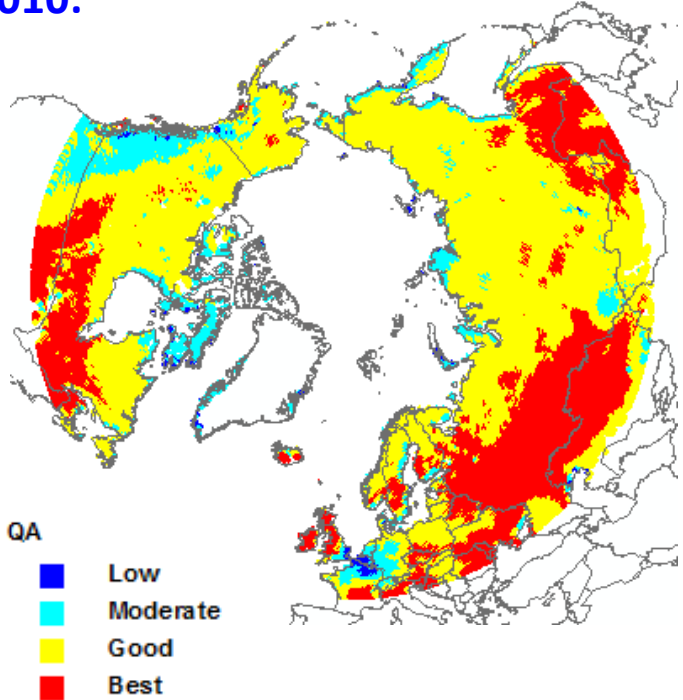
Funding source: NASA Making Earth System Data Records for Use in Research Environments (MEaSUREs) program

<http://freezethaw.ntsg.umt.edu>

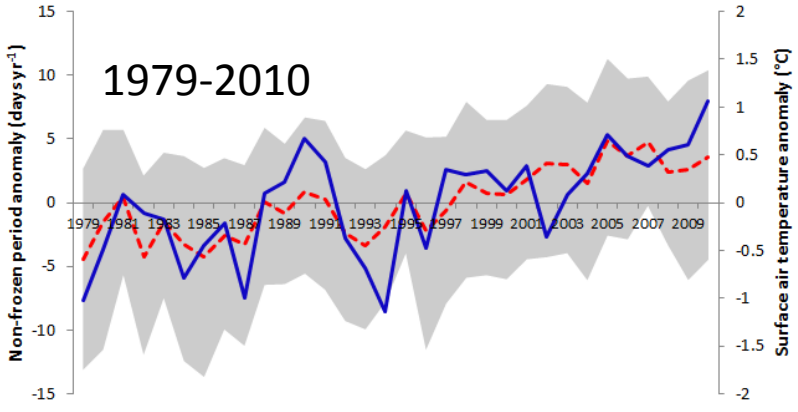
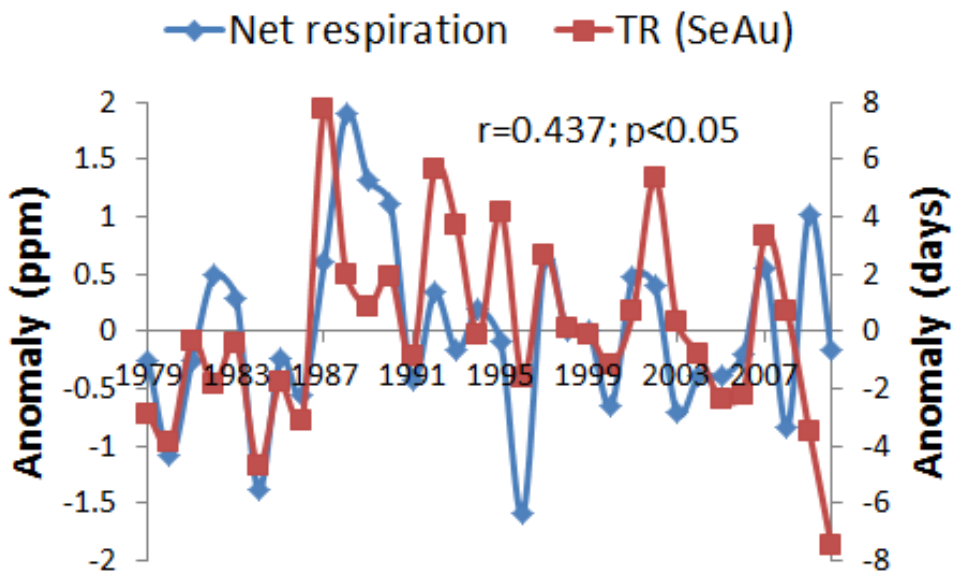


Extra slides

FT-ESDR Quality Assessment (QA) for 1979-2010:



Frozen season influence on NHL atmospheric CO₂ seasonal cycle:



--- Mean T_{av} — Non-frozen period ■ T_{av} uncertainty range