Remote Sensing of Soil Freeze - Thaw Cycles
Growing Season Changes in North America and Eurasia

Nicole V Smith*, Sassan S. Saatchi[1], and James T. Randerson[2]
***California Institute of Technology, Pasadena, CA 91125**
nicolev@gps.caltech.edu

EPA Science Forum 2004
Healthy Communities and Ecosystems

1. Introduction:

Goal: To detect annual dates of
- **soil freeze and thaw using**
- **microwave satellite data.**

Importance: The timing of soil
- **freeze and thaw sets the growing**
- **season length for plants and**
- **determines when significant**
- **decomposition of soil organic**
- **matter can occur. Major**
- **implications for global carbon**
- **cycle**

2. Theory and Methods:

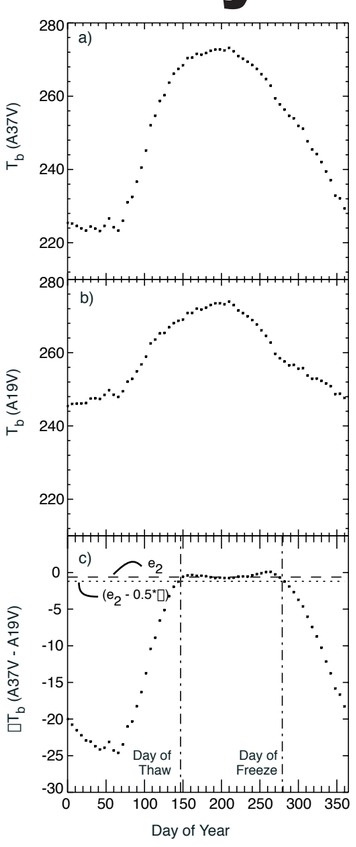


Figure 1. Average 37 GHz (a), 19 GHz (b) and 37-19GHz (c) signals. Smith et al. in press

$T_b(\Box)$ = Brightness Temperature measured by satellite at frequency ($\Box$)

$T_b(\Box) = T_{surface} * \text{emissivity}(\Box)$

$\text{emissivity}(\Box) = \Box(\Box)$

We use the difference between measurements at 37 and 19 GHz

$$\Box T_b(37\text{-}19) = T_b(37) - T_b(19) =$$
$$(T_s * \Box(37)) - (T_s * \Box(19)) =$$
$$T_s(\Box(37) - \Box(19)) =$$
$$\boxed{T_s * \Box\Box}$$

The difference $\Box\Box$ provides the sensitivity to the freeze-thaw state of a pixel

If soil is frozen $\Box\Box < 0$
If soil is thawed $\Box\Box\Box 0$ [2]

This leads to a plateau shaped curve, where the width of the plateau corresponds to the length of time soil is thawed

3. Results:

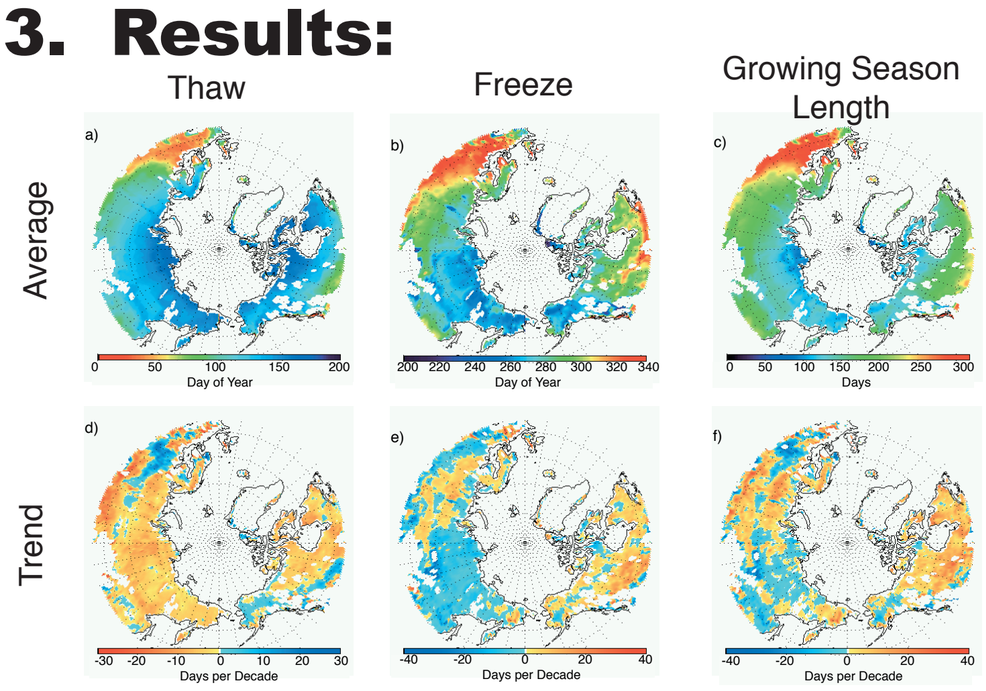


Figure 2. Average date of thaw (a), freeze (b) and growing season length (c) for all latitudes north of 45° N. Trend in thaw (d), freeze (e) and growing season length (f) over the period 1988-2002. Smith et al. in press.

4. Results Continued:

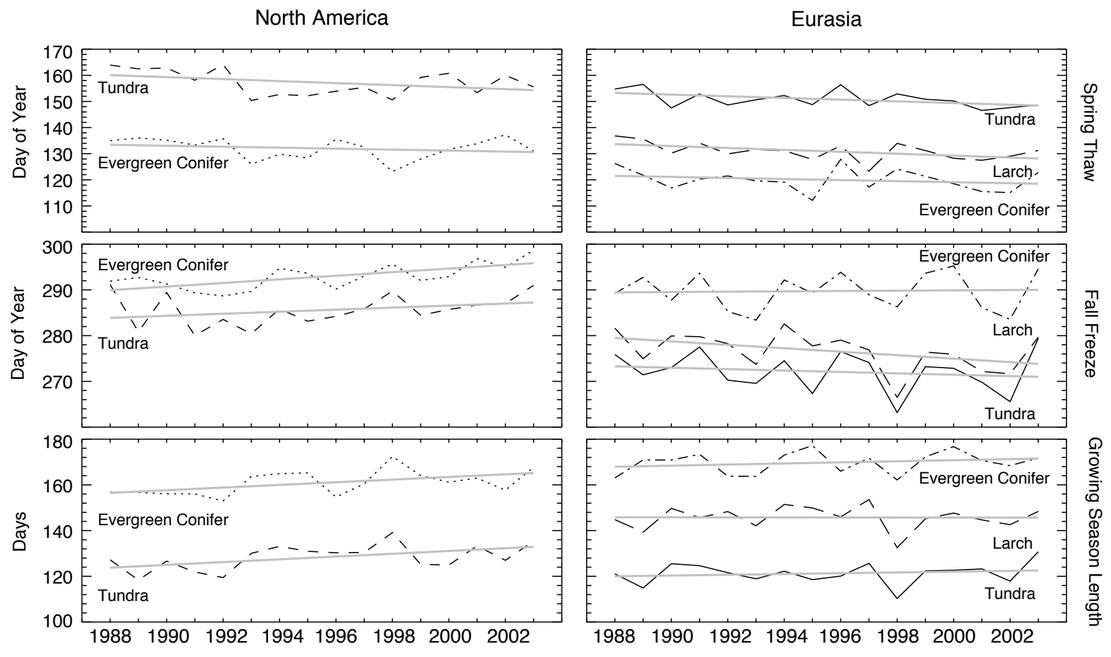
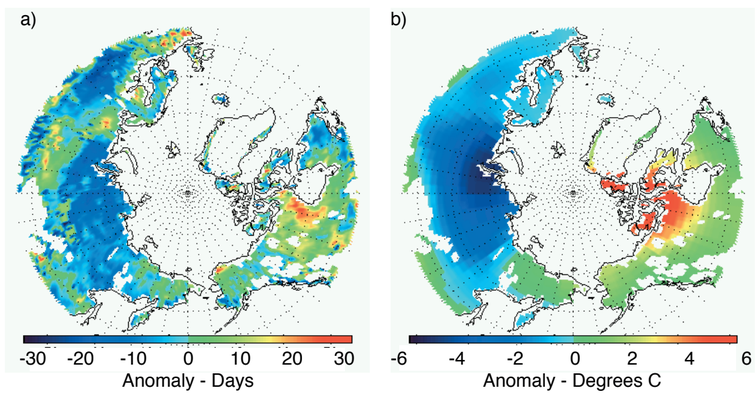


Figure 3. Biome level trends in thaw, freeze and growing season length for North America and Eurasia. Smith et al. in press.

The growing season length is INCREASING by ~5 days/decade in North America and is SHIFTING ~5 days/decade earlier in Eurasia

5. What is causing these changes?



Smith et al. in press

Figure 4. 1998 anomaly in fall freeze (a) and fall surface air temperature (b). Air temperature data from Hansen et al. 2001.

Anomalies in freeze and thaw are highly correlated to anomalies in surface air temperature.

6. Impact on Health and the Environment:

-Implications for the global carbon cycle
- **Increased CO_2 emissions during fall in**
- **North America.**
- **May increase plant growth and CO_2**
- **uptake in Eurasia (Especially Russia)**

-Increased melting of permafrost

N. Smith is supported by the NCER STAR Program, EPA

1. S.S. Saatchi, NASA Jet Propulsion Laboratory, Pasadena, CA USA
2. J.T. Randerson. Department of Earth Systems Science. University of California, Irvine, CA USA

Smith, N.V., Saatchi, S.S., and J.T. Randerson. (in press) Trends in High northern latitude soil freeze and thaw cycles from 1988 to 2002. Journal of Geophysical Research, Atmospheres.

Science and Innovation to Protect Health and the Enviroment