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Study of deciduous needle-leaved forests phenology changes in Siberia

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DATA AND METHODS

Aim

Study of deciduous needle-leaved forests phenology changes in Siberia on satellite data.

Data and Methods

We estimated day of year (DOY) of the start of growing season (SOS) and the end of growing season (EOS) of Siberia deciduous needle-leaved forests for each year (1982-2015) from daily NDVI values based on GIMMS NDVI3g dataset. The SOS and EOS were calculated using the "Midpointpixel" method. According this method, the SOS and EOS are reached in the day of year when NDVIratio (1) value exceeds threshold 0.5 in the beginning and falls below 0.5 in the end of growing season, respectively.

$$NDVIratio = \frac{\mathrm{NDVI} - \mathrm{NDVImin}}{\mathrm{NDVImax} - \mathrm{NDVImin}} \quad (1)$$

where NDVI is the daily NDVI values and NDVImax and NDVImin are the annual maximum and minimum values of the NDVI curve.

In addition to the SOS and EOS, the productivity of the vegetation was also estimated. Productivity was approximated using the area under the seasonal NDVI curve (the time-integrated NDVI (TI-NDVI) is the sum of daily NDVI values above 0 between SOS and EOS dates).

To analyze the relationship between the time-integrated NDVI and cumulative of air temperature during growing season we calculated summer warmth index (SWI) values based on the ERA-Interim data. The SWI is the sum of daily average air temperatures above 0°C between SOS and EOS dates and is in units of °C day.

The linear trend of all studied parameters were analyzed by least squares method and their significance analyzed by Mann-Kendall (MK) test.

Study area

We defined areas of deciduous needle-leaved forests growth using the land cover map of northern Eurasia. The areas of larch growth are cover in two climatic zones - subarctic and temperate. In this regard, the study area on subarctic (Figure 1b) and temperate (Figure 1c) zones was divided. The study area was limited to lowland and plateau mask, which excludes elevations above 600 meters.

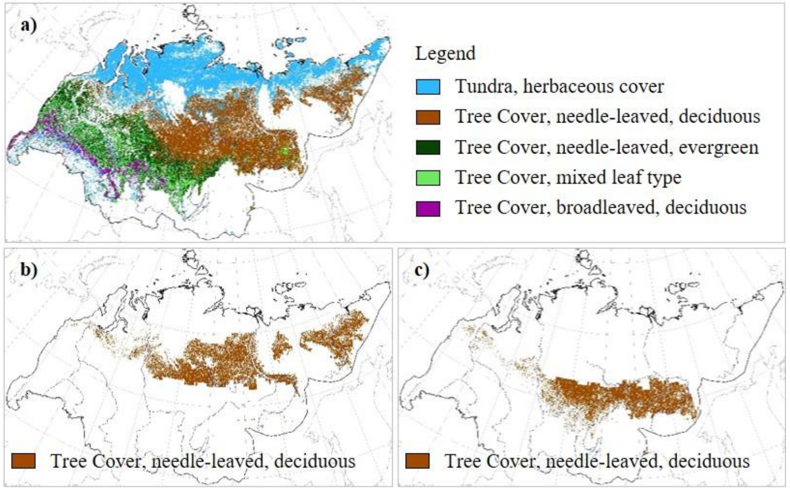

Figure 1. Areas of deciduous needle-leaved forests growth in Siberia: a) the vegetation map; b) subarctic zone; c) temperate zone.

RESULTS

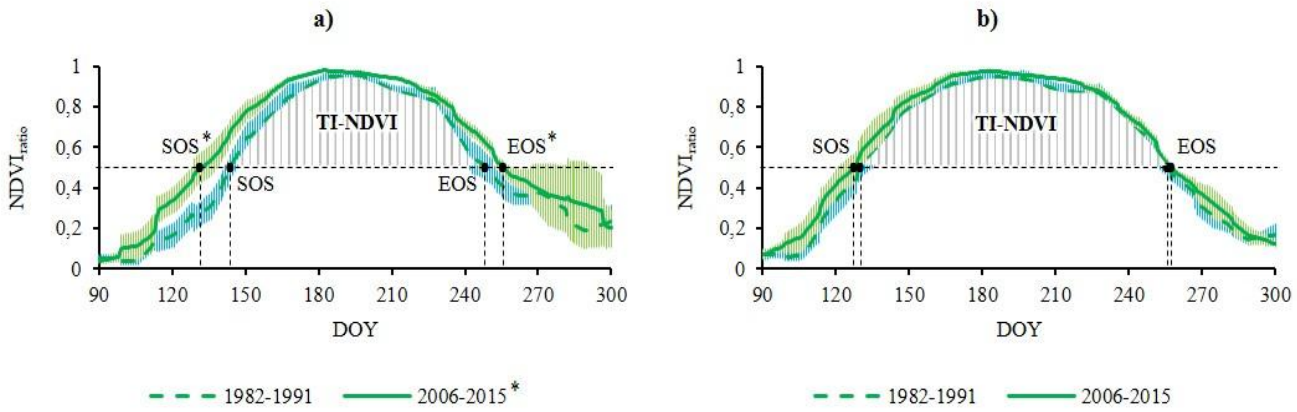

Figure 2. The $NDVI_{ratio}$ seasonal changes of deciduous needle-leaved forests in Siberia for 1982-1991 and 2006-2015: a) subarctic zone; b) temperate zone. Vertical lines of blue depict standard error of the mean from 1982-1991, and vertical lines of green depict standard error of the mean from 2006-2015.

	SOS	EOS	LOS	T
Subarctic zone	-16 (±5)*	12 (±4)*	28 (±7)*	1.7 (±0.8)*
Temperate zone	-6 (±4)	4 (±3)*	10 (±5)*	1 (±1.1)

Table 1. The trend values of phenology (SOS, EOS and LOS) parameters of deciduous needle-leaved forests in Siberia in units of number of days and the trend values of average annual air temperature (T) in units of degree Celsius (°C) during 1982-2015 for subarctic and temperate zones. The standard error of the estimate, which is indicate a measure of the accuracy of predictions, is shown in brackets. Stars indicate the trend significant based on nonparametric Mann-Kendall test (p-value <0.05*).

RESULTS

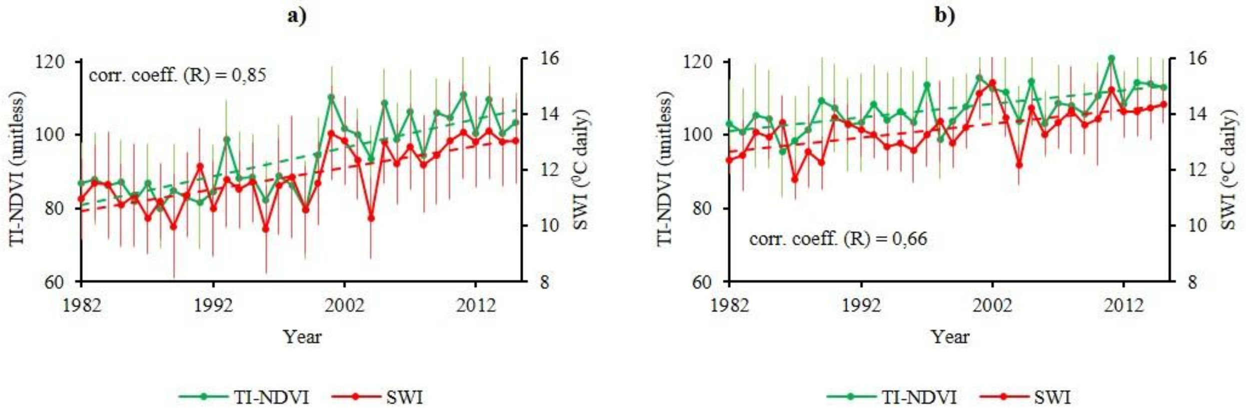

Figure 3. Variations of TI-NDVI and SWI values in areas of deciduous needle-leaved forests growth in Siberia for 1982-2015: a) subarctic zone; b) temperate zone. Vertical lines of green/red depict field standard deviation of TI-NDVI/SWI from fields of subarctic (a) and temperate (b) zones.

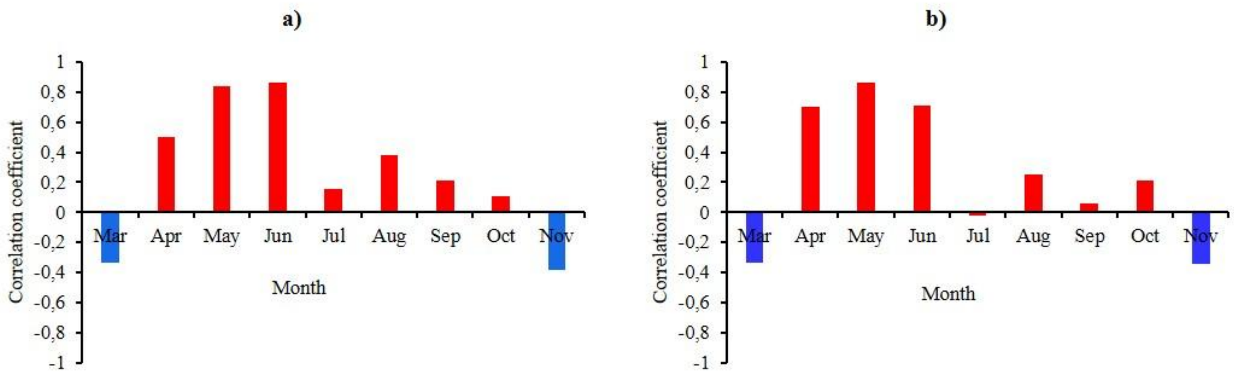

Figure 4. The correlation coefficient values between variations of monthly mean values of $NDVI_{ratio}$ and air temperature for 1982-2015: a) subarctic zone; b) temperate zone.

CONCLUSIONS

An analysis of phenology variations of deciduous needle-leaved forests in Siberia during 1982-2015 showed the significant increase of the length of growing season on ~28/±7 days in subarctic zone and in temperate zone on ~10/±5 days. The increase of the length of growing season is due to the earlier of beginning and the later of the end of growing season. At that time, the shift of dates of the start of growing season in both zones is greater than the shift of dates of the end. Perhaps this is due to a close relationship (R>0.8) between $NDVI_{ratio}$ and surface air temperature variations only in beginning of growing season because the correlation in the end of growing season is weak.

The phenology trends of deciduous needle-leaved forests during the study period in subarctic zone is ~2–3 times higher as compared with temperate zone. For same time, there is a significant increase (~1.7°C/±0.8) of average annual air temperature in subarctic zone but the trend of temperature in temperate zone is negligible.

The significant increase of the time integrated NDVI values in both zones are observed and their variations a close relation with changes of summer warmth index values: there is a high (R=0.85) correlation in subarctic zone and moderate (R=0.66) correlation in temperate zone. The trend values of the time integrated NDVI and the summer warmth index in subarctic zone are also higher as compared with temperate zone.

There is a positive trend of the annual amount of precipitation values in subarctic and temperate zones, but their correlation with phenology variations is low.