Inter- and Intra-annual Variability in Vegetation in the Northern Hemisphere and its Association with Precursory Meteorological Factors

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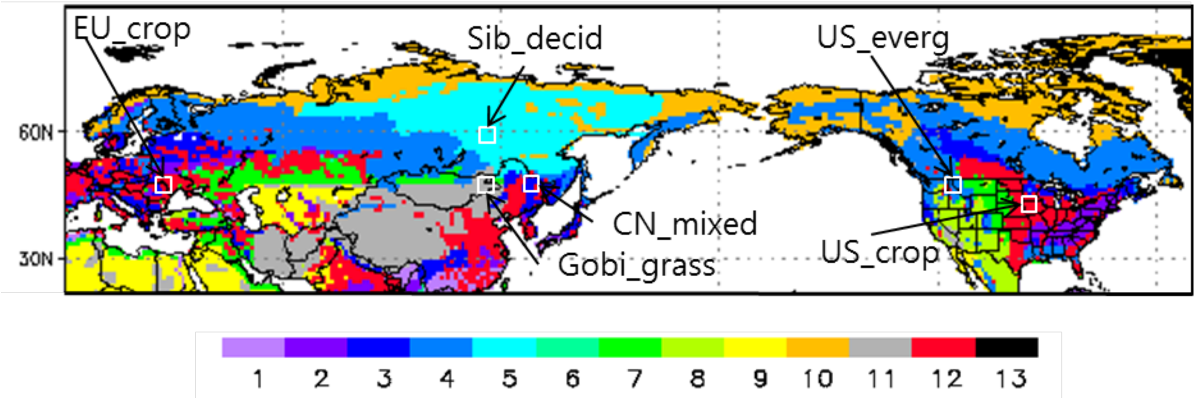
Abstract

Determination of phenological variation is one of the most critical challenges in dynamic vegetation modeling, given the lack of strong theoretical frameworks. Previous studies generally placed their focus on the timing of a phenological event (e.g., bud-burst and senescence) and its atmospheric prompts, but not on the interactive variations across phenological stages that may be affected by different dominant meteorological factors. This study investigates 1) inter- and intra-annual variability existent in all the phenological stages and 2) meteorological impacts on the variability by applying Empirical Orthogonal Function (EOF) analysis to a 25-year dataset of leaf area index (LAI) from Advanced Very High Resolution Radiometer (AVHRR). Our study sites consist of four natural and two cultivated vegetation regions located in the mid-latitudes of the Northern Hemisphere (Fig. 1).

The first mode (EOF1) is associated with the amplitude of the seasonal variation in LAI, while the second mode (EOF2) reflects the skewness of the LAI seasonal variation between late spring and early fall (Fig. 2). A correlation analysis of the principal components of EOF1 and EOF2 with preceding meteorological variables, yielded the following results (Fig. 3): (1) EOF1 is negatively correlated with vapor pressure deficit in all the study regions. It is positively correlated with springtime precipitation, but negatively correlated with temperature only in the natural vegetation regions. (2) Like EOF1, EOF2 is also influenced by meteorological variables, but the relationship between the variables varies across regions. (3) Absence of positive correlations of EOFs with precipitation in the cultivated vegetation regions can be attributed to the well-watered conditions introduced by advanced irrigation systems implemented in the croplands. The associations between the LAI and the precursory meteorological factors are possibly mediated by the environment, vegetation type, and the degree of human intervention. We expect that the present results of the space-viewed LAI will greatly improve our understanding of the interactions between the biosphere and the atmosphere.



0	sea point
1	broadleaf-evergreen trees (tropical forest)
2	broadleaf-decidous trees
3	broadleaf & needle leaf trees (mixed forest)
4	needleleaf-evergreen trees
5	needleleaf-deciduous trees (larch)
6	broadleaf trees w/groundcover (savana)
7	groundcover only (perenial)
8	broadleaf shrub w/perenial groundcover
9	broadleaf shrub w/bare soil
10	dwarf tree & shrub w/ground cover (tundra)
11	bare soil/grass
12	cultivations
13	glacial

Fig. 1. Map of the six study regions: A mixed forest region in north-eastern China (CN_mixed), a deciduous needle-leaf forest region in central Siberia (Sib_decid), an evergreen needle-leaf forest region in the United States (US_everg), a grass region in the eastern periphery of the Gobi Desert (Gobi_grass), a crop region in the United States (US_crop), and a crop region in Europe (EU_crop). Land-use types based on NCEP land cover data set (1°×1°) are indicated with colors.

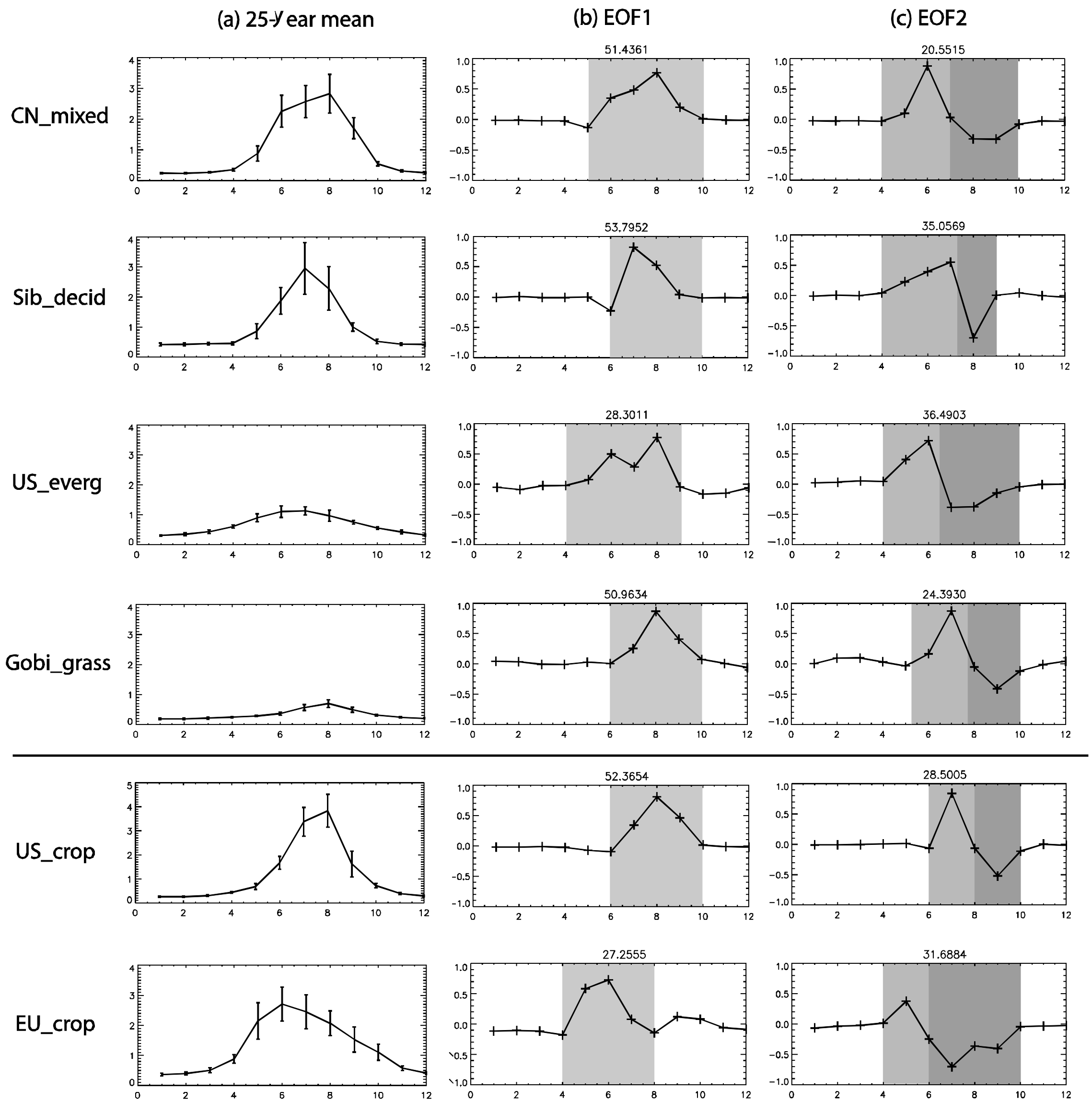
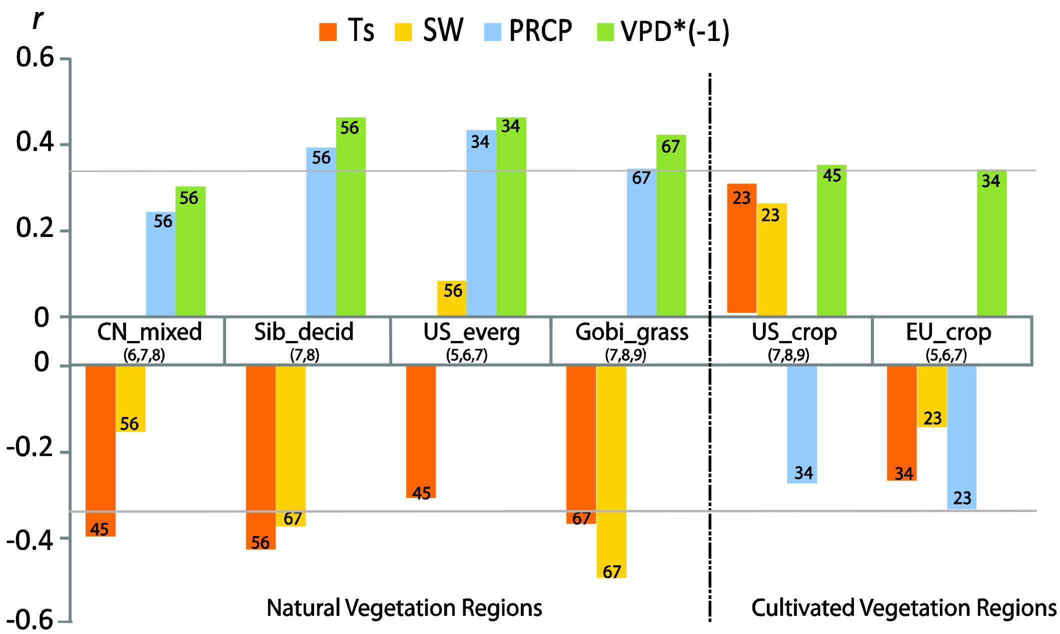
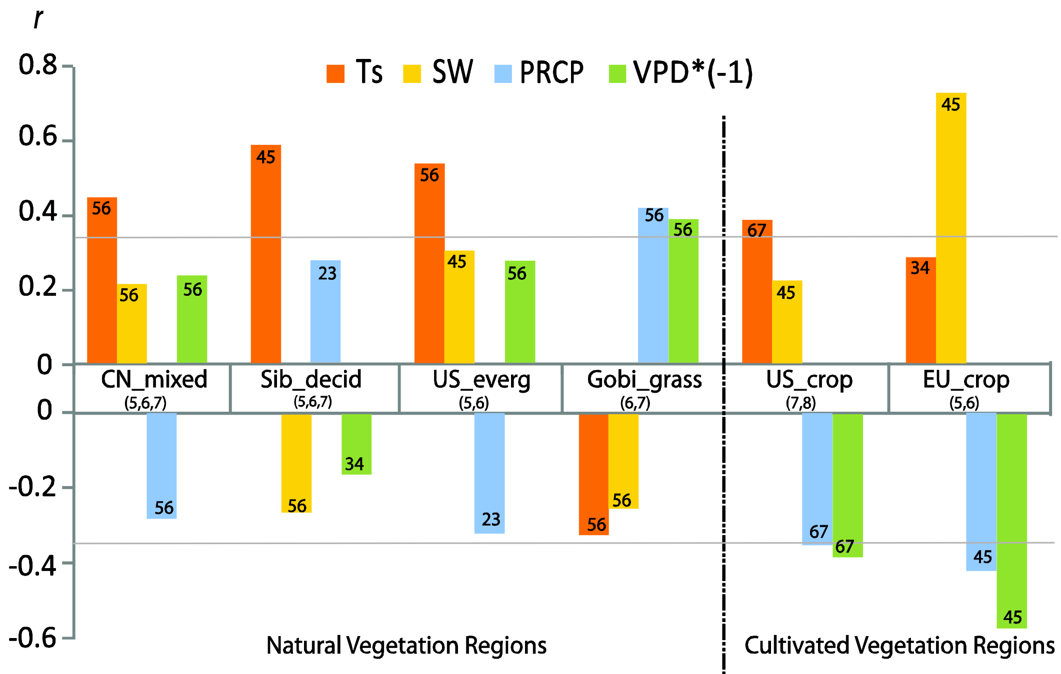


Fig. 2. (a) A 25-year mean of monthly LAI with error bars, (b) EOF1, and (c) EOF2 of the six regions in the study. The first four regions (CN_mixed, Sib_decid, US_everg, and Gobi_grass) are those with natural vegetation and the other two are those with cultivated vegetation. The X-axis represents the months. The numbers in the sub-title of each EOF mode indicate the variability (%) explained by the mode. The light-shaded period in (b) refers to the newly defined growing season, and, similarly, the light- and dark-shaded periods in (c) indicate the newly defined late spring and early fall, respectively.



(a)



(b)

Fig. 3. Correlation coefficients (*r*) of the four meteorological variables with PC1 (a) and PC2 (b) of LAI in each study region. T_s, *SW, P, and VPD* refer monthly-averaged 2-m temperature, short-wave radiation at surface, and precipitation, and vapor pressure deficit, respectively. Note that the correlation coefficients of PCs with *VPD* were multiplied by (−1.0) to make it easy to compare these with those of *P*. Numbers specified inside the bars are indicative of the months in which the highest correlation occurs. The months of the growing season and the early

spring of each study region defined in Fig. 2 are also shown below the names of the study regions in (a) and (b), respectively. Gray lines indicate the 90% confidence level.