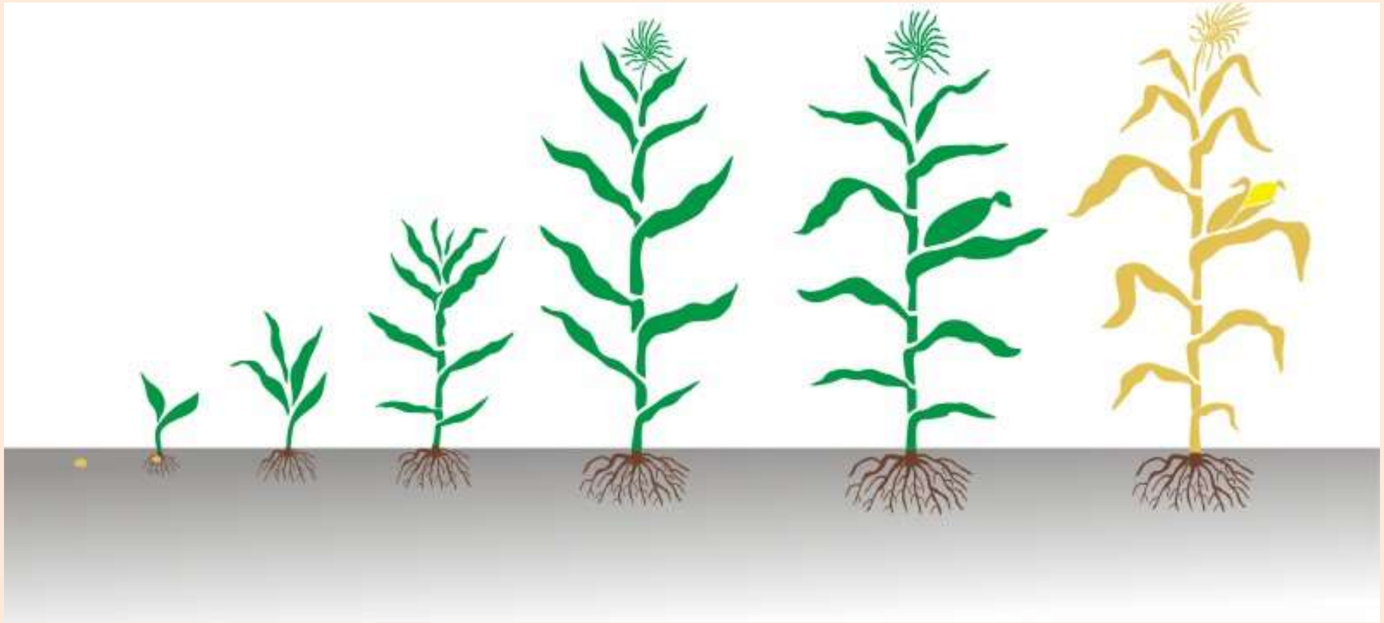
THE USE OF SATELLITE INFORMATION (MODIS/AQUA) FOR PHENOLOGICAL AND CLASSIFICATION ANALYSIS OF PLANT COMMUNITIES

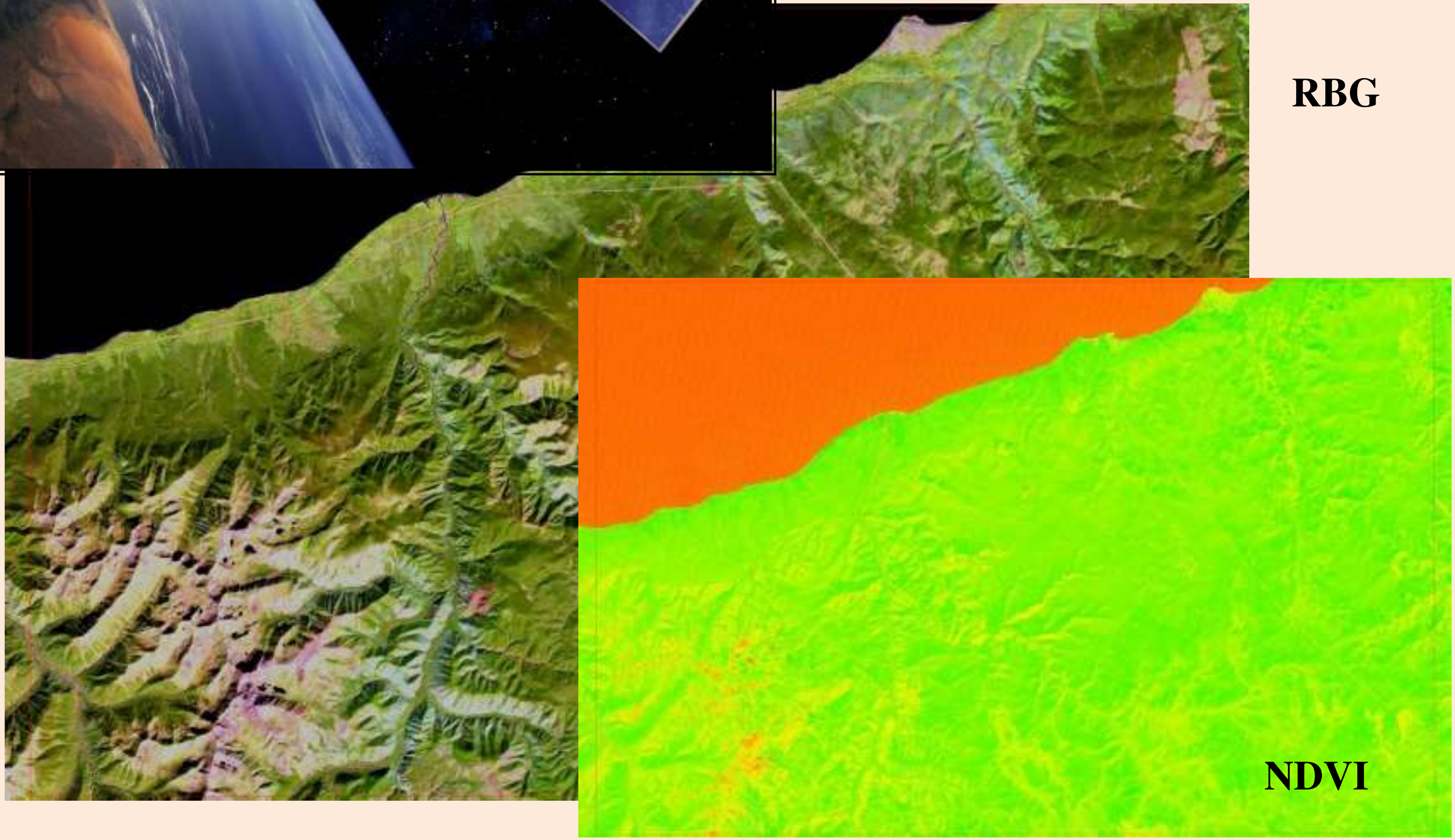
Y. Ivanova[1], V. Soukhovolsky[2], A. Kovalev[3] , O.E. Yakubailik[4]

[1]Institute of Biophysics of Siberian Branch of Russian Academy of Sciences, Krasnoyarsk
[2]Sukachev Institute of Forest Siberian Branch of Russian Academy of Sciences, Krasnoyarsk
[3]Krasnoyarsk Scientific Center Siberian Branch of Russian Academy of Sciences, Krasnoyarsk
[4]Institute of Computational Modeling Siberian Branch of Russian Academy of Sciences, Krasnoyarsk

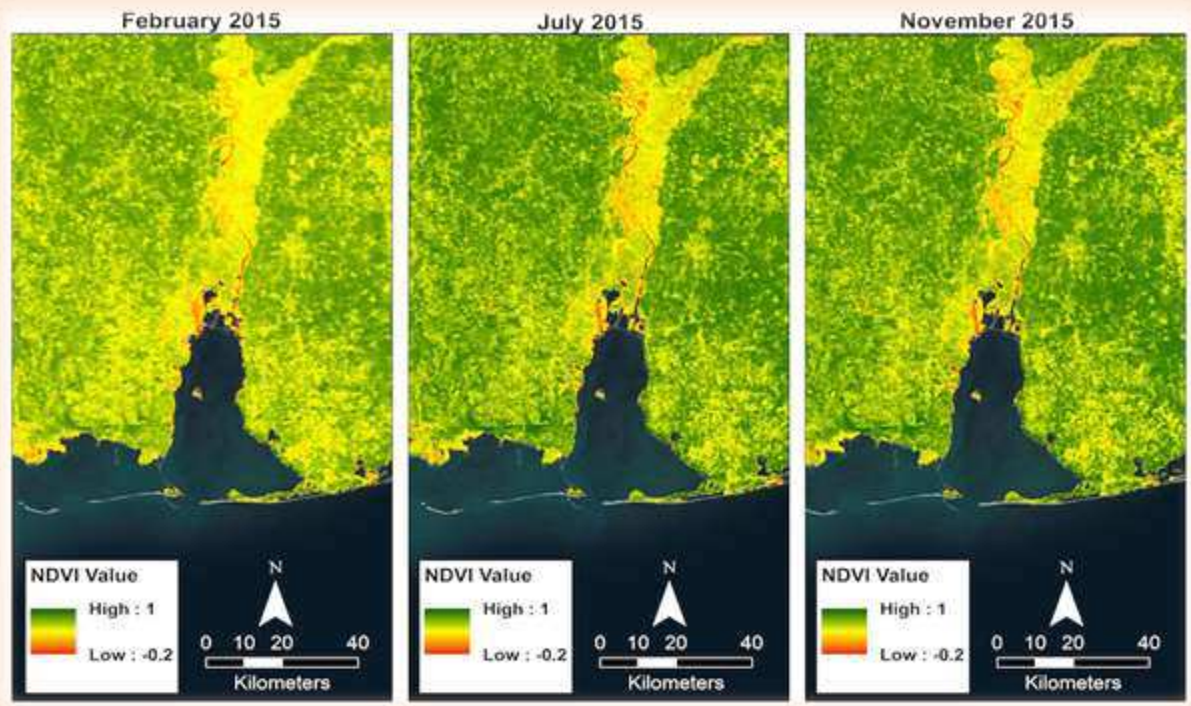
- **Vegetation phenology** is the study of periodic plant's life cycle events and how these are influenced by seasonal and interannual variations in climate and habitat factors. Examples include the date of emergence of leaves and flowers, the date of leaf coloring and fall in deciduous trees etc.
- Phenology is related to productivity and biophysical properties of an ecosystem and is a responsive indicator of climate change. The beginning of phenological events depends on plants and the temperature of atmosphere, soil, water interaction so that phenology is one of the most relevant indicators of the vegetation dynamic.



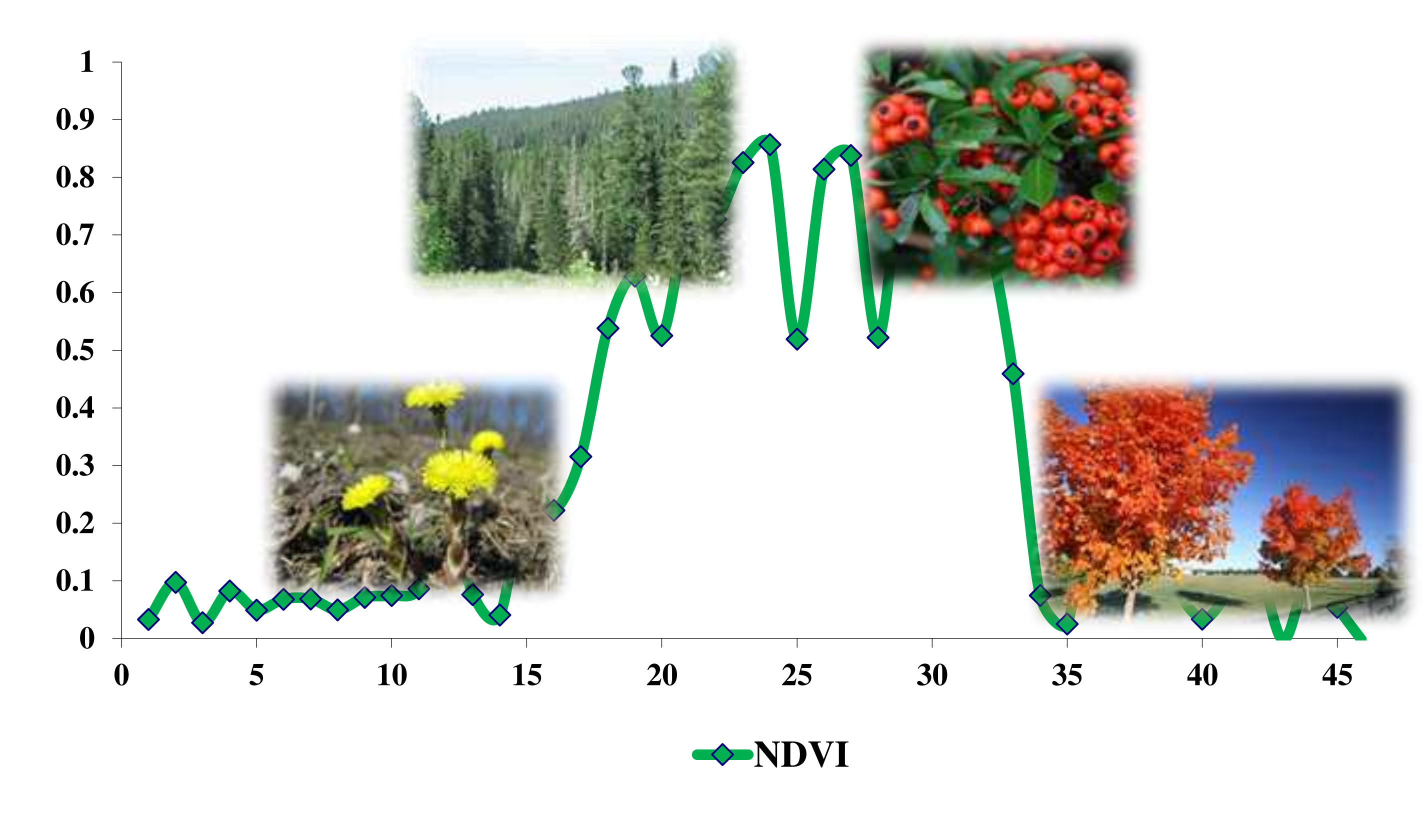
MODIS/AQUA, NASA,
Average orbit altitude is 7000 km.



- **Land surface phenology** (**LSP**) is the study of spatio-temporal development of the vegetated land surface by satellite sensors.
- **LSP** is indirectly related to plant phenology via the absorption and reflectance of radiation but is influenced by atmospheric scatter, cloud and snow cover, bidirectional reflectance effects and non-climatic factors influencing the land surface (biogenic or anthropogenic disturbances).



- Similar on-land phenology observations, remote sensing data also was focused on obtaining and estimating key date of phenological events, taking place on annual vegetation indexes curves. For example date of the start-of-spring (SOS), maximum vegetation index, etc.

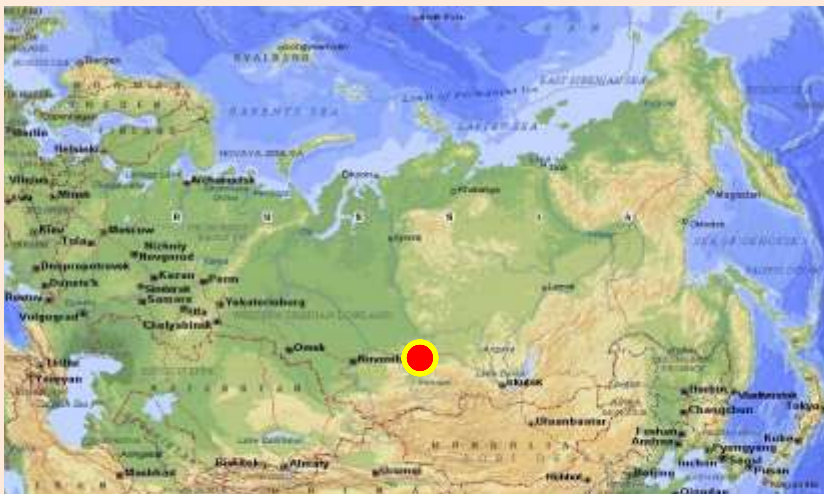


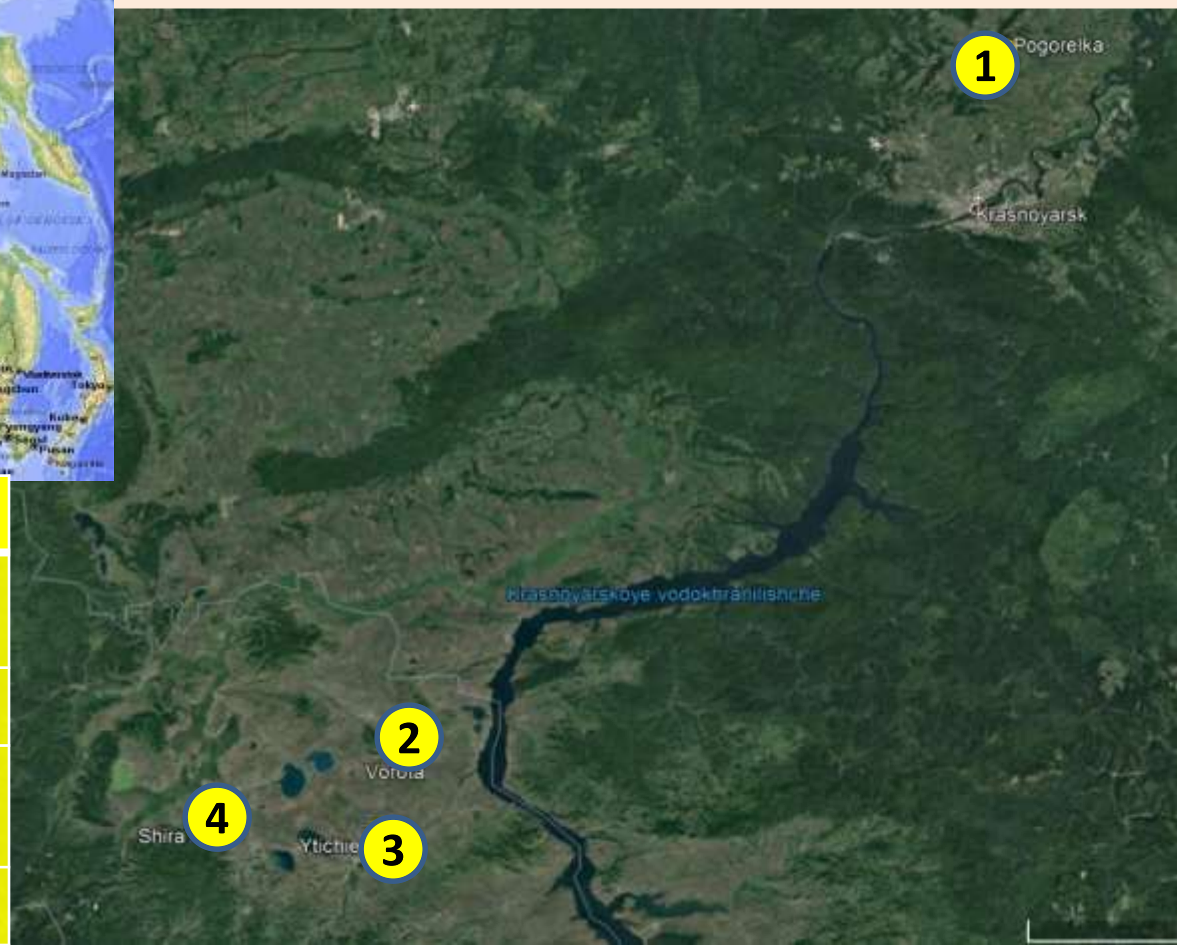
- Different species of plants, which are members of the same plant community, react to temperature, humidity changes and other weather phenomena individually.
- Different respond rate of plants to weather changes determines **specific peculiar phenology dynamic of a plant community** during vegetation season.

- Therefore, now, there is a high demand for **a more reliable approach to detect long-term phenological changes**, which are determined by changes in the composition of plant communities and its’ boundaries as a result of climatic or other impacts.

- The aim of our work is the use of annual phenological variations to classify species of plant communities according to remote sensing data NDVI (MODIS/AQUA).

- The objects of the study were plant communities of meadows, steppes and forest (deciduous and coniferous-deciduous) of the Krasnoyarsk Territory and Khakassia, Russia.





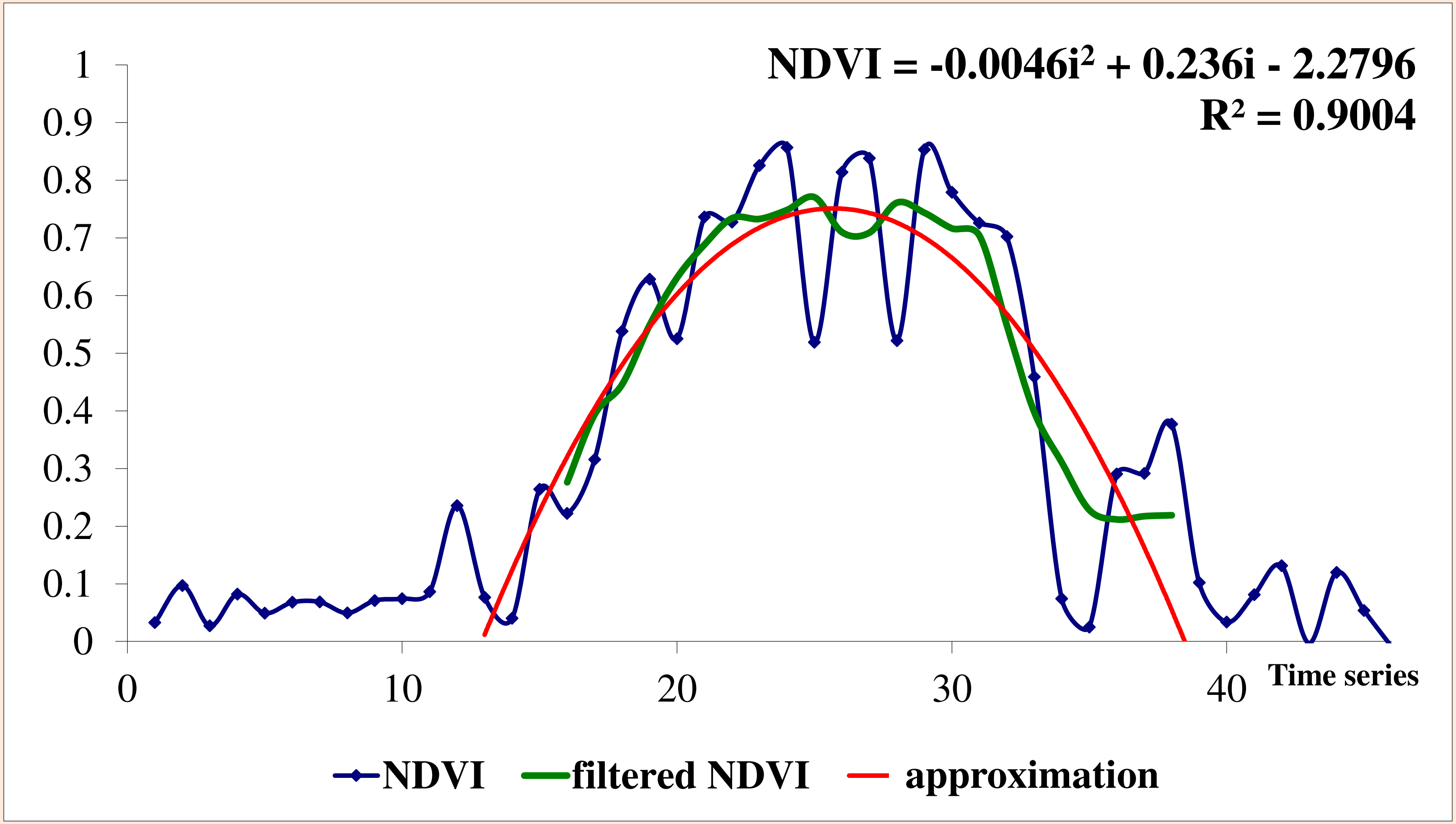
№	plant communities
1	steppes, coniferous-deciduous forests
2	steppes, deciduous forests
3	meadows, deciduous forests and coniferous-deciduous forests
4	steppes

- For the analysis of phenological dynamics in plant communities we used 8-day composite products MODIS for the value of NDVI (Normalized Difference Vegetation Index).
- A nonlinear regression analysis of the ***NDVI (t)*** time series was carried out from 2003 to 2017.

- Time series ***i*** (8-day composite) for year ***j*** was approximated with parabolic function:

$$NDVI(i,j) = a(j)i^2 + b(j)i + c(j)$$

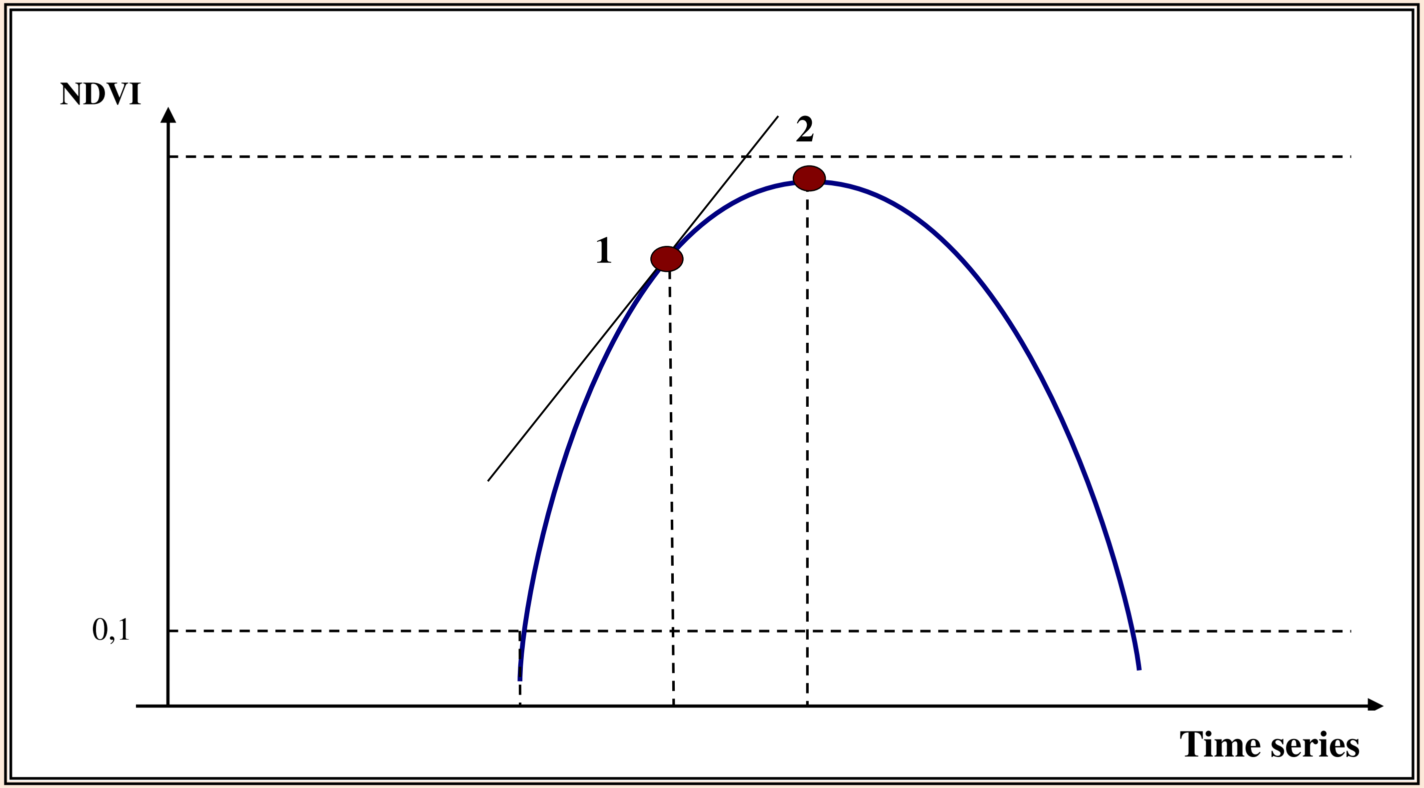
The annual dynamics of NDVI for deciduous forest (2016, site № 2)



- Every studied plant community was described by matrix S(16x3) of approximation parameters of NDVI time-series:

$$S = \begin{Vmatrix} a(1) & b(1) & c(1) \\ \dots & \dots & \dots \\ a(16) & b(16) & c(16) \end{Vmatrix}$$

where in the string ***j*** are parameters ***a, b, c*** of the regression equation approximated positive numbers of NDVI series of the year ***j***.



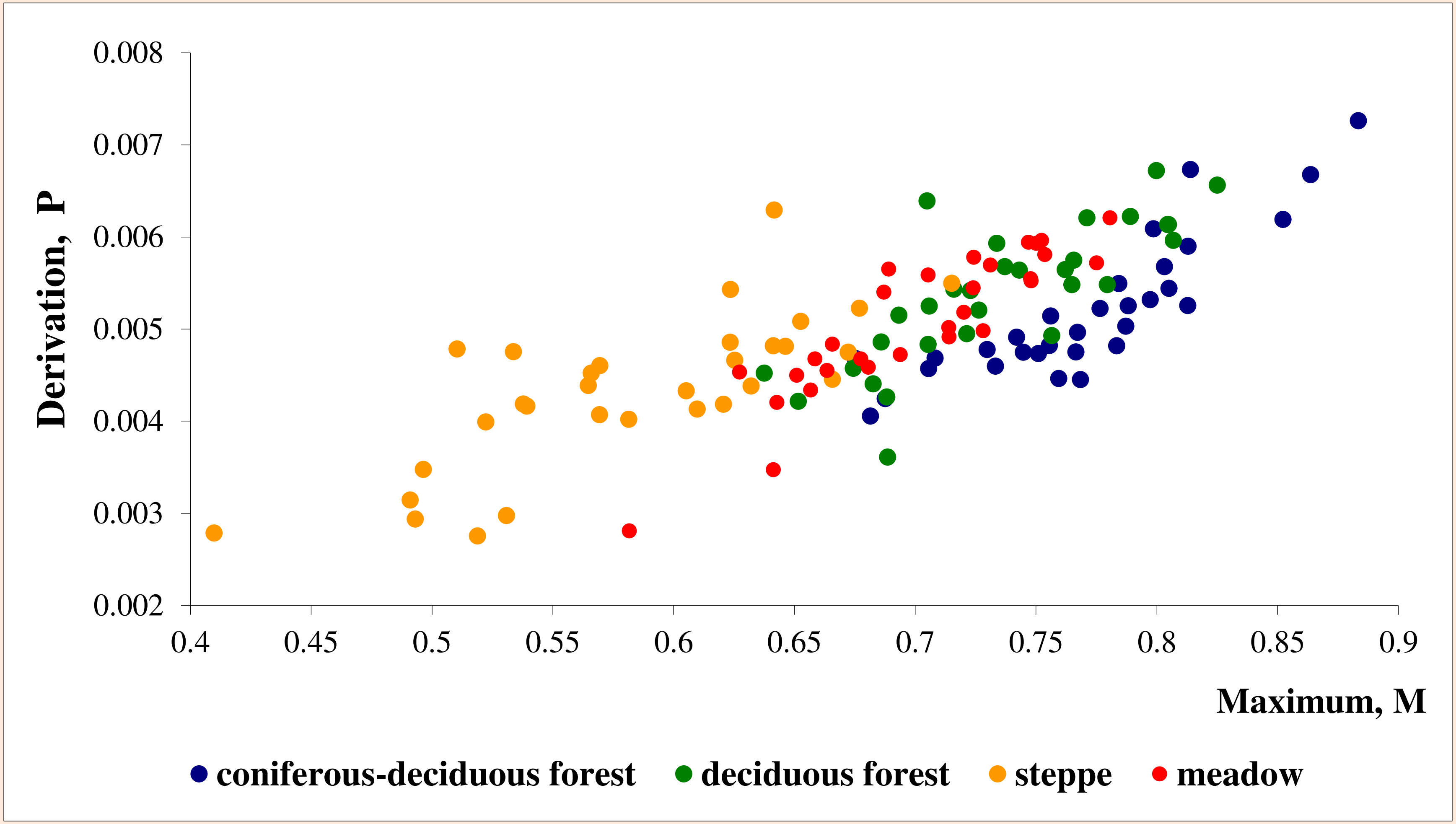
Parameters of estimation the annual dynamic of NDVI:

P – derivation of the curve in the point **1** (1/4 of the vegetation season).

M – yearly maximum value of NDVI in the point **2.**

- Analysis of the relationships between the values of the parameters of regression equations of different years has shown that the "clouds" of values in the space of the parameters for different plant communities (forest, meadow, steppe) **differ significantly** from one another. And it is possible to classify plant communities.

Parameters of annual dynamics of NDVI time-series for different plant communities






- To estimate how each observed plant community respond to the variations of weather, dependence of parameters of approximation of NDVI time-series on weather factors we used the average monthly hydrothermal coefficient (HTC).
- HTC is ratio between integral precipitation and average monthly temperature in the region of observations. Matrix HTC was built:

$$HTC = \begin{Vmatrix} HTC(A,1) & HTC(M,1) & HTC(Ju,1 & HTC(J,1 & HTC(Ag,1) \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ HTC(A,16) & HTC(M,16) & HTC(Ju,16) & HTC(J,16) & HTC(Ag,16) \end{Vmatrix}$$

where ***HTC(A,j), HTC(M,j), HTC(Ju,j), HTC(J,j), HTC(Ag,j)*** are average monthly hydrothermal coefficients of April (A), May (M), June (Ju), July (J), August (Ag) of year ***j***

- Then **canonical correlations** between matrix ***S*** of parameters of approximation of NDVI time-series and weather factors ***HTC*** were calculated.
- Calculations showed that value of the first canonical coefficient between matrices ***S*** and ***HTC*** are significant and reach 0.7 - 0.8.

Correlation matrix for forest and meadow

0 - coefficients are not significant,

± coefficients are significant

Forest

weather	**NDVI**		
	a	**b**	**c**
HTC apr	**-**	**+**	0
HTC mai	0	0	0
HTC juny	0	0	0
HTC julay	0	0	0
HTC aug	0	0	0

Meadow

weather	**NDVI**		
	a	**b**	**c**
HTC apr	0	0	0
HTC mai	**+**	**-**	**+**
HTC juny	0	0	0
HTC julay	0	0	0
HTC aug	0	0	0

Conclusion

- Using long-term observations of NDVI along with weather data **it is possible to classify and divide** forest, steppe and meadow plant communities.

- In comparison with early studies, the use of this statistical approach improves the ability to identify different plant communities, despite significant annual changes in the NDVI time-series related to climatic and non-climatic factors.

Thank you for your attention!

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