Land cover land use change effects on surface water quality: Integrated MODIS and SeaWiFS assessment of the Dnieper and Don River basins and their reservoirs

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Questions we aim to answer

- To what extent can the significant changes in surface water quality following the collapse of the Soviet Union be linked to the significant changes in land cover and land use?

- Can inland water quality be effectively monitored using SeaWiFS and MODIS standard data products and new value-added products?

Why observe reservoirs?

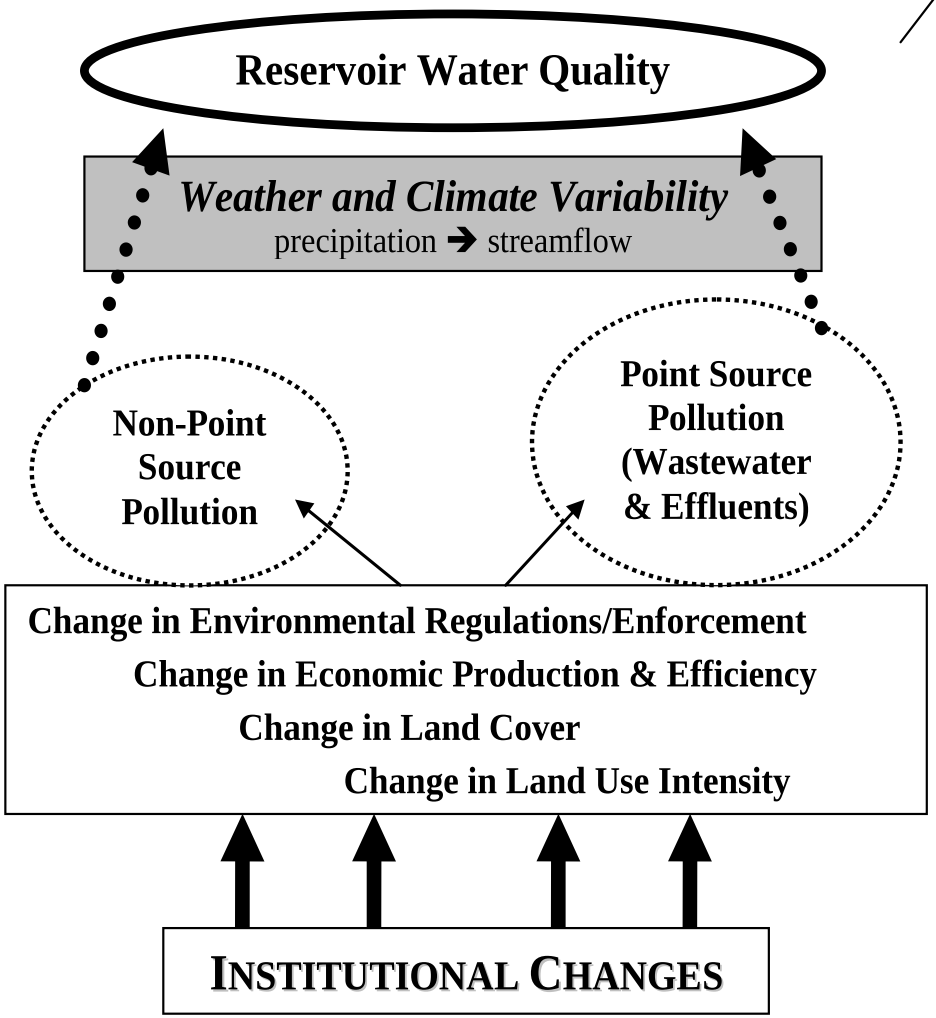
- Flow of water over and through land influences the chemical composition of the receiving waters.
- Streams and rivers can be considered as "integrators" of the environmental and ecological conditions of watersheds and basins.
- Significant changes in land cover and/or land use can affect surface water quality.

Reservoir water quality responds to

1. <u>**weather**</u> **in the form of the hydraulic forcing of changing flows,**
2. <u>**anthropogenic activities**</u> **in the form of the influxes of suspended sediments and dissolved and/or adsorbed nutrients and toxicants, and**
3. <u>**ecological processes**</u> **in the form of the aquatic and benthic biota's responses to changing environmental conditions induced by weather and humans.**

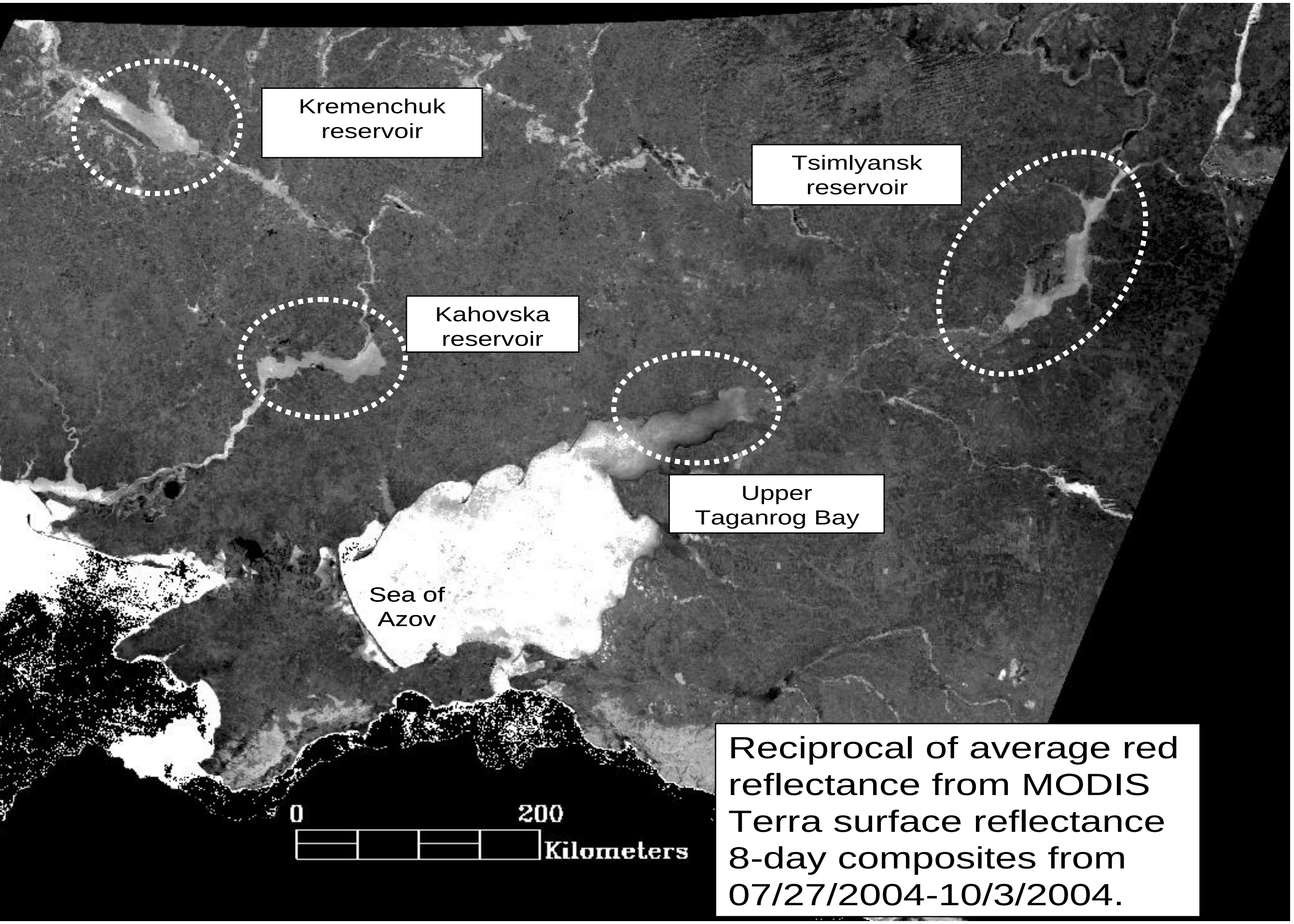
Conceptual linkages between institutional change, climatic variation, and observable water quality in major reservoirs

Vast reservoirs are not unusual in the NEESPI region: the Volga, Don, Dnieper, Kuban, and Dniester all have large hydrotechnical constructions to regulate seasonal flooding, generate hydroelectric power, and supply irrigation water.



Study areas

Tsimlyansk area is 39% of Chesapeake Bay, but 57% of its volume!



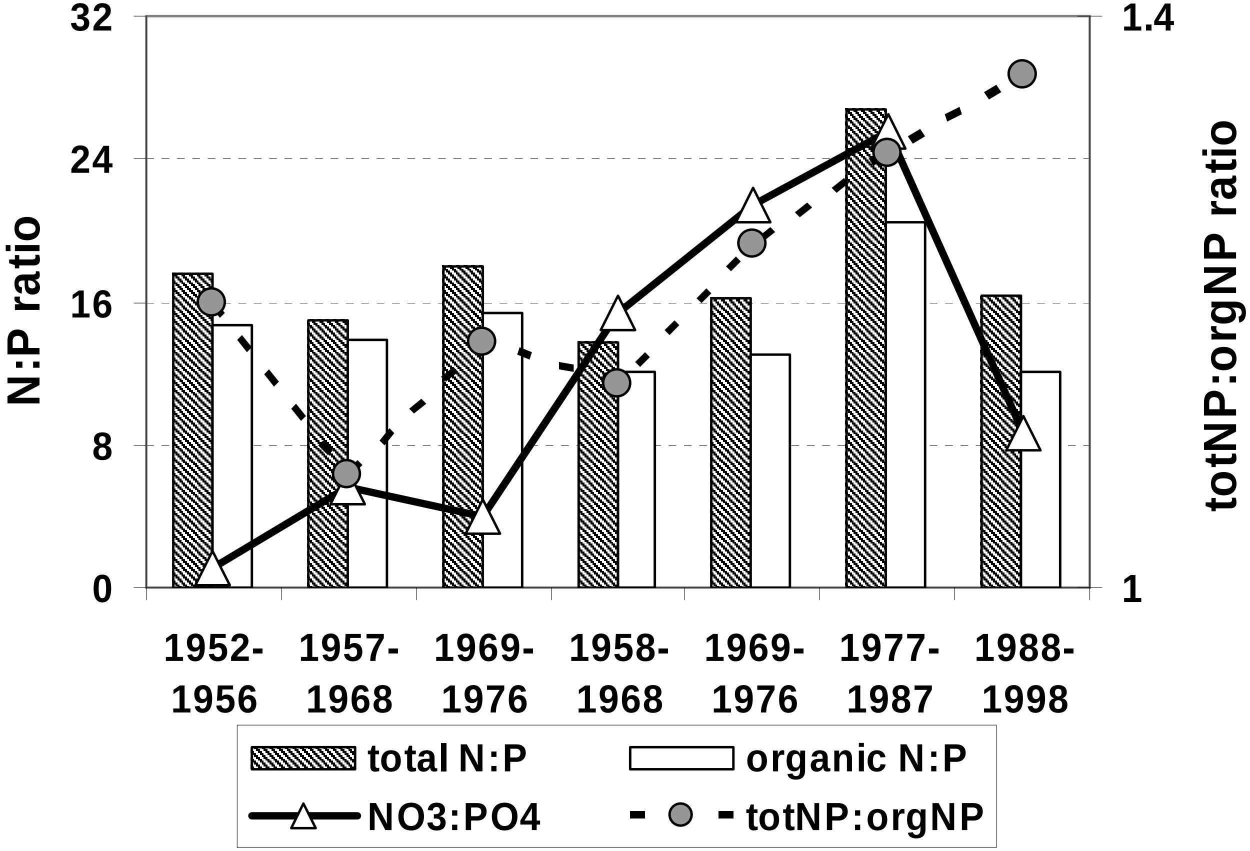
Tsimlyansk Reservoir on the Don River
Area: 272,000 ha
Length: 300 km
Width: 40 km (avg)
Depth: 9 m (avg)

Kremenchuk Reservoir on the Dnieper River
Area: 225,200 ha

Kahovska Reservoir on the Dnieper River
Area: 215,500 ha

Of the 75 largest reservoirs on planet, the countries of the Former Soviet Union host 29 with a total surface area of more than 5,000,000 ha.

Gulf of Taganrog



The Don River empties into the Gulf of Taganrog.

Trends in elemental ratios reveal increasing eutrophication until the collapse of the Soviet Union and the concomitant drop in fertilizer use.

Data from Studenikina et al., 1999.

Redfield ratio (N:P::16:1) describes the mean stoichiometric proportions of phytoplankton in the open ocean.

When N:P=16, phytoplankton are limited by P availability.

When N:P < 12, N becomes limiting and cyanobacteria blooms are likely.

When N:P > 20, the system is N-polluted.

Figure displays three kinds of N:P ratios—the classic total N:P, the ratio of organic N to organic P, and the ratio of nitrate to phosphate, which provides an indication of agricultural nonpoint-source pollution from fertilizers.

Methodology

UNL component

- Developed and tested the applicability of an inversion technique to retrieve chlorophyll-*a* concentrations from reflectance spectra of turbid productive waters.
- Now testing these algorithms using SeaWiFS and MODIS data to monitor chlorophyll-*a* and total suspended matter concentrations in reservoirs of Dnieper and Don river basins.

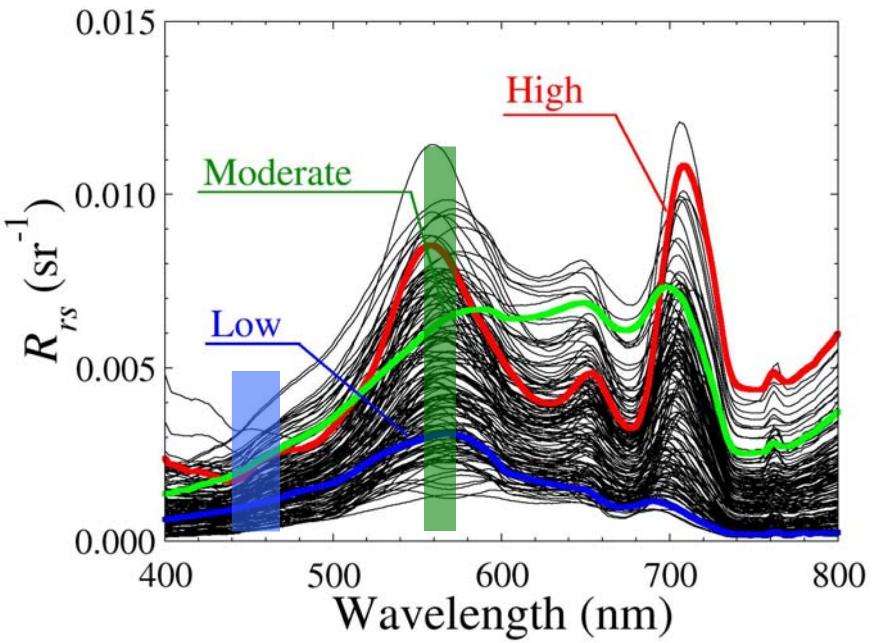
SDSU component

- Applying a statistical framework developed in our previous LCLUC project to partition the variation arising from interannual climatic variability, changes in sensors, and institutional change.
- Apply change analysis approach to both the terrestrial and aquatic image time series used in the project.

UNL Component

- Algorithm development for retrieval chlorophyll-*a* and total suspended matter concentrations from MODIS and SeaWiFS data
- Algorithm calibration and validation
- Monitoring of key surface water quality variables

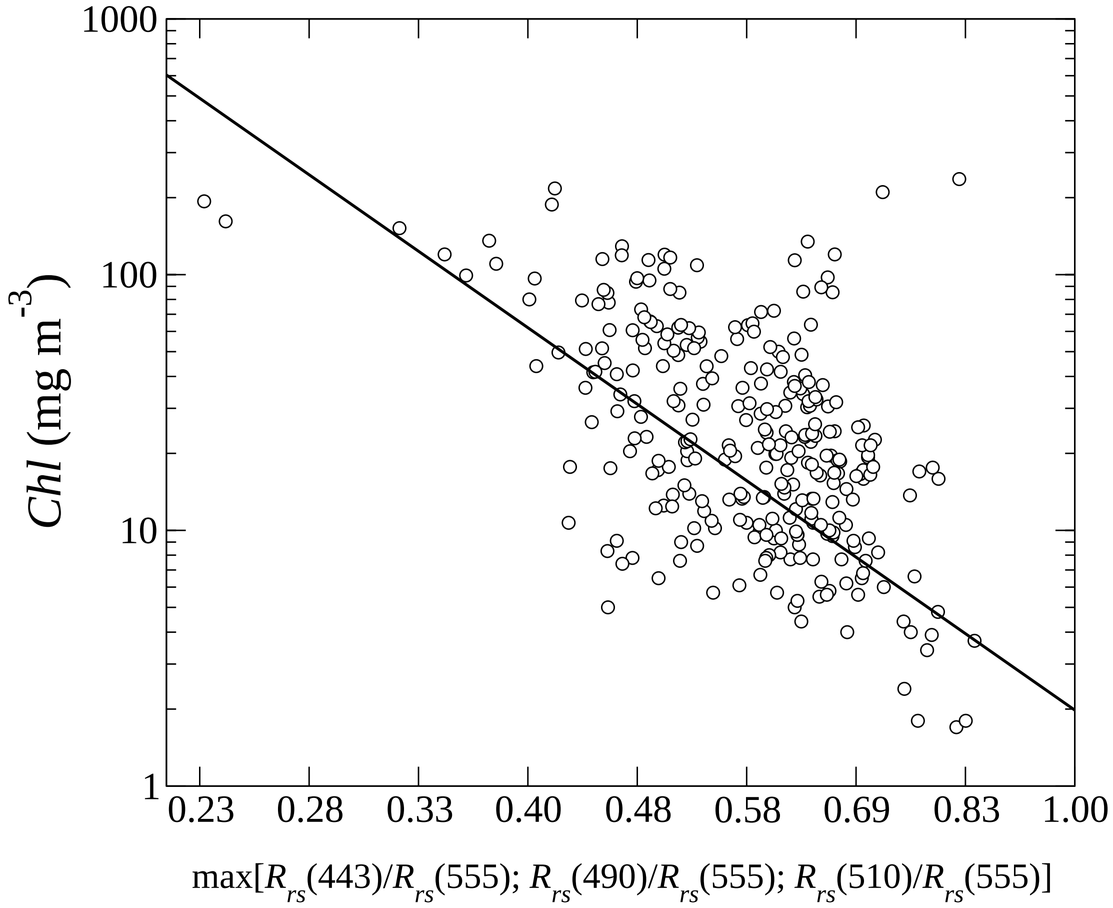
Reflectance Spectra of Inland Waters



MODIS blue band is affected by many sources of absorption in addition to Chl, such as colored dissolved organic matter (CDOM), and by scattering from all suspended particulate matter in addition to planktonic biomass.

The standard blue-green ratio for retrieval of Chl in case 1 waters fails in eutrophic inland waters. Thus, accuracy of the current MODIS Chl algorithm in inland waters is sharply diminished.

MODIS Algorithm vs. chlorophyll concentration in inland waters



Dall'Olmo and Gitelson, 2006, RSE

Bio-optical model

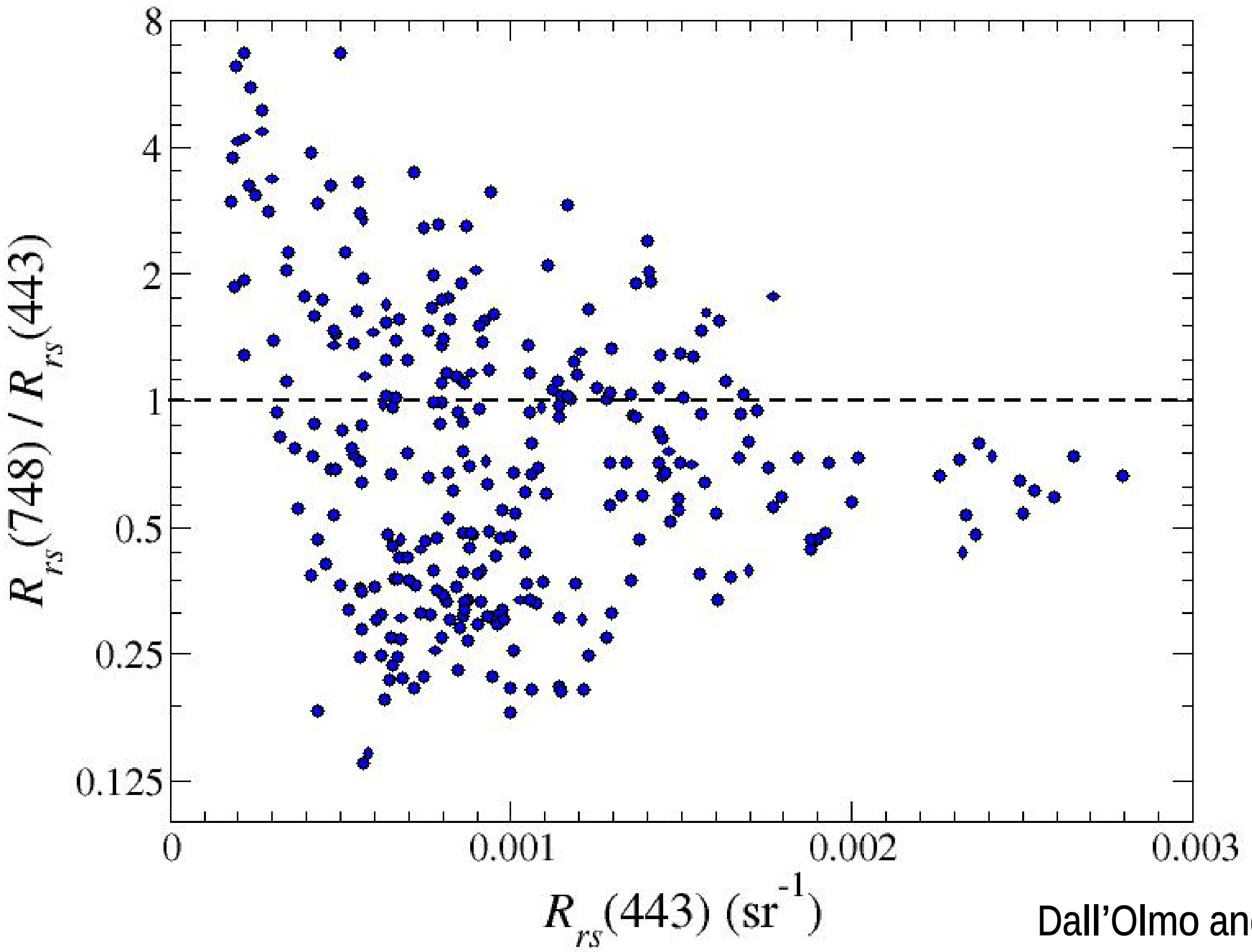
$$R_{rs}^{-1}(red) \propto \frac{Q}{f} a_{Chl}(red) \quad R_{rs}(NIR) \propto \frac{f}{Q} b_b$$

$$\frac{R_{rs}(NIR)}{R_{rs}(red)} \propto a_{Chl}(red)$$

Gitelson et al., 2000, J. Phycology; Dall'Olmo and Gitelson, 2005, Applied Optics

SeaWiFS: bands 6 (670 nm) & 7 (765 nm)
MODIS Ocean: bands 13 (667 nm), 14 (678 nm), 15 (748 nm)

NIR reflectance in inland waters



Dall'Olmo and Gitelson, 2006

NIR reflectance in inland waters is high enough to detect!

Progress to date (since June 1)

UNL Component

- Analysis of algorithm accuracy with MODIS & SeaWiFS bands
- Model calibration with simulated MODIS & SeaWiFS bands
- Validation of algorithms for Chl-*a* concentration estimation in inland waters
- Evaluation of NASA Chl and TSS retrievals for selected areas in Russia and Ukraine
- Two data campaigns in Taganrog Bay (Russia)
- One data campaign in Kahovska Reservoir (Ukraine)
- Evaluating atmospheric correction procedures for MODIS NIR & red ocean bands

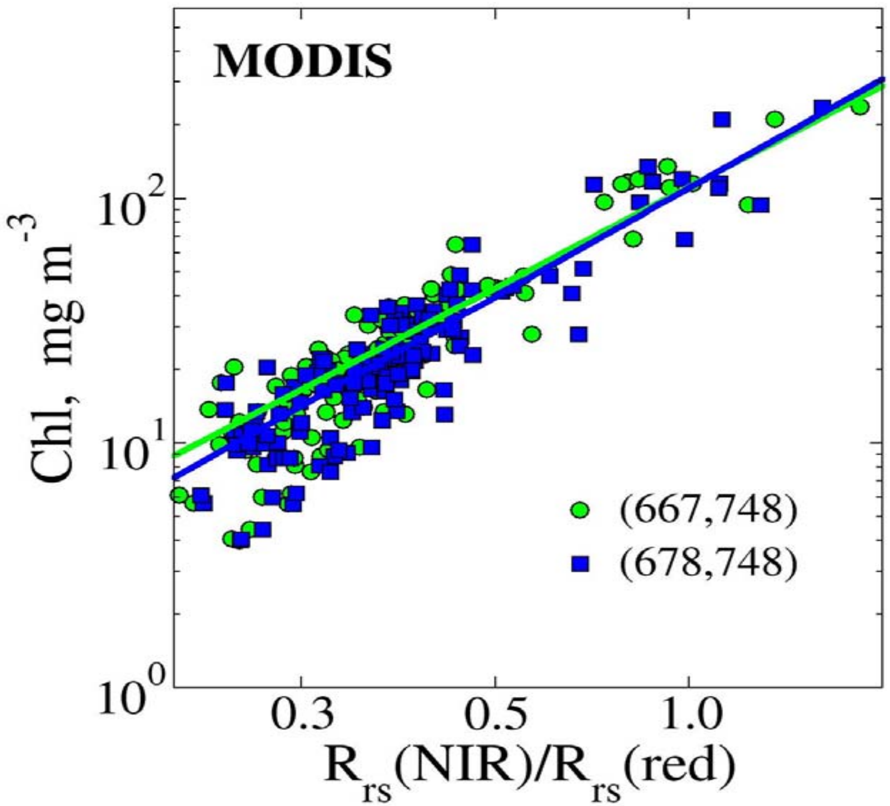
Algorithm Accuracy

Simulated MODIS and SeaWiFS NIR and Red Bands based on AISA data from MN, IA, NE targets

Algorithm	Model Fitted	y_0 (se)	a (se)	b (se)	r^2
SeaWiFS(670,765)	$Log(Chl) = y_0+aLog(I)+b[Log(I)]^2$	2.04 (0.03)	1.3 (0.1)	-0.4 (0.2)	0.83
MODIS(667,748)	$Log(Chl) = a[1+Log(I)]^b$	-	2.065 (0.032)	0.609 (0.025)	0.82
MODIS(678,748)	$Log(Chl) = a[1+Log(I)]^b$	-	2.0 (0.6)	0.64 (0.02)	0.84

All parameters are highly significant ($p<0.0001$).

Algorithm Calibration



Fit is not optimal at low Chl (<5 mg/m^3), but linear at higher concentrations.

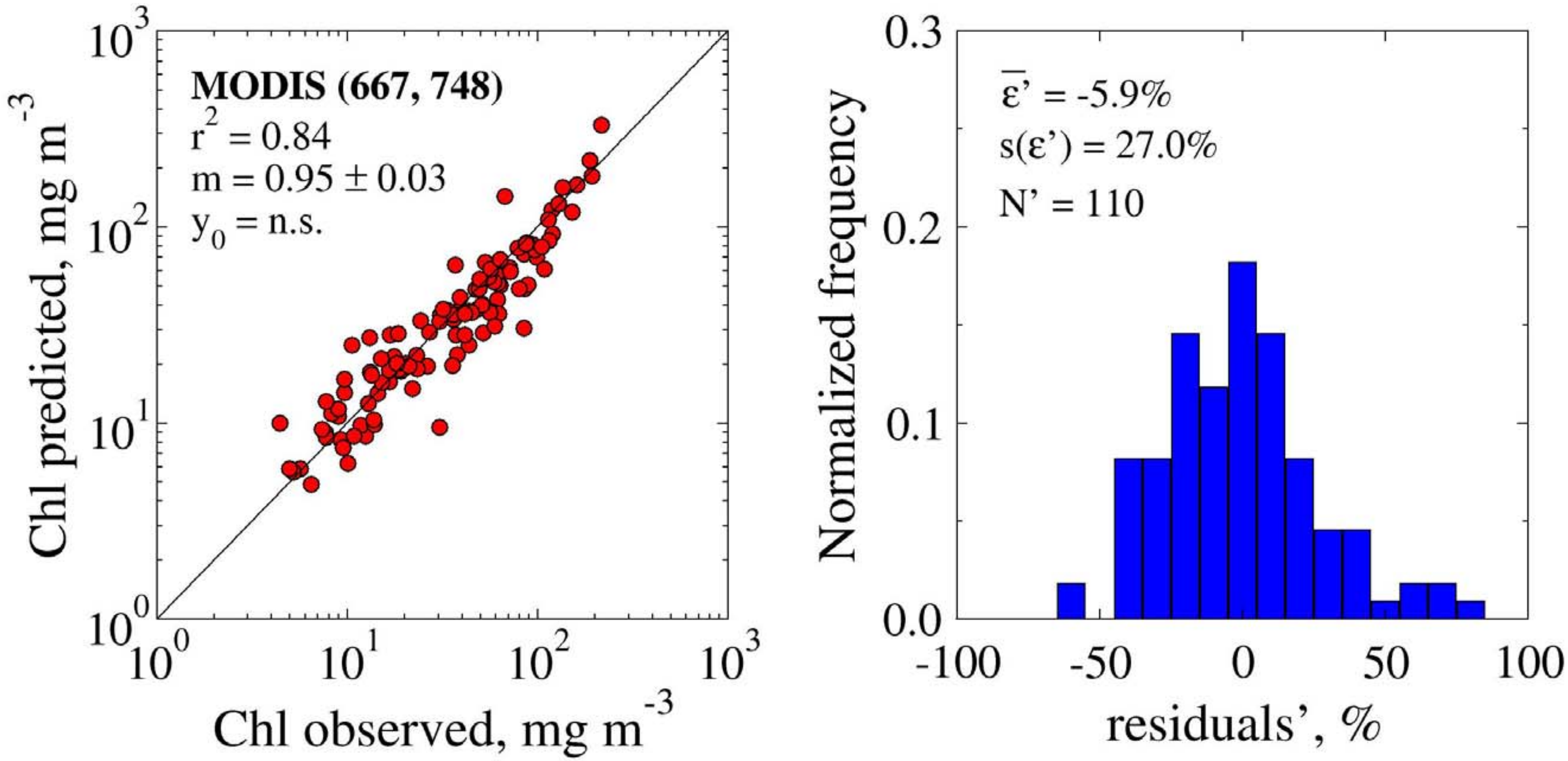
Typical *minimal* Chl concentrations in Ukraine and Russia are 5-10 mg/m^3

MODIS (667 & 748 nm)

$Chl=10^{[2.05+1.37*Log10(R_{rs}15/R_{rs}13)]}$

STE = 11.2 mg Chl m^{-3}, r^2=0.90

Validation



MODIS (667 & 748 nm)

$Chl=10^{[2.05+1.37*Log10(R_{rs}15/R_{rs}13)]}$

STE=11.2 mg Chl m^{-3}, r^2=0.90

Ancillary data we collect

For calibration and validation of algorithms for chlorophyll-a and total suspended matter concentrations retrieval from MODIS and SeaWiFS data in reservoirs of Dnieper and Don river basins, the following ancillary data are necessarily:

- Chlorophyll-*a* concentrations
- Total suspended matter concentrations
- Secchi disk depth
- Total Nitrogen
- Total Phosphorus

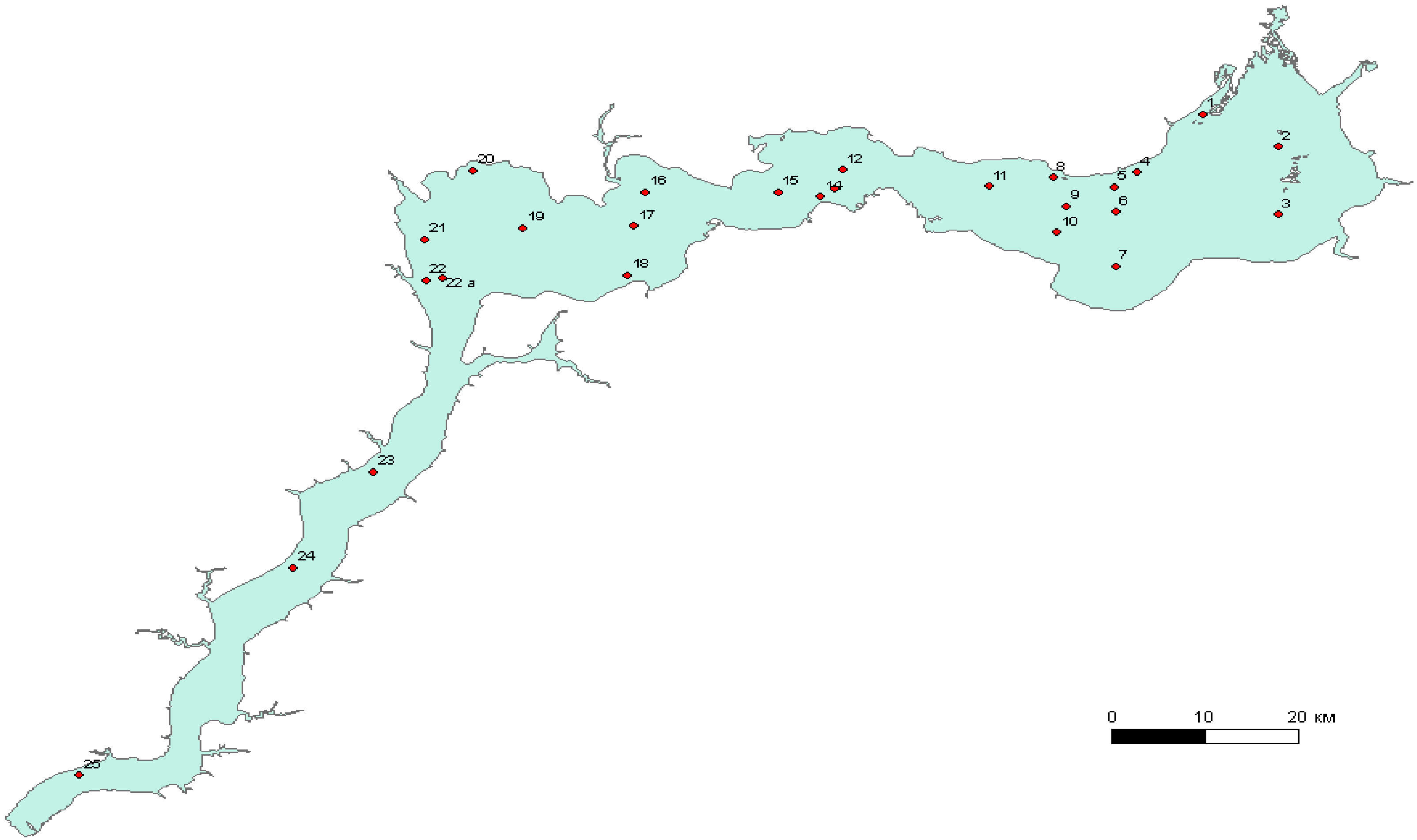
These data need to be collected during satellite overpasses at least three times in season (April, August, and October)

➔ <u>algorithm calibration</u> in the second year of the project.

➔ <u>algorithm validation</u> in the third year.

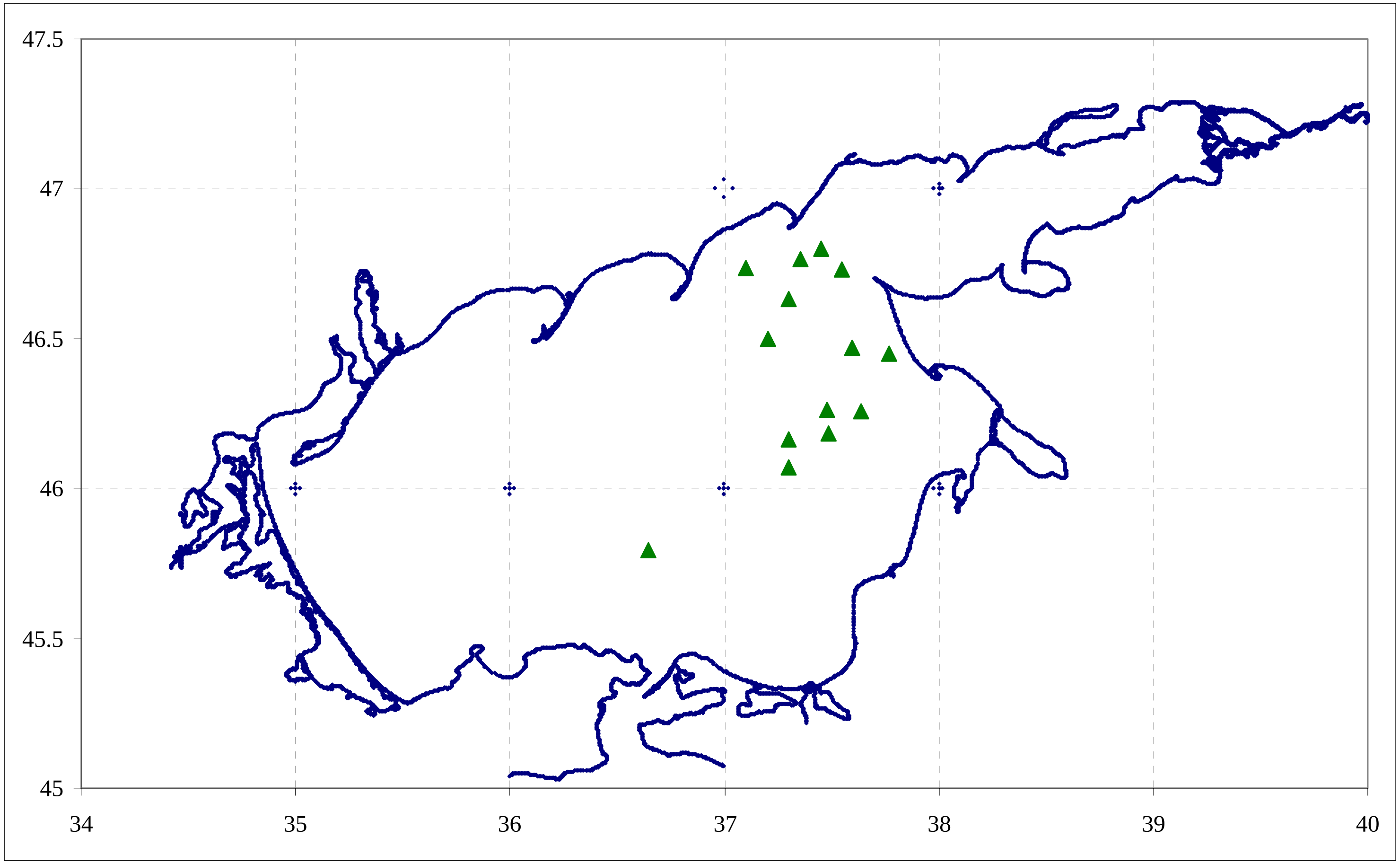
Kahovska Reservoir

9/19/06-9/20/06



Azov Sea

08/15/06 and 09/20/06

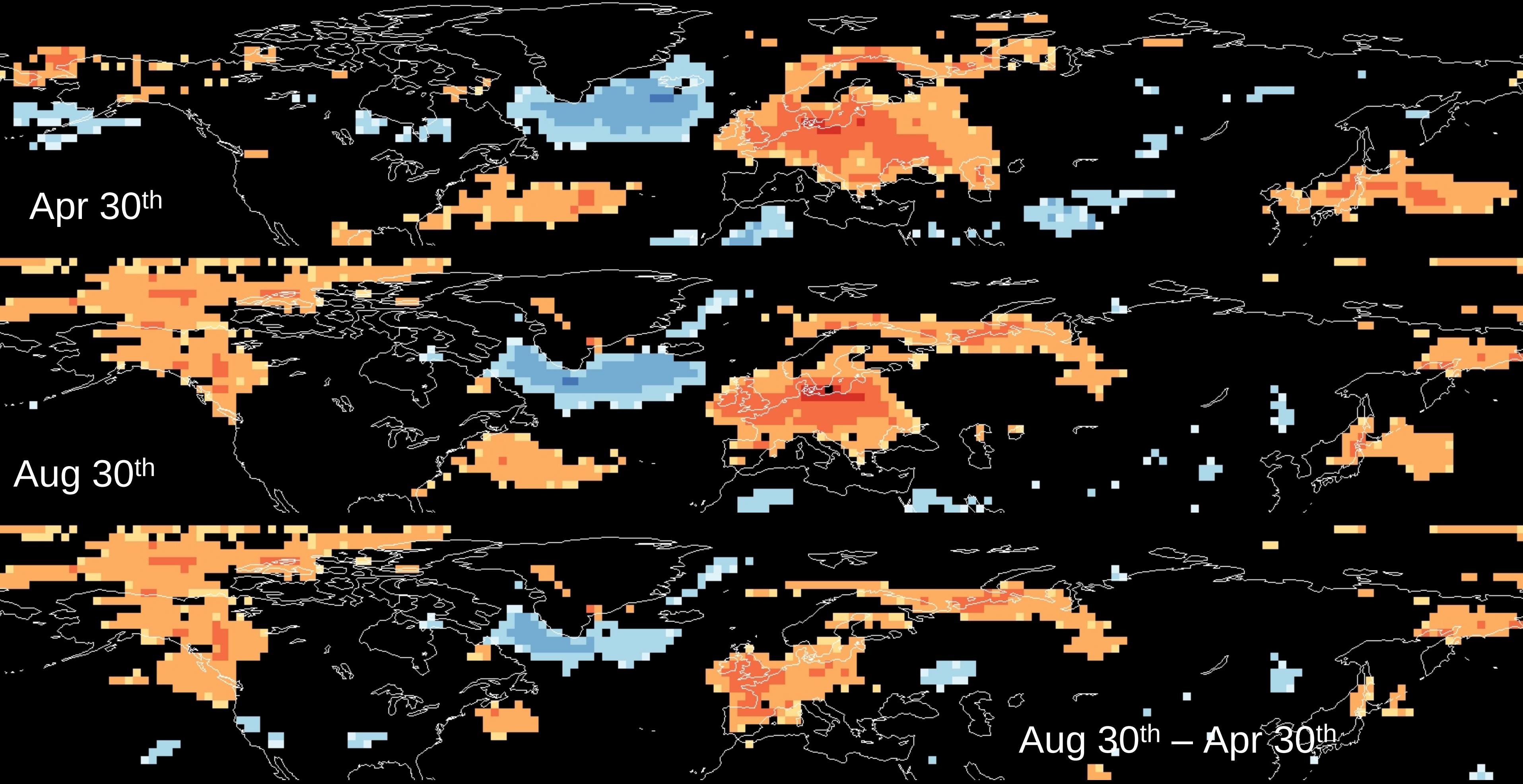


Progress to date (since June 1)

SDSU Component

- Focus on influence of climate modes on land surface phenology (LSP) within Don and Dnieper River basins.
- Focus on climate mode influence on snow seasonality as snow melt is particularly important for Don flow dynamics.
- Currently assessing LSP variability as retrospective function of contemporary land cover using PAL, GIMMS, and MODIS land cover (to be presented at Fall AGU meeting in special session on “Land surface phenology, seasonality, and the water cycle”).

Correlations between NAO and AGDD using NCEP/NCAR Reanalysis 2

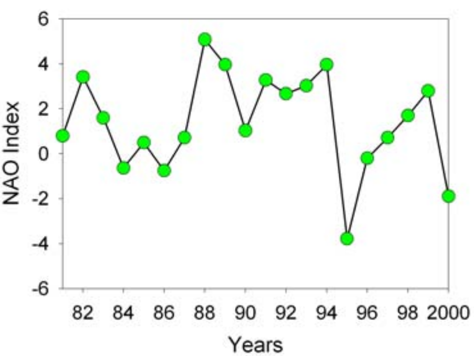


NAO positive phase strongly affects temperatures in Western Eurasia, Western Canada, and Alaska.

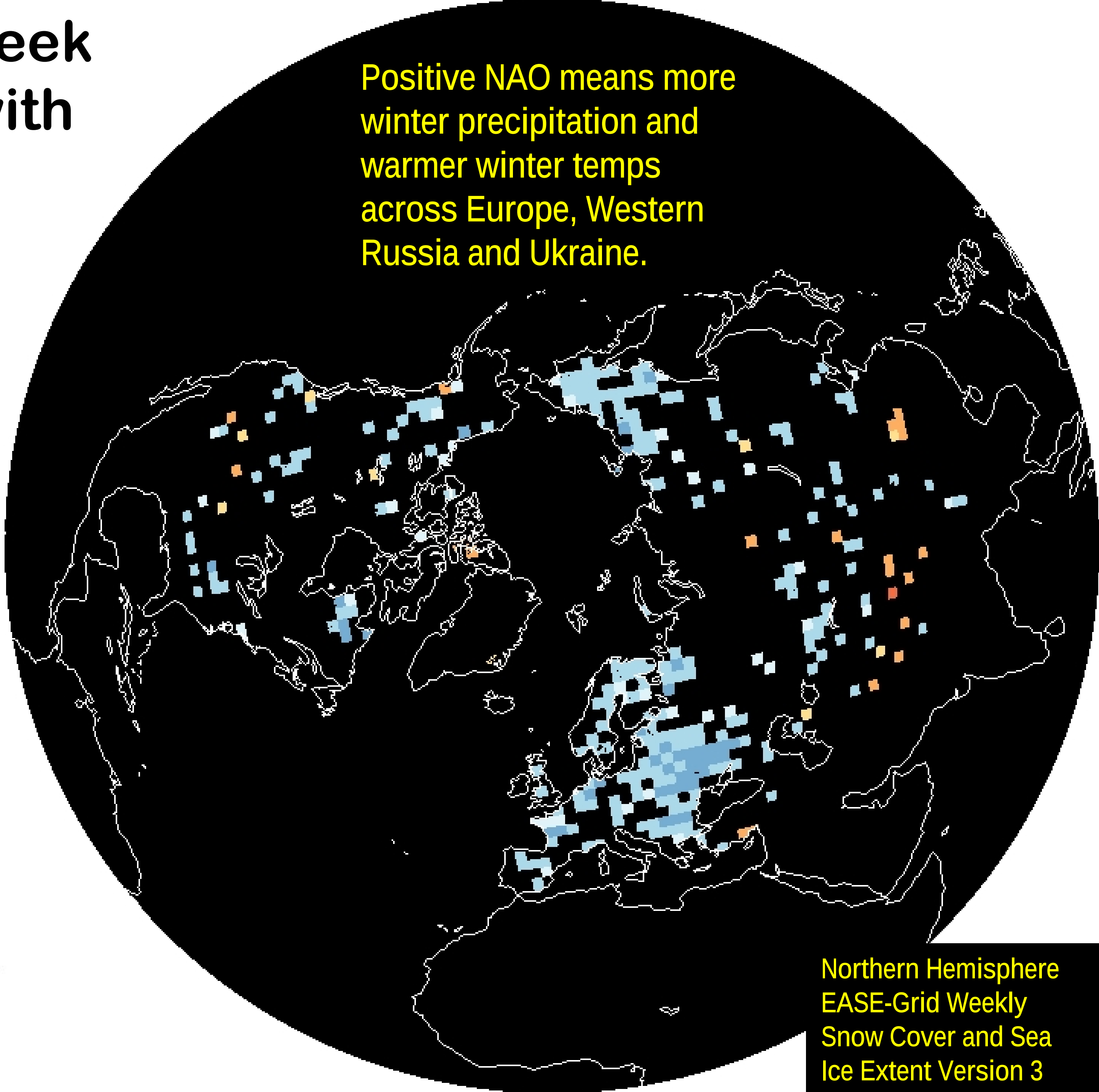
Last snow week correlated with Spring NAO

Positive correlation:
NAO index up → later snow melt.

Negative correlation:
NAO index up → earlier snow melt.



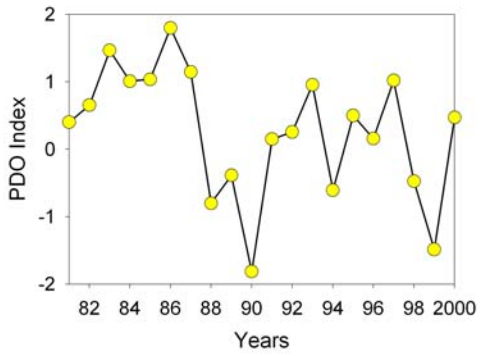
1982-2001

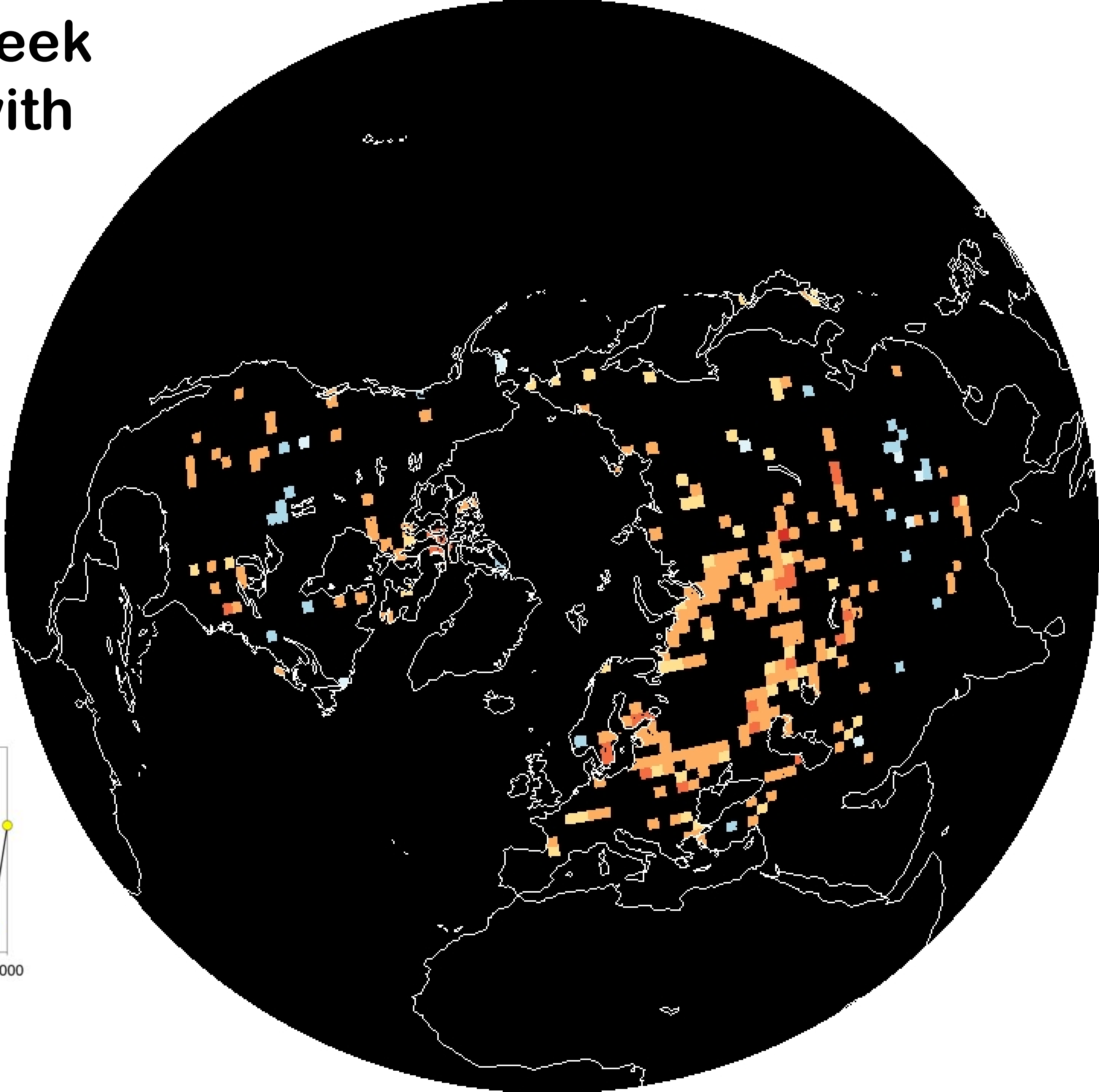


Last snow week correlated with Spring PDO

Positive correlation:
PDO index up →
later snow melt.

Negative correlation:
PDO index up →
earlier snow melt.





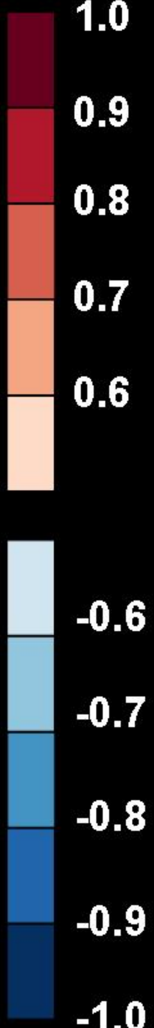
1982-2001

Correlations between NAO & quadratic LSP model

$$VI = \alpha + \beta*AGDD + \gamma*AGDD^2$$

Correlation between NAO and LSP model intercept (= α)

Correlation between NAO and LSP model peak position (= $-\beta/2\gamma$)



A work in progress…

QUESTIONS?

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