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Remote sensing assessment of the feedbacks between climatic, environmental and societal changes in Siberia over 30 years: the CLASSIQUE project

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SCIENTIFIC OBJECTIVES

The CLASSIQUE French research project is focused on the impacts of climate change in Siberia, with a special attention to land cover evolution, forest vulnerability and permafrost reduction. It mobilizes climatologists, hydrologists, agronomists, demographers and specialists of scientific mediation in a trans-disciplinary effort to better quantify (1) future changes of climate and vegetation properties in Siberia; (2) the consecutive evolution of the agricultural potential of the region; (3) the demographic and societal effects of these changes; and (4) the interactions and feedbacks induced.

METHODOLOGY

The chosen approach aims to develop integrated models able to predict the evolutions of land cover and hydrology and the links with the Russian population. To predict the future impacts of climate change on Siberian ecosystems, the two French vegetation models (ISBA and ORCHIDEE land surface models) will be used and various databases will be developed for their validation on the past thirty years and to identify possible trends. A large interest is devoted to remote sensing archives which provide surface monitoring and spatial integrated variables on the last thirty years. Various satellite products are gathered and developed at different scales to assess land surface variables like, land cover / land use and changes, albedo, surface temperature, fire and vegetation dynamics as well as soil moisture, wetlands, snow cover, freezing and thawing periods, etc. Preliminary products developed and satellite database status are presented.

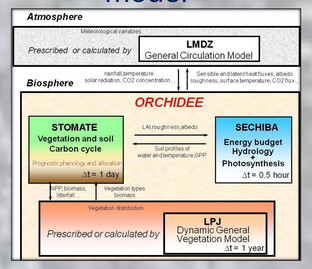
CLIMATE MODELING

Both land surface models, ISBA (Meteo France, CNRM) and ORCHIDEE (IPSL), have been recently improved to better represent the main cryospheric, hydrologic, carbon, methane and energy processes of boreal ecosystems. They both include a Dynamic General Vegetation Model with a Fire module, a representation of Wetlands, a Soil carbon decomposition module, a new representation of the freezing/thawing of permafrosts, and a realistic Snow model able to represent the soil / vegetation / snow interactions.

Both models will be implemented over Siberia at 1km scale and forced with meteorological analysis (Watch & ERA-Interim, /3hours) on the 1979-2011 period (Weedon et al., 2011 ; Piani et al., 2011 ; Alkama et al., 2012). The remote sensing database developed in the framework of this project will help to evaluate / validate the land surface models on the recent past climate.

Once validated, the models will be used in predictive mode, to simulate the future climate up to 2100, (CMIP5 climate simulations, forcing scenarios RCP4.5 and RCP8.5).

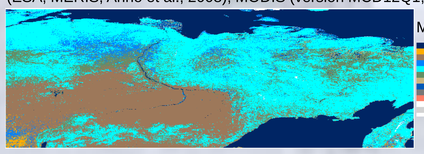
Exemple of the ORCHIDEE model



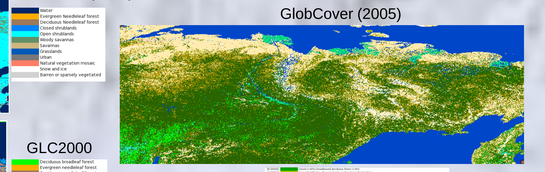
REMOTE SENSING DEVELOPMENTS

LAND COVER MAPPING & CHANGE

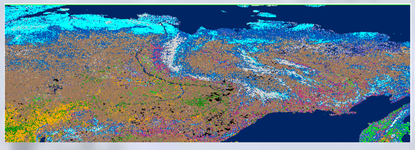
Various land cover products have been compared on the Yakoutian region (Sakha republic) and some discrepancies have been highlighted. The products regridded at 1km scale are : GLC2000 (SPOT/VGT, Bartholomé et al., 2005) for the Year 2000, Globcover (ESA, MERIS, Arino et al., 2008), MODIS (version MCD12Q1, Friedl et al.,2002) for 2005.



MODIS LC (2005)



GlobCover (2005)



GLC2000

In terms of legends comparison, GlobCover and GLC2000 contain more classes than MODIS with sometimes no correspondence between classes. As examples, the class "bare areas" don't exist in MODIS classification but class "Savannas" is not present in GLC2000 and GlobCover classifications. There is a rather good agreement between GlobCover and GLC2000 maps but not with MODIS.

Indeed, on MODIS map, shrubs cover almost all the region of Sakha and Needleleaf deciduous trees cover only a part of the south. It is the opposite in GLC2000 and GlobCover where Needleleaf deciduous trees , and trees in general , cover most of the region. In the extreme north of the region, GlobCover and GLC2000 maps present some discrepancies. Grasslands appear in GlobCover (and MODIS) but not in GLC2000. As GlobCover and MODIS cover the same period of time, these differences may reveal vegetation changes in the extreme north of the Sakha region."

URBANIZATION EVOLUTION ON YAKUTSK REGION

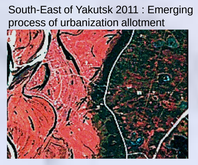
Urban land cover change modeling from 1992 to 2011 made with Landsat 5 TM series: growth of Yakutsk city and emergence of suburbanization dynamics mostly on allotment gardens

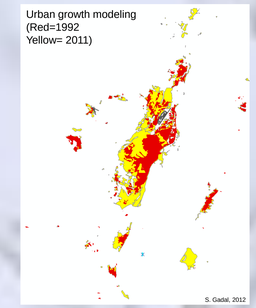
North of Yakutzk: 1992

South-East of Yakutzk 1992

North of Yakutsk 2011 : Urban growth

South-East of Yakutsk 2011 : Emerging process of urbanization allotment

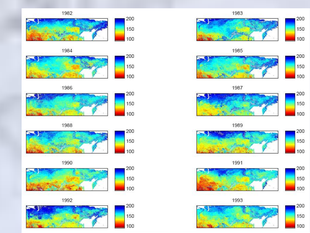


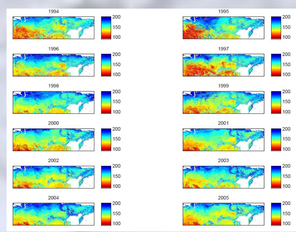


VEGETATION PHENOLOGY

The analysis of optical reflectance seasonal variations allows to estimate the timing of the vegetation phenology (greening up and senescence dates) and their evolution over the last 30 years. The SPOT/VGT and NOAA/AVHRR instruments have been used for that purpose.

Remote sensing greening up dates (Day of the year), calculated over times series of reflectances from AVHRR Pathfinder and SPOT-VGT S10 data, averaged over the Siberian region (50°N-72°N ; 45°E-180°E).





Use of :

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR}$$

$$NDSI = \frac{BLUE - SWIR}{BLUE + SWIR}$$

At spring, reflectances evolve following snow cover melting and foliation. Special care was given to separate snowmelt effect from foliation :

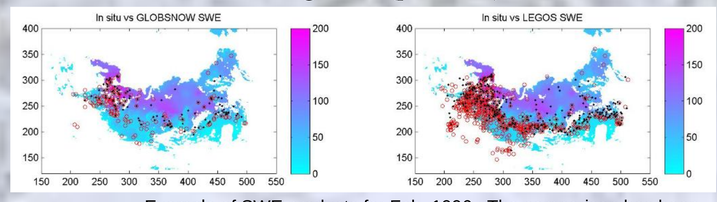
✓On SPOT-VGT, this was performed by using a combination of middle infrared and near infrared reflectances which makes the distinction easier than using the NDVI.

✓On NOAA-AVHRR, a NDVI threshold approach was calibrated using SPOT VGT results on the common years.

SNOW COVER

Two satellite-derived snow water equivalent (SWE) products have been validated by in situ observations from former Soviet Union snow network. The FMI GLOBSNOW product outperforms the LEGOS product in bias. At the same time, the temporal correlations with in situ observations are very low. LEGOS product reproduces well the temporal variation of SWE but is strongly biased compared to in situ observations on Siberian territory.

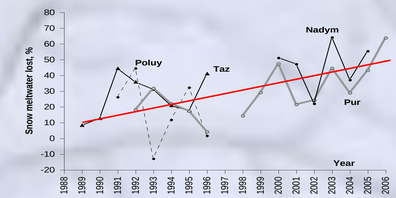
In situ stations with significant (p-val<0.05) correlation



Example of SWE products for Feb. 1996 ; The comparison has been performed over more than 1000 in situ stations.

HYDROLOGY WETLANDS REGIME

The ratio of water lost (water kept into lakes/wetlands or loss by evaporation) is increasing for north of Western Siberia - climate change or anthropogenic impact?

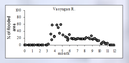


Temporal evolution of difference between snow volume (from SSM/I) and spring flood (from in situ), i.e. % of snow lost, for 4 NW Siberian catchments

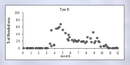
Need for assesment of hydrological role of wetlands

FROM RADAR ALTIMETRY **(ENVISAT)**

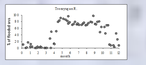
Type 1: Small permanent flooding (one peak) and well pronounced drying/draining



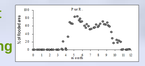
Type 1a: Same as 1 but with two peaks

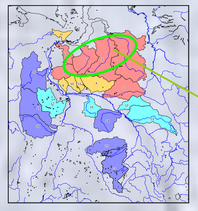


Type 2: High permanent flooding with insignificant draining



Type 3: Medium permanent flooding with two peaks and well pronounced draining

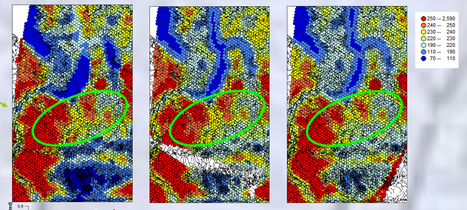


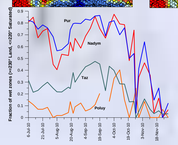


Although SMOS signal is more noisy, there is a good agreement between ENVISAT and SMOS, with same regional patterns.

FROM MICROWAVE RADIOMETRY **(SMOS)**

SMOS (TBH, 40°), high TB - dry, low TB - wet





Fraction of wet zones from SMOS (summer 2010) for 4 rivers of third flood type zone over NW Siberia (220K is the limit between wetlands and soils)