HYPERSPECTRAL DATA AS A TOOL FOR ASSESSMENT OF TEMPORAL CHANGES IN NORWAY SPRUCE FOREST CONDITIONS IN A HISTORICALLY HEAVILY POLLUTED MOUNTAINOUS REGION OF CZECH REPUBLIC AFFECTED BY LONG-TERM ACIDIC DEPOSITION.

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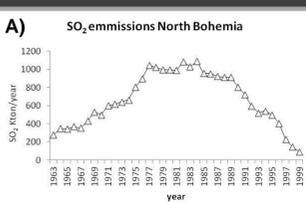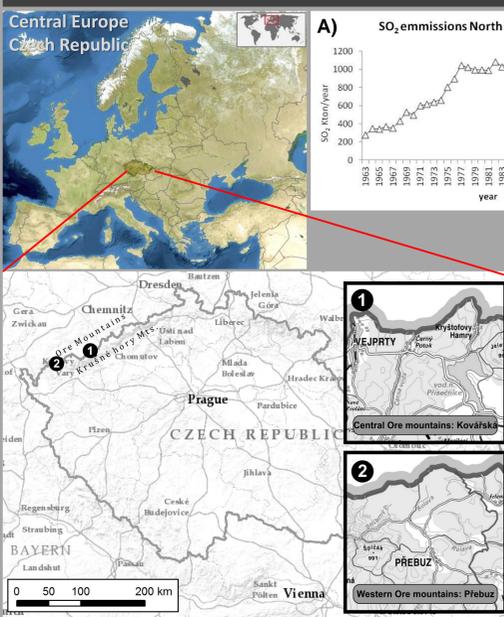
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INTRODUCTION

The physiological status of the trees within the ecosystem determines its proper functioning in biogeochemical cycles of carbon, mineral nutrients and water in the landscape. The Krušné Hory Mts. located in the western part of the Czech Republic suffered since the 1950´s till the 1990´s heavy atmospheric pollution due to the mining activities and coal combustion adjacent to the mountain range. Acidic deposition in combination with harsh climatic conditions led to forest decline there. Although the load of SO_2 has significantly decreased since 1991, tree damage was still visible in 1998 in terms of high defoliation or dead trees. Nowadays Norway spruce trees do not exhibit visible symptoms of damage but we suppose that the full recovery of Norway spruce forests is not complete yet due to persisting adverse soil conditions.

Hyperspectral data in combination with chemical analyses of tree foliage and soil offer a tool for large-scale diagnostics of vegetation physiological status. In 1998 a hyperspectral dataset was acquired in the Krušné Hory Mts. during the NASA project using a prototype ASAS sensor. In 2013 the next hyperspectral dataset was acquired using APEX sensor in purpose to 1) assess the actual physiological status of Norway spruce stands and to 2) compare the physiological status of trees between 1998 and 2013 based on hyperspectral images. In 2013 the complex field sampling was accomplished as a ground-truth: The evaluation of crown status (defoliation, LAI), foliar chemistry, soil chemistry, laboratory spectroscopy of needles and soil.

The next step of the project is to design the predictive models for pigments and other biochemical stress indicators based on laboratory spectroscopy and upscale the models to the canopy level. The final complex conclusion about the temporal change in Norway spruce physiological status after processing the hyperspectral data will provide the information on a larger spatial scale for the local forest management.

## Study Area: Central Europe – Czech Republic – Krušné Hory Mts.

Acidic deposition 1997 – 2013

A) SO_2 emmissions North Bohemia

B) SO_2 immissions Krušné Hory

C) NO_x immissions Krušné Hory

A) SO_2 emmissions in North Bohemia between 1963 and 1999. Data provided by the Czech Hydrometeorological institute.
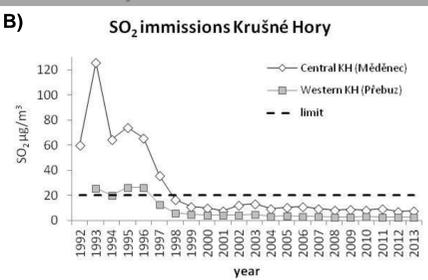
B) and C) Pollutant concentration data provided by the Czech Hydrometeorological institute, www.chmi.cz; limit values according to the Czech decree on air, ecosystem and vegetation protection.
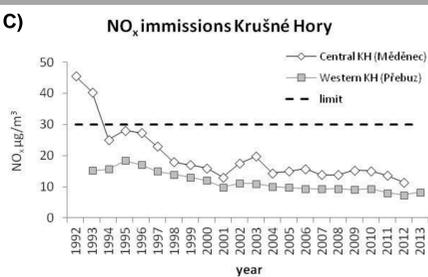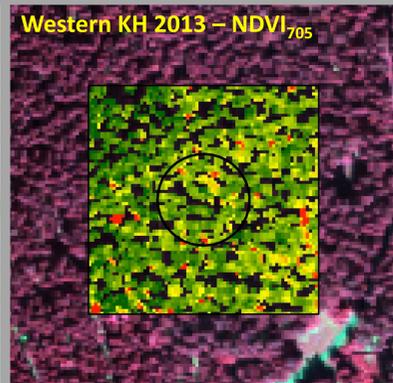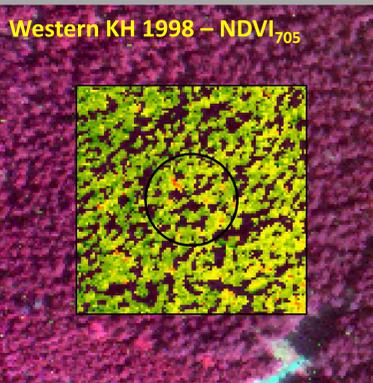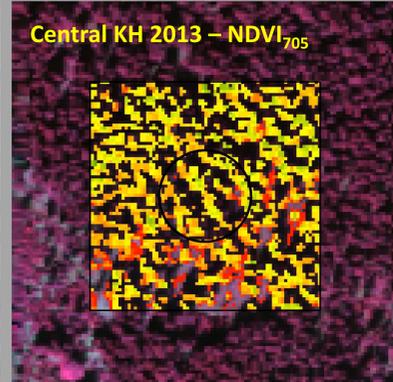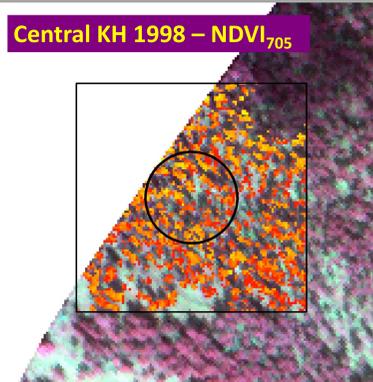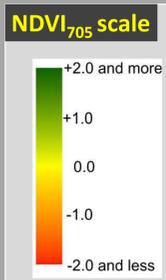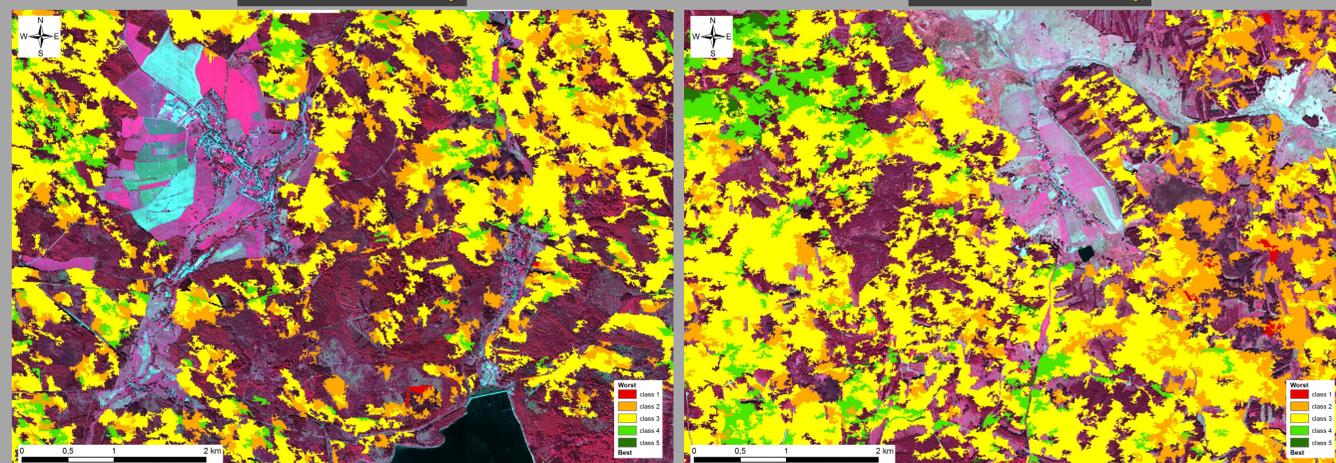
Norway spruce health status classification 2013

Statistical classification of the Norway spruce health status by integrating REP and SIPI indices from APEX data 2013 (model based on Mišurec et al. 2012). First, the areas covered by vegetation were classified using Maximum Likehood and Artificial Neuron Networks. Further classification distinguished mature Norway spruce stands and the zonation of health status classes was applied. Five classes of relative Norway spruce health status expressed by colour coding.
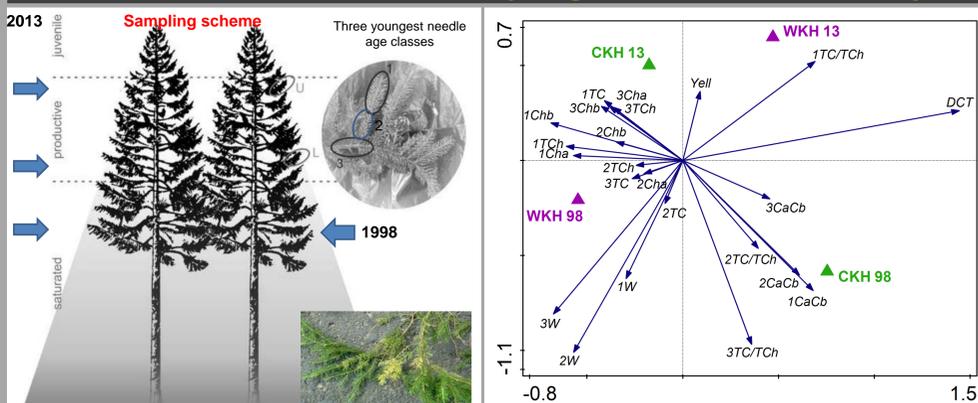
Central Krušné Hory

Western Krušné Hory

Ground Truth: Needle Sampling and Foliar Chemistry

2013

Sampling scheme

Three youngest needle age classes

1998

Cha/Chb ratio in three youngest needle age classes significantly decreased, similarly as the Car/Cab ratio in three-year old needles. Both shifts in pigment ratios corresponded to improvement of Norway spruce physiological status in the Central KH comparing 1998 and 2013. The Car/Cab ratio better responded to the temporal change than to the difference between two studied areas.

AIMS

The main goal of the project is to assess the temporal changes in the physiological status of Norway spruce forests in the Krušné Hory Mts. using two hyperspectral datasets acquired in 1998 (ASAS sensor) and in 2013 (APEX sensor).

- Assesment of actual physiological status of the Norway spruce in the Krušné hory Mts. based on foliar chemistry and crown status.

- To assess forest health condition via statistical integration of optical indices (REP and SIPI) retrieved from HS image data (according to Mišurec et al. 2012).

- Comparison of results based on two different HS sensors and comparison of forest health status between 1998 and 2013.

Airborne Hyperspectral Imagery and Comparison of Vegetation Indices Based on ASAS and APEX Data

1998 ASAS sensor:
Advanced Solid-state Array Spectrometer
Spectral coverage: 410 – 1032 nm
Number of bands: 62
FWHM: 9,5 – 11,5 nm
Radiometric resolution: 16-bit
Spatial resolution: 1,5 x 2,0 m
flight elevation: 2500 m
flight line width: (m): 820 m
flight line width:(pix): 512 pix

2013 APEX sensor:
Airborne Prism EXperiment
Spectral coverage: 380 – 2500 nm
Number of bands: 313
FWHM: 6 nm (VNIR), 10 nm (SWIR)
Radiometric resolution: 14-bit (VNIR), 13-bit (SWIR)
Spatial resolution: 1.5 m
flight elevation: 4300 m
flight line width: 1500 m
flight line width:(pix): 1000 pix

ASAS

APEX

$NDVI_{705}$ scale

+2.0 and more
+1.0
0.0
-1.0
-2.0 and less

Central KH 1998 – $NDVI_{705}$

Central KH 2013 – $NDVI_{705}$

Western KH 1998 – $NDVI_{705}$

Western KH 2013 – $NDVI_{705}$

Comparison of the normalized values of $NDVI_{705}$ between 1998 (ASAS data, right column) and 2013 (APEX data, left column). Selected study stands clearly demonstrated an increase of $NDVI_{705}$ in the Central KH (above), which indicates the health status improvement, and no dramatic changes in Western KH. The changes in vegetation indices corresponded well with the results of ground truth assessments (foliar chemistry and crown status).

CONCLUSIONS

- Comparing 1998 to 2013 data, according to a crown status (total tree damage class) the Norway spruce fitness improvement in the Central KH was observed in 2013 and the conclusion was supported by biochemically determined photosynthetic pigments ratios. However, in the Western KH the changes in health status of Norway spruce have not change dramatically between 1998 and 2013.

- Statistical classification (REP and SIPI) of Norway spruce health status was retrieved from APEX image data.

- Comparison of $NDVI_{705}$ between 1998 and 2013 corresponded to ground truth results and revealed improvement of Norway Spruce health status between 1998 and 2013, particularly in the area of the Central KH.