Automated spaceborne detection of degraded vegetation around Monchegorsk, Kola Peninsula, Russia

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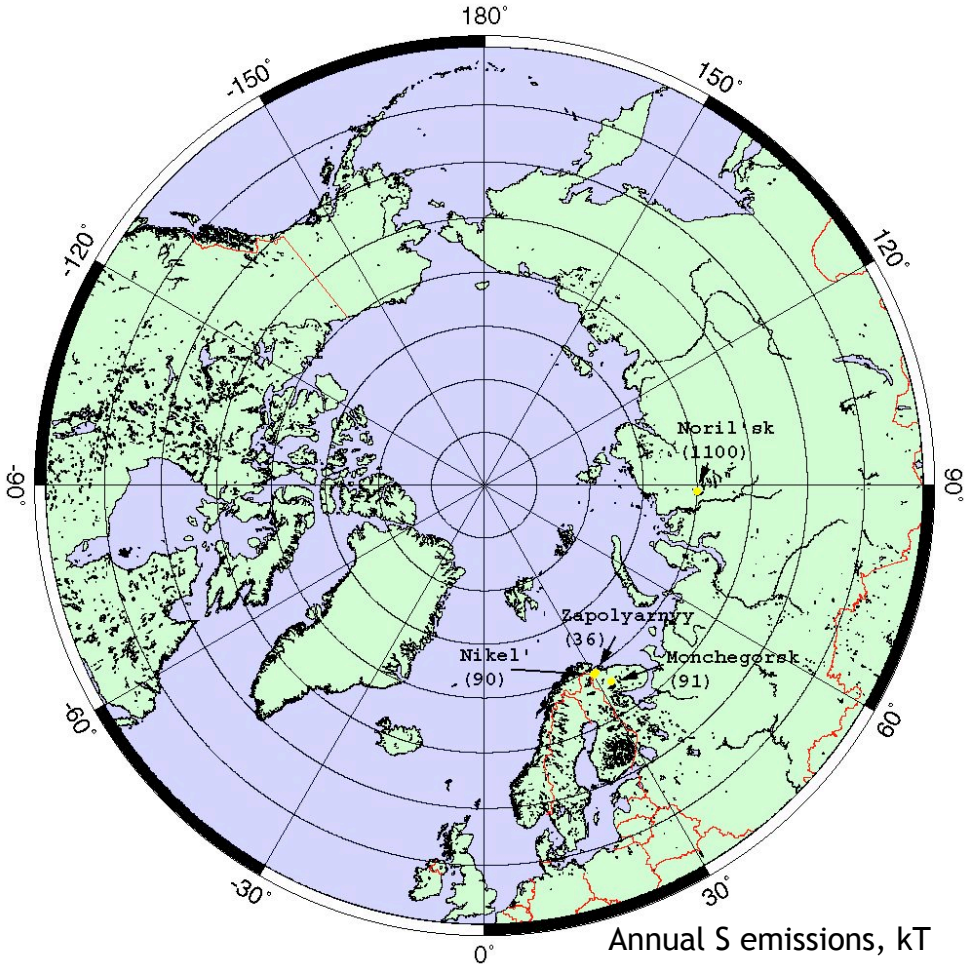
Background

- industrialisation in arctic/subarctic
- acidfying emissions from nickel smelting is significant local/regional issue, especially in Russia
- monitoring by satellite remote sensing is favourable

Change detection can be based on post-classfication analysis but training of historical data can be a problem

Goal is an automatic method to detect damaged/altered vegetation with as few as possible operator decisions



Annual S emissions, kT

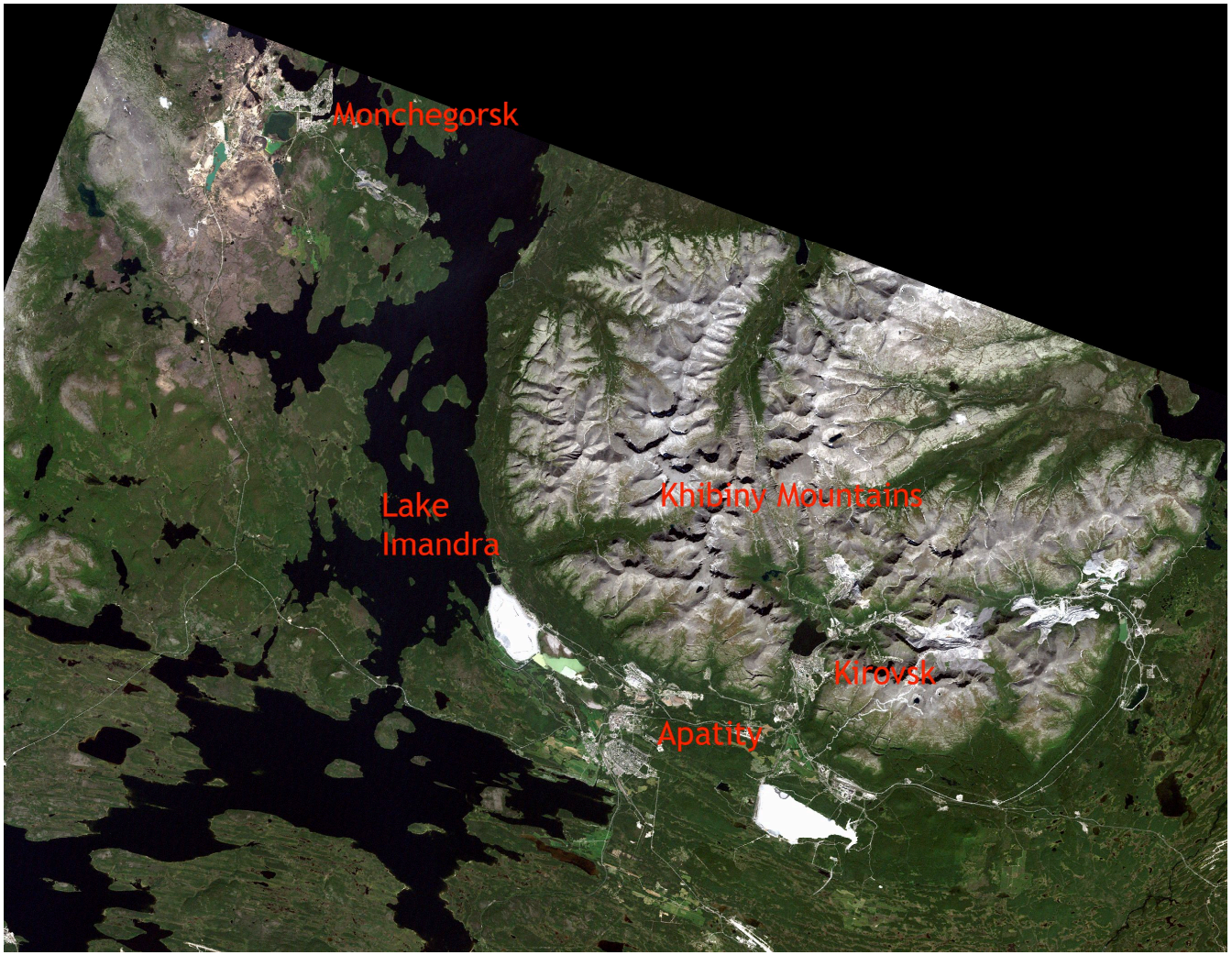
Study area: Monchegorsk, Kola Peninsula, Russia

Severonikel nickel-smelting plant:

major source of acidifying emissions and heavy metal pollution

object of environmental monitoring by Russian-UK group since 1993

Study area

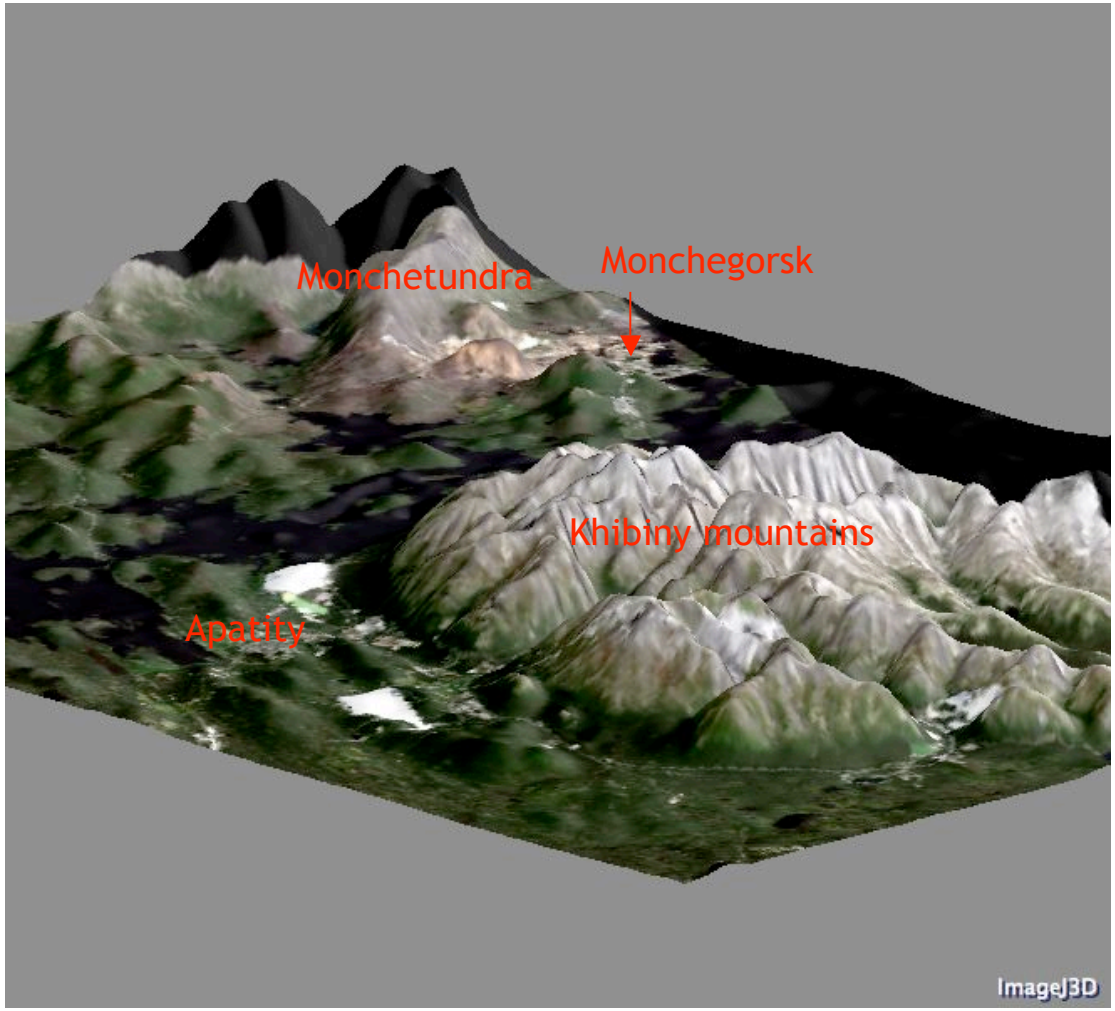


Landsat-7 ETM+, 2000.07.28

Draping Landsat image on DEM is suggestive:

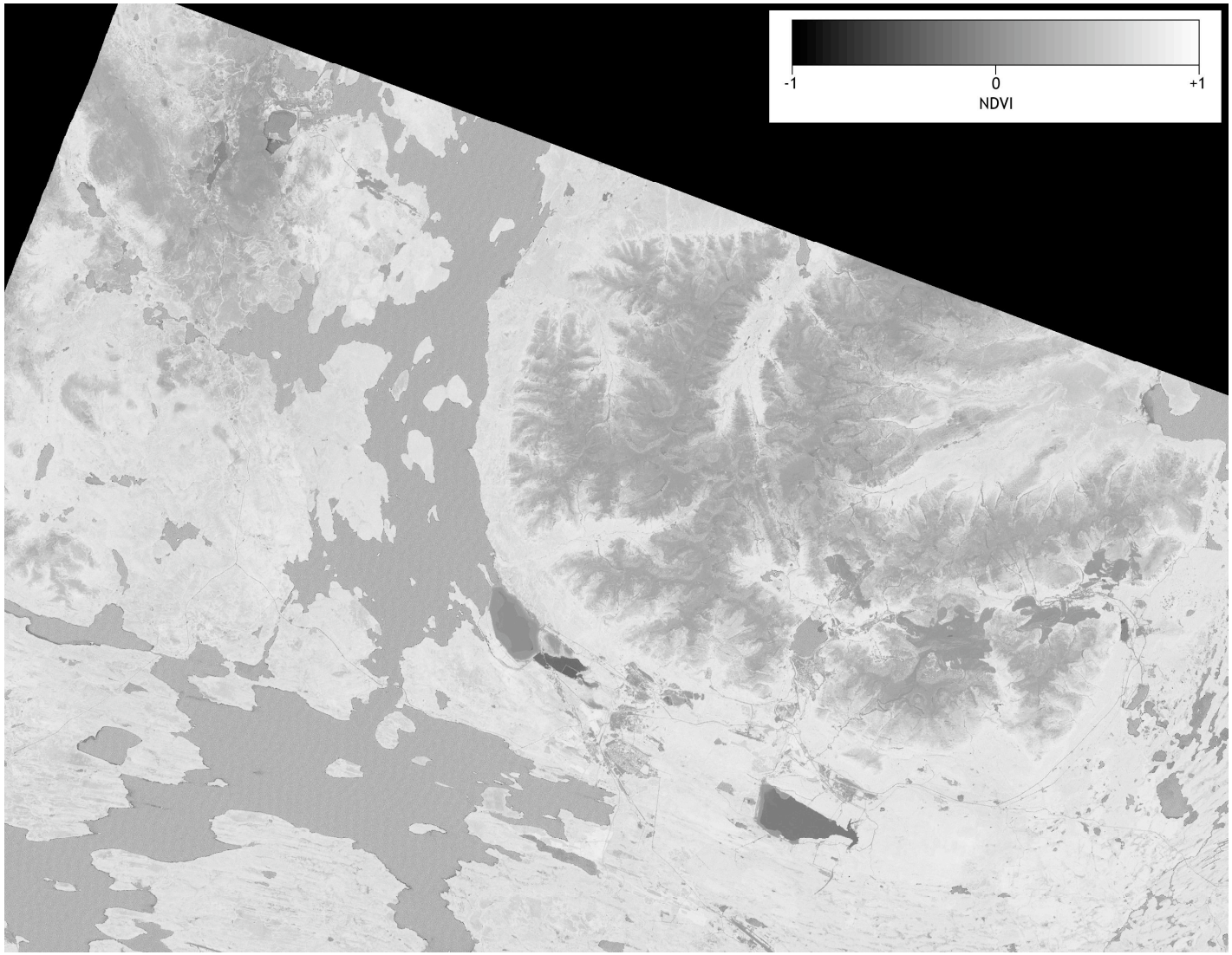
vegetation amount is strongly dependent on altitude, but

relationship is perturbed in vicinity of smelter



NDVI

$$\text{NDVI} = \frac{r_4 - r_3}{r_4 + r_3}$$



Needs calibrated data and dark-object subtraction for atmospheric correction

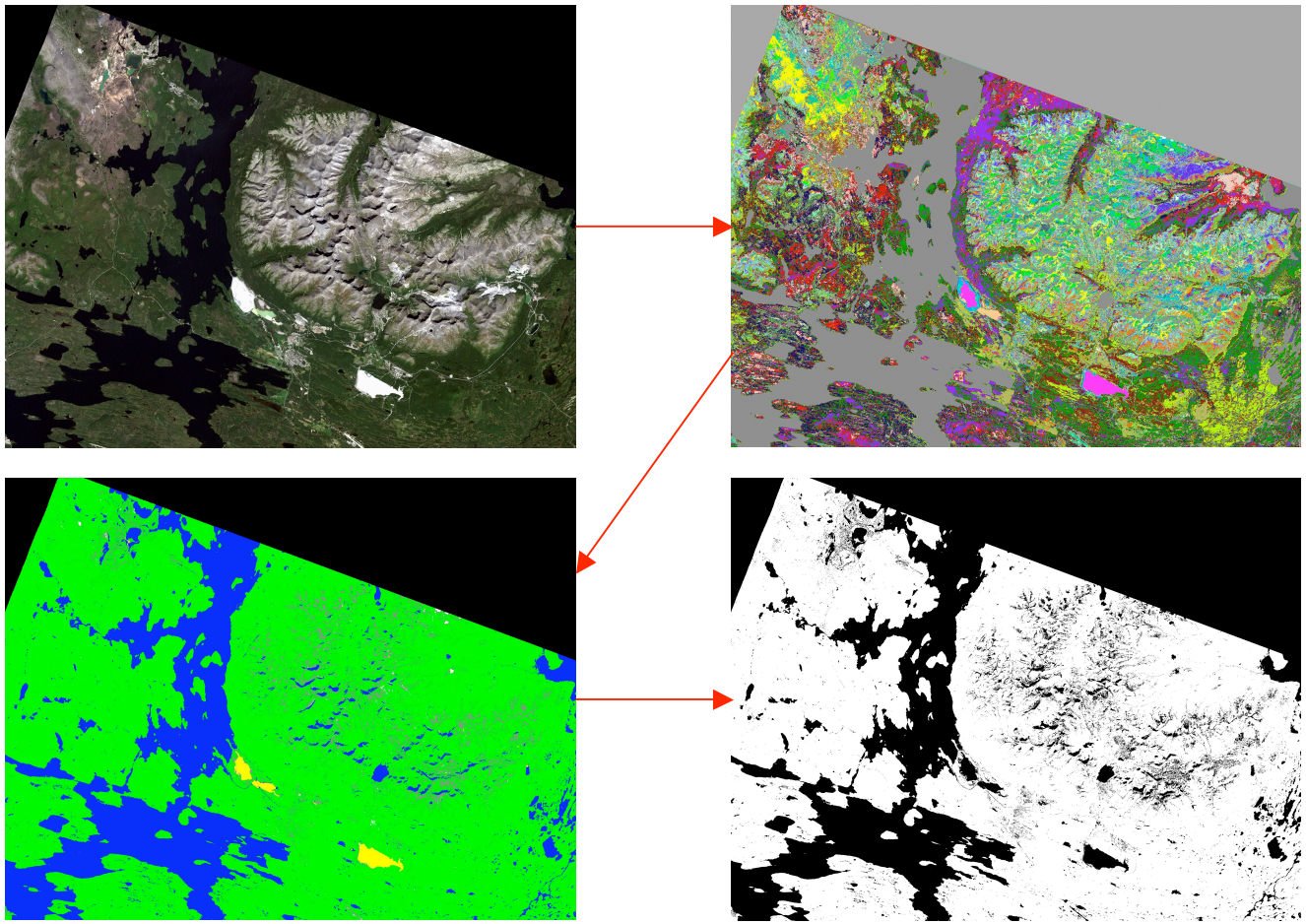
Hypothesis:

> In the absence of pollution impact, NDVI of vegetated areas is mainly controlled by topographic variables; and
>
> Pollution impact is manifested as a lowering of the NDVI relative to the 'topographically expected' value

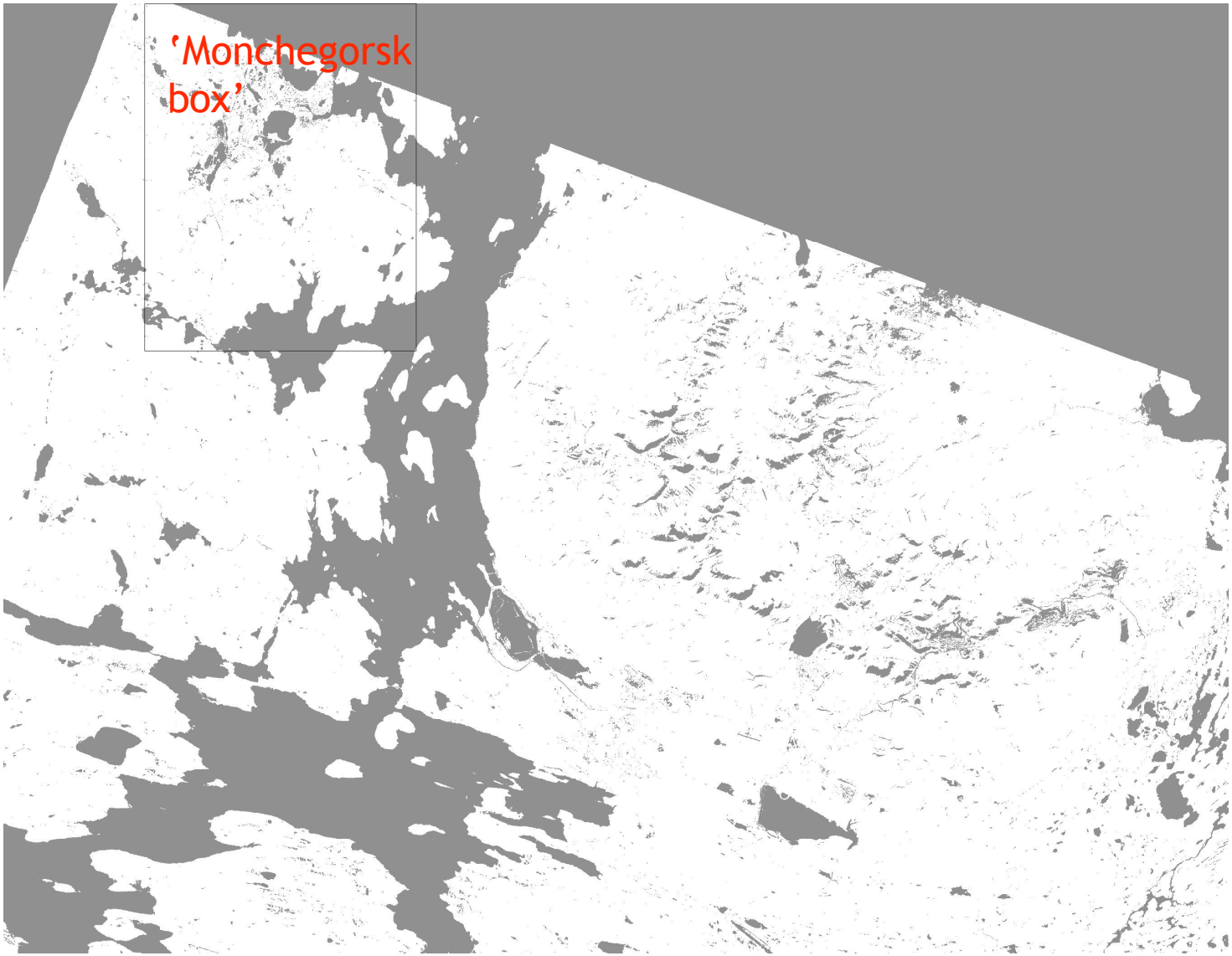
If the hypothesis is true, it can form the basis of a very simple method of identifying anomalously low NDVI values attributed to pollution.

Necessary to exclude areas of water, snow, cloud, tailing ponds, shadow etc.

Create a vegetation/other mask by performing a 60-class unsupervised classification then interpreting the classes (~manual but reasonably straightforward)



Vegetation mask



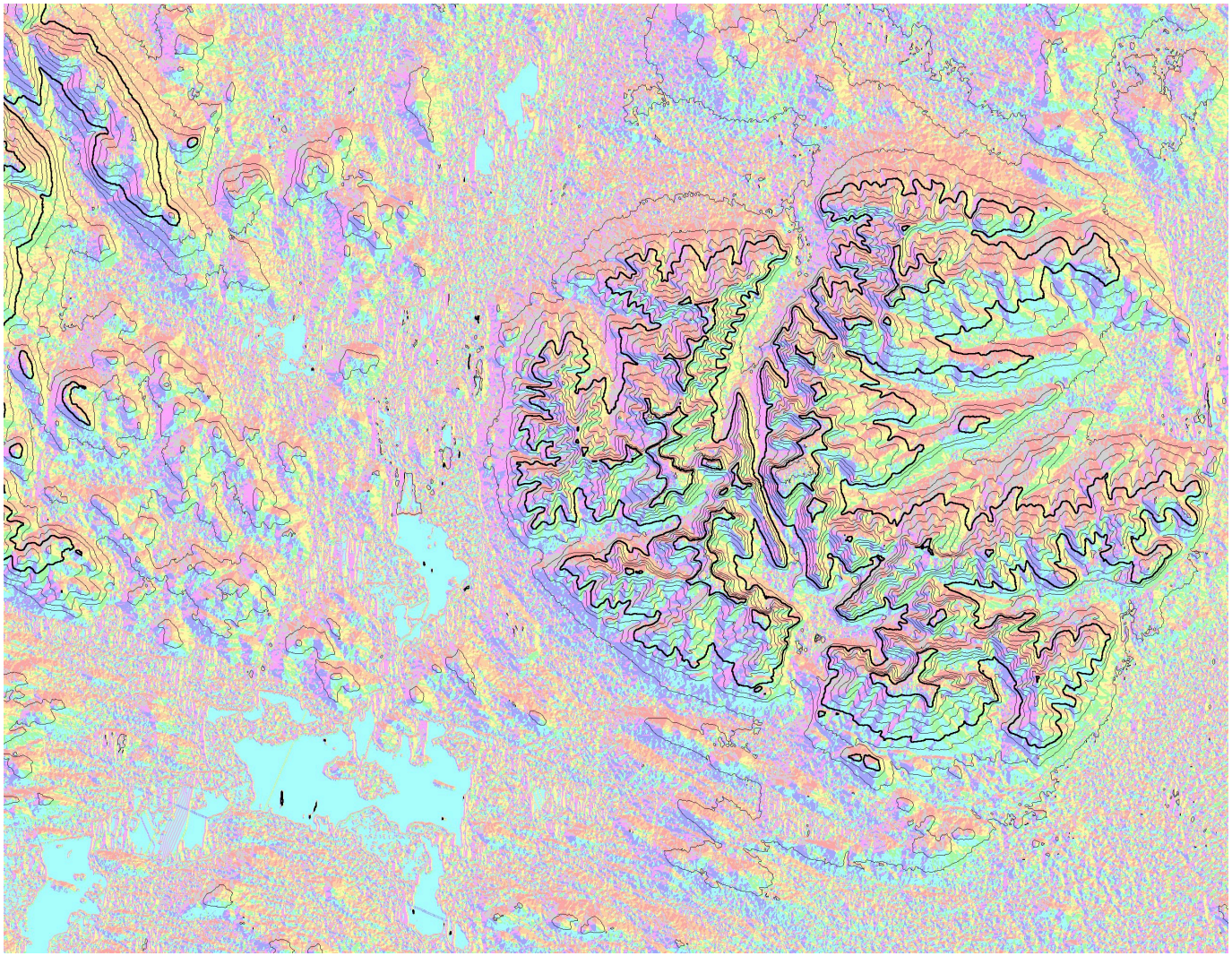
NDVI of unmasked areas:

μ= 0.609

σ = 0.185

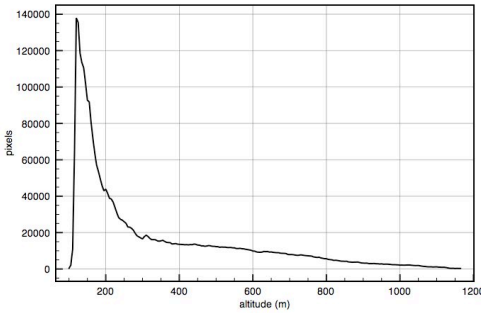
Topographic variables from ASTER GDEM

spatial resolution ~ 100 m, height accuracy ~ 10 m



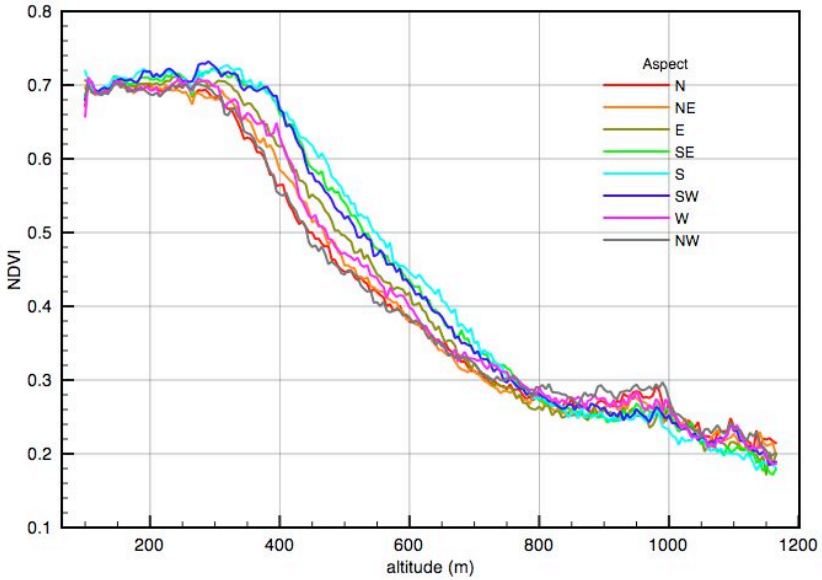
Contours at 100 & 500 m intervals; aspect coded as hue at 45˚ intervals.

Hypsometry of unmasked areas



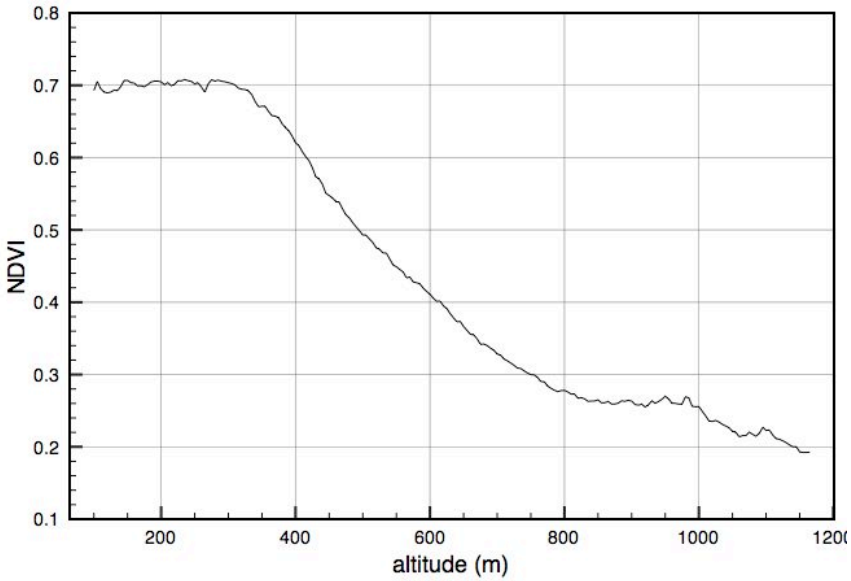
Dependence of NDVI on (a) altitude and aspect; (b) just altitude, for vegetated areas outside the Monchegorsk box.

Not parameterised, although 4th order polynomial is reasonable



rms residual = 0.111

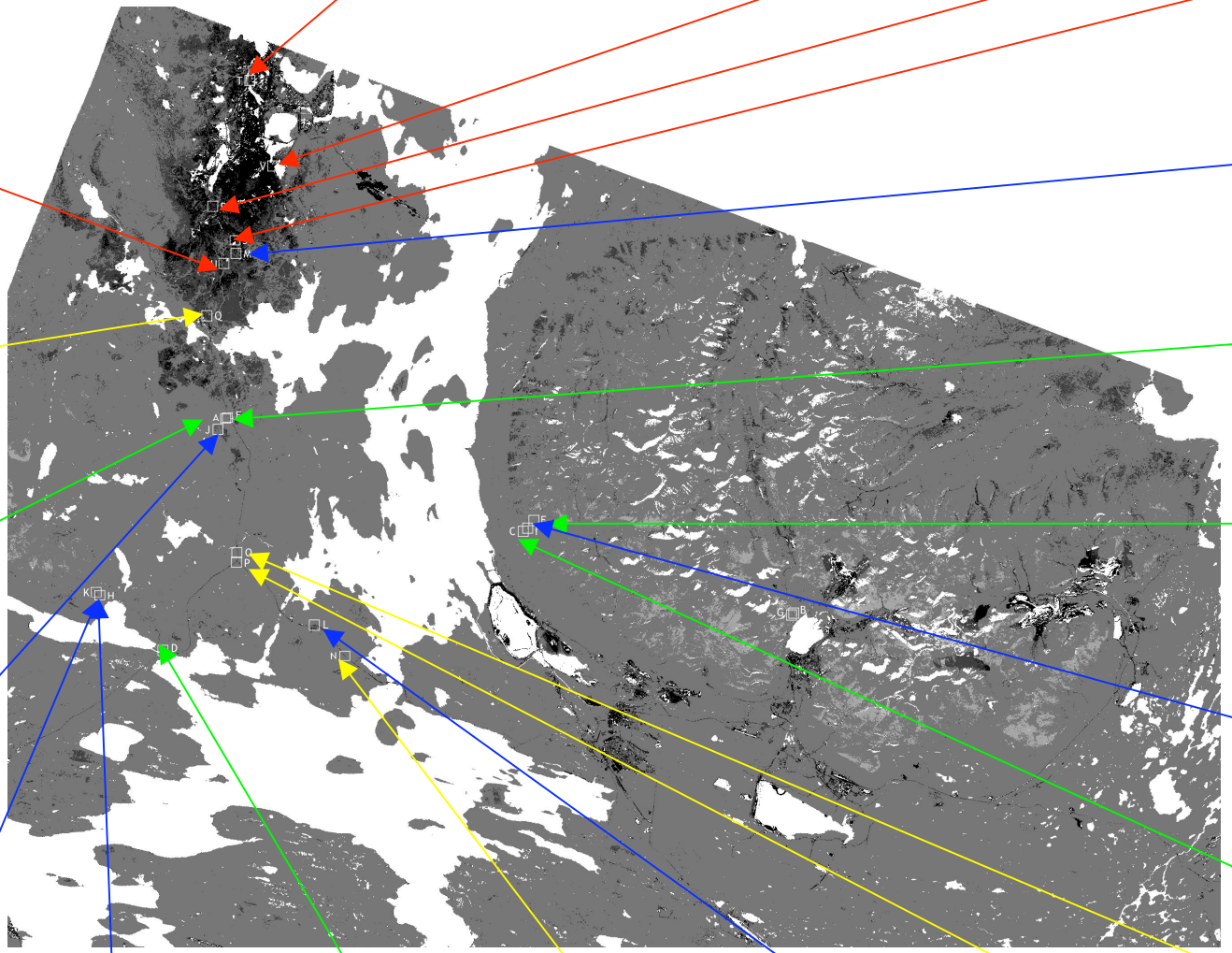
r^2 = 0.641

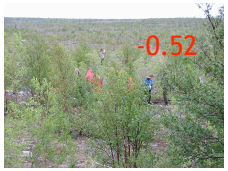


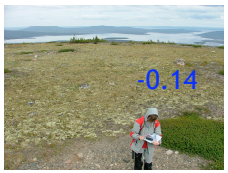
rms residual = 0.112

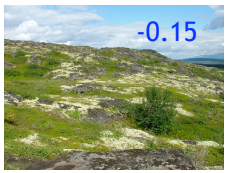
r^2 = 0.631

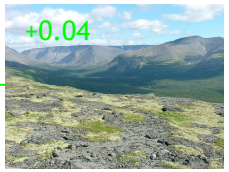
NDVI anomalies







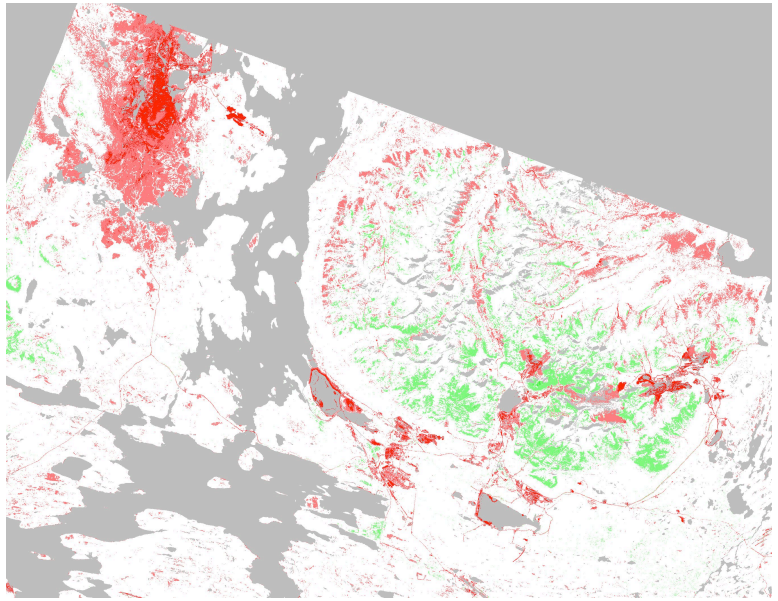




Strong negative anomalies (ΔN<-0.4) are all believable: towns, quarries, tailings, damaged vegetation

Weaker negative anomalies believable around Monchegorsk, but also see some on lower slopes of Khibiny mountains

Positive anomalies not explained but could be statistical artefacts.



Effect of altitude on baseline vegetation has been largely successfully removed

Alt: 207
Modelled N: 0.70
Actual N: 0.78
D: 20 km S

Alt: 205
Modelled N: 0.70
Actual N: 0.18
D: 10 km S

Alt: 547
Modelled N: 0.44
Actual N: 0.48
D:32 km SW

Alt: 160
Modelled N: 0.71
Actual N: 0.47
D: 28 km S

Conclusions

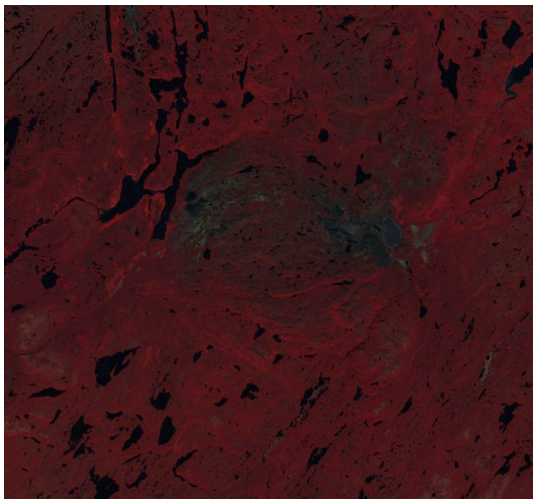
- Excluding masked areas, topographic data alone can explain >60% of NDVI variance in study site
- RMS residual after removal of nonparametric topographic trend is ±0.11
- Anomalies as large as –0.6 are observed
- Most negative anomalies of -0.2 or more can be obviously associated with vegetation damage or loss

Generalisation to other sites?

- not tested yet!
- needs

  NDVI to be mainly controlled by topography (testable)

  image area significantly larger than impacted area (testable)
- doesn't need accurately calibrated data
- other candidate areas on Kola Peninsula and Noril'sk
- potential application to any form of ground disturbance that reduces vegetation cover
- application to historical data for change analysis



Nikel-Zapolyarnyy 2009