

**Машинное обучение в прикладных задачах,
решаемых в Лаборатории информационных
технологий им. М.Г. Мещерякова**

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О машинном обучении и его применении к задачам физики высоких энергий. Ососков Г.А. 15.10

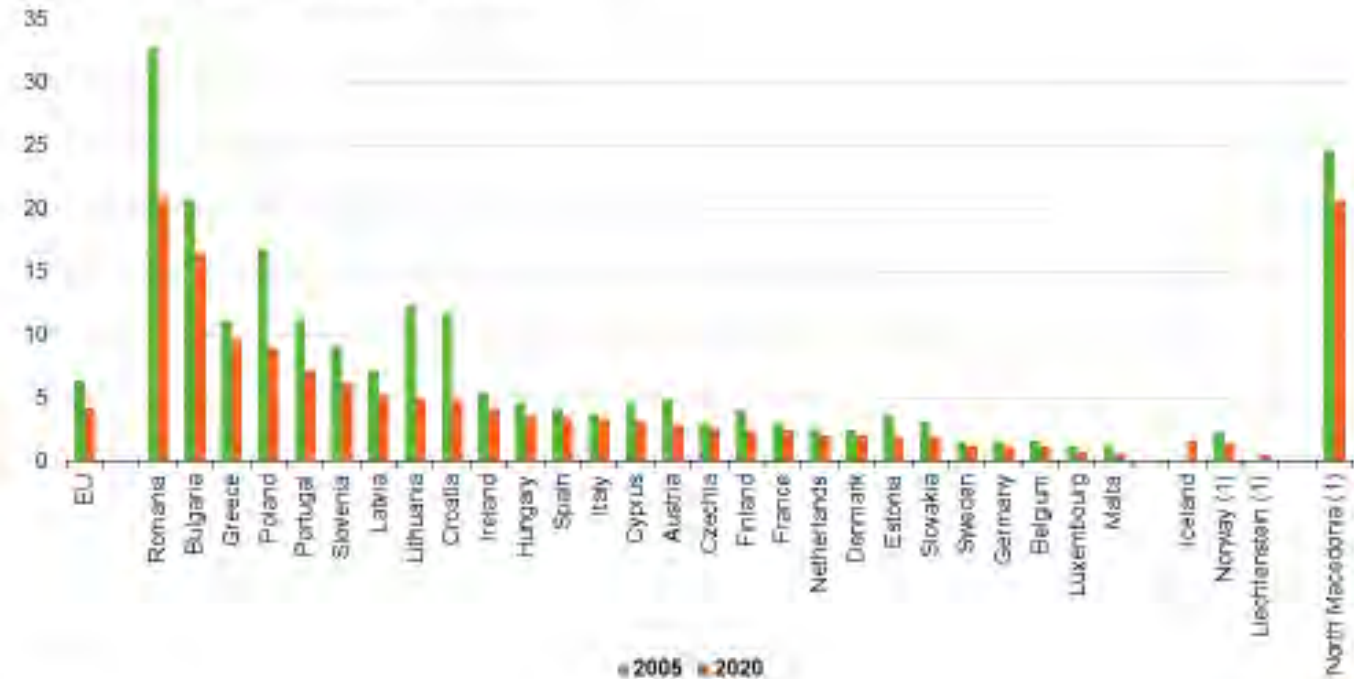
Применение машинного обучения в задаче идентификации частиц. Папоян В.В.

1. Распознавание болезней и проблем в развитии растений
2. Контроль загрязнения тяжелыми металлами

Background



Employment in agriculture
(% of total employment, 2005 and 2020)



(1) 2019.
Source: Eurostat (online data code nama_10_a04_e)



Advanced technologies in agriculture



- IoT, sensors,
- remote sensing,
- big-data analysis,
- robots,
- drones,
- digitalization,
- artificial intelligence,
- etc.

There are also many interesting projects in chemistry-, biology-, genetic- and other areas

Animal husbandry is very interesting area with great impact of advanced technologies, but it is out of scope of the report!

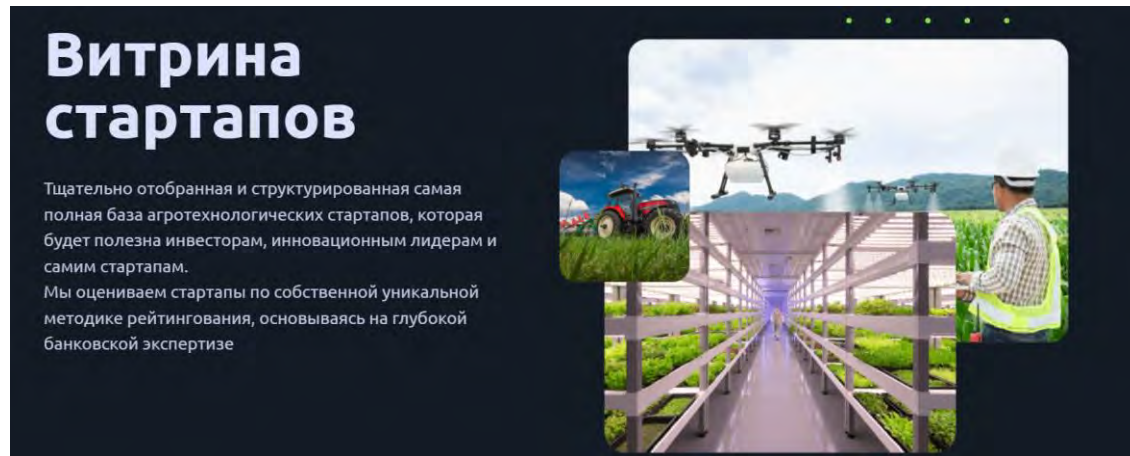
Artificial intelligence in agriculture



- Soil management,
- problems detection,
- crop health monitoring,
- yield prediction,
- price forecasting,
- yield mapping,
- optimization of pesticides and fertilizers usage,
- etc.

Where to find data?

<https://rshbdigital.ru/startups>



Витрина стартапов

Тщательно отобранная и структурированная самая полная база агротехнологических стартапов, которая будет полезна инвесторам, инновационным лидерам и самим стартапам.
Мы оцениваем стартапы по собственной уникальной методике рейтингования, основываясь на глубокой банковской экспертизе

<https://data-economy.ru/reports>



ЭКОНОМИКА

Эффективные отечественные практики на базе технологий искусственного интеллекта в сельском хозяйстве

МАЙ 2022

Эффективные отечественные практики на базе технологий искусственного интеллекта в сельском хозяйстве

01.06.2023



https://t.me/svoe_fermerstvo

https://t.me/agrotech_startup

<https://t.me/fermerznaet>

...

ОБЗОР РЫНКА АГРОТЕХНОЛОГИЙ

(ВКЛЮЧАЯ FOODTECH) ПО ИТОГАМ 2022 ГОДА



РоссельхозБанк

From Top to bottom – soil & crop management

<https://www.aerospace-agro.com/>

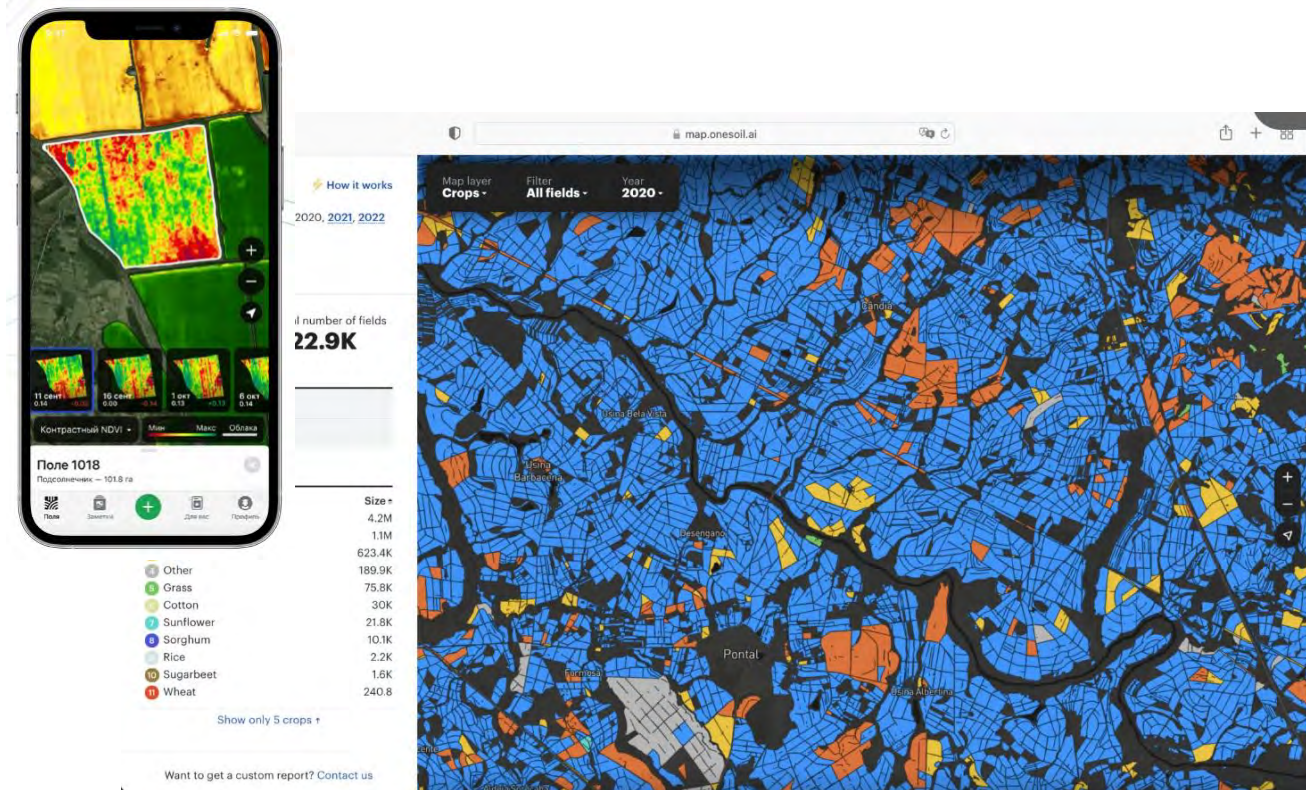
We study territories and cultures using information and aerospace technologies in order to increase the yield and revenue of the enterprise.



Commercial programs

<https://onesoil.ai/>

Helps to remotely monitor the condition of land, crops, increase yields, reduce the cost of seeds and fertilizers



Open programs. 10 -15 m resolution

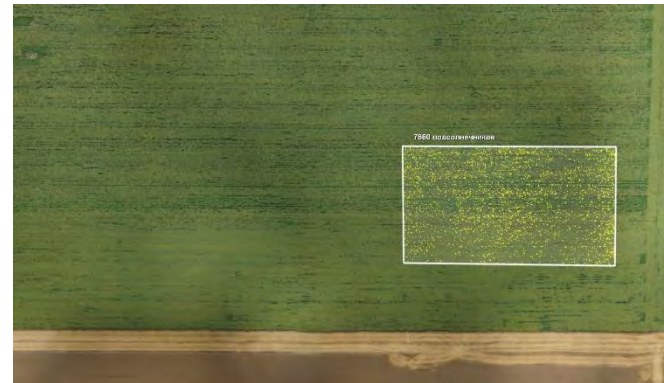
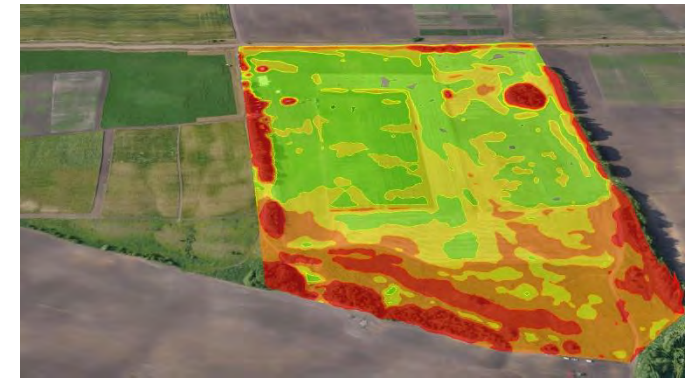
"Teleagronom" - InnoGeoTech, Innopolis University, etc
TERRA TECH presented a complex of geoservices "DigitalEarth"

Geoscan

Geoscan is a Russian group of companies engaged in the development and production of unmanned aerial vehicles (UAS), as well as the development of software for photogrammetric data processing and 3D visualization

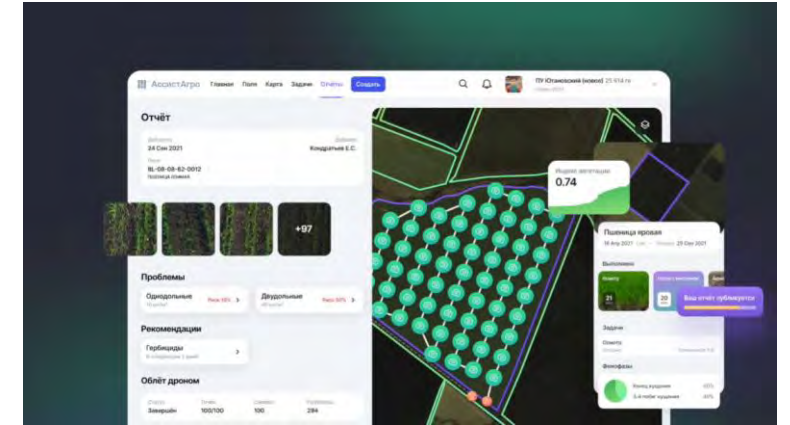


Sputnik AgroGeoinformation system focused on solving the problems of precision farming.



AssistAgro

AssistAgro is a digital platform for effective agribusiness management

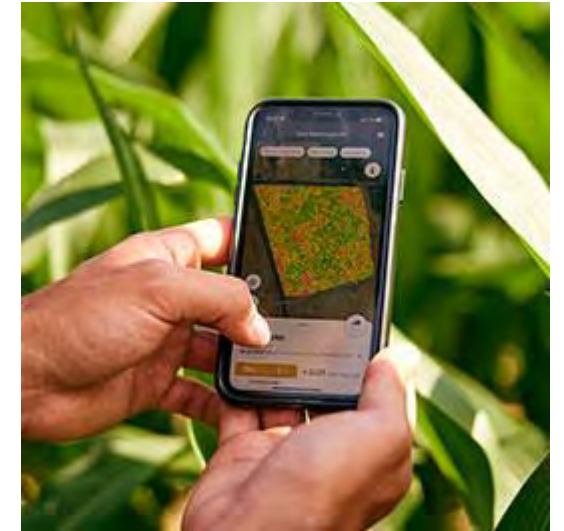


AssistAgro allows one to solve the following tasks:

- forecast of emergence and development of weeds;
- calculation of the density of the condition and the quality of the placement of crop plants;
- forecast of occurrence and development of diseases of agricultural plants;
- forecast of the emergence and development of pests of agricultural plants;
- obtaining recommendations on the optimal dates for agroscouting, pesticide application, tank mix composition and consumption rate;
- yield forecast;
- independent field status control



Sure, there are lots of foreign companies with same functional!

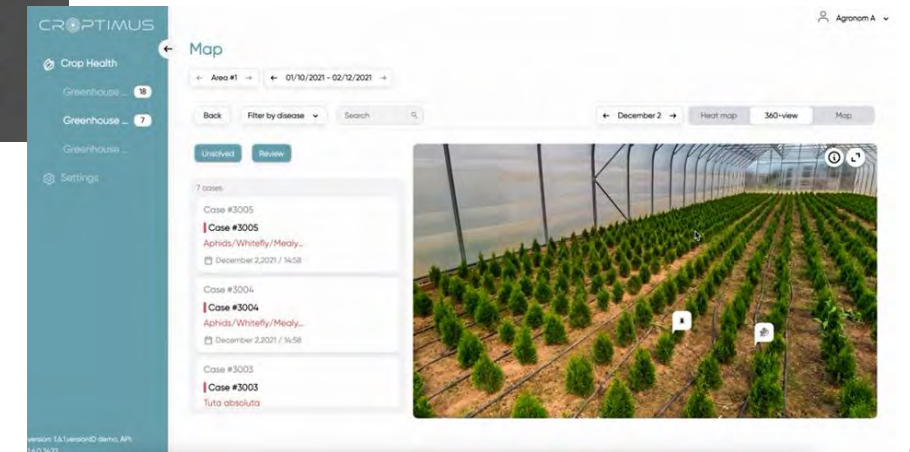


<https://www.taranis.com/>

<https://www.fermata.tech/>



CROPTIMUS



And many others

SiberianTiger – field robot (project stopped)



Датчики

Датчик температуры почвы

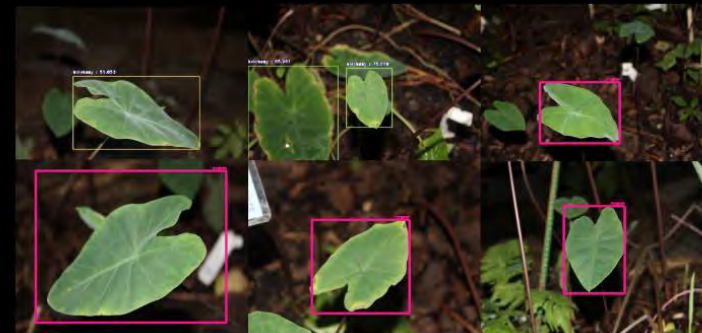
Ph метр почвы

Датчик влажности почвы

Датчик солёности почвы



Работа детектора и классификатора



P.s. Метод обучения с подкреплением. Baseline на keras с YoloV3

Autonomus agro-robots

<https://ravenind.com/> omnipower-3200



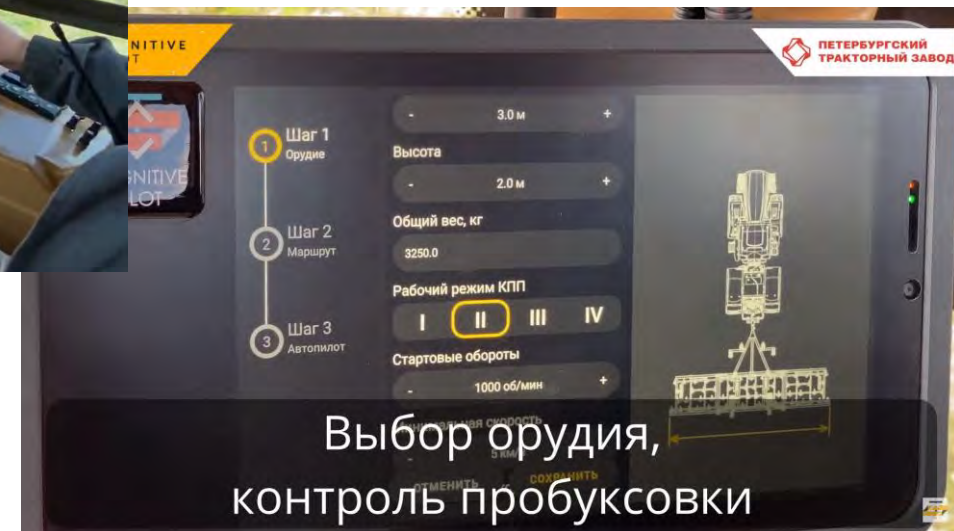
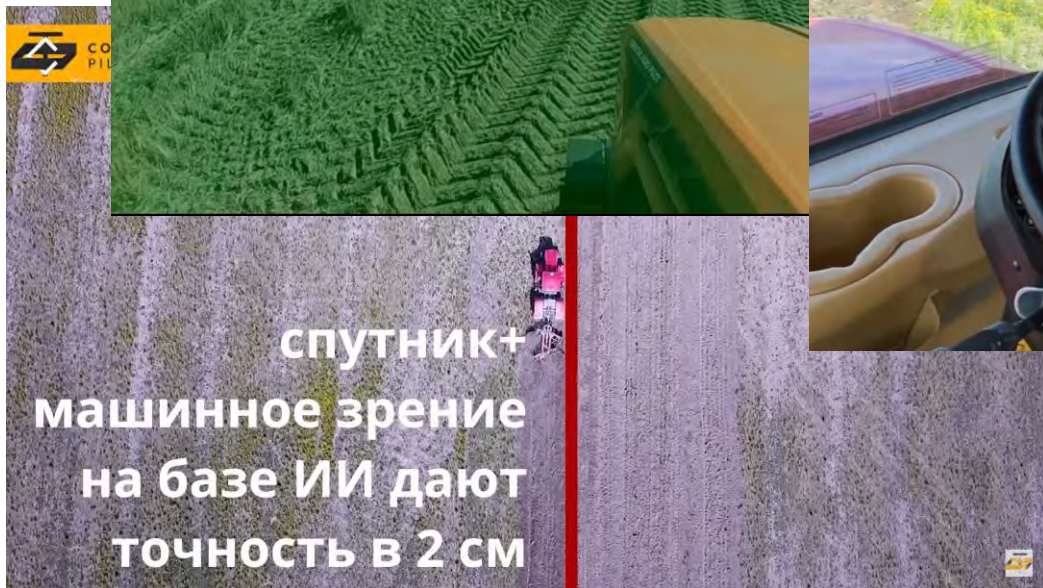
Case IH Magnum (concept)

Cognitive Technologies (<https://cognitive.ru/>)



Has installed artificial intelligence (AI)-based autonomous control systems for agricultural transport on more than 1,000 combines in Russia. Since the spring of 2023, the systems have been installed on more than 100 tractors in Russian agricultural enterprises from Pskov to Blagoveshchensk. They are serially equipped with tractors "Kirovets" at the St. Petersburg Tractor Plant.

According to experts, the cost of such a complex is no more than 5-10% of the total cost of the machine. Using the system allows you to increase labor productivity up to 25%, save fuel (7%) and other resources.



Harvesting robots

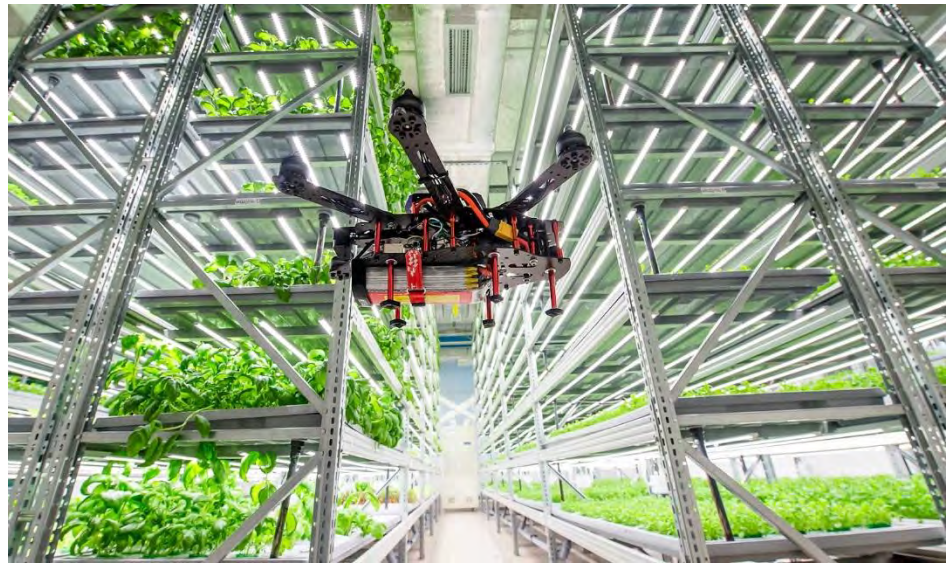
Root AI



Controlled environment farming

iFarm (<https://ifarm.fi/>)

GALAD Green Line (<http://npcsvet.ru/>)



<https://agrotechfarm.com>



КРУГЛОГОДИЧНОЕ ВЫРАЩИВАНИЕ В ЗАКРЫТОМ ПОМЕЩЕНИИ



<https://city-farmer.ru/>),
Healthy garden (<https://healthygarden.ru/>)



Foreign companies: GreenLabs, Plenty, Pure Harvest Smart Farms iFarm и т.д.

<https://farm.bot> – plants printer



What about LIT activities?

Specialization

Classification



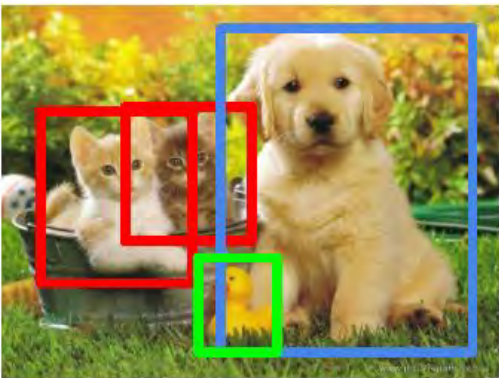
CAT

Classification + Localization



CAT

Object Detection



CAT, DOG, DUCK

Instance Segmentation



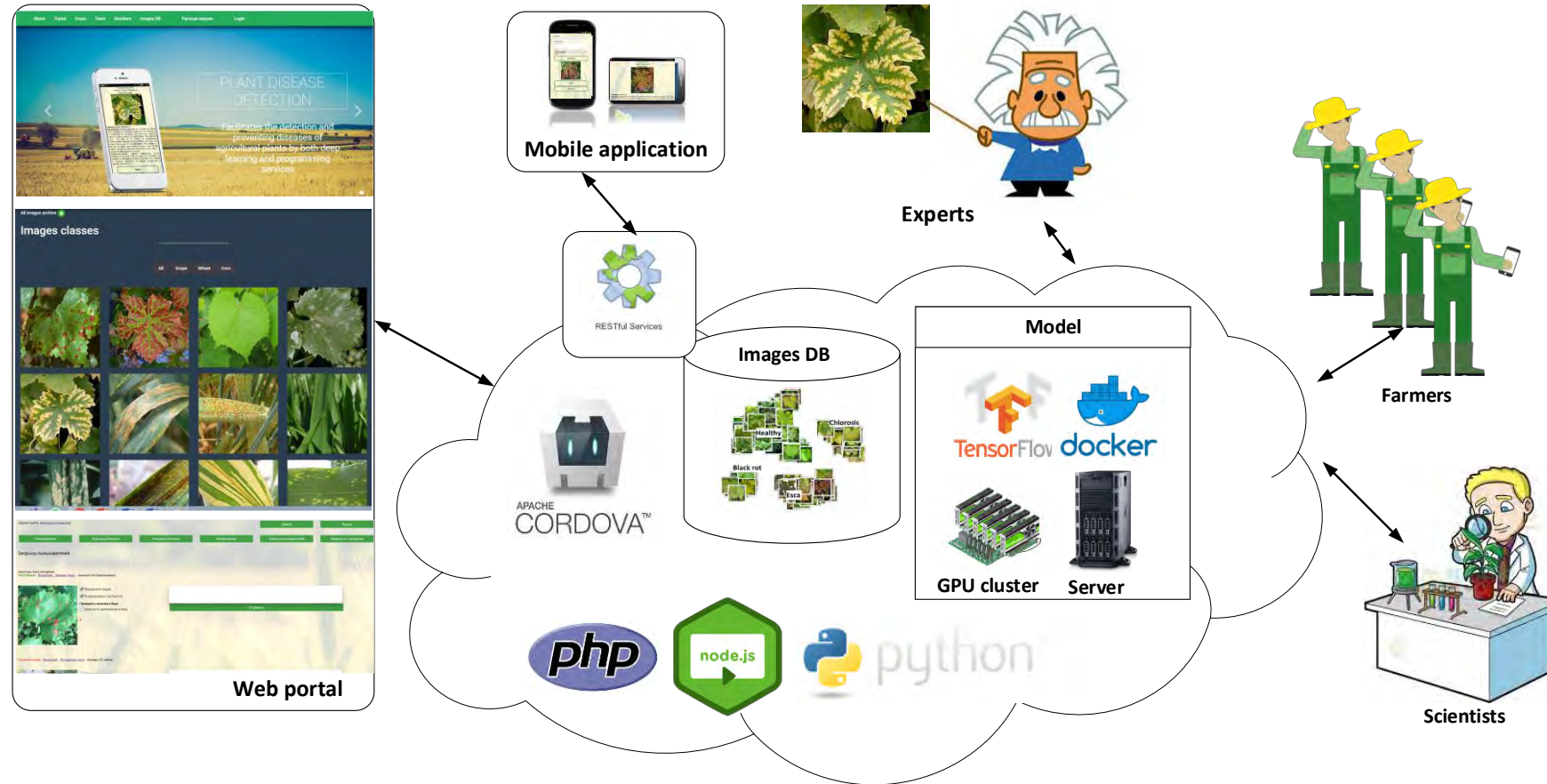
CAT, DOG, DUCK

Single object

Multiple objects

- Choosing the optimal architecture and mechanisms to solve the problem
- Developing a pre-built solution, training models, and implementing a software environment based on proven approaches and methods
- Choosing the equipment and creating devices to support the operation of the models

Palnts disease detection platform



PDDP consists of a set of interconnected services and tools developed, deployed and hosted with the help of the JINR cloud infrastructure. Our web-portal (pdd.jinr.ru – old. Doctorp.org - new), was developed with the Node.js and PHP. It provides not only a web-interface but also the API for third-party services. We have the Pytorch model in the Docker realized as a Tensorflow serving. The model can work at the virtual server, or at a GPU cluster.

We have a mobile App for Android that was developed using the Flutter, so we could build it for iOS, and Windows.

PDDP database

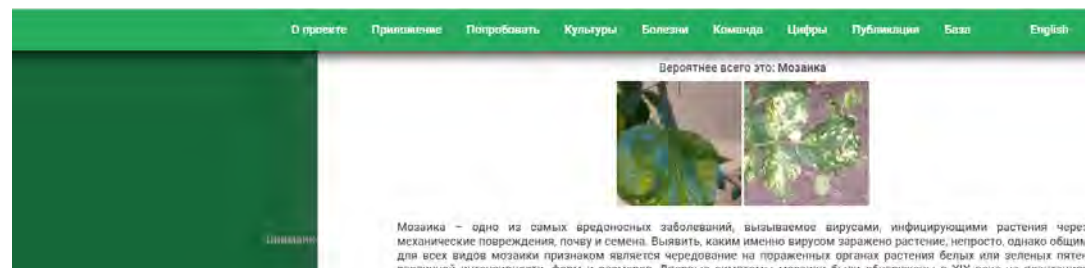
В настоящий момент у нас есть отдельные модели для следующих культур: яблоки, барбарис, вишня, хлопок, пшеница, кукуруза, конопля, огурцы, смородина, виноград, орхидеи, томаты, клубника.



manioc
 tradescantia tomatoes crassula
 anthurium barberry balsam
 mango aglaonema
 dracaena rosemary blackberry potatoes bamboo
 monstera currant chrysanthemum zamioculcas laurel peas cotton
 cactus grape peonies corn launel cabbage violet
 pepper spadeles aster chlorophytum begonia maranta raspberry host
 decembrist geranium aloccasia aloe spathiphyllum orchid succulent
 lettuce roses hydrangea geranium aloe spathiphyllum parsley beet
 basil ficus hydrangea geranium aloe spathiphyllum parsley beet
 blueberry onion dieffenbachia marigold
 carrot tulip thuya petunia avocado
 hibiscus chamaedorea wheat
 coleus lavender dahlias

General model > 65 classes
 Corpse model > 70 classes
 Specialized models > 25 classes

Web-portal, telegram-bot, API, app



Мозаика – одно из самых вредоносных заболеваний, вызываемое вирусами, инфицирующими растения через механические повреждения, почву и семена. Выявить, каким именно вирусом заражено растение, непросто, однако общим для всех видов мозаики признаком является чередование на пораженных органах растения белых или зеленых пятен различной интенсивности, форм и размеров. Впервые симптомы мозаики были обнаружены в XIX веке на плантациях восточных штатов США. Вскоре выяснилось, что причиной заболевания являются вирусы, а не бактерии. В настоящее время известно, что за ним болеют соседние растения, и вскоре вся плантация стала непригодна для выращивания табака. В настоящее время мозаика является одной из самых распространенных болезней табака. Мозаика – это вирусное заболевание, которое передается через сок растений, насекомых, тлю, цикадок, клещей, трипсов, муравьев. Вирус сохраняется в переносчике в течение нескольких часов и попадает на здоровое растение при укусе вредителя к новому источнику питания. Вирус не передается через пыльцу, семена, растительные остатки и сорняки. Вирус не передается через воду и человека. Мозаика распространяется при вегетативном размножении, если используются зараженные клубни, черенки, подвой и привои. Даже при неудачной прививке, если не произошло срастания, инфекция может перейти в здоровые ткани. Замена, что заражение происходит быстрее на травянистых растениях, чем на древесных. Мозаика распространяется с помощью садового инвентаря: прививочного ножа, секатора и ножниц при обрезке, когда садоводы игнорируют их дезинфекцию. Мозаика поражает огурцы, томаты, перцы, капусту, яблоно, редис, картофель, смородину, а также цветы.

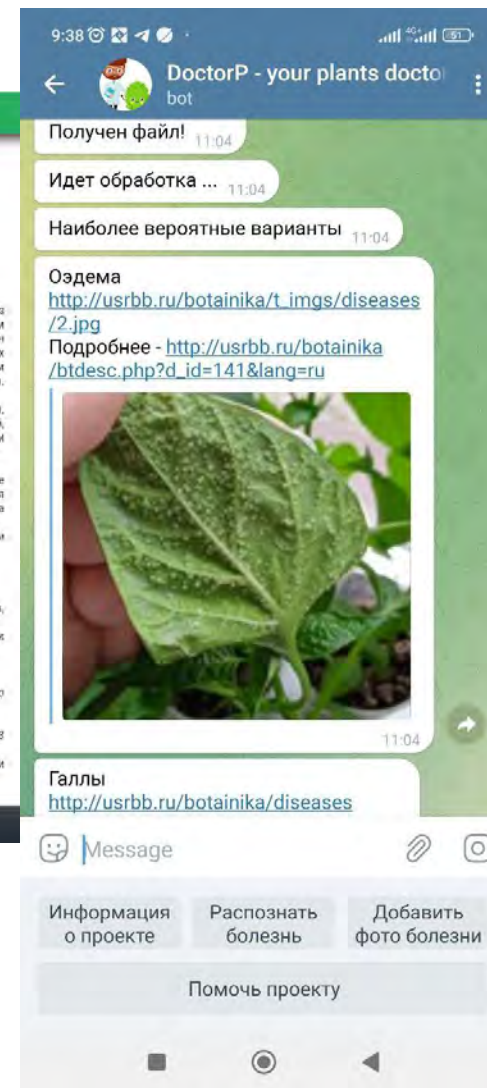
Пораженные вирусом табачной мозаики, спасти невозможно. В настоящее время пока нет средств, которые бы уничтожали вирус. В настоящее время пока нет средств, которые бы уничтожали вирус. В настоящее время пока нет средств, которые бы уничтожали вирус.

Мозаика является одним из самых распространенных заболеваний растений. Главная задача – укрепить защитные силы растений, так как в настоящее время, самое слабое из них. Не менее важна борьба с вредителями-переносчиками вируса.

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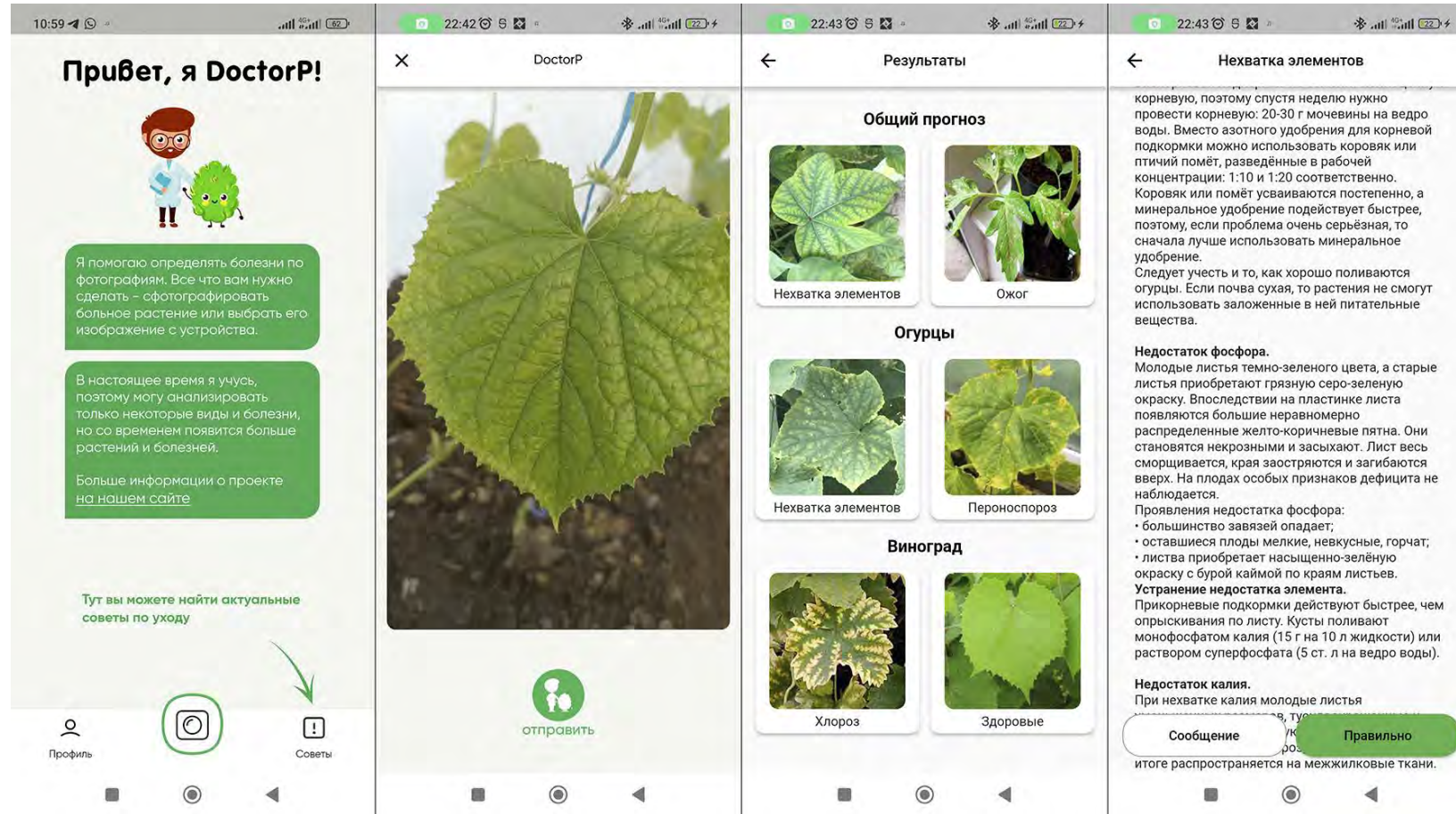
```
{
  "error": 0,
  "general_predictions": [
    { ... },
    { ... },
    { ... }
  ],
  "custom_predictions": [
    { ... },
    {
      "type": "розы",
      "prediction": [
        {
          "name": "Мозаика",
          "sample": "http://usrbb.ru/botainika/diseases/rmv1.jpg",
          "description": "<p>Это наиболее распространенное заболевание вирусного типа. Узнать его очень просто – листья покрываются хлоротичными пятнами и узорами, которые могут перейти в прожилковый хлороз. Листья деформируются (узколистность, курчавость, морщинистость) и постепенно опадают. Рост побегов замедляется, и они не вызревают. Побеги, которые больны, вырезают. При дальнейшем распространении болезни растение уничтожают</p>"
        }
      ]
    }
  ]
}
```



- FASCO company with the HoGa application.
- Several organizations have already been granted test access to our API.
- The Plant Care Service from the Russian Agricultural Bank
- Andijan Institute of Agriculture and Agrotechnics of the Republic of Uzbekistan have utilized our API in their respective applications, which focus on describing plant diseases and pests.

Mobile App

Google play: "DoctorP". * Only android version is available



The user has the opportunity to photo a diseased plant and get a prediction for the disease and treatment suggestions. It is possible to download images from device store. The application requires access to the Internet to work.

We can run the model on the mobile device directly (we have tried it) but models changing too often.

Server side

Здравствуйте, [Александр Ужинский](#)

[Пользователи](#) [Рекомендации](#) [Культуры/Болезни](#) [Описание](#) [Уход](#) [Аналитика](#) [Изображения](#) [Домой](#) [Выход](#) [Запросы пользователей](#) [Запросы от экспертов](#)

Описание/Лечение:

|

Орхидеи - Антракноз



Описание:

Paragraph **B** *I* Source

Заболевание антракноз относится к разряду инфекционных. Возбудители – грибы рода *Colletotrichum*. Встречается несколько подвидов:

- *Colletotrichum gloeosporioides* поражает преимущественно фаленопсис;
- *Colletotrichum orchidearum* и *Colletotrichum boninense* – катлею;
- *Colletotrichum karstii* и *Colletotrichum crossandrae* – ванду;
- *Colletotrichum coccodes* и *Colletotrichum crassipes* – цимбидиум.

На разных сортах цветка болезнь проявляет себя по-разному. Симптомы зависят от структуры и толщины листьев. На антракноз можно указывать:

- сухие белесые пятна на листьях орхидей;
- коричневые пятна;
- черная пятнистость, постепенно светлеющая;
- круглые подушечки спор (белые, розовые, желтые, бурые) – появляются со временем.

Пятна антракноза постепенно увеличиваются и сливаются.

Антракноз развивается в результате инфицирования. Споры грибов легко переносятся по воздуху, попадают на руки, одежду, инструменты при работе с зараженными растениями. Нередко источником инфекции становится недавно приобретенный комнатный цветок.

При низкой влажности воздуха в оранжерее (60 % и меньше) антракноз может долгое время не проявлять себя.

В условиях повышенной влажности и жары инкубационный период в среднем занимает от 4 до 10 дней. Чаще всего распространение болезни происходит при температуре +25 °C и влажности 90 %. Однако антракноз способен развиваться и в гораздо более неблагоприятной среде (при температуре от +4 °C до +30 °C).

Здравствуйте, [Татьяна Жеремина](#) [Домой](#) [Выход](#)

[Запросы пользователей](#) [Аналитика](#) [Описание/Лечение](#) [Уход](#) [Общие рекомендации](#)

Запросы пользователей

123 1

N:51580 (2023-05-18 14:26:20)

Прогноз модели: **Общая модель**. Нехватка элементов, Ожог | **томаты**. Нехватка элементов, Здоровые | **картофель**. Курчавость, Фитофтороз | **перец**. Курчавость, Мозаика

{'success': 'true', 'cropsel':'tomatoes', 'cropsel2':'potatoes', 'cropsel3':'pepper', 'full1':'Nutrient deficiency', 'full2':'Burn', 'full3':'Yellow leaves', 'cropsel_disease1':'Nutrient deficiency', 'cropsel_disease2':'Healthy', 'cropsel_disease3':'Leaf miners', 'cropsel_disease4':'Leaf curl', 'cropsel2_disease2':'Late blight', 'cropsel_disease3':'Colorado beetle', 'cropsel_disease1':'Leaf curl', 'cropsel_disease2':'Mosaic virus', 'cropsel_disease3':'Nutrient deficiency'}

Расовозманию:

- не понятно
- правильно
- неправильно

Запросить добавление в базу

Требуется проверка

Ерунда, удалить

Культура

Неопределено

Культура, если нет в списке выше:

Болезнь

Неопределено

Болезнь, если нет в списке выше:

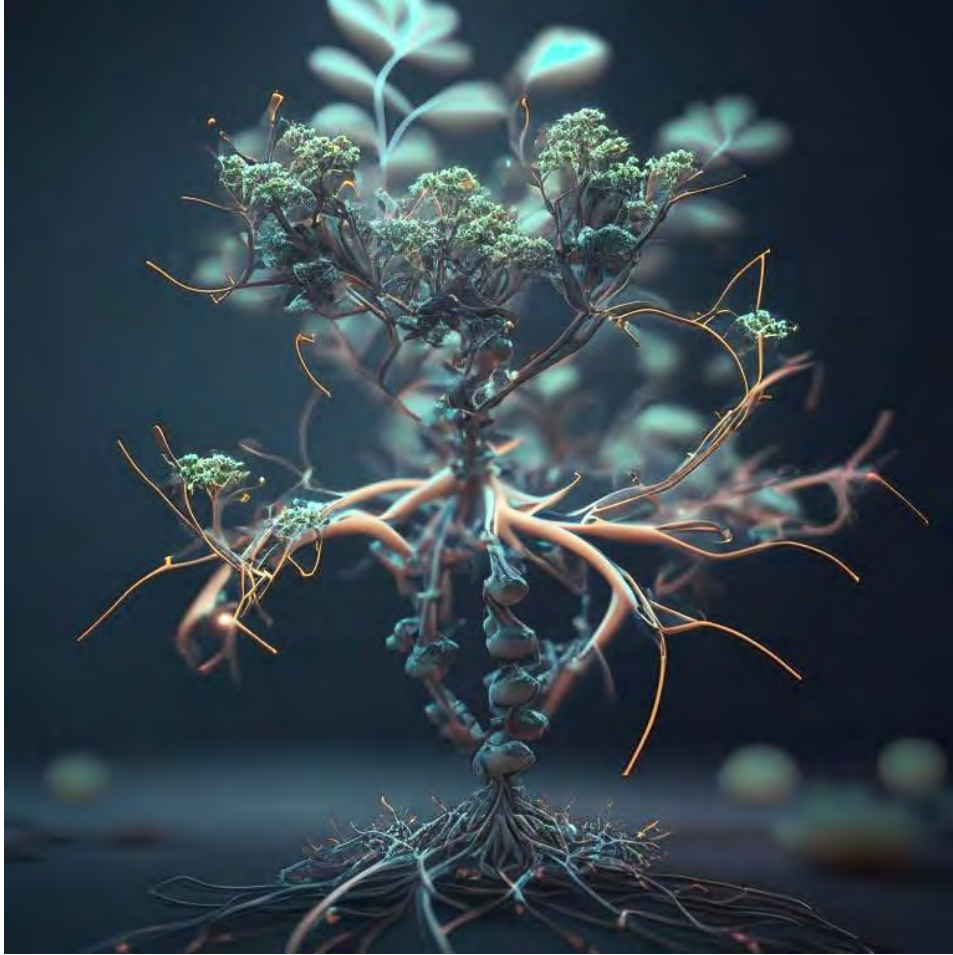
Комментарий, если нужен

threat to cucumbers and zucchini, as it can destroy a significant part of the crop.

The disease develops as a result of infection. Fungal spores are easily carried through the air and can land on hands, clothes, and tools when working with infected plants. A recently acquired indoor flower can also become a source of infection.

With low humidity in the greenhouse (60% or less), anthracnose may not manifest itself for a long time. In conditions of high humidity and heat, the incubation period averages from 4 to 10 days. The spread of the disease is most common at a temperature of +25 °C and a humidity of 90%. However, anthracnose can also develop in a much more unfavorable environment (at temperatures from +4 °C to +30 °C).

What's under the hood



We conducted research in the field of optimizing neural network architectures for models.

We tested various state-of-the-art neural network architectures, explored methods for automatically selecting optimal data augmentation policies (auto-augmentation), and experimented with different loss minimization functions (including contrastive, triplet, arcface, cosface, and sphereface).

We identified the optimal approaches for training the models

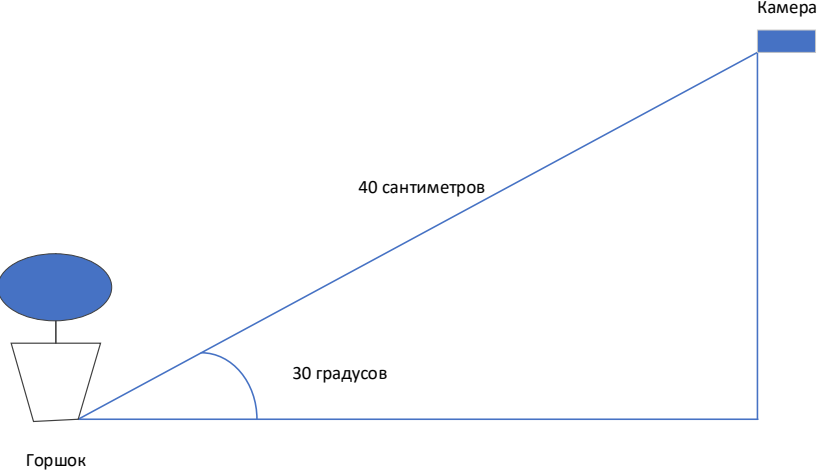
MobileNet/ ConvNeXt + No augmentation + No quantization + Triplet loss

General model -> corpse model -> custom models

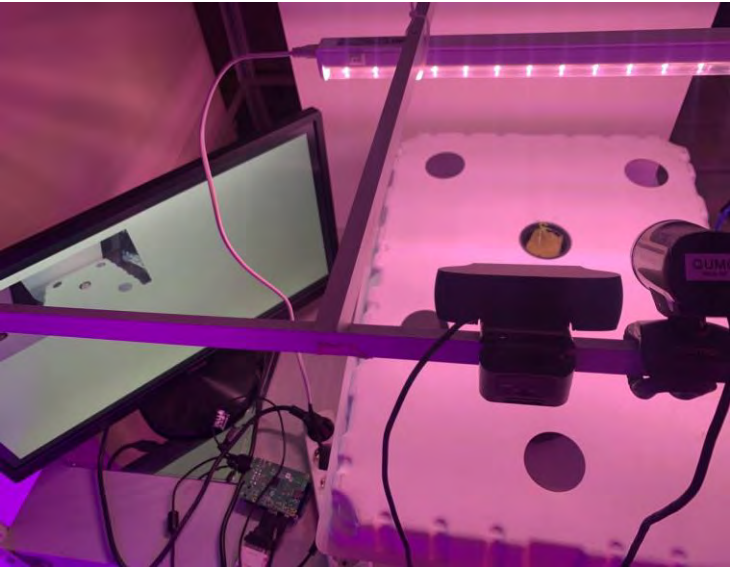
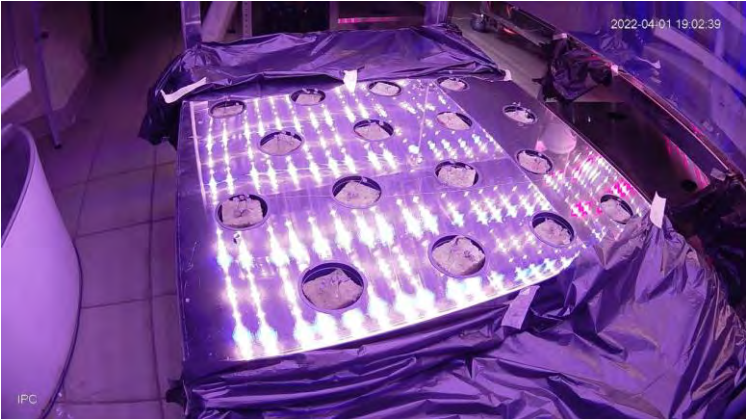
Validation accuracy > 97%

Plant state tracking

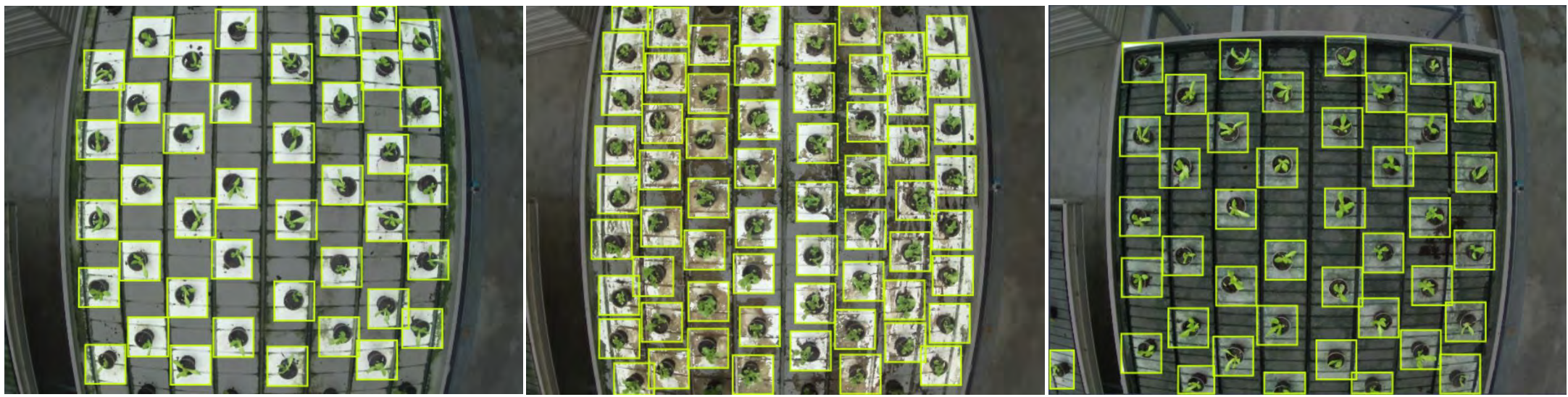
Joint project with the Temiryazev Academy within the framework of the project World-class Scientific Center "Agrotechnologies of the Future"



- Classification of the degree of development of the plant.
- Determination of the weight group of the plant.



Salads classification

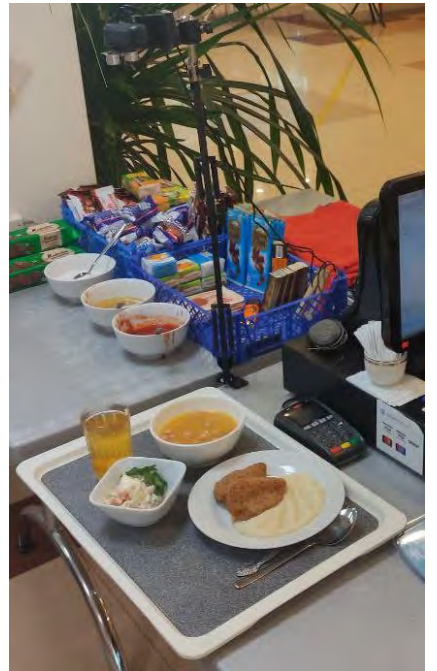


Object detection – 1 class
Classification – 6 classes

Accuracy > 99%

Set of images

Data collection was carried out in automatic mode using raspberry pi 4, a digital camera with manual focus, and sonar.



A set of images in 5 days:



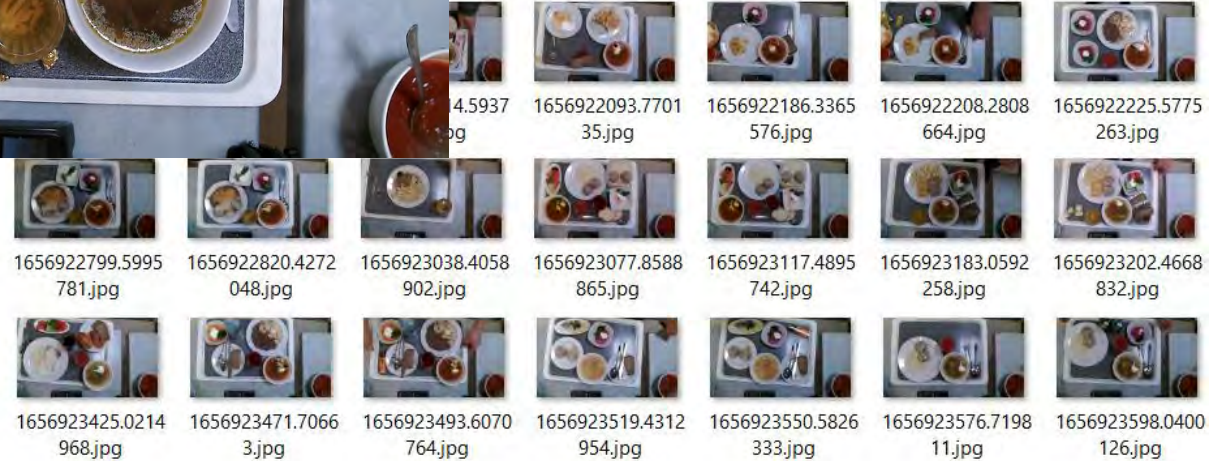
446 images



More than 150 different classes of objects



Dining room LIT JINR



Final results

Yolo v5s

Metrics results

Recall	0.856
Precision	0.723
mAP	0.906

Yolo v6s

Metrics results

Recall	0.805
Precision	0.687
mAP	0.854

Yolo v7

Metrics results

Recall	0.901
Precision	0.845
mAP	0.925

Yolo + Triplet

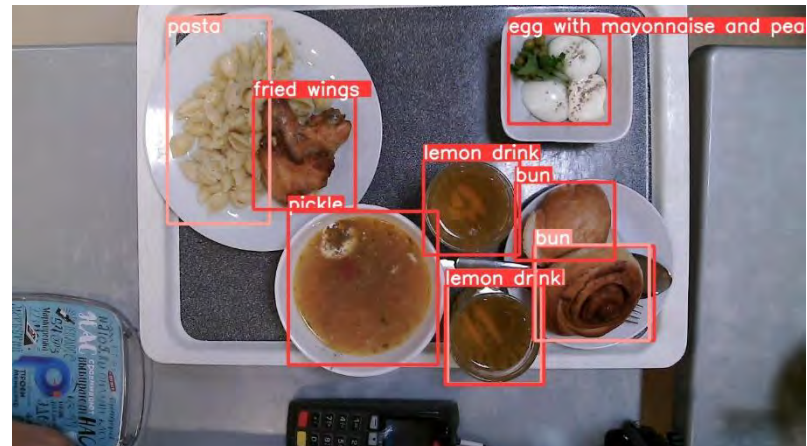
Metrics results

Recall	0.995
Precision	0.994

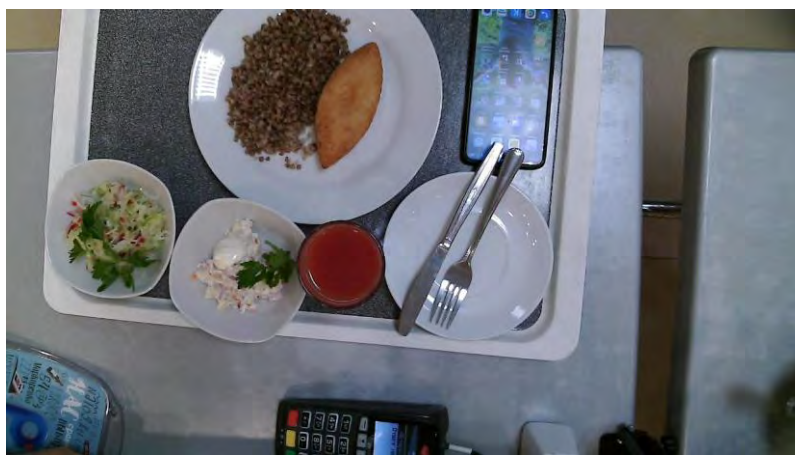
Examples

Input images

Output images

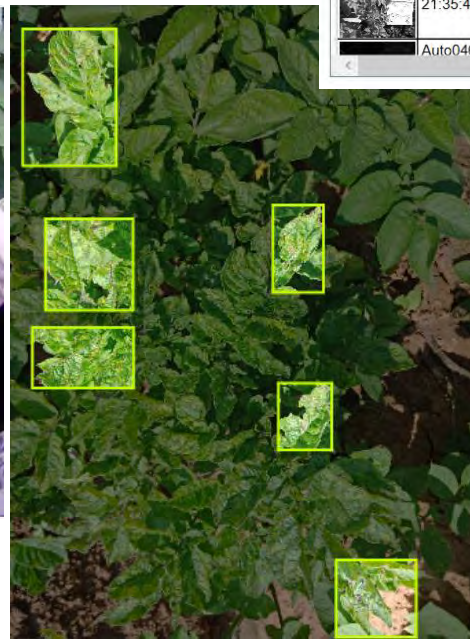
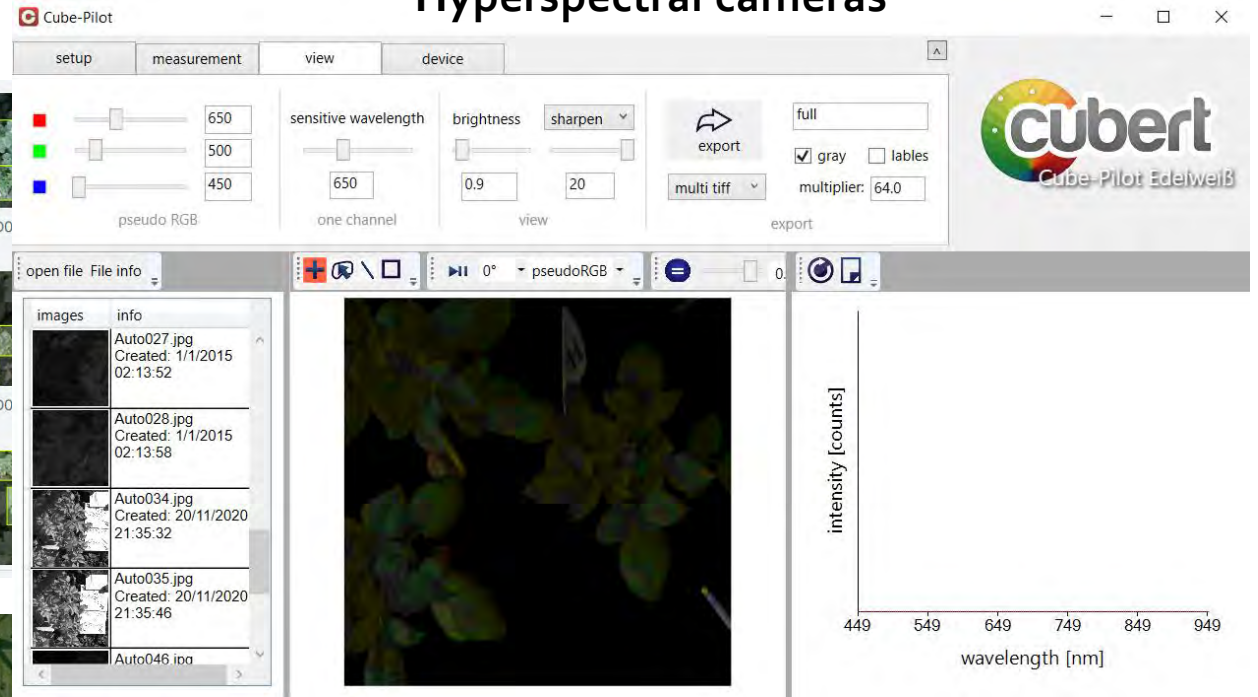
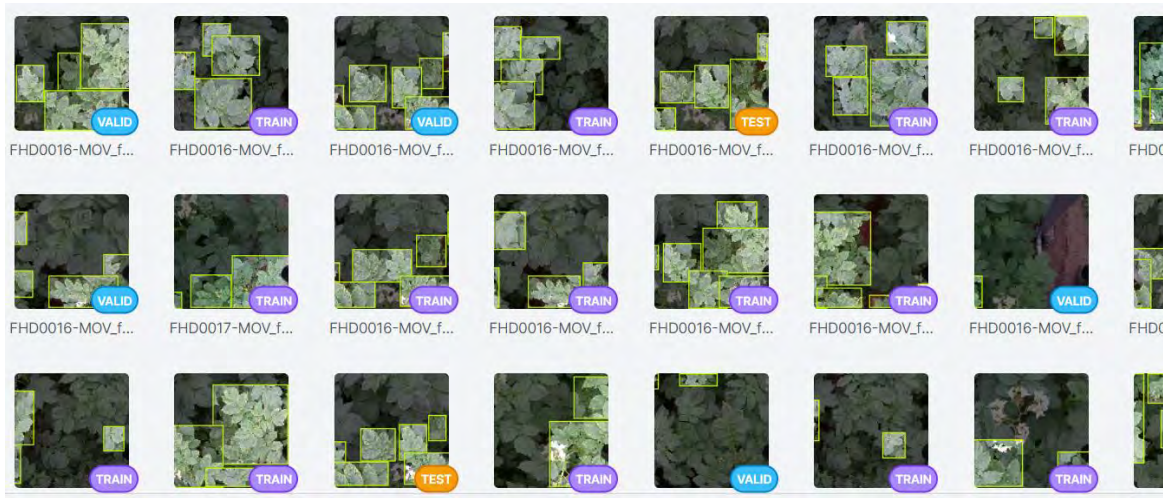


Processing



Potatoes disease (Doka-Gennyye Tekhnologii)

Hyperspectral cameras



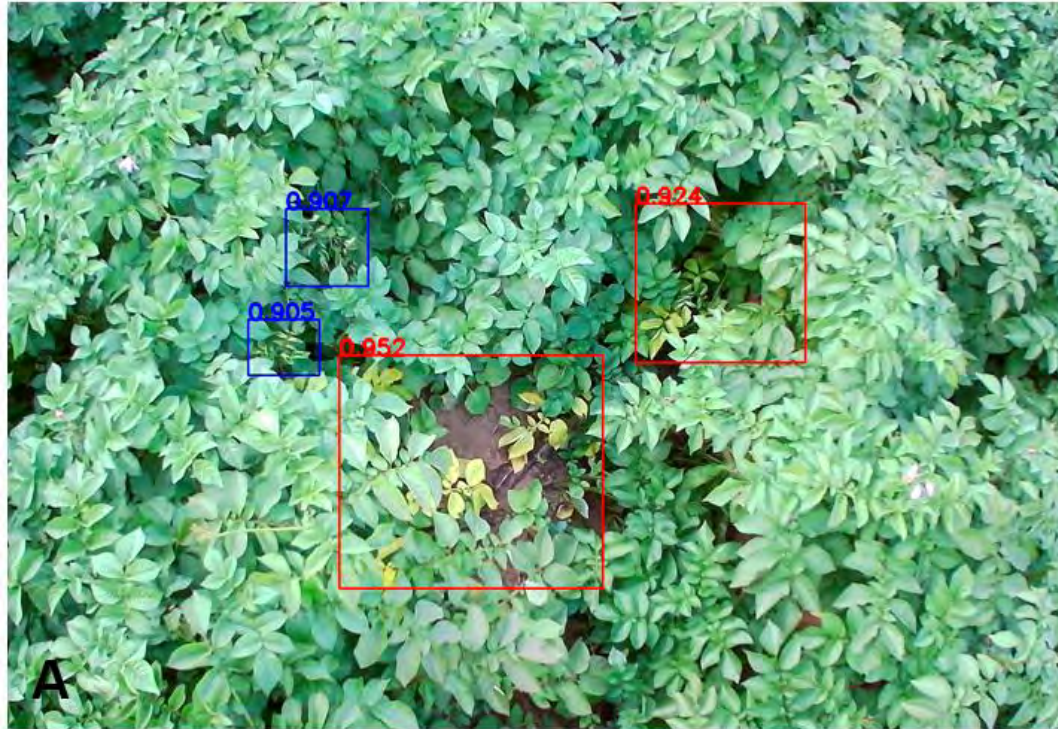
YOLOv7

YOLO-NAS

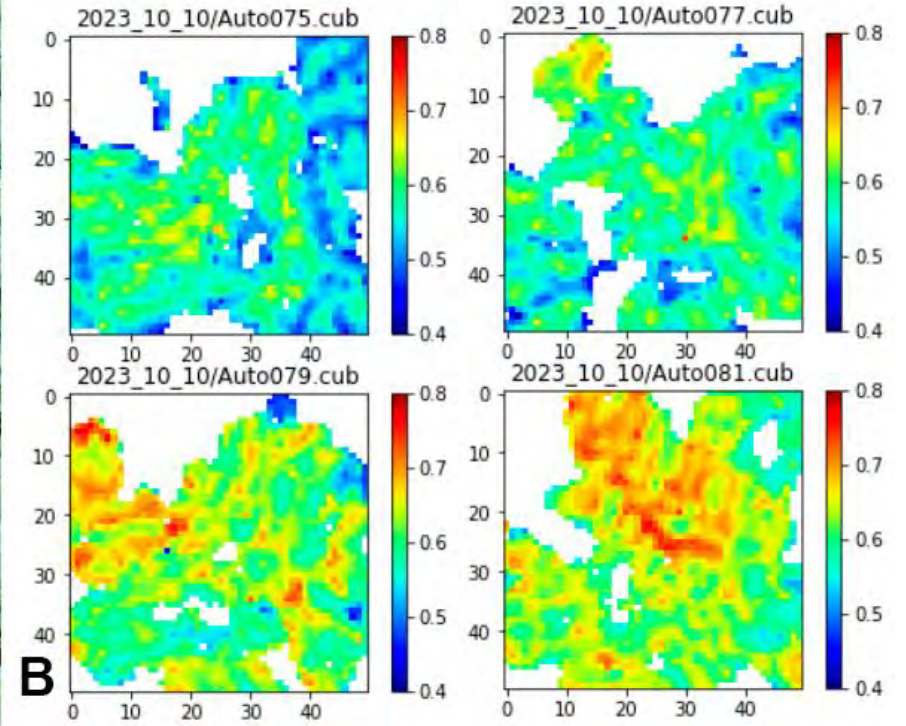
ultralytics
YOLOv8

Potatoes disease (Doka-Gennyye Tekhnologii)

RGB



Hyperspectral cameras



Automated analysis of the state of plants in the greenhouse complex



<https://skoltech.space/greenhouse-robot-the-first-test-run-turned-successful>

Контроль загрязнения тяжелыми металлами

Environmental Concerns

The environmental problems like global warming, acid rain, air pollution, urban sprawl, waste disposal, ozone layer depletion, water pollution, climate change and many more affect every human, animal, and nation on this planet.

Over the last few decades, the exploitation of our planet and the degradation of our environment has gone up at an alarming rate. As our actions have been not in favor of protecting this planet, we have seen natural disasters striking us more often in the form of flash floods, earthquakes, blizzards, tsunamis, and cyclones.



Air pollution

Air pollution has a significant **negative impact** on the various components of ecosystems, **human health**, and ultimately, causes significant **economic damage**.

More than nine out of 10 of the world's population – 92% – lives in places where **air pollution exceeds safe limits**, according to research from the World Health Organization (WHO).



There are regional and international **environment control programs**. They use different techniques and tools but as a result, they all want to understand **what is the current situation** and how it will evolve.

Approaches



Generally, studies are based on the data obtained at the sampling sites in manual or automatic mode. The collected material is analyzed using various techniques in the field or in special laboratories. Air quality (AQ) monitoring stations provide information about regulatory air pollutants such as gaseous pollutants, PMs, and rarely about heavy metals. To get detailed information samples should be processed in laboratories.

After collection, the data are aggregated and interpreted, and quite often the results are ambiguous and require the involvement of experts.

In most cases such kind of researches are limited, both spatially and temporally



Modeling - Motivation & Benefits

Modelling of air pollution can be a good option for overcoming gaps in the data gathering.

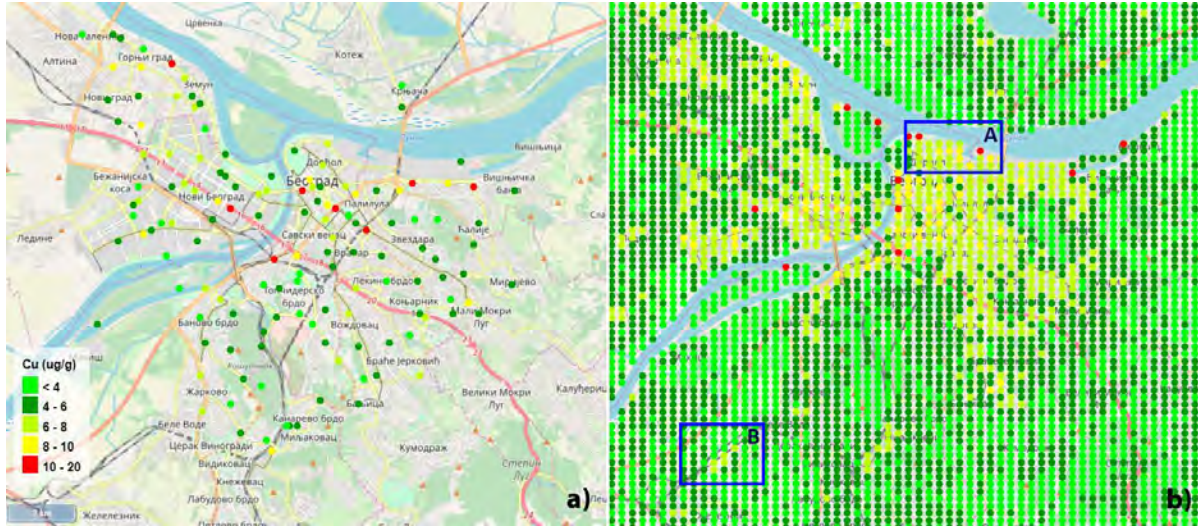


Figure 1. Concentration of Cu in the summer of 2013 (Belgrade): a) real measurements, and b) prediction values; area A represents central part of Old Belgrade with permanently high traffic flow; area B represents a large railway terminal

Modelling allows us to:

- monitor the evaluation of situation when it needed,
- get detailed information about areas of interests,
- check the situation at the cross border areas,
- partly automate the environment control process.

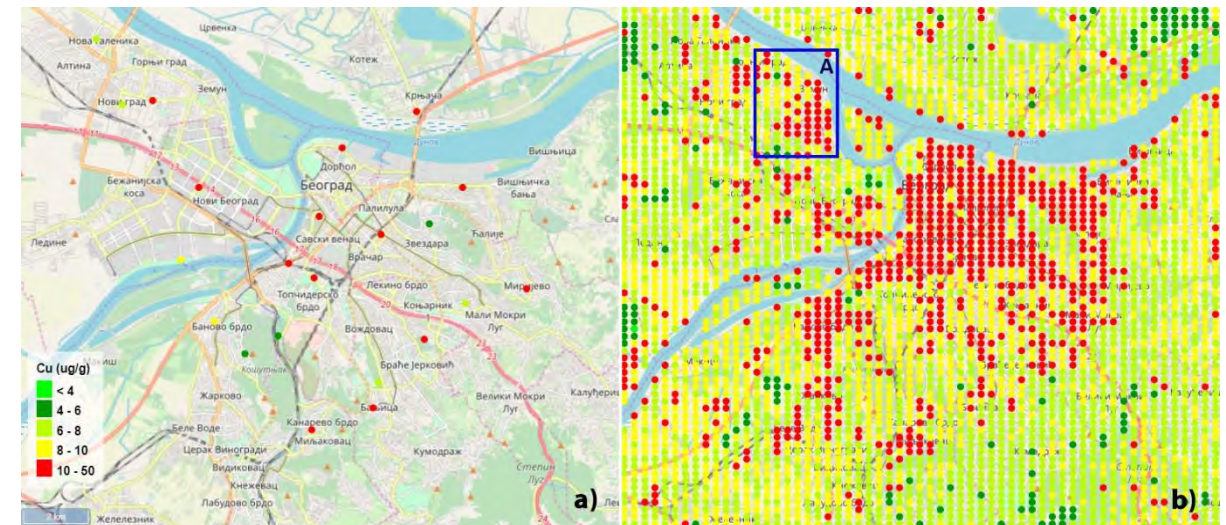
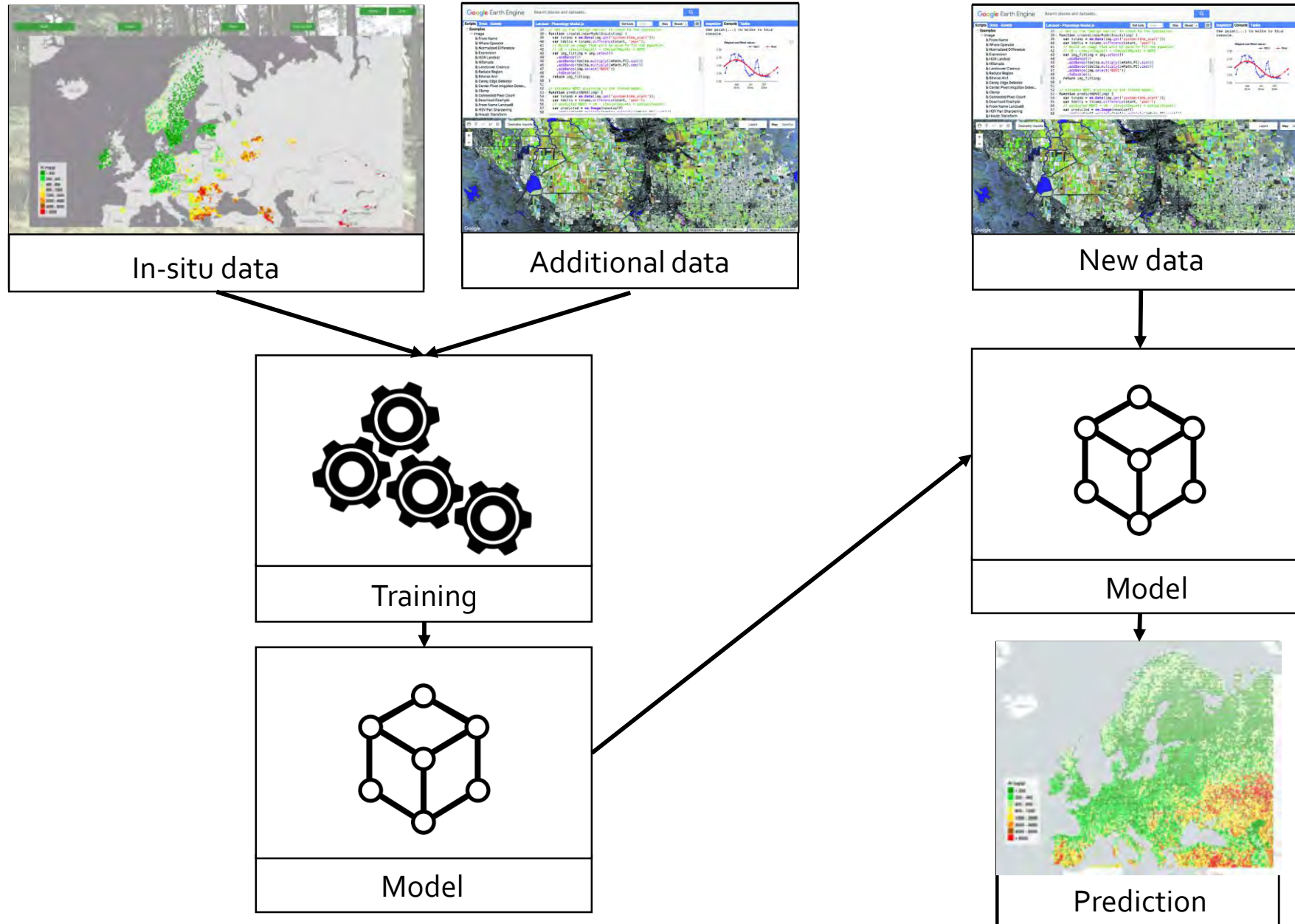


Figure 2. Concentration of Cu in the winter season 2013/2014 (Belgrade): a) real measurements, and b) prediction values; area A represents an old city core highly polluted in winter season

Machine learning (Supervised learning)



Satellite programs



OSTM/Jason 2
(NOAA)

Aquarius

QuikSCAT

TRMM

Terra

ISS-RapidScat,
CATS

EO-1

SMAP

Landsat 7
(USGS)

Aqua

Suomi NPP
(NOAA)

SORCE,
TCTE (NOAA)

Landsat 8
(USGS)

Aura

GPM

GRACE (2)

CALIPSO

CloudSat

OCO-2

Differences

Task: Map all change between 2000 – 2010 over a specific forest

Old solution:

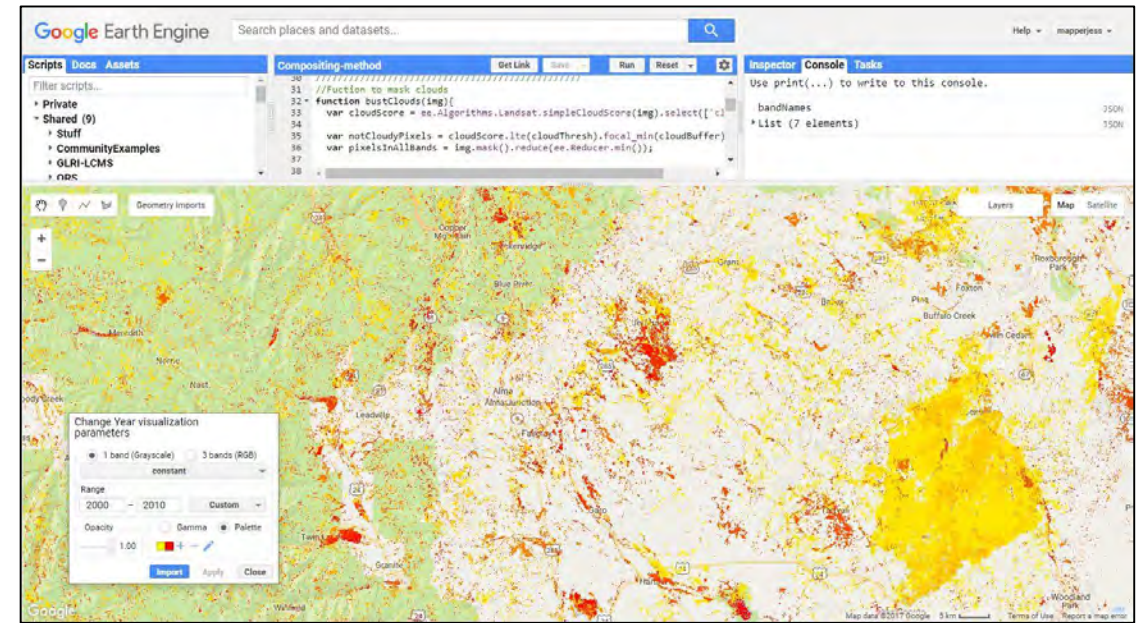
- Select Area of Interest
- Find WRS path/row(s) – assume an area of 4 scenes

Data Prep:

- Download and store all Landsat during growing season (1 GB / zipped scene)
- Extract and layer stack all Landsat (1.75 GB / scene)
- ~48 scenes per year * 11 years = ~528 scenes, or 924 GB
- Apply atmospheric correction (924 more GB)
- Normalize scenes
- Apply FMASK or similar to remove clouds and shadows
- Create composite and mosaic by year
- Generate vegetation index per year (NDVI and/or NBR)

Analysis:

- Build spatial model in ERDAS to compare year pairs
- Generate change layer
- Classify pixels > certain value as “change”
- Build spatial model to apply year attribute to each pixel
- Repeat for each year pair
- Build spatial model to stack all attributed change layers into a single raster image, with the most recently changed pixel on top
- Apply color ramp visually demonstrating change



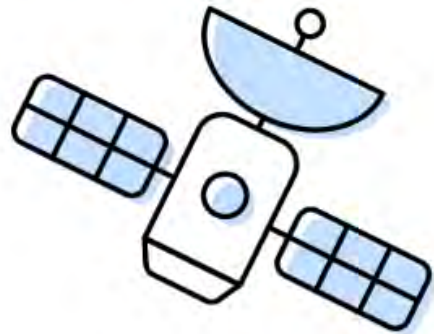
The new method took an experienced geospatial programmer about an hour and ~100 lines of code to generate a raster layer showing the extent of landscape change thematically colored by year of change (in this case, yellow changed closer to the year 2000 and red colors changed closer to 2010).

Users can change the AOI very simply and run this same process anywhere in the world, then export the results to a raster TIFF image.

This represents an extremely dramatic improvement in efficiency. In fact, it allows us to ask new questions.

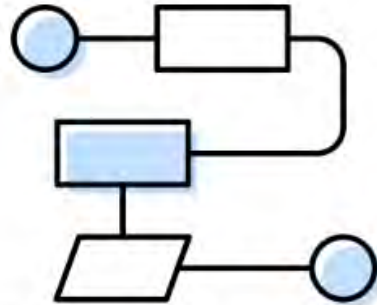
Google Earth Engine

Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities. Scientists, researchers, and developers use Earth Engine to detect changes, map trends, and quantify differences on the Earth's surface. Earth Engine is now available for commercial use, and remains free for academic and research use.



Satellite Imagery

+



Your Algorithms

+



Real World Applications

Earth Engine provides easy, web-based access to an extensive catalog of satellite imagery and other geospatial data in an analysis-ready format. The data catalog is paired with scalable compute power backed by Google data centers and flexible APIs that let you seamlessly implement your existing geospatial workflows. This enables cutting-edge, global scale analysis and visualization.

The Earth Engine Data Catalog



Landsat & Sentinel 1, 2
10-30m, weekly



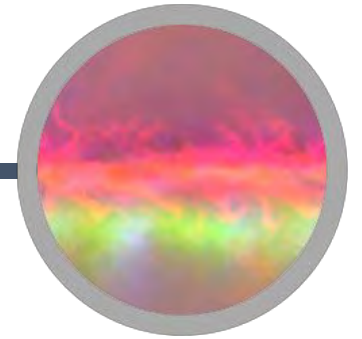
MODIS
250m daily



Vector Data
WDPA, Tiger



**Terrain &
Land Cover**



Weather & Climate
NOAA NCEP, OMI, ...

... and upload your own vectors and rasters

> 200 public datasets

> 5 million images

> 4000 new images every day

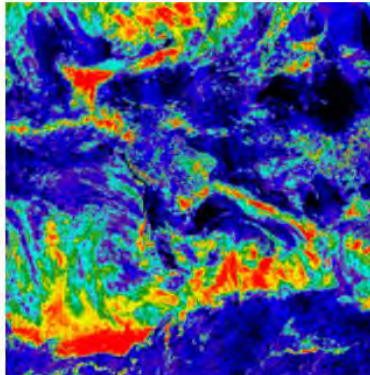
> 80 petabytes of data

The Earth Engine Data Catalog

Datasets tagged climate in Earth Engine

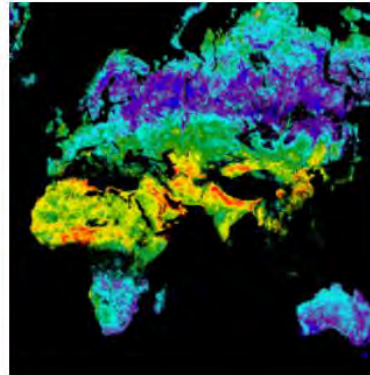
Filter list of datasets

Sentinel-5P NRTI CLOUD: Near Real-Time Cloud



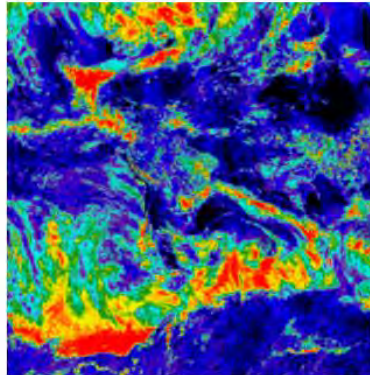
NRTI/L3_CLOUD This dataset provides near real-time high-resolution imagery of cloud parameters. The TROPOMI/S5P cloud properties retrieval is based on the OCRA and ROCINN algorithms currently being used in the operational GOME and GOME-2 products. OCRA retrieves the cloud fraction using measurements in the UV/VIS spectral ...

Sentinel-5P OFFL CH4: Offline Methane



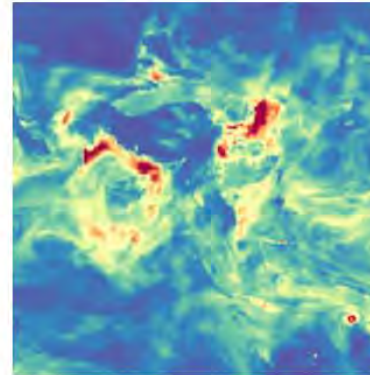
OFFL/L3_CH4 This dataset provides offline high-resolution imagery of methane concentrations. Methane (CH4) is, after carbon dioxide (CO2), the most important contributor to the anthropogenically enhanced greenhouse effect. Roughly three-quarters of methane emissions are anthropogenic and as such it is important to continue

Sentinel-5P OFFL CLOUD: Near Real-Time Cloud



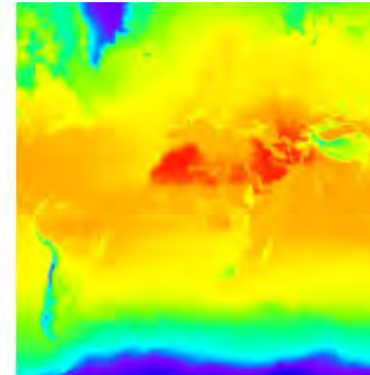
OFFL/L3_CLOUD This dataset provides offline high-resolution imagery of cloud parameters. The TROPOMI/S5P cloud properties retrieval is based on the OCRA and ROCINN algorithms currently being used in the operational GOME and GOME-2 products. OCRA retrieves the cloud fraction using measurements in the UV/VIS spectral regions ...

Copernicus Atmosphere Monitoring Service (CAMS) Global Near-Real-Time



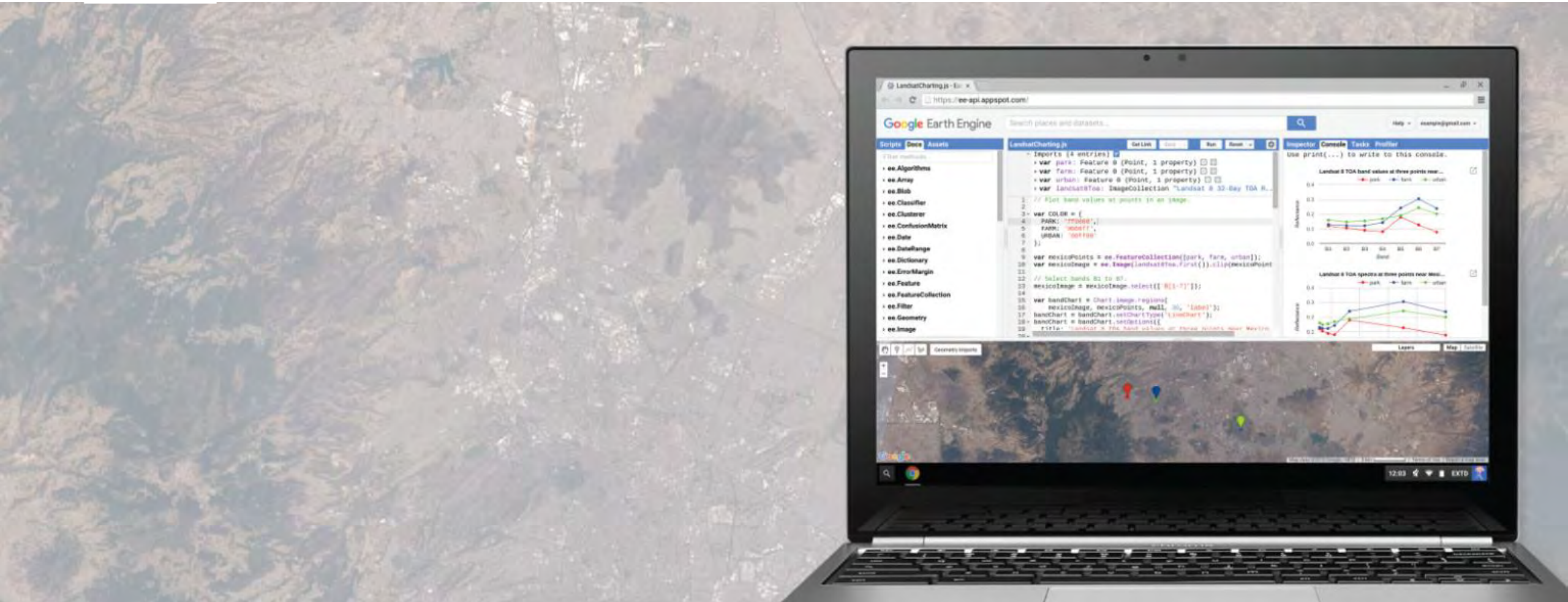
The Copernicus Atmosphere Monitoring Service provides the capacity to continuously monitor the composition of the Earth's atmosphere at global and regional scales. The main global near-real-time production system is a data assimilation and forecasting suite providing two 5-day forecasts per day for aerosols and chemical ...

ERA5 Daily Aggregates - Latest Climate Reanalysis Produced by ECMWF / Copernicus Climate



ERA5 is the fifth generation ECMWF atmospheric reanalysis of the global climate. Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset. ERA5 replaces its predecessor, the ERA-Interim reanalysis. ERA5 DAILY provides aggregated values for each day for ...

JavaScript code editor <https://code.earthengine.google.com/>



* Python API too and also Google colab!

Example of map

The screenshot displays the Google Earth Engine web interface. At the top, the "Google Earth Engine" logo is on the left, and a search bar with the text "Search places and datasets..." is in the center. On the right side of the top bar, there are icons for help, notifications, and a user profile.

Below the top bar, there are three main sections:

- Scripts:** A sidebar on the left showing a tree view of folders and scripts. The "tutorial (copy)" script is selected and highlighted.
- Script Editor:** The main area in the center shows the code for the "tutorial (copy)" script. The code includes:

```
3  
4 Map.setCenter(37.16, 56.73);  
5 Map.setZoom(11);  
6  
7  
8  
9  
10  
11  
12 function maskL8sr(image) {  
13   // Bit 0 - Fill  
14   // Bit 1 - 0:11, 1:01, 1
```
- Inspector/Console:** On the right, there are tabs for "Inspector", "Console", and "Tasks". The "Console" tab is active, showing the instruction "Use print(...) to write to this console."

At the bottom of the interface is a large satellite map. The map shows a landscape with green vegetation, brownish areas, and a prominent dark river or road winding through the terrain. In the top-left corner of the map area, there are navigation controls including a hand icon, a location pin, a zoom in (+) and zoom out (-) button, and a full-screen button. In the top-right corner of the map area, there are tabs for "Layers", "Карта" (Map), and "Спутник" (Satellite). The "Карта" tab is currently selected. At the bottom of the map, there is a status bar with the text "Быстрые клавиши" (Keyboard shortcuts), "Картографические данные © 2022 Google" (Map data © 2022 Google), "2 км" (2 km), and "Условия использования" (Terms of use).

Cloud free map

The screenshot displays the Google Earth Engine web interface. At the top left is the Google Earth Engine logo and a search bar. Below the search bar are tabs for 'Scripts', 'Docs', and 'Assets'. The 'Scripts' tab is active, showing a file tree on the left with folders like 'Ivanovo', 'Poland', 'Sweden', 'ndvi', 'ndvi_calculation', and 'razm2'. The main script editor shows a code block titled 'tutorial *' with the following JavaScript code:

```
16 var qaMask = image.select('QA_PIXEL').bitwiseAnd(parseInt('11111', 2)).eq(0);
17 var saturationMask = image.select('QA_RADSAT').eq(0);
18
19 // Apply the scaling factors to the appropriate bands.
20 var opticalBands = image.select('SR_B.').multiply(0.0000275).add(-0.2);
21 var thermalBands = image.select('ST_B.*').multiply(0.00341802).add(149.0);
22
23 // Replace the original bands with the scaled ones and apply the masks.
24 return image.addBands(opticalBands, thermalBands, qaMask, saturationMask);
```

Below the code editor are buttons for 'Get Link', 'Save', 'Run', 'Reset', and 'Apps'. To the right of the code editor are tabs for 'Inspector', 'Console', and 'Tasks'. The 'Console' tab is active, displaying the text 'Use print(...) to write to this console.' Below the console is a large satellite map of a forested area with a river. The map has a grid overlay. In the top right corner of the map area, there are buttons for 'Layers', 'Карта', and 'Спутник'. In the bottom left corner of the map area, there are zoom in (+) and zoom out (-) buttons. At the bottom of the map area, there is a scale bar showing '1 км' and a 'Google' logo in the bottom left corner. At the bottom right of the map area, there are links for 'Быстрые клавиши', 'Картографические данные © 2022 Google', and 'Условия использования'.

Data Types and Geospatial Processing Functions

- **Image** - band math, clip, convolution, neighborhood, selection ...
- **Image Collection** - map, aggregate, filter, mosaic, sort ...
- **Feature** - buffer, centroid, intersection, union, transform ...
- **Feature Collection** - aggregate, filter, flatten, merge, sort ...
- **Filter** - by bounds, within distance, date, day-of-year, metadata ...
- **Reducer** - mean, linearRegression, percentile, histogram
- **Join** - simple, inner, outer, inverted ...
- **Kernel** - square, circle, gaussian, sobel, kirsch ...
- **Machine Learning** - CART, random forests, bayes, SVM, kmeans, cobweb ...
- **Projection** - transform, translate, scale ...

over 1000 data types and operators, and growing!

Reduce

Aggregate everything in a collection

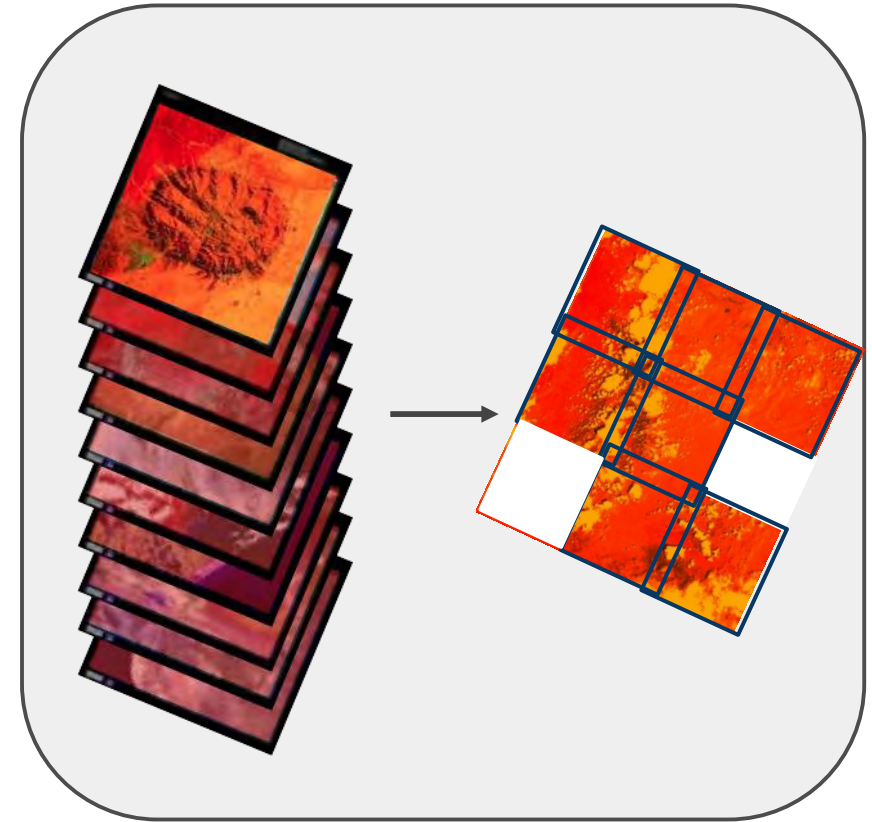
"Reduction"

Examples

Summed area over all features

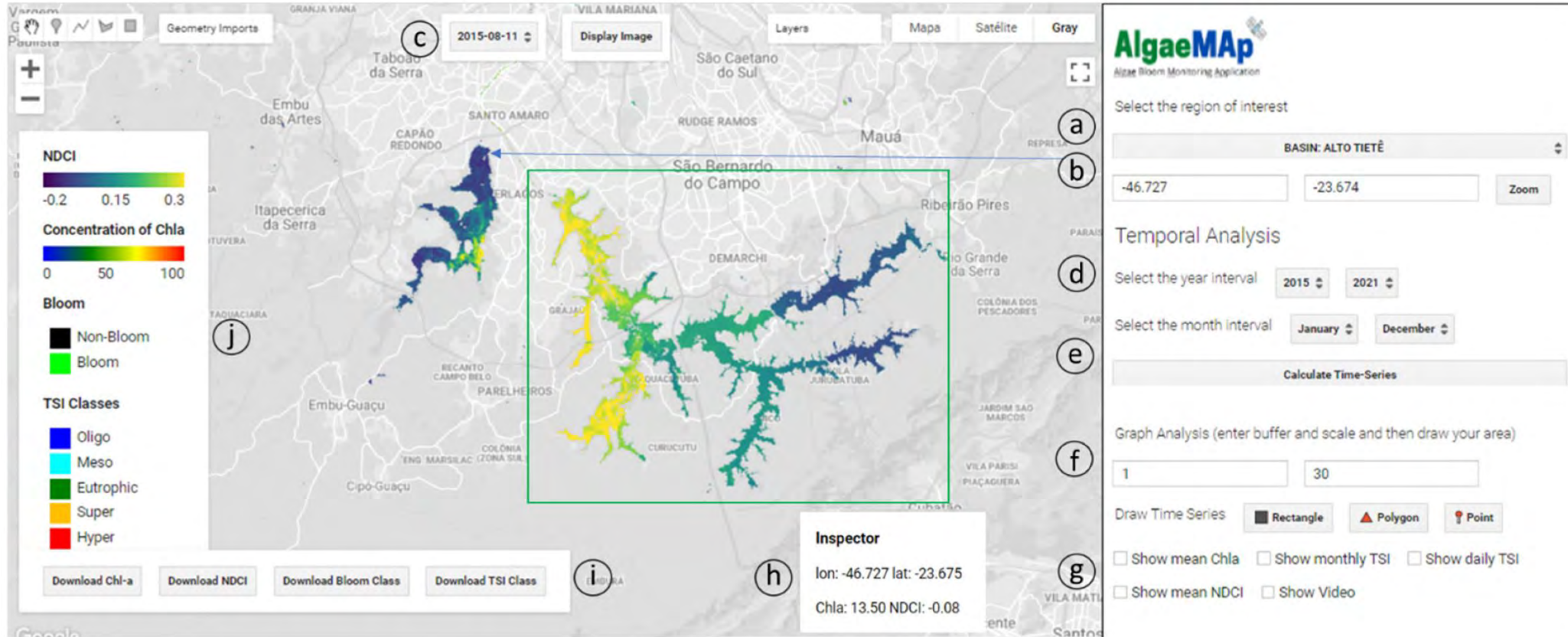
Median-pixel composite

Train a classifier



Alert System for Algal Bloom

Algae blooms occur when certain kinds of algae grow very quickly, forming patches, or "blooms," in the water. These blooms can be indicators of water degradation and emit powerful toxins that can endanger human and animal health.



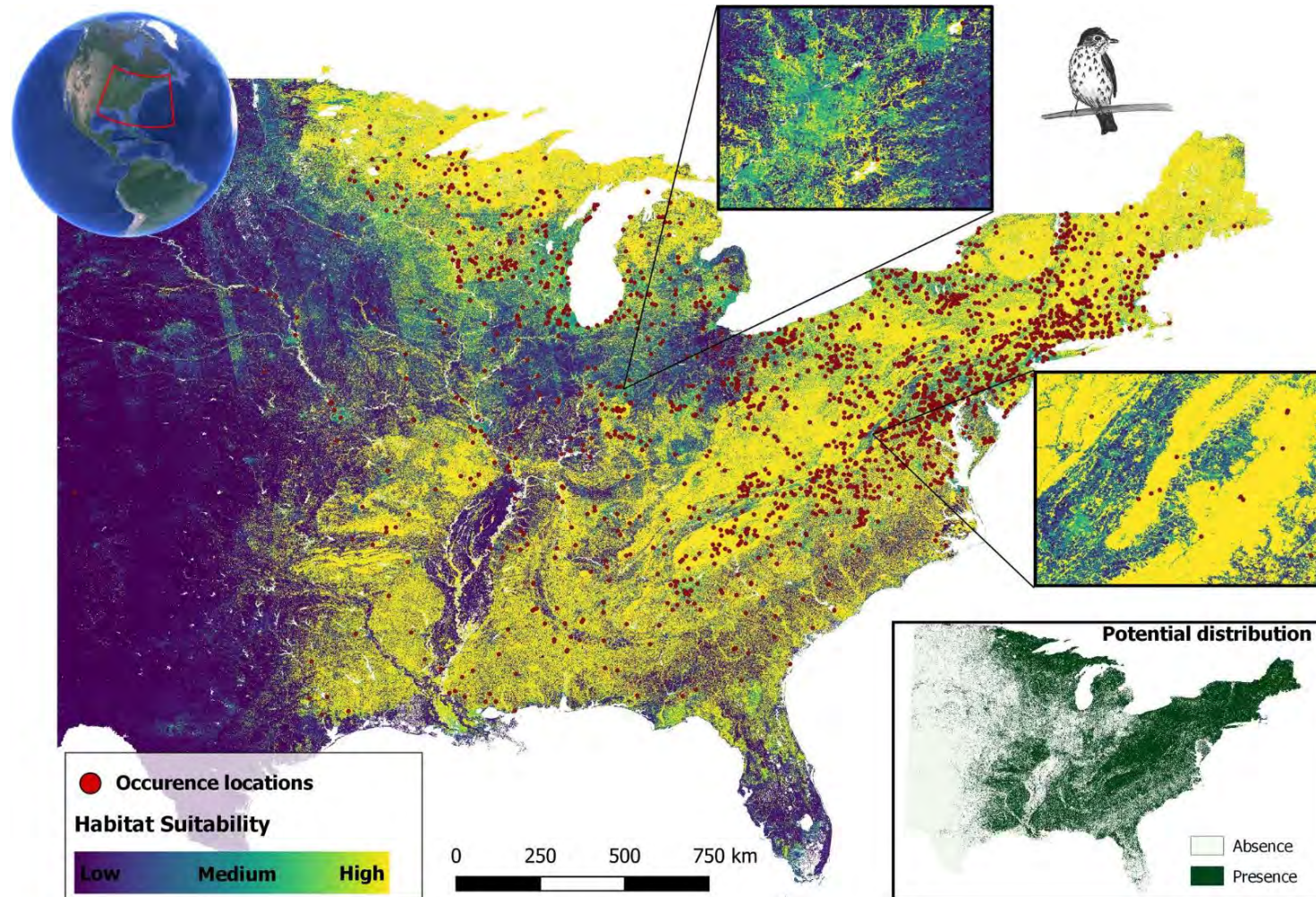
Trends.Earth

Through this project, we will develop a cloud-based platform dedicated to mapping land degradation which identifies potential land restoration opportunities at national to regional scale, allowing communities to prioritize areas to protect, manage, and restore in order to achieve land degradation neutrality.

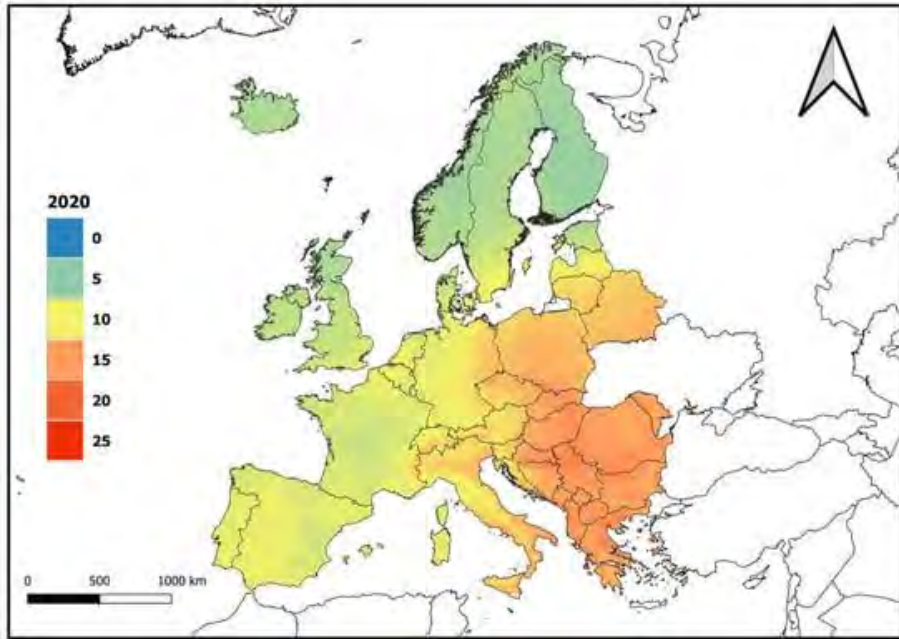


Essential Biodiversity Variables - ScaleUp

We implemented a workflow for species distribution modelling in GEE that includes importing species occurrence data into the GEE platform, selecting and preparing predictor variables, and performing model fitting with spatial or temporal split-block cross-validation techniques.



The determination of different gaseous and PMs based on satellite imagery

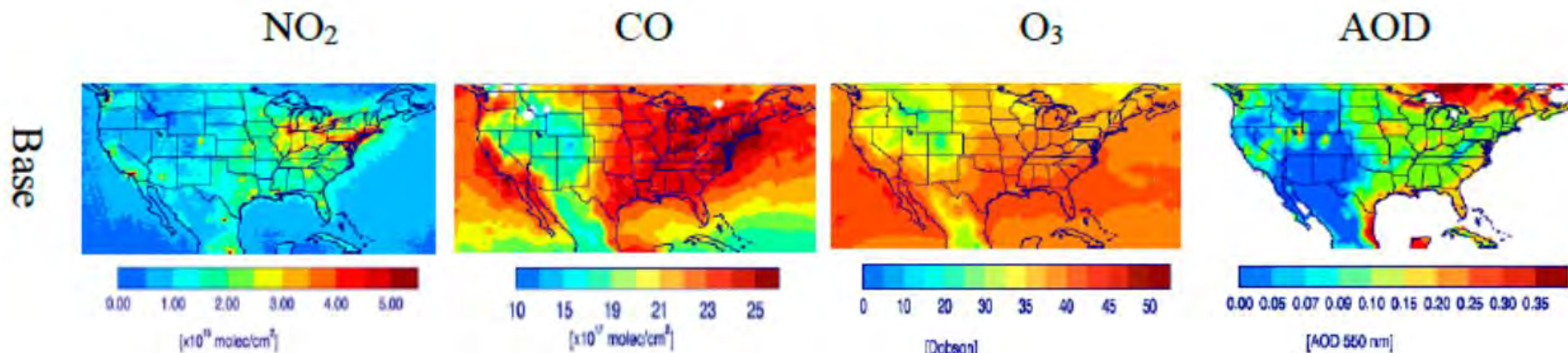


Tongshu Zheng, Michael H. Bergin, Shijia Hu, Joshua Miller, David E. Carlson. (2020). Estimating ground-level PM_{2.5} using micro-satellite images by a convolutional neural network and random forest approach. *Atmospheric Environment*, Volume 230, 117451, ISSN 1352-2310, <https://doi.org/10.1016/j.atmosenv.2020.117451>.

Ibrahim, S.; Landa, M.; Pešek, O.; Brodský, L.; Halounová, L. Machine Learning-Based Approach Using Open Data to Estimate PM_{2.5} over Europe. *Remote Sens.* 2022, 14, 3392. <https://doi.org/10.3390/rs14143392>

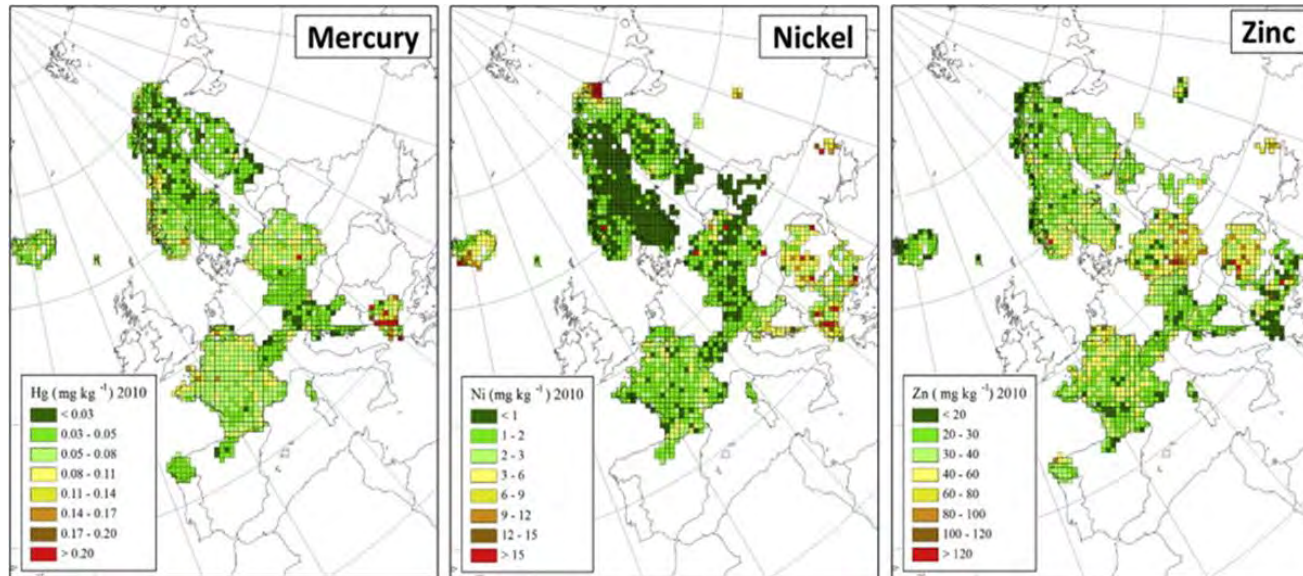
Elshorbany, Y.F.; Kapper, H.C.; Ziemke, J.R.; Parr, S.A. The Status of Air Quality in the United States During the COVID-19 Pandemic: A Remote Sensing Perspective. *Remote Sens.* 2021, 13, 369. <https://doi.org/10.3390/rs13030369>

Seham S. Al-Alola, Ibtesam I. Alkadi, Haya M. Alogayell, Soha A. Mohamed, Ismail Y. Ismail, Air quality estimation using remote sensing and GIS-spatial technologies along Al-Shamal train pathway, Al-Qurayyat City in Saudi Arabia, *Environmental and Sustainability Indicators*, Volume 15, 2022, 100184, ISSN 2665-9727, <https://doi.org/10.1016/j.indic.2022.100184>.

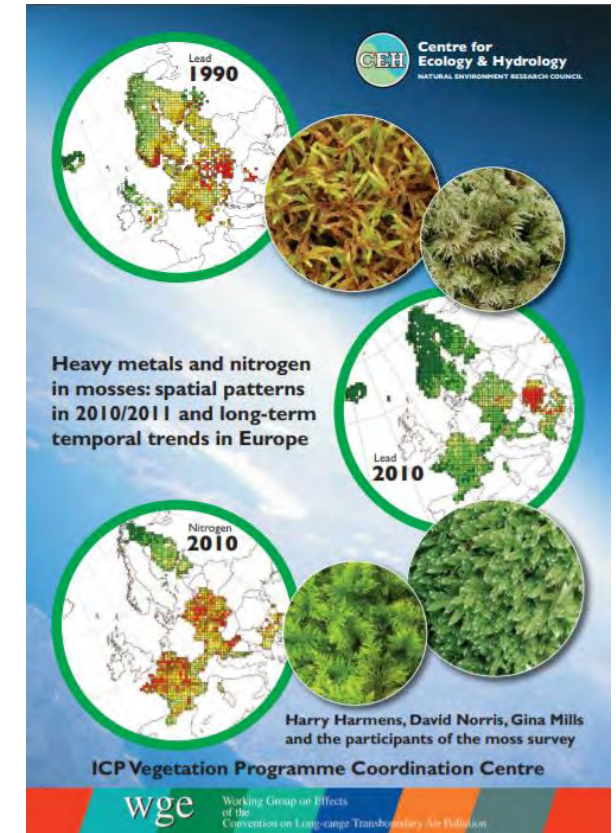


ICP Vegetation

The aim of the **UNECE International Cooperative Program (ICP) Vegetation** in the framework of the United Nations Convention on Long-Range Transboundary Air Pollution is to **identify the main polluted areas of Europe**, produce regional maps and further develop the understanding of the long-range transboundary pollution. Atmospheric deposition study of heavy metals, nitrogen, persistent organic compounds (POPs) and radionuclides is based on the analysis of naturally growing mosses through moss surveys carried out **every 5 years**. The program is realized in **39 countries of Europe and Asia**. Mosses are collected at thousands of sites

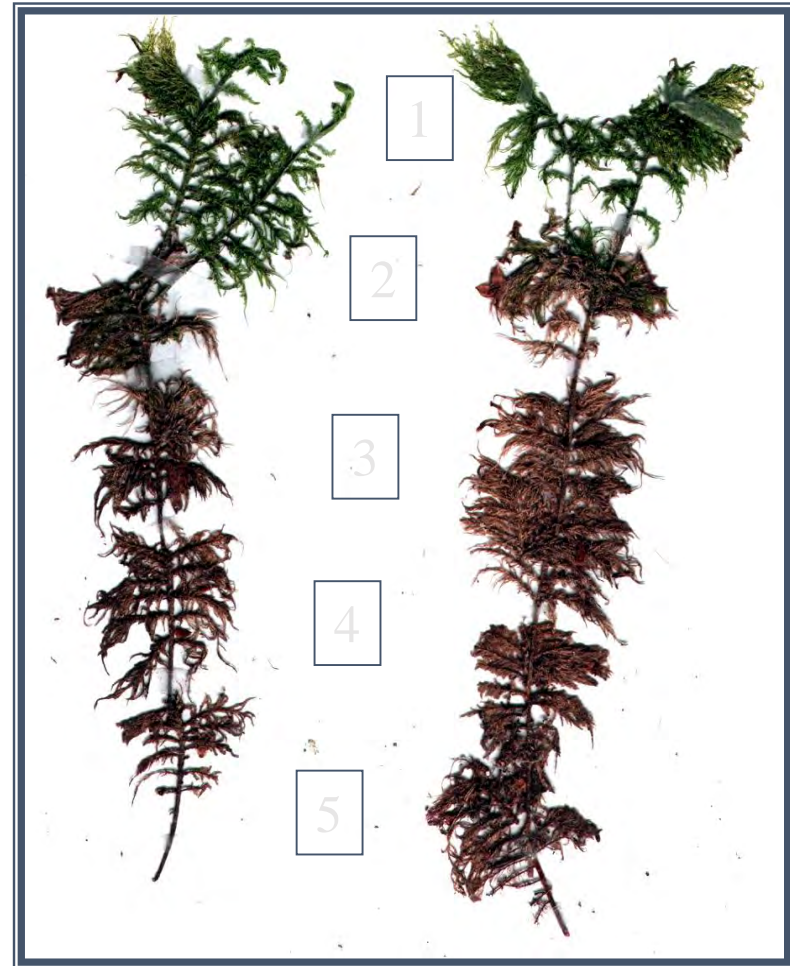


Examples of distribution maps in old Atlas



Since 2014 the JINR Frank Laboratory of Neutron Physics sector of neutron activation analysis is the **coordinator of the ICP Vegetation program**

Moss biomonitor

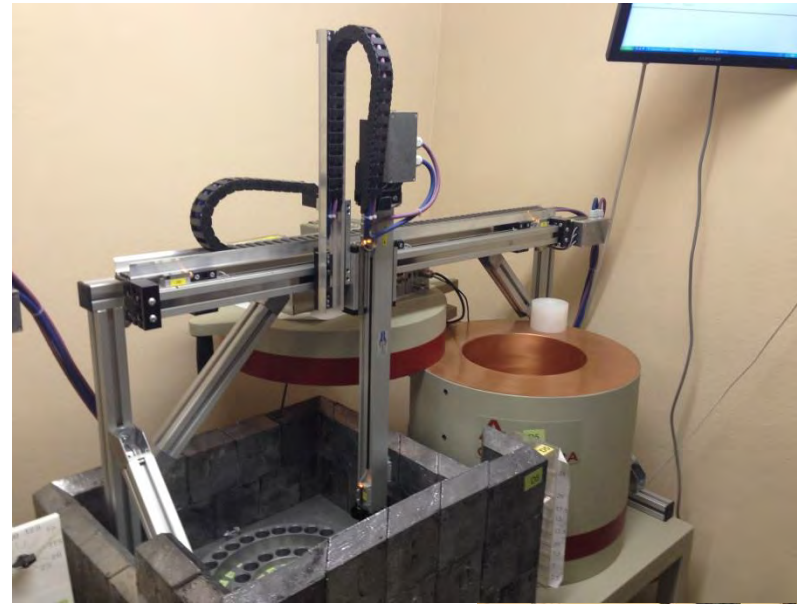
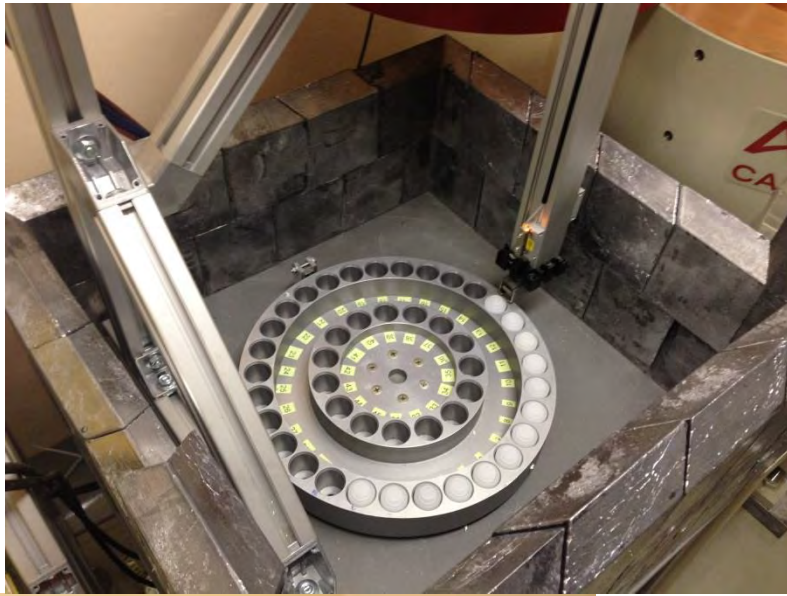


Annual segments

Sampling







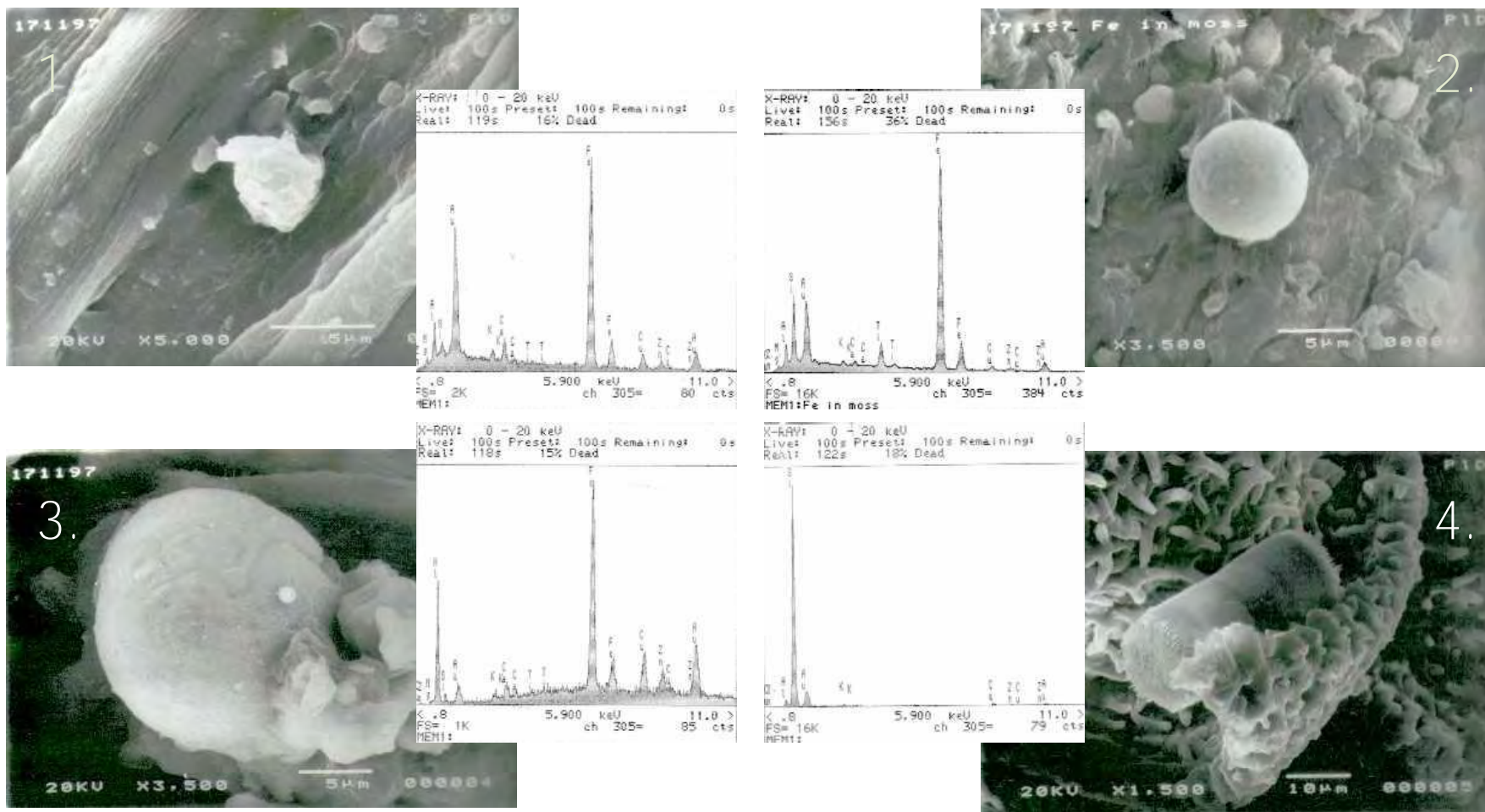
Three sample changers were installed

Each sample changer consists of:

- ❖ two axes linear movement device M202A (DriveSet, Germany)
- ❖ Rotated disk with 40 cells for samples (JINR)
- ❖ Three axes Xemo Motion controller with software and cables (Systec GmbH, Germany)



Scanning electron microscope images of captured particles on the moss surface and corresponding spectrograms



1 - Fe particle with Mg impurity; **2** - Spherule of pure iron;
3 - Al-Fe cluster particle with impurities of Zn, Cu, and Ti; **4** - Diatomic alga

ICP Vegetation (Past)



The UNECE ICP Vegetation program had a serious drawback related to its **weak adoption of modern informational technologies**. Information on collecting and processing of samples was carried out **manually** or with minimum automation.

Until 2016, data mostly was stored in Excel files. It was aggregated and processed in different packages (ArcGIS, MATLAB, etc.) **manually by the coordinator**.

Files from respondents were usually passed to the coordinator **by email**. There were **no common standards** in data transfer, storing and processing software.

Such a situation does not meet the modern standards for quality, effectiveness, and speed of research and demands developing a **single platform** to provide a comprehensive solution for biological monitoring and forecasting tasks

ICP Vegetation (First steps)

The idea was to create a cloud platform for data management to facilitate IT aspects of all biological monitoring stages starting from a choice of collection places and finishing with generation of pollution maps of a particular area or state-of-environment forecast in the long term

to more complicated one:

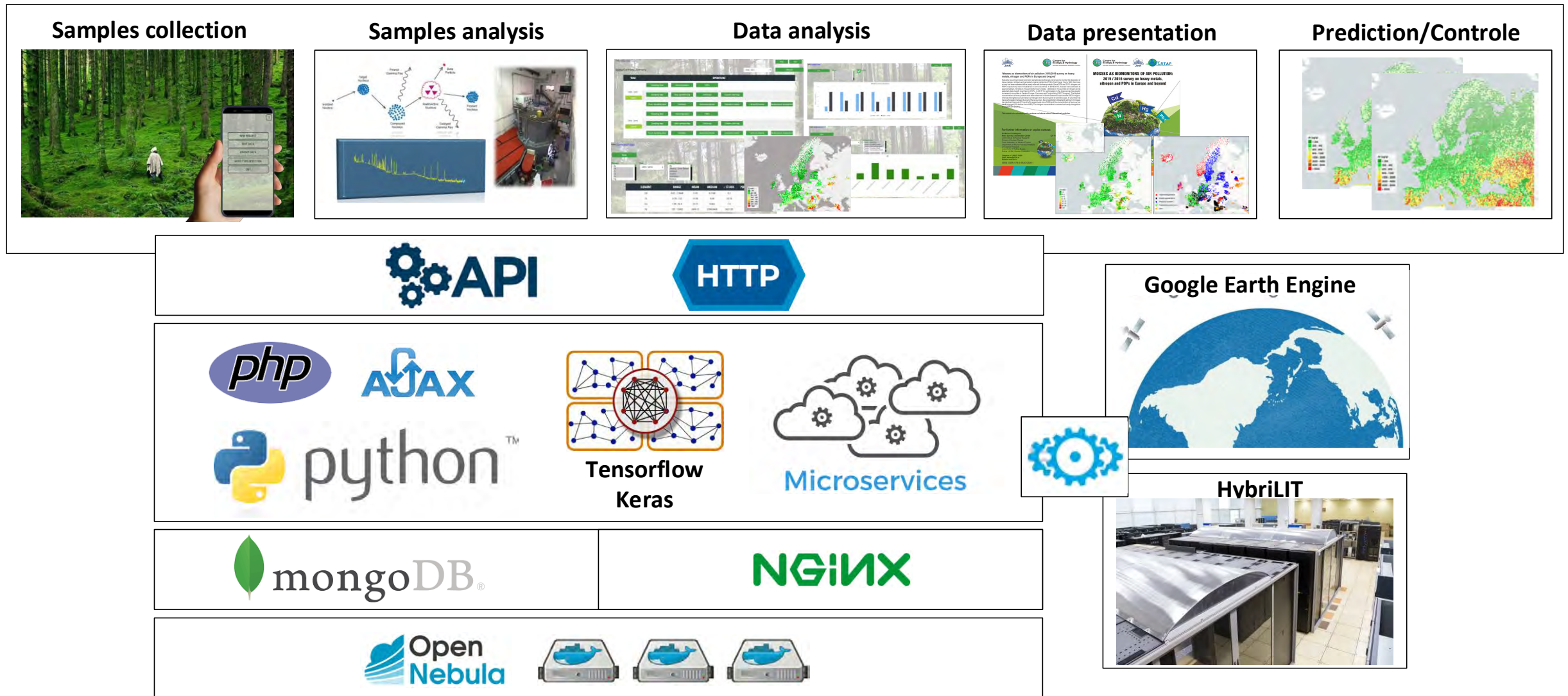
- optimization of the sample collection spatial distribution
- advanced mathematical methods for multi-level intelligent statistical analysis,
- geostatistical analyses,
- atlases and reports creation
- and others.

We was going to move from simple tasks:

- storing and manipulating with data,
- processing of data,
- calculation of basic statistics,
- creation of simple maps
- etc.



The platform now



Since the launch of the first version of the platform, a mobile application has been developed to simplify the process of collecting and verifying data, deep learning models for image classification and pollution prediction based on remote sensing data, various functional blocks implemented in a microservice architecture to automate a number of operational tasks, and the analytical capabilities of the system are also expanded.

WHY IT'S USEFULL

Fast verification of data structure and it completeness

Cannot find required data for sampling site - 70(land cover, topography, distance to the nearest projection of the tree canopy (m), further details,). This sampling site was not added.

Cannot find required data for sampling site - 71(land cover, topography, distance to the nearest projection of the tree canopy (m), further details,). This sampling site was not added.

Cannot find required data for sampling site - 72(land cover, topography, distance to the nearest projection of the tree canopy (m), further details,). This sampling site was not added.

86 rows were inserted.

Hello, 1

No file selected import:

Home/1_1/2020 - 2021 - Sampling sites:

SITE NAME	SAMPLE DATE	LONGITUDE	LATITUDE	MOSSMET	OPERATIONS		
100	2019-7-30	38.666	55.678	No	<input type="button" value="Edit"/>	<input type="button" value="Copy"/>	<input type="button" value="Delete"/>
101	2019-7-30	38.460	55.834	No	<input type="button" value="Edit"/>	<input type="button" value="Copy"/>	<input type="button" value="Delete"/>

Easy way to find human made mistakes



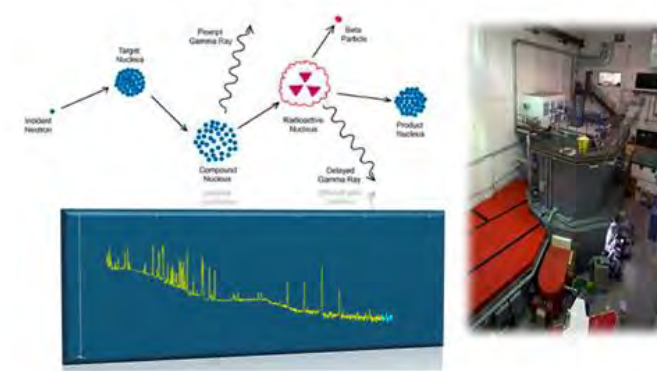
- Nice tool to analyze data.
- Access to yours data from anywhere.
- Online processing and results.
- Ability to store historical data and analyze trends

Workflow

1. Collecting samples



2. Processing samples



Samples metadata

HM concentrations

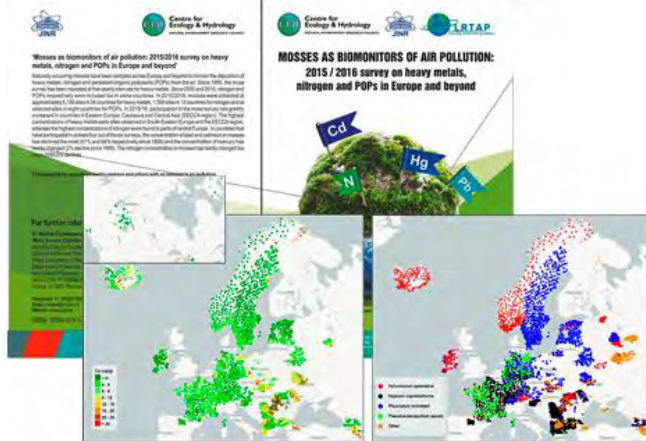
moss.jinr.ru

3. Filling in the information about the concentrations

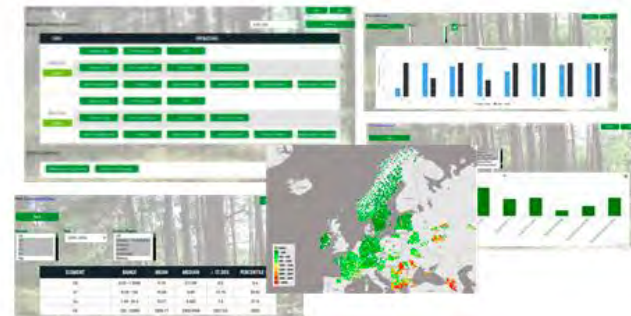
Site names

HM concentrations

5. Reports



4. Analysis



DMS

The Data Management System (DMS) of the UNECE ICP Vegetation was developed at the Laboratory of Information Technologies and consists of a set of interconnected services and tools deployed and hosted at the Joint Institute for Nuclear Research (JINR) cloud infrastructure. DMS is intended to provide its participants with a **modern unified system of collecting, analyzing and processing of biological monitoring data.**

OPERATIONS

YEAR: 2020-2021

Name of persons who samples mosses and conducted analyses

OPERATIONS

- Sampling sites
- Intercomparison
- POPs
- 2015 - 2016
- Sampling map
- Grad. symbols map
- Color map
- Custom color map
- Delete
- Edit general info
- Check sampling sites
- Statistics
- Advanced statistic
- Correlation matrix
- Factors & Indexes
- Medianvalues.com
- Clustering
- PCA
- 2010 - 2011
- Sampling sites
- Intercomparison
- POPs
- Sampling map
- Grad. symbols map
- Color map
- Custom color map
- Delete
- Edit general info
- Check sampling sites
- Statistics
- Advanced statistic
- Correlation matrix
- Factors & Indexes
- Medianvalues.com

Historical trends

ELEMENT	RANGE	MEAN	MEDIAN	± ST.DEV.	PERCENTILE 90
Al	445-6890	1536.67	1240	1239.58	2942
As	0.118-1.06	0.33	0.318	0.17	0.6942
Cd					
Cr					
Cu					
Fe					
Ni					
Pb					
Sr					
Mn					
Se					
Co					
Mg					
Ca					

Median concentrations

Element	2010-2011	2015-2016
Al	~0.8	~1.2
Cu	~0.8	~1.2



'Mosses as biomonitors of air pollution: 2015/2016 survey on heavy metals, nitrogen and POPs in Europe and beyond'

Naturally-occurring mosses have been sampled across Europe and beyond to monitor the deposition of heavy metals, nitrogen and persistent organic pollutants (POPs) from the air. Since 1990, the moss survey has been repeated at five-yearly intervals for heavy metals. Since 2005 and 2010, nitrogen and POPs respectively were included too in some countries. In 2015/2016, mosses were collected at approximately 5,100 sites in 34 countries for heavy metals, 1,500 sites in 12 countries for nitrogen and at selected sites in eight countries for POPs. In 2015/16, participation in the moss survey has greatly increased in countries in Eastern Europe, Caucasus and Central Asia (EECCA region). The highest concentrations of heavy metals were often observed in South-Eastern Europe and the EECCA region, whereas the highest concentrations of nitrogen were found in parts of central Europe. In countries that have participated in at least four out of the six surveys, the concentration of lead and cadmium in mosses has declined the most (81% and 64% respectively since 1990) and the concentration of mercury has hardly changed (2% decline since 1995). The nitrogen concentration in mosses has hardly changed too since 2005 (5% decline).

This report is for scientists, policy makers and others with an interest in air pollution.

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MOSSES AS BIOMONITORS OF AIR POLLUTION: 2015 / 2016 survey on heavy metals, nitrogen and POPs in Europe and beyond



Marina Frontasyeva, Harry Harmens, Alexander Uzhinskiy
and the participants of the moss survey



wge

Working Group on Effects
of the
Convention on Long-range Transboundary Air Pollution

Google Earth Engine

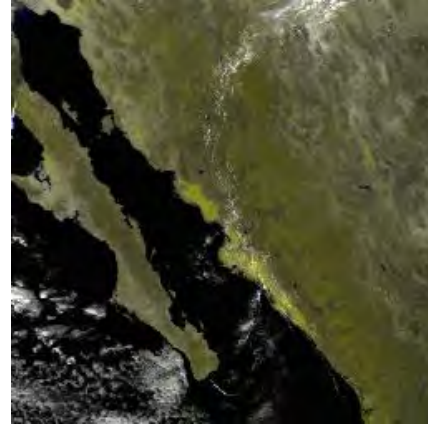
There are more than **100 satellite programs** and modeled datasets. Google Earth Engine has **JavaScript online editor** to create and verify code and **python API** to communicate with user's applications.



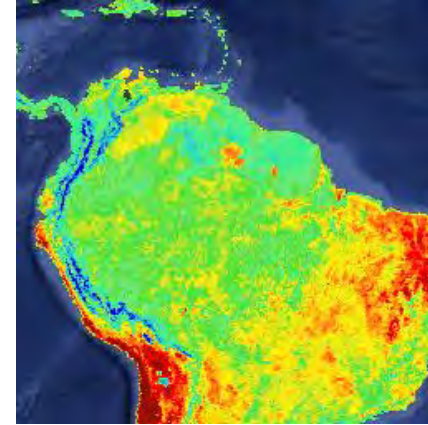
Landsat (15-30m Resolution)



Modis (250-500m Resolution)



Sentinel (250-500m Resolution)



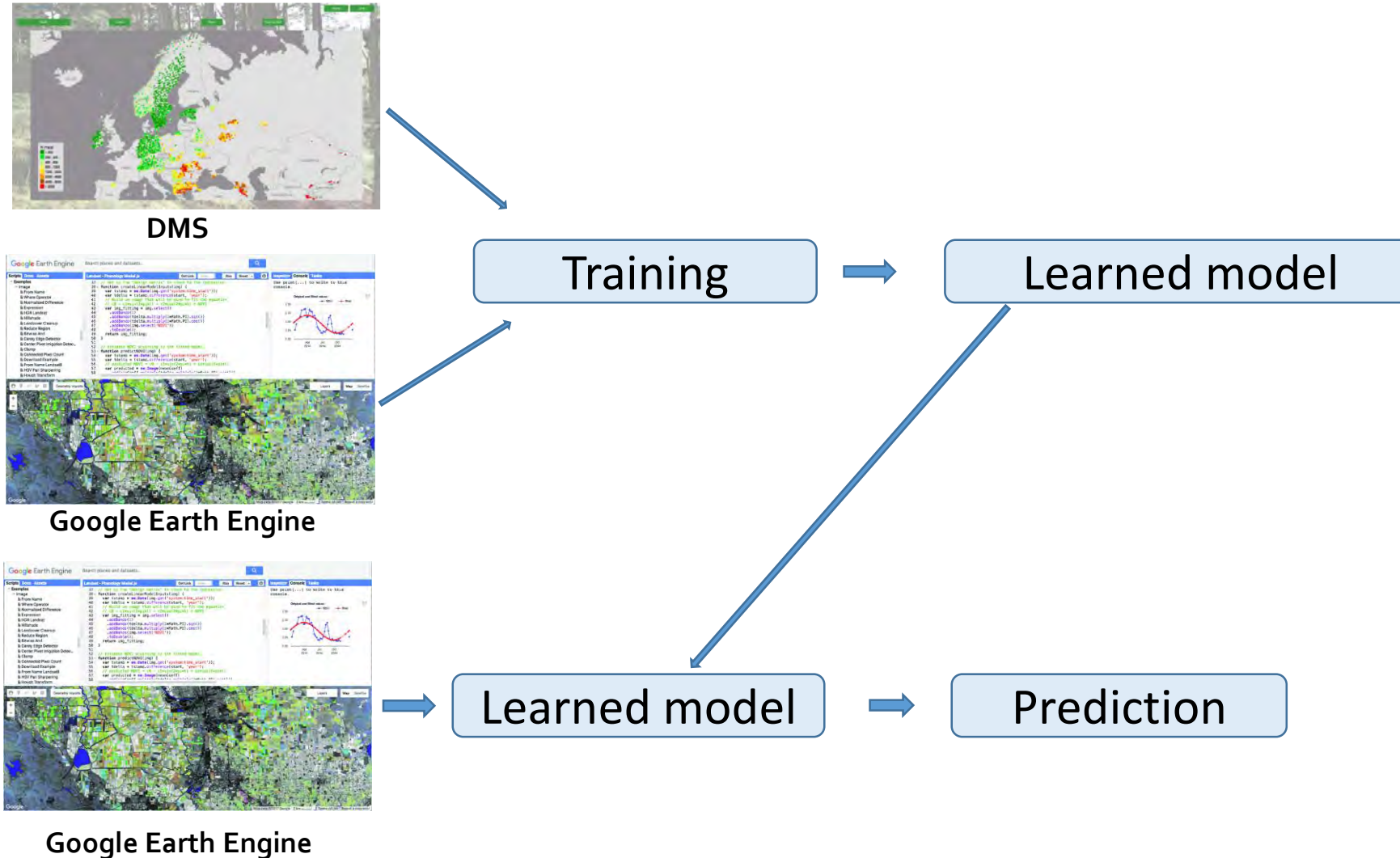
The MOD11A2 V6 average 8-day land surface temperature (LST) in a 1200 x 1200 kilometer grid.

```
13 var point = ee.Geometry.Point([20.415833, 44.832778]);
14 Map.addLayer(point);
15
16 var collection = ee.ImageCollection('LANDSAT/LC8_L1T')
17   .filterDate('2013-06-15', '2013-08-15')
18   .filterBounds(point)
19   .sort('CLOUD_COVER', true);
20
21 var median = collection.median();
22
23 // Get a dictionary of means in the region. Keys are bandnames.
24 var mean = median.reduceRegion({
25   reducer: ee.Reducer.mean(),
26   geometry: region,
27   scale: 30
28 });
29
30 print(mean);
31
```

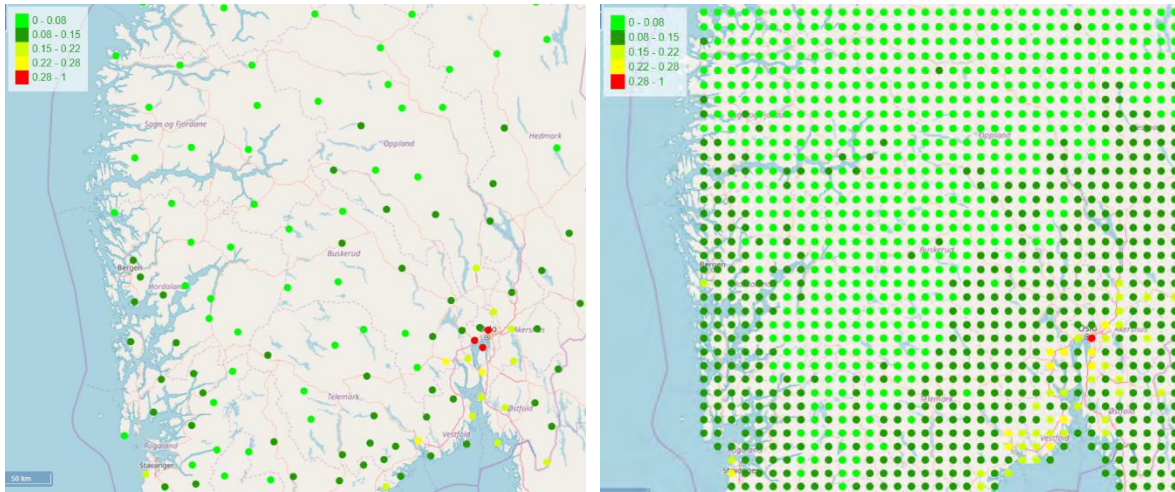
Specify program and time-period to get a collection of images, for example, program – “MODIS/oo6/MOD09A1” from 2013-06-15 to 2013-08-15 (the period relevant for in situ biomonitoring). Then, define the analyzed area, for example, a square kilometer, with center at the coordinates where sampling was performed. During the satellite data collection, under the bands (channels) of the median image, we execute some mathematical functions (max, min, median, etc.) and get the numerical values.

Schema

We use **satellite imagery data** and the **artificial neural network** to **predict concentration**. The general idea is to use data that we can get from satellite images together with sampling data from DMS to learn NN and then use only data from satellite images to predict concentration.

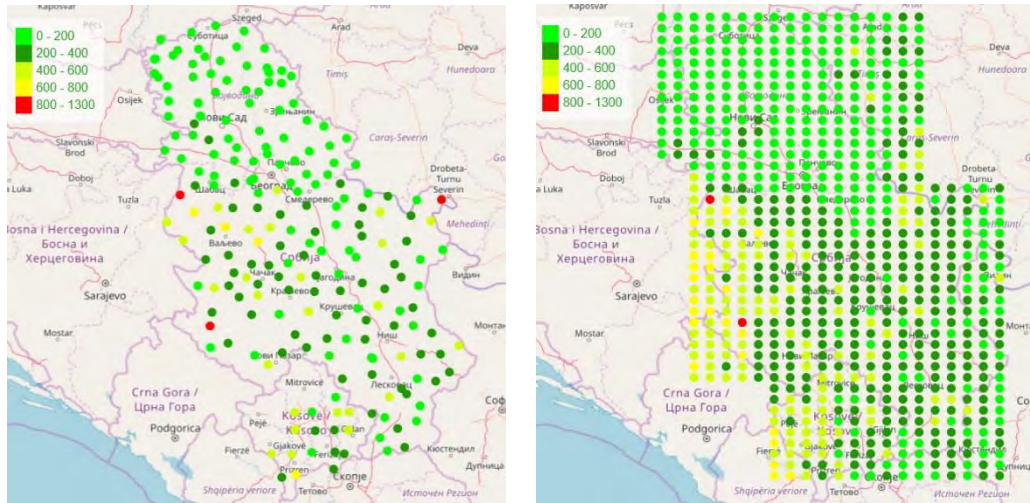


Results on the regional level

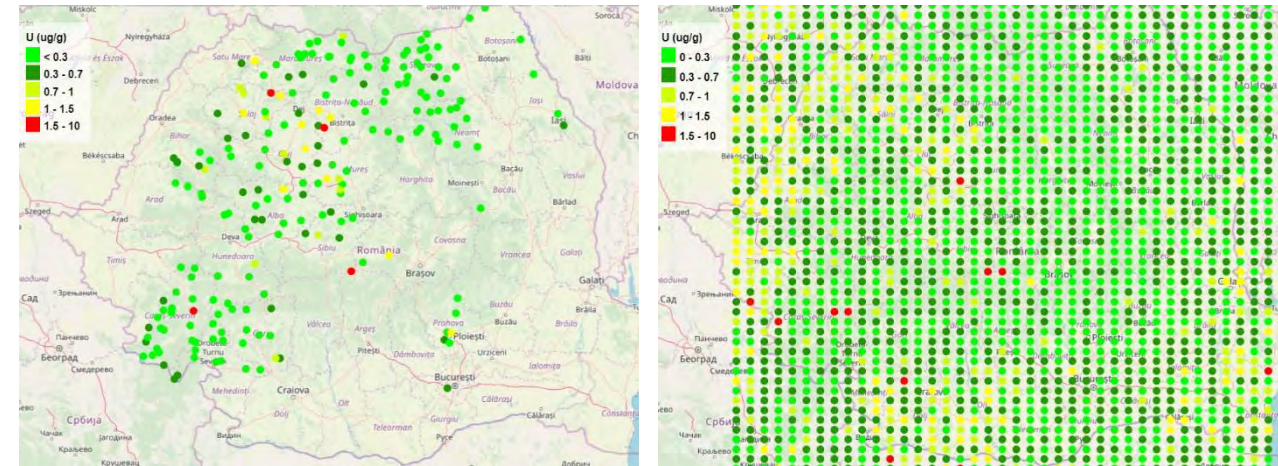


Sb at Norway. Left – real life, right - prediction

Candidates for modeling:
Al, As, Cr, Cu Fe, Mn, Ni, Pb, V, Sb, U ...



Mn at Serbia. Left – real life, right - prediction



U at Romania. Left – real life, right - prediction

Urban Level (Belgrade)

The goal of this study was to facilitate the highly resolved mapping of the presence of potentially toxic elements in the air of an urban area, which is typically characterised by high and variable pollution. + to check whether model can keep appropriate accuracy during long time period.

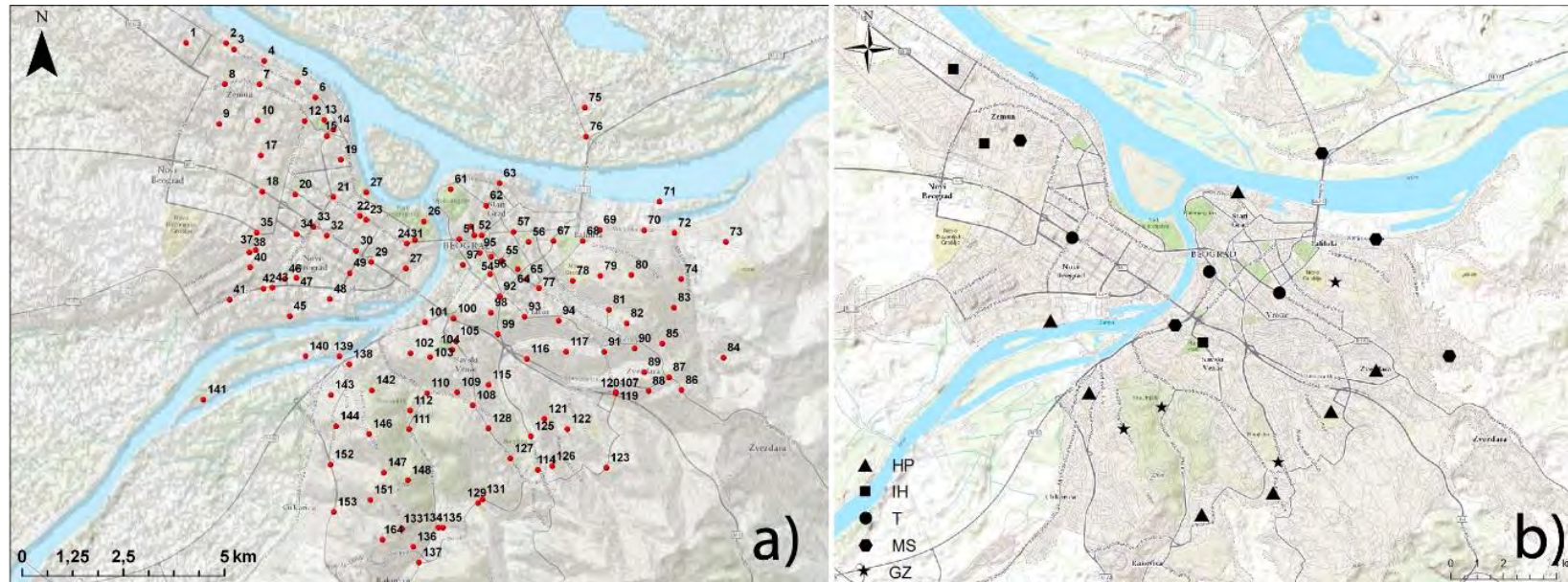


Figure 1. Moss bag biomonitoring across the Belgrade urban area; maps of the sampling sites during two seasons: (a) summer (urban, suburban and green zones) and (b) winter (U–urban sites, GZ–green zones)

Urban Level (Belgrade)

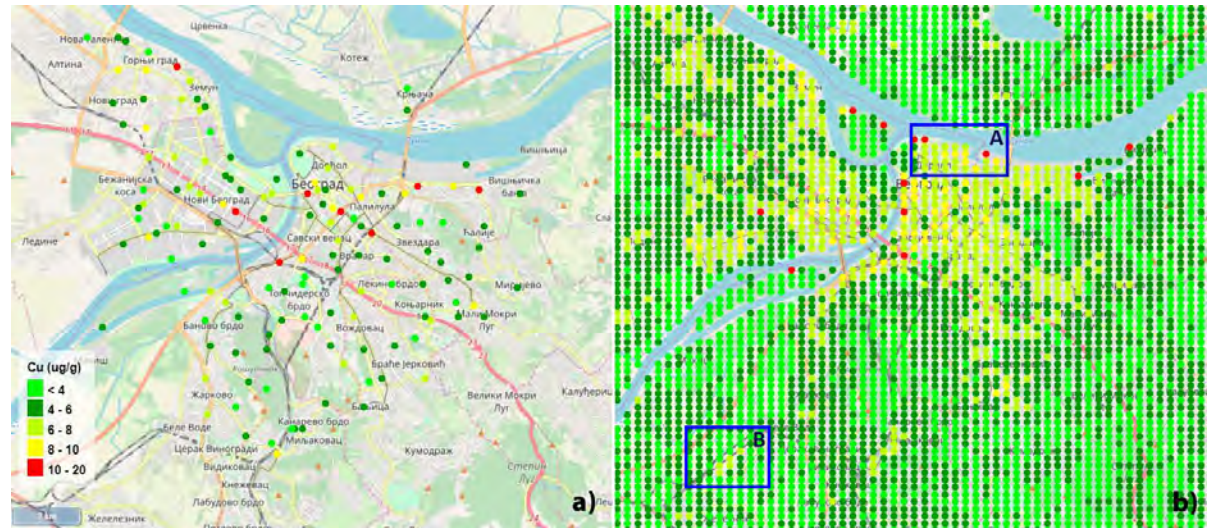


Figure 3. Concentration of Cu in the summer of 2013 (Belgrade): a) real measurements, and b) prediction values; area A represents central part of Old Belgrade with permanently high traffic flow; area B represents a large railway terminal

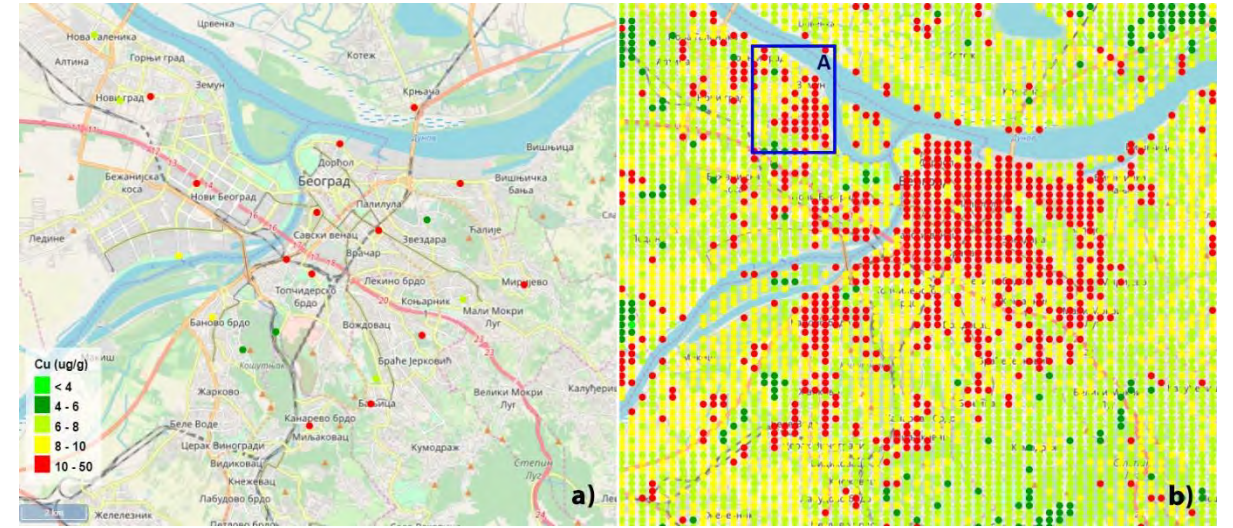


Figure 4. Concentration of Cu in the winter season 2013/2014 (Belgrade): a) real measurements, and b) prediction values; area A represents an old city core highly polluted in winter season

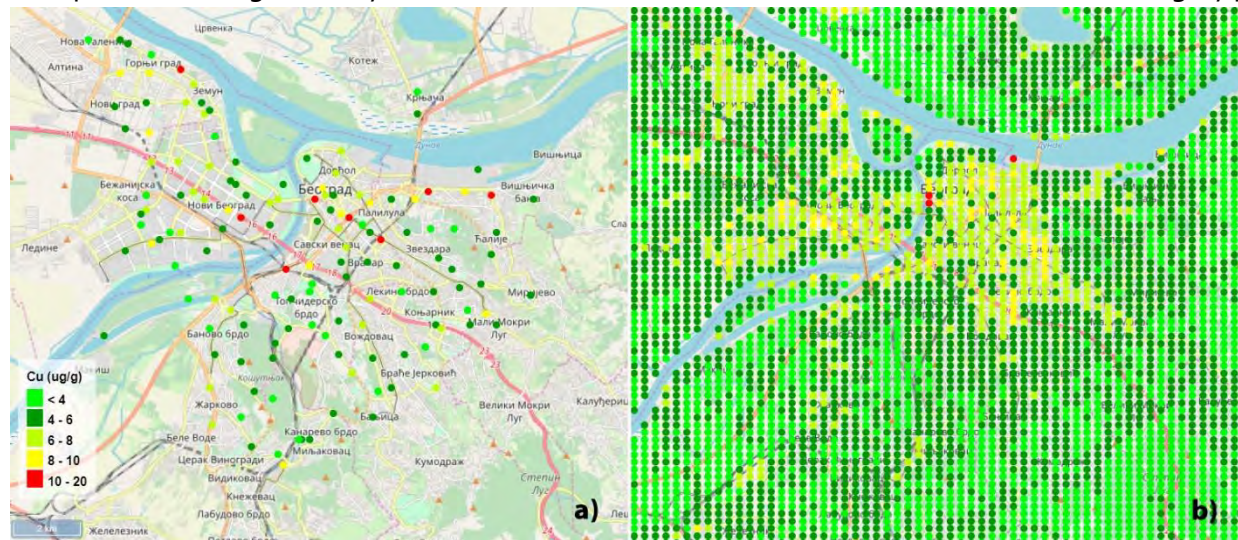
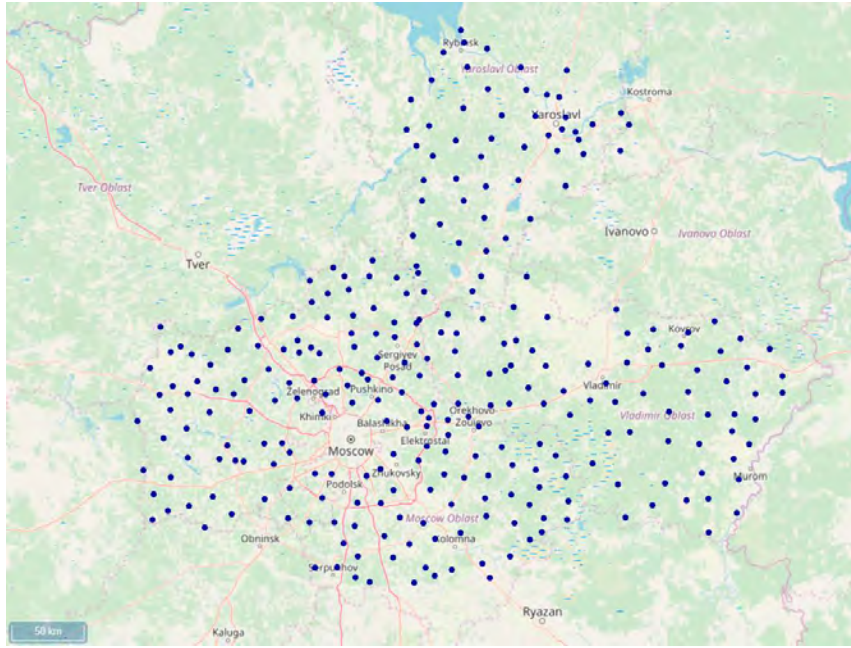


Figure 5. Concentration of Cu in Belgrade: a) biomonitring measurements in the summer of 2013, and b) prediction for 2018

Machine learning and neural networks



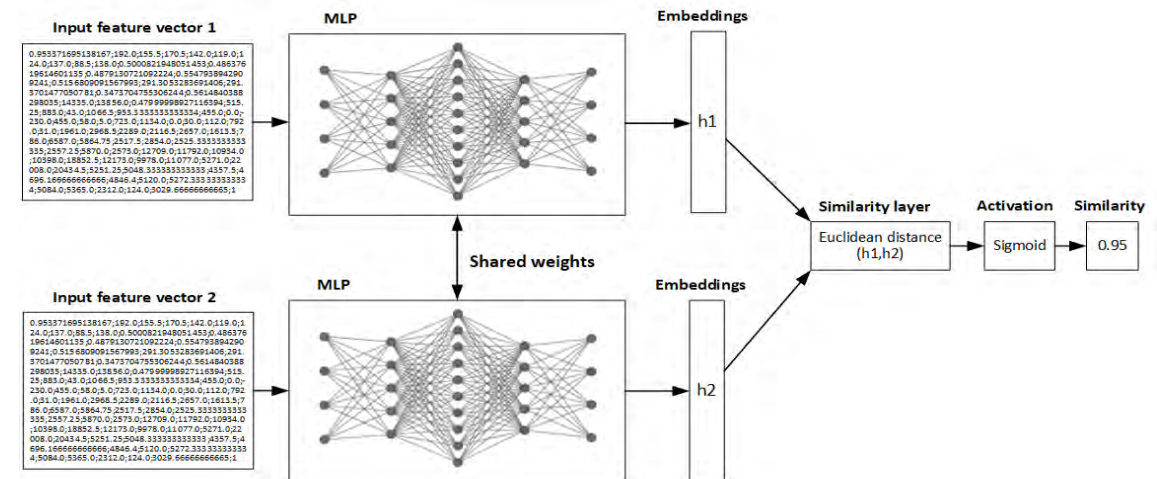
We use the information on 73, 53, and 156 samples from the Vladimir, Yaroslavl, and Moscow regions gathered in 2018 - 2019.

The indices are gathered based on data from 13 programs for 281 sampling sites, and their linkage with the concentration of 18 heavy metals is verified. Altogether 9 HMs, i.e., Al, Fe, Sb, Na, Sc, Sm, Tb, Th, and U, look very prospective for modeling.

We examine three approaches: Gradient Boosting, Multilayer perceptron, and Siamese network.

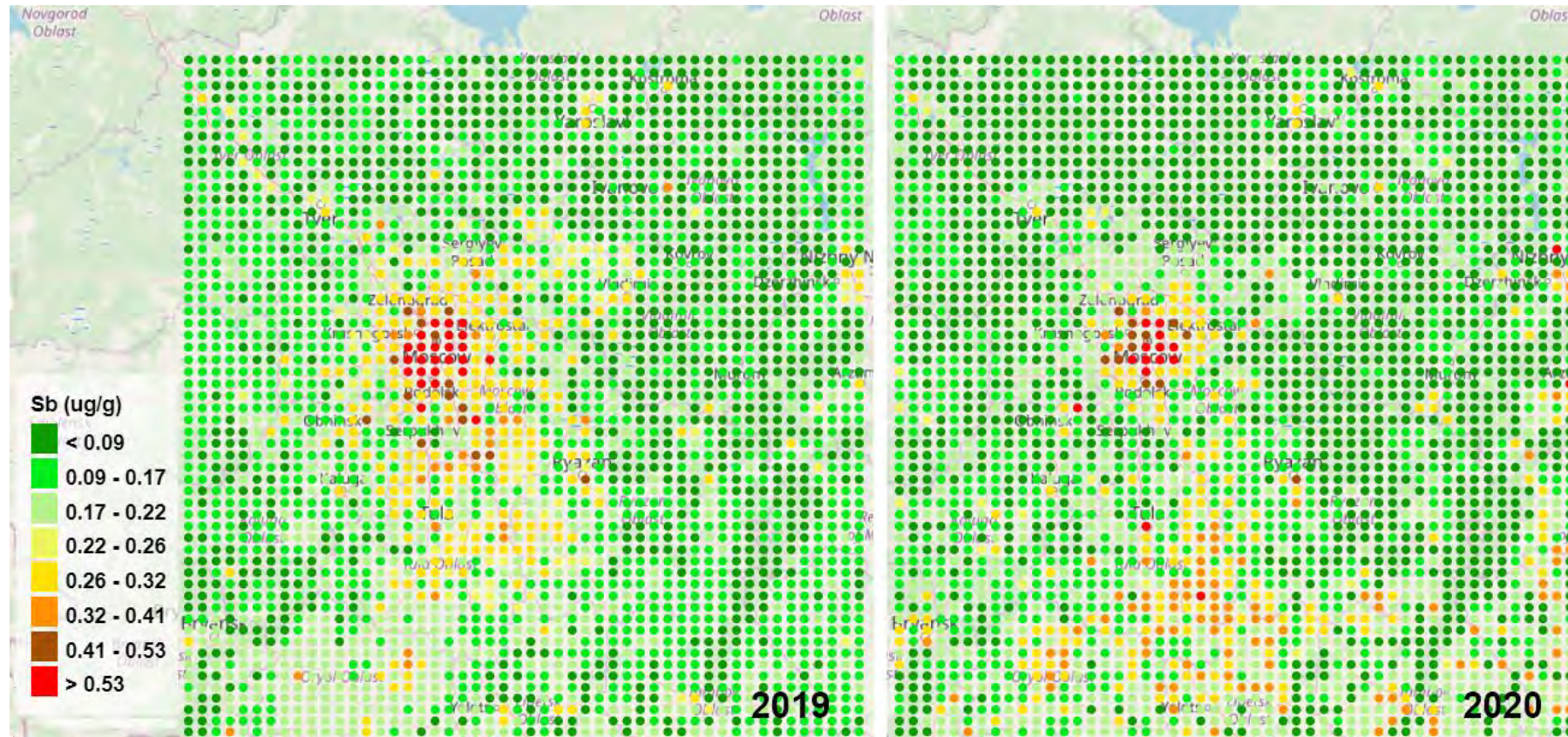
	Al		Fe		Sb	
	Acc si	Acc ai	Acc si	Acc ai	Acc si	Acc ai
GB	0.91	0.92	0.92	0.93	0.94	0.94
MLP	0.89	0.91	0.92	0.92	0.89	0.92
SNN	0.92	0.93	0.93	0.93	0.93	0.94

Table 2. Mean accuracy of the models. GB is gradient boosting. MLP is the multilayer perceptron. SNN is the Siamese neural network. Acc Si is the accuracy on the selected indices. Acc Ai is the accuracy on all indices.



Siamese network architecture

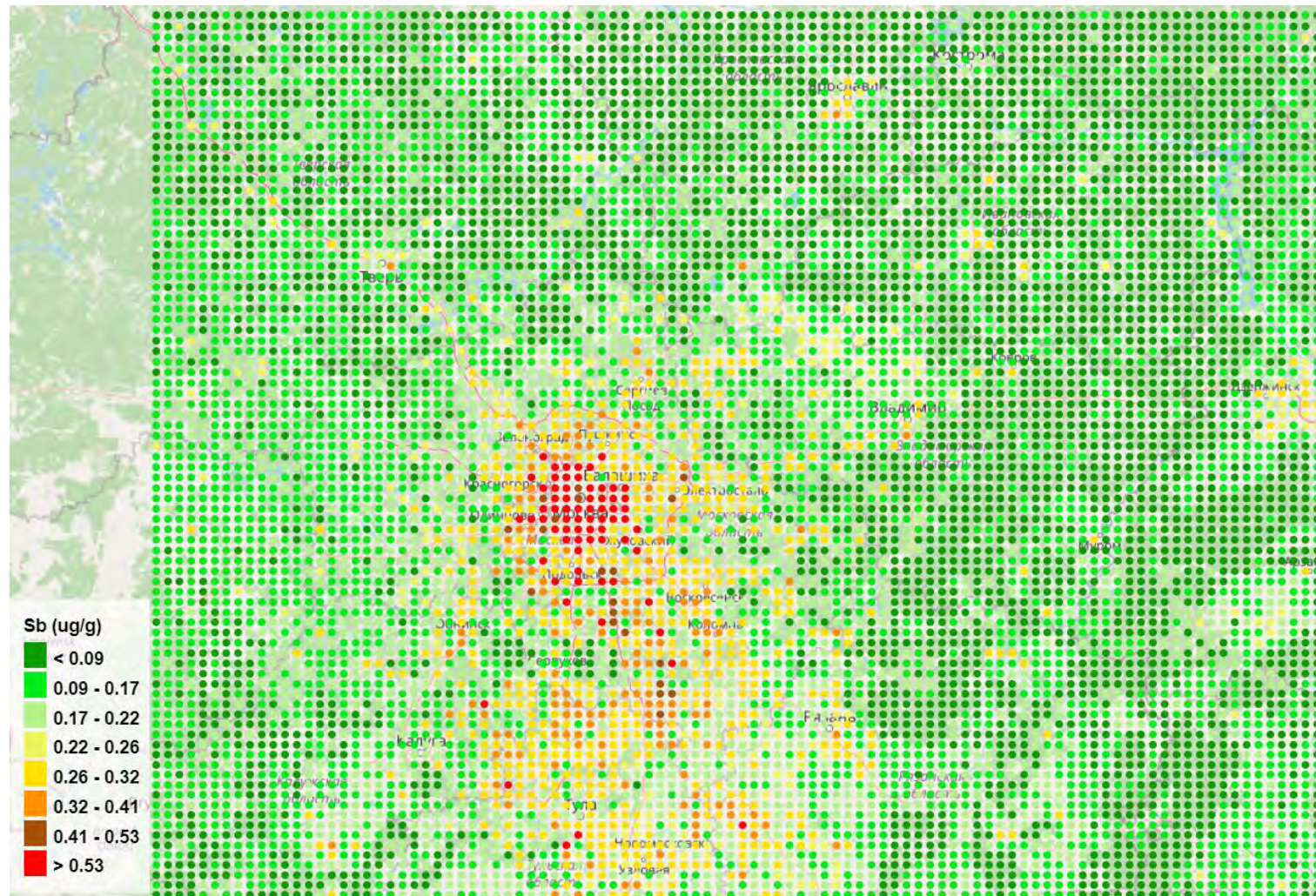
Results (2019 – 2020)



Sb contamination prediction for 2019 (left) and 2020 (right)

The lockdown in Russia that lasted for approximately 1.5 months imposed different limitations. Most of the limitations restricted the movement activities of the population. According to the official statistics, industrial production in Russia decreased by 2.9% from the past, by the end of 2020.

Results (High spatial resolution)



High spatial resolution of the SNN model prediction of Sb contamination

The Tula region stands out on the map. There is a multitude of industrial enterprises located in the region, i.e., chemical, metallurgical, and machine-building, besides several large thermal power plants. Huge transport nodes and federal freeways are seen, rather clearly, on the map.

Moscow is a thickly populated city, and the population is increasing at a fast pace. Published information reveals, there are about 12.5 million habitants in Moscow. Therefore the Sb contamination level there is bound to be very high.

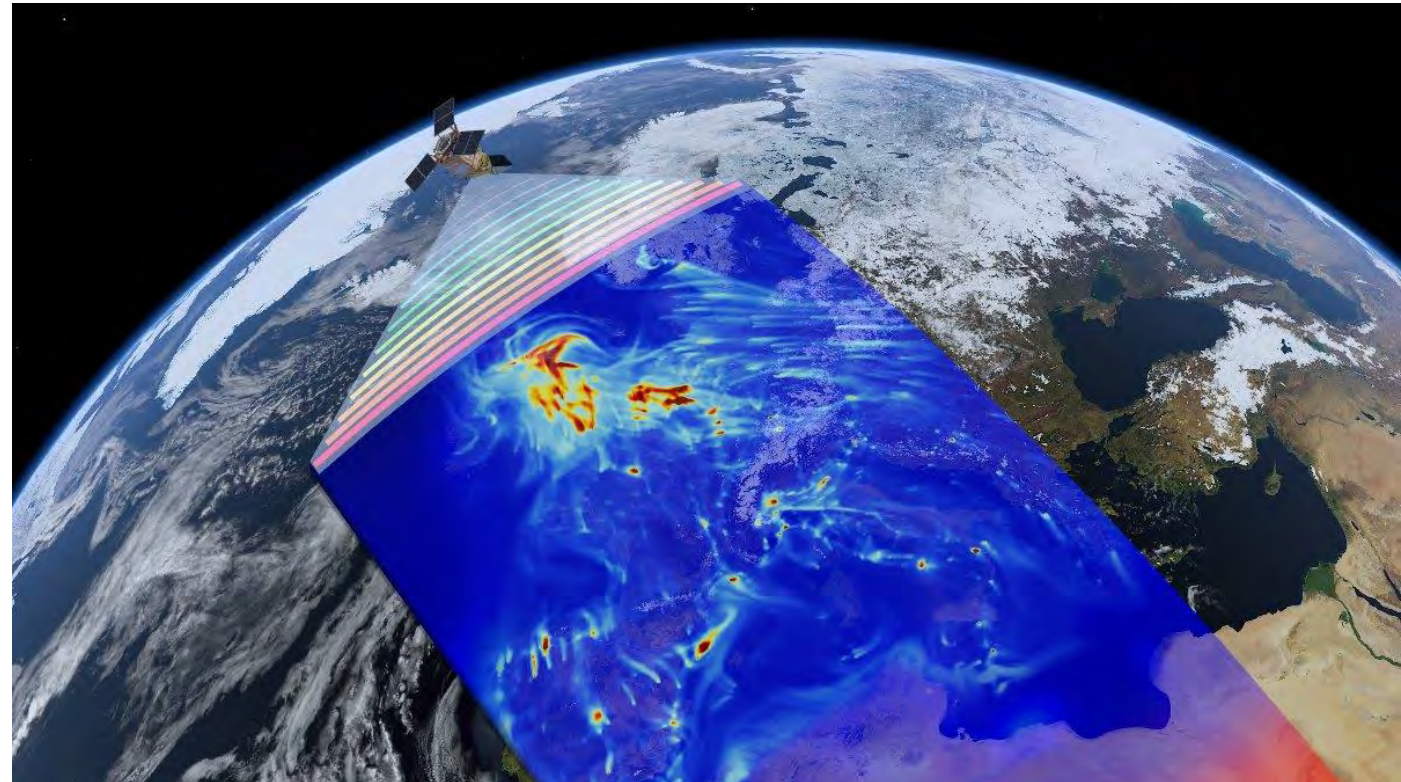
The map also reveals clusters of hot spots in large cities, such as Tula, Kaluga, Vladimir, Tver, Nizhny Novgorod, Yaroslavl, etc. It is also seen that from Sergiyev Posad to the north direction, the contamination level is rather low, except Yaroslavl, where the working oil refinery is located.

Sentinel-5

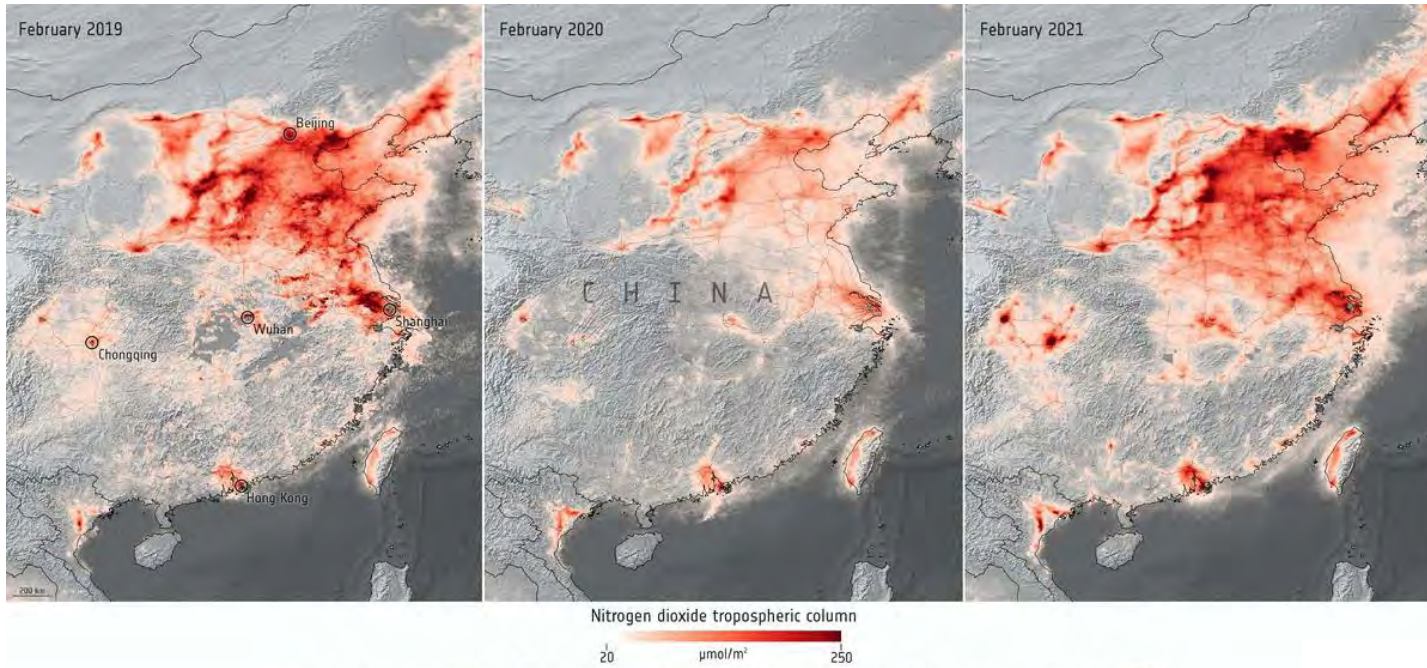


Sentinel-5 is focused on air quality and composition-climate interaction with the main data products being O_3 , NO_2 , SO_2 , HCHO, CHOCHO and aerosols. Additionally Sentinel-5 will also deliver quality parameters for CO , CH_4 , and stratospheric O_3 with daily global coverage for climate, air quality, and ozone/surface UV applications.

The Sentinel-5 mission is part of the European Earth Observation Programme "Copernicus" which is coordinated and managed by the European Commission (EC). The space component of the Copernicus observation infrastructure is developed under the aegis of the European Space Agency (ESA).



Sentinel-5

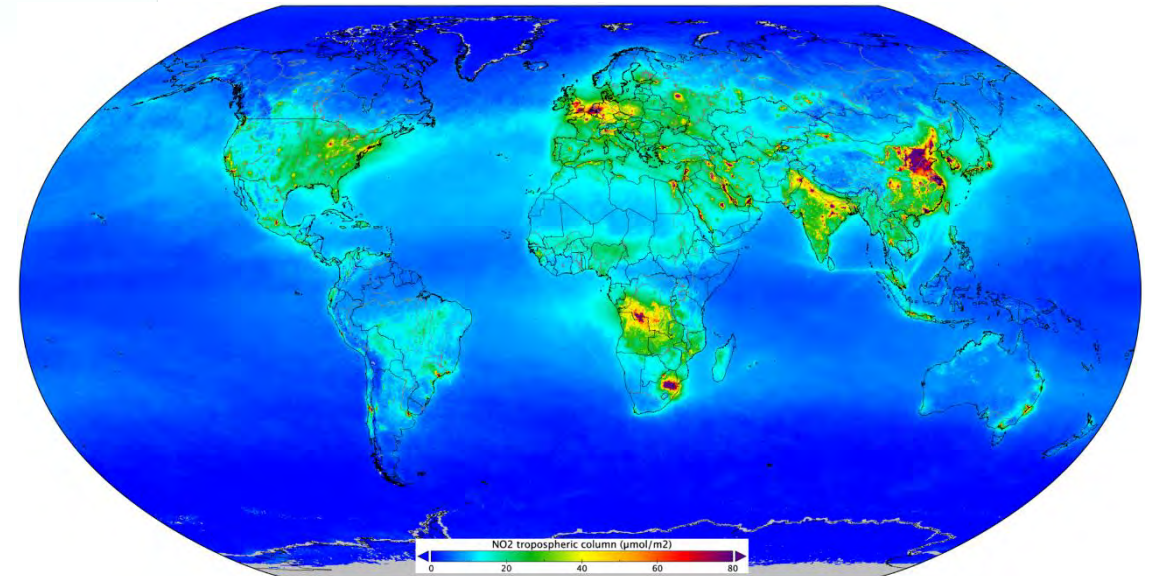


contains modified Copernicus Sentinel data (2019-21), processed by ESA

Resolution ~ 1114 m,
Orbital cycle 16 days.

Sentinel 7 (CO2M - Copernicus Anthropogenic
Carbon Dioxide Monitoring) 2025 - 2026

The Sentinel-5 mission consists of high resolution spectrometer system operating in the ultraviolet to shortwave infrared range with 7 different spectral bands: UV-1 (270-300nm), UV-2 (300-370nm), VIS (370-500nm), NIR-1 (685-710nm), NIR-2 (745-773nm), SWIR-1 (1590-1675nm) and SWIR-3 (2305-2385nm).



Nitrogen dioxide worldwide 12/03/2019



Formula 1 Miami Grand Prix

2019

Daily, less than 3m resolution, 4 spectral channels





PlanetScope
Always-on Monitoring

~200
Satellites

3.7 m (3.0 NIIRS)
GSD

8
Spectral Bands

Not required
Tasking



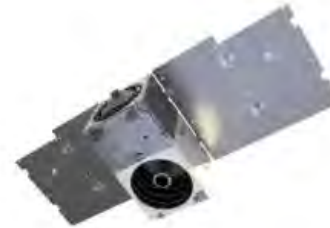
SkySat
High-Resolution Tasking

21
Satellites

0.5 m (4.0-5.0 NIIRS)
GSD

RGB, Pan and NIR
Spectral Bands

Sub-daily
Tasking



Pelican
Very High Resolution

~32
Satellites

0.3 m (>5.5 NIIRS at-nadir)
GSD

7
Spectral Bands

Up to 12 revisits/day
Tasking

Now



Hyperspectral
Broad Spectral Range

2
Satellites

30 m
GSD

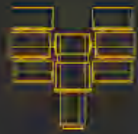
400-2500nm
(5nm spacing)
Spectral Bands

Tasking Required
Tasking



1999
~ 3 days, 3m resolution, 3
spectral channels

ON ORBIT

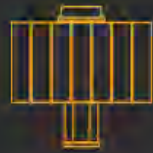


WORLDVIEW-1

- Electro-Optical
- 50 cm resolution
- <5.0 m CE90

[Download datasheet](#)

From 2007
~ 2 days
1 spectral channel



GEOEYE-1

- Electro-Optical
- 41 cm resolution
- <5.0 m CE90

[Download datasheet](#)

From 2008
< 2 day
5 spectral channels



WORLDVIEW-2

- Electro-Optical
- 41 cm resolution
- <5.0 m CE90

[Download datasheet](#)

From 2009
~ 1.2 day
9 spectral channels



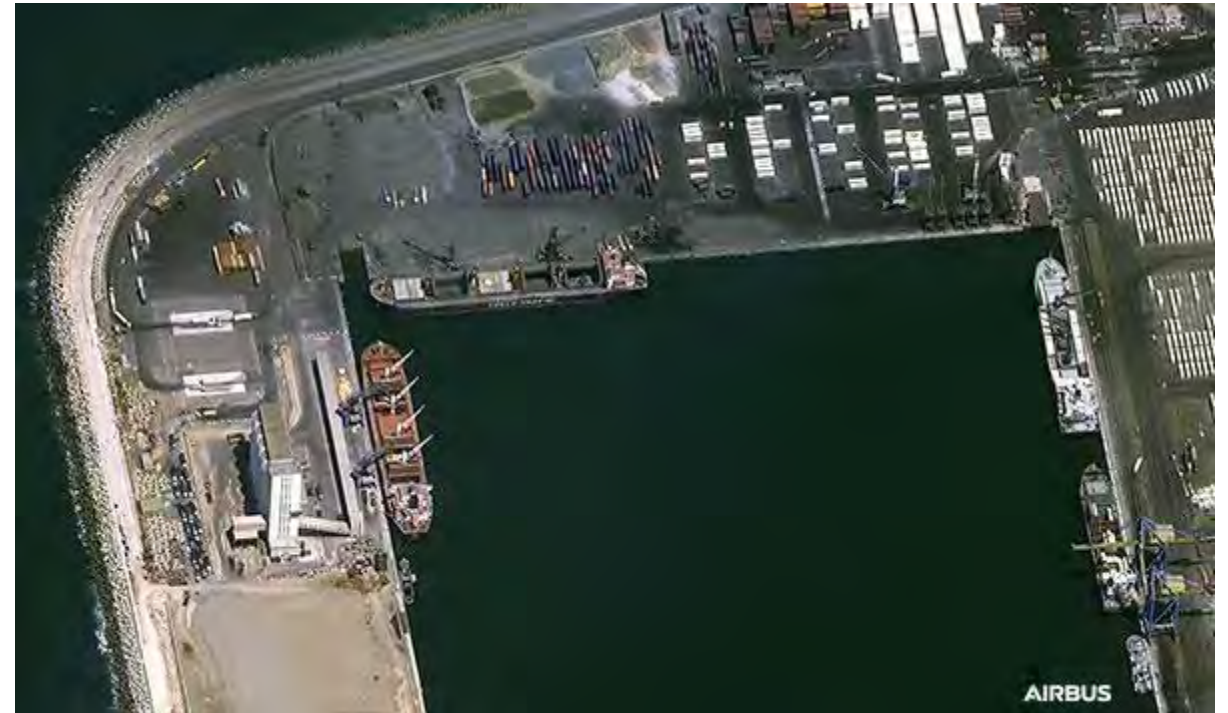
WORLDVIEW-3

- Electro-Optical
- 31 cm resolution
- <5.0 m CE90

[Download datasheet](#)

From 2014
< 1 day
29 spectral channels

Commercial programs - Airbus



Commercial programs - Airbus

Pléiades Neo
📷 30 cm
Revisit capacity
Daily, anywhere.
Daily acquisition capacity:
1,000,000 km²

Pléiades 1A/1B
📷 50 cm
Revisit capacity
Daily, anywhere
Daily acquisition capacity:
700,000 km²

Vision-1
📷 90 cm
Revisit capacity:
Daily to 8 days, anywhere,
depending on latitude and
partner satellites
Daily acquisition capacity:
20,000 km²

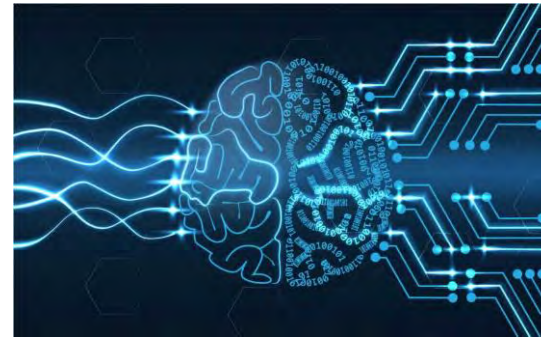
SPOT 6
📷 1.5 m
Revisit capacity
Daily, anywhere
Daily acquisition capacity:
3,000,000 km²

RADAR Constellation
📷 From 25cm to 40 m
Revisit capacity
Daily for most latitudes
Daily acquisition capacity:
5,400,000 km²

DMC Constellation
📷 from 12 to 24 m
Revisit 3-5 days anywhere
Daily acquisition capacity:
10,000,000 km²




Google Earth Engine
More than
80 Pb of data



The total number of AI publications doubled, growing from 162,444 in 2010 to 334,497 in 2021.

According to UCS, there are 4,852 active artificial satellites orbiting the Earth as of January 1, 2022, 2,944 belong to the United States.



Monitoring is the first step to control, so I look in the future with optimism and believe that Earth will become clearer and safer.

Если хотите попробовать порешать интересные задачи и поучаствовать в проектах:

email: auzhiskiy@jinr.ru

<https://t.me/bigzmey>

Спасибо за внимание!

Если осталось время – то будет небольшой tutorial!