EO School Lab (Draft 1.0 18-04-2014)

1 INTRODUCTION

1.1 Background

During the IEEE Geoscience and Remote Sensing Symposium (IGARSS) 2012, in Munich, a School Laboratory (School Lab) was organised by DLR and ESA. The School Lab consisted of hands-on experiments demonstrating EO principles and techniques with the aid of instruments including a spectrometer, thermal camera and radar imager. The experiments were held during periodic group sessions to visiting school classes throughout the week long symposium in a dedicated open area. While they were mainly targeted to secondary school students and teachers, hundreds of interested conference participants from varying age groups and backgrounds were attracted, both during the group sessions and during the breaks.

Radar experiment　Spectroscopy　Infrared techniques

Figure 1: Illustration of School Labs.

Following the success of the IGARSS 2012 School Lab, the event was repeated at the ESA Living Planet Symposium in 2013 in Edinburgh. In addition to ESA and DLR, the UK Space Agency (UKSA) also contributed. Activities included thermal imaging of water bodies, spectroscopy of plants and other materials, computer practicals with EO data, and 3D demonstrations. From Edinburgh alone, around 200 high school students and teachers attended the School Lab, and as with IGARSS, many interested conference participants also attended.

1.2 Objectives

Having seen the impact and educational utility of the School Lab held during the various symposia, ESA and DLR decided to develop jointly a tutorial which describes the experiments that were developed. The ultimate goal of this tutorial is to provide teachers and students a description of EO principles and techniques in a stimulating and fun practical environment, emphasising the relevance and vital role of EO in real world applications.

1.3 Remote Sensing Experiments at the DLR_School_Lab

The DLR_School_Lab Oberpfaffenhofen, operated by the German Aerospace Center (DLR) is a typical extracurricular science lab, its main objective being to attract secondary school students to Mathematics, Informatics, Natural Sciences, and Technology (MINT). It has been developed and operated since 2003 and offers thirteen hands-on experiments for secondary school classes, as well as advanced teacher trainings in physics and geography. Since it opened in 2003, the DLR_School_Lab Oberpfaffenhofen has been visited by more than 20,000 students and 2,000 teachers.
Students in the DLR_School_Lab have the choice to conduct thirteen high-tech experiments each with a remote sensing background to a greater or lesser extent. To give an example, the following six experiments are closest to the subject matter: Radar Measuring Technology, Laser Technology, Infrared Measuring Technology, Optical Environmental Remote Sensing, Satellite Navigation and Earth Observation with Satellite Data. Table 1 gives an overview of the experiments, their subject-specific keywords and the instruments available.

All of these experiments have in common that they start with a short introduction to the subject. The physical basis of almost all those experiments is the theory of electromagnetic radiation. The students are taught the general definitions of radiation and its characteristics as well as the specific theoretical background of the current experiment.

Experiment	Keywords	Instruments
Radar Measuring Technology	Microwaves, Echo, Doppler Effect, Frequency, SAR, Tandem-X	Imaging Radar (SAR), One Dimensional Radar, Radar Speed Sensor
Laser Technology	Polarisation, Emission, Monochromatic Light, Quantum Optics, Signal Transmission, LIDAR, HALO	Infrared Class IV Laser, Class II Laser for signal transmission, simulating 3D-Laserscanner
Infrared Measuring Technology	thermometry, emissivity, black body, prism, BIRD, Herschel, Boltzmann	2 FLIR-Cameras, Pyrometer, special coated examination objects
Optical Environmental Remote Sensing	sun spectrum, ozone, reflectance, spectroscopy, VNIR, NDVI	portable Spectrometer, Sun Photometer, Pyrometer
Satellite Navigation	relativity, Einstein, geo caching, travel time measurement, atomic timing device, GALILEO, GPS	GPS Handhelds, simulation tools
Earth Observation with Satellite Data	resolution, multispectral sensor, image processing, change detection, Landsat	Leoworks image processing software, Landsat Data

Table 1: Summary of remote sensing experiments with subject-specific keywords and available instruments

Subsequently the focus lies on actively exploring and discovering, so the students are given the possibility to use several technical devices, depending on the experiment, in order to learn about remote sensing in more depth. These instruments can range from comparatively simple ones like a pyrometer or a class II Laser right up to complex instruments such as a portable field spectrometer or an imaging SAR. The students are supervised by a capable tutor whose main task is to support the students exploring on their own rather than to teach them.

In summary, the three major components of the experiments are technology, methodology and application, with a varying main focus depending on the experiment. The Infrared, Laser, and Radar experiments in particular focus on technological aspects, whereas for Optical Environmental Remote Sensing and Satellite Navigation, the emphasis lies more on methods and theoretical background. Earth Observation with Satellite Data is, by contrast, distinctive for its high degree of practical application.

2 EARTH OBSERVATION SCHOOL LAB MODEL

Following the model of the DLR School lab, the following joint school labs have been based on a set of experiments to be carried out by/with groups of young people (mainly secondary school students), under the direction of the EO School Lab instructors. The experiments vary in duration and complexity, and involve the use of state-of-the-art instruments.

Figure 2: Description by an instructor of the thermal radiation.

2.1 Instruments

Applications in EO rely on specific satellite sensors. To explain within the EO School Lab how these sensors can be used to monitor the Earth, various instruments are required. This section provides a non-exhaustive list of instruments that can be considered within an EO School Lab.

2.1.1 Spectrometer

The focus is on measuring reflectance by the use of a portable spectrometer. After a brief introduction on how it functions and how to operate it, various measurements are taken and interpreted. Potential targets for demonstration of spectroscopy and reflectance behaviour are, e.g., different-coloured paperboards (both dry and wet), a pot plant showing the typical reflectance of active vegetation, dead leaves by contrast and liquid water in a pot.

2.1.2 Thermal camera

Based on the historical investigation by Wilhelm Herschel leading him to the discovery of infrared radiation over 200 years ago, a thermal camera allows students to convert heat radiation into visible images and thus comprehending the physical background and the principles of infrared radiation. Potential targets for the demonstration are, e.g., a wire which is heated up electrically until it begins emitting light, weakly heated surfaces with a different emissivity and targets which differ in transmissivity compared to the visible spectrum (e.g., glasses, plastic bags).

2.1.3 Stereo camera

TO BE WRITTEN

2.1.4 Further instruments

TO BE WRITTEN. Including:

- Drone
- 3D visualisation hardware

2.2 Activities

Practical applications using the instruments described in section 2.1 are presented below.

2.2.1 Spectroscopy

a) Introduction to the Electromagnetic Spectrum

Experiment:

- Introduce the spectrum and colours of light seen by the human eye with the aid of a prism.

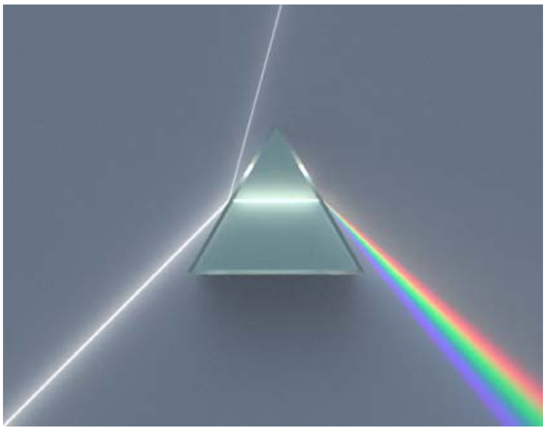

Figure 3: Light dispersion using a prism

- Explain the electromagnetic spectrum and compare the sensitivity range of a spectrometer with human eye.

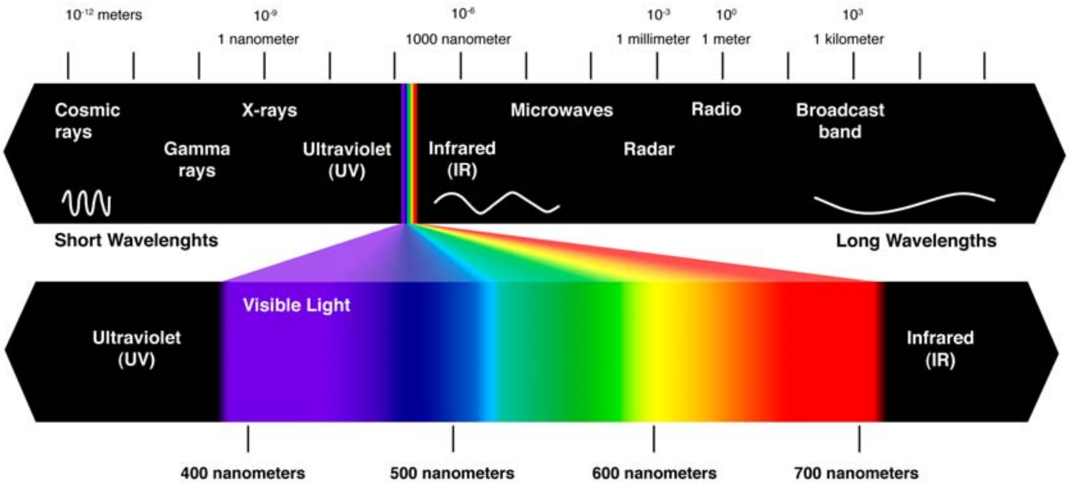

Figure 4: Spectrum range

- Explain the operation of the spectrometer.

Accessories:

- Prism
- Source of light with light cache
- ESA poster - Spectrum

b) Vegetation monitoring

Experiment:

- Show spectrum of healthy vegetation. Explain why we see the plant is green. Explain red absorption due to photosynthesis and NIR reflectance to avoid the plant overheating.

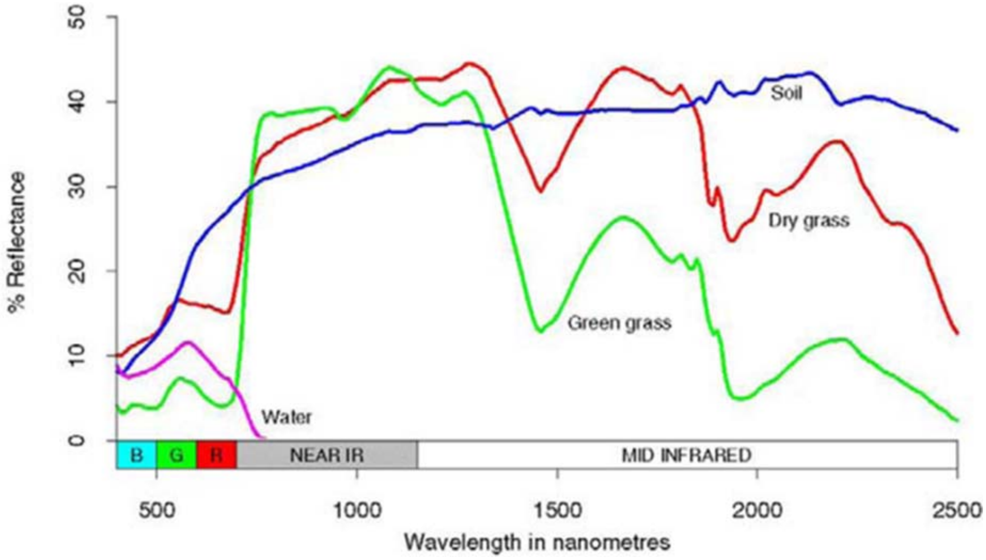

Figure 5: Spectra comparison between different materials.

- Compare spectrum of healthy vegetation to dry vegetation. Explain why spaceborne sensors have red and NIR bands for vegetation monitoring. Explain the concept of vegetation indices.
- Show spectrum of white paper, see how similar it is to vegetation.
- Show spectrum of coloured paper and note that only difference is in visible range.
- Compare spectra of wet and dry soil. Note the IR absorption by water.

Accessories:

- Spectrometer
- Samples: healthy plant, dead plant
- (Computer)
- (Large screen TV or Projector)
- (Tripod)

c) Black body radiation

Experiment:

- Compare spectra of different black and white items to see if they are really black or white. A particularly good experiment would be to show the spectra of different items of students' black coloured clothing, and show that some of them may be close to a true black body and absorb IR light (thus heating up when exposed to e.g. sunlight), while other items may only be black in the visible spectrum, reflect more in the IR, and would therefore heat up less when exposed to sunlight (more comfortable to wear in summer).

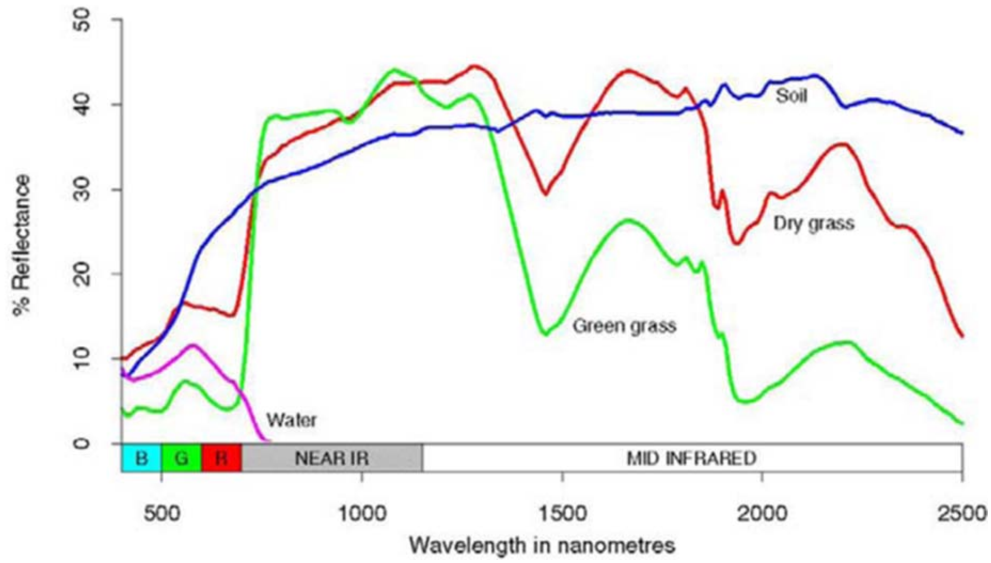

Figure 6: Comparison of the spectrum derived for black and white objects.

Accessories:

- Spectrometer
- Samples: white and black objects
- (Computer)
- (Large screen TV or Projector)
- (Tripod)

d) Additional activities

Experiment:

- Look at the spectrum of other objects suggested by students.

Accessories:

- Spectrometer
- Samples: objects suggested by students

- (Computer)
- (Large screen TV or Projector)
- (Tripod)

2.2.2 Thermal Imaging

a) Introduction to thermal radiation

Experiment:

- Explain the difference in wavelength between the thermal IR and the spectrometer range.

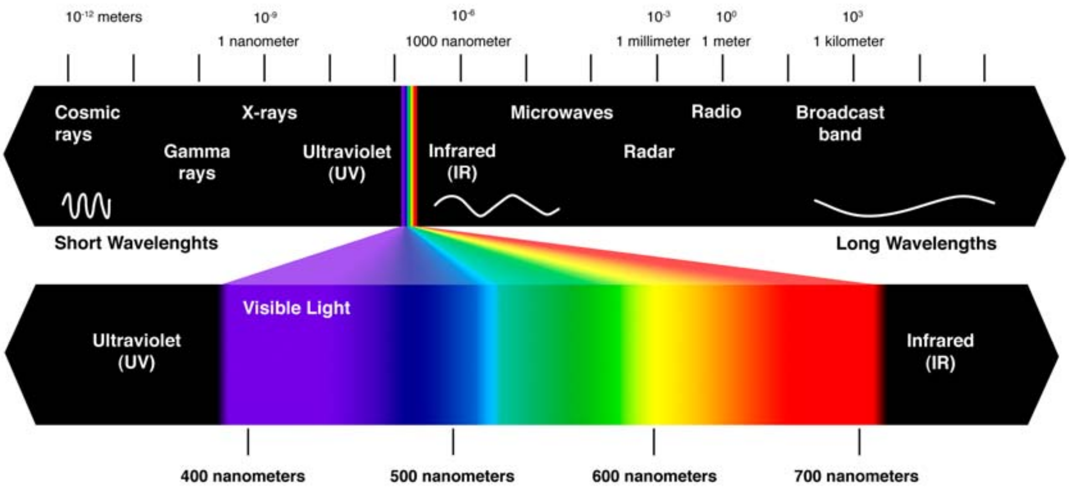

Figure 7: Spectrum range

- Explain the concept of Planck's law of black body emission (concept only, not the name), and why this region is used to measure sea and land surface temperature.
- Show radiation of different samples (finger prints on table, students' faces, etc.).

Accessories:

- Thermal camera
- Samples: objects suggested by students
- ESA poster - Spectrum
- (Computer)
- (Large screen TV or Projector)
- (Tripod)

b) Monitoring of sea surface temperature:

Experiment:

- Demonstrate the dynamic nature of water temperature by filming hot water poured into a basin of cold water.
- Describe the utility of thermal remote sensing to monitor ocean currents.

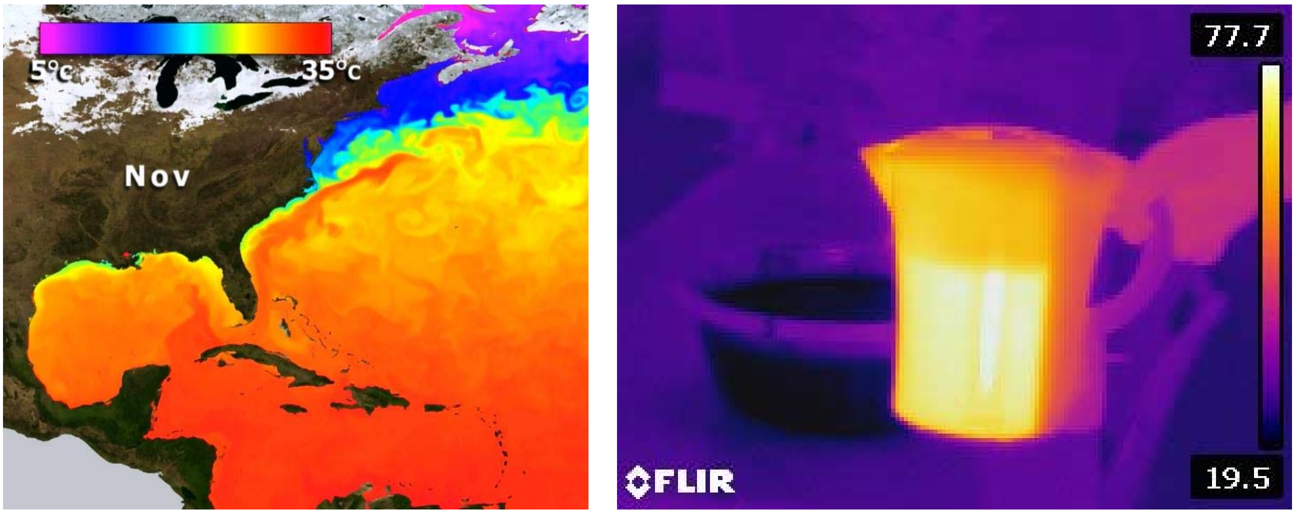

Figure 8: Comparison between the Atlantic Sea Surface Temperature (SST) and the temperature measured for hot water poured into a basin of cold water.

Accessories:

- Thermal camera
- Cup, basin, hot and cold water
- (Computer)
- (Large screen TV or Projector)
- (Tripod)

2.3 Further activities

2.3.1 Microwaves

a) Introduction to microwave radiation

Experiment:

- Explain Microwave spectrum

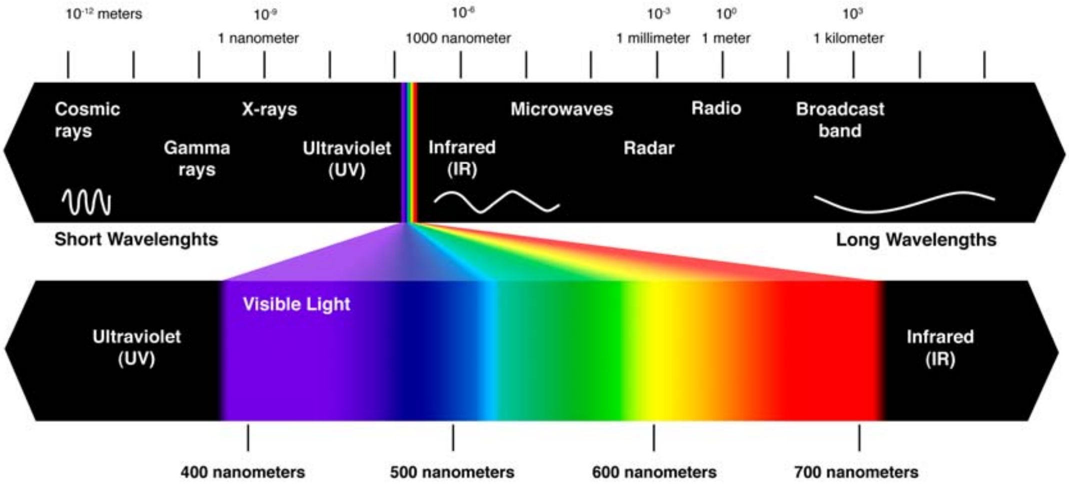

Figure 9: Spectrum range

- Explain how microwave ovens work
- Explain how microwaves interact with water molecules
- Demonstrate how microwaves interact with different objects by heating them in microwave oven:
    - Water
    - Dry sand
    - Wet sand
- Estimate microwave wavelength used by oven:
    - Insert flat tray of e.g. cheese in oven,
    - Heat briefly
    - Remove and see where the microwaves have heated the cheese, and where not (distance between two heated, or two unheated, parts corresponds approximately to wavelength)

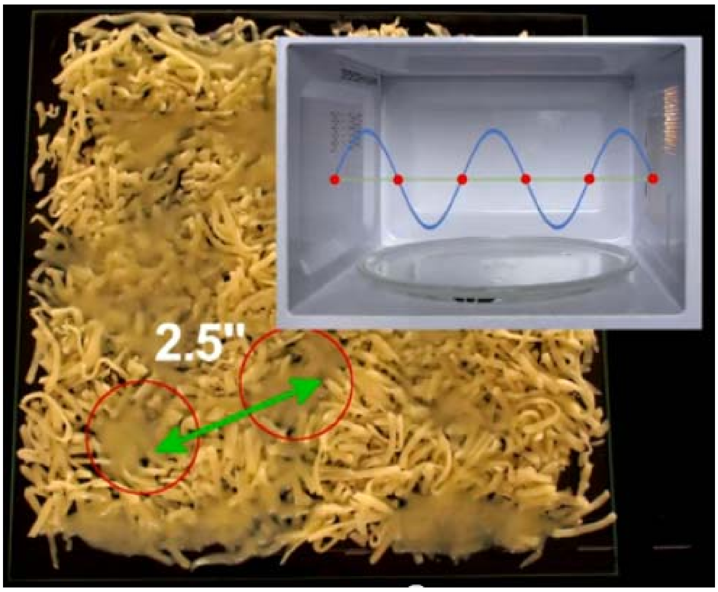

Figure 10: Estimation of the microwave wavelength.

Accessories:

- Microwave oven
- Cheese on a flat tray
- Sand
- Basin of water

2.3.2 Stereo Imaging

Three dimensional imaging applications

Experiment:

- Introduction to the concepts of stereoscopy.
- Experiment EO and DEM derivation (DEM at small scale)

Accessories:

- Stereo camera
- (Software for photogrammetry)

2.3.3 Remote Sensing Platforms

a) Drone flight

Experiment

- Explain analogy and difference between Drones and Satellites (scale, atmosphere, etc.)
- Experiment EO and drone flight

Accessories

- Drone

3 LATEST ESA EO SCHOOL LAB EVENT – ESRIN, MARCH 2014

The newly set-up ESA EO School Lab has been put into practice for the first time during the ESRIN open days, from 18 to 21 March 2014.

Figure 11: Comparison of infrared and optical scenes with school students

In this period hundreds of Italian school children of different school years came to ESRIN and attended 1.5 hour sessions of the ESA EO School Lab. The sessions included the following activities:

3.1 Introductory Presentation

(5 mins) Introduction of the ESA kids website and ESA mascot.

3.2 Presentation: Introduction to EO

(10 mins) Introductory presentation of Earth Observation, with images and animations: Earth in the context of the galaxy, the solar system; introduction to orbits (geostationary, polar-orbiting); examples of satellites with these orbits; examples of applications.

3.3 3D Demonstration

(15 mins) 3D demonstration to illustrate satellite orbits and applications (showing GOCE orbit in 3D, geoid and Etna volcano movement due to fluctuations in magma chamber)

3.4 Presentation: Introduction to Radiation

(5 mins) Continuation of presentation explaining the principles of radiant emittance (with simple words!) Show EO imagery acquired at night. See lights of cities.

3.5 Thermal Infra-Red Experiments

(15 mins) Show students in the room using infra-red camera.
Show features of student volunteers in infra-red: glasses, hair, facial features.
Demonstration showing hot water poured into cold water, explaining the concept of ocean current circulation, and comparing to satellite images of SST over oceans and the Mediterranean (seasonal cycles; el Ninyo; the Guld Stream …).

3.6 Presentation: Introduction to the EM Spectrum

(5 mins) (only to older students) TO BE WRITTEN

3.7 Imaging Spectrometer Experiments

(15 mins) Experiment with imaging spectrometer, explaining spectrum of healthy vegetation and comparing this with unhealthy vegetation.
Show spectrum of material/clothes of student volunteers.

3.8 Explanation of Platforms

(10 mins) Presentation and video of drones.
Show a drone to students (during another session the drone is flown outside).

3.9 Presentation of COPERNICUS for kids

(10 mins) Presentation of COPERNICUS for kids programme.