Topic 2a - Overview of types of mission, instrumentation and data

Many international space agencies are involved in the endeavour to collect information about our planet. The European Space Agency in particular has had a very innovative programme of satellites that have developed brand new technologies that are now transitioning from an experimental into the more continuous and operational phase of deployment.

The Copernicus system, recently launched by Europe, is going to provide continuous data streams to many parameters of our planet. And that's going to be transformative and revolutionary in how we respond to climate change and how we provide valuable information that allow politicians and society to make decisions to act in response to such change.

This really is the first time that we've had that sort of continuity of data available from space from anything other than meteorological platforms in the past. And it's something of a holy grail that we've been able to achieve this. NASA, very famously; ESA; and other space agencies have typically been undertaking research missions to understand better the planet to support scientific research into Earth system science.

Now usually, these have been one-off missions lasting for a fixed period of time. Sometimes there's been a follow up. One exception, perhaps, on the non-meteorological side has been Landsat. With Copernicus, we have for the first time long-term, guaranteed continuity of observations for a whole suite of different elements which are important for understanding the Earth and monitoring the status of the Earth's system.

And this opens opportunities for all sorts of new areas of work. Not only is science very well served by this-- because even science is not satisfied by a one-off mission which tells us something about how the world is operating. Particularly for issues like climate, one needs long-term, typically 30 years or more, data sets. And so one needs these long-term series of information coming from many different satellites.

But if we're trying to establish a more fundamental role for Earth observation data in the wider world, then it becomes even more important that we are able to guarantee with these potential new user communities that they're going to be able to change their business practises in such a way that the new methods that they adopt will be there for the long term.

These days earth observation missions come in a wide variety of sizes-- from CubeSats, which are basically 10 by 10 by 10 centimetres, to large missions like this which is Sentinel-3, one of a new range of ESA satellites. You can see on this animation the typical range of structures that Earth observation missions have-- from solar panels to generate electricity, antennas to communicate with the Earth and to transmit the data.

And here, we can see some apertures on an instrument called SLSTR. This is a passive remote sensing instrument which is designed to measure long-wave radiation emitted from the Earth. And what we're going to do that is to measure sea surface temperature to unprecedented levels of accuracy. It can also measure land surface temperature, detect fires, measure the distribution of vegetation.

There are two main categories of satellite Earth observation instrumentation-- active instruments and passive instruments. Sentinel-3 contains a mixture of passive and active remote sensing instrumentation. Active instruments actually generate electromagnetic radiation at particular wavelengths.

For example, in the case of radar, this would be microwave radiation. And in the case of lidar, it would be laser radiation-- typically at visible or infrared wavelengths. And they're used for particular tasks-- for example, measuring vegetation canopy height, the height of ice sheets.

Sentinel-3 also has an active remote sensing instrument on it in the form of a radar altimeter. This generates pulses of microwave radiation which are bounced off the surface of the earth and remeasured at the satellite. The primary mission of this instrument is to generate sea surface height information.

Passive remote sensing instrumentation, by contrast, uses just reflected sunlight or thermal-emitted radiation from the Earth. Most remote sensing instruments are passive.

Active instruments generally require more power because they have to generate the electromagnetic radiation themselves. And this means it's often impossible to keep those instruments on operating all the time. So they may only be operating, for example, 10%, 20%, 30% of the time the satellite is actually orbiting the Earth. Passive instruments require less power typically and can be on 100% of the time.

To observe the earth's surface from space, we have to look through the atmosphere, and that has impacts on these measurements of electromagnetic radiation that we use. One of the impacts is atmospheric scattering. So this is where molecules or particles in the Earth's atmosphere actually cause the direction of radiation to change.

Usually, this effect is different at different wavelengths. So for example, short-wave radiation is scattered more than long-wave radiation by the atmosphere. Scattering explains why the sky looks blue, because sunlight from the Earth is scattered preferentially at shorter wavelengths-- which are blue-- than longer wavelengths-- which are red, green, et cetera.

Absorption occurs when particular molecules in the atmosphere absorb electromagnetic radiation at specific wavelengths and re-emit that energy across a wider spectral range. This can actually be a benefit because we can design instrumentation to measure the specific wavelengths that certain gases in the atmosphere absorb at-- for example methane or carbon dioxide-- and look at the amount of electromagnetic radiation coming from the Earth in those particular wavelengths and at wavelengths close by to them.

If we look at the difference, we can provide information on the actual concentration of those gases in the Earth's atmosphere and how that changes in space and in time. Examples of instruments or missions that use this principle are OCO-2, IASI, GOSAT for example-- all targeted at the measurement of the concentration of particular gases in the atmosphere.

When we're trying to observe the surface of the Earth, we usually want to observe in an atmospheric window. This is the region of the electromagnetic spectrum where the atmosphere has minimal effect on the radiation-- so little scattering, little absorption.

Properties of the Earth we can estimate using those sort of observations are-- for example-- ocean colour, land surface temperature, vegetation condition.

However, if we want to probe the properties of the atmosphere itself-- for example, the concentration of carbon monoxide-- we might want to observe in an actual atmospheric absorption band where carbon monoxide has a noticeable effect on electromagnetic radiation. Using those measurements, we can actually try to estimate the concentration of that gas in the atmosphere and map its distribution over space and over time.