# PRESENTING DATA AND TELLING STORIES

**Philip Eales[1], Andrew Wayne[1], Kevin M. Tildsley[1], Tim Wilkinson[1], Diego Fernàndez Prieto[2]**

*[1]Planetary Visions Limited, 8 Mimosa Drive, Shinfield, Reading RG2 9AQ, UK, Email: philip@planetaryvisions.com*
*[2]European Space Agency ESA-ESRIN, Via Galileo Galilei, 00044 Frascati, Italy, Email: diego.fernandez@esa.int*

## ABSTRACT

Earth observation data are now readily available at a range of scales and becoming increasingly familiar to the general public. Observations built up over several decades enable us to show long-term change and tell increasingly complex stories about the Earth and other planets. Data visualisation and computer graphics can help present these stories to a non-specialist public audience. In addition to high visual quality and clear design, we have found it useful to present data within its geographical and scientific context, in natural colour, in a realistic and immersive environment, using familiar visual and physical metaphors. The internet increasingly allows direct communication with the public and this places renewed emphasis on basics such as good story-telling. Examples are shown of work in television, print and digital media, and from ESA's Earth observation and planetary exploration programmes.

## 1. INTRODUCTION

Earth observation (EO) data are being generated at a prodigious rate, adding to archives built up over thirty years or more. Climate models are becoming more detailed, and are also able to produce considerable amounts of data. Data visualisation is a powerful tool for analysing these large datasets, but it also has a role to play in explaining observations and their scientific significance to a public audience.

In addition to the traditional media outlets for such presentations of data – newspapers, books and tv – we now have the web, social networking sites, and low cost computer software (apps and e-books). These new media are increasingly used by universities, research centres and space agencies to engage directly with the public.

While the new media free scientists from some of the constraints of the traditional media, many of the lessons learned presenting science through the traditional media still apply. We have found a number of techniques to be helpful in the effective communication of Earth science stories to a public audience, some of which are outlined here, with illustrations drawn from recent projects for the European Space Agency (ESA).

## 2. BACKGROUND

A survey of climate scientists in 2008 showed that 58% of those surveyed used visualisation techniques to make scientific results comprehensible to decision makers, stakeholders and the media - almost as many as used them to explore unknown patterns and structures (69%) [1]. In a world facing challenges such as climate and environmental change, both are important tasks, but they have different goals, a different audience, and different routes to success. Images generated for analysis or presentation at scientific conferences are often not well-suited for communicating with the wider public.

Computer graphics (cg) are widely used in the entertainment industry and the public have become used to the extremely high visual quality of computer graphic animation in feature films, television, advertising and computer games. While not competing head-on with Hollywood for a viewer’s attention, factual computer graphics are inevitably judged by the public against this benchmark.

Traditional computer graphics techniques have been used by space agencies to produce public relations material such as “beauty shots” of launch vehicles and spacecraft. Previous work by the Planetary Visions team has combined computer graphics with data visualisation to bring scientific data alive in collaboration with documentary film-makers, print and digital publishers, and museum curators.

In parallel with the growth of Earth observation data, the internet has opened up new channels for direct engagement with the public, offering outlets for science communication and public outreach in addition to the traditional mass media of broadcasting and the popular press.

When presenting to the public directly, with no “mediation” from the media, the emphasis is not just on high visual quality, but also on the construction of a clear and coherent narrative – the art of good story-telling.

## 3. PRESENTING THE UNFAMILIAR

When presenting unfamiliar information to a non-specialist audience, it seems sensible to build on those aspects of the data that might already be familiar to the viewer, and to bring in other datasets to support this where necessary:

***Context:*** Rather than show data in isolation, we place it

*Presented at the European Space Agency Living Planet Symposium, Edinburgh, 9-13 Sept 2013.*

in its geographical context, using a background map to orientate a global dataset or locate a study site. Historical context might also be provided in the form of the previous state of knowledge from precursor data, by showing the process of data acquisition, or relevant newsworthy events that the viewer may remember.

***Natural Colour:*** Particularly for background maps, natural colour, cloud-free satellite image mosaics present an easily-understood representation of the "real world" being measured by the data. These can be based on Landsat for local areas, or weather satellites for continental and global scales. Seasonal background maps can help establish the time of year. It can also aid understanding to apply natural or intuitive colours to the main data being presented (see section 4 below).

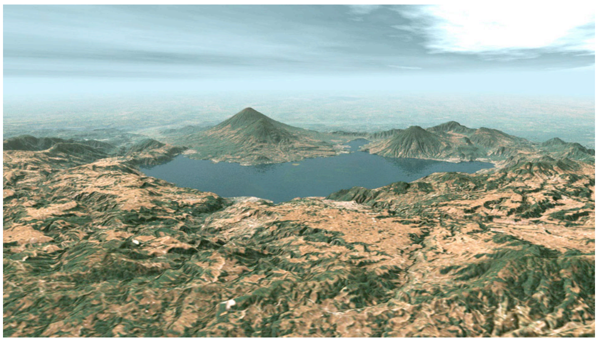

*Figure 1. Lake Atitlan, Guatemala. Still from the archaeological documentary film "Mayan Blue" (Standoff Studios, 2011), rendered using Landsat 7 ETM+ imagery and SRTM digital terrain.*

***3D:*** We all live in a three-dimensional world, so presenting data in 3D, or at least against a 3D backdrop, can engage the viewer at a more visceral level than showing the abstraction of a traditional 2D map. Digital terrain data can be used to present data in the context of major physical features such as mountain ranges and basins. 3D can also be used in the mapping of data values, but care should be taken to do this in a physically meaningful way.

***Realism:*** Beyond natural colour and 3D, we can use computer graphic simulations of phenomena such as atmospheric haze, clouds and reflection from water surfaces to add realism to a scene (Fig. 1). Apart from raising our presentation closer to the levels of visual quality delivered by computer graphics in tv, films and computer games, effects such as atmospheric haze add useful depth cues to a 3D scene, can focus attention on the foreground, and, very practically, hide the edges when data maps are of limited extent.

***Immersion:*** There are no edges to the real world, and nor should there be to our virtual world if it is to be a convincing representation of the real world. Datasets sometimes have geographical limits, and we may want to show them, but this should be a deliberate choice, and we may still use a context map background extending to the edge of the frame and the horizon. For high resolution data, this may involve several levels of context imagery at different scales and animation through a multi-scale zoom. In an exhibition setting, multiple screens and hemispheric projection can add to the effect.

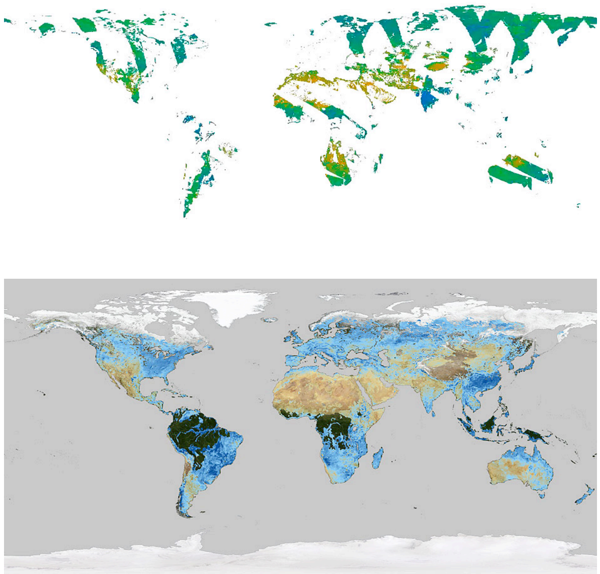

*Figure 2. Satellite-derived soil moisture data for one day (top), and one month (bottom). Monthly data still shows data gaps due to algorithm failure over rainforest, desert and snow. A natural colour satellite image background helps explain these data gaps.*

***Data Quality:*** EO systems often produce data with gaps or "drop-out" caused by, among other things, cloud cover, the wide spacing of orbital tracks, or the breakdown of the data-retrieval algorithm in extreme conditions. While a data analyst familiar with the characteristics of a particular dataset will be used to such artefacts, they can be quite distracting for a non-specialist viewer. In animation, rapidly-varying gaps in data sequences can dominate the presentation to such an extent that effective communication is impaired. In such cases an extra stage of "cosmetic" data cleaning can be useful, such as averaging data over a longer time period or a larger area, temporal or spatial interpolation across small gaps, or masking data from mixed land/sea pixels in coastal zones.

***Integrity:*** An over-arching principle throughout the foregoing should be to maintain data integrity. When resampling, colouring, cleaning, etc, care is taken to maintain the geometric and radiometric fidelity of the data. A presentation carries more weight and credibility the more authentic it is (which is why we show the data used by scientists when explaining scientific results). A working knowledge of EO data, as well as the use of geographic information systems, digital mapping and data analysis tools helps maintain data integrity throughout our work.

## 4. PRESENTING NUMBERS

Quantitative data maps can often be quickly "read", sometimes without the need for explanation, by using appropriate and familiar *physical metaphors*. Terrain and cloud-top height can obviously be shown with a 3D surface map. For atmospheric constituents such as ozone or aerosols, however, opacity is a more intuitive metaphor (Fig. 4). Colour-coding works well for some data, but care should be taken in the selection of colours, so that colour schemes are both meaningful to the viewer, and do not bias the "reading" of the data.

### 4.1. Colour Palettes

In scientific data analysis software, data can be colour-coded to allow data value to be read by comparison with a colour key. The spectrum or rainbow palette commonly found in such software, with smooth transitions through saturated colours from violet to red, has received criticism on a number of counts. Some question its effectiveness for analytic purposes, let alone for public presentation of results [2].

The shortcomings of the spectrum palette stem from its basis in the physical order of light wavelengths, which bares little relation to the principles of human colour perception. It presents particular problems for people with colour-impaired vision (approximately 8% of Caucasian males) [3]. Some packages allow other palattes to be applied, but their construction is usually based on the mechanics of computer displays (red, green, blue), rather than the human visual system (hue, saturation, intensity). Simpler colour palettes have been recommended that monotonically increase brightness or saturation across the data range and use a limited range of hues.

One of the key requirements of an effective colour palette is that *perceived* colour change should be proportional to data value change. Perceptual colour palettes have been proposed by Cynthia Brewer and others, with particular schemes suitable for use on sequential or divergent data [4][5].

Colour palettes that are more intuitively understood are often more effective when communicating with a non-specialist audience. We have used a modification of the rainbow, reducing brightness variation and limiting the colour range to the progression from "cold" blue to "hot" red, to represent sea surface temperature (see Fig. 3). Simpler palettes with careful choice of dominant colour can produce easily-assimilated maps that intuitively represent the physical parameter being shown (eg, green for chlorophyll in vegetation maps).

Perceptual and intuitive palettes may give less discrimination between actual data values, but can make overall spatial structure and motion easier to follow. To paraphrase the statistician John Tukey, they give an approximate answer to the right question, rather than a precise answer to the wrong question.

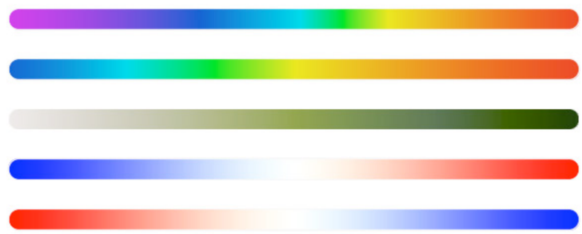

*Figure 3. Colour palettes, from top: standard spectrum; modified spectrum used for sea surface temperature; intuitive scheme for normalised difference vegetation index; divergent scheme for sea level anomalies (red=positive, blue=negative); inverted divergent scheme for soil moisture anomalies (red=dry, blue=wet).*

When comparing two datasets, some viewers report confusion if the same colour scheme is used for different physical parameters [6]. For this reason it is sometimes worth developing deliberately distinct colour palettes, as we are doing on a current project for ESA's Climate Change Initiative, where the ability to compare one climate variable with another is a key requirement.

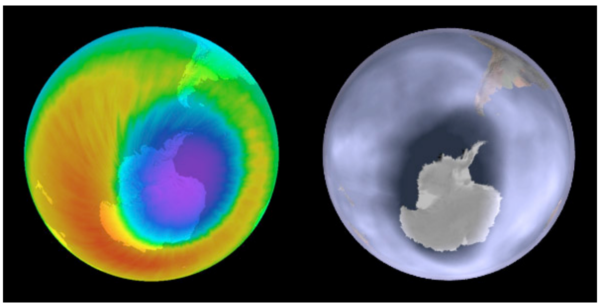

*Figure 4. Stratospheric ozone concentration shown in pseudocolour (left), and as a transparency map (right).*

### 4.2. Derived Data

When presenting some data sets, it can be more meaningful to present derived data than the data itself. For example, by computing the deviation of sea surface temperature at a point from the average for its latitude (latitudinal anomaly), we can highlight warm and cold ocean currents. When presenting thirty years of soil moisture, the monthly anomalies were considered more meaningful than the absolute measures of soil moisture.

In this case we mapped excess soil moisture to height, an appropriate physical metaphor since extremely high values of soil moisture result in rising floodwater. But excessively dry ground does not generally sink, so we showed negative anomalies without surface distortion, using only colour (Fig. 5).

### 4.3. Data Reduction

Scientific data visualisation can be considered an exercise in data reduction, distilling vast quantities of data down to a few key measures or insights. Similarly when presenting scientific data to the public, although we have high quality 3D computer graphic tools at our disposal for presenting images and image sequences, we should not forget about the simple 2D tools available for presenting scalar data. Sometimes a set of data points plotted on a graph can tell a clearer story than the sequence of data maps from which they were derived.

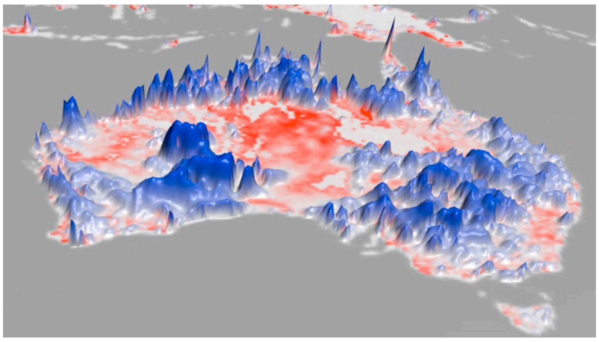

*Figure 5. Soil moisture anomaly data visualised with colour coding and surface distortion.*

It is particularly important for presentations on computer or video screens, which have lower resolution than print, that the labelling of numbers and units on graphs, colour keys and time lines should be done sparingly, both to aid legibility and in order not to distract from the data itself. Edward Tufte talks of reducing "non-data ink" and unnecessary "chartjunk" [7].

## 5. TELLING A STORY

A good data visualisation should allow the data to tell a story. How we do this depends on the intended audience and the chosen medium. We focus here on a current project for ESA's Support to Science Element (STSE). We were asked to produce a series of animations aimed at the general public illustrating scientific results from ESA's Earth observation satellites. Although supported by explanatory text and still graphics on ESA's website, so not entirely self-contained, these animations need to be more than the presentation of a single dataset. The scientific context – the problem being addressed and the significance of the findings - are also part of the story.

Compared with the short, single-shot graphics usually required for tv documentaries, these animations for web are more complex, with multiple ideas to communicate, requiring multiple shots and a longer duration. In the terminology of tv news, they are "picture packages" - short "movies" that require their own narrative structure. Where television is an inherently passive medium, when we surf the web we are actively engaged and free to follow our interests. We can therefore rely on having an interested viewer who has sought out our information; we are "narrowcasting" to a motivated audience, not broadcasting to a general audience.

Compared with cg for television, which is just one element in a mix of interviews, events, specially-filmed and archive footage, our cg packages for the web have to carry more of the story. But without the benefit of a tv director or graphics designer to construct the narrative, where do you start?

### 5.1. Narrative

In his study of ancient Greek theatre, Aristotle suggested that every good story has a beginning, a middle and an end, with actions and events linked by cause-and-effect. Modern documentary films are often constructed with this three-act narrative structure (sometimes referred to as *tease, body, conclusion*), and this basic but trusted formula can be applied to our scientific "short stories".

At the beginning we set the scene – we might show a satellite building up its observations, or the geological or meteorological context for the story. In the middle, the satellite data is revealed and explored; we might illustrate steps in the data processing, eg from synthetic aperture radar image to interferogram to displacement map; new knowledge about the world is presented. At the end, the significance of the new knowledge is shown; the data may be distilled to a graph or a single number; remaining unknowns and future directions of work may be identified.

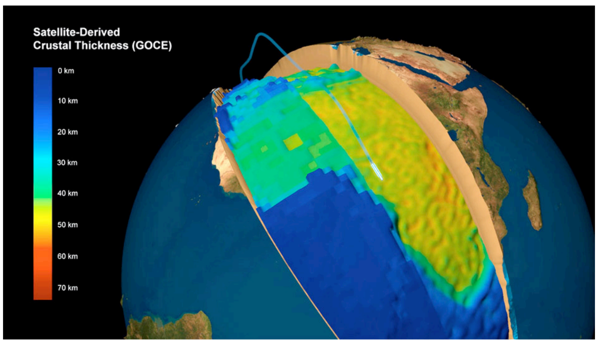


*Figure 6. Crustal thickness measured by the GOCE satellite, compared with the previous-best map, based on seismic measurements.*

### 5.2. Visual Language

We can also use the visual language of film-making to help construct the narrative. The beginning is often in long shot, the middle in close-up, and the end might withdraw again to a long shot. Camera lens angle can convey immersion (wide angle) or detachment (narrow angle).

Camera movement can be used to focus attention, with reinforcement from overlaid labels and captions if necessary. We can also use camera motion, instead of cutting, to move from one "shot" to the next, reinforcing a feeling of immersion within a seamless virtual world. But this should be done with restraint if we are to avoid the disorientation of a rollercoaster ride.

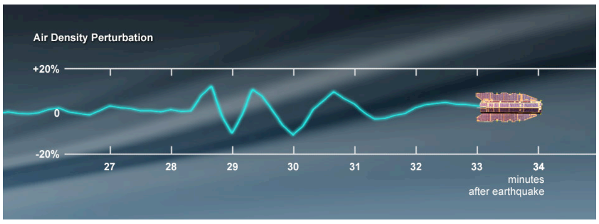


*Figure 6. Integration of data from numerical model with cg model of spacecraft and graph overlay to show variations in air density from the 2011 Tohoku earthquake measured by the GOCE satellite.*

The timing of transitions, their rhythm and pace, and the choreography of elements within a scene all have a role to play. Finally, we can bring numerical information into our virtual world by smoothly integrating visualisation "action" with graphical overlays (Fig. 6).

### 5.3. Process

Success also relies on a robust and collaborative process of story development. On our STSE project we followed a sequence of seven steps, with scientist and ESA manager involved at each stage:

1. *The Brief:* The important topics of the story and characteristics of the data are discussed with the science team leader.
2. *Preliminary Analysis:* The Preliminary Analysis is a text summary of the story, identifying its "must-have" and secondary editorial points, the main science data to be used, and any supporting data.
3. *Storyboard:* The visual treatment to be applied to the data, including framing of shots, transitions and captions - the definitive guide to the animation production.
4. *Data look and feel:* Colour schemes for the data, how it is processed and combined with any background maps, are proposed and agreed.
5. *Animation rushes:* The animation production stage starts with stills showing each key frame of the storyboard, The rushes iterate toward the final full-motion version of the animation.
6. *Titles, captions and transitions:* Once animation motion is locked, the position and wording of story titles, data titles, data keys, timelines, labels and credits, and their timing, can be finalised.
7. *Final version:* Once rushes and titles are approved, the animation is rendered at full HD (high definition) size, titles applied, and movie files encoded for delivery at HD, SD (standard definition) and web sizes.

## 6. RECENT PROJECTS

In addition to linear computer graphic animations for web and television, we have produced maps and artwork for books [8]; multi-screen, immersive and interactive material for museums and exhibitions; and content and software for digital publications (CDROMs and apps). Each medium has strengths and weaknesses that inform the creation of the work. Some examples of recent work involving Earth and planetary science data are summarised below.

### 6.1. STSE Visuals

The *STSE Visuals* project involves the production of 16 animation sequences of 1 to 4 minute duration for ESA's STSE programme, including 30 years of soil moisture observations from seven satellites, mapping the thickness of the Earth's crust, East African Rift Valley dynamics (Fig. 7), and earthquake detection from space (Fig. 6).

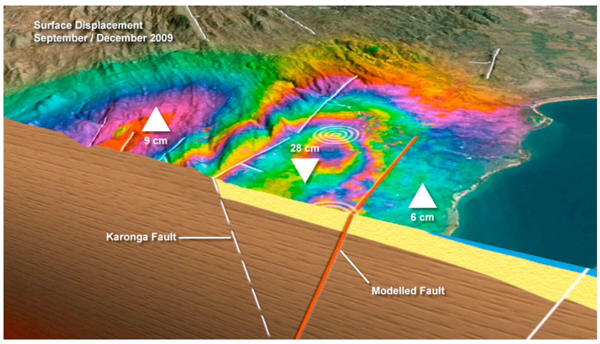


*Figure 7. SAR interferometry reveals a previously-unknown fault in Africa's Great Rift Valley. Known faults and recent earthquake locations are also shown.*

### 6.2. CCI Visualisation Tool

The *CCI Visualisation Tool* is an interactive software package for exhibition at conferences, showcasing the thirteen Essential Climate Variables (ECVs) developed for ESA's Climate Change Initiative (CCI) from multiple satellite archives dating back over thirty years. Our brief is to present the results of the project for scientists who are not subject specialists and for other stakeholders, and allow the comparison of one dataset with another.

A beta version of the software is presented in the exhibition area at this conference, showing one ECV parameter for each CCI project (Fig. 8). With some of the CCI datasets still in production, it is very much a work in progress and it is planned that a later version will include all 35 ECV parameters.

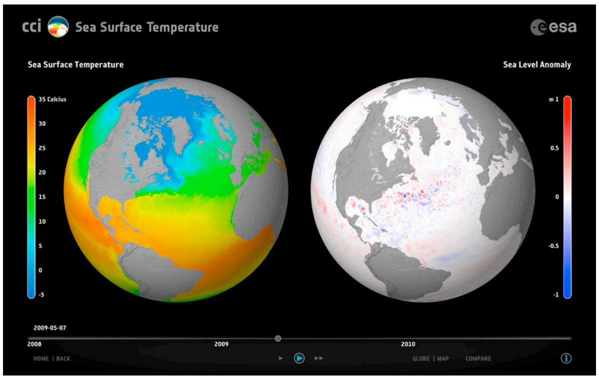


*Figure 8. Comparison of satellite-derived climate variables in ESA's CCI Visualisation Tool.*

### 6.3. Solar System for iPad

An example of more commercial work, but still based on scientific data from ESA and other space agencies, *Solar System for iPad* was produced in partnership with publishers Faber & Faber and software developers Touch Press. The Planetary Visions team worked closely with author Marcus Chown to identify engaging stories in planetary science that could be illustrated well with the available space probe imagery.


*Figure 9. Solar System for iPad.*

We provided texture maps and 3D models for interactive globes for over forty solar system bodies (Fig. 9); algorithms and data for a virtual orrery giving their position and motion through time; animated illustrations of phenomena including Saturn's gravitational bulge, Earth's tides, Mercury's precessing orbit and possible past water levels on Mars and Venus; and 600 images (with captions) drawn from the archives of ESA, NASA, the Japanese Space Agency and others.

*Solar System for iPad* was so successful, topping the book app charts in many countries, that it has been repurposed with custom high-resolution graphics as a printed book, translated into seven languages including French, German, Spanish and Japanese [9].

## 7. CONCLUSIONS

While visualisation techniques are used for both analysis and presentation, these are two different tasks, aimed at different audiences. We have highlighted some of the guiding principles we use when presenting data to the public, including high visual quality, realism, connecting with the viewer's own experience of the world by using meaningful visual metaphors, and setting up simple narratives.

We have successfully applied these principles in our commercial work for clients aiming at a mass audience in tv, print, museums and digital publishing.

These same principles have now been applied in projects for ESA's STSE, CCI and Cryosat programmes. ESA have used the resulting material for public outreach on the web, at scientific and intergovernmental conferences, and at trade shows such as the Paris Air Show. Several stories have been picked up for wider circulation through broadcast tv and on the web through news sites and social media.

## 8. ACKNOWLEDGEMENTS

We are grateful to the STSE science teams across Europe, with members too numerous to mention individually here, who have shared their data and stories with us over the last year.

## 9. REFERENCES

1. Nocke, T., Sterzel, T., Böttinger, M. & Wrobel, M. (2008). Visualisation of Climate and Climate Change Data: An Overview. *Digital Earth Summit on Geoinformatics 2008*, Heidelberg, pp226-232

2. Rogowitz, B. & Treinish, L.A. (1998). Data Visualisation: the End of the Rainbow, *Spectrum*, IEEE **35** (12), 52-59

3. Light, A. & Bartlein, P.J. (2004). The End of the Rainbow? Color Schemes for Improved Data Graphics, *EOS* **85** (4), 385 & 391

4. Brewer, C.A. (2005). *Designing Better Maps: A*

*Guide for GIS Users*, ESRI Press, Redland, CA.

5. Wijffelaars, M., Vliegen, R., van Wijk, J.J. & van der Linden E.-J. (2008). Generating Colour Palettes using Intuitive Parameters, *EuroVis'08 Proc 10th Joint Eurographics/IEEE-VGTC Conference on Visualisation*, 743-750

6. Phipps, M. & Rowe, S. (2010). Seeing Satellite Data, *Public Understanding of Science* **19** (3) 311-321

7. Tufte, E.R. (2001). *The Visual Display of Quantitative Information 2nd Edition*, Graphics Press, 91-137.

8. Eales, P. (2007). *map:satellite*, Dorling Kindersley, London, UK.

9. Chown, M. (2011). *Solar System.* Faber & Faber, London, UK.