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Building a video wall for earth observation data

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Abstract

Earth observation satellites are generating large amounts of data as they monitor the earthâĂŹs environment. Large scale visualisation represents a powerful mechanism to explore and communicate this data; however, conventional tools and screens are limited by their size, while large shared screens are limited in their resolution. In this paper, we describe the motivations and design for a multi-panel video wall facility for the new International Space Innovation Centre. We further describe two visualisation applications which have been designed to demonstrate some of the potential of this wall to share data visualisations with a large audience, while providing a highly detailed view on the data

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1. Introduction

Earth observation satellites such as Cryosat (see `http://www.esa.int/esaLP/LPcryosat.html`) or ENVISAT (see `http://envisat.esa.int`) are now generating large amounts of data as they constantly monitor the earth's environment. These data need to be analysed to determine the changing state of the planet, and presented in a visual form to give an accessible view of the data, and to share and communicate the results to a wider audience. Thus visualisation tools are common place. In particular, over the last few years, the wide availability of Google Maps and Google Earth and similar tools has led to a rapid increase in the use of interactive web applications to view geospatial data. These tools have the advantages of ease of use and accessibility for outreach and presentation. However, due to their relatively low resolution and bandwidth, they remain of limited use for shared presentation spaces. Further, their use for combining and exploring data in new ways to generate new scientific insights remains quite limited. Satellites produce Tb of data with complex spatial-temporal coverages which need to be combined with data produced by other observations, or with simulations which themselves generate large data sets as they model the interactions of atmosphere, oceans, land and ice caps. Providing visualisations of these data which allow both the combination of different data sets, retaining the detail and interaction required for scientific insight, together with the broad overview and communal space required for sharing with others is a significant challenge to both visualisation infrastructure and software.

The International Space Innovations Centre at Harwell (ISIC - see `http://www.stfc.ac.uk/ISIC`) has been established in April 2011 as a focus for space-related activities within the UK. It links existing expertise in UK industry, academia and Government and provides a unique concentration of facilities to support research, collaboration, operations and business growth. Within ISIC, the Visualisation Centre supports interactive visualisations for space data, with currently a particular focus on Earth Observation data. A major aim of this centre is been the provision of a video wall, a large scale visualisation display surface, which can be used for public outreach events and presentation, but also has the resolution and processing capability to support detailed exploration of and interaction with data to generate new science.

In the rest of this paper, we will discuss the requirements of the video wall, and give some details on its design and realisation. We then give some examples of the type of applications which the Video wall can support. We conclude by considering how the video wall may be used in the future.

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2. Video wall requirements

It was intended from the beginning that the visualisation dispay surface should be a high-profile facility of ISIC, with potential for high impact and different modes of use. There was a desire to provide a rare, if not unique combination of hardware and software functionalities to support these different modes. In order to clarify the likely usage of the facility and generate requirements, a number of high level usage scenarios were developed, defining the physical setting in which the facility was likely to be used, and capturing a set of science functional requirements developed in consultation with science users. These scenarios were as follows.

- **Cinema mode**. A pre-prepared presentation or film, with an audience (up to 100 people) seated away from the screen in a darkened space viewing a prepared presentation mixing animation, video insets and sound. This meant that the video wall had to handle both normal video and also very high-resolution video specially commissioned to be displayed on the wall, with synchronised sound.
- **Presentation mode**. One or more presenters is giving a conference style presentation to a large (> 50) seated audience, in dimmed but not blacked out light. This may mean that different parts of the wall are displaying different applications, such Powerpoint presentations, analysis tools, visualisations, and graphics. The presenter would normally be at a lectern, but also could go up close to picture to point out features, and possibly interact with the image. The content may be provided by the wall hardware, but there also should be the option that the wall could be partitioned and controlled from plugged in laptops. There also should be the possibility of video feeds of remote participants appearing on windows in screen.
- **Reception mode**. Large numbers (> 20) of people standing and talking informally, with coffee or drinks with (probably predefined, but could be adaptable) presentations going on in the background for people to view, probably up close. Light level quite high.
- **Research mode**. Small groups of researchers (< 20) meeting to discuss specific points on a visualisation. They would want to stand back to see whole picture, and come up close to point out particular points and use high resolution and be quite interactive, needing several local points of control over what the screen display. This scenario would need to have access to remote data via appropriate services, and be able to move data and visualisations to and from other parts of the visualisation centre.

Clearly these scenarios presented a challenging set of requirements for the video wall, with a large number of alternative inputs. The second and fourth scenarios are the most challenging, so these were used to develop a series of functional usage scenarios to be provided by a combination of the video wall control software and the science visualisation software.

For earth observation science, the visualisation software needed to support discovery of data from different sources, as well as the ability to manipulate and display the data as images in a number of ways. Data sources include earth observation satellites, providing images and data, earth system model outputs and in situ data in point and vector form. Specific functions a scientist/ data user may wish to perform are:

- the discovery of datasets (both from earth observation and generated from models) from catalogue(s), the generation of plots of gridded data, and ability to overlay different datasets;
- the production of difference maps of gridded data (data on same grid, initially);
- the output of high quality graphics, and animations of results, including onto virtual globes, including KML for use on Google Maps. Secondly, the synchronisation of multiple data analysis sessions, particularly:
- the selection and display of multiple datasets (parameters) simultaneously in separate windows;
- the synchronisation of location and scale across display windows (so the same area gets shown at the same scale);
- the interactive control of pan and zoom across windows via one master, i.e. pan and zoom on one master display and the others follow;
- the interactive control of time across windows, i.e. step forward a time step on one master display and the others follow; and
- the interactive selection of which parameters are displayed in which window, implicitly, shuffling of the location/order of the display of different parameters on the video wall.

These requirements for a very high-resolution display which supports real-time processing and interaction, led to the decision to build a video wall - a display surface constructed from a number of flat-screen panel displays, rather than a projected display as for example [WAB*05]. The geospatial nature of applications, with datasets typically projected onto maps of the earth's surface for viewing, rather than the immersive exploration of a virtual environment, also were considered most suited to a 2D display. Multi-panel displays, however, do not present a seemless display, but one broken into a grid formed by the panel bezels, giving the impression of viewing a single image through a multi-pane window. As pointed out in [NWJ*09], viewers are willing to accept this interpretation, but it was felt that there should be a priority to mitigate this effect by using a smaller number of large sized panels, combined with the minimum bezel size practically available.

Projected displays, which although offering a seamless display and typically provided with active or passive stereo giving the potential for immersive 3D viewing, may not be able to deliver the resolution required at a reasonable cost (including ongoing maintenance). A further consideration was the limitations imposed by the physical dimensions of

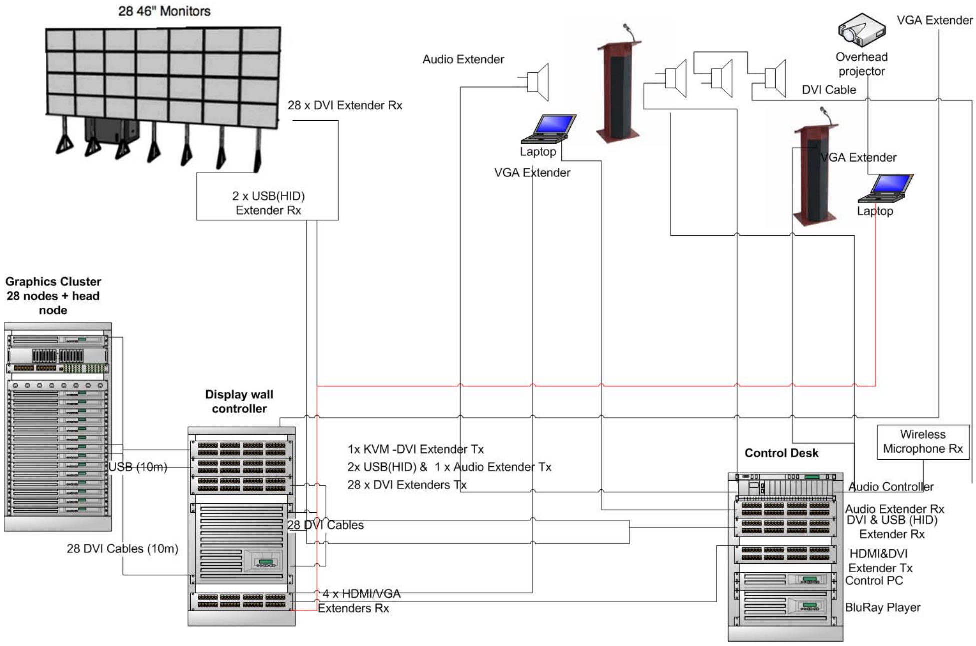

Figure 1: *Component architecture of the ISIC video wall facility.*

the accommodation provided. This was a relatively narrow space (c. 8 x 16 m) with a low ceiling (less than 2.5m) rather than a purpose built theatre, which did not allow for adequate front or back projection. It was considered that front projection would lead to too many intrusive shadows as the projectors could not be placed high enough. To accommodate rear projection satisfactorily, a large part of the limited space in the room would need to be reserved behind the screen, even if a complicated arrangement of mirrors were used, which in addition would be hard to calibrate."

Requirements for large-scale display walls have also been considered in for example [NWJ*09] and [MTL08], which are in correspondence with our approach. The former emphasises the benefits of improved human-computer interaction resulting from increased display size, the very large resolution potentially available for exploring large data sets, and the symbiosis with large-scale processing which can generate large amounts of analysis or simulation data creating ultra-resolution images; this paper recommends tiled displays rather than projection as an economic and easy to maintain option to deliver high resolution. The latter considers a number of different modes of use: individual exploration, group interaction, and group presentation, the latter two mapping approximately to our research and presentation modes. Individual exploration while certainly a benefit offers fewer advantages for us as immersion in a virtual environment is not a envisaged usage scenario.

Such multi-panel or tiled wall displays (variously known as video walls, visualisation walls, hyper walls or power walls) have been constructed in a number of facilities which share the characteristic of constructing a large display surface using an array of standard screens (see for example [NWJ*09]). In the Earth Observation and Space domains, an early hyper wall was constructed at the NASA Ames facility, with a 7x7 array of 19" monitors [HLES03, SHL03]; the Hyperwall-2 raised this to 128 panels [Hyp08]. These offered very high resolution, but with smaller panels and wide bezels, making it highly suitable for a large number of different images simultaneously rather than one image across the whole surface. Also at NASA, the Center for Climate Simulation (NCCS) at Goddard Laboratory has a Data Exploration Theater features a 5 x 3 multi-screen visualization wall for engaging visitors and scientists with high-definition movies of simulation results (see `http://www.nasa.gov/topics/earth/features/climate-sim-center.html`); this latter facility is closer to the aims of our project, operates in a closely related application area and consequently was a major source of inspiration for our work. Other walls have been constructed at Leeds University, which has a 60 million pixel 7 x 4 array, used for environmental management and medical applications [RR08], as does the 4 x 4 facility at OERC, Oxford University used for modelling heart data [Wal09].

3. Designing the video wall

The overall design of the video wall infrastructure is given in Figure 1. The main components are a 28 panel display surface which is controlled via a display wall controller. This is served by a visualisation cluster for rendering and serving video images. This set up can be controlled via a control desk at the rear of the display room, with additional inputs and outputs include the audio infrastructure. Further peripheral inputs can be supplied by plugged in laptops and an auxiliary overhead projection system which can be used to display presentations and images in an adjacent room; this can be used separately, or in synchronisation with the video wall. We consider the major components in more detail.

3.1. The display surface

The main display surface is formed by 28 panels arranged in a 7 x 4 matrix. Each panel is a Samsung SN460UT LCD, with a resolution of 1366 x 768 pixels giving a display area of 9562 x 3072 , that is over 29 million pixels, and a physical size of 1025 x 580 mm (46" diagonal width) to give a display area of 7177 x 2320 mm. This panel was chosen over higher resolution alternatives as it is has a large surface area combined with an ultra-thin bezel (6mm between display surfaces), giving a display surface with less intrusive borders. This was seen as a priority over resolution, as given the size of the display surface, resolution capacity was amply achieved, especially when viewed from a distance, while a narrower bezel would significantly enhance the viewing experience. Consequently, the resolution of the wall is not as great as some other walls constructed from smaller higher-resolution panels; this could be a possible upgrade route as higher-resolution panels become economically available

The matrix of panels was mounted on a custom built frame attached to the concrete under floor and ceiling allowing easy access to the back, and easy removal of panels from the front. This was aligned to be as flat as possible; no angling of any screens was felt to be necessary for the chosen modes of use, and this decision simplified the calibration of the surface.

For the display wall controller, a HARP Merlin video wall processor, a multi-headed PC running Windows 7 is used. This is configured to have 36 video input and 32 video outputs. 28 inputs are connected to the cluster, with the remaining available for other devices such as laptops and Blu-ray player. One additional input is from an additional "vizapp" node in the cluster, used to run visualisation applications directly, as a backup in case of node failure. Twenty-eight outputs are connected to the screen, while one is sent to the overhead projector for auxiliary presentation in the adjoining room. The whole system can be managed from the control desk, where a HARP CommandaNT remote control PC can be used to select the appropriate inputs. Thus this controller gives a highly flexible configuration which allows the wall to be used in the variety of modes discussed above, and also have capacity for expansion.

3.2. The visualisation cluster

The visualisation cluster has 29 Viglen HX425Gi nodes with Intel Xeon E5620 (Quad Core 2.4GHz) processors and each with 1 NVIDIA Quadro 5000 GPU, and 1.5GB video RAM. 28 of these nodes are used as graphics servers to the panels (one per panel), while the remaining "vizapp" node has additional memory and CPU power and is used to run applications directly. The cluster is controlled via a head node, a Viglen HX425Hi with Dual Intel Xeon X5680 (Six Core 3.33GHz) Processors. Each node has 12 Gb RAM capacity, while the head node has 48GB. The cluster has 4.8TB of disk available to the head node, with each node having an additional 500GB. Each node has an Infiniband interconnect switch for intra-cluster communication

The cluster runs RedHat Enterprise Linux v. 5.5, with a modified version of Distributed Multihead X (XDMX) to present the panels to the user as a unified screen. SAGE is used to present the wall as a single desktop; MPlayer is used for video streaming onto the wall. In the future, IDL and other visualisation toolkits will be available for application development onto the wall.

3.3. Installing the video wall

The video wall was designed and commissioned by STFC staff in consultation with ISIC stakeholders, and installed by HARP Visual Communication Solutions Ltd (see `http://www.displaywall.co.uk/`) contracted to STFC, with panels supplied from Samsung UK, the whole project being undertaken between May 2010 and March 2011. It was decided that it would be appropriate to use a company with experience in building large-scale displays for commercial media presentations for this component rather than building the system ourselves, in order to simplify the build, including frame and audio configuration. A separate contract to Viglen supplied the visualisation cluster and the combination was configured by STFC staff. Lighting in the room was modified to allow control of the light levels depending on the mode of use, lecterns with laptop inputs added at the front of the room, and the control desk was introduced at the rear. Finally a light-proof entry was introduced so that the impact of the wall could be maximised to visitors.

The resulting display surface is shown in Figure 2, which shows the video wall displaying an animation of data being served by the visualisation cluster. These data are from the METEOSAT geostationary satellites operated by the ESA EUMETSAT programme (see `http://www.eumetsat.int/Home/Main/AboutEUMETSAT/index.htm?l=en`). The central two globes show data from the SEVIRI instrument, showing the earth in visible and infrared over a 24 hour period. The four images arranged around these are images from the GERB (Geostationary Earth Radiation Budget - a collaboration between Imperial College London and STFC Rutherford Appleton Laboratory, lead by Prof. John Harries

Figure 2: *ISIC video wall displaying data from the GERB; images courtesy of Dr. H E Brindley, Imperial College London.*

of Imperial College), showing the reflected and emitted energy of the Earth on the left, with the calculated net positive and negative energy streams on the right.

4. Applications Development

The video wall thus offers the opportunity for a powerful and flexible visualisation platform for space data. To demonstrate the potential of the video wall facility, ISIC commissioned two visualisation applications: the CEDA Science Visualisation Service client for analysing and displaying earth observation data from different sources; and the Interactive Visualisation Client, which provides a more interactive demonstration of the real-time processing capability of the video wall.

4.1. The CEDA SVS client for earth observation applications

The Science Visualisation Service for Earth Observation (SVSeo) has been developed as a web based application to allow users in ISIC and the wider community to visualise and make use of Earth Observation data and climate model simulations. The application uses an OGC (Open Geospatial Consortium) standard Web Map Service (WMS - see `http://www.opengeospatial.org/standards/wms`) interface to display datasets as maps in the visualisation client. Users can visually explore large and complex environmental datasets from observations and models, view, step through and zoom in to gridded datasets on a map view, export images as figures and create animations. Different views can be easily overlaid, e.g. different parameters in the same data, or different datasets. The images and animations can be exported for viewing and manipulation on the ISIC video wall, on Google Earth or other viewing software. A typical view of the ISIC SVS is given in Figure 3, showing data produced by the National Centre for Earth Observation/Plymouth Marine Laboratory

The SVSeo displays datasets which are made available through the CEDA (Centre for Environmental Data Archival) archives through the CEDA OGC Web Services framework (COWS) [PSL10] but can include any remote data which are exposed via a WMS interface. The COWS server uses an XML schema, Climate Science Modelling Language (CSML) [LWLP09], to describe the underlying datasets which are in a binary data format (CF-netCDF).

The SVSeo can be used at ISIC in conjunction with the video wall, and is available for use by scientists in the wider community via a web service (see `http://isicvis.badc.rl.ac.uk/viewdata/`).

4.2. The Interactive Visualisation Client

The Interactive Visualisation Client (IVC) has been developed to demonstrate the potential of the video wall as an earth observation platform. It can be used to display one or more views of either a globe or a flat mapped image, which people can gather around to explore and compare. The configuration of these views would determine how they would be split over the full 28 screens and their individual contents. This can range from a single image on each screen through to

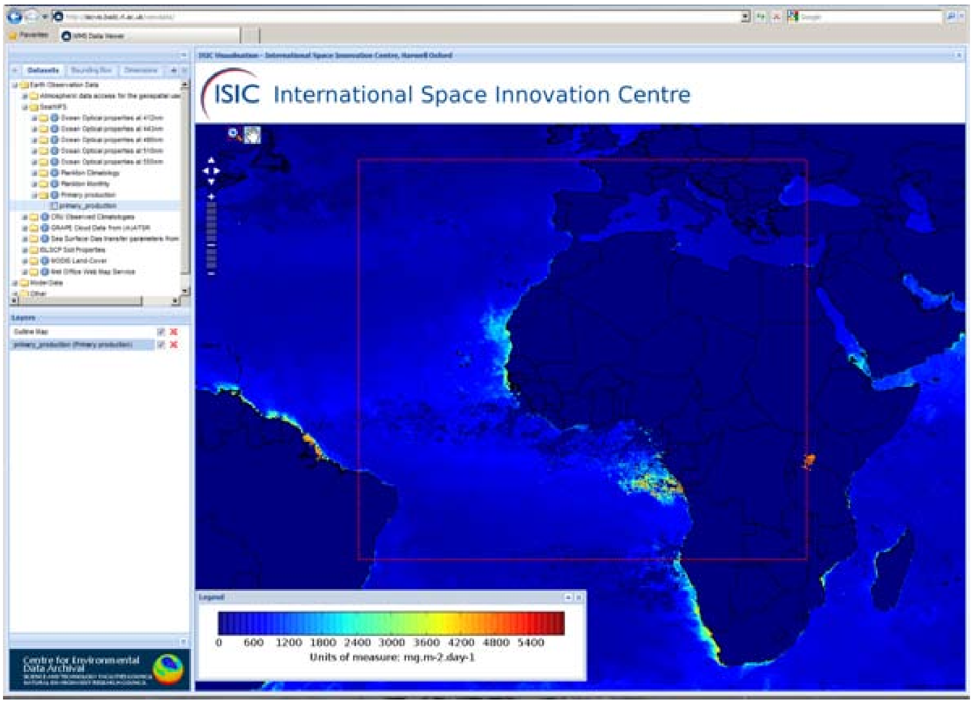

Figure 3: *ISIC Science Visualisation Service web application: displaying primary productivity data from Earth Observation measurements. Data courtesy National Centre for Earth Observation/Plymouth Marine Laboratory*

one big one split over all 28. It could also use combinations of sizes, for instance two large globes each taking two full columns on the left portion of the wall, and with the remaining 12 screens each displaying an individual globe. A use for this could be the 12 smaller globes displaying monthly data, with the larger ones used to compare specific months at higher resolution. Figure 4 shows the IVC configured to use 24 screens on the wall, with each screen displaying half a globe, showing mean significant wave height information for each month of the year, generated by TOPEX (TOPography EXperiment for Ocean Circulation). Thus this configuration would be a useful tool for demonstrating monthly data at a reasonable resolution.

To support high resolution imagery and to maximise performance, the system has been developed to be used in cluster mode. The head node controls and oversees the main application, but individual cluster nodes running their own client applications can control each of the 28 screens. The main scene is shared as a clustered scene graph, but only for the base object content and updates for translations. This keeps the scene graph network traffic to a minimum, and ensures synchronisation and responsiveness between all the screens. Each client node application is responsible for retrieving and formatting its own image data to wrap around its globe or plane object, and these can either be retrieved from a local image or as an external WMS GetMap request. Multiple layers of these textures can be added on top of each other, with areas of transparency providing visibility to those below. Support has also been included to allow the client nodes to synchronously switch between multiple images. This animation can be used to show different time steps, for instance daily images over a month for a textured globe. An added benefit of animated textures is to be able to use the IVC as a movie player or image viewer to synchronously display streams of images at the walls native resolution.

Due to the complexity of the full functionality of the IVC, the application was developed to support users with differing levels of experience. Its main configuration is through an XML file that describes which nodes in the cluster will be used, what their initial views will be displaying, and the general make up of the scene (globe or plane, layers, and image information). A number of these have been predefined for some common layouts, and it is assumed that these would be sufficient for the majority of scenarios. Once the application has started viewers are able to navigate around the scene, being able to zoom in/out of the objects, or pan/rotate depending on whether planes or globes are being displayed. By default all the views are synchronised to move together, however this can be disabled to allow each to be individually selected. Initial support has been added for 3D controllers such as the 3DConnexion SpaceExplorer to ease navigation. A more advanced UI is provided for expert functionality,

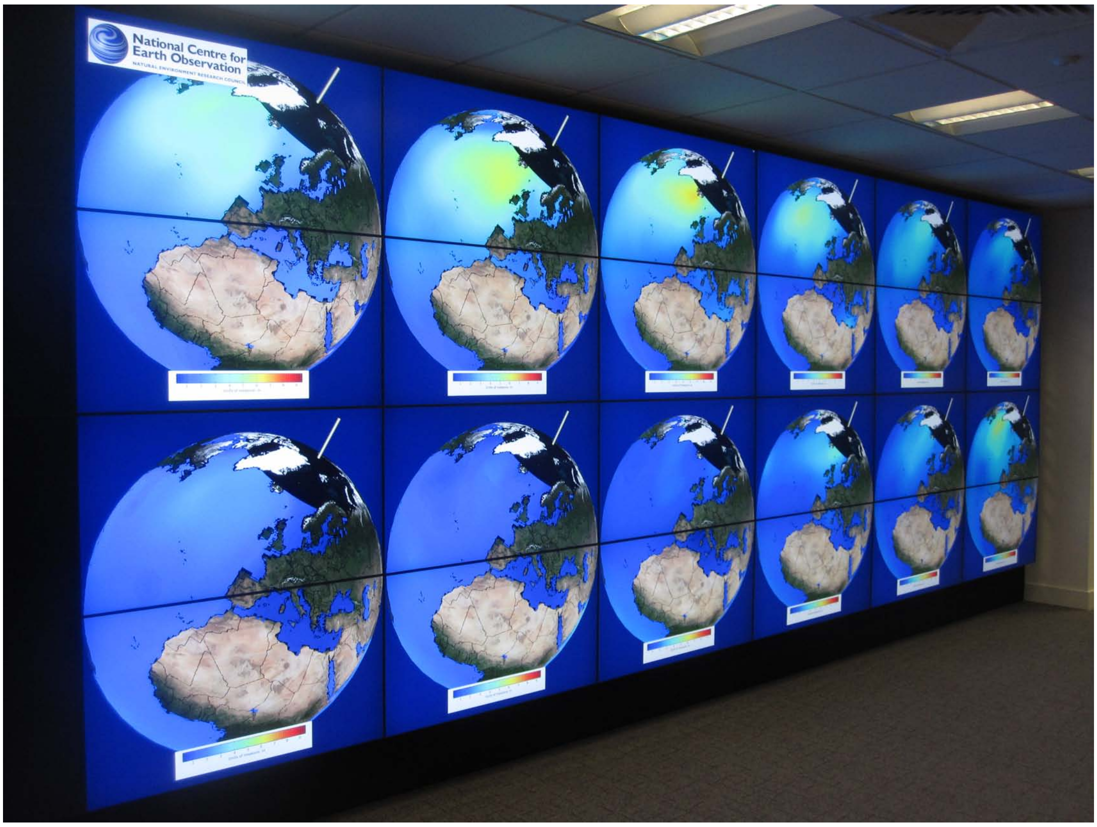

Figure 4: *Interactive Visual Client displayed on the video wall. Data courtesy of the Centre for observation of Air-Sea Interactions and FluXes (CASIX) and National Centre for Earth Observation (NCEO)*

such as modifying the displayed textures, importing saved animations from SVSeo, or creating textures or 3D volumes directly from NetCDF data files.

5. Conclusion

The build phase of the ISIC video wall has now been completed and ISIC was formally opened on 6th May 2011, where a number of demonstrations of the wall's capability were given, including a full-screen video presentation prepared by the UK National Space Centre (see `http://www.spacecentre.co.uk`). This latter proved challenge in itself in splitting and sychronising the video over the 28 panels. The ISIC video wall represents a flexible and high capability facility for UK space research which can be exploited in a number of different scenarios, which as we have discussed in this paper, supplies a combination of high resolution with the capability of sharing with a large audience in a number of different of interaction modes. The SVS demonstrates the capacity to integrate data from a wide variety of sources which ISIC has access to; the IVC demonstrates how those data can be displayed in an arresting and interactive manner.

The wall has generated great interest in ISIC and the use of visualisation facilities, but nevertheless represents the first phase of the facility and its capacity for exploring earth observation data in novel ways has yet to be fully developed. We would not claim that the scale or capacity of the ISIC video wall is unique; there are other facilities with greater resolution for example. However, we would suggest that combination of cluster and display controller is not usual in either commercial multi-screen display applications, which typically use just a display controller, or in scientific installations, which typically drive the display directly from a cluster. This gives the video wall a particular flexibility for the combination of modes of use which we discuss above.

At this stage its history, this flexibility has not been fully developed or evaluated in this community. This is now the aim of current and future developments. In the next phase of ISIC, we plan to use the video wall to explore space data in a wide number of scenarios, including presentations and demonstrations of space data as outreach activities. We further intend to develop specialised visualisation capability, extending the clients and services, allowing richer overlays and interactions, and the combination of visualisation and analysis which can be undertaken on the visualisation cluster.

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References

[HLES03] HENZE C., LEVIT C., ELLSWORTH D., SANDSTROM T.: *The hyperwall: A multiple flat-panel display wall for high-dimensional visualization*. Tech. rep., NASA white paper, 2003. http://technology.arc.nasa.gov/docs/ARC15037_whitepaperCCV.pdf.

[Hyp08] NASA develops world's highest resolution visualization system. NASA Press Release, June 2008. http://www.nasa.gov/centers/ames/multimedia/images/2008/Hyperwall.html.

[LWLP09] LOWE D., WOOLF A., LAWRENCE B., PASCOE S.: Integrating the climate science modelling language with geospatial software and services. *Int.J. Digital Earth 2* (2009), 29–39. doi:10.1080/17538940902866161.

[MTL08] MCDERBY M. J., TURNER M. J., LEAVER G. W.: Modes of virtual environments integrated within collaborative environments. In *EG UK Theory and Practice of Computer Graphics* (2008), Lim I. S., Tang W., (Eds.), Eurographics Association, pp. 129–135.

[NWJ*09] NAVRÁTIL P. A., WESTING B., JOHNSON G. P., ATHALYE A., CARRENO J., ROJAS F.: A practical guide to large tiled displays. In *Proceedings of the 5th International Symposium on Advances in Visual Computing: Part II* (Berlin, Heidelberg, 2009), ISVC '09, Springer-Verlag, pp. 970–981.

[PSL10] PASCOE S., STEPHENS A., LOWE D.: Pragmatic service development and customisation with the ceda ogc web services framework. In *Geophysical Research Abstracts*, vol. 12. 2010. EGU2010-9325-1, 2010, EGU General Assembly 2010.

[RR08] ROONEY C., RUDDLE R.: A new method for interacting with multi-window applications on large, high resolution displays. In *Proceedings of the 6th Theory and Practice of Computer Graphics Conference (TP.CG.08)* (2008), pp. 75–82.

[SHL03] SANDSTROM T., HENZE C., LEVIT C.: The hyperwall. In *International Conference on Coordinated and Multiple Views in Exploratory Visualization* (July 2003), pp. 124– 133. doi: 10.1109/CMV.2003.1215010.

[WAB*05] WALLACE G., ANSHUS O. J., BI P., CHEN H., CHEN Y., CLARK D., COOK P., FINKELSTEIN A., FUNKHOUSER T., GUPTA A., HIBBS M., LI K., LIU Z., SAMANTA R., SUKTHANKAR R., TROYANSKAYA O.: Tools and applications for large-scale display walls. *IEEE Computer Graphics and Applications 25* (2005), 24–33.

[Wal09] WALTON J.: *Implementation of large-scale 3D heart data visualization*. Tech. rep., NAG Ltd, 2009. http://www.nag.co.uk/IndustryArticles/vizwal_report.pdf.