

BAMS Inbox contribution entitled:

The International Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative

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Over the last 3 years, the international Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative (<http://www.met-acre.org/>) has provided new and unique historical weather data and reanalyses for user needs worldwide. The initiative is particularly keen to encourage the use of such products in global, regional, and local climate, climate variability and climatic change applications.

ACRE is led by a consortium of three core partners - the Queensland Climate Change Centre of Excellence (QCCCE) in Australia, the Met Office Hadley Centre (MOHC) in the UK and the US National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) and Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado. Most recently, following important support for ACRE, the University of Giessen in Germany has become a core partner in the initiative.

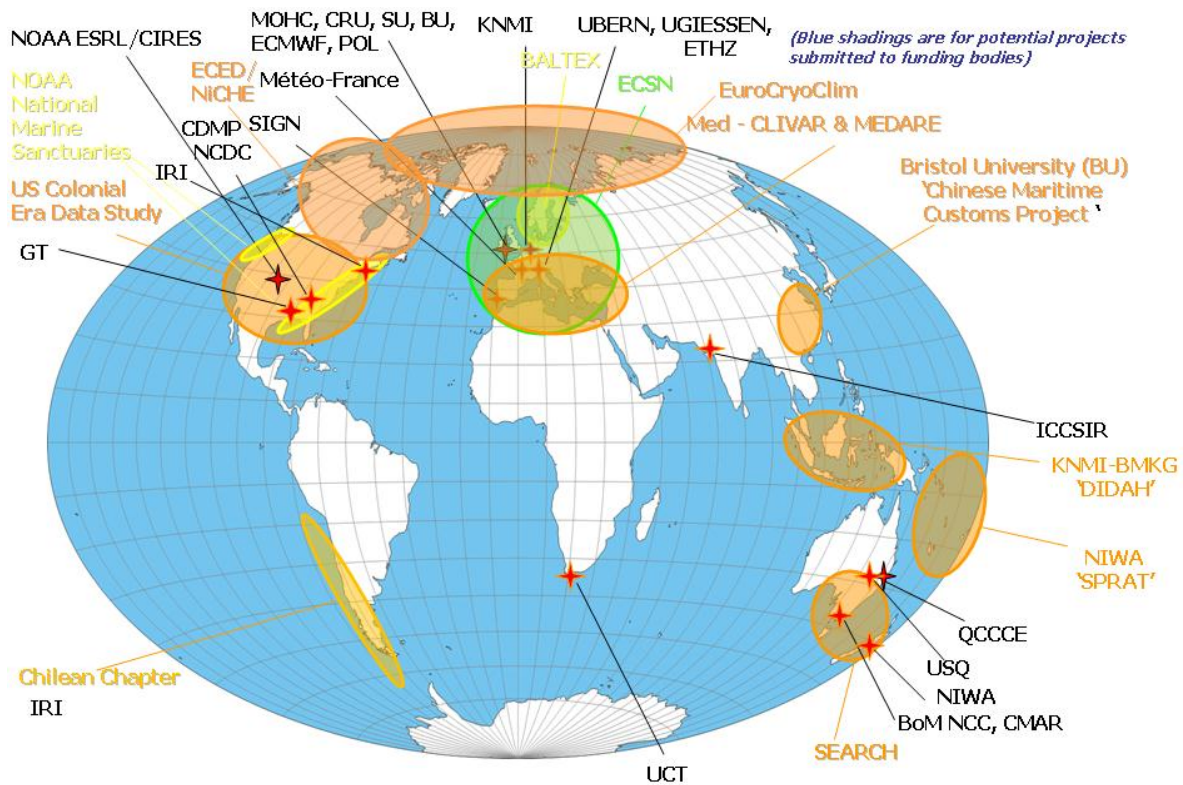
ACRE works closely with the international surface weather and climate observations community, particularly the International Surface Pressure Databank (ISPD) and the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). The weather observations recovered by ACRE have already provided the enhanced database assimilated by the 20th Century Reanalysis Project (1871-present). Two additional reanalyses are envisioned by ACRE's US partner, covering even longer periods: a Surface Input Reanalysis for Climate Applications (SIRCA) (1850-2011), and a Chemical and Surface Input Reanalysis for Climate Applications (CSIRCA) (1800-2016) reanalysis. These reanalyses will produce dynamically consistent reconstructions of tropospheric and stratospheric global historical weather conditions using state-of-the-art scientific capabilities. Vital to the latter, is the use of citizen science mass digitisation of large amounts of new surface observations via approaches that ACRE and its Galaxy Zoo/The Citizen Science Alliance partnership are developing.

Together with the raw data, metadata, data images and data sources, the ACRE-facilitated reanalyses will provide a unique long-term weather database which can be 'downscaled' to finer resolution, and through state-of-the-art visualisation capabilities will serve the full range of users – from climate researchers, the diverse climate applications community, to educators, students and the general public.

ACRE is embracing efforts in the areas of citizen science, massive scale data handling and web-based, state-of-the-art high resolution visualisations of the data and reanalyses products. The successful development of this technology is crucial to making the full impact of the output and outreach from the initiative as user friendly, tailored and shaped as is possible.

Recovery, imaging and digitisation of historical global surface weather observations

With endorsement from organizations such as the World Meteorological Organisation (WMO), the Group on Earth Observations (GEO), the Global Climate Observing System (GCOS), wide international support and the aid of various working groups of GCOS and the World Climate Research Program (WCRP), ACRE provides an umbrella that links together some 35+ projects, institutions, organisations, data rescue and climate applications activities around the globe (Figure 1). In 2010, ACRE and its activities were ratified by the WMO Commission for Climatology, extolled in a letter of recognition from GCOS, and endorsed by the JCOMM Expert Team on Marine Climatology and, most recently, WCRP.



International Projects, Sources & Repositories linked to ACRE

IEDRO ICOADS ISPD WMO DARE RECLAIM GLOBE GLOSS ETCCDI VACS ICHM Galaxy Zoo
 CoRRaL SEARCH EU FP7: EURO4M EU FP7: ERA-CLIM NERC: AUSTRAL

Figure 1: The full global range of collaborations, linkages, projects and proposals involved in ACRE to date. The acronyms are expanded in the appendix.

The initiative works closely with the international surface weather observations data community, linking with the international RECLAIM (REcovery of Logbooks And International Marine data) (<http://icoads.noaa.gov/reclaim/>), ISPD (global maps of historical terrestrial atmospheric pressure station distribution can be found at: <ftp://ftp.ncdc.noaa.gov/pub/data/ispd/add-station/>) through the National Climatic Data Centre (NCDC) in the US and ICOADS (<http://icoads.noaa.gov/>) projects, plus the Climatological Database for the World's Oceans; 1750 to 1850 (CLIWOC) (<http://www.ucm.es/info/cliwoc/>) and UK Colonial Registers and Royal Navy Logbooks (CoRRaL) (<http://www.corrall.org.uk/>) project participants, and various international academics and archives, to expand the recovery, imaging and digitisation of historical instrumental weather observations in terrestrial registers and marine logbooks. All of this material is then available to ACRE's US partners for their historical global reanalyses - these have begun with the 20th Century Reanalysis Project (http://www.esrl.noaa.gov/psd/data/20thC_Rean/).

Major current activities continue to focus on data held in various UK repositories (e.g. The British Library, the Met Office Archives and the National Archives) plus the efforts in Chile and hopefully in India and China. However, these activities require considerable time and resources. To put this into perspective, even working closely with US digitisers from the specialist NOAA Climate Data Modernisation Program (CDMP) (<http://www.ncdc.noaa.gov/oa/climate/cdmp/>), a MOHC project to image and digitise records to fill major gaps in the World War 2 coverage of surface marine weather observations took two years.

The broad international data community and infrastructure which ACRE is integrated into can be seen in Figure 2, while the following lists the range and extent of various specific data recovery, imaging and digitisation projects that ACRE has undertaken over the last 3 years.

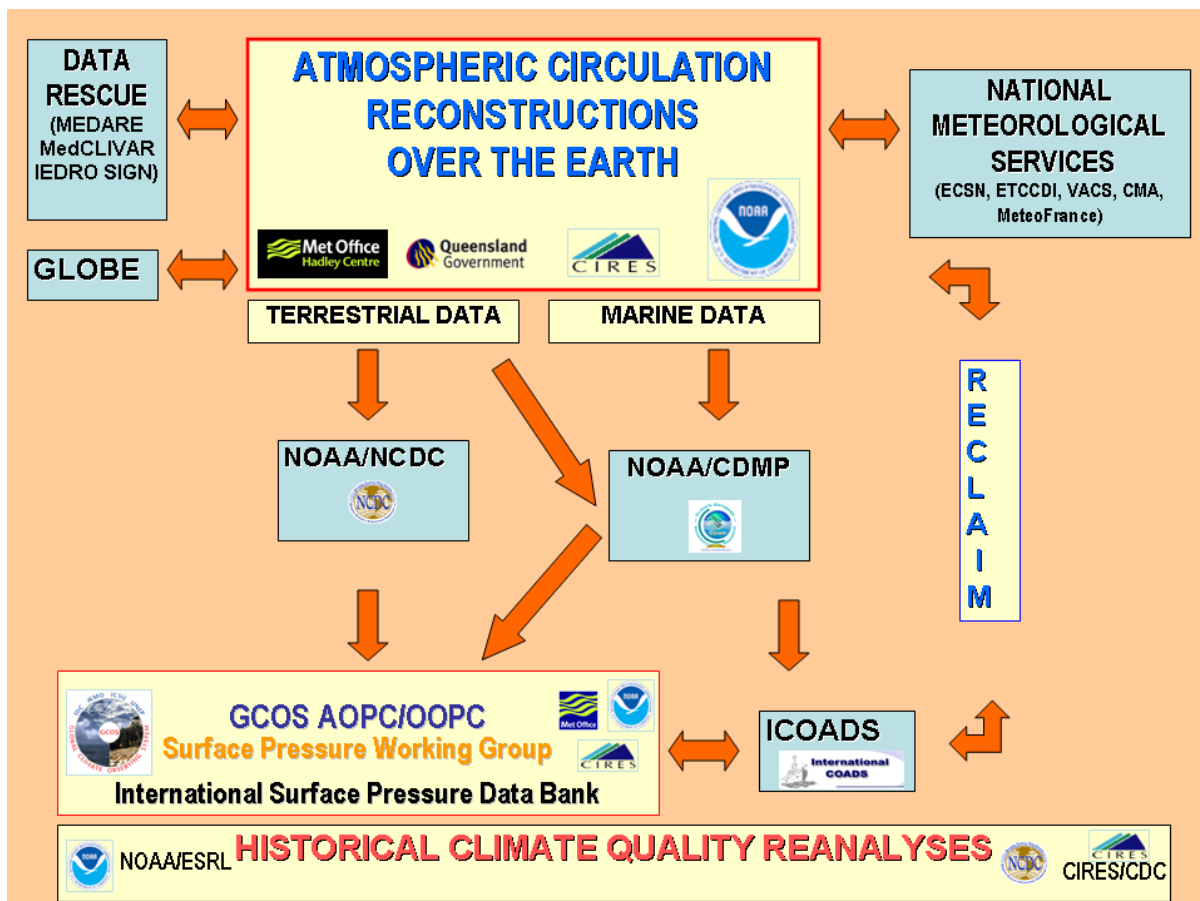


Figure 2: ACRE data flow within the international surface terrestrial and marine infrastructure

a. Ship Logbook and Assorted Terrestrial Collections

2007/2010: **The English East India Company (EEIC) (1780s-1830s)** - 900 logbooks from ships of the EEIC held in the British Library contain **historical instrumental pressure, air temperature and sea surface temperature data**. These have now all been imaged by the British Library; they are being digitised by CDMP and the digitised data from about half of the logs have been completed and made available for preliminary checking (see the latest report on these data at: http://philip.brohan.org.transfer.s3.amazonaws.com/EIC_summary.pdf).

2008/09: **CoRRal: UK Colonial registers and Royal Naval Logbooks** – A UK Joint Information Systems Committee (JISC) Digitisation Programme: *Enriching Digital Resources project provided the funds to image and digitise logbooks of ships on voyages of discovery (1700-1850*: ADM-55 at The National Archives in the UK), and attached to the UK Hydrographic Survey (1830-1850: held at The National Archives) plus **UK colonial meteorological registers, journals and gazettes** (held at The National Archives and the Met Office Archives). ACRE digitised large portions of the records of six Bahamian Lighthouses (1870s-1905) and from St Helena (1892-1930) in the South Atlantic and Malden Island (1888-1926) in the Pacific. Digital images of the latter island observations, together with those from other developing countries in the Caribbean, Africa and the Indo-Pacific region have been provided to the British Atmospheric Data Centre (BADC) for display and access on their WWW site (<http://badc.nerc.ac.uk/browse/badc/corral/images/metobs>). This will ultimately be extended to provide an interim repository of all the images of historical weather observations made by ACRE.

2008/2010: **An extended period during and following World War 1 (1914-1923)** - 7,000-8,000 Royal Navy logbooks held in the UK National Archives containing **instrumental pressure, air temperature and sea surface temperature data**. Imaging is being undertaken by the UK National Archives, and with tighter fiscal conditions images of instrumental data from a little over 3,000 logs have been received on hard disc. ACRE and Galaxy Zoo/Citizen Science Alliance have now obtained funding from JISC for a pilot project to use their citizen science approach to mass digitise the extended World War 1 images, following their success with the public categorisation of images of galaxies.

b. Ship Remarks Books

2008: **British hydrographic and survey vessel remarks books (1759-1909)** – 6,000 remarks books with weather observations useful to ACRE are held at the UK Hydrographic Office (UKHO). At a minimum, these books contain **instrumental pressure, air temperature and sea surface temperature data**. An inventory was completed at the end of August 2008, but no funds are available to image and digitise them.

c. Expeditions, travels, circumnavigations and ships of exploration

A small, on-going initiative under ACRE continues to digitise various marine and terrestrial weather data from printed/published books, journals, ship logbooks and reports that had been scanned and made generally available on the WWW – such as via Google Book Search. Though secondary sources, they often provided valuable insights into the type and extent of instrumental weather observations made, and sometimes are the only surviving source of data if the original material cannot be found or has been destroyed. The latter material was especially valuable in providing essential weather observations for Antarctic regions for the 20th Century Reanalysis Project: 1891-2008 and Brohan *et al.* (2010).

d. Inventory of historical Chinese and South China Sea instrumental weather observations

In 2008, ACRE was able to provide funds (from the MOHC's Integrated Climate Program and an AHRC Knowledge Catalyst Scheme grant) for members of the Chinese Maritime Customs Project at Bristol University (<http://www.bristol.ac.uk/history/customs/>) to undertake an inventory of old daily to sub-daily historical meteorological observations made at Chinese inland stations, and by ships travelling along its rivers, coastline and in the South China Sea. This has provided the basis for the imaging, digitisation and archiving of these data, and ultimately their use in the 20th Century Reanalysis Project and future reanalyses.

e. ACRE Chile

Visits to Chile in 2009 and 2010 explored the potential for important data rescue and digitisation activities in conjunction with the initiative. Most recently, ACRE's participation in a successful ECMWF led EC FP7 proposal called ERA-CLIM has provided the basis to secure the level funding needed to develop this enterprise. The Direccion Meteorologica de Chile (DMC) will be a partner in this EC FP7 project together with the involvement of the new Centro para el Cambio Global, Universidad Católica de Chile (PUC) and the University of Chile (Department of Geophysics) in Santiago. The terrestrial and marine data recovered, imaged and digitised by this activity have not previously been available to the scientific community in Chile, let alone internationally.

f. SEARCH South Eastern Australian Recent Climate History

SEARCH (<http://climatehistory.com.au/>) will provide the impetus for improved climate management options, and will fill a critical gap in Australian climate science by assembling a range of pre-20th century data suitable for annual temperature, rainfall and atmospheric pressure reconstructions for south-eastern Australia for the past 200–500 years. Instrumental surface terrestrial and marine observations digitised by SEARCH are being provided to ACRE projects (Gergis *et al.*, 2009, 2010) and sent on the ISPD.

ACRE-facilitated reanalyses

ACRE has been working to improve the quality and quantity of historical global surface terrestrial and marine instrumental weather observations going into the ISPD and ICOADS repositories respectively. These vastly improved data bases have provided the historical daily to sub-daily instrumental data required by ACRE's US partners 20th Century Reanalysis Project to produce a reanalysis dataset spanning the entire twentieth century (1871-2008), assimilating only surface observations of synoptic pressure, monthly sea surface temperature (SST) and sea-ice distributions. The SST and sea-ice data are courtesy of the UK MOHC from their HadISST dataset. The pressure observations dataset, the ISPD, has been assembled through international co-operation under the auspices of not only ACRE, but via links with the working groups of GCOS and WCRP.

The above activities have been developed as part of international reanalysis activities. At a recent technical workshop on reanalysis hosted by NASA's Global Modelling and Assimilation Office (GMAO), ACRE's data activities were expanded still further to cover the needs of all reanalyses, such as the upcoming shorter reanalyses by JMA (JMA-55) and ECMWF (ERA-CLIM), but also NCEP's next effort back to the 1950's. This has been further strengthened by the involvement of ACRE in two new EC FP7 projects, the KNMI-led EURO4M, European Reanalysis and Observations for Monitoring, and ECMWF-led ERA-CLIM, European Reanalysis of Global Climate Observations, projects.

The first ACRE-facilitated reanalysis product, global four-times-daily atmospheric and surface analysis fields spanning 1871 to 2008 from the 20th Century Reanalysis Project Version 2 dataset are available at (http://www.esrl.noaa.gov/psd/data/gridded/data.20thC_ReanV2.html) in netCDF format, courtesy of the NOAA ESRL, Physical Sciences Division (PSD), and CIRES/CDC. Reanalyses fields are now also available for the 1871-2008 period via ESRL/PSD/CDC partners at the US National Center for Atmospheric Research (<http://dss.ucar.edu/datasets/ds131.1>) in GRIB format, and will become available via our partners at NOAA's National Climatic Data Center (NCDC) through the

NOAA Operational Model Archive and Distribution System (NOMADS) (<http://nomads.ncdc.noaa.gov>) and the NCDC Data Archive in the near future. Additional fields will also become available at ESRL/PSD/CDC.

Beta composite plotting tools for **four-times-daily and monthly mean fields from 1871-2008** are now available courtesy of NOAA/ESRL/PSD and CU/CIRES/CDC at (http://www.esrl.noaa.gov/psd/data/composites/day_20thc/).

Pre-generated synoptic maps showing the **ensemble mean analysis and analysis uncertainty of Sea Level Pressure and 500 hPa height over the Northern and Southern Hemispheres and for Sea Level Pressure and 850 hPa zonal wind in the tropics** are available at (http://www.esrl.noaa.gov/psd/data/20thC_Rean/hem_images.html).

The Project's home page can be found at (http://www.esrl.noaa.gov/psd/data/20thC_Rean/), and a solicited overview of the 20th Century Reanalysis Project is currently being prepared for publication (Compo *et al.*, 2010).

Future planned extensions of these ACRE-facilitated reanalyses aim to ultimately cover the last 200+ years:

- SIRCA: 1850-2011 [Autumn 2015]
- CSIRCA: 1800-2016 [Autumn 2018]

The impact that ACRE's data activities will ultimately have on the amount of global historical surface weather observations available for 20th Century Reanalysis Project, future ACRE-facilitated reanalyses and international reanalyses in general can be seen in Figure 3.

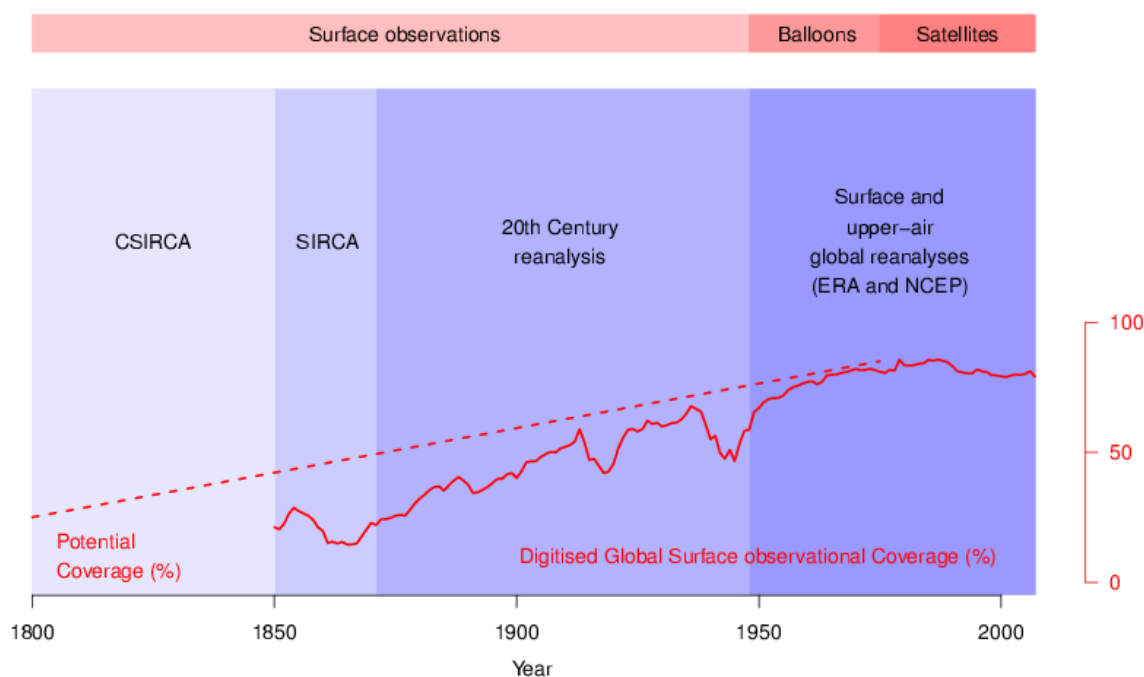


Figure 3: Potential impact of ACRE data activities on surface observations available for historical reanalyses

Users of ACRE-facilitated Data and Reanalyses

As user interaction and engagement is a fundamental component of ACRE, strenuous efforts have been made to work with climate researchers, the diverse climate applications community, educators, students and the general public. In addition, ACRE is engaging with wider cross and interdisciplinary initiatives such as the international student GLOBE Program and its Student Climate Research Campaign (SCRC) for 2011-2013 (<http://www.globe.gov/content/scrc>) and Galaxy Zoo (<http://www.galaxyzoo.org/>)/Citizen Science Alliance (<http://www.citizensciencealliance.org/>). The latter grouping is using a recently-funded citizen science pilot project to showcase the potential of **mass weather data digitisation via citizen science**. It is hoped that this will help to engage the wider public at a time when climate and climate change research findings are being questioned. In fact, in the wake of the so-called 'climate gate' incident, land surface temperatures dynamically reconstructed by the ACRE-facilitated historical weather reanalyses will be used to provide an independent data base with which to check and access the observed historical surface temperature record.

The following subsections provide an overview of the current international usage of ACRE-facilitated data and reanalyses products:

a. International Climate Science

The listing below provides something of a flavour of the range of projects and studies amongst the climate science community that are known to be using the ACRE-facilitated data and reanalyses:

Reassessment of **historical global tropical cyclone activity** (United States) – (Emanuel, 2010)

Global surface air temperature reassessment following ‘Climate Gate’ (United States & United Kingdom) – (Thorne + Parker)

Reassessment of **historical ENSO events** and dynamics (United States) - (Geise *et al.*, 2009)

Reassessment of **major drought episodes around the world** (United States) – (Cook *et al.*, 2010)

Variability of **large-scale atmospheric circulation indices and storminess for the Northern Hemisphere** (Europe and Canada) (Brönnimann *et al.*, 2009; Wang *et al.*, 2010)

Investigation of key climate drivers of **rainfall variability plus tracks and intensities of tropical and extra-tropical cyclones** (Australia) (Fairweather + Klingaman)

South Pacific Convergence Zone (SPCZ), tropical cyclones and ENSO (New Zealand) – (Lorrey & co)

Early 20th century Arctic warming in retrospect (United States) – (Wood and Overland, 2009)

Forcing of global Parallel Ocean Program model for historical oceanic reanalysis (United States) - (Geise & co)

Marine zoology and oceanography (Australia) – (Baird *et al.*, 2010)

b. Climate Applications and Impacts Projects involving ACRE

As the ACRE-facilitated data and reanalyses products and their user potential become more widely known, their value will increase. One has only to think of the impact of temporally shorter NCEP and ECMWF reanalyses in the climate science community and beyond. Early projects looking to use the ACRE-facilitated data and reanalyses products are listed below:

Extremes, climate modes and reanalysis-based approaches to agricultural resilience: *Funder: Australian Grains Research and Development Corporation (GRDC), Managing Climate Variability Innovation Call project, commenced in September 2008.*

EURO4M: European Reanalysis and Observations for Monitoring: *EC FP7 – Seventh Framework Programme Co-operation Theme 9 “Space” for 4 years starting in April 2010.*

ERA-CLIM: European Reanalysis of Global Climate Observations: *Funder: EC FP7 – Seventh Framework Programme Co-operation Theme 6 “Environment” for 3 years, starting in early 2011.*

Addressing Uncertainty in Southern and Tropical Reconstructions of Atmospheric Linkages (AUSTRAL): Modelling the Past to Constrain Future Climate Change: *Funder: Proposal to the UK Natural Environment Research Council (NERC).*

Helping Australia cope with drought, What do droughts actually look like and how often do they occur? *Funder: Proposal to Australian Research Council (ARC) Laureate Fellowship 2009.*

Devon Community Climate Change Local Histories Project (CCHP): *Funder: UK Heritage Lottery Fund, commenced in September 2008.*

c. Recent ACRE-linked projects to support outreach and cross/interdisciplinary interactions

Initially as a result of the vast amount of contextual material available in the images of the raw observational data created as ACRE evolved, but now being seen as important in their own right, the initiative has embraced the merits of the wider cross/interdisciplinary interest its activities have created. A series of recently funded projects in

collaborations between ACRE and citizen science, social science and humanities partners, have made the above interactions an essential component of the initiative. Such projects are listed below:

Centre for e-Research, King's College London: *e-Research Approaches to Historic Weather DATA: Sources, Collaborations, and Methodologies for Researching Environmental Change (Successfully funded for 12 months from July 2010 under an AHRC Networks grant)*

Galaxy Zoo/Citizen Science Alliance + ACRE/MOHC & Naval-History.net: *Digitizing data for disparate communities: Naval history and climate science. (Successfully funded for 6-months (April to September 2010) from JISC Grant Funding Call 13/09)*

Centre for e-Research, King's College London & Corbett Centre for Maritime Policy Studies, Joint Service Command and Staff College, Wiltshire, UK : *SAILS: Shipping Archives and Integrated Logbooks of Ships: Linking WW1 Naval Records (JISC Grant Funding Call 2/10: Deposit of research outputs and Exposing digital content for education and research: Strand B: Expose (Successfully funded from July 2010 for a year by JISC)*

International Environmental Data Rescue Organisation (IEDRO): *ClimateZoo (Funding requests to annual US NOAA/Voluntary Cooperation Program (VCP) plus Earth Observing Systems)*

International student GLOBE Program + NOAA linked colleagues in US + Galaxy Zoo/Citizen Science Alliance & ACRE/MOHC: *Project to support GLOBE's Student Climate Research Campaign (SCRC) for 2011-2013 (<http://www.globe.gov/content/scrc>) (To be submitted in June 2010 to the US NOAA Office of Education's Environmental Literacy Grants (ELG) for Formal K-12 Education)*

Euro-Mediterranean Center on Climate Change (CMCC), Italy + Met Office partnership : *European Topic Centre on Climate Change Impacts, Vulnerability and Adaption 2011-2013: ETC-CCA. (Successfully funded European Environment Agency [EEA] from January 2011 for 3 years)*

School of Environment and Technology, University of Brighton: *Climate Histories in Southern Africa (Submitted April 2010 to British Academy, International Partnerships, e-GAP2).*

Conclusion

In summary, ACRE has shown what can be done with very limited resources and funding to develop and fuse together global data, reanalyses and user interactions, activities and engagements. This overview highlights the scope of the initiative, and its ongoing capacity to both evolve and initiate coherent linkages between national and international projects, organizations and institutions. Thus, ACRE is implementing major elements of the global plans and calls of the international scientific community, and generates outputs and outreach which satisfy and engage users worldwide.

In undertaking the above, ACRE has developed a viable international data recovery, imaging and digitization program that combines a mixture of activities covering the full spectrum from small 'cottage' to extensive 'industrial' scale projects. The initiative's imaging component has also provided the basis for ACRE's engagement with researchers and institutions in the social sciences and humanities, by capturing a mass of contextual material that such disciplines need but can rarely access in such quantities through their usual funded activities.

ACRE was a response to user needs, and through its core linkages between data, reanalyses and the tailoring, shaping and downscaling of that material in alignment with user requirements, the initiative is filling a vital role in making climate science products freely available and their generation transparent to all users. Through its efforts to develop state-of-the-art visualization technology, ACRE is building the infrastructure to deliver the initiative's output and outreach globally.

Acknowledgements

The initiative owes much to the huge range of individual colleagues, institutions, organizations and projects around the world who have not only eagerly supported it and the core partners but, as hoped, made it their own. This listing in the acknowledgements does not do full justice to them or their various vital inputs that have made the initiative and its aims and activities possible. In no particular order, many thanks are due to: J.S. Whitaker, P. D. Sardeshmukh, N. Matsui, B. Henry, R. Vose, S.D. Woodruff, T.F. Ross, R.I. Crouthamel, M. Brunet, P.D. Jones, G.J. Marshall, Ø. Nordli, M.A. Valente, R.M. Trigo, I. Auer, D. Wheeler, C. Wilkinson, C. Ward, S. Jourdain, A. Klein-Tank, J. Luterbacher, S. Bronnimann, D. Dee, S. Uppala, X. Wang, R. Przyblak, K.R. Wood, J. Overland, M. Maugeri, M. Brunetti, D. Jones, P. Arkin, K. Casey, J. Carton, A.S. Cofiño, J.W. Buchanan, M. Haylock, P. Della-Marta, R. Bickers, C. Reason, E. Hanna, H. Meinke, C. Marzin, J. G. Guzman-Gutierrez, J. Gergis, E. Parsons, P. Woodworth, R. Solberg, A. Lorrey, A. Tasker, E. Geary, S.J. Worley, M. Kuettel, C. Lintott, L. Hughes

For Further Reading

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