AUSTRALIA'S COMPOSITE OBSERVING SYSTEM: IDENTIFYING FUTURE DIRECTIONS

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ABSTRACT

Australia's meteorological observing system has served well in providing the data required by its various domestic and international users for many years, but has recently suffered from steadily increasing pressure on available resources, combined with a rapidly increasing demand for data. These trends necessitate finding more efficient and effective solutions for data delivery via implementation of more novel and automated observing technology and techniques.

To this end, during 2005 a study of the Bureau's Composite Observing System was carried out, the broad aims of which were to identify the system needed to deliver efficiently and effectively on agreed outputs, and to develop end-to-end strategies for migration from the existing to the specified system. This presentation briefly reports on the conduct and key findings of that study, and their implications for the future direction of Australia's Composite Observing System.

Introduction

During 2005, the Australian Bureau of Meteorology carried out an examination of the current and future requirements for its Observing System. The so-called Basic Observing System Study 2005 (BOSS05) aimed to identify the observing system necessary for the Bureau of Meteorology to deliver effectively and efficiently on its agreed outputs to the Australian Government over the next 5 to 10 years, as well as to develop end-to-end strategies for delivering that system, including strategies for migrating from existing to specified systems. Key requirements placed on the BOSS05 Study Team were that the study be strategic, pragmatic but thorough, that it draw on the work of previous studies that have covered similar or related ground, and that it involve a broad range of participants from program areas across the organisation.

With a focus on the efficient delivery of the Bureau’s overall national observations program, the study was broadened from the traditional ‘basic’ system to embrace the Bureau’s overall (composite) multi-purpose observing system: that is, the system required to fulfill all of the Bureau’s functions, including, inter alia, space-based observations, the observing networks previously considered to be ‘special’ rather than ‘basic’, such as Aviation, Defence and Atmosphere Watch, the new or more recently expanded areas of responsibility in the Bureau, such as the observing programs and networks of the National Tidal Centre and Australian Tsunami Warning System, with consideration also given to inclusion of third party and shared observational data or systems.

The content of the newly titled **Bureau Composite Observing System (BCOS)** comprises all those surface-based and space-based components of the entire Bureau Observing System that are long term, robust and whose data and system performance are of known and suitable quality. In extent, it also includes components under developmental trial by the Bureau, which may not strictly satisfy the aforementioned three criteria, but which serve the primary purpose of attaining more effective BCOS performance. In depth, the boundaries of the BCOS are set by the point at which the end-to-end service delivery chain delivers observational data into the data handling or services systems. While the manner in which data are used and archived were thus technically outside the BCOS, the study team was well-equipped to offer some insights into how these could be improved to provide increased value for the Bureau from the BCOS.

Specification of Services Requirements for BCOS Data

The documentation of a comprehensive analysis of national and international service requirements was facilitated by the participation of a cross-program team in the conduct of BOSS05. As well as being a milestone within the overall study, the analysis of national requirements was a significant achievement in its own right.

The effort required to complete this step, however, demonstrated that provision of quantified, scientifically objective and/or economically justifiable service specifications of data requirements are a key challenge for many service areas in the Bureau. A more analytical approach, assisted by targeted data impact studies and improved performance monitoring, would assist in developing and routinely updating specifications of services' requirements.

The study also revealed that some international (GOS, GCOS) specifications for data provision are too stringent to be scientifically achievable outside the laboratory, or, where scientifically achievable, to be economically impractical for countries other than the more densely populated and advanced nations of the northern hemisphere.

Adequacy and Value of the Current BCOS

The study provided a comprehensive description of the BCOS as it is currently configured and applied a number of methodologies to an assessment of its adequacy and value.

In some specific respects, particularly relating to the efficiency of operating the existing observations program, the current BCOS represents world's best practice. In scale and extent, the BCOS is similar to that of Canada, the country most like Australia in terms of economy, population and areal extent. At the same time, however, it was demonstrated that the BCOS falls short of meeting national and international requirements for observational data, particularly in relation to spatial and temporal density, and adherence to climate monitoring principles.

The assessment highlighted many issues that have contributed to the increased difficulty in managing and operating the BCOS in recent years, with a key factor being the progressively tightening resource environment, in the face of growing user demands and a need for continuously increasing efficiency and accountability.

Key imbalances exist in relation to the spatial distribution of observations, with a bias towards populated areas, and in relation to the climate requirement for a more even distribution of manual sites relative to automatic weather station (AWS) sites. The study identified specific deficiencies within individual user groups, such as special purpose data for agriculture and sophisticated measurements for aviation.

Automation has delivered some distinct benefits in coverage and frequency of data, but has also created some negative impacts such as a shortage of 'visual' element data, which are of particular value to climate and aviation service users. The Bureau is unable to meet the growing demand for both AWS and weather radar coverage, with gaps in radar coverage identified over increasingly populous and industrialised provincial centres along the tropical coastline and at key inland locations.

The degree to which the BCOS represents 'value for money' in delivering outcomes is extremely difficult to assess and further, more quantitative work is required to support current and future resourcing proposals. Nevertheless, it was apparent from existing studies and a number of proxy measures that investment in the BCOS provides excellent return on investment and contributes positively to service provision, including, inter alia, through improved assimilation of BCOS data, especially satellite data, into NWP.

Trends in Requirements and Capabilities

BOSS05 documented trends and future expectations in service requirements over the coming decade and their implications for data requirements, and the opportunities that new and emerging technology may provide for the BCOS to deliver data more efficiently and effectively over the same time frame. The study also considered a range of operational and management issues likely to impact on the operation and effectiveness of the BCOS, including human and financial resource pressures, quality management, equipment lifecycle management, data handling and management, spectrum management, observational research and development, and shared or third party observing systems or data. Finding a sustainable balance between automated and manual systems, capitalising on efficiencies where possible but still meeting effectiveness criteria, will be an ongoing challenge.

Trends likely to impact on the design, operation and required deliverables of the BCOS in the future include:

- Service requirements are generally expected to become more demanding in all respects;
- Climate monitoring will demand significantly greater emphasis than it does today compared to weather service provision;
- Numerous opportunities are emerging for the implementation of more advanced and automated observing technology in the BCOS (wind profilers, AMDAR water vapour, video cameras, dual polarisation radar, hyper-spectral satellite sounders, redundant sensors, etc.), but many of these are yet to be proven as suitable for operational provision of data of adequate quality;

- Requirements for quality management are expected to increase, including the need for more formal accountability;
- Increasingly more stringent Occupational Health and Safety (OH&S) and regulatory environments will impose increased maintenance workloads and operational (human and financial) costs;
- Communications costs are expected to decrease as technology advances, and computing and communications security requirements are expected to increase;
- Increased demand and competition in relation to access to and protection of radiofrequency bandwidth;
- Need to explore more fully the scope for, and implications of, use of shared and third party data and systems.

Major Issues, Findings and Recommendations

The study, in mapping out a proposed future strategy for delivery of the BCOS, drew together a large number of major issues and individual findings. In many cases, they included specific recommendations, mostly for the consideration of the Manager of the Bureau's Observations and Engineering Programs, but given the cross-program involvement and end-to-end approach, some were also referred to other Program Managers (eg all services areas, communications, computing) for their consideration in planning their respective program activities over the coming decade.

Foremost amongst the findings of the study was a clear need for the Bureau to be making more effective and extensive use of satellite information, both to harness the intrinsic value and information of these data, and to explore the extent to which they can supplement and, in some circumstances, partially replace some more traditional surface-based systems, such as within the upper air network. There are proven benefits achievable in NWP assimilation of satellite data, but an increased effort in visualisation of data, such as for atmospheric temperature and moisture profiles, and in greater integration of satellite and in situ data in data display systems, will offer substantial advantages in data utilisation.

Operation of a robust and sustainable BCOS in the future requires a more structured long-term approach to the evaluation and implementation of new technologies. The study highlighted a number of emerging technologies at varying levels of maturity that may offer operational efficiencies and meet requirements more effectively. In assessing the potential value of new technologies, particularly automated systems, the full lifecycle cost must be taken into account, including operation, maintenance and end-of-life replacement. Some of the new systems already under development, such as the Bureau's Next Generation AWS and associated metadata management system, SitesDb, have identified clear savings and operational efficiencies, and these should proceed on their development and evaluation tracks as soon as possible. The AMDAR program is also in this category and will benefit from high-level support for evaluation of humidity sensors and expansion of the national program. Wind profilers, while already implemented at several sites across the Bureau's network, require further evaluation with respect to their ability to replace wind-finding radar systems and deliver data appropriate to user requirements.

While there was an increased emphasis on automation and general assumptions about the ability of the program to operate with gradually decreasing staffing levels, the BOSS05 demonstrated that the Bureau has already achieved a high level of operational efficiency compared to many other national meteorological services and the scope for further real staff savings from automation requires careful consideration. There is an ongoing critical need for annual recruitment and training of specialised observing staff to refresh the skill levels and age mix of the program, especially considering the particularly distributed nature, in Australia, of the field program and necessity for staff mobility. Similarly, engineering maintenance resources and staffing need to be consistent with the increasing reliance on automated system, with ongoing refreshment through recruitment of specialist engineering staff.

Perhaps not surprisingly, a clear message from services areas was the need for greater network coverage, particularly for surface observations and radar, and increased frequency of observations, particularly for surface and upper air observations. The extent to which more effective use of satellite data and application of some newer technologies can address these requirements requires more extensive investigation. There are some culture change issues to be addressed in increasing forecasters' confidence in a more composite network approach and reducing their reliance on more traditional data sources, such as manual visible observations and radiosondes. The study indicated an ongoing role for the latter, with a strong desire amongst users for restoration of a more extensive 12Z network, although some future rationalisation of the network may be possible once other sources, such as satellite derived profiles and AMDAR temperature and moisture profiles are operational.

The need for greater accountability in the operation of the BCOS was recognised through recommendations for more systematic performance reporting and introduction of a formal quality system, preferably across the whole Bureau but at least within the Observations and Engineering Programs. Consistent information about system performance and operation would assist not only in more effective whole-of-life planning, including operating, maintenance and replacement strategies, but also in assessing the value of observations.

Improved network design and quantification of impacts likely to flow, inter alia, from changes in observational coverage, would benefit from the conduct of rigorous data impact studies. Currently, the Bureau is ill-served in this respect and a recommendation of the BOSS05 was the establishment of a data impacts group within the Bureau's Research Centre, BMRC.

To ensure seamless and high quality climate monitoring, any potential changes to the BCOS, such as new technology or revised techniques, should be fully evaluated prior to implementation and their introduction into operation should adhere to all elements of the climate monitoring principles, especially in respect of overlaps with existing systems.

To aid in focusing the study on the BCOS per se, the BOSS05 set the boundaries for when data effectively left the BCOS via various data handling routes. At the same time, the study took an end-to-end approach to ensure that any factors that impinged on how the data could be used more effectively were taken into account. This approach highlighted key deficiencies in the areas of data archival and retrieval, and data display. The former, data archival and retrieval, is an issue that tends to be overlooked in traditional program planning and there is currently no consistent Bureau policy that addresses it holistically. Multiple and diverse approaches exist, with little interoperability. Development and implementation of a standardised Bureau-wide policy is clearly an urgent requirement and would facilitate greater sharing and integration of data across the Bureau.

Similarly, data display systems within the Bureau have traditionally been developed to meet the needs of individual observing and/or data processing systems, and there is no single display system that allows forecasters to compare or composite information from different sources, such as upper air data from satellites, profilers, AMDAR and radiosondes. For the BCOS to be used effectively, attention should be focused on such a universal data display concept.

Proposed BCOS Strategy 2006-2016

The study concluded that the BCOS could not be maintained and developed at a level adequate to meet services requirements for data over the coming decade within the currently-projected resource profile. In order to avoid or minimise a decrease in service outcomes and, in particular, a long-term, negative impact on the national climate record, a staged resource and implementation strategy was developed.

The strategy proposed by BOSS05 requires a significant short to medium term boost in investment to consolidate BCOS performance and enable development and implementation of alternative automated technologies. A more automated BCOS could then be implemented operationally and deliver, in the long term, significant and ongoing efficiency gains, in particular with regard to the human resource levels, enabling ongoing and sustainable operation of the BCOS into the future.

This new BCOS would be characterised by the supply of larger data volumes, but of reduced raw data quality. While automated systems appear unlikely to outperform manual systems in this respect, an upgraded BCOS quality management system and more optimal utilisation of data would at least maintain BCOS effectiveness at levels similar to those achieved today, in the face of expected increases in service demand.

Increases in short to medium term resource allocations required to test and implement more efficient solutions would be largely repaid through medium to longer term reductions in staffing and infrastructure. Modest ongoing savings should follow once the BCOS stabilises.

This recommended strategy for the evolution of the BCOS over the next ten years comprises four overlapping stages:

Stage 1: Consolidation of the existing BCOS (Years 1 to 4)

Stage 1 comprises a number of immediately practicable initiatives which address significant shortcomings in some key areas without making significant changes to the techniques and technology employed within the BCOS. It includes upgrades to satellite data reception, ingestion and applications software, immediate restoration of the 12Z radiosonde program, modest changes to surface observations networks and restoration of the Atmosphere Watch Program.

Stage 2: Overarching and underpinning initiatives (Years 1 to 4)

Stage 2 comprises initiatives mostly in program areas outside of the BCOS per se, which are aimed at indirectly improving BCOS effectiveness and data utilisation, and upgrading the Bureau's capacity to plan and provide for the BCOS. It includes upgrading the Bureau's performance, impact and value measurement capabilities, improved BCOS quality management and spectrum management, upgrading NWP, data display and data storage and retrieval systems, and developing means of utilising satellite data for climate analysis.

Stage 3: Development and testing of new technology (Years 1 to 7)

Stage 3 comprises further development of satellite applications software, development and trialing of Next Generation AWS and SitesDb, radar wind profilers, lightning sensors, automated evaporimeters, other advanced and automated sensors for providing visual element observations, new agrometeorological sensors, and unattended operation of the Autosonde. It also includes experimenting with a redundant sensor model for basic surface quantities, and investigating the needs for further expansion and upgrade of the weather watch radar network, and for multi-tiered networks, and third party and shared data and systems.

Stage 4: Migration to a new and sustainable configuration for the BCOS (Years 1 to 9)

The last stage of the proposed strategy involves implementation of various new technologies, subject to their successful development and trialing, as a partial replacement for the manually-intensive technology currently employed. It includes:

- expansion of the AMDAR program, including deployment of advanced water vapour sensors on commercial aircraft;
- deployment of boundary layer and stratosphere-troposphere profilers at many wind-only upper air sites and some existing radiosonde sites;
- deployment of local lightning sensors on all AWS and the implementation of various other new technologies in the surface network;
- establishment of a GPS water vapour network; and
- a major expansion and upgrade to the weather radar network.

Conclusions

The Basic Observing System Study 2005 (BOSS05) adopted a cross-program and end-to-end approach to assessing the adequacy of the existing Bureau Composite Observing System (BCOS) and identifying a future BCOS that would deliver effectively and efficiently on the Bureau's agreed outputs to government over the next 5 to 10 years. The proposed strategy includes elements beyond the observing systems per se in order to ensure the data outputs of the BCOS are utilised effectively to deliver the specified service outcomes. The strategy considered whole-of-life costings for operation and support and for ongoing sustainability, and provides a sound framework for development of specific implementation plans within the Bureau's Observations and Engineering Program, such as development of new technologies, network configurations and maintenance strategies, and associated plans and strategies in other program areas, particularly Communications and all Services. The proposed strategy requires a significant investment of resources but delivers partial offsets within the decade and more substantial offsets over an extended period. Some elements of implementation will proceed within the currently projected resource profile, but full implementation will be subject to development and consideration of detailed funding submissions.