# EASTERN SEABOARD CLIMATE HAZARD TOOL – MATCHES

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With a significant proportion of the New South Wales and southern Queensland population and infrastructure concentrated in the corridor between the coast and the tablelands, knowledge of the highly variable weather systems that cause significant impacts in this region is vital. The Bureau of Meteorology (BoM), in partnership with the NSW Office of Environment and Heritage under the Eastern Seaboard Climate Change Initiative, has developed the Eastern Seaboard Climate Hazard Tool aka Maps and Tables of Climate Hazards of the Eastern Seaboard (MATCHES). The tool identifies significant rainfall/wind/wave/water-level events on the Eastern Seaboard according to user specified thresholds while simultaneously displaying east coast low (ECL) tracks. This allows easy analysis of the relationship between the movement and location of an ECL and where its impacts are subsequently felt.

MATCHES draws on the BoM's rainfall and wind datasets and Manly Hydraulics Laboratory's wave height and water-level datasets, which are displayed graphically for each event, and available for download. An objective analysis is used to identify ECL tracks using the National Centers for Environmental Prediction (NCEP) Mean Sea Level Pressure (MSLP) reanalysis dataset. Each ECL track point is linked to the corresponding Australian daily gridded rainfall map to enable users to visualize the spatial extent of rainfall impacts with each system.

MATCHES will be accessible via a 'registered-users page' hosted on the BoM website and will provide users across a range of sectors with the ability to assess their own climatic risk associated with ECL. The authors would like to acknowledge the funding providing by the NSW Environmental Trust.

## Introduction

The Eastern Seaboard of Australia (ESA; Figure 1) is increasingly being recognised as a separate climate entity. The climatology of this region can be characterised by its high annual rainfall variability, low correlation to the climate of adjacent areas and poor correlation with the tropical climate indices known to have an influence in the Australian region (Timbal 2010). But current understanding about the dominant climate drivers and their relative contributions to the climatology of the ESA is limited and this hinders the ability to forecast over seasonal and longer timescales. It also makes it difficult to estimate current and future risks to the community and thus poses a significant barrier to developing management and adaptation responses across multiple sectors.

Potential drivers of the different climatology of the ESA are the influence of the Great Dividing Range, the region's proximity to the Tasman Sea and the occurrence of East Coast Low pressure systems (ECL). The role and relative contribution of each of these drivers is unknown but research being undertaken under the auspice of the Eastern Seaboard Climate Change Initiative is seeking to identify the role and importance of ECL in influencing climate along the ESA.

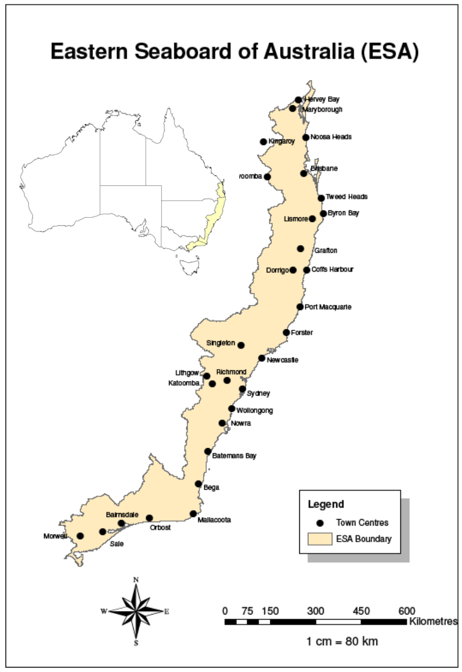


**Figure 1: The Eastern Seaboard of Australia (ESA) stretching from Hervey Bay, Queensland in the north to Wilsons Promontory, Victoria in the south.**

Obtaining a good appreciation of past weather along the ESA can assist in developing an understanding of this variable climate and form a base from which future changes can be measured. To help increase the knowledge base of the climate, its drivers and their impacts, the BoM has been developing MATCHES.

MATCHES brings together multiple disparate datasets into an integrated interactive data viewer. Specifically, it brings together datasets containing information on impacts such as heavy rainfall, strong winds, storm waves, peak water levels, water level anomalies and ECL events. The search capabilities allow users to select their desired threshold and period of interest and download the associated data, providing a superior functionality to most other hazard interfaces.

Because of this functionality the MATCHES interface is believed to be a world first in terms of linking datasets associated with a range of hazard impacts with significant low pressure systems; analogous hazard databases on the internet are generally static lists of events selected via a subjective process that doesn't facilitate user input. For example: http://www.ncdc.noaa.gov/oa/climate/severeweather/rainfall.html

Key design elements of the project were:

- Identification and access to impacts related datasets and the identification of relevant thresholds,
- Development of an objective ECL event database,
- Development of the data viewing interface, and
- End-user engagement.

The presentation and discussion of these design elements form the basis of this paper and are detailed below.

## Data and Methods

### *Impacts Databases*

A key aspect of MATCHES is its capacity to draw on existing impact related datasets. Four types of hazardous impacts were chosen to be included in the interface, based on data availability and their relevance as indicated by end-users. These were heavy rainfall, severe wind, extreme waves and extreme water levels, with several parameters for each as outlined in Table 1. Minimum thresholds were established to ensure the interface was used primarily as a data source relating to hazardous weather, rather than simply a climate data access point. All data used within MATCHES has undertaken strict quality control processes by the relevant agency.

**Table 1: Impacts data included in the interface**

| | Length of record | Search Parameters | Minimum threshold | Maintained by |
|---|---|---|---|---|
| **Rainfall** | 01/01/1970 to present[1] | Daily (mm)<br>Hourly (mm)<br>6 min (mm) | 25mm<br>10mm<br>5mm | BoM[2] |
| **Wind** | 01/01/1970 to present[1] | Gust (kts)<br>Sustained (kts) | 37kts<br>28kts | BoM[2] |
| **Waves** | Mid 70s to present[1] | Peak Wave Height (m)<br>Wave Power (MW/m) | 2.5m<br>25MW/m | MHL[2] / DERM[2] / SPC[2] |
| **Water Level** | Mid 80s to present[1] | Peak Water Level (m)<br>Peak Water Level Anomaly (m) | 0.5m<br>0.1m | MHL[2] / SPC[2] |

[1]Dependent on station
[2]BoM – Bureau of Meteorology, MHL – Manly Hydraulics Laboratory, DERM – QLD Department of Environment and Resource Management, SPC – Sydney Ports Corporation.

*Rainfall data*

Rainfall data used in the MATCHES is sourced from the BoM climate data archives and includes total rainfall, the peak hourly rainfall total and peak six-minute rainfall total experienced within 24 hours. The time-span covered by the rainfall records is station dependent with good coverage from 1970 to present. Minimum rainfall thresholds were based on the lowest 1 in 5 year Average Return Interval (ARI) in the ESA region.

*Wind data*

Wind data used in the MATCHES is also sourced from BoM climate data archives and includes both maximum sustained wind speeds and maximum wind gust speeds experienced within 24 hours. The time-span covered by the wind records is station dependent with good coverage from 1990 to present. Minimum wind thresholds were determined using the 'near gale' category on the Beaufort scale. As similar categories and thresholds do not exist for wind gusts, the Beaufort scale categories were converted from sustained winds to wind gusts using the Durst (1960) curve.

*Wave data*

Wave data used in the MATCHES is sourced from Manly Hydraulics Laboratory (MHL), Queensland Department of Environment and Resource Management (DERM) and Sydney Ports Corporation (SPC) and includes daily maximum Significant Wave Height and Wave Power. The time-span covered by the wind records is station dependent with coverage from the mid 1970s to present; Botany Bay has the earliest observations, beginning in

April 1971. The minimum threshold for wave heights was determined using the Classification of Storms by Intensity, as outlined in Table 2 (Blain et al 1985).

**Table 2: Storm wave intensity classification scheme of Blain et al (1985) was used to define thresholds in the hazard tool.**

| Category | Significant Wave Height (m) | Severity |
|---|---|---|
| X | >6.0 | Extreme |
| A | 5.0-6.0 | Severe |
| B | 3.5-5.0 | Moderate |
| C | 2.5-3.5 | Low |

*Water level data*

Water level data used in the MATCHES was sourced from a recent study of NSW Ocean Water Levels (MHL, 2011) and includes peak water level and peak water level anomaly data for 22 stations along the NSW coast, most recording from the mid-eighties. Fort Denison is the main exception, with records dating back to 1915. Unlike the other data sets these are not continuous and are based on an analysis of the top 20 events experienced at each of the recording stations along the ESA. When real time data sets for water level and water level anomaly are readily available they will be incorporated into the hazard tool. As a result of the top 20 events being selected for each station the minimum thresholds for peak water level and water level anomaly were based on values identified in the NSW Ocean Water Level study (MHL, 2011).

***Establishing the Climate Hazard database***

*Climate hazard – East Coast Low*

For the purposes of this study the definition of ECL used in the development of the MATCHES is "a system with a closed cyclonic circulation at the surface, forming and/or intensifying in a maritime environment within the vicinity of the east coast". This is the same practical working definition used in the NSW Regional Office of the Bureau of Meteorology.

At present ECL are the only climatic system captured by the MATCHES, although the nature of the MATCHES does allow for additional climate systems to be incorporated. Irrespective, ECL are responsible for a large proportion of significant weather affecting the ESA, (Hopkins and Holland 1997 identified ECL as being responsible for 16% of all heavy rain events and 7% of major Australian disasters). Speer and Geerts (1994) found that ECL are a primary cause of flooding in the Sydney Metropolitan area, while Pepler et al (2009) identified ECL as an important contributor to Sydney water supplies. ECL are also associated with severe winds and ocean swell and have been responsible for numerous ships running aground along the ESA coast (Callaghan 2004) – the most recent of these being the Pasha Bulker in June 2007.

*Existing ECL databases*

A database of ECL (maritime lows) and their impacts has been developed in the NSW Climate Services Centre of the Bureau of Meteorology. The database currently extends back to 1970 and contains entries listing periods during which there was a closed surface low between 20°S and 40°S and between the NSW coastline and 160°E (Speer et al 2009). The maritime low database was developed from a manual visual analysis of the MSLP charts to subjectively determine the presence, or lack there of, of an ECL. This is an intense and time consuming task and potentially inaccurate when considering early MSLP analyses may lack some of the necessary detail (particularly over the oceans) to identify ECL. Despite this, the maritime low database is currently considered to be the most robust and comprehensive dataset in terms of capturing ECL that have occurred along the ESA since 1970.

*Development of an objective ECL database*

Because of the resource intensive nature of updating the maritime low database it was desirable to identify an alternative approach that would allow the dataset to be extended back in time and easily kept up-to-date. With the advent of MSLP reanalysis datasets, such as ERA-Interim and NCEP, it is now possible to identify and track ECL using an automated computer based scheme.

This study uses an objective low finding and tracking scheme that was employed by Jones and Simmonds (1993) to develop a climatology of Southern Hemisphere extratropical cyclones. The scheme is fully objective, with no manual intervention after the initial prescription of a series of search and tracking parameters. Both closed (those systems possessing a closed isobar at a given interval) and open depressions (those not containing a closed isobar) are identified by the scheme. The position of the closed depressions were defined by the minimisation of the pressure functions, while open depressions, indicating inflexions in the pressure field, were found by a search for minima in the absolute value of the local pressure gradient (Jones and Simmonds 1993).

*Selection of a reanalysis dataset*

The NCEP MSLP reanalysis data was used to develop the objective ECL database. This reanalysis dataset spans from January 1950 to December 2008 with a grid resolution of 2.5 degrees at six hourly time intervals. This dataset was chosen above other reanalysis datasets primarily due to its length of record. The 58 year long record from NCEP enables decadal scale variability to be assessed along with long term changes in the intensity, frequency and distribution of ECL along the ESA. The nature of the MATCHES makes it possible for improved ECL datasets, based on future reanalysis datasets, to be incorporated in the future.

## Verification of the ECL finding tracking scheme performance

The verification step will use the maritime low database (Speer et al. 2009) to identify the occurrence of an ECL against which the objective dataset is to be verified. The maritime low database uses historical observations of barometric pressure reduced to Mean Sea Level Pressure (MSLP). Entries contained in the database from 1970-2006 meet the strict criteria of a closed surface low between 20°S and 40°S and between the NSW coastline and 160°E and 4hPa in 100km pressure gradient.

A number of statistics are commonly used in the verification of forecasts including Probability of Detection (POD), the False Alarm Ratio (FAR) and the Critical Success Index (CSI). CSI will be used to verify the performance of the ECL identification and tracking scheme as it represents the fraction of observed and predicted events that are correctly predicted, rewarding hits, while also penalising both misses and false alarms.

## Data visualization and interface development

### *Design principles*

Data visualisation is a powerful tool that allows the graphical presentation of multi-dimensional data in a way that allows users to understand relationships that can be hidden in data.

The design of the MATCHES interface was based on three user-centred design principles, the interface should be:

1. intuitive to use,
2. engaging, and
3. aesthetically pleasing.

*An interface that users find intuitive*

It is important to consider 1) how much knowledge a user needs to have about the interface in order to get what they need out of MATCHES and 2) how much knowledge likely users of MATCHES will actually have about the interface. To minimise the gap and make MATCHES intuitive to use we opted for frequently used toolsets with which users were likely to be familiar. A help feature was also incorporated into the interface that would lead the user through the steps needed to find the information they were after.

*Engaging the user*

Quite often using interfaces that access large quantities of data over the internet can be frustrating and thereby disengage the users. Our primary aim, with respect to user engagements, was to minimise frustration and where possible 'delight' the user. This largely came down to optimising the response time for each event query. With the application accessing a database containing over 3 million land based and 1 million sea based observations it was vital to devise an efficient method of accessing and displaying the requested data. This also led to imposing limits on how much information can be displayed at any one time, with a maximum of 1 year being applied to the possible date ranges.

*Interface aesthetics*

An emphasis was placed on getting a consistent look and feel across the interface and to ensure that the ratios of the various panels worked well for both large and small screens. A large amount of time was also spent adjusting colours, changing the size of icons (and their borders), and the choice of symbols to represent the different features.

### ***Construction of the MATCHES backend and interface***

The tool was built using open source toolsets - OpenLayers for the map, ExtJS for the interface and Postgresql for the database - with the majority of the backend written in Python. The background map uses Web Map Service (WMS) with additional map layers provided by the BoM. The ESA region boundary was provided by the BoM's NSW Climate Services Centre and is rendered as a WMS layer. The interface was built using an extensible architecture, enabling the addition of new layers in future development.

A set of scripts was developed for extracting and ingesting data. For data maintained by the BoM, the climate database ADAM (an Oracle installation) was queried to get quality controlled data meeting the required specifications. This data was transferred to intermediate files which were then ingested into MATCHES (a postgresql installation), running in parallel. Finally a set of scripts were created to ingest the data from the ECL objective analysis which included any track that had at least one six-hourly location within the MATCHES ocean grid (40°S, 140°E), (20°S, 160°E).

The MATCHES database includes four tables; station metadata, ECL fixes, land observations and sea observations. The ECL fixes table includes a 'source' field which enables the incorporation of data from different models, eg. for use in comparison, verification or other purposes. The data is returned after a query using GEOJSON, a standard format for geographic features and is displayed in column and line graphs, with the data available for download in CSV format.

### *Appearance and interactivity*

On accessing MATCHES the user is presented with the event view – a map of the ESA and dropdown boxes that allow the user to select wind, rain or ocean state thresholds (see Figure 2). Two alternate views exist, which can be accessed by clicking on a tab and allows the user to view the layer controls or the Legend. After selecting a date range the user can refresh the view and this will update the map with points of central pressure and tracks for the ECL that have occurred during that date range. By clicking on the central pressure of the ECL the user is given information on the central pressure and is able to view the corresponding daily gridded rainfall (Figure 2a). By entering a threshold for an impact (e.g. 50mm of rainfall) and refreshing the view all the stations where that impact threshold have been exceeded are displayed. The user is then able to click on the station icon and a chart of the rainfall for that period is displayed with the option to download the data in a comma space value (CSV) file format (Figure 2b).

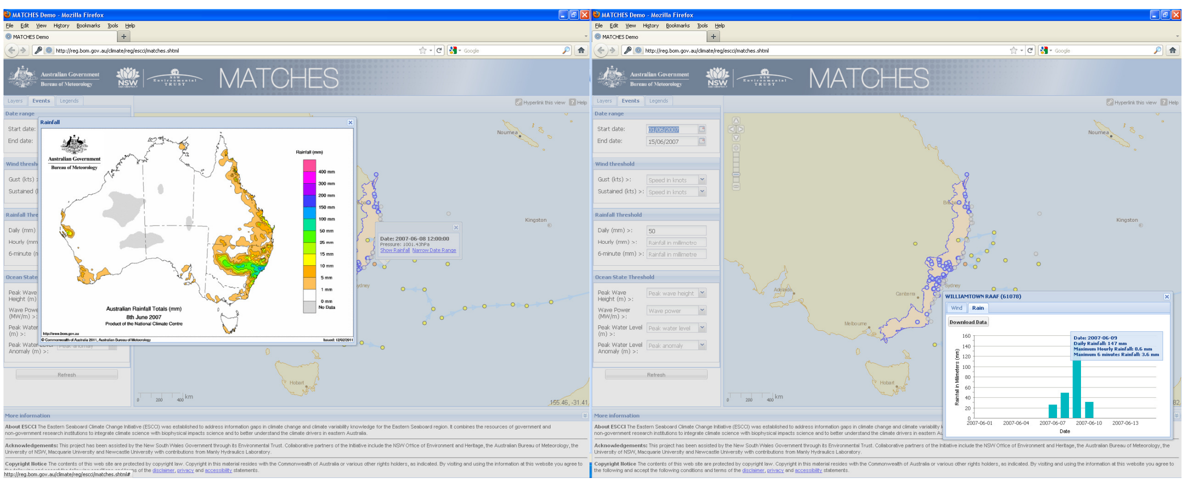


**Figure 2: Image of the MATCHES interface showing ECL tracks for the period 01-15/06/2007 and a) the corresponding daily gridded rainfall and b) a chart of daily rainfall totals.**

### *Stakeholder engagement*

To ensure the MATCHES interface was developed in line with end-user requirements, regular meetings were held with stakeholders, such as the NSW State Emergency Management Council – Climate Change Working Group (SEMC-CCWG). These meetings were used to obtain input and feedback as to what hazard-related information was needed, where it could be sourced and how functional the MATCHES interface was. End-users were also asked for an insight as to how they envisaged using the application within their operations and how it might improve their current work practices.

## Finalisation and future directions

MATCHES is now near completion. Key elements to be implemented prior to completion are:

- the verification of the objective ECL dataset,

- incorporating the continuous peak water level and water level anomaly datasets, and
- linking the ECL central pressures to their corresponding Australian region MSLP maps.

Once completed MATCHES will be formally released and accessible via a 'registered-users page' on the BoM website.

In the longer term, the nature of MATCHES and its extensible architecture allow for the future inclusion of:

- additional types of hazardous climatic events, in particular heatwaves, tropical cyclones and severe thunderstorms;
- additional or longer-term ECL datasets based on differing methodologies and reanalysis datasets; and
- inclusion of gridded datasets for comprehensive analysis of rainfall impacts of historical ECL over the entire ESA.

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