

## (1) Introduction

- The Environmental Systems Science Centre (ESSC) has developed extensive experience in analysing the ability of forecast models to predict storms.
- The TRACK software of Hodges (1995) has been used to identify and track storms in forecasts data and error statistics have been produced to determine the ability of forecast models to predict storm position, intensity, growth and propagation speed (e.g. Froude 2009, 2010).
- The potential values of this storm prediction information has been recognised by a number of industry sectors, including the marine, insurance and oil and gas. However the question of how these industry sectors interpret and utilise this information presents a major barrier.
- This knowledge exchange project will overcome this barrier by working with BMT ARGOSS (<http://www.bmtargoss.com/>) to develop tools to visualise and interpret storm prediction information useful to a range of operational activities at sea.

## (2) Background

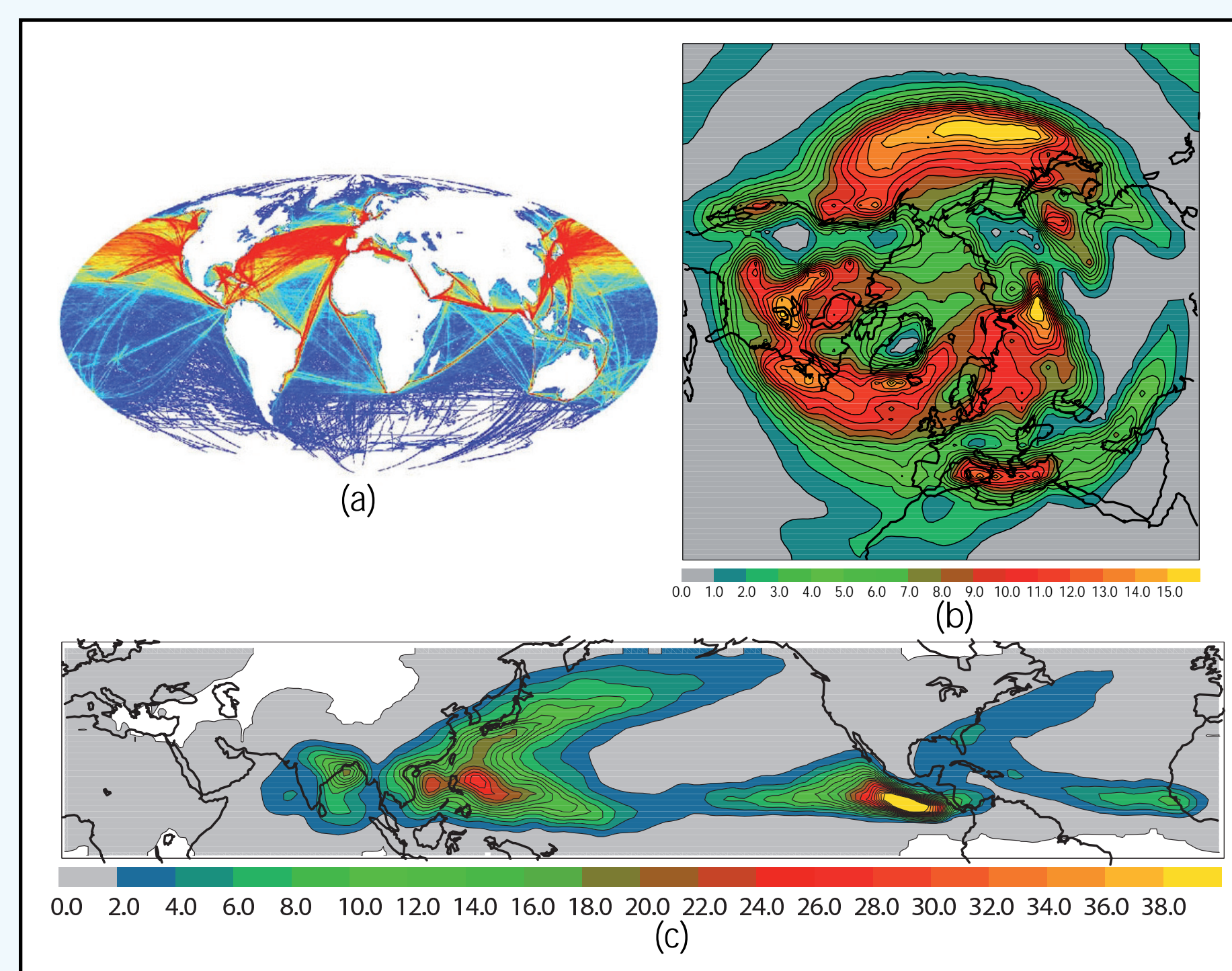


Figure 1. (a) World shipping lanes colour coded according to use, (b) winter time northern hemisphere climatology of extratropical cyclones in term of their track density (number per month per unit area) and (c) climatology of tropical cyclones in terms of track density (number per year per unit area).

- Accurate forecast information about storms is vital for decision making at sea. Activities ranging from ship routing to resource exploration require such information to optimise operations and to prevent economic and human losses.
- The weather conditions that effect operations at sea will in general be related to storms (both tropical and extratropical). To illustrate this figure 1a shows the global shipping lanes and 1b and c show spatial maps of the average number of storms per unit area (climatologies) in the northern hemisphere for extratropical and tropical storms respectively. It is clear that many of the major shipping lanes are exposed to risk from storms.
- BMT ARGOSS are a technical consulting company, specialist provider and leading innovator in the supply of marine environmental information. This project will extend the forecast information BMT ARGOSS can offer its clients by developing tools to extract storm prediction information from forecast data.

## (3) Forecast Tools

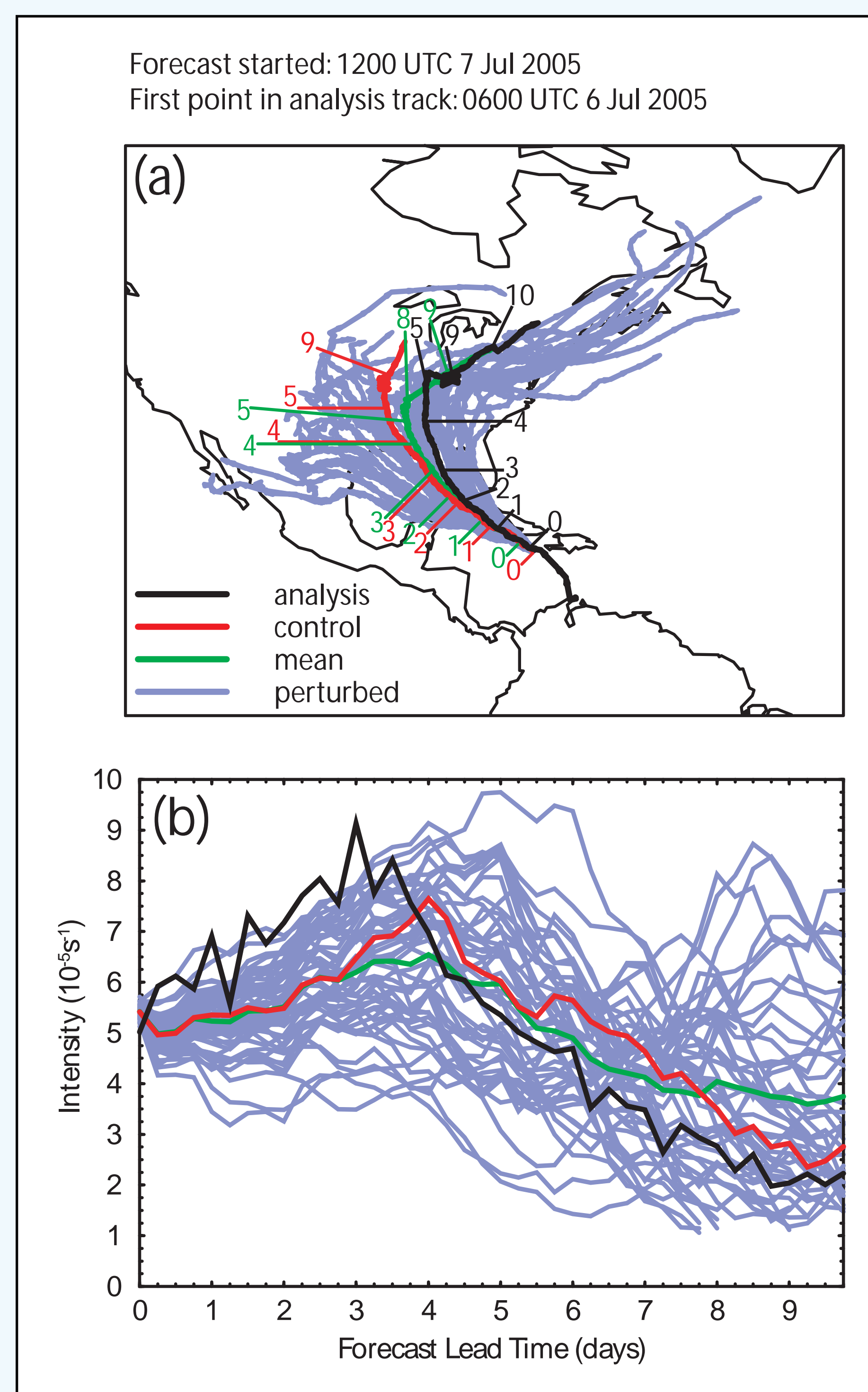


Figure 2. Tracks (a) and intensities (b) of hurricane Dennis predicted by the ECMWF EPS, from Froude (2009). Intensity is shown as the vorticity of the storm in units of  $10^{-5} s^{-1}$  (relative to  $dceni\ tqwpf\ Lgf\ Tg\ o\ qxcn\ ugg\ Htqwfjg\ 422\ ;\ %qt\ hvvtvj\ gt\ fgvc\ kmu\ =\ Vj\ g\ pw\ o\ dgtu\ cnapi\ ;\ jg\ vt\ cemu\$  correspond to the forecast time in days).

- Our previous storm prediction research has included the analysis of Ensemble Prediction Systems (EPS). An EPS involves running a model multiple times from slightly different initial states to generate an ensemble of forecasts (ensemble members) providing information about the uncertainty/probability of forecasts of severe weather events.
- This uncertainty information is essential to decision making at sea. For example a severe storm may be forecast to strike an oil platform in 3 days time, but a day later the more up to date forecast suggests the storm is propagating at a slower speed and will not reach the oil platform until a later time. Since the cost of shutting down the oil platform is high (of the order of millions of pounds per hour), information about the uncertainty of these forecasts is clearly vital for making an informed decision of when to do so.
- Figure 2 shows the predicted tracks and intensities of Hurricane Dennis by the European Centre for Medium Range Weather Forecasts (ECMWF) EPS, from Froude (2009). The uncertainty in the prediction of the track of this hurricane is clearly vast. The predicted intensities also have a very large spread, and all underpredict the hurricanes strength (compared with the analysis/truth shown in black).

- Plots such as those shown in figure 2 present a large amount of forecast information in a concise, clear and useful way. Forecast tools, including these types of plots, are being incorporated into BMT ARGOSS' computing systems using National Centres for Environmental Prediction (NCEP) EPS data.

- BMT ARGOSS has a weather room where meteorologists actively create, monitor and modify forecasts based on all the information available to them. Storm prediction information from EPS data will therefore be very useful.

## (4) eScience Methodologies

- The development of the forecast tools will make use of eScience methodologies (collaborative science performed using distributed computing and data resources). ESSC has extensive experience in the field of eScience; hosting the Reading eScience Centre (ReSC, <http://www.resc.rdg.ac.uk/>).
- In previous work a web application was developed, which allowed TRACK to be run from a web browser using remote datasets and distributed computing (Froude 2008). Figure 3 shows a schematic of how the web application worked. The data was accessed remotely over the Internet using the OPeNDAP protocol (Open-source Project for a Network Data Access Protocol, <http://opendap.org/>, previously known as DODS) and the distributed processing of the data was performed using Condor (<http://www.cs.wisc.edu/condor/>).
- The forecast tools of this project will be developed using OPeNDAP to access the NCEP EPS data, thereby reducing the amount of data that needs to be downloaded and stored locally, which is important in marine information systems.
- The processing will be performed using distributed computing on BMT ARGOSS' computer cluster to reduce computation time.

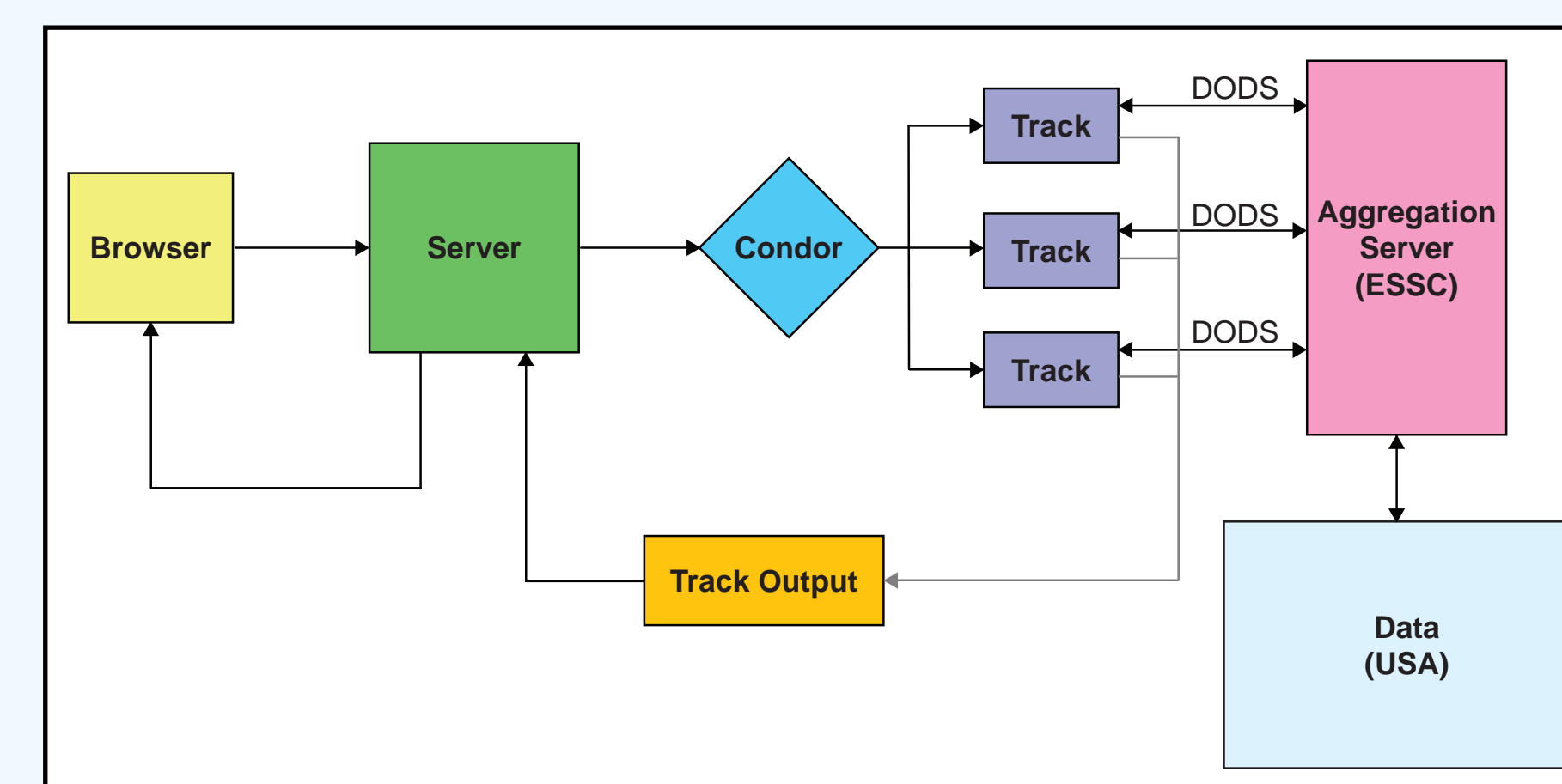


Figure 3. Flow chart illustrating how TRACK Web Application worked using eScience methodologies.

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- The research into the prediction of storms by EPS, performed at ESSC, provides new and detailed information about storms (e.g. Froude 2009, 2010), which it is not possible to obtain from the standard diagnostics produced at operational centres.
- For example figure 4 shows the ensemble mean error in northern hemisphere extratropical cyclone position and intensity for 9 different EPS archived as part of the THORPEX Interactive Grand Global Ensemble (TIGGE) program (<http://tigge.ecmwf.int/>). There are large differences in skill between the different EPS.

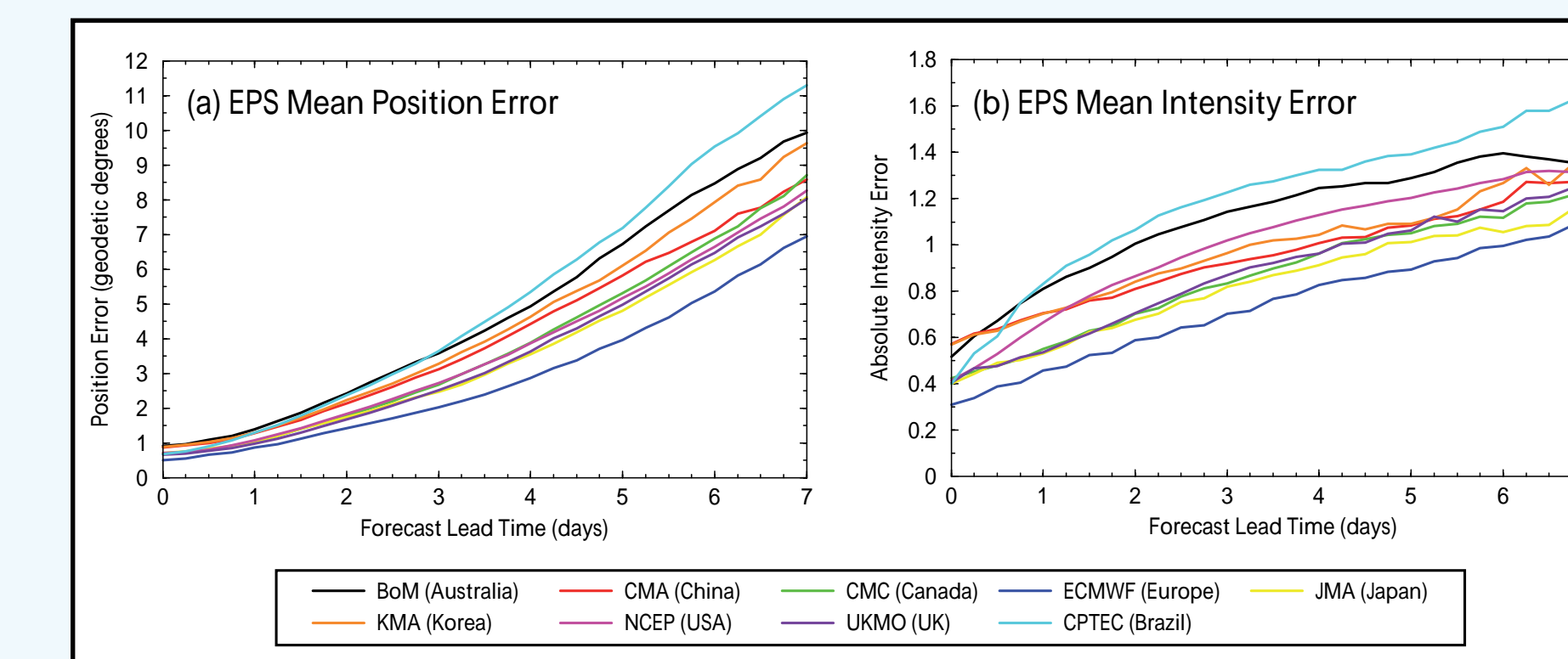


Figure 4. Ensemble mean error of extratropical storm position (a) and intensity (b) by 9 different EPS for the period of 1 Feb - 31 July 2008, from Froude (2010).

- This project will make use of the NCEP EPS, since this data is freely available via the Internet. However, the statistics of figure 4 provide BMT ARGOSS with useful information if they need to consider the use of another EPS in the future.
- Figure 5 shows the bias in the prediction of extratropical storm intensity and propagation speed for 9 different EPS archived in TIGGE. Some EPS significantly underpredict storm intensity and all EPS underpredict the propagation speed of the storms (i.e. storms will arrive before they are forecast to). The cumulative effect of the propagation speed bias will result in the 5 day forecast of the cyclone being of the order of 200-400 km behind the real cyclone.
- Information about any biases in a forecasting system is highly important to decision making at sea. If information that forecast storms generally propagate too slowly is available, a decision to close an oil platform earlier may be made.
- BMT ARGOSS make use of the Weather Research and Forecasting Model (WRF). The performance of this model will be assessed to determine whether it also has a bias for storms to propagate too slowly.
- Further analysis will be performed with WRF to determine if increasing the spatial or temporal resolution reduces the speed bias. Figure 5 suggests this may be the case since the ECMWF deterministic forecast (which has a higher spatial and temporal resolution) has a smaller bias.

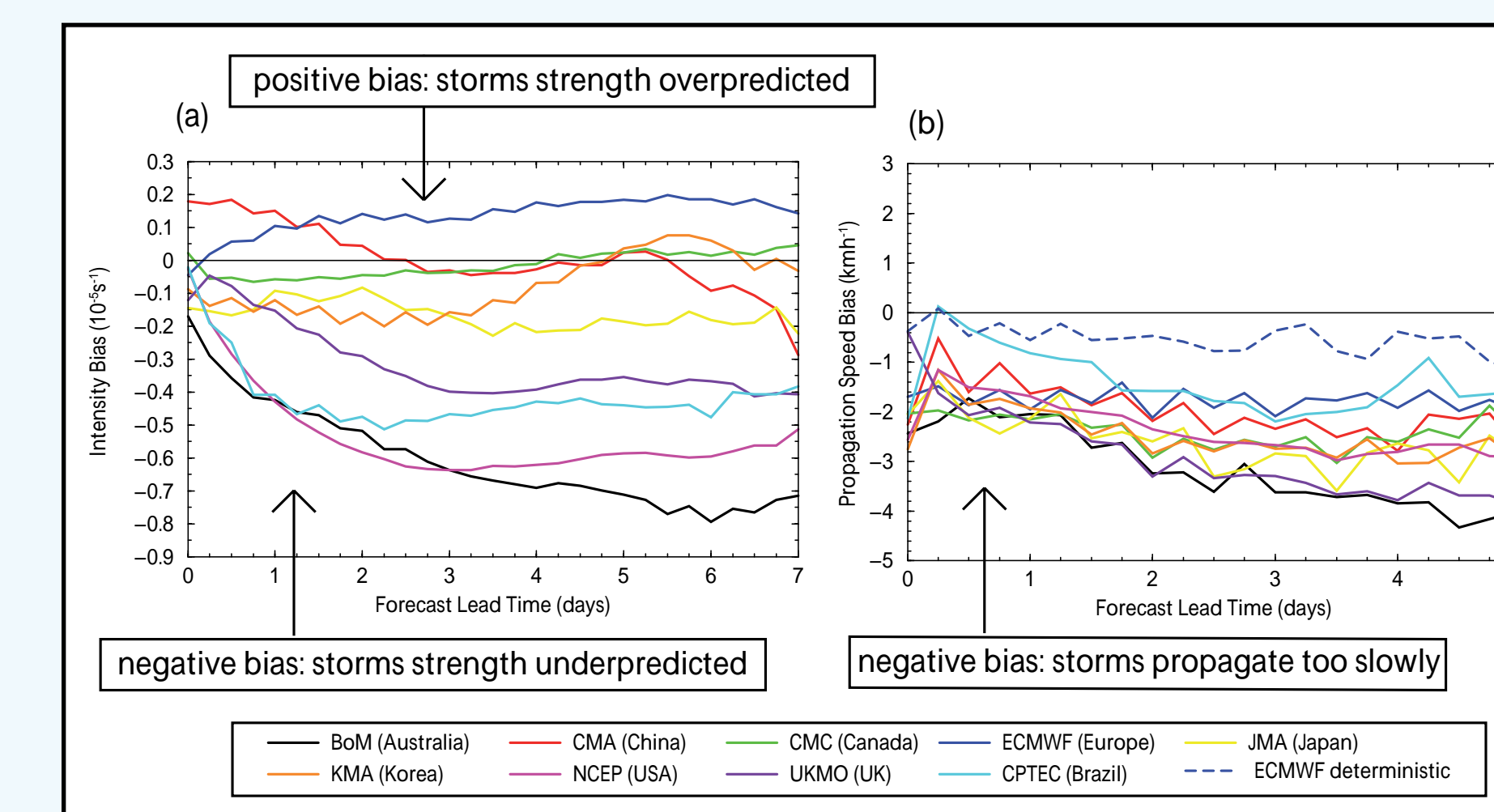


Figure 5. Bias in prediction of extratropical storm intensity (a) and propagation speed (b) by 9 different EPS for the period of 1 Feb - 31 July 2008, from Froude (2010).

## References

- Froude, L. S. R., 2008: Storm Tracking with Remote Data and Distributed Computing. *Computers and Geosciences*, **34**, 1621-1630.  
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Hodges, K. I. 1995: Feature Tracking on the Unit-Sphere. *Mon. Wea. Rev.*, **123**, 3458-3465.