Designing Interactive Graphics for Validating and Interpreting Storm Track Model Outputs

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Abstract— We report on some initial work in which we designed interactive graphics to help climate scientists identify and extract good examples of simulated storm-tracks from a large dataset to help disseminate information to various audiences. A side-effect of this work was that the exploratory potential offered by the interactive graphics helped our climate scientist coauthors validate and interpret their data in a way that was not previously possible for them.
We are extending this work to provide support for a wider range of validation and interpretative tasks, with a focus on answering questions of relevance to the insurance industry. We describe our collaborative approach, that draws on ideas from 'patchwork prototyping' [2, 5] in which a rapid iterative process of design, implementation and testing, is used to help provide the functionality to support a set of 'user stories'.

Index Terms—Visualization, hurricane, wind storm, insurance, collaborative.

1 Introduction

Advances in supercomputer technology are enabling climate scientists to run increasingly large and detailed climate simulation models [3]. These help gain a better understanding of the dynamics and natural variability of the global climate system, but create large amounts of data which need to be processed and validated prior being analysed.

The NCAS (National Centre for Atmospheric Science) is using high resolution GCMs (General Circulation Models) that allow individual storms to be resolved. A feature tracking algorithm [4] developed at the University of Reading, is used to extract storm tracks from the simulations. This process produces datasets containing thousands of simulated storm tracks at a temporal resolution of six-hours that span many decades. These have the potential to provide a more realistic reflection of natural variability in the climate system than from historical records alone, and are being used to advise the insurance industry on its exposure to atmospheric risk. This is made possible through our membership of the Willis Research Network, the world's largest collaboration between academia and the insurance industry.

In recent collaborative work [6], we designed and implemented a tool that enabled climate scientists to visually identify storm-track configurations of interest and export these as video clips. These video clips contained tangible examples of storm-track genesis and development and they were used to illustrate examples about atmospheric risk to the insurance industry.

2 The tool

The tool was designed to be a simple means of identifying examples to illustrate presentations about atmospheric risk and then exporting these as video clips.

It animates storm-track genesis and development through time, on a zoomable world map and within a user-definable temporal window.

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Transparency along the track indicates age within the chosen temporal window and its thickness indicates vorticity. Users can jump to any position along the timeline with a simple mouse movement and can display the tracks at different pressure levels. Track configurations that are visually interesting can be identified and exported to video clips. A video that demonstrates this is available [6].

3 Exploratory visual analysis for climate science

Although the tool was not initially intended for exploratory visual analysis, our climate science coauthors quickly recognised its exploratory potential as it provided a level of interaction with their data not previously experienced. In particular, they appreciated being able to explore the dataset without *a priori* assumptions. This was in contrast with the existing tools available in climate science, where *a priori* assumptions are required when preparing and processing the data. They found that visually exploring the dataset interactively, helped them identify and develop hypotheses to test, making their existing analysis tools more useful.

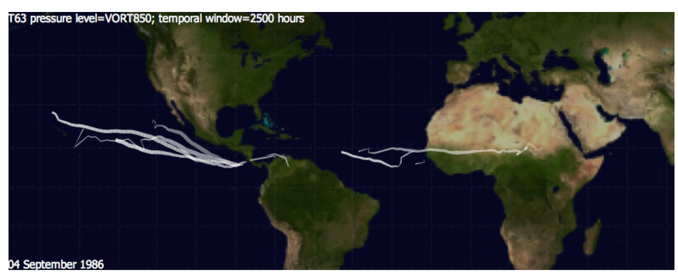

Fig. 1. Co-genesis of tracks in Central America and West Africa.

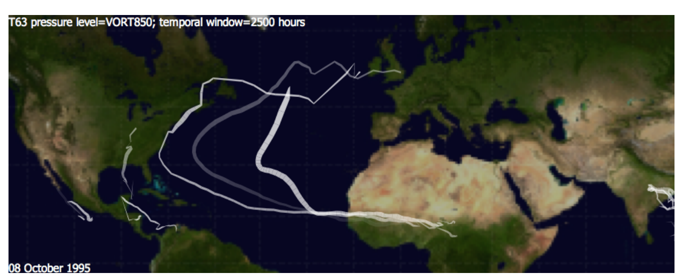

Fig. 2. Storm-tracks that initially form together, but subsequently diverge. Similar to those during last year's Atlantic season (2010).

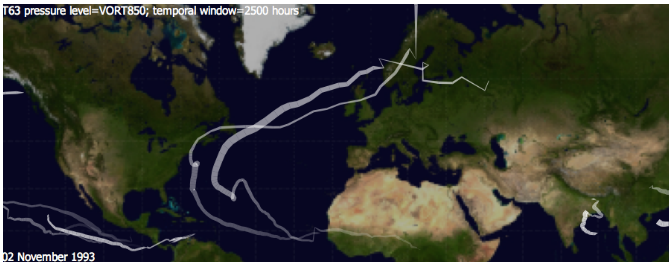

Fig. 3. Storm-tracks that go through an 'extra-tropical' transition.

In addition to the original purpose of the tool, the tool assisted model validation and helped identify the effects of climate conditions on the characteristics and configuration of storm-tracks. Some useful observations included:

- The spatial and temporal clustering of track genesis in Fig. 1 indicates time periods where conditions appear to be favourable for tropical cyclone development. Sometimes, these tracks develop along similar paths. In other cases, such as in Fig. 2, they diverge, following different paths. These differences are likely due to the relative effects of local and large-scale conditions. Establishing these steering conditions is important to understanding storm behaviour.
- Fig. 3 shows tracks that make an extra-tropical transition, i.e. change from tropical storms (warm core storms) to those that affect higher latitudes (cold core storms). Again, conditions under which this occurs needed to be established.
- Fig. 2 was recognised as being similar to the Atlantic season last year (2010), prompting the question of whether the conditions were also similar, an observation which merits further exploration of model and observational data.
- Increasing the time window enables comparison of basins over several seasons. In some years, the season starts earlier than in others and the precise reasons for this are not known.

4 Designing further functionality

We are extending this initial work by adding functionality to support other types of task.

The process we are using to achieve this draws on some of the ideas from 'patchwork prototyping' [2] where ideas are implemented quickly and there is a rapid turnaround between implementation and testing and strong collaboration throughout. This approach work has worked well for us in the past [5].

To guide the process of designing new functionality, we use scenarios that describe what a user is trying to find out and why. Scenarios can be thought of as stories [1] and term these 'user stories', which are descriptions of focussed tasks, and why they are important. It is important that user stories are written in terms of the task that needs to be fulfilled rather than in terms of functionality that might be required.

Our designs are informed by the information visualisation literature and our experience of designing visual analysis techniques.

5 User stories

We have identified user stories which describe tasks which the climate scientists would like to carry out using interactive visualisation.

- *What climatic conditions lead to the co-genesis of tracks, the co-development of tracks along the same path and the divergence of paths?* Spatial and temporal clustering is of particular importance to the insurance industry because the impact of multiple events at the same time and place is much greater than for just one event. The insurance industry traditionally considers events as independent, yet storms have been observed to cluster in time and space.
- *How does the geographical location of tropical cyclones tracks change between El Nino, La Nina and neutral years?* This has implications for risk management because the state of the *El Nino* Southern Oscillation (ENSO) can provide an early indicator to seasonal tropical cyclone activity. Improved understanding of the connection between ENSO and tropical cyclone activity could improve our predictive ability.
- *When do storms make extratropical transition (change from tropical storms to storms affecting mid-latitudes)? What climatic conditions lead to this?* It is important, because tropical cyclones and mid-latitude storms are usually considered as independent of each other in the insurance industry, yet they are often just different parts of the same storm track.
- *How many storms make landfall in* ***both*** *in the US (as tropical storms) and Europe (as windstorms)?* Related to the above.
- *How does sea surface temperature affect the location and intensity of our simulated tropical storms in the different basins? Does this relationship agree with observational findings?* This question is important for model validation and our understanding of how climate change may affect tropical cyclone activity.
- *How does sea-surface temperature change with the North Atlantic Oscillation index and how does this affect our simulated tropical cyclone activity?* This question also relates to model validation, but is also important from natural climate variability point of view.
- *What conditions lead to storm seasons starting early or late?*

6 Design considerations

Climatic conditions. Most of these user-stories involve establishing the climatic conditions under which particular configurations of storm-tracks occur. Providing access to these is likely to be useful, but need to establish exactly which to provide.

Comparison. Many of the user stories involve comparison. The tool allows spatial comparison (through the map) but only filtered through a temporal window. Temporal fading helps make temporal comparisons, but only within particular temporal windows. Other temporal comparisons are difficult, including that between different cyclic units of time. Non-spatial and temporal comparisons are difficult.

Filter The tool currently temporally filters, but some user stories would benefit from other types of temporal filtering (e.g. month), spatial filtering (e.g. East Coast of US) and filtering using other attributes.

Highlight/symbolise. Highlighting tracks that meeting particular criteria is likely to aid comparison.

7 Conclusion

We have demonstrated potential for exploratory visual analysis for validating and interpreting of storm-track data. We are designing functionality to support this through a collaborative and iterative process.

Acknowledgments

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