A CIRCUM-ARCTIC ENVIRONMENTAL FORCINGS DATABASE FOR COASTAL MORPHOLOGICAL PREDICTION: DEVELOPMENT AND PRELIMINARY ANALYSES

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Abstract

Understanding the relationship between climate, sea state, and geomorphology is crucial to interpretation of coastal physiography and establishment of predictive capacity, especially for susceptible, "ambulatory" coastlines. Recognizing this fact, the Arctic Coastal Dynamics (ACD) project initiated a climatic component with the following objectives: establishment of a meteorological forcings database based on NCEP/NCAR Reanalysis products; quality assessment of reanalysis data using in-situ data; development and analysis of relevant climatologies (*e.g.* storminess, ice); generation of high-resolution sea level model results; and analysis of spatial and temporal erosion/storminess variability and correlation.

Here we report on progress made toward the first two project objectives. Relevant model and in situ data have been accumulated and prepared for use; criteria for station selection will be reviewed. Quality assessment of the reanalysis data has been conducted for the circum-arctic region for relevant climatic parameters; results from this work will be presented. Finally, spatial and temporal patterns and trends in the data and comparisons will be discussed.

Introduction

The NCEP/NCAR Reanalysis project (NCEP: National Centre for Environmental Prediction; NCAR: Prediction/National Centre for Atmospheric Research) was undertaken to give to the science community accurate, high-resolution data sets for climatological work (Kistler et al. 2001). The data sets produced by this project, and other similar efforts (such as the European Center for Medium Range Weather Forecasting reanalysis project), are known generally as "reanalysis data" and will be referred to here as "NNR data". The Reanalysis project combines an NCAR weather forecasting model and observational data from various sources. The distribution of climate observing sites over the earth is non-uniform, which means the influence exerted by the model on the final reanalysis data result varies according to the location and the parameter under consideration. Given this, it is of interest to compare NNR data back to observed station data ("in situ" data) and to assess its ability to reproduce the observed record for a given time and place. This is especially important if the NNR data are to be used as the basis of analyses conducted in remote, data sparse regions, or if they are to be used as input to other models to derive secondary parameters, such as wave heights (e.g. Proshutinsky 2000, Swail and Cox 2000). Studies that have assessed NNR data for use in sea-state derivation, including Proshutinsky (2000), who examined reanalysis data in the context of driving a storm surge model, and Swail and Cox (2000), who utilized NNR data to drive their north Atlantic wave model, have found that the NNR wind speeds are insufficient during times of observed high-magnitude events.

This paper presents limited results from a detailed comparison of NNR 6-hourly 10 mhag (meters height above ground) winds with observational hourly wind data from weather stations located throughout the circum-Arctic coastal region as well as inland stations from

Canada. Wind speed and direction will be treated separately. In situ data from inland stations were included to determine if discrepancies between observed and NNR data were due to some artefact of coastal proximity. Use of inland stations also offered the opportunity to assess correlation in mountainous terrain, in which stations are presumably heavily influenced by local topographic factors. Given what has been reported in the literature concerning other efforts to correlate NNR data with in situ data, it was anticipated that observed wind speeds would be under-estimated by NNR wind speeds. Thus, another objective of this work was the identification of consistent patterns to the underestimation and development of objective (i.e., computer-based) correction algorithms so the NNR data could be used to satisfactorily drive models generating other environmental data, while minimizing operator intervention.

Data

Specific NNR data elements used for this work consisted of the 6-hourly 10 mhag u and v components of wind. In situ data were obtained from government run surface weather stations. Station selection was guided by ACD project interests, and decisions were based on the following criteria: proximity to designated "ACD monitoring sites", proximity to coast, length of record, uniform spatial distribution, and proximity to major rivers. Data preparation consisted of an initial extraction of suitable data elements for the required time period (1950 – 2000) and interval (6 hourly), separated into files by station. Station locations were then compared to NNR grid point locations. The nearest grid point location was identified and retained, and data for the identified NNR grid point were extracted and merged with the station data file. These files were used for the correlation work in this paper.

Method

Correlation calculations for wind direction were performed using vector correlation methods and for wind speed, Pearson's product moment (r) correlation was used. Analyses included all months and were conducted for two speed categories: all wind speeds (hereafter "all speed category") and >10 m/s (hereafter "high speed category"). The 10 m/s cutoff was based upon the use of this value as a general "storm threshold" described in arctic coastal research (e.g. Solomon et al. 1994). For these types of analyses all available data in the period 1950 – 2000 were retained and for each station a single correlation was performed using a minimum of 30 data pair. Two types of correlation analysis are presented: time aggregate and time series. For the time aggregate analysis all data from a particular point are utilized for a given correlation calculation. For time series analyses all correlation results for a given year are averaged to produce a region-wide time series. The time series data were extracted and smoothed using local linear regression to examine the results for general trends over time and to compare them to a major mode of arctic climatic variability, the Arctic Oscillation.

Correction of systematic underestimation by NNR data of observed high-magnitude wind events was undertaken using an algorithm that searches the NNR data series for "events", which are defined by various combinations of magnitude, curve profile, and length of time above a set threshold. These were compared to similar occurrences in the in situ data to determine how corrections should be applied.

Results

a. Time aggregate results

Overall results in which correlations were performed on data for the entire 1950 – 2000 period indicate that the NNR wind directions have good to very good correlation with in situ data, while wind speeds have moderate to poor correlations. Results are presented for the "all speed" and "high speed" categories (Fig. 1). Direction correlation was good for the all speed category (Fig. 1a), breaking down only in mountainous (e.g., the Yukon) or fiords areas (e.g., Greenland, Baffin Island), or areas in which a strong local forcing agent is at work (e.g., the north coast of Novaya Zemlya). Direction correlation improved noticeably for the high speed category (Fig. 1b). Speed correlation was moderate to good for the all speed category (Fig. 1c), with the best results inland and over areas of low topography, such as central interior Canada. Speed correlation decreased noticeably for the high speed category (Fig. 1d).

b. Time series results

Time series results showed distinct periods when speed and direction correlations were better (Fig. 2). Direction correlation (Fig. 2a) overall was good, and varied over a relatively small range (0.82 – 0.87). There was no overall trend apparent, although during the first decade of the series the correlation rose steadily and rapidly from an initial low value. Speed correlation (Fig. 2b) overall was poor to moderate, ranging between 0.24 and 0.38. Unlike the trend for direction correlation, speed correlation did possess a generally continuous rising trend over the entire period of record: rapid rise from 1950-1960, plateau 1960-1980, and rise 1980 – 2000.

Interestingly, the patterns of variation in both direction and speed correlations appeared to bear relationships with the trend in the index of the Arctic Oscillation. This included both exhibiting inverse correlation before 1965, both exhibiting the more recent high points (~ 1975 and 1990) and low points (~ 1980 and 1995), and in the case of speed correlation, a similar increasing trend since ~1970.

c. Correction

Attempts to correct NNR data proved moderately successful. Many events that had been underestimated were trapped and adjusted (e.g., Fig. 3). In some cases the corrections overestimate the observed, while in other cases the algorithm did not correct the NNR data. Most of the time, however, estimates improved the existing situation, i.e., that the NNR data sometimes underestimated wind magnitudes.

Discussion

The observed patterns in wind direction correlation are consistent with a model-derived wind field being unable to resolve small-scale fluctuations in lower-speed wind regimes (the latitudinal distance between grid points is ~200 km). The dominance of local-scale influences on the wind regime increases as wind speed decreases. The reverse is also true: as wind speed increases the factors influencing the wind regime also grow in scale until they are of a size that the NNR grid and modelled processes can resolve. This is why direction correlation improves at higher wind speeds in all but the most mountainous or fiord terrain (Fig. 1c). In the case of speed correlation, the large grid spacing and 6-hourly time step precludes the complete depiction of the small, strong low-pressure systems that occur in this region. It is because storms, in particular, are not modelled at their full magnitude that the greatest discrepancies occur during times of the largest magnitude winds (Fig. 1d). The correlation results also indicated that the land/sea interface is problematic for the NNR model to capture, as suggested by the fact that the best speed and direction correlations in the all speeds category (Figs. 1 a-b) tended to be clumped in the continental interior, in areas of low relief. This follows from the spacing between the grid points in the model which, at 200 km, precludes detailed portrayal of many features of the planetary surface.

The observed patterns in the time series results suggest the following. First, model functioning improved during the first decade of the reanalysis project, suggested by the rapid rise in both direction and speed correlation values (Figs. 2a-b). Second, the model has difficulty capturing variability associated with the Arctic Oscillation. This is suggested by the apparent correspondence between the patterns in both circum-arctic wide direction and speed correlation results and the Arctic Oscillation index. Between 1950 and ~1965 it appears as though the correspondence between the two is inverse, however this may also be attributed to the NNR results effectively "stabilizing" during this period, as per the previous conclusion.

The effort to undertake correction of NNR wind speed underestimation, while reasonably successful, does currently have two limitations. The first is that the occurrence of a large-magnitude wind event is not always reflected in the NNR record. Usually there was some response from the NNR data; however, sometimes there was not. If an event has no representation in the NNR record, it is impossible to make any sort of objective correction, and the event will be missed. The second limitation concerns the magnitude of correction that is applied. It has proven difficult to consistently estimate how much correction to apply because a given pattern in the NNR record can correspond to a variety of observed events. For this reason the correction parameter is fixed, which results in some underestimation and some overestimation, and some events being missed. However, the correction effort is still underway. It is likely that more region-specific corrections will yield more accurate results. Despite some shortcomings, overall the corrected NNR data provide a more realistically representation of the observed record. In terms of ACD project requirements, the corrected NNR wind field will prove adequate to generate the necessary derived environmental fields.

References

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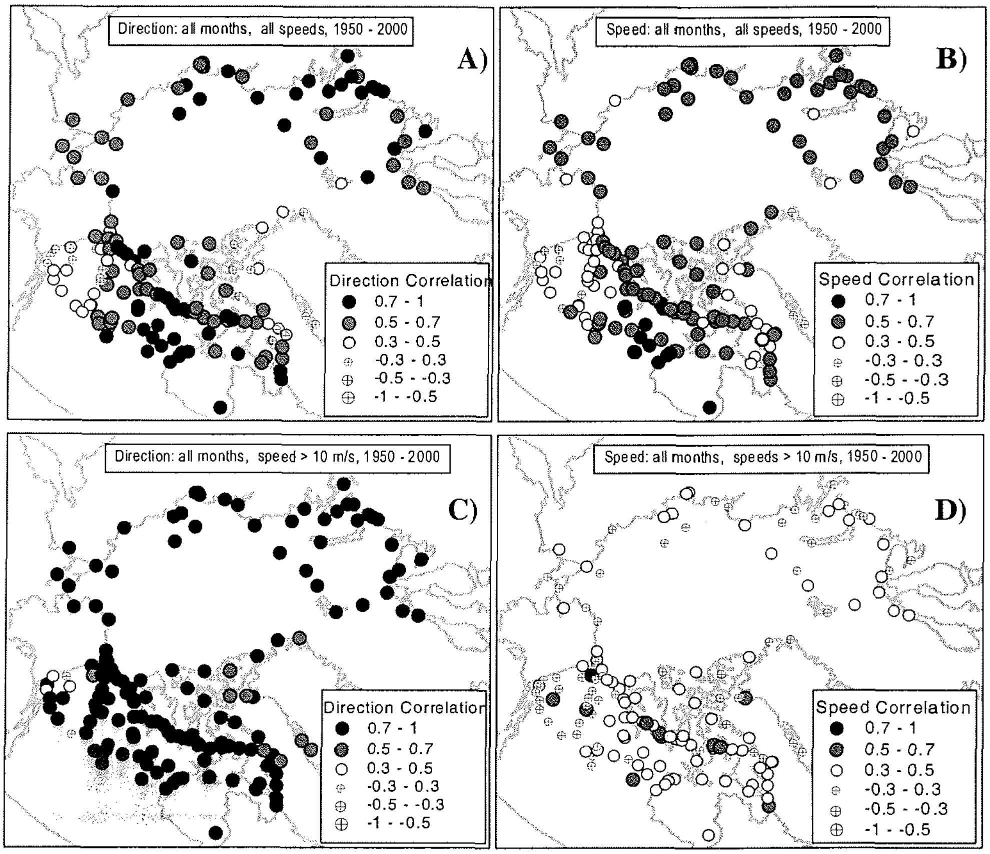

Figure 1. Time aggregate correlation results between wind directions and speeds from NCEP/NCAR 6hly reanalysis data and observed in situ data from weather stations: a) direction correlation results, 1950 – 2000, for all speeds over all months of the year, b) speed correlation results, 1950 – 2000, for all speeds over all months of the year, c) direction correlation results, 1950 – 2000, for high speeds (> 10 m/s) over all months of the year, d) speed correlation results, 1950 – 2000, for high speeds (> 10 m/s) over all months of the year.

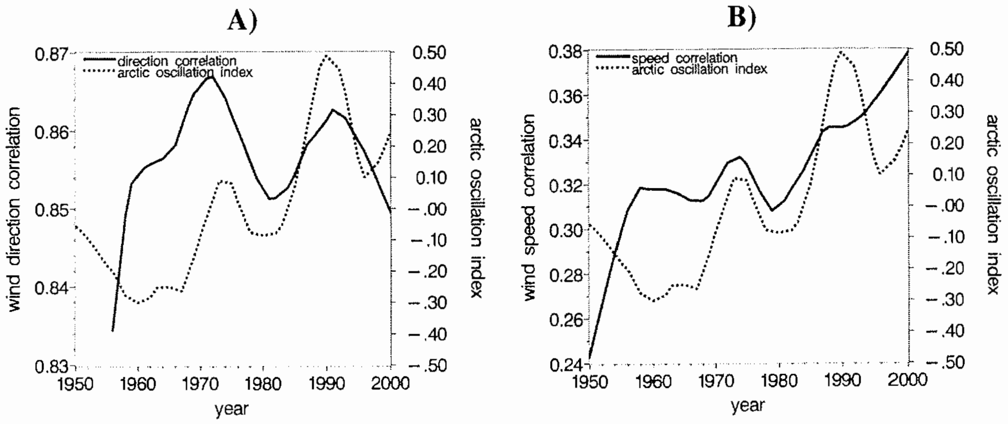

Figure 2. Time series of results of correlations performed between NNR data and circumpolar weather station data. a) Wind direction correlation, all months, and the annual index of the Arctic Oscillation. b) Wind speed correlation, all months, and the annual index of the Arctic Oscillation. All data series smoothed using a local linear regression technique (loess, smoothing factor = 0.25).

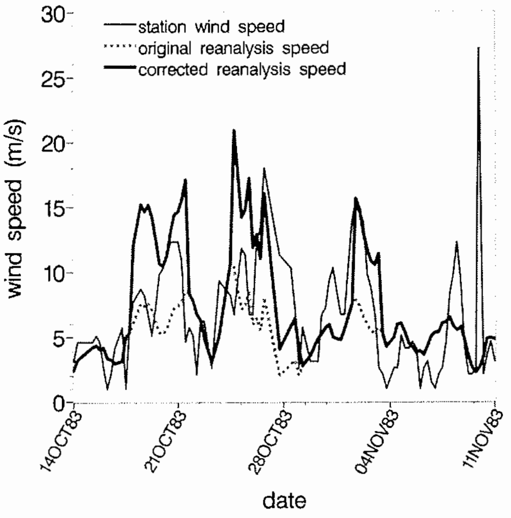

Figure 3. Example of results from the application of a correction algorithm to the NNR wind speed data.