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TO THE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Joint Hurricane Testbed (JHT) Opportunities for Transfer of Research and Technology into Tropical Cyclone Analysis and Forecasting Operations
For the
Atlantic Oceanographic and Meteorological Laboratory
403 Rickenbacker Causeway
Miami, FL 33149

Title: A 7-day Climatology and Persistence Model for track and phase for the Atlantic, East Pacific and West Pacific basins

Principal Investigator: **Sim D. Aberson** **NOAA/AOML**

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Endorsements:

Sim D. Aberson, PI, Meteorologist
NOAA/AOML, 4301 Rickenbacker Causeway, Miami, FL 33149
Phone: (305) 361-4334
E-mail: sim.aberson@noaa.gov

Frank Marks, Director, HRD
NOAA/AOML, 4301 Rickenbacker Causeway, Miami, FL 33149
Phone: (305) 361-4321
E-mail: frank.marks@noaa.gov

Robert Atlas, Director, AOML
NOAA/AOML, 4301 Rickenbacker Causeway, Miami, FL 33149
Phone: (305) 361-4334
E-mail: sim.aberson@noaa.gov

Catherine M. Steward, Chief Financial Officer
NOAA/AOML, 4301 Rickenbacker Causeway, Miami, FL 33149
Phone: (305) 361-4321
E-mail: frank.marks@noaa.gov

ABSTRACT

A 7-day Climatology and Persistence Model for track and phase for the Atlantic, East Pacific and West Pacific basins

Sim D. Aberson NOAA/AOML

The National Hurricane Center (NHC) and Joint Typhoon Warning Center (JTWC) provide tropical cyclone (TC) track, intensity, structure, and phase forecasts in the northern Atlantic and Pacific Ocean basins once a TC has developed; they later provide post-processed best estimates (the best track) of these parameters for verification. Specifically, the track forecast is the TC center latitude and longitude; the intensity forecast is for the maximum sustained surface (10-m) wind and gust speeds; the structure forecasts contain maximum gale-, storm-, and hurricane-force surface (10-m) wind-speed radii in four quadrants. The phase forecasts now contain information as to whether the TC is expected to be tropical, extratropical[1], subtropical, a remnant low or wave, or dissipated (including being absorbed into a larger, extratropical system or frontal zone). Though baseline forecasts to evaluate the track (CLIPER – Aberson 1998), intensity (SHIFOR – Knaff et al. 2003), and structure (McAdie 2004, Knaff et al. 2007) forecast skills have been derived, no equivalent for the phase forecasts has as yet been derived. Since the purpose of a baseline is to provide a very simple statistical model for the forecast variable, a linear discriminant analysis scheme using the same climatological predictors as CLIPER and SHIFOR is derived for phase forecasts (Aberson 2013). In addition, the current 5-day CLIPER (Aberson 1998, Aberson and Sampson 2003 is extended to at least 7 days from the current 5 days based on interest in the extension of forecast length by the operational centers. This project directly addresses JHT Program Priority NHC-9/JTWC- 15.

1 Both extratropical systems and remnant lows are also classified by NHC as “post-tropical.”

A 7-day Climatology and Persistence Model for track and phase for the Atlantic, East Pacific and West Pacific basins

PI: Sim Aberson
NOAA/AOML/Hurricane Research Division
Miami, FL 33149

Statement of Work

Duration of project: One year

Description of Project:

1. Introduction

The National Hurricane Center (NHC) and Joint Typhoon Warning Center (JTWC) provide tropical cyclone (TC) track, intensity, structure, and phase forecasts in the northern Atlantic and Pacific Ocean basins once a TC has developed; they later provide post-processed best estimates (the best track) of these parameters for verification. Specifically, the track forecast is for the TC center latitude and longitude; the intensity forecast is for the maximum sustained surface (10-m) wind and gust speeds; the structure forecasts contain maximum gale-, storm-, and hurricane-force surface wind-speed radii in four quadrants. The phase forecasts contain information as to whether the TC is expected to be tropical, extratropical, subtropical, a remnant low or wave, or dissipated (including being absorbed into a larger, extratropical system or frontal zone). Though baseline forecasts to evaluate the skill of track (CLIPER – Aberson 1998), intensity (SHIFOR – Knaff et al. 2003), and structure (McAdie 2004, Knaff et al. 2007) forecast have been derived, no equivalent for phase forecasts is available. Since the purpose of a baseline is to provide a simple statistical model for the forecast variable, a linear discriminant analysis scheme using the same climatological predictors as CLIPER and SHIFOR was derived (Aberson 2013). In addition, the current 5-day CLIPER (Aberson 1998, Aberson and Sampson 2003) will be extended to at least 7 days. This project directly addresses JHT Program Priority NHC-9/JTWC- 15, and is for one year.

2. Model development

A. Phase

Official forecasts contain predictions of whether the current system at each forecast time is likely to be a tropical cyclone, a subtropical cyclone, an extratropical cyclone, a remnant low or

wave, or dissipated. Dynamical models also may forecasts the anticipated phase of each system; however, such forecasts are derived from model fields. and no systematic, objective derivation of all the phase possibilities currently exists. This proposal includes the implementation of a climatology and persistence technique as a baseline for these forecasts. Since the phases are distinct states and the baseline should be a simple statistical forecast, a linear discriminant analysis technique (Aberson 1997) is used. Linear discriminant analysis is a statistical technique to find an optimal linear combination of predictors (discriminators) to separate a set of objects into multiple classes. The procedure directly provides posterior probabilities that the event resides within each of the possible classifications in addition to the actual classification (Morrison 1969, Mason and Mimmack 2002, Kerns and Zipser 2009, Kerns and Chen 2013). The predictors are the same as those used in CLIPER and SHIFOR (i.e., the current latitude and longitude of the TC center, the current maximum sustained surface wind speed, changes in these three quantities during the previous 12 h, and the current Julian day).

a. Dependent data (1980-2010)

Best track data from a recent 31-year period (1980-2010) was chosen to train the discriminant analysis; this period is seen as a compromise between dataset quality and quantity due to the difficulty in assessing TC track, intensity, and phase before regular satellite monitoring began, though any set of best track data can be used. All initial times in which the seven predictors are available (starting 12-h after the first best-track data for each system) and in which the phase is initially tropical are used, a total of 7043 cases. Though consecutive cases are serially correlated, the use of cases that are separated by at least 24 h does not substantially change the results.

The discriminant analysis classifies the 7043 dependent cases at each forecast time, and the classifications are compared to the best track. The scheme is able to correctly classify almost all the cases from data 12 h earlier (Fig. 1), but the numbers decline to about 2/3 of the cases by 72 h before leveling off. Therefore, climatology alone is able to classify at least 2/3 of the cases through 120 h. Since this is a baseline forecast analogous to CLIPER and SHIFOR, the skill is, by definition, zero.

b. Independent data (2011)

The resulting discriminant functions are tested on independent data from 2011. For 2011, operational values of the seven predictors are used instead of the post-processed best track values in order to mimic what the forecasts would be if provided in real time. The result is phase forecasts of the 19 Atlantic TCs identified operationally, initiated every 6 h and verifying every 12 h through 120 h, a total of 405 forecasts.

The 2011 Atlantic season was unusual in that only 4 of the 19 TCs identified operationally underwent ET, and 9 of the 19 degenerated into a remnant low before dissipation. Tropical Storm Lee was one of only a very few TCs that ever transitioned to a subtropical cyclone before dissipation. Despite the unusual independent data, the discriminant analysis is able to

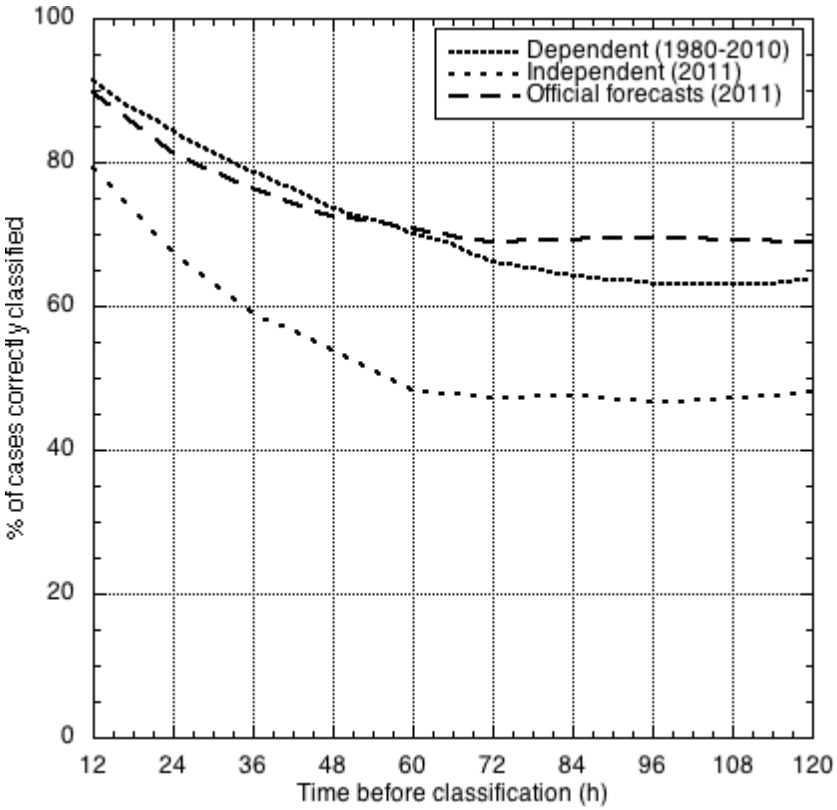

Figure 1: Percentage of cases correctly classified for the dependent and independent samples, and for NHC Official forecasts for the years specified. The two 2011 samples are homogeneous.

accurately forecast about 80% of the cases at 12 h (Fig. 1), and this accuracy decreases in time to about 50% by 60 h before leveling off. Any forecasting technique must be able to perform better than this to be said to have skill.

c. Comparison to operational (OFCL) forecasts

A forecast technique must perform better than that from a simple scheme based upon climatology in order to be considered skillful. All OFCL forecasts issued during the 2011 Atlantic season for systems which were identified as tropical in the best track are compared to those from this scheme, a total of 373 cases. These forecasts have a considerably higher percentage of correct classifications than the climatological scheme (Fig. 1), and thus can be said to have considerable skill.

d. Example of forecasts

Hurricane Irene was a strong storm that originated from a tropical wave but did not develop until reaching the western Atlantic ocean. The discriminant analysis incorrectly predicted a quick transition to the extratropical phase and dissipation during the first day of the lifetime of

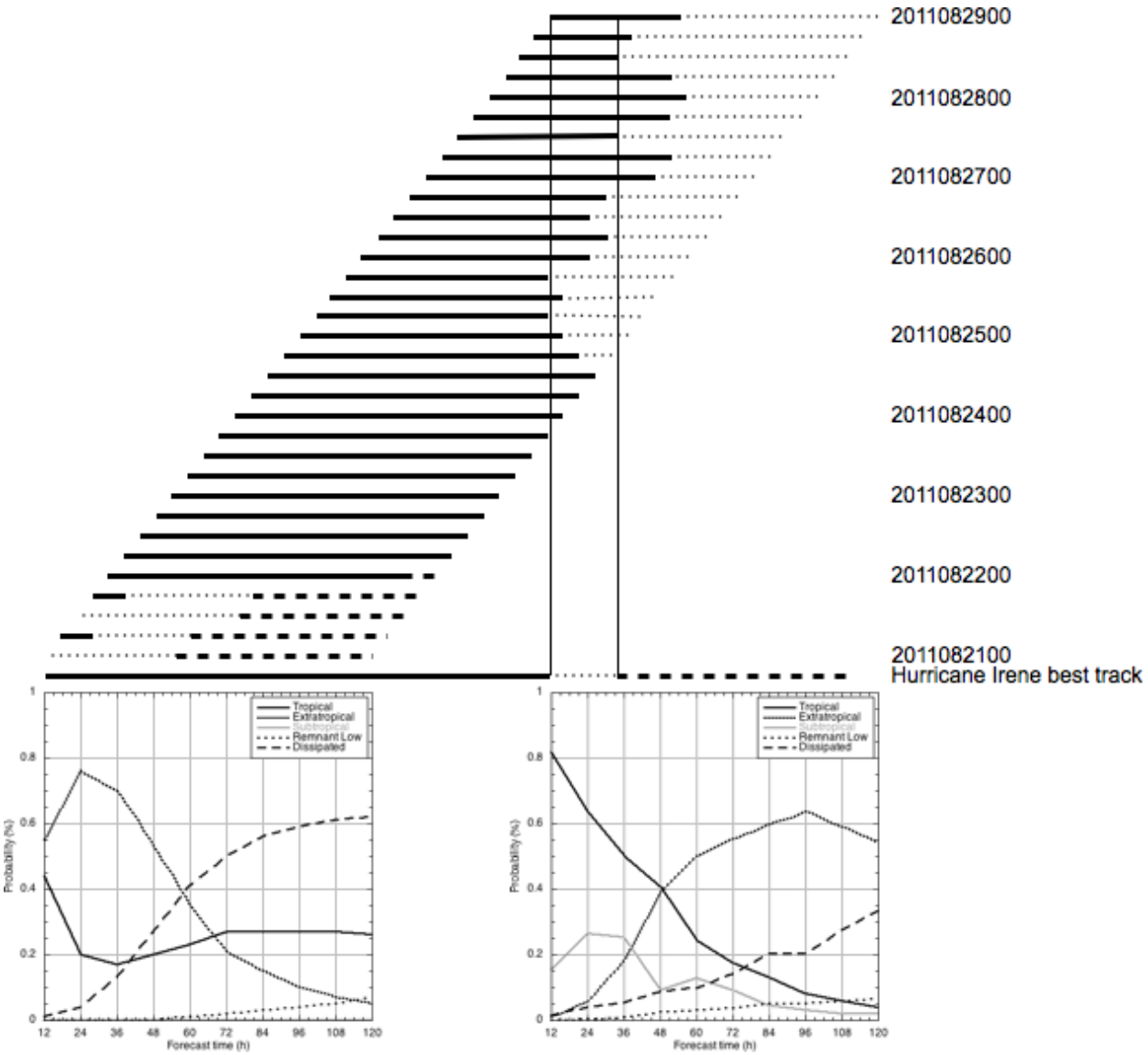

Figure 2: Phase forecasts from the linear discriminant analysis for Hurricane Irene and the best track verification. Initial times of each forecast are shown to the right. Probabilities for the cases initialized at 0000 UTC 21 September and 0000 UTC 29 September are shown, and the time range has been scaled to the corresponding forecast above. A vertical line is used to show the time of a phase change in the best track.

Irene, though the probabilities that Irene would remain tropical suggested this as a possibility (Fig. 2). After Irene turned more to the west and intensified, the scheme correctly predicted that Irene would remain tropical and then transition to an extratropical cyclone. The timing of the ET was within 2 days, but the scheme incorrectly forecast that Irene would remain an extratropical cyclone for a long period of time, when in fact Irene was absorbed by a large, powerful extratropical cyclone. The probability of dissipation increased during this period, suggesting dissipation as a strong climatological possibility.

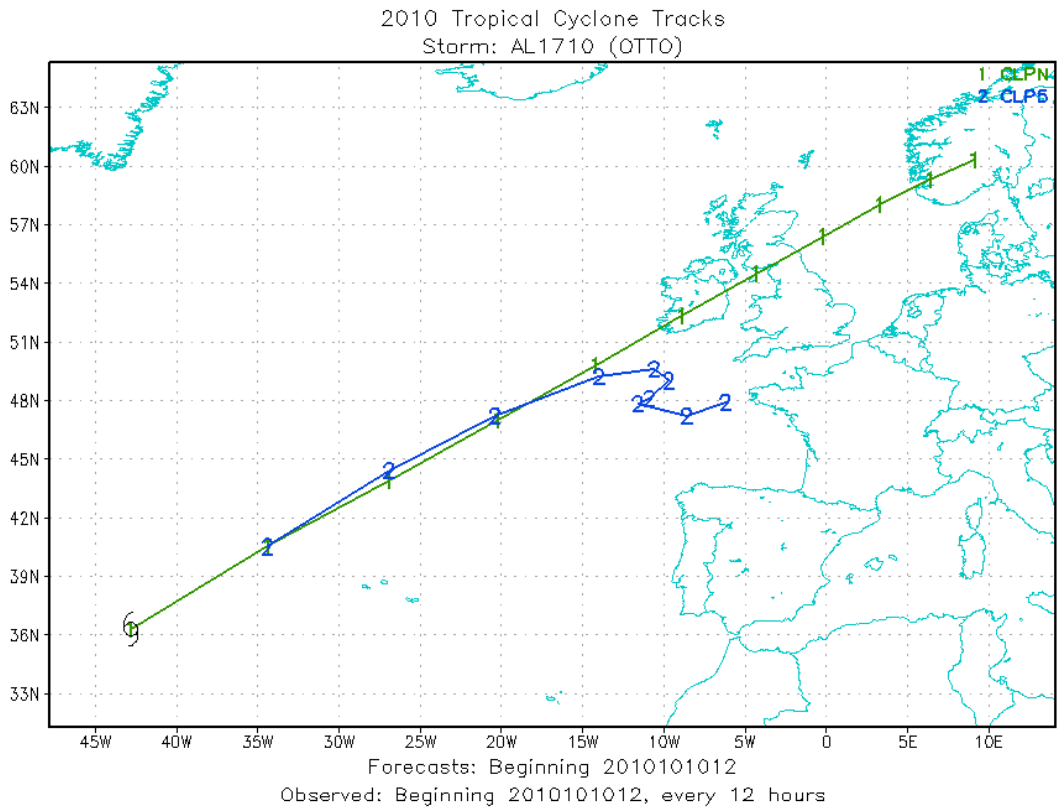

Figure 3: CLIPER forecasts for Tropical Storm Otto initialized 10 October 2010 1200 UTC. The current CLIPER track (blue) becomes erratic due to the dependent data only having very slow-moving storm at long ranges. A new version of CLIPER (green) would avoid this.

B. Track (CLIPER)

Numerous issues must be addressed in the creation of a new track-forecast baseline. The accuracy of the climatological data before the era of regular aircraft-reconnaissance and satellite monitoring is questionable. Additional errors may be due to inconsistencies in the best track data (Landsea 1993). The most important issue may be the way in which the forecasts are derived. Previous versions of CLIPER were derived in order to make 3- or 5-day forecasts in every case. Tropical cyclones moving toward the basin boundaries are likely to dissipate due to landfall or encountering of hostile environmental conditions such as a cold sea surface. Therefore, the dependent data for longer-range forecasts will only include very slow-moving storms that would not reach these negative conditions, thus introducing a bias into the forecasts. For example, Fig. 3 shows a CLIPER forecast for the final Tropical Storm Otto case. Otto was moving rapidly northeastward steered by strong, deep-layer zonal flow. Such systems tend to continue to move rapidly. However, the CLIPER forecast in this case is for slow and erratic motion after 48 h.

The approach used to solve this problem is, like the current CLIPER model, based on multiple linear regression. The current models make individual forecasts for each time step (0-12 h, 12-24 h, through 108-120 h). In the current CLIPER version, a tropical cyclone having a particular set of predictors would have a different forecast depending upon when during the 120-h forecast the conditions reside. These differences are not climatological, only resulting from the way the model was derived. The new technique solves this problem by creating individual12-h forecasts through 120 h using newly forecast storm parameters; since intensity is one of the predictors, the SHIFOR forecast is used. This technique will eliminate unusual forecasts in the longer-range, especially near the basin boundaries. In the Otto example, a new version of CLIPER removes the erratic track forecast, with the new version showing a gradual turn toward the east and slowing of the forward motion. The new technique will be used to extend CLIPER to 7 days and is appropriate for even longer forecasts. It should be noted that similar issues are not seen in the phase-CLIPER since "dissipated" is one of the possibilities.

The extension of the no-skill baselines can be a difficult problem. The operational centers may not want to introduce a new version of the track baseline that differs wildly from previous versions. Because different techniques are to be introduced necessarily, some combination of the different techniques may be needed in the formulation of the final forecast model.

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Work Plan:

The principal investigator sees no needs for hardware beyond that already available. The discriminant and regression analyses are being developed using IMSL, which has been used for other JHT projects; the code can be modified to accommodate whatever is available in the operational environment.

The operational centers have not wanted to introduce new versions of the baselines that differ wildly from previous ones. Because different techniques are to be introduced necessarily, some combination of the different techniques may be needed in the formulation of the final model, and multiple baselines may be needed. The testing and evaluation will be done in concert with the operational center(s) to ensure that the baseline forecasts are acceptable for their use.

The newly-derived version will be considered successful if the points of contact at TPC/NHC (and possibly JTWC) recommend that the new versions be operationally implemented, and the required supervisory approval is provided.

The deliverable will be code to create the baseline forecasts in each basin.

The timeline is that an initial version of the code can be made available as soon as three months after the award. The final code, made in consultation with the operational center, will be made available within one year of the award.

No non-public real-time operational data are needed during testing of the code. Recent best track files for the particular basins are needed for development. Final testing will use operational ATCF a-decks.

The code will require some coordination with other code, such as SHIFOR, whose forecasts would be required for operational implementation. No special installation at operational centers save linkage with the ATCF are foreseen.

Time line:

As the baseline track model is mostly an update of currently available baselines, no special training is likely to be necessary. Though the phase baseline is new, it will run automatically and no special training is likely to be necessary. Training can be provided if requested. Since the baseline forecasts have no skill, by definition, they are unlikely to be used extensively in an operational setting, but are necessary for verification. Technical documentation similar to that provided during the previous JHT project to create the track baseline will be provided with the final version of the code by the completion of the project.

Expected travel:

The only required travel is to the annual IHC during the one year of the proposal. The PI is local to NHC; no travel to JTWC is likely to be necessary.

JHT staff requirements:

Only minimal JHT staff requirements will be required. The main operational issue will be implementation of the new code and coordination with current systems, especially the ATCF.

Current and pending Federal Support:

No current or pending federal support.

Budget (one year):

Personnel			
AOML	S. Aberson	1.5 months	$15,747
AOML	computer support	0.5 months	$ 4,816
Subtotal			$20,563
Fringe Benefits			
AOML			$ 6,375
Total Salaries and Fringe Benefits			$26,938
Indirect Costs			
AOML			$13,738
Total Labor Costs			$40.676
Travel Costs			$ 5,000
Other Costs			$ 2,500
Total			$48,176

The request is for 1.5 months of salary for the PI for the development of the models. The successful 2003 proposal for only the track version of the model was for 1 month; the extra half month is for the phase versions of the model. Funding is requested for the PI and for computer support, which is done only by NOAA employees at HRD. In general, base funds cover about 75% of federal employee salaries, the rest to be made up with other funding such as this proposal. The funding requests for both are less than the 25% not covered by base funds.

The request includes support for IMSL software needed for the regression and discriminant analyses. The request is for one trip to the Interdepartmental Hurricane Conference to report on the work. The proposal is for one year only.

Sim David Aberson
Curriculum Vita

Meteorologist, ZP-1340-IV
NOAA/OAR/AOML-Hurricane Research Division

Education:
B.S. Pennsylvania State University 1985 Meteorology, Mathematics Minor
M.S. Pennsylvania State University 1987 Meteorology
Ph.D. University of Maryland 2003 Atmospheric Sciences

Employment history at NHRL and HRD:
1981-1982: Community Laboratory Research Internship
1982-1986: Various periods over summers and winter holidays
1987-1988: TEM contractor
1988- : Meteorologist

Awards:

2011 NASA Group Achievement Award

2007 National Academy of Science Kavli Frontier Fellow

2006 Department of Commerce Bronze Medal (group award for the Hurricane Research Division)

2005 GLBT Scientist Award from the National Organization of Gay and Lesbian Scientists and Technical Professionals

2003 Presidential Early Career Award for Scientists and Engineers

National Oceanic and Atmospheric Administration Research Employee of the Year (2003)

National Oceanic and Atmospheric Administration / Environmental Research Laboratories / 1999 Outstanding Scientific Paper Award for "The Impact of Omega Dropwindsondes on Operational Hurricane Track Forecast Models," Bulletin of the American Meteorological Society, 77 (5), 925-933 (1996). [Co-authored with Burpee, Lord, Franklin, and Tuleya.]

Committee memberships:

Hurricane Forecast Improvement Project Observations Team Chair
NOAA Northeast Area Regional Team (NART)

Selected publications (last three years):

Aberson, S. D., 2013: Climatological forecasts of tropical cyclone phase. *Wea. Forecast.,* in review.

Vukicevic, T., A. Aksoy, P. Reasor, S. Aberson, K. Sellwood, F. Marks, 2013: Joint impact of forecast tendency and state error biases in Ensemble Kalman Filter data assimilation of inner-core tropical cyclone observations. *Mon. Wea. Rev.,* in review.

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