On the Desirability and Feasibility of a Global Reanalysis of Tropical Cyclones

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ON THE DESIRABILITY AND FEASIBILITY OF A GLOBAL REANALYSIS OF TROPICAL CYCLONES

Kerry Emanuel, Philippe Caroff, Sandy Delgado, Charles "Chip" Guard, Mark Guishard, Christopher Hennon, John Knaff, Kenneth R. Knapp, James Kossin, Carl Schreck, Christopher Velden, and Jonathan Vigh

Historical observations of tropical cyclones have proven to be of great value to scientific research, to forecasting, and to many industries, such as insurance and reinsurance. But in almost all cases, the observations were made in support of immediate forecasting needs and were not quality controlled with an eye toward the uniformity and consistency that we demand of climatological datasets. Yet the increasing use of such data for risk assessment and in the detection of trends and variability warrants both a careful reanalysis of existing data and the application of uniform standards to future observations.

The North Atlantic NHC "best track" hurricane database (HURDAT2; available from www.nhc.noaa.gov/data/#hurdat; Landsea and Franklin 2013) has profited enormously from detailed reanalyses (Landsea et al. 2012) that apply modern knowledge and newly discovered measurements to historical tropical cyclone events to arrive at best estimates of the history of each storm in the record. Relative to other ocean basins, the North Atlantic region lends itself to a relatively robust cyclone record thanks to its comparatively small size, dense shipping, and the availability of aircraft reconnaissance going back to the mid-1940s. Analyses of historical events in other regions have suffered from a paucity of in situ measurements, changing standards of analysis, and the absence of a single agency that takes full responsibility for the data and oversees their quality. Thus, there have been few, if any, attempts to revisit the records and produce reanalyses that take advantage of contemporary practices and/or that add newly discovered data sources. Yet risk modeling and insurance rates depend on historical data in these regions as much as they do in the North Atlantic.

For these reasons, we convened a workshop in Asheville, North Carolina, on 22–23 May 2017 to explore the feasibility of performing a global reanalysis of tropical cyclones and to lay the foundations for a set of standards for future observations. The workshop was funded by the Bermuda Institute of Ocean Sciences' Risk Prediction Initiative (RPI), a nonprofit organization supported by the risk transfer industry and focused on questions surrounding the quantification of catastrophic risk. The meeting consisted of a series of 30-min presentations and discussion about desired outcomes and possible paths forward. Here, we summarize those discussions for the benefit of the broader meteorological community.

In contemplating the general idea of a global tropical cyclone (TC) reanalysis, we discussed the problem of addressing quite disparate user needs. On the one hand, there is a demand for the best possible reconstruction of each individual storm, based on all

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What: Accurate records of historical tropical cyclones are invaluable for scientific research and risk quantification. Yet most tropical cyclone data were collected in aid of operational forecasting with mixed attention to their use as a climate archive. To remedy this, as far as possible, a comprehensive reanalysis of Atlantic tropical cyclones was undertaken and is enjoying widespread use. To explore the feasibility of undertaking a similar effort for the rest of the globe, covering about 88% of all tropical cyclones, a workshop was convened, involving 12 scientists from around the world, including researchers, data analysts, and forecasters.

When: 22–23 May 2017

Where: Asheville, North Carolina

the available historical data and bringing to bear the expertise of a forensic team. This is the philosophy behind the reanalyzed Atlantic dataset (Landsea and Franklin 2013). But there is also a demand for a more homogeneous reanalysis that treats each event the same way, to aid in, for example, the detection of trends in activity, even at the expense of a degradation of the quality of some individual events. In both cases, there is a strong desire to quantify the uncertainty of the reanalysis of each of the variables.

We also discussed performing a third reanalysis that attempts to blend in situ and satellite-based data with an eye toward producing the best-state estimates for each event in a purely objective manner.

Altogether, we contemplate five reanalysis tasks:

1) A global homogeneous record based strictly on a reanalysis of satellite data and covering the period 1982–present. This could be accomplished by a team of professional Dvorak analysts and/or an automated application of techniques such as the advanced Dvorak technique (ADT) developed at the University of Wisconsin–Madison (Olander and Velden 2007) to a homogenized (spatiotemporal) record of satellite imagery (Kossin et al. 2013) and by crowd-sourced analyses of homogeneous satellite records as undertaken by the Cyclone Center (Hennon et al. 2015). An objective blend of these two approaches might also be advantageous.
2) Global best-state estimates of each tropical cyclone, based strictly on satellite data but taking advantage of higher-resolution sensors, more rapid scanning, etc., available at each observation time, with no attempt at homogeneity. This record would also extend from 1982 to the present, though reanalyses for the early part of the record would not be expected to differ much from the homogeneous record in task 1. Given the pure volume of data, this approach might not be feasible for Dvorak analysts but could be tractable for an ADT application. Such a record could provide a baseline, or first guess, for the approaches discussed below. An effort like this has just begun in the Australian region (C. Velden 2017, personal communication).
3) Comprehensive, best-state reanalyses of all western North Pacific tropical cyclones during the period of aircraft reconnaissance, 1946–87. This would parallel the ongoing reanalysis of North Atlantic tropical cyclones (using a similar approach in terms of data gathering and analysis methods) with the objective of obtaining the best estimate of the state of the cyclone at each time. One issue that arises here is the degree to which such a reanalysis should affect the reanalyzed Atlantic data; for example, one might try to add uncertainty estimates.
4) Possibly a best-state reanalysis of selected events outside the North Atlantic and western North Pacific (1946–87). These would be chosen based on the level of interest in and the availability of nonsatellite data for the individual storms, possibly based on a stakeholder survey. Objective techniques could be used to blend the results with those resulting from the analyses of satellite data described in task 2. The ongoing reanalysis of south Indian Ocean tropical cyclone data by Météo-France is an excellent example of what might be achieved.
5) A comprehensive, best-state reanalysis for all basins that utilizes objective state estimation methods to blend all available data. This reanalysis would be in parallel to the other reanalysis efforts outlined in tasks 2–4 above. The goal of this effort will be to provide a transparent, fully reproducible database that can be easily and quickly updated when new (or legacy) data become available and/or when significant advances in scientific knowledge or methodologies occur. The use of objective state estimation methods is particularly amenable to the generation of time-dependent uncertainty

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bounds, subject to the characteristic uncertainty of each data type. The influence (e.g., weight) of each input datum will also be quantitatively estimated and recorded by storing the weighting factors for each analysis time. This objective reanalysis will have the added benefit that it can be updated provisionally in real time. This reanalysis can be considered as a metareanalysis in the sense that the parameter estimates of state-of-the-art objective satellite-based techniques will be blended with operational fixes, surface observations (buoys, ships, land based), land-based radar, aircraft data (when available), and certain parameters obtained from dynamical atmospheric reanalysis data. A preliminary foray into this approach created a new historical database that uses objective state estimates from aircraft data to refine HURDAT2 parameter values and add additional parameters (Vigh et al. 2016).

Participants agreed that all the reanalyzed data should include quantitative estimates of uncertainty for all the variables analyzed and should also include comprehensive metadata. All of the reanalyzed data and metadata should be freely and openly available.

Much of the rest of the workshop was spent discussing the details of such issues as what variables should be provided and at what frequency, how to define the beginning and end of each event, and the application of uniform conventions to such matters as conversions between maximum wind speed and central surface pressure, between 10- and 1-min sustained winds, and between gust and sustained wind (gust factors), in what units to express the variables and at what precision, consistency in the definitions of, for example, subtropical cyclones and extratropical transitioning systems, and whether and how to include tropical cyclone–like phenomena such as medicanes and polar lows. We also discussed the possibility of applying numerical weather prediction (NWP) techniques to the reanalysis of tropical cyclones, for example, whether the initial conditions used in NWP models can be brought to bear on tropical cyclone reanalysis.

Participants agreed that the National Centers for Environmental Information (NCEI) is the natural home for most and perhaps all reanalyzed datasets, especially with the precedent set by the International Best Track Archive for Climate Stewardship (IBTrACS; Knapp et al. 2010). We also agreed that with international cooperation, the various data streams we propose to create or enhance could be sustained on an annual basis to avoid the need for future reanalyses looking back before the previous year. That is, we propose to lay out standards and guidelines for archiving tropical cyclone data going forward so as to minimize the need for future reanalyses.

The workshop concluded with detailed discussions of the financial and human resources that would be required to carry out the proposed work. We laid out a road map toward a proposal to create comprehensive tropical cyclone reanalyses for the benefit of scientific research, forecasting, government, industry, and society in general.

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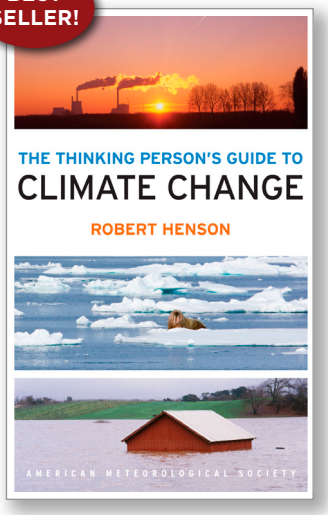

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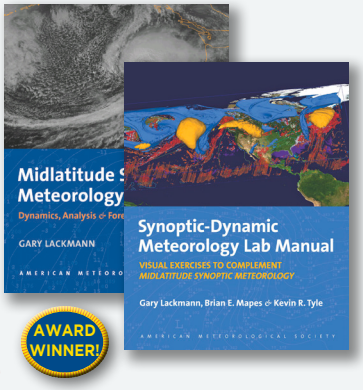

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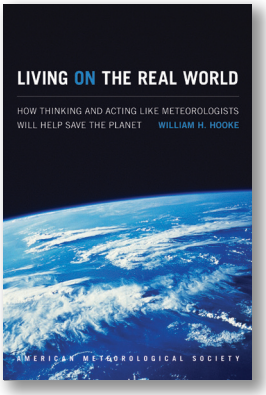

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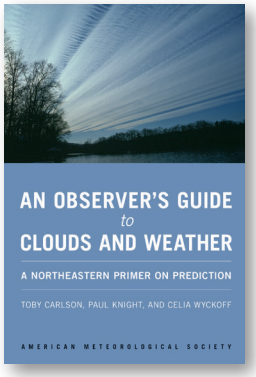

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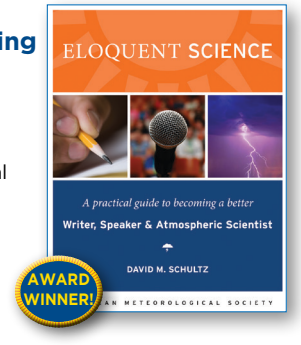

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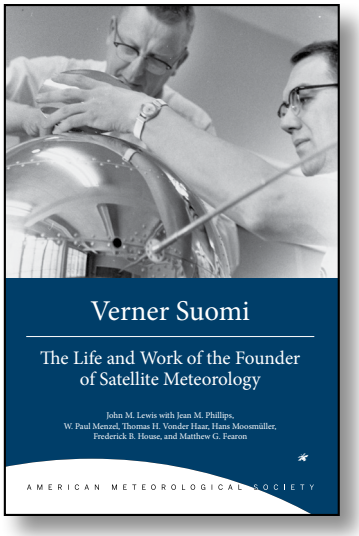

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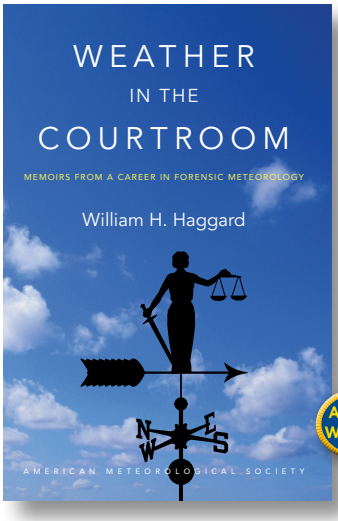

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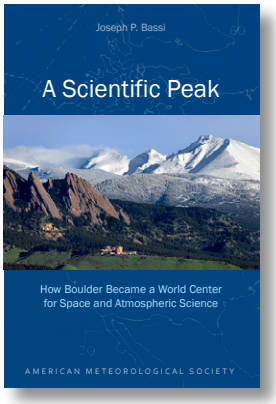

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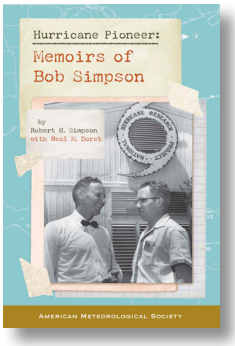

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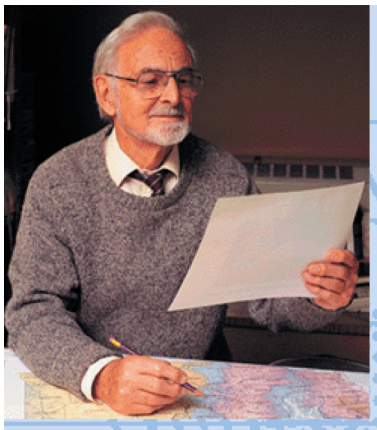

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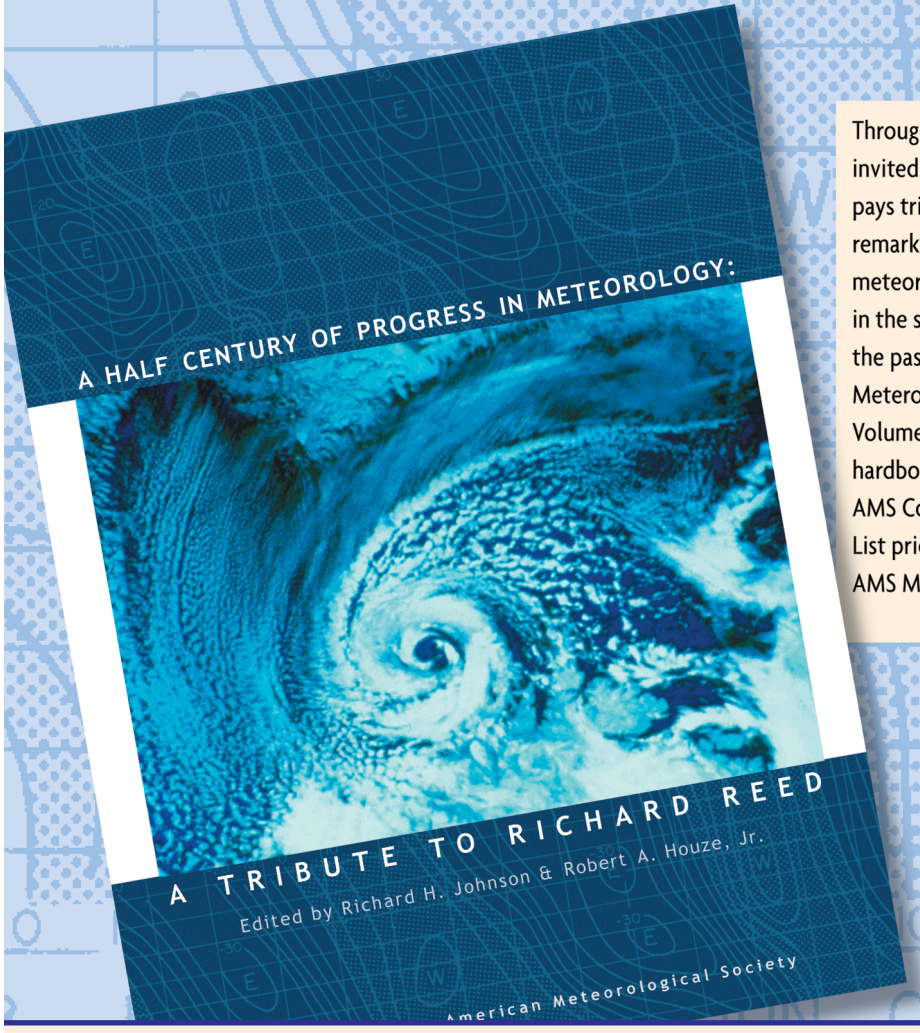

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