The Potentially Deleterious Impact of Using the Standard Sea-Level Pressure Field from the NCEP GFS model to Determine Cyclone Intensity and Track

ROBERT E. HART (rhart@fsu.edu) and LEVI P. COWAN (levicowan@tropicaltidbits.com)

Department of Earth, Ocean, and Atmospheric Science, Florida State University

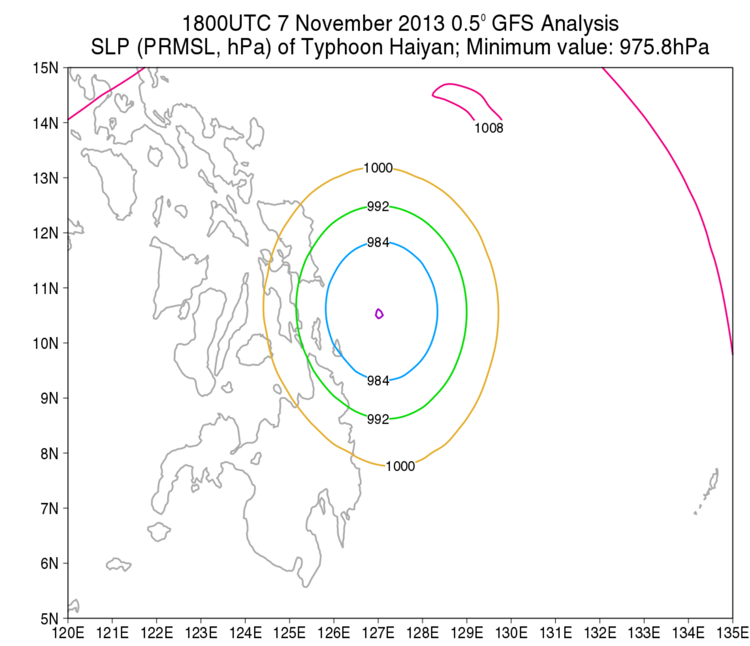
INTRODUCTION, DATA AND METHOD

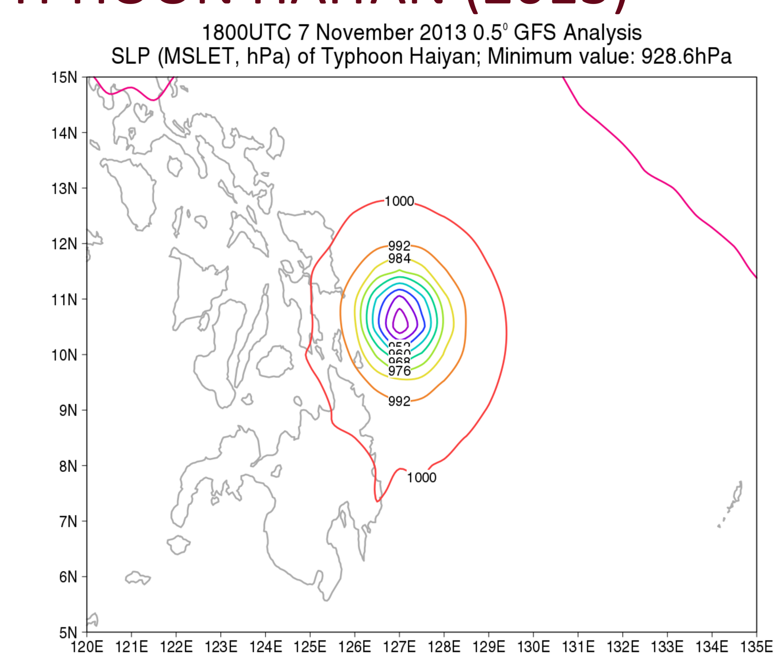
Several methods have been developed for estimating sea-level pressure (SLP) when the base of the atmosphere resides above sea level due to terrain. Most use the lapse rate in the lower troposphere to extrapolate below the ground. Generally, differences in the output of these algorithms are not large and mostly result from the choice of lapse rate used during the extrapolation – along with the constraints applied (if any) to the "underground" areas. A detailed discussion of these aspects can be found in Harrison (1970) and more recently, Mesinger and Treadon (1995).

For the NCEP GFS model uniquely, two SLP fields are output by the post-processor. The first, MSLET, uses unsmoothed atmospheric fields, and computes below-ground extrapolated temperature by relaxing Laplace's equation. The second, PRMSL, for legacy reasons spectrally truncates fields to T80 (approximately 150km effective resolution) everywhere – even over water -- before calculating SLP (H.-Y. Chuang, personal communication, 2017). This results in a much smoother SLP field than obtained by MSLET. Unfortunately, this smoothing often causes the analyzed intensity (minimum SLP) of cyclones using PRMSL to be significantly and artificially weaker than that obtained by MSLET. Perhaps more disturbing, the analyzed tracks of cyclones can be significantly in error when using PRMSL, leading to biases in human and derived guidance issued using this field.

Here we demonstrate those errors through three case studies: two tropical cyclones and an extratropical cyclone. For the extratropical cyclone, there is evidence that forecasters tailored short-term blizzard predictions based on misleading track guidance from the operational GFS and GFS ensemble generated using PRMSL output, which erroneously showed a track farther offshore than the model actually predicted, and prompted a much snowier forecast for New York City and Long Island.

EXAMPLE: SUPERTYPHOON HAIYAN (2013)





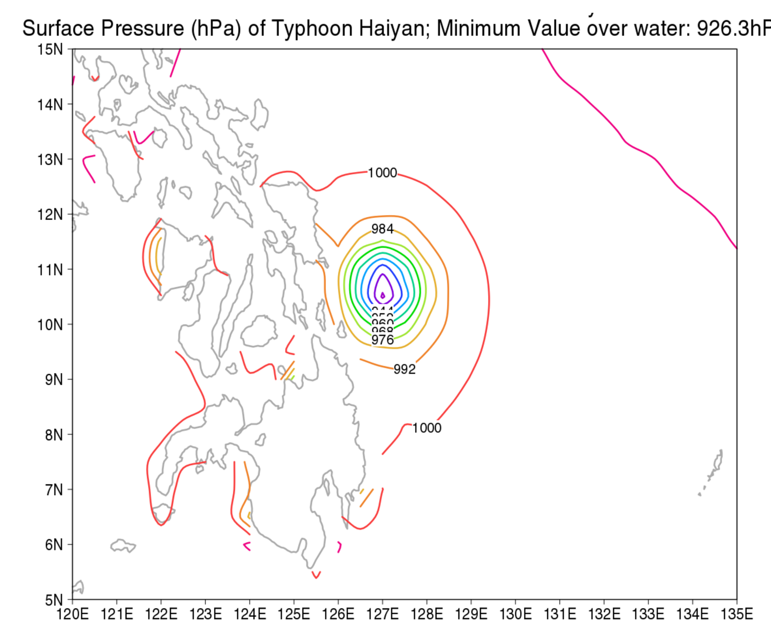


Fig. 1. Comparison of 0.5° GFS Analysis for SuperTyphoon Haiyan at 1800 UTC 7 Nov. 2013. Shown is the SLP analysis using the PRMSL field (upper left), SLP analysis using the MSLET field (upper right), and over-water surface pressure field (lower left). The dramatic impact of using PRMSL on TC intensity is clear, and MSLET shows markedly better consistency with the true surface pressure field over water.

EXAMPLE: 13-14 MARCH 2017, NORTHEAST US BLIZZARD

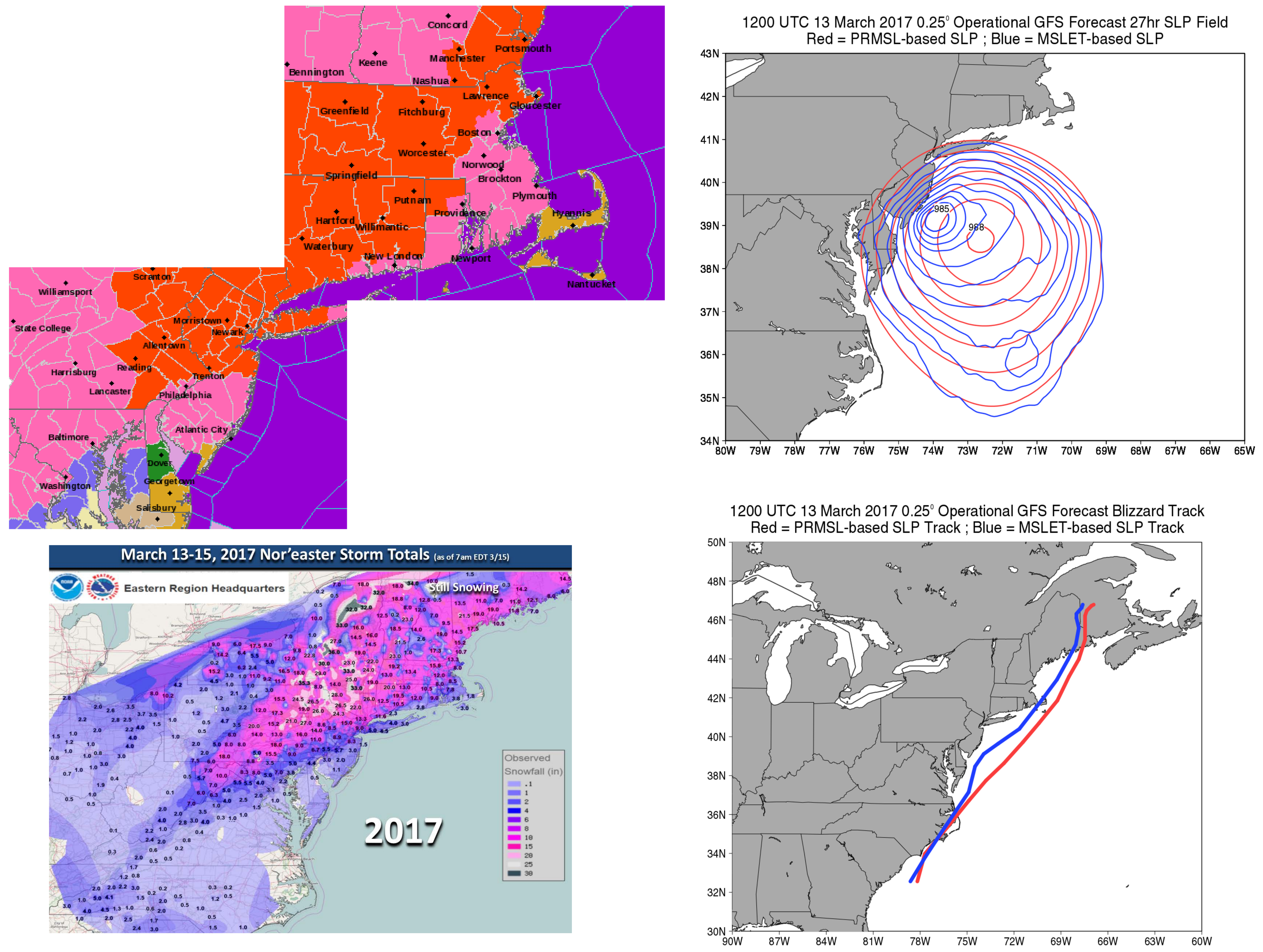


Fig. 2. A major northeast U.S. blizzard was forecast for March 14, 2017. In the face of widespread blizzard warnings for the megalopolis (orange shading, upper left), the cyclone track trended west in GFS operational and ensemble forecasts. The bias introduced by using the PRMSL SLP field instead of MSLET (upper right) caused the track to appear significantly farther east than in reality (lower right) – for the same GFS run. NWS Area Forecast Discussions (AFDs) from some coastal offices suggested that some forecasters were using the PRMSL-based tracks for the GFS operational run and/or GEFS ensemble, instead of the more appropriate MSLET-based tracks. This choice would have led forecasters to identify the storm track too far offshore, by nearly 100 km, resulting in a much colder and snowier forecast based on that guidance. This may have also led to the retention of blizzard warnings for NJ, NYC, and LI for far longer than was warranted by the raw numerical guidance – areas where minimal snowfall was eventually observed (immediate coast, lower left) despite those warnings.

EXAMPLE: TC GENESIS CASE (PRE-TS BRET 2017: INVEST92L)

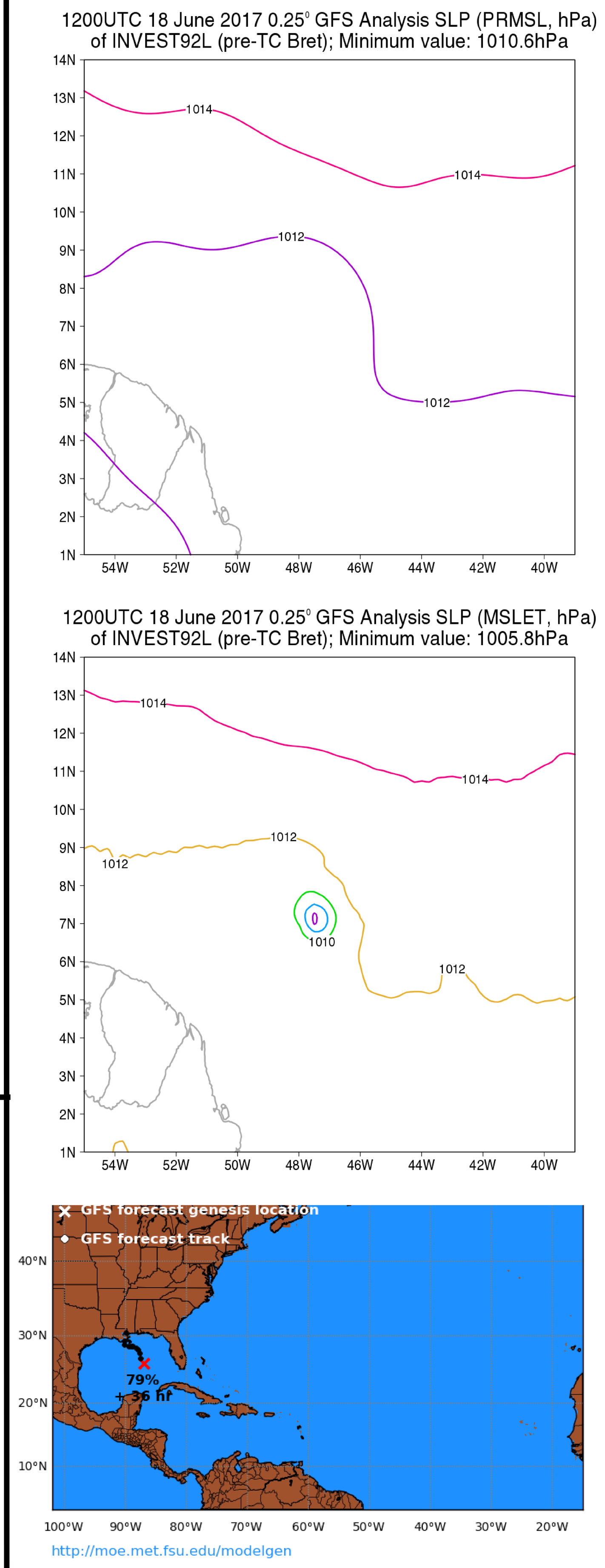


Fig. 3: A case of TC genesis illustrating the potentially dramatic impact of using PRMSL (top) vs. MSLET (middle) on the identification of a closed circulation. This also has a severe impact on derived TC genesis probabilities from Joint Hurricane Testbed (JHT) experimental products (bottom, from Halperin et al. 2017 and http://moe.met.fsu.edu/modelgen). These probabilities are currently based on the PRMSL SLP field. The lack of a closed isobar in the top panel (and subsequent PRMSL forecast fields) prevented experimental diagnosis of TC genesis and generation of JHT guidance probabilities for that system (lower left). Switching this experimental guidance to use the MSLET SLP field would result in a dramatic increase in TC genesis probabilities given the decrease in SLP magnitude. Recalibration of the logistic regression equations in Halperin et al. (2017) using MSLET is planned, but it is important to note that the developmental dataset for using MSLET would only be approximately six years in length, since the NCEP GFS model did not output the MSLET SLP field until May 2011.

DISCUSSION

As of the presentation of this poster, it is not clear that the entire scientific community is aware that the standard MSLP field (PRMSL) output by the GFS model is inaccurate, and that the more correct MSLET SLP field even exists. Since PRMSL is the default MSLP field in GRIB tables, many official NWS websites and unofficial websites show the PRMSL SLP field from model forecasts, and the GFS appears to be the only major operational model (globally) in which the PRMSL SLP field is so biased. Thus, given the examples shown here, many users of graphically displayed GFS forecasts may be misled by unacceptable biases in cyclone intensity and track. Accordingly, we strongly recommend that NCEP consider associating the PRMSL GRIB variable with the unsmoothed MSLP field (currently MSLET), as many other operational models around the world do.

ACKNOWLEDGMENTS AND REFERENCES

The authors are grateful for the personal communication and feedback of Drs. Hui-Ya Chuang of NCEP and Tim Marchok of GFDL for clarifying feedback on the topic at hand. We are also appreciative of the feedback from Dr. Daniel Halperin for clarification regarding the TC genesis guidance described above and potential impacts in that guidance product from shifting the SLP field from PRMSL to MSLET.

Mesinger, F. and R. E. Treadon, **1995**: Horizontal Reduction of Pressure to Sea Level: Comparison against NMC's Schuell Method. *Mon. Wea. Rev.*, 123, 59-69.

Harrison, L. P., **1970**: Reduction of surface pressure to functions useful in analysis and forecasting. Meteorological Observations and Instrumentation, Meteor. Monog., No. 33., *Amer. Meteor. Soc.*, 121-136.