NATIONAL WEATHER ASSOCIATION

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VADM Conrad C. Lautenbacher, Jr., USN (Ret)
Undersecretary of Commerce for Oceans and Atmosphere
U.S. Department of Commerce
1401 Constitution Ave., NW
Washington, D.C. 20230

Dear Admiral Lautenbacher:

The National Weather Association (NWA) is a member-led, non-profit, professional organization supporting and promoting excellence in operational meteorology and related activities. Excellence in daily weather observing and forecasting for the public good can best be achieved by continual modernization of observing equipment and quickly taking advantage of new technologies.

Therefore, on behalf of the over 3,000 NWA members from all sectors of the meteorological community, the NWA President, with the advice and consent of the NWA Council and NWA Remote Sensing Committee, requests the support of all concerned for the rapid transition of the Global Positioning System (GPS) Meteorology (GPS-Met) network from development to operational status sooner than current plans allow.

Sincerely,

Stephen W. Harned CCM
Executive Director
National Weather Association

National Weather Association
Letter of Support
for an

Operational GPS Meteorology Network

Executive Summary: Decision-makers are increasingly reliant on public and private forecasts for daily planning, hurricane evacuations, fuel distribution, agriculture pricing policy, positioning fire weather assets and positioning road chemicals for winter storms. These same decision-makers can benefit from better forecasts resulting from the availability of measurements of atmospheric water vapor from ground-based GPS-Met Integrated Precipitable Water (IPW) retrievals. These GPS-IPW data are being used in weather prediction models to help produce more accurate analyses and forecasts of the atmospheric moisture pattern over the U.S. as well as in a wide range of other forecast applications. The GPS-Met-IPW network provides unattended, continuous, independent, frequent, and accurate observations of IPW at very low cost. More importantly, the improved situational awareness to forecasters leads to better short-term regional warnings and forecast services potentially resulting in reduction of life and property.

Current budget planning by the National Oceanic and Atmospheric Administration (NOAA) does not call for the National Weather Service (NWS) to begin funding the transition of this valuable network from experimental to operational status until FY09, with preliminary commissioning expected in FY11. Consequently an immediate funding shortfall exists in FY07 and FY08, severely limiting staffing for current operation and maintenance of the network. As a result, problems that limit or impair performance of the network will not be addressed until full funding becomes available in FY09, increasing the potential for degraded performance of numerical weather prediction (NWP) models and impacting verification of radiosonde and satellite moisture sounding products. Therefore, the NWA strongly recommends that the transition of the GPS-Met network into NOAA/NWS operations be undertaken at the earliest possible opportunity.

Background: GPS satellite radio signals are slowed as they pass through the Earth's atmosphere. This delays the arrival time of the transmitted signal from what is expected if there were no atmosphere. The delay in the signal as it travels through the atmosphere originates from both the ionosphere and the neutral atmosphere. The ionospheric-caused delays can be corrected for by using dual-frequency GPS receivers as they are frequency dependent. The delays from the neutral atmosphere, however, are not frequency dependent as they depend on its constituents which are a mixture of dry gases and water vapor. Using the techniques first described by Bevis et al. (1992, 1994) and Duan et al.

(1996), the signal delays caused by water vapor in the troposphere can be estimated and used to retrieve the total column water vapor or integrated precipitable water (IPW). This new technology opened the door for the development of a ground based GPS-Met-IPW network in the 1990s led by the NOAA Earth Systems Research Laboratory (ESRL) (Wolfe and Gutman, 2000 and Gutman et al., 2004). Today the network has grown to nearly 400 sites across the United States, Canada, Mexico, and the Caribbean (http://gpsmet.fsl.noaa.gov/cgi-bin/get_site_info.cgi).

GPS-Met-IPW complements other systems capable of measuring atmospheric moisture such as radiosondes, surface-based radiometers, satellite-based infrared and microwave sensors, and research aircraft. (Note: GPS-Met-IPW observations do not provide information about moisture profiles and, therefore, are not intended to replace moisture profile measuring systems, such as radiosondes). Radiosondes provide moisture profiles in the atmosphere but have limited spatial coverage and are launched twice-daily only and in some countries only once a day. Surface-based radiometers are capable of high temporal resolution but are costly, require frequent calibration and their performance is affected by the presence of rain. Satellite-based infrared and microwave sensors offer planetary scale coverage but IR sensors are reliable only in cloud-free regions and microwave sensors, although valid in cloudy regions, are only available over oceans and have limited temporal resolution. Aircraft can provide routine observations using the Water Vapor Sounding Systems (WVSS) or Tropospheric Airborne Meteorological Data Reports (TAMDAR). However, these systems are generally expensive, take information useful to weather forecasting only during ascent and descent, and are severely impacted by interruptions in flight schedules.

The GPS-Met-IPW network provides unattended, continuous, independent, frequent, and accurate observations of IPW at very low cost (installation of a new site usually costs less than $7,000 if collocated with a surface meteorological observation station or around $10,000 otherwise with an average annual operating cost of around $500.00. Per verbal communication with Seth Gutman, NOAA ESRL). The GPS-Met-IPW observations are also unaffected by weather conditions or time of day. The main limitations of the GPS-Met-IPW network are that the IPW retrievals do not provide information about the vertical distribution of water vapor, and the spatial resolution is limited (although this is becoming somewhat alleviated by the fast expansion of the network). *It also meets essential water vapor monitoring requirements not met by all other sensors like its ability to monitor water vapor under all weather conditions which is critical during potential severe weather events (*U.S. Weather Research Program Prospectus Development Team report published at http://box.mmm.ucar.edu/uswrp/PDT/PDT1.html (1995). In addition, GPS-Met-IPW accuracy of 1 to 2 mm (Deblonde et al. 2005) is equal to or better than integrated radio-sonde moisture soundings at a fraction of the cost which provides a way of assuring that every radiosonde moisture sounding used is accurate (Gutman et al. 2005).

But why bother measuring atmospheric water vapor? Water vapor is one of the most significant constituents of the atmosphere because it is the means by which moisture and latent heat are transported to cause "weather". Water vapor is also a greenhouse gas that plays a critical role in the global climate system. This role is not restricted to absorbing and radiating energy traveling through the atmosphere, but includes the effect it has on the formation of clouds and aerosols and the chemistry of the lower atmosphere. Despite its importance to atmospheric processes over a wide range of spatial and temporal scales, water vapor is one of the least understood and poorly described components of the Earth's atmosphere. This is because water vapor moves rapidly through the atmosphere, redistributing energy through evaporation and condensation. This can occur abruptly over extremely short distances. Because of this, water vapor is under observed in time and space, especially during severe weather. This conclusion is supported by multiple scientific reports, among them a special report on water vapor in the climate system by the American Geophysical Union (AGU), published online at http://www.agu.org/sci_soc/mockler.html (1995), which states that although the Earth's "*basic operation of the hydrologic cycle is well known*", "*some details are poorly understood, mainly because we do not have sufficiently good observations of water vapor*". The first U.S. Weather Research Program Prospectus Development Team report published at http://box.mmm.ucar.edu/uswrp/PDT/PDT1.html (1995) made as one of its key recommendations "*the support of research seeking to determine optimal combinations of satellite and* ***ground-based remote sensing****, aircraft, balloon, and surface observations as well as the support of key technological developments such as satellite-borne active sensing techniques,* ***near-field remote sensing of atmospheric water vapor****, and observations from commercial and, perhaps, pilotless aircraft*" as a condition to achieve forecasts improvements "*at the 2-7-day range*" which "*could have enormous potential economic benefits but will require greatly improved data over the oceans and other data sparse areas*". The Global Climate Observation System (GCOS) workshop report on the Upper-Air Network available at http://www.oco.noaa.gov (2006) also includes recommendations concerning GPS-Met. The GPS-Met-IPW network makes it possible to make observations of IPW with high horizontal resolution (provided the network is large enough), high temporal resolution, high accuracy, long-term measurement stability, and high reliability under all weather conditions.

Decision-makers are increasingly reliant on public and private forecasts for daily planning, hurricane evacuations, fuel distribution, agriculture pricing policy, the positioning of fire weather assets for the best situational awareness and assisting with road chemicals to help mitigate winter storms. They (decision makers) can benefit from better forecasts resulting from the availability of GPS-Met-IPW retrievals and their use in a wide range of forecast applications. For example, assimilation of GPS-Met-IPW data into Mesoscale Numerical Weather Prediction (NWP) models has been proven to reduce model precipitable water bias/errors by as much as 50%. This results in a 10% improvement in 3h RH forecasts below 500 hPa in the Midwest US, and about 6% over the entire CONUS region. Significant improvements in 3h Convective Available Potential Energy (CAPE) forecast and skill scores (ETS) for heavy precipitation events are also well documented (Smith et al., 2007; Deblonde et al. 2005; Benjamin et al., 1998, 2004a-c; Macpherson et al., 2007). This performance has resulted in the incorporation of these data into two National Centers for Environmental Prediction (NCEP) operational models, namely, the Rapid Update Cycle (RUC) in June 2005 and the North American Mesoscale (NAM) in June 2006 (Smith et al., 2007). These improvements are essential to help NOAA meet its strategic goals of improving severe weather forecasts, aviation forecasts, hydro-meteorological forecasts, and climate forecasts (http://www.spo.noaa.gov/) through its different Line Offices. Additionally, the ability to retrieve atmospheric water vapor content from GPS signals has enabled up to 19% improvement in real time kinematic positioning from GPS signals widely used in surveying techniques (Ahn et al. 2006) and positioning accuracies on the order of centimeters (Dodd and Bisnath, 2005). These side benefits mean that the development of this technology has benefited the society at large beyond the weather enterprise. This goes to the core of NOAA's mission in support of the Nation's Commerce.

Additional benefits of the GPS-Met-IPW network include: 1) GPS-Met-IPW installed at Upper-Air Sites provides quality control for global Radiosonde Observation (RAOB) moisture soundings which leads to detection of bad soundings, resulting in improved moisture observations for NWP, climate statistics, satellite calibration and validation, and research (McMillin et al. 2007, Rama Varma Raja et al. 2007, Gutman et al. 2005); 2) more importantly, use of Real-Time GPS-Met-IPW results in forecaster improved situational awareness which will lead to better short-term regional warnings and forecast services, as well as likely resulting in more lives saved and reduced property damage (verbal communications with Science and Operations Officers at NWS field offices); and 3) verification of satellite and other moisture sensing systems which provides an independent check on the quality of remotely-sensed measurements from satellites and/or *in situ* measurements from sondes (Birkenheuer, D. and S. Gutman, 2005).

The NWA believes that given the relative low cost and tremendous benefits of the GPS-Met network, its development and transition to operations should not be delayed any further. This is one of the most effective total moisture measuring networks available today. The NOAA/NWS strategic plan calls for a gradual improvement in forecast and warning services and to put the availability of this network at risk is counterintuitive to the spirit of the strategic plan and its goals.

<u>Summary</u>: We strongly recommend the transition of the GPS-Met-IPW network into operations at the earliest possible opportunity. This will continue to provide public and private forecast services across the nation with the capability of monitoring moisture at temporal and spatial scales not possible previously and thus improve our Nation's weather, climate, and water services.

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