# An End to End Water Cycle Mission Focusing on Cloud and Precipitation Processes

**NOAA – NESDIS, OAR, NWS**

Over the past fifteen years, much has been learned about various components of the water cycle through high quality satellite observations from new, never flown before sensors. NASA based missions such as Aqua (AMSR-E, MODIS and AIRS sensors), CloudSat (CPR sensor) and TRMM (TMI, PR and LIS sensors) and most recently, GPM (GMI and DPR sensors) have advanced our understanding about surface properties, atmospheric temperature and moisture distribution, cloud properties and three-dimensional precipitation characteristics. *(At the time of this writing, SMAP radiometer measurements are just emerging)*. In some instances, these missions have served as risk reduction for many of the current/upcoming operational sensors flying on NOAA and EUMETSAT satellites (e.g., MODIS for VIIRS; AIRS for IASI; LIS for GLM). Although a tremendous amount of scientific insight has been gained from each of these missions, difficulties remain in co-registering all of these measurements (in both time and space) to get a robust integrated, easy to use scientific data set. In some sense, this has limited their potential value since no, comprehensive program or science team has been focused on such an endeavor. This is not a criticism of these highly successful missions, but more of a reality in terms of how these missions are conceived, developed, launched and then exploited by the community. As we move forward, the next logical step is to develop a dedicated mission that can simultaneously measure several aspects of the water cycle which will continue to help us learn more about these synergistic physical processes and be managed (both scientifically and data wise) in a more efficient manner. Such a concept has also been recognized by several international satellite observing programs, including GEO, CEOS and CGMS. Furthermore, fusing the satellite data with high quality surface observations has been gaining momentum and should be a priority of any future satellite program.

"Total Water" is an increasingly high priority item at NOAA; the National Water Center (NWC) in Tuscaloosa, AL is just one component of NOAA's focus to be able to improve its monitoring and prediction of water quantity and quality. NWC is a joint activity between NOAA, USGS, FEMA and the Army Corp of Engineers. NOAA's primary satellite missions – JPSS and GOES-R – are the backbone of global water monitoring, primarily for water vapor, clouds and precipitation. They supplement ground observations (in particular, over the United States) but offer greater spatial coverage where the ground observations are scarce or of limited quality (i.e., mountainous regions, sparse populated areas and off shore locations). The derived satellite products themselves, especially when combined (i.e., merged IR and microwave, as well as radar and rain gauge), serve NOAA's forecasting and climate needs. In addition, the radiances from the satellite observations are critical input for operational Numerical Weather Prediction (NWP) models. The new instruments on these satellites will improve NWP forecasts; however, challenges remain in terms of data assimilation, especially in cloudy and precipitating atmospheres. For NWP community, advances can be made through improved physical understanding of the water vapor, cloud and precipitation processes, and their coupling to surface moisture. Improving land surface process and radiative transfer models will come about with a better understanding gained from remotely sensed observations. *For this assortment of reasons, the need for an advanced, end to end water observing system from space is desired, and is a topic ripe for NASA to pursue in its future earth observations.*

A vision for such a mission could be based on the CloudSat, GPM and SMAP heritage. If technologically feasible, radar that would have the combined capabilities of the GPM DPR and CloudSat CPR would potentially yield the sensitivity to obtain cloud particle distributions and precipitation characteristics, including both solid and liquid forms. Additionally, adding in a vertical Doppler capability would enhance information regarding particle shape and size. Furthermore, adding in a SMAP-type radar and/or a shorter wavelength synthetic aperture radar would also be beneficial. These instruments would be useful in the retrieval of near-surface soil moisture, surface water depth and extent, and freeze/thaw information which would provide surface "memory" of precipitation that fell during times where the satellite measurements were unavailable. A microwave radiometer that spans the frequency ranges of the GPM GMI and SMAP radiometer would provide both the surface and atmospheric information required to monitor atmospheric water vapor, clouds, precipitation, snow water equivalent, soil moisture, and land surface characteristics. Additionally, extension of the radiometer to L-band would also provide information on salinity over the oceans that could help determine fresh water fluxes. And finally, a MODIS class visible/IR sensor would further help in providing cloud information. Enhanced sensors with some of these attributes are being pursued/considered by several research and operational agencies in Japan, China and Europe.

In order for operational agencies like NOAA to further exploit such measurements beyond the basic science understanding anticipated from such a mission, a challenge posed to NASA would be to develop the proper synergistic measurements from this wide array of sensors (i.e., co-registered in time and space, including across as much of the orbital swath as possible), manage the observations in a way that can be easily exploited, and then to make them available with relatively low data latency. So besides the basic engineering challenges for such a mission, a further obstacle that needs to be part of the mission requirements is to put the level 1 radiances from all sensors in an innovative, co-registered form with low latency comparable to operational weather satellites that are exploitable by both the scientific and operational communities.

It is envisioned that this new mission would "anchor" a global "virtual constellation" of both research and operational missions, with the research mission providing detailed measurement to focus on the physical processes and develop the "science" that can then be exploited on the operational missions; this would include sensor risk reduction activities that can then feed into future operational sensors. In some sense, the GPM model would be followed, but would consider satellites/sensors related to all of the water cycle and not just to precipitation alone.