Continuity of Air-Sea Climate Variables

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1. What are the key challenges or questions for Earth System Science across the spectrum of basic research, applied research, applications, and/or operations in the coming decade?

One of the greatest consequences of our warming climate will likely be related to changes in the hydrologic cycle and general circulation. Droughts, floods, and severe storms have enormous impacts on society. Both the hydrological cycle and general circulation are driven by exchanges of moisture, momentum, and energy between the world's oceans and atmosphere. This air-sea interaction is one of the most important and the least understood mechanisms of the climate system. Reliable observational quantification of these fluxes – and their accurate portrayal in climate models – is a major scientific challenge.

The dynamics of the air-sea boundary layer are characterized by a set of climate variables that change in a correlated manner on timescales ranging from hours to decades. On short time scales, there are the hourly life-cycles of mesoscale convective systems. On longer time scales, there are the intra-seasonal Madden-Julian Oscillation, the inter-annual El Niño/Southern Oscillation, and the decadal oscillations observed in the large ocean basins. To understand climate change, it is essential that scientists have accurate measurements of the complete array of air-sea climate variables on this full range of timescales.

A number of the air-sea climate variables can be simultaneously measured using satellite microwave (MW) sensor technology. These variables include sea-surface temperature (SST) and wind stress, near-surface vector winds, and atmospheric moisture in the form of vapor, clouds, and rain. Climate data records (CDR) for these air-sea variables, going back 2 to 3 decades (depending on variable), have been constructed by merging together MW observations from a diverse set of satellites, some of which were never intended to be used as climate sensors. The existing air-sea CDRs have been used by literally thousands of scientists for a variety of different purposes, including model evaluation, studies of natural internal variability, and anthropogenic signal detection. Such research has been a central part of the recent IPCC Assessments. The grand challenge for the future is to continue observations of these temperature, moisture, and circulation variables in a better and more systematic manner than the patchwork approach employed in the past. For reliable quantification of future climate change, it is imperative to continue these observations in an affordable and sustainable manner. This will require the development of low-cost MW sensor technology and launch systems.

2. Why are these challenge/questions timely to address now especially with respect to readiness?

The existing programs and plans for continuing the record of air-sea climate variables are inadequate. The measurement of global SST requires a MW channel near 7 GHz. The only two satellite sensors currently operating at this low frequency are NRL's WindSat and JAXA's AMSR-2. There are no planned follow-ons for either sensor, and WindSat is near its end-of-life. Inferring SST with infrared technology is impeded by contamination from clouds, aerosols, and water vapor. In contrast, MW measurements can easily see through thick layers of clouds and are essentially unaffected by water vapor and aerosols. NASA's GPM program flies a single MW imager called GMI. The lowest GMI frequency is 11 GHz, which does allow for SST retrievals in warm water (about half of the oceans), but GMI has no vector wind capability. Plans for a GMI follow-on are uncertain.

EUMETSAT MetOp satellites carry a C-band MW scatterometer, ASCAT, that measures vector winds and stress. There is no accompanying radiometer for measuring other air-sea variables. MetOp-A and -B are in nearly the same sun-synchronous orbit and hence have limited (12 hour) diurnal information. The EUMETSAT 2nd Generation MetOp satellites will carry a microwave imager, but this sensor will not have the lower frequency channels necessary for SST, accurate winds, and intense precipitation.

In the coming year, ISRO plans to launch the Ku-band scatterometer ScatSat, which will be followed by OSCAT2 in 2018-19. However, there is no accompanying MW radiometer with the full channel set necessary for measuring the complete array of climate variables.

3. Why are space-based observations fundamental to addressing these challenges/questions?

Improving scientific understanding of the nature and causes of climate change requires a complete and continuous picture of the dynamics of the air-sea variables. In turn, this requires global data coverage over all time scales mentioned above.

In situ observations are too sparse to provide the spatial-temporal detail needed. Additionally, a number of air-sea variables are either poorly measured or not measured at all by in situ instrumentation. In contrast, space-based sensor technology is extremely stable (in most cases), and can provide both global and regional decadal trends to an accuracy unobtainable from in situ data.

Furthermore, regional trends differ substantially from the global mean trend, and have a much larger impact than the global averaged trend. The interaction of these regional changes contributes to the global trend and to regional trends.

This is not to say in situ measurements are unimportant. They have always been used as the absolute calibration reference for satellite retrievals, and this need for calibration will continue into the future. Measurements from various types of satellite sensors are also needed for inter-calibration and validation activities. Precision validation requires consistency from a large array of similar in situ and satellite measurements.

The satellite sensor we envisage to meet future needs is a combined active-passive scatterometer/radiometer, which will measure all the above mentioned air-sea variables simultaneously. By flying the sensor in an inclined orbit, the diurnal cycle of the climate variables can be resolved. The combination of a C-band scatterometer and a multi-frequency polarimetric radiometer will, for the first time, provide unique vector winds (i.e., no ambiguities) under all weather conditions. The C-band scatterometer diurnal measurements will complement the sun-synchronous C-band measurements taken by MetOp's ASCAT. The observations obtained from this sensor would be a significant boon to oceanography, meteorology, and climate research and would support a continuing climate record. Additional operational scenarios include flying multi-frequency polarimetric MW radiometers in the same orbits as ASCAT and the ISRO scatterometers.