

Adding Uncertainty Information to the Ocean Suite of ESDRs from Microwave Imaging Instruments

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A NASA Earth System Data Records Uncertainty Analysis Project



Project Goals

- Add **realistic** and **useful** uncertainty information to Earth System Data Records (ESDRs) from Microwave Imagers
 - SSM/I, SSMIS, AMSR, AMSRE, WindSat, TMI
 - Over the ocean, we retrieve Wind Speed, Column Water Vapor, Cloud Water, Rain, and sometimes SST.
- We consider **3** general types of errors:
 - **Formal Input-Induced Error** – This is the error caused by errors in the measured radiances, when propagated through the retrieval algorithms.
 - **Modified Input-Induced Error** – This is additional error not captured by the Formal Input-Induced Error . Examples include errors due to undetected rain, proximity to land, or large spatial gradients in the geophysical field.



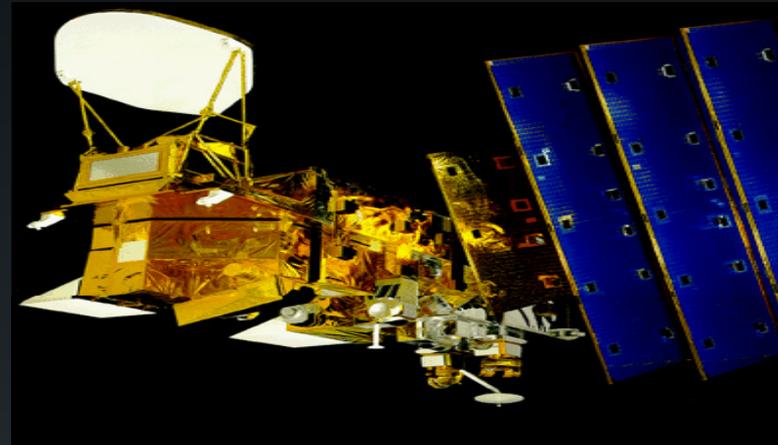
Project Goals

- **Long-Term Errors** – Errors that occur over multi-year time scales. Causes of this type of error include:
 - Drifts in sensor calibration
 - Between-satellite calibration errors
 - Changes in local measurement time due to orbital drift
 - **These are the most difficult to estimate accurately.**
- I will show examples of the analysis for the first two types of error. (Long-term error estimates are not ready for prime time)
- All examples are from the AMSR-E instrument mounted on the AQUA satellite.



Overview of AMSRE

- Conical Scanning Microwave Imager
- 12 Channels
 - 6.9 GHz (V,H)
 - 10.6 GHz (V,H)
 - 18.7 GHz (V,H)
 - 23.8 GHz (V,H)
 - 36.5 GHz (V,H)
 - 89.0 GHz (V,H)
- We use 10 channels to retrieve Sea Surface Temperature (SST), and either 6 or 8 channels to retrieve **Wind Speed**.





Adding Formal Input-Induced Errors to AMSRE

- **Approach:**

- We assume that the noise in the different channels is not correlated, so we can add the contributions to the uncertainty in any given geophysical parameters in quadrature.

$$\sigma_{SST}^2 = \sum \left(\frac{\partial SST}{\partial T_{B,CH}} \right)^2 \sigma_{T_{B,CH}}^2$$

$\sigma_{T_{B,CH}}^2$ is different for each channel, footprint size, and location in swath.

$\frac{\partial SST}{\partial T_{B,CH}}$ depends on channel, geophysical scene, and target footprint size.



Adding Format Input-Induced Errors to AMSRE

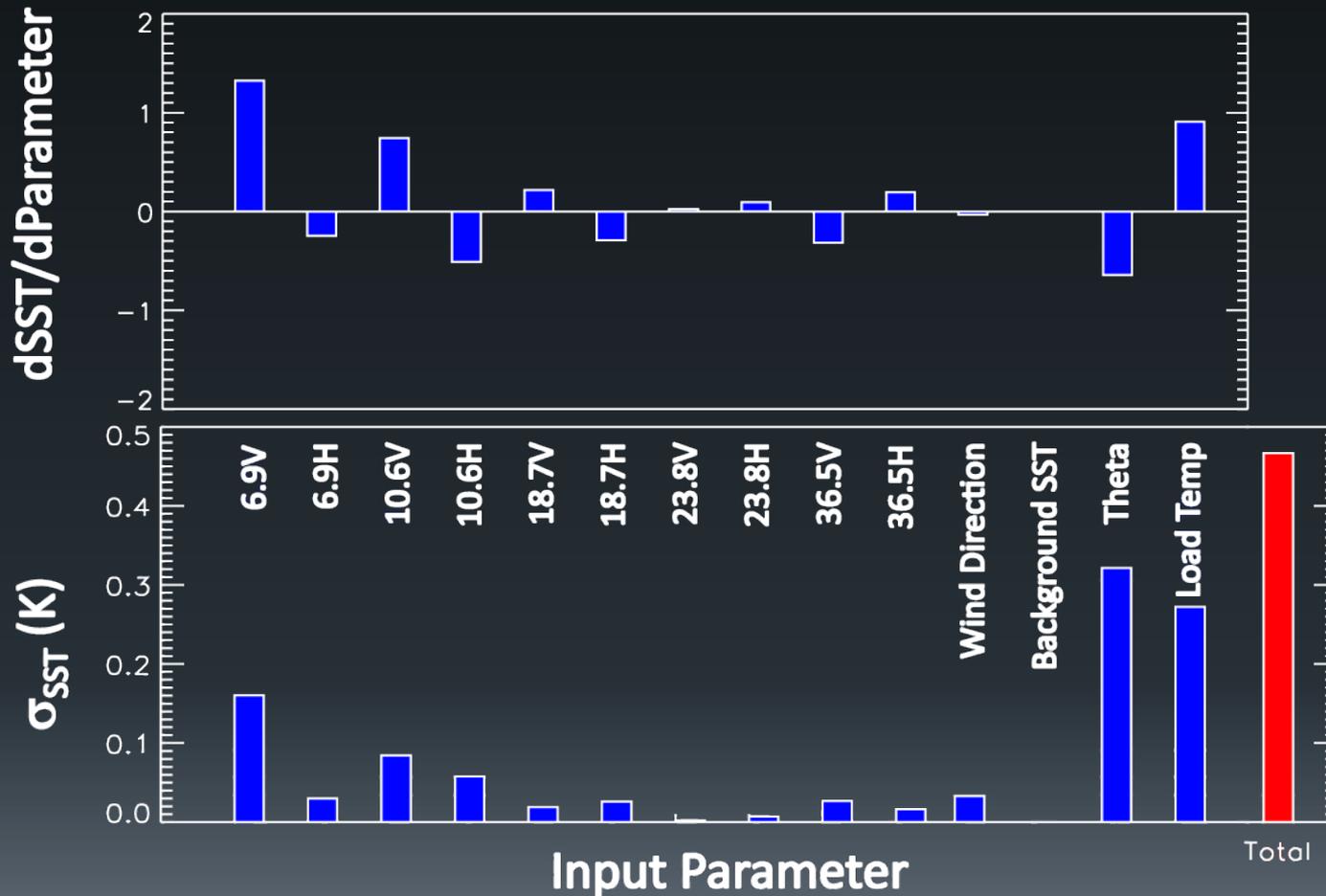
- There are also a number of sources of ancillary data that are used by the retrieval algorithm. These are:
 - Wind Direction (obtained from the NCEP GDAS Analysis)
 - Earth Incidence Angle
 - Background SST (obtained from the Reynolds OI SST)
- The results are also sensitive to errors in the specification of the temperature of the hot calibration load. This is correlated across all channels.
- Sensitivity to all these factors is calculated “brute force” by re-running the algorithm multiple times with perturbed inputs.



Results at a single grid point

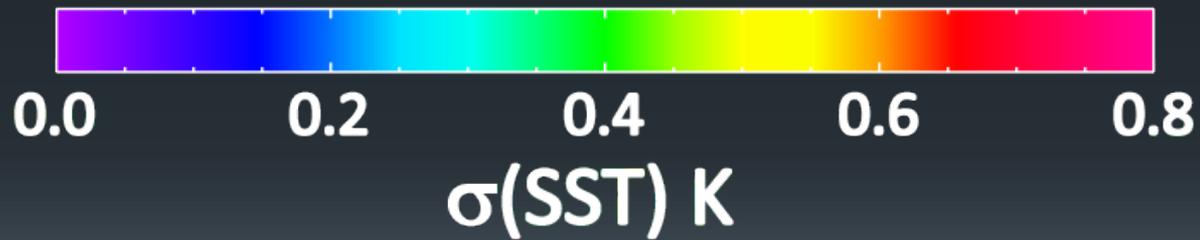
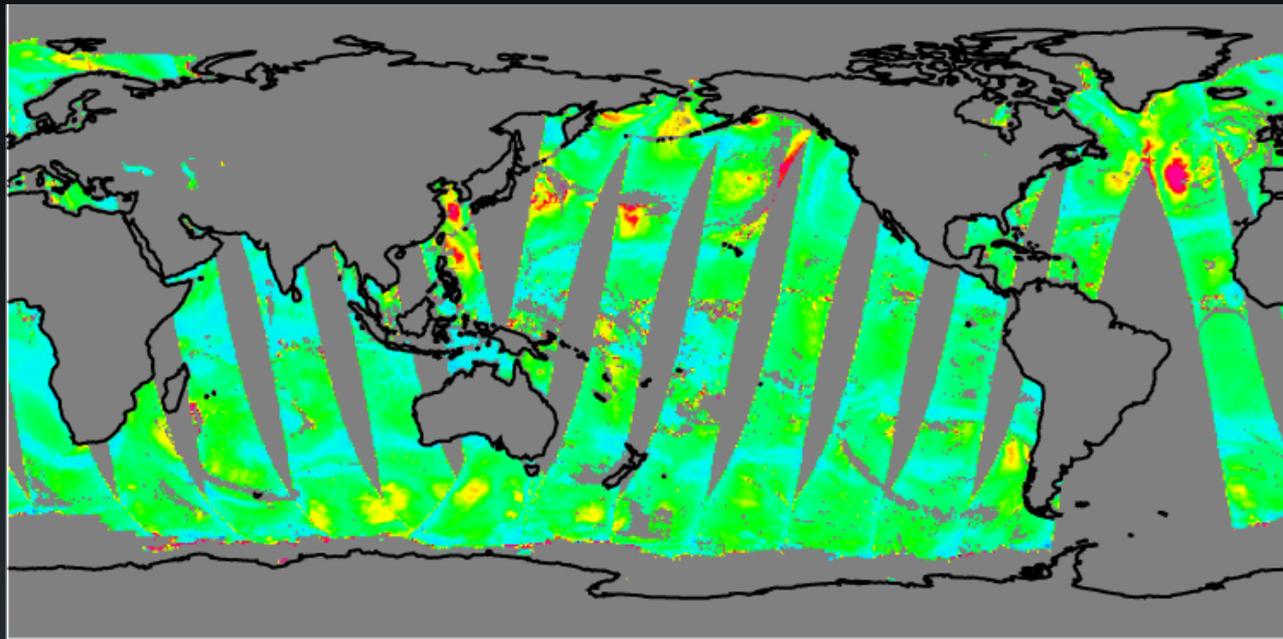
(7.04N, 103.69E) -- SST = 29.1, Wind = 7.1, Vapor = 43.25, No Clouds

$$\sigma_{EP}^2 = \sum \left(\frac{\partial EP}{\partial T_{B,CH}} \right)^2 \sigma_{T_{B,CH}}^2 + \left(\frac{\partial EP}{\partial \phi_r} \right)^2 \sigma_{\phi_r}^2 + \left(\frac{\partial EP}{\partial SST_{OI}} \right)^2 \sigma_{SST_{OI}}^2 + \left(\frac{\partial EP}{\partial EIA} \right)^2 \sigma_{EIA}^2 + \left(\frac{\partial EP}{\partial T_{CAL}} \right)^2 \sigma_{T_{CAL}}^2$$





Map of Formal SST Errors for 7 orbits

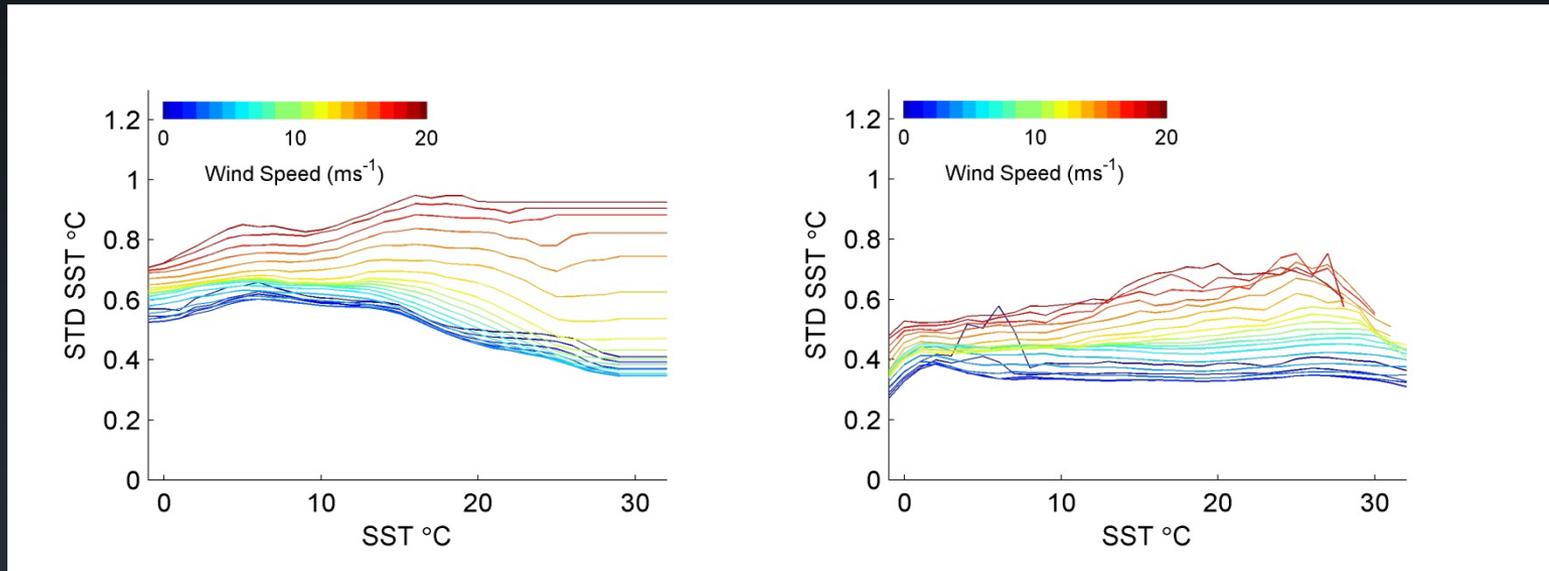




SST Errors as function of Wind and SST

Measured Differences
AMSRE vs. Buoys

Formal Errors in SST



Actual differences are larger than formal errors (as expected).
Formal errors capture dependence on Wind Speed



Other Error Sources

- ***Modified Input-Induced Error (MIIE)***
 - ***“We anticipate that the formal error estimate will often underestimate the observed error because of other unmodeled processes coming into play”***



Examples:

- Contamination of Tb's by land/ice emission
- RFI
- **Grid Points adjacent to rain**
- Large spatial gradients in the retrieved parameters, such as SSTs near the Gulf Stream or winds near gap-flow regions
- Extreme conditions, such as very high winds behind a mid-latitude front or in a tropical cyclone

- **We know that grid points adjacent to rain are degraded.**
 - (but not all our users know this!)
- **We typically exclude data near for climate analysis.**
- **Here, we quantify this degradation.**



Errors in Wind Speed Due to Adjacent Rain

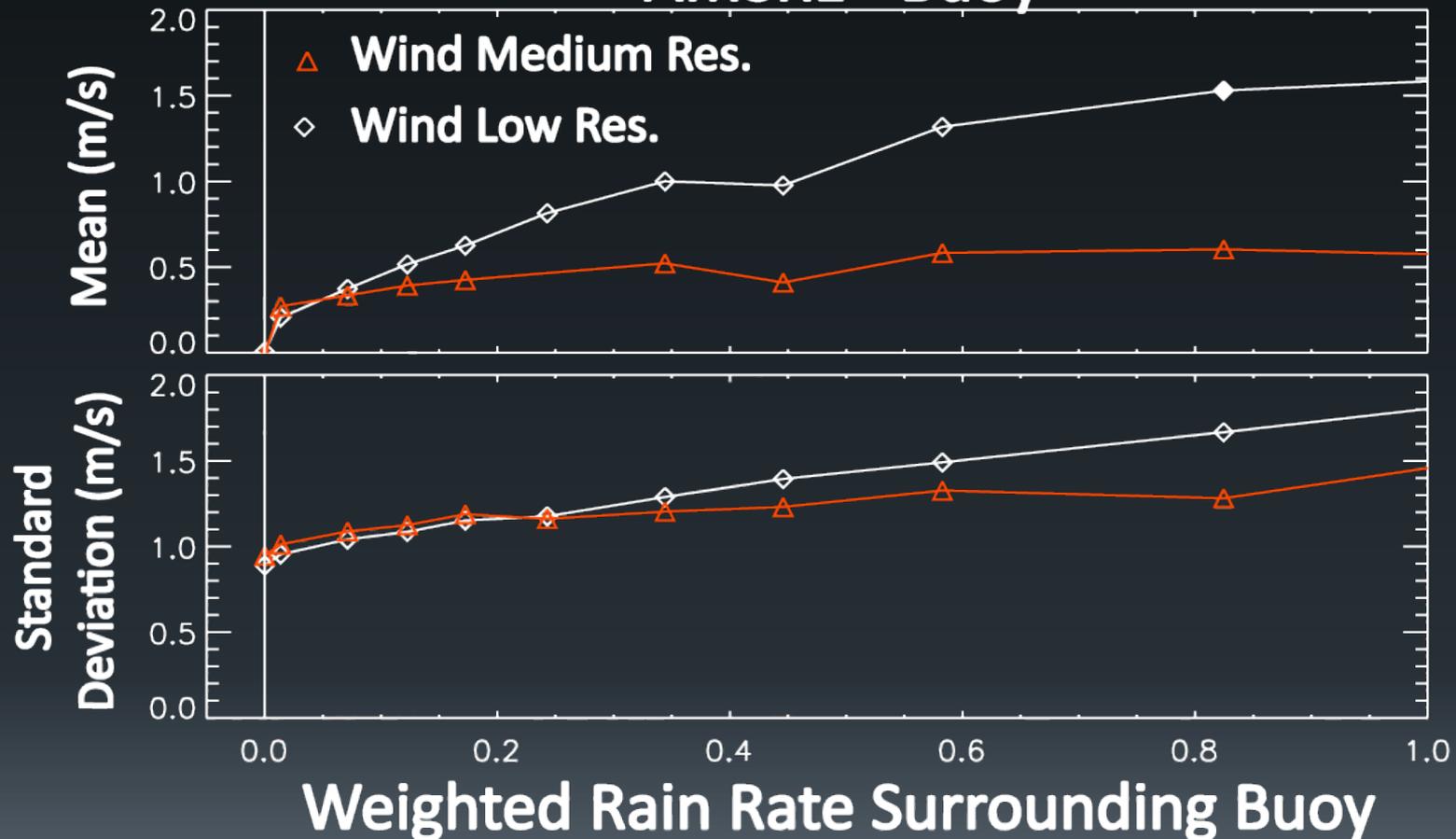
- Approach
 - Study Collocations with Moored Oceanic Buoys
 - Calculate Statistics as a function of nearby rain
- AMSRE (2002 – 2011)
 - 334,563 Collocations with Buoys with valid wind measurements
 - 292,810 (~88%) with no rain in adjacent grid points
 - 41,753 (~12%) have rain in adjacent grid points
- We produce 2 wind products from AMSRE
 - “Low resolution” 8-channel algorithm uses 10.6 GHz channels
 - “Medium Resolution” only uses 18.7, 23.8, and 36.5 GHz channels. Higher spatial resolution, but reduced performance far from rain.



Proximity To Rain Adds Error to AMSRE Wind Speed Retrievals

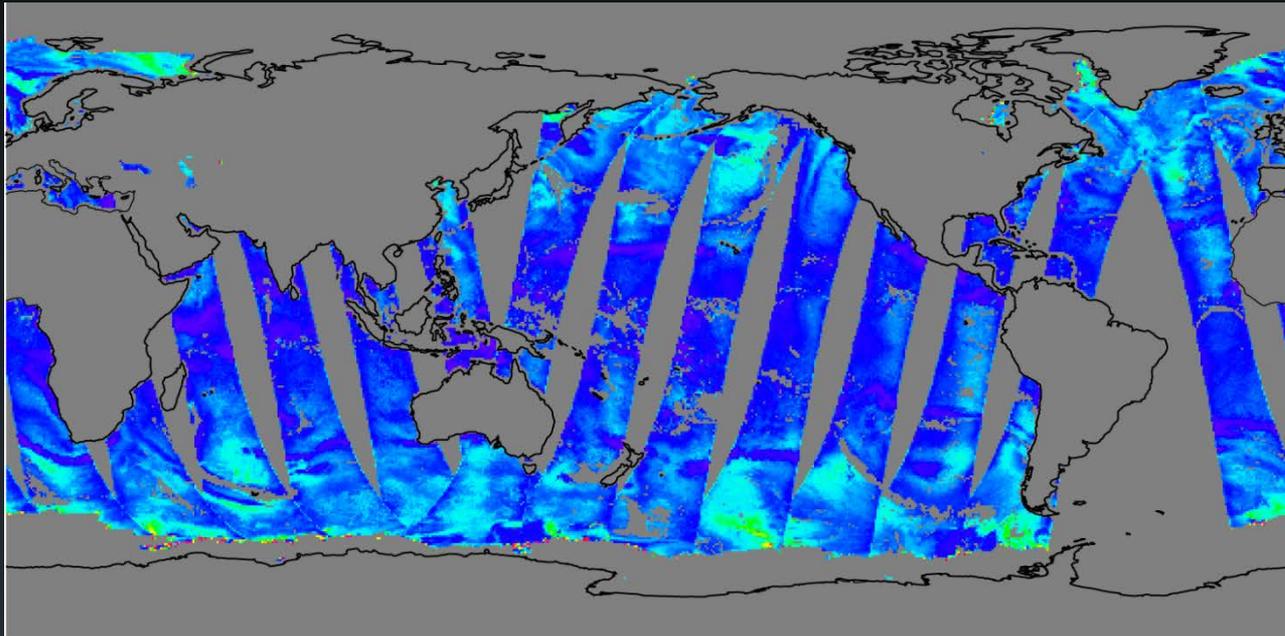
Wind Speed Differences as a Function of Rain

AMSRE - Buoy

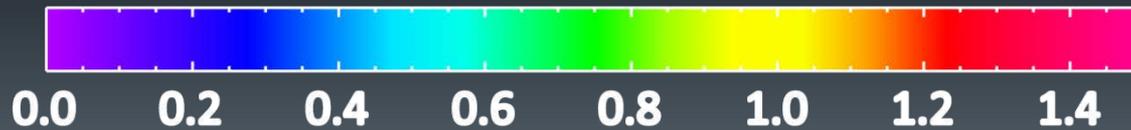




Wind Speed Error, Formal Error only

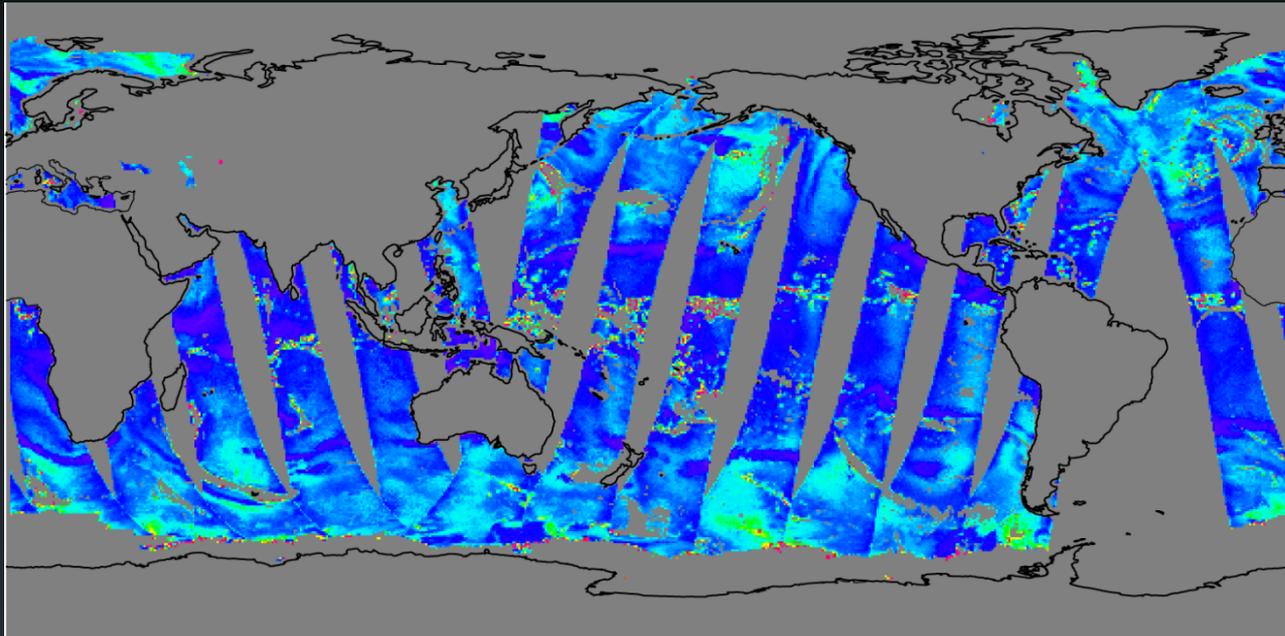


Estimated Wind Speed Error (m/s)





Wind Speed Error, Rain Proximity Effects Added



Estimated Wind Speed Error (m/s)



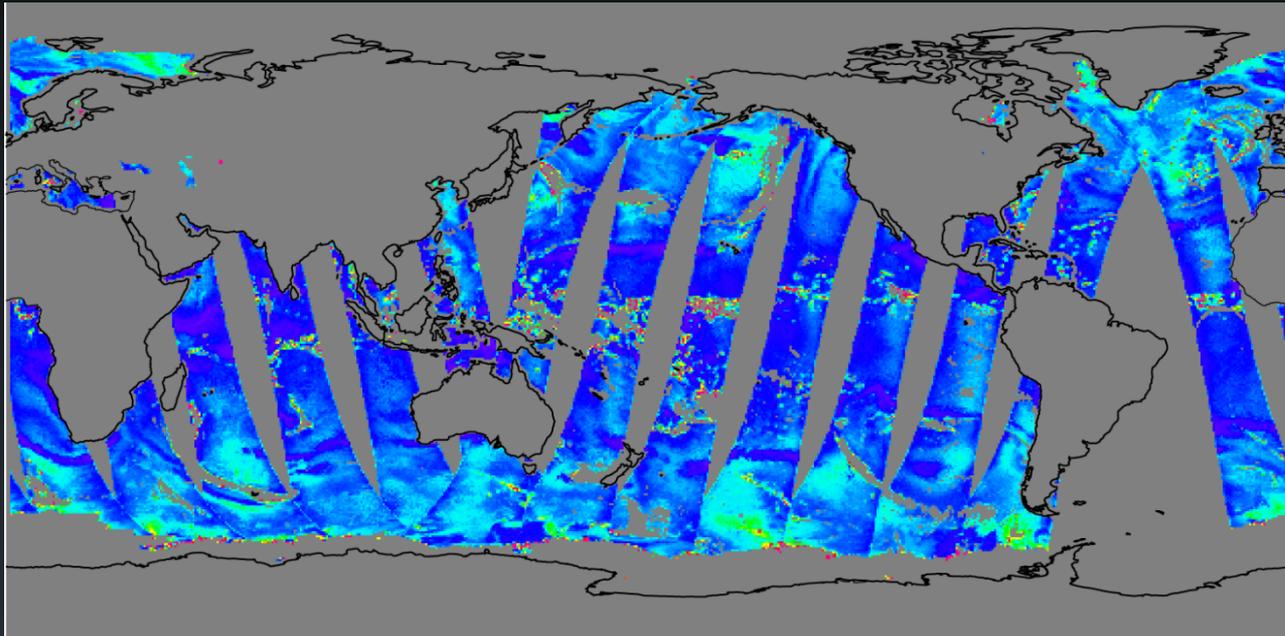


Summary

- We are developing algorithms to add uncertainty information to Earth System Data Records (ESDRs) from Microwave Imagers
- Formal Errors are well characterized for AMSRE
 - Method is easy to extend to other instruments
- We are evaluating and modeling additional error sources starting with cases where reliable *in situ* data is available
- Preliminary error product available in about a year



Wind Speed Error, Rain Proximity Effects Added



Estimated Wind Speed Error (m/s)

