Achieving Superior Tropical Cyclone Intensity Forecasts by Improving the Assimilation of High-Resolution Satellite Data into Mesoscale Prediction Models

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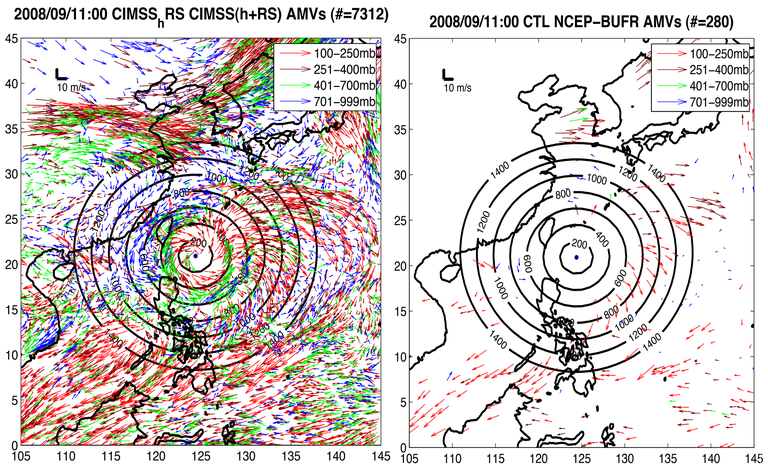
Goals

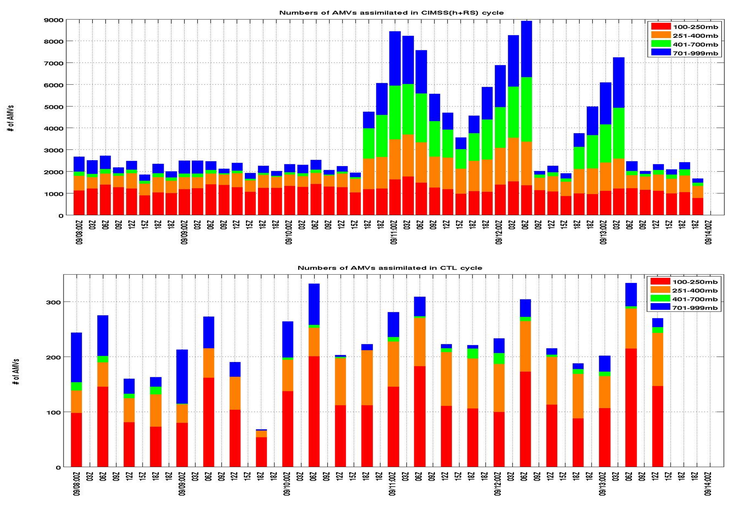
- Use integrated satellite data sets at their highest resolutions to improve forecasts of tropical cyclone intensity and track
- Quantify how to best combine these high-resolution datasets with high-resolution models
- Seek an optimal assimilation strategy for combined satellite data, using ensemble assimilation techniques, such as the EnKF-based DA within NCAR's WRF/DART

Satellite observation sets

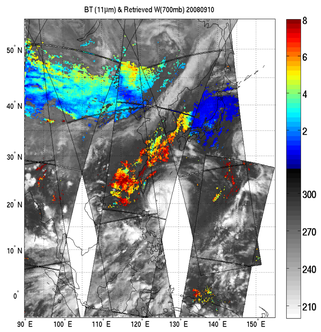
- Hourly and rapid-scan Atmospheric Motion Vectors (AMVs) from CIMSS
- Surface wind from ASCAT
- Hyper-spectral IR/MW temperature and moisture soundings (13.5km at nadir) from CIMSS
- Total Precipitable Water (TPW) from MW AMSR-E (17km)



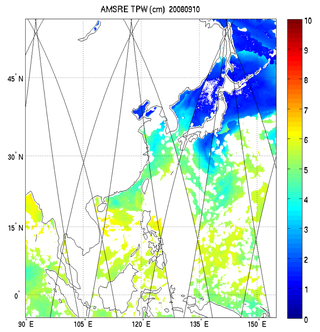
The hourly and rapid-scan AMVs from CIMSS used in this study (left) and the AMVs used by the NCEP/GFS in 2008 (right).



Number of hourly and rapid scan AMVs from CIMSS used in this study (top) and those used by the NCEP/GFS in 2008 (bottom).



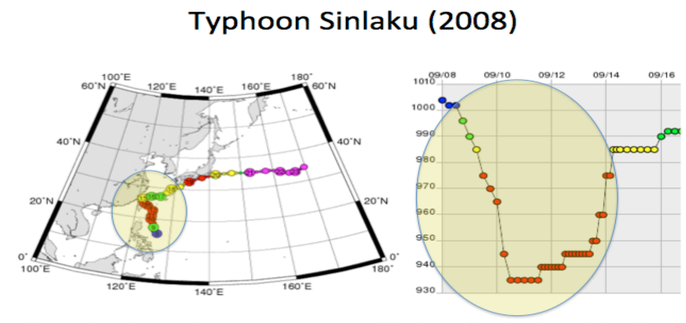
AIRS 700 hPa water vapor mixing ratio for 10 September 2008 in clear skies. The spatial resolution is 13.5 km at nadir.



AMSR-E microwave TPW images over ocean for 10 September 2008. The spatial resolution is 17 km (The white space near the TC is due to screening precipitating clouds).

Approach

- Use multiple and integrated satellite data sets at their full resolution in a high-resolution analysis/forecast system
- WRF/ARW and the ensemble adjustment Kalman filter in the NCAR Data Assimilation Research Testbed (DART); 84 ensemble members
- Assimilation/analyses every 3-hour, cycled continuously
- A 9km nest centered at TC center with feedback to 27km grid when a TC is present
- Satellite observations within plus/minus 1 hour of analysis times are used
- Typhoon Sinlaku (2008) with rapid intensification is studied

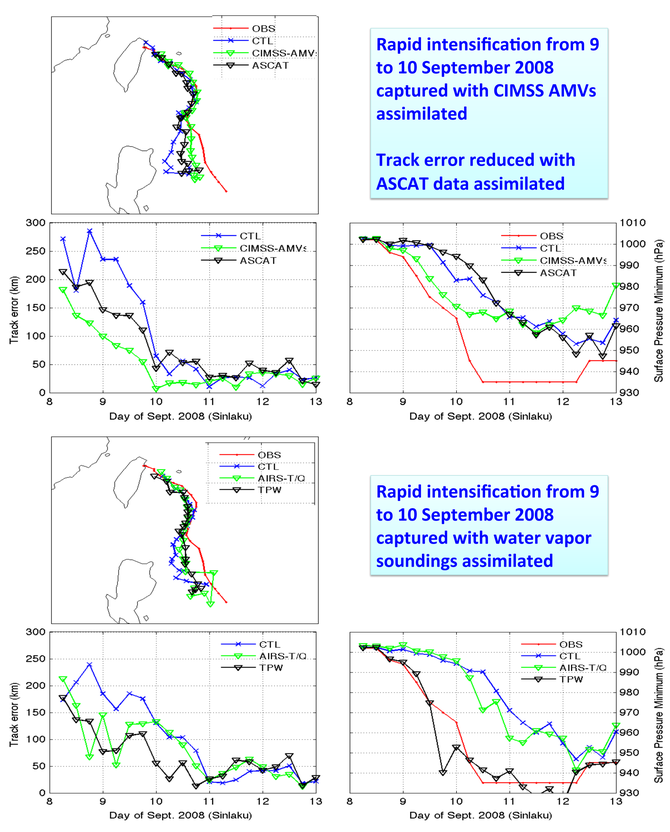


The track and central minimum pressure of Typhoon Sinlaku from JMA. The colors indicate the storm's category.

Assimilation Experiments Setup

- Control (CTL): Radiosondes, AMVs as used in NCEP/GFS, ACARS and aircraft data, station and ship surface pressure data, JTWC advisory TC positions; the assimilation started one week before TC genesis (September 1-14, 2008)
- CIMSS-RS3h: Replace the AMVs in CTL with CIMSS hourly and rapid-scan AMVs
- ASCAT: Add ASCAT surface wind data to CTL
- AIRS T/Q: Add AIRS T and Q profiles to CTL
- TPW: Add AMSR-E MW TPW data to CTL
- COMBINED: Add hourly and rapid-scan AMVs, ASCAT surface wind, AIRS T/Q soundings and AMSR-E TPW data to CTL

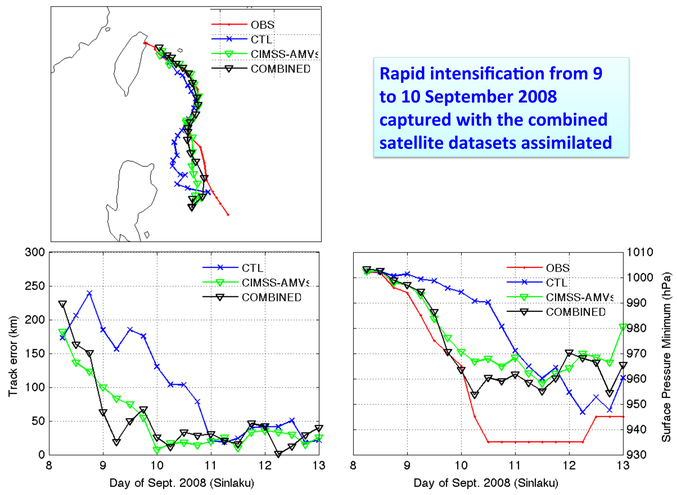
Impact on analyses of TC intensity and track



Rapid intensification from 9 to 10 September 2008 captured with CIMSS AMVs assimilated

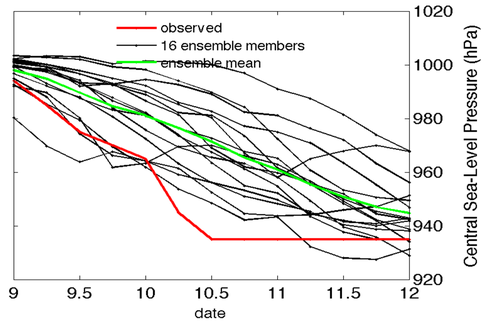
Track error reduced with ASCAT data assimilated

Rapid intensification from 9 to 10 September 2008 captured with water vapor soundings assimilated

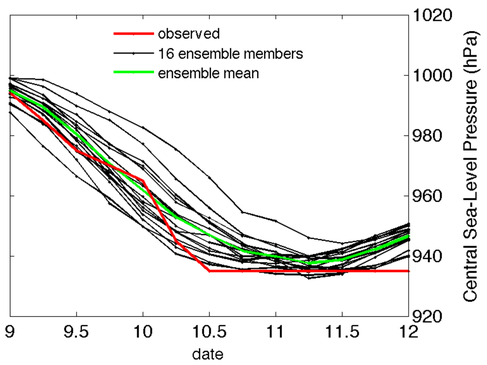


Rapid intensification from 9 to 10 September 2008 captured with the combined satellite datasets assimilated

Impact on 72-h TC intensity ensemble forecasts (initialized from 00Z September 9, 2008)



CTL forecasts do not capture the rapid intensification from 9 to 10 September 2008 and have large ensemble uncertainty.



COMBINED forecasts capture the rapid intensification from 9 to 10 September 2008. The ensemble forecast uncertainty is also much reduced.

Summary

- Assimilation of the hourly and rapid-scan AMVs from CIMSS produces noticeable improvement to the analyses of intensity and track in early stages
- Assimilation of the ASCAT surface wind and the AIRS T/Q data also improves the intensity and track analyses
- Assimilation of the combined observation sets produces overall better improvement to analyses and forecasts of the intensity and track
- Assimilation of the AMSR-E TPW data has potential to improve the analyses of intensification and track, although the very large improvement needs further study to be confirmed

References

Wu, Ting-Chi, Hui Liu, Sharan Majumdar, Chris Velden, and Jeffrey Anderson, 2013: Influence of Assimilating Satellite-Derived Atmospheric Motion Vector Observations on Numerical Analyses and Forecasts of Tropical Cyclone Track and Intensity, *Monthly Weather Review* (in press)

Acknowledgements

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