Remotely Sensed Surface Turbulent Fluxes and Validation with In Situ Observations

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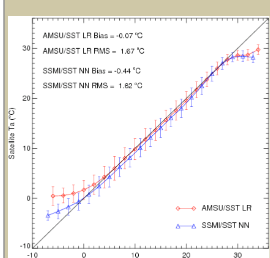
Introduction

- Surface turbulent fluxes are pathways coupling the atmosphere and ocean.
  - Energy, momentum, moisture, and gas transfer – many applications
- Fluxes can be computed from
  - Surface observations (in situ) or
  - Satellite observations (remotely-sensed)
- Each has advantages and known issues.
  - Satellite-derived fluxes have greater biases and random errors but advantageous spatial resolution and often better temporal sampling.
  - In situ derived fluxes have variability in spatial/temporal sampling depending on the region and the weather conditions.

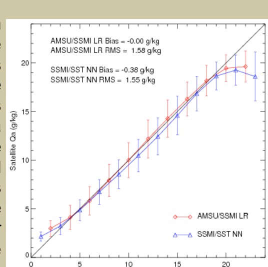
Retrieval Methods

- Satellite-derived turbulent surface fluxes are computed using radiances or backscatter, to determine bulk variables:
  - Vector winds
  - Air temperature
  - Atmospheric humidities
- Improved retrieval techniques have been developed to better resolve the flux input variables
  - Multiple linear regression (Jackson, et al., 2009)
  - Neural network regression (Roberts, et al., 2010)



Figures: Scatter plot of satellite-derived 10m air temperature (**left**) and 10m specific humidity (**below**) versus ICOADS (height-adjusted in situ data). The red curve represents Jackson et al. (2009) multiple linear regression technique. The blue curve, Roberts et al. (2010)'s neural network regression technique.

Both techniques perform well overall, but have biases near the tails. This also serves to validate the satellite-derived variables since these in situ data were not used to calibrate the satellite derived values. The relative bias and root mean square difference are shown for each retrieval technique (Bourassa et al. 2010)



Biases & Accuracies

- The bias is approximately uniform over most of the data distribution. Tails are an obvious exception. Work is underway to provide more data and better tuning for these tails.
- For the cases shown here, very few of the observations come from values near the tails
- Retrieved humidities and temperatures are bias corrected based on the comparison to the ICOADS data, and then used to estimate fluxes.
  - Biases due to neglecting these adjustments are shown below.
- The random error associated with satellite-derived data is approximately 1.5 times the random error associated with in situ data.
- The increased spatial resolution offered by satellite-derived data (with only a modest decrease in accuracy) helps to reduce the random error (Bourassa, et al., 2010).
  - Therefore, the use of satellite-derived data to compute the surface turbulent heat fluxes is a valuable approach to flux estimation over the global oceans.

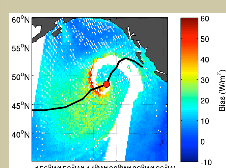


Figure (left): The bias associated with the latent heat flux for a large mid-latitude cyclone on 08 Oct 2004 18Z. The black line indicates track data of the storm, and the red dot, the center of the storm.

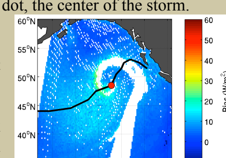
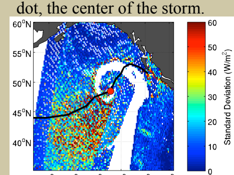


Figure (right): The bias associated with the sensible heat flux for a large mid-latitude cyclone on 08 Oct 2004 18Z. The black line indicates track data of the storm, and the red dot, the center of the storm.



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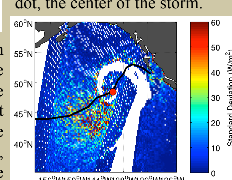

Figure (right): The random error associated with the sensible heat flux for a large mid-latitude cyclone on 08 Oct 2004 18Z. The black line indicates track data of the storm, and the red dot, the center of the storm.

References

Bourassa, M. A. (2006), Satellite-based observations of surface turbulent stress during severe weather, Atmosphere - ocean interactions, Vol 2., W. Perrie, 35-52.

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Satellite Retrieved Fluxes

- Bias adjusted satellite-derived bulk input variables are used to estimate the fluxes by the bulk aerodynamic flux approach.
  - Flux component variables are used to determine heat, moisture, and drag transfer coefficients
  - Transfer coefficients and component variables are input to the bulk aerodynamic formulae

$$LHF = -\rho L_v q_* |\mathbf{u}_*| \approx \rho L_v C_{eEN} (q_{10} - q_{sfc}) |\mathbf{U}_{10EN}|$$

$$SHF = -\rho C_p \theta_* |\mathbf{u}_*| \approx \rho C_p C_{hEN} (\theta_{10} - \theta_{sfc}) |\mathbf{U}_{10EN}|$$

ρ	air density	$\mathbf{u}_*$	friction velocity
C_D	drag coefficient	θ_*	temperature scale factor (analogous to friction velocity)
C_H	heat transfer coefficient		
C_E	moisture transfer coefficient	q_*	moisture scale factor
U_s	mean surface motion	T	mean air temperature
U_{10EN}	equivalent neutral wind at 10m	q	mean specific humidity
L_v	latent heat of vaporization	C_p	heat capacity

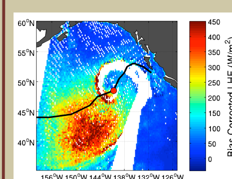

Figure (left): The bias-corrected latent heat flux associated with a large mid-latitude cyclone on 08 Oct 2004 18Z. The black line indicates track data of the storm, and the red dot, the center of the storm. These fluxes are computed from SeaFlux data version 0.75 using a modified version of the Bourassa (2006) algorithm with parameterizations from the CFC flux model.

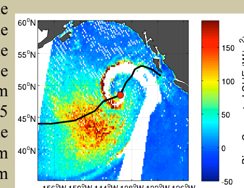

Figure (right): The bias-corrected sensible heat flux associated with a large mid-latitude cyclone on 08 Oct 2004 18Z. The black line indicates track data of the storm, and the red dot, the center of the storm. These fluxes are computed from SeaFlux data version 0.75 using a modified version of the Bourassa (2006) algorithm with parameterizations from the CFC flux model.

Summary

- Both in situ and satellite data are needed
- The benefits from the increased spatial sampling of the satellite data out-weigh the disadvantages of the reduced accuracy due to larger random errors in the satellite fluxes random error.
- The satellite temporal sampling is better outside of buoy arrays and major ship tracks, and spatial sampling is clearly better.
- Data from strong storms will improve our knowledge of the marine climate.

Acknowledgements

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