Diurnal Variations in Upper Ocean Temperature from Argo: Implications for the Ocean Mixed Layer

Sarah Gille

Scripps Institution of Oceanography
UCSD, La Jolla, CA
sgille@ucsd.edu
Assessing Diurnal Variability

- **Challenge:** What is the diurnal variability at the depth of the foundation temperature?

- **Upper Ocean Temperature:** Diurnal variability detectable from differences between AMSR-E microwave SST versus Argo top-of-profile temperatures.

- **Implications:** Wind also undergoes diurnal cycle. Relative phasing of diurnal temperature and wind variability can govern mean mixed-layer depth.

http://www.ghrsst.org/SST-Definitions.html
Diurnal Variability in Upper Ocean Temperature

- AMSR-E measures “sub-skin” temperature.
- Sun-synchronous orbit: roughly 1:30 am/1:30 pm
- Use Remote Sensing Systems level 2 product, version 5
- Day/night inconsistencies expected, so compare with Argo floats
Argo sampling

- Benefits
  - Global coverage (3000 floats with 10-day sampling)
  - Quality controlled data
  - Provide measure of sub-surface variability

- Challenges
  - No skin temperature
  - Coarse vertical resolution
  - Incomplete time information for profile
Matching Argo to AMSR-E

- Analysis period: 1 June 2002 through 10 Sept 2010
- Sample profile (float 4900275): 37.782 N, 147.143 W
- 26 September 2002, 15:30 GMT (equivalent to 5:40 local time)
- Consider top 5 measurements.
- Top measurement (6 m depth): $T = 21.673^\circ C$. 
Matching Argo to AMSR-E

- Linear interpolation to match position
- Consider multiple time separations: Descending passes (1:30 local time or 11:30 GMT) versus Argo profile at 5:40 local time
Matching Argo to AMSR-E: Observations Within ± 3 Hours

- AMSR-E minus Argo temperature for daytime satellite observations, “delayed mode” Argo data only.
- 40,169 data points, all latitudes, all seasons.
- Generally good agreement.
Matching Argo to AMSR-E: Parameter Dependence

- 43,704 nighttime (solid) and 38,119 daytime (dotted) AMSR-E/Argo pairs.
- Dong et al. (2006) also saw dependence on water vapor, wind speed.
- Are dependencies artifacts of wind?
Matching Argo to AMSR-E: Wind Effect Removed

- Suppressing wind effects reduces day/night differences but does not eliminate dependence on cloud water or columnar water vapor.
- Dependencies on latitude, temperature, season show less clear patterns when wind effects removed.
Daytime Argo minus AMSR-E

- Diurnal cycle evident, even with large time separations between observations.
• Diurnal cycle evident, even with large time separations between observations.
• Comparable in amplitude for ascending and descending satellite passes.
• AMSR-E and Argo differ by $O(0.1 \degree C)$: $\Delta T \neq 0$ at zero time lag.
Variations with latitude

- Diurnal variability visible at all latitudes.
- Amplitude smaller at high latitudes.
• Amplitude largest near equator.
• Stronger in summer.
• Tapers toward poles, but statistically significant.
• Daytime and nighttime amplitudes agree.
Phasing of diurnal signal

- Daytime and nighttime roughly agree.
- Maximum upper ocean T around 6 pm.
- Zero amplitude implies ill-determined phase.
How deep is the summer diurnal cycle detectable?
Summary

• Argo and AMSR-E agree well in upper ocean. Differences show satellite retrieval problems, Argo QC issues, and physical differences.

• Differences consistent with subsurface diurnal cycle.

• Diurnal cycle strongest in summer; amplitude varies with latitude.

• Maximum SST near 6 pm at surface.

• Phasing of diurnal wind relative to diurnal surface heating has potential to govern mixed-layer depth.

adapted from Gille et al, GRL, 2005
Putting SST in Context with Wind

QuikSCAT/ADEOS-2 tandem mission:
April-October 2003
Global Diurnal Phase for Wind Stress

adapted from Gille et al, GRL, 2005
Timing Diurnal Signals

- Sensible heat and upper ocean temperature stable in time
- Wind phasing varies geographically.
- What are implications?
How Much Impact Can Diurnal Variability Have?

- Price-Weller-Pinkel (PWP) model (JGR, 1986) implemented to look at mixed-layer depth $\langle \tau \rangle = 0.05 \text{ N m}^{-2}$.
- Constant winds show diurnal mixed layer depth.
How Much Impact Can Diurnal Variability Have?

- Price-Weller-Pinkel (PWP) model (JGR, 1986) implemented to look at mixed-layer depth $\langle \tau \rangle = 0.05 \, \text{N m}^{-2}$.

- Constant winds show diurnal mixed layer depth.

- Sinusoidal winds with zero phase delay deepening of mixed layer. ($\tau' = 0.02 \, \text{N m}^{-2}$.)
How Much Impact Can Diurnal Variability Have?

- Price-Weller-Pinkel (PWP) model (JGR, 1986) implemented to look at mixed-layer depth $\langle \tau \rangle = 0.05 \text{ N m}^{-2}$.
- Constant winds show diurnal mixed layer depth.
- Sinusoidal winds with zero phase delay deepening of mixed layer ($\tau' = 0.02 \text{ N m}^{-2}$.)
- Sinusoidal winds with other phases change mean depth of mixed-layer by ±10% and timing of deepening.
Varying wind strength and varying phasing

- Mean mixed-layer depth depends on strength of diurnal wind variability and on timing relative to radiative forcing.
Summary

- Argo and AMSR-E agree well in upper ocean. Differences show satellite retrieval problems, Argo QC issues, and physical differences.
- Differences consistent with subsurface diurnal cycle.
- Diurnal cycle strongest in summer; amplitude varies with latitude.
- Maximum SST near 6 pm at surface.
- Phasing of diurnal wind relative to diurnal surface heating governs mixed-layer depth.