Creation of the Systematically Merged Pacific Ocean Regional Temperature and Salinity (SPORTS) Climatology For Typhoon Intensity Forecasts: Haiyan

C. E. McCaskill, L. K. Shay, and J. K. Brewster

NOAA NESDIS
Motivation

- Ocean Heat Content (OHC) and tropical cyclones (TC)
  - Estimate OHC (and Evaluate Product)
    - Create a climatology (SPORTS) for OHC estimation following Meyers et al. (*JAOT*, 2014) for SMARTS

Super Typhoon Megi as seen from NASA's Terra satellite at 1am EDT Sunday 17 Oct 2010
Background

- OHC is an important factor in hurricane intensification
  - Opal, 1995 (Shay et al., 2000)
  - Katrina, 2005 (Jaimes and Shay, 2009)
  - Ivan, 2004 (Mainelli et al., 2008)
  - Megi, 2010
  - Haiyan, 2011
- Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008)
Background

Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008)
Background

- Proven to improve Statistical Hurricane Intensity Prediction Scheme (DeMaria et al., 2005; Mainelli et al., 2008)

Hurricane Opal
just south of Mobile, AL
4 October 95  2055 UTC

Hurricane Katrina
2005

OHC is an important factor in hurricane intensification

- Opal, 1995 (Shay et al., 2000)
- Katrina, 2005 (Jaimes and Shay, 2009)
- Ivan, 2004 (Mainelli et al., 2008)
- Megi, 2010
- Haiyan, 2011
Background

- Proven to improve Statistical Hurricane Intensity Prediction Scheme (DeMaria et al., 2005; Mainelli et al., 2008)

Images:
- Hurricane Opal, 1995 (Shay et al., 2000)
- Hurricane Katrina, 2005 (Jaimes and Shay, 2009)
- Hurricane Ivan, 2004 (Mainelli et al., 2008)
- Hurricane Megi, 2010
- Typhoon Haiyan, 2011
Background

- Proven to improve Statistical Hurricane Intensity Prediction Scheme (DeMaria et al., 2005; Mainelli et al., 2008)

Hurricane Opal, 1995 (Shay et al., 2000)
Hurricane Katrina, 2005 (Jaimes and Shay, 2009)
Hurricane Ivan, 2004 (Mainelli et al., 2008)
Hurricane Megi, 2010
Hurricane Haiyan, 2011

OHC is an important factor in hurricane intensification.
Background

- OHC is an important factor in hurricane intensification
  - Opal, 1995 (Shay et al., 2000)
  - Katrina, 2005 (Jaimes and Shay, 2009)
  - Ivan, 2004 (Mainelli et al., 2008)
  - Megi, 2010
  - Haiyan, 2011

- Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting
  (DeMaria et al., 2005; Mainelli et al., 2008)
OHC is an important factor in hurricane intensification

- Opal, 1995 (Shay et al., 2000)
- Katrina, 2005 (Jaimes and Shay, 2009)
- Ivan, 2004 (Mainelli et al., 2008)
- Megi, 2010
- Haiyan, 2011

Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008)
OHC is an important factor in hurricane intensification. For instance, Hurricane Opal in 1995 (Shay et al., 2000), Hurricane Katrina in 2005 (Jaimes and Shay, 2009), Hurricane Ivan in 2004 (Mainelli et al., 2008), and others have been shown to improve the Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008).

Background

Hurricane Ivan

2004
Background

- OHC is an important factor in hurricane intensification
  - Opal, 1995 (Shay et al., 2000)
  - Katrina, 2005 (Jaimes and Shay, 2009)
  - Ivan, 2004 (Mainelli et al., 2008)
  - Megi, 2010
  - Haiyan, 2011
- Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008)
OHC is an important factor in hurricane intensification.

- Opal, 1995 (Shay et al., 2000)
- Katrina, 2005 (Jaimes and Shay, 2009)
- Ivan, 2004 (Mainelli et al., 2008)
- Megi, 2010
- Haiyan, 2011

Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008).
OHC is an important factor in hurricane intensification.

- Opal, 1995 (Shay et al., 2000)
- Katrina, 2005 (Jaimes and Shay, 2009)
- Ivan, 2004 (Mainelli et al., 2008)
- Megi, 2010
- Haiyan, 2011

Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008).

Typhoon Megi
2010
Background

- OHC is an important factor in hurricane intensification
  - Opal, 1995 (Shay et al., 2000)
  - Katrina, 2005 (Jaimes and Shay, 2009)
  - Ivan, 2004 (Mainelli et al., 2008)
  - Megi, 2010
  - Haiyan, 2011

- Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008)
Motivation

- OHC is an important factor in hurricane intensification
  - Opal, 1995 (Shay et al., 2000)
  - Ivan, 2004 (Mainelli et al., 2008)
  - Katrina, 2005 (Jaimes and Shay, 2009)
  - Megi, 2010
  - Haiyan, 2011

- Proven to improve Statistical Hurricane Intensity Prediction Scheme (SHIPS) intensification forecasting (DeMaria et al., 2005; Mainelli et al., 2008)
Conceptual Model

- SST – Sea Surface Temperature
- MLD – Mixed Layer Depth
- D26 – Depth of the 26°C isotherm
- D20 – Depth of the 20°C isotherm
- OHC – Ocean Heat Content

- Integrated Thermal Energy
  Leipper (1967)

\[ OHC = c_p \rho \int_{D_{26}}^{Sfc} (T_z - 26^\circ) dz \]
Basin-Wide SPORTS OHC

2.5-layer model uses SPORTS climatology with daily SSHA and SST to estimate daily OHC
Climatologies for SPORTS

- Generalized Digital Environmental Model v3.0 (GDEM)
- GDEM v2.1
- World Ocean Atlas 2001 (WOA)

(Figure from Shay and Brewster, 2010)
SPORTS Climatology

- Weighted blend of GDEM v2.1 and WOA climatologies
  - Based on 267,540 quality controlled in-situ profiles
  - Measuring accuracy of each climatology

\[ RMSD = \sqrt{\frac{\sum (x'_i - x_i)^2}{n}} \]

- Weighting equation for SPORTS value

\[ x_{SPORTS} = \frac{x_{GDEM}^2 RMSD_{WOA}^2 + x_{WOA} RMSD_{GDEM}^2}{RMSD_{GDEM}^2 + RMSD_{WOA}^2} \]
SPORTS Weighting Maps

Typhoon Season

Off Season

D20

D26

MLD

WOA Favored

GDEM Favored
SPORTS Verification

~267,540 qc-ed data points over 12-yr period (00-2011)
SSHA Mapping Error Field From Mariano and Brown (DSR, 1992)
SPORTS in Action – Typhoon Haiyan

11/03/2013
T(z) Time Series During Haiyan at TAO Mooring
Obs and Climatological T(z) (left) and Difference (right)
S(z) Time Series During Haiyan at TAO Mooring
24-hr Low-Pass Filtered 10-m Currents During Haiyan
Concluding Remarks

- 2.5 Layer model used to calculate OHC basin wide
- Satellite OHC good estimation (267,000 thermal Profiles!)
- Super Typhoon Haiyan
  - Intensified and sustained over high OHC (SSTs were relatively flat)
  - Progress on TAO mooring
    - Pre-storm conditions
      - In Situ OHC agreement with SPORTS
      - Warming at depth relative to climatology, Cooling in Mixed Layer
      - Salinity max below MLD.
    - Oceanic Response
      - Reduction in OHC
      - Tightening of salinity gradient
      - Near-Inertial Current response at 8N periods of ~3 days
- ARGO Float Analyses