JTWC Operations Overview
&
Tropical Cyclogenesis Monitoring

E. M. Fukada
JTWC Technical Adviser
• Provide tropical cyclone reconnaissance, forecast, warning, and decision support to the United States Government agencies for the Pacific and Indian Oceans as directed by Commander, United States Pacific Command.

• Provide tsunami decision support to Department of Defense - U.S. Navy shore installation and fleet assets as directed by Commander, Fleet Forces Command.
**JTWC Tropical Cyclone AOR**  
West coast of Americas to east coast of Africa

* Including WMO-sponsored Regional Specialized Meteorology Centers (RSMC) and percent of tropical cyclones by region

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**Joint Typhoon Warning Center**  
**Forward, Ready, Responsive Decision Superiority**
JTWC Personnel Responsible for 24hr/day Monitoring and Forecasting “Watch Section”

- Typhoon Duty Officer - the focal point
  - USN & USAF (civilian) with graduate degree in Meteorology
  - USN (military), 3 year tour

- Satellite Analyst/Forecaster
  - USAF journeyman forecaster

- Geophysics Technician
  - USN forecaster in-training

USN – United States Navy
USAF – United States Air Force
Watch requirements

• Analyze existing situation (synoptic & mesoscale)
• Locate and assess all tropical disturbances/tropical cyclones in AOR
• Review numerical model output
• Make TC track and intensity forecast
• Communicate analyses and forecasts to U. S. DoD weather and NWS personnel
Tropical Cyclone Warning Content

- “Strategic” parameters provided by JTWC
  - TC winds over open ocean/waters
  - No forecasts for precipitation
  - No forecasts for seas, surf, waves or surge
- “Tactical” forecast parameters provided by U. S. military and/or U. S. National Weather sites for specified areas/region
  - U.S. Navy weather provides forecasts for Japan
  - NWS WFO Tiyan provides forecasts for Guam
TC Operations

• Multiple “fixes” are utilized to determine tropical disturbance location and intensity
  – Multiple sensors
  – Multiple sites

• Remotely sensed data analysis/interpretation conducted by Sat Analyst who is co-located with the Typhoon Duty Officer
  – Co-location optimizes interaction between analyst and forecaster

Fix - Tropical cyclone position and intensity determined through specified reconnaissance datas
Position/Intensity Fixes
- Exclusively remotely sensed data – satellite/radar
- A/C recon ended 1987
- Infrared/Visible Imagery Fixes every 3 hours
- Microwave Imagery fixes as imagery is available

Satellite Fixes by Agency
- 2012 Total 12,734 fixes
- 8,321 completed at JTWC
- Multiple fixes aids in TC position & intensity estimation
The JTWC AOR encompasses over 110 million sq. miles and nearly 89% of global TC activity. Process efficiency must be a critical performance parameter consideration for R&D transition.
Automated Tropical Cyclone Forecasting System (ATCF)

• A product of more than 15 years of Navy / NHC collaboration
• Used in all the U.S. tropical cyclone forecasting centers and their support agencies
• Provides a common framework and common data formats, facilitating coordination among operational sites
• Major functions performed
  – Fix entry and display
  – Best tracking
  – Objective aid computation and display
  – Forecast creation and dissemination
Model and Forecast Trackers

FNMOC:
- NGPS
- JNJP
- GFDN
- COTC-GFS(NRL)
- COFN-NAVGEM
- C01C-C10C (ensemble)

NCEP:
- AVNO
- JAVN
- HWRF

NHC/CPHC:
- OFCL (forecasts)
- OKMO (moonfish)

AFWA:
- AFWA (WRF)
  - ME01-ME10 (4 m ensemble)
  - TM01-TM10 (30 m ensemble)

Hong Kong:
- VHHH (forecast)

New Zealand:
- NZKL (forecasts)

Japan Met Agency:
- JGSM
- JENS
- JJGM
- RJTD (forecast)

Kenya:
- KMA (forecast)
  - KMA T426 Global Model
  - KMA Barotropic Model

Australias Bureau of Meteorology:
- ADFR, etc. (forecasts)
- ACES

IMD:
- DEMS (forecast)

PAGASA:
- RPMM (forecast)
  - (NOT AUTO ENTERED)

Indonesia:
- (forecasts)
  - (NOT AUTO ENTERED)

Canada:
- CMC
  - CEMN
  - (NOT AUTO ENTERED)

Germany:
- Model
  - (NOT AUTO ENTERED)

UK Met Office:
- EGRR
- UKMO
- JUKM

Fiji Met Service:
- NFFN (forecasts)

Taiwan CWB:
- RCTP (forecast)
  - TWRF

CMA:
- BABJ (forecast)

METEO France:
- FMEE (forecasts)
  - ARPG

ECMWF:
- ECMF
- EMX
- EEMN

NMFC/JTWC:
- BAM
- WBAR

Australia Bureau of Meteorology:
- AGRM

12 March 2014
JMA/WMO Workshop on Effective TC Warning SEASIA
Tropical Cyclogenesis Monitoring
Terms Used

• METWATCH
  – “Meteorological watch”; monitoring of area/region for which a SUSPECT AREA or INVEST has been determined

• SUSPECT AREA
  – Area or region for which the possibility of TC development exists

• INVEST
  – “Investigative Area”; location for which best tracking is conducted and “SAT Windows” are produced.

• SAT Window
  – @ 16 deg lat X 16 deg lat area centered over disturbance or TC

• TDO
  – JTWC Typhoon Duty Officer
NRL & FNMOC Tropical Cyclone Pages

- METSAT data windows made from JTWC, NHC and CPHC best track positions
- Data available for review from websites www.nrlmry.navy.mil/TC.html or https://www.fnmoc.navy.mil/tcweb/cgi-bin/tc_home.cgi
- Data also available for review via the ATCF
- JTWC primarily uses the Microwave data from the TC page
Sat Window Website

- Invest Area Sat Window centered based on JTWC, NHC or CPHC input best track position
- Invest Area designated as a 90-series cyclone in ATCF
Monitoring Overview

Constant metwatch conducted for AOR

- 24hr/day, 7-day/week looping of water vapor geostationary data
  - MET-7
  - MTSAT: http://www.ssd.noaa.gov/mtsat/twpac/wv-animated.gif
  - GOES: Eastern Pacific Ocean

- 12 hourly manual streamline analysis produced for 200mb (hPA) and surface levels

- Numerical forecast fields reviewed 6/12 hourly
  - GFS, NAVGEM, JGSM, out to 120hrs.
Conditions Required for Formation

- Warm SST (> 78 F)
- Pre-existing sfc disturbance
- Upper level divergence
- Lack of vertical shear
- Coriolis parameter above a minimum value
  - Excludes belt between 5 - 8 deg either side of Equator
Genesis Potential or Status Determination Guidelines

- **Metwatch** constantly conducted throughout AOR for convective maxima and/or areas of turning
- **Suspect Area** or **Invest** can be designated at Typhoon Duty Officer discretion to monitor location or region for development
  - Example: Invest area set when GFS model calls for TD to form near Guam and this forecast was made for 2 days of model runs
  - Example: Invest area set near Guam when one model run indicated TD to present close to island in 36 hours.
Data/Websites Used in Genesis Monitoring

- **CIMSS** Data Website
  - Regional data coverage used to help determine synoptic scale environment

- **RAMMB** Data Website
  - Cyclone or disturbance centric data used to determine structure or structure change

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* CIMSS – Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison

* RAMMB – Regional and Mesoscale Meteorology Branch, NOAA, co-located with the Cooperative Institute for Research in the Atmosphere, Colorado State University
Additional Data Used in Genesis Monitoring

Global Tropics Hazards and Benefits Outlook - Climate Prediction Center

Week 1 - Valid: Feb 19, 2014 - Feb 25, 2014

Week 2 - Valid: Feb 26, 2014 - Mar 04, 2014

Confidence
High
Moderate

Tropical Cyclone Formation
Development of a tropical cyclone that eventually reaches tropical storm/cyclone strength.

Above-average rainfall
Weekly total rainfall in the upper third of the historical range.

Below-average rainfall
Weekly total rainfall in the lower third of the historical range.

Above-normal temperatures
7-day mean temperatures in the upper third of the historical range.

Below-normal temperatures
7-day mean temperatures in the lower third of the historical range.

Produced: 02/18/2014
Forecaster: Baxter

Product is updated once per week. The product targets broad scale conditions integrated over a 7-day period for US interests only. Consult your local responsible forecast agency.
JTWC Effort to Increase Objectivity in Genesis Forecast Process

- **The low/medium/high (LMH) worksheet** is used to assess the potential for development of an invest area into a significant tropical cyclone.
- The worksheet is an attempt to utilize a systematic forecasting process to classify low, medium, and high tropical cyclogenesis potential from regularly observable factors.
- Genesis factors used in the worksheet:
  - Symmetry of the low level circulation center
  - 850mb vorticity
  - Dvorak final T-numbers
  - Global model development
  - Status of the Madden-Julian Oscillation
  - Vertical wind shear
  - Upper-level outflow pattern.
- A completed classification worksheet provides "trigger-based" recommendations for classifying genesis potential: If certain factors or combinations of factors exist, the worksheet advises the forecaster to upgrade or downgrade development potential on the appropriate analysis bulletin.
- Results from the worksheet are used as a guide to the TDO in determining appropriate invest classification levels: If the TDO does not follow (upgrade or downgrade) the worksheet results he/she will log the reasoning/explanation in the TDO E-log.
Low, Medium & High Criteria/Definition

- “Low” formation potential describes an area that is being monitored for development, but is unlikely to develop within the next 24 hours.

- “Medium” formation potential describes an area that is being monitored for development and has an elevated potential to develop, but development will likely occur beyond 24 hours.

- “High” formation potential describes an area that is being monitored for development and is either expected to develop within 24 hours or development has already started, but warning criteria have not yet been met.
  - All areas designated as “High” will be accompanied by a Tropical Cyclone Formation Alert.
Genesis Monitoring Example
JTWC WP012013 (Sonamu)

• Looped metsat data not recreated but is a fundamental part of the metwatch effort
• Continuity on the metwatch effort effected through use of logs (records) to ascertain TDO actions.
• Primary log is known as the TDO log
  – Following slide is excerpt of TDO log for @ 24hrs starting at watch (shift start) 1500Z (UTC), 1 Jan 2013
Excerpt from JTWC TDO log for 92W (later Sonamu) with TDO names removed
Genesis Monitoring Continuity Through Best Track Log – WP012013 (Sonamu)

01/00Z:
C. 4.4N 141.0E, 15 kts. A 0032z ascat pass suggests the llcc is located within the easterly wave feature, but is not well defined. ADL
D. 5.0N 140.7E bsd on 0032Z ASCAT AMB and 2352Z TRMM 37H. Concur 15kt DB. EMF

***Looked like Broad wave prior to this. Recommend deleting posits. JDC***

01/06Z:
A. 4.4 139.3E 15kts
B. 4.8N 138.4E BO 0537Z AMSU image. JDC
C. Concur with B. ADL
D. 5.0N 138.5E bsd on 0516Z N18 IRBD and 0537Z AMSU. Concur 15kt DB. EMF

01/12Z:
A. 4.5N 137.3E 15kts
B. 5.0N 136.3E BO extrap from 0854 SSMIS 37GHZ and 1612Z AMSU image. JDC
C. Concur with B as the VIS/IR imagery available does not improve this posit. ADL
D. Concur posit and int based on very sparse data. EMF

01/18Z:
A. 5.1N 134.0E 15kts.
B. 5.7N 133.8E BO 1622Z AMSU with weakest turning. JDC
C. Concur with B, as an 1818z f15 vis2km suggests the center is near this posit BO the observed banding features meeting in this vicinity. ADL
D. 5.7N 134.2E bsd on 1818Z F15 2km vis & 1830A SSML. Concur 15kt DB. EMF
Note common occurrence that fix scatter decreases as intensity/organization increases.
WP012013(Sonamu) 01 Jan 1800Z

01 1800Z position just south of Palau with intensity of 15kts
WP012013 (Sonamu) 1830Z SSMI 85H
Sonamu 011818Z DMSP F15 2km VIS
In Addition to Previously Noted Analysis Data – Following Data Review

• Full disk water vapor loop
  – JTWC routinely monitors water vapor for upper tropospheric convergence/divergence and convective patterns.

• Numerical model forecasts (two model output provided as example)
  – NAVGEM
    • U. S. Navy global spectral model
  – GFS
    • U. S. NWS global spectral model
Example of JTWC Cyclogenesis Monitoring

4 Power Point Slides from JTWC Morning Discussion
24 Feb 2014
Updates:

• 93W – Low
• 92P – New invest
93W

- Broad LLCC, 10-15 knots on periphery
- Persistent easterly VWS
- Most convection removed to NW of center
- 28°C + SSTs
- Multiple model development (~ 96 hrs +)
92P

- Low VWS, favorable outflow
- Limited deep convection
- SST ~ 30°C
- Multiple model development (~ 72 hrs)
Forecasting Tropical Cyclogenesis: Development Efforts at JTWC

Mr. Matthew Kucas – JTWC Techniques Development Team Chief
Focus on TC genesis:  
Low/Medium/High Worksheet

- **Goals:**
  1) Develop a realistic, quantitative framework for low, medium, and high development potential
  2) Provide forecasters a repeatable method to determine low, medium, and high development potential from available observational data

- Developed list of data and observable phenomena that influenced subjective poor/fair/good determinations

- Recorded values (binned) for eight “development factors” – 48 hour period prior to first warning for 17 developers and prior to invest closure for 17 non-developers

- Identified logical relationships between development factors to determine low, medium, and high classification recommendations

<table>
<thead>
<tr>
<th>Development Factor</th>
<th>Dataset Referenced</th>
<th>Value “Bins”</th>
</tr>
</thead>
</table>
| LLCC symmetry                    | ASCAT, visible and microwave satellite imagery, radar | Long axis diameter divided by short axis diameter: 
Between 1.5 and 2  
Between 1.2 and 1.5  
Less than 1.2 (~ symmetric) |
| 850 mb vorticity                 | CIMSS vorticity product | < 25/ s x 10^6  
25-50 / s x 10^-6  
50-75 x 10^-6/s x 10^-6  
>75 / s x 10^-6 |
| Dvorak T numbers                 | PGTW and KNES final T-numbers | 1.0  
1.5 or greater |
| Global model development         | NOGAPS, GFS, UKMET, JGSM, and ECMWF surface wind fields | Development Yes/No within 24 hours and within 48 hours |
| MJO OLR anomaly                  | Australian CAWCR OLR anomaly “waterfall” diagram | No or positive anomaly  
< -4 W/m^2  
< -12 W/m^2 |
| Vertical wind shear              | CIMSS vertical wind shear product | < 15 kts  
15-20 kts  
20-30 kts  
30+ kts |
| Upper level outflow pattern      | CIMSS upper-level feature track winds | Weak to no diffuence  
Moderate to strong diffuence, but no trough interaction  
Moderate to strong diffuence, with trough interaction |
| Core temperature anomaly         | CIMSS AMSU | 0-0.5 C  
5.- 1 C  
2.C  
>2C |
Logical relationships (version 1)

Classify as low if any of the following bulleted criteria are met:

- Long axis diameter divided by short axis diameter < 2 > 1.5
- 850 mb vorticity > 25 < 50 /s x 10^-6
- PGTW AND KNES final T = 1.0
- 2 or more global models indicate development within 48 hours
- Vertical wind shear less than 30 kts AND no convergence over LLCC AND MJO-associated OLR anomaly < -4 W/m^2
- Medium criteria met

Classify as medium if any of the following bulleted criteria are met:

- Long axis diameter divided by short axis diameter < 1.5 > 1.2 AND 850 mb vorticity > 50 < 75 /s x 10^-6
- PGTW final T = 1.5 OR KNES final T = 1.5
- 3 or more global models indicate development within 48 hours
- Vertical wind shear 20-30 kts AND divergence aloft over LLCC AND MJO-associated OLR anomaly < -4 W/m^2
- High criteria met

Classify as high if any of the following bulleted criteria are met:

- Long axis diameter divided by short axis diameter < 1.2 AND 850 mb vorticity > 75 /s x 10^-6
- PGTW final T = 1.5 AND KNES final T = 1.5
- 5 global models indicate development within 48 hours
- 3 or more global models indicate development within 24 hours
- Long axis diameter divided by short axis diameter < 1.2 AND vertical wind shear < 15 knots AND divergence aloft with outflow into an upper level trough
- At least four of the following are true: Long axis diameter divided by short axis diameter < 1.5 > 1.2, 850 mb vorticity > 50 < 75 /s x 10^-6, MJO-associated OLR anomaly < -12 W/m^2, vertical wind shear < 15 knots OR divergence aloft with outflow into an upper level trough, Long axis diameter divided by short axis diameter < 1.2, 850 mb vorticity > 75 /s x 10^-6
- Long axis diameter divided by short axis diameter < 1.5 > 1.2 AND 850 mb vorticity > 50 < 75 /s x 10^-6 AND EITHER PGTW final T = 1.5 OR KNES final T = 1.5
- At least four of the following are true: Long axis diameter divided by short axis diameter < 1.5 > 1.2, 850 mb vorticity > 50 < 75 /s x 10^-6, MJO-associated OLR anomaly < -12 W/m^2, vertical wind shear < 15 knots OR divergence aloft with outflow into an upper level trough, Long axis diameter divided by short axis diameter < 1.2, 850 mb vorticity > 75 /s x 10^-6

Classify as invest only if all low, medium, or high criteria remain unmet.
Study results

- Increased lead-times and more consistency using LMH method compared to the control (subjective poor/fair/good method)
Guided Worksheet
Genesis Potential Index

Peng et al. (2011) and Fu et al. (2011):

- Used TRMM satellite and NOGAPS analysis data to quantify key meteorological parameters related to TC genesis in the western North Pacific

- Applied nonlinear regression formulation to construct model to predict TC genesis in the 24 to 48 hour forecast period

- Trained model with 5 years worth of global analysis and TC best track data run in hindcast mode to derive Genesis Potential Index (GPI) applied in forecast mode

- Operational test for JTWC 2011 & 2012 - GPI parameters derived from NOGAPS analysis and TRMM combined satellite rainfall data:
  - 800 mb voriticity (maximum value associated with the disturbance)
  - 750 mb du/dy
  - 3-hour rainfall


Developing systems tended to show either a distinct increasing trend in GPI, particularly between 48 and 24 hours prior to formation, or a steady trend over several days at values exceeding the 0.2 development threshold.

Non-developing systems tended to maintain GPI values below 0.2 and, in the cases in which values exceeded 0.2, GPI tended to decrease.
Genesis Signals from Infrared Satellite Imagery

Piñeros et al. (2010):

- Office of Naval Research (ONR)-funded research supported by National Oceanographic Partnership Program (NOPP)

- Applied procedure (from Piñeros et al. (2008)) to transform infrared imagery into “variance” data based on symmetry of convection distributed around cloud cluster center

- Lower variance values, associated with more symmetric cloud clusters, found to be directly correlated with tropical cyclogenesis potential

- Key variance thresholds determined by training algorithm with satellite data
  - Must provide reliable positive detection, low false alarm rate, and useful detection (lead) time


DAV Study: 2012

- Threshold DAV value separated developers from non-developers (higher than previously-cited threshold – further study needed)

- Potential correlation between pre-genesis DAV and future storm intensity
NPS Statistical-Dynamical Forecast System

• Developed by Dr. Tom Murphree and David Meyer, Naval Postgraduate School

• Statistical-dynamical predictions of tropical cyclone formations with up to 90 day lead

  • Ensemble of climate model runs used to determine expected values of Large-Scale Environmental Factors (LSEFs) associated with TC formation – LSEF values used to determine probability of TC formation in different areas
• Actively involved in identifying potential TC formation areas during weekly Global Tropical Hazards/Benefits Outlook teleconference with Climate Prediction Center
• Coordinating application of AFWA’s MEPS ensemble to TC forecasting with the AFWA ensemble modeling group (20 km and 4 km resolution – 10 members each)

• Trackers in ATCF format now available for designated systems – evaluation ongoing
ECMWF Ensemble Op Test 2012: Observations

• 15 day ensemble more useful than 32 day ensemble for short-lead forecasting due to daily frequency

• A few false alarms with large number of members developing, but mostly the exception

• Cases with multiple clusters in same area – perhaps same system?

• Number of developing members – distinct increase over time for classified TCs

• Subtropical cyclones included in storm cluster analysis
ECMWF Ensemble Op Test 2013: Recommendations

• Provide “raw data” – number of tracks in cluster and average positions during forecast period

• Forecast continuity – label cyclone identified in subsequent runs with same number/designator

• Test “cyclone phase flag” to identify subtropical cyclones

• Flag instances when individual track cluster mean track is expected to outperform overall mean based on percentage of members present in cluster

• Proposals for evaluation/feedback:
  • Automatic integration of developing members and trends into LMH worksheet
  • Monthly reports
Questions?
References


• Piñeros, M.F., E.A. Ritchie, and J.S. Tyo, 2010: Detecting tropical cyclone formation from satellite infrared imagery. Preprints, AMS 29th Conf. on Hurricanes and Tropical Meteorology, Tucson, 9-14 May.