Extracting Weather Data from a Hybrid PAR

Tim Maese, BCI

Randy Case, US Navy PEO C4I & Space

18 November 2009

Ship-based Meteorological Radar Sensing

L-class Amphibious Ships

Cruisers / Destroyers

Aircraft Carriers

- US Navy aviation ships rely heavily on current and future weather conditions to conduct operations
    - Flight operations
    - Ship navigation
    - Amphibious landings

- Although meteorology personnel are onboard (Navy aerographers), equipment is limited to satellite imagery, upper air (rawinsonde systems), and local observations (temp. pressure, etc).
    - No onboard weather radar capability

- Adding a top-side weather radar sensor is too costly
    - Limited mast space for another sensor
    - Costly installation / maintenance for new equipment
    - Frequency compatibility issues

- *Solution: Use existing air-defense radar to provide weather data in addition to tactical mission – 'Through-the-sensor' Weather*
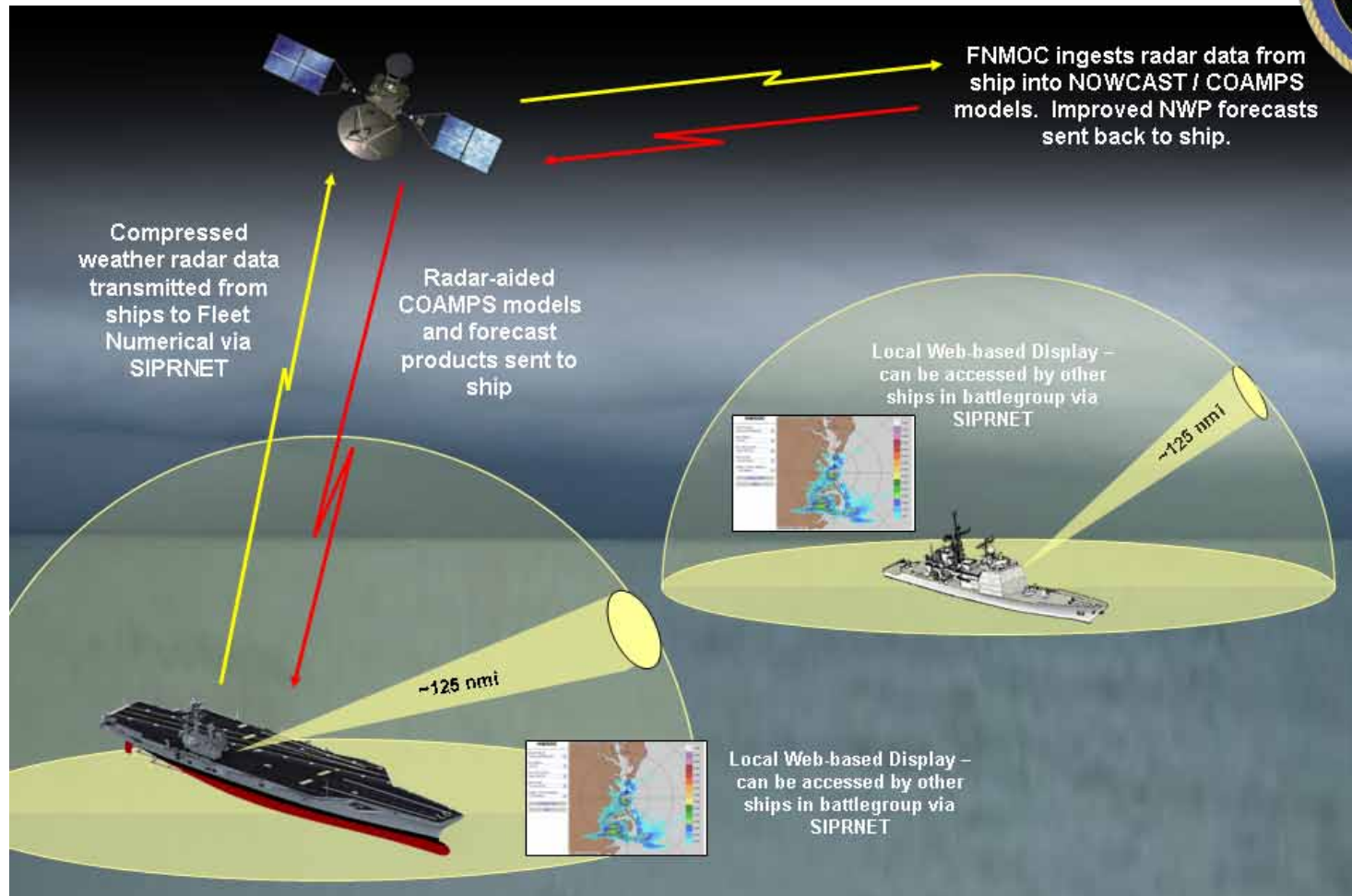
WRTTS – "Now we can see!"

Hazardous Weather Detection and Display Capability

FNMOC ingests radar data from ship into NOWCAST / COAMPS models. Improved NWP forecasts sent back to ship.

Compressed weather radar data transmitted from ships to Fleet Numerical via SIPRNET

Radar-aided COAMPS models and forecast products sent to ship

Local Web-based Display – can be accessed by other ships in battlegroup via SIPRNET

~125 nmi

~125 nmi

Local Web-based Display – can be accessed by other ships in battlegroup via SIPRNET

HWDDC/TEP Provide Local Weather Radar Coverage to Ships at Sea and In-situ Data for Improved Forecasts

WRTTS – "Now we can see!"

BCI

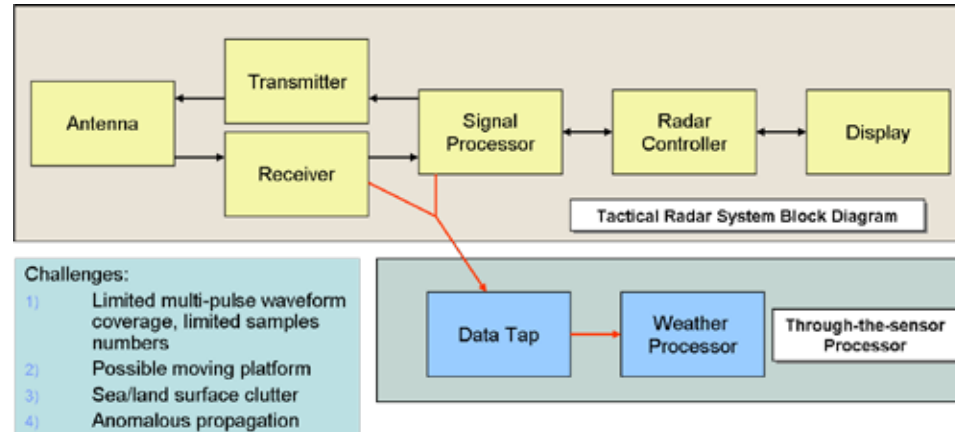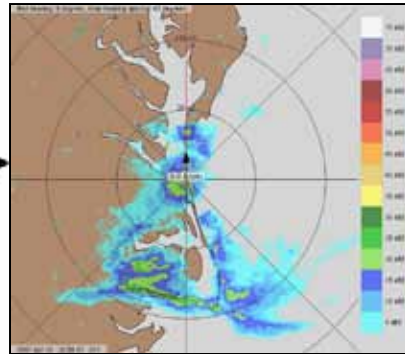# Weather Radar Through-the-Sensor (WRTTS)

AN/SPS-48E Radar

q WRTTS Processing provides weather radar data from tactical radar sensors using passive data extraction and off-line processing

    q Technology proven on US Navy radars (SPY-1 and SPS-48E)

    q Transitioning to ground-based radars for US Air Force

Digital Radar Return Data / Radar Scan Information

SIPRNET Connection – Weather Product Distribution

Commercial PC Weather Processor

Tactical Radar System Block Diagram

Antenna — Transmitter — Receiver — Signal Processor — Radar Controller — Display

Data Tap — Weather Processor — Through-the-sensor Processor

Challenges:
1) Limited multi-pulse waveform coverage, limited samples numbers
2) Possible moving platform
3) Sea/land surface clutter
4) Anomalous propagation

Through-the-sensor Weather Processing Eliminates the Need to Field Entire Radar Systems for Weather Detection
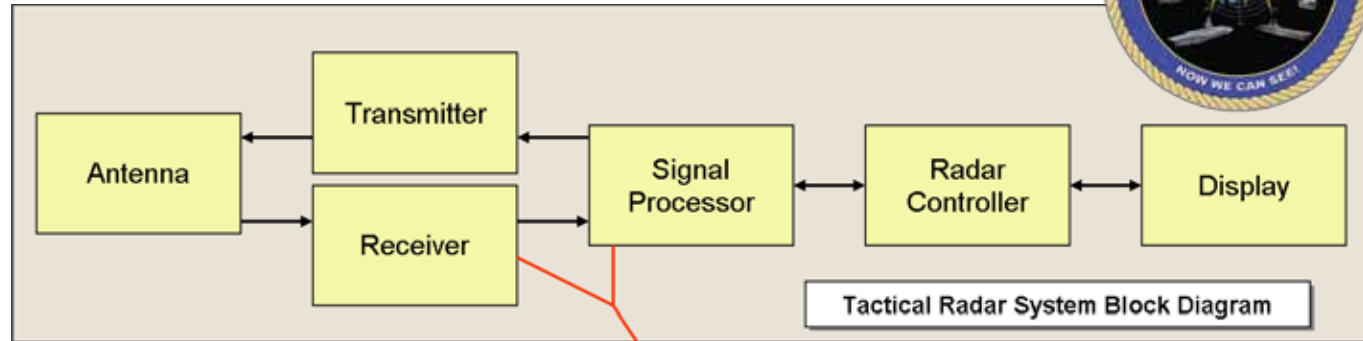
Processing Done in Parallel on Tactical Scan Data - No Impact to Tactical Mission or Performance

WRTTS – "Now we can see!"

HWDDC Processing Architecture

Tactical Radar System Block Diagram

Antenna — Transmitter — Receiver — Signal Processor — Radar Controller — Display

Challenges:
1) Limited multi-pulse waveform coverage, limited samples numbers
2) Possible moving platform
3) Sea/land surface clutter
4) Anomalous propagation

Data Tap → Weather Processor — Through-the-sensor Processor
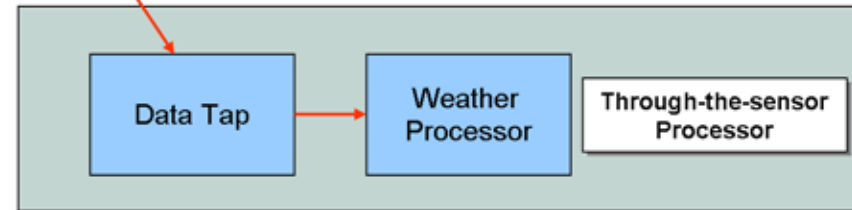
- Non-interfering data tap to prime radar
- Commercial rackmount PC servers
  - Linux operating system, 'soft real-time'
- Modular processing algorithms
  - Portable across radar systems
- Automated operation
  - Web-based Display and Data Dissemination

WRTTS – "Now we can see!"

Naval Air Surveillance Radars for TTS Processing

AN/SPS-48E Radar
CVN and L-class Amphibs

Main Challenges for TTS System:

1. **Effective clutter filtering with limited waveforms**

2. **Wind Profiling / Dealiasing with limited velocity coverage**

3. **Anomalous Propagation**

4. **Range Folding in MTI Waveforms**

- q 3-Dimensional Long Range Radar
  - q S-band Operating Frequency
    - q Similar frequency to NEXRAD
  - q High Peak Transmit Power (non-pulse compressed)
    - q Higher Power Than NEXRAD
  - q ~1.5 degree Antenna Beamwidth
    - q Wider than NEXRAD
  - q Linear Horizontal Polarization
  - q Mechanically Scanned in Azimuth (~4 second scan rate), Frequency (Phase) Scanned in Elevation
    - q Track-While-Scan Architecture
    - q Multiple Simultaneous Beams in Elevation
  - q Mixed Single Pulse and Multiple Pulse (MTI) Waveforms
    - q MTI fixed at low elevation angles only

Naval Air Surveillance Radars for TTS Processing

AN/SPY-1B/D
Cruisers and Destroyers

- 3-Dimensional Long Range Radar
  - S-band Operating Frequency
    - Similar frequency to NEXRAD
  - High Peak Transmit Power (Pulse Compressed)
    - Higher Power Than NEXRAD
  - ~1.5 degree Antenna Beamwidth
    - Wider than NEXRAD
  - Linear Vertical Polarization
  - Single / Dual Beams – Phase Scanned in Azimuth and Elevation
    - Fixed Volume Scan with Active Track Architecture
  - Mixed Single Pulse and Multiple Pulse (MTI) Waveforms
    - MTI scheduled based on clutter conditions or manually selected by radar operator

Main Challenges for TTS System:

1. **High Bandwidth Data Processing**

2. **Effective clutter filtering with limited waveforms**

3. **Wind Profiling / Dealiasing with limited velocity coverage**

4. **Anomalous Propagation**

BCI

US Navy WRTTS History

- 1997-1998: SPY-1 Weather Radar Experiment (Lockheed Martin – Office of Naval Research)
  - Proved weather extraction possible for SPY-1 radar waveforms

- 1998-2004: SPY-1 Tactical Environmental Processor (Lockheed Martin)
  - Two at-sea tests on USS OKANE (DDG77) and USS NORMANDY (CG60)
  - Validate system performance in operational environment
  - Characterized performance of Refractivity from Clutter (RFC) algorithms

- 2005-present: SPS-48E Hazardous Weather Detection and Display Capability (BCI)
  - Two at-sea deployments of prototypes: USS PELELIU (LHA5) in 2006-07 and currently on USS GEORGE WASHINGTON (CVN73)
  - Back-fit effort underway for 14+ SPS-48E equipped ships (CVN, LHA, LPD classes)

- 2007-present: SPY-1D(mod) Tactical Environmental Processor (BCI / Lockheed Martin)
  - Development of a TEP adjunct processor based on HWDDC technology for the SPY-1 Multimission Signal Processor (MMSP) radar upgrade
  - Planned 22+ shipset installation starting in 2013 (tied to SPY-1 upgrade schedule)

TEP and HWDDC System Capabilities and Architecture Merged to Provide a Common System Architecture for TTS Weather Sensing between SPY-1 and SPS-48E/G.
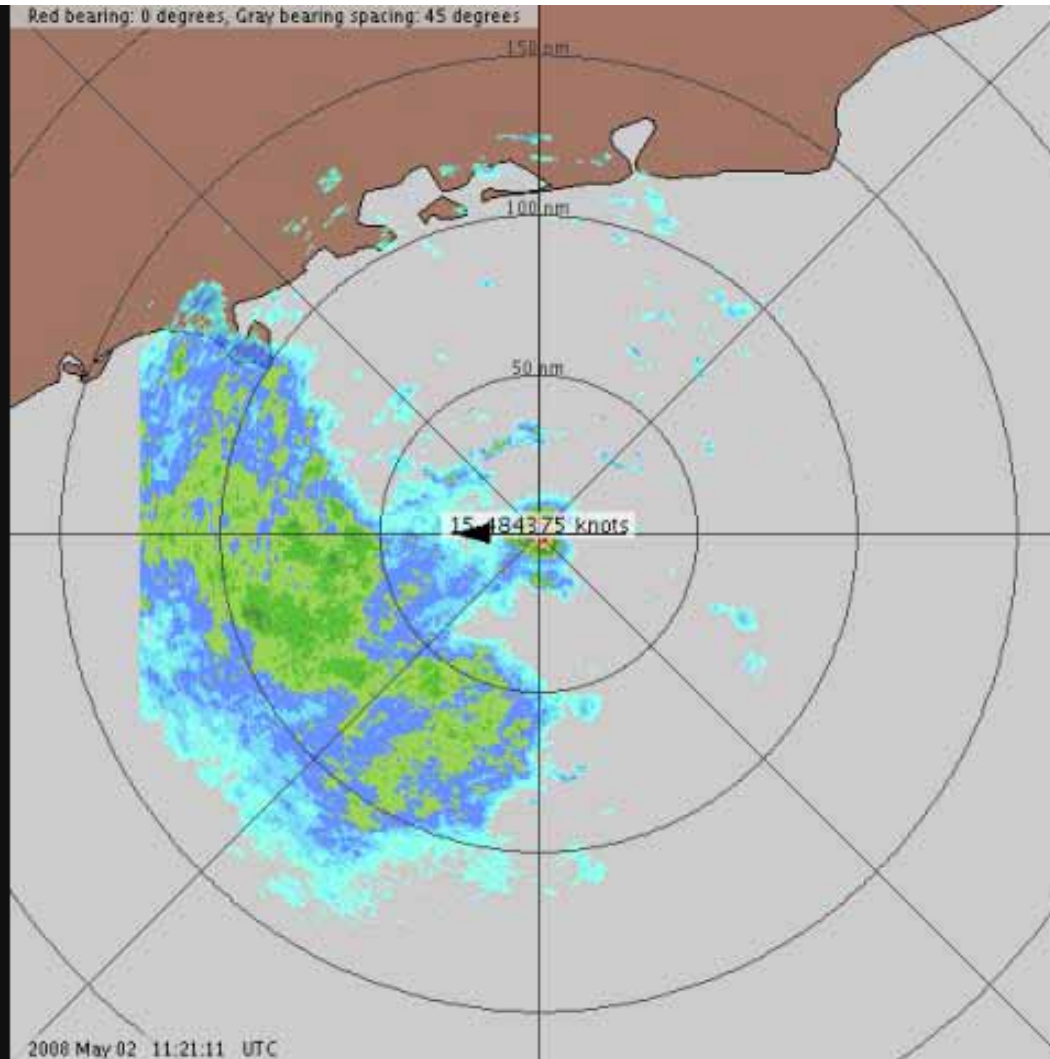
This Technology Can Be Applied to Many Different 3-D Surveillance Radars With Characteristics that Support Weather Detection

USS GEORGE WASHINGTON (CVN73) Demonstration

Red bearing: 0 degrees, Gray bearing spacing: 45 degrees

150 nm
100 nm
50 nm

15-4843.75 knots

2008 May 02 11:21:11 UTC

HWDDC System Installed on USS GEORGE WASHINGTON (CVN73) for Transit from Norfolk, VA to Yokosuka, Japan - Movie loop from 02 May 2008 off the coast of Brazil

System Development and Demonstration to Fielding in Under 5 Years

BCI

WRTTS – "Now we can see!"

Naval HWDDC System Capabilities

- Display and Dissemination Capability
  - Direct connection to SIPRNET
  - SIPRNET Service-oriented web-based displays
  - 'Pub-sub' type data access and dissemination off ship
    - Data and imagery access tested at SSC-SD and NRL-Monterrey
  - Real-time video feed to 23-TV and SVDS

- Derived Products
  - Composite Reflectivity
  - Wind Fields
    - 'Smart-VAD' vertical profile for non-homogeneous conditions
    - 2-D Wind Field Extraction (NCAR TREC)
  - Storm Track and Prediction
  - Echo Tops
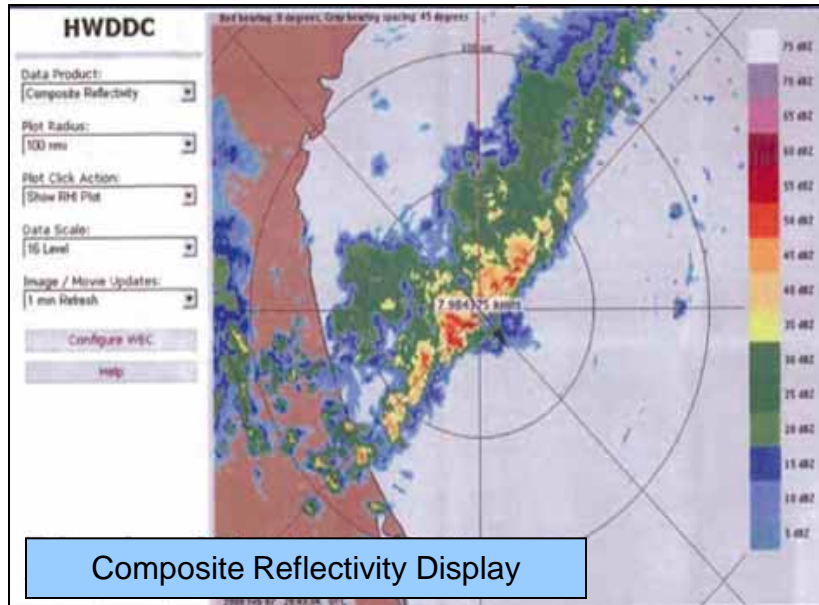 - Refractivity from Clutter (RFC)

- Spectral Moment Processing
  - Single Pulse Reflectivity and Pulse Pairs Processing
    - Base Reflectivity
    - Mean Radial Velocity
    - Spectrum Width
    - Dealiased Radial Velocity
    - Signal Quality Index (SQI)
  - Adaptive Sea/Land Surface Clutter Filtering
  - Point Clutter Rejection
  - Data Quality Control
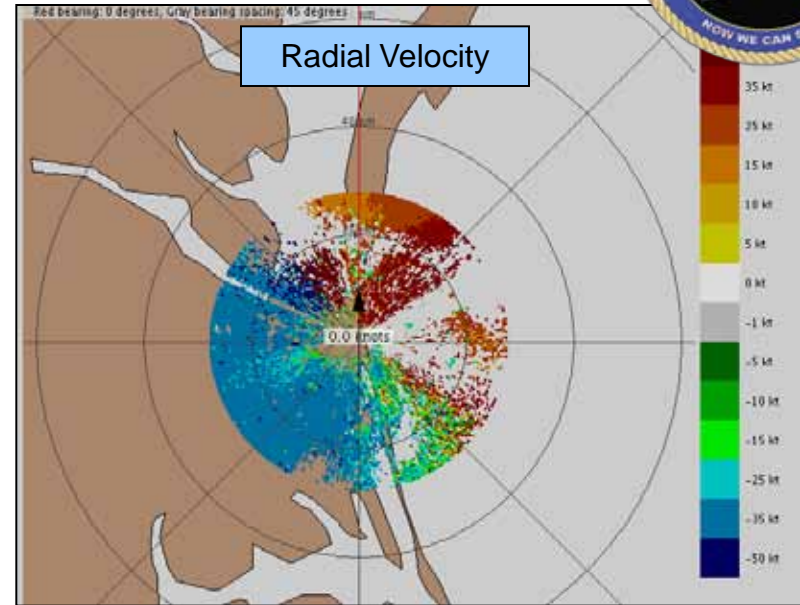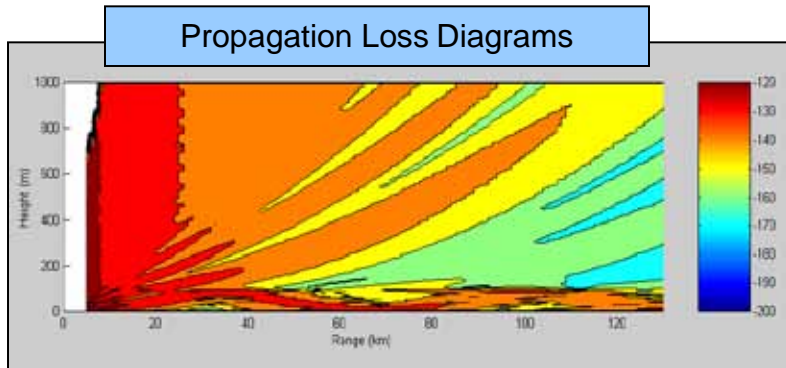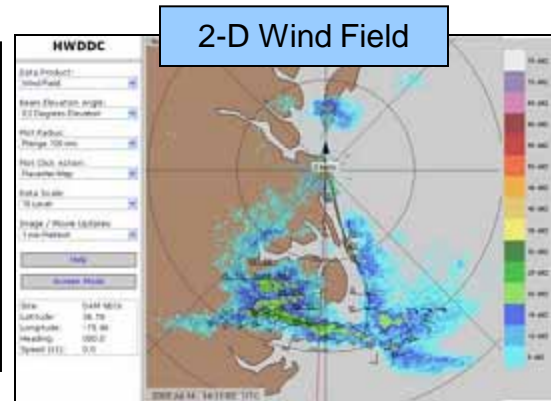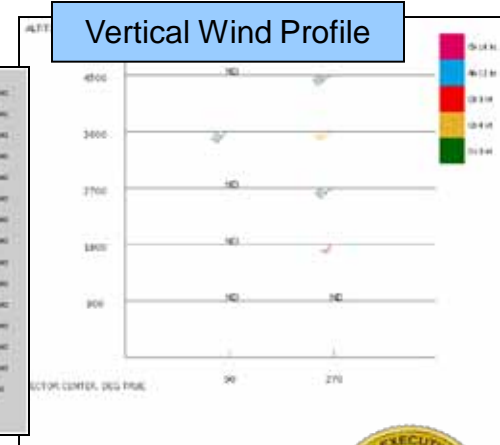
Example HWDDC Data Products

Composite Reflectivity Display

Radial Velocity

Propagation Loss Diagrams

2-D Wind Field

Vertical Wind Profile

USS GEORGE WASHINGTON (CVN73) Demonstration

From Military Utility Assessment for HWDDC System

System \ Features	NOAA-GOES	NOAA-DMSP	FNMOC	NEXRAD	TAF	Observations	HWDDC
Products	Visible and IR image	Visible and IR image	Model of all atmospheric tendencies	Composite and base reflectivity	Forecast of atmospheric conditions	Observe local atmospheric conditions	Composite and base reflectivity
Coverage	Western Hemisphere: Geostationary orbit	Global: Sun synchronous polar orbit	Global: Quality dependent on available data	CONUS, HI, AK, PR, GU, Okinawa, South Korea, Azores	Global: Population centers	Global: Ship-based (~12 mile radius)	Global: Ship-based (~ 150 mile radius)
Time latency	<30 min for prime weather zones; 2-3 hrs for other zones (i.e. S. Atlantic)	2 per day (day/night)	12 hrs	10 min in clear air mode; 6 min in precip mode	6 hrs	1 hr	5 min
Application of product	Planning	Planning	Planning	Operational response and planning	Operational response and planning	Operational response	Operational response and planning

🟥 = utility gap due to geography 🟨 = limited utility 🟩 = high utility

BCI

Summary – Potential Benefits to MPAR

- Research and Development Lessons Learned
  - First operational dual-use radar approach in DoD
  - Extracting useful, high-quality weather data from air surveillance scan strategies and waveforms
    - Pulse compression with Doppler tolerant sidelobe suppression
    - Effective clutter filtering with limited pulses
    - Intelligent wind profile extraction
    - Ingestion of at-sea radar data into COAMPS numerical weather models

- Open systems architecture / modular software processing
  - Commercial PC-based processing and data interfaces
  - Modular software algorithms can be easily combined to support various radar capabilities and missions
    - Integrated 3rd part software algorithms (TREC winds from NRL, RFC from SPAWAR)

- Detection and characterization of propagation conditions
  - Benefit to homeland security / defense missions for MPAR?

MPAR Can Benefit from R&D and Operational Fielding Work Being Performed by the Navy