Extracting Weather Data from a Hybrid PAR

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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

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

WRTTS – “Now we can see!”
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

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HWDDC Processing Architecture

- 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

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Naval Air Surveillance Radars for TTS Processing

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

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

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Naval Air Surveillance Radars for TTS Processing

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

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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
US Navy WRTTS History

  - 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

  - 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

WRTTS – “Now we can see!”
USS GEORGE WASHINGTON (CVN73) Demonstration

System Development and Demonstration to Fielding in Under 5 Years

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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
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

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Example HWDDC Data Products

- Composite Reflectivity Display
- Propagation Loss Diagrams
- Radial Velocity
- Vertical Wind Profile
- 2-D Wind Field

WRTTS – “Now we can see!”
## USS GEORGE WASHINGTON (CVN73) Demonstration

### From Military Utility Assessment for HWDDC System

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

- Red = utility gap due to geography
- Yellow = limited utility
- Green = high utility

**WRTTS – “Now we can see!”**
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

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