NOAA’s National Water Level Program Overview

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Caribbean Training Course for Operators of Sea Level Stations
UPR, Mayagüez, PR - June 23-27, 2008
NOAA’s National Water Level Program

- Program Description
- NWLON Attributes
  - Station Operation
  - Vertical Datum Reference
  - Data Collection, Processing, and Delivery
- NWLON Operations
NWLP Program Description

- End to end system of data collection through product delivery
- National standard for legal certification and technology transfer
- Liable for accuracy of products
- Supports NOAA and other federal mission goals
National Water Level Program

- Provides a national reference system for tides and water level data
- Provides tidal datum and water level datum references for the entire U.S coastal zone
- Provides for geodetic datum connection and references to tidal datums for the entire coastal zone
- Provides for updated nation-wide information on relative sea level trends and land movement
The National Ocean Service operates and maintains a National Water Level Observation Network (NWLON), which is the backbone observing system of the NWLP.

- The NWLON has 200 continuously operating water level stations.
- All water level stations are equipped with NOS’ Next Generation Water Level Measurement Systems (NGWLMS).
- The NGWLMS consists of a Primary and Backup Data Acquisition System.
National Water Level Observation Network

200 Stations as of 2007 (planned expansion to 300 stations pending increased base funding)

Remote Pacific Island Stations Not Shown
Programs Supported by the NWLP

- Nautical Charting/Shoreline Mapping
- Navigation Safety
- Tidal Datums and Sea Level Determination
- Boundary Determinations
- Dredging/Harbor Improvements
- Tsunami Warning System
- NWS Storm Surge Program
- Long-term SL studies
- Tide Predictions
- Other State and Federal WL Networks
- Environmental Monitoring
- Recreational Boating
- International Lake Level Regulation/Treaty Compliance
- International Datum Determinations
Support of Hydro Operations

- Coordination with Hydro Planning Team for changes to the annual plan
- Update the Hydro Hot List as needed
- Coordination with FOD for gage installations and data quality monitoring
- Station configuration in DPAS
- Data quality monitoring/datum control
- Data processing/new datum determination
- Preparation of smooth tides
- Coordination meetings with OCS as needed
Tide Data Path through CO-OPS

- **GOES Satellite**
  - Wallops Island, VA

- **NWS DOMSAT NWSTG Server**
  - DOMSAT Seattle
  - DOMSAT Chesapeake

- **Water Level Station**
  - Sutron Xpert DCPs:
    - primary - also records 1-min values
    - backup - 15 sec average (not transmitted, but available via phone or direct serial connection)

- **CORMS**
  - Quality Control Operator

- **CO-OPS Web Page**
  - CO-OPS Tsunami Web Page (in its final review stages)

- **FTP Server**

- **Tsunami Warning Centers**

(6) Averaged 1-min WL values **plus**
(1) Averaged 6-min WL value

Every 6 minutes for our stations in AK, West Coast and Pacific Islands
RELATIVE MEAN SEA LEVEL TRENDS FROM TIDE STATIONS ARE HIGHLY VARIABLE DUE TO VARYING RATES OF VERTICAL LAND MOVEMENT
Assessing Sea Level Rise

GRAND ISLE, LOUISIANA
VARIATIONS IN MONTHLY AND ANNUAL MEAN SEA LEVEL

Relative Mean Sea Level Trend is 9.85 mm/yr
NWLOM provides for standardization and reference for tidal datums computed by regional observing systems

Texas Coastal Ocean Observation Network (TCOON)

Supported by a consortium of State and Federal agencies
NWLOON Expansion

Network Gaps Analysis identifies locations where additional NWLOON stations are required to provide datum coverage.

Strategic planning will attempt to fund the additional station installations.
No NWLON Gaps in Caribbean Area
NOAA’s Role in the Tsunami Warning System

- Research
- Warning Guidance
- Hazard Assessment
- Preparedness & Response
Following the 2004 Sumatra event, there was an emphasis on strengthening tsunami warning networks around the world.

In the US and US territories, 16 locations were identified for new NWLON sites, and 33 existing NWLON stations were identified for upgrade to the new Xpert system.

- Coordinated Locations with TWCs and Pacific Marine Environmental Lab (PMEL)
- Strategy Included Hardware and Software Upgrades of Existing Stations
NOAA’s 49 NATIONAL WATER LEVEL OBSERVATION NETWORK
TSUNAMI TIDE STATIONS

ALASKA
- Cordova, AK
- Yakutat, AK
- Seward, AK
- Sitka, AK
- Kodiak, AK
- Alitak, Kodiak, AK
- Sand Point, AK
- Atka, AK
- Unalaska, AK
- Adak, AK
- Nikolski, AK

HAWAII
- Nawiliwili, HI
- Mokuoloe, HI
- Honolulu, HI
- Kahului, HI
- Kawaihao, HI
- Hilo, HI

PACIFIC ISLANDS
- Midway
  - Wake Island
- Guam
- Kwajalein
- Pago Pago

WEST COAST
- Neah Bay, WA
- La Push, WA
- Westport, WA
- Toke Point, WA
- Garibaldi, OR
- Charleston, OR
- Port Orford, OR
- Crescent City, CA
- North Spit, CA
- Arena Cove, CA
- Point Reyes, CA
- Monterey, CA
- Port San Luis, CA
- Santa Barbara, CA
- Santa Monica, CA
- Los Angeles, CA
- La Jolla, CA

PUERTO RICO & VIRGIN ISLANDS
- Aguadilla
- Ponce
- Culebra
- Vieques, Esperanza
- St. John
- Mona Island

NEW STATIONS WITH TSUNAMI CAPABILITY (16)
- Mona Island
- Vieques, Esperanza
- St. John

EXISTING STATIONS WITH TSUNAMI CAPABILITY (33)
- Neah Bay, WA
- La Push, WA
- Westport, WA
- Toke Point, WA
- Garibaldi, OR
- Charleston, OR
- Port Orford, OR
- Crescent City, CA
- North Spit, CA
- Arena Cove, CA
- Point Reyes, CA
- Monterey, CA
- Port San Luis, CA
- Santa Barbara, CA
- Santa Monica, CA
- Los Angeles, CA
- La Jolla, CA

CENTER for OPERATIONAL OCEANOGRAPHIC PRODUCTS and SERVICES
CO-OPS TIDE STATIONS SUPPORTING TSUNAMI
10 NEW AND UPGRADED CARIBBEAN STATIONS
M 5.5, east of the Kuril Islands
November 15, 2006 11:48:04 GMT
USGS Info
The Need for Hazard Warning in the Caribbean

- Approximately 30% of the population and 50% of the building infrastructure are located in areas prone to damaging earthquake related hazards, including tsunamis

- On a normal day over a 100,000 people live and work along the coastal perimeter of Puerto Rico alone

- 4% of the earth’s total tsunami events occur in the Caribbean basin, along with active volcanoes and earthquakes, as well as weather-related coastal flooding and hurricanes

- Economic zones including the tourism, shipping, and oil-gas refineries are co-located along these hazard-vulnerable coasts

- Efforts are underway to develop an integrated approach to hazard mitigation in the Caribbean. Real time water level data will provide an important piece of this system.

- Every effort will be made to provide sufficient coverage without duplicative efforts.
Multiple Applications of a Real-Time, Long-Term Water Level Observation Network in the Caribbean

- Tsunami
- Hurricane & Storm Surge
- Climate Observation
- Navigation

- Inundation
- Meteorological Observations
- Ecosystem Science

GRAND ISLE, LOUISIANA
VARIATIONS IN MONTHLY AND ANNUAL MEAN SEA LEVEL

Relative Mean Sea Level Trend is 9.85 mm/yr
National Ocean Service Support for Puerto Rico Seismic Network (PRSN) Tide Station Network

- Provide training and technical assistance
- Common data formats
- Common data standards
- NOAA provides redundant data dissemination
- All 6 stations operational
NWLONN Attributes

- Station Operation
- Vertical Datum Reference
- Data Collection, Processing, and Product Delivery
NWLOON Station Operations

- Water Level
- Wind Speed/Direction
- Barometric Pressure
- Air/Water Temp.
- Conductivity/Temp
- Chart Datum (MLLW)
- Tsunami/Storm Surge

- Long-term sustained operation
- Continuous time series including extreme events
- Vertical stability of supporting structure and sensors

Fort Pulaski, GA
National Water Level Network Station
Aguadilla, PR

DCP Enclosure, well, sensor

Complete station
Water Level Data Collection Systems

Sutron 900/8200
Sutron Xpert System

Sutron Xpert and Xpert Dark DCPs

WaterLog Pump System
<table>
<thead>
<tr>
<th>DCP Type</th>
<th>Normal Mode</th>
<th>Emergency Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data Sample Interval</td>
<td>Data Transmission</td>
</tr>
<tr>
<td>Sutron 9000 (primary)</td>
<td>1-minute averages logged but not transmitted</td>
<td>6-minute average water level hourly via GOES</td>
</tr>
<tr>
<td>Sutron 8200 (backup)</td>
<td>Continuous sampling at 15-seconds with 5-days of storage on RamPak</td>
<td>6-minute data transmitted via serial cable to primary DCP. Hour and half-hour values sent with primary GOES transmission</td>
</tr>
<tr>
<td>Xpert (primary)</td>
<td>Six 1-minute average water level and One 6-minute average water level</td>
<td>6-minutes via GOES</td>
</tr>
<tr>
<td>Xpert (backup)</td>
<td>15-second and 6-minute average water level</td>
<td>6-minutes via GOES; Modem or direct serial connection to Xpert primary for 15-second</td>
</tr>
</tbody>
</table>
Water Level Measurement Systems

Primary Measurement System

- Aquatrak® Air Acoustic water level sensor
  - Self-calibrating measurement technique
  - Directly Leveled to local benchmark network
- Sutron data collection platform
  - Multitasking Operating system
  - 6 Minute GOES Data Transmission
  - Iridium Satellite Data Transmission for Remote Sites
  - 30 Days of Data Storage
  - Satellite Data Telemetry; GPS-controlled timing
  - Telephone Modem - Data retrieval and software upgrades
Water Level Measurement Systems

Backup Measurement System

- Pressure-based water level sensor
- Sutron Data Collection Platform
  - 60 Days of Data Storage
  - Transfers data to Primary Measurement System
Water Level Measurement System

Water Level Measurements

- 3 Minute average of discrete 1 second samples
- 1 Minute and 15 second averages for Tsunami data
- Measurement includes Standard Deviation
- Includes a 3 Sigma outlier data filter
Short-term Water Level Measurement Stations

- Data Collection Platform
- Acoustic or pressure sensor
- Solar Panel
- GOES Transmitter
Ocean Systems Test & Evaluation Program (OSTEP)

- Develop & Implement New Sensors
- Selection of Cost Effective Devices
- Establish National Sensor Standards
- Acquire NIST NVLAP Certification
- Certify Sensors Before Deployment
Maintenance and repair for all CO-OPS WL measurement systems
Calibration of acoustic WL sensors for CO-OPS and partner organizations
Test and checkout of CO-OPS current measurement systems
Manages the procurement of virtually all of CO-OPS field measurement systems
Inspection and Acceptance testing of new sensors and systems
General CO-OPS measurement systems and sensor inventory control
Vertical Datum Reference

- Water levels accurately known and referenced to:
  - Latest tidal datum and NTDE
  - The land and tidal bench mark network
  - The National Spatial Reference System by precise leveling and GPS
REFERENCING OF THE SENSOR ZERO TO STATION DATUM THROUGH LEVELING AND BENCH MARKS

Primary Bench Mark and GPS Mark:
BG4867 87209840 M TIDAL
Leveling at Water Level Stations

- NGS Accuracy Standards
  - 2nd Order, Class I for long-term stations
  - 3rd Order for short-term stations
- Electronic Digital Barcode Leveling Equipment standard
- Annual leveling for NWLON; installation and removal levels for short-term stations
- Emergency leveling for storm events
Bench Marks

- Requirements for WL Stations
  - Minimum 5 marks
  - Minimum 3 rod marks or bedrock marks for long term stations
  - 10 or more marks for NWLON stations
  - Minimum 200 ft. spacing
  - Tie to NAVD88 marks if possible

- Types of Bench Marks
  - Surface (concrete monument)
  - Surface (structure)
  - Class B deep rod mark
  - Class A deep rod mark
  - Bedrock
NWLOON GPS Operational Plan

- Requirements: NOS NGS-58, CO-OPS User’s Guide for GPS Observations, CO-OPS Standing Project Instructions, and contractor specifications
- Frequency: coordinated with rate of sea level rise – annually or every five years
- Station GPS mark identified in project instructions
- Documentation: all data required for OPUS-DB submissions
- Monitoring: Track and compare solutions over time
Operational Plan for Periodic GPS Observations
National Water Level Observation Network

- GPS Annually at Selected stations, Every 5 Yrs at others
- GPS Every 5 Yrs
- GPS Annually at

North America Map with GPS observation intervals indicated.
CORS Co-located with NWLON

- Coordinate with NGS to co-locate CORS sites with long-term NWLON stations
- Level to the CORS GPS reference marks bi-annually as a minimum
- 12 co-located sites in the Great Lakes
- NGS performing recons at seven NWLON sites on the east coast; Key West completed in January 2007
- NGS planning to install CORS at many of the Alaskan NWLON stations

9099004 Point Iroquois, Lake Superior
Tide Gauge Senses $\Delta T$ ($T_2 - T_1$) over many years
However, those changes are due to both absolute sea level rise and subsidence!!

Thus, $\Delta T = \Delta h - \Delta SSH$ or
$\Delta SSH$ (absolute sea level rise) = $\Delta h$ (from GPS) – $\Delta T$(from tide gauge)
Data Collection

- Continuous and valid data sets required
  - Backup sensor used to fill gaps in primary
- Data collected continuously and transmitted every six minutes
- Near real time quality control performed immediately upon receipt at CO-OPS
- Data can also be downloaded from the DCP by phone
- Data stored in DCP in case of transmission failure
- Primary and backup systems operate independently
Data Quality Control and Processing

- Each data transmission undergoes multiple quality control checks
- QC flags are entered into the database and investigated by CORMS
- CORMS uses case-based and rules-based decision-making
- System and data problems addressed by IT and field personnel 24x7
- Data processing and product generation follows standard operating procedures
Continuous Operational Real-Time Monitoring System (CORMS)

Real-Time 24x7 QA/QC
- Human Analysis
- Data Quality Flags (e.g. Rate of Change)
- Corrective Action

Post-Processing
- Error in Data (e.g. spikes, missing data)
- Data Quality Flags: shifts, bias, changes
- Tabulation & Product Generation
- Backup Gain and Offset
- Verification & Acceptance

9752895 Vieques Island, PR
Water Levels

Produced by NOAA/NOS/CO-OPS
Data Monitoring Tools

- Email status reports
  - CORMS Morning Report
  - Transmission Report
  - Invalid Sensor Report
  - Check QC Report
  - Satellite Message Report
  - Wallops Error Messages
  - Missing PWL Report

- Web Site Tools
  - Station Plot Monitor
  - Station Status Board
  - Backup gain/offset report
  - Tides Online
  - Hydro Hot List

- Database Tools
  - Excel DMS
  - Powerbuilder
Database Configuration

- New Installations/Annual Maintenance
  - Station Parameter Metadata
  - Maintenance Actions: DCP and Sensor Config.
  - Transmission Parameters
  - Sensor Parameters: sensor and datum offsets
  - Protective well and sounding tube information
  - Bench mark vertical mark data, descriptions
  - Leveling equipment information
  - Bench mark and sensor elevations above station datum
Data and Product Delivery

- NWLON supports multiple NOAA missions
  - Storm surge monitoring
  - NWS AWIPS system
  - Marine forecasts
  - Tsunami warning
- 24x7 internet access to products and services after QC checks
  - Services transferred to a mirror DB if primary system fails; Continuity of Operations Plan ensures availability of critical data
Thank You!

Questions?

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National Water Level Observation Network (NWLO2N) Meteorological (Met) Sensor Upgrades

Total Stations: 200
Planned Met Upgrades: 88
Background and Requirements

- Multi-mission capability designed into data collection system upgrade in late 1980’s.
- Initially specific upgrades in conjunction with partnership agreements (i.e. PORTS, Coastal Storms Program, etc.)
- NWS Central Region requests (2004-2005) to upgrade Great Lakes stations.
- NWS Eastern Region/Hurricane Isabel Assessment (2006) to upgrade Chesapeake Bay stations.
- FY08 budget request ($1M) to upgrade 35 stations; additional $1M requested for FY09 to upgrade 49-53 stations
NWLon Met Upgrade

- Met Parameters Measured:
  - Dual Wind Speed/Direction
  - Barometric Pressure
  - Air Temperature

- Marine Weather Significance:
  - Data source for local weather analyses/models
  - Fills significant data gaps
  - Available on AWIPS
  - Planned use for forecast verification
  - Expected to improve forecast accuracy
  - Real-time data for safe marine navigation
Integration Efforts

- Coordinated NOS-NWS DMAC approach to data formats, QA/QC procedures and data transport formats
- NOS provides >70,000 obs/month to NDBC, NCEP and the Global Telecommunications System
- One of the top priorities of the IOOS Regional Associations
- NOSC FY2008 Investment Analysis Findings:
  - On “Tier 1” list – appears in every efficient portfolio in the range +/- 10% from the FY2008 “base cost” budget point.
  - Recommendation: Fund the addition of met sensors to the 88 NWLON sites.
- NOSC assistance requested:
  - “One NOAA” list of prioritized sites for upgrade in FY 08 and FY 09.
  - Assess impact of upgrades on forecast and model accuracy.
GLOSS Network

18 NWLON stations support GLOSS Climate Reference Network (CRN):
8 in the Pacific;
10 on the Atlantic and Gulf of Mexico

29 NWLON Stations contribute to the JASL
Physical Oceanographic Real-Time System (PORTS®)

- PORTS® is a decision support tool which improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information.

- PORTS® measures and disseminates observations and predictions of water levels, currents, salinity, bridge air gap and many meteorological parameters, e.g. winds, air temperature and barometric pressure, needed and requested by the mariner to navigate safely.

- PORTS® currently operating in the Gulf Coast Region include Tampa Bay and Houston/Galveston.
New PORTS in FY08

Center for Operational Oceanographic Products and Services
Water Level Activities on the Gulf Coast

Current Water Level Network

- 23 NWLON Long-term Stations
- 8 Short-term Project Specific Stations
- 25 Texas A&M Cooperative Stations (TCOON)

Developing Partnerships

- 31 Stations - USACE, Mobile Dist.
- Selected stations - USACE, New Orleans Dist.
- 13 Stations - University of South Florida (COMPS)
- Potential Mexico data through Texas A&M MOU
Overview of NOAA Activities
Gulf of Mexico

- Station Hardening
  - Single Pile Instrumentation Platforms in MS and LA
  - Elevated Frames in AL and LA
  - Four pile platforms in Texas
- IDIQ Task Orders - PORTS®
New and Hardened NWLON Stations
Gulf of Mexico
From Hydro to NWLON – the Big Leap in Level of Effort

Hydro Station: $45K  
NWLON Station: $100K  
Single Pile Hardened Station: ~ $500K
Elevated Platform Station

USCG New Canal Station (New Orleans) installed after Hurricane Katrina
NOAA’s Sentinels of the Coast
National Water Level Stations Designed to Survive Category 4 Hurricanes

Hardened Tide Station Engineering Design

Equipment fabrication and staging In Berwick, LA
Texas NWLON Platforms

8772447 USCG Freeport

8770570 Sabine Pass North
IDIQ Task Orders in the Gulf

- Gulf Coast NWLON O&M (MDI)
- Mobile PORTS® (DNR)
- Pascagoula/Gulfport PORTS® (DNR)
- New Orleans PORTS® (MDI)
- Lake Charles PORTS®
- Sabine/Neches PORTS® (DNR)
- Houston/Galveston PORTS® (DNR)
- Texas NWLON O&M (DNR)