Online Tidal Datum Computations

February 8, 2017

Nathan Wardwell
Outline

* Overview of JOA Surveys
* Why build an Online Tidal Datum Computation Tool
* Example uses for the tool
JOA Surveys, LLC (JOA), is an Alaska based surveying company specializing in tides and water level measurement, vertical datums and geodetic networks.

Since 2003, we have supported shoreline mapping, hydrographic surveys, bathymetric lidar surveys, and special datum determination projects in the Gulf of Maine, Massachusetts, Chesapeake Bay, Florida Keys, Puerto Rico and the Virgin Islands, the Gulf of Mexico, California, Oregon, the Inside Passage of Alaska, the Gulf of Alaska, the Aleutian Islands, Bristol Bay, Kuskokwim River and Bay, Bering Sea, Norton Sound, the Chukchi Sea and the Beaufort Sea.

JOA, LLC is a partnership of Erik Oppegard, Nathan Wardwell, Cody Mayfield and Mike Ziesel. We are always looking for interesting and challenging projects along the coast of Alaska and beyond.
Map of Tide Stations Installed and/or Maintained by JOA
Unimak Pass Alaska 2009

Vented Pressure Sensor
Non-Vented Pressure Sensor deployed under sea Ice

Winter site visit to download data with acoustic modem
GPS Buoy

Aleutian Islands 2005
Non-Vented Pressure Sensor on Tidal Bench Mark

Western Alaska 2016
Why Build an Online Tidal Datum Computation Tool?

- There are lots of water level data not collected to CO-OPS standards that may be used for tidal datum determination

- An exercise in automation to increase efficiency
Water Level Data Sources

- USGS Water Data for the Nation
- USACE
- National Weather Service
- National Park Service
- National Estuarine Reserve Research System (NERRS)
Map of Tidal Datums
Computed by JOA and
Published by CO-OPS
Used excel routines and spreadsheets for datum comps

It took a tide analyst about 40 hrs to compute a datum from 1 month of data!
Water Level Processing Interface (WALI)
CO-OPS Online tool for processing water levels.

Data must be installed to CO-OPS standards.

Metadata reviewed by CO-OPS before user can process data.
Online Interface for TIDELAB

Tool only requires 4 inputs from the user:

1) Data file
2) Control Station (optional)
3) Name of the processor
4) Email address to send results

It takes about 5 minutes to compute a datum and you do not need to be a tide analyst to use.
Input Requirements for the Tool

* Input data file must be in a specific format
* Date/time must be in GMT
* Data must be in meters
* Input file can have gaps
* Sample interval can be anything from 1 second to 60 minutes
* Data files with irregular sample intervals work (some times)
* Input file must span at least 24 hrs
* The user needs to know what control station (i.e. NWLON) to use for the datum comp
What the Tool Does

- Frequency analysis to find optimal low-pass filter cutoff frequency
- Select and designate high and low tides
- Download control station data from CO-OPS API (if required)
- Compute final datums
- Print solution to web browser and email to user
TIDE DATUM COMPUTATION REPORT

USER INFO

PROCESS DATE: May 09, 2016
PROCESS TIME: 23:17:53 LOCAL
USER FILE: Nitrogenalallstd.txt
FILE START: 2004/04/20 03:12:00
FILE END: 2004/04/20 23:30:00
ELAPSED TIME: 30.76 seconds

CONTROL STATION INFO

STATION NUMBER: 9455450
STATION NAME: Sand Point, AK
DATUM: STD
TIME UNITS: GMT
DATA UNITS: METRIC

FILTER PARAMETERS

FILTER TYPE: BUTTERWORTH LOWPASS
FILTER ORDER: 4
CUTOFF FREQ: 3.20 cycles/day
1-SIGMA: 0.019

COMPUTATION PARAMETERS

DESIGNATION ALGORITHM: SEMIDIURNAL
DATUM COMP METHOD: MMSC
HIGHS COUNT: 237
LOWS COUNT: 238

TIDAL DATUMS

HIGHEST   MHNV   MHW   DTL   MTL   MSL   MLW   MLLW   GT   MN   DBOQ   DLQ   HWI   LVI   LOWEST
DIRECT:   9.562  8.846  8.601  NaN  NaN  NaN  NaN  NaN  NaN  NaN  NaN  0.245  NaN  11.21  NaN  NaN

MONTHLY MEANS

YEAR  MONTH  HIGHEST  MHNV  MHW  DTL  MTL  MSL  MLW  MLLW  GT  MN  DBOQ  DLQ  HWI  LVI  LOWEST

NOTES:
The input data is filtered prior to selecting the high and low tides. The filter is an adaptive lowpass
Butterworth filter. The filter parameters will vary based on the length and timespan of the input file.
The 1-SIGMA value in the filter parameters is 0.019 of the differences between the input and filtered data.

DISCLAIMERS:
The data for the control station is downloaded from the CO-OPS API. The datums for the subordinate station are in
the same EPHCM as the datums for the CONTROL station. The datums were computed without knowledge of the accuracy
of the input data. The software assumes the height and time of the water levels in the input file are in meters
and GMT, respectively. Values that are NaN represent no data.
TIDE DATUM COMPUTATION REPORT

USER INFO

USER: Nathan Wardwell
PROCESS DATE: May 09, 2016
PROCESS TIME: 23:17:53 LOCAL
USER FILE: Nitrofationalallstd.txt
FILE START: 2004/04/29 03:12:00
FILE END: 2004/04/30 23:30:00
ELAPSED TIME: 38.76 seconds

CONTROL STATION INFO

STATION NUMBER: 9459450
STATION NAME: Sand Point, AK
DATUM: STD
UNITS: GT
DATA UNITS: METRIC

COMPUTATION PARAMETERS

DESIGNATION ALGORITHM: SEMIDIURNAL
DATUM COMP METHOD: MESC
HIGHS COUNT: 237
LOWS COUNT: 238

FILTER PARAMETERS

FILTER TYPE: BUTTERWORTH LOWPASS
FILTER ORDER: 4
CUTOFF FREQ: 3.20 cycles/day
1-SIGMA: 0.019

TIDAL DATUMS

HIGHEST MHHV MHW DTL MTL MSL MWL MLW CT MN DHQ DLQ HWI LV1 LOWEST
DIRECT: 9.562 8.842 8.601 NaN NaN NaN NaN NaN NaN NaN NaN NaN

MONTHLY MEANS

YEAR MONTH HIGHEST MHHV MHW DTL MTL MSL MWL MLW CT MN DHQ DLQ HWI LV1 LOWEST

NOTES:
The input data is filtered prior to selecting the high and low tides. The filter is an adaptive lowpass
Butterworth filter. The filter parameters will vary based on the length and timespan of the input file.
The 1-SIGMA value in the filter parameters is one of the differences between the input and filtered data.

DISCLAIMERS:
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the same EPOCH as the datums for the CONTROL station. The datums were computed without knowledge of the accuracy
of the input data. The software assumes the height and time of the water levels in the input file are in meters
and GMT, respectively. Values that are NaN represent no data.
TIDE DATUM COMPUTATION REPORT

USER INFO
---------------------
USER: Nathan Wardwell
PROCESS DATE: May 09, 2016
PROCESS TIME: 23:17:53 LOCAL
USER FILE: Kitrofanialallstd.txt
FILE START: 2004/04/20 03:12:00
FILE END: 2004/04/20 23:30:00
ELAPSED TIME: 30.76 seconds

FILTER PARAMETERS
-------------------
FILTER TYPE: BUTTERWORTH LOWPASS
FILTER ORDER: 4
CUTOFF FREQ: 3.20 cycles/day
1-SIGMA: 0.019

CONTROL STATION INFO
----------------------
STATION NUMBER: 9459450
STATION NAME: Sand Point, AK
DATUM: STD
TIME UNITS: GMT
DATA UNITS: METRIC

COMPUTATION PARAMETERS
------------------------
DESIGNATION ALGORITHM: SERNADJUML
DATUM COMP METHOD: MSSC
HIGHS COUNT: 237
LOWS COUNT: 238

TIDAL DATUMS
-------------------
HIGHEST  MHHW  MHW  DTL  MTL  MSL  MHW  MLLW  GT  MN  DHIQ  DLQ  HNI  LNI  LOVH
DIRECT:      9.562  8.846  8.601  NaN   NaN   NaN   NaN   NaN   NaN   0.245  NaN   11.21  NaN   NaN

MONTHLY MEANS
-------------------
YEAR  MONTH  HIGHEST  MHHW  MHW  DTL  MTL  MSL  MHW  MLLW  GT  MN  DHIQ  DLQ  HNI  LNI  LOVH

NOTES:
The input data is filtered prior to selecting the high and low tides. The filter is an adaptive lowpass
Butterworth filter. The filter parameters will vary based on the length and timespan of the input file.
The 1-SIGMA value in the filter parameters is of the differences between the input and filtered data.

DISCLAIMERS:
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the same EPOCH as the datums for the CONTROL station. The datums were computed without knowledge of the accuracy
of the input data. The software assumes the height and time of the water levels in the input file are in meters
and GMT, respectively. Values that are NaN represent no data.
TIDE DATUM COMPUTATION REPORT

USER INFO
-------------------
USER: Nathan Wardwell
PROCESS DATE: May 09, 2016
PROCESS TIME: 23:17:53 LOCAL
USER FILE: KitsapE Flood Calc.stnstd.txt
FILE START: 2004/04/20 03:12:00
FILE END: 2004/05/04 23:30:00
ELAPSED TIME: 38.76 seconds

CONTROL STATION INFO
----------------------
STATION NUMBER: 9459450
STATION NAME: Sand Point, AK
DATUM: STND
TIME UNITS: GMT
DATA UNITS: METRIC

FILTER PARAMETERS
-------------------
FILTER TYPE: BUTTERWORTH LOWPASS
FILTER ORDER: 4
CUTOFF FREQ: 3.20 cycles/day
1-SIGMA: 0.019

COMPUTATION PARAMETERS
------------------------
DESIGNATION ALGORITHM: SEMIDIURNAL
DATUM COMP METHOD: MNDC
HIGHS COUNT: 237
LOWS COUNT: 238

TIDAL DATUMS
---------------

HIGHEST  MHHW  MHW  DTL  MTL  MSL  MLW  MLW  GT  MW  DHQ  DLQ  HWI  LVJ  LOWEST
DIRECT: 9.562 8.842 8.601 NaN NaN NaN NaN NaN NaN NaN NaN NaN NaN NaN NaN

MONTHLY MEANS
---------------

YEAR MONTH HIGHEST  MHHW  MHW  DTL  MTL  MSL  MLW  MLW  GT  MW  DHQ  DLQ  HWI  LVJ  LOWEST
2004  7 9.400 0.099 9.571 7.632 7.739 7.722 6.906 6.376 2.512 1.663 0.316 0.532 11.19 4.83 5.704

NOTES:
The input data is filtered prior to selecting the high and low tides. The filter is an adaptive lowpass
Butterworth filter. The filter parameters can vary based on the length and timespan of the input file.
The 1-SIGMA value in the filter parameters is the difference between the input and filtered data.

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of the input data. The software assumes the height and time of the water levels in the input file are in meters and
GHT, respectively. Values that are NaN represent no data.
TIDE DATUM COMPUTATION REPORT

USER INFO
=================================
USER: Nathan Wardwell
PROCESS DATE: May 09, 2016
PROCESS TIME: 23:17:53 LOCAL
USER FILE: Kitrofianalallstd.txt
FILE START: 2004/01/20 03:12:00
FILE END: 2004/09/08 23:30:00
ELAPSED TIME: 38.76 seconds

CONTROL STATION INFO
=================================
STATION NUMBER: 9459450
STATION NAME: Sand Point, AK
DATUM: STND
TIME UNITS: GMT
DATA UNITS: METRIC

FILTER PARAMETERS
=================================
FILTER TYPE: BUTTERWORTH LOWPASS
FILTER ORDER: 4
CUTOFF FREQ: 3.20 cycles/day
1-SIGMA: 0.019

COMPUTATION PARAMETERS
=================================
DESIGNATION ALGORITHM: SEMIDIURNAL
DATUM COMP METHOD: MNSC
HIGHS COUNT: 237
LOWS COUNT: 238

TIDAL DATUMS
=================================

<table>
<thead>
<tr>
<th>HIGHEST</th>
<th>MHW</th>
<th>MH</th>
<th>DT</th>
<th>ML</th>
<th>MS</th>
<th>MLW</th>
<th>MLLL</th>
<th>GT</th>
<th>MN</th>
<th>DBQ</th>
<th>DLQ</th>
<th>HWI</th>
<th>LWI</th>
<th>LOWEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT: 9.662</td>
<td>8.846</td>
<td>8.601</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>0.245</td>
<td>0.404</td>
<td>11.21</td>
<td>NaN</td>
<td>NaN</td>
</tr>
</tbody>
</table>

MONTHLY MEANS
=================================

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH</th>
<th>HIGHEST</th>
<th>MHW</th>
<th>MH</th>
<th>DT</th>
<th>ML</th>
<th>MS</th>
<th>MLW</th>
<th>MLLL</th>
<th>GT</th>
<th>MN</th>
<th>DBQ</th>
<th>DLQ</th>
<th>HWI</th>
<th>LWI</th>
<th>LOWEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>7</td>
<td>9.400</td>
<td>0.009</td>
<td>9.571</td>
<td>7.622</td>
<td>7.739</td>
<td>7.722</td>
<td>6.900</td>
<td>6.376</td>
<td>2.512</td>
<td>1.663</td>
<td>0.316</td>
<td>0.532</td>
<td>11.19</td>
<td>4.03</td>
<td>5.704</td>
</tr>
</tbody>
</table>

NOTES:
The input data is filtered prior to selecting the high and low tides. The filter is an adaptive lowpass filter. The filter parameters will vary based on the length and timespan of the input file. The 1-SIGMA value in the filter parameters is one of the differences between the input and filtered data.

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TIDE DATUM COMPUTATION REPORT

USER INFO
==================
USER: Nathan Wardwell  
PROCESS DATE: May 09, 2015  
PROCESS TIME: 23:17:53 LOCAL  
USER FILE: Mirotianiallstand.txt  
FILE START: 2004/04/20 03:12:00  
FILE END: 2004/04/20 23:30:00  
ELAPSED TIME: 20.76 seconds

CONTROL STATION INFO
======================
STATION NUMBER: 9459450  
STATION NAME: Sand Point, AK  
DATUM: STD  
TIME UNITS: GMT  
DATA UNITS: metric

FILTER PARAMETERS
==================
FILTER TYPE: BUTTERWORTH LOWPASS  
FILTER ORDER: 4  
FILTER freq.: 3.20 cycles/day  
1-SIGMA: 0.019

COMPUTATION PARAMETERS
=======================
DESIGNATION ALGORITHM: SEMIDIJURNAL  
DATUM COMP METHOD: NOSC  
HIGH COUNT: 237  
LOWS COUNT: 238

TIDAL DATUMS
==================

<table>
<thead>
<tr>
<th>HIGHEST</th>
<th>MHVW</th>
<th>MHW</th>
<th>DTL</th>
<th>TTL</th>
<th>MSL</th>
<th>MLW</th>
<th>MLW</th>
<th>CT</th>
<th>MW</th>
<th>D0Q</th>
<th>DLQ</th>
<th>HWI</th>
<th>LVI</th>
<th>LOWEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT: 9.562</td>
<td>8.846</td>
<td>8.601</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>NaN</td>
<td>0.245</td>
<td>NaN</td>
<td>11.21</td>
<td>NaN</td>
<td>NaN</td>
</tr>
</tbody>
</table>

MONTHLY MEANS
=====================

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH</th>
<th>HIGHEST</th>
<th>MHVW</th>
<th>MHW</th>
<th>DTL</th>
<th>TTL</th>
<th>MSL</th>
<th>MLW</th>
<th>MLW</th>
<th>CT</th>
<th>MW</th>
<th>D0Q</th>
<th>DLQ</th>
<th>HWI</th>
<th>LVI</th>
<th>LOWEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>6</td>
<td>9.562</td>
<td>8.810</td>
<td>8.507</td>
<td>7.576</td>
<td>7.663</td>
<td>6.863</td>
<td>6.343</td>
<td>2.467</td>
<td>1.648</td>
<td>0.303</td>
<td>0.516</td>
<td>11.18</td>
<td>4.88</td>
<td>5.785</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>7</td>
<td>9.400</td>
<td>8.099</td>
<td>8.571</td>
<td>7.632</td>
<td>7.739</td>
<td>6.906</td>
<td>6.376</td>
<td>2.512</td>
<td>1.663</td>
<td>0.316</td>
<td>0.532</td>
<td>11.19</td>
<td>4.83</td>
<td>5.704</td>
<td></td>
</tr>
</tbody>
</table>

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Recomputed datums for all stations in CO-OPS data base with published tidal bench marks

- Datum must be based on less than 1 year of data
- Datum must not be based on multiple time periods (i.e. Sep and Dec 2011)
- There are 429 station that meet these requirements
TIDELAB Testing

- Compute Datums for the 429 stations 6 different ways
  - Using original data series
  - Resample to 10 min, 15 min, 30 min, and 60 min intervals
  - Use only 7 days of data with original 6 min sample interval
RMS of differences between published tidal datums and those computed using TIDELAB with the original data series

RMS for 58% of the stations is 5 mm or less

RMS for 99.5% of the stations is 10 cm or less
TIDELAB Testing Results

Comparison of published tidal datums to datums computed using the original water level data resampled at different intervals and only 7 days of data from the original data series. Shown as a percentage of stations within each category. **Total sample size of 429.**

<table>
<thead>
<tr>
<th>RMS of Diff btw Published and TIDELAB</th>
<th>Sample Interval</th>
<th>Data Series Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 min</td>
<td>10 min</td>
</tr>
<tr>
<td>Less than 5 mm</td>
<td>51.7%</td>
<td>54.8%</td>
</tr>
<tr>
<td>Less than 5 cm</td>
<td>74.5%</td>
<td>76.4%</td>
</tr>
<tr>
<td>Less than 10 cm</td>
<td>99.8%</td>
<td>99.8%</td>
</tr>
<tr>
<td>Greater than 10 cm</td>
<td>0.2%</td>
<td>0.2%</td>
</tr>
<tr>
<td>N failed</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Example Uses for the Tool

- Quick Analysis of Tidal Propagation

- VDatum Validation

- Analysis of Long Term Trends
GT is the tide range

HWI and LWI are metrics for phase of the tide

What is the range ratio and time offset between stations?

<table>
<thead>
<tr>
<th>Location</th>
<th>GT (meters)</th>
<th>HWI (hours)</th>
<th>LWI (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South of Nunivak</td>
<td>1.232</td>
<td>6.72</td>
<td>0.76</td>
</tr>
<tr>
<td>Eastern Nunivak</td>
<td>2.214</td>
<td>8.25</td>
<td>2.22</td>
</tr>
<tr>
<td><strong>Ratio and Differences</strong></td>
<td><strong>0.556</strong></td>
<td><strong>-1.53</strong></td>
<td><strong>-1.46</strong></td>
</tr>
</tbody>
</table>
VDatum Validation

- Tool for transforming between vertical datums (i.e. NGVD29 to LMSL)
- Or estimating tide range (Tide Range = MHHW – MLLW)

Courtesy of NOAA, http://vdatum.noaa.gov
<table>
<thead>
<tr>
<th>ID</th>
<th>Agency</th>
<th>Begin Date</th>
<th>End Date</th>
<th>Years</th>
<th>Modeled</th>
<th>Computed</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>021720710</td>
<td>USACE</td>
<td>Jan 28, 2014</td>
<td>Jan 27, 2017</td>
<td>3.00</td>
<td>1.758</td>
<td>1.741</td>
<td>0.017</td>
</tr>
<tr>
<td>021720711</td>
<td>USACE</td>
<td>Oct 01, 2007</td>
<td>Jan 27, 2017</td>
<td>9.33</td>
<td>1.758</td>
<td>1.760</td>
<td>-0.002</td>
</tr>
<tr>
<td>021720709</td>
<td>USACE-SCDOT</td>
<td>Oct 01, 2007</td>
<td>Jan 27, 2017</td>
<td>9.33</td>
<td>1.785</td>
<td>1.780</td>
<td>0.005</td>
</tr>
<tr>
<td>021720698</td>
<td>BCDCOG</td>
<td>Oct 01, 2007</td>
<td>Jan 27, 2017</td>
<td>9.33</td>
<td>1.858</td>
<td>1.862</td>
<td>-0.004</td>
</tr>
<tr>
<td>021720869</td>
<td>USGS</td>
<td>Jun 03, 2016</td>
<td>Jan 27, 2017</td>
<td>0.65</td>
<td>1.976</td>
<td>2.001</td>
<td>-0.025</td>
</tr>
<tr>
<td>021720825</td>
<td>USGS</td>
<td>Jan 24, 2017</td>
<td>Jan 27, 2017</td>
<td>0.01</td>
<td>1.428</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0217206935</td>
<td>USGS</td>
<td>Jun 30, 2016</td>
<td>Jan 27, 2017</td>
<td>0.58</td>
<td>1.793</td>
<td>1.758</td>
<td>0.035</td>
</tr>
<tr>
<td>021720677</td>
<td>USACE-BCDCOG</td>
<td>Oct 01, 2007</td>
<td>Jan 27, 2017</td>
<td>9.33</td>
<td>1.799</td>
<td>1.832</td>
<td>-0.033</td>
</tr>
<tr>
<td>02172053</td>
<td>USACE</td>
<td>Oct 01, 2007</td>
<td>Jan 27, 2017</td>
<td>9.33</td>
<td>1.577</td>
<td>1.648</td>
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</tr>
<tr>
<td>021720508</td>
<td>USGS</td>
<td>Jun 03, 2016</td>
<td>Jan 27, 2017</td>
<td>0.65</td>
<td>1.377</td>
<td>1.350</td>
<td>0.027</td>
</tr>
</tbody>
</table>

RMS 0.032
Comparison of LMSL above NGVD29 modeled by VDatum and Computed

<table>
<thead>
<tr>
<th>ID</th>
<th>Years</th>
<th>Vertical Datum</th>
<th>Local Mean Sea Level Above Datum in Meters</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>021720710</td>
<td>3.00</td>
<td>NGVD29</td>
<td>Modeled 0.233, Computed 0.230</td>
<td>0.002</td>
</tr>
<tr>
<td>021720711</td>
<td>9.33</td>
<td>NGVD29</td>
<td>Modeled 0.233, Computed 0.240</td>
<td>-0.007</td>
</tr>
<tr>
<td>021720869</td>
<td>9.33</td>
<td>NGVD29</td>
<td>Modeled 0.260, Computed 0.274</td>
<td>-0.013</td>
</tr>
<tr>
<td>02172053</td>
<td>9.33</td>
<td>NGVD29</td>
<td>Modeled 0.417, Computed 0.355</td>
<td>0.062</td>
</tr>
</tbody>
</table>

RMS 0.032
Long Term Trends
NERRS Water Level Station at Homer

CO-OPS NWLON Station at Seldovia
Long Term Trends

Monthly Mean Sea Level

HOMER NERRS  Seldovia NWLON

Homer NERRS Meters  Seldovia NWLON Meters

The tool was developed for computing tidal datums from water level data. It was not developed for cleaning and processing water level data nor assessing sensor stability.

The tool will accept data on sample intervals from 1 sec to 1 hr and data series spanning at least 24 hours.

Reduces the need for the user to have in-depth knowledge of datum computations which frees up more time for data analysis.
Thanks

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VDatum estimated MCU for South Carolina is 14.8 cm at 1-sigma.

RMS of Differences between VDatum and Computed values is 3.2 cm