TOPEX/Poseidon Sea Level Grids Description

version WOCE-PODAAC-v3.0-PF9.0 0.5deg
version WOCE-PODAAC-v3.0-PF9.0 1.0deg

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OVERVIEW

This DVD folder contains gridded sea level from the Topex Poseidon (T/P) satellite mission. The values at each bin represent the difference between the average sea level measured in that space-time bin, and the 9-year average (1993-2001) of the measurements in that spatial bin.

Two types of grids are included, whose difference is clarified later:

- 0.5-degree, 10-day binned (version WOCE-PODAAC-v3.0PF9.0 0.5deg)
- 1.0-degree, 5-day interpolated (version WOCE-PODAAC-v3.0PF9.0 1.0deg)

In both cases, the data cover all latitudes between 66 North and South, and the times are from October 1992 to December 2001. The data are stored in millimeters, and the file includes a scale_factor of 0.001, so software that abides by the COARDS NetCDF convention will return the heights in meters.

The T/P data are based on the T/P MGDR-B data released by NASA and CNES in 1997, as described in Benada, 1997; the NASA/JPL and CNES/AVISO versions have small differences, usually roundoff and very near land. The Topex/Poseidon mission is described in Chapter 2 of the same document.

The MGDR-B data are input to a processing scheme designed and implemented by the Altimeter Pathfinder Task, which replaces some MGDR-B parameters with newer and more accurate versions. The overall version of the Altimeter Pathfinder processing is 9.0.

DATA EDITING

The T/P Project makes its data available in the form of an MGDR, with data samples about once per second, and a variety of flags and corrections for the user to choose from depending on the application.

Almost the same edit criteria were applied to 'ALT', the NASA altimeter which is ON about 90% of the time, and to 'SSALT', the CNES altimeter which is ON about 10% of the time.

NASA ALT Records are deleted (rather, set to the undefined value of 32767) if any of the following conditions is true.

Unavailable altimeter range or any ocean dynamic corrections

Significant Wave Height > 15 m or < 0
Dry Trop < -2600 mm or > -2000 mm
Wet Trop < -1000 mm or > 0
Ocean Tide < -10000 mm or > 10000 mm
IB < -1000 mm or > 1000 mm
Ocean Load < -200 mm or > 200 mm
Solid Earth Tide < -1000 mm or > 1000 mm

Ionosphere < -600 mm or > 0

CNES SSALT Records are deleted with the same criteria.

Before gridding, we deleted from the input PF9.0 alongtrack data on these two additional criteria:

depth < 200m (to exclude inaccurate tides in some coastal areas)

absolute value of sea surface height about 9 year mean > 1500mm.

CORRECTIONS APPLIED

The altimetric corrections and models of the ocean surface which are applied to the altimetric range data are listed below. They are explained in some detail in Chapter 3 of Benada (1997), the MGDR-B manual. Corrections are from the MGDR-B, except inverted barometer, Wallops calibration, TMR drift, MSS, and ocean tides. When two or more options for a correction are included in MGDR-B, the chosen option is explicitly named below. If you used the previous data version, please note that this version 3 of the WOCE Topex 0.5 degree grids has some systematic differences from version 1 and 2. Changes from previous versions are indicated below *in italic type*.. Changes from MGDR-B are indicated by ** below.

Corrections

- Orbit height, from the NASA (JGM-3) orbit (Marshall et al. [1995], Nerem et al. [1993] and Tapley et al. [1994a])
- Ionospheric path delay for ALT data: from the Topex dual frequency altimeter, averaged over 17 alongtrack points (about 100 km). **
- Ionospheric path delay for SSALT data: from the Doris-assimilated model.
- Dry Tropospheric Path delay
- Wet Tropospheric path delay, from the TMR (onboard microwave radiometer)
- *TMR drift, recomputed with revised TB18 (Ruf, 2000)***
- *Wallops Altimeter Drift,* **not temperature corrected**, from http://topex.wff.nasa.gov/docs/RangeStabUpdate.html **
- *Bias of 7 mm applied to ALT B sea surface height (from Mitchum, 1999)* **

Sea Surface models

- *Ocean tide: GOT00.2 (R. Ray) ocean tide model* **
- Solid Earth tide
- Pole Tide
- *Sea State Bias, from the Gaspar model, but with corrected SWH (Queffelou, 1999) for ALT B and during period of ALT A drift, and revised TOPEX sigma0 calibration (http://topex.wff.nasa.gov/docs).* **
- *Mean Sea Surface: GSFC00.1 MSS. This includes a cross-track geoid gradient correction from the same surface.* **
- Inverted barometer effect (the time-independent value of 1013.3 mbar in the MGDR is replaced by the daily-mean surface pressure over the global oceans, from the NCEP model. **

Although we are actively working on a high-frequency correction to dealias altimetry from the fast (< 20 day) response to wind (Hirose et al, 2002), this correction was **not** applied to the data in this set.

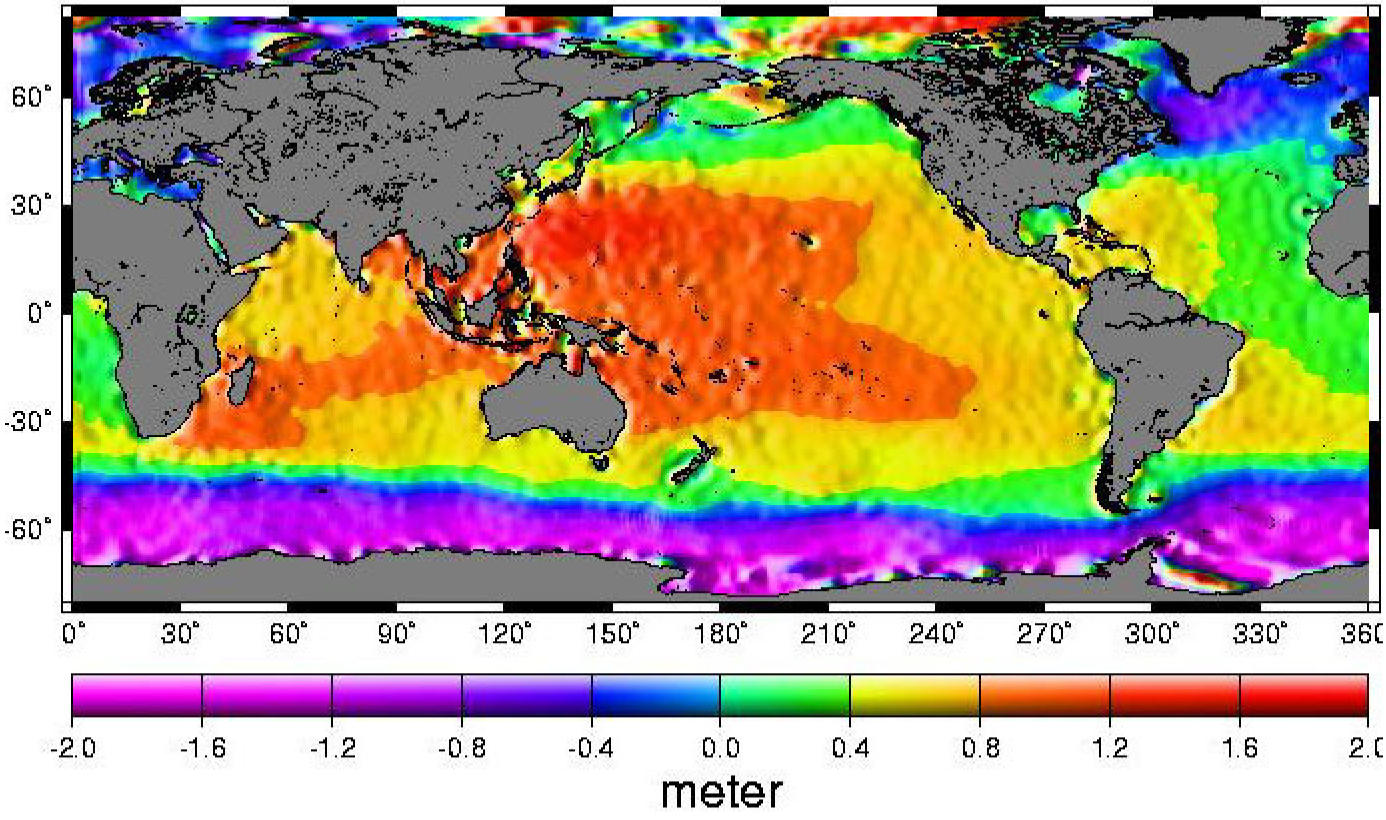
ALONGTRACK GRIDDING and TIME-MEAN REMOVAL

The T/P observations are reported about once per second (the time interval varies with the height of the satellite above the Earth' surface). Although the orbit repeats within +/- 1 km every 9.915625 days (1 'cycle'), the points along the ground track where sampling is reported do not repeat. The Pathfinder processing interpolates sea level residuals to a nominal set of points that remains fixed in latitude-longitude from cycle to cycle. This process involves using the 10/sec samples from adjacent 1-sec MGDR records, the using time as the independent variable to recombine 10 samples at a position that coincides with the nominal point.

The resulting dataset looks like a set of 6746 points along each one of the 127 revolutions T/P draws on the Earth's surface in one cycle. Since about 1/3 of these are over land, the result is a set of approximately 450,000 virtual tide gages (ocean points only), with a sample every 9.915625 days.

From each such 'virtual tide gage', the time-averaged height between January 1993 and December 2001 is removed, a 9-year mean. This is necessary in order to remove residual geoid signals, because at present, errors in the geoid models exceed ocean signals over much of the ocean, and removing a time-mean is more accurate than removing the GDR Mean Sea Surface. So, all the data are sea level residuals above the 9-year mean. Their estimated accuracy is better than 40 mm at each bin.

Users of the previous version of this WOCE Satellite Sea Level data requested an estimate of the sea level above the geoid, not just above the time-mean. The figure below, from Yan-Min Wang (http://magus.stx.com/mssh/readme.html) , shows the height of the mean sea surface above the EGM-96 geoid (http://cddisa.gsfc.nasa.gov/926/egm96/egm96.html). In general, the slope of this surface (the slope of sea level relative to the horizontal) is proportional to the time-mean geostrophic currents, but the accuracy of such a calculation is debatable. We decided not to include data files with the values that went into this map, precisely because the accuracy of such a map for oceanographic applications is much lower than the accuracy of the height anomalies.



UNIFORM TIME-LAT-LON GRIDDING

The 'virtual tide gage' observations are then either

- averaged in bins whose size is 0.5 degree in longitude, 0.5 degree in latitude, and 10.0 days, **OR**

- interpolated to a grid separated by 1.0 degrees in latitude and longitude, and 5.0 days.

0.5-degree, 10-day binned (version WOCE-PODAAC-v3.0 0.5deg)

For the 0.5-degree grids, the choice of 10.0 days averages is prompted by the choice of 5.0 days averaging for the sea surface temperature grids in the accompanying DVD folder. The 10.0 day binning is over 2 hours (7290 seconds) longer than the 9.915625 day exact repeat. As a consequence, the start of each 10 day map is further shifted from the start of each T/P cycle. The actual times at which each cycle starts are found in a Table of Cycle Start Times based on the T/P orbit navigation files..

Also, the 0.5 degree binning is larger than the approximately 6 km per second alongtrack sampling but smaller than the approximately 313 km spacing at the Equator between neighboring tracks. Therefore, each bin usually contains an average of data measured a few seconds apart. The exception occurs at crossover points, where the time difference between the two tracks is of a few days. The latitudes where crossovers occur, and the time difference between ascending and descending tracks, are contained in a Table of Crossover Time Differences in Chapter 9 of Benada, 1997.

The advantage of these grids is that they show the data distribution and the actual values measured (in 0.5 degree averages). The disadvantage is that data gaps exist, and that we do not provide in this DVD time for each bin. Users who wish to use the alongtrack data should contact PO.DAAC.

A list of summary statistics on each grid, the dates corresponding to the grid, as well as links to the browse images can be found in the the Table of SSH statistics (0.5-deg). A Java program to animate a time series of images between any two dates is also available.

1.0-degree, 5-day interpolated (version WOCE-PODAAC-v3.0 1.0deg)

The 1.0-degree, 5day grids, are obtained by a gaussian weighted average centered at the grid node. Specifically, the sea surface height (or sea level) H at latitude ϕ, longitude λ, time t, is a linear combination of observed sea surface heights at points i as follows:

$$H(\phi,\lambda,t) = \Sigma_i \left[H(\phi_i, \lambda_i,t_i) * \exp(-0.6931 * ((\phi - \phi_i)^2/ w_\phi^2 + ((\lambda - \lambda_i)\cos\phi)^2/ w_\lambda^2 + (t - t_i)^2/w_t^2))\right]$$

where $w_\phi = 1$ deg, $w_\lambda = 2$ deg, $w_t = 5$ days

The Σ is performed over all points i inside the volume

$|\phi - \phi_i| < 2$ deg, $|\lambda - \lambda_i| < 4$ deg, $|t - t_i| < 10$ days

The advantage of these grids is that no data gaps exist. The disadvantage is that relatively large absolute values cancontaminate over relatively large distances. Another disadvantage is that, at high latitudes the relatively coarse spatial smoothing blurs energetic eddies with small spatial extent, so the ACC appears weaker than it is (compare the ACC in a 0.5 deg average and in the corresponding 1 deg gaussian maps)

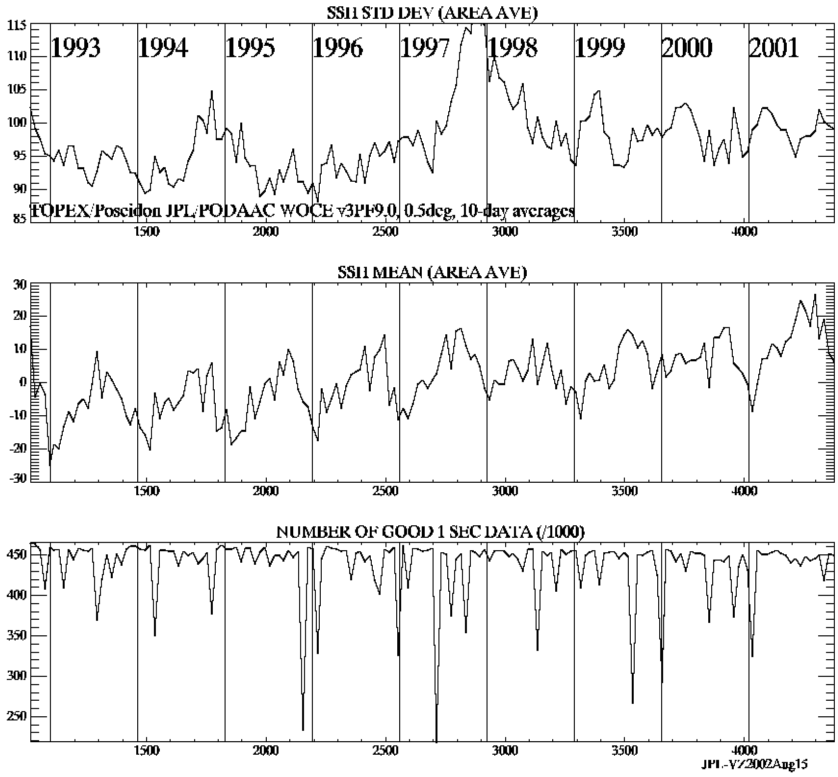
The five day periods begin on January 1, 1990, but the Topex grids start in October 1992. The specific dates, summary statistics on each grid, and browse images of each, can be found in the the Table of SSH statistics (1.0-deg). A Java program to animate a time series of images between any two dates is also available.

SUMMARY PROPERTIES

The accompanying figure shows areal averages over each 0.5-degree map of certain quantities, plotted as a function of time; latitudinal weights proportional to cos(lat) were applied, so these are true global area averages. The top panel, the standard deviation of heights, shows no obvious differences between the various altimeters (CNES, CNES retracked after May 1996, NASA-A, NASA-B after Feb 9, 1999). The PF9.0 processing has succeeded at eliminating most systematic differences between sensors. The larger values of both the mean and the standard deviation in 1992 are due to pointing errors discovered in November 1992 and fixed in December 1992.

The strong increase in the std. dev. in the second half of 1997 simply reflects how different the ocean surface became during the 1997 El Niño relative to the 1993-2001 mean surface.

The lower panel shows the total number of 1-second valid data input to the maps. For a variety of reasons, there are several 10 day periods with insufficient data to make a complete map; many CNES altimeter cycles have relatively fewer points than usual. This 0.5-deg binning was intended to describe such data outages, rather than interpolate across them.



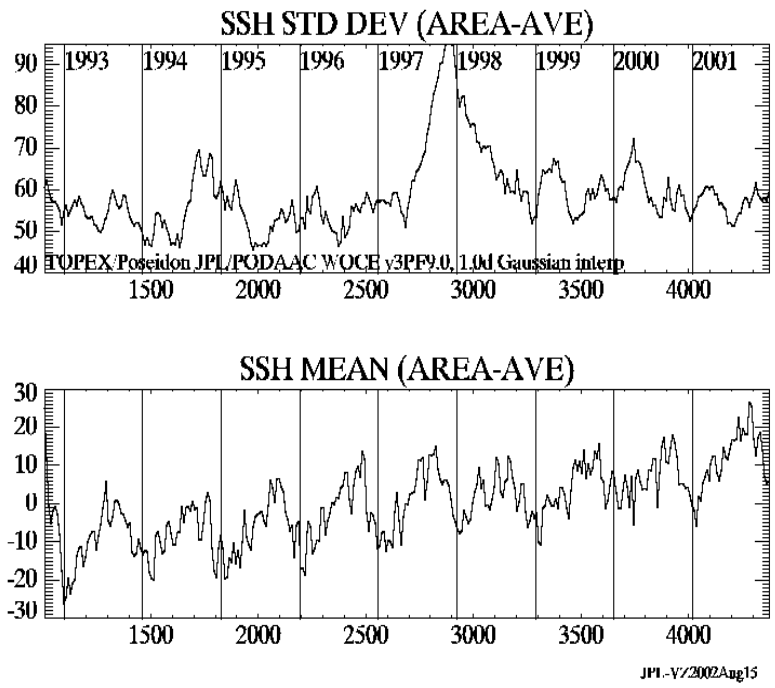
What the figure does not show are any strong discontinuities either between the two altimeters, or before and after cycle 132, where a major processing change was introduced, and the absence of such features is good.

The increase in mean sea level evident in the second plot is trustable, as the PF 9.0 processing used a careful match to tide gage data to ensure that trends as small as 1-2mm/yr in the global average are reliable.

A postscript version of this figure is also available.

The figure corresponding to the 1.0-degree interpolated grids has similar mean values. The fact that the standard deviation (1st panel) is significantly lower than for the 0.5-deg binned maps simply reflects two facts: (a) that the data are smoother (less noisy) because of the broader averaging, and (b) that the data gaps in the data do not occurr systematically in certain higher or lower energy regions of the ocean (by contrast, a comparable grid of sea surface temperature shows large differences between gridded and binned statistics, because clouds preferentially obscure the same regions of the oceans much of the time).

A postscript version of this figure is also available.



DATA FORMAT

The data are stored in NetCDF (network Common Data Form). The netCDF software was developed at the Unidata Program Center in Boulder, Colorado. Freely available software and user support can be obtained from the Unidata netCDF Home Page. A NetCDF primer written by Nathan Bindoff provides an introduction on how to read and understand netCDF files.

All data files contain the following variables:

- **woce_date**
  The woce_date represents the *center day* of the averaging period, in the format YYYYMMDD.

- **woce_time**
  The woce_time is the nominal *center time* of the averaging period. The units are in Universal Time Coordinate, using the time convention HHMMSS.DD.

- **time**
  The time represents the Julian day equivalent of the woce_date, set to 0 for 1990-01-01.

- **latitude**
  The units are in positive degrees for north latitude, negative degrees for south latitude. The values are in a 4-byte signed real array of dimension 360 for the 0.5-degree grids (dimension 180 for the 1.0-degree grids). The grid nodes are centered on -89.75, -89.25, etc for the 0.5-degree grids (on -89.5, -88.5, etc for the 1.0-degree grids).

- **longitude**
  The units are in positive degrees. The values are in a 4-byte signed real array of dimension 720 for the 0.5-degree grids (dimension 360 for the 1.0-degree grids). The grid nodes are centered on 0.25,

0.75, etc for the 0.5-degree grids (on 0.5, 1.5, etc for the 1.0-degree grids).

- **depth**
  The units are in meters. This value is set to zero.

- **sea_level**
  The sea level are stored in millimeters in the file, but will return in meters after the scale_factor and add_offset attributes values are applied by COARDS-compliant software. The data are stored as a 2-byte SIGNED INTEGER array of dimension 720 x 360 for the 0.5-degree grids (360x180 for the 1.0-degree grids). The **unscaled** value 32767 indicates *missing* data; the unscaled value 32766 indicates *land*; since COARDS NetCDF readers will automatically scale everything, then the real values 32.767 and 32.766 will usually be returned by the read routine.

- **bin_count**
  (This variable only exists for the 0.5-degree grids)
  The bin_count contains the number of data points per bin, in a 1-byte array of dimension 720 x 360. The value 0 indicates either *missing data* or *land*. NOTE: bins exist which are labelled land in the data grid, but have non-zero bin count. This happens when there is at least one data point in the bin, but more than half of the bin is covered with land (according to the landmask we used).

See the Table of Variable Attributes (0.5-deg) and Table of Variable Attributes (1.0-deg) for details.

The filenames for the NetCDF files are of the form ssh05d19921012.nc or ssh10d19921014.nc, depending on whether they are 0.5-deg binned, or 1.0-deg interpolated; this is a WOCE Data Products Committee agreement. However, the filenames for the corresponding GIF files are ssh05d1015.gif or ssh10d1017.gif, where the date is given in cumulative days, with day 000=1990-01-01, because the data animation software expects monotonically increasing numbers in the filename. The correspondence between both conventions is in the Table of SSH statistics (0.5-deg) or the Table of SSH statistics (1.0-deg)

MORE INFORMATION

The MGDR-B User Manual, Benada, 1997, has much more information about the T/P mission, various corrections, etc. Please, also check the latest version of the same manual, at the PO-DAAC Web site, for any updates or errors discovered in either the Manual or the data after this DVD folder was created. To avoid confusion, however, it is important to keep in mind that the data and formats described therein are the input to the processing described above.

The Altimeter Pathfinder Task's website has more details on the processing, has alongtrack data, and also will indicate any updates to, or known errors in, the processing of the data.

The PO.DAAC website will likewise have the most up-to-date version of these grids, gridded data beyond the year 2001, and Errata information in case bugs are found.

Further information on corrections to and applications of T/P data can be found in two special issues of the J. Geophysical Research, volume 99 (C12), of December 1994, and volume 100 (C12), of December 1995. More references can be found at http://topex-www.jpl.nasa.gov/

REFERENCES

These references document corrections used in the PF9.0 processing but not present in the MGDR.

Hirose, N., I. Fukumori, V. Zlotnicki and R. Ponte, 2002: High Frequency Barotropic Response to

Atmospheric Disturbances: Sensitivity to forcing, topography and friction. J. Geophys. Res. Vol. 106, No.C12 , p.30,987 (this correction was NOT applied)

Keihm S., V. Zlotnicki and C. Ruff, 2000. TOPEX Microwave Radiometer Performance Evaluation, 1992-1998. IEEE Trans. Geosci. Remote Sens., 38, p1379-1386.

Mitchum G.T. 1998: Monitoring the stability of satellite altimeters with tide gauges. J Atmos Oceanic Tech 15 (3), p721-730

Ray R.D., Eanes R.J., Egbert G.D., et al, 2001. Error spectrum for the global M-2 ocean tide, Geophys Res Lett 28 (1): 21-24

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Wang Y.M., 2001: GSFC00 mean sea surface, gravity anomaly, and vertical gravity gradient from satellite altimeter data J Gophys Res, 106 (C12), p31167-31174

[DVD FOLDER HOME] [Benada, 1997]