Computing Structural Dip – Program dip3d



Computation flow chart

Program **dip3d** uses a seismic amplitude volume as its input and generates estimates of inline dip, crossline dip, dip magnitude, dip azimuth, and a confidence measure of these estimates. The inline and crossline dip components are critical for almost all subsequent AASPI computations. The dip magnitude and dip azimuth are useful if you wish to display dip azimuth modulated by dip magnitude using the multiattribute display program **hlplot**. The confidence volume is used to remove artifacts in the dip volumes using program **image_filt3d**. Initially, these input seismic amplitude volume will be either your time- or depth-migrated amplitude or acoustic impedance. However, as we progress through the AASPI software, we shall wish to recompute the dip components from the data that have been subjected to structure-oriented filtering using the program **sof3d**, or have been spectrally balanced using the program **spec_cmp**.



Parameter description

<u>dip3d</u>	Srmation attributes Display Foois Other Othites AASPI	Default Parameters
format <u>image_filt3d</u> <u>similarity3d</u>	sion format conversion AASPI QC Plotting (Batch Mod s) (single file)	de) Prestack Utilitie
SEGY s <u>o</u> f3d <u>c</u> urvature3d	ck seismic volumes from SEGY to AASPI format	
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AASPI spec_cwt		
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Byte loc. of Y-Coord:	185 4 byte int 💌	
Byte loc. of line (inline) no.:	189 4 byte int 💌	
Byte loc. of cdp (xline) no.:	193 4 byte int 💌	
Override scalco	0 - use value in header 💌	
Override the time of the first sam	ole (ms) : 0	
Vertical Unit:	s 💌	
Horizontal Unit:	ft 🔽	
Amplitude Threshold:	1E+10	
Read text header as ASCII:		
Execute		

We are now ready to begin computing attributes. At the top of the **aaspi_util** GUI, click the 'Volumetric Attributes' tab, located to the right of the 'File' tab. A downdrop menu will appear containing the major AASPI programs – **dip3d**, **image_filt3d**, **similarity3d**, **sof3d**, **curvature3d**, **apparent_cmpt**, **euler_curvature**, **spec_cmp**, **glcm3d**, and **azimuthal_intensity**. In general, we will proceed from top to bottom, with the output of **dip3d** being required input for **similarity3d**, **sof3d**, **curvature3d**, and **glcm3d**. AASPI has "AASPI Workflows (Batch Mode)", with which you can run set of programs in sequence with one click, which saves time and effort (ChapterXX). The output of **sof3d** can be used for either **dip3d** or **similarity3d**, providing iterative structure-oriented filtering capabilities.

😑 \ominus 🕞 📉 AASPI – program dip3d (Release Date: October 4	, 2012)
<u> </u>	<u>H</u> elp
dip3d - calculate 3d dip attributes using analytic semblance	
1nic Input (*.H):sville/d_mig_boonsville.H Browse	
2 Nue Project Name: boonsville	
3	
Typical Extended	
4 eta Max:(degrees) 15	
5elta Theta (degrees): 3	
6 . Velocity: 15000	
7 Window Height: 0.01	
Convert theta_max from degrees to 0.00393046 Calculate	
s/trace, m/trace or ft/trace:	
Want Dip Components Result? 🗹 required	
Want Dip Magnitude Result?	
Want Dip Azimuth Result?	
Want Dip Confidence Result?	
Save dip3d parameters for AASPI Geometric Attribute Workflow	
Save parameters and return to geom_attr_workflow	
(c) 2008-2012 AASPI - University of Oklahoma	Execute dip 3d

Click (1) *Browse,* and select $d_mig_boonsville.H$ as your input seismic data set. You also need to (2) choose a unique project name, which will be tacked on to an attribute descriptor to organize the output. We purposely used my project name in the conversion from segy to SEP format, but this is not necessary. Type in 'boonsville'.Then (3) select a *Suffix.* If this is the original migrated data and you wish to distinguish between it and a data volume that has gone through two passes of structure-oriented filtering, you might give this run a *Suffix* = 0 or *Suffix* = orig, and the 2nd run a *Suffix* = pc_2.

The default dip search will be from -25° to $+25^{\circ}$ at increments of 5° . The reflectors in the Boonsville survey are very flat, rarely exceeding 5° . Therefore, I set the value of (4) *Theta_max* = 15, and (5) *dTheta* = 3. The discrete searches will occur over inline dip components, *p*, and crossline dip components, *q*, forming a rectangular grid of discrete dips. Thus, for the values of 15 and 3 above, there will be $(5+1+5)^*(5+1+5) = 121$ discrete semblance evaluations along candidate dips. Doubling the dip search range (*Theta Max*) but retaining the same search increment (*dTheta*) would quadruple the computational effort. Note that this search is more exhaustive than that provided in commercial algorithms which limit the search to inline and crossline ((5+1+5)+(5+5)=21 discrete semblance evaluations. The more exhaustive search provides superior results for aliased data and very steep dips.

Alternatively, you might wish to compare the effect of values of (5) *dtheta*, or of window size of 20 ms and set your suffix to 'dtheta_2.5' or 'window_20ms'. Remember that you will need to use characters that can form a valid Linux file name (no = plus signs, slashes, blanks, etc.) Also, remember that the binary files are being stored in a directory defined in file ~/.datapath .Even if you run programs from different directories, files with the same name will overwrite each other in the directory defined by .*datapath*. If you wish, you can copy and modify the contents of .*datapath* in your local project directory. This local version of *datapath* will take precedence over that in your home directory.

The reference velocity (6) is read in from the file <code>aaspi_default_parameters</code>, which is currently set to be 15,000 ft/sec. For the Boonsville data, we may wish to use a slower velocity of about 10,000 ft/sec. The *dip window height* (7) is defaulted to be 5**dt*, which in this case is 0.002, or the sample rate (2 millisecond data). We will use this setting for our first run. Clicking the *calculate* button will tell us the time each dip calculation will take so we can estimate how long the process will run. Finally, lets put a check in the boxes for 'Want dip magnitude result?', 'Want dip azimuth result?', and 'Want dip confidence result?'.

File Hel dip3d - calculate 3d dip attributes using analytic semblance Seismic Input (*,H): hsville/d_mig_boonsville.H Browse *Unique Project Name: boonsville Browse *Unique Project Name: boonsville Suffix: 0 Typical Extended V Processors per node: 12 10 Processors per node: 12 Node list: tripolite 12 Verbose: V Verbose: V 13 Inline Window Radius (m or ft): 110.015 14 Crossline Window Radius (m or ft): 109.998 Kuwahara window search: Search overlapping vertical windows?: Image: Search overlapping lateral windows?: Image: Search overlapping lateral windows?: 15 Search overlapping lateral windows?: Image: Search overlapping lateral windows?: Image: Search overlapping lateral windows?: 18 s_upper: 0.85 Image: Search overlapping lateral window?: Image: Search overlapping lateral window?: <t< th=""><th></th><th>🗙 AASPI - program dip3d (Release Date: Septer</th><th>mber 21, 2012)</th><th> X</th></t<>		🗙 AASPI - program dip3d (Release Date: Septer	mber 21, 2012)	X
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Last CDP Out: 206		Last CDP Out:	206	
(c) 2008-2012 AASPI - University of Oklahoma <u>Execute dip3r</u>		(c) 2008-2012 AASPI - University of Okla	homa	Execute dip3d

If you click the *Extended* option in the middle of the menu, you will obtain the window above. We will wish to (9) use MPI so place a checkmark in front of it. I am logged onto a machine called '*tripolite.ou.edu*' and wish to run locally so I (11) type *tripolite* as my node list. I wish to use (10) all 12 processors on *tripolite*. Nodes typically will have 1, 2, 4, 8, 16, 32, or even 64 processors in a single box. If you are running on your local computer, you simply type in *localhost*. If you were running on three machines with names of 'jade','hematite', and 'tripolite', you would type in 'jade hematite tripolite' in this line. Note the blank space delimiters! If each of these nodes has 8 processors, you would use a total of 24 processors. In principal, the maximum number of processors is the number of cdps in a given seismic line, but improvement in performance levels off for distributed processors when the computation time on any given processor approaches the network communication time to copy input data into the processor and results back to the master node. If you are fortunate to own a shared-memory, 64-processor computer, MPI simply copies the data from one memory bank to another such that the speed increases almost linearly with the number of processors.

In an earlier section on defining your computational environment, I discussed copying the following file from the AASPI installation location to your home directory by typing:

cp ~\${AASPIHOME}/par/aaspi_default_parameters .

Don't forget the dot '.' at the end. My aaspi_default_parameters file on my cluster account looks like this:



where d009, d010, ..., d014 are each 8-processor nodes. The (12) *verbose* option does just that – it turns a great deal more information as the program runs allowing one to track any previous problems.

Analysis window description in AASPI software

Most, but not all, of the AASPI algorithms work within a running analysis window. Typically these windows are defined by their length and width in m (or ft) and height is s (or km, kft, m, ft), and are oriented along structural dip and azimuth. The figure below shows a typical rectangular analysis window. Let's assume the trace separation is dcdp=12.5 m in the inline direction and dline=25 m in the crossline direction. If you wanted to have the same dip resolution in both directions you may choose an *inline_window_radius=2*dcdp=25* m and *crossline_window_radius=dline=25* m. The program default is to set the window radii to be the inline and crossline trace spacing (bin size) resulting in a 5-trace analysis circular window. Larger analysis windows result in longer run times, increased angular resolution, and decreased spatial resolution (smearing). If the data are noisy, a circular window radius equal to 2 bins is a good place to start, resulting in a 13-trace analysis window if dcdp=dline.

The window above corresponds to a survey with *dcdp*=12.5 m and *dline*=25 m. A circular window with inline and crossline radii of 25 m therefore contains 7 traces.



If we place a check mark in the (17) *Use rectangular window?* option in the Extended tab, we will obtain the window above which contains 15 traces.

While the vertical_window_height parameter defines the half-height of the analysis window, the window itself will always be centered along dip, as in the following image:



A good rule of thumb is to select a vertical window about the size of the dominant frequency in your data. Thus, if your dominant frequency is 20 Hz, the dominant period is 0.050 s, suggesting a half-window height of 0.025 s. If your dominant frequency is about 50 Hz, giving a period of 0.020 s, you may wish to use a half-window height would be 0.010 s. The default is to set the half window height to be 5**dt*, where dt is the seismic sample rate in *unit1* (e.g. ms, s, ft, m, kft, km). In contrast to the window radii, the window height does not significantly impact run times, but larger windows can result in vertical smearing. If your data are particularly noisy, you will want to use larger vertical analysis windows, at least until you have the opportunity to run structure-oriented filtering.

For the first run, I will choose an (13) inline_window_radius=110 ft, a (14) crossline_window_radius=110 ft, and on the previous tab (7) a vertical analysis half window of 0.010 s.

Kuwahara Windows

Programs **dip3d**, **sof3d**, and **sof_prestack** all use a modification of overlapping window parameter estimates introduced by Kuwahara et al. (1976) in medical imaging. The original idea is fairly simple. If an analysis window contains five traces, then there are total of five windows (a centered window and four adjacent, offset windows) that contain the analysis point. In Kuwahara et al.'s (1976) original work and Luo et al.'s (2002) edge-preserving smoothing algorithm, one calculates the mean and standard deviation of each window. That window which has the smallest standard deviation is hypothesized to be less noise-contaminated. The mean of this window is then used as the output for the analysis point. Marfurt (2006) modified this approach for volumetric dip calculations where he used 3D rather than 2D overlapping windows. Also, the semblance of the analytic signal is used rather than the standard deviation to determine which window is least contaminated by noise. The inline and crossline components of reflector dip of this 'best' window are then assigned to be the output at the analysis point.

For reasonably good quality seismic data, place a checkmark to (16) *search lateral windows.* If the data are very noisy, using Kuwahara windows can give rise to a 'patchy' appearance on the dip components. If this occurs, remove the checkmark in front of *search lateral windows.* For very good quality seismic data, place a checkmark in front of (15) *search vertical windows.* This option will avoid smearing angular unconformities, onlap, toplap, and other configurations important to seismic stratigraphy interpretation.

To minimize the 'patchy' appearance that can occur when using Kuwahara windows, (18) set a threshold value of the analytic semblance, s=0.85. If the semblance of the centered window is greater than this value of *s*, its value of dip and azimuth will be used. If the semblance is less than this value of *s*, the Kuwahara window concept will be implemented, with the dip components of the (centered, laterally offset, or vertically offset) window having the highest value of semblance assigned to the analysis point.

Execution

After selecting all your parameters, type '*Execute*'. Intermediate output comes to the xterm from which you launched **aaspi_util**. some of which appears below:

clockwise = F							
inline_azimuth	91,00						
crossline_azimuth	1.00						
clockwise	F						
in routine init 3d h	istoru file						
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in routine init_30_n	iscory_file						
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0 master_process	start_cdp	end_cdp		num_cdp			
0:	0 1	133					
0 slave_process	start_cdp	end_cdp		num_cdp			
0: 0	1	133		13	3		
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0. 2	13	23		1	1		
<u>0</u> , <u>3</u>	24	34		1	1		
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0: 9	90	100		1	1		
0: 10	101	111		1	1		
0: 11	112	122		1	1		
0: 12	123	133		1	1		
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0: first_line_out,c	urrent_line,last_	line_out,EIA		105	113	201	0,015 h
0: first_line_out,c	urrent_line,last_	line_out,ETA		105	114	201	0.015 h
12: left_cdp_index,c	dp_index,right_cdp	p_index 1	.96	200	206		
3: left_cdp_index,c	dp_index,right_cdp	p_index	97	100	107		
0: first_line_out.c	urrent_line,last_	line_out,ETA		105	115	201	0.015 h
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Ot first line out of	urrent line last	line out FTA		105	120	201	0.013 h
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V: first_line_out,c	urrent_line,last	line_out,EIH		105	123	201	0.013 h
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3: left_cdp_index,c	dp_index,right_cdp	p_index	97	100	107		
0: first_line_out,c	urrent_line,last_	line_out,ETA		105	125	201	0.012 h
0: first_line_out,c	urrent_line,last_1	line_out,ETA		105	126	201	0,012 h
0: first_line_out,c	urrent_line,last_	line_out,ETA		105	127	201	0.012 h
0: first_line_out.c	urrent_line,last_	line_out,ETA		105	128	201	0.012 h
0: first_line_out.c	urrent_line,last	line_out,ETA		105	129	201	0,012 h
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0: first line out o	urrent line last	line out FTA		105	131	201	0.011 h
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12: left_cap_index.c	up_index,right_cdp	p_index 1	.36	200	206		

dip3d echoes out the current line it is working on, and an Estimated Time of Arrival (ETA) or expected time to completion. At the end, you will see the following:

7 : deallocate memory on master and 7 : memory deallocated	slaves	ok	
7 : after 99999 loop, use_mpi= T 7 : before call to mpi_barrier.use.	_mpi =	т	
8 : deallocate memory on master and	claues	1	
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12 : before call to mpi_barrier. use	_mpi =	Т	
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0: seno data via mri 0: receive data via MPI		0,000	0,000
0: send results via MPI		0,000	0,000
0: receive results via MPI		0,001	0,000
0: Hilbert transform		0.000	0,000
0: scan discrete dips		0,000	0,000
0: Interpolate up		0.000	0.000
0: total time		0.016	0,001
total data written to disk: 38703 traces		800 samples	
total data written to disk: 123,850 Mbytes	1-		
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6 :normal completion. routine dip3d			
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5 :normal completion. routine dip3d			
Closing file: /home/kmarfurt/projects/boonsvil	le/conf.	_boonsville_0.	•H
5 Inormal completion, routine dip3d			
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11 :normal completion. routine dip3d			
10 :normal completion, routine dip3d			
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8 inormal completion, routine dip3d			
Closing file: /home/kmarfurt/projects/boonsvil	le/cros	sline_dip_boom	nsville_0₊H
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uiosing tile: /nts/raid1/home/kmarfurt/project: [kmarfurt0tripo]ite_boonsuille]\$ ■	s/boons	ville/d_mig_bo	oonsville₊H
Ivala La capitholice popusatile]*			

which give some computational statistics for each process and shows that each of the 12 processes (number 0 is the master, while 1-12 are slaves) completed successfully. In this case, slave 12 was the last of the 12 to complete. The total elapsed time was 0.016 h.

So far, we have created the following files:

-rw-rr	Τ.	KMarturt	aasp1	57	Dec	- 3	20111	live_processor_list
-rw-rr	1	kmarfurt	aaspi	2175	Dec	3	20:12	inline_dip_boonsville_0.H00
-rw-rr	1	kmarfurt	aaspi	2178	Dec	-3	20:12	crossline_dip_boonsville_0.H00
 -rw-rr	1	kmarfurt	aaspi	2169	Dec	-3	20:12	conf_boonsville_0.H00
-rw-rr	1	kmarfurt	aaspi	5202	Dec	-3	20:12	inline_dip_boonsville_0.H
-rw-rr	1	kmarfurt	aaspi	44445	Dec	-3	20:12	dip3d_boonsville_0.out
-rw-rr	1	kmarfurt	aaspi	5211	Dec	-3	20:12	crossline_dip_boonsville_0.H
-rw-rr	1	kmarfurt	aaspi	5003	Dec	-3	20:12	conf_boonsville_0.H
[kmarfurt@	in:	ipolite bo	ponsvil	le]\$				

The file, *dip3d_boonsville_0.out* is a copy of the results that came to the screen. Program **dip3d** has generated three SEP-format output files: *conf_boonsville_0.H, crossline_dip_boonsville.H, dip_azimuth_boonsville.H, dip_magnitude_boonsville.H, inline_dip_boonsville.H,* (the SEP history files) and corresponding *.H@@ (header file format). The corresponding *.H@ (binary results), and *.H@@@ (binary trace headers) will reside in the directory you defined earlier in the .datapath file that resides in your home directory.

The file *live_processor_list* contains just that:

```
[kmarfurt@tripolite boonsville]$ cat live_processor_list
localhost slots=1
tripolite slots=12
[kmarfurt@tripolite boonsville]$
```

The master processor which does minimal computation but all of the input/output is called *localhost* with one 'slot' or CPU. *tripolite* does all of the computation and has 12 slots or CPUs. If we had used more processors, we would have used more slots. The software is clever enough to not use dead or misspelled processors (by first *pinging* them). Program **ping** is one of those Linux survival commands. Here at OU let's ping three different computers



You will need to click *Ctrl-C* to kill the ping job. In the first case, *ping opal.ou.edu* ping, keeps repeating until we hit Ctrl-C. We have full (passwordless ssh) to this computer from the machine I am on (*tripolite.ou.edu*).

It's easy to mistype a computer name. Here I mistakenly type *jadexx.ou.edu* rather than *jade.ou.edu*. **ping** cannot find this machine.

[kmarfurt@tripolite boonsville]\$ ping jadexxx.ou.edu ping: unknown host jadexxx.ou.edu

If you do not have access to a machine, or if it is offline for maintenance, you will obtain a similar error message. Again we type *Ctrl-C* to kill the job. If you are not on the OU

system (at your desk in an oil company), you will be able to *ping opal.ou.edu*, but not obtain access to it.

We can plot our dip components to QC the results by clicking the AASPI QC Plotting tab in the **aaspi_util** GUI:

🗙 AASPI program aaspi_util - Post Stack Utilities (R	elease Date: September 21, 2012	2)			×
<u>Eile V</u> olumetric Attributes <u>F</u> ormation at	tributes <u>D</u> isplay Tools <u>O</u>	<u>)</u> ther Utilitie	s <u>A</u> ASPI Default Pa	rameters	<u>H</u> elp
SEGY to AASPI format conversion (multiple files)	AASPI to SEGY prmat conversion AASPI Qu (single file)	C Plotting	AASPI Workflows (Batch Mode)	AASPI Prestack Utilities	
AASPI QC Plotting - A quick tool to display	AASPI-fromat attribute volu	mes			
AASPI format input file name (*.H):	/inline_dip_boonsville_0.H	Browse			
Colorbar file:	NONE	Browse			
Enter plot title:	inline dip	-			
Plot section:	Timeslice				
Minimum Time/ Depth:	0				
Maximum Time/ Depth:	1.598				
Time/Depth Increment:	0.1				
Minimum CDP:	74				
Maximum CDP:	206				
CDP Increment:	1				
Minimum Inline:	105				
Maximum Inline:	201				
Inline Increment:	1				
Gain panel:	every 🔟				
Reverse x-axis?	n 🗕				
Reverse y-axis? (Default is positive down)	auto 🖃				
Want scale bar?	у 🚽				
Auto Scale?	On				
Min Amplitude :	-15				
Max Amplitude :	15				
All positive?	n 🖃				
Execute					
(c) 2008-2012 AASPI - The University of Okl	ahoma				

Browse and choose 'inline_dip_boonsville_0.H' as the file to be plotted, set the Time/Depth Increment to be 0.1 s, use the default Min Amplitude and Max Amplitude values, and click *Execute*. The SEP window pops up and we capture the slice at t=1.1 s and display it below.



Notice, there are some small glitches in my data. We also plot the confidence that we have in each of our dip estimates. Since program **dip3d** uses a Kuwahara multiple overlapping window dip search, the confidence is simply the coherence (in this case semblance of the analytic data) of the window used.



The low semblance areas correspond to the edges of the karst collapse features known to occur at this (Barnett Shale) level.

Next, let's evaluate the impact of using a larger analysis window. I set the inline and crossline radii to be 220 ft and set my *Suffix*=220x220ft to give the output files a different name. The run time of this 13-trace window is about three times longer than that for the smaller 5-trace window:

	_V ‡ena 100	p over 11	nes			
process				task	time (hr)	time/trace (s)
0:		read	and scale data	1	0,000	0,000
0:		sei	nd data via MPI		0,000	0,000
0:		recei	ve data via MPI		0,000	0,000
0:		send i	results via MPI		0,000	0,000
0:		receive	results via MPI		0,002	0,000
0:		Hi	lbert transform	1	0.000	0,000
0:		scal	n discrete dips	:	0.000	0,000
0:			interpolate dip	1	0,000	0,000
0:		write (results to disk		0,000	0,000
0:			total time	:	0,042	0,004
total data	written to	o disk:	38703 trace	s	800 samples	
total data	written to	o disk:	123,850 Mbyte	s		
transfer r	ate	:	212,435 Mbyte	s/s		
	E . 1 C .	1 11				

The inline dip component at t=1.1 s looks like this:



Note that it significantly smoother than that computed using the previous 5-trace window. The confidence is displayed below:



Attribute-Assisted Seismic Processing and Interpretation

Careful inspection will show that the discontinuities in dip occur at areas where the confidence falls below s=0.85, as set by the parameters in the GUI.

Plotting a vertical slice through the inline dip (line 175) gives the following image:



We note the (dark) collapse feature under CDP 100, but also note many horizontal 'stripes' which correlate to the stronger wavelets. Increasing the *Dip Window Height* = 0.02 s, gives the following image



As anticipated, the computation time is almost identical due to the add-drop semblance computation scheme.

					•		
process					task	time (hr)	time/trace (s)
0:			rea	ad and scale	data	0.000	0,000
0:			s	end data vi	a MPI	0.000	0,000
0:			rece	eive data vi	a MPI	0.000	0,000
0:			send	l results vi	a MPI	0.000	0,000
0:		1	receive	e results vi	a MPI	0,002	0,000
0:			H	lilbert tran:	sform	0,000	0,000
0:			so	an discrete:	dips	0.000	0.000
0:				interpolate	e dip	0.000	0,000
0:			write	e results to	disk	0,000	0,000
0:				total	time	0.041	0,004
total data	a written	to (disk:	38703 -	traces	800 samples	
total data	a written	to	disk:	123,850	Mbytes		
transfer r	ate		:	213,534	Mbytes/s		
	4.0 1 0				-	 -	

We will try to further improve our dip estimates with some simple median filtering using program **image_filt3d.**

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