Appendix F: Checking Horizontal Orientations for Polarity Reversals and Channel Misnaming

1. Motivation

While processing the horizontal orientations for Cascadia Year 2, the OBSIP Management Office was asked to validate that there were no misnamed channels or polarity reversals in the Cascadia Year 1 and Year 2 data. To empirically verify that there were no such errors or to find such errors, the OMO tested the horizontal orientation code to determine that it is sufficiently sensitive to detect polarity reversals or misnamed channels.

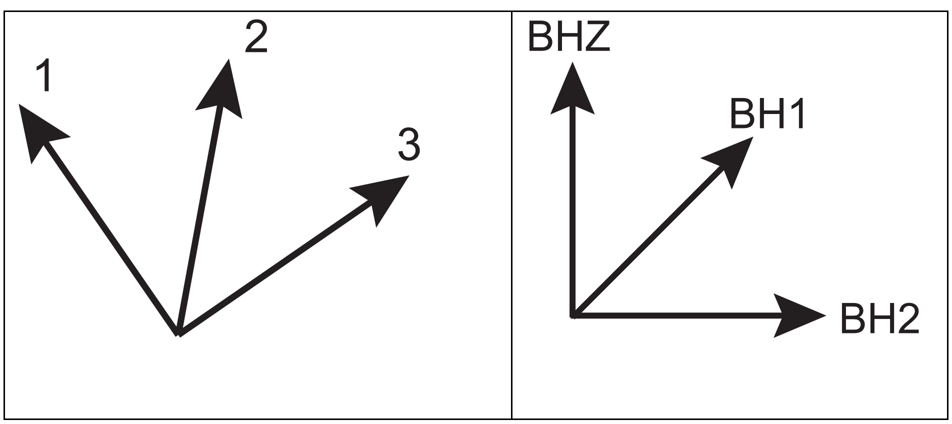
2. Determining convention change cases

All Cascadia ocean bottom seismometers use a three-component seismometer in which each component is orthogonal - comprised of one vertical and two horizontal channels. The OBS instruments are designed to position the sensor so that the horizontal components of the seismometer are leveled shortly after it is deployed.

For each channel, the following errors are possible:

1) the channel was misnamed as another channel
2) the polarity of the channel was reversed
3) any combination of polarity reversal and channel misnaming

2.1. Vertical Channel Determination



The total number of unique cases of channel naming or polarity convention errors for a single channel is 108.

To reduce the number of unique cases, we first determined if the vertical channel was correctly identified. Vertical channels have significantly lower noise levels and different noise characteristics than the horizontal channels. The spectral PDF plots for each station were examined for anomalous vertical channels. We determined that there were no misnamed vertical channels. This step reduced the number of potential errors for single channel to 36.

To determine if the polarity of a channel is reversed, record sections of the vertical channels were reviewed for several large earthquakes. The Cascadia stations are tightly grouped so there should be consistent P-wave polarities between adjacent stations. After viewing several record sections, all of the P-wave polarities indicate that the vertical channels did not have a polarity reversal. This step in the verification process reduced the number of potential errors for single channel to 8.

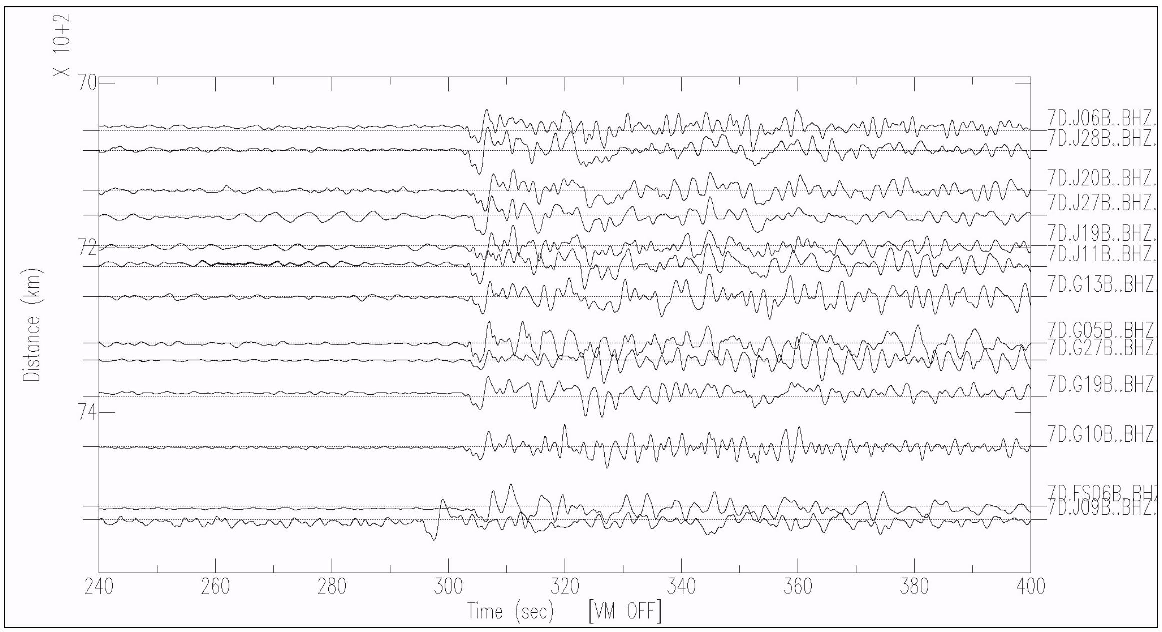
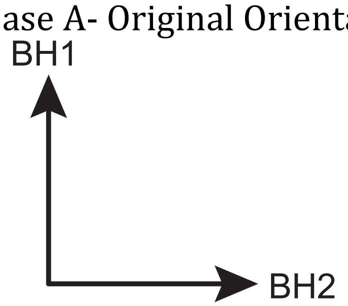


Figure 1. Example of vertical channel record section. Subset of Cascadia stations for the 08:18:23 2012/12/07 Mw 7.3 Japan earthquake. The P-wave polarities of the stations are consistent.

2.2. Horizontal Channel Determination

With all of the vertical channels are properly identified and polarized, we validate the two horizontal components. First we make an initial assumption that **BH2 is oriented 90° clockwise from BH1**. This is the convention used by all of the IICs. We will call this Case A.

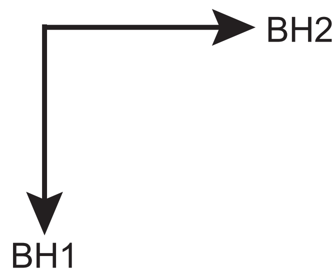
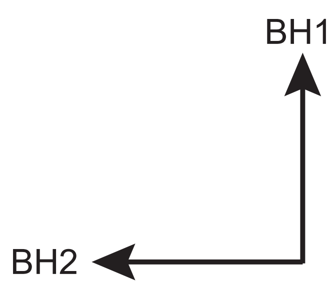
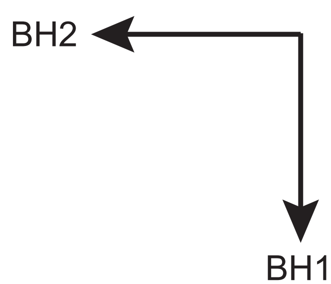
Case A- Original Orientation



2.2.1. Polarity Changes

There are three possible polarity changes.

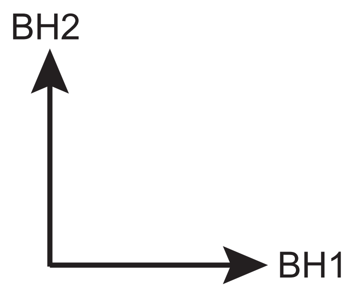
1) BH1 has a reversed polarity
2) BH2 has a reverse polarity
3) Both BH1 and BH2 have a reversed polarity

Case B- Polarity BH1 Reversed  	After reversing the polarity of channel BH1, the orientation convention has changed. **BH2 is now 90° counterclockwise from BH1**. This is a separate case from the original. We will call this Case B.
Case B- Polarity BH2 Reversed  	After reversing the polarity of channel BH2, the orientation convention has changed from the original**. BH2 is now 90° counterclockwise from BH1.** This is the same as Case B just rotated 180°.
Case A- Both Polarities Change  	After reversing the polarity of both channels, the orientation convention is the same as the original. **BH2 is oriented 90° clockwise from BH1.** This is the same as Case A (original) just rotated 180°.

2.2.2. Misnamed Channels

There is one possible misnamed channel orientation.

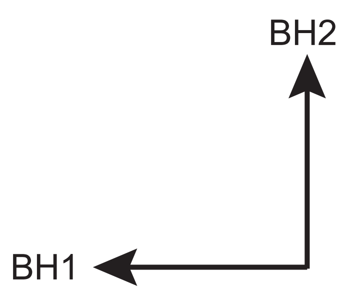
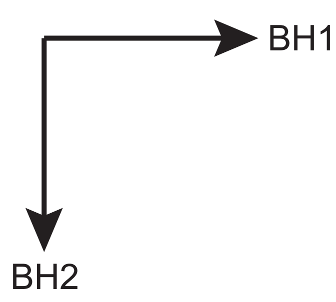
1) BH1 and BH2 were misnamed

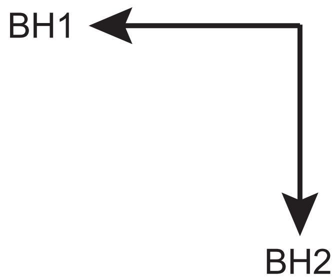
Case B- Misnamed Channels 	After misnaming the channels, the orientation has changed from the original. **BH2 is now 90° counterclockwise from BH1.** This is the same as Case B just rotated 270°.

2.2.3. Misnamed Channels and Polarity Reversals

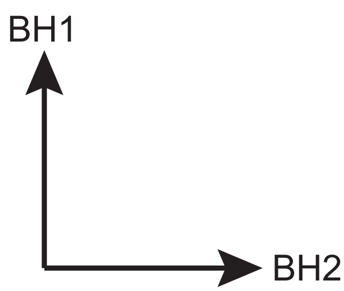
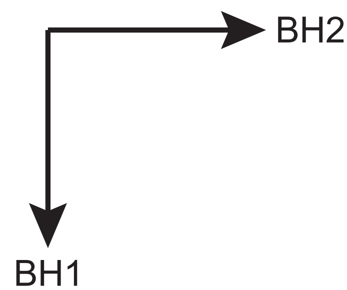
There are three new possibilities for misnamed channels and polarity reversals.

1) The channels are misnamed and polarity of BH1 is reversed
2) The channels are misnamed and polarity of BH2 is reversed
3) The channels are misnamed and polarity of both BH1 and BH2 is reversed

Case A- Misnamed and Polarity BH1 Reversed 	After misnaming the channels and reversing the polarity of channel BH1, the orientation convention is the same as the original convention. **BH2 is oriented 90° clockwise from H1.** This is the same as Case A (original) just rotated 270°.
Case A- Misnamed and Polarity BH2 Reversed 	After misnaming the channels and reversing the polarity of channel BH2, the orientation convention is the same as the original convention. **BH2 is oriented 90° clockwise from BH1.** This is the same as Case A (original) just rotated 90°.

<table>
<tr>
<td>Case B- Misnamed Channels and both Polarities Reversed

</td>
<td>After misnaming the channels and reversing the polarity of both channels, the orientation convention has changed from the original convention. BH2 is now 90° counterclockwise from BH1. This is the same as Case B just rotated 90°.</td>
</tr>
</table>

With all the possible changes to the orientation, only two cases emerge. Case A, where BH2 is oriented 90° clockwise from BH1, and Case B where BH2 is oriented 90° counterclockwise from BH1.

<table>
<tr>
<td colspan="2">Case A Original</td>
<td colspan="2">Case B</td>
</tr>
<tr>
<td colspan="2">BH2 is oriented 90° clockwise from BH1</td>
<td colspan="2">BH2 is oriented 90° counterclockwise from BH1</td>
</tr>
<tr>
<td colspan="2">
</td>
<td colspan="2">
</td>
</tr>
<tr>
<td>Permutations:
Both polarities reversed
Misnamed/Polarity BH1 rev.
Misnamed/Polarity BH2 rev.</td>
<td>Factor:
180
270
90</td>
<td>Permutations:
Polarity BH2 Reversed
Misnamed Channels
Misnamed/Both polarities rev.</td>
<td>Factor:
180
270
90</td>
</tr>
</table>

2.3. Algorithm Results

All the permutations are identical to either Case A or Case B, just rotated by some factor. The statistical nature of comparison of the horizontal orientation algorithm should be able to distinguish between Case A and Case B, but it will not be able to distinguish between the different permutations (rotations of 90 degrees) within each case. Since we are solving for the rotated degrees from North, each permutation would give an identical result, just shifted by the rotation factor.

The orientation code was run using the convention from Case A and the convention from Case B and the results were compared.

3. Method validation with TA stations

In order to verify that the horizontal orientation code can distinguish between Case A and Case B, OMO processed a segment of TA station data. The TA stations have a known horizontal component orientation and are very precisely oriented to North (within .1°). Therefore these provide an excellent 'test case' of well known, high quality data.

TA stations have BHN and BHE components, where BHE (BH2) is oriented 90° clockwise from BHN (BH1) (Case A). We analyzed a total of 743 TA stations that were operated during 2010. We selected data for all earthquakes with M > 6. The horizontal orientation results from the TA stations showed that the method can distinguish between the two cases: Case A and Case B. If the wrong convention is used when running the horizontal orientation code, the standard deviation of data points increases significantly.

An example of a TA station horizontal orientation result is shown below in Figure 2. The Case A (the correct orientation convention) result is shown on the left and Case B (the incorrect convention) result is shown on the right. Both plots have some high correlation measurements (plotted in blue and green). For Case A, these high correlation measurements cluster around 0°, which is expected for a properly oriented seismometer. For Case B, there are many high correlation measurements, but they are spread over a wide range of estimated orientations from 30° to 180°.

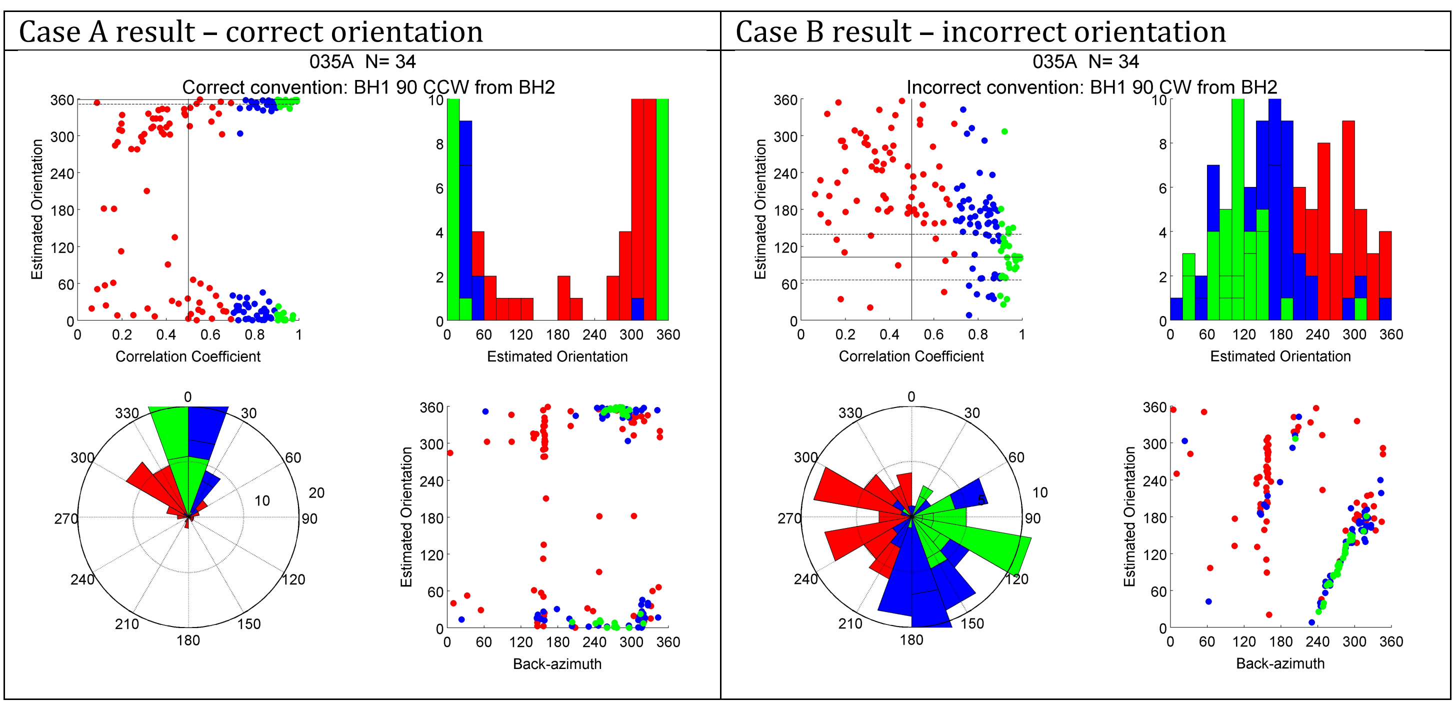


Figure 2. TA station 035A orientation estimates; subplots show correlation coefficient vs. estimated orientation with mean value and uncertainty range (top-left), standard histogram of estimated orientation (top-right), polar histogram of estimated orientation (bottom-left), and earthquake back azimuth vs. estimated orientation (bottom-right). The orientation estimate on the left is the results

using the correct orientation convention (Case A). The orientation estimate on the right is the results using the incorrect orientation convention (Case B).

4. Results from Cascadia

After validating the method of calculating orientations with the TA data, OMO reprocessed all the Year 1 Cascadia data with both Case A convention and Case B convention. Because OBSIP instruments are built and operated by three different IIC's, the usage of horizontal orientation convention of channels varied in Year 1. In Year 2, all of the data was intended to follow the GSN convention (Case A convention). The Cascadia data has been corrected for both Year 1 and Year 2 so that all data from both years follows the GSN convention (BH2 90° CW of BH1).

4.1. Horizontal conventions

4.1.1. Current conventions

Year 1	
IIC	Convention
LDEO	HH2 oriented 90° clockwise from HH1
SIO	BH2 oriented 90° clockwise from BH1
WHOI	BH2 oriented 90° clockwise from BH1

Year 2	
IIC	Convention
LDEO	HH2 oriented 90° clockwise from HH1
SIO	BH2 oriented 90° clockwise from BH1
WHOI	BH2 oriented 90° clockwise from BH1

4.1.2. Previous conventions

Year 1	
IIC	Convention
LDEO	HH2 oriented 90° counterclockwise from HH1
SIO	BH2 oriented 90° clockwise from BH1
WHOI	BH2 oriented 90° counterclockwise from BH1

Year 2	
IIC	Convention
LDEO	HH2 oriented 90° counterclockwise from HH1
SIO	BH2 oriented 90° counterclockwise from BH1
WHOI	BH2 oriented 90° clockwise from BH1