Global Environmental Modelling Systems

# Balla Balla

# Causeway Impact Studies

***Prepared for***

***Forge Resources***

***Interim Report***

***January 2013***

## ABOUT GEMS

Global Environmental Modelling Systems (GEMS), a wholly owned Australian company, has expertise in the development and application of high-resolution computer models to realistically predict atmospheric and oceanographic conditions for use in riverine, coastal and oceanic settings.

The GEMS team is made up of qualified and experienced physical oceanographers, meteorologists, numerical modellers and environmental scientists. GEMS is a leading developer of numerical models in Australia. It has developed a system of validated environmental models and rigorous analytical procedures that provide solutions to a variety of environmental, engineering and operational problems.

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## DOCUMENT HISTORY

| Version | Date | Status | Author |
|---|---|---|---|
| V0 | 30 January 2013 | Client Draft | G. Hubbert |
| V1 | 5 February | Client Draft | G. Hubbert |
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# SECTION 1. INTRODUCTION

## 1.1 Background to the Study

Global Environmental modelling Systems Pty Ltd (GEMS) has particular expertise in ocean modelling and has undertaken a large number of major coastal impact modelling projects in Western Australia for local planning, environmental impact and engineering design studies.

Forge Resources plans to build a solid causeway part of the way out to the proposed barge loading facility for the export of iron ore from their mine near Whim Creek in Western Australia. GEMS has been commissioned by Forge Resources to undertake high resolution modelling studies of the impact of the proposed solid causeway on local flows to support investigations of any environmental impacts.

The aim of this report is to:

- Set out the methodology used in the study; and
- Provide results appropriate for planning.

For this modeling study, the local topography of the region was modified so as to include a breakwater extending from high ground on the mainland to the furthest proposed extent of the solid causeway. The remainder of the causeway will be piled. The height of the causeway was set at a level of 1m above Highest Astronomical Tide (HAT).

## 1.2 Conventions

The following conventions apply in this report:

- unless otherwise stated, water levels are referenced to Australian Height Datum (AHD);
- wind directions are the direction 'from' and are referenced to true North, and
- all geographic locations are based on the GDA94 coordinate system.

## SECTION 2. THE GEMS 3D COASTAL OCEAN MODEL (GCOM3D)

For studies of hydrodynamic circulation and sea level variation under ambient and extreme weather conditions, GEMS have developed the GEMS 3D Coastal Ocean Model (GCOM3D). GCOM3D is an advanced, fully three-dimensional, ocean-circulation model that can determine horizontal and vertical hydrodynamic circulation due to wind stress, atmospheric pressure gradients, astronomical tides, quadratic bottom friction and ocean-thermal structure. GCOM3D is fully functional anywhere in the world using tidal constituent and bathymetric data derived from global, regional and local databases. As the model is fully three dimensional, output can include current data at any or all levels in the water column.

GCOM3D (Hubbert 1993, 1999) calculates water currents in both the horizontal and vertical planes. The model operates on a regular grid (in the x and y directions) and uses a z-coordinate vertical-layering scheme. That is, the depth structure is modelled using a varying number of layers, depending on the depth of water, and each layer has a constant thickness over the horizontal plane. This scheme is used to decouple surface wind stress and seabed friction and to avoid bias of current predictions for a particular layer caused by averaging of currents over varying depths, as used in sigma co-ordinate and “depth-averaged” model schemes. GCOM3D is also formulated as a freely scalable and relocatable model and nesting to any number of levels is supported in order to suit the hydrodynamic complexity of a study area. The three-dimensional structure of the model domain, tidal conditions at the open boundaries, and wind forcing are defined for each model application by extraction of data stored in gridded databases covering a wider geographical area of interest. A full description of the model physics is provided in Hubbert (1999).

GCOM3D may be operated as a barotropic model, for applications where tidal and wind forcing are dominant, or as a fully baroclinic model, where temperature and salinity structure exerts a significant effect on water flow.

Sometimes it is important to take non-tidal, non-wind driven flows into account in the modelling process, in the absence of full thermodynamic fields for barotropic modelling. In order to achieve this, GEMS has linked GCOM3D with the output of the joint Bureau of Meteorology/CSIRO BLUELINK project, which enables the inclusion of large scale ocean currents such as the Leuwin and East Australian Currents (excluding tide and local wind). These data can be assimilated into GCOM3D to incorporate these geostrophic currents as well as the local tidal and wind driven currents. This is the approach adopted by GEMS in the Australian Search and Rescue system, based on ocean currents from GCOM3D, developed for AUSSAR in Canberra.

GCOM3D has been used in a wide range of ocean environmental studies including prediction of the fate of oil spills, sediments, hydrotest chemicals, drill cuttings, produced formation water and cooling waters as well as in other coastal ocean modelling studies such as storm surges and search and rescue.

GCOM3D was also the ocean model used in the last two attempts by Australia to win back the America’s Cup.

## 2.1 Model Set-up for the Current Project

### 2.1.1 Model Grids

To investigate the impacts of the solid causeway, model grids were established at two resolutions as shown in Figures1 and 2.

Bathymetric depths were extracted directly from Australian Marine Chart AUS 740. Topographic data were extracted from a US Radar data set.  LIDAR data provided by the client was also included although these data were concentrated along the causeway corridor and the region of the proposed barge loading facility.

The topography of the fine scale (inner) grid, as shown in Figure 2, was adjusted to include the solid causeway at a height of 1m above HAT.

### 2.1.2 GCOM3D Settings

The GCOM3D coarse grid must extend far enough from the study area so as to capture the broad scale ocean response to the regional tidal forcing. The inner grid must be large enough to capture the local topography and bathymetry and be of sufficiently high resolution to allow inundation processes to be accurately represented. Testing was undertaken to optimize these grids so that processes at all scales are captured.

### 2.1.3 Model Output

GCOM3D computes total water levels and currents at a number of levels in the water column at each model grid point at each model time step. The model can output the water levels and currents as time series at nominated output locations.

For this study model time series data were stored at locations chosen to test the impacts of the solid causeway as shown in Figure 2.

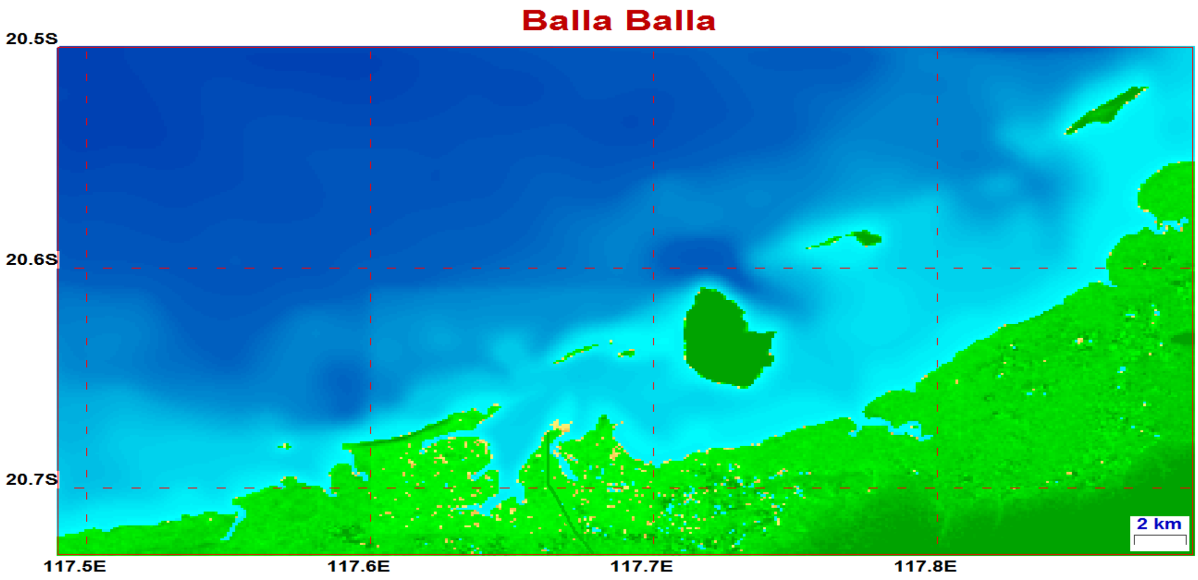


Figure 1. The large scale grid used to define boundary conditions for the 20m grid.

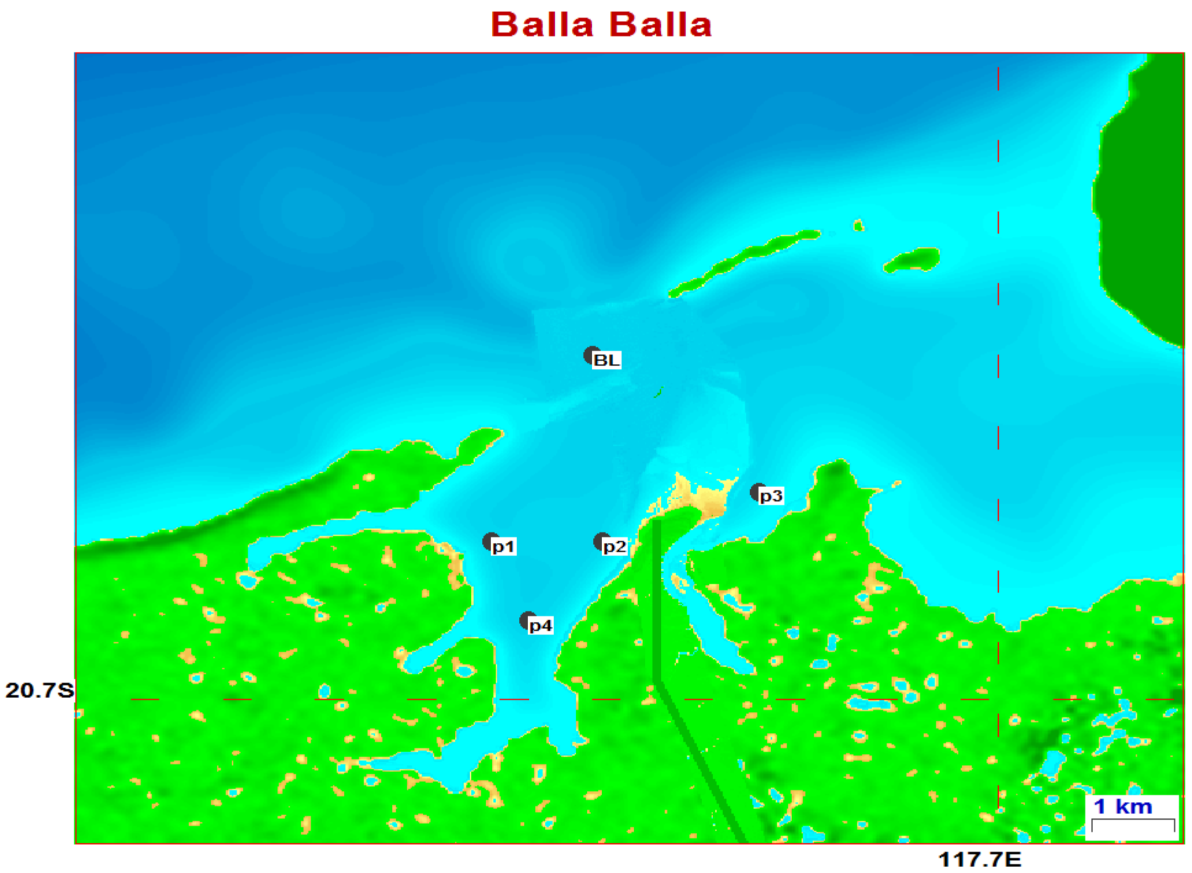


Figure 2. The 20m grid established to investigate the impacts of the proposed causeway showing data comparison points.

# SECTION 3. RESULTS AND DISCUSSION

## 3.1 Spatial Variations in Flow Patterns

Figures 3 and 4 compare the spatial flows at mid tide during the ebb and flood tides in the vicinity of the causeway. There is very little variation in the flows but to examine any variations in greater detail the sea levels and currents at specific points are discussed in the next section.

## 3.2 Time Series

Water level and current speed and direction time series data were stored at 5 locations as indicated in Figure 2.

Figures 5 to 9 compare water levels at locations BL, P1 , P2, P3 and P4 respectively for the two cases studied (pre and post causeway). Figures 10 to 14 compare current speeds at the five locations and Figures 15 to 19 compare current directions at the five locations.

**The results presented in Figures 5 to 19 indicate that the solid causeway will produce:**

**1) No impact on water levels in the region;**

**2) Small variations in the flow occur at all four of the shallow water locations (P1, P2, P3 and P4) but no significant change in speed or direction is observed.**

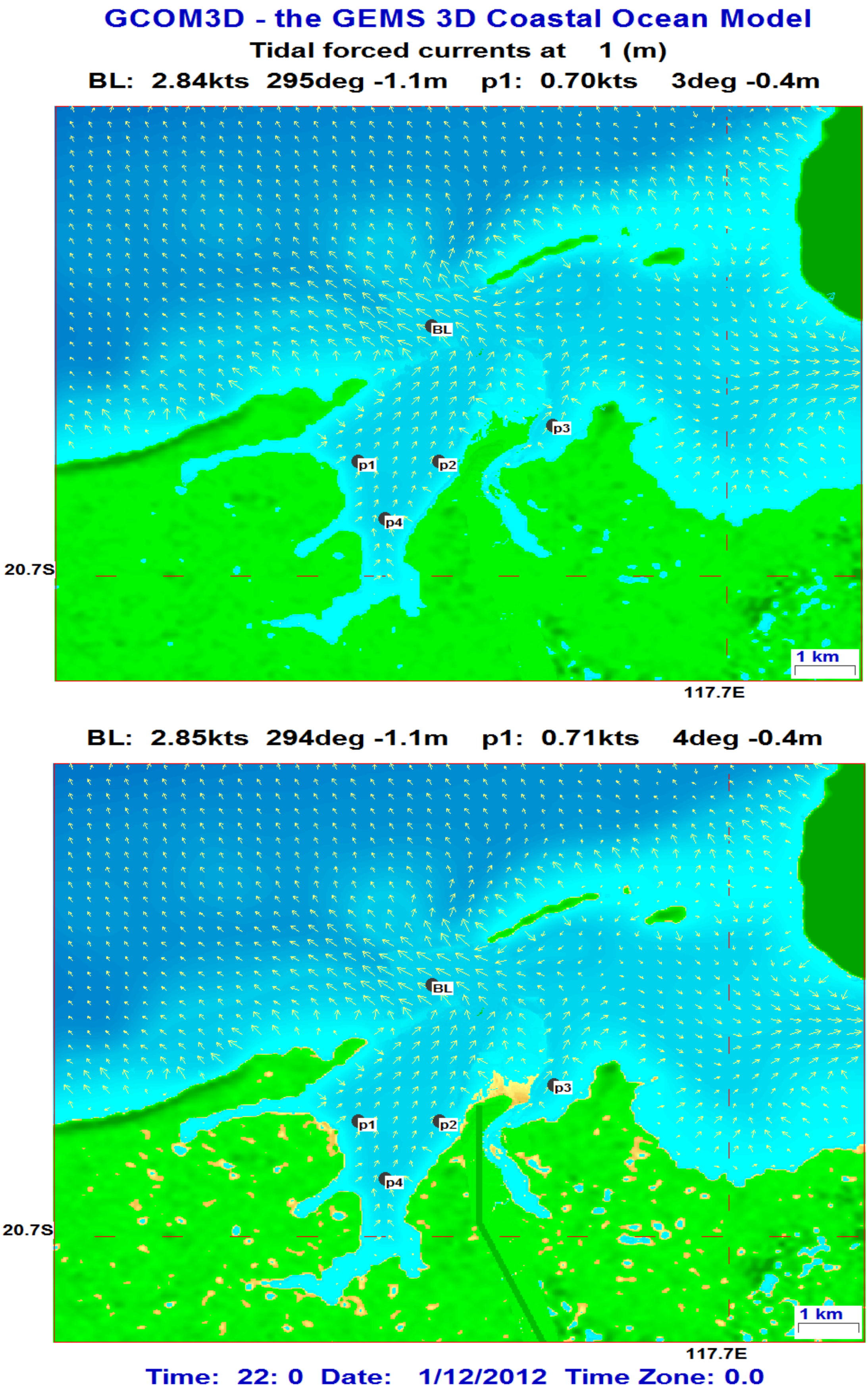


Figure 3. Comparison of ebb tides before and after the solid causeway at 2200 on Dec 2, 2012.

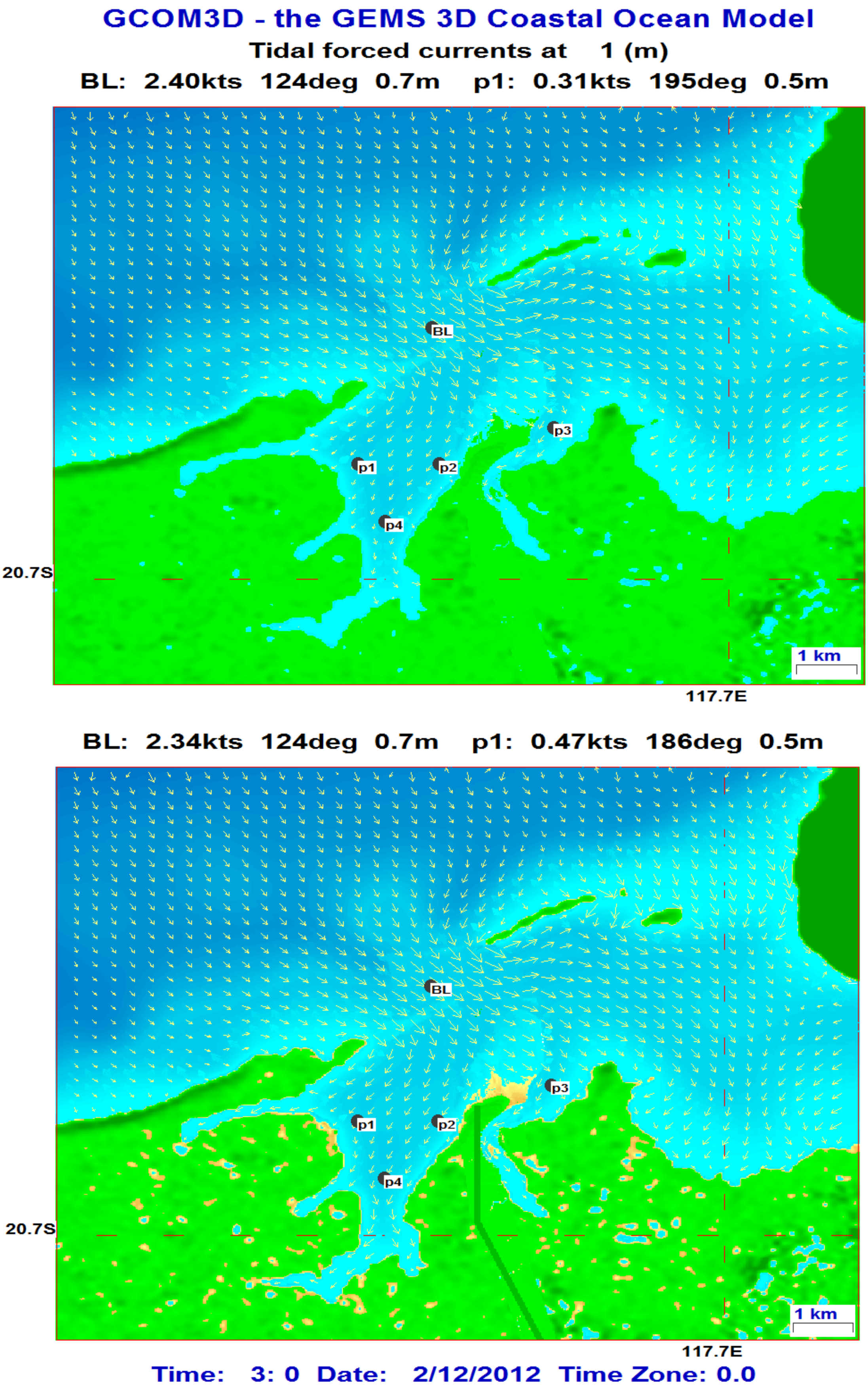


Figure 4. Comparison of flood tides before and after the solid causeway at 0300 on Dec 3, 2012.

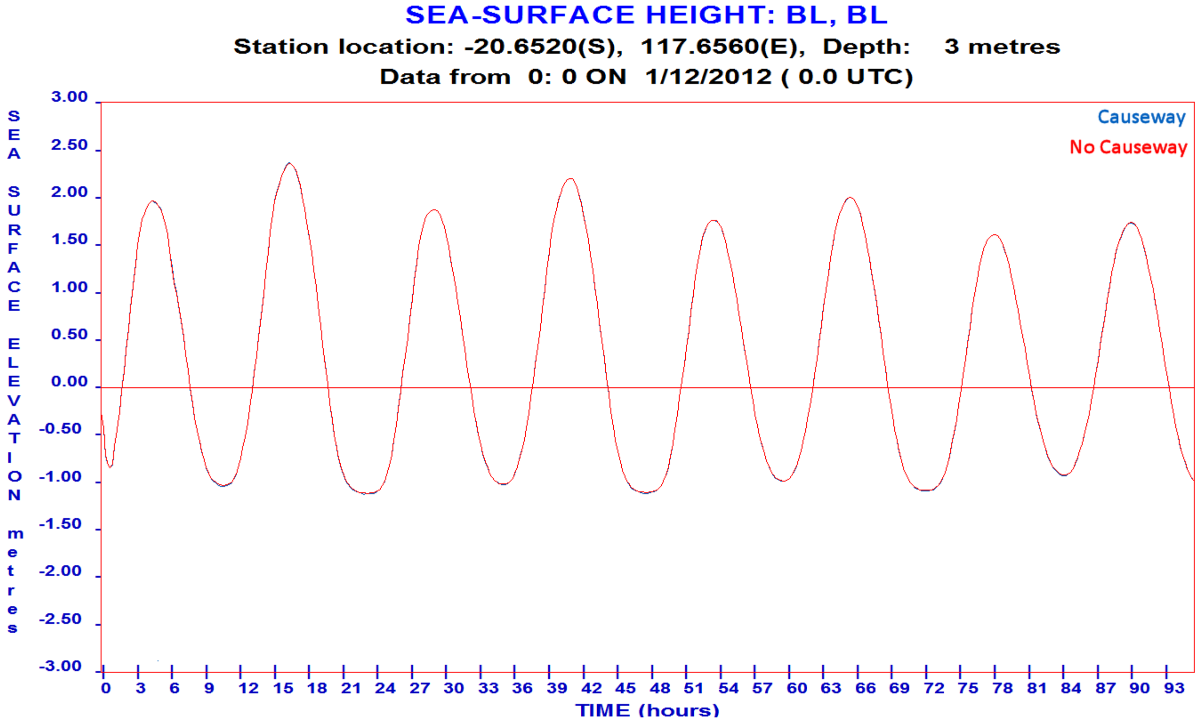


Figure 5. Comparison of water levels at point “BL” for 4 days in December 2012.

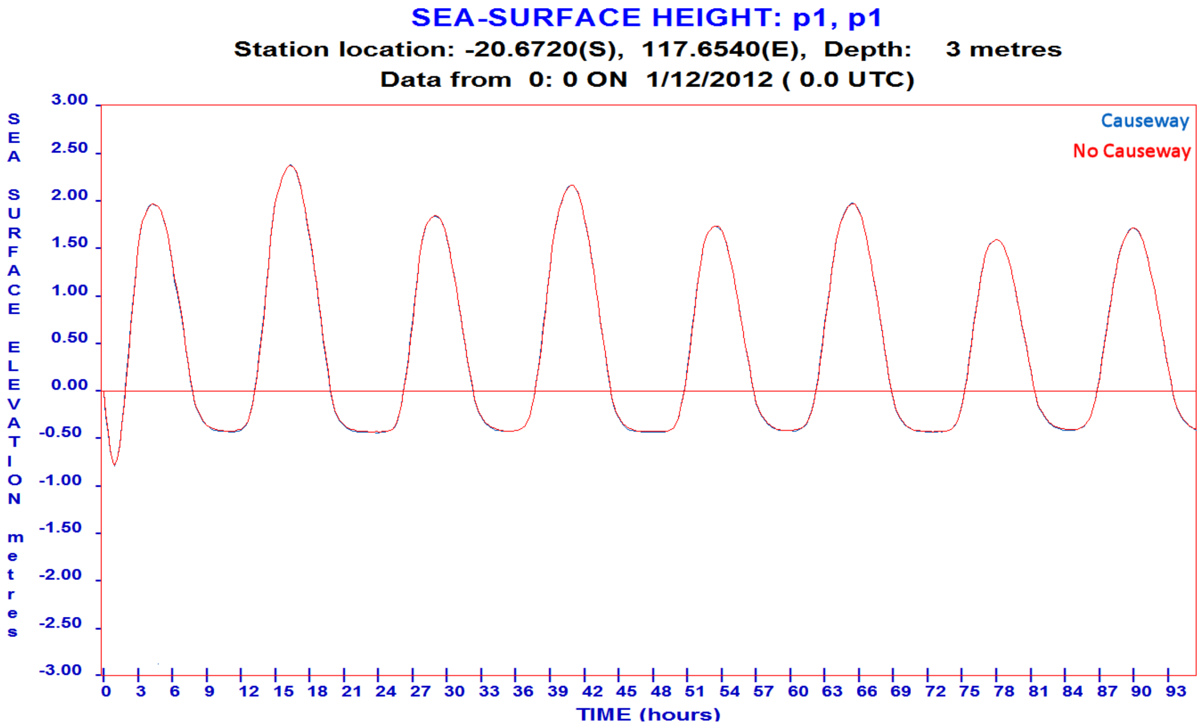


Figure 6. Comparison of water levels at point “P1” for 4 days in December 2012.

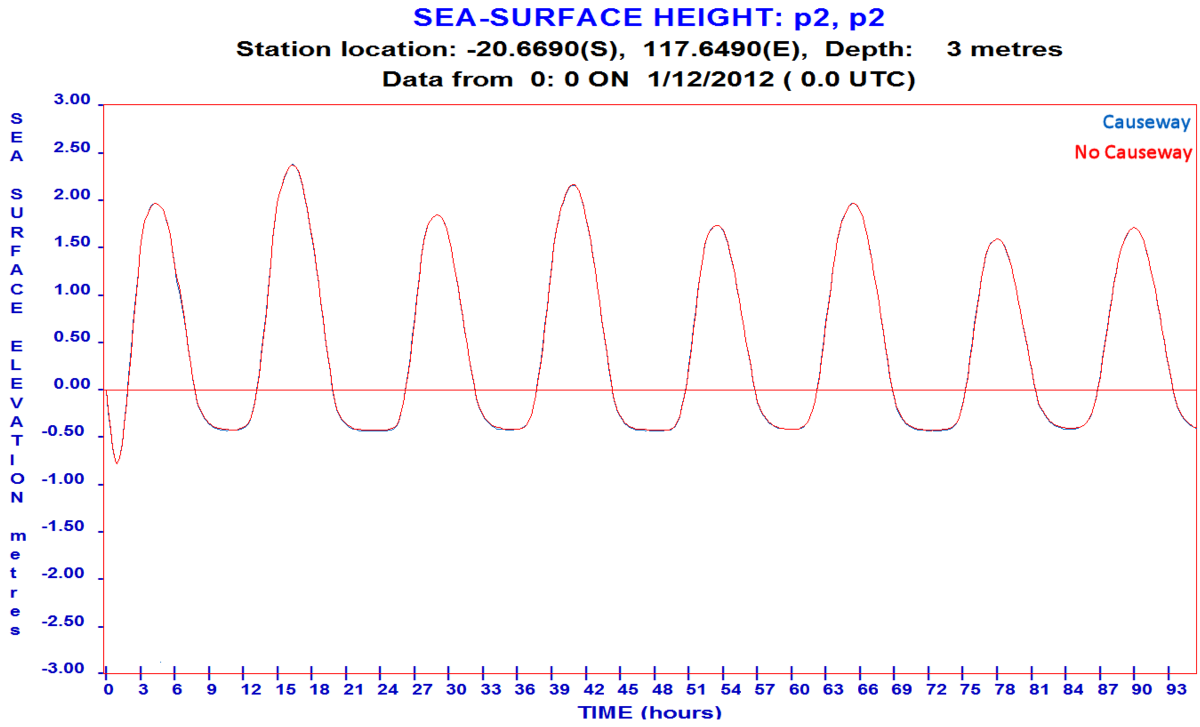


Figure 7. Comparison of water levels at point “P2” for 4 days in December 2012.

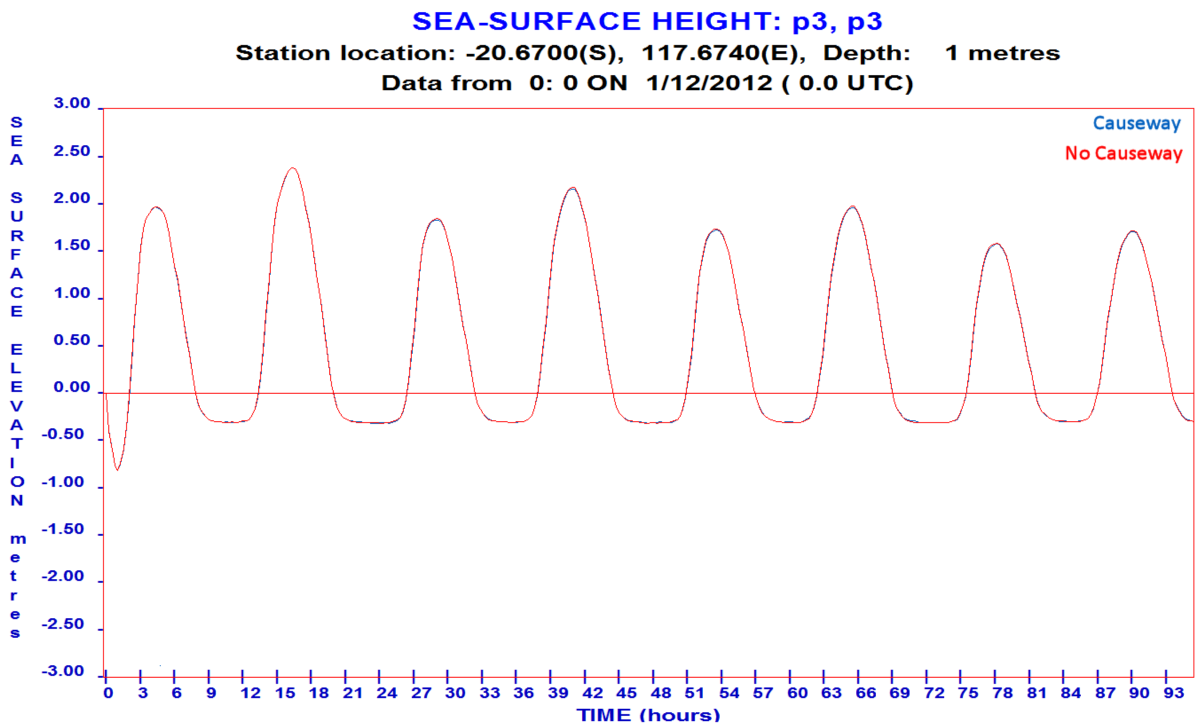


Figure 8. Comparison of water levels at point “P3” for 4 days in December 2012.

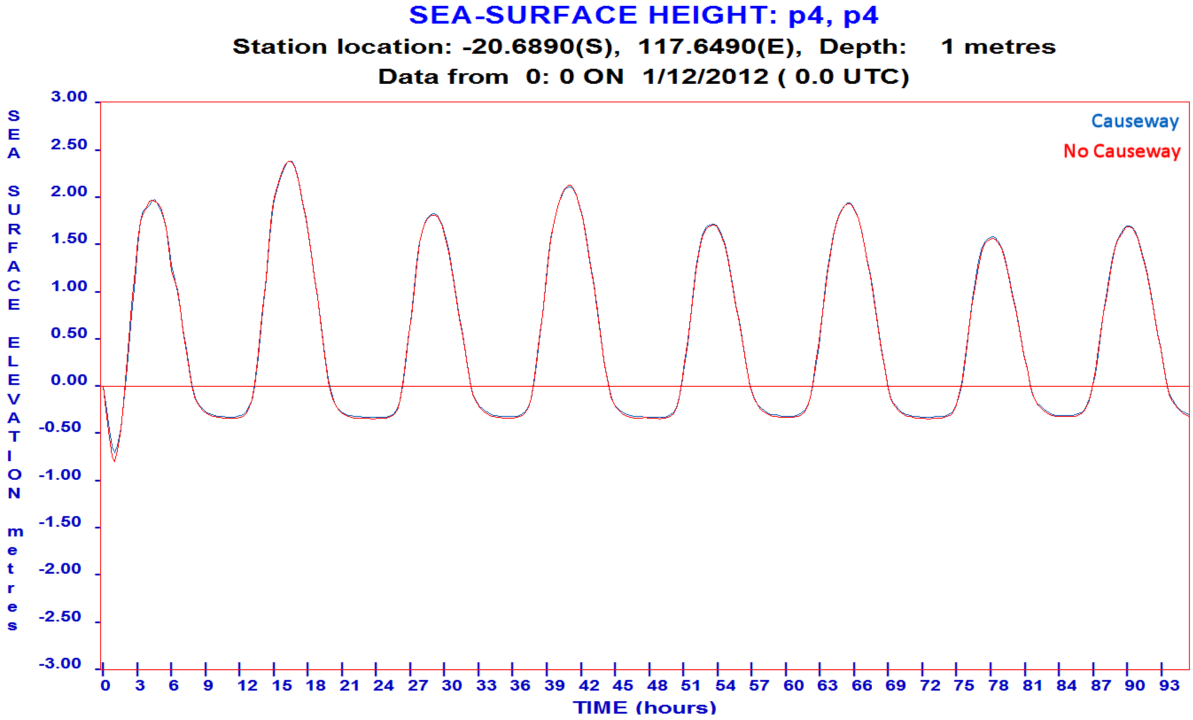


Figure 9. Comparison of water levels at point “P4” for 4 days in December 2012.

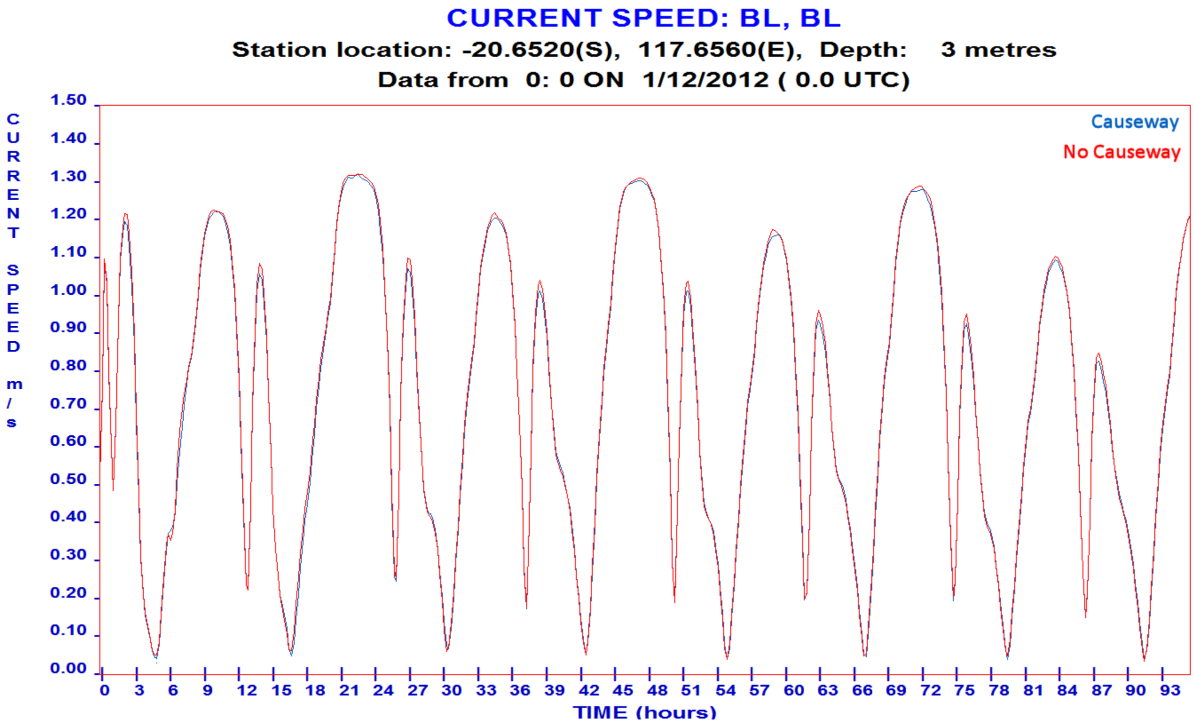


Figure 10. Comparison of current speeds at point “BL” for 4 days in December 2012.

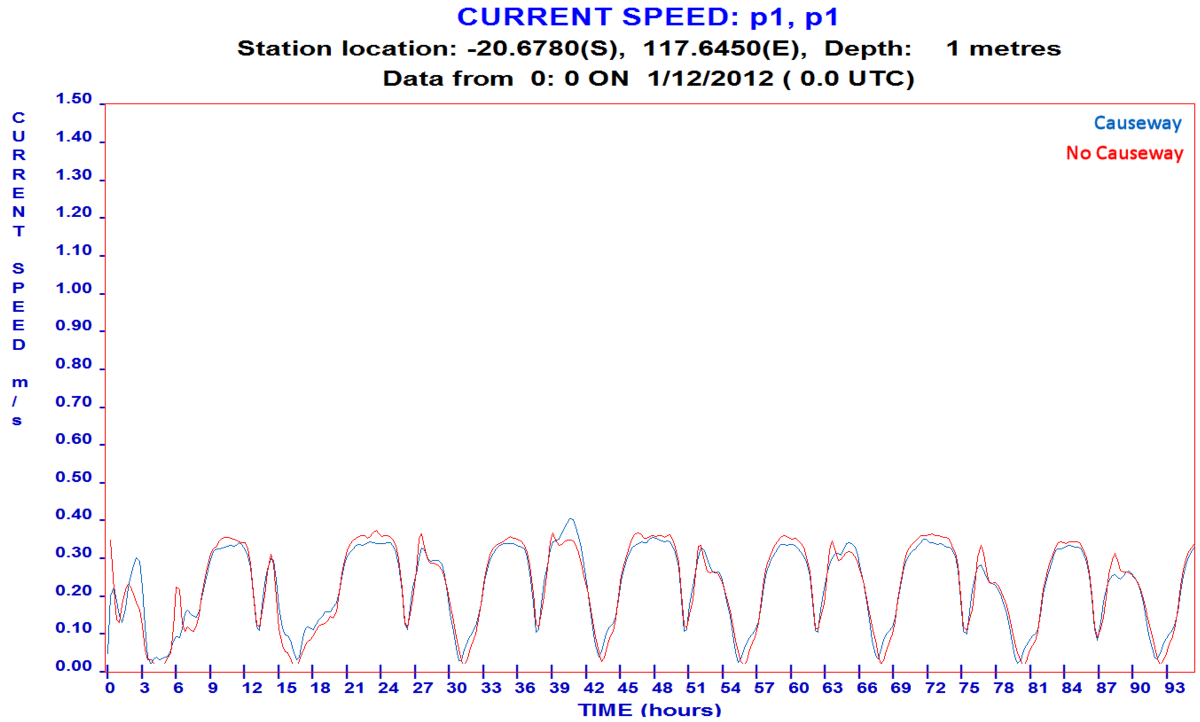


Figure 11. Comparison of current speeds at point "P1" for 4 days in December 2012.

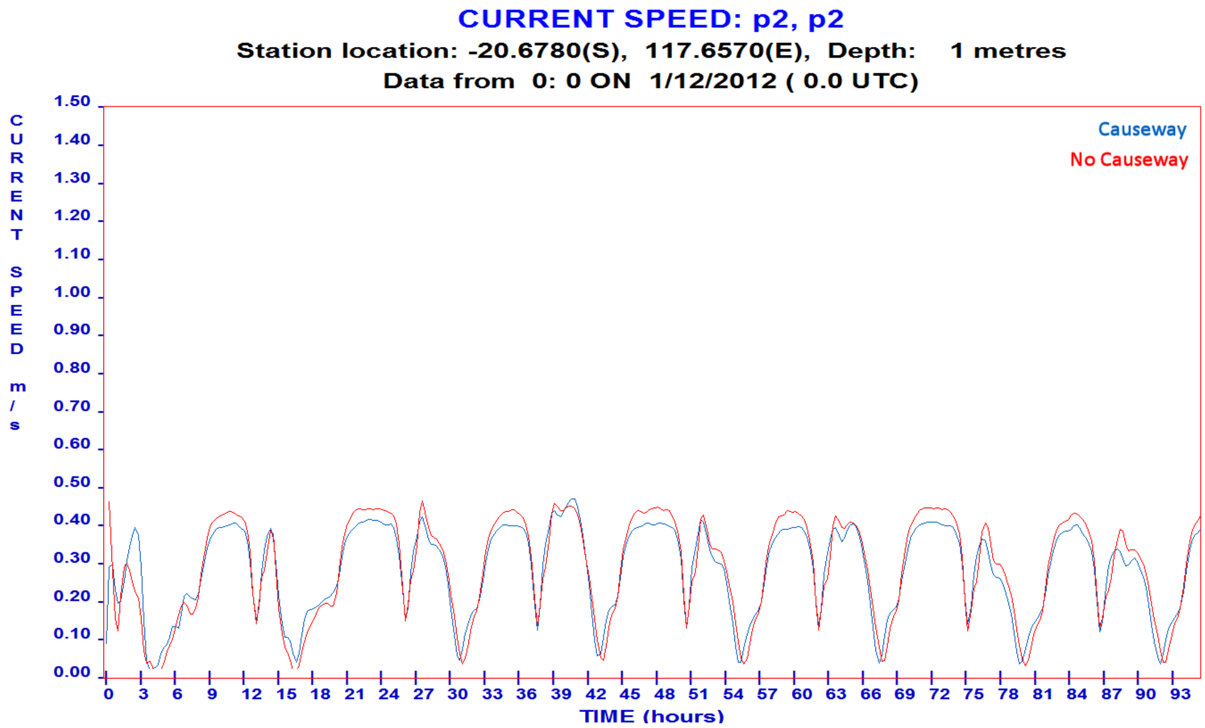


Figure 12. Comparison of current speeds at point "P2" for 4 days in December 2012.

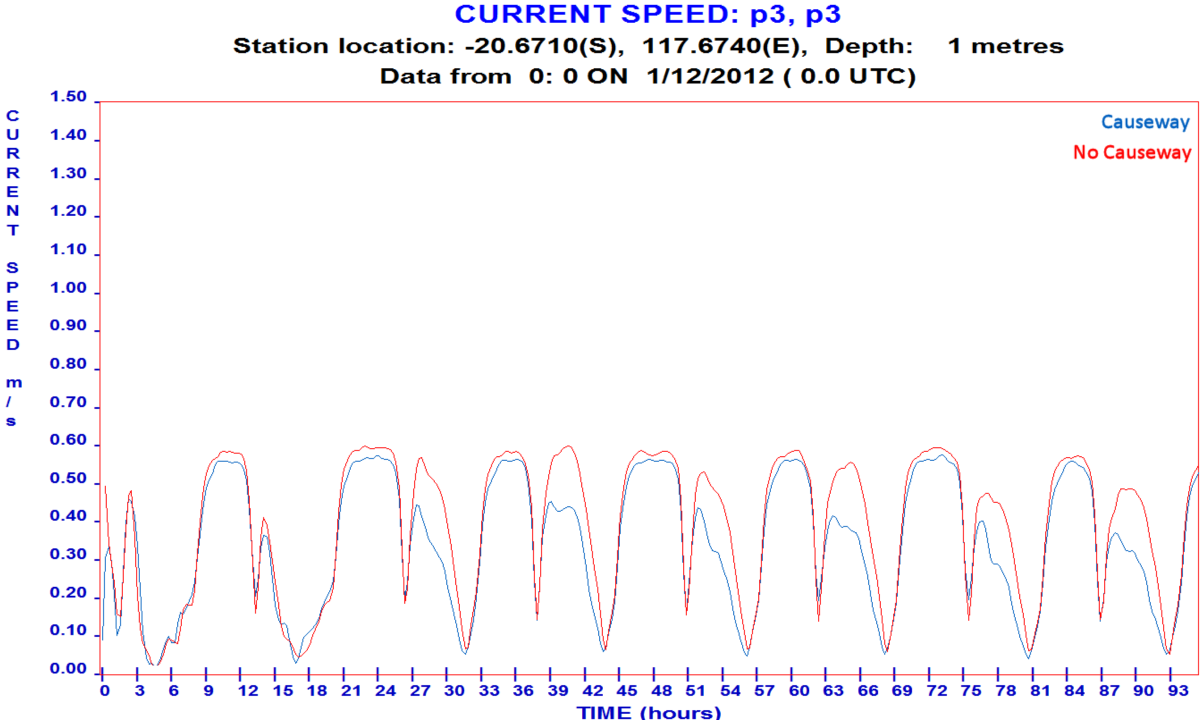


Figure 13. Comparison of current speeds at point "P3" for 4 days in December 2012.

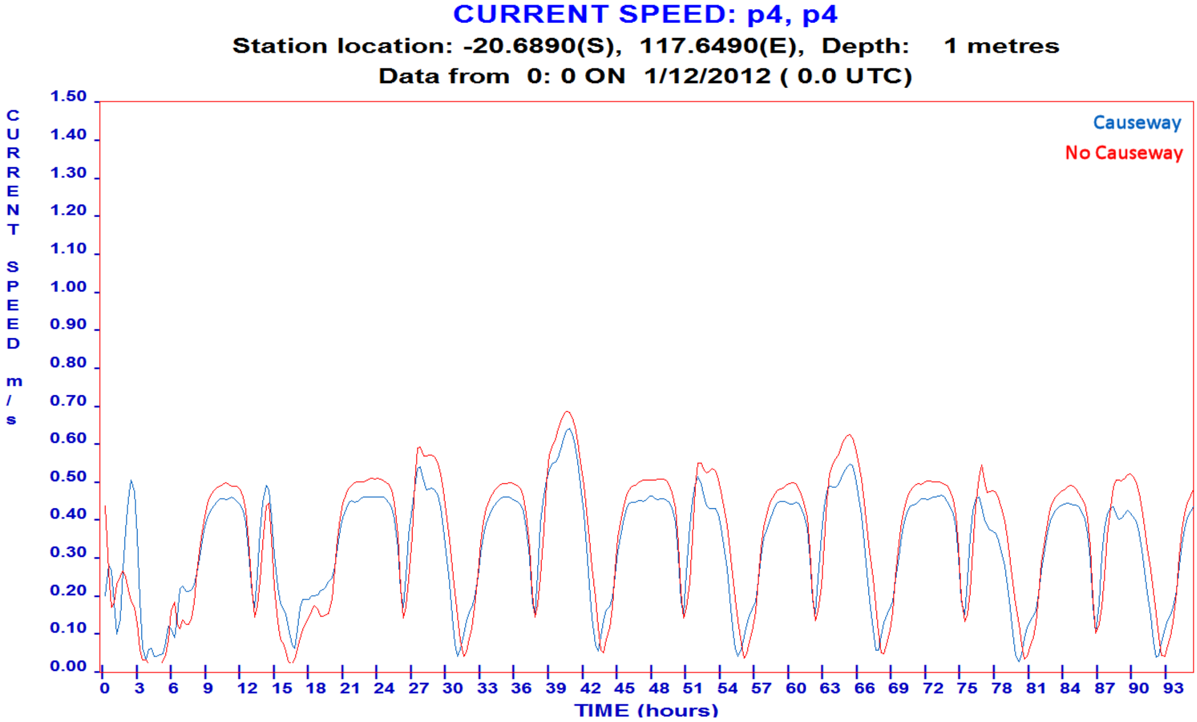


Figure 14. Comparison of current speeds at point "P4" for 4 days in December 2012.

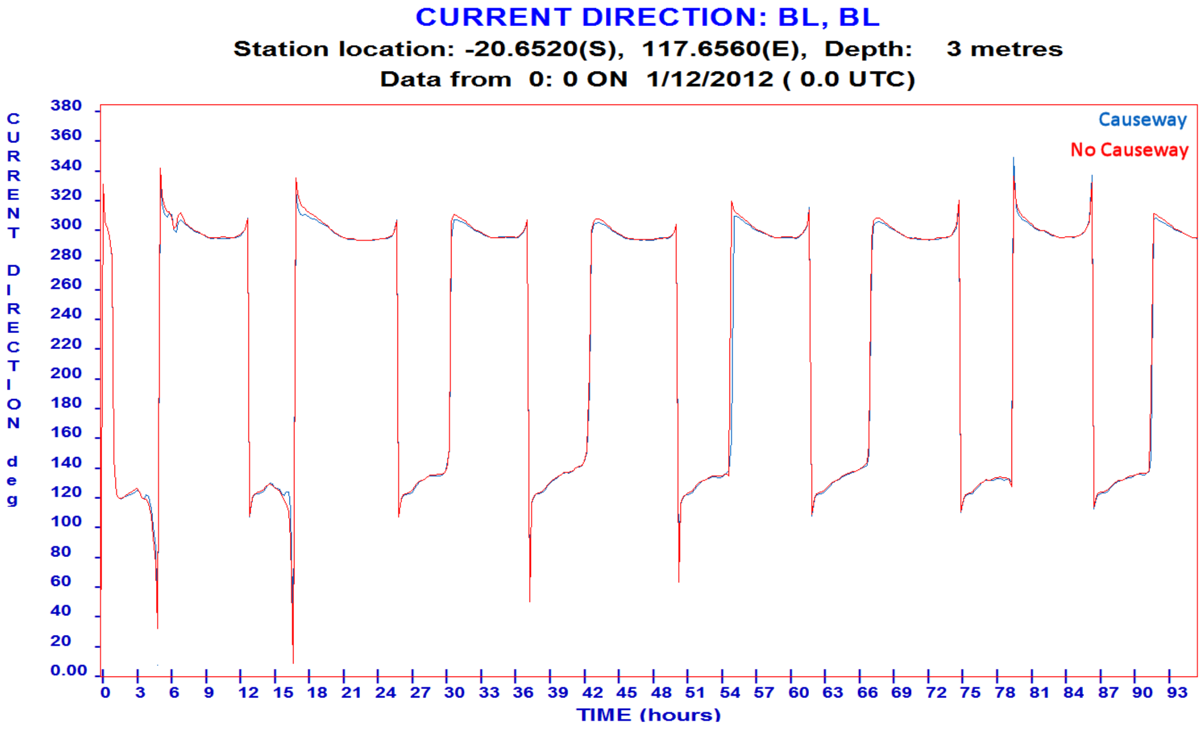


Figure 15. Comparison of current directions at point “BL” for 4 days in December 2012.

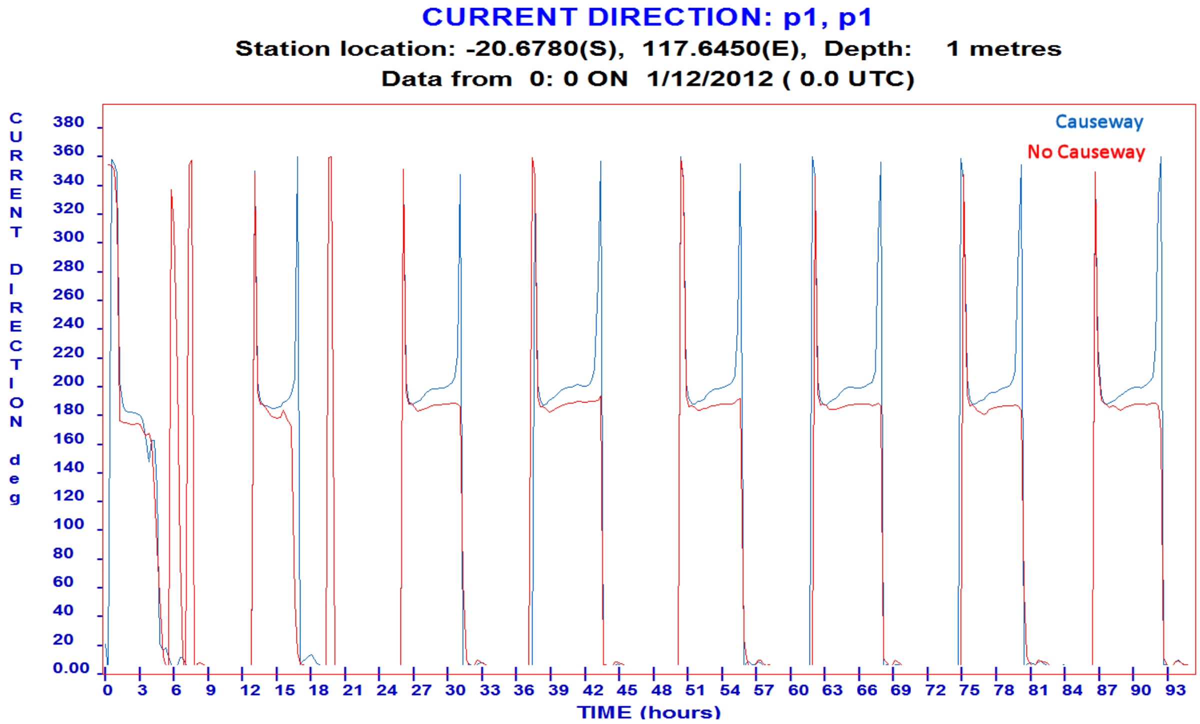


Figure 16. Comparison of current directions at point “P1” for 4 days in December 2012.

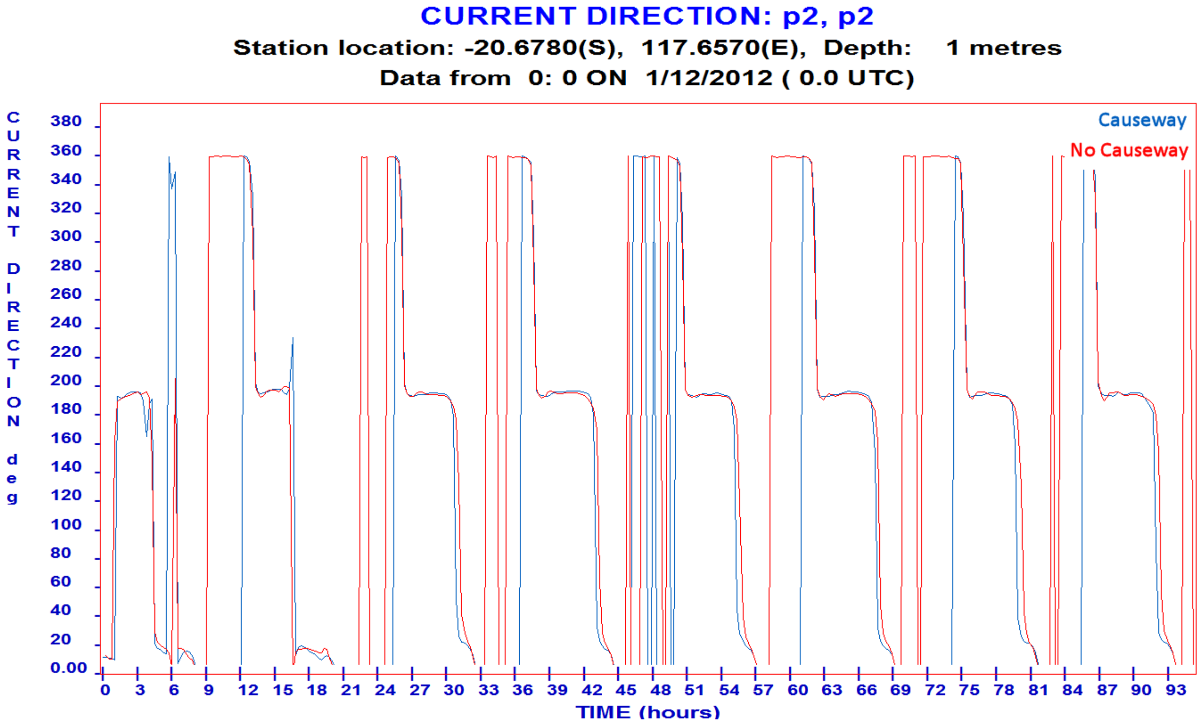


Figure 17. Comparison of current directions at point "P2" for 4 days in December 2012.

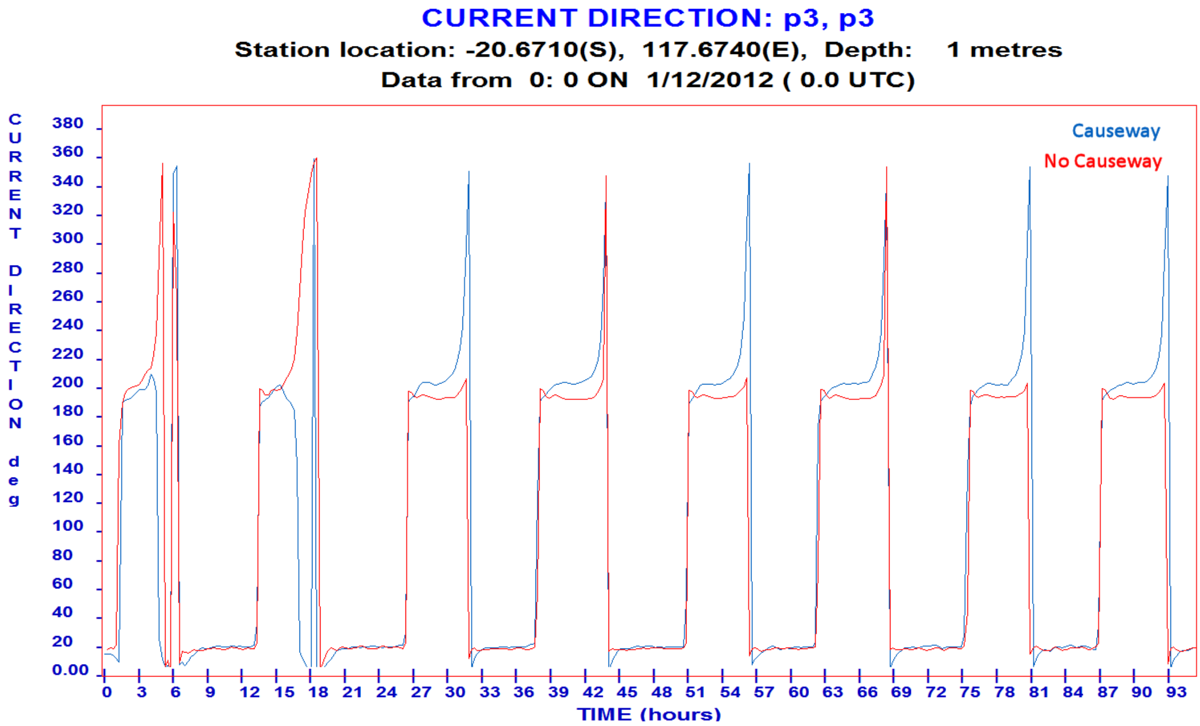


Figure 18. Comparison of current directions at point "P3" for 4 days in December 2012.

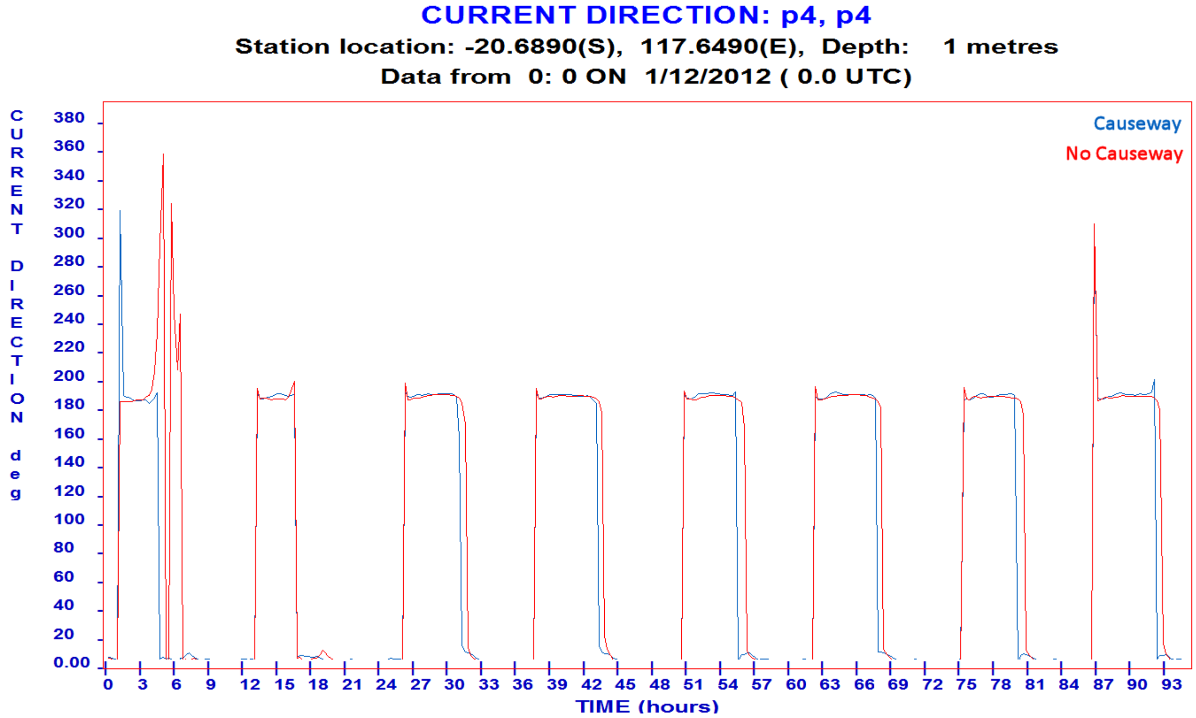


Figure 19. Comparison of current directions at point “P4” for 4 days in December 2012.