J. Schröter[1], R. Rietbroek[2], O. Boebel[1]
[1]AWI, Bremerhaven, Germany, [2]University of Twente, Netherlands

Validation of altimetry by using in situ observations of pressure and acoustic travel time in the Southern Ocean

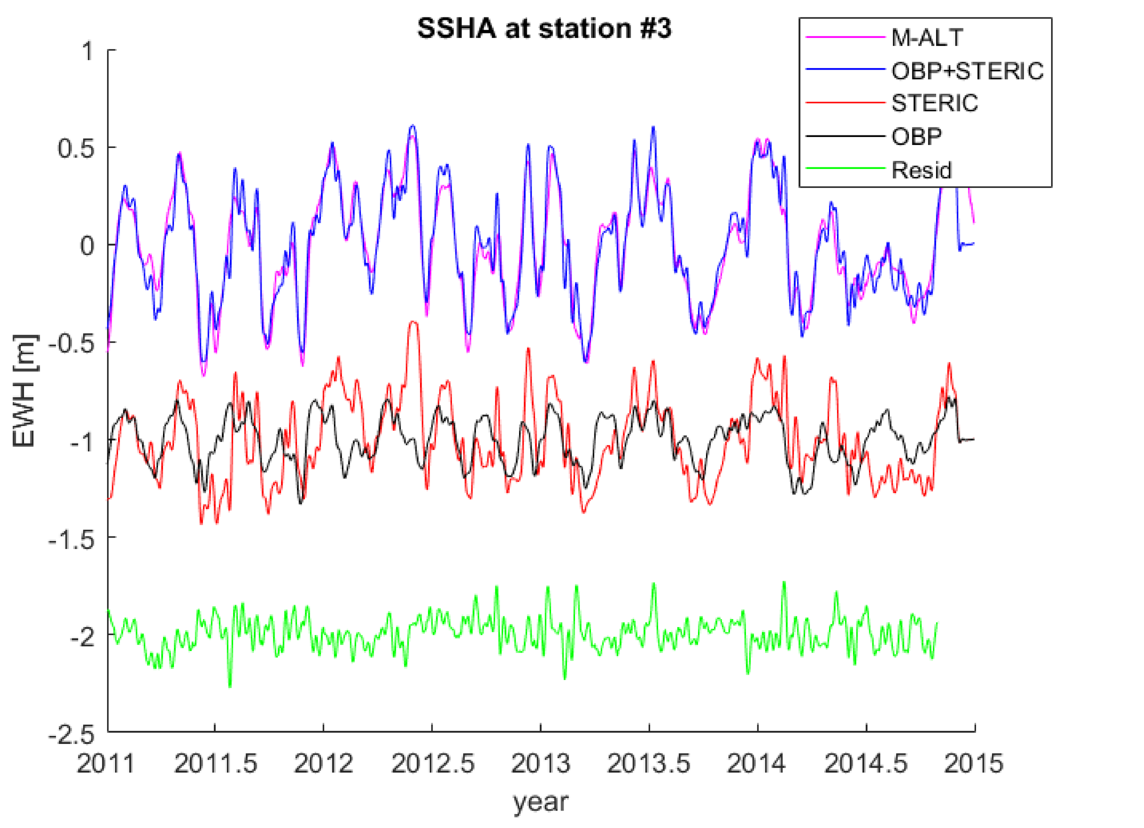

Figure 1. The sum of the steric (red) and OBP (black) PIES estimates, results in sea surface variations which closely follow the altimetry estimate(magenta). The difference in plotted green.
All data are expressed in EWH. Curves are offset by 1m.

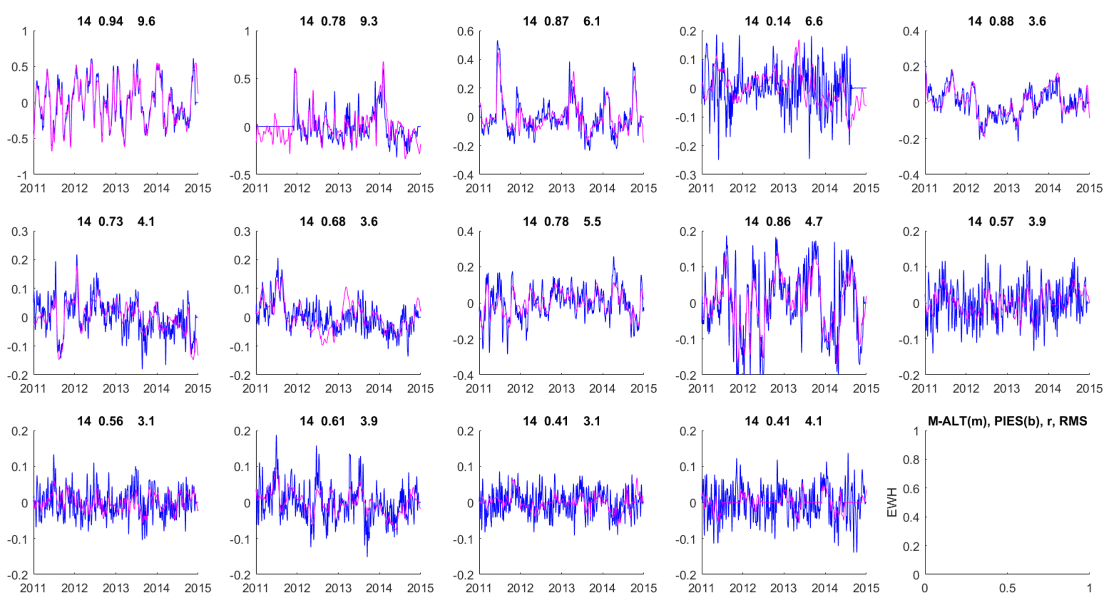

Figure 3: For most stations, the PIES estimates of sea surface height (blue) agree with estimates from altimetry(magenta). Indicated are station# correlation coefficient r and the RMS difference (in cm).

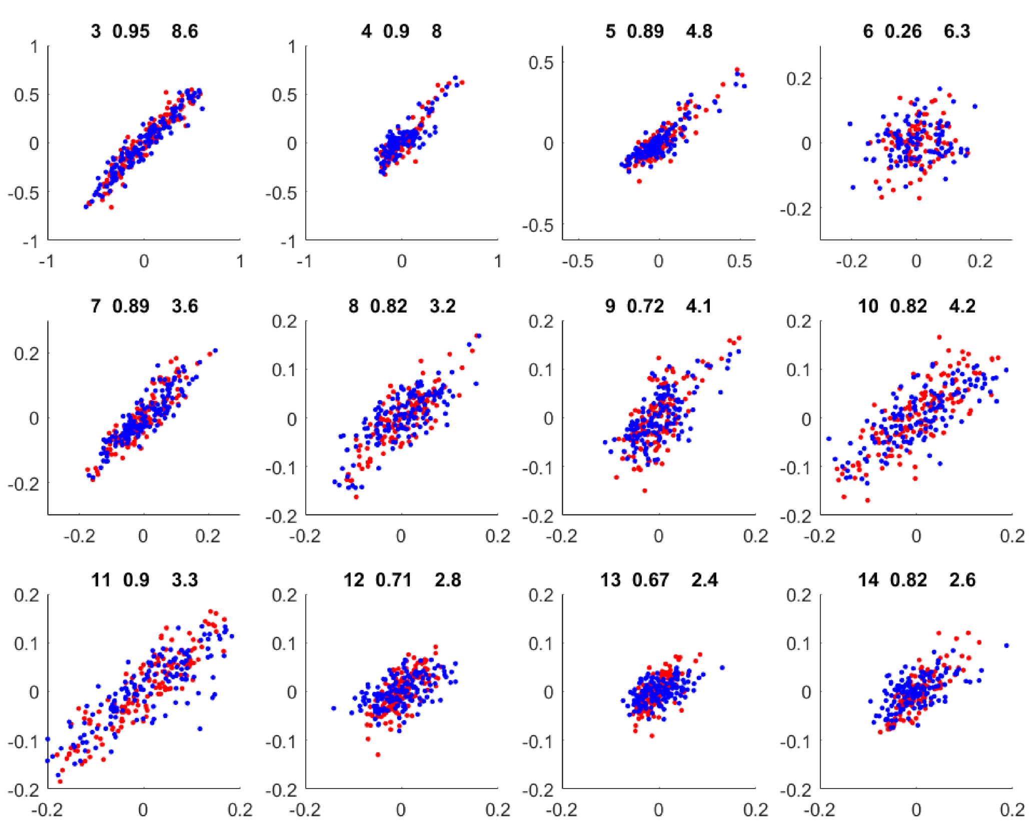

Figure 5: Correlation between RADS (red) and ocean estimate PIES. Indicated are station#, correlation r and the RMS difference (in cm).
SSHA from multi mission altimetry is shown in blue.

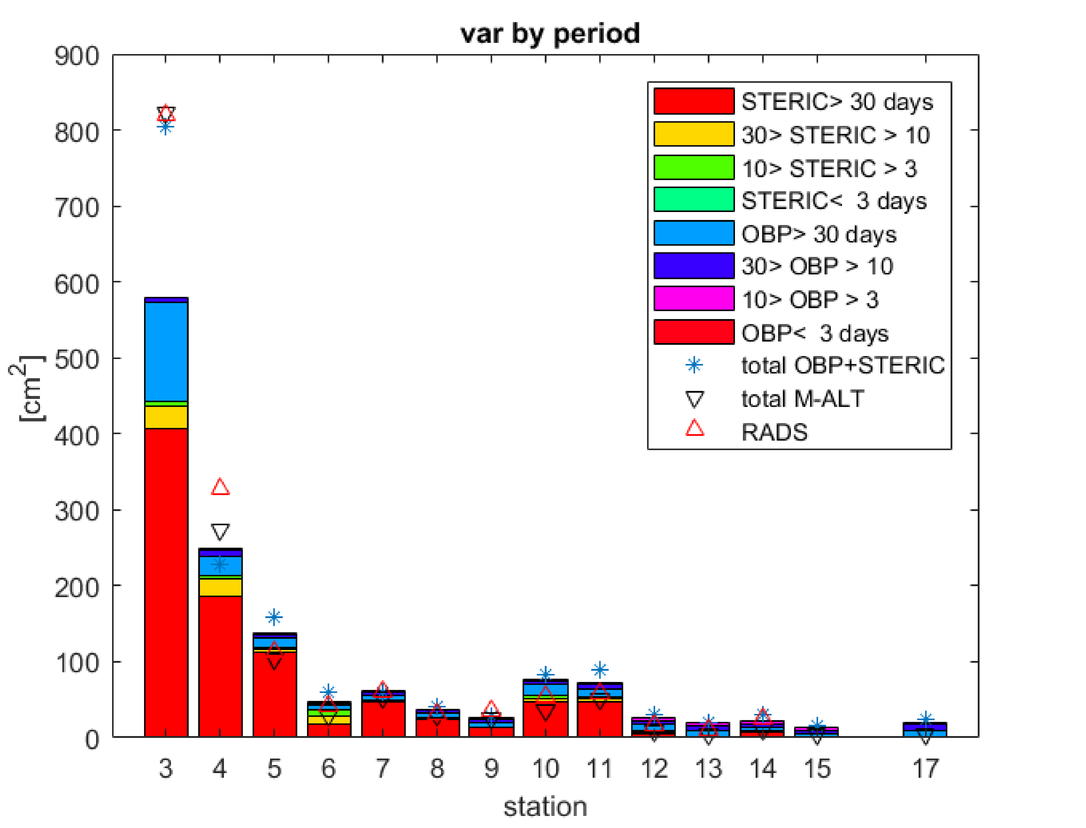

Figure 6: Variances of SSHA measured by PIES, M-ALT, RADS, coloured: variances of OBP and steric for 4 period bands, note: OBP and steric are correlated.

In large parts of the Southern Ocean stratification and dynamics are relatively uniform and allow the application of the "Gravest Empirical Mode" (GEM) concept. Among other characteristics, the concept describes how variations of heat content are linearly related to those of salt content and steric height. The slope of the function depends on the local background stratification.

Furthermore heat content variations are a function of vertical acoustic travel time. This leads to the conclusion that measuring ocean bottom pressure (OBP) and vertical travel time τ with pressure inverted echo sounders (PIES) allows us to calculate sea surface height anomalies. The concept has been developed during the Sub-Antarctic Flux and Dynamics Experiment (SAFDE) experiment south of Australia (Sun et al., 2001). Its validity has been confirmed south of Africa (Behnisch et al., 2013).

$$SSHA_{PIES} = OBPA + SSHA_{steric}$$
$$SSHA_{steric} = K(T,S)_{backgrd.} * \tau A$$

Anomalies of SSH are estimated from in situ OBP and vertical travel time τ of sound

An array of 14 PIES deployed south of Africa was used to generate oceanic sea surface height variability estimates. These are compared to the gridded multi satellite altimetry analysis M-ALT produced by AVISO/CMEMS, and JASON2 cross-over point estimates from the along track Radar Altimetry Database (RADS).

In previous studies GEM was primarily applied by using altimetry and learn about the stratification of the ocean. Here we turn the question around and try to use in situ observations to predict and explain altimetry using GEM.

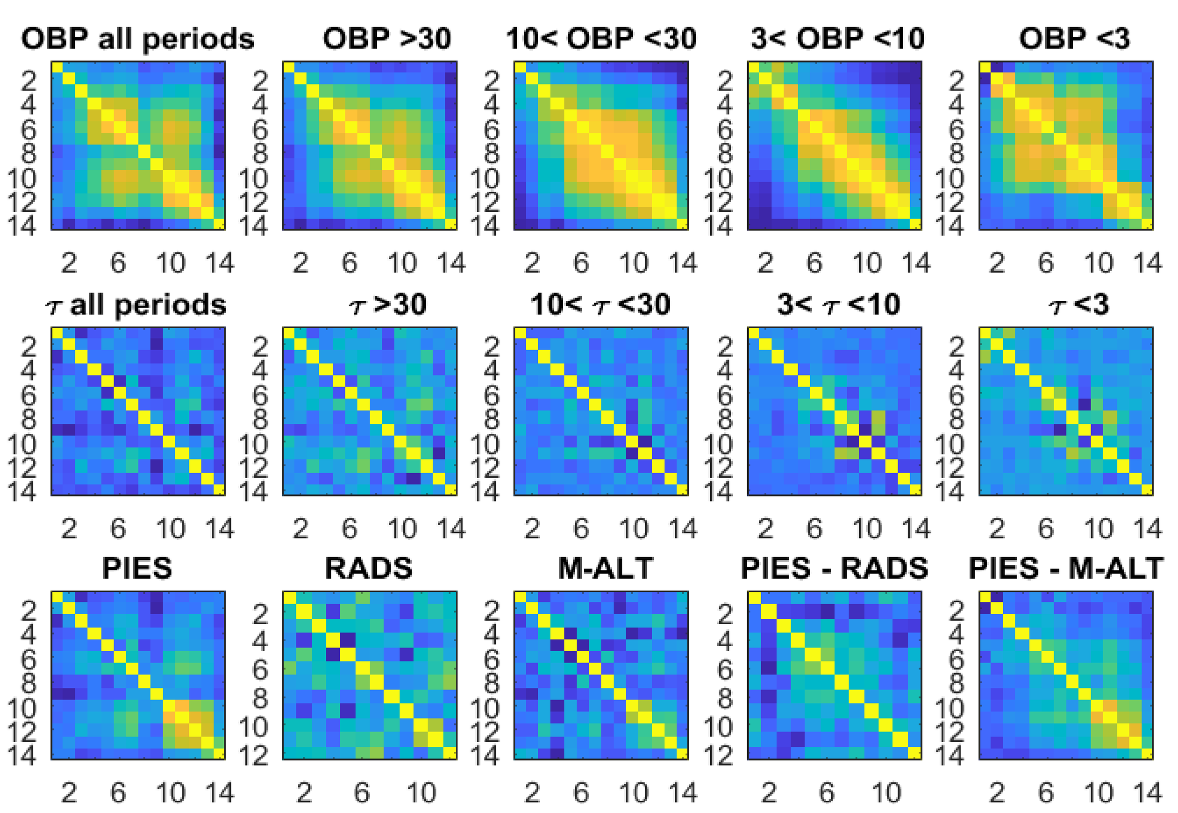

Figure 7: spatial cross-correlations for: top row: OBP for 4 frequency bands; middle row: travel time τ for 4 frequency bands; bottom row: total signals PIES, RADS, M-ALT, and error correlations for PIES-RADS and PIES - M-ALT. The larger off diagonal elements in the top row indicate spatially coherent OBP signals. These OBP signals remain visible in the SSH of the southern locations and are better captured (smaller residual) with RADS than with the gridded altimetry.

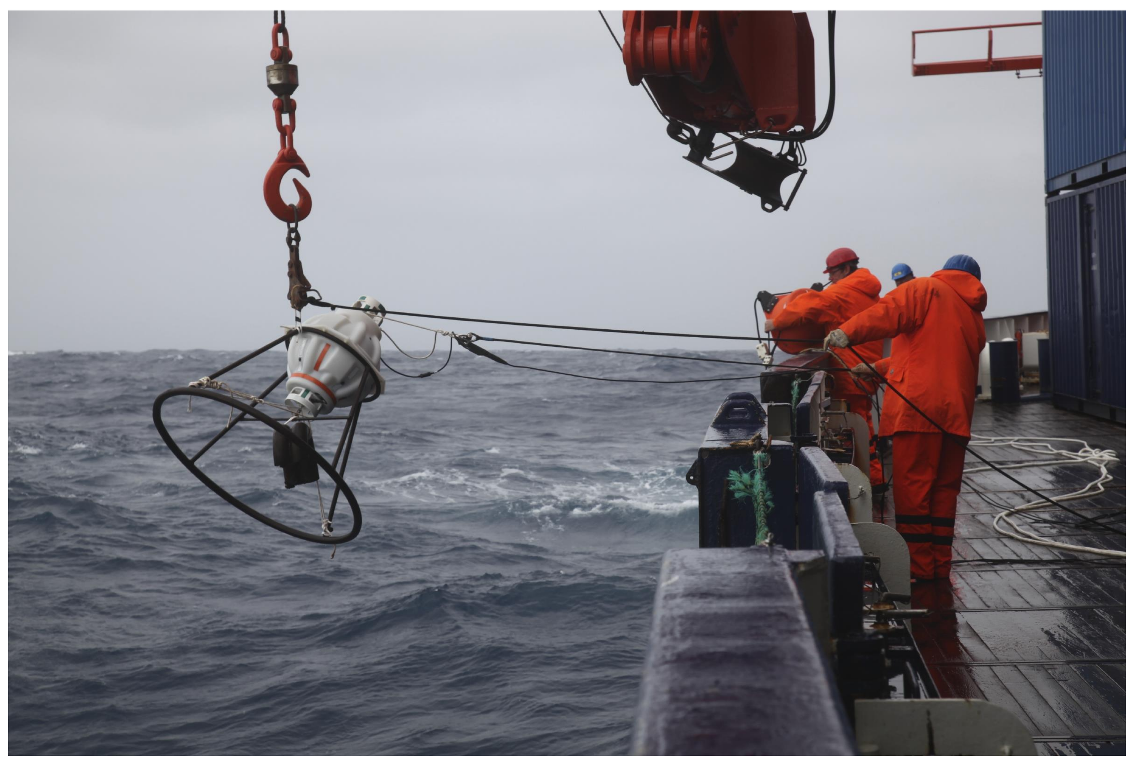

Figure 2. PIES deployment during the experiment ANT XXVII/02 Dec 4 2010 c F. Roedel/AWI

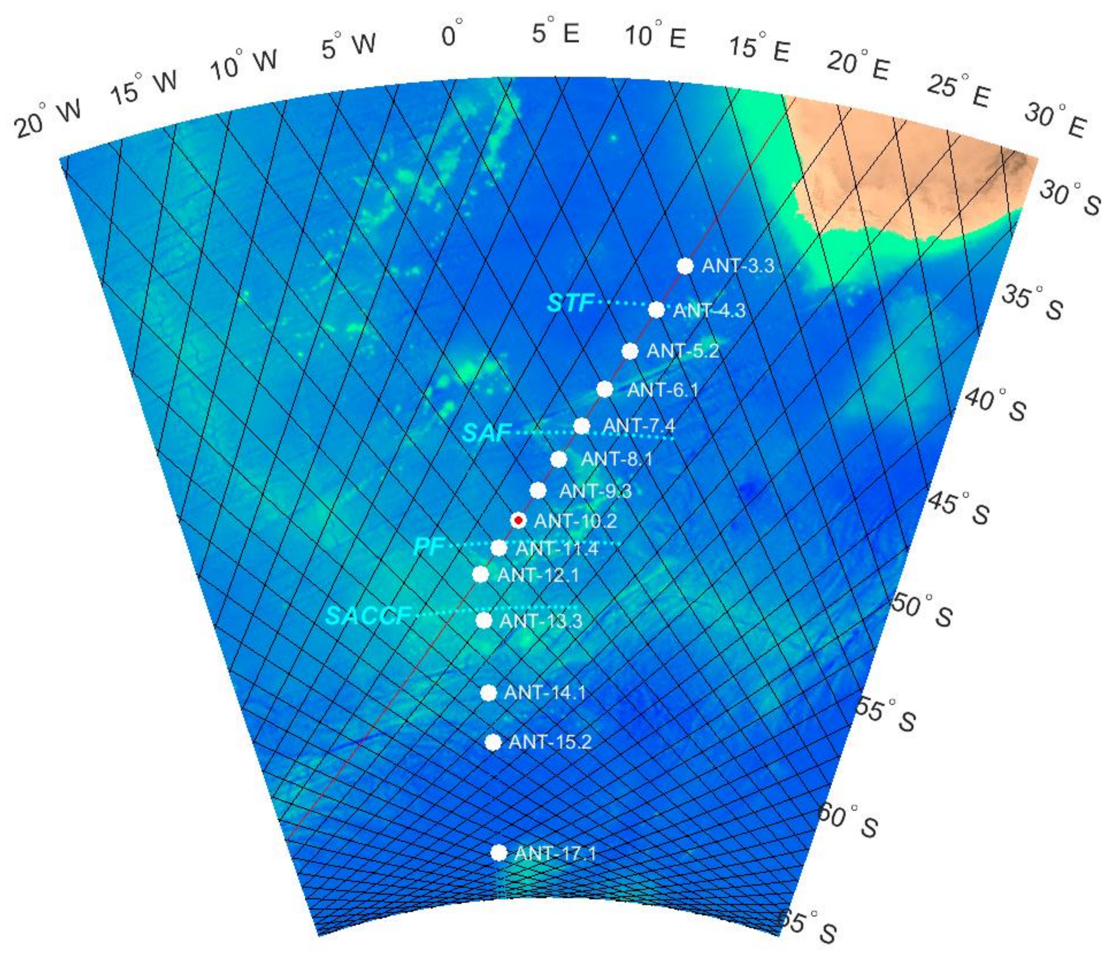

Figure 4: Location of deep ocean bottom pressure recorders between South Africa and Antarctica in 2011-2014. Indicated are oceanic fronts: SAF subtropical front, SF subarctic front, PF polar front, SACCF southern Antarctic circumpolar current front. In addition bathymetry and Jason2 ground tracks are indicated.

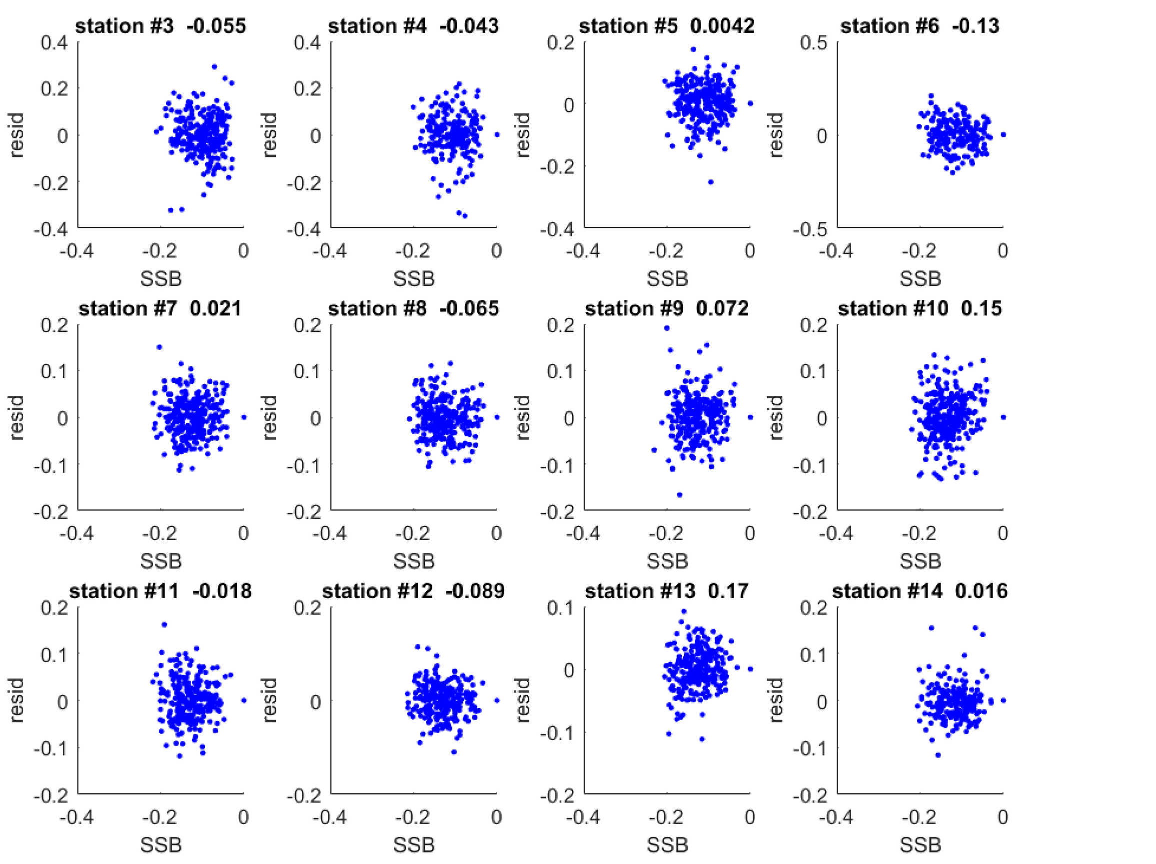

Figure 8. Difference of RADS and PIES at X-over points, shown as a function of sea state bias (SSB) correction. Indicated is the correlation coefficient. No clear dependence appears visible.

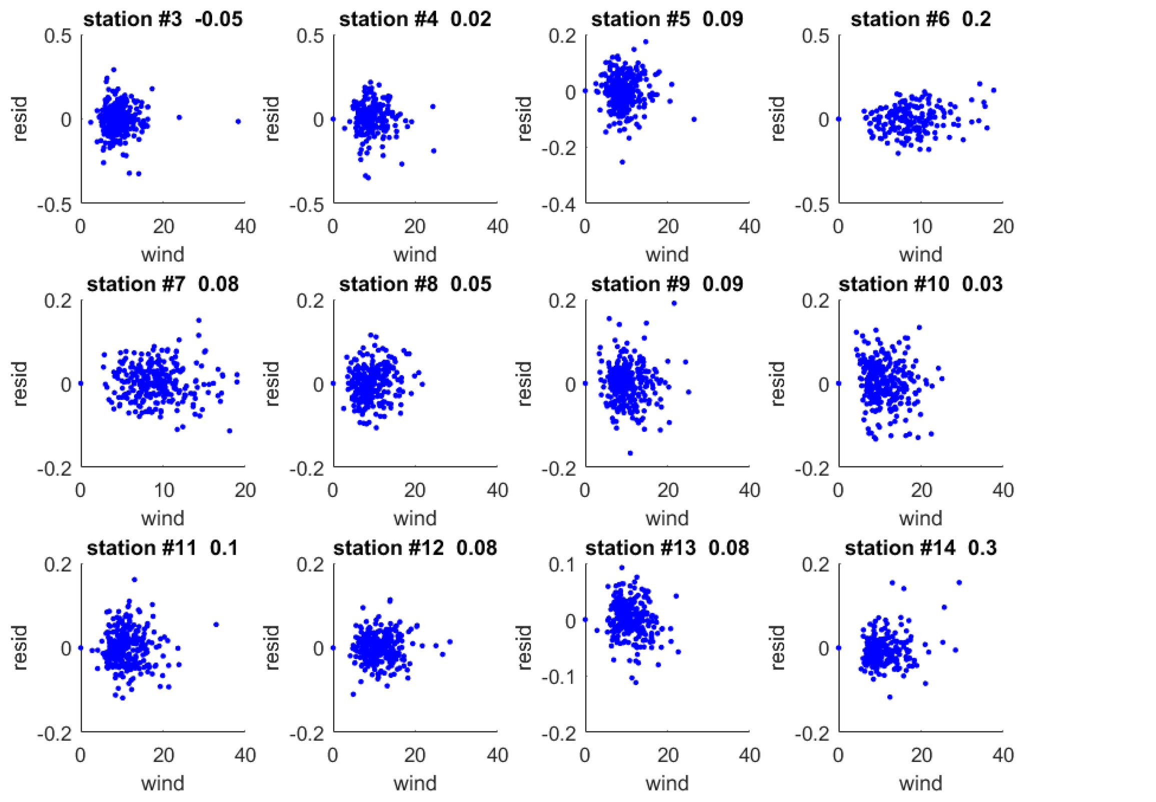

Figure 9. Difference of RADS and PIES at X-over points, shown as a function of wind speed. Indicated is the correlation coefficient. No clear dependence appears visible.

REFERENCES Sun, C., and D.R. Watts, 2001: A circumpolar gravest empirical mode for the Southern Ocean hydrography. J. Geophys. Res. - Oceans, 106, 2833-2855.
Behnisch, M. , Macrander, O. , Boebel, O. Wolff, J. O. and Schröter, J., 2013: Barotropic and deep-referenced baroclinic SSH variability derived from Pressure Inverted Echo Sounders (PIES) south of Africa, Journal of Geophysical Research-Oceans, 118 (6), pp. 3046-3058. doi:10.1002/jgrc.

BREMERHAVEN
Am Handelshafen 12
27570 Bremerhaven
Telefon 0471 4831-0
www.awi.de