Consistency of observed sea surface height changes, bottom pressure changes and temperature, salinity variations in a South Atlantic transect of the Antarctic Circumpolar Current

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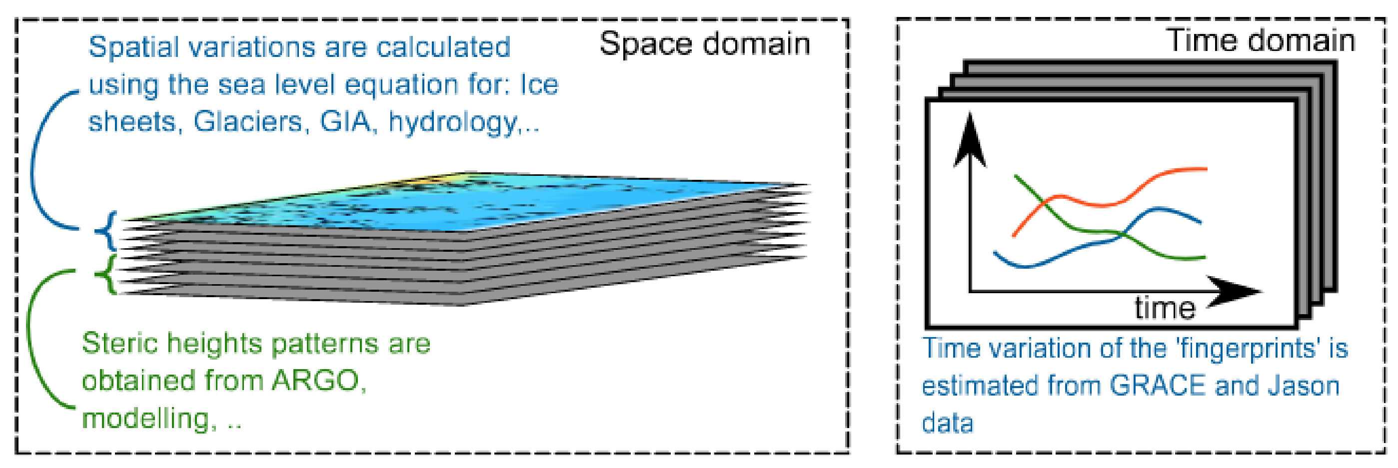
Before: Joint Fingerprint Inversion - Estimate Sea Level Budget Components with Satellite Observations (Rietbroek et al., 2016)

Idea:

- estimate: steric and mass induced sea level changes, and changes in superimposed signals (ice covers, GIA, hydrology)
- use: GRACE and Radar Altimetry data
- method: determine the magnitude of each signal with spatial fingerprints



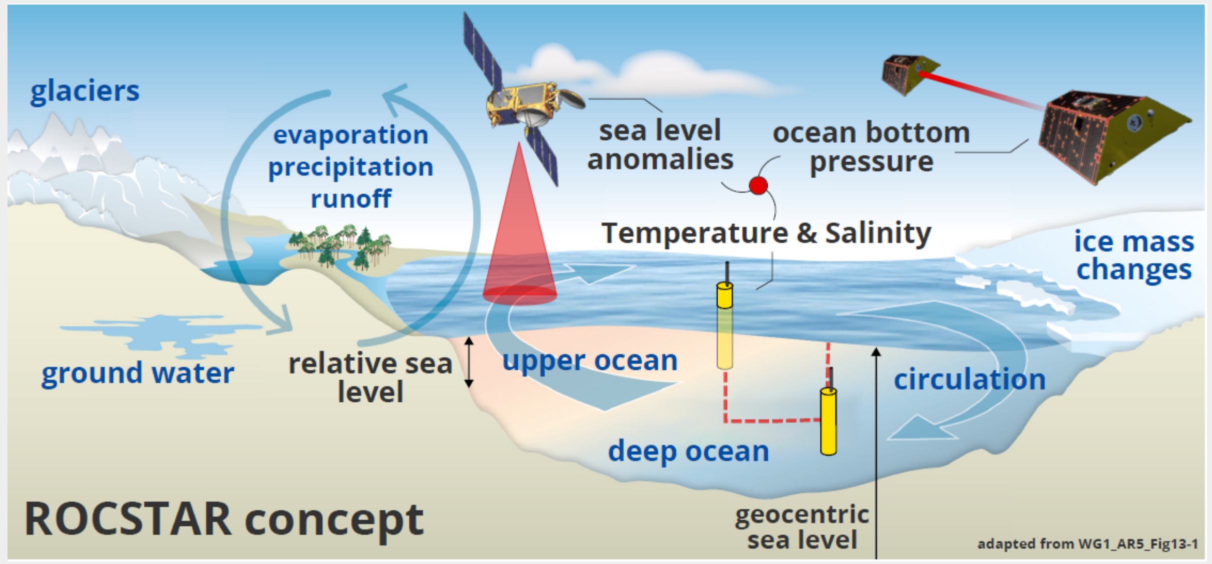
Results:

- global sea level budget - closed
- regional sea level budget - "closed" with larger uncertainties

Now: Advanced Joint Inversion - Additionally Coestimate 4D Temperature and Salinity Profiles (Rocstar Project)

Idea:

- estimate: changes in the geoid, dynamic SSH, atmospheric surface pressure anomaly, and discretized T,S profiles
- use: GRACE, Radar Altimetry and ARGO data
- method: **constrain mass and geometry** of the entire ocean column



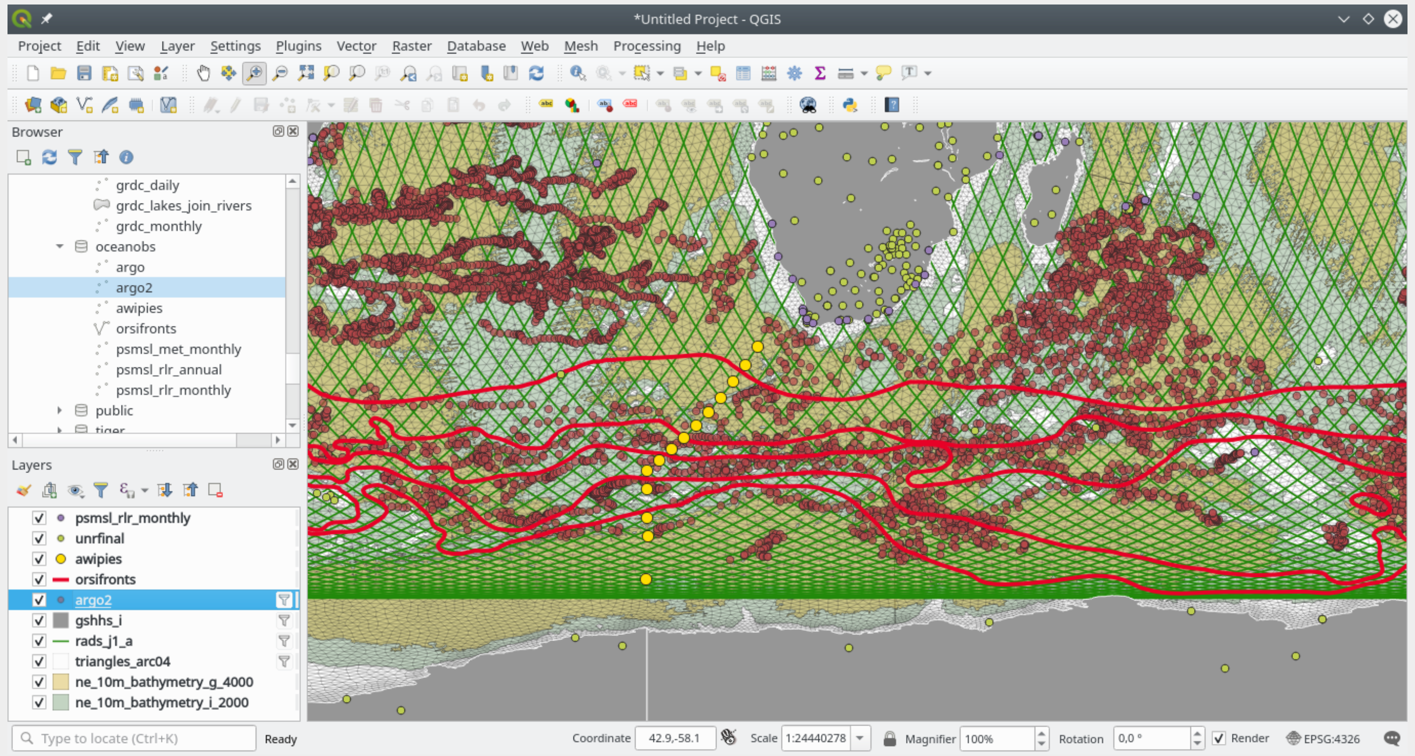
Expectations:

- increase the accuracy and consistency of 4D T,S fields
- better understand the sparsely sampled areas (deep ocean, shallow ocean)
- identify ocean heat hotspots and study their link to the terrestrial water cycle

- close regional sea level budget and provide realistic error estimates (focus SE-Asia)

Infrastructure

- manage data with PostGreSQL+PostGIS database ([‘geoslurp’ on github])



- process data using jupyter-hub and jupyter notebooks
- follow the progress and learn more about the ROCSTAR on project website

ROCSTAR

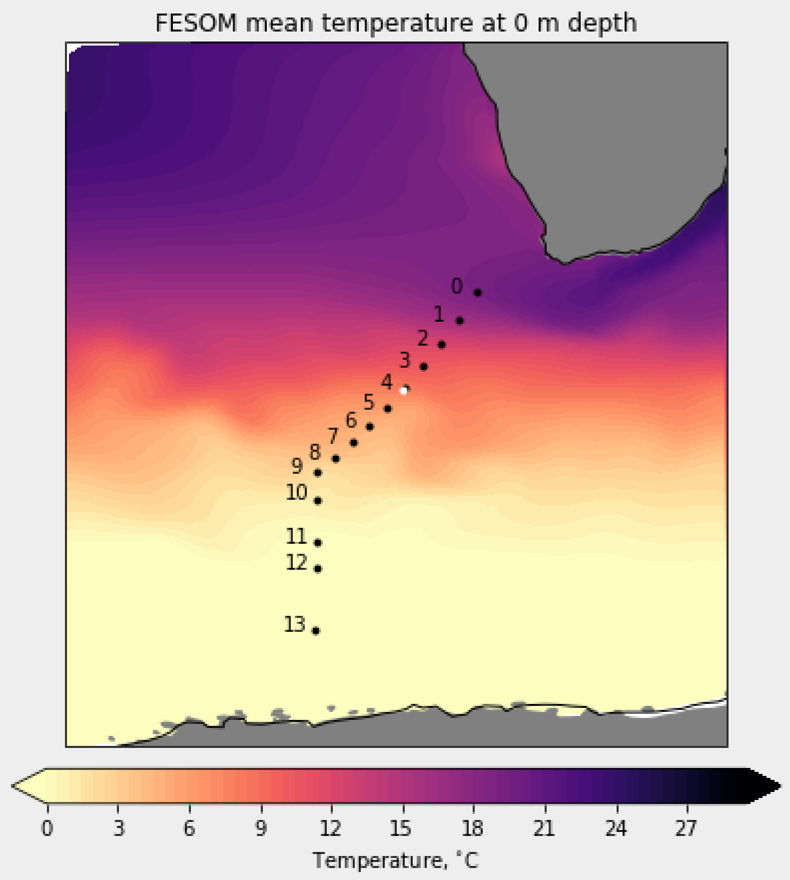
Test Joint Inversion in South Atlantic through Comparison with In-Situ OBP Measurements

- estimate T, S, SSH, OBP at OBP-sites

Info sheet: OBP in-situ measurements (AWI)

- when: monthly mean in 2011-2014
- where: in the South Atlantic transect of the Antarctic Circumpolar Current
- where exactly: at the intersections of Jason-2 accending and descending tracks
- number of sites: 14

In [12]:
```
plotFesomTemp('temp',Obp.lon(),Obp.lat(), f_xy,
    minind_run, f_temp_mean, point,topo[lvl],
    Obp.boundingbox(format='corners'))
```



Test Joint Inversion in South Atlantic through Comparison with In-Situ OBP Measurements

- estimate T, S, SSH, OBP at OBP-sites

Questions to be answered:

- Are the T,S estimates realistic and comparable to models (FESOM) in terms of variability?
- Do we improve the fit of measured OBP wrt direct-GRACE estimates?
- Do we reproduce observed sound travel times (linked to the density of the ocean column)?

First Steps: Estimate Temperature Profiles at OBP-sites using Least Squares Collocation and FESOM Outputs

1. define depth levels the Least Squares Collocation based on the thermocline
2. select suitable ARGO observations and determine their covariance
3. estimate temperature profiles at OBP-sites with Least Squares Collocation (Moritz, 1972)

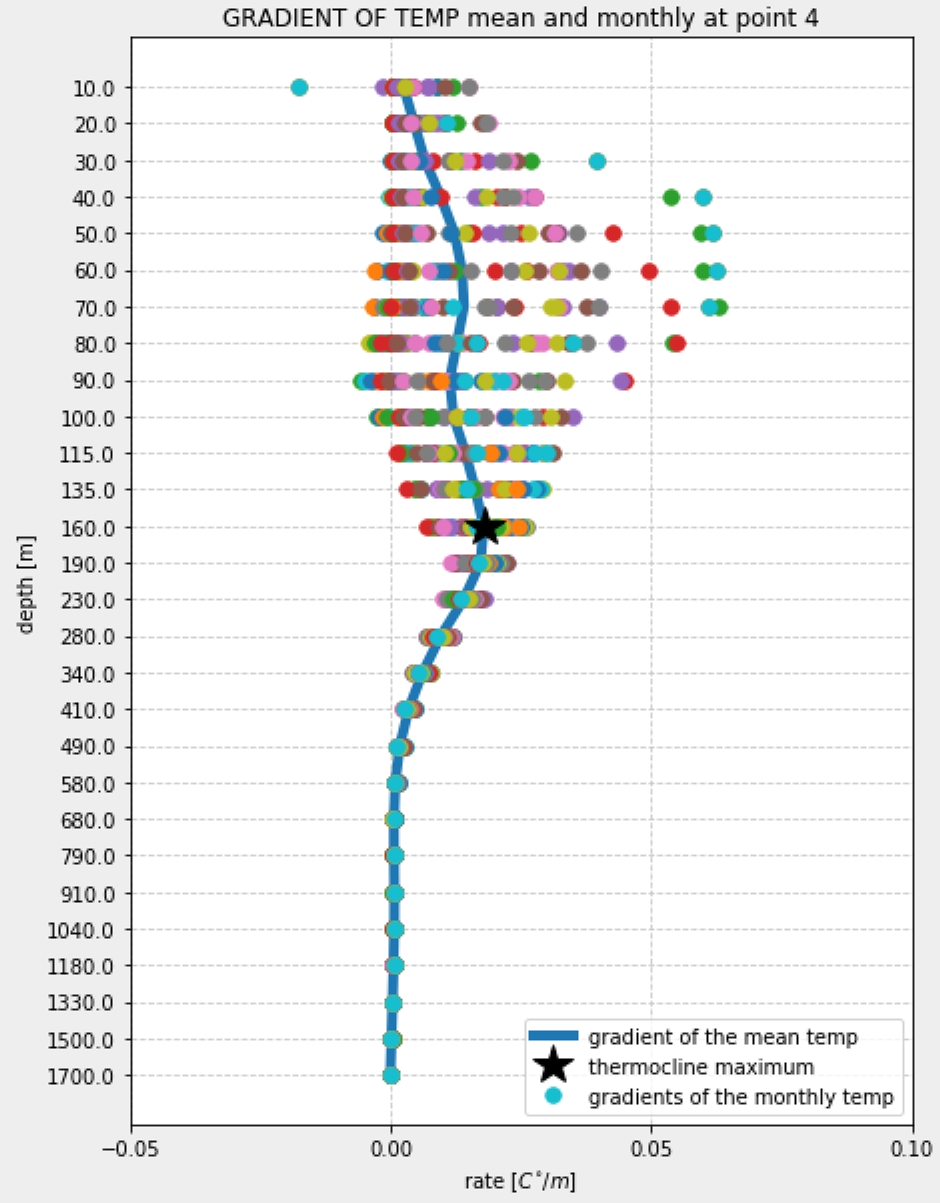
Vertical Discretization: Where does the temperature change most?

Define depth levels for the Least Squares Adjustment based on the thermocline

- compute gradient of the temperature profile
- define maximum of the temperature gradient as the bottom of the mix layer
- below that choose sparser discretization

First guess: FESOM depth levels

In [46]:
```
plotFesomTempGradientMonthly(point, grad_filt,
                             grad_mean_filt, topo)
```

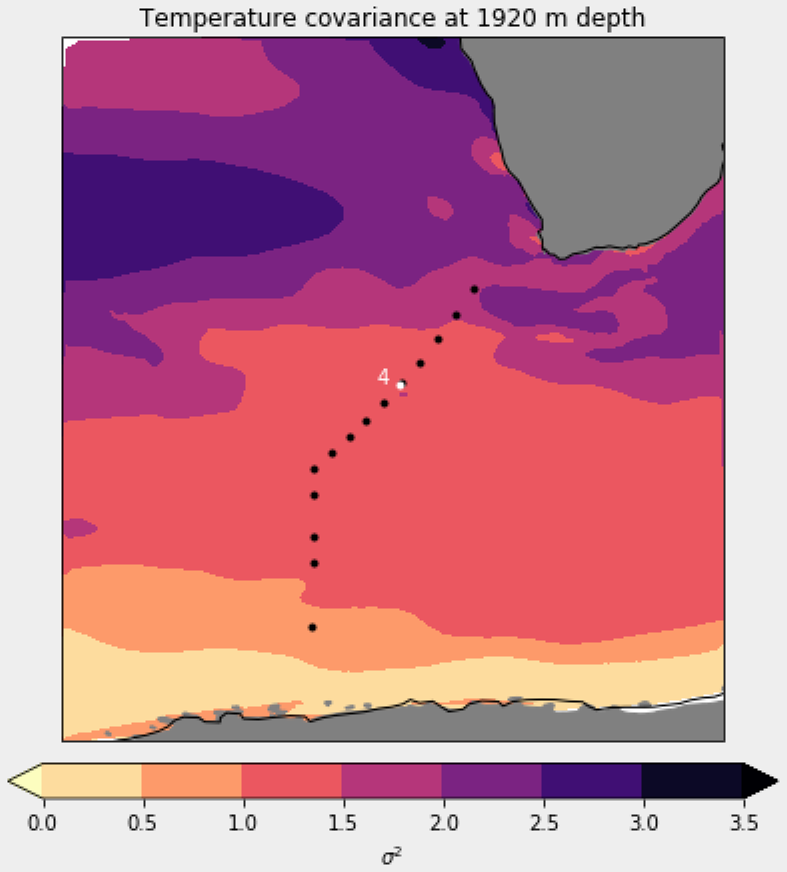


Problem for LSC: Find realistic Signal Covariance

Select Suitable Correlated ARGO Observations

- compute signal covariance from FESOM
    - same period as OBP observations 2011-2014
    - example for OBP-site nr.4

In [17]:
```
plotFesomTemp('cov',Obp.lon(),Obp.lat(), f_xy,
        minind_run, cov_sample[:,point],
        point, topo[lvl],
        Obp.boundingbox(format='corners'))
```



South Atlantic Experiment, Yakhontova et al., 2020

Problem for LSC: Find realistic Signal Covariance

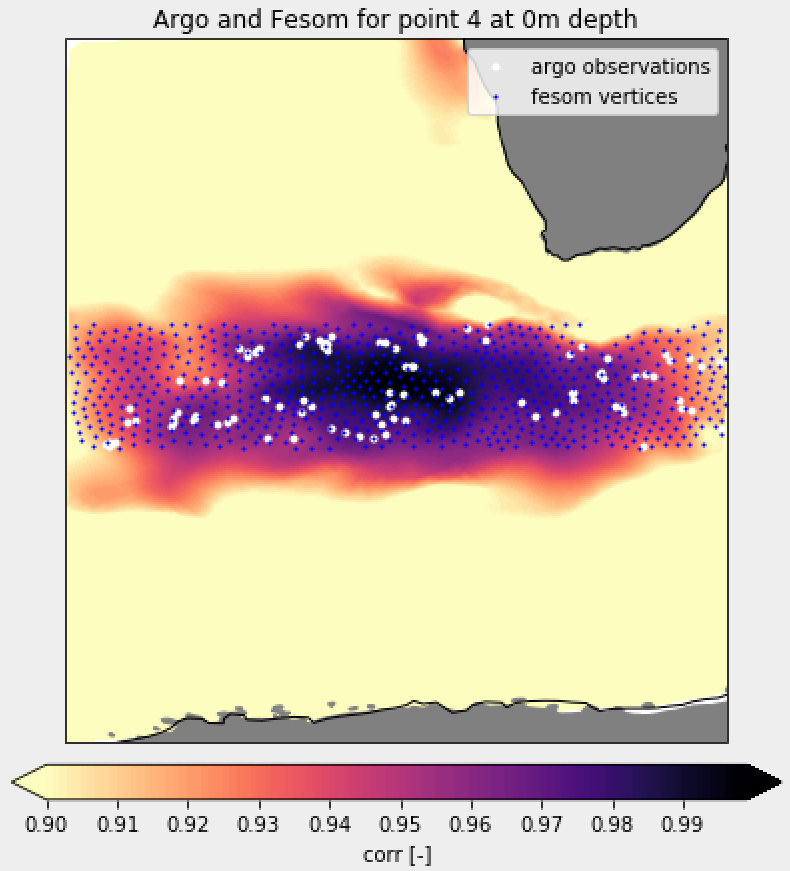
Select Suitable Correlated ARGO Observations

- assign covariance and correlation of the closest FESOM vertex to each ARGO observation
- select only ARGO observations inside the latitudinal belt $[Obp.\,lat \pm 5^{\circ}]$ and with corresponding FESOM correlation ≥ 0.9 to ensure temperature similarity

correlation pattern:

- determined by (modeled) circulation
- similar for all OBP-sites

```
In [24]:
_, _, _, _ =argoInCorrArea(mesh, topo, lvl, zlvlid,
     f_xy, f_xyPoint, corr_sample[:,point],
     a_area_xy, a_area_temp_lvl, a_area_temp_err_lvl,
                            plot=True)
```



Estimate Temperature Profiles at OBP-sites with Least Squares Collocation

- Least Squares Collocation:

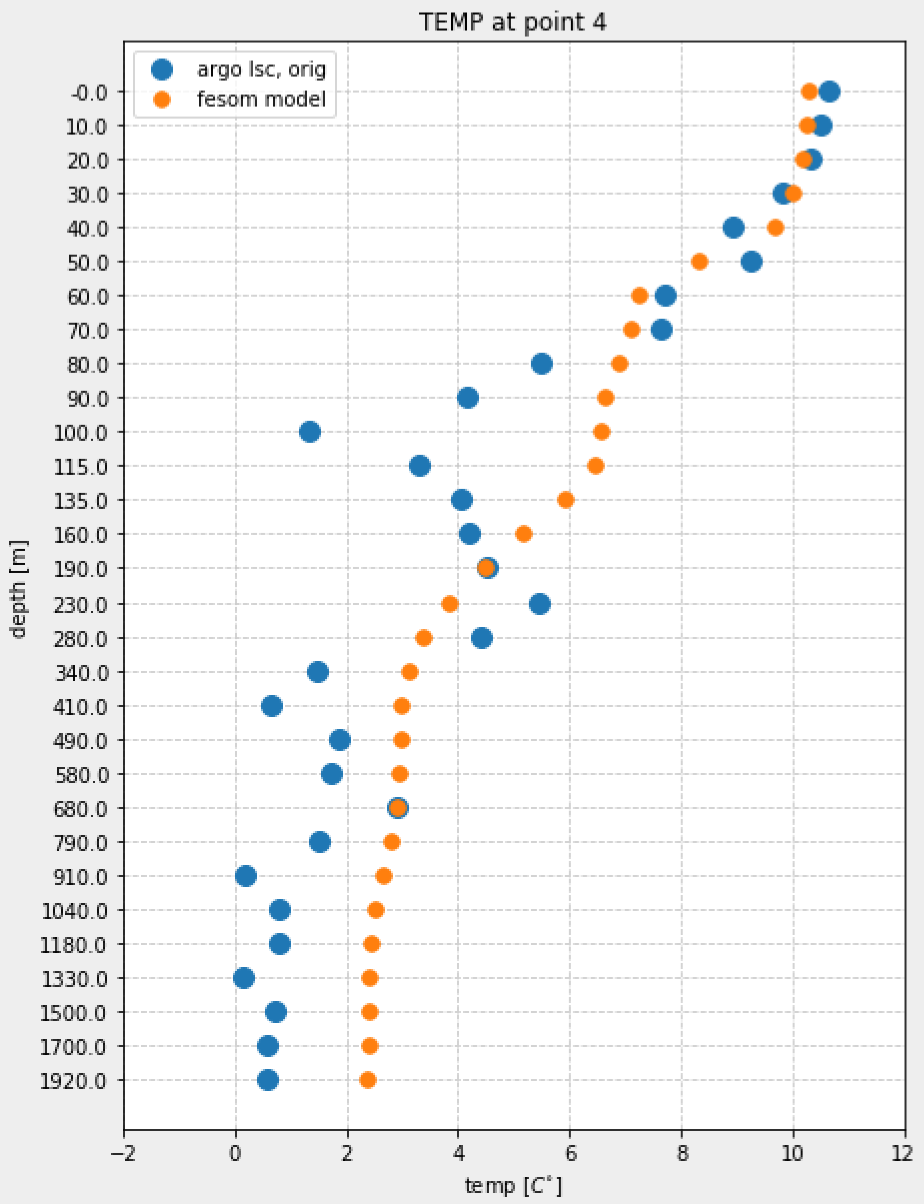
$$b = \alpha C_{sl}(\alpha C_{ll} + C_A)^{-1} x$$

  - C_A - variance of selected ARGO points
  - C_{ll} - covariance of selected ARGO points
  - C_{sl} - covariance of the OBP-site to selected ARGO points
  - $\alpha = 10^{-4}$ - scaling factor to weigh provided variance
  - x - observed temperature at selected ARGO points

- perform for each depth level

In [28]:

```
plotLSC(point,a_temp_lsc,
        f_temp_obp)
```



Parametrization of ARGO Profiles

Why parametrize?

- reduce storage (per profile: 10 parameters instead of 100 in-situ measurements)
- condense the vertical T,S discretization
- define inversion parameters

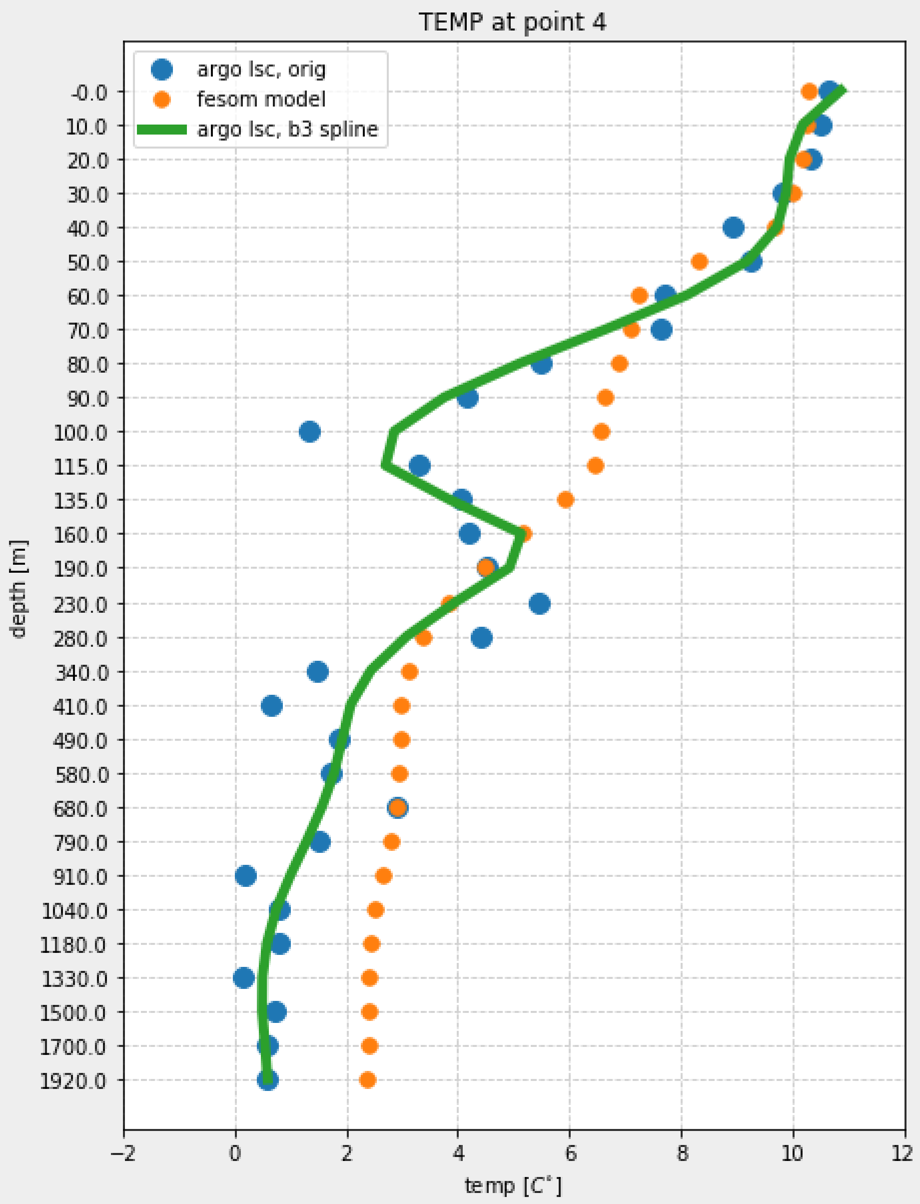
Cubic B-splines fit best:

- smallest rms error
- number of parameters: 8-10
- knots at depths:

$$[0,50,100,150,200,500,1000,1500,2000]m$$

In [31]:

```
plotLSCb3spline(point,a_temp_lsc,t_argo_b3spline,
                            f_temp_obp)
```



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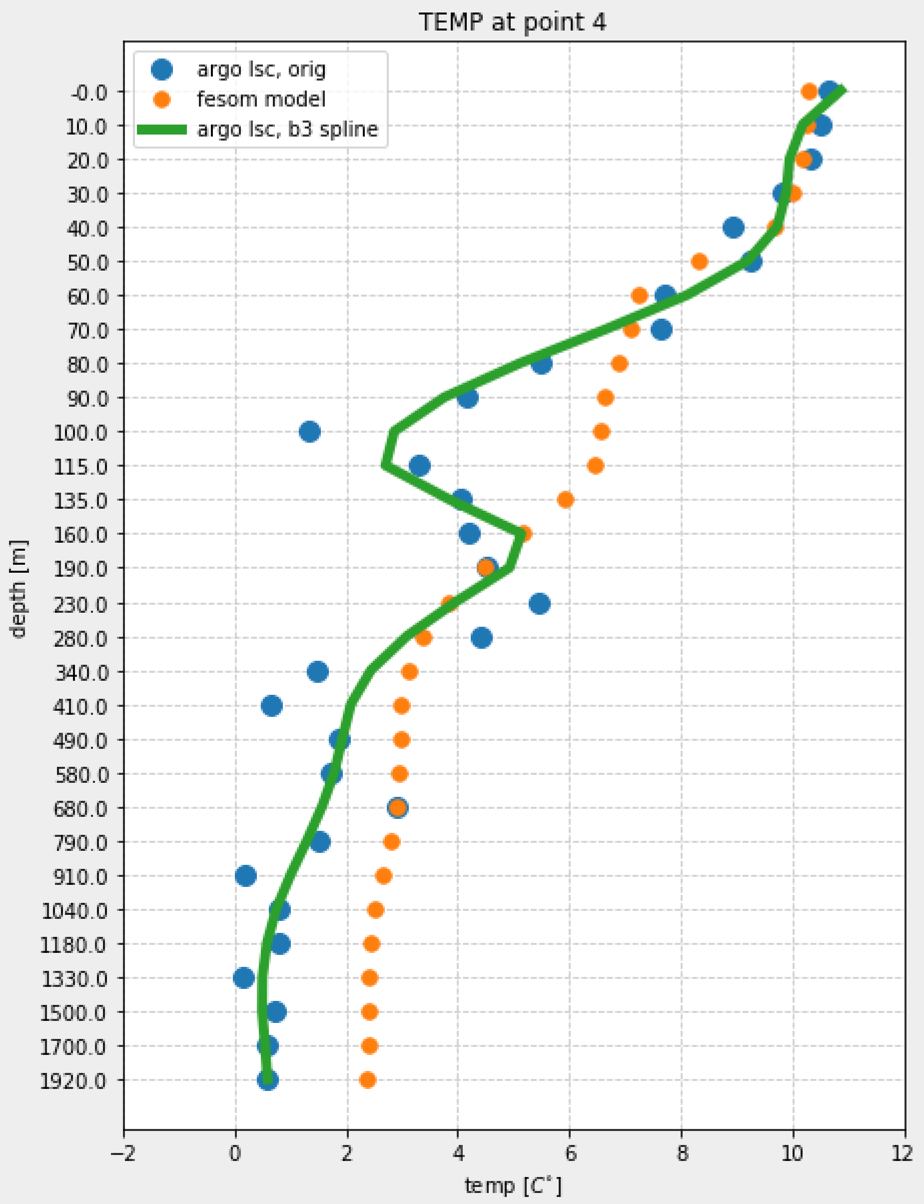
Parametrization of ARGO Profiles

Results:

- Is there a bias in FESOM vs ARGO below $300m$?
- Anomaly at $150m$ depth?

In [31]:
```
plotLSCb3spline(point,a_temp_lsc,t_argo_b3spline,
                          f_temp_obp)
```



Next Steps:

- use climatology as a first guess, where ARGO data is missing
- compare models (FESOM) and ARGO variabilities instead of absolute monthly values
- determine whether the signal covariance is stationary using monthly batches
- ARGO outlier test and quality screening

- use parametrized profiles to perform the joint inversion with GRACE and Radar Altimetry

Summary

- start of ROCSTAR project (compute 4D fields of temperature and salinity in the Inversion Framework)
- testbed in South Atlantic
  - in-situ OBP measurements
  - signal covariance from model data (FESOM)
  - suitable discretization with depth
  - temperature estimates at OBP-sites using Least Squares Collocation

I hope you will visit our website for more info: https://rocstar.wobbly.earth/