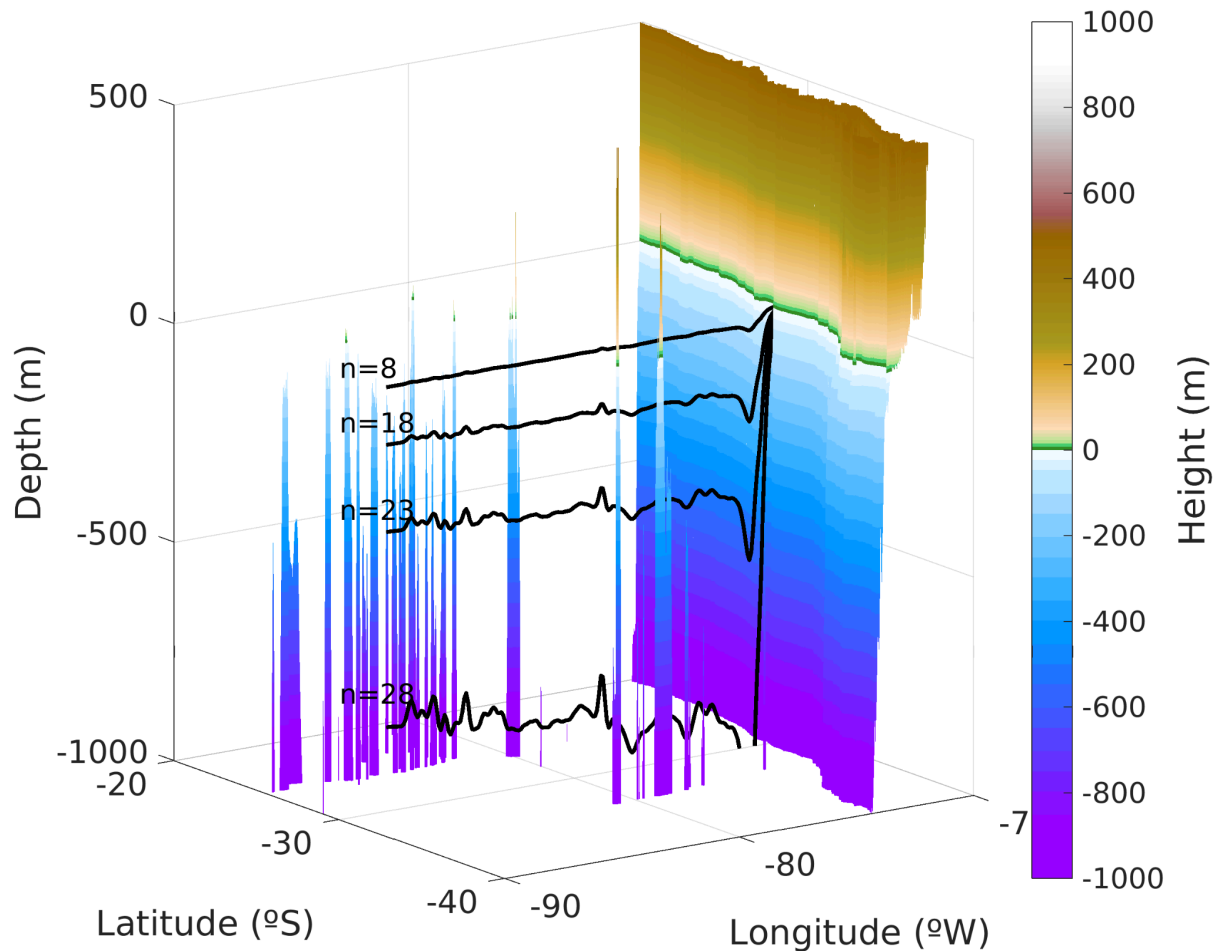# Supplementary material

## Figures



**Figure S1. Bathymetry of the study zone. The study area extends between 20 - 40ºS, from the coast to 90ºW and includes the first 1000 m of depth, where eddies have a higher incidence. The color map distinguishes between the marine area (blue and purple colors) and the terrestrial area (brown and green colors). Model configuration includes n=37 sigma levels, with n=28 spanning from the surface to approximately 1000 m depth and 9 additional levels for depths >1000 m. At 30ºS we illustrate some sigma levels (black lines) corresponding to the stratification in January 2002 as an example. The displayed sigma level are: n=8 (range: -27 to -47 m), 18 (range: -150 to -260 m), 23 (range: -340 to -570 m), and 28 (range: -760 to -1280 m) These depth ranges are independent of the slope area.**
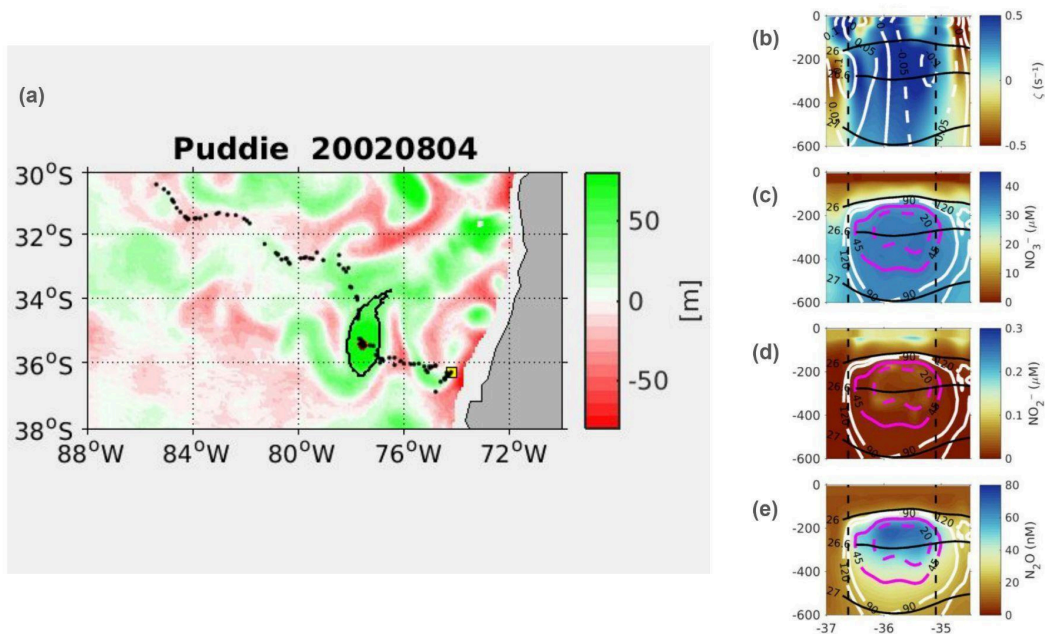
**Figure S2. Identification and vertical characterization of a Puddy. It was identify with the Faghmous algorithm where we used the maximum positive anomaly of the layer thickness ($\delta h$, colormap) that is bounded by the density surfaces $S_{upper}$ = 26.0 kg m$^{-3}$ and $S_{lower}$ = 26.9 kg m$^{-3}$, $\delta h > 0$ indicates the anticyclonic polarity, the largest closed contour around the geographical location of $\delta h_{max}$ is considered as the edge of the eddy (black close contour), as $\delta h_{max}$ is associated with the center of the eddy (black points; see Section 2.5). Eddy was located at 76.5ºW, 35.8ºS with ~21 weeks of life. (b-e) Vertical structure of Puddy shows the isopycnal layers $S_{upper}$, $S_{core}$ and $S_{lower}$ (black contours). The edge (black dotted line) with a radius of 73 km. b) Relative vorticity and velocity field, zonal component velocity (white lines) indicates westward flow (dashed line) and eastward flow (solid line). c) NO$_3^-$, d) NO$_2^-$ and e) N$_2$O. The core with low oxygen (magenta lines) encloses hypoxia (O$_2$ < 45 µM, solid line) and suboxia (O$_2$ < 20 µM, dashed line). White contours enclose oxygen concentrations of 90 and 120 uM.**
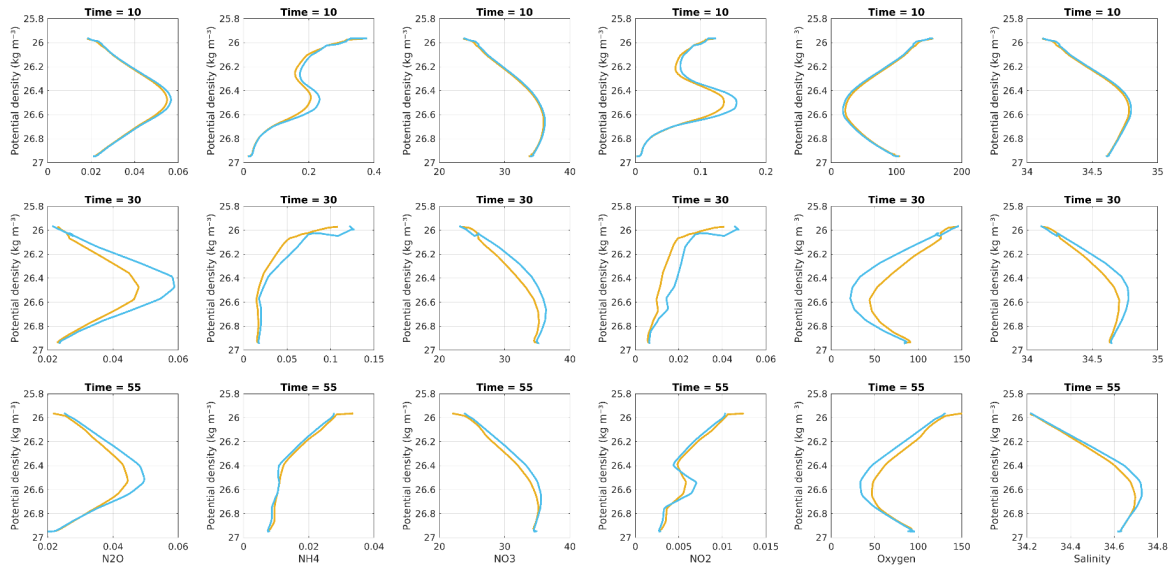
**Figure S3. Comparison of the average vertical profile considering an eddy delineated with a circular boundary (orange line) versus an irregular boundary obtained by the Faghmous method (blue line) for each biogeochemical tracer ($N_2O$, $NH_4$, $NO_3$, $NO_2$, $O_2$ in μmol) and absolute salinity (in g/kg). The selected times correspond to the early stage (t=10, ~2 months), mid-stage (t=30, ~6 months), and late stage (t=55, ~11.5 months) of the eddy's life cycle. The vertical profile was obtained following the methodology outlined in Section 2.6.2.**
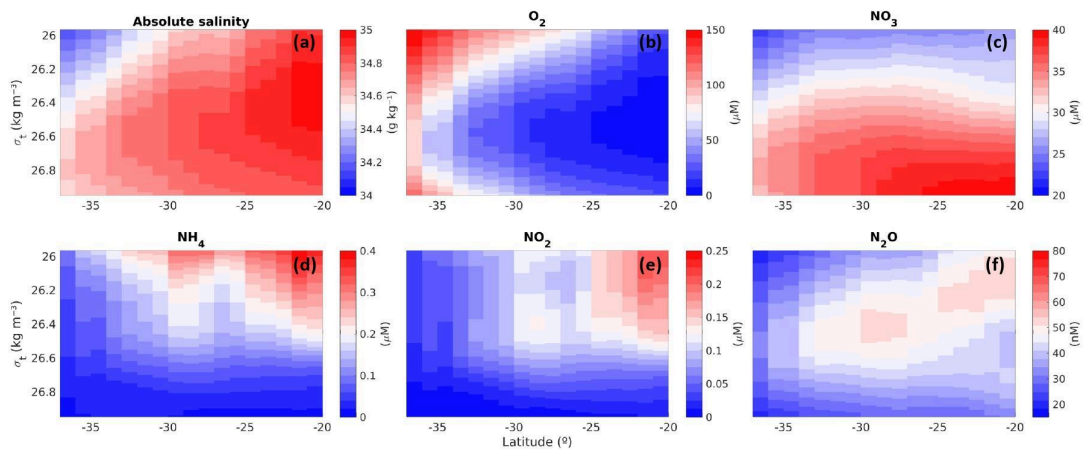


**Figure S4. Mean state of different properties at the first ~100 km from the slope where there are higher occurrence Puddies (strip in color red, Figure 1 - right box). The typical characteristics were obtained averaging in areas of 1ºx1º along the coast between the isopycnals layers $S_{upper}$ and $S_{lower}$ by 9 years (See Methods 2.2). (a) absolute salinity, (b) oxygen, (c) nitrous oxide, (d) ammonium, (e) nitrite, (f) nitrate.**
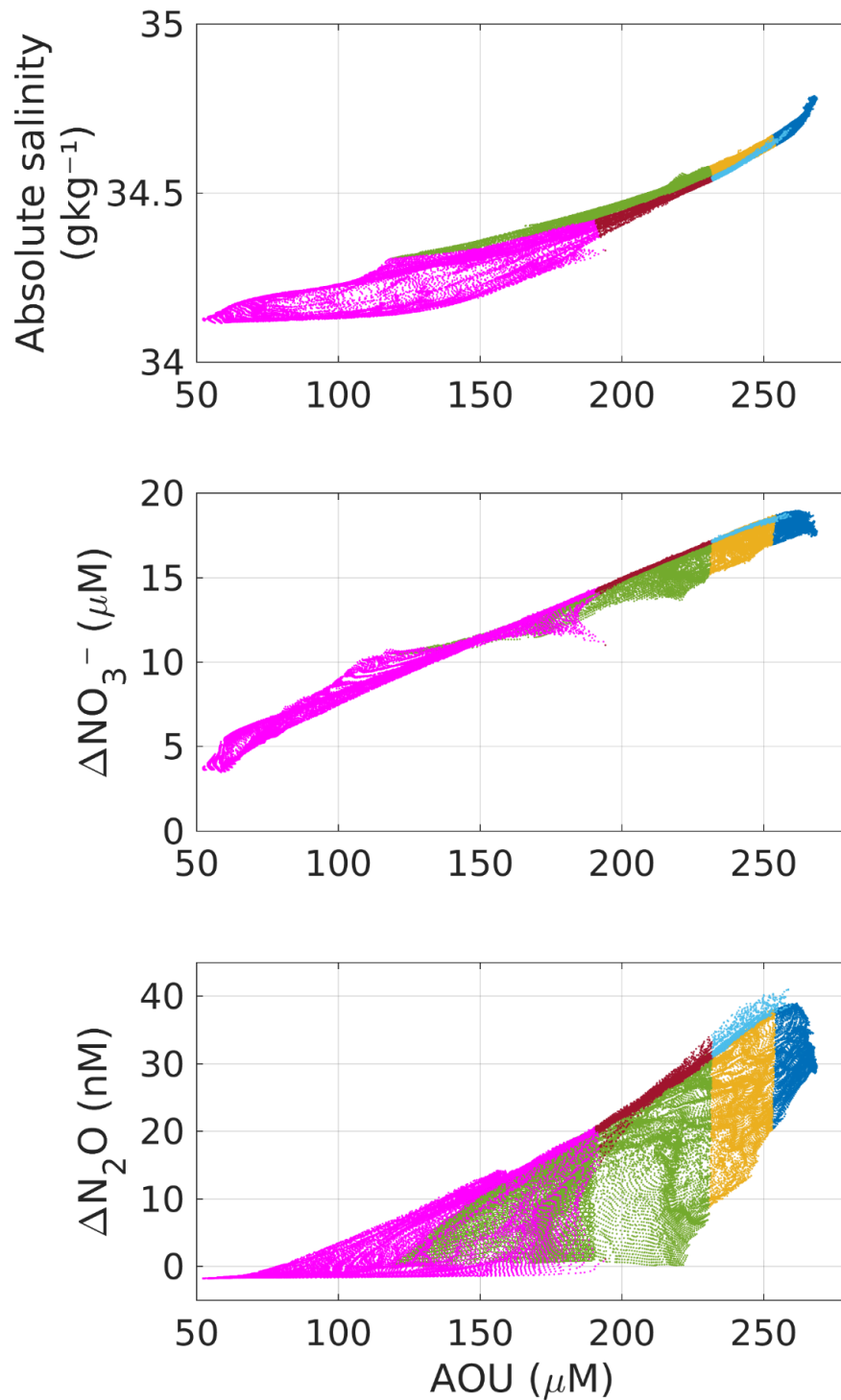
**Figure S5. Mean state of biogeochemical characteristics in the $S_{core}$ layer (26.6 kg m$^{-3}$) in the six subregions. Relations between AOU and (b) absolute salinity, (c) $\Delta NO_3^-$, and (d) $\Delta N_2O$. The subregions are: Northern Coastal Zone (NCZ - dark blue); Northern Transition Zone (NTZ - yellow); Northern Oceanic Zone (NOZ - green); Southern Oceanic Zone (SOZ - magenta); Southern Transition Zone (STZ - brown) and Southern Coastal Zone (SCZ - light blue).**
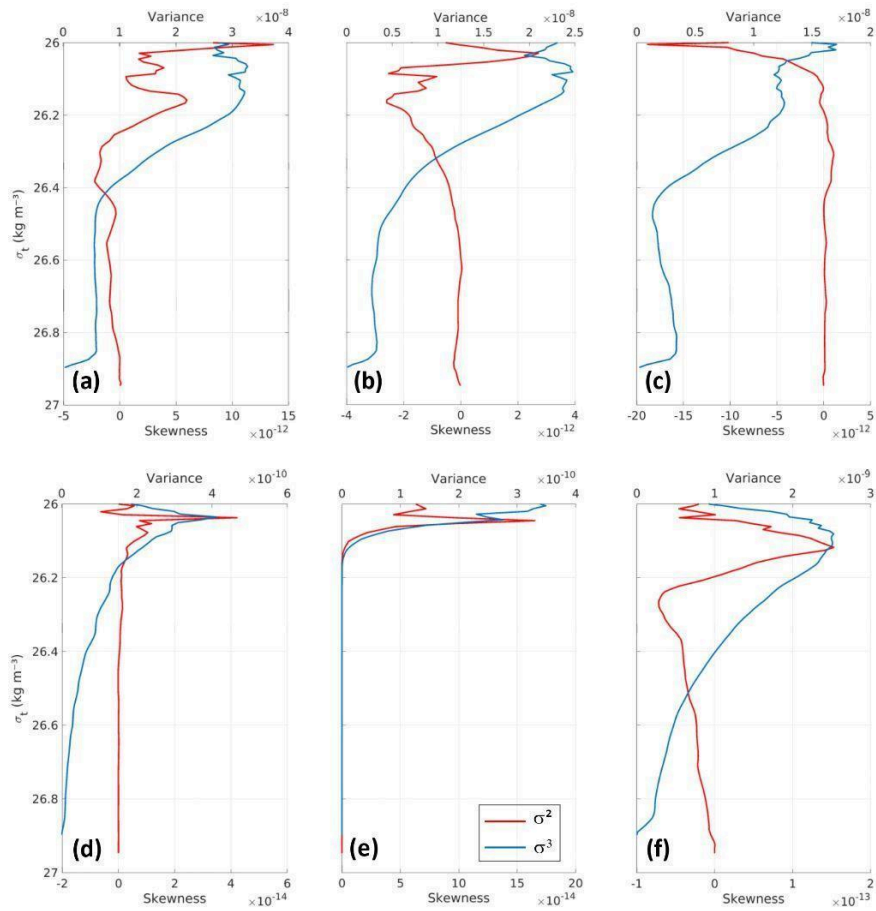
**Figure S6. Mean vertical variance, and skewness associated with the terms involved in the oxygen budget inside the Puddies at first ~100 km from the slope where there are higher occurrence Puddies (strip in color red, Figure 1 - right box). (a) XADV, (b) YADV, (c) VADV, (d) HMIX, (e) VMIX, (f) PHYS. Details of the terms are similar to Figure 7. The variance (red line) and skewness (blue line) were calculated for each profile following the same method as Figure 3 and averaging along the coast.**

# Tables

**Table S1.** Average values of AOU (µM), absolute salinity (g/kg), $NH_4^+$ (µM), $\Delta NO_3^-$ (µM), and $\Delta N_2O$ (nM) inside and outside the Puddies (mean state) on the $S_{core}$ surface ($\sigma_\theta = 26.6$ kg m$^{-3}$). $< >_{9-year}$ indicate the mean value of the corresponding variable in the corresponding region, while $< ' >$ the average value of the variable inside the Puddies (see Methods 2.3 and 2.6.1).

| Zones | $< AOU>_{9-year}$ | $< AOU' >$ | $< S>_{9-year}$ | $< S' >$ | $< NH_4>_{9-year}$ | $< NH_4' >$ | $< \Delta NO_3>_{9-year}$ | $< \Delta NO_3' >$ | $< \Delta N_2O>_{9-year}$ | $< \Delta N_2O' >$ |
|---|---|---|---|---|---|---|---|---|---|---|
| NCZ | 259.8±1 | 265.0±2 | 34.9±0.01 | 34.9±0.01 | 0.06±0.007 | 0.11±0.026 | 17.85±0.1 | 18.3±0.7 | 28.79±1 | 33.4±2 |
| NTZ | 241.4±2 | 256.6±5 | 34.8±0.01 | 34.8±0.01 | 0.02±0.003 | 0.07±0.03 | 17.1±0.1 | 18.7±0.5 | 23.5±1 | 34.9±3 |
| NOZ | 202.0±22 | 223.9±23 | 34.5±0.06 | 34.7±0.07 | 0.01±0.0003 | 0.017±0.02 | 14.7±1.5 | 16.6±1.7 | 16.4±7 | 26.8±6 |
| SOZ | 124.2±40 | 180.5±31 | 34.2±0.08 | 34.5±0.08 | 0.01±0.001 | 0.02±0.01 | 9.5±2.9 | 13.6±2.3 | 5.4±7 | 17.0±8 |
| STZ | 208.1±3 | 236.8±15 | 34.6±0.01 | 34.6±0.009 | 0.02±0.003 | 0.06±0.03 | 15.4±0.2 | 17.6±1.2 | 24.5±1 | 33.8±6 |
| SCZ | 240.4±1 | 249.8±7 | 34.8±0.004 | 34.8±0.004 | 0.08±0.005 | 0.09±0.03 | 17.7±0.1 | 18.4±1 | 34.65±0.5 | 37.8±3 |

**Table S2.** Percentiles 50$^{th}$, 75$^{th}$, and 90$^{th}$ (P50, P75, P90) of AOU (µM), absolute salinity (g/kg), $NH_4^+$ (µM), $\Delta NO_3^-$ (µM), and $\Delta N_2O$ (nM) on the $S_{core}$ surface ($\sigma_\theta = 26.6$ kg m$^{-3}$). The profiles were obtained from random samples (# pro.) using Montecarlo's method, for each region.

| Reg | # pro. | AOU P50 | AOU P75 | AOU P90 | S P50 | S P75 | S P90 | $NH_4^+$ P50 | $NH_4^+$ P75 | $NH_4^+$ P90 | $\Delta NO_3^-$ P50 | $\Delta NO_3^-$ P75 | $\Delta NO_3^-$ P90 | $\Delta N_2O$ P50 | $\Delta N_2O$ P75 | $\Delta N_2O$ P90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NCZ | 1246 | 257 | 266 | 269 | 34.72 | 34.77 | 34.79 | 0.06 | 0.12 | 0.17 | 18.08 | 18.47 | 18.87 | 32.48 | 35.6 | 39.56 |
| NTZ | 1474 | 244 | 254 | 261 | 34.6 | 34.64 | 34.69 | 0,009 | 0,019 | 0,048 | 16.98 | 17.92 | 18.61 | 25.28 | 32.24 | 37.78 |
| NOZ | 3509 | 209 | 224 | 239 | 34.48 | 34.53 | 34.58 | 0,002 | 0,004 | 0,008 | 14.38 | 15.84 | 17.2 | 15.7 | 23.03 | 29.66 |
| SOZ | 6808 | 72 | 95 | 121 | 34.12 | 34.16 | 34.22 | 0,006 | 0,009 | 0,013 | 5.58 | 7.74 | 9.60 | -1.44 | -1.11 | 1.77 |
| STZ | 521 | 222 | 236 | 248 | 34.49 | 34.55 | 34.6 | 0,018 | 0,033 | 0,054 | 16.36 | 17.52 | 18.52 | 29.07 | 34.96 | 41.13 |
| SCZ | 235 | 240 | 256 | 264 | 34.57 | 34.65 | 34.7 | 0,052 | 0,119 | 0,188 | 17.69 | 18.69 | 19.44 | 36.14 | 42.96 | 47.11 |