Modelling the Evolution of Currents South of South Africa since Mid-Miocene Times

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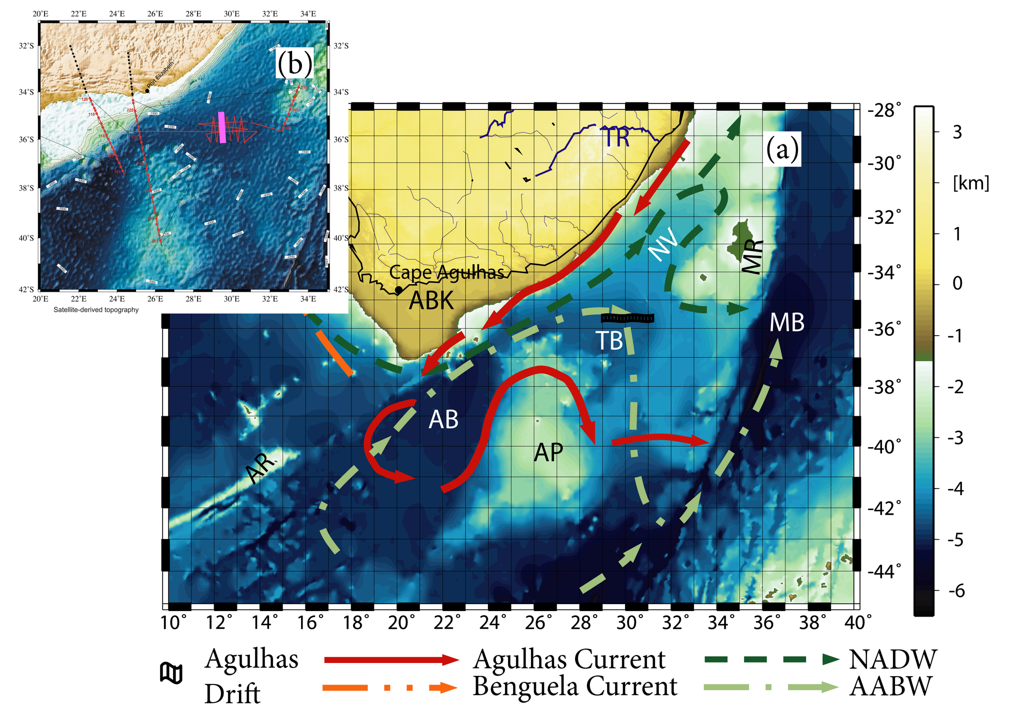
Introduction



Abbreviations:
AB = Agulhas Basin,
ABK = Agulhas Bank,
AP = Agulhas Plateau,
AR = Agulhas Ridge,
MB = Mozambique Basin,
MR = Mozambique Ridge,
NV = Natal Valley,
TB = Transkei Basin,
TR = Tugela River.

Fig. 1. *(a) Oceanographic setting south of South Africa. Water mass flow paths are schematic, and based on the literature cited in the reference. The location of the Agulhas Drift is labeled. (b) RV Sonne SO-182 Cruise track map with seismic reflection and refraction lines, and OBS/seismic land stations indicated. The position of the parasound profile along Line AWI-2005009 (Fig. 2) is marked as pink line.*

The area south of South Africa has been intensively studied since this region is a critical gateway for the exchange of water masses from Atlantic, Indian and Southern Ocean (Fig. 1(a)). During the R/V SONNE cruise SO-182 in spring 2005, extensive parasound and reflection seismic data across the Agulhas Drift has been recorded (Fig. 1 (b)). These data indicate that the Agulhas Drift was built up by east-west flowing currents (Fig. 2), which are identified as the inflows of NADW and AABW.

For a better understanding of the temporal evolution of the Agulhas Drift and the development of the palaeocirculation south of South Africa, the Regional Ocean Modeling System (ROMS) is applied. It is coupled with a sediment transport model. Preliminary simulation is based on the present topography, forcing (wind, heat and salinity) and climatology datasets.

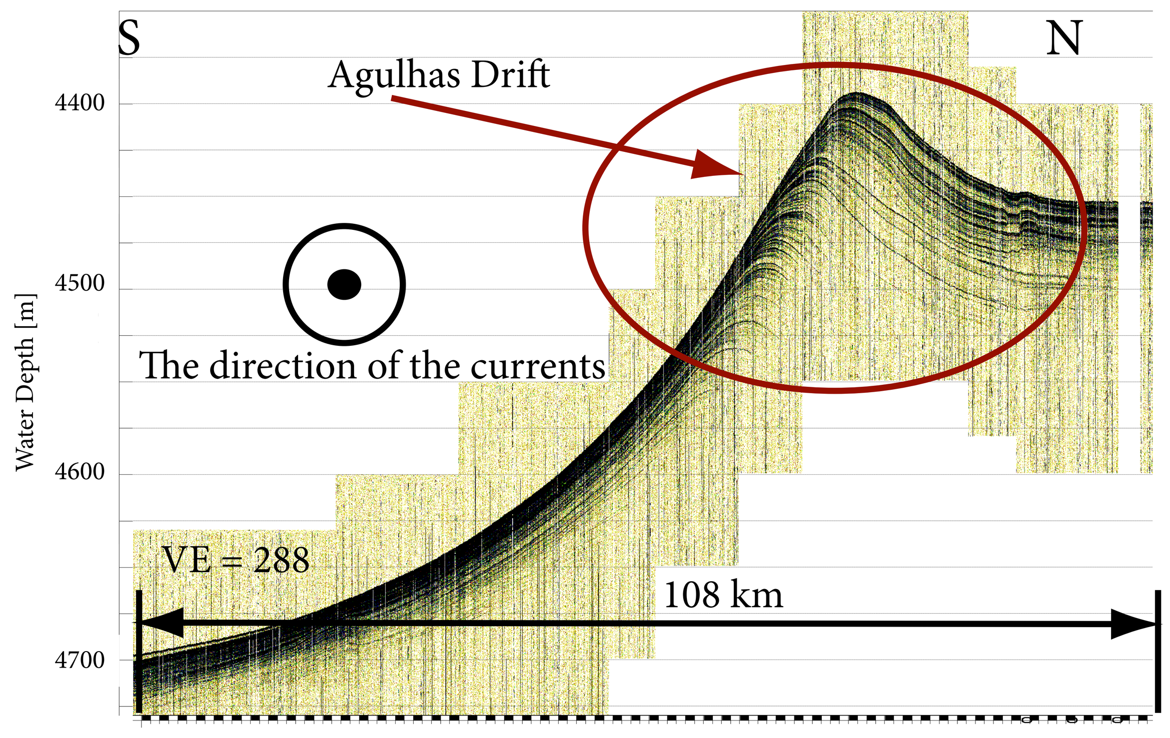


Fig. 2. *Parasound profile along Line AWI-20050009. The Agulhas Drift and the suggested flow direction are shown.*

ROMS

ROMS it is an advanced open-source model. It is a 3D, free-surface, hydrostatic, primitive equation model with stretched, terrain-following vertical coordinates and orthogonal, curvilinear horizontal coordinates. Furthermore, the sediment transport algorithms have been incorporated.

(See also http://www.brest.ird.fr/Roms_tools/)

Agulhas Drift Model (ADM) configuration:

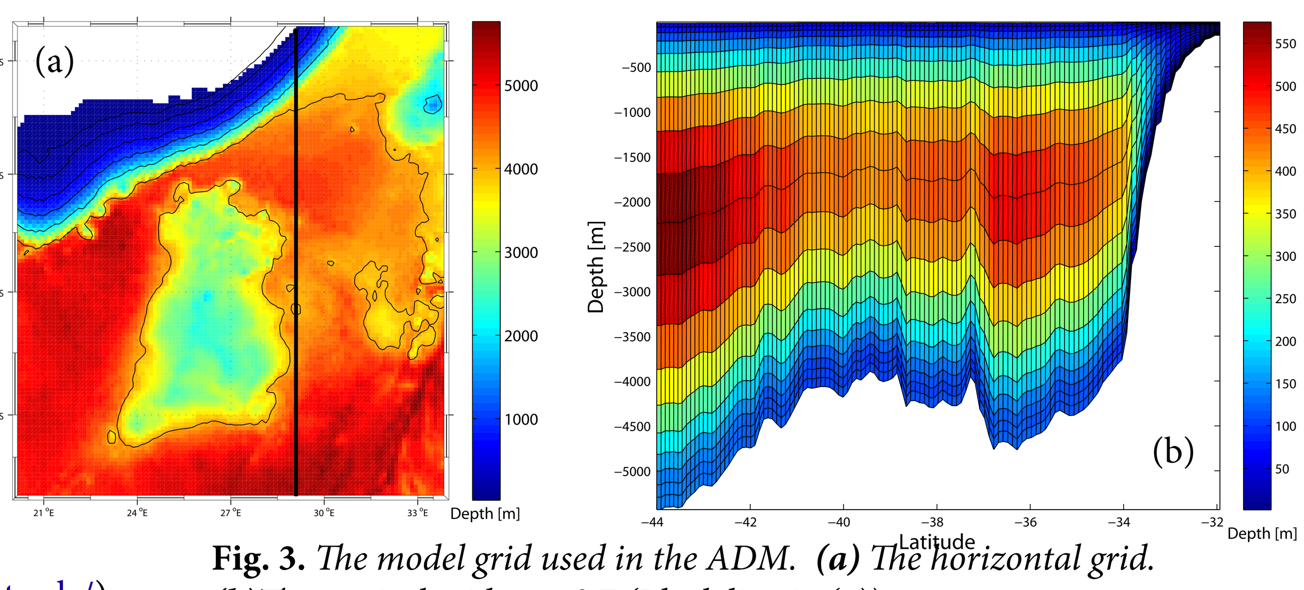


Fig. 3. *The model grid used in the ADM.* ***(a)*** *The horizontal grid.* ***(b)****The vertical grid at 29° E (Black line in (a)).*

ADM domain: 34° S - 42° S, 20° E - 35° E

ADM grid:

horizontal: 0.125° grid width

vertical: 20 topography following l ayers (Enhanced resolution both at the surface and in the deeper layer)

Boundary condition: active open boundaries

Period: one model year

Topography: ETOPO2 dataset

Forcing: wind, heat, and salinity fluxes extracted from Comprehensive Ocean-Atmosphere Data Set (COADS)

Climatology: an ocean monthly climatology, World Ocean Atlas (WOA 2001)

Sediment Transport Model (SMT) configuration:

Based on current velocities adopted from the ADM model, sediment transport pathways are calculated

SMT configuration -> see ADM

Five different sediment classes are tested:

d [mm]	0.125	0.05	0.0125	0.005	0.0025
ρ_s [kg/m^3]	2650	2650	2650	2650	2650
W_s[mm/s]	9.4	1.6	0.10	0.02	0.004
E_u [kg/m^{2}s]	$2.5*10^{-4}$	$4.2*10^{-5}$	$2.6*10^{-6}$	$4.2*10^{-7}$	$1.0*10^{-7}$
τ_{cr} [N/m^2]	0.15	0.10	0.05	0.02	0.01

d: Diameter of grain size class *ρ_s: Density of sediment material of size class*
W_s: Settling velocity of size class *E_u: Erosion rate of size class*
τ_{cr}: Critical shear stress for sediment motion

Initial concentration (spatially uniform): 4 mg/l

Porosity *p*=0.4

Model Results

1) The ADM model reproduces the strong Agulhas current in the vicinity of the Agulhas Bank. NADW and AABW flow eastward through the Agulhas Passage into Transkei Basin (Fig. 6). The current system in the model agrees well with the scheme of currents in the Fig. 1.

2) Hydrographic results in the model are stable. The Agulhas Current is found in the surface layers with potential temperatures of around 20° C and salinities of more than 35. NADW in this region has lower temperatures of about 2° C, and higher salinities of about 34.8 at depth between 2000m and 3500m. AABW has temperatures of 0.1 to 1.1° C and salinities of 34.6 to 34.7. These results agre quite well with the reference data in the literature.

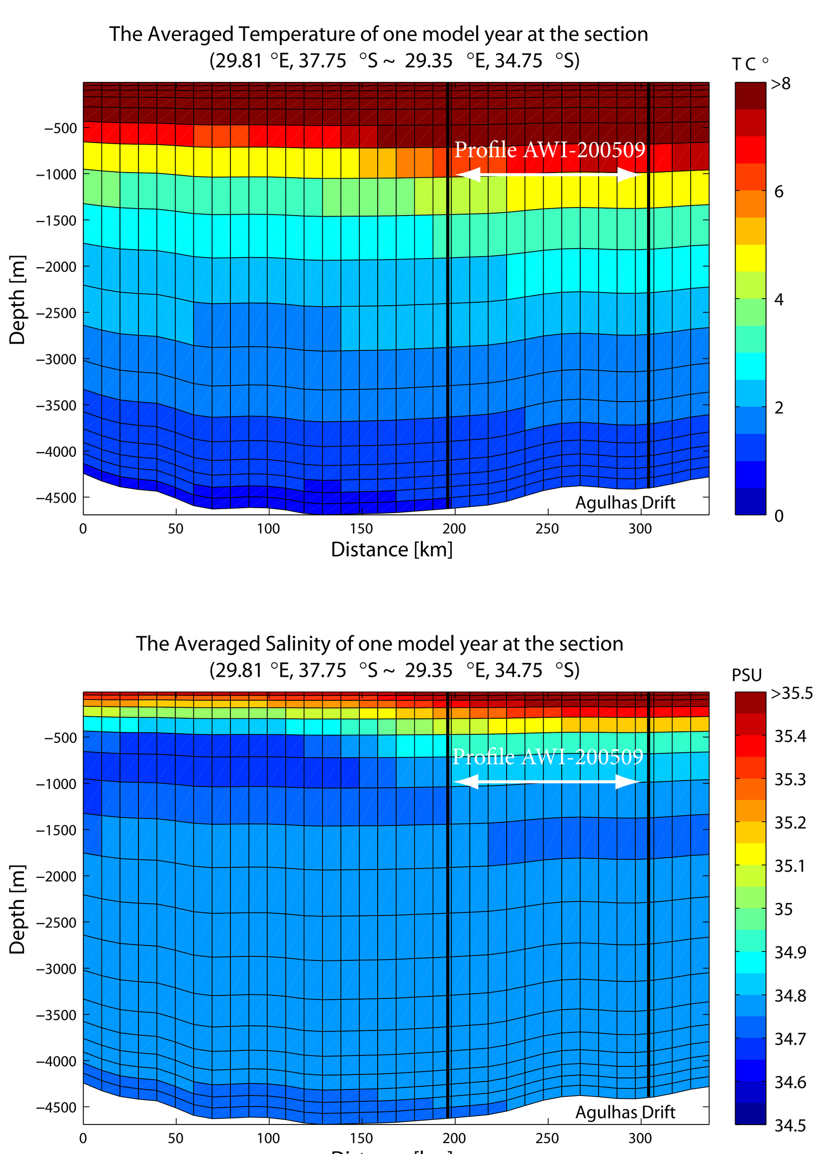


Fig. 4. *The averaged potential temperature and salinity at the vertical section along the profile AWI-2005009 for one model year .*

3) Furthermore, these simulations show that the sediment transport patterns along the Agulhas Drift are strongly influenced by mesoscale eddies . In general, sediment resuspension occurs during the eddy events, and materials are transported away from the Transkei Basin if the eddy breaks up.

Vertical

Fine Sand (Sd = 0.05 mm) **Middle Silt (Sd = 0.005 mm)**

Before eddy

During eddy

After eddy

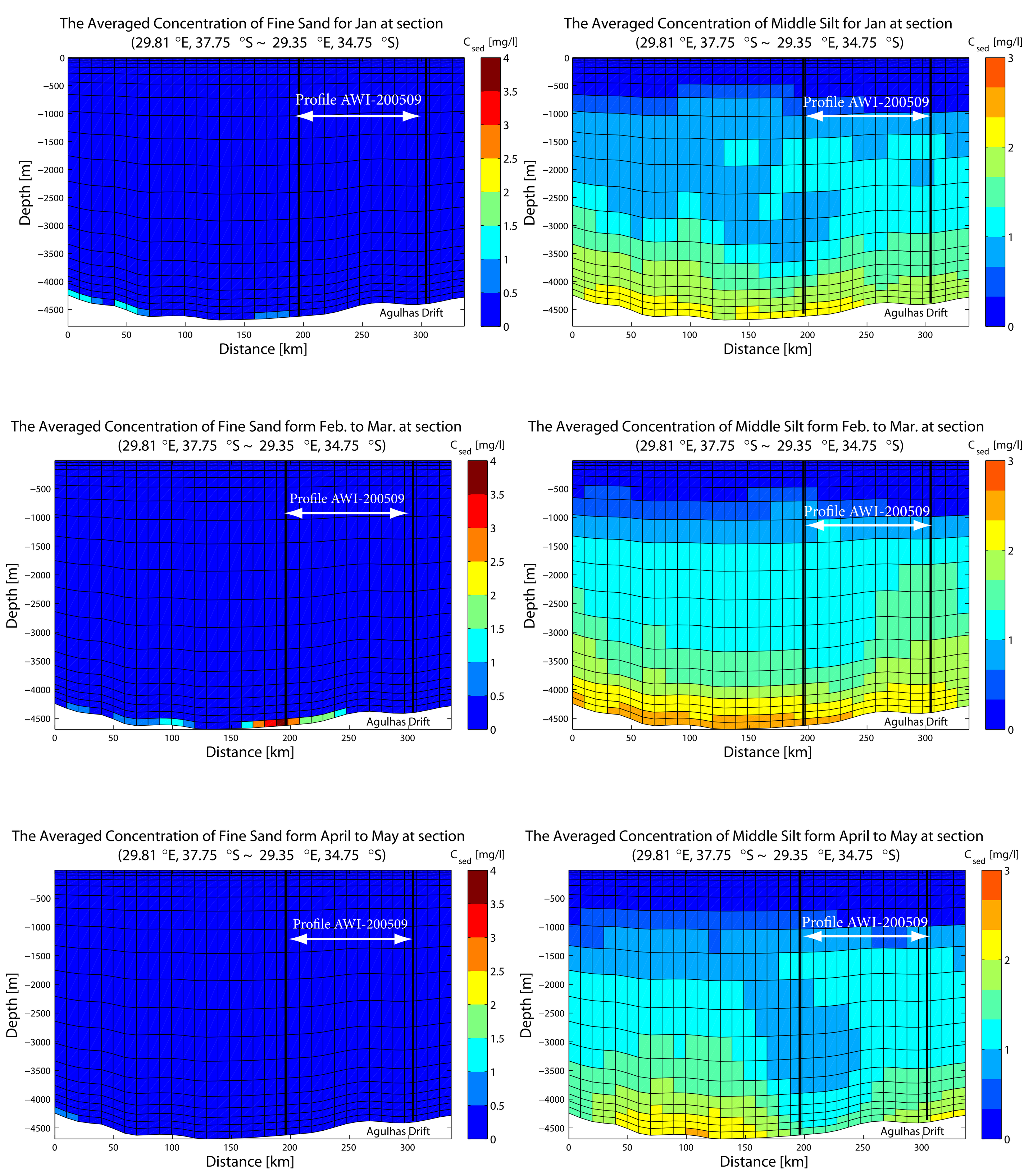


Fig. 5. *The sediment concentrations in the water column at the vertical section along the profile AWI-2005009 (Fig. 1a, Fig. 2 and Fig. 6).*

As a result, we found, that the middle sands with a diameter of 0.125 mm are carried out of Transkei Basin after the first half model year. Thus, the middle sand can not be deposited in the Transkei Basin. The sediment concentrations of two grain classes in the water column, before, during and after an eddy event are compared in Fig. 5. and Fig. 6.

Horizontal

Fine Sand (Sd = 0.05 mm) **Middle Silt (Sd = 0.005 mm)**

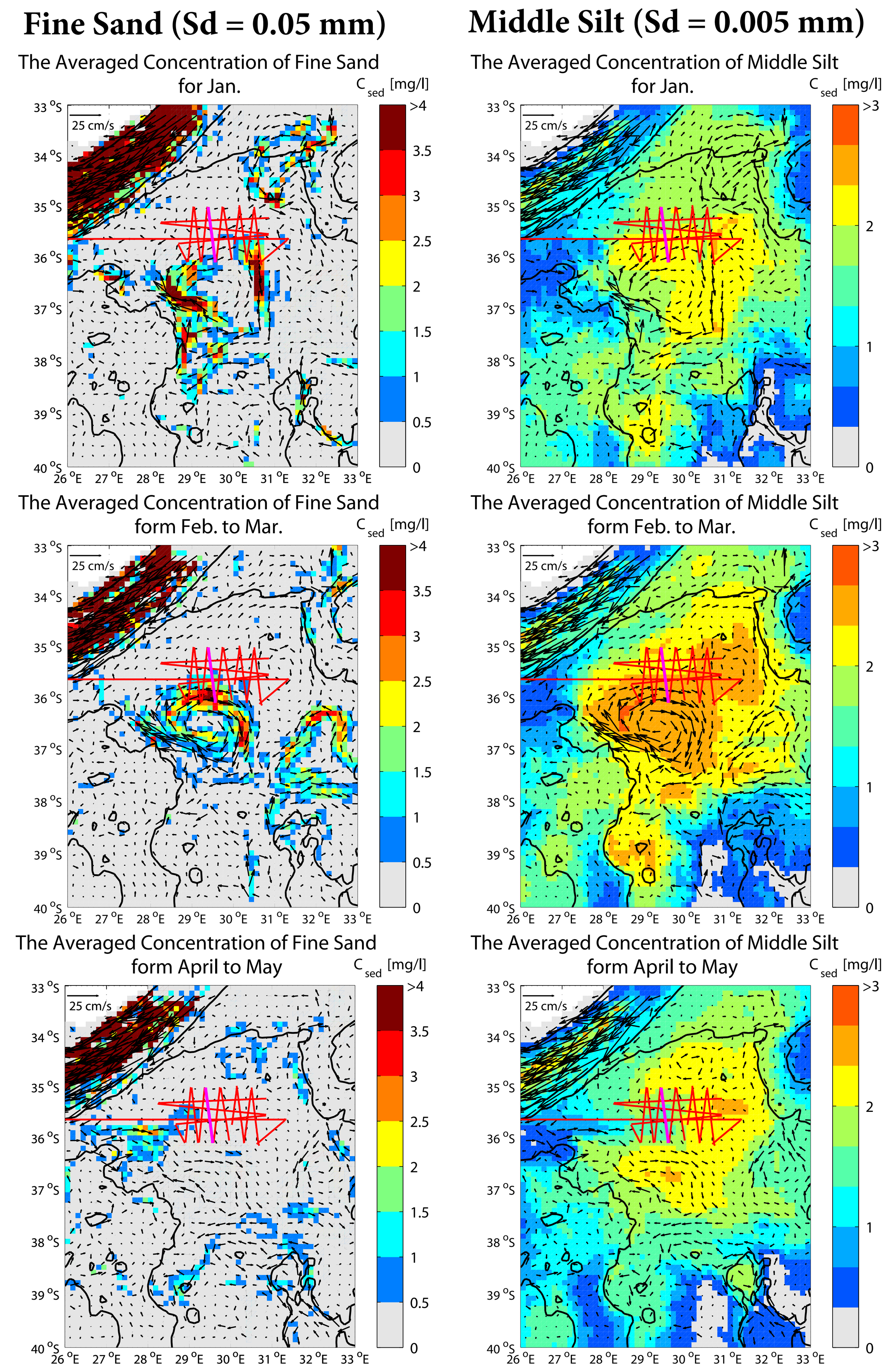


Fig. 6. *The sediment concentration and the velocity field along the bottom layer of the model (Fig. 3b). The position of the parasound profiles are labed as red lines and the Line AWI-2005009 (Fig. 2) is marked as pink line.*

Outlook

Further simulations will be developed in the following aspects:

- build up the model with finer grid in Transkei Basin
- set the sediment sources and test more sediment spectra
- simulate the regional sediment transport under LGM conditions

Reference

Dingle, R.V. Birch, et al., 1987. Deep-sea sedimentary environments around southern Africa (south-east Atlantic and south-west Indian Oceans), Annals of the south African Museum, 98, 27 pp.

Niemi, T.M. Ben-Avraham, et al., 2000. Post-Eocene seismic stratigraphy of the deep ocean basin adjacent to the southeast African continental margin: a record geostrophic bottom-current systems. Mar. Geol. 162, 237-258