PREDICTING ARGO FLOAT DISTRIBUTIONS USING A GENERAL CIRCULATION MODEL

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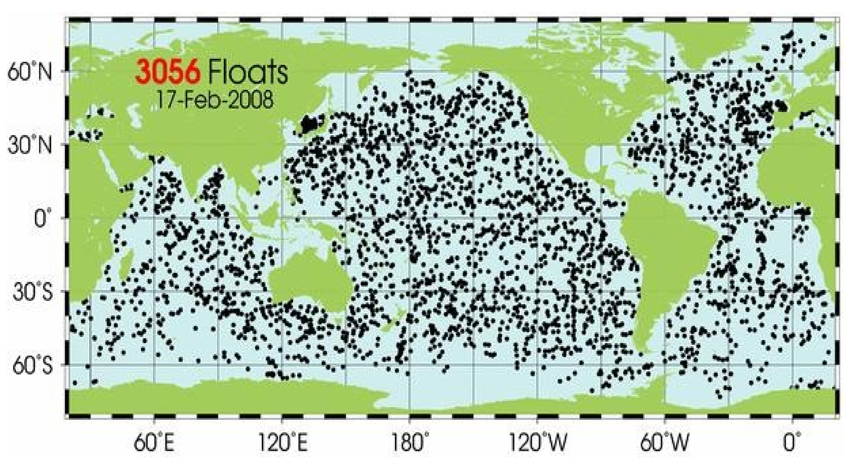
SIMULATION OF ARGO FLOATS

The global Argo array consists of 3000 floats. An optimal distribution of these floats in the ocean results in a coverage of 1 float per 3° x3° -box. Because Argo floats are free-drifting, deviations from the optimal coverage emerge. Predicting float distributions on 3° x3° -boxes helps to detect problematic areas and to develop deployment strategies that minimize these deviations. Float distributions are predicted by integrating trajectories of virtual floats in the mean velocity field of a general circulation model. Sub-grid scale processes, which are not resolved by the model, are parameterized by a random walk algorithm. Counting the number of floats per box gives the predicted float distribution.

Analyses within my diploma thesis [2] show that the mean model velocities underestimate absolute velocities at the Argo float parking depth. Therefore, float distributions could not be predicted correctly. Alternatively, predictions are derived from mean drifts of real Argo floats.



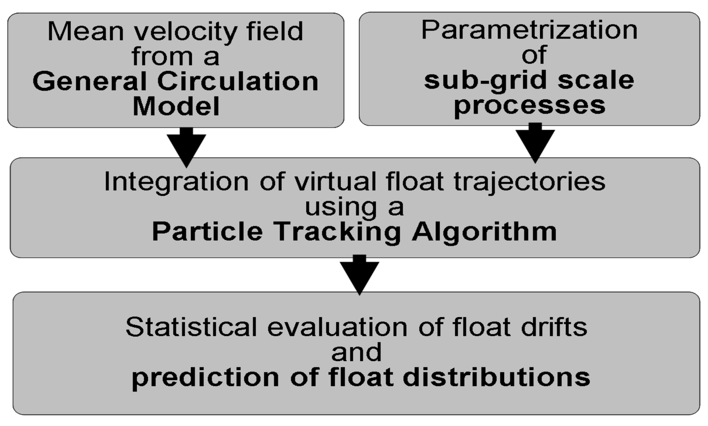


Figure 1: Global Argo float distribution. A problematic area is for example the Southern Ocean, where the poor coverage results from sparse float deployments. From the Argo home page, [1].

I. THE GENERAL CIRCULATION MODEL

GECCO - A 50-year Ocean Synthesis

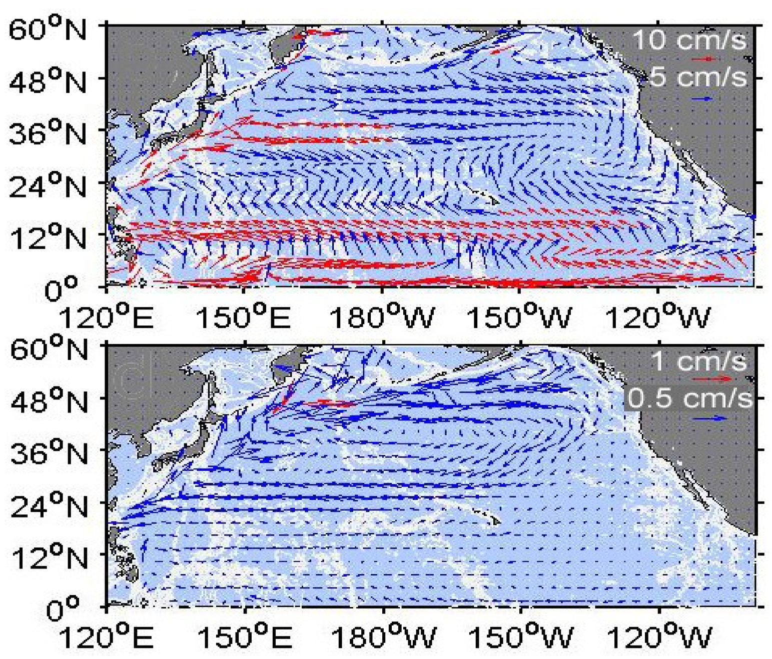


Figure 2: GECCO circulation, [3].

Float simulations use the mean field of the GECCO model. The GECCO model simulates the ocean state on a 1° x1° -grid between 1952 and 2001. The circulation results from assimilating a general circulation model to observational data from the simulation period. Argo floats are simulated in the North Pacific Ocean. Figure 2 shows the velocity fields at the surface and at Argo floats parking depth (1000m), because floats stay in both depths during one cycle. Short stays in high velocity regimes stand vis-a-vis with long stays in low velocity regimes.

II. THE PARTICLE TRACKING ALGORITHM

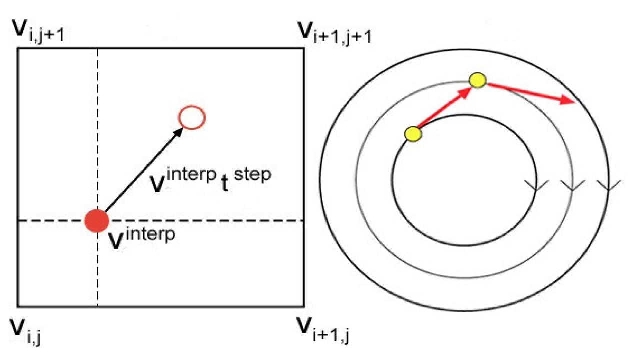


Figure 3 - left: Particle tracking, right: Numerical approximation error.

The particle tracking algorithm uses the Euler method for integration. Mean model velocities are linearly interpolated to the float position and advected to its new position (Figure 3, left). Trajectories, being a sequence of tangents, include a numerical approximation error (Figure 3, right). Tests in a rectangular basin model have shown that the error is negligible when the time step size is set to 1 hour.

The effect of profiling

The effect of profiling on float trajectories is examined by using different approximations of the Argo float working cycle (Figure 4). One cycle drifts in the North Pacific circulation of the GECCO model lead to following conclusions:

- Vertical current shear results in unacceptable deviations from A when exclusively integrating at parking depth (D)
- Profiling is considered sufficiently when applying a vertically averaged velocity field (B).

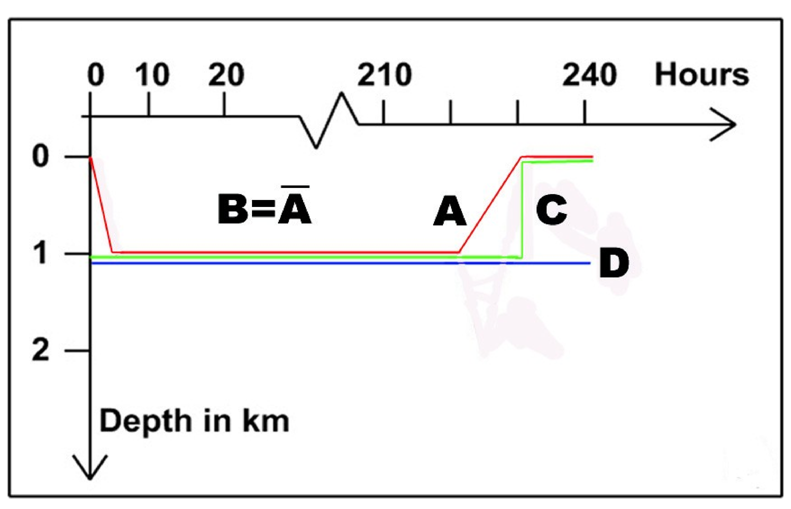


Figure 4

III. SUB-GRID SCALE PROCESSES

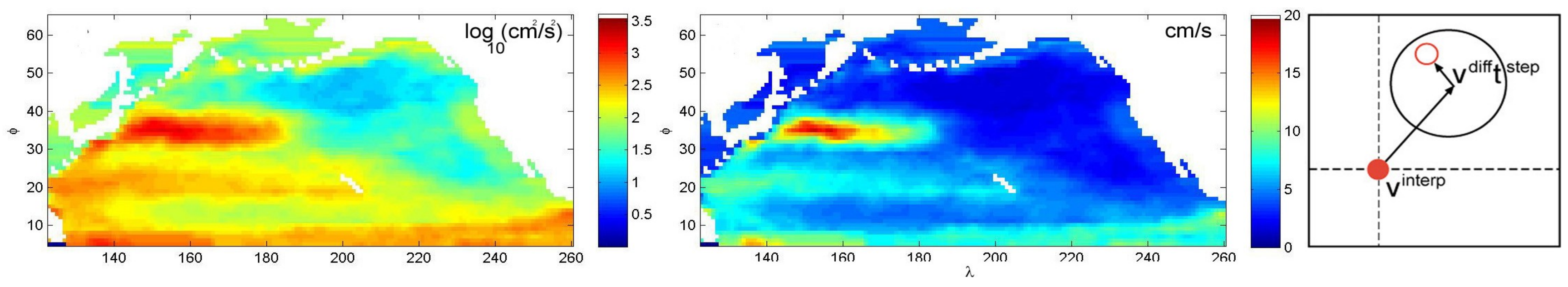


Figure 5 – EKE from satellite data (left, [4]) – EKE-mask (center) for Monte Carlo diffusion.

Monte Carlo diffusion

Sub-grid scale processes can be interpreted as a diffusive process. The used random walk algorithm reflects the chaotic character of the ocean's velocity field. An additional diffusion velocity is added with every time step (Figure 5, right). It is randomly picked out from a velocity interval, being the bandwidth of Monte Carlo diffusion**.** A mask for the bandwidth is derived from the eddy kinetic energy (EKE) computed altimetric satellite data (Figure 5).

Sub-surface EKE

Satellite EKE from altimeter data is an estimate for the energy content of the near surface layers. Satellite EKE has to be adapted to the Argo float parking depth of 1000 m. For this, it is compared to the kinetic energy measured by moored current meters in the Northwest Atlantic. Figure 6 gives an approximate estimate for the vertical structure of EKE. Further studies have show that, concerning EKE, the North Pacific is comparable. EKE at Argo float parking depth makes up between 10 and 30% of satellite EKE. It is concluded that satellite EKE can be adapted by multiplication with a constant factor F. The bandwidth is :

$$v_{band} = \sqrt{F \cdot EKE_{satellite}}$$

Figure 5 (center) gives the mask for F=0.2.

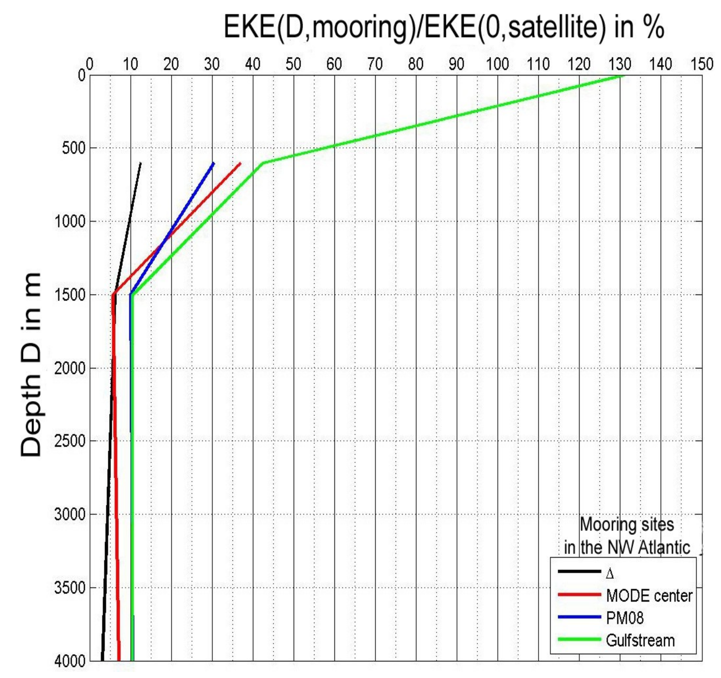


Figure 6

IV. PREDICTION OF FLOAT DISTRIBUTIONS

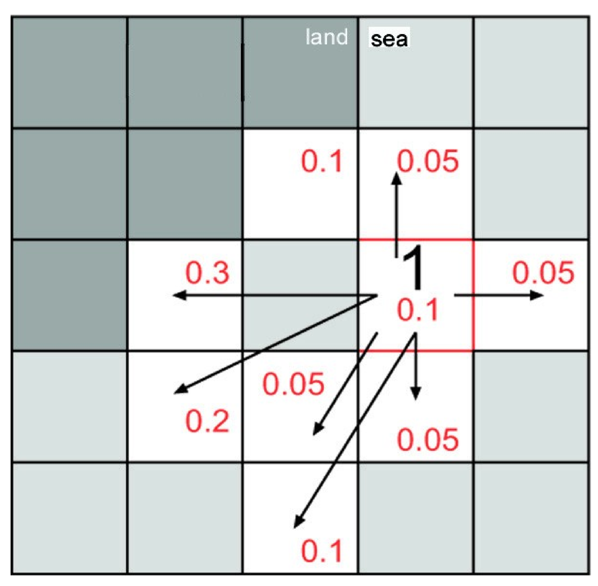


Figure 8: Red numbers give the probable spreading of an Argo float initially deployed in the red box.

Generation of prediction masks

The intention is to make a 1-year forecast for an Argo float that is deployed in a 3° x3° -box. This is done by generating a prediction mask that uses float drift data. Drift data consist of the initial and final positions of float trajectories that start in a particular box and cover one year. The distribution of final positions on 3° x3° -boxes forms the prediction mask. It gives the statistical spreading for a float, deployed in a 3° x3° -box. The normalized mask (Figure 8) includes the probabilities for the float's final position. When predicting float distributions, the normalized masks of single 3° x3° -boxes are multiplied by the number of floats they initially contain. The super-position of these masks give the predicted float distribution.

1-year prediction masks

As Argo floats are deployed from ships, a forecasting horizon of one year seems sufficient to include predictions in cruise planning. Figure 9 shows the predicted spreading of floats deployed in some example boxes (X). For the GECCO prediction mask, 50 virtual float are deployed in every 3° x3° -box and integrated for one year. In comparison real Argo floats are widely spread (ARGO). One reason is the small number of available drift data leading to a high statistical uncertainty. Another reason is that mean advection is underestimated by the model (see Figure 10).

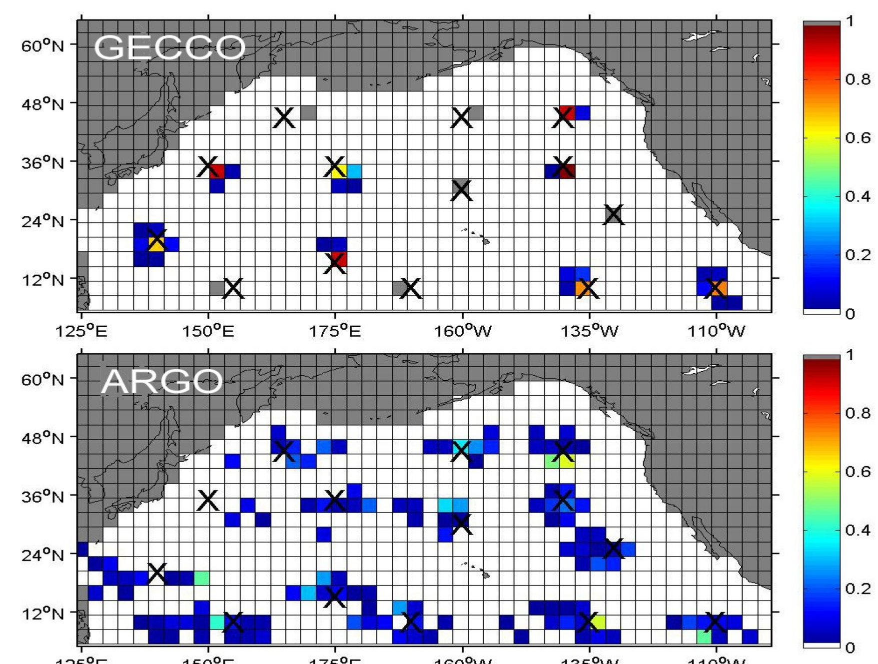


Figure 9

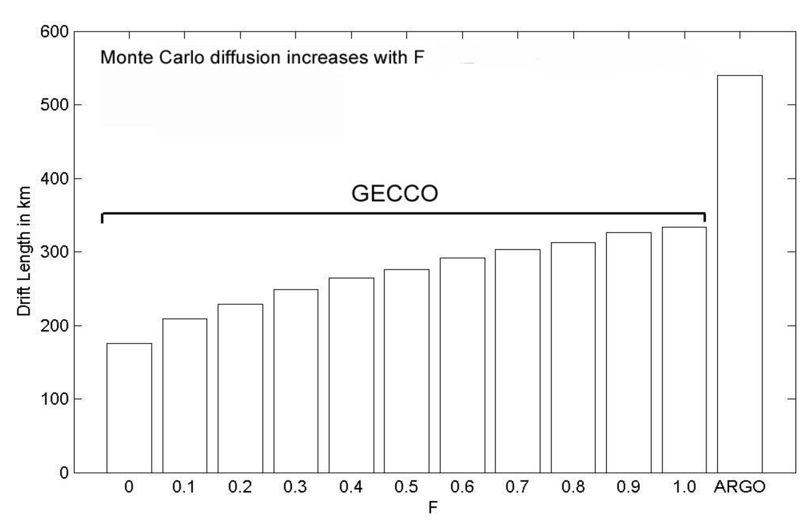


Figure 10: Mean 1-year drift length from virtual floats and real floats.

Conclusion

Figure 10 shows that Monte Carlo diffusion cannot balance the discrepancy deriving from mean advection. The method used for simulating Argo floats is not capable to make 1-year forecasts, as model velocities at the Argo float parking depth are too low compared to observational data. Alternatively, prediction masks are derived from real Argo float drifts. Because very little independent drift data per 3° x3° -box are available, these masks include a high statistical uncertainty. Still, they lead to better predictions than the model simulations. For details on the generation of these masks see my diploma thesis [2].

REFERENCES
[1] Argo home page. http://www.argo.ucsd.edu, [2] Maschwitz, 2008, Predicting Argo Float Distributions, Diploma Thesis, University of Hamburg, 70 pp.
[3] see Köhl et al, 2006, ECCO Report No 40, [4] data from the TOPEX/POSEIDON altimetric satellite mission.

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