Acknowledgements

An ERA40-based atmospheric forcing for simulations and reanalyses of the global ocean circulation between 1958 to present

Travaux réalisés dans le cadre du projet international DRAKKAR de simulation multi-échelles de la circulation océanique globale

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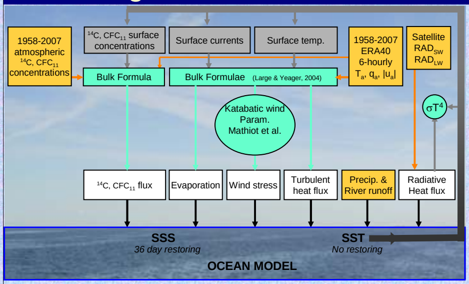
1. Forcing function of Ocean GCMs



The forcing procedure of an Ocean General Circulation model is a complex system involving :

- Atmospheric Surface Variables
- Empirical Bulk Formulas

Uncertainties are large on both

Why focus on input atmospheric variables rather than on flux parameterization to improve forcing?

Fig. 1. Schematic of the forcing procedure used in DRAKKAR model configurations (NEMO numerical code)

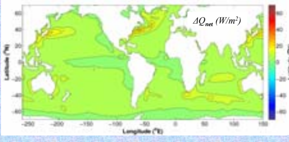


Fig. 2a: Change in net heat flux induced by changing the bulk parameterization from Large & Yeager (2004) to Fairall (2003).

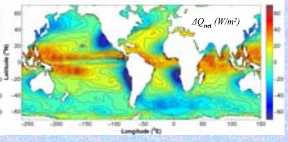


Fig. 2b: Chance in net heat flux induced by changing the down-welling short-wave radiation from ERA40 to ISCC/FD.

Differences in bulk formulas have a lesser impact on air-sea flux estimates than differences between atmospheric variables of different sources.

2. Heat Flux Evaluation

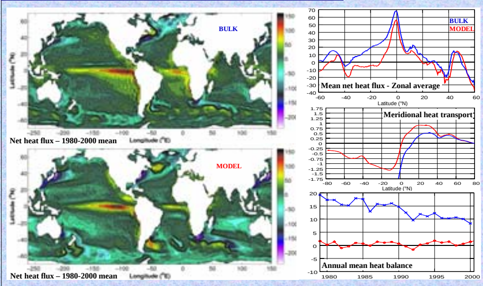


*Fig. 3. Net heat flux obtained with the **Bulk** and the **Model** approach, respectively: (left plot) the 1980-2000 mean net heat flux, and (right plots, from top to bottom) the zonal mean net heat flux, the meridional heat transport (estimated from surface flux divergence), and the time evolution over the period 1980-2000 of the annual mean heat balance.*

How to evaluate the impact of a particular atmospheric data set (NCEP or ERA40 for example) in the forcing of an OGCM?

1 - Straight BULK approach (FOTO):
- Use "observed SST" and atmospheric surface variables in bulk to calculate fluxes
- Compare flux with other estimates
- Verify global balance is near zero

2 – Ocean MODEL approach (ORCA2):
- Drive coarse resolution OGCM
- Compare flux with other estimates
- Verify global balance is near zero
- Analyse impact on model solution

- The LY2004 bulk formula is use in both approaches.
- BULK uses the Hurrell (2007) SST product.
- MODEL uses the 2° resolution ORCA2 model (NEMO code), integration goes from 1958 to 2000.

3. Objectives and Methods

Objective is to produce a set of atmospheric data relevant to drive the DRAKKAR* hierarchy of global ocean/sea-ice model configurations.

*See OST/ST Poster by Penduff et al.

Method: The 2°resolution ORCA2 model (based on NEMO) has proved to be an efficient tool to investigate, combine and validate different sets of input data.

The present work summarizes the different steps that contributed to construct the DRAKKAR Forcing set #3 and #4, respectively named DFS3 and DFS4.

principally by blending corrected ERA40 surface atmospheric state fields (wind and air temperature and humidity) with the satellite products (based on ISCCP for radiation and CMAP for precipitation) processed by Large & Yeager (2004, LY04) for the CORE data set.

Steps are:

- Include surface temperature, humidity and wind of ERA40 into CORE, as a replacement for NCEP-extracted fields.
- Extend ERA40 until 2004 with ECWMF operational product and compare with CORE.
- Correct major ERA40 flaws such as biases and inter-annual discontinuities.
- Adjust CORE shortwave radiation and precipitation products
- Quantify changes in forcing with a series of inter-annual ORCA2 simulations (see Table below), over the period 1958-2004, that assess the impact of every forcing variable on the model solution.

RUN	Forcing	θ_air	q_air	Wind_10	rad. LW	rad. SW	precip.
G57	LY04	LY04 (10m)	LY04 (10m)	LY04	ISCCP	LY04	LY04
G70	DFS3	ERA40(2m)	ERA40(2m)	ERA40	ISCCP	LY04	DFS3
G71	DFS3.1	DFS4 (2m)	DFS4 (2m)	ERA40	ISCCP	LY04	DFS3
G77	DFS4	DFS4 (2m)	DFS4 (2m)	DFS4	ISCCP	DFS4	DFS3

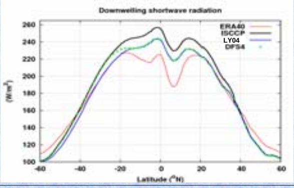


Fig. 8: Zonal average of the mean (1980-2004) Shortwave Radiation for different data sets.
The decrease of the original ISCCP product proposed by LY04 is applied only between [20°S 30°N] instead of [50°S 30°N]. This is justified by model results showing improved prognostic SST in the 50°S 20°S band when original ISCCP data are used.

4. Constructing DFS4

ERA40 wind module was increased at every latitude to fit 2D averaged values of the QUICKSCAT wind product.

ERA40 surface air humidity and temperature were corrected at low latitudes to agree with recent values of the ECMWF operational analysis. Corrections were adapted to the two periods 1958-1978 and 1979-2000.

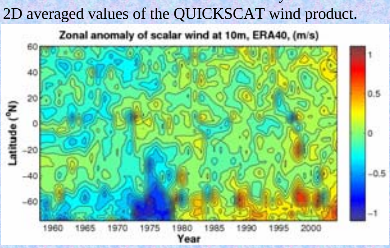


Fig. 4. Illustration of the spurious underestimation of the intensity of the winds prior to 1979 in the ACC region.

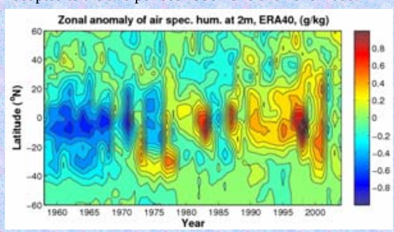


Fig. 6. Illustration of the spurious underestimation of ERA40 air specific humidity prior to 1979 in the inter-tropical band.

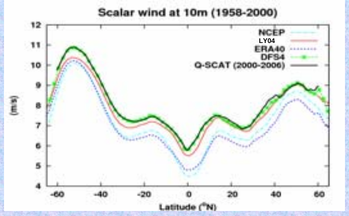


Fig. 5: Result of the 2D recalibration of ERA40 wind speed towards the mean Q-SCAT wind speed (2000-2006). 3 periods have been distinctly corrected: 1958-1972, 1973-1978 and 1979-2004.

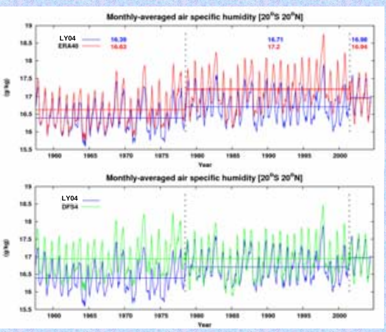


Fig. 7. Equatorial correction of ERA40 surface air humidity towards a same zonal mean value for the whole period. Year 1979 marks the beginning of data assimilation of new products for both ERA40 and NCEP reanalysis.

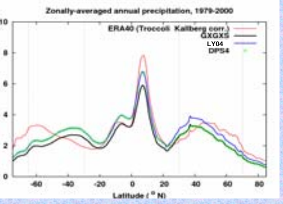


Fig. 9: Zonal average of precipitation for different data sets. The original GXGXS precipitation product developed by LY04 is kept unchanged under [30°N 90°N], the correction proposed by LY04 (an increase) is retained elsewhere.

4. ORCA2 Simulations 1958-2004

ORCA2 is a NEMO-based global ocean/ice model configuration (Madec, 2008), based on a tripolar 2° resolution grid with 31 levels, using partial steps for the bathymetry. No SST restoring and a gentle SSS restoring are used. Inter-annual simulations are carried out from **1958** to **2004** without spin-up. Bulk formulae parametrisation from Large and Yeager (2004) are used to compute surface fluxes with prognostic SST and atmospheric data every 6 hours. The four simulations only differ from the forcing configuration they use (see table).

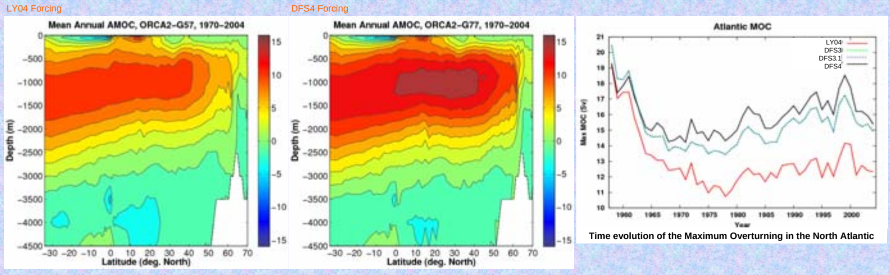


Fig. 12: Enhancement of the Atlantic MOC with the DFS4 forcing (right) compared to the original LY04 (left). Air humidity and temperature from ERA40 as well as the wind increase are directly responsible for this improvement, the decrease of precipitation on the Nordic Seas plays a lesser role.

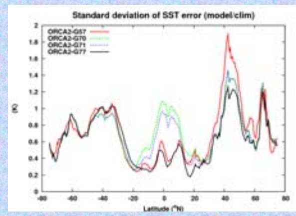


Fig. 10. Zonally-averaged standard deviation of error between model SST and Hurrell (2006) SST, 1970-2004. Introduction of ERA40 turbulent variables induces a warm bias in tropical regions (G57 vs G70). This is slightly improved with the humidity correction (G70 vs G71) and greatly improved with the wind increase (G71 vs G77). SST error is also minimized in mid-latitude northern regions.

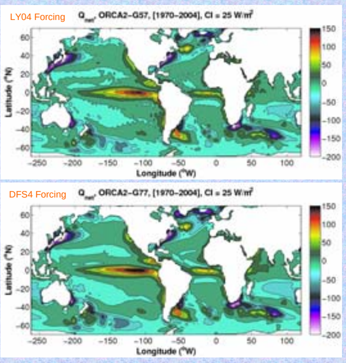


*Fig. 11: Mean net heat flux (1970-2004) in simulations driven by LY04 (Top, G57) and by DFS4 (bottom, G77). DFS4 leads to a cooler SST in regions where **Qnet** is positive (such as the tropics) which tends to increase the amount of heat received.*

Prospective

The presented forcing datasets are actively tested by the NEMO community in configurations of higher resolution (eddy permitting to eddy resolving) and different regional domains (Barnier et al. 2006, Drakkar group, 2007). DFS4 undergoes continuous improvements, taking full advantage of the feedbacks from the community. Reported weaknesses can rapidly be corrected and validated with the coarse resolution model. Next correction will include a recalibration of ERA40 winter temperatures in sea-ice covered regions of the Arctic since they are considered too high compared to observations.

References:

Large and Yeager, 2004 : Diurnal to Decadal Global Forcing For Ocean and Sea-Ice Models: The Data Sets and Flux Climatologies. NCAR technical note, 62 pp.
Liu, Tang and Polito, 1998 : NASA Scatterometer provides global ocean-surface wind fields with more structures that NWP. Geophys. Res .Lett.,25, 761-764.
Madec, 20086 : NEMO, the ocean engine. Notes de l'IPSL, Université P. et M. Curie, B102 T15-E5, 4 place Jussieu, Paris cedex 5.
Troccoli and Kållberg, 2004 : Precipitation Correction in the ERA-40 Reanalysis. ERA-40 Project Report Series No. 13. ECMWF.
Barnier et al., 2006 : Impact of partial steps and momentum advection schemes in a global ocean circulation model at eddy-permitting resolution. Ocean Dynamics, 56, 543-567.
DRAKKAR Group, 2007: Eddy-permitting Ocean Circulation Hindcasts of past decades. *CLIVAR Exchanges*, No 42 (vol 12 No3), 8-10.
Uppala et al., 2005 : The ERA-40 re-analysis. Quart. J. Roy. Meteor. Soc., 131, 2961-3012.
Zhang, Rossow, Lacis, Oinas, and Mishchenko, 2004 : Calculation of radiative fluxes from the surface to top of atmosphere based on ISCCP and other global data sets. J. Geophys. Res., 109.
Hurrell, Hack, Shea, Caron, and Rosinsk, 2006 : A new sea surface temperature and sea ice boundary data set for the Community Atmosphere Model Journal of Climate: submitted as a note.