Comparison of GloSea5 and POAMA2.4 Hindcasts
1996-2009: Ocean Focus

Xiaobing Zhou, Jing-Jia Luo, Oscar Alves and Harry Hendon

December 2015
Comparison of GloSea5 and POAMA2.4 Hindcasts
1996-2009: Ocean Focus

Xiaobing Zhou, Jing-Jia Luo, Oscar Alves and Harry Hendon

Bureau Research Report No. 010
December 2015
Enquiries should be addressed to:

Xiaobing Zhou

Bureau of Meteorology
GPO Box 1289, Melbourne
Victoria 3001, Australia

Contact Email: x.zhou@bom.gov.au

Copyright and Disclaimer

© 2015 Bureau of Meteorology. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of the Bureau of Meteorology.

The Bureau of Meteorology advise that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law and the Bureau of Meteorology (including each of its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.
Contents

Abstract .................................................................................................................................................. 1

1. Introduction .................................................................................................................................. 2

2. Ocean model descriptions ....................................................................................................... 3
   2.1 Australian Community Ocean Model (ACOM2) ............................................................ 3
   2.2 NEMO3.2-based GO3 ........................................................................................................ 4

3. Results ....................................................................................................................................... 5
   3.1 Observations ....................................................................................................................... 6
   3.2 Climatology .......................................................................................................................... 7
   3.3 Prediction skill .................................................................................................................... 22
   3.4 ENSO teleconnections ....................................................................................................... 28
   3.5 Equatorial and coastal ocean currents ................................................................................ 32

4. Conclusion and discussions ...................................................................................................... 37

5. References ................................................................................................................................ 40
   Acknowledgement ....................................................................................................................... 42

6. Appendix .................................................................................................................................... 43
   6.1 MOM2-based ACOM2 model namelist: ........................................................................ 43
   6.2 NEMO3.2-based GO3 namelist: ...................................................................................... 48
List of Figures

Fig. 1  SST climatology (contour intervals: 1°C. Green lines denote SST higher than 28°C) and one standard deviation (colour shading) for the period of 1996-2009 in May based on 0.25° AVHRR satellite observations, 5-member mean of GloSea5 and P24 hindcast at 1-month lead. ................................................................. 8

Fig. 2 As in Fig. 1 but at lead months 0-3. ..................................................................................... 9

Fig. 3 As in Fig. 1 but at lead month 6. ........................................................................................ 10

Fig. 4 As in Fig. 1 but initiated from 1 November. ........................................................................ 12

Fig. 5 As in Fig. 4 but at lead month 3. ........................................................................................ 13

Fig. 6 As in Fig. 4 but at lead month 6. ........................................................................................ 14

Fig. 7 The SST bias of P24 (left panels) and GloSea5 (right panels) at lead months 0-3. .......... 15

Fig. 8 As in Fig. 7 but for the temperature (averaged over 2°S -2°N) along the equator. .......... 16

Fig. 9 As in Fig. 7 but the heat content over the upper ocean 300 m depth. ............................... 18

Fig. 10 The differences of mean SST and temperature along the equator between lead month 3 and 0 for POAMA24 and GloSea5. ................................................................................. 19

Fig. 11 As in Fig. 10 but for SSS only. ........................................................................................ 21

Fig. 12 The climatology of sea surface height (SSH) at lead months 0 and 1 and their differences for POAMA2.4 (left panels) and GloSea5 (right panels). .................................................. 22

Fig. 13 The SSTA correlations between model predictions and observations at lead months 0-3. P24 is in left panels and GloSea5 right panels................................................................. 23

Fig. 14 As Fig. 13 but for RMSE ................................................................................................. 24

Fig. 15 As Fig. 14 but for the RMSE normalized by the observed SSTA standard deviation. ...... 25

Fig. 16 The SSTA standard deviation from the lead months 0 to 3 for POAMA2.4 (left panels) and GloSea5 (right panels). ......................................................................................... 26

Fig. 17 As for Fig. 16 but for the SSTA standard deviation errors ................................................ 27

Fig. 18 The time series of Niño 3.4 SSTA index for the observed (black curve), POAMA2.4 (green curve) and GloSea5 (red curve) at lead months 0-3. .................................................... 28

Fig. 19 Regression onto Niño 3.4 SSTA index of global SSTA based on the observed OISST dataset. .............................................................................................. 29

Fig. 20 As Fig. 19 but for POAMA2.4 (left panels) and GloSea5 (right panels) at lead months 0-3. ......................................................................................................................... 30

Fig. 21 Regression onto Niño 3.4 SSTA index of global SSH anomaly based on the observed satellite dataset.......................................................... 30

Fig. 22 As Fig. 21 but for P24 (left panels) and GloSea5 (right panels) at lead months 0-3. ........ 31

Fig. 23 The annual mean Equatorial Undercurrent (EUC) in the observations (left) and PEODAS reanalysis (right). .................................................. 32

Fig. 24 The climatology of EUC in P24 (left panels) and GloSea5 (right panels) at lead months 0-3. Green line stands for 0.5m/s..................................................................................... 33

Fig. 25 Ocean surface layer (0-50 m) temperature (CI: 0.5°C) and current climatology for the period of 1996-2009 in November along the east coast of Australia based on GLORYS2V3 ocean reanalysis, GloSea5 and P24 predictions from 1st November. .... 34
Fig. 26  As in Fig. 25, but for the model climatology in November predicted from 1st May. ............. 35

Fig. 27  Ocean surface layer (0-50 m) temperature (CI: 0.5°C) and current climatology for the period of 1996-2009 in May along the west coast of Australia based on GLORYS2V3 ocean reanalysis, GloSea5 and P24 predictions from 1st May. .................................................... 36

Fig. 28  As in Fig. 27, but for the model climatology in May predicted from 1st November. .......... 37
ABSTRACT

Seasonal hindcasts from the Predictive Ocean Atmosphere Model for Australia version 2.4 (POAMA2.4) are compared to the UK Met Office Global Seasonal Forecast System version 5 (GloSea5) during the period 1996-2009 with a focus on the ocean. POAMA2.4 and GloSea5 use different models, different initialization methods and a different ensemble-generation method. A key difference between them is that GloSea5 has much higher model resolutions than POAMA2.4 especially in the ocean for which GloSea5 uses a 0.25° horizontal grid with ~1 m vertical resolution near the surface and POAMA uses a 2° grid with 15 m vertical resolution near the surface. Our analyses show that GloSea5 has a better performance than POAMA2.4 in a number of aspects. For example, GloSea5 has a smaller SST bias overall and particularly in the eastern Pacific coastal region than POAMA2.4. Although overall predictive capability of El Nino is similar between the two systems, GloSea5 makes better predictions across the “spring” predictability barrier and also better predicts the strength of the big 1997/1998 El Niño event. GloSea5 also better simulates ocean current structures and temperatures in the Australian coastal regions, but this does not necessarily translate to substantial improvement in predictions of near coastal temperatures and currents. Some shortcomings of GloSea5 were also uncovered, including simulating stronger SSTA standard deviation (STD) than observed in the tropical Indo-Pacific oceans.
1. INTRODUCTION

Accurate seasonal prediction plays an important role in managing risks arising from climate variability and benefitting decision-making in the climate-sensitive sectors of the economy. The Australian Bureau of Meteorology (BOM) has been implementing dynamical seasonal forecasts since a decade ago. The dynamical forecast system, Predictive Ocean Atmosphere Model for Australia (POAMA) developed jointly by BOM and the CSIRO Division of Marine and Atmospheric Research (CMAR), is comprised of a coupled climate model, initialization and ensemble generation. POAMA has been continuously improved and updated from its original version 1.0 to the current version 2.4 over the past decade, however these developments have been in improved data assimilation and ensemble generation rather than in improved model components.

The present POAMA coupled climate model is now out of date in both model resolution and physics compared to other operational seasonal forecast systems such as those at the UK Met Office, ECMWF, and NCEP. In order to further improve multi-week and seasonal prediction skill, the next version of POAMA system such as POAMA3.0 or 4.0 needs to employ the state-of-the-art coupled climate model. At the present stage, one possible option for this climate model is to use a model similar to the UK Met Office Global Seasonal Forecast System version 5 (GloSea5), which is a high-resolution seasonal forecast system with advanced model physics (MacLachlan et al. 2014). Newer version of this coupled model can be provided through the ACCESS partnership and so evaluation of the performance of GLOSE5 should provide a benchmark for what might be achievable with future versions of a high resolution ACCESS model.

GloSea5 is based on the high-resolution coupled HadGEM3 (Hewitt et al. 2011). Its atmospheric component is Met Office Unified Model (Brown et al. 2012, Walters et al., 2011), Global Atmosphere 3.0 with 85 vertical levels and roughly 65 km horizontal resolution. The ocean component is Global Ocean 3.0 based on NEMOv3.2 (Nucleus for European Modelling of the Ocean, Madec, 2008) and has 0.25 deg horizontal resolution. Land surface model, Global Land 3.0, uses Joint UK Land Environment
Simulator (JULES; Best et al., 2011). The sea ice model, Global Sea-Ice 3.0, is the Los Alamos Sea Ice Model (CICE, Hunk and Lipscomb, 2010).

This study will make an intercomparison of seasonal forecasts over the period 1996-2009 between POAMA model experiment e24a (referred to as P24 hereafter) and GloSea5 with a focus on oceanic performance. Zhao et al. (2015) presents a similar analysis but with a focus on atmospheric predictions. The motivation of this work is to provide guidance for the future development of the next generation of high-resolution seasonal forecast systems at BoM. This report is organized as follows. Section 2 describes the ocean components in P24 and GloSea5. Section 3 provides the analyses of model hindcast results. The conclusion and discussions will be presented in the last section.

2. OCEAN MODEL DESCRIPTIONS

Zhao et al (2015) provides brief descriptions of the model configurations, the strategies of initialization, and ensemble generation for P24 and GloSea5. Here we introduce the ocean models with further detail provided in the attached Appendix namelists.

2.1 Australian Community Ocean Model (ACOM2)

The ocean component of P24 is the Australian Community Ocean Model (ACOM2) based on the Modular Ocean Model (MOM2; Pacanowski, 1995). Its zonal resolution is a uniform 2°. Its meridional resolution is enhanced up to 0.5° within 8° of the equator and is gradually increased to 1.5° near the poles. There are 182x196 horizontal grid points and 25 vertical levels, eight of which are in the uppermost 120 m. The level thickness ranges from 15 m near the sea surface to almost 1000 m near the bottom. The maximum depth is 5000 m.

The model’s topography has been modified in the Indonesian Throughtflow (ITF) region, allowing for a transport of water masses through the Lombok Strait and Timor Sea (Schiller et al. 2002). Note that there is no throughflow in Torres Strait, Karimata
Strait and Bering Sea due to the model’s coarse horizontal resolution. The Drake Passage is widened to enhance the transport of the Antarctic Circumpolar Current (ACC).

ACOM2 uses a rigid-lid, which means that thermal expansion of the oceans, for instance as a result of anthropogenic climate change, is not directly simulated. Most current Ocean General Circulation Models (OGCMs) have given up this obsolete algorithm and use free sea surface height (SSH). SSH, which is a useful diagnostic for tropical interannual variability associated with El Nino, is diagnostic in ACOM2 rather than a prognostic variable. The SSH variations for each grid cell are determined by the horizontal pressure gradients in the momentum equations. It reflects the contributions from the baroclinic and barotropic circulation and dissipation processes.

The vertical mixing is parameterised with a one-dimensional mixing scheme (Chen et al., 1994), which calculates the mixed layer depth (MLD) through the surface fluxes of heat, freshwater and momentum and then obtains the vertical diffusion and viscosity coefficients. Below the MLD, an integer power mixing scheme, which depends on a gradient Richardson number derived from the vertical current shear, is applied (Wilson, 2000). This results in a tight and sharp thermocline in the eastern equatorial Pacific. ACOM2 has not yet implemented tidal mixing parameterisation, although tidally induced vertical mixing has a large impact on the water mass structure in the coastal regions. In order to correctly simulate the ITF, the time-independent vertical mixing coefficients in the Banda Sea and the viscosity in Lombok Strait have been increased to compensate for the absence of a tidal mixing scheme.

### 2.2 NEMO3.2-based GO3

The ocean component of GloSea5 is GO3 which is based on version 3.2 of NEMO (Megann et al. 2014). Its horizontal resolution is 1/4° which has 1442 zonal grid points and 1021 meridional grid points. There is an isotropic Mercator grid in the Southern Hemisphere and a quasi-isotropic bipolar grid in the Northern Hemisphere with poles at
107°W and 73°E. The model has 75 vertical levels where the level thickness is a double tanh function of depth such that the level spacing increases from 1 m near the surface to 200 m at a depth of 6000 m. This level set was chosen to provide high resolution near the surface for short to midrange forecasting purposes while retaining reasonable resolution at mid-depths for long-term climate studies.

The model uses a linear free surface and an energy and enstrophy conserving momentum advection scheme. The horizontal viscosity whose coefficients are reduced polarward use bi-Laplacian scheme. Tracer advection applies a total variance dissipation scheme (Zalesak, 1979). Lateral tracer mixing is along isoneutral surfaces. The isopycnal mixing scheme of Gent and McWilliams (1990) is not used in this configuration, since the high resolution of the model allows the meso-scale eddies to be resolved.

With regard to diapycnal mixing processes, the vertical mixing of tracers and momentum is parameterised using a modified version of the Gaspar et al. (1990) turbulent kinetic energy (TKE) scheme (Madec, 2008). Additionally, the NEMO implementation of the scheme includes a number of parameterisations to represent additional unresolved turbulent processes, including surface wave breaking (Craig and Banner, 1994) and Langmuir turbulence (Axell, 2002). It should be noted that in NEMO v3.2, the enhanced vertical diffusivity was erroneously used in the prognostic equation for the TKE, resulting in a deep bias in wintertime mixed layer depths owing to the non-conservative increase in the calculated TKE. The model also accounts for a double diffusive mixing parameterisation and tidal mixing parameterisation (Simmons et al. 2004) with a special formulation for the ITF (Koch-Larrouy et al., 2008). In addition, a climatological geothermal heating parameterisation is included in the ocean model.

3. RESULTS

The hindcast period of P24 is from 1981 to the present initialised at 5-day intervals on the 1st, 6th, 11th, 16th, 21st and 26th of each month. A 33 member ensemble is available
from P24. GloSea5 covers a shorter hindcast period from 1996 to 2009 and is initialised on the 1st, and 9th of February, May, August and November and on the 25th of the preceding months. In order to make a fair intercomparison of P24 and GloSea5 prediction skill, we only choose the shorter hindcast period of GloSea5 with a 5-ensemble-member results starting from the 1st of February, May, August and November. The model climatologies are computed for the period 1996-2009. P24 produces lead times up to 8 months, but at present GloSea5 has only at 3-month leads for February and August, and 6-month leads for May and November. Here the first month of the forecast is defined as lead month 0, the second month is lead month 1, and so on. The analyses of model climatology, prediction skills, El Niño and Southern Oscillation (ENSO) teleconnections and ocean currents in the hindcast period 1996-2009 are presented in different subsections as follows.

3.1 Observations

We verify the hindcast climatology using observed climatological temperature data derived from the World Ocean Data 2013 (WOA13, Locarnini et al., 2013), which was downloaded from the website: http://www.nodc.noaa.gov/cgi-bin/OC5/woa13/woa13.pl. The WOA13 data are time averaged over two distinct periods, 1995-2004 and 2005-2012, so the 1995-2012 observed climatological period is close but not identical to the model hindcast period of 1996-2009. These small differences should not affect the conclusion of our results. The horizontal resolution of the WOA13 temperature datasets is ¼° and there are 102 vertical levels from the sea surface to 5500 m depth.

We verify hindcast predictions using observed sea surface temperature (SST) analyses from the NOAA optimum interpolation 1/4° daily SST analysis (OISST), which are available on http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.oisst.v2.html (Reynolds et al 2007). The data are available from 1981 to present. Monthly mean data used here for model evaluation are derived from the daily data.
The *Advanced Very High Resolution Radiometer (AVHRR)* dataset mentioned in this report is the same as the OISST data.

We also compare subsurface temperatures and currents to the GLORYS2V3 reanalysis (http://sextant.ifremer.fr/record/7a7b31cb-9e7b-4b5b-9ff3-c1165b51f79b/). This reanalysis is created using the NEMOv3.1 ocean model with ¼ degree horizontal resolution and 75 vertical levels. The ocean model is forced with ERA-Interim atmospheric surface forcing while assimilating the observations of salinity, temperature, sea level anomaly and sea ice concentration. The data assimilation technique is a multivariate reduced order Kalman filter based on the Singular Extended Evolutive Kalman (SEEK) filter formulation and includes a bias correction scheme for temperature and salinity. In addition, we also compare to observed sea surface height anomaly (SSHA) altimeter data, which are downloaded from the website: http://aviso.altimetry.fr/index.php?id=1272.

### 3.2 Climatology

#### a. Global perspective

Figs. 1-3 show the SST climatology and standard deviation (STD) during the period 1996-2009 for May, August and November based on 0.25° resolution OISST observations and five-member mean predictions of GloSea5 and P24 initialised on 1 May. The STD was calculated by averaging the STD of each ensemble member. An apparent advantage of the high-resolution of GloSea5 is that it is able to realistically reproduce more detail in the global distribution of the SST climatology and variance. This includes the sharp front of high variance along the Kuroshio Extension region in the North Pacific and zonally extended fronts along the Antarctic Ocean. The western boundaries currents that transport warm waters from the tropics to extratropics, and the narrow coastal upwelling regions on west coasts of the South America and tropical Africa are also better depicted. In addition, the warm water and high variance associated with the Leeuwin Current along the west coast of Australia and the warm waters along the west coasts of North America and North Africa owing to narrow coastal
downwelling are also well captured by the high-resolution model. In contrast, most of these important details are not captured in the coarse resolution P24 model.

Fig. 1 SST climatology (contour intervals: 1°C. Green lines denote SST higher than 28°C) and one standard deviation (colour shading) for the period of 1996-2009 in May based on 0.25° AVHRR satellite observations, 5-member mean of GloSea5 and P24 hindcast at 1-month lead.
Fig. 2  As in Fig. 1 but at lead months 0-3.
GloSea5 hindcasts at 3 and 6 months lead display cold biases and overestimated variance in the eastern equatorial regions of the Pacific, Atlantic and Indian Ocean; this is particularly true in August (Fig. 2). In contrast, the P24 hindcasts produce warm biases and underestimated variance over these regions. The zonal gradient of SST across the tropical Atlantic is better captured in GloSea5 compared to P24, although the cold bias in the eastern Atlantic in GloSea5 may help to improve the zonal SST gradient for the wrong reason.
Model hindcasts initiated from 1 November (Figs. 4-6) display similar features to those described above. Again, the GloSea5 high-resolution model displays advantages over P24 coarse resolution model in reproducing details of the SST climatology and variance over the global ocean. The GloSea5 hindcasts in February and May (i.e., at 3 and 6 months lead) also produce strong cold biases and overestimated variance in the eastern equatorial regions of the Pacific and Atlantic. The biases in the eastern equatorial Indian Ocean, however, are reduced probably due to a limited IOD-like air-sea coupling there in the first half of the year. Compared to its predictions initiated from 1 May, P24 hindcasts initiated from 1 November show improved performance including less warm pool shrinking and realistic ENSO variance at 3 and 6 months lead, despite many similar biases that are still visible. One exceptional problem is that P24 largely overestimates the SST variance along the Antarctic Ocean in February. Underlying reasons for this error are unclear and need to be investigated.
Fig. 4  As in Fig. 1 but initiated from 1 November.
Fig. 5  As in Fig. 4 but at lead month 3.
**b. Tropical Indo-Pacific**

Figure 7 displays the SST biases for P24 and GloSea5 at different lead months in the tropical Indo-Pacific regions. Generally, the bias increases with increasing lead time. The SST bias in P24 is positive and large (exceeding 3°C) along the west coast of North and South America, but P24 exhibits a pronounced overall cold bias in most other areas.
The coastal warm bias is probably related to weak upwelling due to the coarse resolution in both the atmosphere and ocean component models of P24.

![SST bias comparison between POAMA2.4 (left panels) and GloSea5 (right panels) at lead months 0-3.](image)

Fig. 7  The SST bias of P24 (left panels) and GloSea5 (right panels) at lead months 0-3.

This warm bias, which has been an ongoing problem for coupled models, has been significantly reduced in the high-resolution GloSea5. The SST bias in GloSea5 is
generally smaller than in P24 at all lead times over most parts of the Indo-Pacific oceans except the Pacific cold tongue region, where the cold bias develops quickly and reaches -3°C at lead times beyond 1 month. Note that Zhao et al. (2015) also presents some comparison of SST bias between these two models. However, they used the SST data from GloSea5 that is derived from the output of the atmospheric model rather than the ocean model, so their SST data has the same horizontal resolution as the atmospheric model and lower resolution than the ocean model; thus their analysis did not highlight any of the detail that we report here.

Fig. 8  As in Fig. 7 but for the temperature (averaged over 2°S-2°N) along the equator.
Figure 8 exhibits the zonal section of model temperature biases along the equator (averaged over 2°S-2°N). Along the thermocline region in the eastern Pacific, P24 has a large warm bias in lead months 2 and 3. However, GloSea5 has a large cold bias in this region. It indicates that the thermocline depth in P24 is deeper (flatter) whereas GloSea5 is shallower (steeper) than observed. At lead month 0, both P24 and GloSea5 have a similar spatial distribution that features a cold bias in the western Pacific (maximum error occurs around 150 m) and warm bias in the subsurface of the eastern Pacific, but GloSea5 has a larger cold bias in the subsurface of the western Pacific than P24. The cold bias in GloSea5 looks to propagate eastward from the western Pacific to the eastern Pacific along the path of thermocline depth and result in a smaller cold bias in the west and larger cold bias in the east with lead month. The warm bias in GloSea5 shown in lead month 0 gradually disappears and shifts to a cold bias state beyond lead month 1.

In the Indian Ocean (IO), both GloSea5 and P24 have a similar spatial pattern of bias that shows a warm bias in the eastern IO but a cold bias in the western IO. P24 has less of a warm bias in the western IO than GloSea5 at all lead months and less of a cold bias in the eastern IO at lead month 0-1. At lead months 2 and 3, both P24 and GloSea5 have comparable errors in the eastern IO.

Figure 9 shows the bias of heat content at upper 300 m (HC300), which is defined as averaged temperature of the top 300 m weighted by level thickness. GloSea5 has a larger cold bias in the equatorial Pacific and a larger warm bias in the ITF regions than P24. However, P24 has a larger cold bias in the western North Pacific near 15°N at all lead times and a larger warm bias at lead months 2-3 in the eastern Pacific. Both P24 and GloSea5 have comparable biases in the other regions. In the tropical IO, both P24 and GloSea5 display errors resembling the dipole structure of the Indian Ocean Dipole (IOD) with cold biases in the eastern IO and warm biases in the west. This could be related to the wind biases in these regions.
c. Climate drift

If a model and initial conditions are perfect, the model should have an identical climatology at all lead months. However, the model climatology will gradually drift from its initial mean state (which is closer to the observed) towards the model’s own mean state of a free long-term coupled run with increasing lead time due to deficiencies in model physics, numerical schemes, initialization scheme etc. Figure 10 shows the differences of monthly mean state between lead month 3 and 0. The SST in
P24 has a large climate drift towards a warmer state in the Arctic, South Ocean, eastern Pacific and eastern Atlantic coastal areas (Fig. 10a). However, the mean SSTs in other areas have a drift towards a colder state. The drift in the polar region is perhaps associated with the absence of sea ice model in P24. The drift in the eastern Pacific coastal region is consistent with the large warm bias shown in Figs.1a-d. Compared to the SST drift in P24, GloSea5 has much smaller drift in the Arctic, ACC and eastern Pacific and Atlantic coastal regions (Fig. 10c). But GloSea5 has a larger drift towards a colder state in the equatorial Pacific cold tongue.

Fig. 10 The differences of mean SST and temperature along the equator between lead month 3 and 0 for POAMA24 and GloSea5.
Figures 10c and 10d show the drift of temperature along the equator for P24 and GloSea5. Both models have a similar drift in the IO with a cold drift occurring in the eastern IO but a warm drift in the western IO. However, the drifts in the Pacific and Atlantic are almost opposite for the models. P24 tends to be warmer along the thermocline in the eastern Pacific and Atlantic oceans with lead time, but GloSea5 is colder. The spatial patterns of drift are similar to that of the temperature bias along the equator at lead month 2 or 3 shown in Fig. 2.

The difference in sea surface salinity (SSS) climatology between lead month 3 and 1 is shown in Fig. 11. The SSS climate drift in P24 is rather small. It is partly accounted for by the weak nudging of SSS to the observed climatology with a two-year time scale. However, evaporation-minus-precipitation is also realistically simulated in P24. In contrast, the SSS drift in GloSea5 is much larger in the tropical oceans, Arctic and the regions with strong currents. The drift in the tropics is perhaps attributed to the rainfall climate drift in the atmospheric model. Wet biases occur in the convergence zones and western IO but dry biases occur in the eastern IO and western Pacific (Zhao et al. 2015). The SSS drift in the Arctic is possibly caused by the sea ice model. Note that the SSS drift in the Arctic looks big compared to other oceans, despite a small SST drift in that region.

Figure 12 exhibits the mean sea surface height (SSH) at lead months 0-1 and their differences. P24 displays a very large SSH difference within the first month lead particularly in the western Pacific (more than 20 cm). But the SSH differences between lead months 1 and 3 are small (not shown). The SSH climatology in lead months 1-3 is comparable to that in the ocean analysis of PEODAS. This suggests the possibility of unknown problems in P24. The SSH climate drift in GloSea5 is very small everywhere. The largest drift (~5 cm) occurs in the central equatorial Pacific which is possibly associated with the temperature drift (recall Fig. 10) in this area.
Fig. 11  As in Fig. 10 but for SSS only.
Fig. 12 The climatology of sea surface height (SSH) at lead months 0 and 1 and their differences for POAMA2.4 (left panels) and GloSea5 (right panels).

3.3 Prediction skill

Figure 13 displays the correlation skill of predicted SST anomalies (SSTA) at lead month 0-3. Correlations below 0.5 are shaded blue and typically represent lower skill than a climatological forecast. Both POAMA2.4 and GloSea5 have a very similar spatial distribution at all lead times. At lead month 0, both models generally produce high correlation skill. Prediction skill rapidly decreases in most regions except the tropical
Pacific where the prediction skill remains high out to 3-month lead due to the high predictability of ENSO. At lead months 2 and 3, P24 seems to have slightly higher correlations in the western IO and in the Pacific mid-latitudes than GloSea5. The correlation skill in these regions is largely impacted by ENSO teleconnection through the atmosphere.

Figure 14 shows the root-mean-square-error (RMSE) of SST. Both P24 and GloSea5 have a larger RMSE in the ACC and the western boundary current (WBC) regions such as Kuroshio and Gulf Stream even at lead month 0 than other areas, since these regions...
have a strong interannual variability and abundant mesoscale eddies generated by the instability of strong horizontally sheared motions and baroclinic instability. The high-resolution GloSea5 shows larger RMSEs in the ACC and WBC regions than the low-resolution P24. This indicates that the frontal variability there may be poorly predicted or overestimated in GloSea5. In addition, GloSea5 displays larger RMSEs in the central and eastern Pacific than P24, Perhaps reflecting a stronger than observed El Nino mode (see below) as a result of the cold tongue cold bias.

Fig. 14  As Fig. 13 but for RMSE.
RMSEs normalized with the observed SSTA standard deviation (STD) are shown in Fig. 15. The smallest normalized RMSE (hence highest skill) is mainly confined to the tropical Pacific. This is consistent with the predicted SSTA correlation skill (recall Fig. 13). However, the skills falls rapidly after the first month lead. It appears that the normalized RMSEs are smaller in P24 than GloSea5 over major parts of the global ocean at all lead times. The normalized RMSEs in the ACC and WBC areas are not significantly larger than those shown in Fig. 14.

Fig. 15  As Fig. 14 but for the RMSE normalized by the observed SSTA standard deviation.
Figures 16 and 17 show the standard deviation of model SST in the Indo-Pacific oceans and its error. The SSTA STD in most oceans in P24 decreases with increasing lead time and is weaker than that observed in most regions, particularly in the eastern Pacific beyond 0-month lead. However, GloSea5 overestimates the predicted SSTA STD almost everywhere, particularly in the equatorial Pacific where the SSTA STD in the model is closely associated with the shoaling of the model’s thermocline depth (TD). Deepening TD there will reduce the SSTA STD or vice versa. The TD in the equatorial Pacific is increased in P24 but decreased in GloSea5 (recall Fig. 8) with lead time.

Fig. 16 The SSTA standard deviation from the lead months 0 to 3 for POAMA2.4 (left panels) and GloSea5 (right panels).
Figure 18 illustrates the time series of predicted Niño 3.4 SSTA index (170°W-120°W, 5°S-5°N). Both P24 (green line) and GloSea5 (red line) well capture the observed (black line) ENSO phase at all lead months. However, P24 underestimates the ENSO strength beyond lead month 1 whereas GloSea5 overestimates it. In particular, for the 1997/1998 El Niño event, GloSea5 predicts the peak amplitude much better than P24. The Niño3.4
SSTA index predicted by P24 is almost 1°C lower than that observed at lead months 2-3 for this El Niño event at its peak phase.

Fig. 18 The time series of Niño 3.4 SSTA index for the observed (black curve), POAMA2.4 (green curve) and GloSea5 (red curve) at lead months 0-3.

3.4 ENSO teleconnections

El Niño events are the most dominant and predictable features of climate variability on the interannual timescale and have global climatic teleconnections. The atmosphere can act as a bridge for these teleconnections spanning from the equatorial Pacific to the remainder of the global oceans. Figure 19 displays the regression onto Niño3.4 SSTA index of SSTA for the observed OISST data. Figure 20 is the same as Fig. 19 but for the models at different lead months. For the positive polarity of the Niño3.4 index, the central and eastern equatorial tropical Pacific, the west coast of North America and
South America, and the western IO are characterized by anomalous warming whereas the western Pacific and east IO have negative anomalous SST (Fig. 19). The ENSO teleconnection in P24 becomes stronger in the IO and remains stable in the middle-latitude Pacific with increasing lead time, whereas in GloSea5 it gradually weakens in these regions, with the weak impact in the Indian Ocean and along the Australian west coast being particularly notable.

![Observed regression between SSTA and Niño3.4 SSTA index](image)

Fig. 19 Regression onto Niño 3.4 SSTA index of global SSTA based on the observed OISST dataset.
Fig. 20  As Fig. 19 but for POAMA2.4 (left panels) and GloSea (right panels) at lead months 0-3.

Fig. 21  Regression onto Niño 3.4 SSTA index of global SSH anomaly based on the observed satellite dataset.
Figure 22 displays the regression between sea surface height anomaly (SSHA) and Niño3.4 SSTA index based on the observed dataset. Its spatial structure is similar to the regression onto Niño3.4 SSTA index of global SSTA. During the El Niño phase (positive), the sea level rises in the central and eastern equatorial Pacific, eastern IO, and west coast of North America and South America continents. The regression in P24 is weak in the equatorial Pacific at lead month 0 but becomes stronger at lead months 1-3. However, the regression in GloSea5 becomes weaker with increasing lead time. Zhao et al (2015) also shows that P24 can better represent the ENSO teleconnections than GloSea5 in the atmospheric fields. Future work will further investigate why GloSea5 has weaker ENSO teleconnections than observed.

Fig. 22 As Fig. 21 but for P24 (left panels) and GloSea5 (right panels) at lead months 0-3.
3.5 Equatorial and coastal ocean currents

Pacific equatorial undercurrent (EUC) is a strong eastward current in the subsurface along the equator. It is mainly driven by the pressure gradient force due to the difference of sea level between the western (high sea level) and eastern Pacific (low sea level). The Coriolis force keeps the EUC centered on the equator. Figure 23a shows one estimate of the observed annual mean EUC based on optimum interpolation of in situ observations in the 1990’s. (Johnson et al. 2002). For comparison, the climatology from the PEODAS reanalyses for 1980-2010 is shown in Fig.25b. The maximum amplitude of EUC occurring at about 100 m depth in PEODAS is about 0.8 cm/s and is about 20% weaker than depicted in the Johnson et al. analysis. This difference could be due to interannual sampling or deficiencies in the PEODAS reanalyses in the sensitive region along the equator. Figure 25 displays the model predicted mean EUC at different lead months. The maximum amplitude of EUC in P24 at lead month 0 is similar to that in PEODAS but increases with lead time, reaching up to 1.0 m/s at lead months 2-3 and being closer to Johnson et al. This indicates that the data assimilation may deteriorate the model’s EUC simulation. The EUC in GloSea5 is also weaker than observed at lead months 0-1 and becomes stronger at lead months 2-3.

![Fig. 23 The annual mean Equatorial Undercurrent (EUC) in the observations (left) and PEODAS reanalysis (right).](image-url)
Fig. 24  The climatology of EUC in P24 (left panels) and GloSea5 (right panels) at lead months 0-3. Green line stands for 0.5m/s.

Along the east and west coasts of Australia, the East Australian Current (EAC) and Leeuwin Current carry warm waters from the tropics southward up to the mid-latitudes during most months of the year, and may significantly affect the coastal ecosystem and environment. Figure 25-28 display the observed EAC and Leeuwin Current in November (when the Leeuwin Current is weak) and May (when the Leeuwin Current is strong) and the model predictions at 0 and 6 months lead. With the high resolution GloSea5 model, both the two coastal currents and ocean warm temperature along the coasts are realistically predicted at short lead (0-month) and mid-lead (6-month) times.
The spatial variations of the coastal currents and related temperature are also realistically simulated, including the narrow cooling close to the west coast of Australia at 34°-28°S. In contrast, the coarse resolution P24 model fails to capture both the EAC and Leeuwin current and hence fails to reproduce the warm temperature along the west and east coasts of Australia. This may lead to the exacerbated cold SST biases along the coasts of Australia, superimposed on the global scale cold biases in P24.

Fig. 25 Ocean surface layer (0-50 m) temperature (CI: 0.5°C) and current climatology for the period of 1996-2009 in November along the east coast of Australia based on GLORYS2V3 ocean reanalysis, GloSea5 and P24 predictions from 1st November.
Fig. 26  As in Fig. 25, but for the model climatology in November predicted from 1st May.
Fig. 27 Ocean surface layer (0-50 m) temperature (CI: 0.5°C) and current climatology for the period of 1996-2009 in May along the west coast of Australia based on GLORYS2V3 ocean reanalysis, GloSea5 and P24 predictions from 1st May.
Fig. 28  As in Fig. 27, but for the model climatology in May predicted from 1st November.

4. CONCLUSION AND DISCUSSIONS

In this report, we have validated the ocean hindcasts produced by both low-resolution P24 and high-resolution GloSea5 seasonal forecast systems during the period 1996-2009. The validation results will provide us some useful information in developing our next high-resolution POAMA. Besides the two different model resolutions, P24 and GloSea5 are built on different models, different data-assimilation methods for initialization and different schemes for ensemble generation. Therefore, it is difficult to
identify the exact reasons for the differences in hindcast results for both systems. However, the high-resolution model should have better descriptions of topography, better resolutions of small-scale eddies and better predictions of coastal currents than the low-resolution model.

Compared to P24, GloSea5 has a better performance in several aspects. For example, SST bias and SST climate drift in the hindcast period are smaller in most regions, particularly in the eastern Pacific coastal region. GloSea5 can correctly predict the peak amplitude of the 1997/1998 super El Niño at lead months 2 and 3, but P24 seems to significantly underestimate it at these lead months. The EAC and Leeuwin currents and their transported warm water from the tropics along the east and west coasts of Australia are well predicted in GloSea5 but not in P24.

However, both P24 and GloSea5 have comparable performance in some areas, while GloSea5 is worse in a number of aspects. For instance, the predicted SSTA correlations with that observed are comparable for each system. GloSea5 has a larger RMSE of SSTA in the ACC, WBC and tropical equatorial Pacific regions than P24. GloSea5 has stronger SSTA STD almost everywhere in the tropical Indo-Pacific oceans than the observed, particular in the equatorial Pacific and Sumatra coastal area at all lead months, but the SSTA STD in P24 is weaker in most regions beyond lead month 0, particularly in the eastern Pacific which is the key region for El Niño/La Niña events. Both P24 and GloSea5 have a similar spatial pattern of the regressions between Niño3.4 SSTA index and global SSTA/SSHA, although the teleconnection into the Indian Ocean weakens dramatically in GLOSEA5 with longer lead time. The strength of the EUC simulation in both P24 and GloSea5 is similar and weaker than observed in lead month 0. But P24 tends to be stronger with longer lead time and it is closer to that observed at lead months 2-3 compared with GloSea5.

An obvious deficiency in the HadGEM3-based GloSea5 analysed in this study is a large cold bias occurring in the Pacific cold tongue region. It has reportedly been largely fixed in the updated GC2 version of GloSea5, which replaced the original GLOSEA5
system at UKMO in February 2015. The potential use of the GC2 model for a future version of the POAMA system is now being considered. To this end, the GC2-based GloSea5 has been successfully installed in NCI Raijin supercomputer and a few test hindcast experiments have been conducted. Evaluation of these hindcasts is ongoing.
5. REFERENCES


**Acknowledgement**

Support was provided by the MCV program. The authors appreciate the support from Griffith Young, Drs Craig MacLachlan and Guo Liu with handling the GloSea5 datasets.
6. APPENDIX

6.1 MOM2-based ACOM2 model namelist:

#########################################################
#  ACOM2 set up #
#########################################################

# define i/o control for writing diagnostics.
# if < 0 then output is written to unformatted file and stdout
# if > 0 then output is written to unformatted file only
# if = stdout = 6 then output is written to stdout only
# this applies only to those diagnostics which are "enabled"

set iotraj   =  1 # particle trajectories
set iotavg   =  1 # regional tracer averages
set iotmb    = -1 # tracer meridional balance diagnostics
set ioglen   = -1 # global energetic diagnostics
set iotrmb   = -1 # term balance diagnostic
set iovmsf   =  1 # meridional mass transport diagnostic
set iogyre   =  1 # gyre transport diagnostic
set ioprxz   =  1 # zonal x-z matrix diagnostics
set ioext    = -1 # show external mode (stream function) diagnostic
set iodsdp   =  1 # diagnostic surface pressure diagnostics
set iotai    =  1 # time step integral diagnostics
set iozmbc   = -1 # zonal mean S.B.C. diagnostics
set ioxbt    =  1 # XBT stations

# Bring in real data

# copy model topography to working directory

cp $MOM_DB/kmt.dta       $wrkDir

# copy initial conditions to working directory

cp $MOM_DB/red_med_sp.mom red_med_sp.mom
cp $MOM_DB/optic.mom optic.mom
cp $MOM_DB/sss.mom sss.mom

# copy other data to working directory
cp $cmLib/nc_checkfile_template .
cp $cmLib/snapshots.nc_temp .

sed -e "1,$ s'-WRKDIR-VAR-'$wrkDir'g" nc_checkfile_template >!
c_checkfile
chmod +x nc_checkfile

# --------------------------------------------
#   set namelist variables
# --------------------------------------------
set diag  = 1.
set diag1 = 30.416666666666666
set diag2 = 10.0
set diag3 = 1.0

set NAMELIST_EOF = "/
#
#--- Following namelists are used in setocn.F:
# contrl, mbcin, tsteps, riglid, mixing, diagn, io, ictime, isopyc
#
cat > namelist.contrl << ENDNAMELIST
 &contrl init=.false., runlen=$nday, rununits='days',
    restrt=.false., initpt=.false., segtim=${segtim},icoupler=0,
$NAMELIST_EOF
ENDNAMELIST

cat > namelist.mbcin << ENDNAMELIST
 &mbcin $NAMELIST_EOF
ENDNAMELIST

cat > namelist.tsteps << ENDNAMELIST
&tsteps dtts=900.0, dtuv=900.0, dtsf=900.0
$NAMELIST_EOF
ENDNAMELIST

cat > namelist.riglid << ENDNAMELIST
&riglid mxscan=2000, sor=1.60, tolrsf=1.0e8, tolrsp=1.0e-4,
tolrfs=1.0e-4,
$NAMELIST_EOF
ENDNAMELIST

cat > namelist.mixing << ENDNAMELIST
&mixing am=2.e7, ah=4.5e7, ambi=1.e23, ahbi=5.e22,
kappa_m=20.0, kappa_h=1.0, aidif=1.0,
rmix=17, eb=.true., ncon=1, cdbot=0.0,
acor=0.5,
dampts(1)=7.0, dampts(2)=30.0,
dampdz(1)=15.00e2, dampdz(2)=15.00e2,
$NAMELIST_EOF
ENDNAMELIST

cat > namelist.isopyc << ENDNAMELIST
&isopyc $NAMELIST_EOF
ENDNAMELIST

cat > namelist.diagn << ENDNAMELIST
&diagn tsiint=$diag3,
tavgint=$diag1, itavg=.false.,
tmbint=$diag1, itmb=.false.,
trmbint=$diag1, itrmb=.false.,
snapint=$diag, snapls=-90.0, snaple=90.0,
snapde=5000.0e2,
timavgint=$diag,
glenint=$diag1, vmsfint=$diag1, stabint=$diag3,
zmbcint=$diag1,
gyreint=$diag1, extint=$diag1, prxzint=$diag1,
dspint=$diag2,
trajint=$diag3, xbtint=$diag1, exconvint=$diag1,
cmixint=$diag1,
$NAMELIST_EOF
ENDNAMELIST

cat > namelist.io << ENDNAMELIST
&io expnam='CGCM3-ACOM2',
iotavg=$iotavg, iotmb=$iotmb, iotrmb=$iotrmb,
iozmbc=$iozmbc,
ioglen=$ioglen, iovmsf=$iovmsf, iogyre=$iogyre,
ioprxz=$ioprxz, ioext=$ioext, iodsp=$iodsp,
iotsi=$iotsi, iotraj=$iotraj, ioxbt=$ioxbt,
$NAMELIST_EOF
ENDNAMELIST

cat > namelist.ictime << ENDNAMELIST
&ictime eqyear=.false., eqmon=.false., refinit=.true.,
    year0=${year0}, month0=${month0}, day0=${day0}, hour0=0,
    min0=0, sec0=0,
$NAMELIST_EOF
ENDNAMELIST
#
#--- Where are the following namelists used? blmix, hlmix, chmix
#
cat > namelist.blmix << ENDNAMELIST
&blmix $NAMELIST_EOF
ENDNAMELIST

cat > namelist.hlmix << ENDNAMELIST
&hlmix $NAMELIST_EOF
ENDNAMELIST

cat > namelist.chmix << ENDNAMELIST
&chmix fricmx=0.0, diff_cbt_back=0.01, visc_cbu_back=0.2,
    visc_cbu_limit=266.0, diff_cbt_limit=199.0,
$NAMELIST_EOF
ENDNAMELIST

#--------------------------------------------
# ogcm files and environment setup
#--------------------------------------------
setenv FORT86 ogcm6    # standard output of ogcm
# --------------------------------------------
#  GENERATE o2a.nc
# --------------------------------------------
ACOMv2
if ( $status == 0 ) then
  echo "`dtxx` gen o2a.nc OK."
  ls -l o2a.nc
  rm namelist.contrl
else
  echo "`dtxx` Run ACOMv2 gen o2a.nc fails. Abort."
  exit 1
endif

cat > namelist.contrl << ENDNAMELIST
&contrl init=.false., runlen=$nday, rununits='days',
  restrt=.false., initpt=.false.,
  segtim=${segtim},icoupler=${coupler},
  $NAMELIST_EOF
ENDNAMELIST
6.2 NEMO3.2-based GO3 namelist:

Note that this namelist was provided by Dr. Craig MacLachlan.

```
!! NEMO/OPA : 1 - run manager (namrun)
!! namelists 2 - Domain (namzgr, namzgr_sco, namdom)
!! 3 - Surface boundary (namsbc, namsbc_ana, namsbc_flx, namsbc_clio, namsbc_core
!! namsbc_rnf, namsbc_ssr, namsbc_alb)
!! 4 - lateral boundary (namlbc, namcla, namobc, namagrisf, nambdy, nambdy_tide)
!! 5 - bottom boundary (nambfr, nambbc, namblb)
!! 6 - Tracer (nameos, namtra_adv, namtra_ldf, namtra_dmp)
!! 7 - dynamics (namdyn_adv, namdyn_vor, namdyn_hpg, namdyn_spd, namdyn_lsp)
!! 8 - Vertical physics (namzdf, namzdf_ric, namzdf_tke, namzdf_kpp, namzdf_ddm, namzdf_tmx)
!! 9 - diagnostics (namtrd, namgap, namsp, namflo, namptr)
!! 9 - miscellaneous (namsol, nammp, nammmp_dyndist, namctl)
```

---

```
!! CAUTION: some scripts does not support CAPITALs for logical use .true./.false., not .TRUE./.FALSE.
```

---

```
!! namrun parameters of the run
```
&namrun   ! parameters of the run

nn_no = 0 ! job number
cn_exp = "set_by_umui" ! experience name
nn_it000 = 1 ! first time step
nn_itend = "set_by_umui" ! last time step
nn_date0 = "set_by_umui" ! initial calendar date yymmdd
(used if nrstdt=1)
nn_leapy = "set_by_umui" ! Leap year calendar (1) or not (0)
nn_istate = 0 ! output the initial state (1) or not (0)
nn_stock = 640 ! frequency of creation of a restart file (modulo referenced to 1)
nn_write = 64 ! frequency of write in the output file
(modulo referenced to nit000)
ln_dimgnnn = .false. ! DIMG file format: 1 file for all processors (F) or by processor (T)
ln_cfout = .true.
ln_mskland = .true. ! mask land points in NetCDF outputs (costly: + ~15%)
ln_clobber = .true. ! clobber (overwrite) an existing file
nn_chunksz = 0 ! chunksize (bytes) for NetCDF file
(working only with iom_nf90 routines)
ln_rstart = .false. ! start from rest (F) or from a restart file (T)
nn_rstctl = 0 ! restart control = 0 nit000 is not compared to the restart file value
! = 1 use ndate0 in namelist (not the value in the restart file)
parameters read in the restart file
   cn_ocerst_in = "restart" ! suffix of ocean restart name (input)
   cn_ocerst_out = "restart" ! suffix of ocean restart name (output)
   ln_diafoam = .true.      ! Turn on diafoam diagnostics (false or true)
   nn_diafoam = 0,0,64,0,0,0 ! 1st value: shelf top-middle-bottom diagnostics
                               ! 2nd value: operational foam diagnostics
                               ! 3rd value: Mersea diagnostics
                               ! 4th value: FOAM-LITE diagnostics
                               ! 5th value: operational foam diagnostics
                               ! 6th value: barotropic shelf bc outputs
/
!!=================================================================
=====
!!                      ***  Domain namelists  ***
=====
!! namzgr       vertical coordinate
!! namzgr_sco   s-coordinate or hybrid z-s-coordinate
!! namdom       space and time domain (bathymetry, mesh, timestep)
!!=================================================================
=====

ln_zco      = .false. ! z-coordinate - full steps (T/F)
("key_zco" may also be defined)
COMPARISON OF GLOSEA5 AND POAMA2.4 HINDCASTS 1996-2009: OCEAN FOCUS

ln_zps = .true. ! z-coordinate - partial steps (T/F)
ln_sco = .false. ! s- or hybrid z-s-coordinate (T/F)
/

!------------------------------------------------------------------
-----
&namzgr_sco ! s-coordinate or hybrid z-s-coordinate
!------------------------------------------------------------------
-----

rn_sbot_min = 300. ! minimum depth of s-bottom surface (>0) (m)

rn_sbot_max = 5250. ! maximum depth of s-bottom surface (= ocean depth) (>0) (m)

rn_theta = 6.0 ! surface control parameter (0<=theta<=20)

rn_thetb = 0.75 ! bottom control parameter (0<=thetb<=1)

rn_rmax = 0.15 ! maximum cut-off r-value allowed (0<r_max<1)

ln_s_sigma = .false. ! hybrid s-sigma coordinates

rn_bb = 0.8 ! stretching with s-sigma

rn_hc = 150.0 ! critical depth with s-sigma
/

!------------------------------------------------------------------
-----
&namdom ! space and time domain (bathymetry, mesh, timestep)
!------------------------------------------------------------------
-----

nn_bathy = 1 ! compute (=0) or read (=1) the bathymetry file

nn_closea = 1 ! closed seas and lakes are removed (=0) or kept (=1) from the ORCA domain

nn_msh = 0 ! create (=1) a mesh file (coordinates, scale factors, masks) or not (=0)

rn_e3zps_min= 25. ! the thickness of the partial step is set larger than the minimum
rn_e3zps_rat = 0.2 ! of e3zps_min and e3zps_rat * e3t
(N.B. 0<e3zps_rat<1)

rn_rdt = 1350. ! time step for the dynamics (and tracer if nacc=0) => 5760
nn_baro = 60 ! number of barotropic time step (for the split explicit algorithm) ("key_dynspg_ts")

rn_atfp = 0.1 ! asselin time filter parameter
nn_acc = 0 ! acceleration of convergence : =1 used, rdt < rdttra(k)

rn_rdtmin = 1350. ! minimum time step on tracers (used if nacc=1)

rn_rdtmax = 1350. ! maximum time step on tracers (used if nacc=1)

rn_rdtth = 800. ! depth variation of tracer time step (used if nacc=1)

!!!=================================================================
!!!            ***  Surface Boundary Condition namelists  ***
!!!=================================================================

!!! namsbc        surface boundary condition
!!! namsbc_ana    analytical         formulation
!!! namsbc_flx    flux               formulation
!!! namsbc_clio   CLIO bulk formulae formulation
!!! namsbc_core   CORE bulk formulae formulation
!!! namsbc_cpl    CouPLed            formulation ("key_coupled")
!!! namtra_qsr    penetrative solar radiation
!!! namsbc_rnf    river runoffs
!!! namsbc_ssr    sea surface restoring term (for T and/or S)
!!! namsbc_alb    albedo parameters
&namsbc        ! Surface Boundary Condition (surface module)

nn_fsbc     = 1         ! frequency of surface boundary
                 condition computation
                 (= the frequency of sea-
                 ice model call)

ln_ana      = .false.   ! analytical formulation (T => fill
namsbc_ana )  

ln_flx      = .false.   ! flux formulation       (T => fill
namsbc_flx )

ln_blk_clio = .false.   ! CLIO bulk formulation (T => fill
namsbc_clio)

ln_blk_core = .false.   ! CORE bulk formulation (T => fill
namsbc_core)

ln_cpl      = .true.    ! Coupled formulation    (T => fill
namsbc_cpl )

nn_ice      = 2         ! =0 no ice boundary condition ,
                 =1 use observed ice-cover ,
                 =2 ice-model used

("key_lim3" or "key_lim2" or "key_cice")

nn_ico_cpl  = 0         ! ice-ocean coupling : =0 each nn_fsbc
                 =1 stresses

recomputed each ocean time step ("key_lim3" only)
                 =2 combination of 0 and 1 cases ("key_lim3" only)

ln_dm2dc    = .false.   ! daily mean to diurnal cycle short
                 wave (qsr)

ln_rnf      = .true.    ! runoffs (T => fill namsbc_rnf)

ln_ssr      = .false.   ! Sea Surface Restoring on T and/or S
(T => fill namsbc_ssr)
nn_fwb = 0 ! FreshWater Budget: =0 unchecked
           ! =1 global mean of e-p-r set to zero at each time step
           ! =2 annual global mean of e-p-r set to zero
           ! =3 global emp set to zero and spread out over erp area
/
!------------------------------------------------------------------
-----
&namsbc_ana ! analytical surface boundary condition
!------------------------------------------------------------------
-----
nn_tau000 = 0 ! gently increase the stress over the first ntau_rst time-steps
rn_utau0 = 0.e0 ! uniform value for the i-stress
rn_vtau0 = 0.e0 ! uniform value for the j-stress
rn_qns0 = 0.e0 ! uniform value for the total heat flux
rn_qsr0 = 0.e0 ! uniform value for the solar radiation
rn_emp0 = 0.e0 ! uniform value for the freshwater budget (E-P)
/
!------------------------------------------------------------------
-----
&namsbc_flx ! surface boundary condition : flux formulation
!------------------------------------------------------------------
-----
! file name ! frequency (hours) ! variable ! time interpol. ! clim ! 'yearly'! weights ! rotation ! (logical) ! (T/F) ! 'monthly' ! filename ! pairing !
sn_utau = 'utau' , 24 , 'utau' , .false. , .false. , 'yearly' , '' , ''
sn_vtau = 'vtau' , 24 , 'vtau' , .false. , .false. , 'yearly' , '' , ''
COMPARISON OF GLOSEA5 AND POAMA2.4 HINDCASTS 1996-2009: OCEAN FOCUS

\[ \text{sn}_\text{qtot} = 'qtot', 24, \]
\[ 'qtot', \text{.false.}, \text{.false.}, 'yearly', '', '' \]
\[ \text{sn}_\text{qsr} = 'qsr', 24, \]
\[ 'qsr', \text{.false.}, \text{.false.}, 'yearly', '', '' \]
\[ \text{sn}_\text{emp} = 'emp', 24, \]
\[ 'emp', \text{.false.}, \text{.false.}, 'yearly', '', '' \]

! \[ \text{cn}_\text{dir} = './' \] ! root directory for the location of the flux files
/

!---------------------------------------------------------------
-----
\&namsbc_clio ! namsbc_clio CLIO bulk formulae
!---------------------------------------------------------------
-----

! ! file name ! frequency (hours) ! variable ! time interpol. ! clim ! 'yearly'/ ! weights ! rotation !
! ! ! (if <0 months) ! name !
!(logical) ! (T/F) ! 'monthly' ! filename ! pairing !

\[ \text{sn}_\text{utau} = 'taux_1m', -1, \]
\[ 'sozotalux', \text{.true.}, \text{.true.}, 'yearly', '', '' \]
\[ \text{sn}_\text{vtau} = 'tauy_1m', -1, \]
\[ 'sometauy', \text{.true.}, \text{.true.}, 'yearly', '', '' \]
\[ \text{sn}_\text{wndm} = 'flx', -1, \]
\[ 'socliowi', \text{.true.}, \text{.true.}, 'yearly', '', '' \]
\[ \text{sn}_\text{tair} = 'flx', -1, \]
\[ 'sociot2', \text{.true.}, \text{.true.}, 'yearly', '', '' \]
\[ \text{sn}_\text{humi} = 'flx', -1, \]
\[ 'sociohu', \text{.true.}, \text{.true.}, 'yearly', '', '' \]
\[ \text{sn}_\text{ccov} = 'flx', -1, \]
\[ 'sociocl', \text{.false.}, \text{.true.}, 'yearly', '', '' \]
\[ \text{sn}_\text{prec} = 'flx', -1, \]
\[ 'sociop1', \text{.false.}, \text{.true.}, 'yearly', '', '' \]

! \[ \text{cn}_\text{dir} = './' \] ! root directory for the location of the bulk files are
/!
!------------------------------------------------------------------
!&namsbc_core ! namsbc_core CORE bulk formulae
!------------------------------------------------------------------
!
! file name ! frequency (hours) ! variable !
time interpol. ! clim ! 'yearly'/!
weights ! rotation !
!
! (if <0  months) ! name !
(.logical) ! (T/F) ! 'monthly' !
filename ! pairing !

sn_wndi = 'u10_core' , 6 ,
'u10' , .true. , .false. ,
'yearly' , 'weights_grid02_bicubic_orca1.nc' , 'Ume'

sn_wndi = 'v10_core' , 6 ,
'v10' , .true. , .false. ,
'yearly' , 'weights_grid02_bicubic_orca1.nc' , 'Vme'

sn_qsr = 'qsw_core' , 24 ,
'swrdn' , .true. , .false. ,
'yearly' , 'weights_grid03_bilinear_orca1.nc' , ''

sn qlw = 'qlw_core' , 24 ,
'lwdn' , .true. , .false. ,
'yearly' , 'weights_grid03_bilinear_orca1.nc' , ''

sn_tair = 't10_core' , 6 ,
't2' , .true. , .false. ,
'yearly' , 'weights grid02_bilinear_orca1.nc' , ''

sn_humi = 'q10_core' , 6 ,
'q2' , .true. , .false. ,
'yearly' , 'weights grid02_bilinear_orca1.nc' , ''

sn_prec = 'precip_core', -1 ,
'precip' , .true. , .false. ,
'yearly' , 'weights grid03_bilinear_orca1.nc' , ''

sn_snow = 'snow_core' , -1 ,
'snow' , .true. , .false. ,
'yearly' , 'weights grid03_bilinear_orca1.nc' , ''
sn_tdif = 'taudif_core', 24, 'taudif', .true., .false., 'yearly', 'weights_grid03_bilinear_orca1.nc', ''!

cn_dir = '/projects/ocean/hadgem3/forcing/ocean/DFS4.1/' ! root
directory for the location of the bulk files

ln_2m = .true. ! air temperature and humidity referenced at 2m (T) instead 10m (F)

ln_taudif = .false. ! HF tau contribution: use "mean of stress module - module of the mean stress" data?

rn_pfac = 1. ! multiplicative factor for precipitation (total & snow)
/

!------------------------------------------------------------------
&namsbc_cpl ! coupled ocean/atmosphere model
("key_coupled")
!------------------------------------------------------------------
-----

! send
cn_snd_temperature = 'weighted oce and ice' ! 'oce only' 'weighted oce and ice' 'mixed oce-ice'
cn_snd_albedo = 'weighted ice' ! 'none' 'weighted ice' 'mixed oce-ice'
cn_snd_thickness = 'none' ! 'none' 'weighted ice and snow'
cn_snd_crt_nature = 'none' ! 'none' 'oce only' 'weighted oce and ice' 'mixed oce-ice'
cn_snd_crt_refere = 'spherical' ! 'spherical' 'cartesian'
cn_snd_crt_orient = 'eastward-northward' ! 'eastward-northward' or 'local grid'
cn_snd_crt_grid = 'T' ! 'T'

! receive
cn_rcv_w10m = 'none' ! 'none' 'coupled'
! ! (if <0 months) ! name !
(logical) ! (T/F) ! 'monthly' ! filename ! pairing !
  sn_chl = 'chlorophyll', -1 ,
  'CHLA' , .true. , .true. , 'yearly' , '' , ''

  cn_dir = './' ! root directory for the location of
  the runoff files
  ln_traqsr = .true. ! Light penetration (T) or not (F)
  ln_qsr_rgb = .false. ! RGB (Red-Green-Blue) light penetration
  ln_qsr_2bd = .true. ! 2 bands light penetration
  ln_qsr_bio = .false. ! bio-model light penetration
  nn_chldta = 0 ! RGB : Chl data (=1) or cst value (=0)
  rn_abs = 0.26 ! RGB & 2 bands: fraction of light (rn_si1)
  rn_si0 = 0.35 ! RGB & 2 bands: shortess depth of
  rn_si1 = 23.0 ! 2 bands: longest depth of extinction
  rn_si2 = 62.0 ! 3 bands: longest depth of extinction
  (for blue waveband & 0.01 mg/m2 Chl)
/

!----------------------------------------------------------------------------------
-----
&namsbc_rnf ! runoffs namelist surface boundary condition
!----------------------------------------------------------------------------------
-----
! ! file name ! frequency (hours) ! variable !
! time interpol. ! clim ! 'yearly'! 'yearly'/ ! weights ! rotation !
! ! ! ! (if <0 months) ! name !
(logical) ! (T/F) ! 'monthly' ! filename ! pairing !
  sn_rnf = 'runoff_lm_nomask', -1 ,
  'sorunoff' , .true. , .true. , 'yearly' , '' , ''
  sn_cnf = 'runoff_lm_nomask', 0 ,
  'socoeffr' , .false. , .true. , 'yearly' , '' , ''
cn_dir       = './'    ! root directory for the location of
the runoff files
ln_rnf_emp   = .true.   ! runoffs included into precipitation
field (T) or into a file (F)
ln_rnf_mouth = .true.   ! specific treatment at rivers mouths
rn_hrnf      = 10.e0    ! depth over which enhanced vertical
mixing is used
rn_avt_rnf   = 2.e-3    ! value of the additional vertical
mixing coef. [m2/s]
rn_rfact     = 1.e0     ! multiplicative factor for runoff
/

!------------------------------------------------------------------
-----
&namsbc_ssr   ! surface boundary condition : sea surface
restoring
!------------------------------------------------------------------
-----
!              ! frequency (hours) ! variable   !
time interpol. ! clim    ! 'yearly'/ ! weights ! rotation !
!              ! (if <0 months) ! name     !
logical      ! (T/F)     ! 'monthly' ! filename ! pairing !
sn_sst      = 'sst_data'   ,        -1         ,
'sst'       , .true.     , .true.  , 'yearly' , ''     , ''
sn_sss      = 'sss_data'   ,        -1         ,
'sss'       , .true.     , .true.  , 'yearly' , ''     , ''

- 40.    ! magnitude of the retroaction on
rn_dqdt     =   -40.    ! temperature [W/m2/K]

! root directory for the location of
the runoff files
nn_sstr     =     0     ! add a retroaction term in the surface
heat flux (1) or not (0)
nn_sssr     =     0     ! add a damping term in the surface
freshwater flux (2)
                   ! or to SSS only (1) or no damping
term (0)
rn_dqdt     =  -40.    ! magnitude of the retroaction on
temperature  [W/m2/K]
rn_deds     =   -27.7   !  magnitude of the damping on salinity [mm/day]
ln_sssr_bnd =   .false. !  flag to bound erp term (associated with nn_sssr=2)
rn_sssr_bnd =   4.e0    !  ABS(Max/Min) value of the damping erp term [mm/day]
/
!------------------------------------------------------------------
-----
&namsbc_alb    !   albedo parameters
!------------------------------------------------------------------
-----
rn_cloud    =    0.06   !  cloud correction to snow and ice albedo
rn_albice   =    0.53   !  albedo of melting ice in the arctic and antarctic
rn_alphd    =    0.80   !  coefficients for linear interpolation used to
rn_alphc    =    0.65   !  compute albedo between two extremes values
rn_alphdi   =    0.72   !  (Pyane, 1972)
/
!!=================================================================
=====
!!               ***  Lateral boundary condition  ***
!!=================================================================
=====
!!  namlbc      lateral momentum boundary condition
!!  namcla      cross land advection
!!  namobc      open boundaries parameters
("key_obc")
!!  namagrif    agrif nested grid ( read by child model only )
("key_agrif")
!!  nambdy      Unstructured open boundaries
("key_bdy")
!! namtide Tidal forcing at open boundaries
("key_bdy_tides")
!!=================================================================
=====

---------------------------------------------------------------------

&namlbc     ! lateral momentum boundary condition
---------------------------------------------------------------------

rn_shlat = 0.   ! shlat = 0 ! 0 < shlat < 2 ! shlat = 2 ! 2 < shlat
               ! free slip ! partial slip ! no
slip       ! strong slip
/
!---------------------------------------------------------------------

---------------------------------------------------------------------

&namcla     ! cross land advection
---------------------------------------------------------------------

nn_cla = 0     ! advection between 2 ocean pts separates by land
/
!---------------------------------------------------------------------

---------------------------------------------------------------------

&namobc     ! open boundaries parameters
("key_obc")
---------------------------------------------------------------------

ln_obc_clim= .false.   ! climatological obc data files (T) or not (F)
ln_vol_cst = .true.    ! impose the total volume conservation (T) or not (F)
ln_obc_fla = .false.   ! Flather open boundary condition
nn_obcdata = 1        ! = 0 the obc data are equal to the initial state
'obc.dta' files

! = 1 the obc data are read in

cn_obcdta = 'annual'  ! set to annual if obc datafile hold 1 year of data

! = 1 the obc data are read in

'obc.dta' files

cn_obcdta = 'annual'  ! set to annual if obc datafile hold 1 year of data

month of data

rn_dpein = 1.  ! damping time scale for inflow at east open boundary

rn_dpwin = 1.  ! - - - west

rn_dpnin = 1.  ! - - - north

rn_dpsin = 1.  ! - - - south

rn_dpeob = 3000.  ! time relaxation (days) for the east open boundary

rn_dpwoe = 15.  ! - - - west

rn_dpbon = 3000.  ! - - - north

rn_dpsob = 15.  ! - - - south

rn_volemp = 1.  ! = 0 the total volume change with the surface flux (E-P-R)

! = 1 the total volume remains constant

/!

!------------------------------------------------------------------

&namagrif  ! AGRIF zoom

("key_agrif")

!------------------------------------------------------------------

-----

&namagrif  ! AGRIF zoom

("key_agrif")

-----

nn_cln_update = 3  ! baroclinic update frequency

ln_spc_dyn = .true.  ! use 0 as special value for dynamics

rn_sponge_tra = 2880.  ! coefficient for tracer sponge layer [s]

[63]
rn_sponge_dyn = 2880. ! coefficient for dynamics sponge layer [s] 
/
!---------------------------------------------------------------------
-----
&nambdy        ! unstructured open boundaries
("key_bdy")
!---------------------------------------------------------------------
-----
filbdy_mask    = ''                  ! name of mask file (if
ln_bdy_mask=.TRUE.)
    filbdy_data_T = 'bdydata_grid_T.nc'  ! name of data file (T-
points)
    filbdy_data_U = 'bdydata_grid_U.nc'  ! name of data file (U-
points)
    filbdy_data_V = 'bdydata_grid_V.nc'  ! name of data file (V-
points)
    ln_bdy_clim    = .false.              ! contain 1 (T) or 12
(F) time dumps and be cyclic
    ln_bdy_vol     = .true.               ! total volume
correction (see volbdy parameter)
    ln_bdy_mask    = .false.              ! boundary mask from
filbdy_mask (T) or boundaries are on edges of domain (F)
    ln_bdy_tides   = .true.               ! Apply tidal harmonic
forcing with Flather condition
    ln_bdy_dyn_fla = .true.               ! Apply Flather
condition to velocities
    ln_bdy_tra_frs = .false.              ! Apply FRS condition to
temperature and salinity
    ln_bdy_dyn_frs = .false.              ! Apply FRS condition to
velocities
    nbdy_dta       = 1                   ! = 0, bdy data are
equal to the initial state
    ! = 1, bdy data are read
in 'bdydata .nc' files
COMPARISON OF GLOSEA5 AND POAMA2.4 HINDCASTS 1996-2009: OCEAN FOCUS

nb_rimwidth = 9          ! width of the relaxation zone
volbdy     = 0            ! = 0, the total water flux across open boundaries is zero
                    ! = 1, the total volume of the system is conserved
/
!

!!!=================================================================
=====  ***  Bottom boundary condition  ***
===
!!
!! nambfr   bottom friction
!! nambbc   bottom temperature boundary condition
("key_trabbc")
!! nambbl   bottom boundary layer scheme
("key_trabbl_dif","key_trabbl_adv")
!!=================================================================
====
!------------------------------------------------------------------
\&nambfr        ! bottom friction
!------------------------------------------------------------------
\n\n\nn_bfr          =    2      ! type of bottom friction :   = 0 :
\n\n\nfree slip,  = 1 : linear friction
!                                      = 2 :
\n\n\nn_nlinear friction
\rn_bfri1       =  4.e-4  ! bottom drag coefficient (linear case)
\rn_bfri2       =  1.e-3  ! bottom drag coefficient (non linear case)
\rn_bfeb2       =  2.5e-3 ! bottom turbulent kinetic energy background (m^2/s^2)
\ln_bfr2d      = .true.  ! horizontal variation of the bottom friction coef (read a 2D mask file)
\rn_bfrien      =  50.    ! local multiplying factor of bfr (ln_bfr2d = .true.)
/
!------------------------------------------------------------------
-----
\&nambbc        ! bottom temperature boundary condition
!------------------------------------------------------------------
-----
\nn_geoflx      =    2      ! geothermal heat flux: = 0 no flux
\n\n\n! = 1 constant flux
\n\n\n! = 2 variable flux (read in geothermal_heating.nc in mW/m2)
\rn_geoflx_cst   = 86.4e-3 ! Constant value of geothermal heat flux [W/m2]
/
!------------------------------------------------------------------
-----
\&nambbl        ! bottom boundary layer scheme
!------------------------------------------------------------------
("key_trabbl")

("key_trabbl_adv")

rn_ahtbbl = 1000. ! lateral mixing coefficient in the bbl [m2/s]
/

!!=================================================================

=====

!!                        Tracer (T & S ) namelists

!!=================================================================

=====

!! nameos        equation of state
!! namtra_adv    advection scheme
!! namtra_ldf    lateral diffusion scheme
!! namtra_dmp    T & S newtonian damping
("key_tradmp")

!!=================================================================

=====

!------------------------------------------------------------------

&nameos        !   ocean physical parameters

!------------------------------------------------------------------

-----

nn_eos = 0      ! type of equation of state and Brunt-Vaisala frequency

! = 0, UNESCO (formulation of Jackett and McDougall (1994) and of McDougall (1987) )

! = 1, linear: rho(T) = rau0 * ( 1.028 - ralpha * T )

! = 2, linear: rho(T,S) = rau0 * ( rbeta * S - ralpha * T )

rn_alpha = 2.e-4 ! thermal expension coefficient (neos=1 or 2)
rn_beta     =  0.001  ! saline expansion coefficient (neos=2)
/
!------------------------------------------------------------------
-----&namtra_adv    ! advection scheme for tracer
!------------------------------------------------------------------
-----
  ln_tradvecn2   = .false.  ! 2nd order centered scheme
  ln_tradvtvd    = .true.    ! TVD scheme
  ln_tradvmuscl  = .false.   ! MUSCL scheme
  ln_tradvmuscl2 = .false.   ! MUSCL2 scheme + cen2 at boundaries
  ln_tradv_ubs   = .false.   ! UBS scheme
/
!------------------------------------------------------------------
-----&namtra_ldf    ! lateral diffusion scheme for tracer
!------------------------------------------------------------------
-----
  ! Type of the operator :
  ln_trahdflap   = .true.    ! laplacian operator
  ln_trahdfbilap = .false.   ! bilaplacian operator
  ! Direction of action :
  ln_trahdf_level= .false.   ! iso-level
  ln_trahdf_hor  = .false.   ! horizontal (geopotential)
(require "key_ldfslp" when ln_sco=T)
  ln_trahdf_iso  = .true.    ! iso-neutral
(require "key_ldfslp")

  ! Coefficient
  rn_aht_0       =  300.    ! horizontal eddy diffusivity for tracers [m2/s]
  rn_ahtb_0      =   0.     ! background eddy diffusivity for ldf_iso [m2/s]
  rn_aeiv_0      =   0.     ! eddy induced velocity coefficient [m2/s] (require "key_traldf_eiv")
/ 

!------------------------------------------------------------------
!
&namtra_dmp    !   tracer: T & S newtonian damping
('key_tradmp')

!------------------------------------------------------------------
!

nn_hdmp   =   -1      !  horizontal shape =-1, damping in Med
and Red Seas only

                      ! =XX, damping

            poleward of XX degrees (XX>0)
                      ! + F(distance-to-

nn_zdmp   =    1      !  vertical   shape =0    damping

        throughout the water column

                      ! =1 no damping in the

rn_surf   =  50.     !  surface time scale of damping
[days]

rn_bot    =  360.     !  bottom  time scale of damping
[days]

rn_dep    =  800.     !  depth of transition between rn_surf

and rn_bot [meters]

rn_file   =    1      !  create a damping.coeff NetCDF file

 (=1) or not (=0)
/

!!!=================================================================
!

!!!                      ***  Dynamics namelists  ***
!!!=================================================================
!

!!   namdyn_adv    formulation of the momentum advection
!!   namdyn_vor    advection scheme
!!   namdyn_hpg    hydrostatic pressure gradient
!! namdyn_spg    surface pressure gradient  
(CPP key only)              
!! namdyn_ldf    lateral diffusion scheme  
!!=================================================================  
=====  
!------------------------------------------------------------------  
-----  
&namdyn_adv    ! formulation of the momentum advection  
!------------------------------------------------------------------  
-----  
  ln_dynadv_vec = .true.  ! vector form (T) or flux form (F)  
  ln_dynadv_cen2= .false. ! flux form - 2nd order centered scheme  
  ln_dynadv_ubs = .false. ! flux form - 3rd order UBS scheme  
/  
!------------------------------------------------------------------  
-----  
&namdyn_vor    ! option of physics/algorithm (not control by CPP keys)  
!------------------------------------------------------------------  
-----  
  ln_dynvor_ene = .false. ! enstrophy conserving scheme  
  ln_dynvor_ens = .false. ! energy conserving scheme  
  ln_dynvor_mix = .false. ! mixed scheme  
  ln_dynvor_een = .true.  ! energy & enstrophy scheme  
/  
!------------------------------------------------------------------  
-----  
&namdyn_hpg    ! Hydrostatic pressure gradient option  
!------------------------------------------------------------------  
-----  
  ln_hpg_zco  = .false.   ! z-coordinate - full steps  
  ln_hpg_zps  = .true.    ! z-coordinate - partial steps  
(interpolation)  
  ln_hpg_sco  = .false.   ! s-coordinate (standard jacobian formulation)
ln_hpg_hel  = .false.  ! s-coordinate (helsinki modification)
ln_hpg_wdj  = .false.  ! s-coordinate (weighted density jacobian)
ln_hpg_djc  = .false.  ! s-coordinate (Density Jacobian with Cubic polynomial)
ln_hpg_rot  = .false.  ! s-coordinate (ROTated axes scheme)
rn_gamma    = 0.e0      ! weighting coefficient (wdj scheme)
ln_dynhpg_imp = .true.  ! time stepping: semi-implicit time scheme (T)
                   ! centered time scheme (F)
nn_dynhpg_rst = 1        ! =1 dynhpg restartable restart or not (=0)
/
!------------------------------------------------------------------

!namdyn_spg    ! surface pressure gradient (CPP key only)
!------------------------------------------------------------------

-----
!  ! explicit free surface
("key_dynspg_exp")
!  ! filtered free surface
("key_dynspg_flt")
!  ! split-explicit free surface
("key_dynspg_ts")

!------------------------------------------------------------------

-----
&namdyn_ldf    ! lateral diffusion on momentum
!------------------------------------------------------------------

-----
! Type of the operator :
ln_dynldf_lap  = .false.  ! laplacian operator
ln_dynldf_bilap = .true.  ! bilaplacian operator
                   ! Direction of action :
ln_dynldf_level = .false.  ! iso-level
ln_dynldf_hor = .true. ! horizontal (geopotential)
(requires "key_ldfslp" in s-coord.)
ln_dynldf_iso = .false. ! iso-neutral
(requires "key_ldfslp")

! Coefficient
rn_ahm_0 = -1.5e11 ! horizontal eddy viscosity [m2/s]
rn_ahmb_0 = 0. ! background eddy viscosity for ldf_iso [m2/s]
/

=====
!! Tracers & Dynamics vertical physics namelists
!!=================================================================
=====

!! namzdf vertical physics
!! namzdf_ric richardson number dependent vertical mixing
("key_zdfric"
)
!! namzdf_tke TKE dependent vertical mixing
("key_zdftke"
)
!! namzdf_kpp KPP dependent vertical mixing
("key_zdfkpp"
)
!! namzdf_ddm double diffusive mixing parameterization
("key_zdfddm"
)
!! namzdf_tmx tidal mixing parameterization
("key_zdftmx"
)
!!=================================================================
=====

------------------------------------------------------------------
&namzdf ! vertical physics
!------------------------------------------------------------------
------------------------------------------------------------------

rn_avm0 = 1.2e-4 ! vertical eddy viscosity [m2/s]
(background Kz if not "key_zdfcst")
rn_avt0 = 1.2e-5 ! vertical eddy diffusivity [m2/s]
(background Kz if not "key_zdfcst")
nn_avb = 1 ! profile for background avt & avm (=1)
or not (=0)
nn_havtb = 0 ! horizontal shape for avtb (=1) or not (=0)
ln_zdfevd = .true. ! enhanced vertical diffusion (evd) (T)
or not (F)
nn_evdm = 1 ! evd apply on tracer (=0) or on tracer and momentum (=1)
rn_avevd = 100. ! evd mixing coefficient [m2/s]
ln_zdfnpc = .false. ! Non-Penetrative algorithm (T) or not (F)
nn_npc = 1 ! frequency of application of npc
nn_npcp = 365 ! npc control print frequency
ln_zdfexp = .false. ! time-stepping: split-explicit (T) or implicit (F) time stepping

/!
!------------------------------------------------------------------
&namzdf_ric ! richardson number dependent vertical diffusion
("key_zdfric")
!------------------------------------------------------------------
-----
rn_avmri = 100.e-4 ! maximum value of the vertical viscosity
rn_alp = 5. ! coefficient of the parameterization
nn_ric = 2 ! coefficient of the parameterization
/!
!------------------------------------------------------------------
-----
&namzdf_tke ! turbulent eddy kinetic dependent vertical diffusion ("key_zdftke")
rn_ediff    =   0.1     !  coef. for vertical eddy coef.
(avt=rn_ediff*mxl*sqrt(e) )

rn_ediss    =   0.7     !  coef. of the Kolmogoroff dissipation
rn_ebb      =  60.      !  coef. of the surface input of tke
rn_emin     =   1.e-6   !  minimum value of tke [m2/s2]
rn_emin0    =   1.e-4   !  surface minimum value of tke [m2/s2]
!  rn_bshear  =   1.e-20  !  background shear (>0)
nn_mxl      =   3       !  mixing length: = 0 bounded by the
distance to surface and bottom
                             !                     = 1 bounded by the
                             ! local vertical scale factor
                             !                     = 2 first vertical
derivative of mixing length bounded by 1
                             !                     = 3 same criteria as
case 2 but applied in a different way

nn_pdl      =   1       !  Prandtl number function of richarson
 number (=1, avt=pdl(Ri)*avm) or not (=0, avt=avm)
ln_mxl0     =  .true.   !  mixing length scale surface value as
 function of wind stress (T) or not (F)

rn_lmin     =   0.001     !  interior buoyancy lenght scale
 minimum value
rn_lmin0    =   0.01     !  surface buoyancy lenght scale
 minimum value
nn_etau     =   1       !  exponentially deceasing penetration
 of tke due to internal & intertial waves
                             !                     = 0 no penetration ( O(2 km)
 resolution)

                        !                     = 1 additional tke source
 (rn_efr * en)
                        !                     = 2 additional tke source
 (rn_efr * en) applied only at the base of the mixed layer
                        !                     = 3 additional tke source (HF
 contribution: mean of stress module - module of mean stress)
nn_hetau = 1 ! type of exponential decrease of tke penetration
    ! = 0 constant 10 m length scale
    ! = 1 0.5m at the equator to 30m at high latitudes
    ! = 2 30 meters constant depth
penetration
    ! option used only if nn_hetau = 1 or 2:
    rn_efr = 0.05 ! fraction of surface tke value which penetrates inside the ocean
    ! option used only if nn_hetau = 3:
    ! rn_addhft = -1.e-3 ! add offset applied to the "mean of stress module - module of mean stress" (always kept > 0)
    ! rn_sclhft = 1. ! scale factor applied to the "mean of stress module - module of mean stress"
    ln_lc = .false. ! Langmuir cell parameterisation
    rn_lc = 0.15 ! coef. associated to Langmuir cells
/

!------------------------------------------------------------------
------ &namzdf_kpp ! K-Profile Parameterization dependent vertical mixing ("key_zdfkpp", and optionnally:
!------------------------------------------------------------------ ! "key_kppcustom" or "key_kpplktb")
    ln_kpprimix = .true. ! shear instability mixing
    rn_difmiw = 1.0e-04 ! constant internal wave viscosity [m2/s]
    rn_difsiw = 0.1e-04 ! constant internal wave diffusivity [m2/s]
    rn_rinfty = 0.8 ! local Richardson Number limit for shear instability
    rn_difri = 0.0050 ! maximum shear mixing at Rig = 0 [m2/s]
    rn_bvsqcon = -0.01e-07 ! Brunt-Vaisala squared for maximum convection [1/s2]


rn_difcon   = 1.       ! maximum mixing in interior convection
[m2/s]
nn_avb      = 0        ! horizontal averaged (=1) or not (=0)
on avt and amv
nn_ave      = 1        ! constant (=0) or profile (=1)
background on avt
/
!------------------------------------------------------------------
-----
&namzdf_ddm   ! double diffusive mixing parameterization
("key_zdfddm")
!------------------------------------------------------------------
-----
rn_avts     = 1.e-4    ! maximum avs (vertical mixing on
salinity)
rn_hsbfr    = 1.6      ! heat/salt buoyancy flux ratio
/
!------------------------------------------------------------------
-----
&namzdf_tmx   ! tidal mixing parameterization
("key_zdftmx")
!------------------------------------------------------------------
-----
rn_htmx      = 500.     ! vertical decay scale for turbulence
(meters)
rn_n2min     = 1.e-8    ! threshold of the Brunt-Vaisala
frequency (s-1)
rn_tfe       = 0.333    ! tidal dissipation efficiency
rn_me        = 0.2      ! mixing efficiency
ln_tmx_itf   = .true.   ! ITF specific parameterisation
rn_tfe_itf   = 1.       ! ITF tidal dissipation efficiency
/
!!=================================================================
=====
!!                  ***  Miscelaneous namelists  ***
!!=================================================================
!!   nammpp            Massively Parallel Processing
("key_mpp_mpi"
!!   nammpp_dyndist    Massively Parallel domain decomposition
("key_agrif" && "key_mpp_dyndist")
!!   namctl            Control prints & Benchmark
!!   namsol            elliptic solver / island / free surface
!!=================================================================

-----

&namsol        !   elliptic solver / island / free surface

-----

nn_solv     =      1    !  elliptic solver: =1 preconditioned
conjugate gradient (pcg)
                !                      =2 successive-over-
relaxation (sor)

nn_sol_arp  =      0    !  absolute/relative (0/1) precision
convergence test

rn_eps      =  1.e-6    !  absolute precision of the solver
nn_nmin     =    300    !  minimum of iterations for the SOR
solver

nn_nmax     =   2000    !  maximum of iterations for the SOR
solver

nn_nmod     =     10    !  frequency of test for the SOR solver
rn_resmax   =  1.e-10   !  absolute precision for the SOR solver
rn_sor      =  1.92     !  optimal coefficient for SOR solver

(to be adjusted with the domain)

!/---------

&nammpp        !   Massively Parallel Processing
("key_mpp_mpi")
cn_mpi_send = 'I' ! mpi send/recieve type = 'S', 'B', or 'I' for standard send, 
  !   buffer blocking send or immediate non-blocking sends, resp.
  nn_buffer = 0 ! size in bytes of exported buffer ('B' case), 0 no exportation
/
!------------------------------------------------------------------
&nammpp_dyndist ! Massively Parallel Distribution for AGRIF zoom
("key_agrif" && "key_mpp_dyndist")
!------------------------------------------------------------------
-----
jpni        = 1 ! jpni number of processors following i
jpnj        = 1 ! jpnj number of processors following j
jpnjij      = 1 ! jpnj number of local domains
/
!------------------------------------------------------------------
&namctl     ! Control prints & Benchmark
!------------------------------------------------------------------
-----
ln_ctl      = .false. ! trends control print (expensive!)
nn_print    = 0 ! level of print (0 no extra print)
nn_ictls    = 0 ! start i indice of control sum (use to compare mono versus
  nn_ictle   = 0 ! end i indice of control sum
multi processor runs
  nn_jctls   = 0 ! start j indice of control
over a subdomain)
  nn_jctle   = 0 ! end j indice of control
  nn_isplt   = 1 ! number of processors in i-direction
nn_jsplit  =  1  ! number of processors in j-direction
nn_bench  =  0  ! Bench mode (1/0): CAUTION use zero except for bench
                ! (no physical validity of the results)
nn_bit_cmp =  0  ! bit comparison mode (1/0): CAUTION use zero except for test
                ! of comparison between single and multiple processor runs
/

!!=================================================================
!!                       ***  Diagnostics namelists  ***
!!=================================================================

!------------------------------------------------------------------
&namtrd  ! diagnostics on dynamics and/or tracer trends
("key_trddyn","key_trdtra","key_trdmld")
!              !       or mixed-layer trends or barotropic vorticity ('key_trdmld' or "key_trdvor")
!------------------------------------------------------------------

nn_trd  = 640  ! time step frequency dynamics and tracers trends
nn_ctls = 0       ! control surface type in mixed-layer trends (0,1 or n<jpk)

rn_ucf = 1.       ! unit conversion factor (=1 -> /seconds ; =86400. -> /day)

cn_trdrst_in = "restart_mld"   ! suffix of ocean restart name (input)

cn_trdrst_out = "restart_mld"   ! suffix of ocean restart name (output)

ln_trdmld_restart = .false.       ! restart for ML diagnostics

ln_trdmld_instant = .false.       ! flag to diagnose trends of instantaneous or mean ML T/S
/

!------------------------------------------------------------------
-----
&namgap       ! level mean model-data gap ('key_diagap')
!------------------------------------------------------------------
-----

nn_gap = 720       ! time-step frequency of model-data gap computation

nn_prg = 8760      ! time-step frequency of gap print in model output
/

!------------------------------------------------------------------
-----
&namflo       ! float parameters ("key_float")
!------------------------------------------------------------------
-----

ln_rstflo = .false.       ! float restart (T) or not (F)

nn_writeflo= 75        ! frequency of writing in float output file

nn_stockflo= 5475       ! frequency of creation of the float restart file
ln_argo = .false. ! Argo type floats (stay at the surface each 10 days)
ln_flork4 = .false. ! trajectories computed with a 4th order Runge-Kutta (T)
! or computed with Blanke' scheme (F)
/
!------------------------------------------------------------------
-----
&namptr ! Poleward Transport Diagnostic
!------------------------------------------------------------------
-----
ln_diaptr = .false. ! Poleward heat and salt transport (T)
or not (F)
ln_diazn1 = .false. ! Add zonal means and meridional stream functions
ln_subbas = .false. ! Atlantic/Pacific/Indian basins computation (T) or not
! (orca configuration only, need input basins mask file named "subbasins.nc"
ln_ptrcomp = .false. ! Add decomposition : overturning
nf_ptr = 640 ! Frequency of ptr computation [time step]
nf_ptr_wri = 640 ! Frequency of ptr outputs
/

!------------------------------------------------------------------
-----
! nammoor namelist for creating output at moorings
!------------------------------------------------------------------
-----
&nammoor
path_moor = "./"
noor = 1
nwmoor = 1
ln_moor_out = .false.
ln_moor_pos = .false.
ln_ijproc_moor_read = .false.
ln_ijproc_moor_write = .false.
/
!----------------------------------------------------------------------------------------------------------------------
------
! namdct namelist for creating transports through sections
!----------------------------------------------------------------------------------------------------------------------
------
&namdct
ndct=1
ndctwri=80
nsecdebug=1
ln_verif=.FALSE.
/
!----------------------------------------------------------------------------------------------------------------------
------
! namobs observation operator switch (#ifdef key_diaobs)
!----------------------------------------------------------------------------------------------------------------------
------
! ln_ena Logical switch for ENACT insitu data set
! ln_cor Logical switch for Coriolis insitu data set
! ln_t3d Logical switch for T profile observations
! ln_s3d Logical switch for S profile observations
! lnpto Logical switch for gen profile T obs sfc
! lnpro Logical switch for gen profile Rho obs sfc
! lnpts Logical switch for gen profile T spec sfc
! lnprs Logical switch for gen profile Rho spec sfc
! lnpsz Logical switch for gen profile Z model lev
! lnsla Logical switch for SLA observations
! lnssth Logical switch for SSH observations
! ln_sst Logical switch for SST observations
! ln_sss Logical switch for SSS observations
! ln_reysst Logical switch for Reynolds SST
! ln_ghrsst Logical switch for GHRSSST format SST observations
! enactfiles List of filenames containing profile data in ENACT format
! slafiles   List of filenames containing SLA data in CLS format
! sstfiles  List of filenames containing SST data in GHRSSST
  format
! dobsini  Initial date in window YYYYMMDD.HHMMSS
! dobsend  Final date in window YYYYMMDD.HHMMSS
! n1dint   Type of vertical interpolation method
!        0 = Linear interpolation.
!        1 = Cubic spline interpolation.
! n2dint   Type of horizontal interpolation method
!        0 = Distance-weighted interpolation
!        1 = Distance-weighted interpolation (small angle)
!        2 = Bilinear interpolation (geographical grid)
!        3 = Bilinear remapping interpolation (general grid)
!        4 = Polynomial interpolation
! ln_nea    Logical switch to reject observations near land
! nmsshc   MSSH correction scheme
!        0 = no correction
!        1 = compute online
!        2 = set to mdtcorr
! mdtcutoff MDT cutoff for computed correction
! mdtcorr  MDT correction factor (used if nmsshc = 2)
&namobs
  ln_ena = .false.
  ln_cor = .false.
  ln_t3d = .false.
  ln_s3d = .false.
  ln_pto = .false.
  ln_pro = .false.
  ln_pro = .false.
  ln_prs = .false.
  ln_pzm = .false.
  ln_sla = .false.
  ln_sst = .false.
  ln_ssh = .false.
  ln_sss = .false.
  ln_reysst = .false.
ln_ghrsst = .false.
ln_seaice = .false.
ln_velflo = .false.
enactfiles = 'enact.2.nc'
slfiles = 'sla.2.nc'
sstfiles = 'Surface.2.nc'
seaicefiles = 'seaice.1.nc'
ln_grid_search_lookup = .false.
ln_obs_bound_check = .false.
ln_sla_timechange = .false.
ln_ice_timechange = .false.
bias_file = 'bias.nc'
ln_altbias = .false.
1ldint = 1
n2dint = 3
ln_nea = .false.
msshc = 0
mdtcutoff = 65.0
mdtcorr = 1.61
/
!-----------------------------------------------------------------
!  nambias    bias parameters (#ifdef key_bias)
!-----------------------------------------------------------------
------
&nam_bias
  bias_file = 'bias.nc'
bias_time_unit = 86400.0
ln_obias = .false.
ln_bias_ts_app = .false.
ln_bias_pc_app = .true.
/
