Experiments with JRA-55 forcing dataset in NEMO global eddying configurations

Julien Le Sommer, J.M. Molines, B. Barnier
1. Model set-up, experiments and diagnostics
2. Sensitivity tests with JRA-55 forcing dataset at 0.5° resolution
3. Sensitivity tests with JRA-55 forcing dataset at 0.25° resolution
4. Wrap-up and conclusions
## Two NEMO model configurations

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DRAKKAR standard global configurations (as of 2014)

ORCA025.L75 will be used in several ESMs for CMIP6
Numerical experiments

Five model experiments

- Two ORCA05 experiments
  - ORCA05-JRA sensitivity experiment (JRA, absolute winds)
  - ORCA05-DFS reference experiment (DFS5.2, absolute winds)
  
  over period 1958-2012, no spin-up, one pass

- Three ORCA025 experiments
  - ORCAO25-JRA1 sensitivity experiment (JRA, relative winds)
  - ORCA025-JRA2 sensitivity experiment (JRA, absolute winds)
  - ORCA025-DFS reference experiment (DFS5.2, absolute winds)

- DFS : DFS5.2, ERA-i + corrections (Brodeau et al. 2010, Dussin et al. 2014)
- JRA : JRA-55, corrected data as distributed in Mar. 2015 (v0.2)
Approach and diagnostics

**Question**: order zero difference between runs forced by JRA vs DFS?

Focus on standard metrics for OGCM sensitivity studies

- global trends (temp, sal, ssh)
- mean circulation patterns (gyre, equatorial)
- sea-ice (concentration, thickness)
- air-sea fluxes and mixed layers
- overturning

Plots based on DRAKKAR monitoring system mostly showing averages over 2000-2007
1. Model set-up, experiments and diagnostics
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GLOBAL TRENDS IN ORCA05
Sensitivity experiment with JRA at 0.5° resolution

Global trends: cooling, freshening
Sensitivity experiment with JRA at 0.5° resolution

Global trends: cooling, freshening
MEAN CIRCULATION IN ORCA05
Sensitivity experiment with JRA at 0.5° resolution

Mean sea surface height

ORCA05–GJMRA1 SSHGLp 2000–2007 DEPTH=3.05

ORCA05–GJM189d SSHGLp 2000–2007 DEPTH=3.05
Mean sea surface height

Sensitivity experiment with JRA at 0.5° resolution
Sensitivity experiment with JRA at 0.5° resolution

Barotropic transport

Drake

ITF

Bahamas

Bering
Sensitivity experiment with JRA at 0.5° resolution

Barotropic transport

Drake Passage

ITF

Bahamas

Bering

JRA : red
DFS : black
Sensitivity experiment with JRA at 0.5° resolution

Barotropic transport

Mass Transport - Obs (b)

JRA : red
DFS : black
OBS : blue
Sensitivity experiment with JRA at 0.5° resolution

Mean zonal equatorial currents

ORCA05 Uequat 2000–2007–GJMJRA1

ORCA05 Uequat 2000–2007–GJM189d

Pacific  Atlantic

Pacific  Atlantic

$[m.s^{-1}]$  $[m.s^{-1}]$
Sensitivity experiment with JRA at 0.5° resolution

SEA ICE IN ORCA05
Sensitivity experiment with JRA at 0.5° resolution

Sea ice extent and sea ice area

ARCTIC

Area Arctic March - Obs. (b)

Extent Arctic March - Obs. (b)

Area Arctic September - Obs. (b)

Extent Arctic September - Obs. (b)

Max

Min

JRA: red
DFS: black
OBS: blue
Sensitivity experiment with JRA at 0.5° resolution

Sea ice thickness (September)

Sea Ice Thickness
Sep 2000–2007

ORCA05–GJM189d

DFS

ARCTIC
Sensitivity experiment with JRA at 0.5° resolution

Sea ice thickness (September)

Sea Ice Thickness
Sep 2000–2007

ORCA05–GJM JRA1

ORCA05–GJM189d

JRA

DFS

ARCTIC

Total area = million sq km
Volume = cubic km

Total area = million sq km
Volume = cubic km
Sensitivity experiment with JRA at 0.5° resolution

Sea ice thickness (March)

Sea Ice Thickness
Mar 2000–2007

ORCA05–GJM189d

DFS

ARCTIC

Total area = million sq km
Volume = cubic km (cm)
Sensitivity experiment with JRA at 0.5° resolution

Sea ice thickness (March)
Sensitivity experiment with JRA at 0.5° resolution

Sea ice extent and sea ice area (Antarctic)

ANTARCTIC

Max

Min
Sensitivity experiment with JRA at 0.5° resolution

Sea ice thickness (March)

ANTARCTIC

Sea Ice Thickness
Mar 2000–2007

Sea Ice Thickness
Mar 2000–2007

Total area = million sq km
Volume = cubic km

Total area = million sq km
Volume = cubic km
Sensitivity experiment with JRA at 0.5° resolution

Sea ice thickness (March)

ANTARCTIC

Sea Ice Thickness
Mar 2000–2007

ORCA05–GJM189d

Total area = million sq km
Volume = cubic km

ORCA05–GJM1RA1

Total area = million sq km
Volume = cubic km

JRA

DFS
Sensitivity experiment with JRA at 0.5° resolution

AIR-SEA FLUXES AND MIXED LAYER IN ORCA05
Sensitivity experiment with JRA at 0.5° resolution

Net heat flux

ORCA05–GJMRA1 HeatFlx 2000–2007 DEPTH=3.05

ORCA05–GJM189d HeatFlx 2000–2007 DEPTH=3.05

[W m\(^{-2}\)]

[W m\(^{-2}\)]
Freshwater flux

JRA versus DFS5.2 in ORCA05

ORCA05–GJM1RA1 WaterFlx 2000–2007 DEPTH=3.05

ORCA05–GJM189d WaterFlx 2000–2007 DEPTH=3.05

JRA

DFS

[mm.d$^{-1}$]
Freshwater flux

ORCA05–GJMRA1 WaterFlx 2000–2007 DEPTH=3.05

ORCA05–GJM189d WaterFlx 2000–2007 DEPTH=3.05

\[ \text{mm.d}^{-1} \]

\[ \text{mm.d}^{-1} \]
Sensitivity experiment with JRA at 0.5° resolution

Mixed layer depth
Sensitivity experiment with JRA at 0.5° resolution

Mixed layer depth

ORCA05–GJM189d m03–m09.MLDrho0.03 2000–2007

ORCA05–GJM189d m03–m09.MLDrho0.03 2000–2007
OVERTURNING IN ORCA05
Mean overturning stream function (Atlantic)

MOC ATLANTIC (sv) ORCA05–GJMRA1 y2000–2007

MOC ATLANTIC (sv) ORCA05–GJM189d y2000–2007

Contours de -32 à 14 par intervalles de 2

[Sv]
Sensitivity experiment with JRA at 0.5° resolution

Mean overturning stream function (Global)

MOC GLOBAL (sv) ORCA05–GJMRA1 y2000–2007

MOC GLOBAL (sv) ORCA05–GJM189d y2000–2007

Contours de -32 à 32 par intervalles de 2

[SV]

[SV]
Sensitivity experiment with JRA at 0.5° resolution

Mean overturning stream function (Global)

MOC GLOBAL (sv) ORCA05–GJM189d y2000–2007

[sv]
Sensitivity experiment with JRA at 0.5° resolution

Southern Ocean overturning stream (pressure coordinate)

Max Overturning (-70S 0S 0m-2000m)

Min Overturning (-70S 0S 2000m-5500m)

JRA : red
DFS : black
Sensitivity experiment with JRA at 0.5° resolution

Southern Ocean overturning stream (pressure coordinate)

Max Overturning (-70S 0S 0m-2000m)

Min Overturning (-70S 0S 2000m-5500m)

JRA : red
DFS : black
Overall, the two simulations are very similar, except for

- **mean circulation patterns**
  - slightly contracted subtropical gyre in the north pacific
  - weaker Drake passage transport
  - slightly shallower / less energetic equatorial jets (cf winds)

- **sea-ice**
  - weaker antarctic summer sea-ice extent (cf previous talk)
  - thinner antarctic summer sea-ice
  - slightly thicker arctic sea ice (all-year)

- **mixed layers**
  - deeper winter mixed layers in the Southern Ocean

- **overturning**
  - weaker upper cell overturning in the SO
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GLOBAL TRENDS IN ORCA025
Sensitivity experiment with JRA at 0.25° resolution

3D Global T Mean
3D Global S Mean
3D Global SSH Mean

Global change in T
Global change in S

JRA1 (abs) : black
JRA2 (rel) : red
DFS : green

cooling, freshening

Global trends
TRANSPORTS IN ORCA025
Sensitivity experiment with JRA at 0.25° resolution

Barotropic transport

Drake

ITF

Bahamas

Bering

JRA1 (abs) : black
JRA2 (rel) : red
DFS : green
Sensitivity experiment with JRA at 0.25° resolution

Barotropic transport

JRA1 (abs) : black
JRA2 (rel) : red
DFS : green

Drake

ITF

Bahamas

Bering
Sensitivity experiment with JRA at 0.25° resolution

Barotropic transport

Mass Transport - Obs (b)

Transport cross cable section

JRA1 (abs) : black
JRA2 (rel) : red
DFS : green
OBS : blue

cable section
MIXED LAYER IN ORCA025
Sensitivity experiment with JRA at $0.25^\circ$ resolution

Mixed layer depth

ORCA025.L75–GJM189 m03–m09.MLDrho0.03 1958

Mar  JRA  DFS

Sept
Sensitivity experiment with JRA at 0.25° resolution

Mixed layer depth

ORCA025.L75–GJMRA2 m03–m09.MLDtem0.20 1958

-Mar-

JRA

ORCA025.L75–GJM189 m03–m09.MLDrho0.03 1958

-DFS-

Sept
Sensitivity experiment with JRA at 0.25° resolution

SEA ICE IN ORCA025
Sensitivity experiment with JRA at 0.25° resolution

Antarctic sea ice extent and area

JRA1 (abs) : black
JRA2 (rel) : red
DFS : green
OBS : blue
Sensitivity experiment with JRA at 0.25° resolution

EDDY KINETIC ENERGY IN ORCA025
Sensitivity experiment with JRA at 0.25° resolution

Surface eddy kinetic energy

JRA2

DFS

[cm$^2$.s$^{-2}$]

[cm$^2$.s$^{-2}$]
Sensitivity experiment with JRA at 0.25° resolution

**Surface eddy kinetic energy**

ORCA025.L75 EKEg1 1958 GJMJRA2 DEPTH=10.00

ORCA025.L75 EKEg1 1958 GJM189 DEPTH=10.00

[cm$^2$.s$^{-2}$] [cm$^2$.s$^{-2}$]
Sensitivity experiment with JRA at 0.25° resolution

Surface eddy kinetic energy

\[ \text{JRA2} \]

\[ \text{DFS} \]

\[ \text{ORCA025.L75 EKEg1 1958 GJM189 DEPTH=10.00} \]

\[ \text{ORCA025.L75 EKEg1 1958 GJM189 DEPTH=10.00} \]

\[ \text{[cm}^2\text{.s}^{-2}] \]

\[ \text{[cm}^2\text{.s}^{-2}] \]
Sensitivity experiment with JRA at 0.25° resolution

**Surface eddy kinetic energy**

**JRA2**

![Image of JRA2 map]

**DFS**

![Image of DFS map]

\[ \text{[cm}^2\text{.s}^{-2}] \]
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Wrap-up and conclusions

Forcing ocean/sea-ice models with JRA-55 (corrected v0.2) ?
- sensitivity to forcing depend on model configuration (resolution)
- trends not discussed here but could possibly affect multi-pass runs
- at coarse resolution, JRA-55 forced model solution is « ok »

at 0.5° resolution,
DFS and JRA lead **very similar simulations**, except for
- Southern Ocean : DP transport, mld, overturning, sea ice
- slightly less energetic pacific ST gyre and equatorial circulation

at 0.25° resolution,
DFS and JRA lead **different model solutions**
- spurious polynia in the Admunsen and the Ross seas
- possibly due to (eddy) heat advection from the boundary current
- possibly associated with surface winds (??).
- depend on the period (cf Claus Boning’s results in Kiel)
EXTRA MATERIAL
Sensitivity experiment with JRA at 0.5° resolution

Barotropic stream-function
Sensitivity experiment with JRA at 0.5° resolution

Mixed layer depth

ORCA05–GJMRA1 m03.MLDrho0.03 2000–2007

ORCA05–GJM189d m03.MLDrho0.03 2000–2007
Sensitivity experiment with JRA at 0.25° resolution

Mixed layer depth

ORCA025.L75–GJMRA2 m03.MLDrho0.03 1958

ORCA025.L75–GJM189 m03.MLDrho0.03 2000–2009
Mixed layer depth

Sensitivity experiment with JRA at 0.25° resolution
Sensitivity experiment with JRA at 0.5° resolution

Sea ice thickness (September)

ANTARCTIC

Sea Ice Thickness
Sep 2000–2007

ORCA05–GJMJRA1

JRA

Total area = million sq km
Volume = cubic km

ORCA05–GJM189d

DFS

Total area = million sq km
Volume = cubic km
Sensitivity experiment with JRA at 0.5° resolution

Sea ice concentration (March)
Sensitivity experiment with JRA at 0.5° resolution

Sea ice concentration (September)

Sea Ice Concentration
Sep 2000–2007

ORCA05–GJM189d

Total area = million sq km

DFS
Sensitivity experiment with JRA at 0.5° resolution

Sea ice concentration (September)

Sea Ice Concentration
Sep 2000–2007

ORCA05–GJM189d

Total area = million sq km

ORCA05–GJM189d

Total area = million sq km

DFS
Sensitivity experiment with JRA at 0.5° resolution

Sea ice concentration (March)

Sea Ice Concentration
Mar 2000–2007

ORCA05–GJMJRA1

ORCA05–GJM189d

DFS

Total area = million sq km
Sensitivity experiment with JRA at 0.5° resolution

Sea ice extent and sea ice area (maximum)

[Graphs showing sea ice extent and area for Arctic March and Antarctic September with lines representing JRA (red), DFS (black), and OBS (blue).]
Sensitivity experiment with JRA at 0.5° resolution

Sea ice extent and sea ice area (minimum)

Area Arctic September - Obs. (b)

Extent Arctic September - Obs. (b)

Area Antarctic March - Obs. (b)

Extent Antarctic March - Obs. (b)

JRA : red
DFS : black
OBS : blue