Thermocline and Intermediate circulation in the Solomon Sea from Hydrographic data

Solomon Sea Oceanography Workshop
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Cyril Germineaud
under the supervision of A. Ganachaud, S. Cravatte and J. Sprintall
Mean conditions in the tropical Pacific

Sea Surface Temperature (SST)
Mean conditions in the tropical Pacific

Sea Surface Temperature (SST)
Mean conditions in the tropical Pacific

Sea Surface Temperature (SST)
Mean conditions in the tropical Pacific
Mean conditions in the tropical Pacific

- Solomon Sea
- Warm Pool
- ITCZ
- SPCZ

Intraseasonal variations: The Madden-Julian Oscillation

Seasonal variations

Strong Trade season

Weak Trade season
Mean conditions in the tropical Pacific

Intraseasonal variations: The Madden-Julian Oscillation
Strong Trade season
Solomon Sea
Warm Pool

Seasonal variations
ITCZ

Deep pathways and water properties
ITCZ
SPCZ

Interannual: The El Niño Southern Oscillation (ENSO)

Solomon Sea
Warm Pool
The international SPICE program

- Diagnose the processes and WBC pathways in Southwest Pacific Ocean
- WBC pathways transit through the Coral and Solomon Seas (France)

Thermocline pathways to reach the equator

from Cravatte et al., 2011
Objectives of the thesis (Oct 13-Dec 16)

- Determine a refined description of the Solomon Sea WBCs and inside circulation

- Characterize the water mass property modifications

- Examine the intermediate and deep circulation in the Solomon Sea

- Assess the time flow variability at each exit passage from moorings (c.f. Session 2)
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Results

1. Two exploratory cruises and their climatic context
2. Thermocline and intermediate circulation
3. Deep pathways and water properties
Two cruises to explore the Solomon Sea
Two cruises to explore the Solomon Sea

- Strong trade winds
- Weak trade winds

Jul-Aug 2012

SOI chart
Two cruises to explore the Solomon Sea

- Strong trade winds
- Weak trade winds

SOI
Two cruises to explore the Solomon Sea

- Strong trade winds
- Weak trade winds
- Neutral phases of ENSO
Two cruises to explore the Solomon Sea

Daily OLR anomalies (15°S-15°N)
Two exploratory cruises and climatic context

- Thermocline and intermediate circulation
- Deep pathways and water properties
- Conclusions and perspectives

- Two cruises to explore the Solomon Sea

Daily OLR anomalies (15°S-15°N)

Intraseasonal: no active phase of MJO

from the Bureau of Meteorology, Commonwealth of Australia
Wheeler and Hendon MJO index

from the Bureau of Meteorology, Commonwealth of Australia

2 EOFs combining OLR, 850 hPa and 200 hPa zonal winds
Two cruises to explore the Solomon Sea

- Measurements to sample as much as possible the WBCs
Two cruises to explore the Solomon Sea
- Measurements to sample as much as possible the WBCs
- Currents were measured with
  - A pair of L-ADCPs
  - Two along track S-ADCPs
Two cruises to explore the Solomon Sea

- Measurements to sample as much as possible the WBCs from the surface to the bottom
- Currents were measured with
  - A pair of L-ADCPs
  - Two along track S-ADCPs
Two cruises to explore the Solomon Sea
- Measurements to sample as much as possible the WBCs
- Currents were measured with
  - A pair of L-ADCPs
  - Two along track S-ADCPs

Our objective is to infer pathways and associated transports with a closed mass budget.
We use an Inverse Box Model
- To infer a more synoptic circulation during each cruise
- Determine a circulation that conserves mass and other tracers
- Estimate an adjusted velocity field with transport uncertainties
The tropical Pacific climate

Southwest Pacific: the SPICE program

Two exploratory cruises and climatic context

Thermocline and intermediate circulation

Deep pathways and water properties

Conclusions and perspectives

Jul-Aug 2012

Estimated cross section
S-ADCP velocity

from Germineaud et al., 2016
Estimated cross section S-ADCP velocity
from Germineaud et al., 2016
<table>
<thead>
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<th>The tropical Pacific climate</th>
<th>Southwest Pacific: the SPICE program</th>
<th>Two exploratory cruises and climatic context</th>
<th>Thermocline and intermediate circulation</th>
<th>Deep pathways and water properties</th>
<th>Conclusions and perspectives</th>
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### Jul-Aug 2012

**Estimated cross section**

*Estimated S-ADCP velocity from Germineaud et al., 2016*

- **18 Sv**
- **Strong and confined NGCU**
- **Southern Entrance**
- **2/3 of the Gulf Stream near Florida**
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**Jul-Aug 2012**

Estimated cross section
S-ADCP velocity

From Germineaud et al., 2016

- **8 Sv**
- **18 Sv**

Strong and confined NGCU

North Vanuatu Jet

Southern Entrance

2/3 of the Gulf Stream near Florida

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Jul-Aug 2012

Mar 2014

18 Sv

Strong and confined NGCU

8 Sv

North Vanuatu Jet

Estimated cross section

S-ADCP velocity

2/3 of the Gulf Stream near Florida

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Summer 2012

Mar 2014

Estimated cross section
S-ADCP velocity

2/3 of the Gulf Stream near Florida

18 Sv
North Vanuatu Jet
Strong and confined NGCU

10 Sv
Weaker NGCU
Southern Entrance

Germineaud et al., 2016
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Jul-Aug 2012

Strong and confined NGCU

North Vanuatu Jet

18 Sv

Estimated cross section S-ADCP velocity

2/3 of the Gulf Stream near Florida

Mar 2014

Weaker NGCU

Southern Entrance

Large eddies

Large

eddies

10 Sv

18 Sv

8 Sv

-5 Sv

From Germineaud et al., 2016
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Jul-Aug 2012

Mar 2014

Large eddies

18 Sv

North Vanuatu Jet

Strong and confined NGCU

10 Sv

Weaker NGCU

Absolute surface currents (Mar 2014)

Southern Entrance

-5 Sv
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Jul-Aug 2012

Estimated cross section
S-ADCP velocity

from Germaineaud et al., 2016
Estimated cross section S-ADCP velocity

*from Germineaud et al., 2016*
Anticyclonic eddy

Jul-Aug 2012

6 Sv

Strong SGU

6 Sv

Strong NICU

Absolute surface currents (Jul-Aug 2012)

St Georges Ch. to Solomon Strait
Anticyclonic eddy

Strong SGU

Strong NICU

AVISO surface currents (Jul-Aug 2012)

St Georges Ch. to Solomon Strait

Jul-Aug 2012

Mar 2014
Anticyclonic eddy

Strong SGU

Strong NICU

Weaker SGU and NICU

St Georges Ch. to Solomon Strait

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from Germineaud et al., 2016
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Anticyclonic eddy
6 Sv
Strong SGU
6 Sv
Strong NICU

Mar 2014

Surface Inflow
-6 Sv
Weaker SGU and NICU
4 Sv
3 Sv

St Georges Ch. to Solomon Strait

Estimated cross section S-ADCP velocity

from Germineaud et al., 2016
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**Anticyclonic eddy**

Jul-Aug 2012

- 6 Sv

- 6 Sv

- 6 Sv

Strong SGU

Strong NICU

**Surface Inflow**

Mar 2014

- 6 Sv

- 4 Sv

- 3 Sv

Weaker SGU and NICU

**Absolute surface currents (Mar 2014)**

**St Georges Ch. to Solomon Strait**
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Jul-Aug 2012

High velocity core

8-14 Sv from 20-300 m during WEPOCS
Lindstrom et al. (1987, 1990)

Vitiiaz Strait
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**Jul-Aug 2012**

**Mar 2014**

High velocity core

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Jul-Aug 2012

Transports 0-1000 m (SV)

19 ± 0.5

19 ± 2

36 ± 2.5

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Transports 0-1000 m (SV)

19 ± 0.5

12 ± 2

8 ± 2

36 ± 2.5

Solomon Sea

19 ± 2

11

Jul-Aug 2012

19 ± 2

8

NGCU

NICU

SGU

GPC

Direct NVJ

SEC

SEC

Bismarck Sea

Transports 0-1000 m (SV)

8 ± 2

19 ± 0.5

12 ± 2

36 ± 2.5

Solomon Sea

Bismarck Sea

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19 ± 0.5

19 ± 2

12 ± 2

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11 ± 2.5

Mar 2014

Bismarck Sea

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Mar 2014

Transports 0-1000 m (SV)

Bismarck Sea

Solomon Sea

19 ± 0.5

19 ± 2

12 ± 2

8 ± 2

36 ± 2.5

11 ± 2.5

11 ± 2

4 ± 2
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Jul-Aug 2012

11 ± 0.5
19 ± 0.5

Mar 2014

8
4
11
-2

19 ± 2
2 ± 2

12 ± 2
8 ± 2

Transports 0-1000 m (SV)

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Transports 0-1000 m (SV)

Jul-Aug 2012

Mar 2014

11 ± 0.5

19 ± 0.5

12 ± 2

8 ± 2

19 ± 2

9 ± 2

2 ± 2

36 ± 2.5

11 ± 2.5

Bismarck

Sea

Solomon

Sea

Jul-Aug 2012

Mar 2014

19 ± 2

2 ± 2

11 ± 2.5

SGU

NGCU

NIJU

Direct

NVJ

SEC

SEC

11 ± 0.5

19 ± 0.5

12 ± 2

8 ± 2

9 ± 2

2 ± 2

36 ± 2.5

11 ± 2.5

155°E

158°E

161°E

164°E

146°E

149°E

152°E

12°S

10°S

8°S

6°S

4°S

2°S

Mar 2014

11 ± 2.5

36 ± 2.5

19 ± 2

2 ± 2

9 ± 2

2 ± 2

19 ± 0.5

12 ± 2

8 ± 2

11 ± 0.5

Two exploratory cruises and climatic context

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Bismarck Sea

Solomon Sea

Thermocline (65%)
Intermediate (25%)
Transports 0-1000 m (SV)

Jul-Aug 2012

Direct NVJ
SEC

51
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Bismarck Sea

Solomon Sea

Thermocline (70%)
Intermediate (20%)

Mar 2014

Transports 0-1000 m (SV)

Direct NVJ

Sec

Sec
ARGO profiles
2005-2016
ARGO profiles
2005-2016

Salinity maximum
ARGO profiles 2005-2016

Salinity maximum

WBCs are associated with lower salinity

Narrow currents of ~50 km

Mar 2014

24 < σθ < 26

Jul-Aug 2012

24 < σθ < 26

from Germineaud et al., 2016
What are the major results?

- Strong seasonal variability between the two cruises
  - Enhanced transports in Jul-Aug 2012
  - Fell down by 70% to 11 Sv in March 2014 at the southern entrance
  - Halved at Vitiaz Strait in March 2014
What are the major results?

- Strong seasonal variability between the two cruises
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- Refined picture of the Solomon Sea WBCs over the upper 1000 m
  - Detailed transport partitions through each passage
  - Significant contribution of St Georges Channel
  - Narrow WBCs within the Solomon Sea
  - WBCs extend down to intermediate depths
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The Deep Circulation in the Southwest Pacific

adapted from Kawabe and Fujio (2010)
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2000-3200 m

NPDW

UCDW

adapted from Kawabe and Fujio (2010)
Deep water mass properties
- CTD-Oxygen and bottle measurements
- Historical data from the World Ocean Database 2013 (WOD13)

Deep waters emanate Southeast.
Deep water mass properties
- CTD-Oxygen and bottle measurements
- Historical data from the World Ocean Database 2013 (WOD13)
Deep water mass properties
- CTD-Oxygen and bottle measurements
- Historical data from the World Ocean Database 2013 (WOD13)

Eastern pathway is nearly closed!

Tasman Sea is closed to the north

Upper deep waters emanate from the eastern Coral Sea
Deep water mass properties

- CTD-Oxygen and bottle measurements
- Historical data from the World Ocean Database 2013 (WOD13)

Eastern pathway is nearly closed!

Tasman Sea is closed to the north

Upper deep waters emanate from the eastern Coral Sea
Jul-Aug 2012

Deep Inverse Model

Estimated cross section velocity

**The tropical Pacific climate**

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**Deep pathways and water properties**

**Conclusions and perspectives**

1000-3200 m

Southern Entrance
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Jul-Aug 2012

Deep Inverse Model

S-ADCP velocities

Geostrophic velocities referenced to 1700 m

Estimated cross section velocity

1000-3200 m
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Deep Inverse Model

1000-3200 m

3 ± 2 Sv

Estimated cross section velocity

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Estimated cross section velocity

Jul-Aug 2012

Mar 2014

3 ± 2 Sv
2 ± 1 Sv

Southern Entrance
Jul-Aug 2012

Mar 2014

S-ADCP velocities

L-ADCP velocities below 1000 m

St Georges Ch. to Solomon Strait

Estimated cross section velocity

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**Conclusions and perspectives**

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**Jul-Aug 2012**

Deep waters exit the Solomon Sea

**3 ± 1 Sv**

St Georges Ch. to Solomon Strait

**Mar 2014**

Estimated cross section velocity

2 ± 2 Sv
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Jul-Aug 2012
Mar 2014

Southward inflows

2 ± 2 Sv

Deep waters exit the Solomon Sea

3 ± 1 Sv

St Georges Ch. to Solomon Strait

Estimated cross section velocity
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2000-3200 m

NPDW

North Pacific

adapted from Kawabe and Fujio (2010)
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The tropical Pacific climate

2000-3200 m

The tropical Pacific climate

2-3 Sv

9-10 Sv

DWBC

The tropical Pacific climate

2-3 Sv

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2-3 Sv

9-10 Sv

DWBC

The tropical Pacific climate

2-3 Sv

9-10 Sv

DWBC

The tropical Pacific climate

2-3 Sv

9-10 Sv

DWBC

The tropical Pacific climate

2-3 Sv

9-10 Sv

DWBC

The tropical Pacific climate

2-3 Sv

9-10 Sv

DWBC
What are the major results?

- First picture of the deep Solomon Sea WBCs over 2000-3200 m
- Distinct water properties to trace deep WBC pathways
- Northward transport of 2-3 Sv across the Solomon Sea
- Deep Western Boundary Current 9-10 Sv
What are the major results?
- First picture of the deep Solomon Sea WBCs over 2000-3200 m
- Distinct water properties to trace deep WBC pathways
- Northward transport of 2-3 Sv across the Solomon Sea
- Deep flow feed the deep Western Boundary Current
What are the major results?
- First picture of the deep Solomon Sea WBCs over 2000-3200 m
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What are the major results?

- First picture of the deep Solomon Sea WBCs over 2000-3200 m
- Distinct water properties to trace deep WBC pathways
- Northward transport of 2-3 Sv across the Solomon Sea
- Deep Western Boundary Current 9-10 Sv
General conclusions

- Strong seasonal variability between the two cruises
- Detailed transport partitions through each passage, down to 1000 m
- Narrow WBCs that extend down to intermediate depths

- Northward transport of 2-3 Sv across the Solomon Sea
- Deep Western Boundary Current 9-10 Sv

Perspectives

- Investigate mixing processes causing water mass property modifications
- Comparisons with glider surveys at the southern entrance
- Analysis of trace element collected during the SPICE cruises together with our refined description of the WBCs
General conclusions
- Strong seasonal variability between the two cruises
- Detailed transport partitions through each passage, down to 1000 m
- Narrow WBCs that extend down to intermediate depths

- Northward transport of 2-3 Sv across the Solomon Sea (2000-3200 m)
- Deep Western Boundary Current 9-10 Sv

Perspectives
- Comparisons with glider surveys at the southern entrance (c.f. B. Kessler talk)
- Resolve cross-passage flow variability from moorings (c.f. session 2)
- Analysis of trace element collected during the SPICE cruises together with our refined description of the WBCs
The Seasonal cycle in the Tropical Pacific
- June-November: strengthened trade winds, northward migration of the ITCZ
- December-May: weakened trade winds, ITCZ is shifted equatorward

August-October
- Subtropical gyres spin up

June-July
- Stronger NEC, shifted southward
- SEC is shifted southward
The Seasonal cycle in the Tropical Pacific

- June-November: strengthened trade winds, northward migration of the ITCZ
- December-May: weakened trade winds, ITCZ is shifted equatorward

December-May

- Subtropical gyres spin down
- Weaker NEC, shifted northward and SEC
- SEC is shifted northward
SST anomaly
2007-2015 monthly average for July and March

OLR anomaly
1979-2014 climate average for July-August and March