A stochastic parameterization framework for the MAOOAM model: Supplementary material

Jonathan Demaeyer and Stéphane Vannitsem
Institut Royal Météorologique de Belgique, Avenue Circulaire, 3, 1180 Brussels, Belgium

Abstract

We compile in this document all the figures that were not crucial to the flow of the main article.

Contents

1 Parameterization of the wavenumber 2 atmospheric variables **3**
1.1 DV2017 parameter set . . . 3
1.1.1 PDFs and autocorrelation functions of the resolved variables . . . 3
1.1.2 Kullback-Leibler divergences . . . 12
1.2 DDV2016 parameter set . . . 12
1.2.1 PDFs and autocorrelation functions of the resolved variables . . . 12
1.2.2 Kullback-Leibler divergences . . . 21
1.3 noLFV parameter set . . . 21
1.3.1 PDFs and autocorrelation functions of the resolved variables . . . 21
1.3.2 Kullback-Leibler divergences . . . 30

2 Parameterization of the wavenumber 2 atmospheric baroclinic variables **30**
2.1 DV2017 parameter set . . . 30
2.1.1 PDFs and autocorrelation functions of the resolved variables . . . 30
2.1.2 Kullback-Leibler divergences . . . 40
2.2 DDV2016 parameter set . . . 40
2.2.1 PDFs and autocorrelation functions of the resolved variables . . . 40
2.2.2 Kullback-Leibler divergences . . . 50
2.3 noLFV parameter set . . . 50
2.3.1 PDFs and autocorrelation functions of the resolved variables . . . 50
2.3.2 Kullback-Leibler divergences . . . 60

3 The parameterization of the atmospheric wavenumber 2 and F_4 modes **60**
3.1 DV2017 parameter set . . . 60
3.1.1 PDFs and autocorrelation functions of the resolved variables . . . 60
3.1.2 Kullback-Leibler divergences . . . 69
3.2 noLFV parameter set . . . 69
3.2.1 PDFs and autocorrelation functions of the resolved variables . . . 69
3.2.2 Kullback-Leibler divergences . . . 77

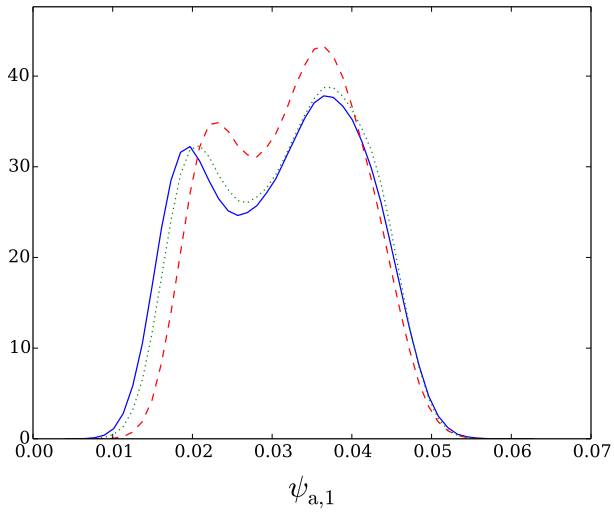
1 Parameterization of the wavenumber 2 atmospheric variables

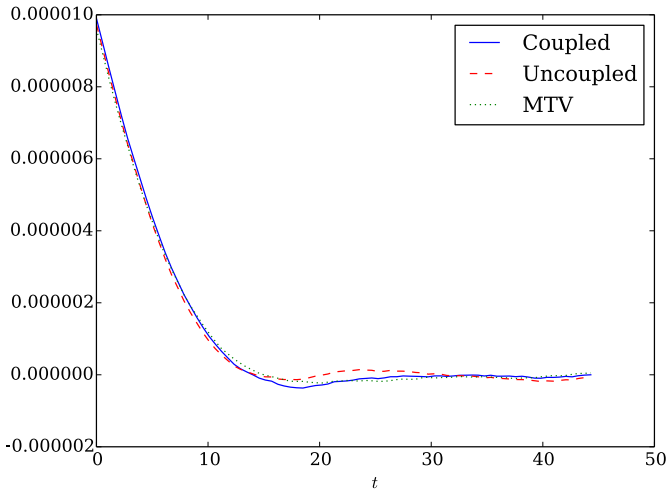
All the figures compiled in this section are related to the experiment described in the section 4.1.2 and concern the "DV2017", "DDV2016" and "noLFV" parameter sets.

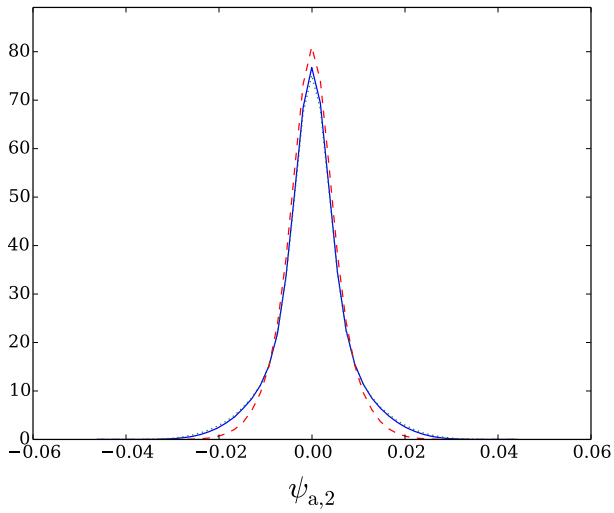
1.1 DV2017 parameter set

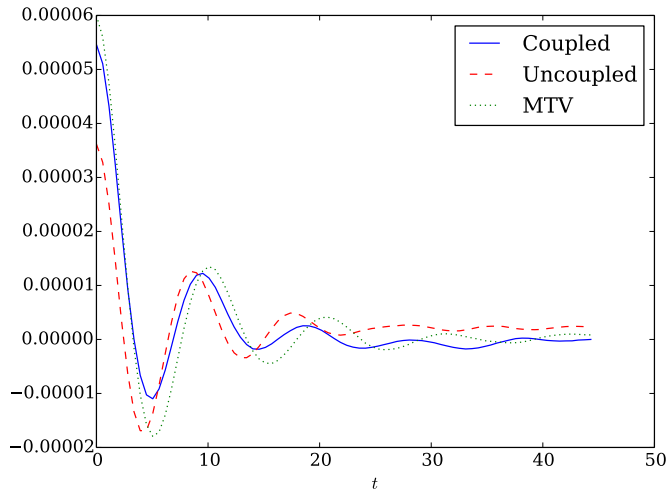
1.1.1 PDFs and autocorrelation functions of the resolved variables

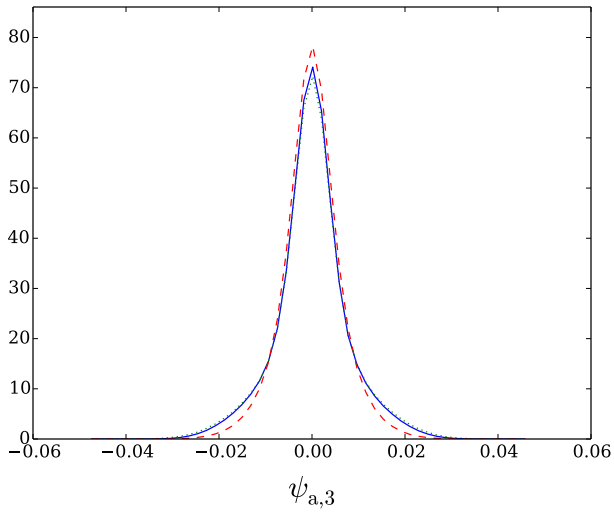
Atmospheric variables of the model.

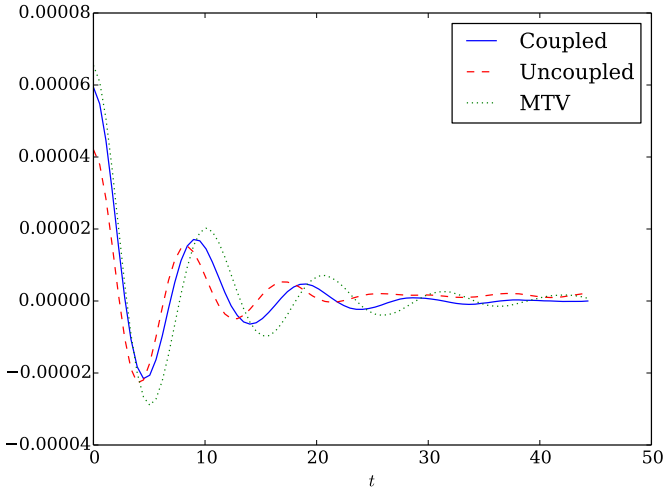


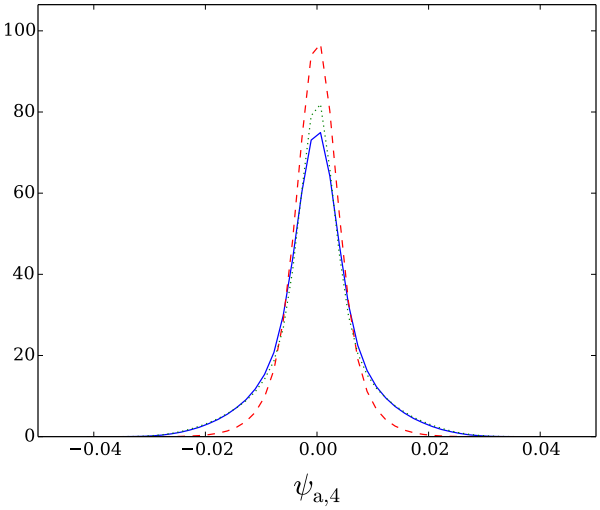


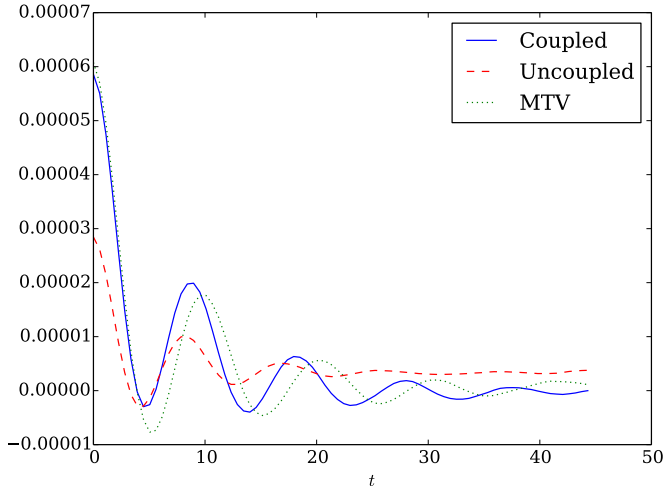


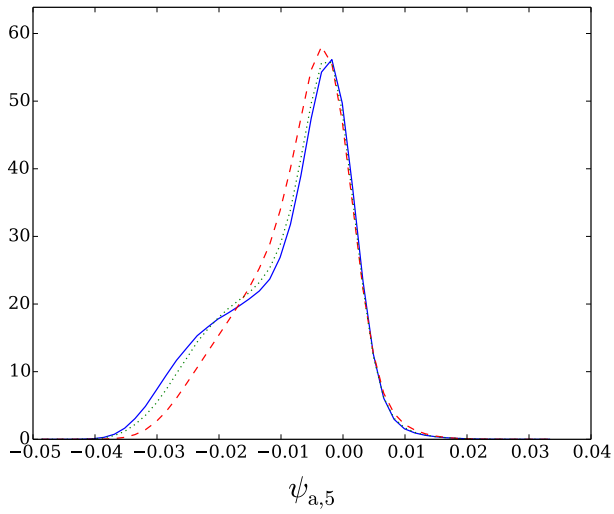


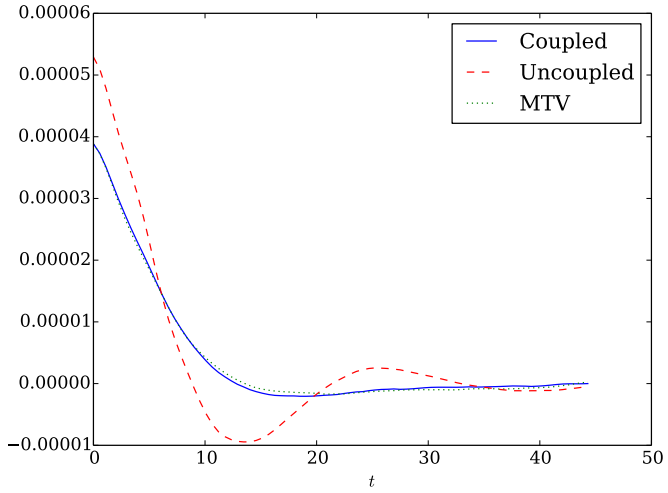

$\psi_{a,3}$

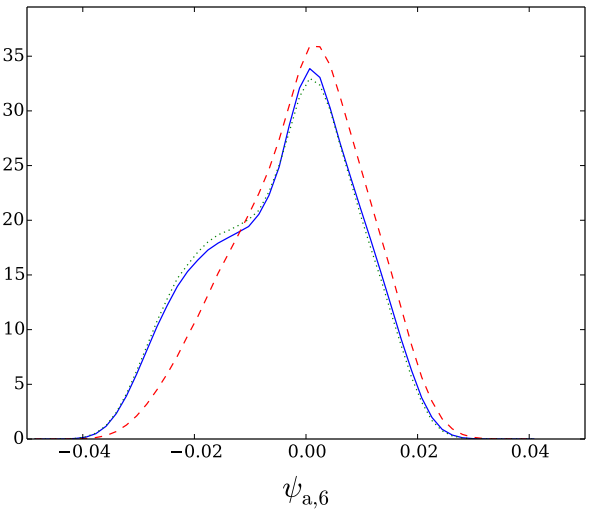

Coupled
Uncoupled
MTV
t


$\psi_{a,4}$

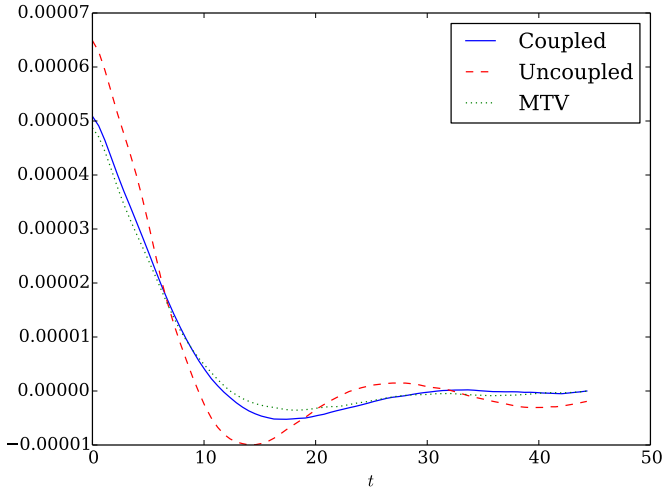

Coupled
Uncoupled
MTV
t

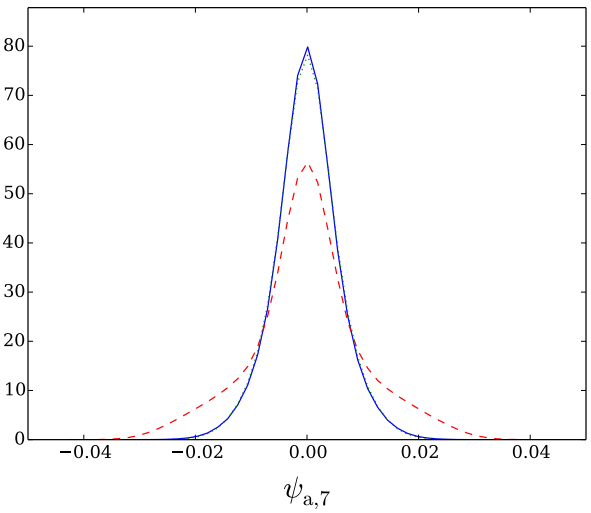

$\psi_{a,5}$


Coupled
Uncoupled
MTV
t

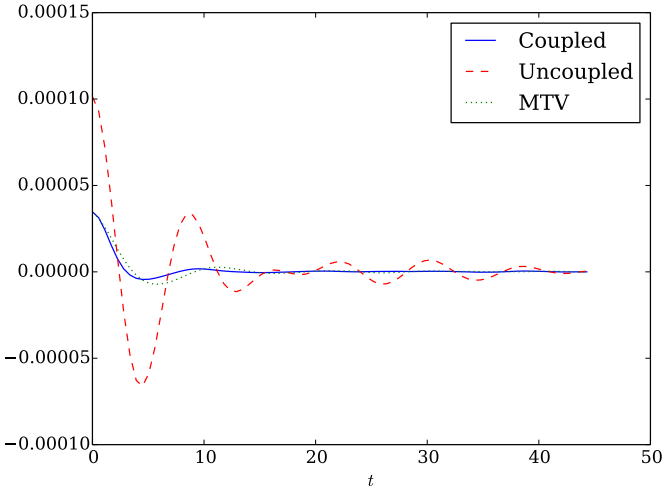


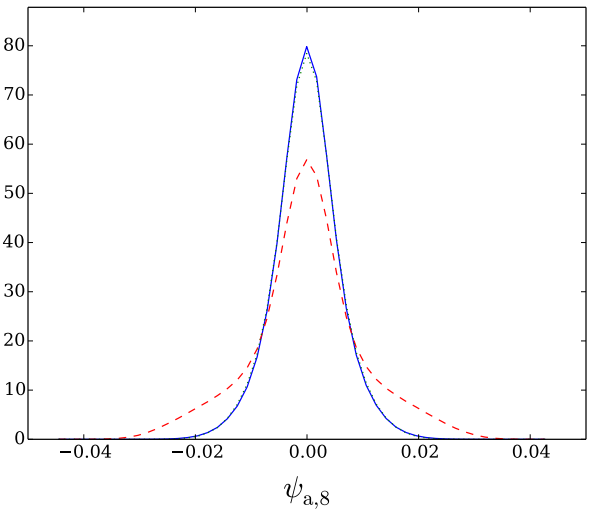
$\psi_{\mathrm{a},6}$



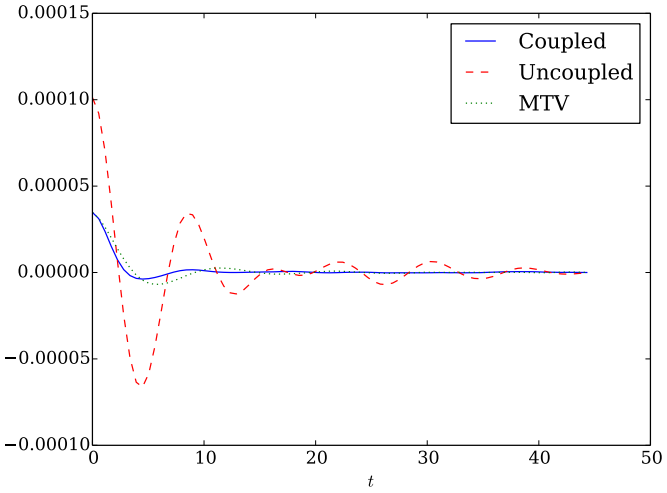


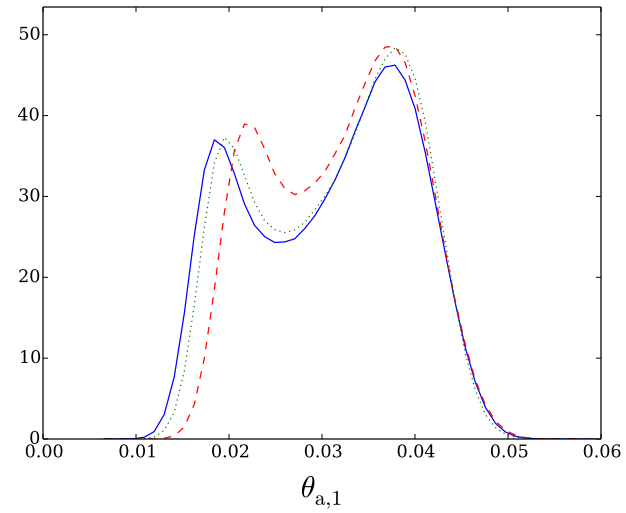
$\psi_{\mathrm{a},7}$

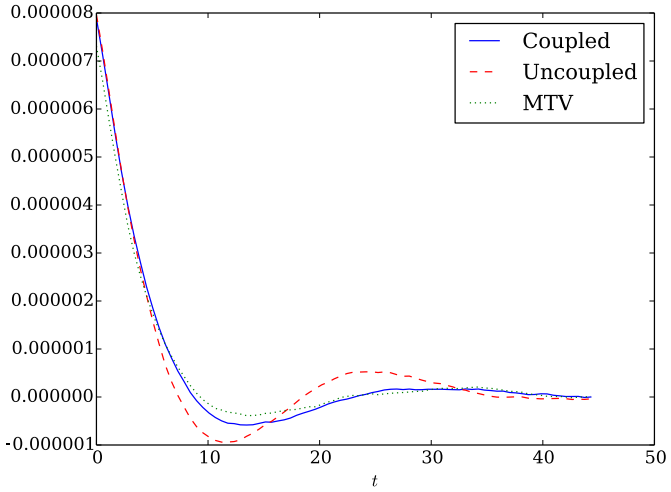


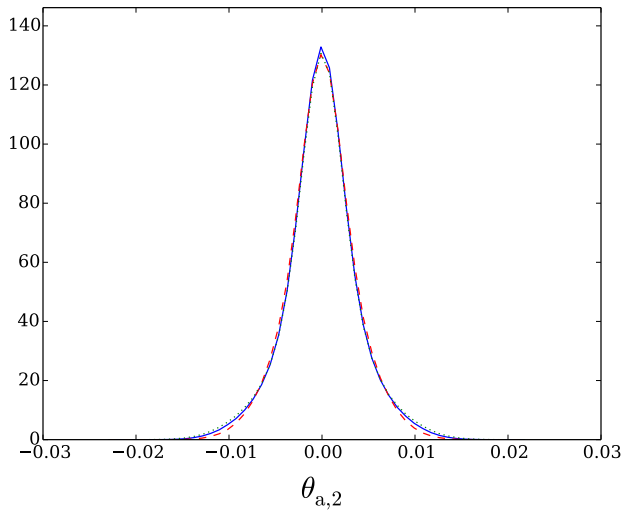


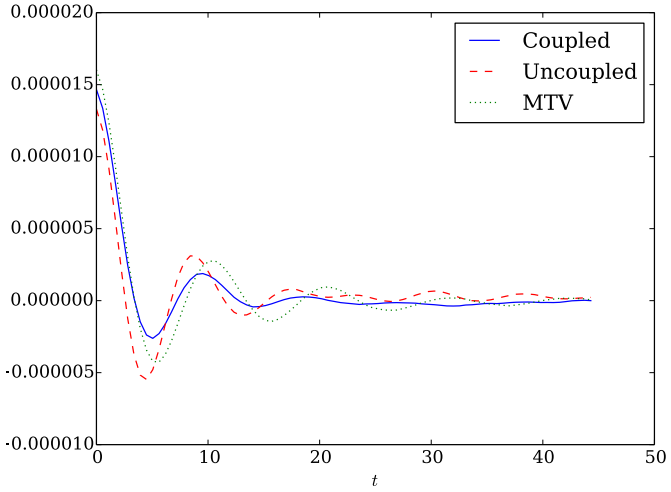
$\psi_{\mathrm{a},8}$

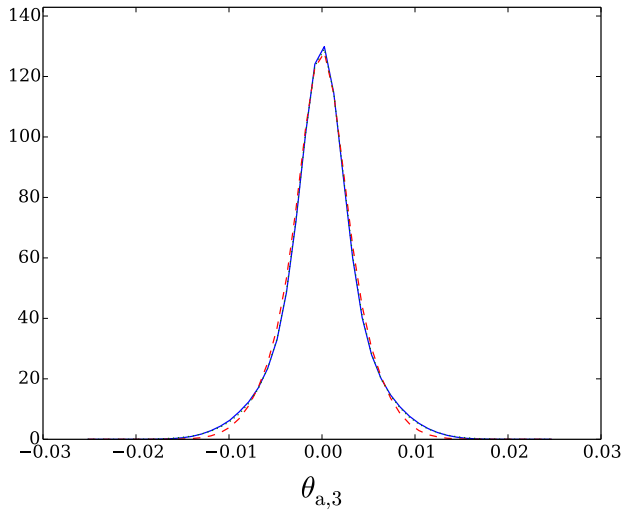


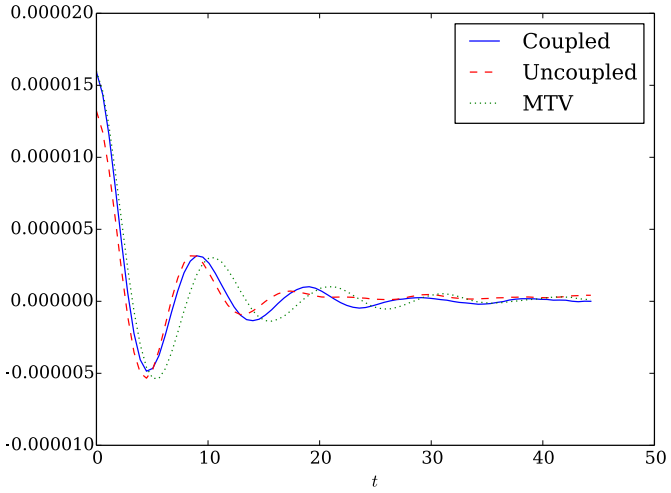

$\theta_{a,1}$

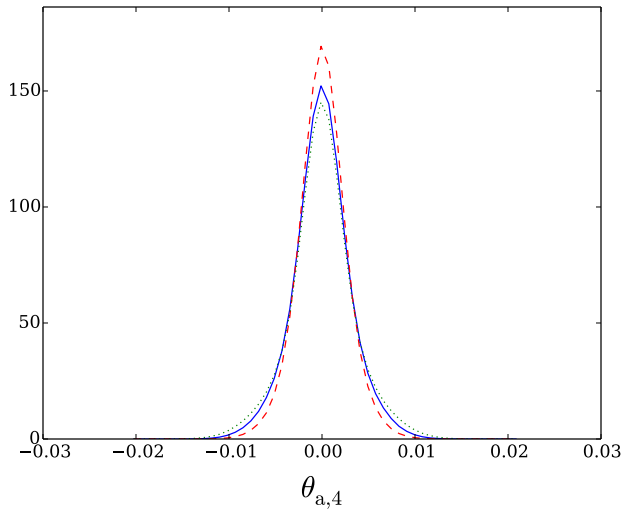

Coupled
Uncoupled
MTV
t

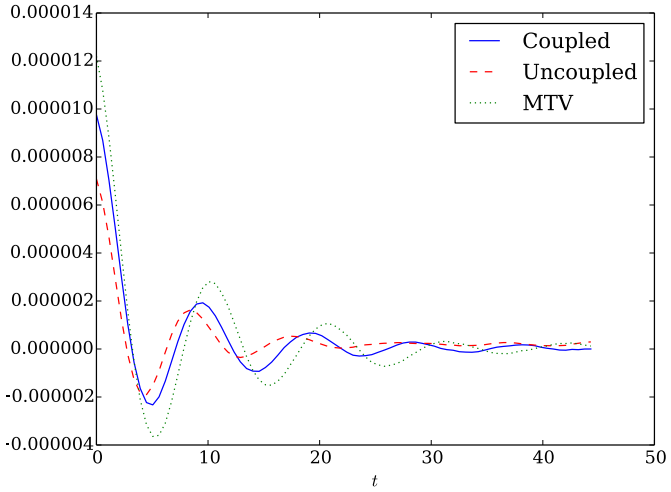

$\theta_{a,2}$

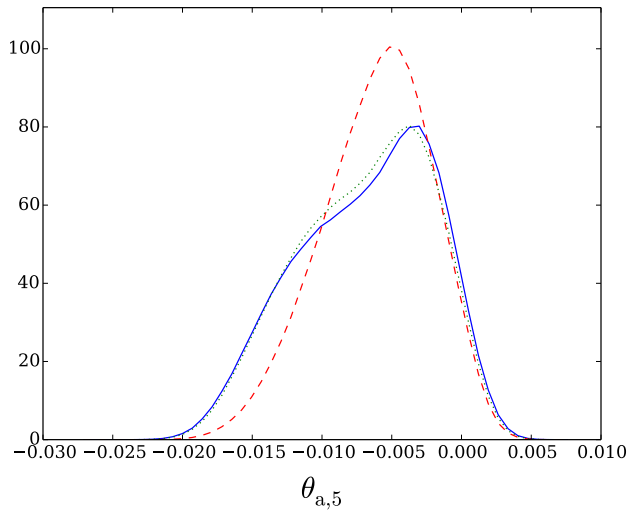

Coupled
Uncoupled
MTV
t

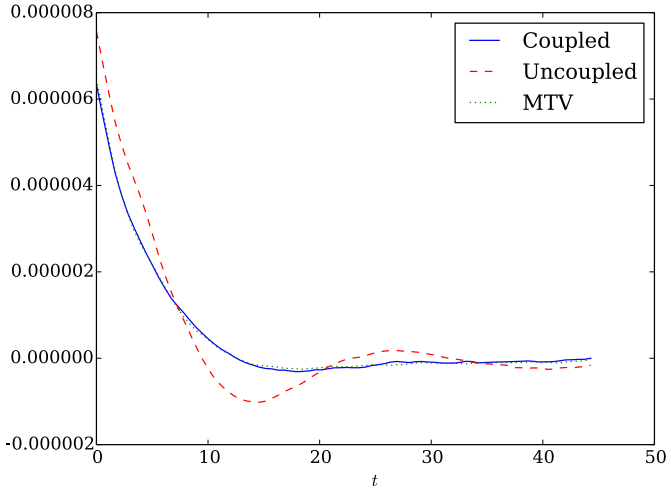

$\theta_{a,3}$

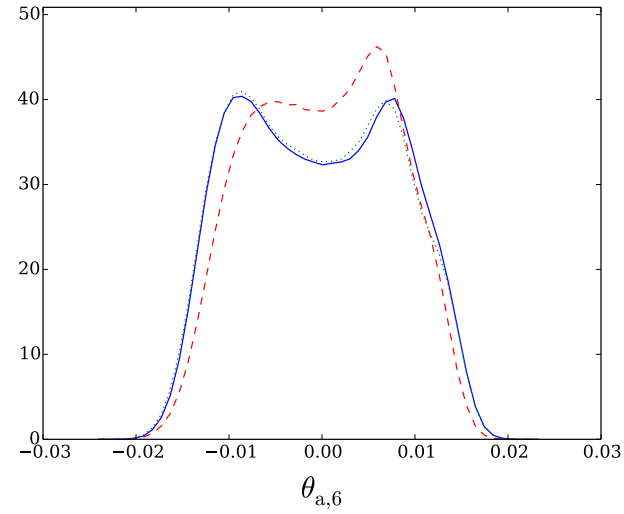

Coupled
Uncoupled
MTV
t

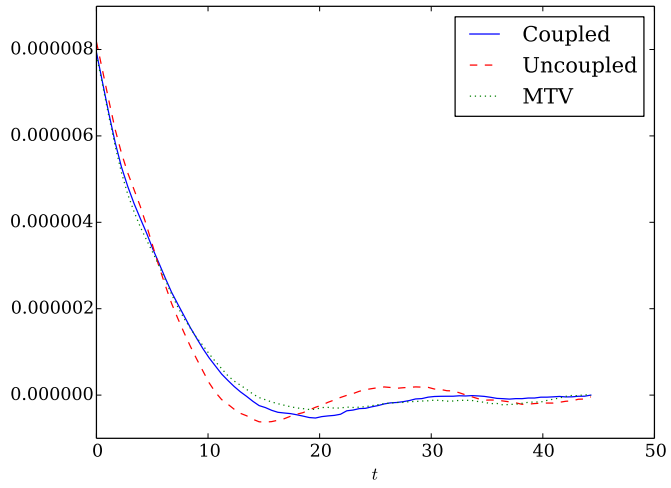

150
100
50
0
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
$\theta_{a,4}$

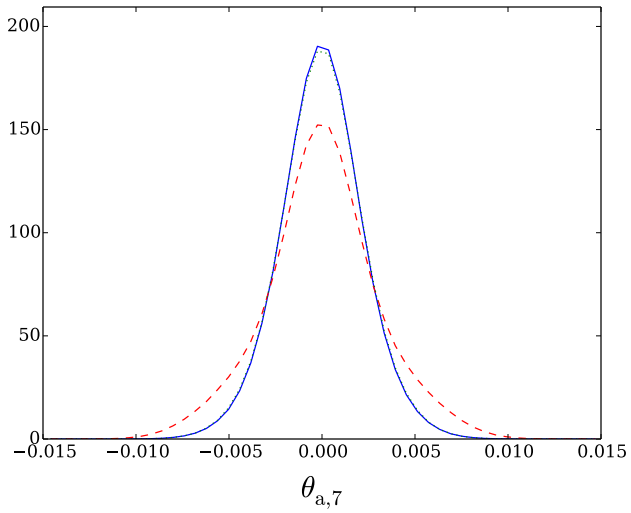

0.000014
0.000012
0.000010
0.000008
0.000006
0.000004
0.000002
0.000000
-0.000002
-0.000004
0
10
20
30
40
50
t
Coupled
Uncoupled
MTV

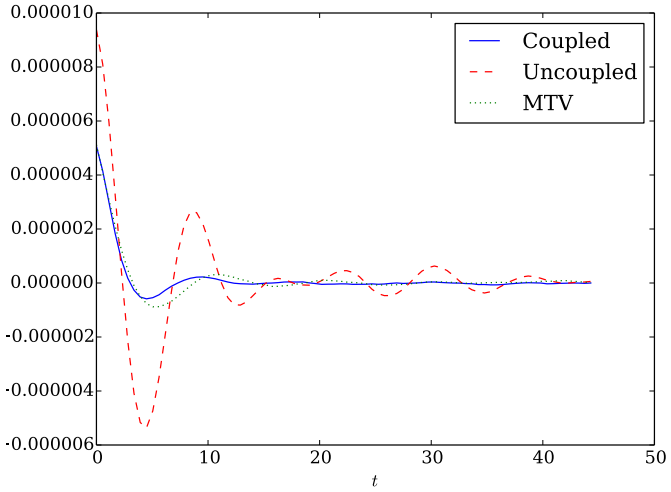

100
80
60
40
20
0
−0.030
−0.025
−0.020
−0.015
−0.010
−0.005
0.000
0.005
0.010
$\theta_{a,5}$

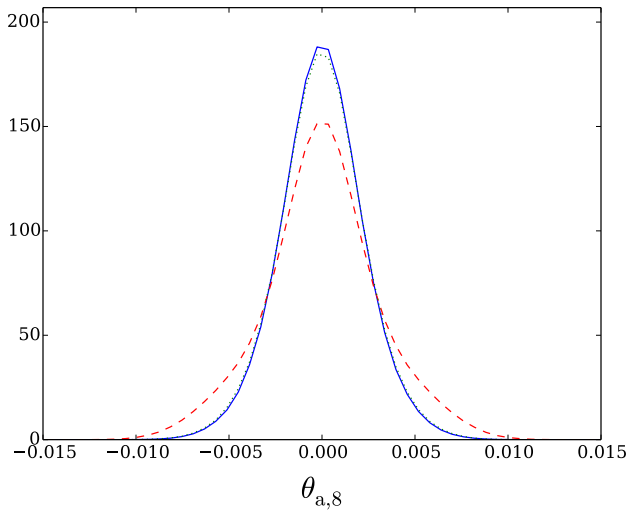

0.000008
0.000006
0.000004
0.000002
0.000000
-0.000002
0
10
20
30
40
50
t
Coupled
Uncoupled
MTV

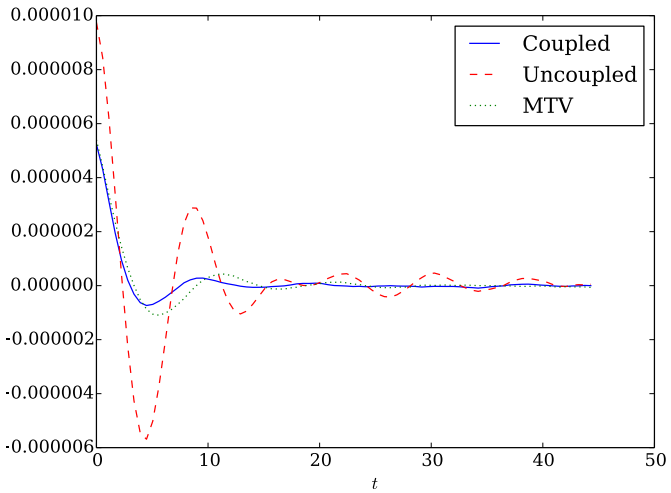

50
40
30
20
10
0
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
$\theta_{a,6}$


0.000008
0.000006
0.000004
0.000002
0.000000
0
10
20
30
40
50
t
Coupled
Uncoupled
MTV

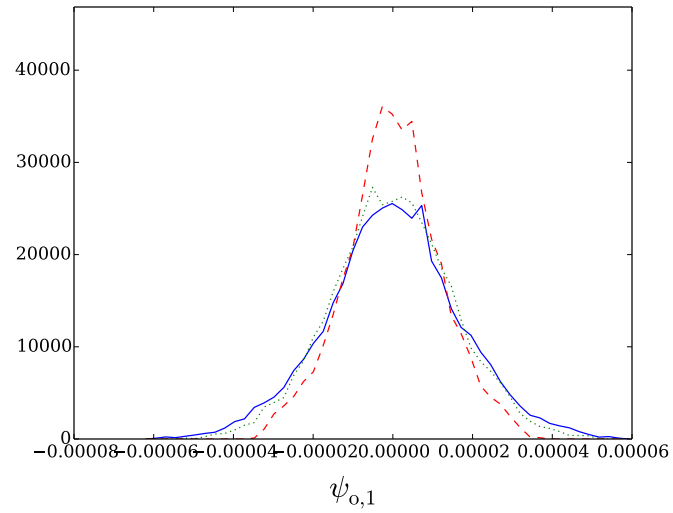




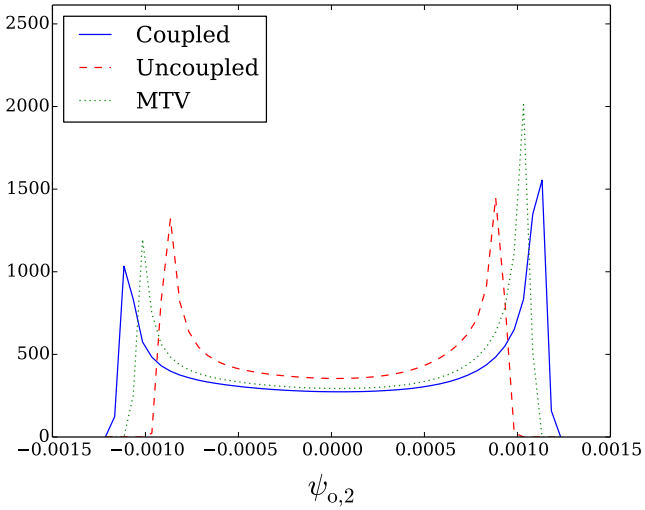




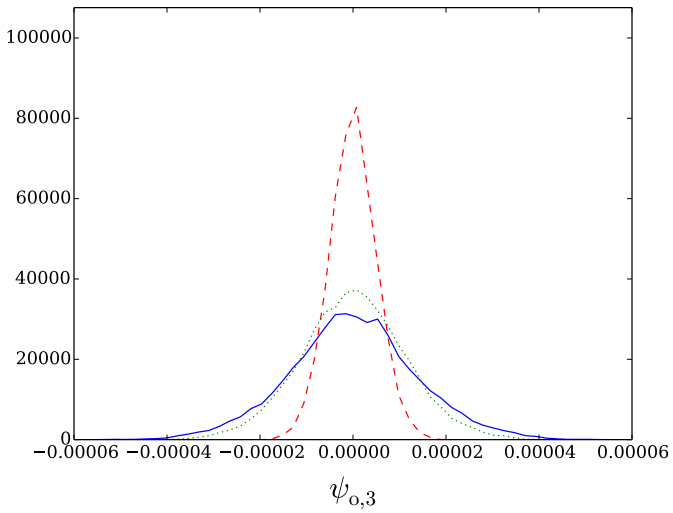
Oceanic variables Only the PDFs are available for these variables.



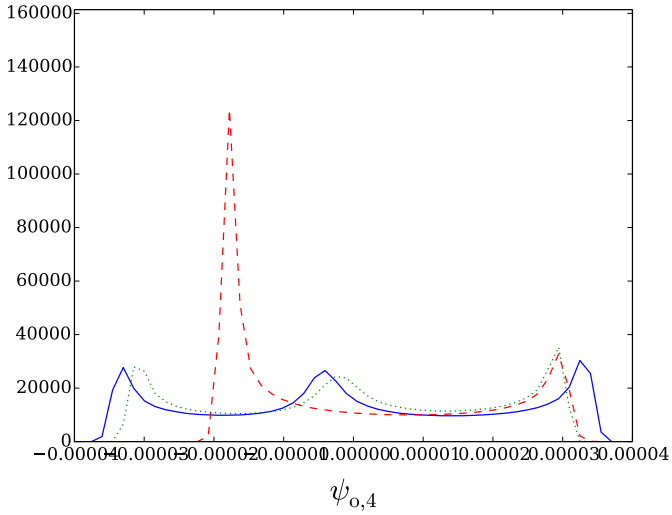
$\psi_{o,1}$



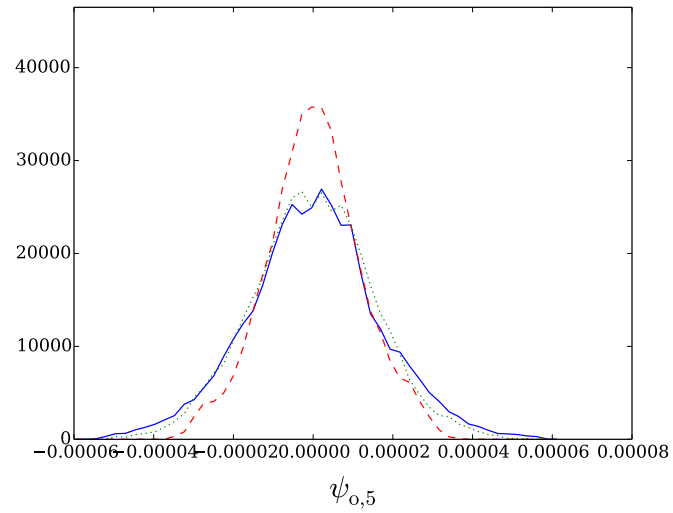
$\psi_{o,2}$



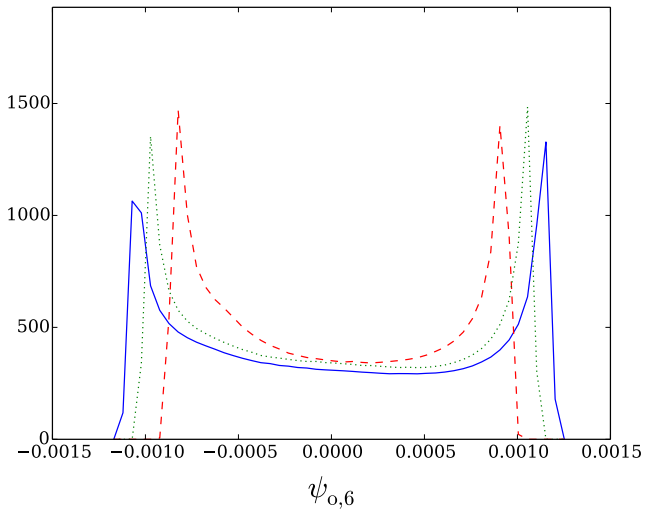
$\psi_{o,3}$



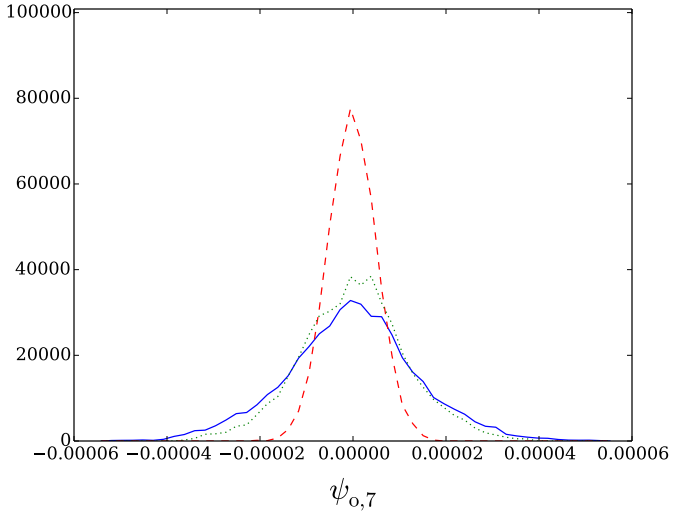
$\psi_{o,4}$



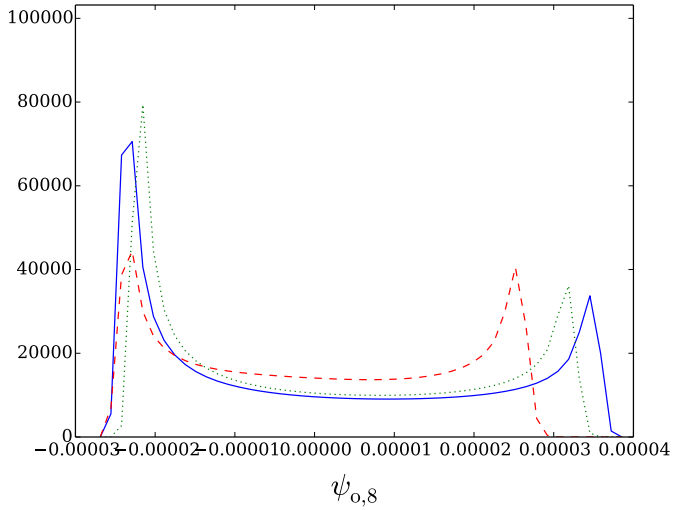
$\psi_{o,5}$



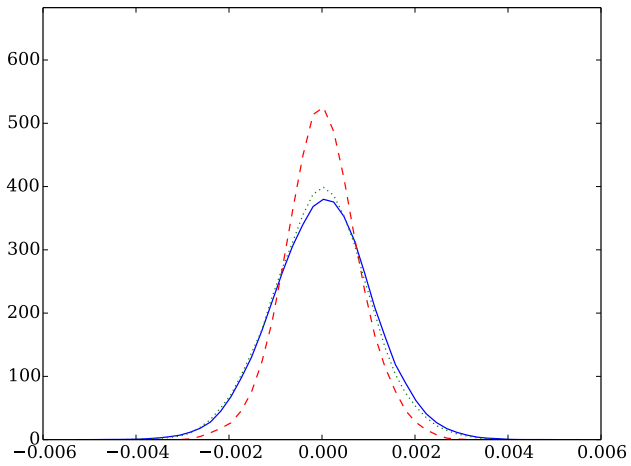
$\psi_{o,6}$



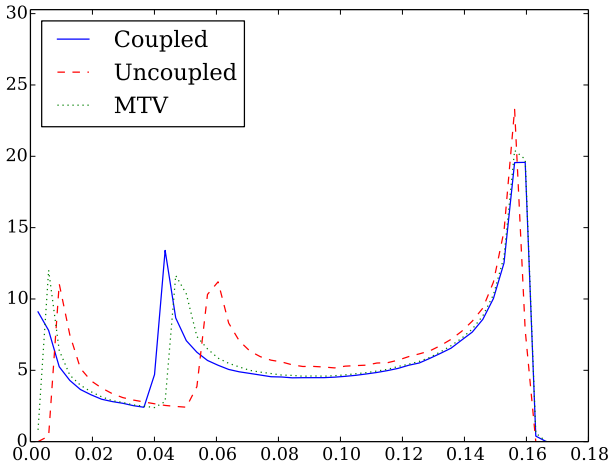
$\psi_{o,7}$



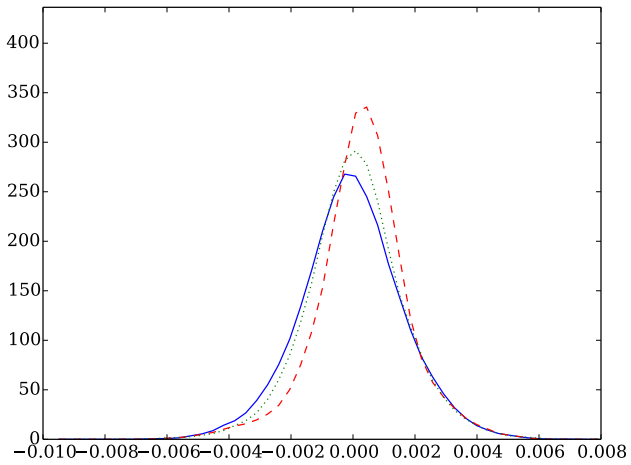
$\psi_{o,8}$



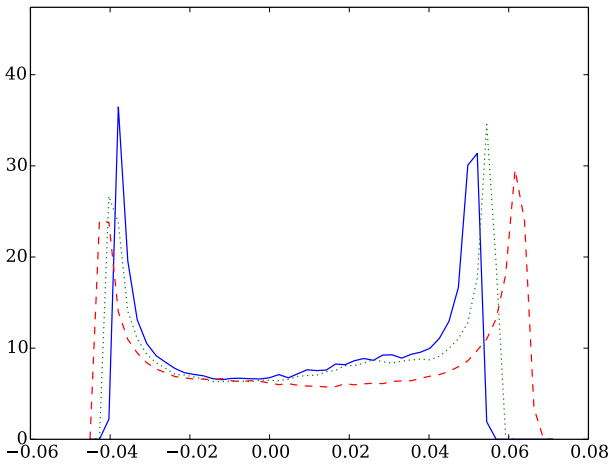
$\theta_{o,1}$



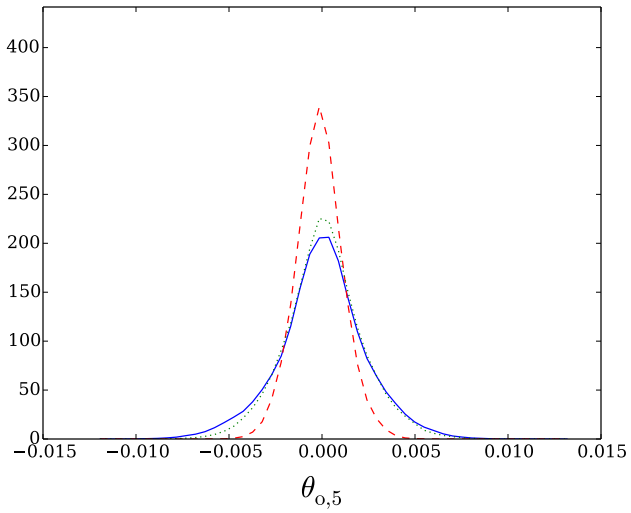
$\theta_{o,2}$

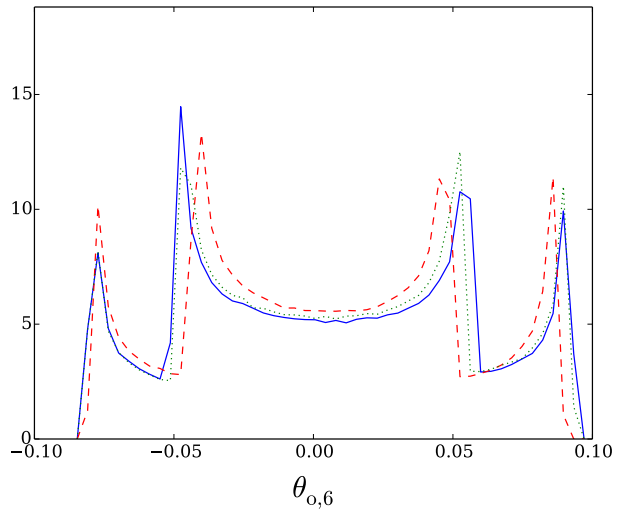


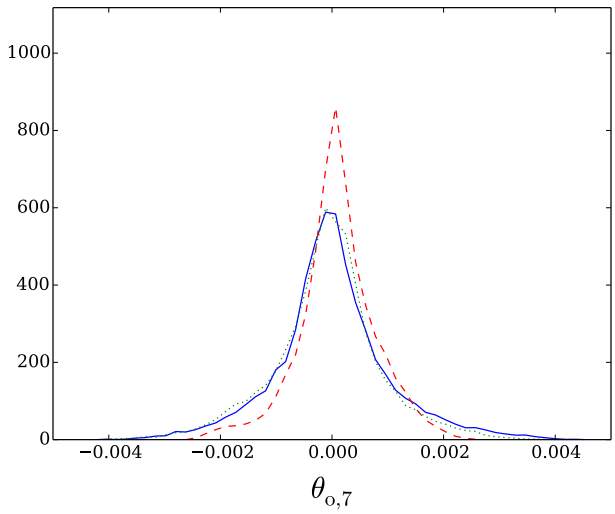
$\theta_{o,3}$

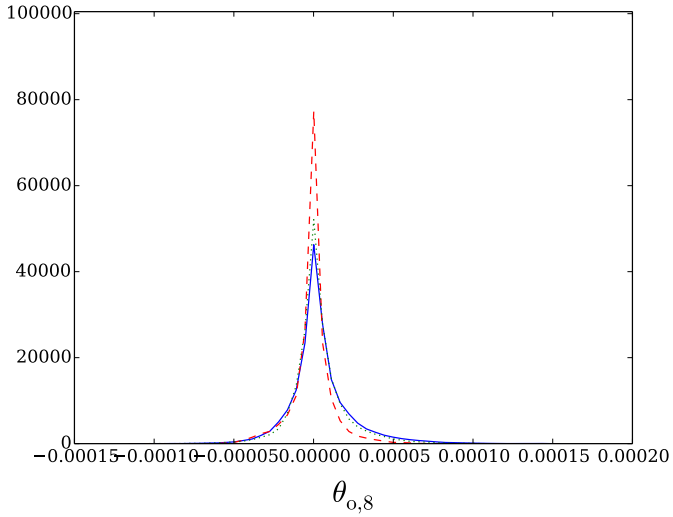


$\theta_{o,4}$

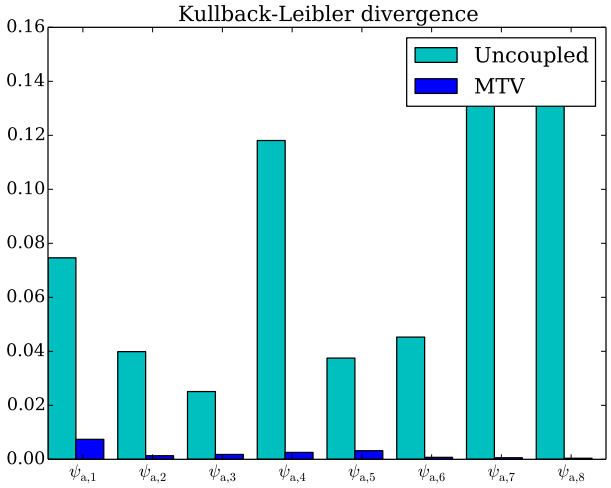

400
350
300
250
200
150
100
50
0
−0.015
−0.010
−0.005
0.000
0.005
0.010
0.015
$\theta_{o,5}$

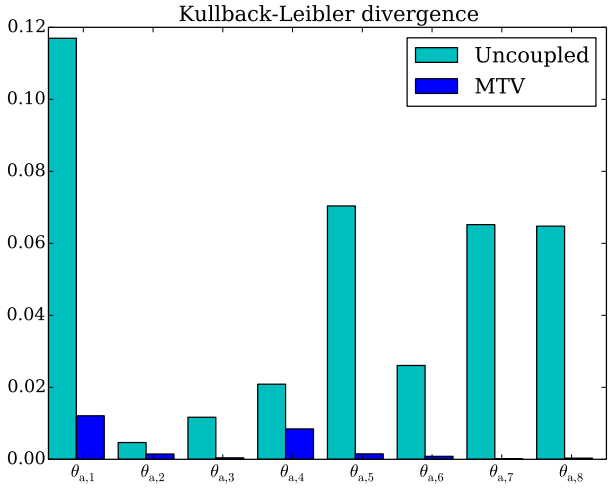

15
10
5
0
−0.10
−0.05
0.00
0.05
0.10
$\theta_{o,6}$

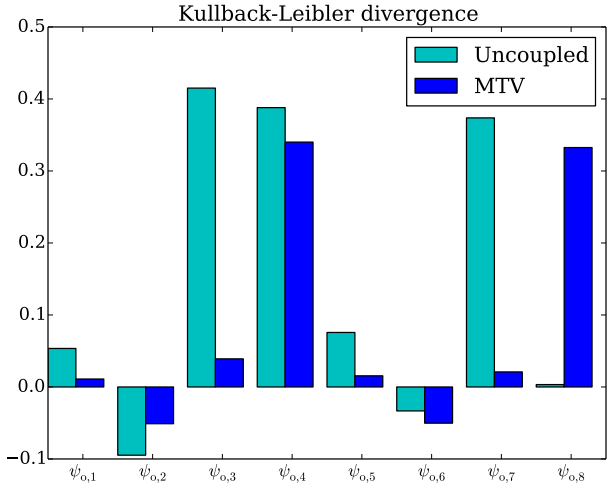

1000
800
600
400
200
0
−0.004
−0.002
0.000
0.002
0.004
$\theta_{o,7}$

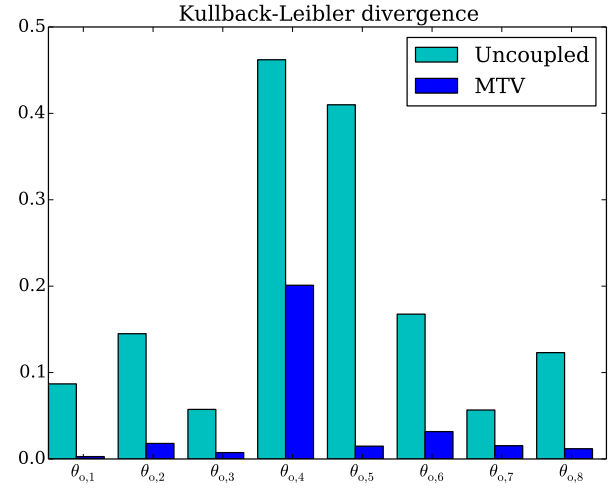

100000
80000
60000
40000
20000
0
−0.00015
−0.00010
−0.00005
0.00000
0.00005
0.00010
0.00015
0.00020
$\theta_{o,8}$

1.1.2 Kullback-Leibler divergences





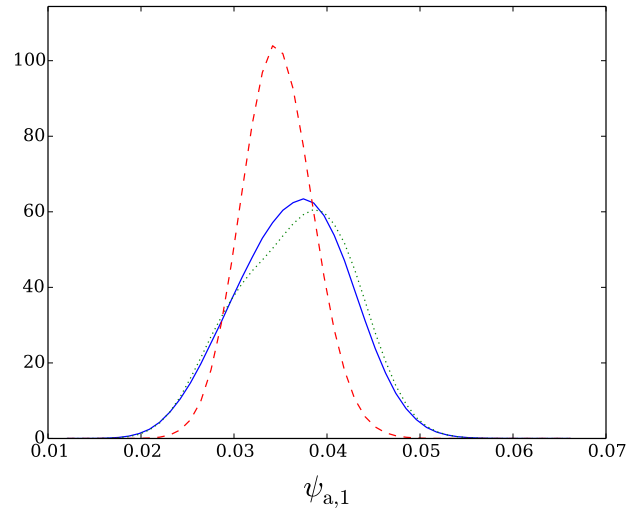


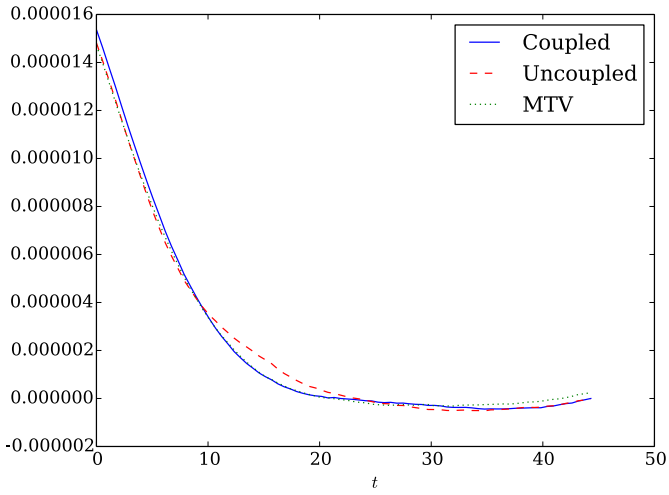


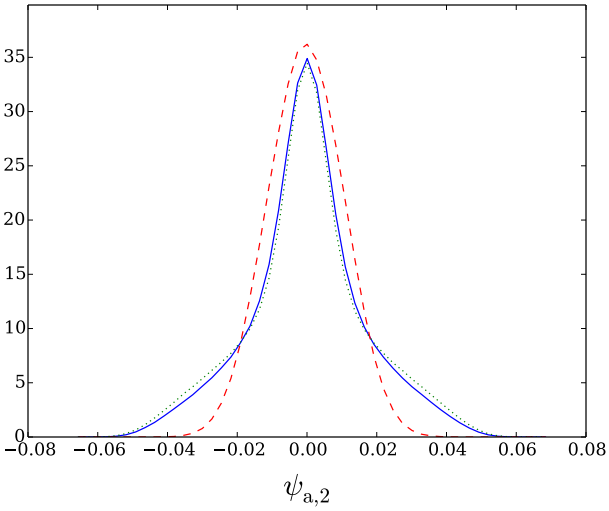
1.2 DDV2016 parameter set

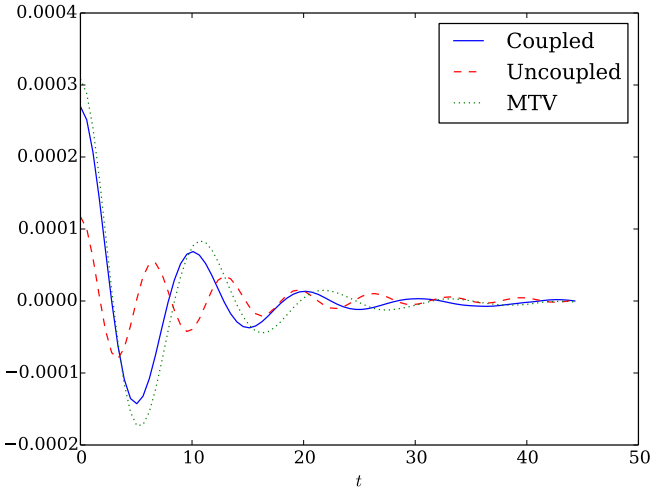
1.2.1 PDFs and autocorrelation functions of the resolved variables

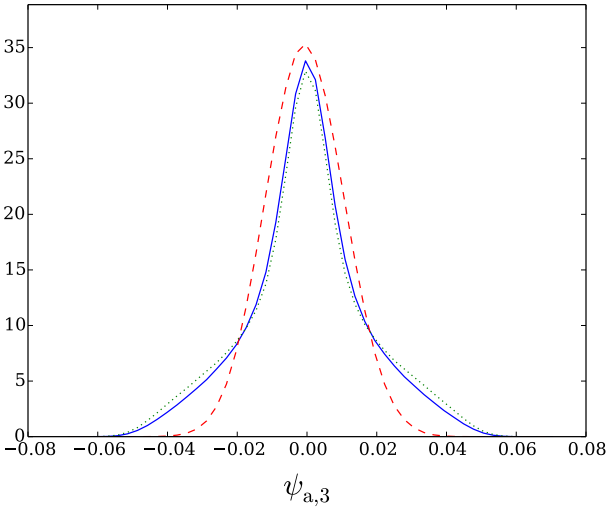
Atmospheric variables of the model.

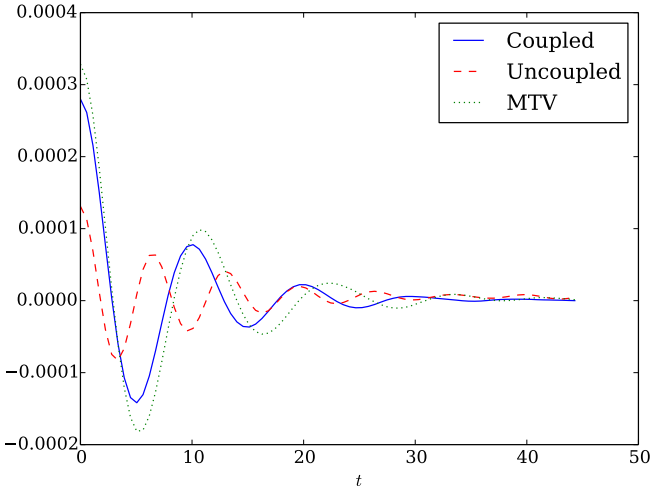


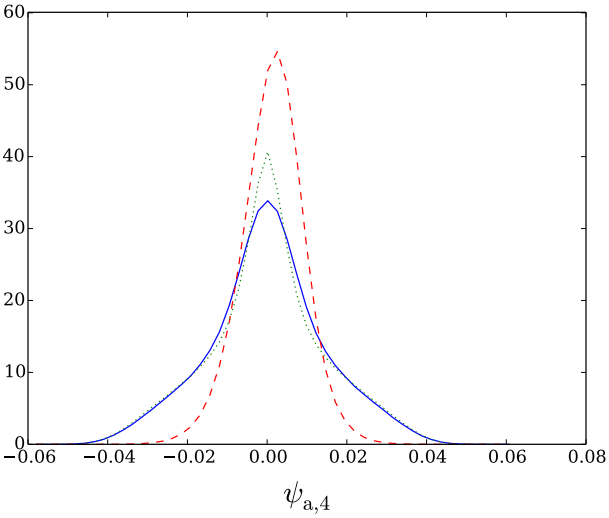


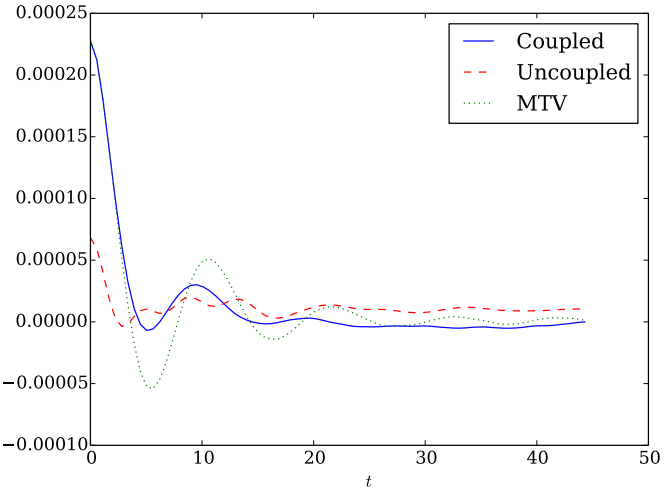

$\psi_{a,2}$

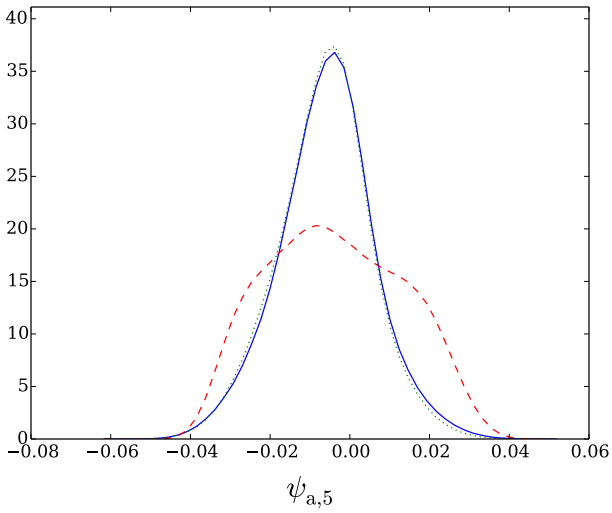

Coupled
Uncoupled
MTV
t

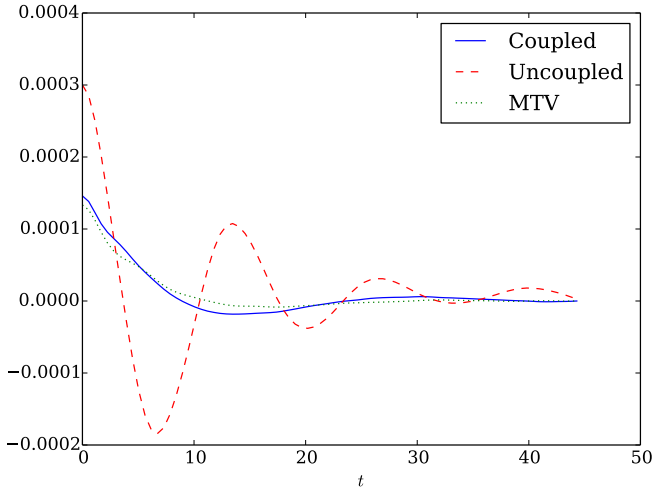

$\psi_{a,3}$

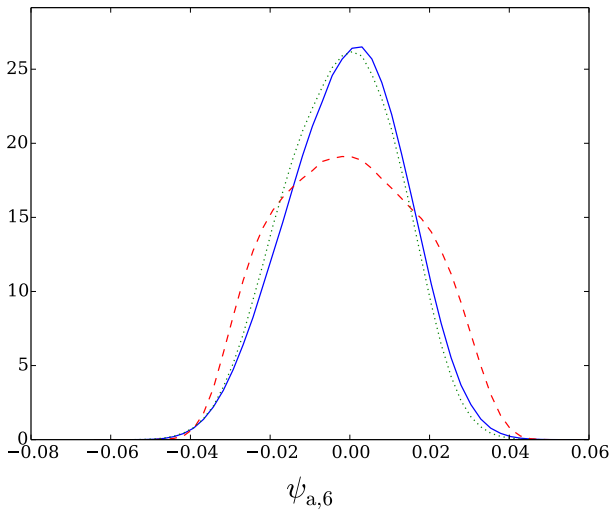

Coupled
Uncoupled
MTV
t

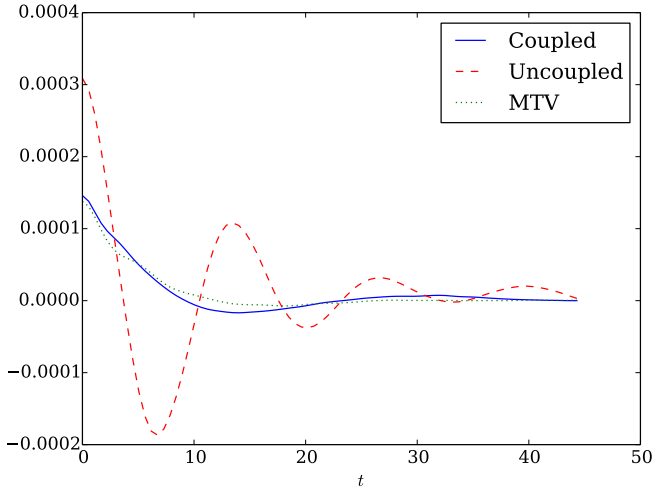

$\psi_{a,4}$

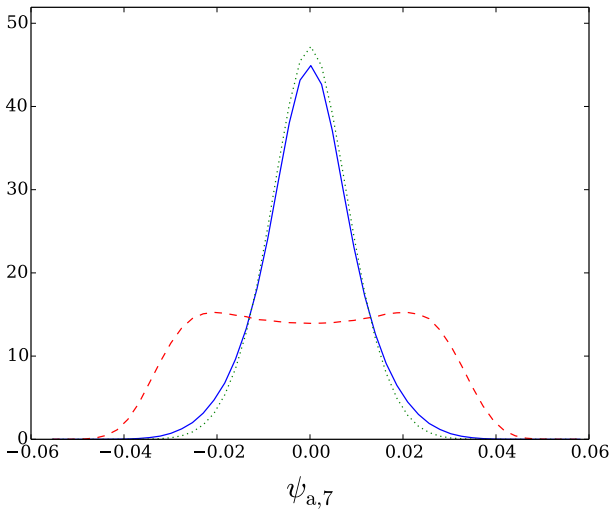

Coupled
Uncoupled
MTV
t

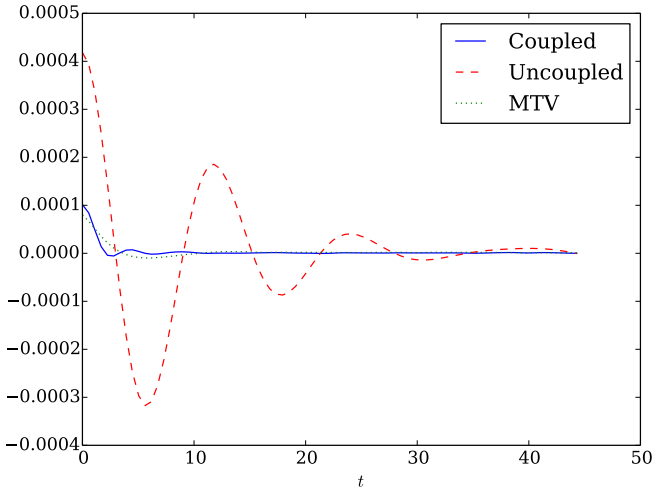

$\psi_{a,5}$

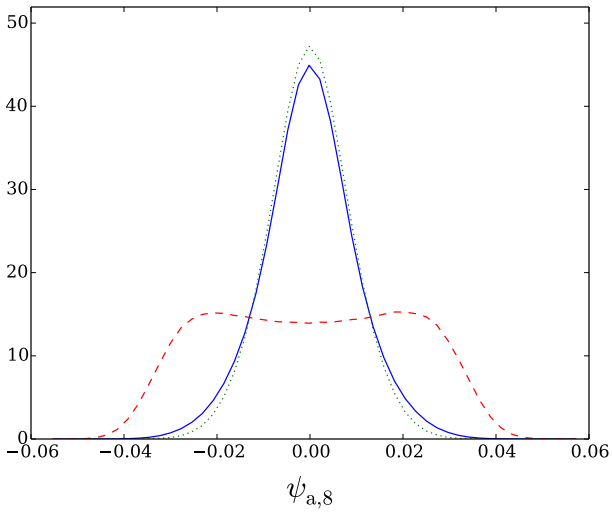

Coupled
Uncoupled
MTV
t

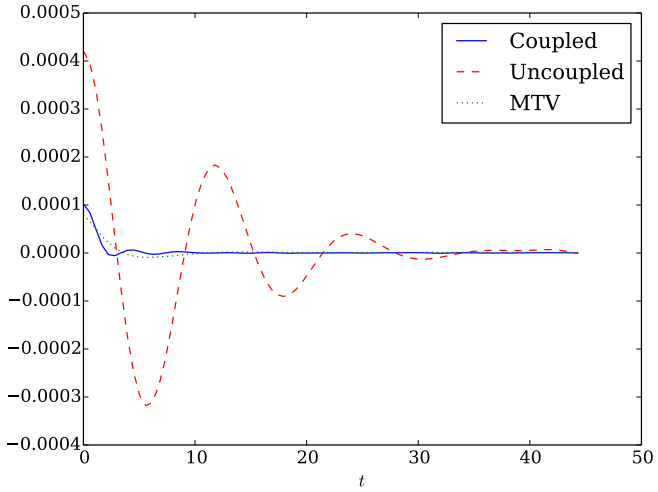

$\psi_{a,6}$

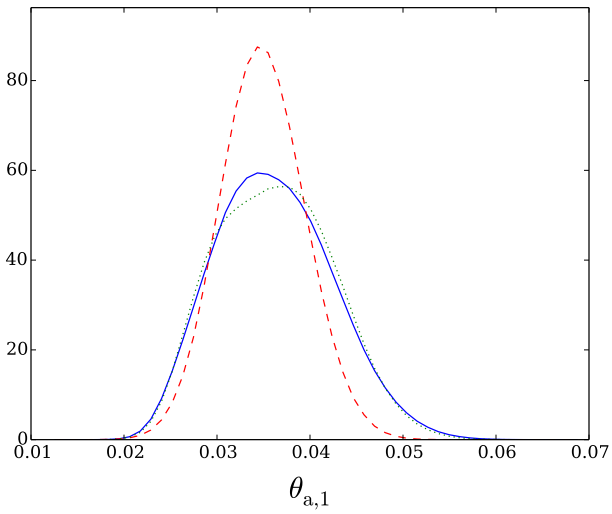

Coupled
Uncoupled
MTV
t

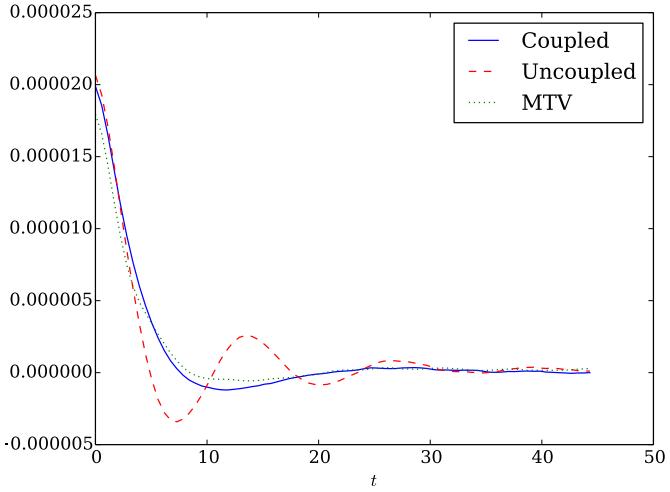

$\psi_{a,7}$

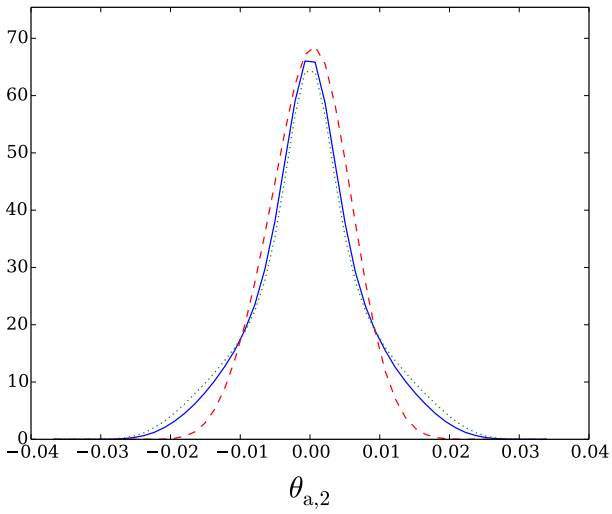

Coupled
Uncoupled
MTV
t

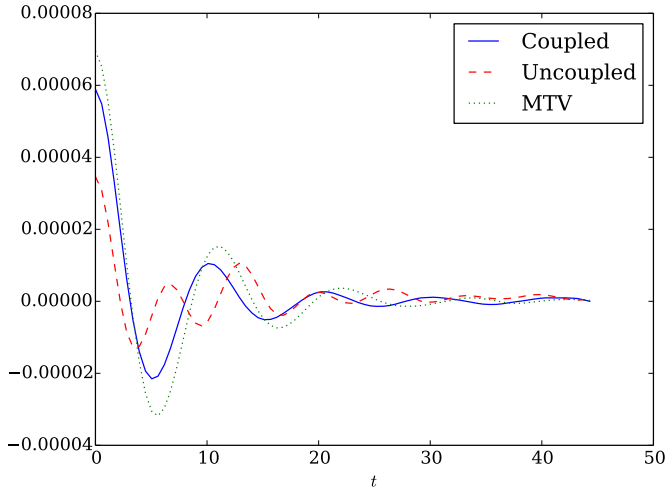

$\psi_{a,8}$

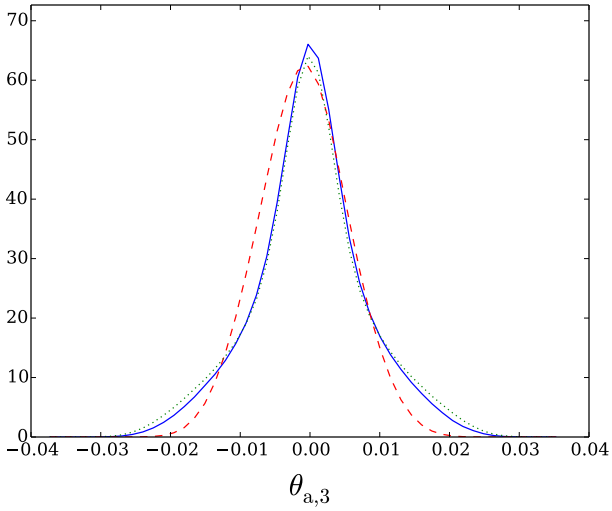

Coupled
Uncoupled
MTV
t

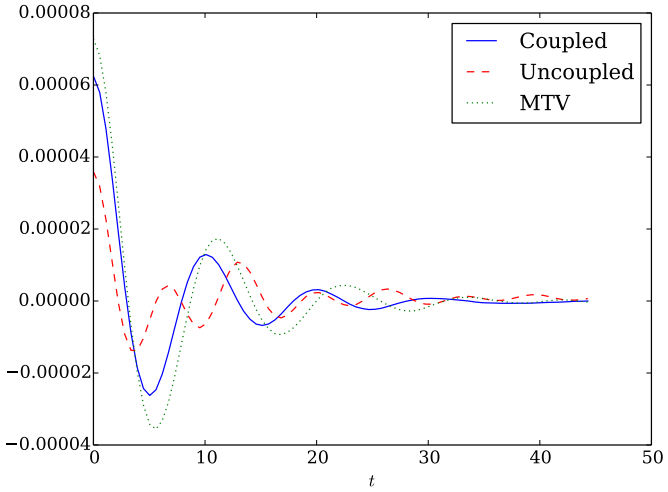

$\theta_{a,1}$

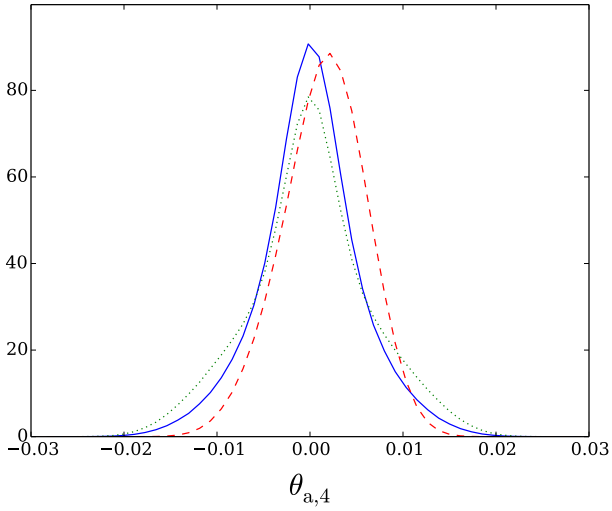

Coupled
Uncoupled
MTV
t

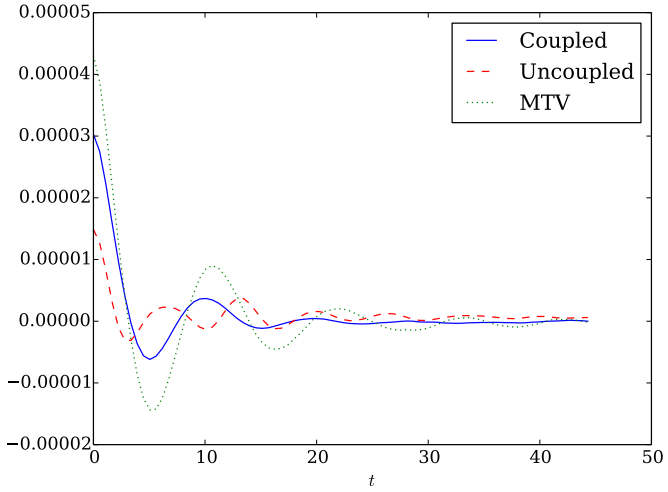

$\theta_{a,2}$

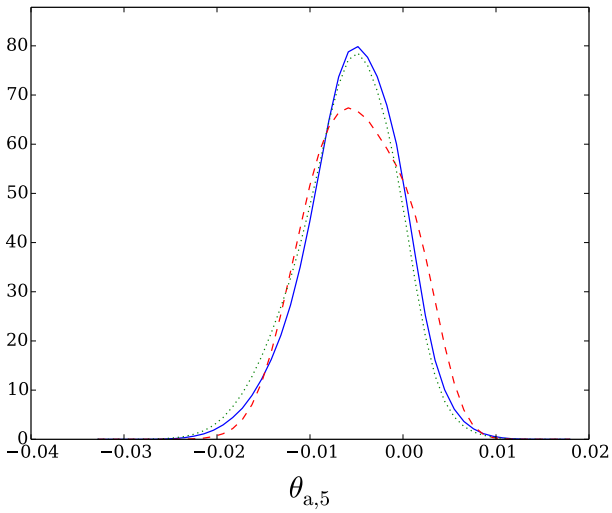

Coupled
Uncoupled
MTV
t

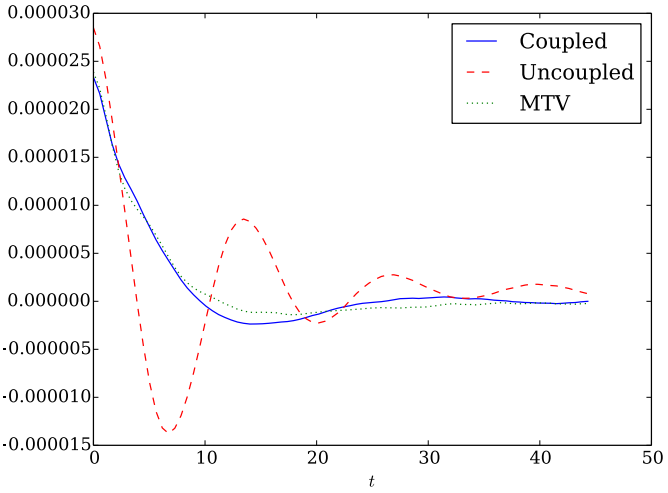

$\theta_{a,3}$

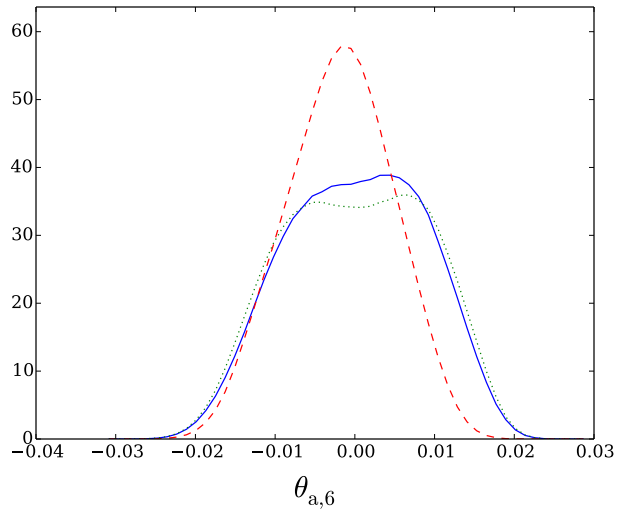

Coupled
Uncoupled
MTV
t

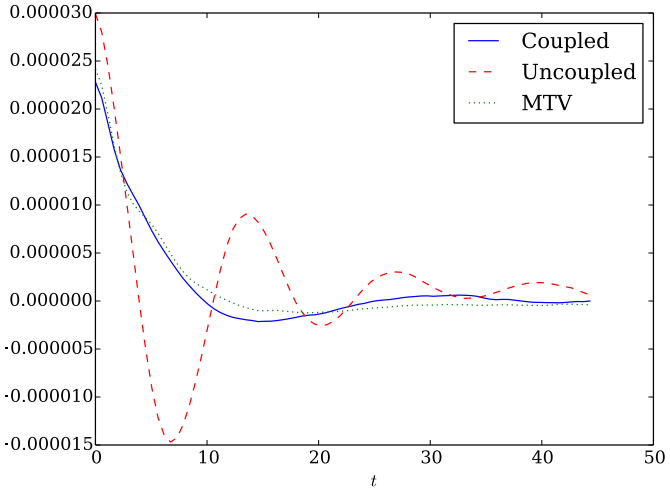

$\theta_{a,4}$

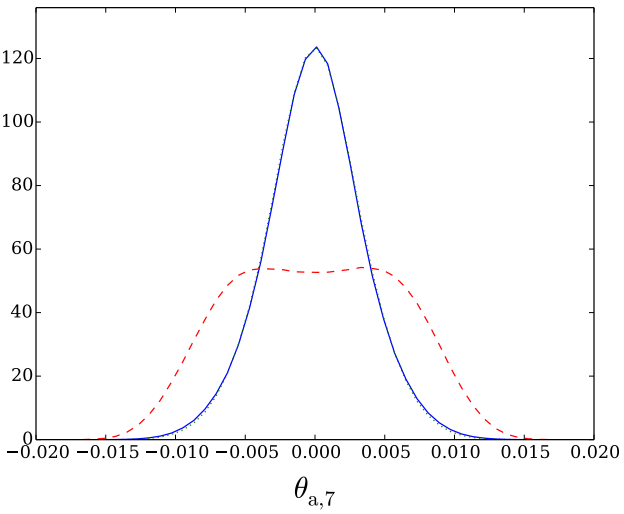

Coupled
Uncoupled
MTV
t

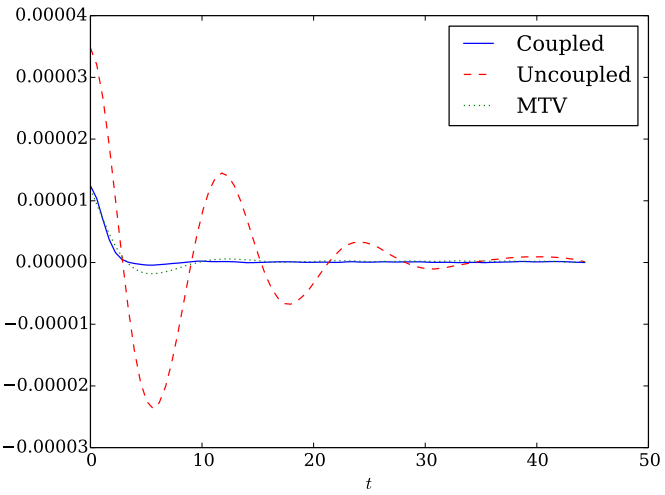

$\theta_{a,5}$

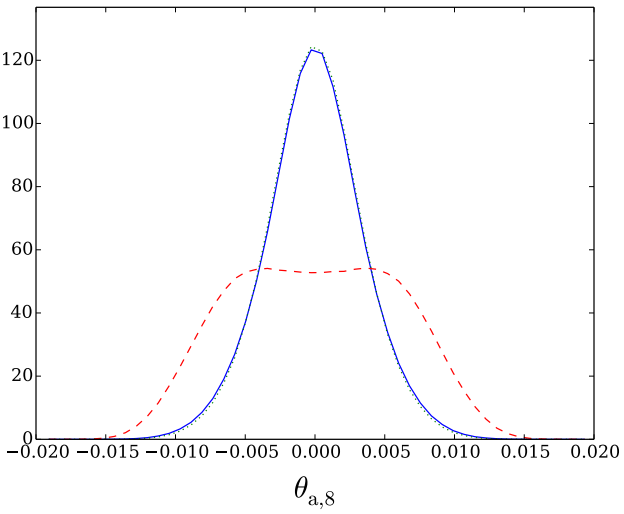

Coupled
Uncoupled
MTV
t

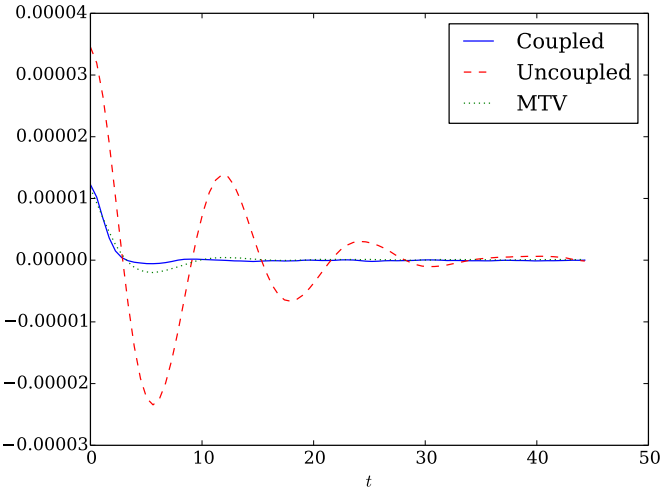




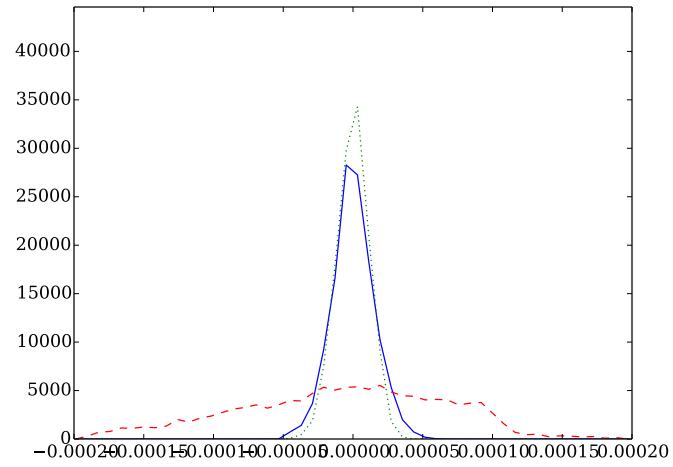




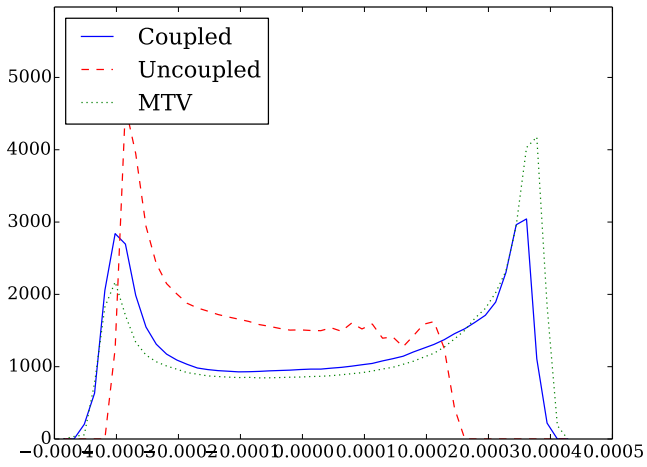




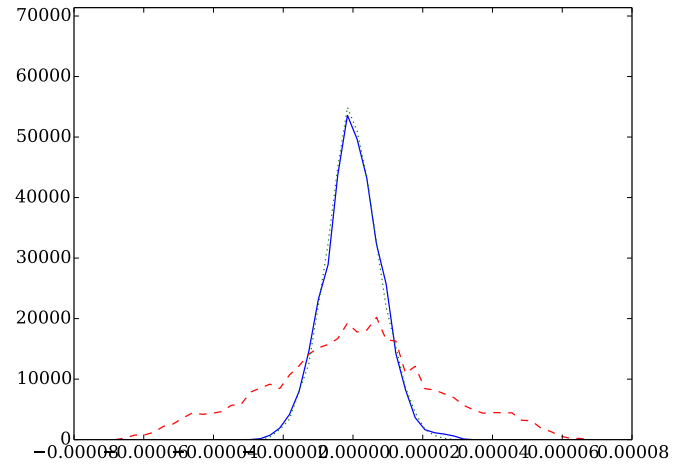
Oceanic variables Only the PDFs are available for these variables.



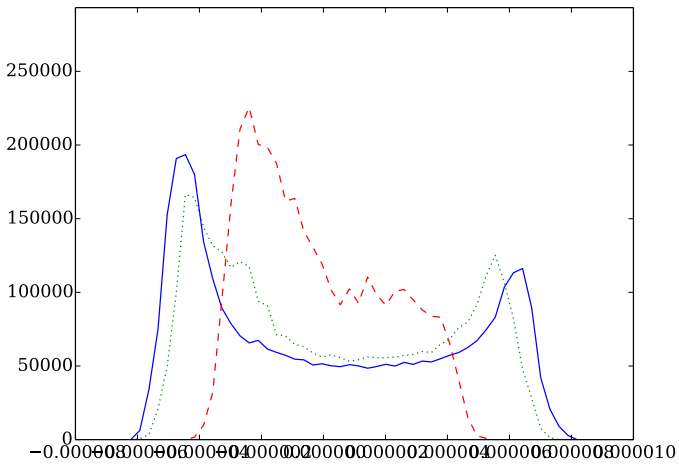
$\psi_{o,1}$



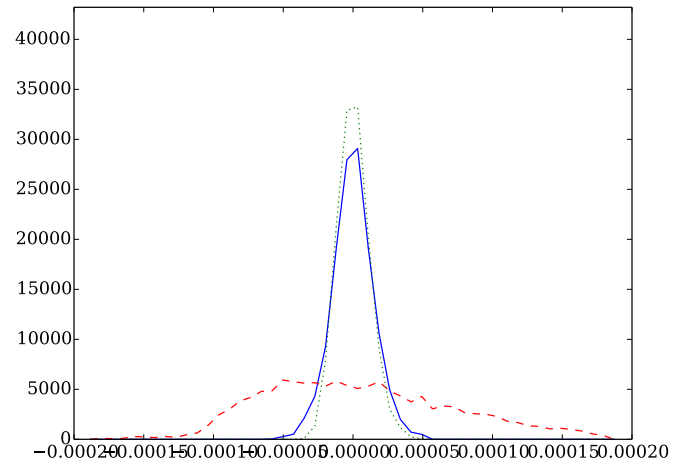
$\psi_{o,2}$



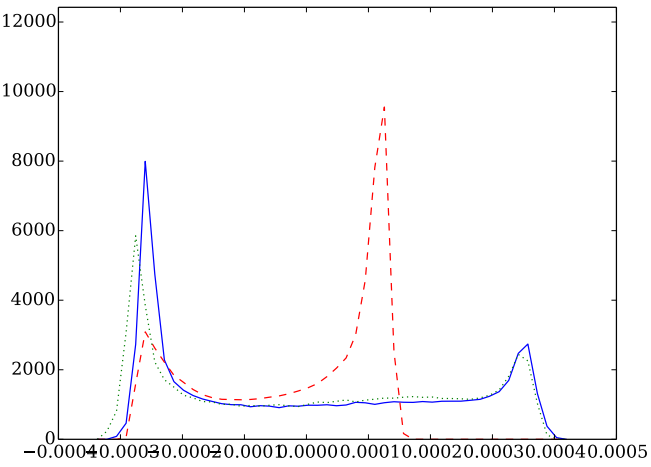
$\psi_{o,3}$



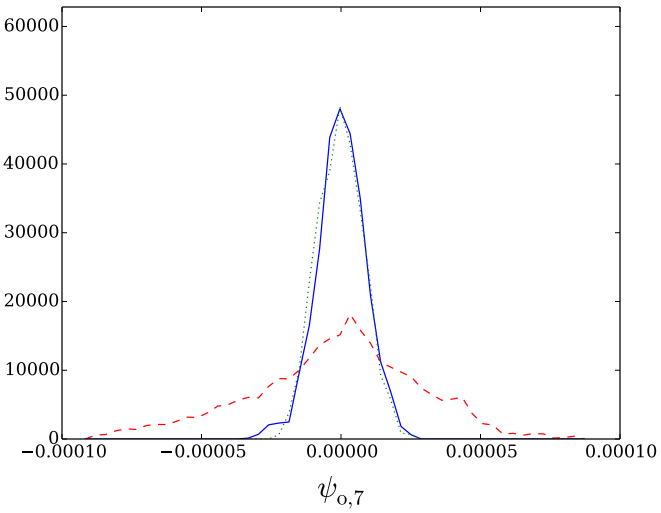
$\psi_{o,4}$



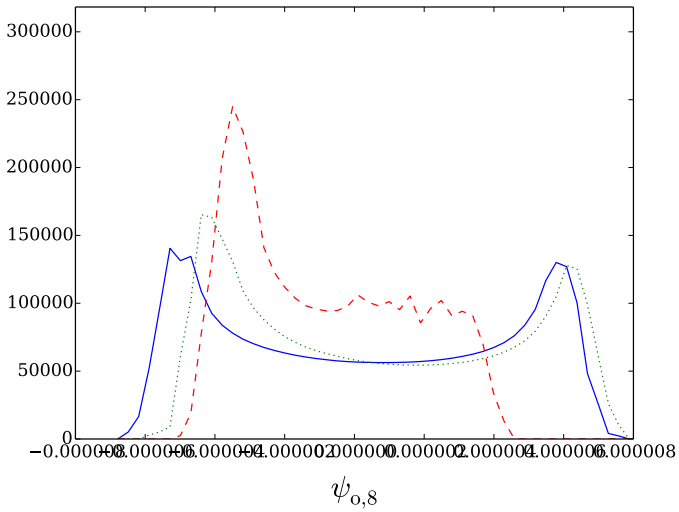
$\psi_{o,5}$



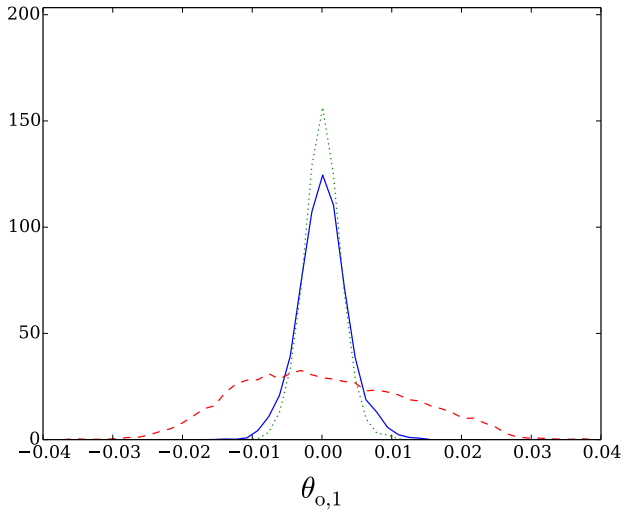
$\psi_{o,6}$



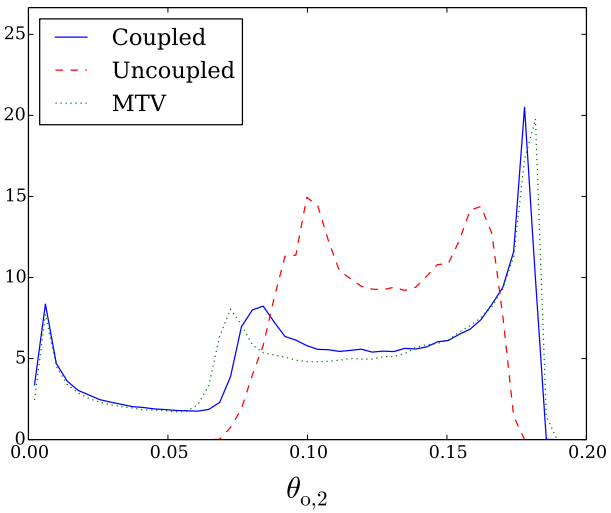
$\psi_{o,7}$



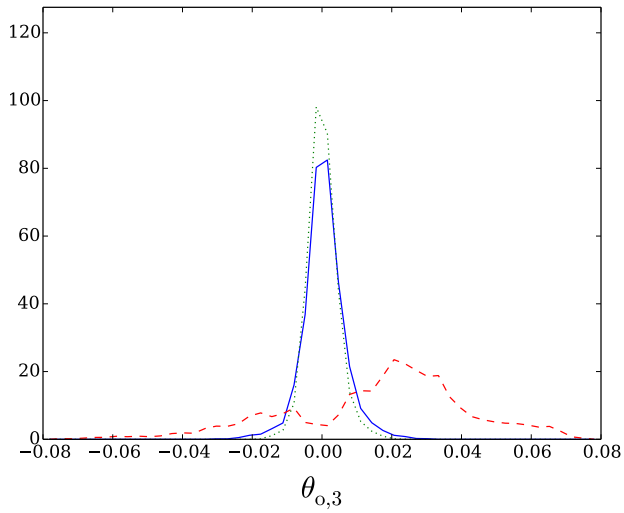
$\psi_{o,8}$



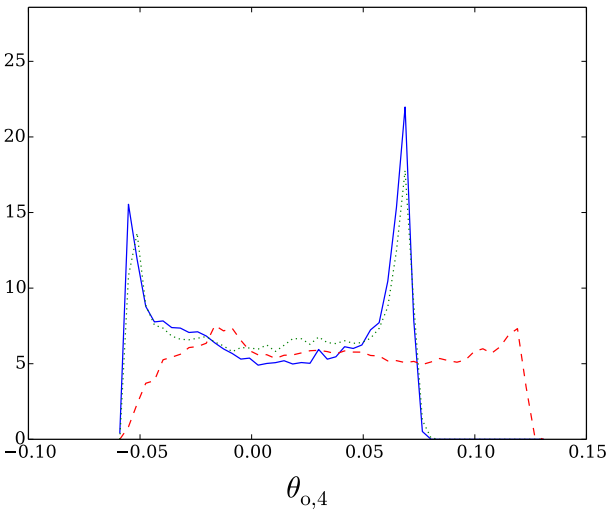
$\theta_{o,1}$



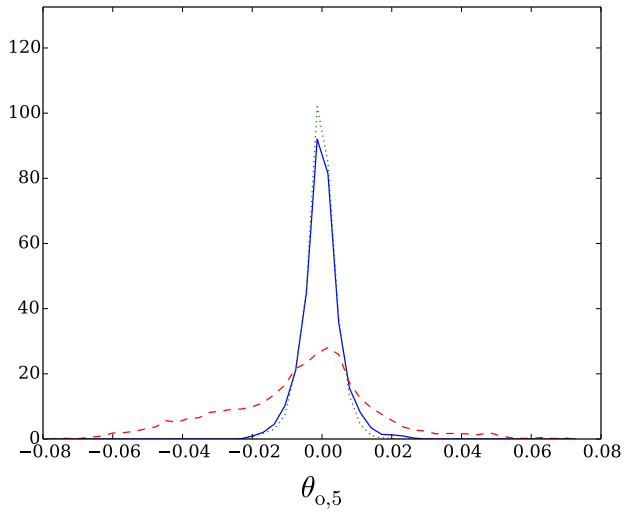
$\theta_{o,2}$

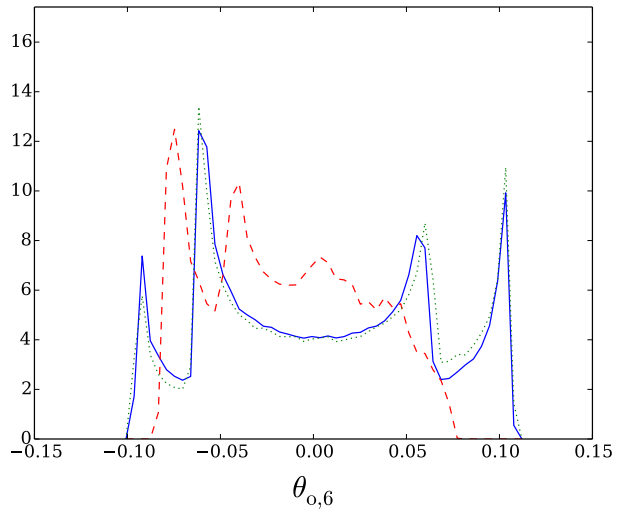


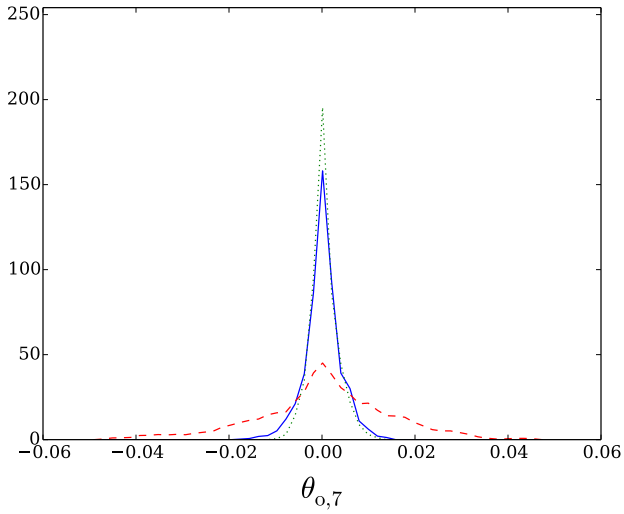
$\theta_{o,3}$

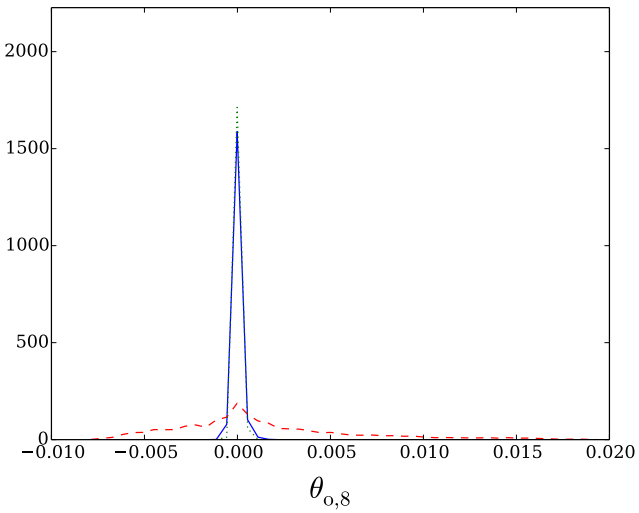


$\theta_{o,4}$

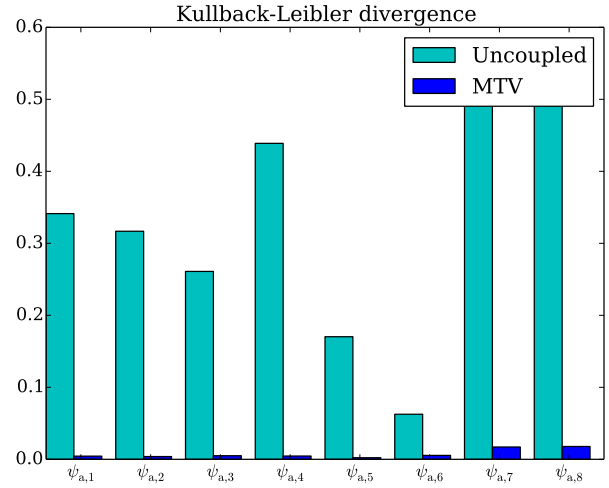

120
100
80
60
40
20
0
−0.08 −0.06 −0.04 −0.02 0.00 0.02 0.04 0.06 0.08
$\theta_{o,5}$

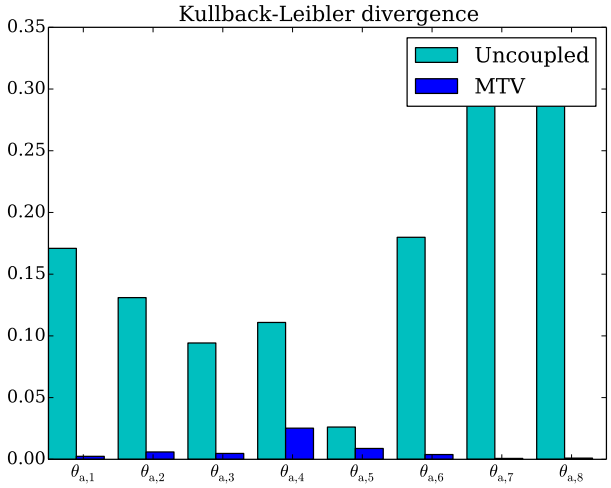

16
14
12
10
8
6
4
2
0
−0.15 −0.10 −0.05 0.00 0.05 0.10 0.15
$\theta_{o,6}$

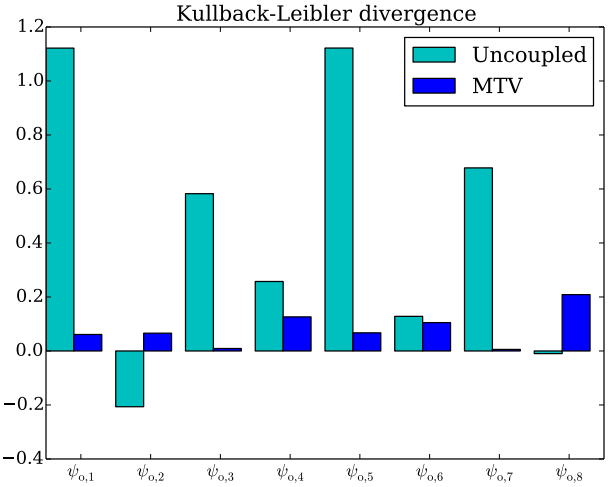

250
200
150
100
50
0
−0.06 −0.04 −0.02 0.00 0.02 0.04 0.06
$\theta_{o,7}$

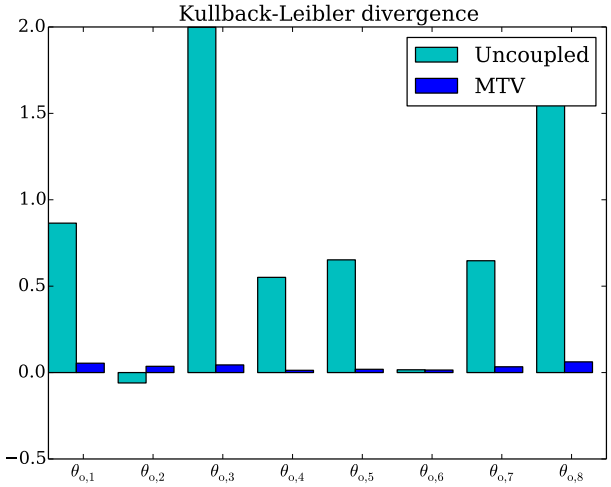

2000
1500
1000
500
0
−0.010 −0.005 0.000 0.005 0.010 0.015 0.020
$\theta_{o,8}$

1.2.2 Kullback-Leibler divergences





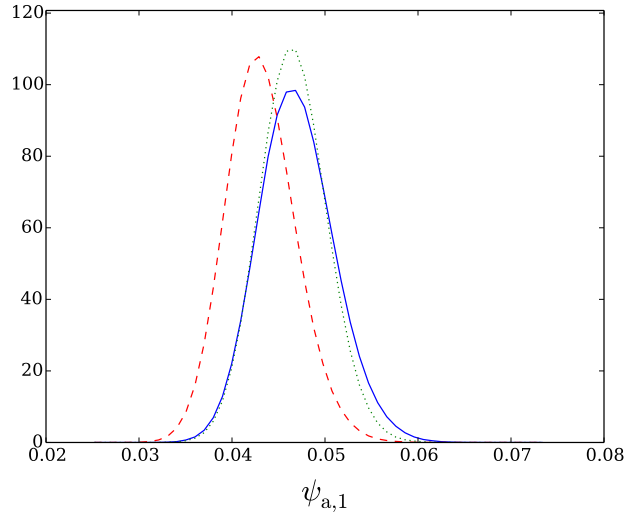


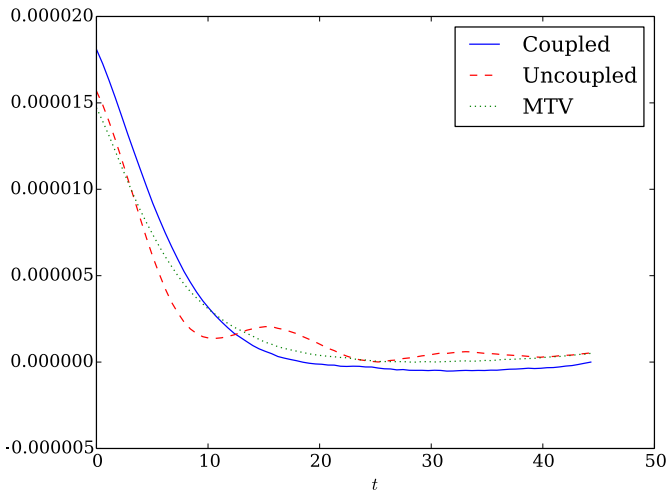


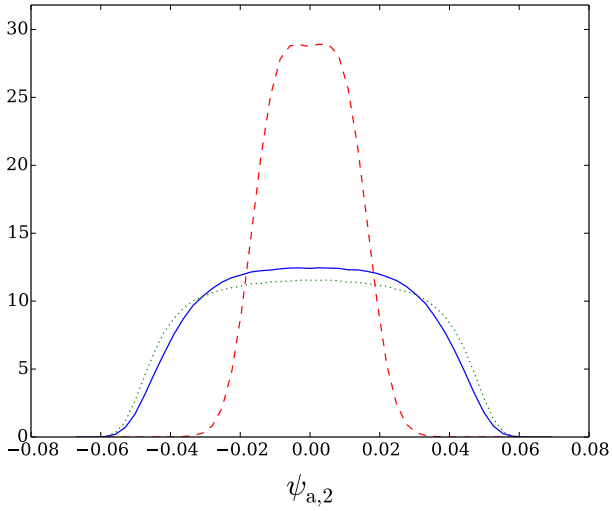
1.3 noLFV parameter set

1.3.1 PDFs and autocorrelation functions of the resolved variables

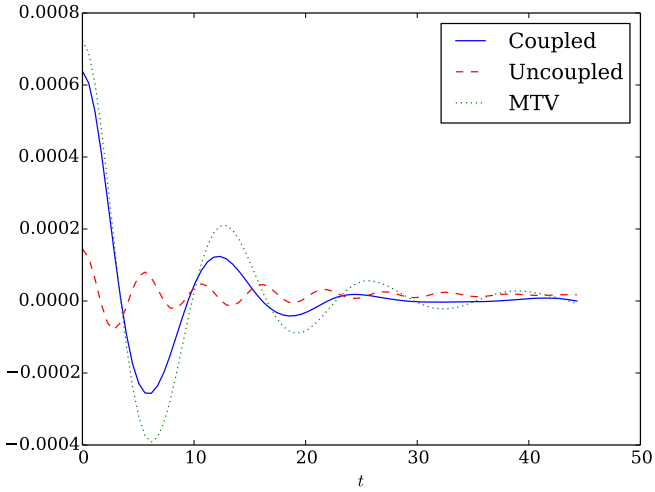
Atmospheric variables of the model.

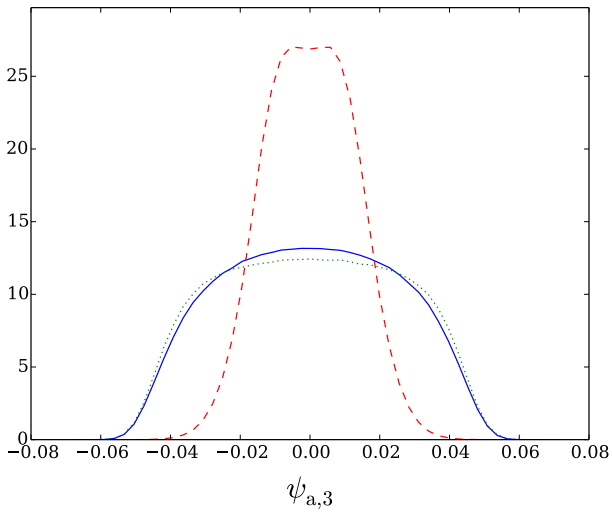




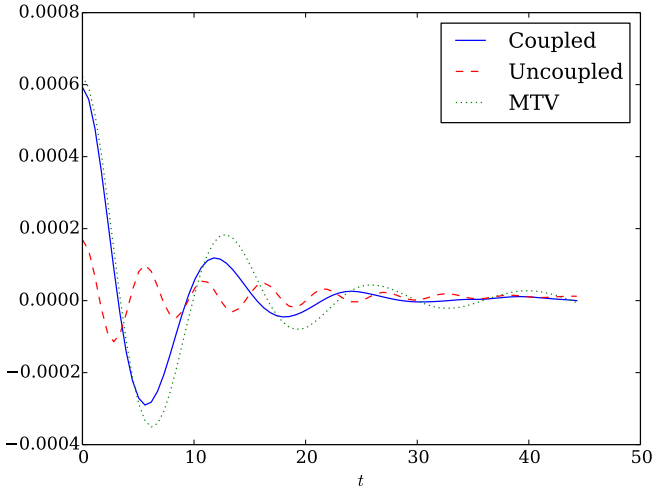


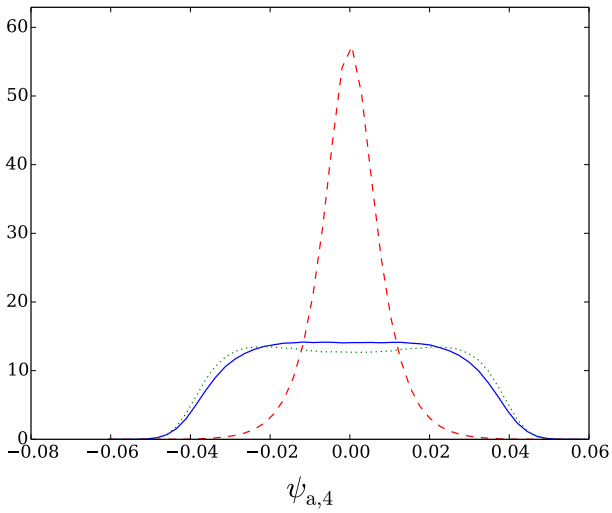
$\psi_{\mathrm{a},2}$



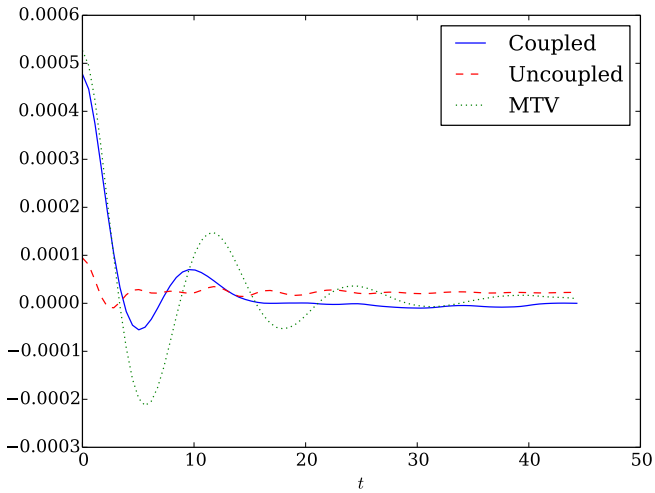


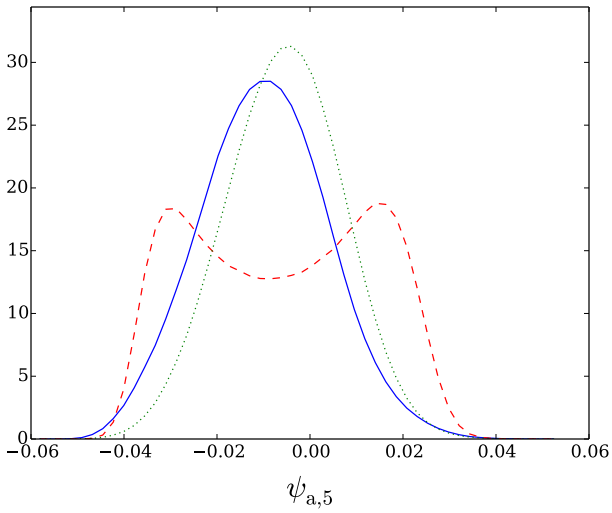
$\psi_{\mathrm{a},3}$

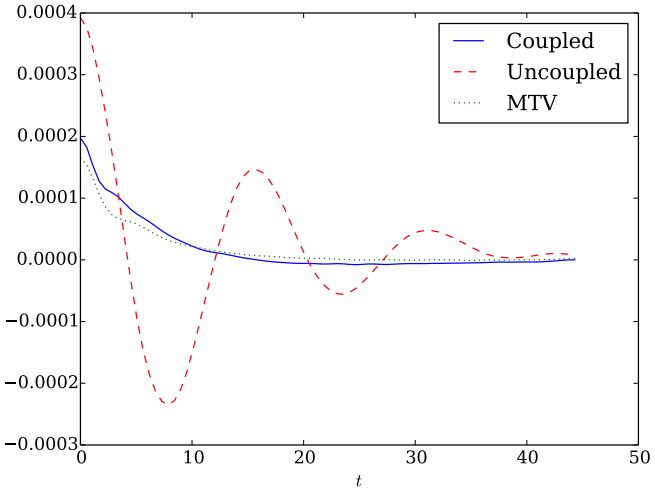


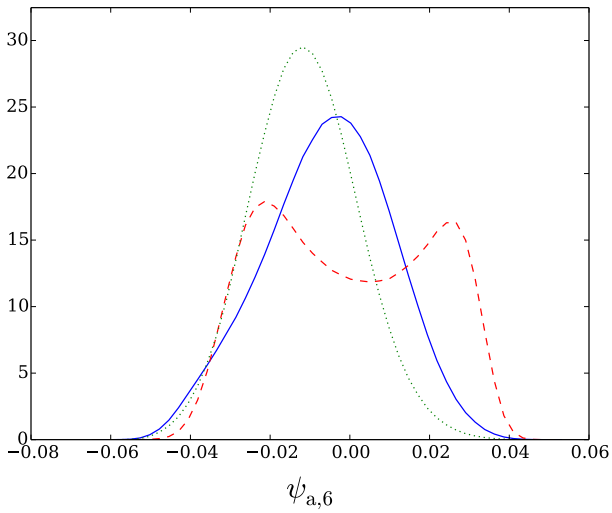


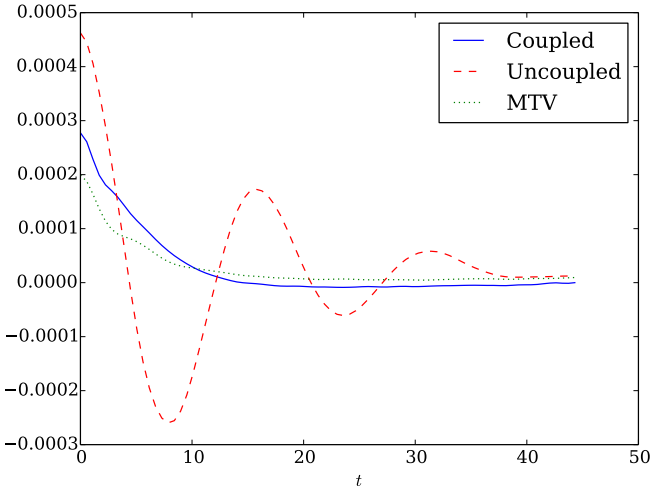
$\psi_{\mathrm{a},4}$

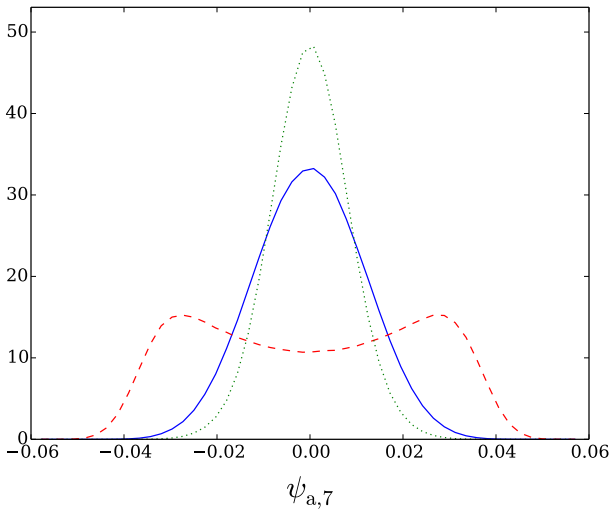


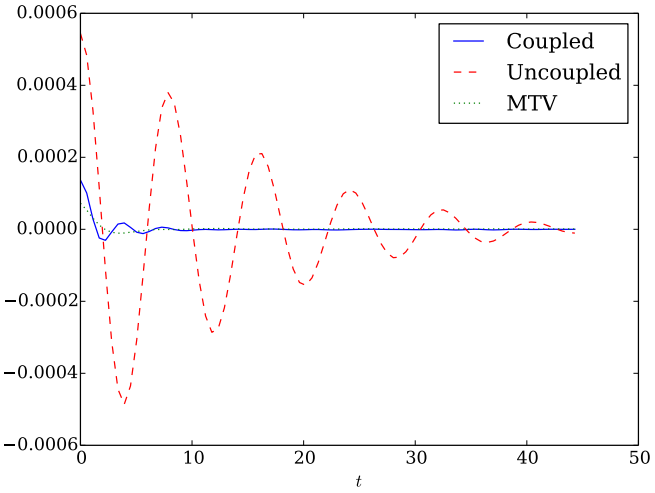

$\psi_{a,5}$

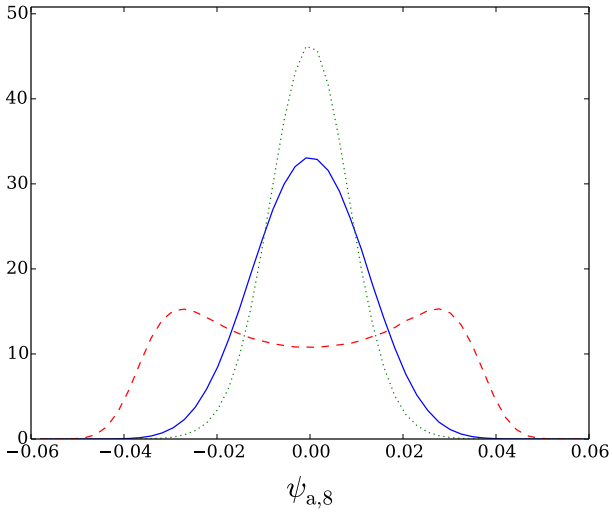

Coupled
Uncoupled
MTV
t

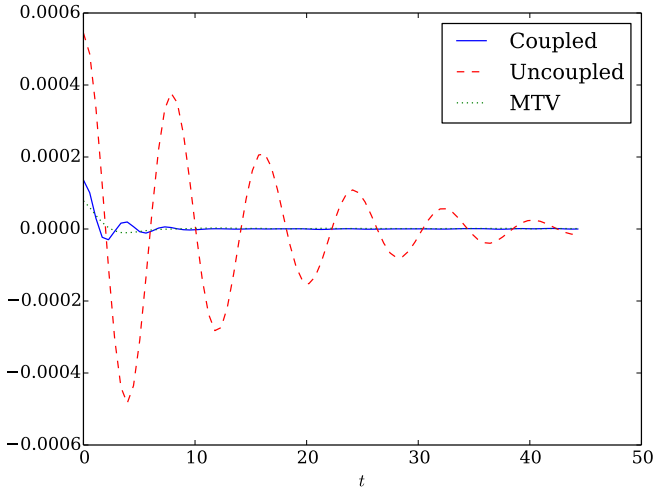

$\psi_{a,6}$

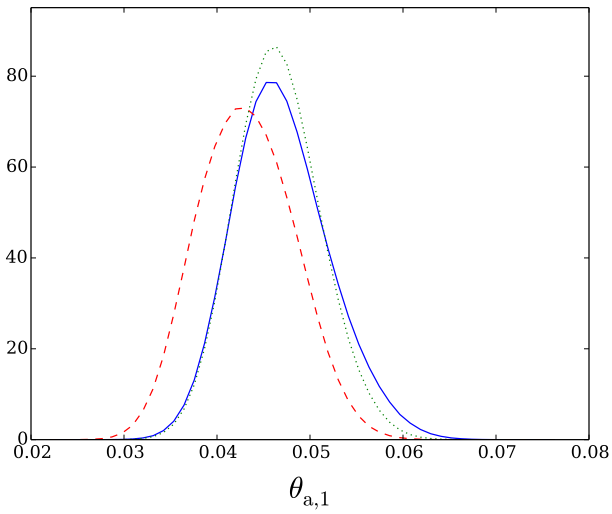

Coupled
Uncoupled
MTV
t

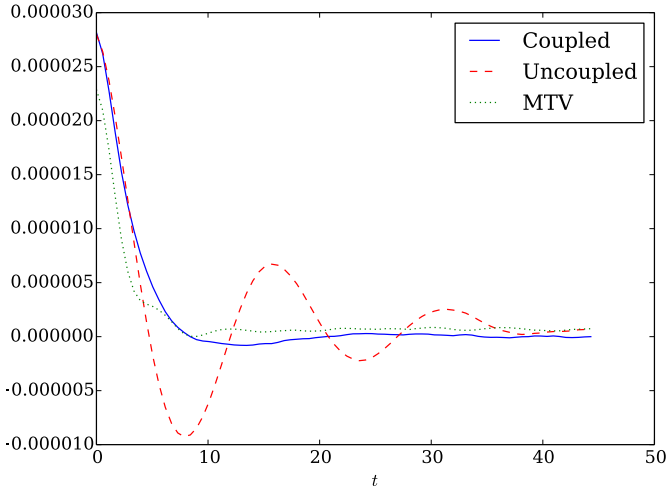

$\psi_{a,7}$

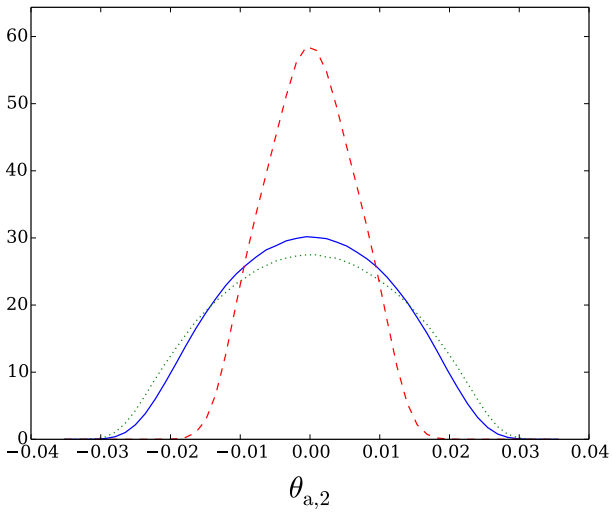

Coupled
Uncoupled
MTV
t

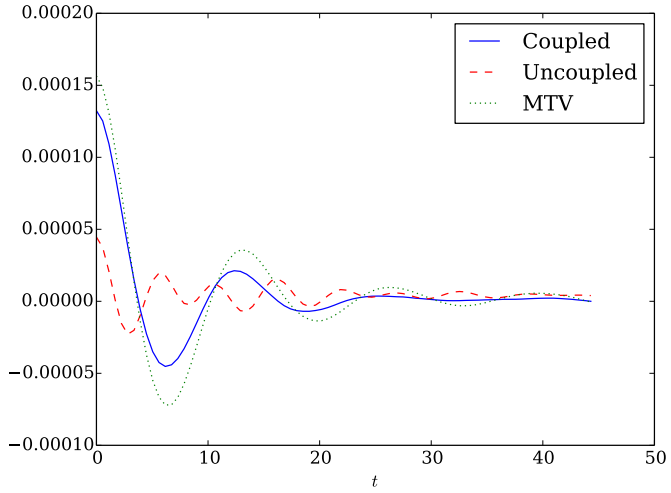

$\psi_{a,8}$

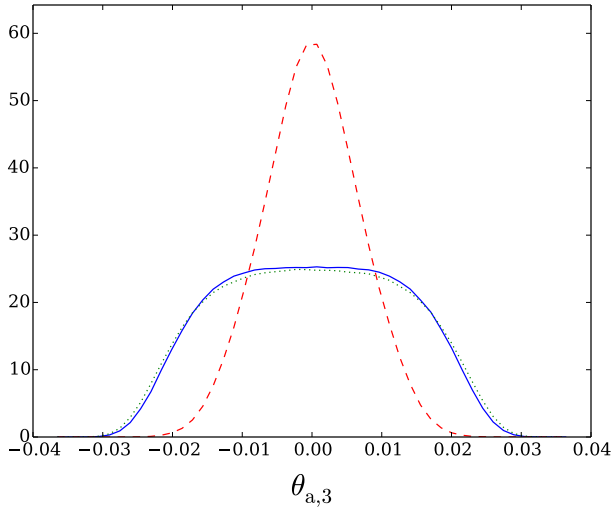

Coupled
Uncoupled
MTV
t

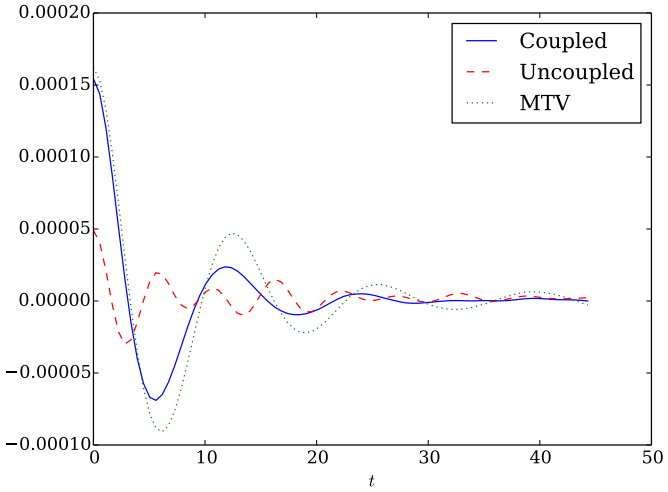

$\theta_{a,1}$

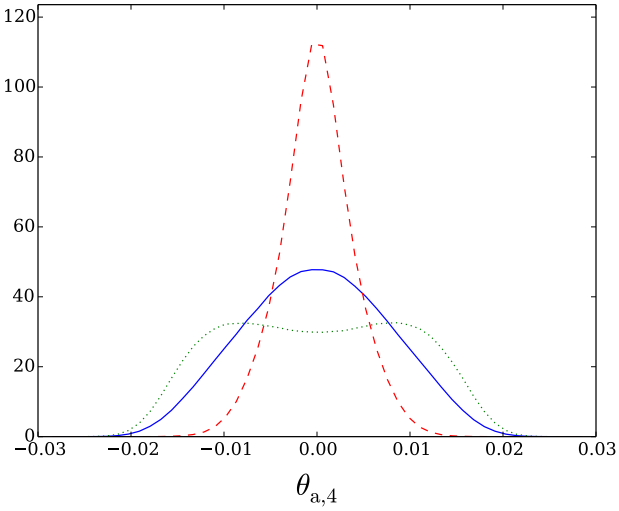

Coupled
Uncoupled
MTV
t

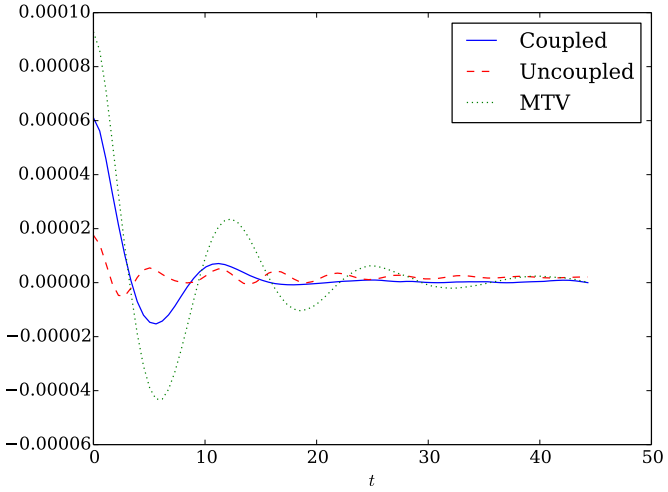

$\theta_{a,2}$

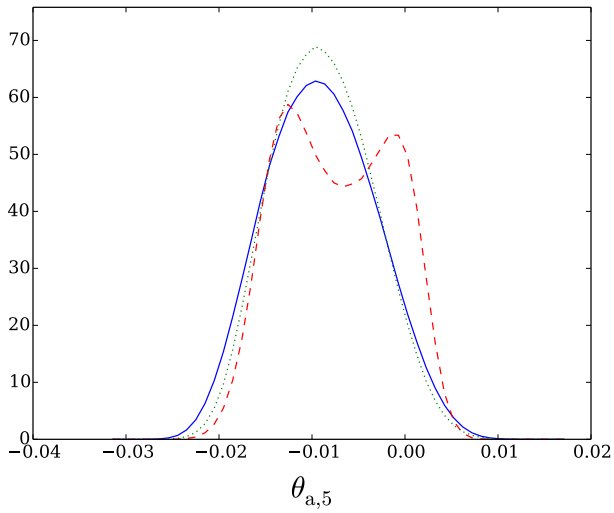

Coupled
Uncoupled
MTV
t

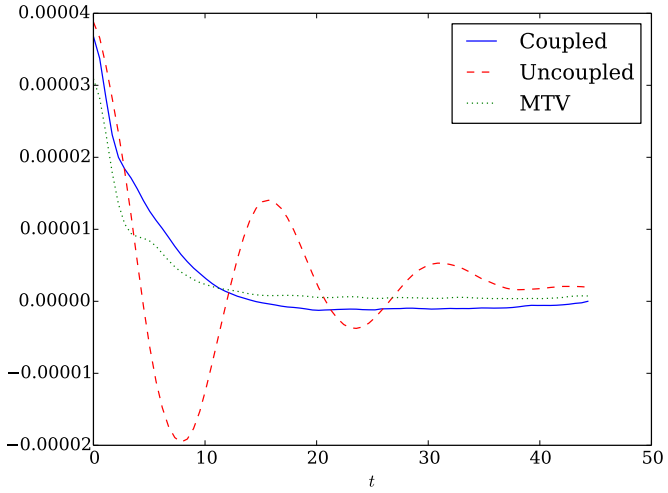

$\theta_{a,3}$

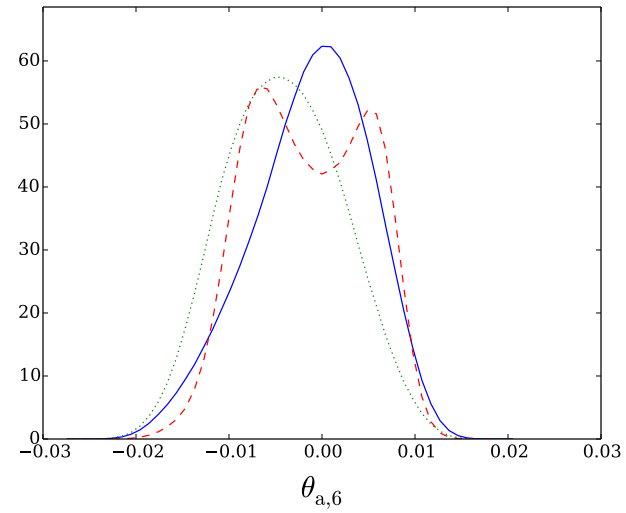

Coupled
Uncoupled
MTV
t

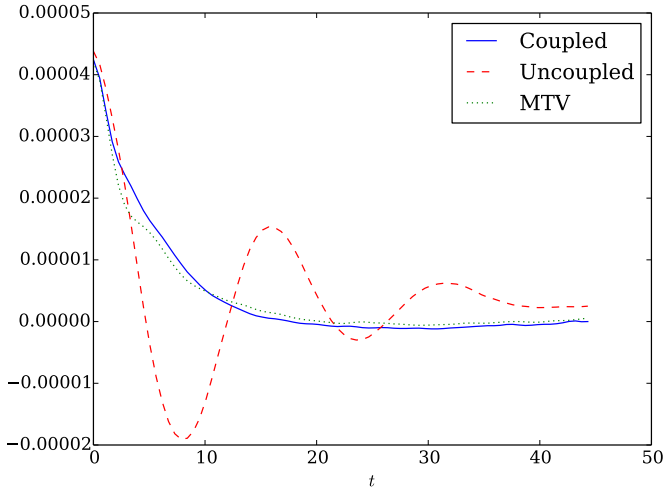

$\theta_{a,4}$

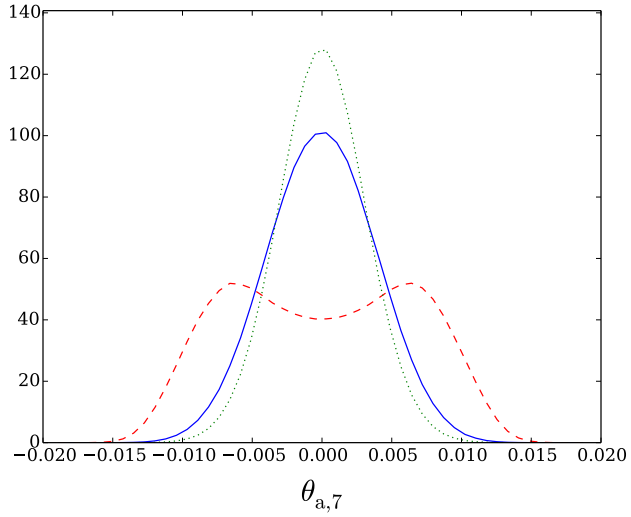

Coupled
Uncoupled
MTV
t

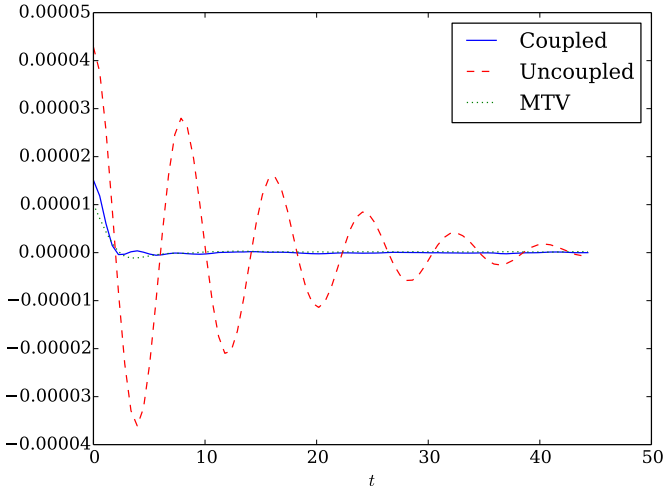

$\theta_{a,5}$

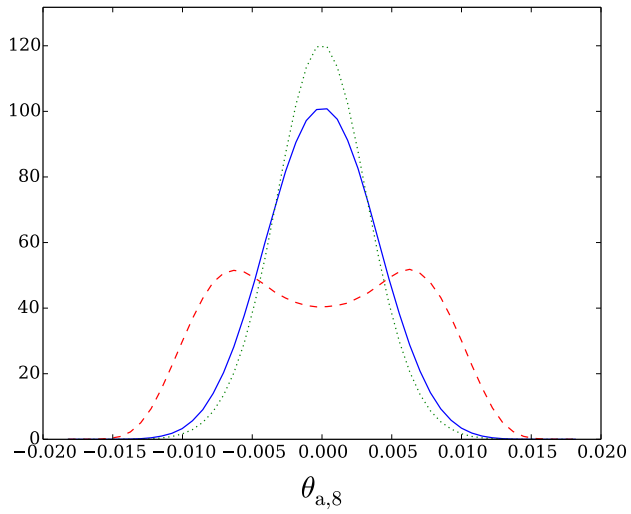

Coupled
Uncoupled
MTV
t

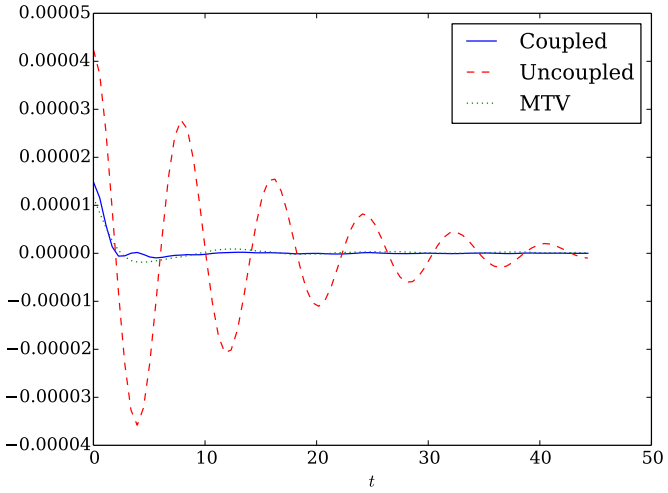




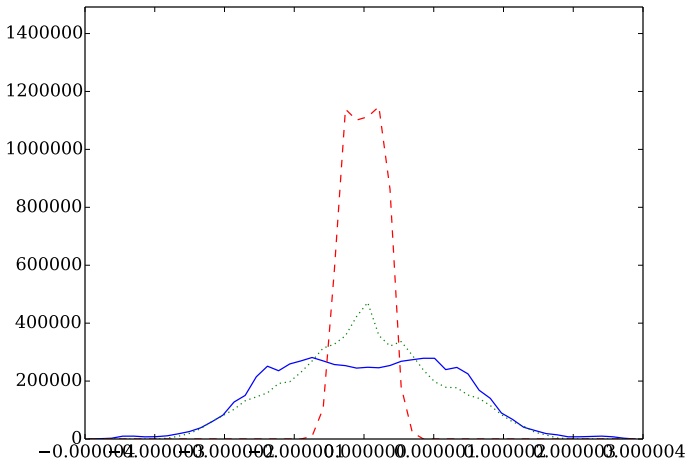




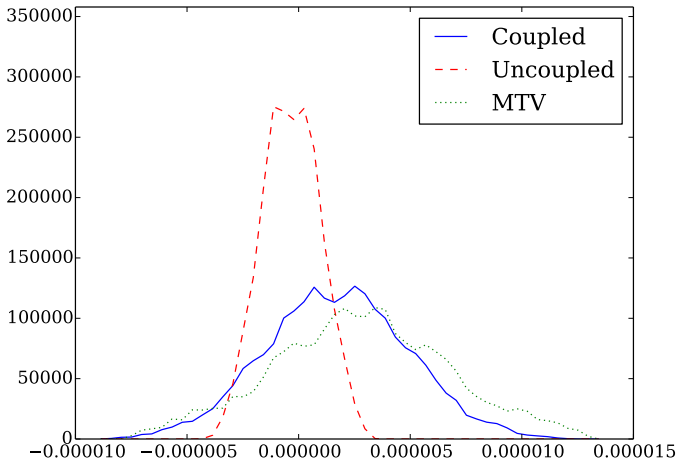




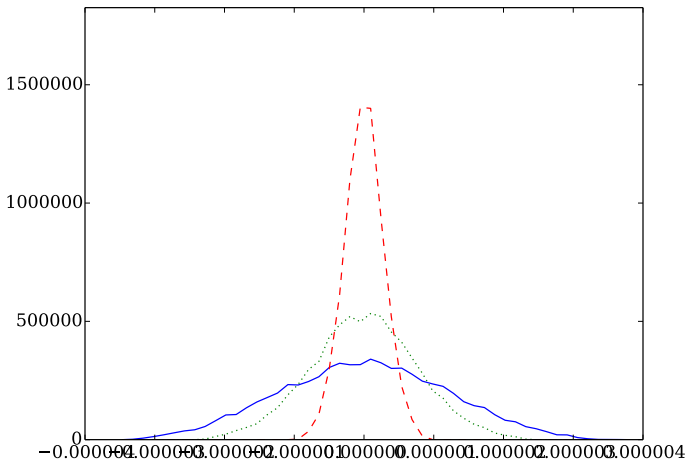
Oceanic variables Only the PDFs are available for these variables.



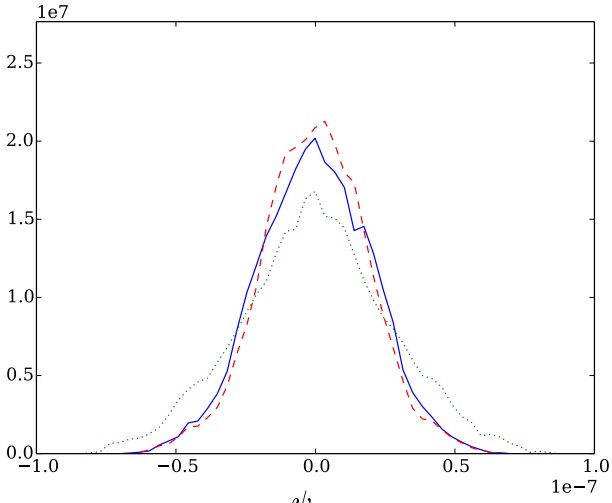
$\psi_{o,1}$



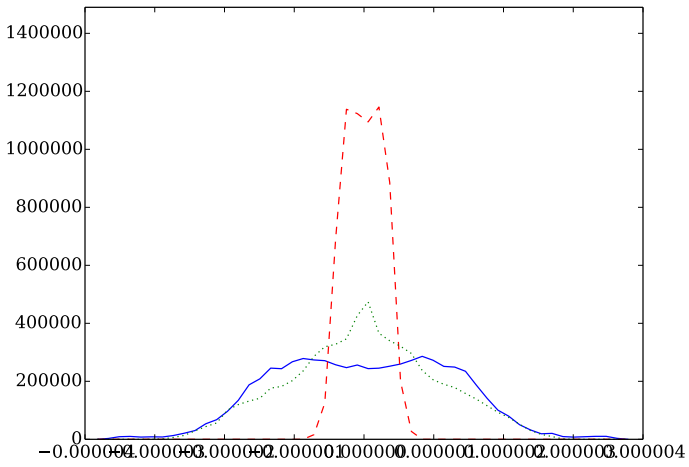
$\psi_{o,2}$



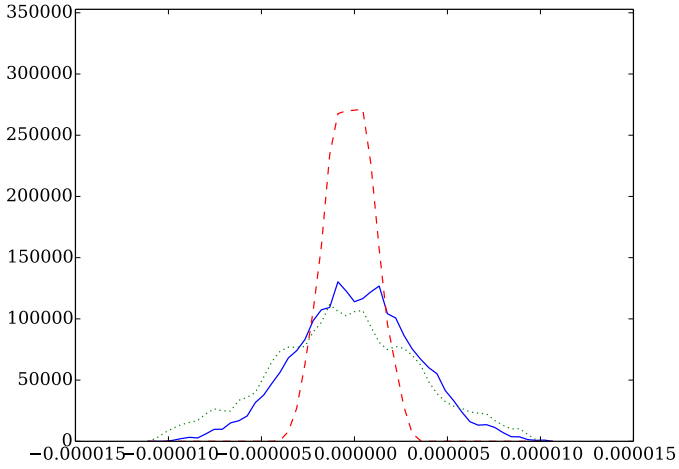
$\psi_{o,3}$



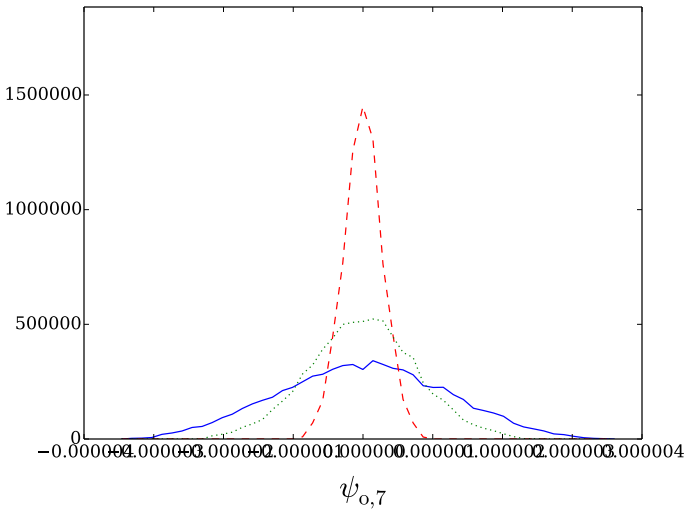
$\psi_{o,4}$



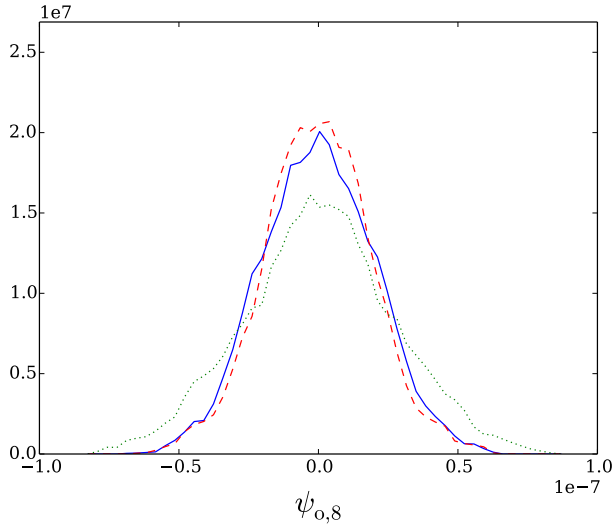
$\psi_{o,5}$



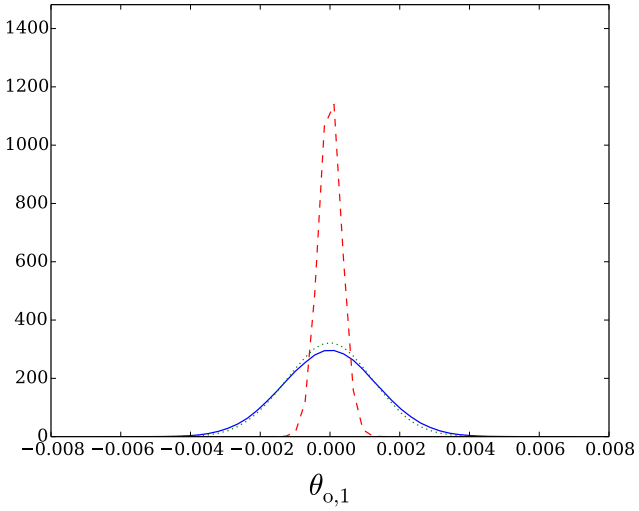
$\psi_{o,6}$



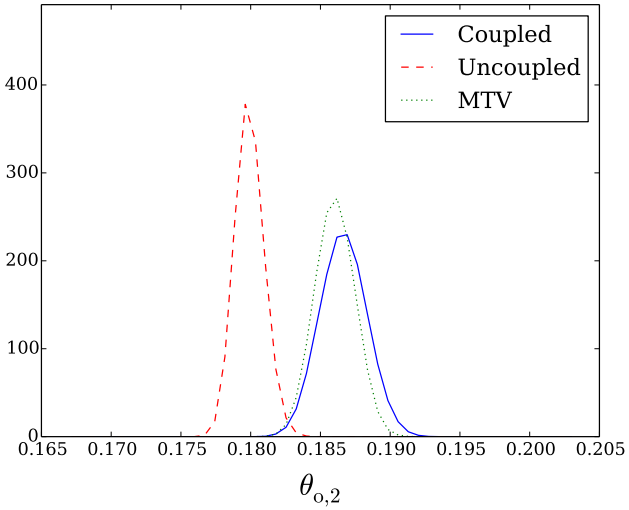
$\psi_{o,7}$



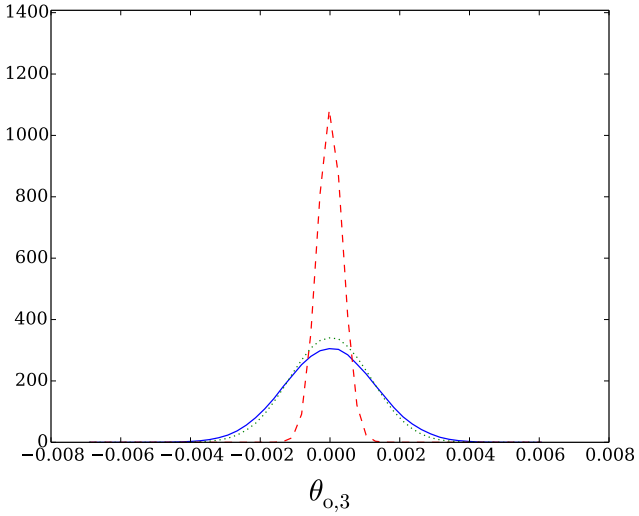
$\psi_{o,8}$



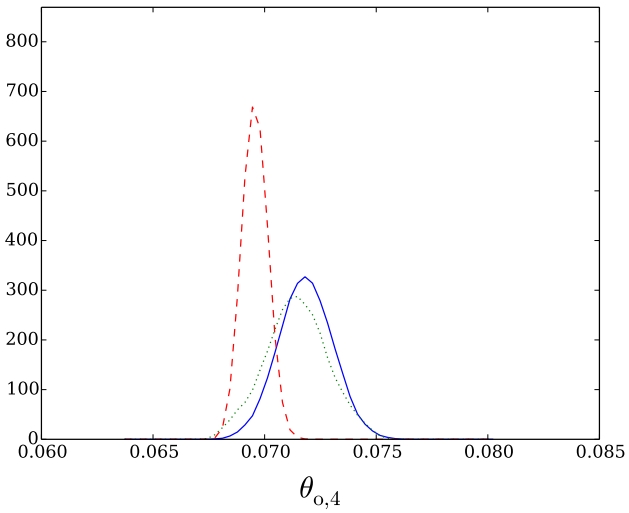
$\theta_{o,1}$



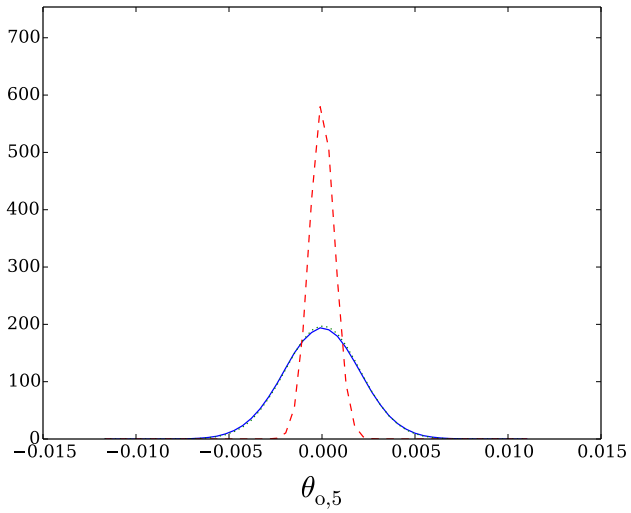
$\theta_{o,2}$

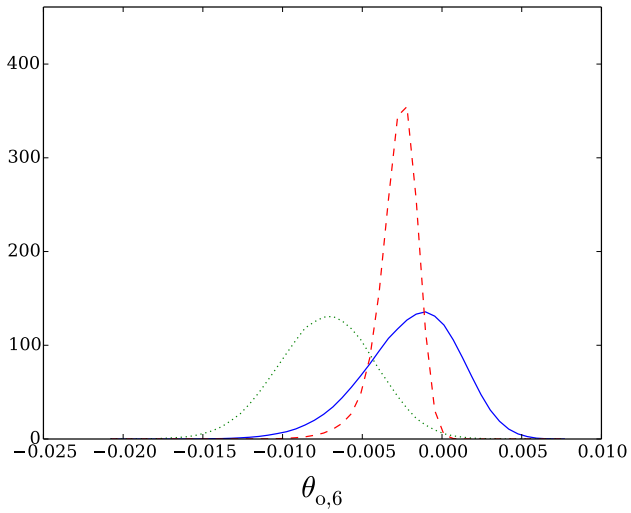


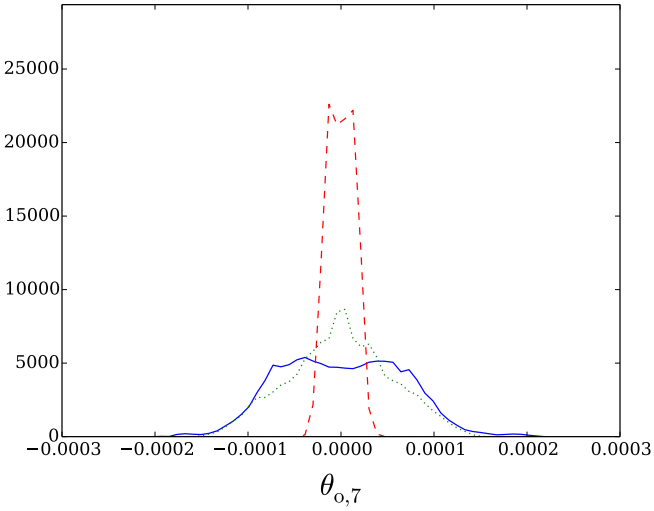
$\theta_{o,3}$

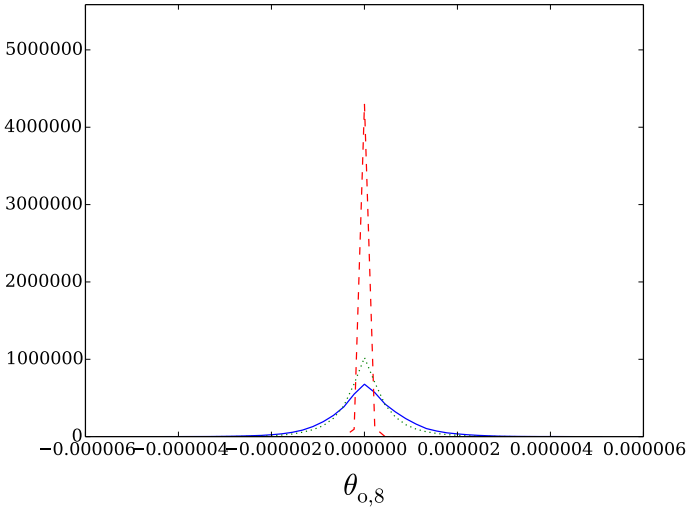


$\theta_{o,4}$

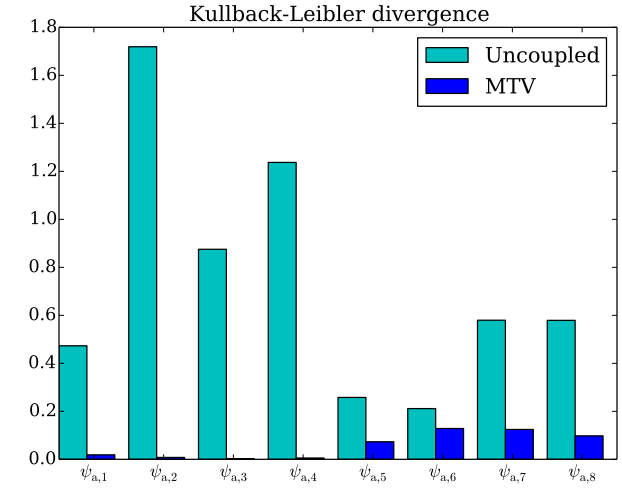

700
600
500
400
300
200
100
0
−0.015
−0.010
−0.005
0.000
0.005
0.010
0.015
$\theta_{o,5}$

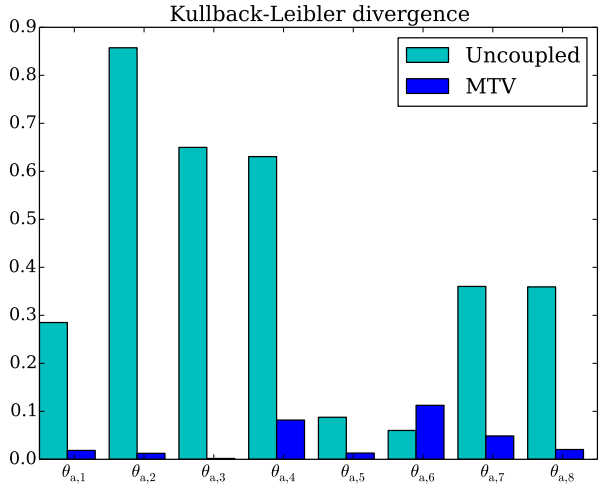

400
300
200
100
0
−0.025
−0.020
−0.015
−0.010
−0.005
0.000
0.005
0.010
$\theta_{o,6}$

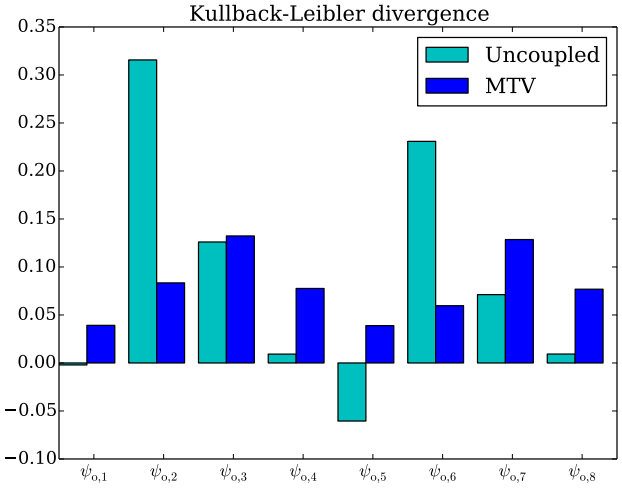

25000
20000
15000
10000
5000
0
−0.0003
−0.0002
−0.0001
0.0000
0.0001
0.0002
0.0003
$\theta_{o,7}$

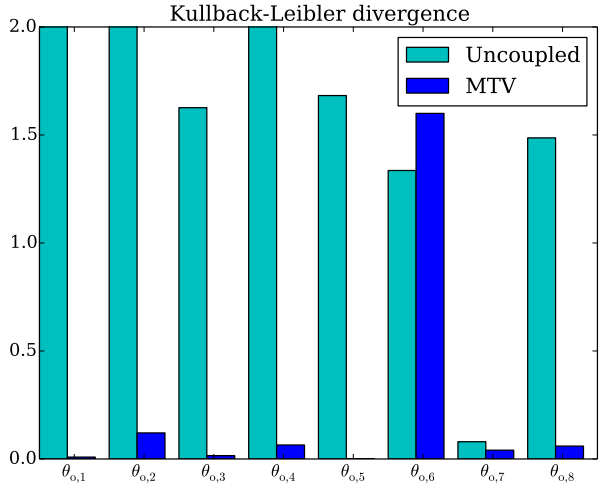

5000000
4000000
3000000
2000000
1000000
0
−0.000006
−0.000004
−0.000002
0.000000
0.000002
0.000004
0.000006
$\theta_{o,8}$

1.3.2 Kullback-Leibler divergences









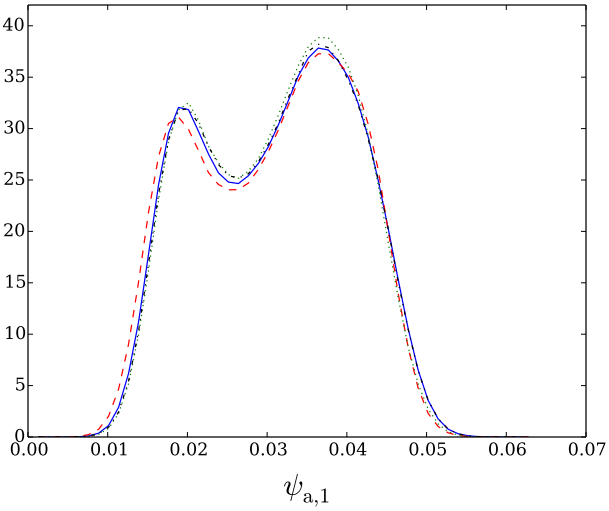
2 Parameterization of the wavenumber 2 atmospheric baroclinic variables

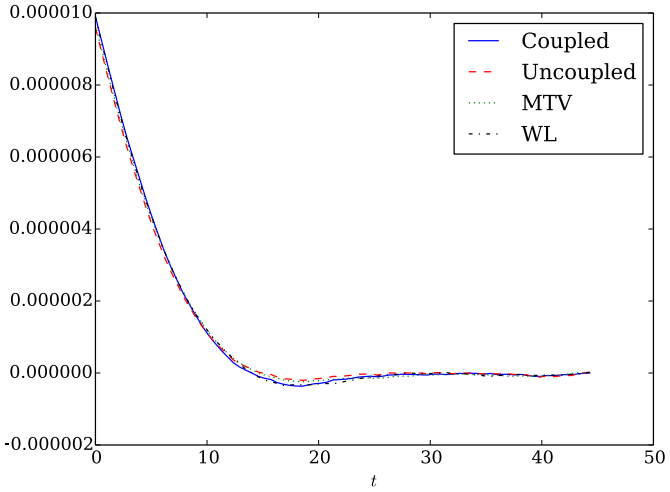
All the figures compiled in this section are related to the experiment described in the section 4.1.3 and concern the "DV2017", "DDV2016" and "noLFV" parameter sets.

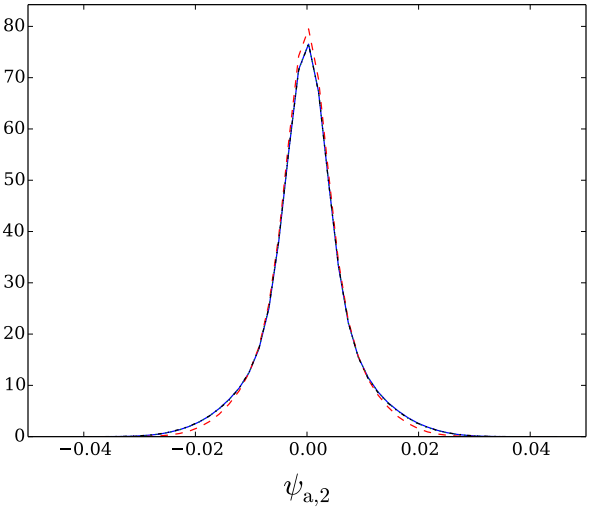
2.1 DV2017 parameter set

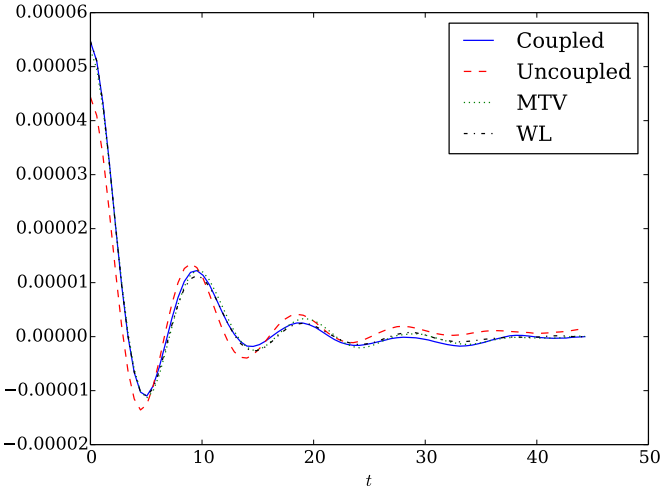
2.1.1 PDFs and autocorrelation functions of the resolved variables

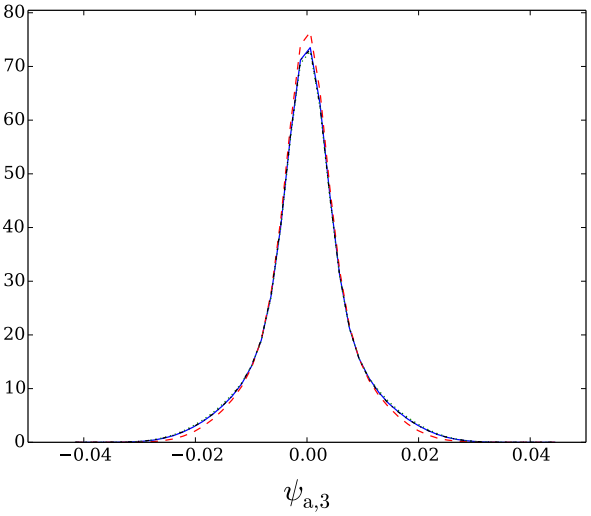
Atmospheric variables of the model.

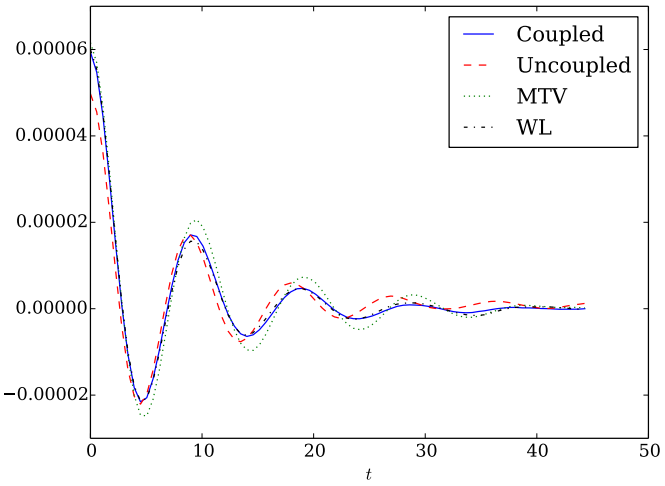

$\psi_{a,1}$

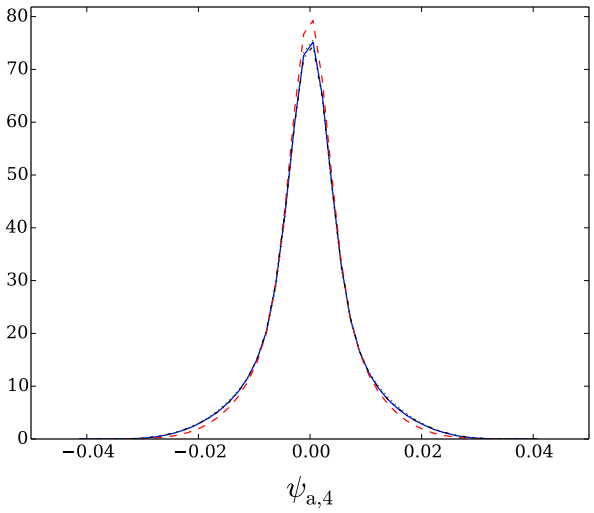

Coupled
Uncoupled
MTV
WL
t

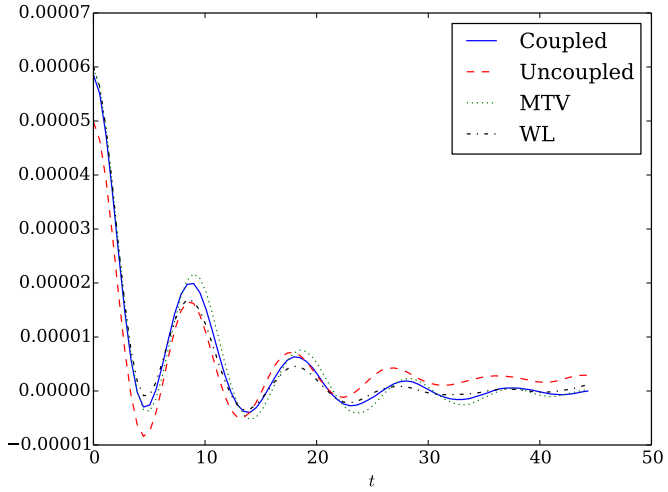

$\psi_{a,2}$

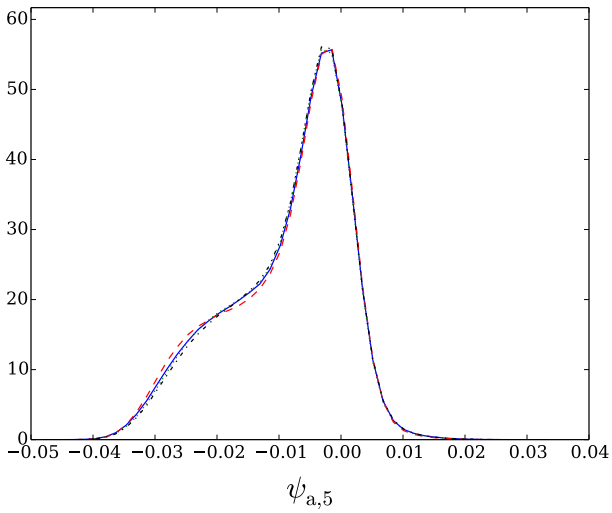

Coupled
Uncoupled
MTV
WL
t

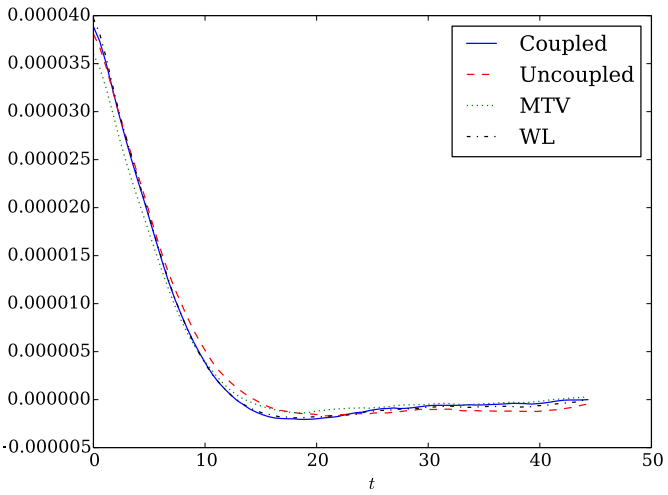

$\psi_{a,3}$

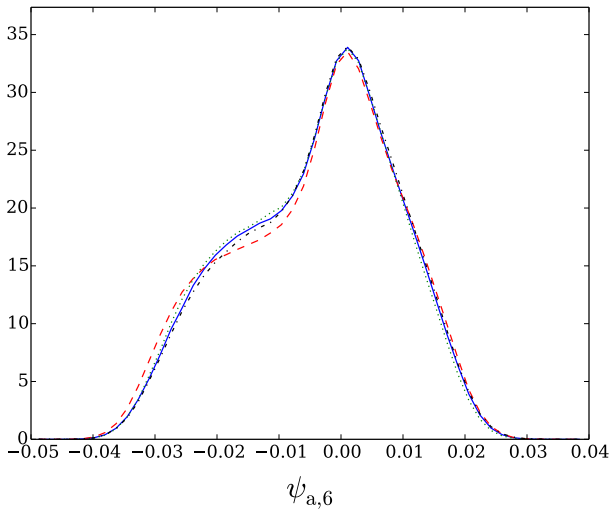

Coupled
Uncoupled
MTV
WL
t

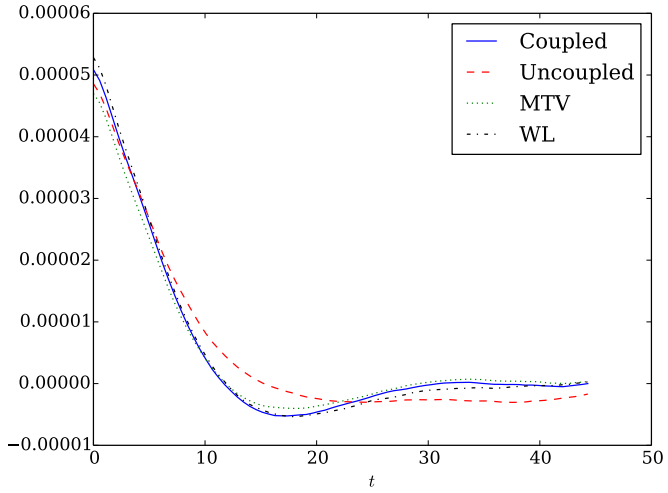

$\psi_{a,4}$

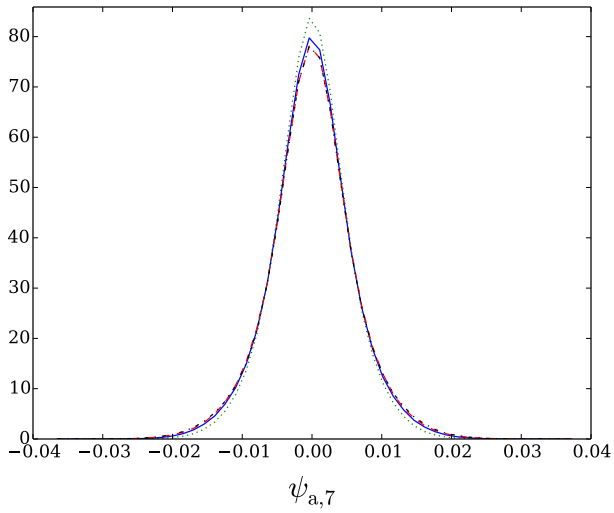

Coupled
Uncoupled
MTV
WL
t

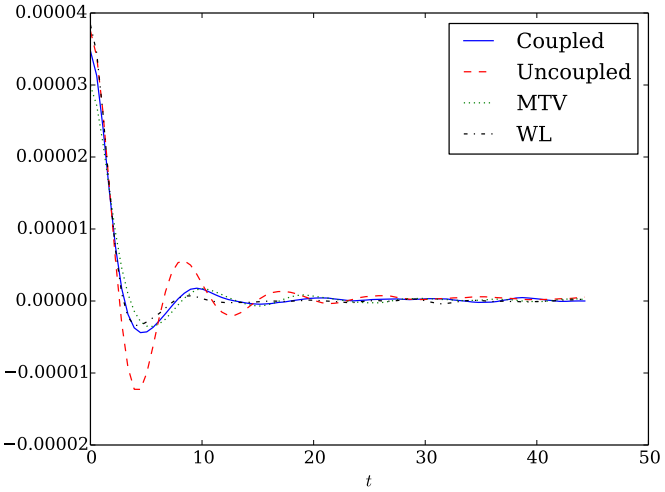

$\psi_{a,5}$

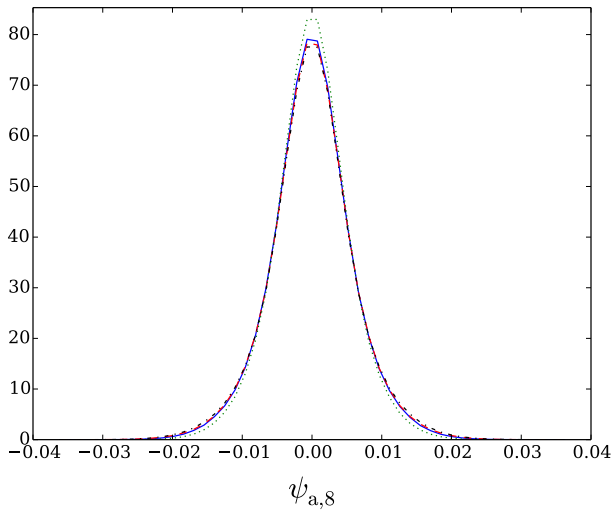

Coupled
Uncoupled
MTV
WL
t

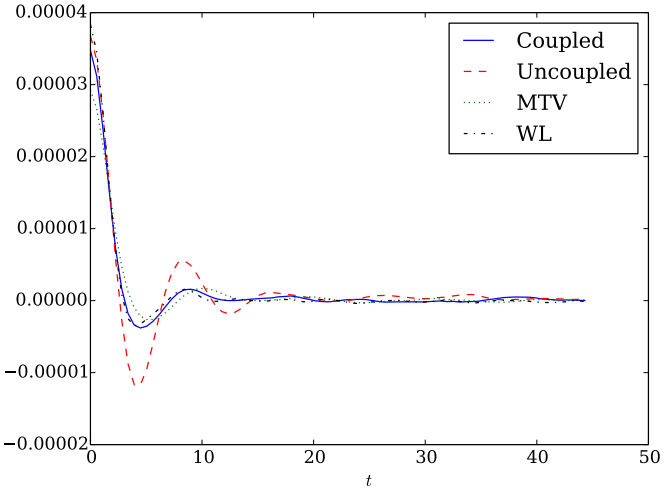

$\psi_{a,6}$

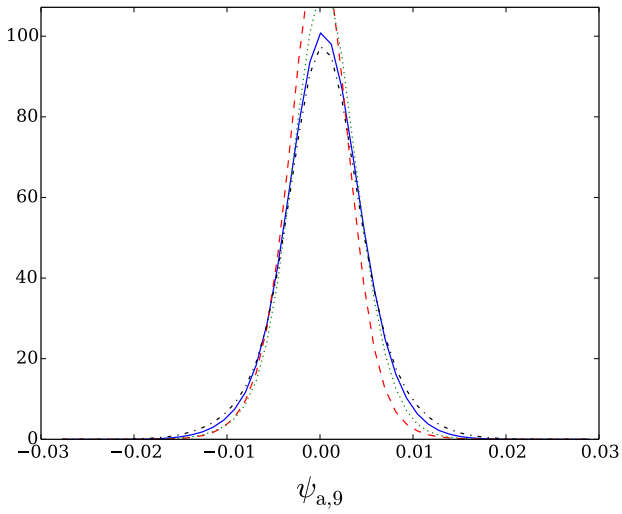

Coupled
Uncoupled
MTV
WL
t

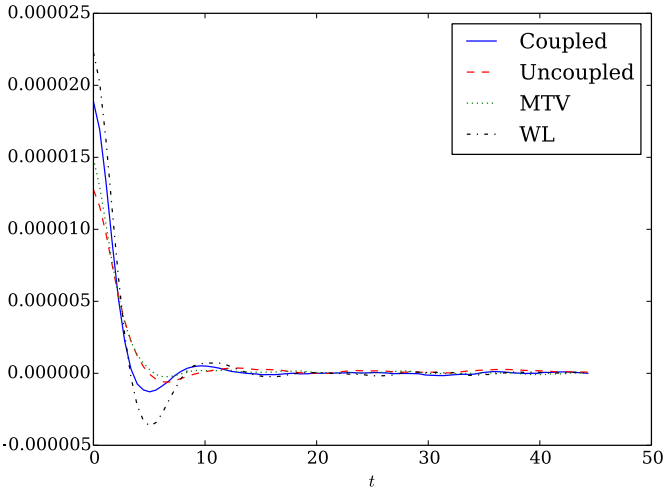

$\psi_{a,7}$

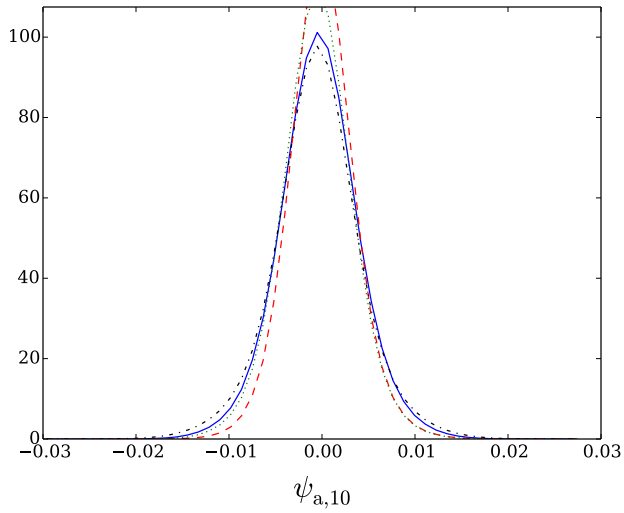

Coupled
Uncoupled
MTV
WL
t

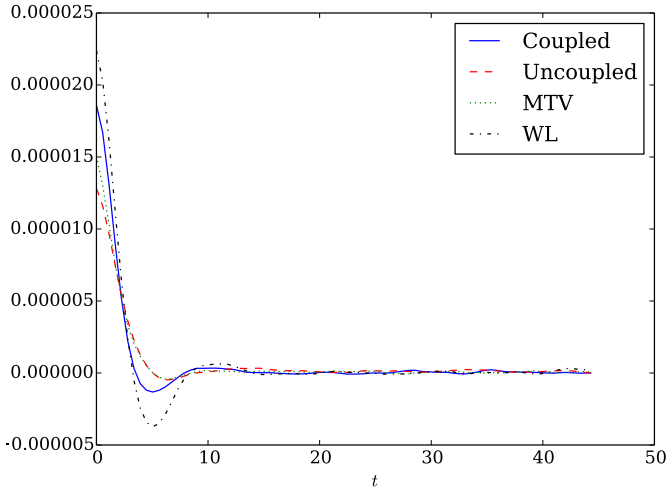

$\psi_{a,8}$

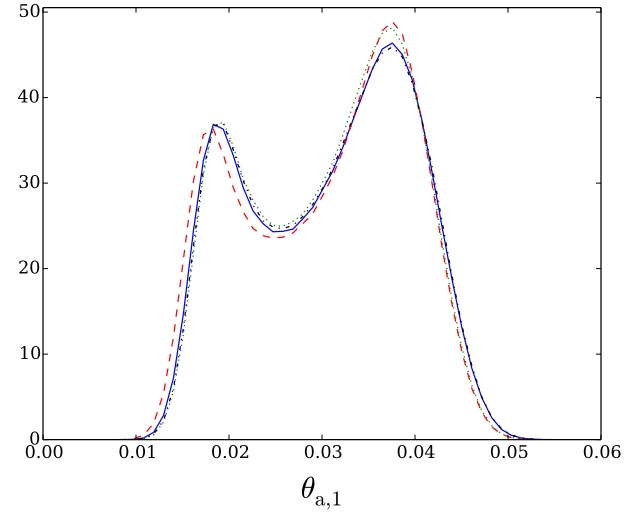

Coupled
Uncoupled
MTV
WL
t

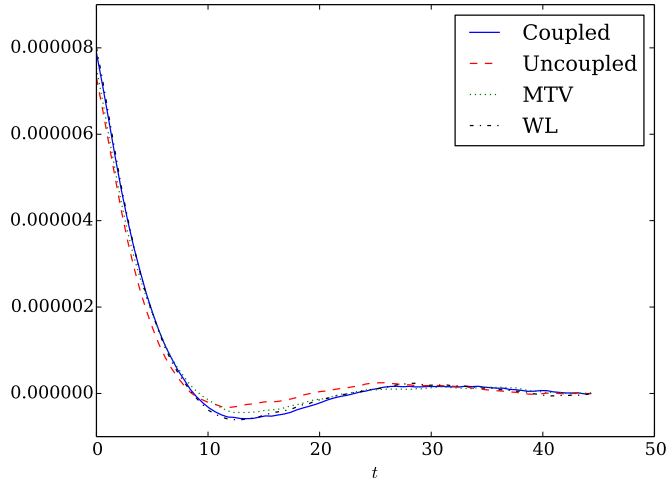

$\psi_{a,9}$

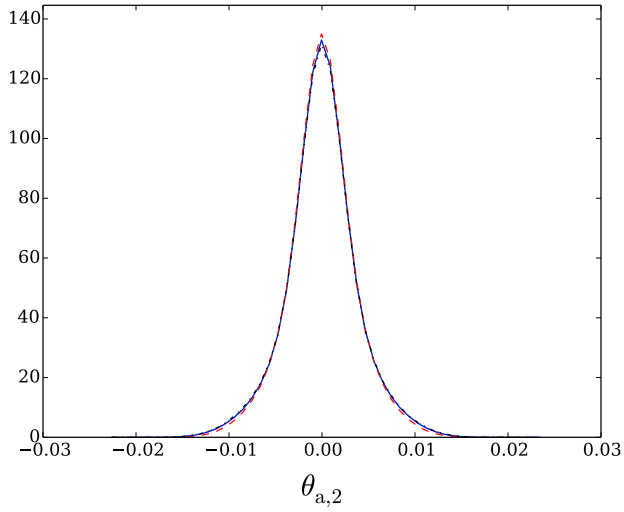

Coupled
Uncoupled
MTV
WL
t

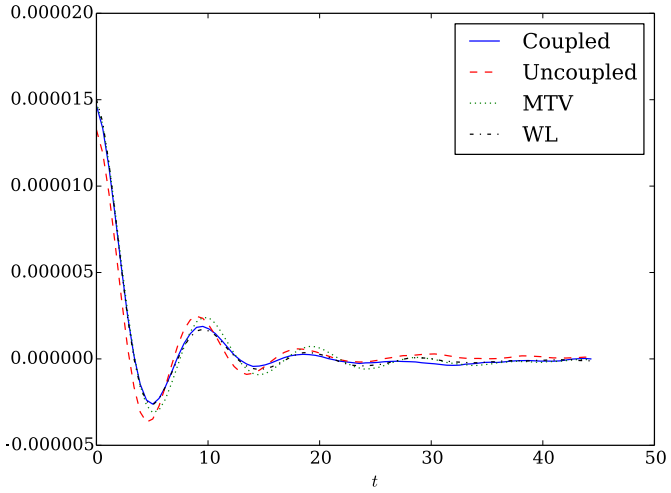

$\psi_{\mathrm{a},10}$

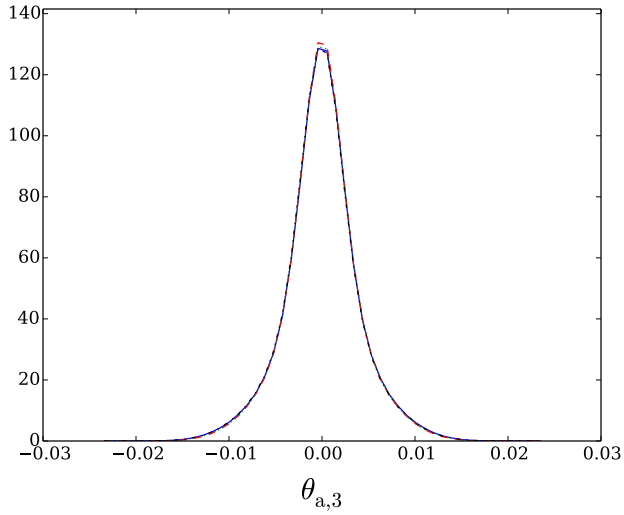

Coupled
Uncoupled
MTV
WL
t

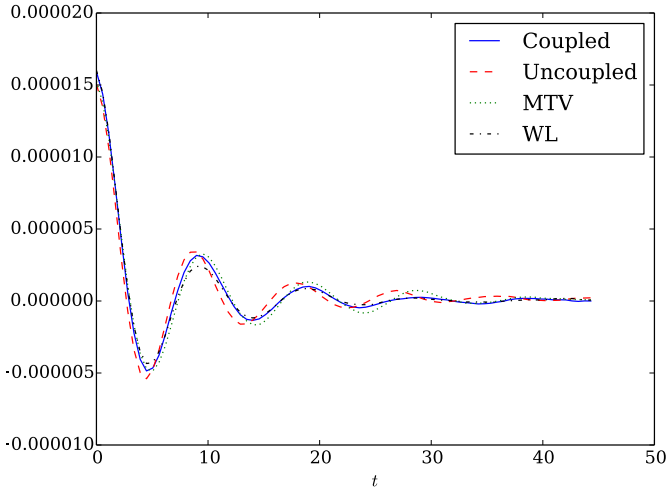

$\theta_{\mathrm{a},1}$

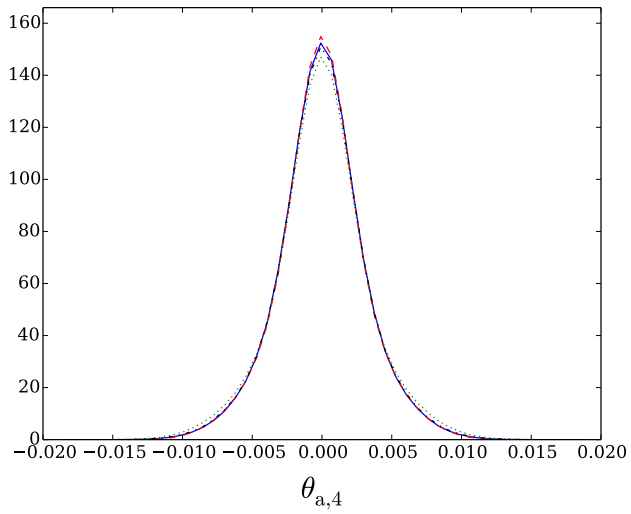

Coupled
Uncoupled
MTV
WL
t

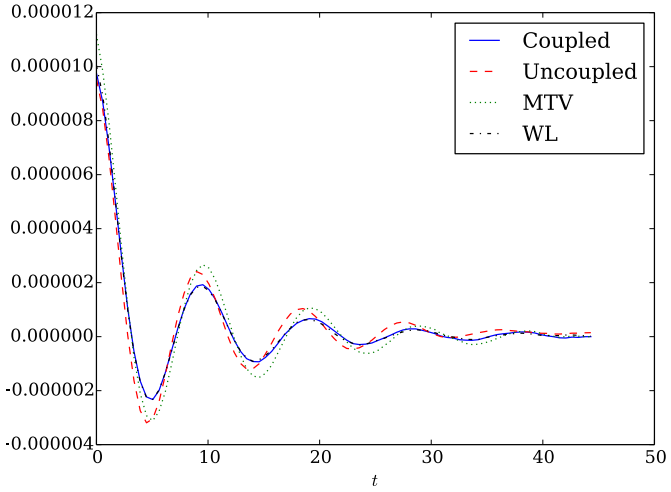

$\theta_{\mathrm{a},2}$

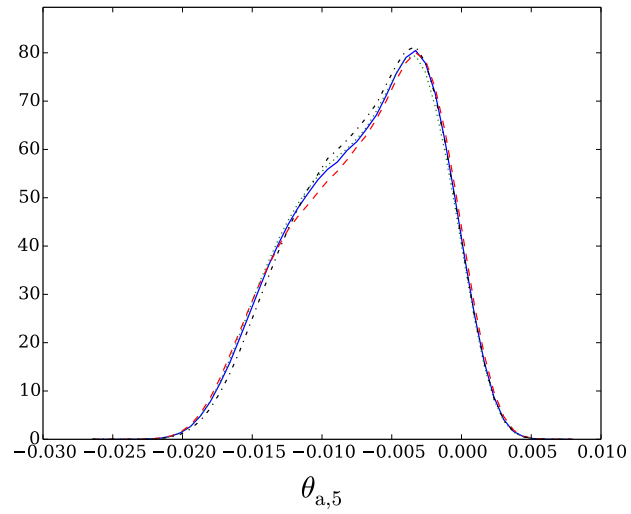

Coupled
Uncoupled
MTV
WL
t

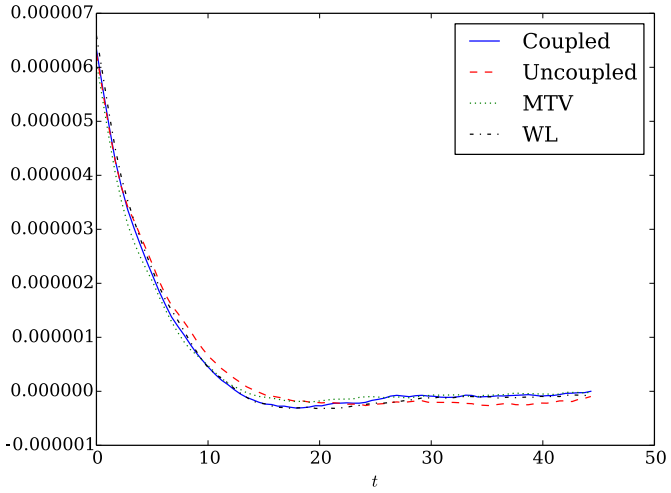

$\theta_{a,3}$

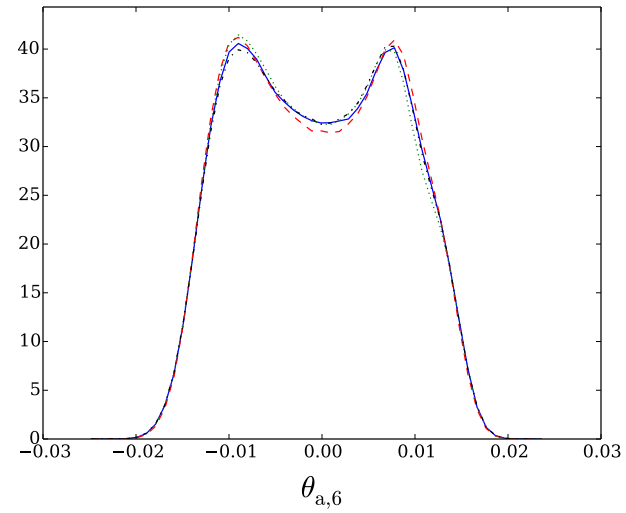

Coupled
Uncoupled
MTV
WL
t

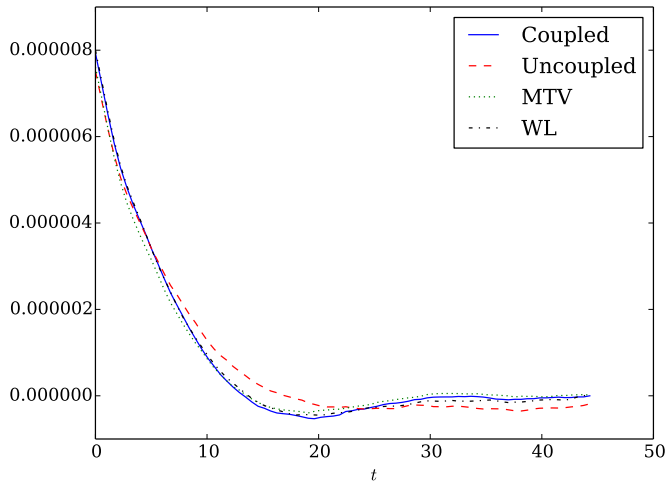

$\theta_{a,4}$

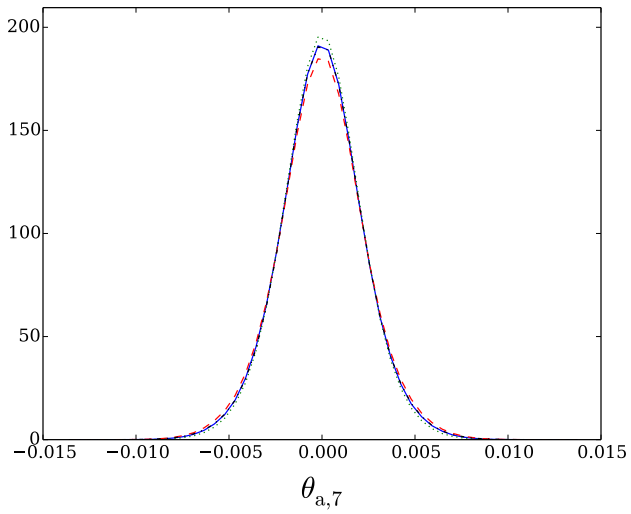

Coupled
Uncoupled
MTV
WL
t

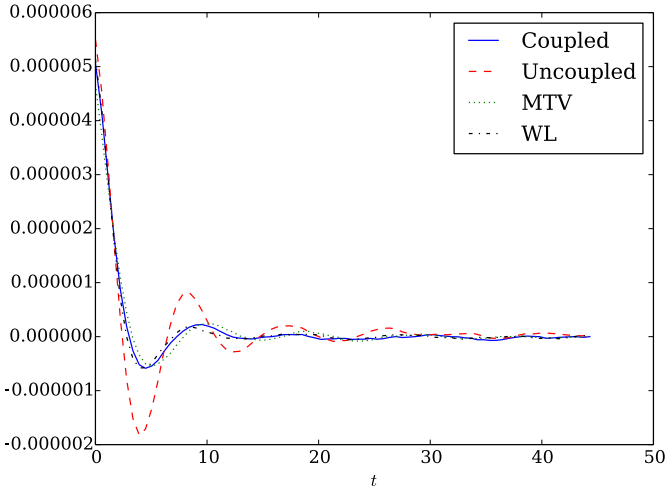

$\theta_{a,5}$

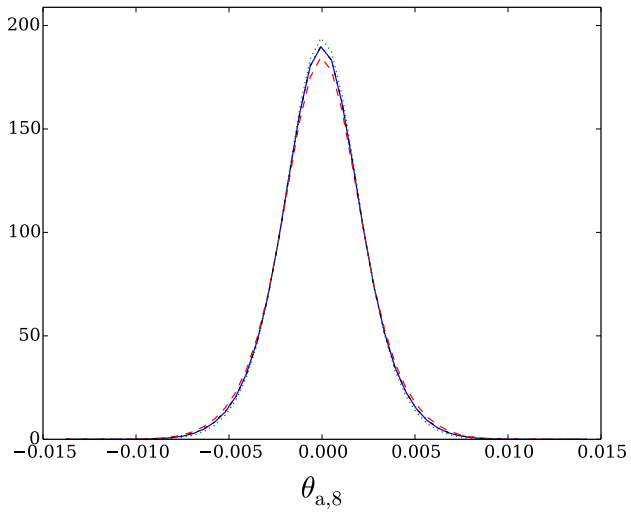

Coupled
Uncoupled
MTV
WL
t

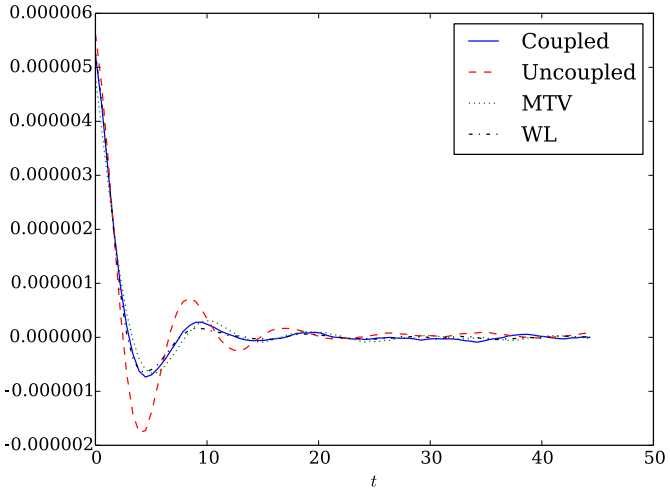




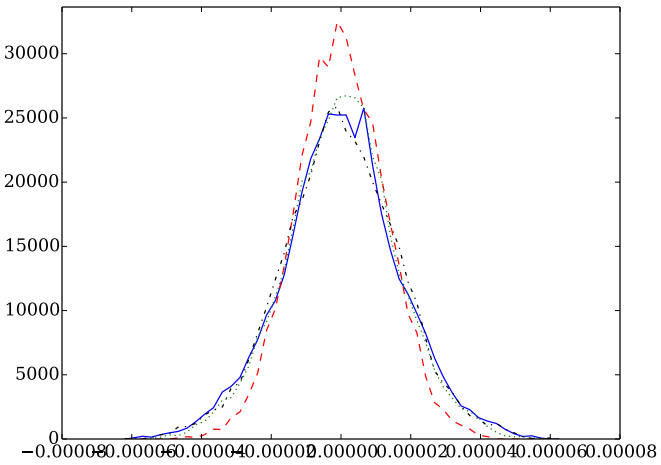




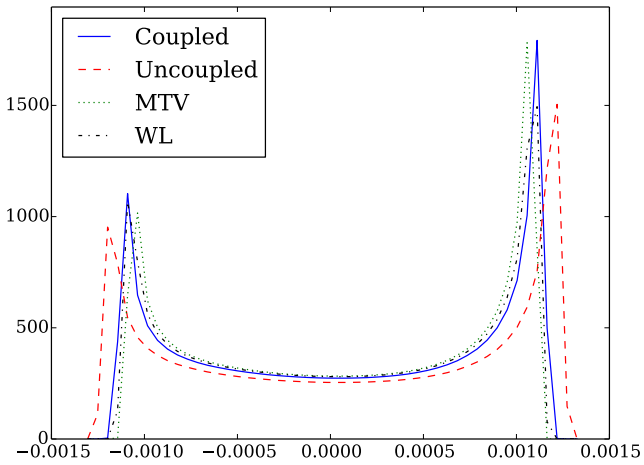




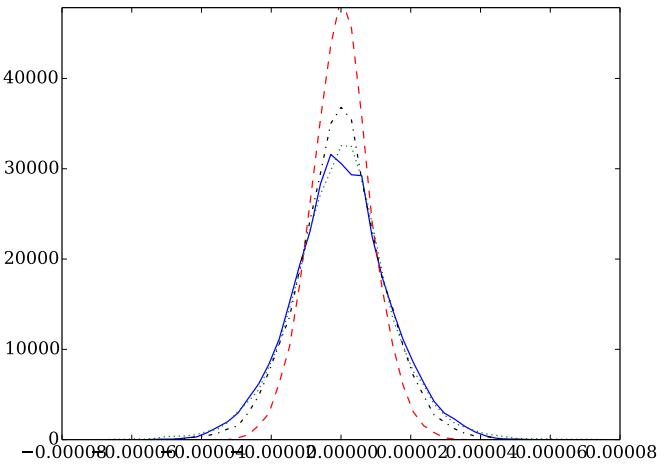
Oceanic variables Only the PDFs are available for these variables.



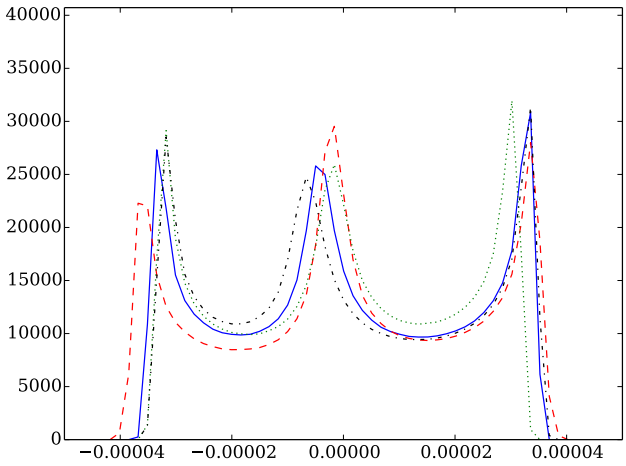
$\psi_{o,1}$



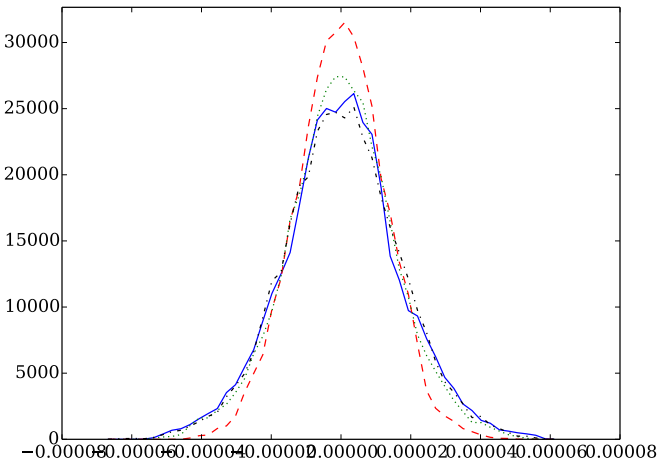
$\psi_{o,2}$



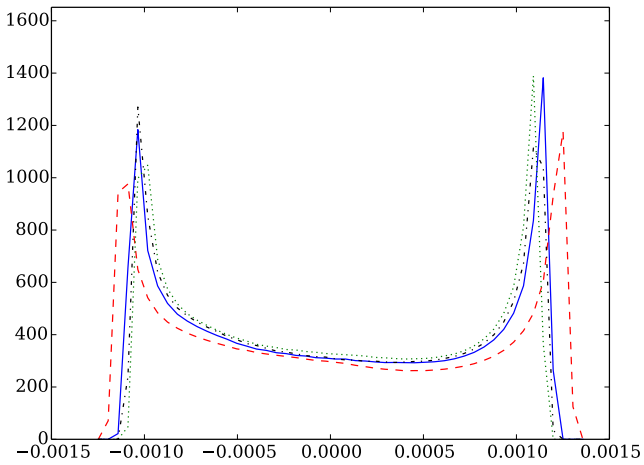
$\psi_{o,3}$



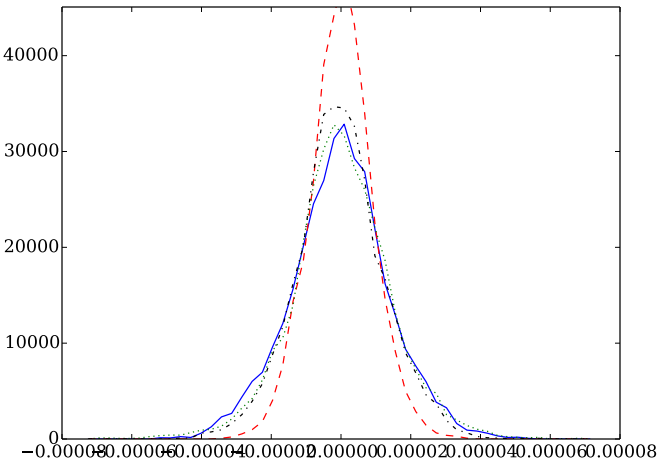
$\psi_{o,4}$



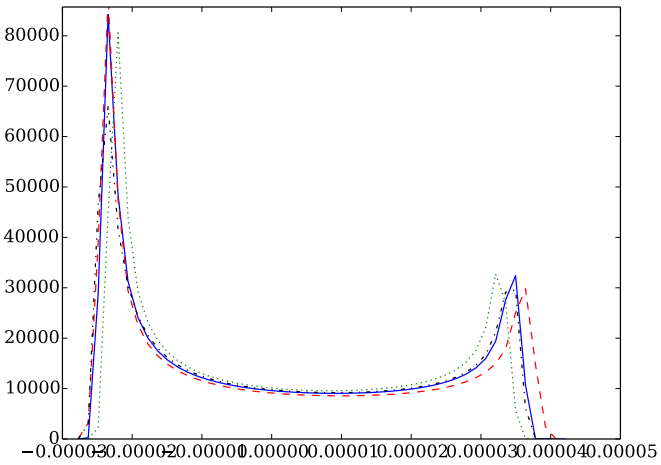
$\psi_{o,5}$



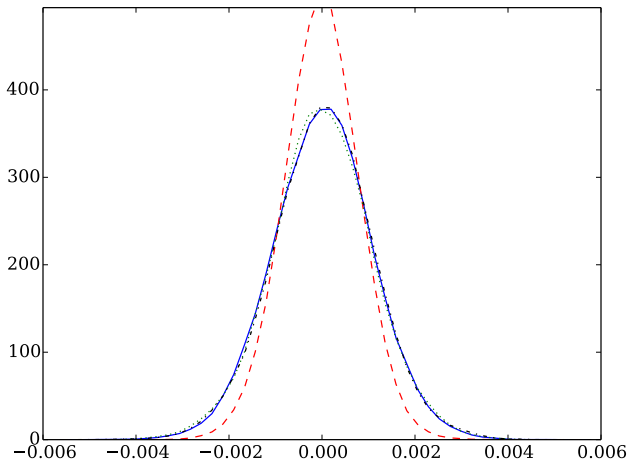
$\psi_{o,6}$



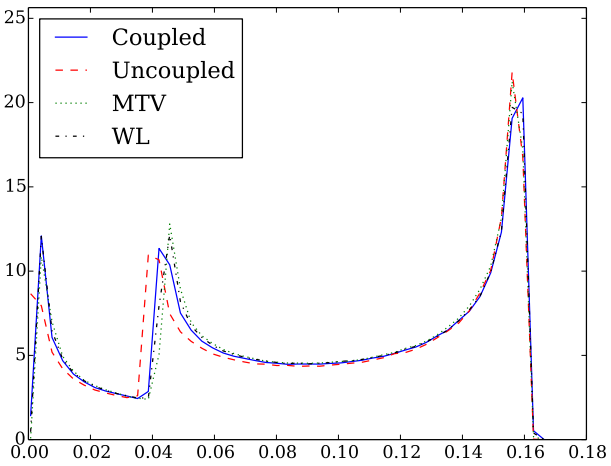
$\psi_{o,7}$



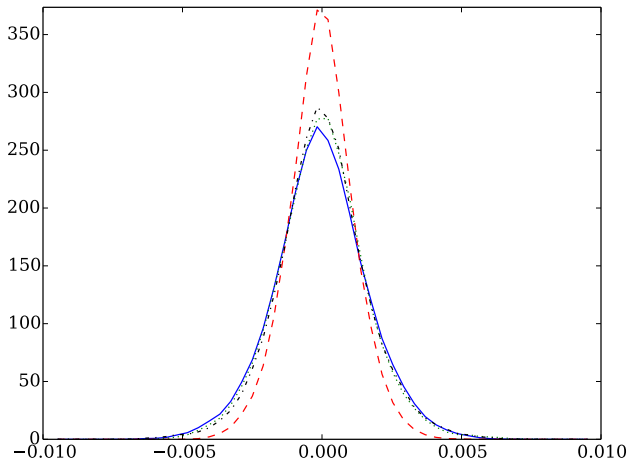
$\psi_{o,8}$



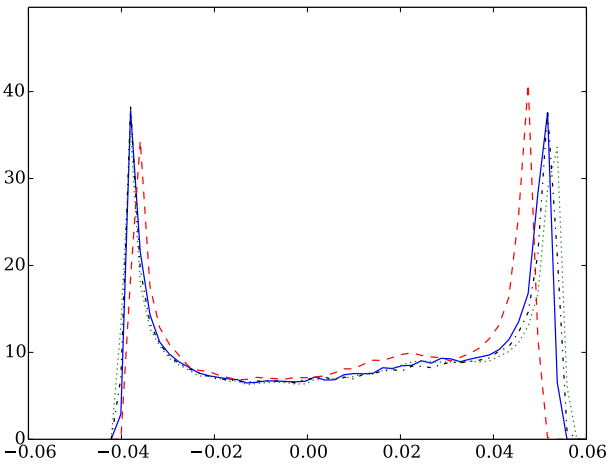
$\theta_{o,1}$



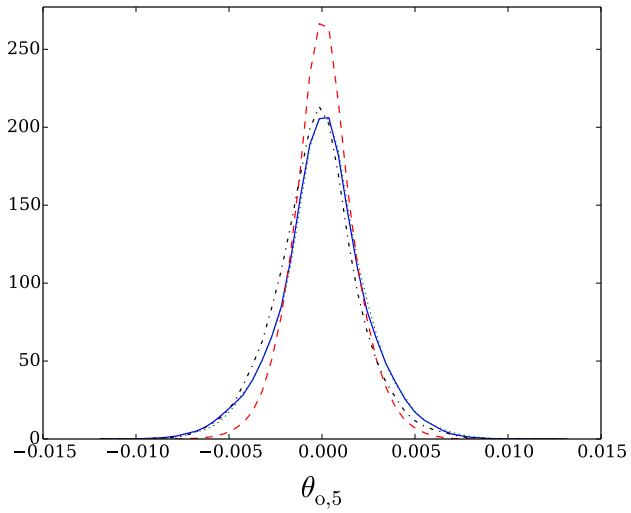
$\theta_{o,2}$



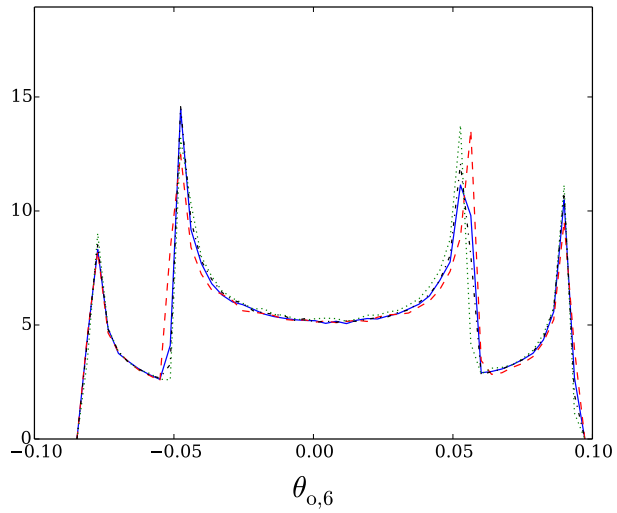
$\theta_{o,3}$



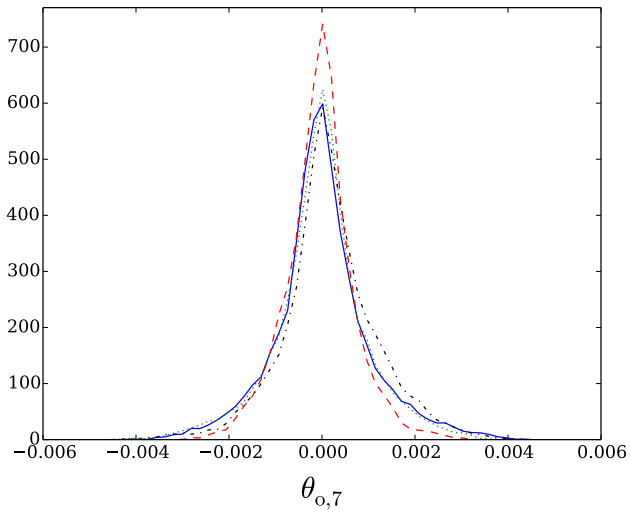
$\theta_{o,4}$



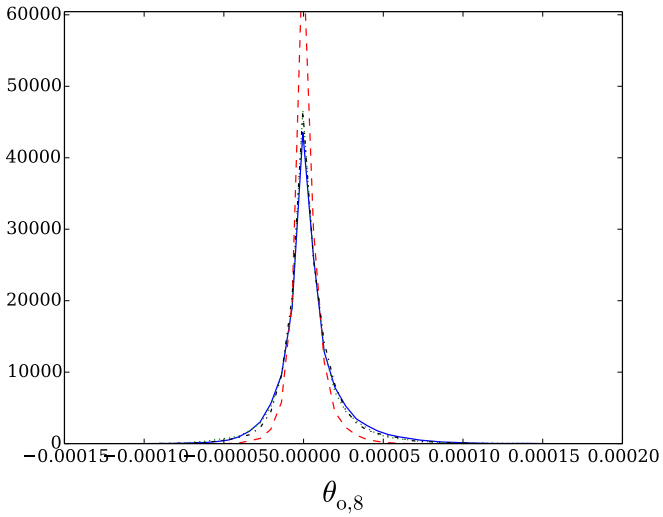
$\theta_{o,5}$



$\theta_{o,6}$

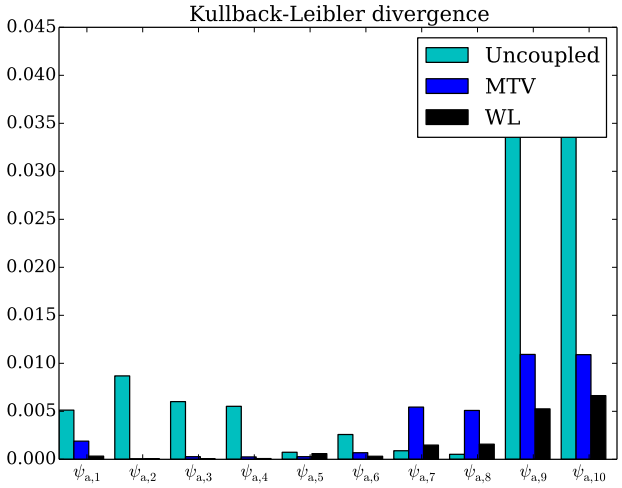


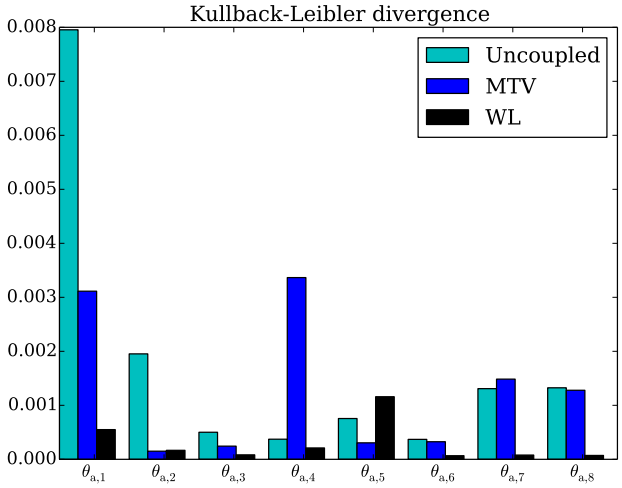
$\theta_{o,7}$

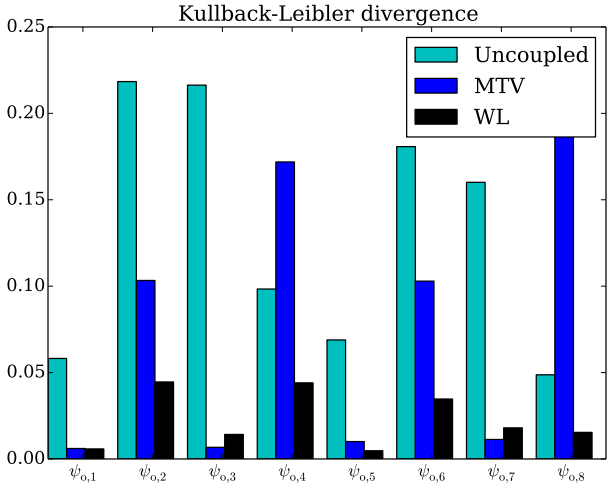


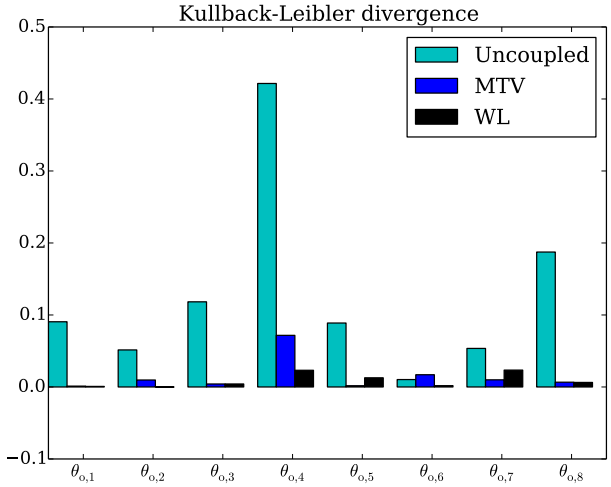
$\theta_{o,8}$

2.1.2 Kullback-Leibler divergences





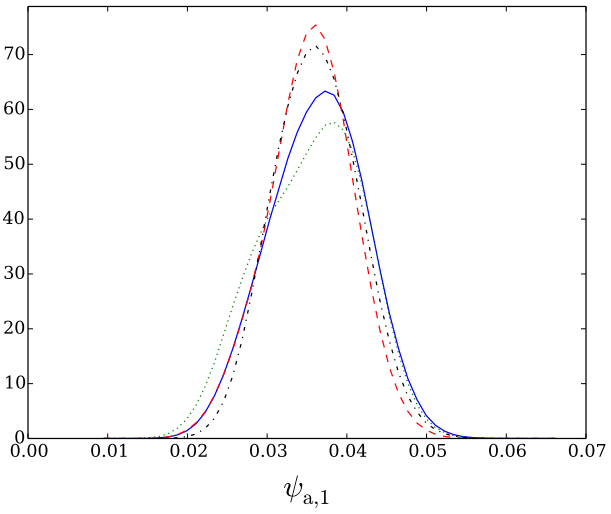


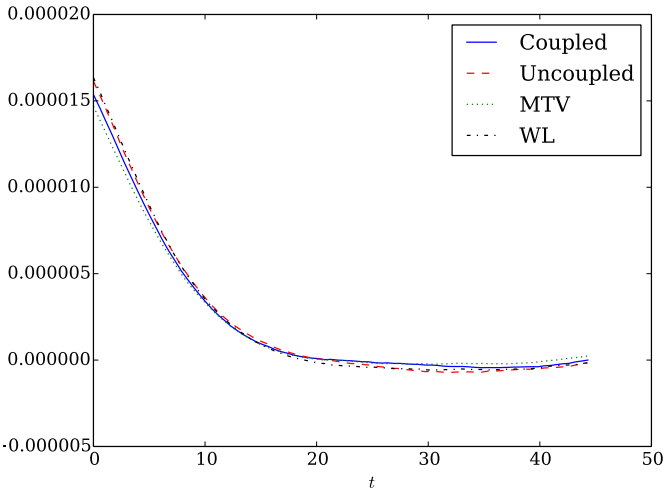


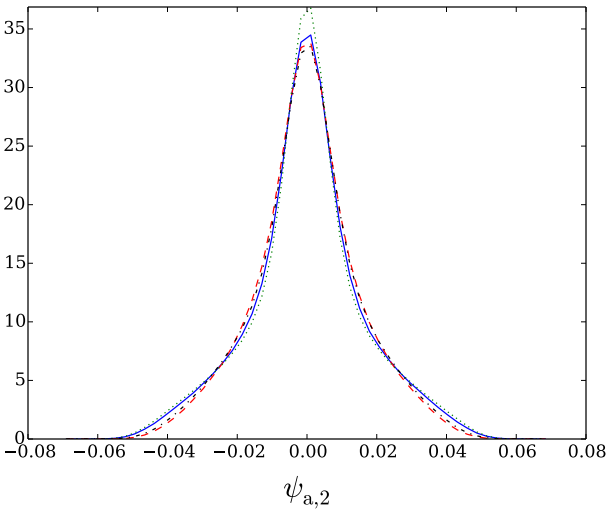
2.2 DDV2016 parameter set

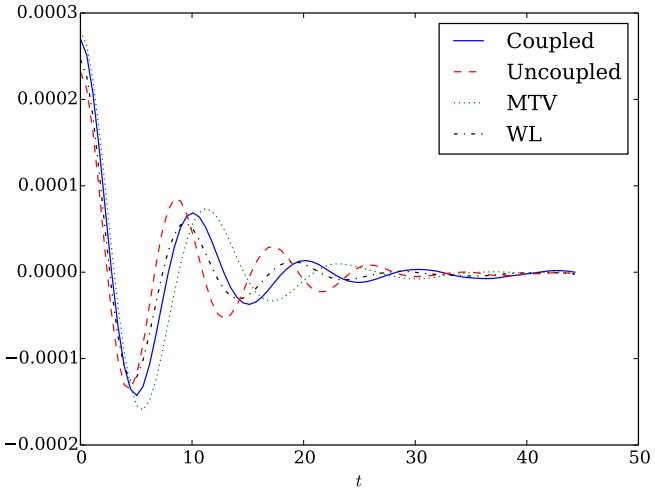
2.2.1 PDFs and autocorrelation functions of the resolved variables

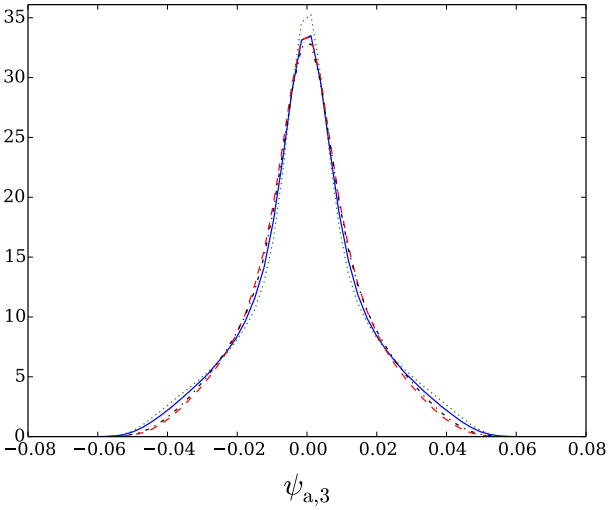
Atmospheric variables of the model.

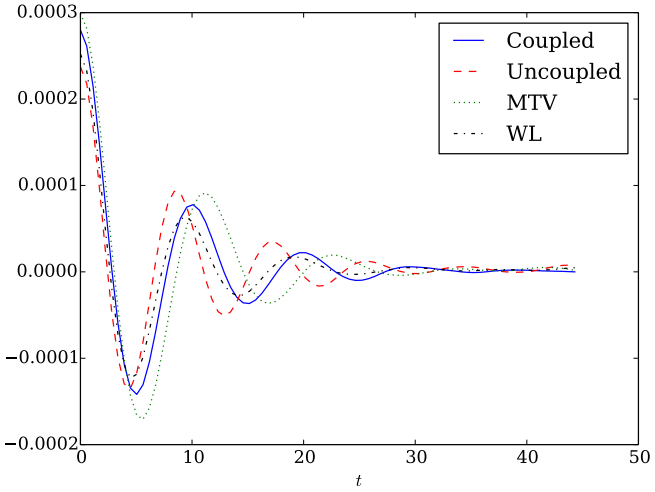


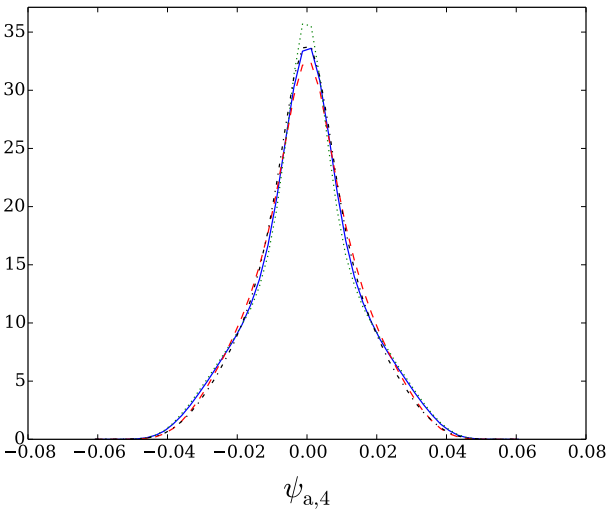


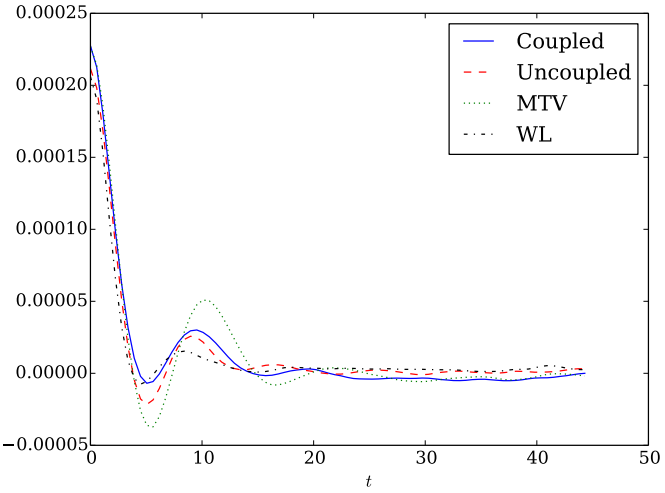

$\psi_{a,2}$

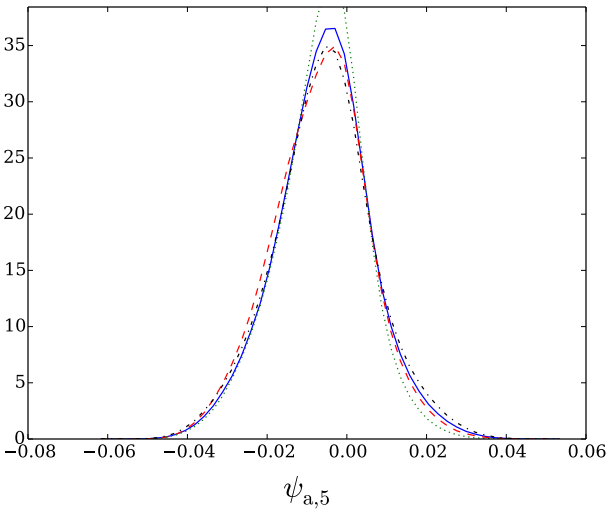

Coupled
Uncoupled
MTV
WL
t

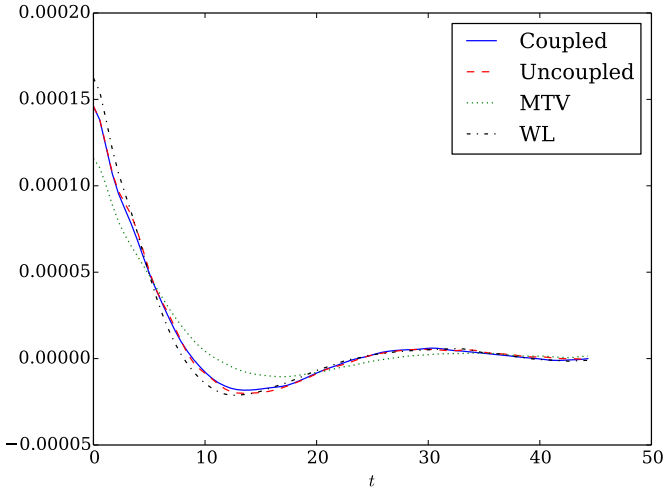

$\psi_{a,3}$

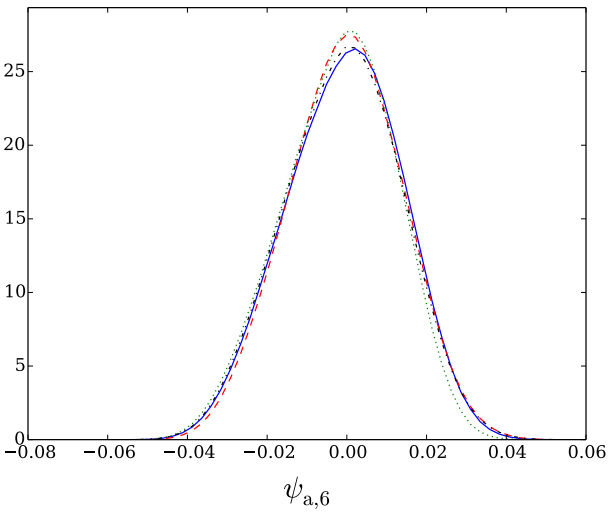

Coupled
Uncoupled
MTV
WL
t

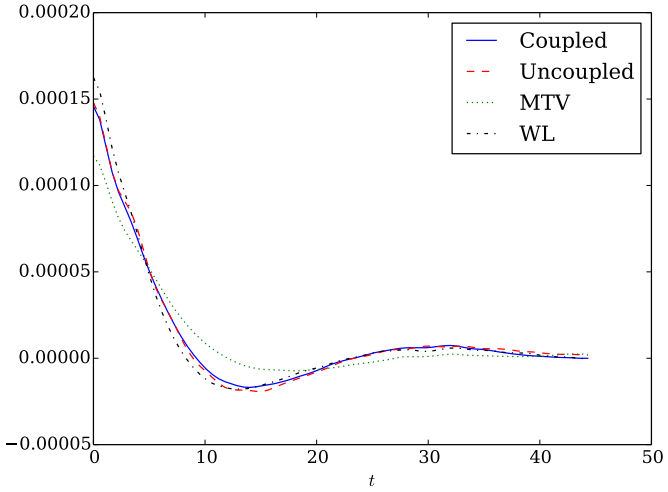

$\psi_{a,4}$

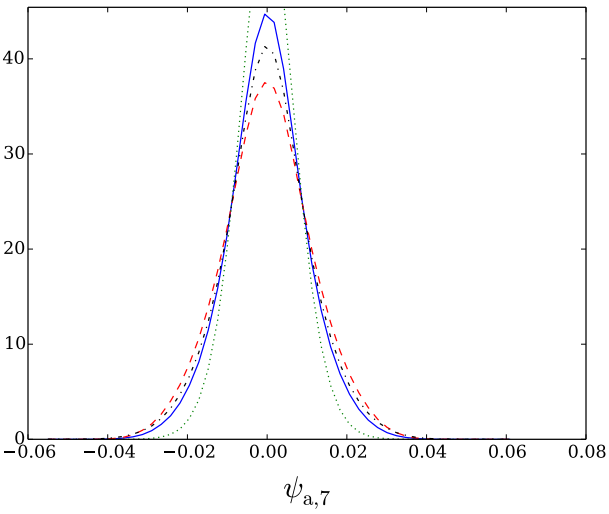

Coupled
Uncoupled
MTV
WL
t

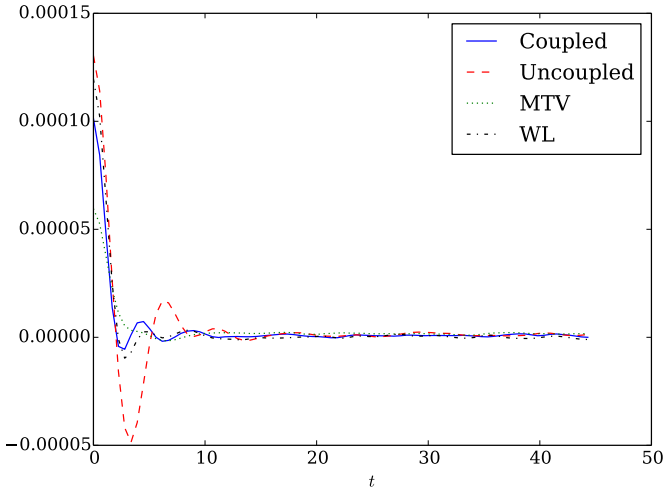

$\psi_{a,5}$

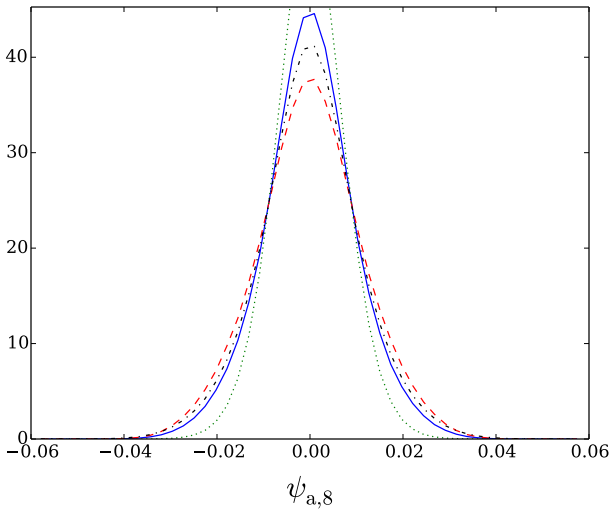

Coupled
Uncoupled
MTV
WL
t

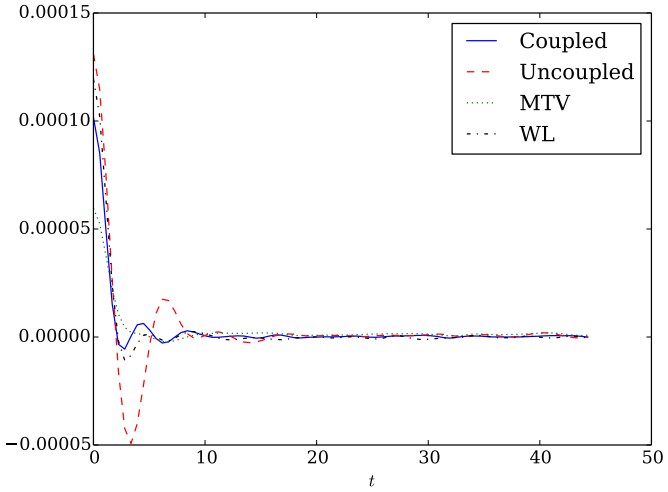

$\psi_{a,6}$

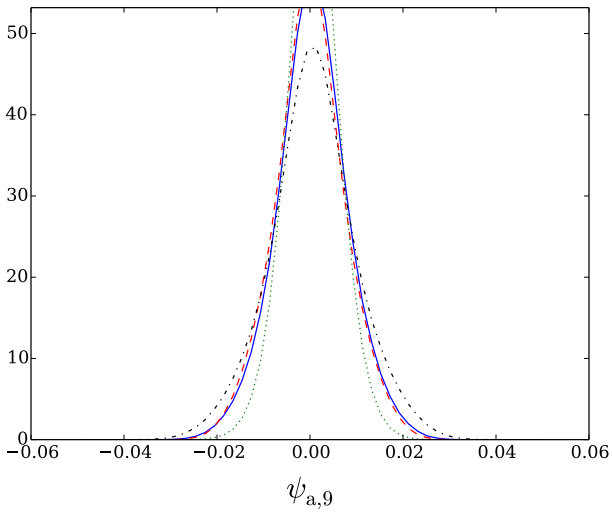

Coupled
Uncoupled
MTV
WL
t

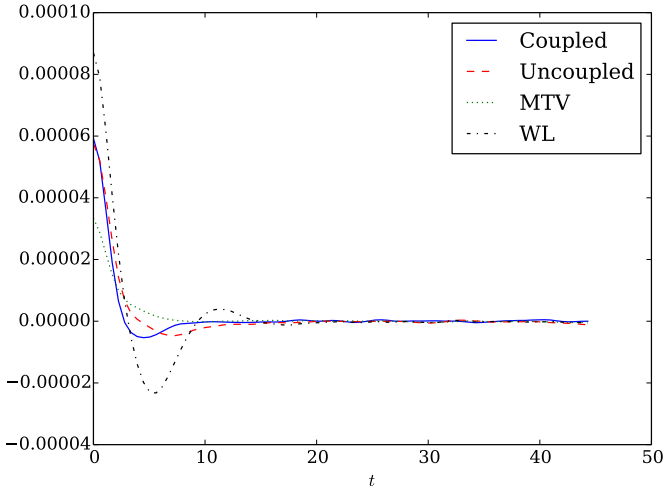

$\psi_{a,7}$

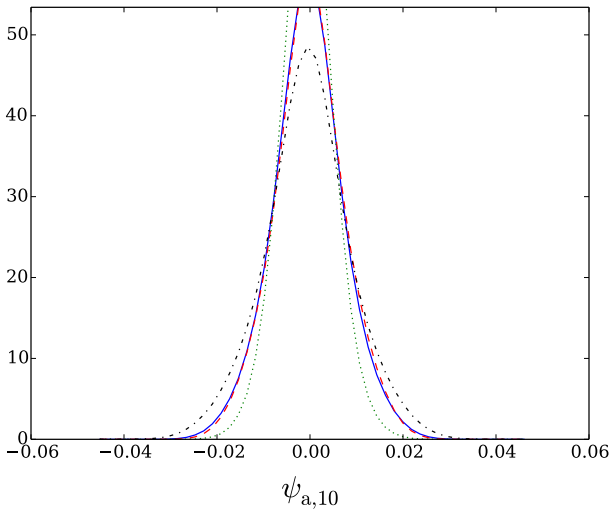

Coupled
Uncoupled
MTV
WL
t

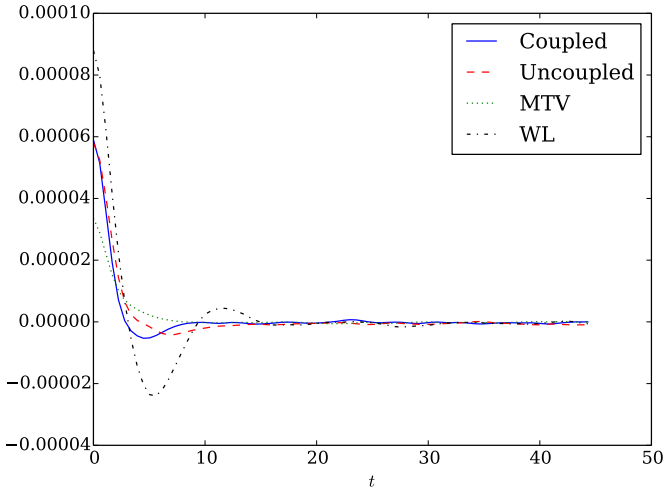

$\psi_{a,8}$

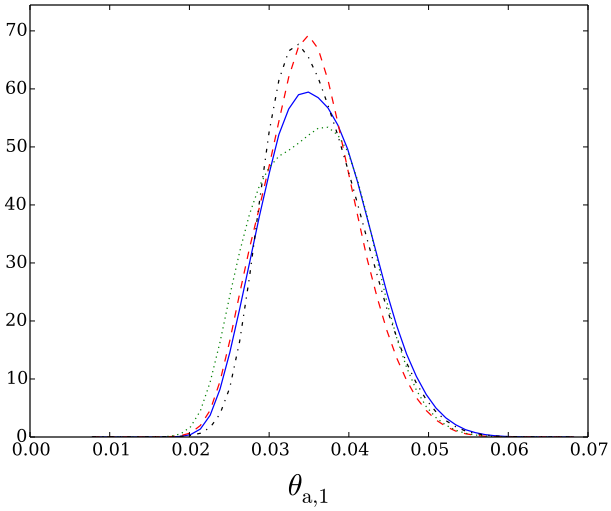

Coupled
Uncoupled
MTV
WL
t

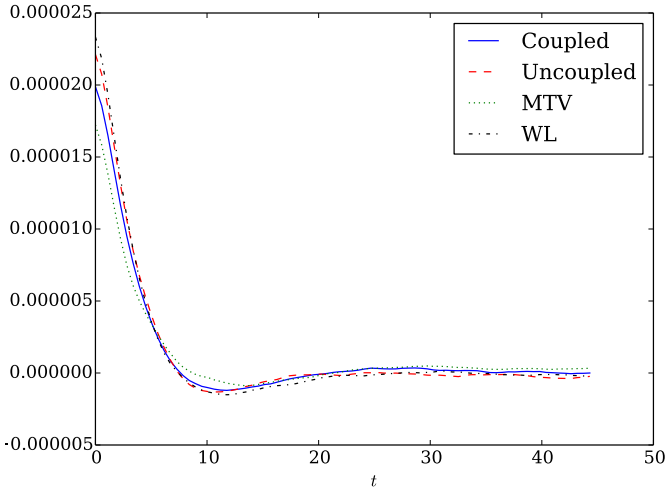

$\psi_{a,9}$

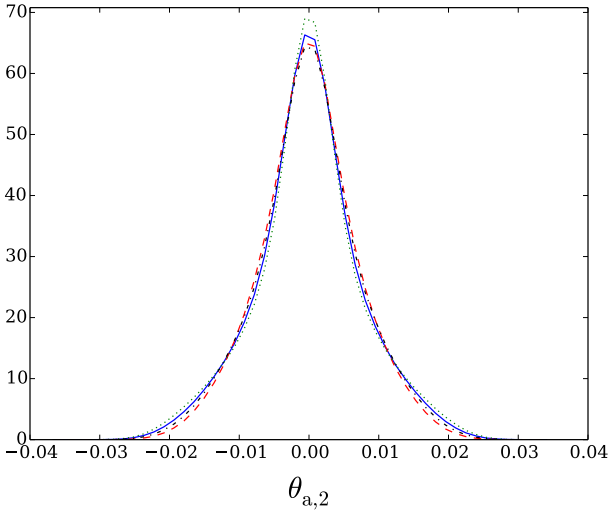

Coupled
Uncoupled
MTV
WL
t

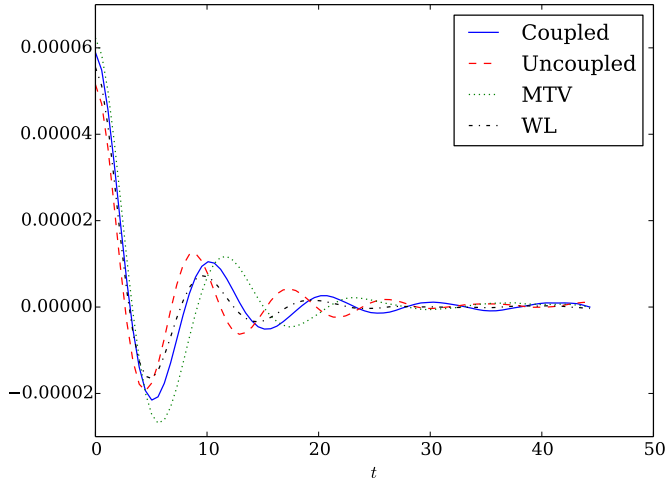

$\psi_{a,10}$

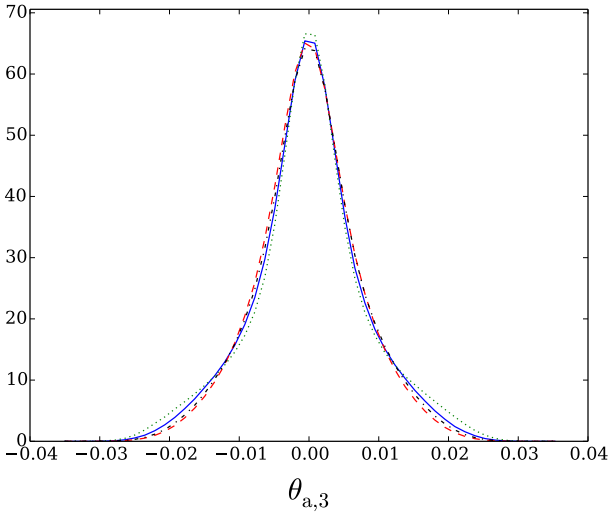

Coupled
Uncoupled
MTV
WL
t

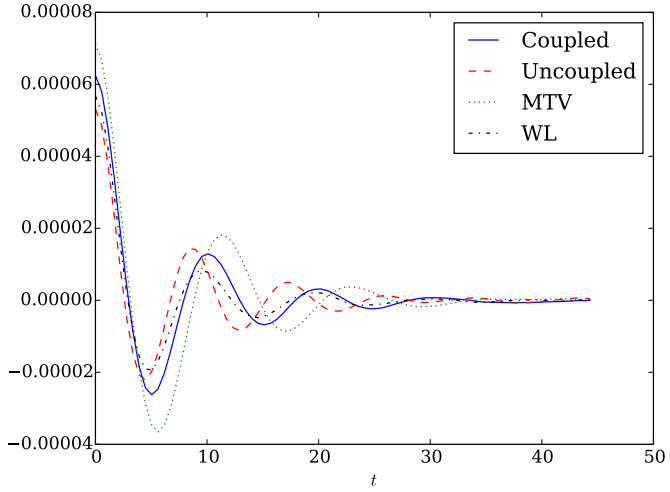

$\theta_{a,1}$

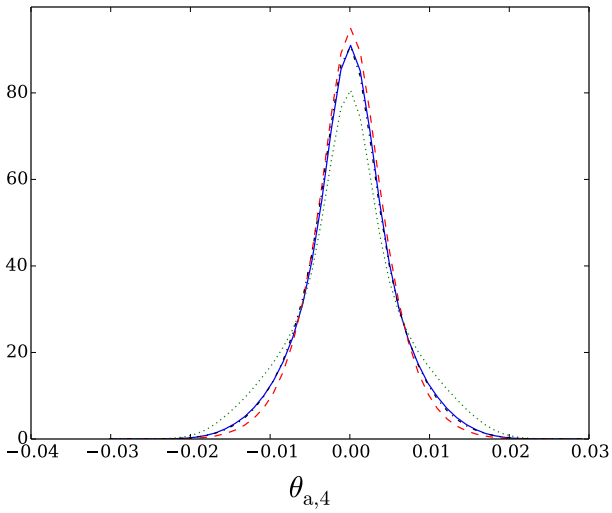

Coupled
Uncoupled
MTV
WL
t

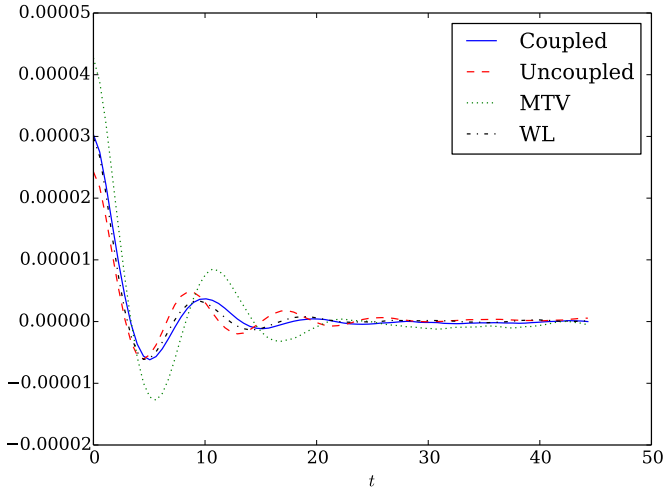

$\theta_{a,2}$

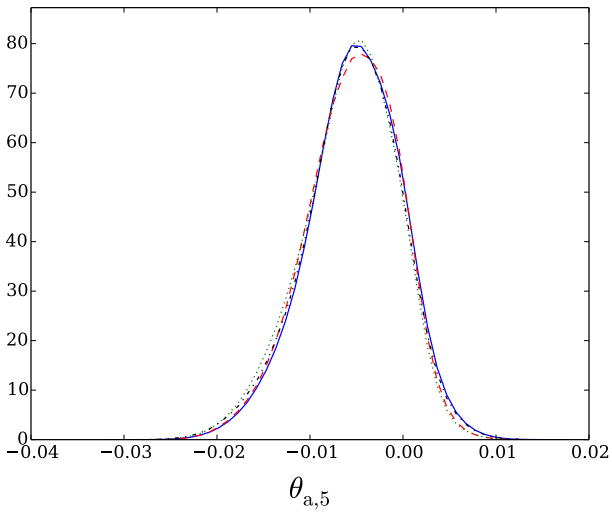

Coupled
Uncoupled
MTV
WL
t

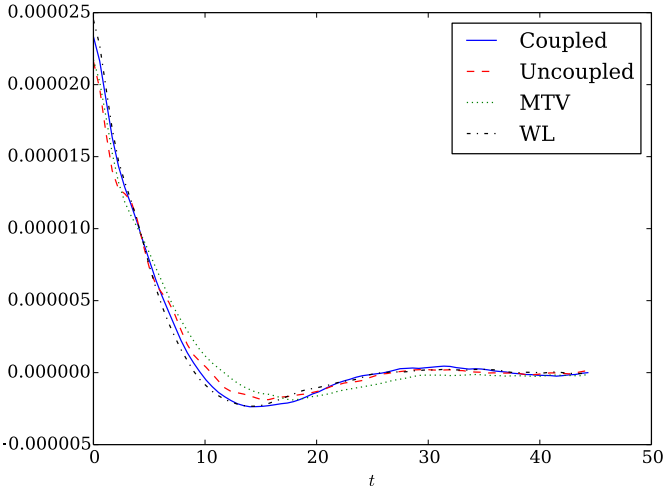

$\theta_{a,3}$

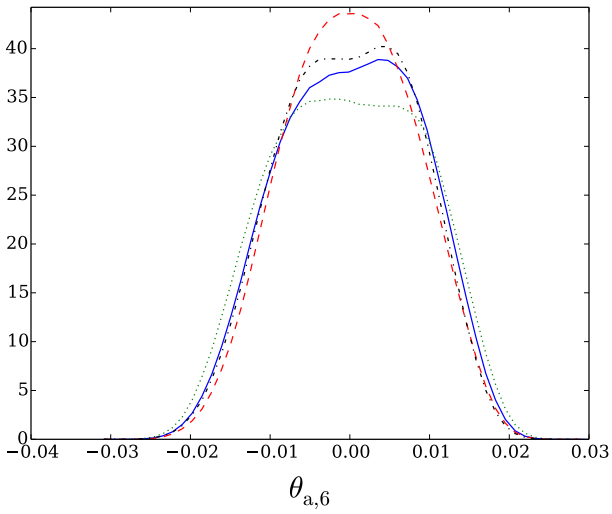

Coupled
Uncoupled
MTV
WL
t

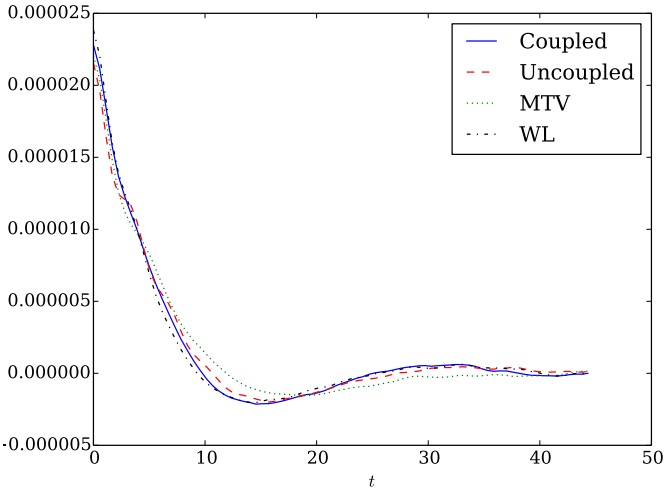

$\theta_{a,4}$

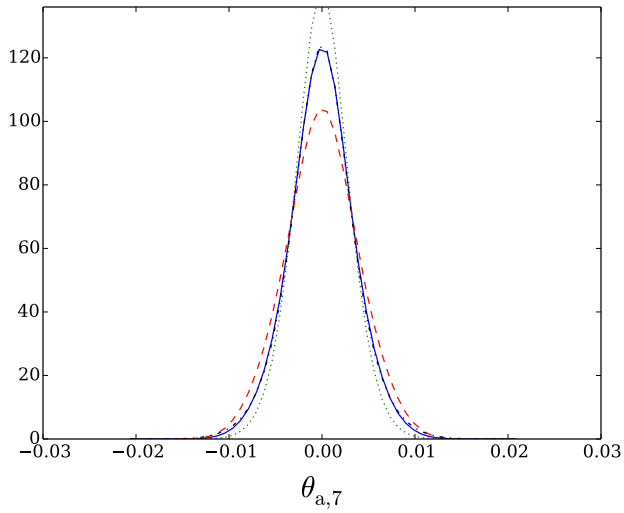

Coupled
Uncoupled
MTV
WL
t

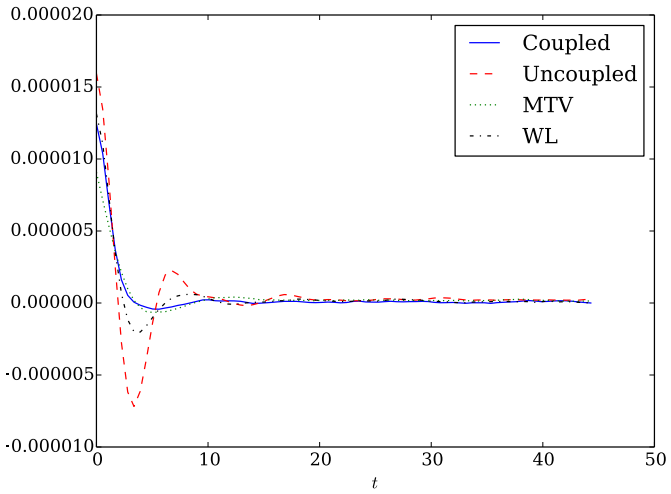

$\theta_{a,5}$

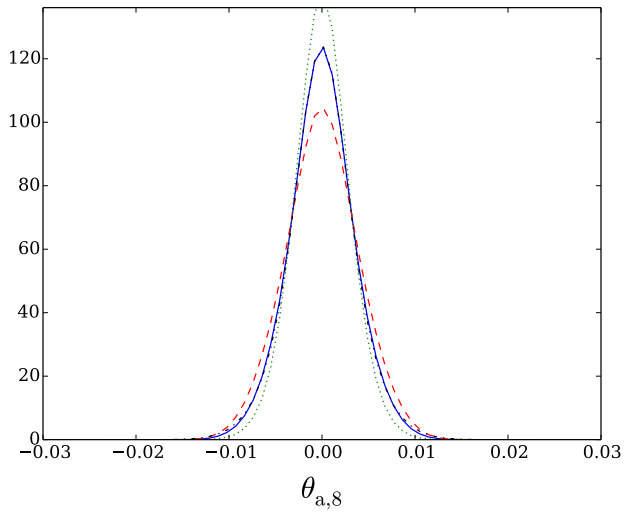

Coupled
Uncoupled
MTV
WL
t

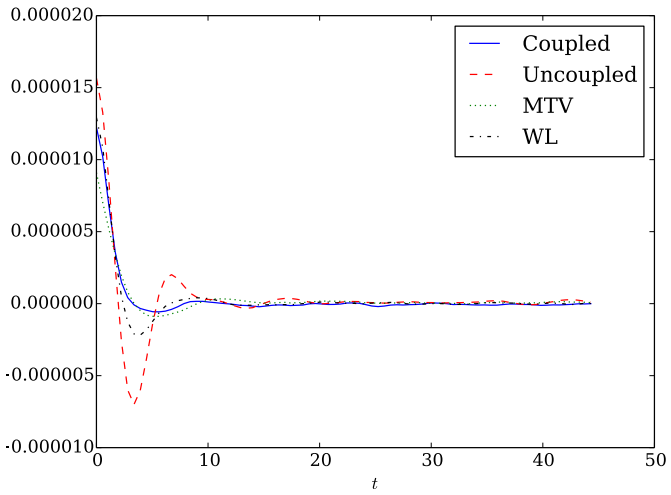

$\theta_{a,6}$


Coupled
Uncoupled
MTV
WL
t

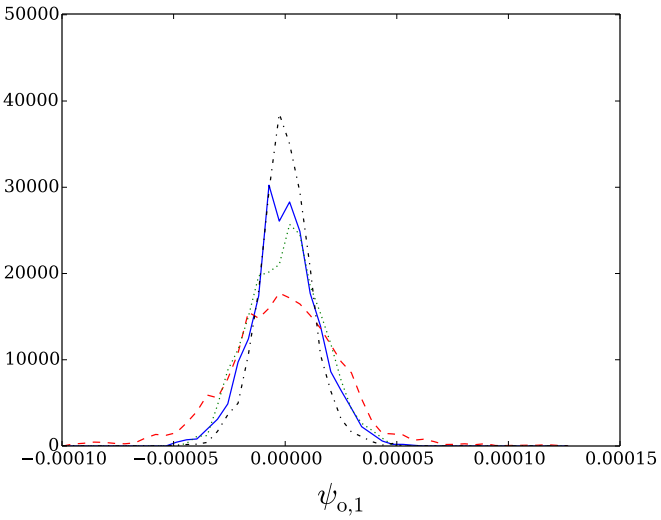




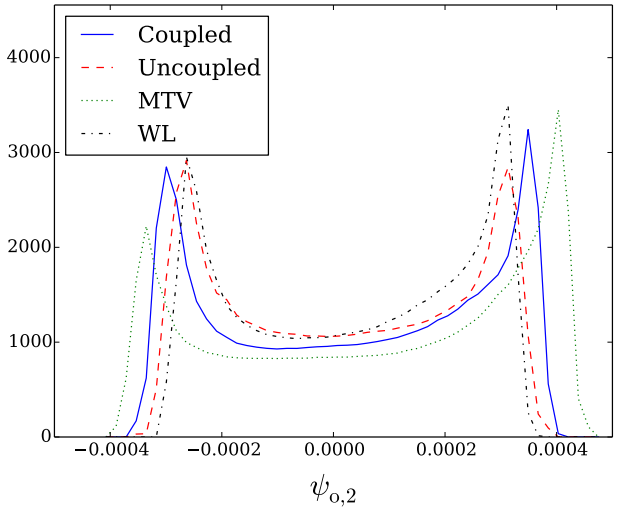




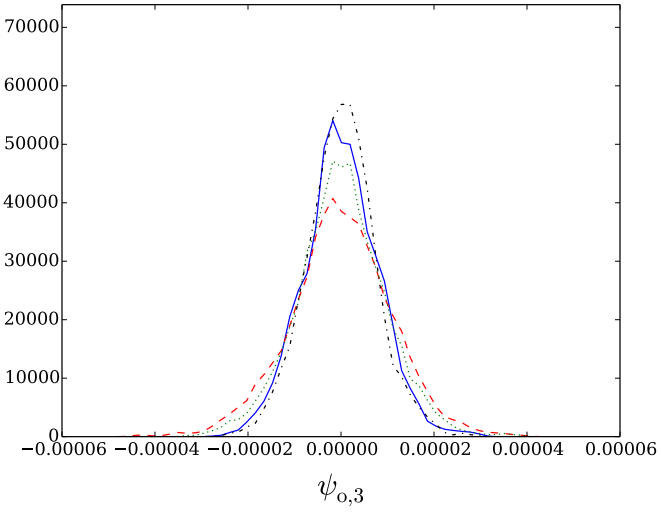
Oceanic variables Only the PDFs are available for these variables.



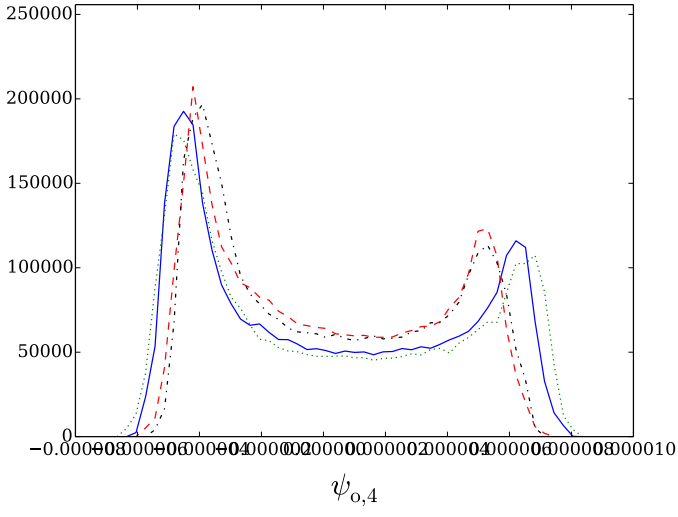
$\psi_{o,1}$



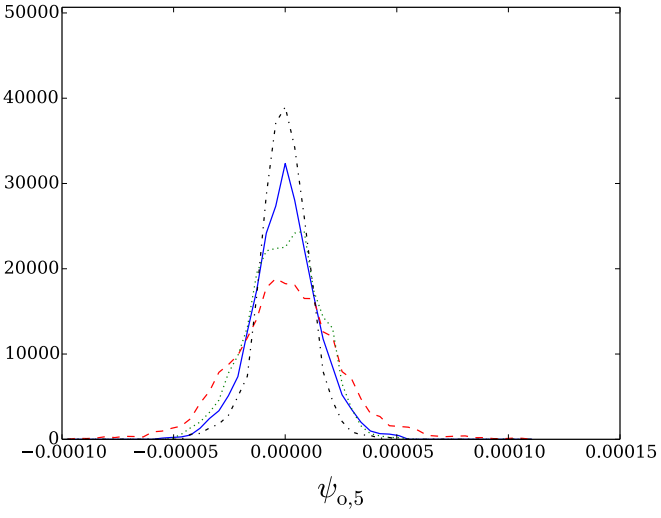
$\psi_{o,2}$



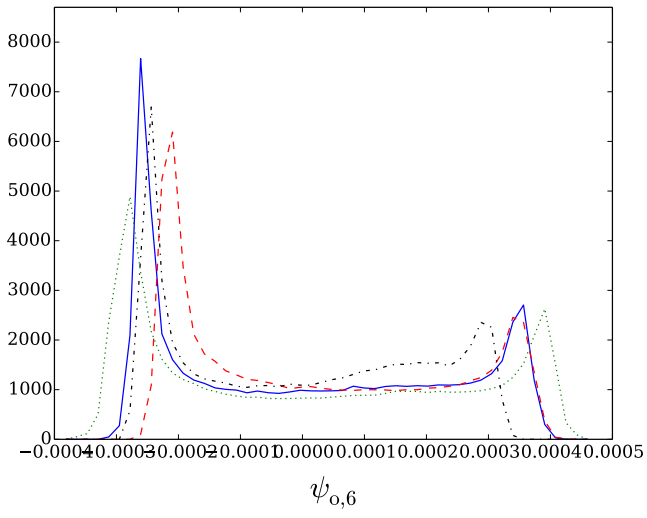
$\psi_{o,3}$



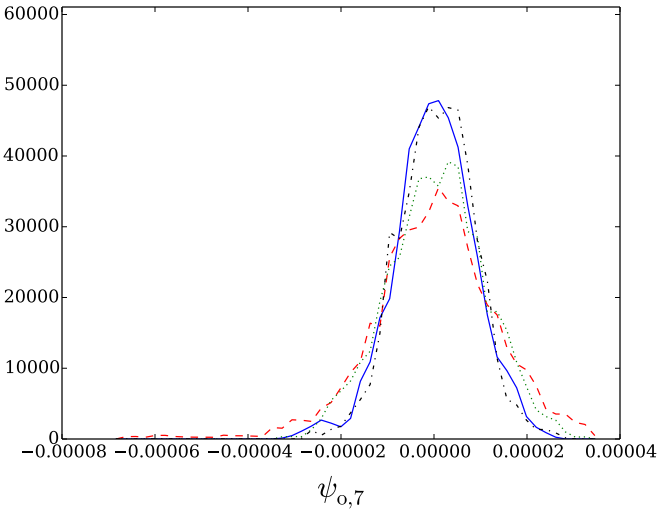
$\psi_{o,4}$



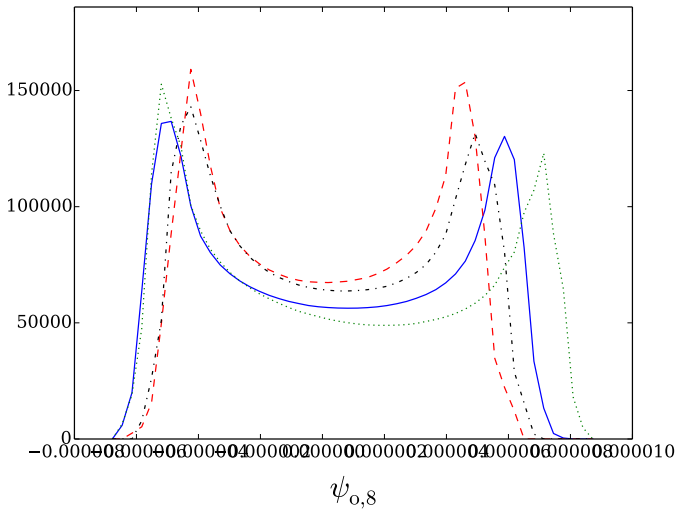
$\psi_{o,5}$



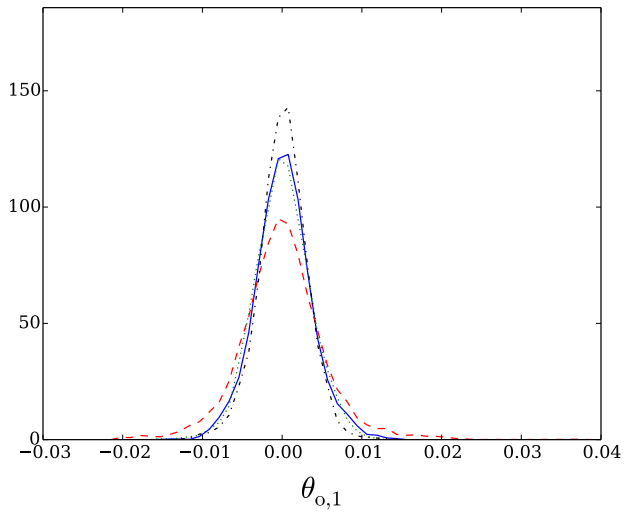
$\psi_{o,6}$



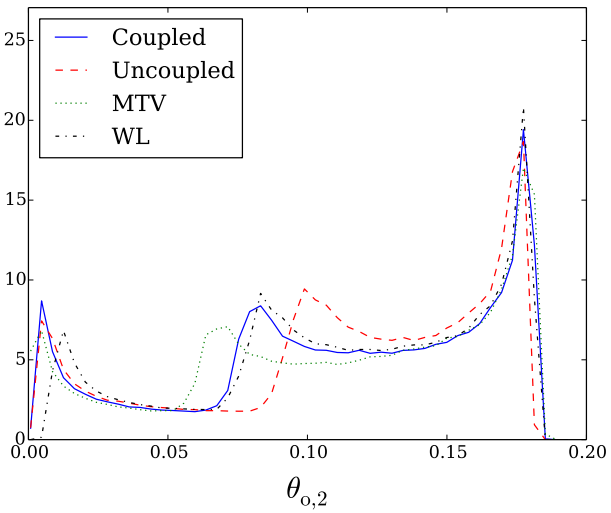
$\psi_{o,7}$



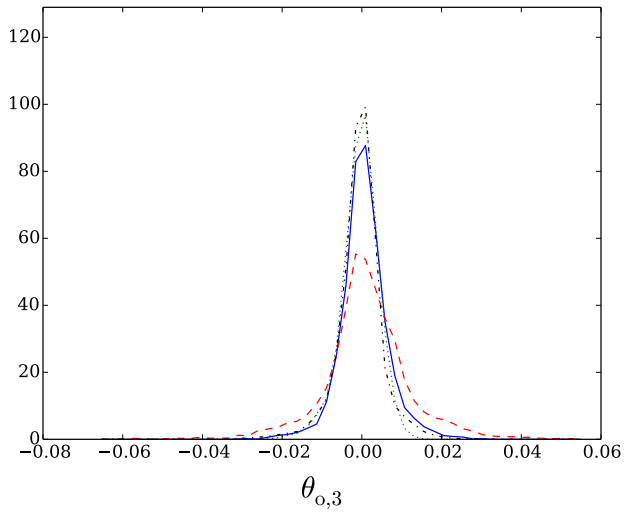
$\psi_{o,8}$



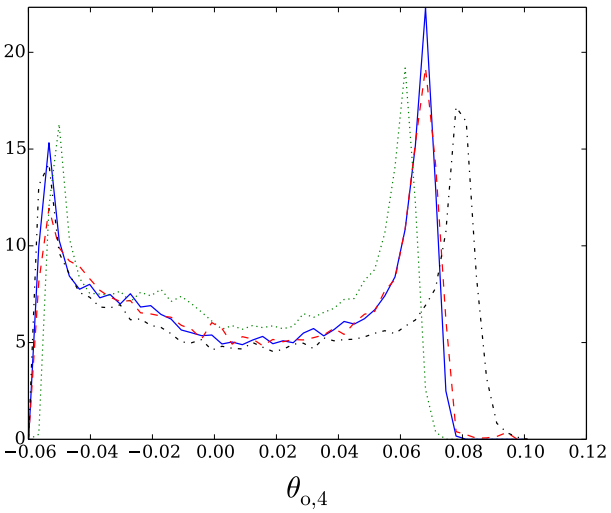
$\theta_{o,1}$



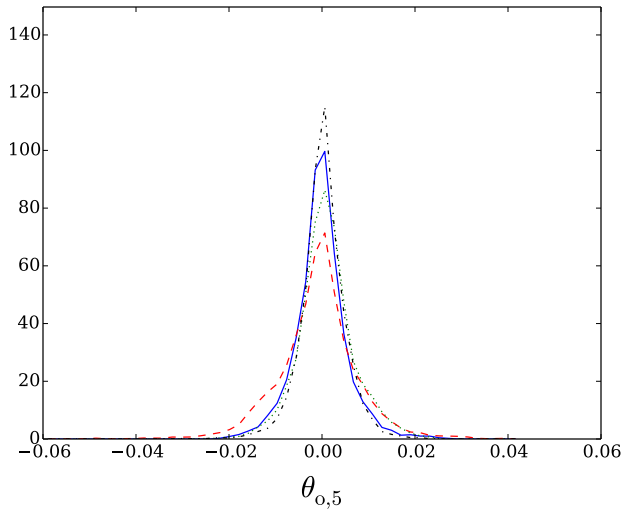
$\theta_{o,2}$

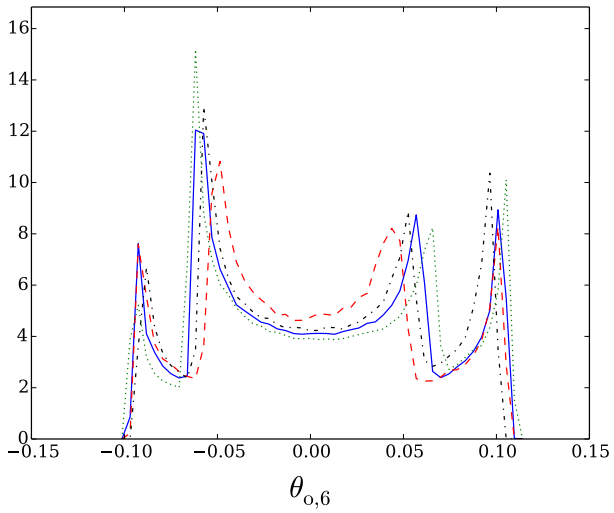


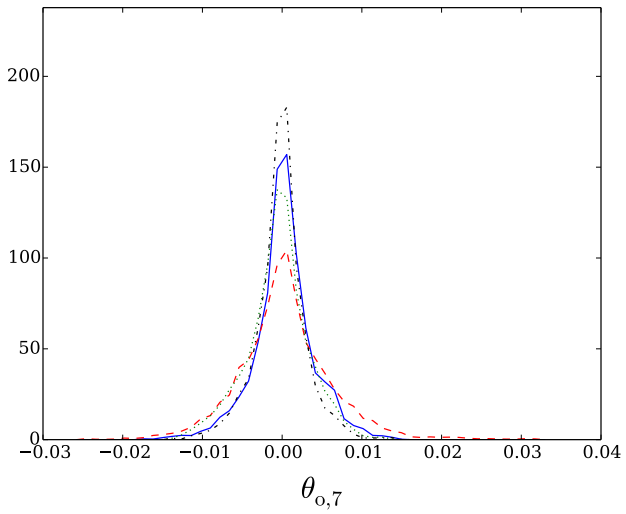
$\theta_{o,3}$

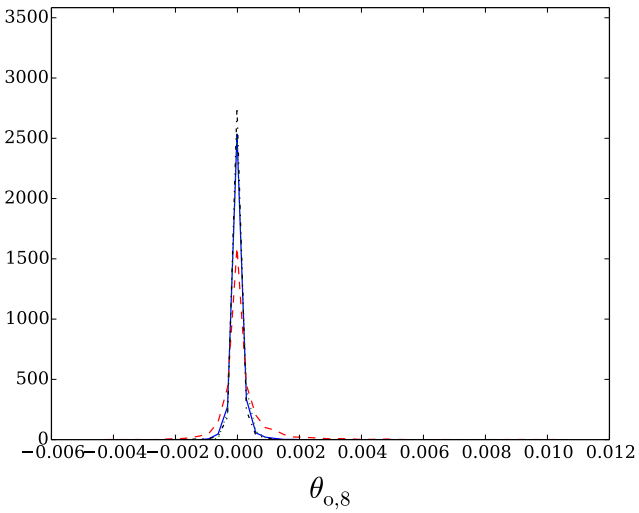


$\theta_{o,4}$

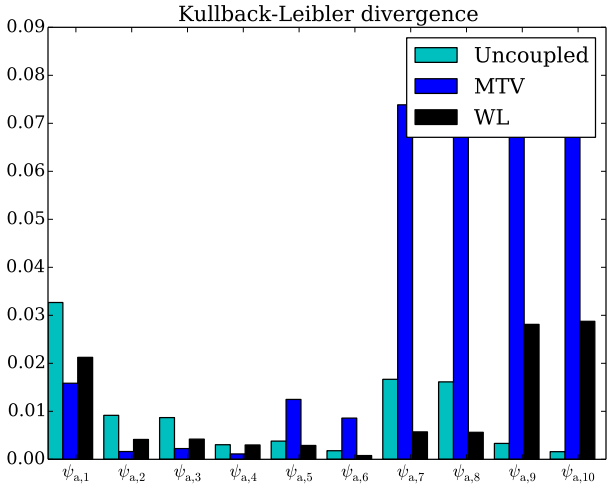

140
120
100
80
60
40
20
0
−0.06
−0.04
−0.02
0.00
0.02
0.04
0.06
$\theta_{o,5}$

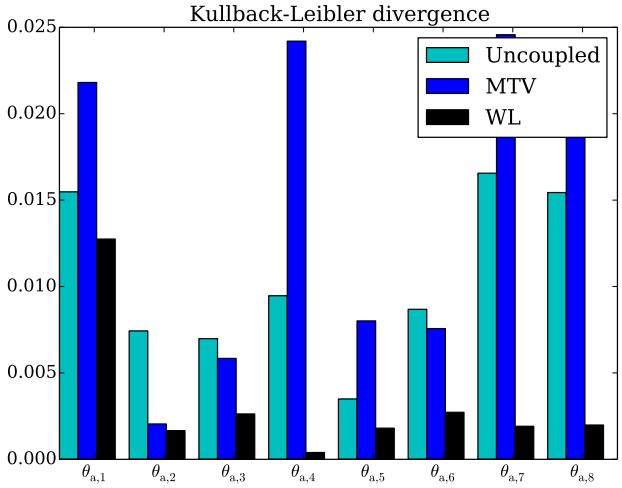

16
14
12
10
8
6
4
2
0
−0.15
−0.10
−0.05
0.00
0.05
0.10
0.15
$\theta_{o,6}$

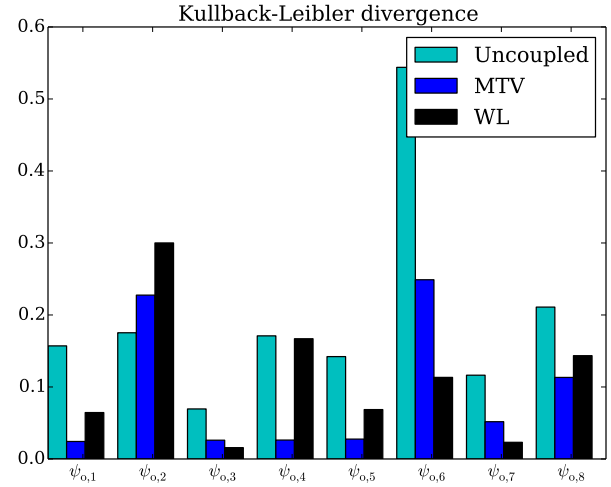

200
150
100
50
0
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
$\theta_{o,7}$

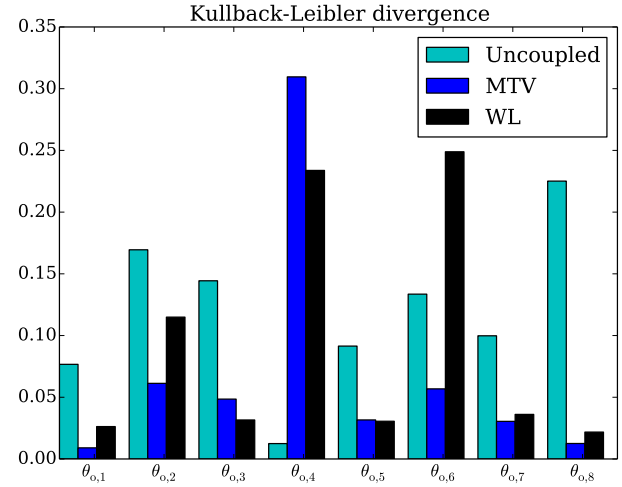

3500
3000
2500
2000
1500
1000
500
0
−0.006
−0.004
−0.002
0.000
0.002
0.004
0.006
0.008
0.010
0.012
$\theta_{o,8}$

2.2.2 Kullback-Leibler divergences





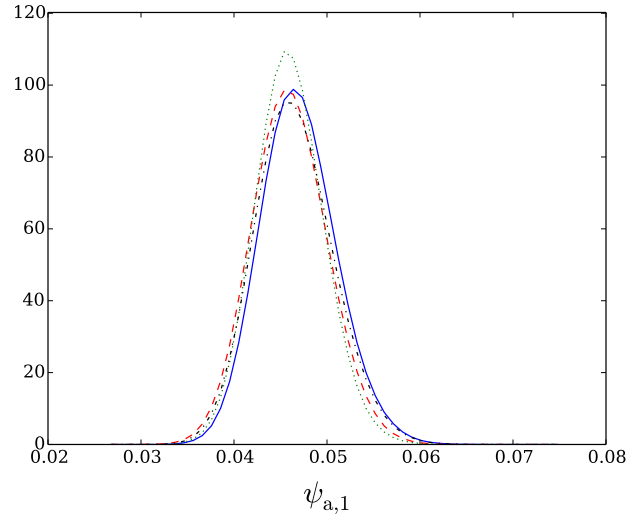


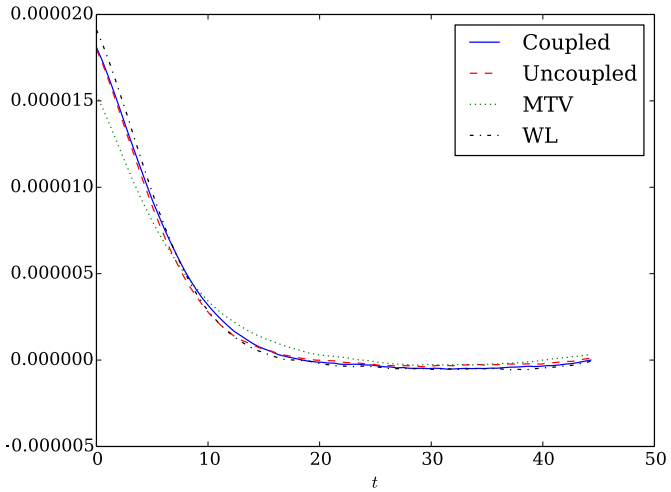


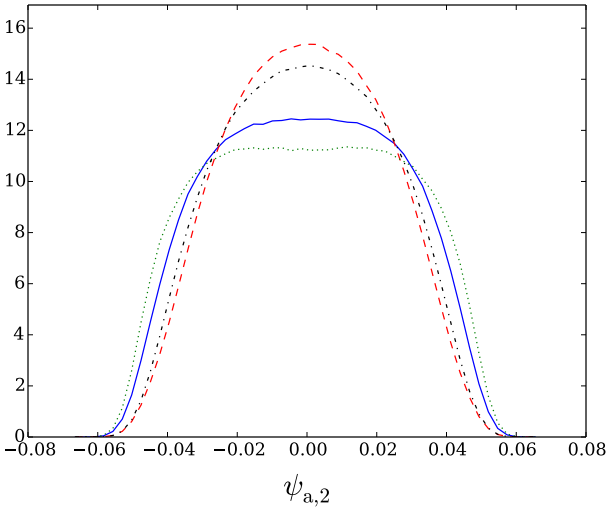
2.3 noLFV parameter set

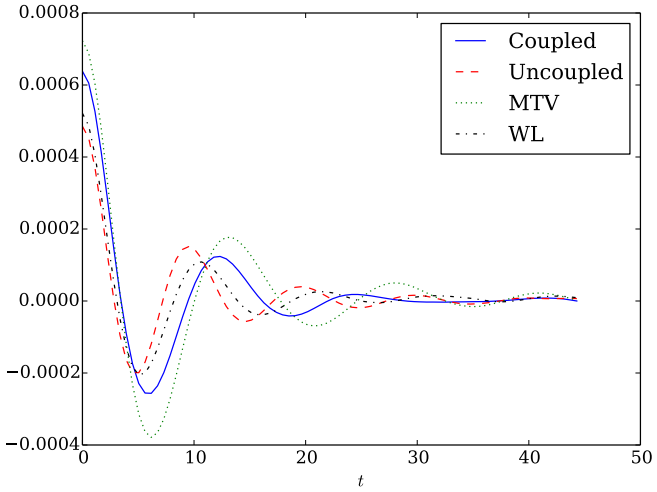
2.3.1 PDFs and autocorrelation functions of the resolved variables

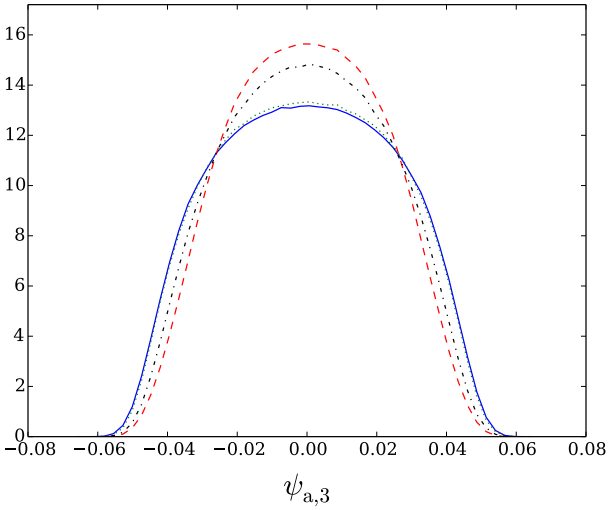
Atmospheric variables of the model.

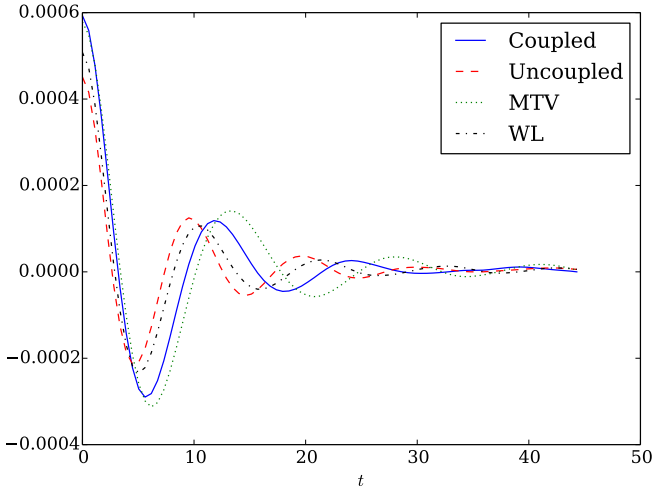


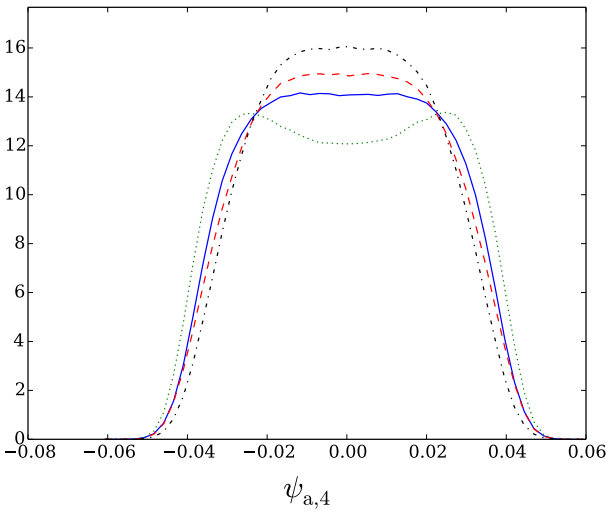


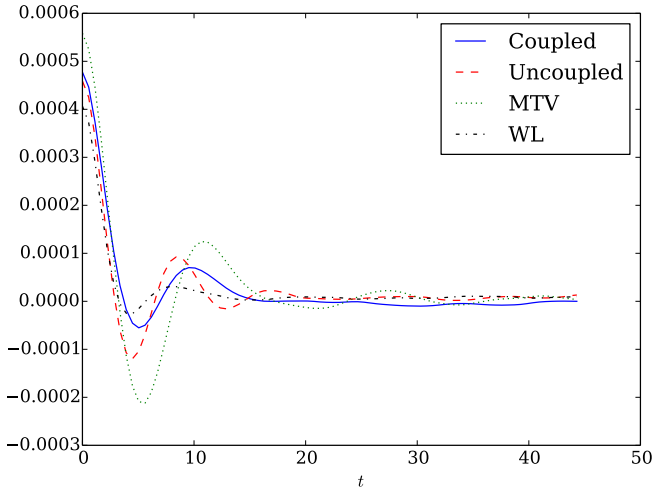

$\psi_{a,2}$

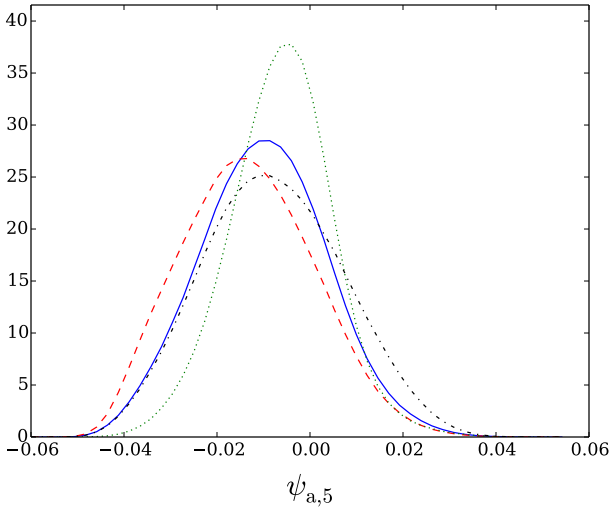

Coupled
Uncoupled
MTV
WL
t

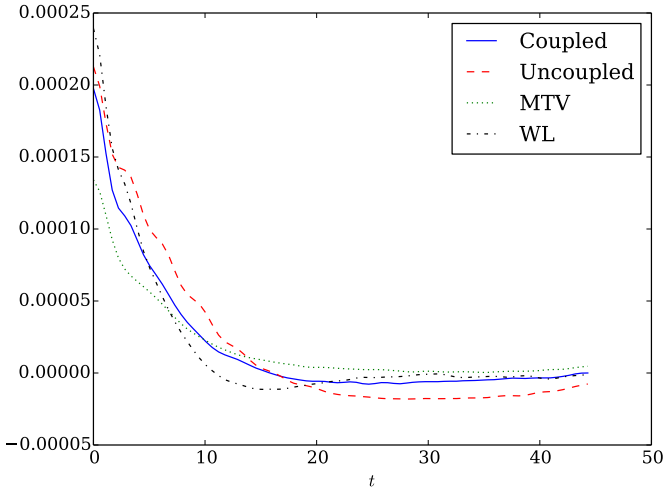

$\psi_{a,3}$

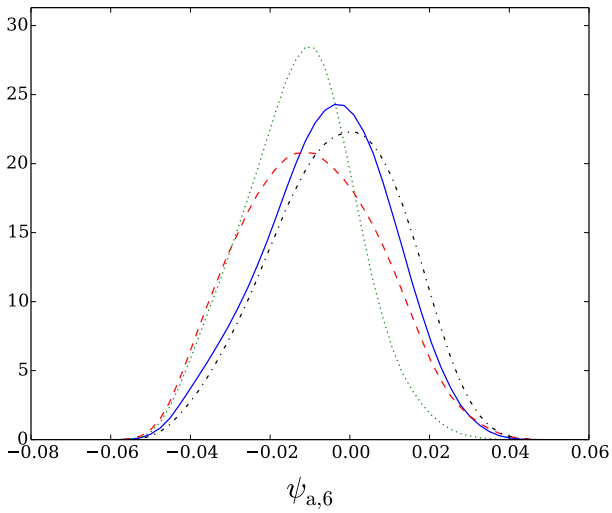

Coupled
Uncoupled
MTV
WL
t

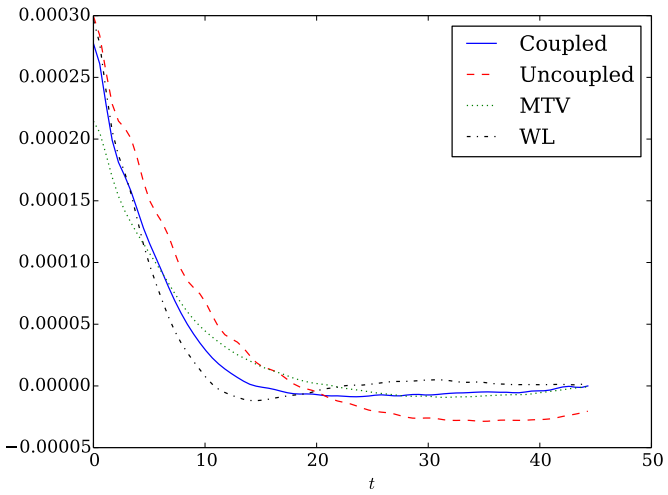

$\psi_{a,4}$

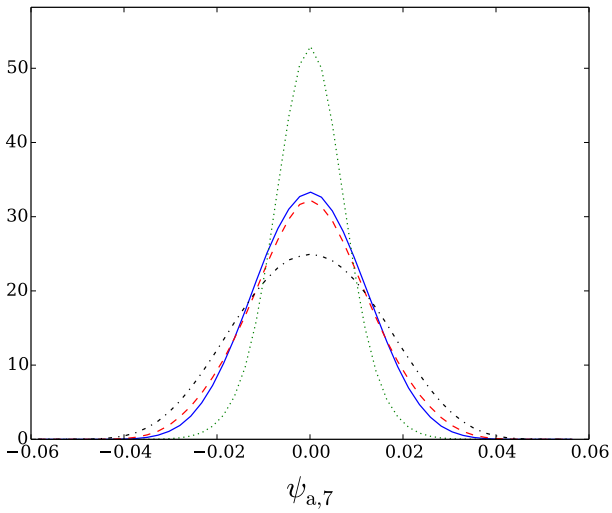

Coupled
Uncoupled
MTV
WL
t

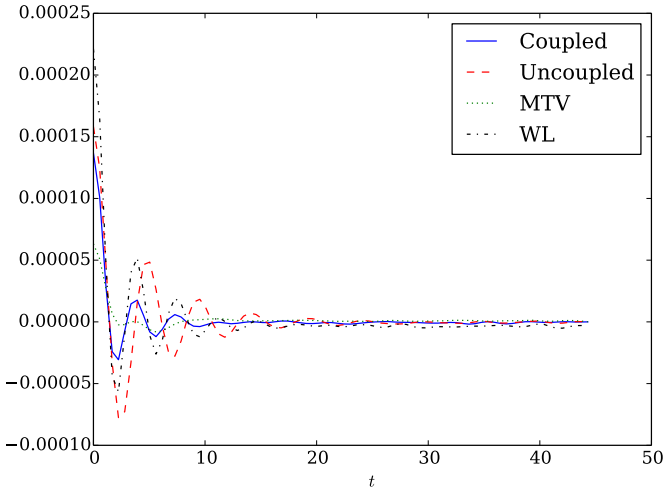

$\psi_{a,5}$

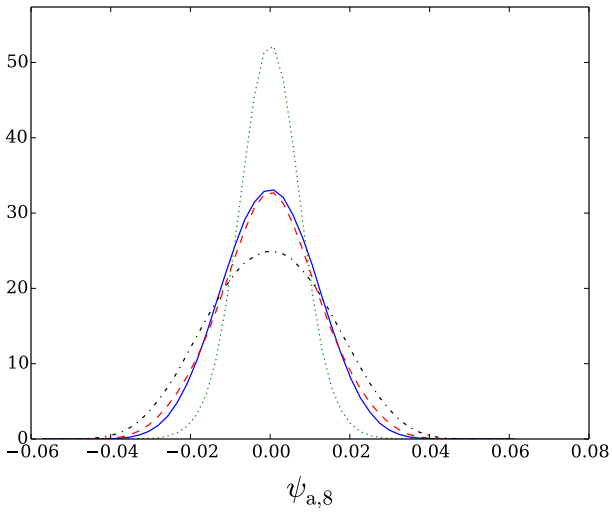

Coupled
Uncoupled
MTV
WL
t

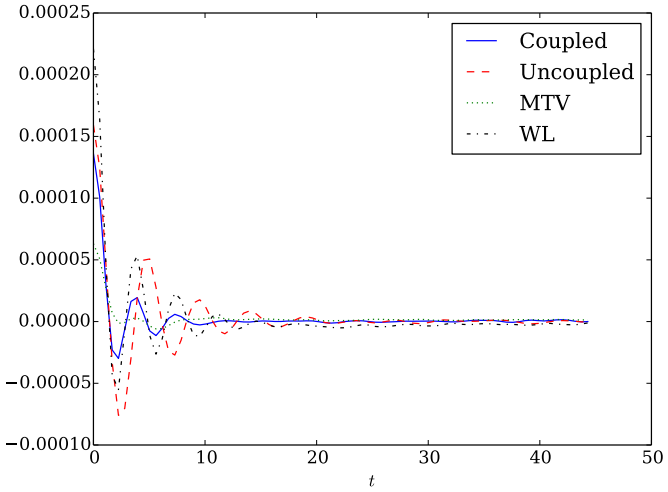

$\psi_{a,6}$

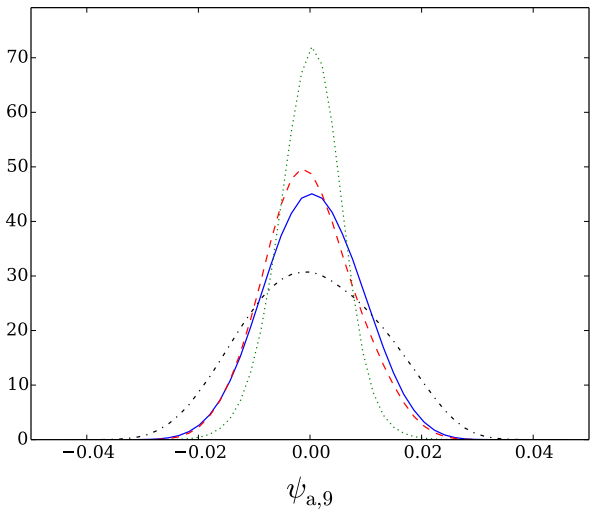

Coupled
Uncoupled
MTV
WL
t

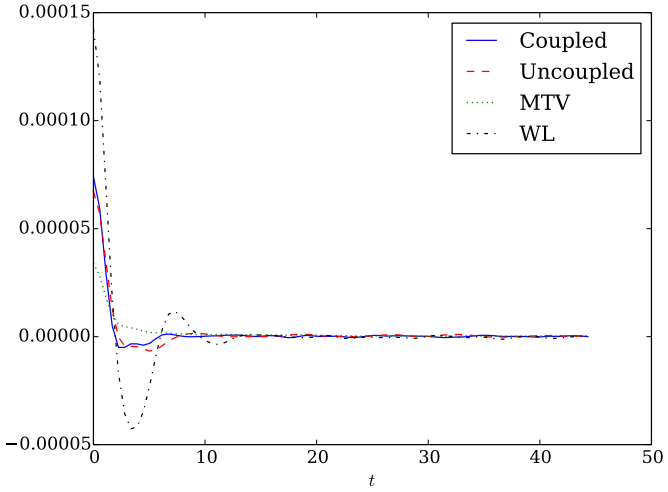

$\psi_{a,7}$

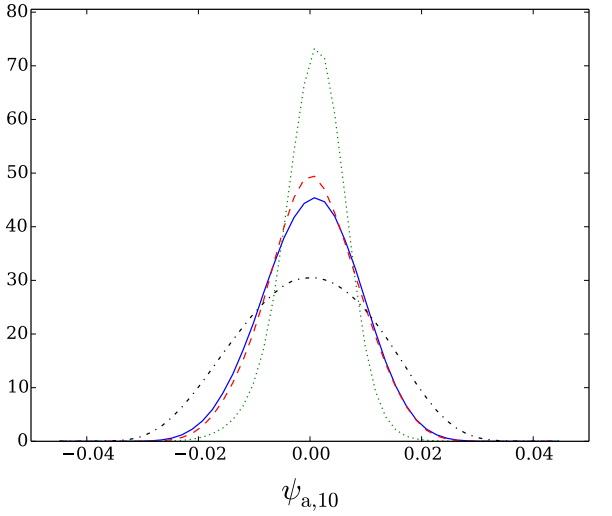

Coupled
Uncoupled
MTV
WL
t

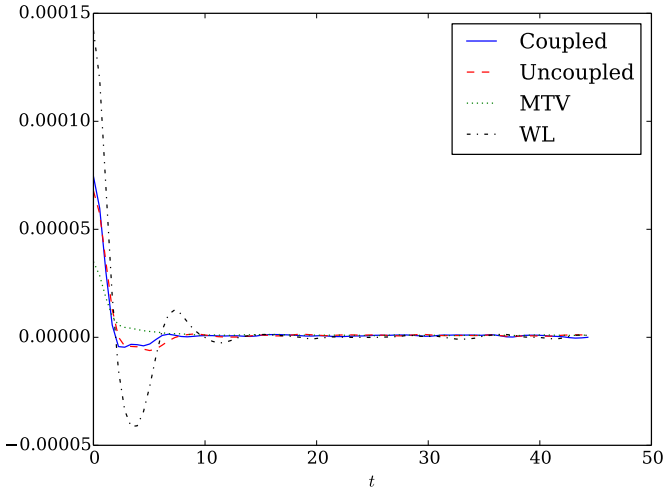

$\psi_{a,8}$

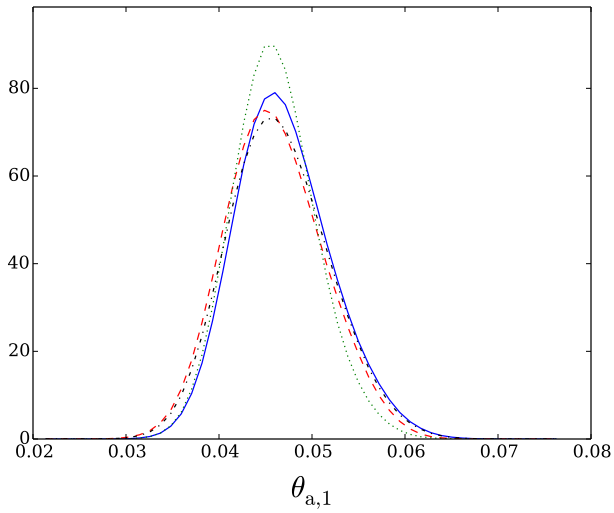

Coupled
Uncoupled
MTV
WL
t

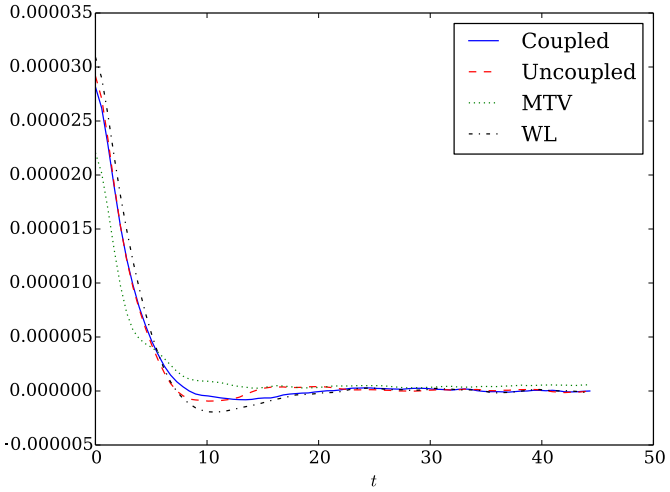

$\psi_{a,9}$

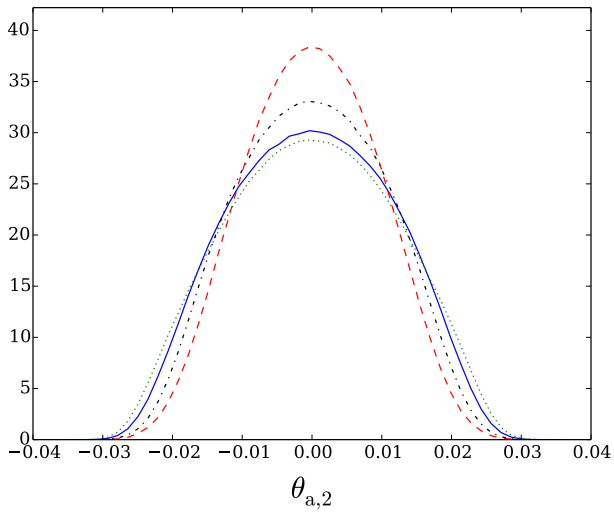

Coupled
Uncoupled
MTV
WL
t

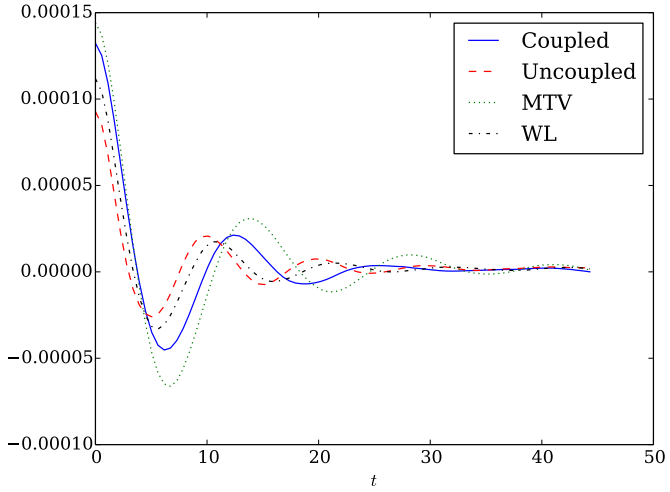

$\psi_{a,10}$

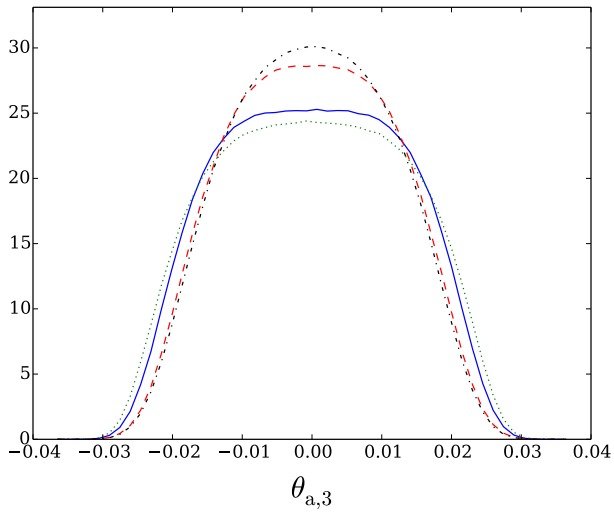

Coupled
Uncoupled
MTV
WL
t

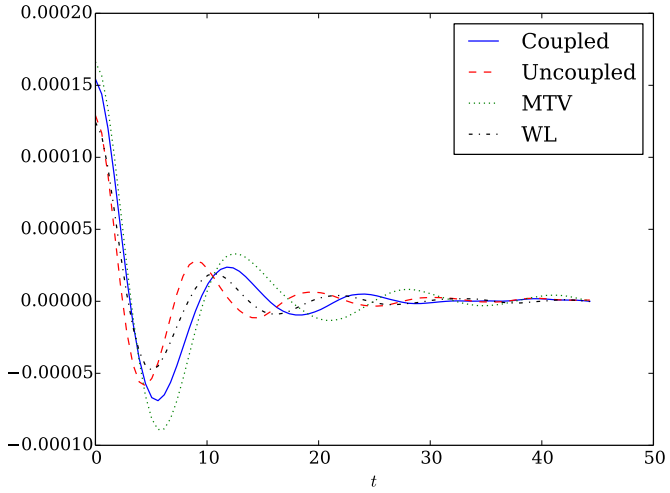

0.02
0.03
0.04
0.05
0.06
0.07
0.08
0
20
40
60
80
$\theta_{a,1}$

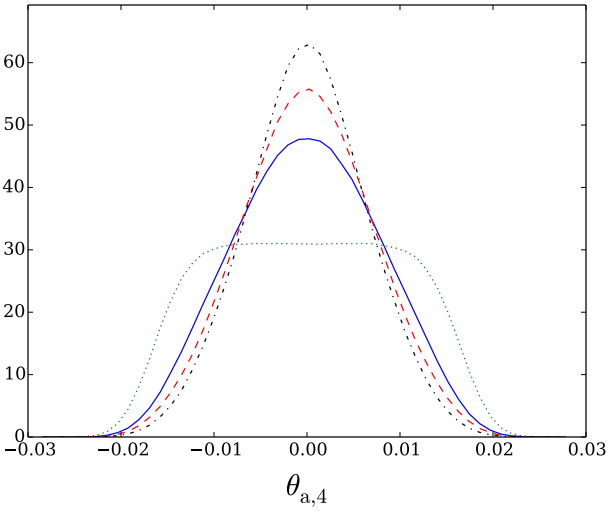

Coupled
Uncoupled
MTV
WL
0.000035
0.000030
0.000025
0.000020
0.000015
0.000010
0.000005
0.000000
-0.000005
0
10
20
30
40
50
t

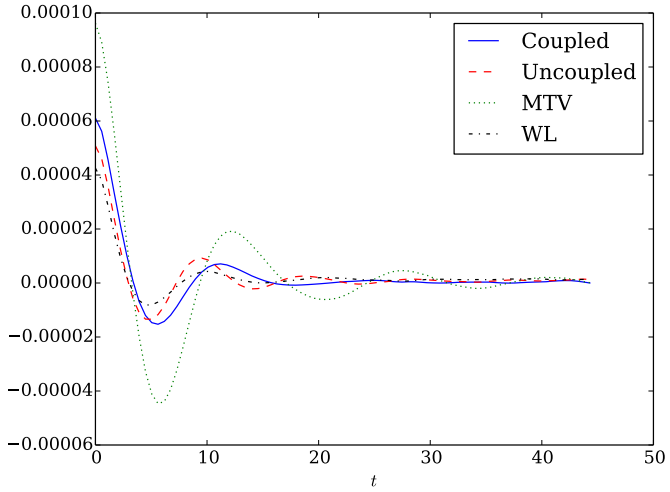

−0.04
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
0
5
10
15
20
25
30
35
40
$\theta_{a,2}$

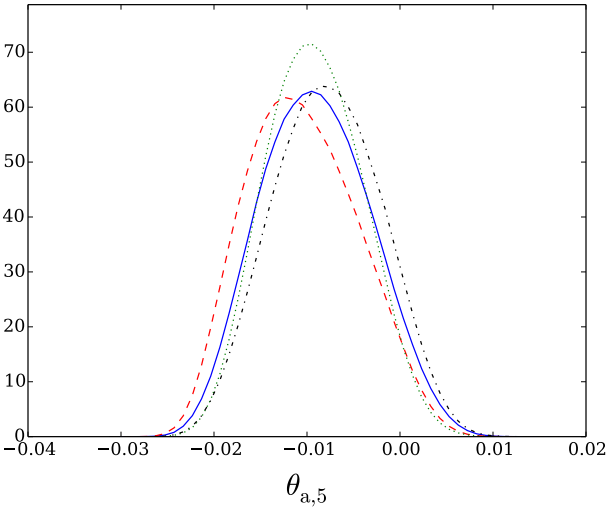

Coupled
Uncoupled
MTV
WL
0.00015
0.00010
0.00005
0.00000
−0.00005
−0.00010
0
10
20
30
40
50
t

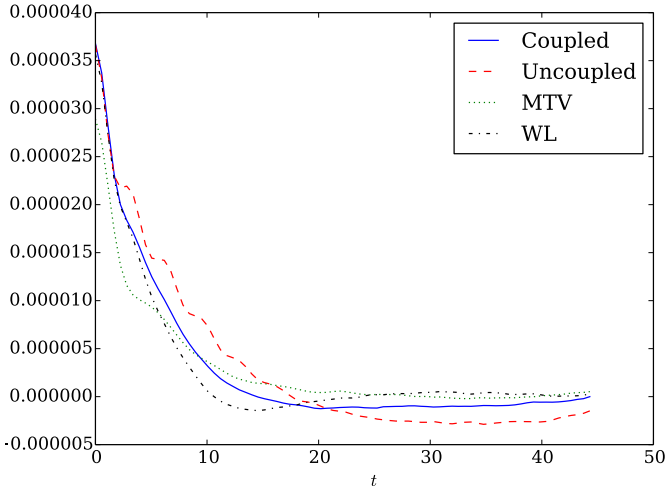

−0.04
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
0
5
10
15
20
25
30
$\theta_{a,3}$

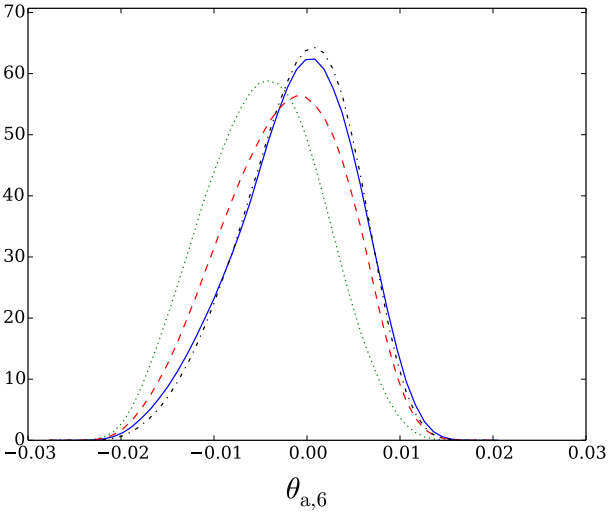

Coupled
Uncoupled
MTV
WL
0.00020
0.00015
0.00010
0.00005
0.00000
−0.00005
−0.00010
0
10
20
30
40
50
t

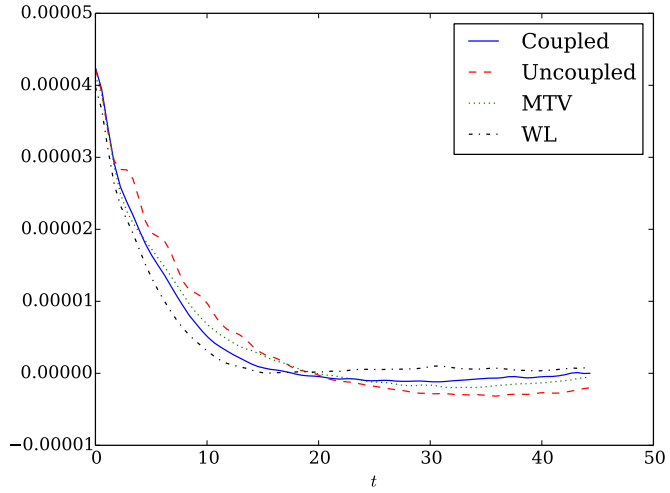

$\theta_{a,4}$

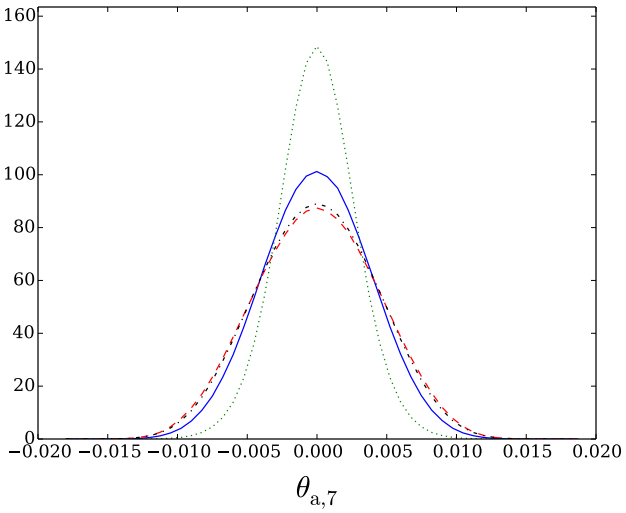

Coupled
Uncoupled
MTV
WL
t

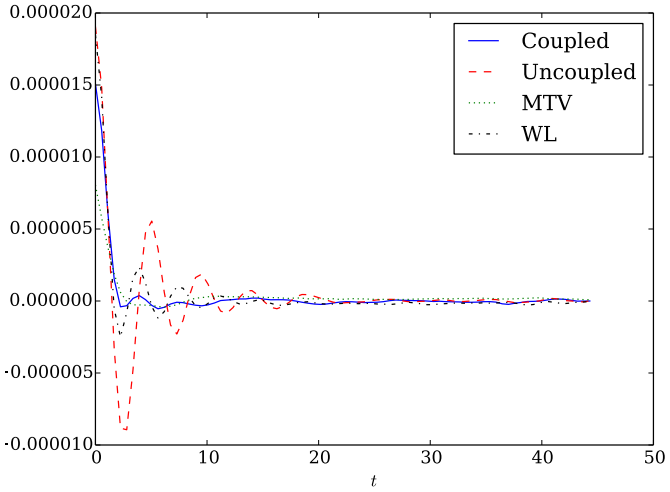

$\theta_{a,5}$

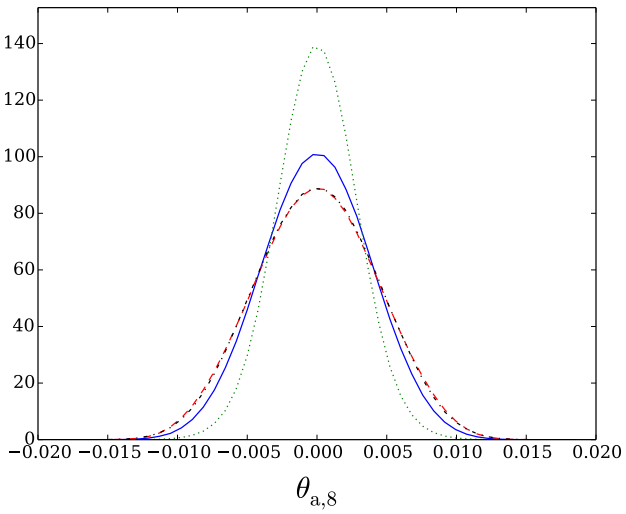

Coupled
Uncoupled
MTV
WL
t

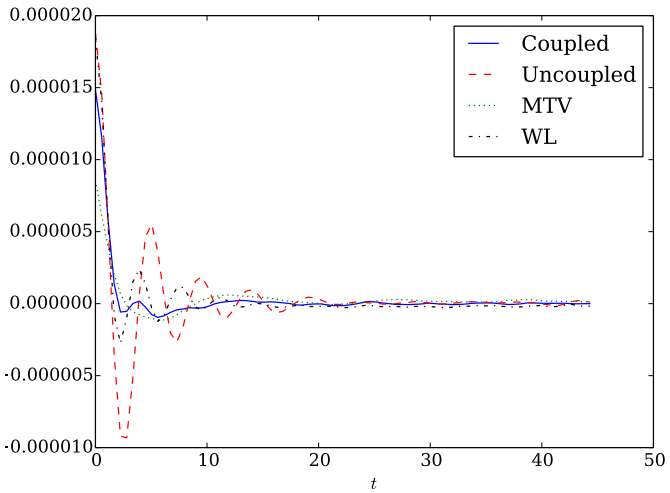

$\theta_{a,6}$


Coupled
Uncoupled
MTV
WL
t

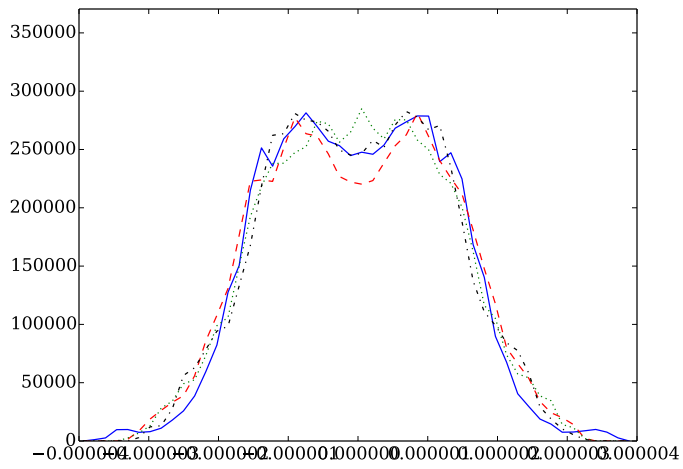




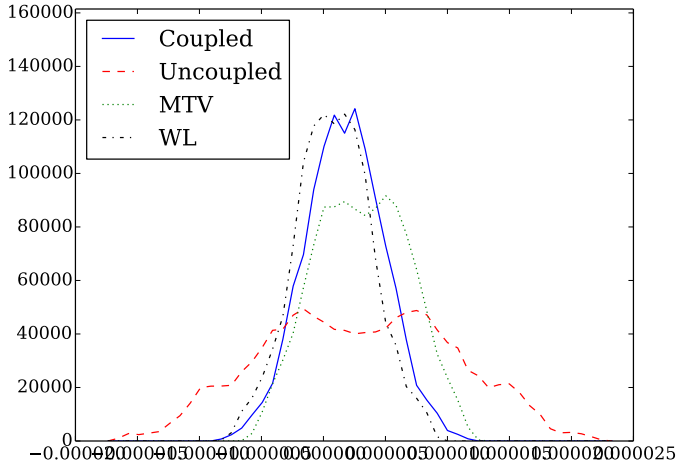




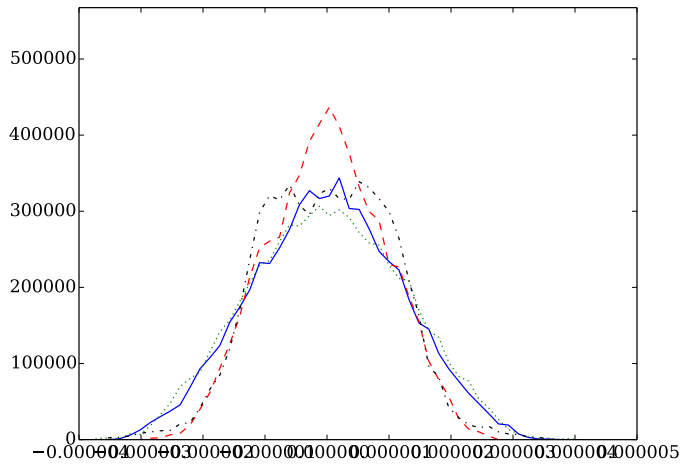
Oceanic variables Only the PDFs are available for these variables.



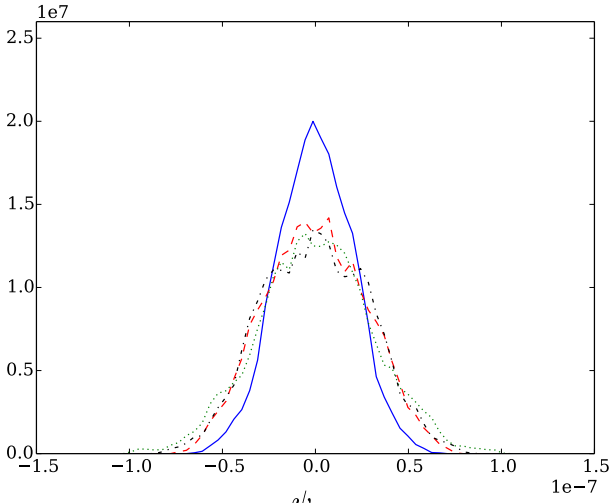
$\psi_{o,1}$



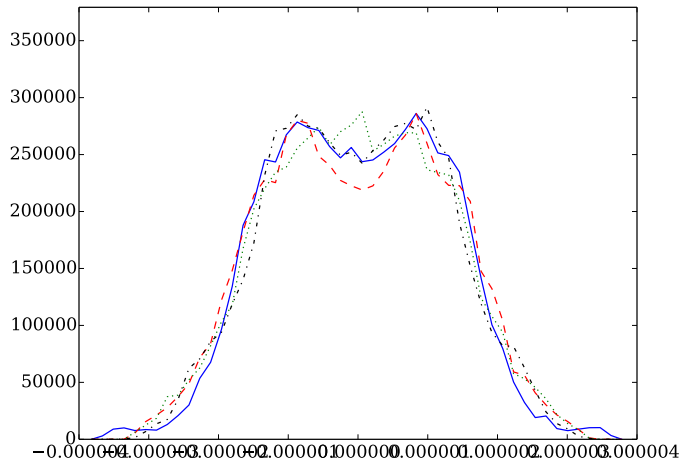
$\psi_{o,2}$



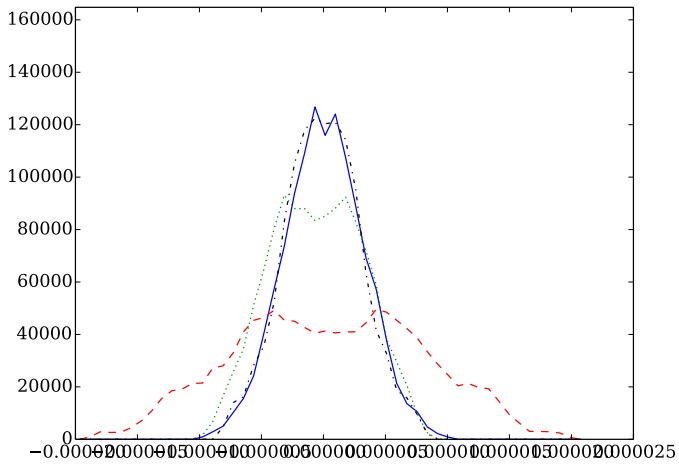
$\psi_{o,3}$



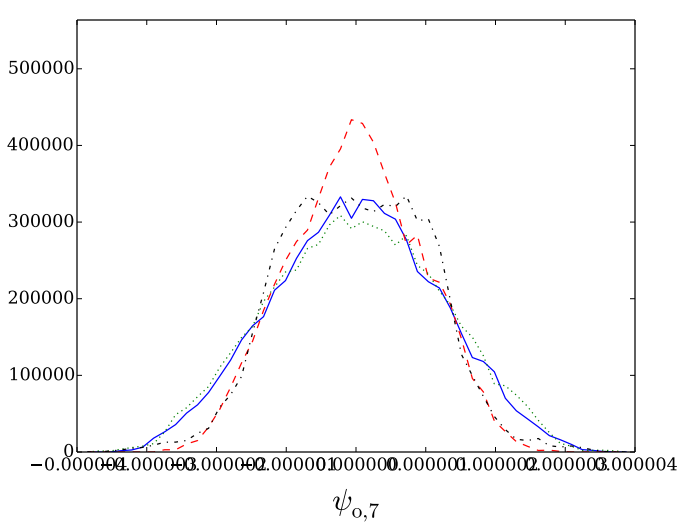
$\psi_{o,4}$



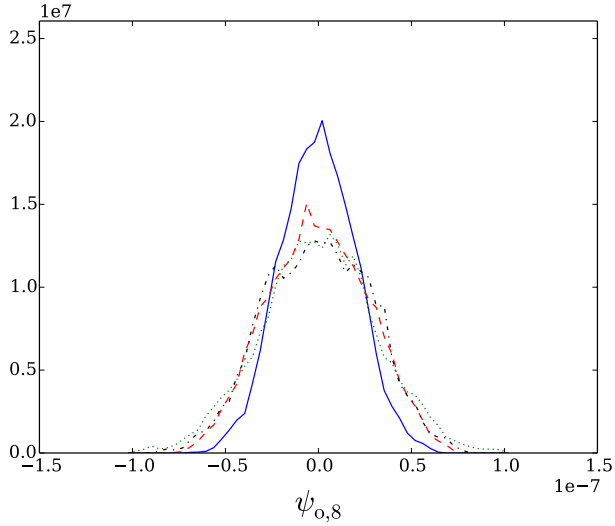
$\psi_{o,5}$



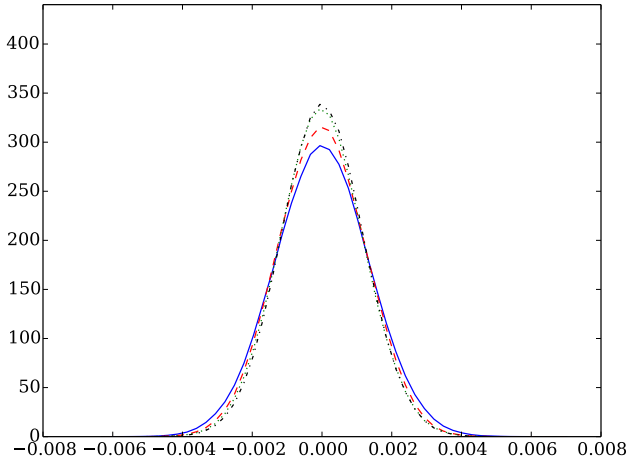
$\psi_{o,6}$



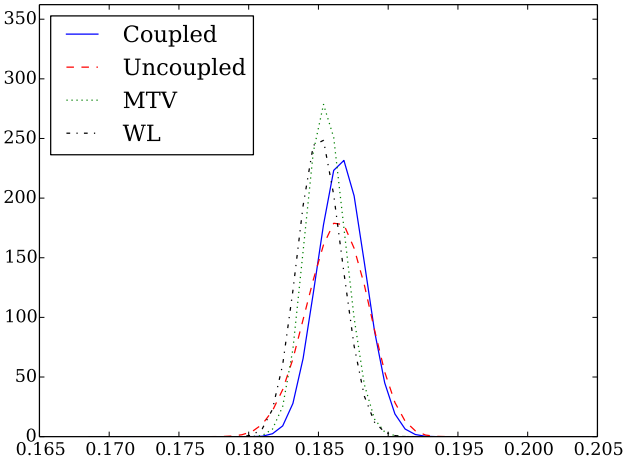
$\psi_{o,7}$



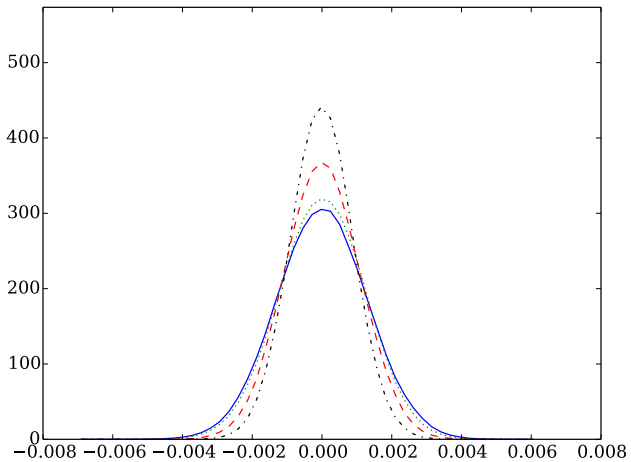
$\psi_{o,8}$



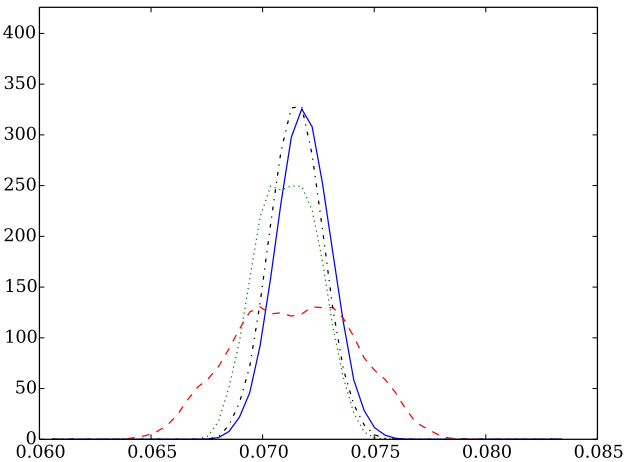
$\theta_{o,1}$



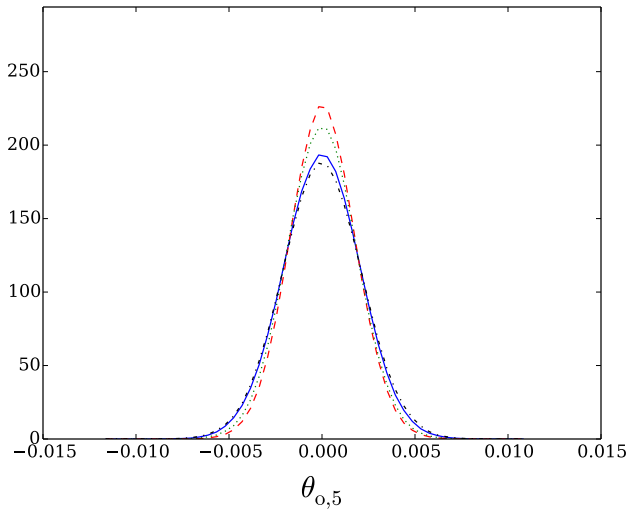
$\theta_{o,2}$

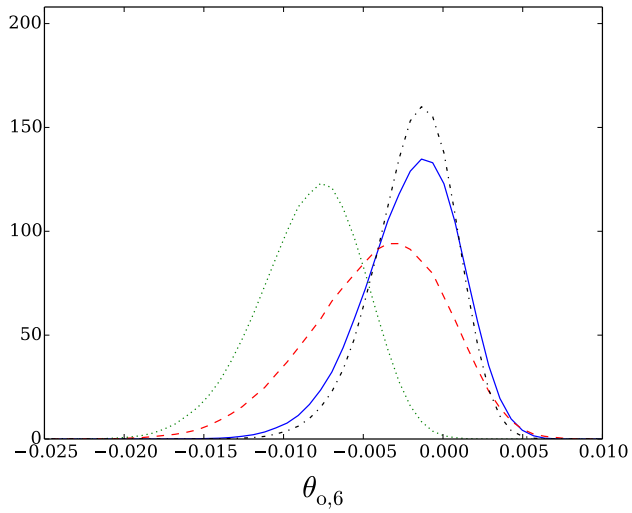


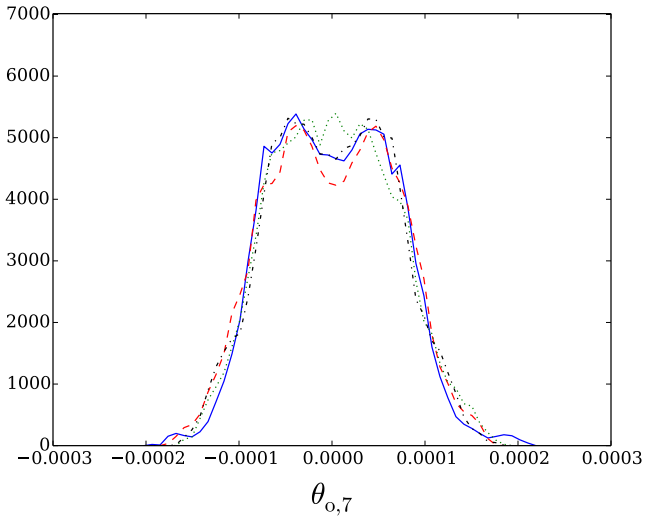
$\theta_{o,3}$

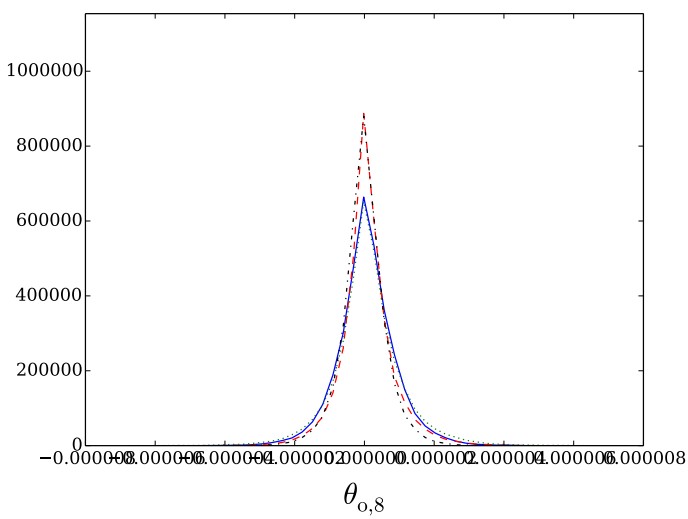


$\theta_{o,4}$

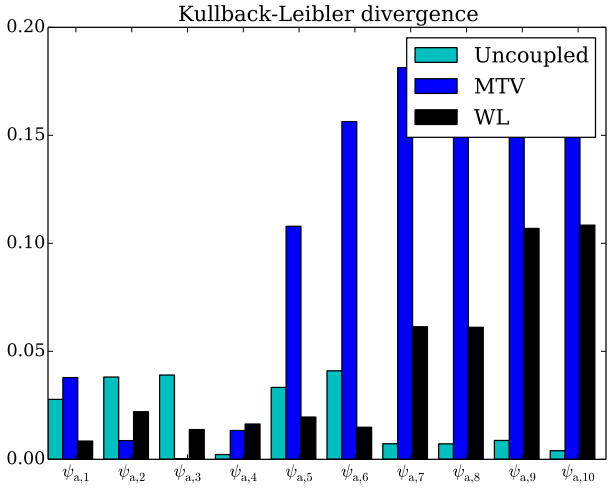

250
200
150
100
50
0
−0.015
−0.010
−0.005
0.000
0.005
0.010
0.015
$\theta_{o,5}$

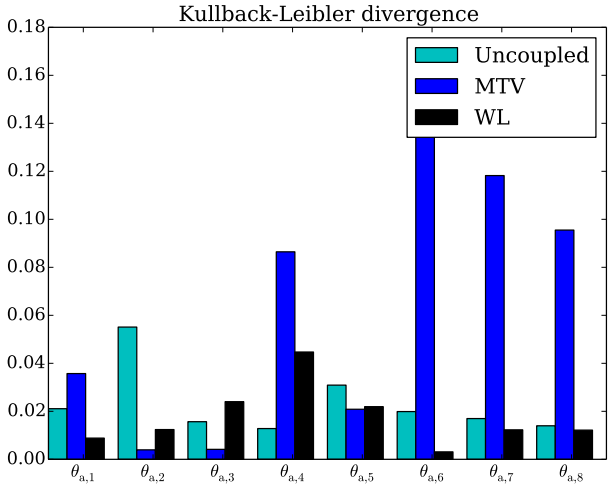

200
150
100
50
0
−0.025
−0.020
−0.015
−0.010
−0.005
0.000
0.005
0.010
$\theta_{o,6}$

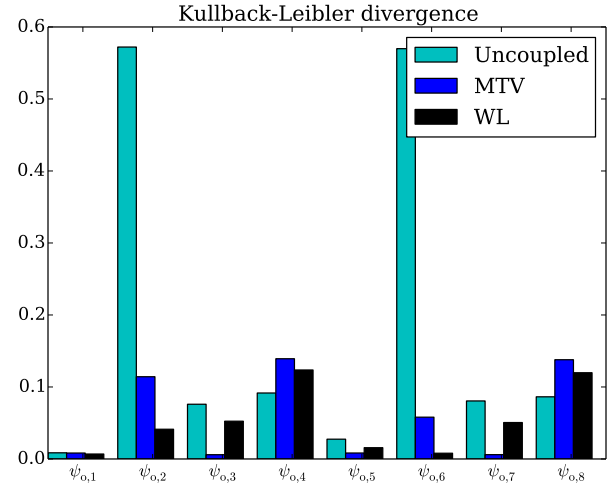

7000
6000
5000
4000
3000
2000
1000
0
−0.0003
−0.0002
−0.0001
0.0000
0.0001
0.0002
0.0003
$\theta_{o,7}$

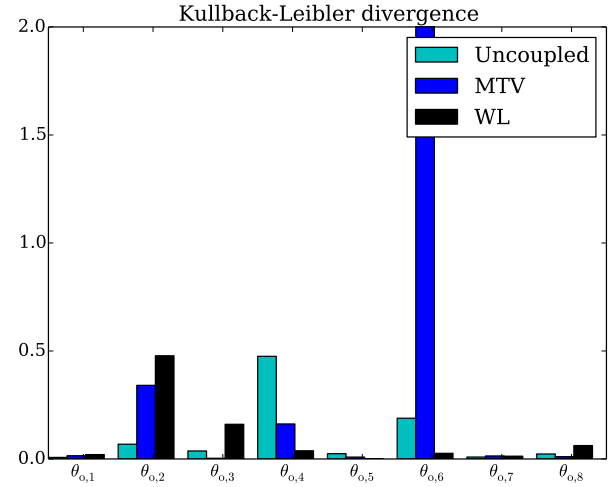

1000000
800000
600000
400000
200000
0
$\theta_{o,8}$

2.3.2 Kullback-Leibler divergences









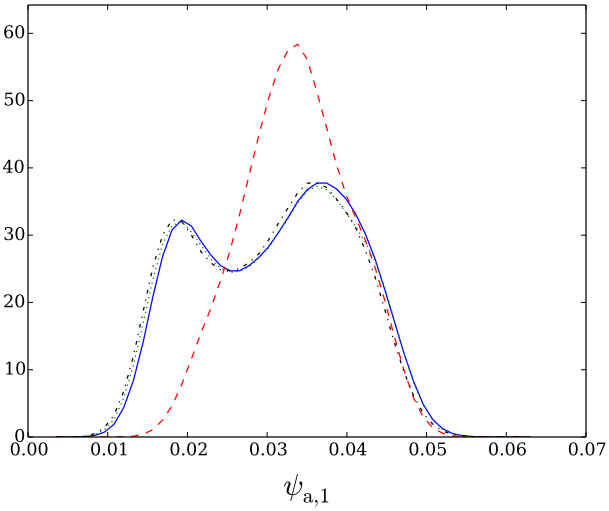
3 The parameterization of the atmospheric wavenumber 2 and F_4 modes

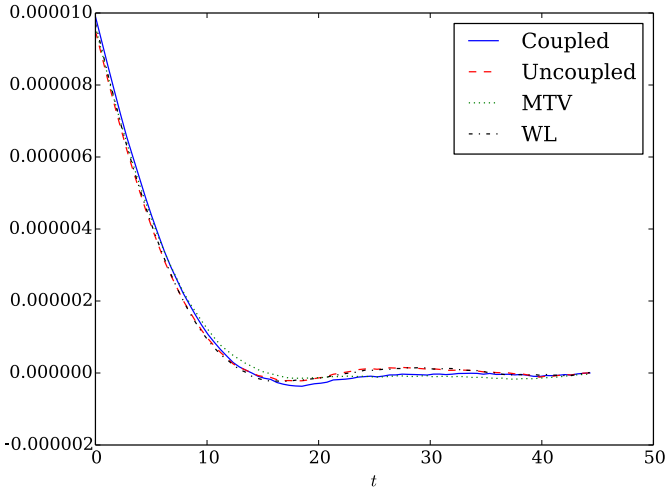
All the figures compiled in this section are related to the experiment described in the section 4.1.4 and concern the "DV2017" and "noLFV" parameter sets.

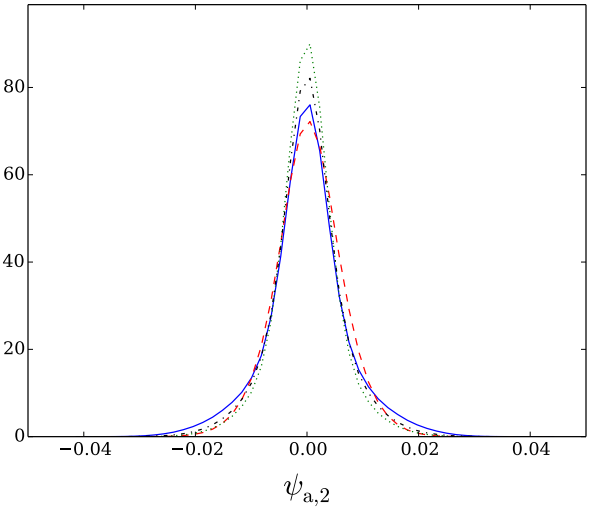
3.1 DV2017 parameter set

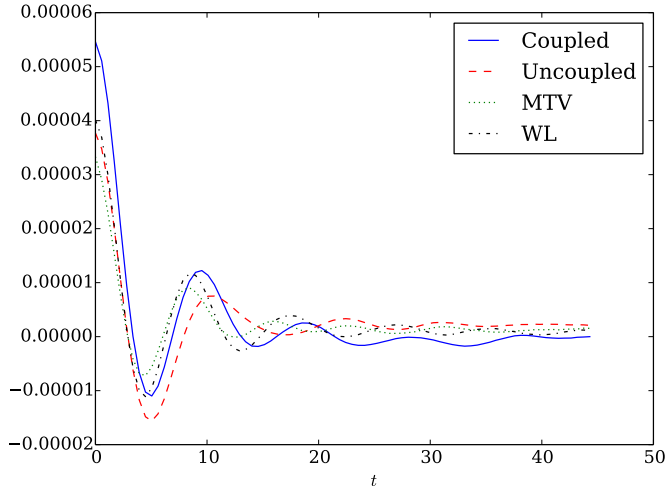
3.1.1 PDFs and autocorrelation functions of the resolved variables

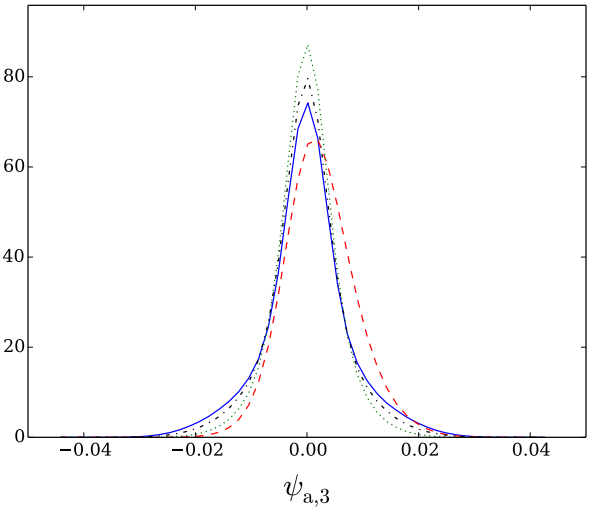
Atmospheric variables of the model.

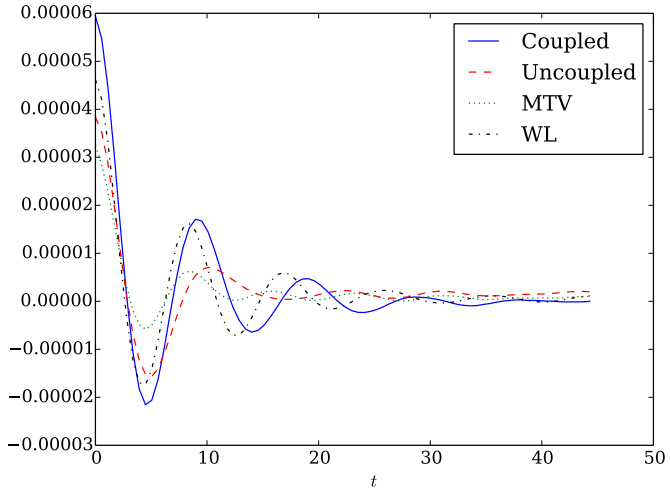

$\psi_{a,1}$

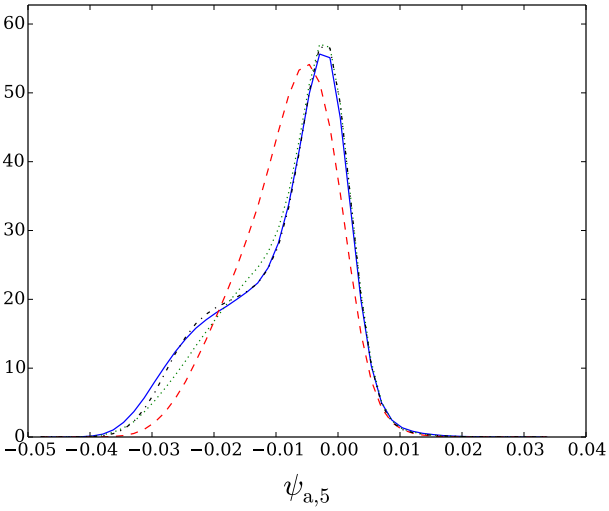

Coupled
Uncoupled
MTV
WL
t

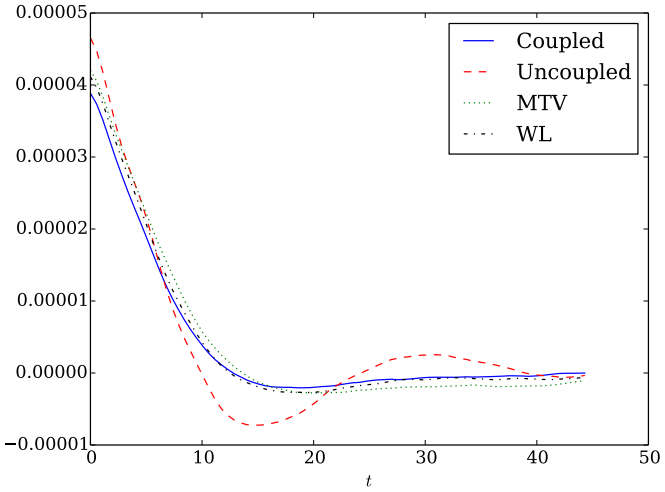

$\psi_{a,2}$

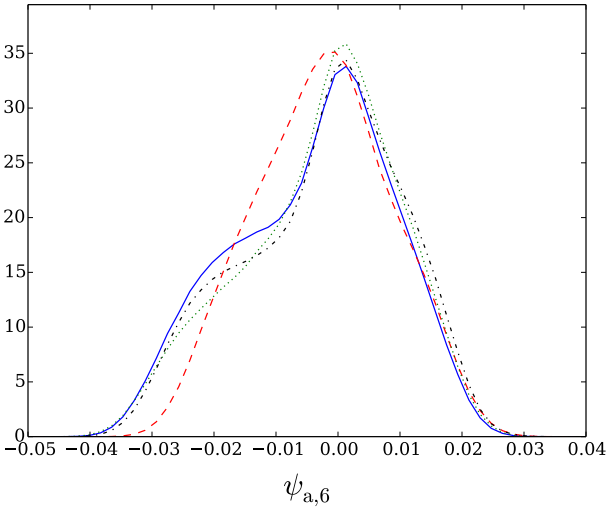

Coupled
Uncoupled
MTV
WL
t

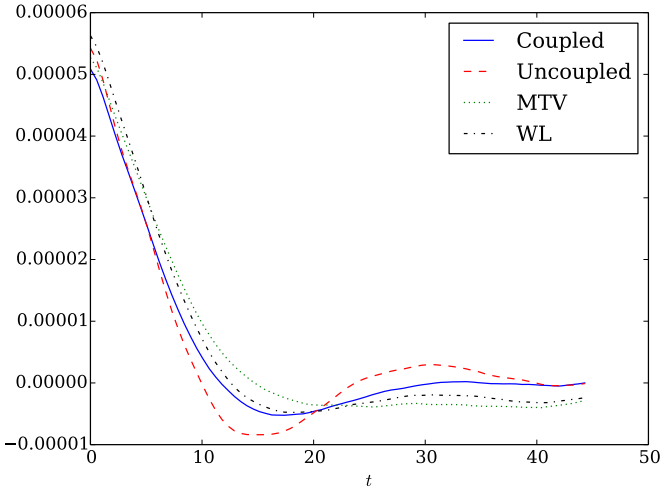

$\psi_{a,3}$

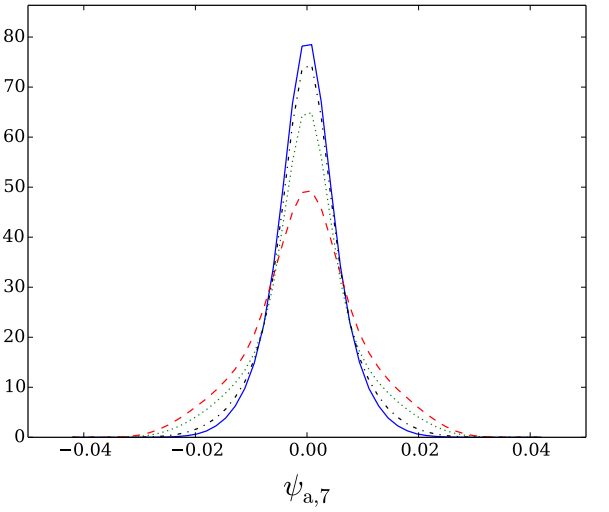

Coupled
Uncoupled
MTV
WL
t

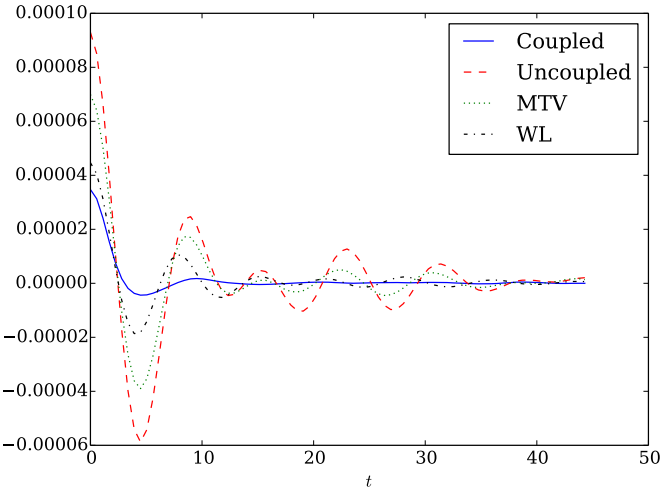

$\psi_{a,5}$

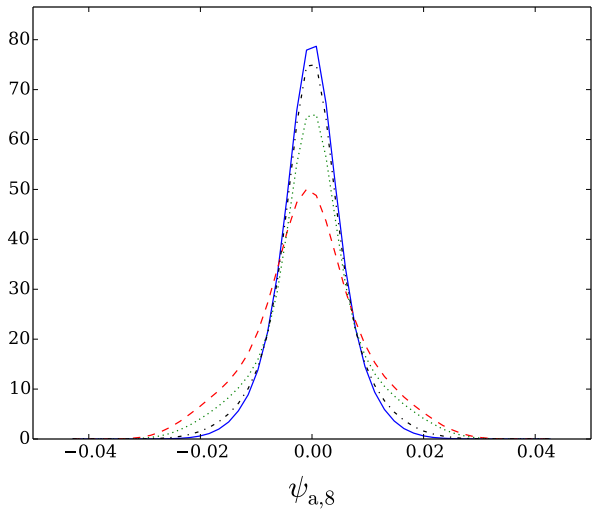

Coupled
Uncoupled
MTV
WL
t

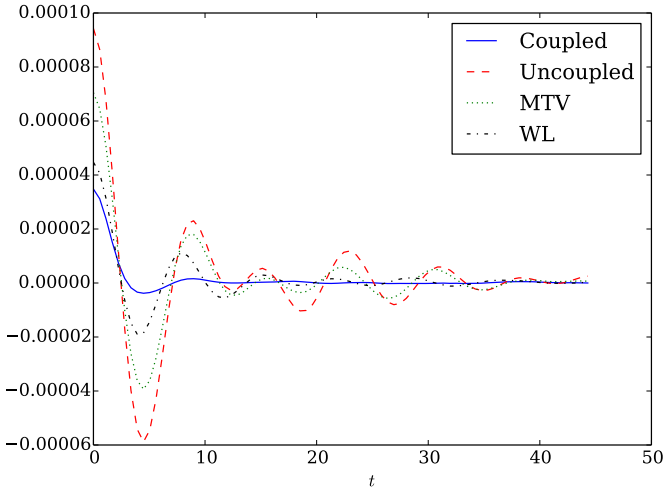

$\psi_{a,6}$

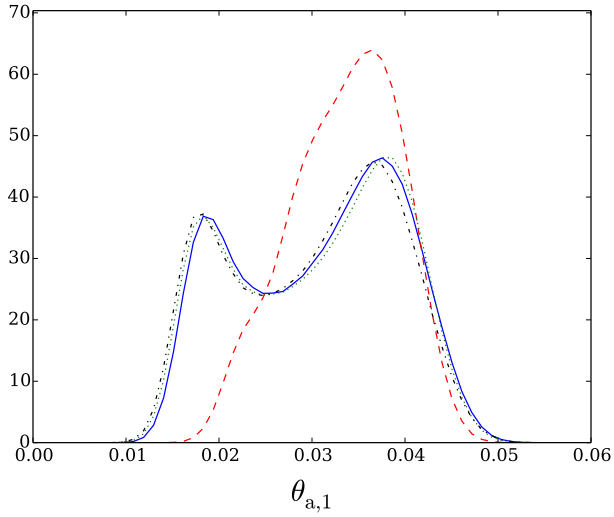

Coupled
Uncoupled
MTV
WL
t

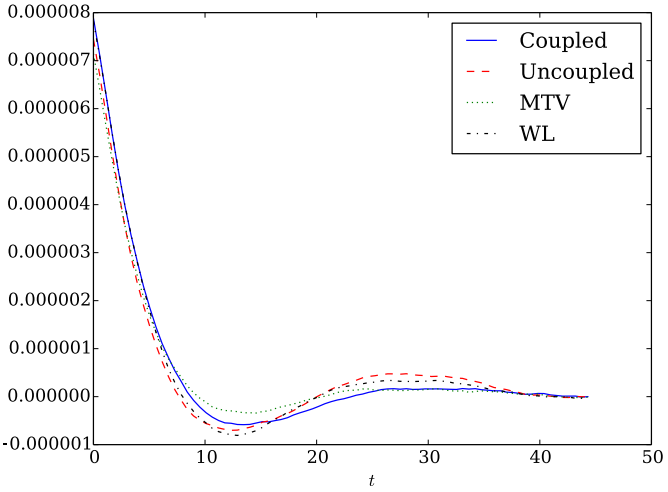

$\psi_{a,7}$

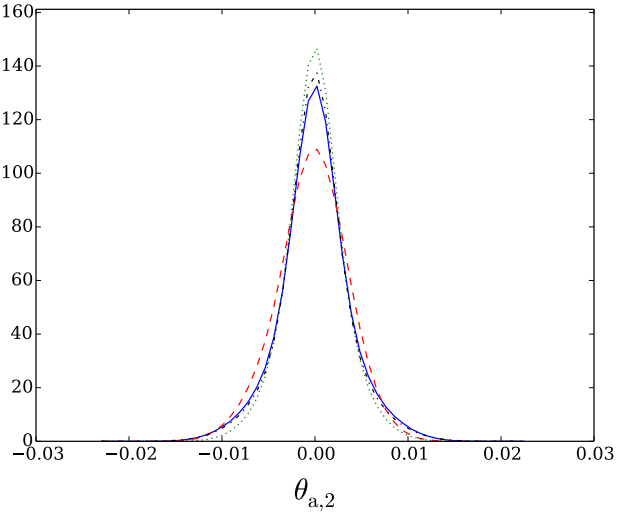

Coupled
Uncoupled
MTV
WL
t

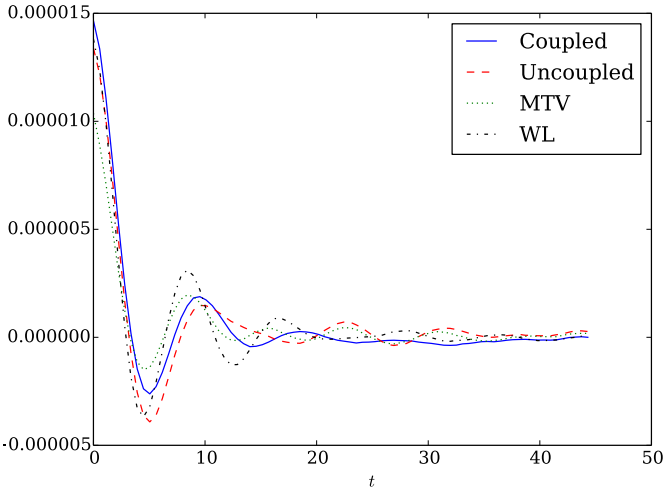

$\psi_{a,8}$

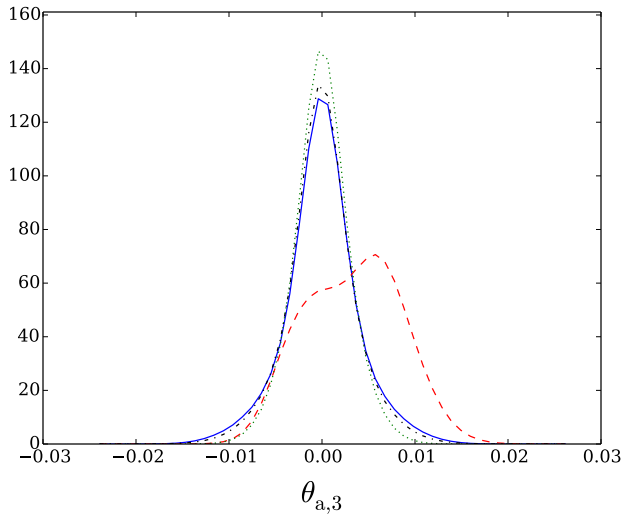

Coupled
Uncoupled
MTV
WL
t

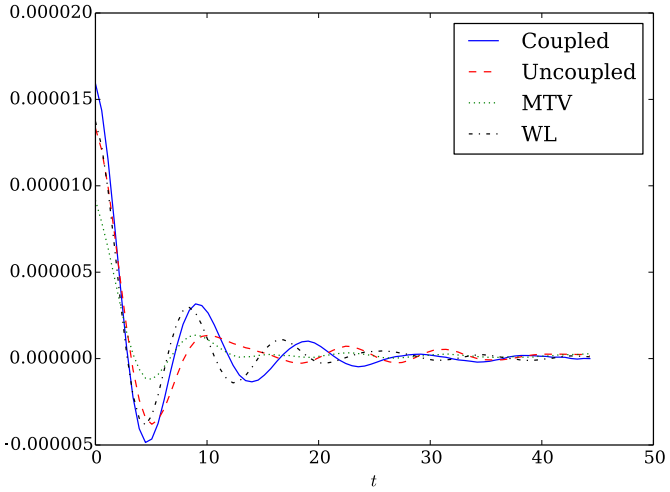

$\theta_{a,1}$

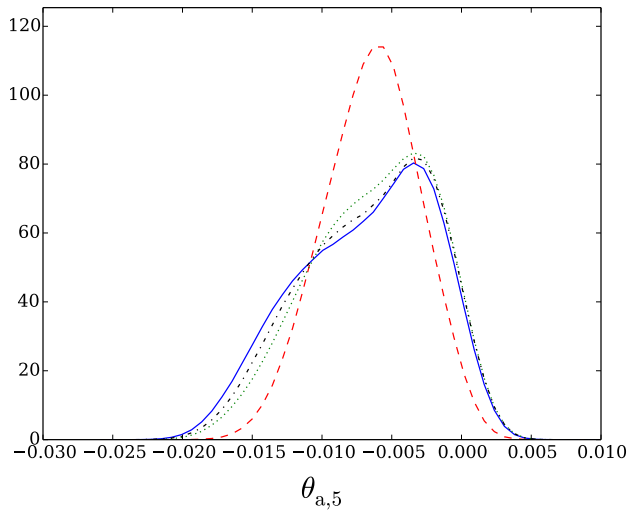

Coupled
Uncoupled
MTV
WL
t

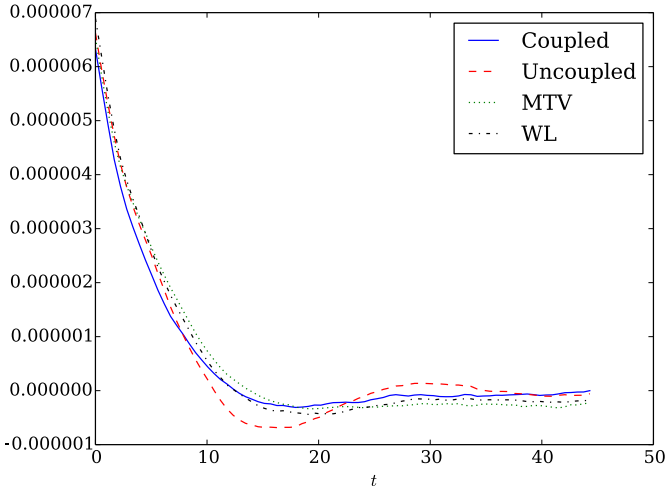

$\theta_{a,2}$

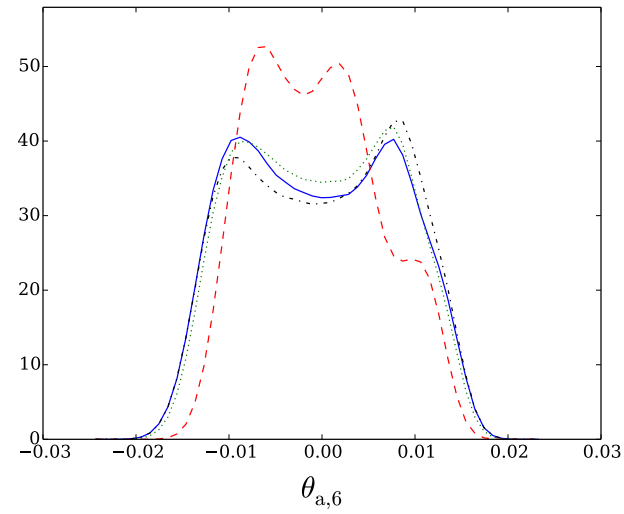

Coupled
Uncoupled
MTV
WL
t

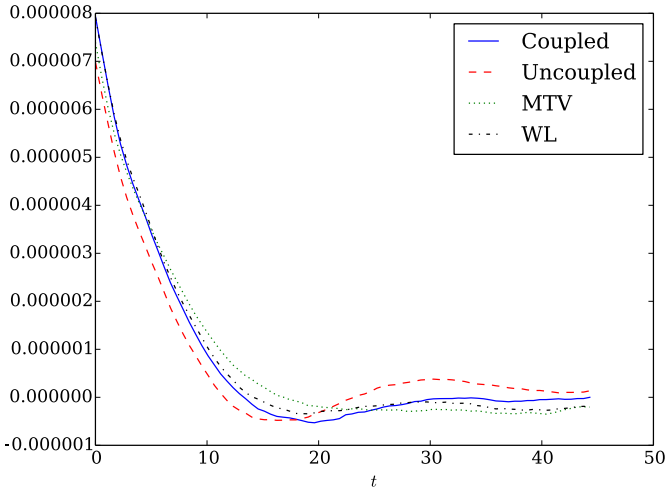

160
140
120
100
80
60
40
20
0
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
$\theta_{\mathrm{a},3}$

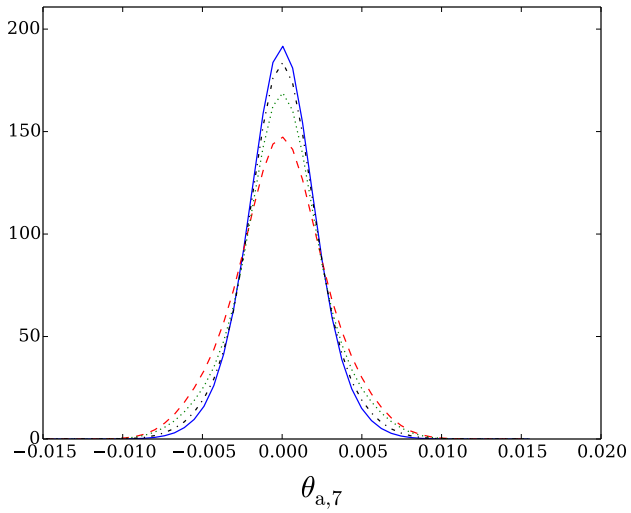

0.000020
0.000015
0.000010
0.000005
0.000000
-0.000005
0
10
20
30
40
50
t
Coupled
Uncoupled
MTV
WL

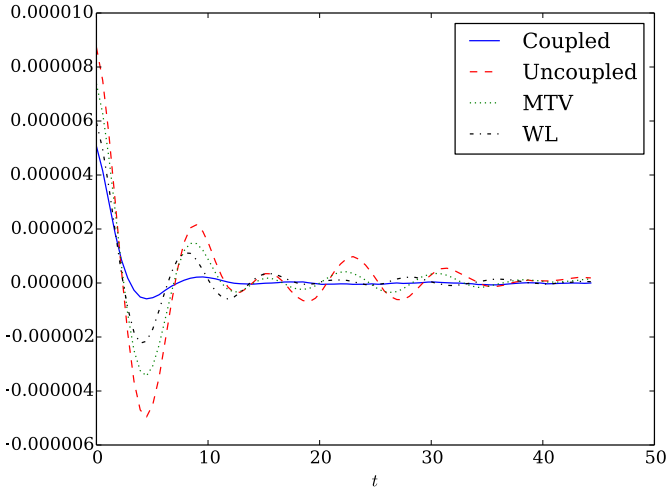

120
100
80
60
40
20
0
−0.030
−0.025
−0.020
−0.015
−0.010
−0.005
0.000
0.005
0.010
$\theta_{\mathrm{a},5}$

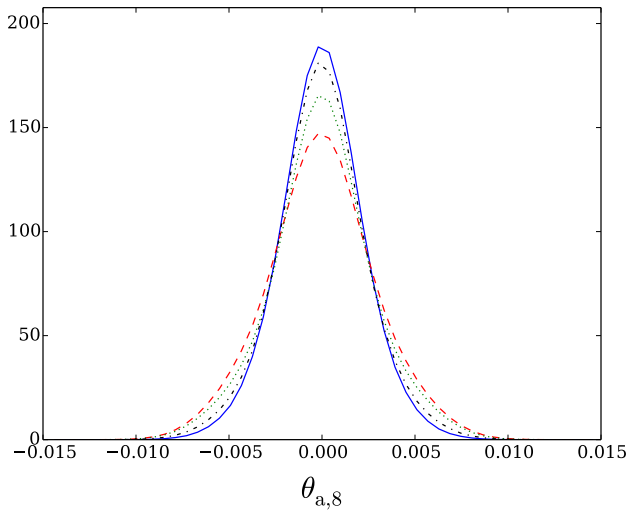

0.000007
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
0.000000
-0.000001
0
10
20
30
40
50
t
Coupled
Uncoupled
MTV
WL

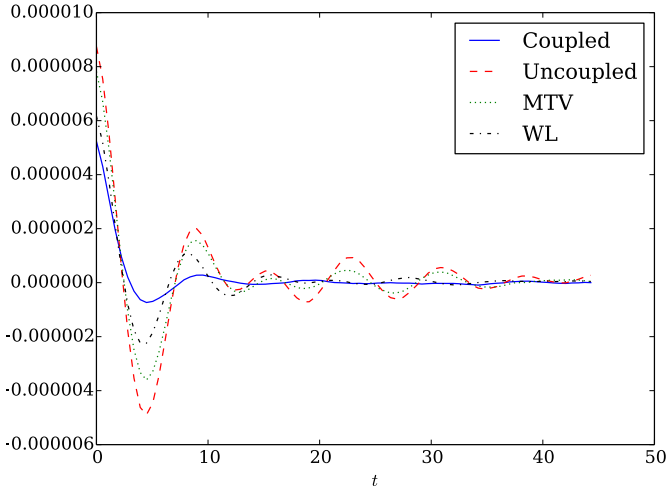

50
40
30
20
10
0
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
$\theta_{\mathrm{a},6}$


0.000008
0.000007
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
0.000000
-0.000001
0
10
20
30
40
50
t
Coupled
Uncoupled
MTV
WL

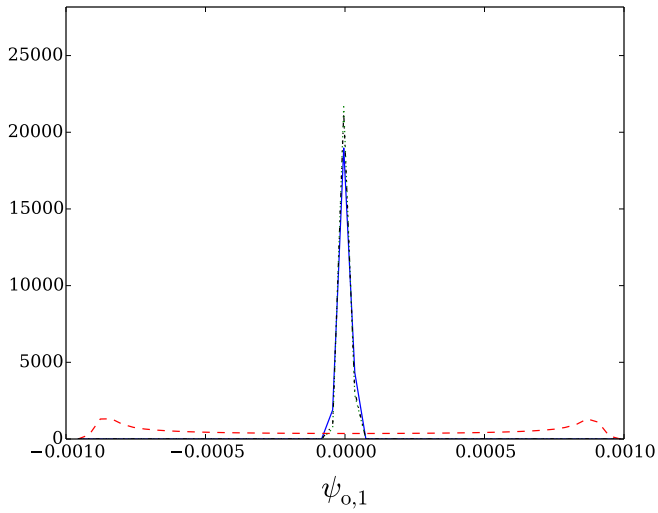




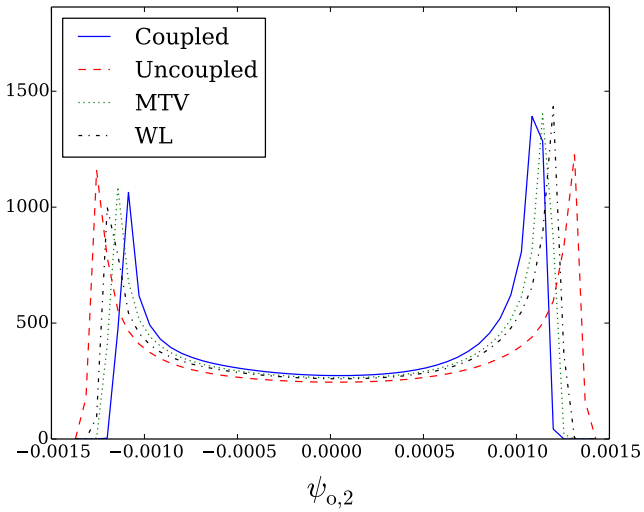




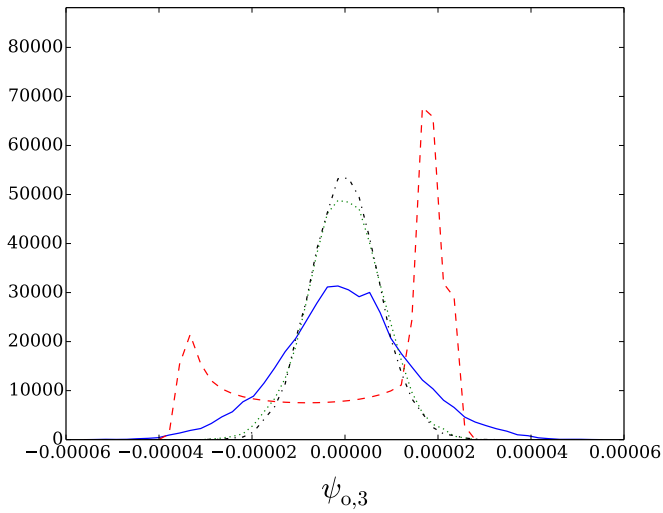
Oceanic variables Only the PDFs are available for these variables.



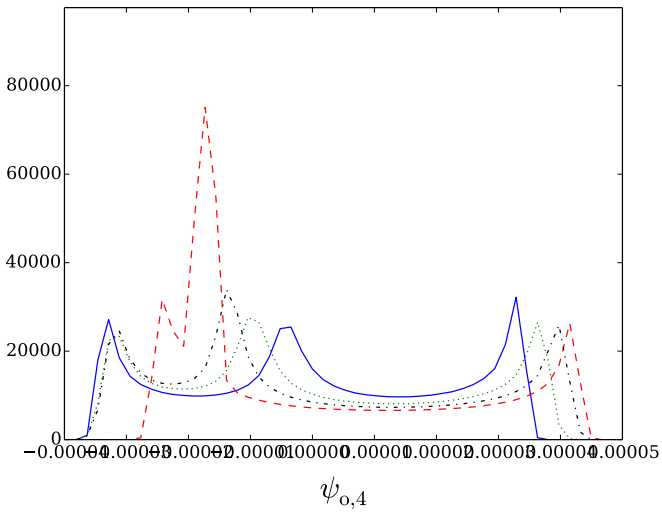
$\psi_{o,1}$



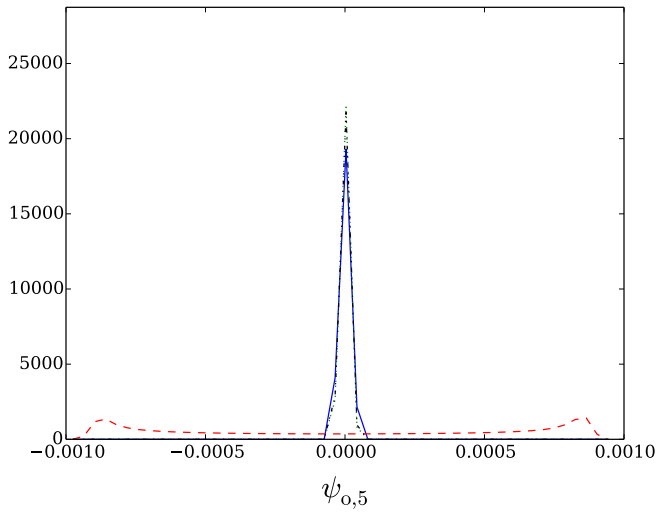
$\psi_{o,2}$



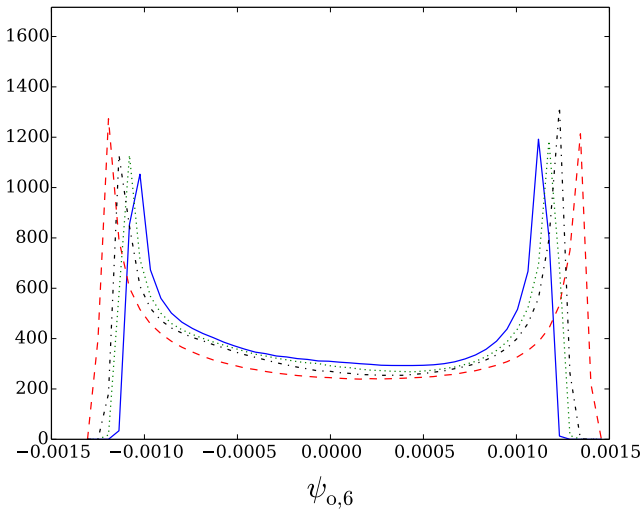
$\psi_{o,3}$



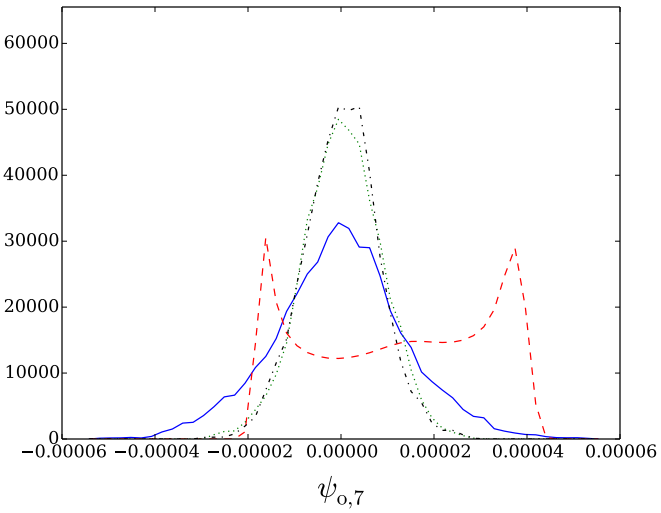
$\psi_{o,4}$



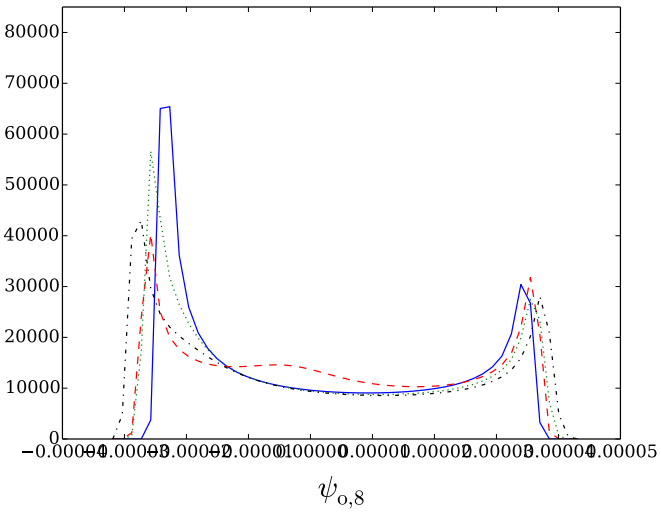
$\psi_{o,5}$



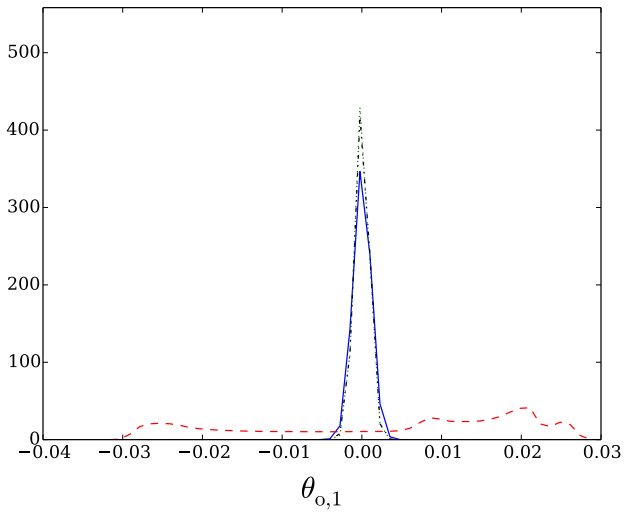
$\psi_{o,6}$



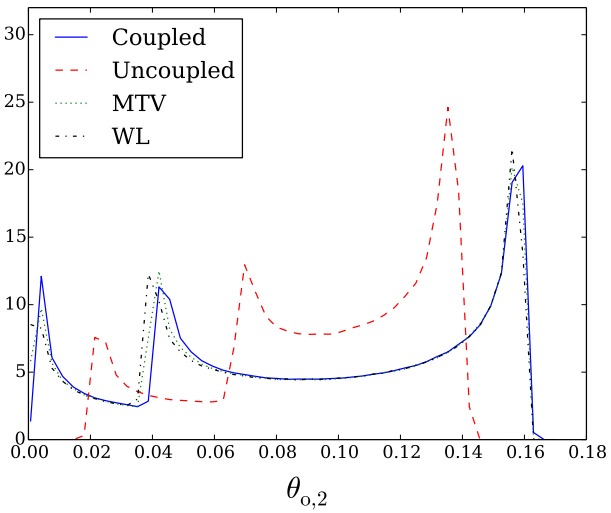
$\psi_{o,7}$



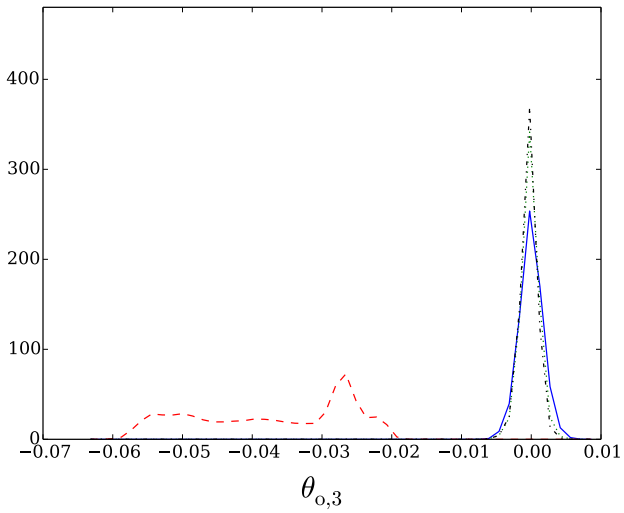
$\psi_{o,8}$



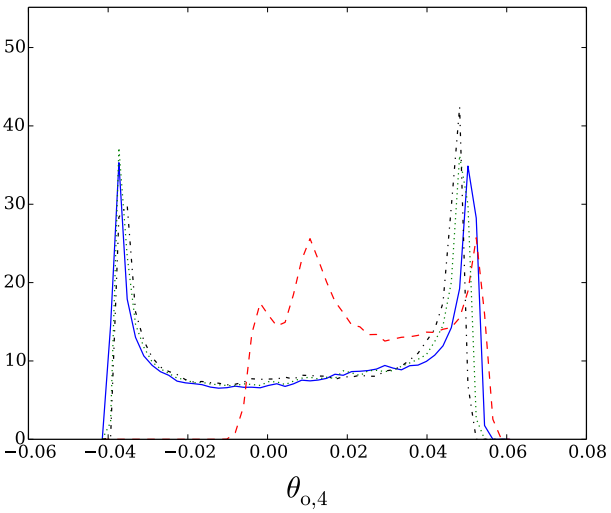
$\theta_{o,1}$



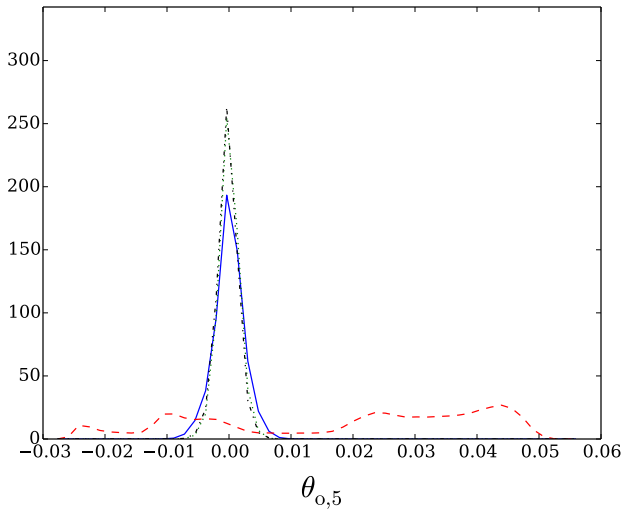
$\theta_{o,2}$

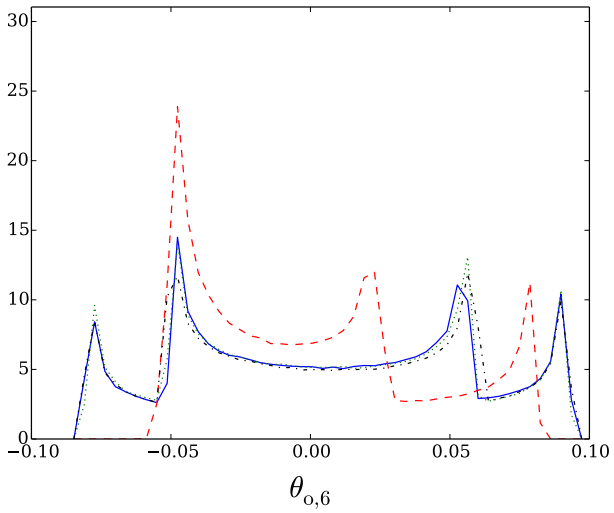


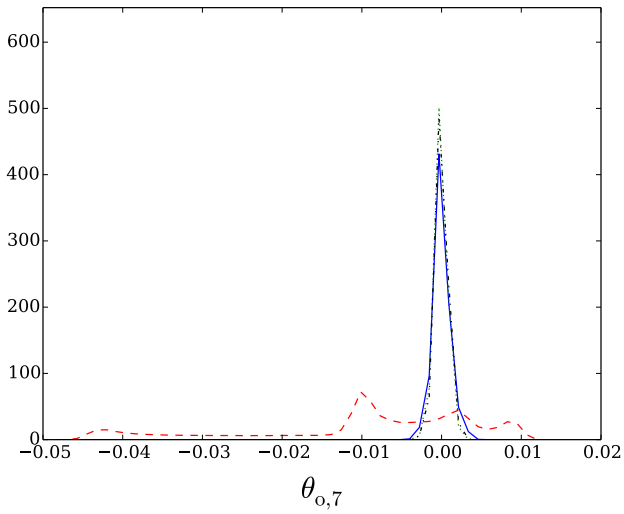
$\theta_{o,3}$

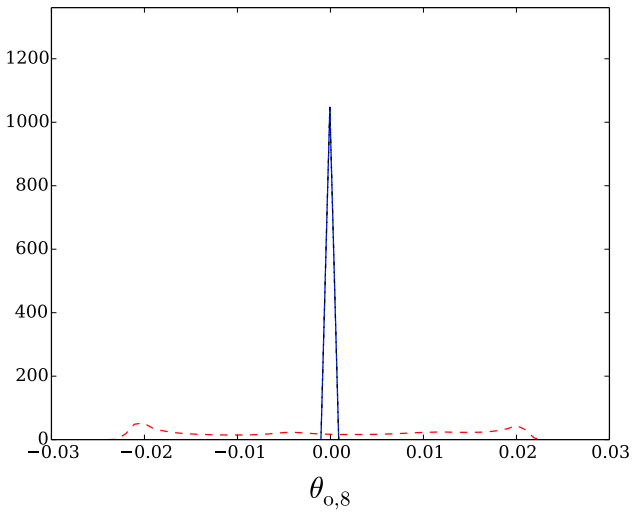


$\theta_{o,4}$

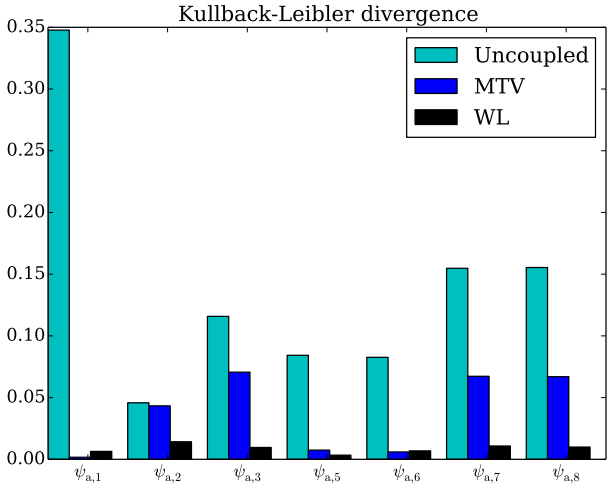

300
250
200
150
100
50
0
−0.03 −0.02 −0.01 0.00 0.01 0.02 0.03 0.04 0.05 0.06
$\theta_{o,5}$

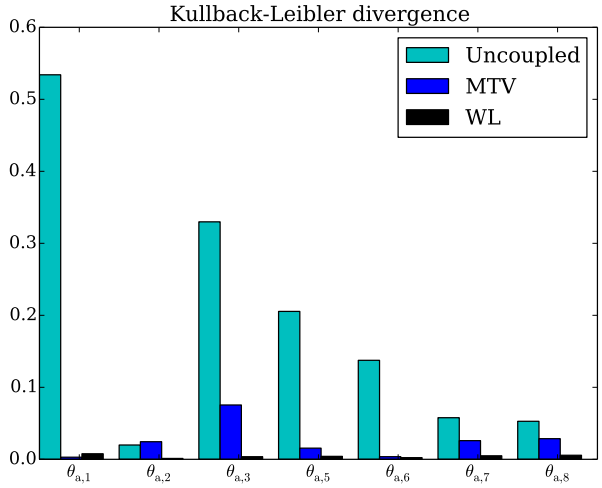

30
25
20
15
10
5
0
−0.10 −0.05 0.00 0.05 0.10
$\theta_{o,6}$

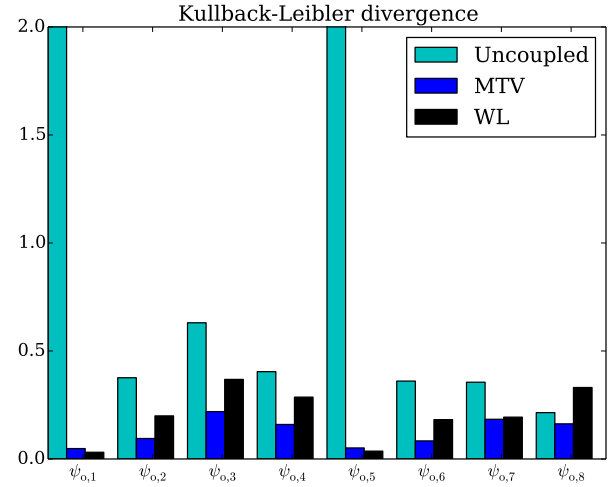

600
500
400
300
200
100
0
−0.05 −0.04 −0.03 −0.02 −0.01 0.00 0.01 0.02
$\theta_{o,7}$

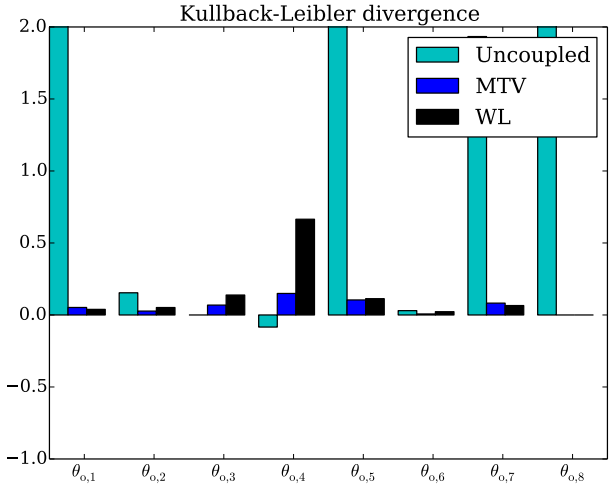

1200
1000
800
600
400
200
0
−0.03 −0.02 −0.01 0.00 0.01 0.02 0.03
$\theta_{o,8}$

3.1.2 Kullback-Leibler divergences





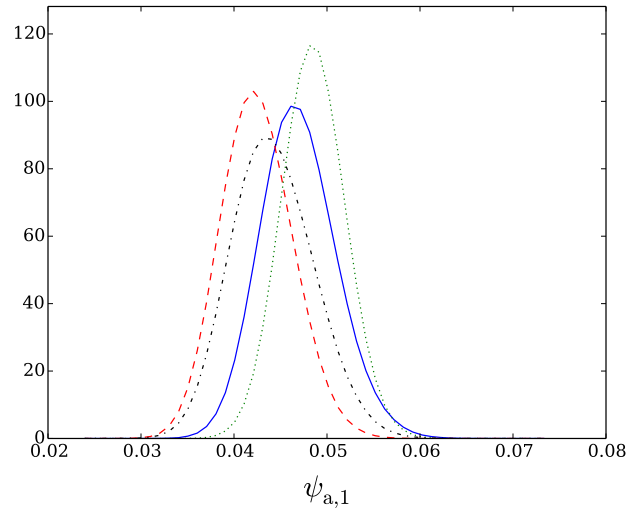


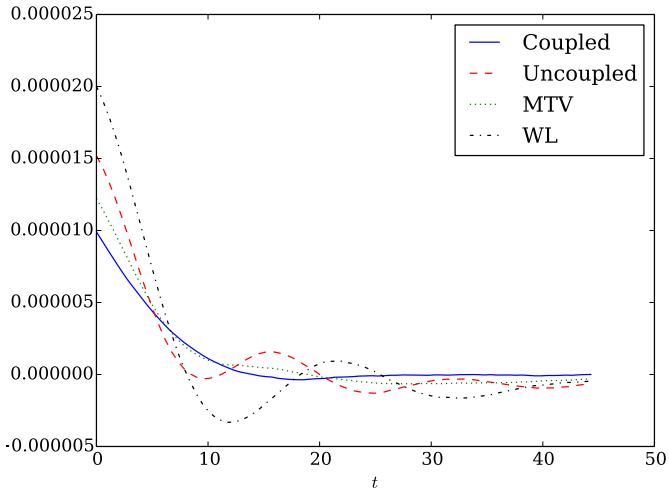


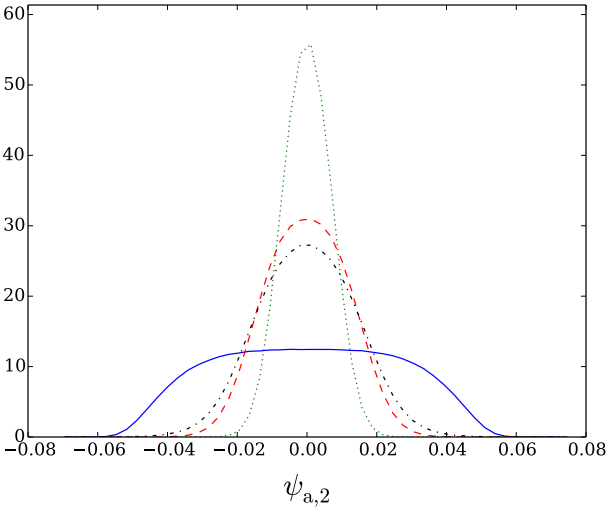
3.2 noLFV parameter set

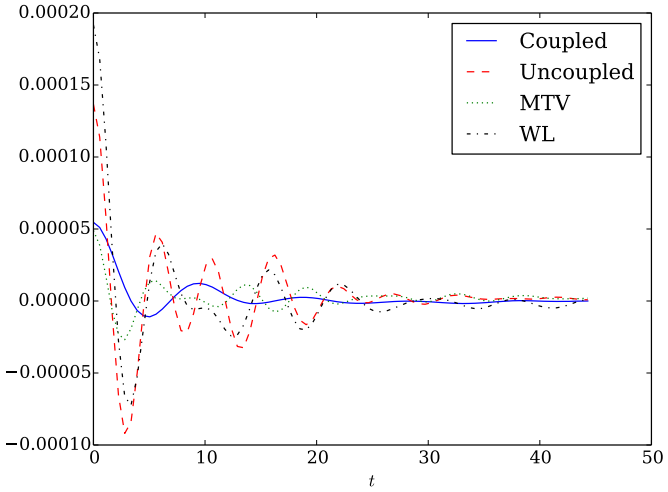
3.2.1 PDFs and autocorrelation functions of the resolved variables

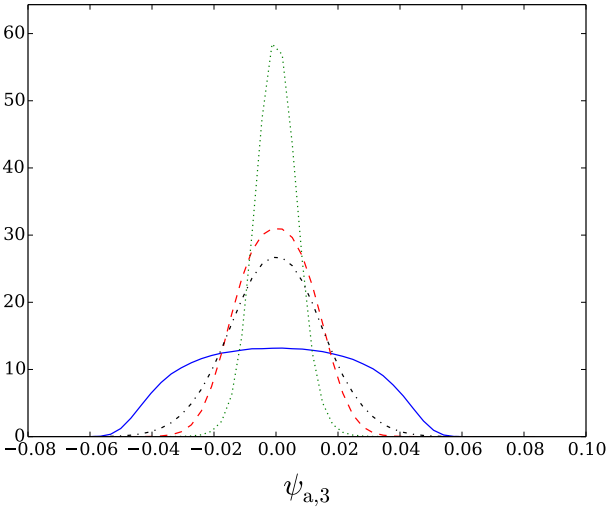
Atmospheric variables of the model.

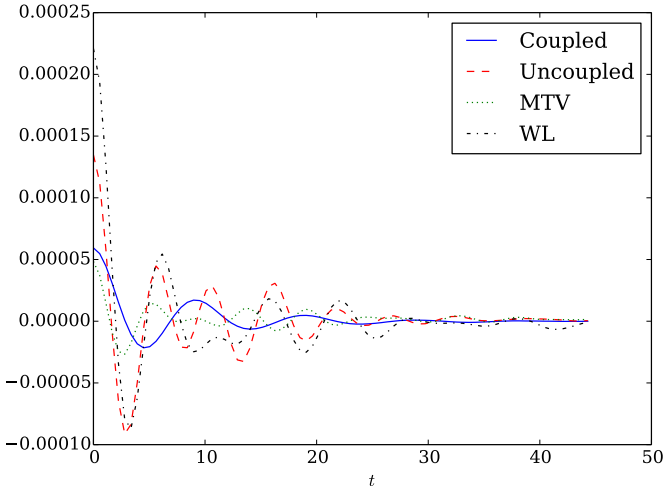


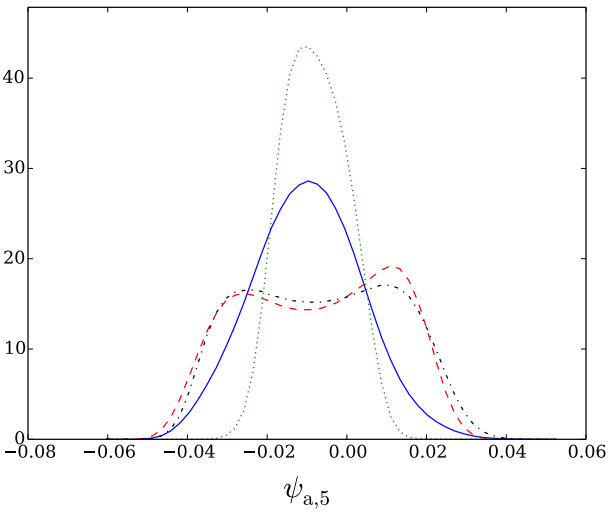


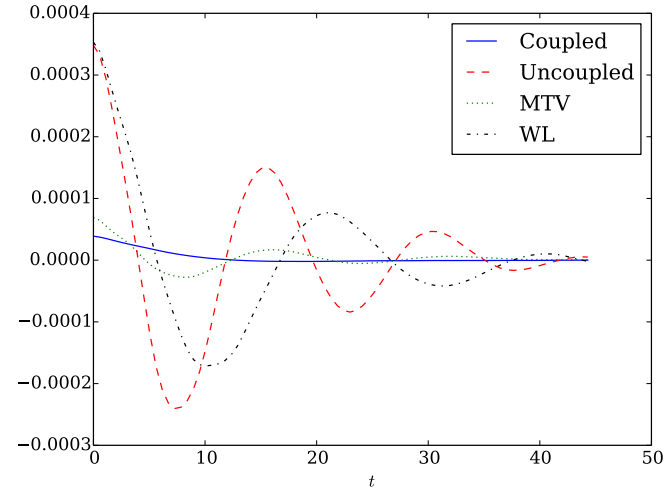

$\psi_{a,2}$

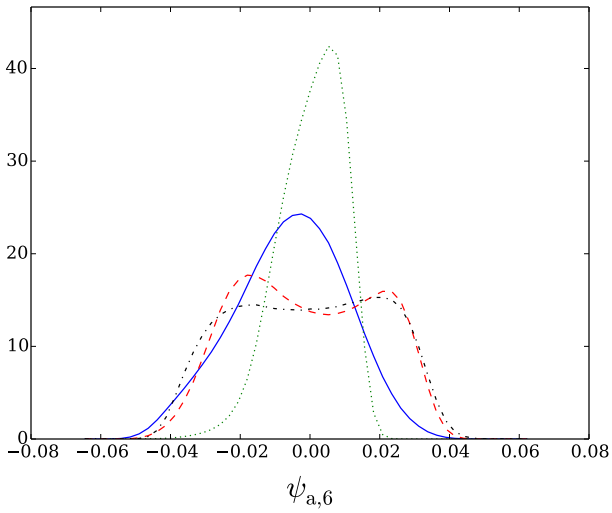

Coupled
Uncoupled
MTV
WL
t

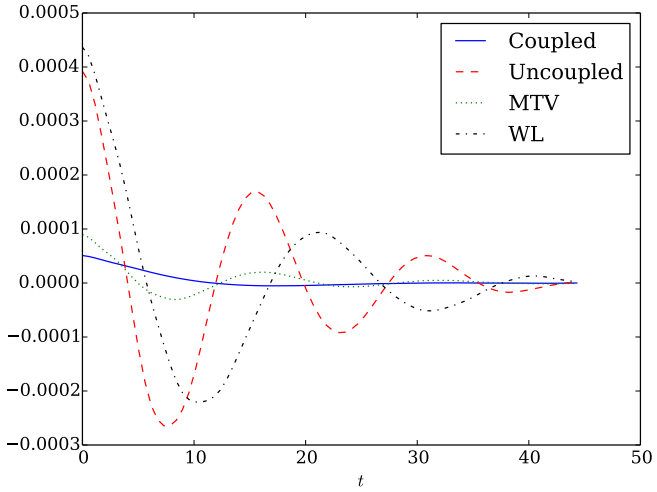

$\psi_{a,3}$

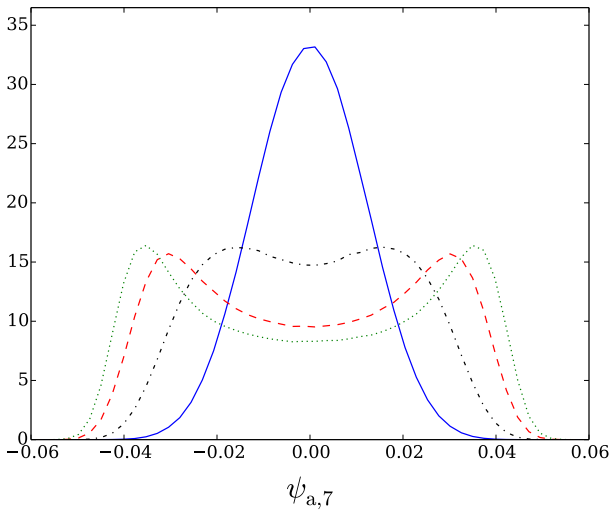

Coupled
Uncoupled
MTV
WL
t

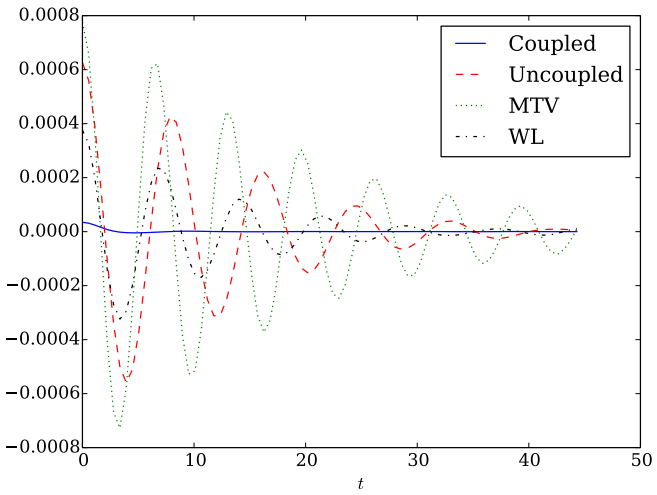

$\psi_{a,5}$

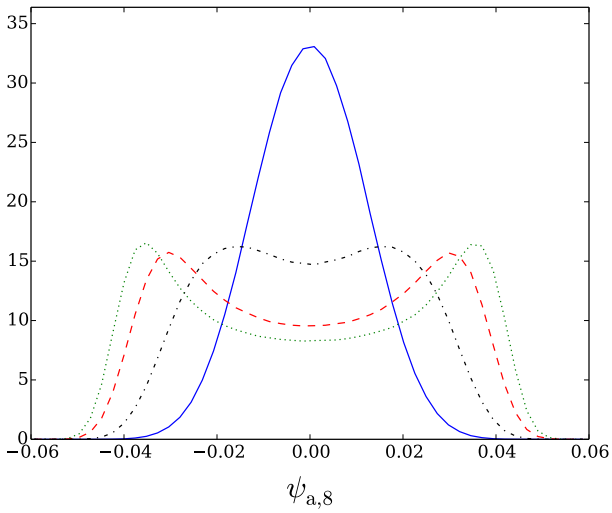

Coupled
Uncoupled
MTV
WL
t

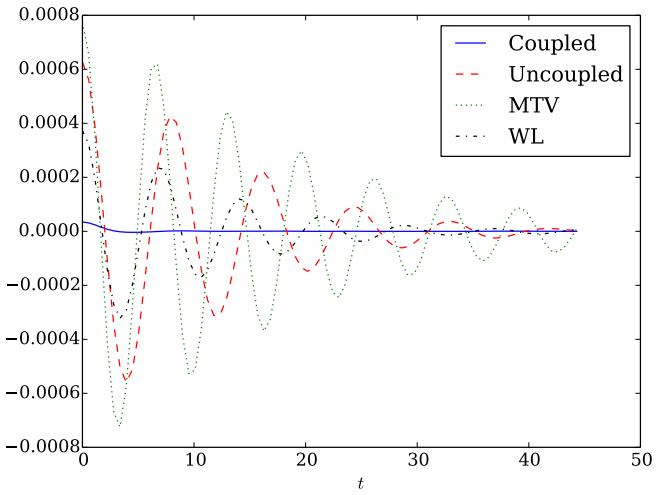

$\psi_{a,6}$

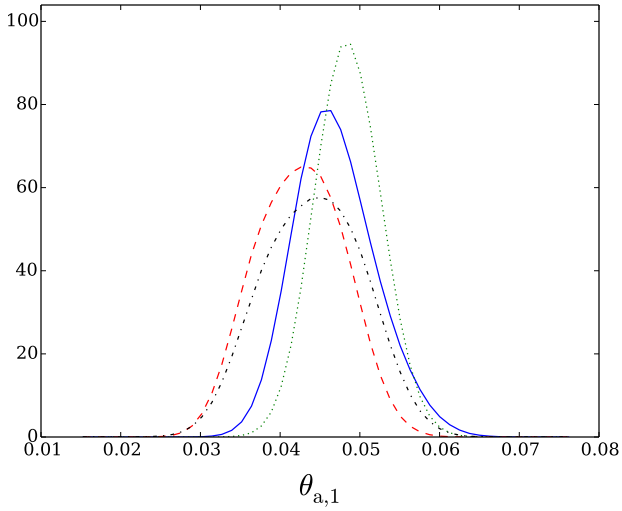

Coupled
Uncoupled
MTV
WL
t

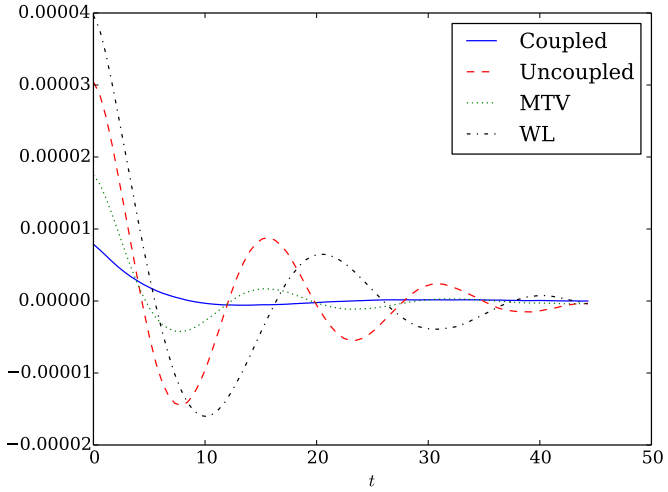

$\psi_{a,7}$

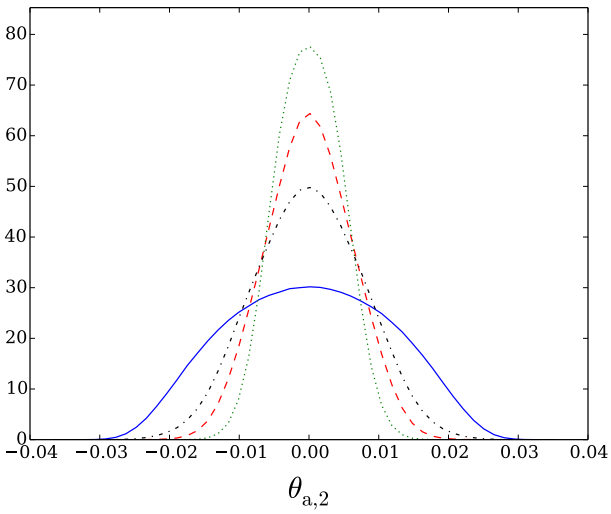

Coupled
Uncoupled
MTV
WL
t

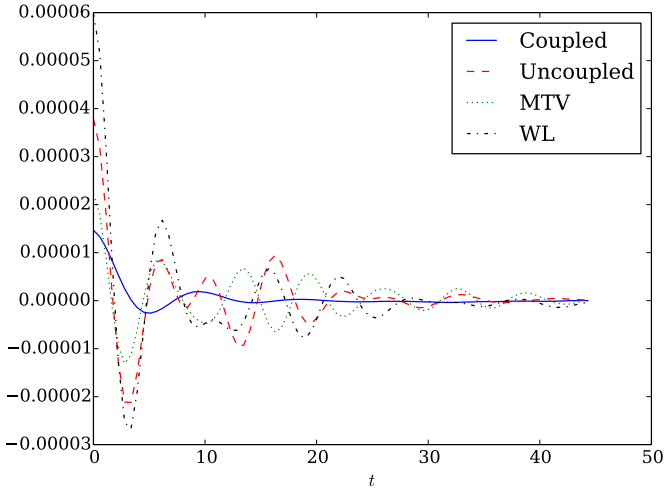

$\psi_{a,8}$

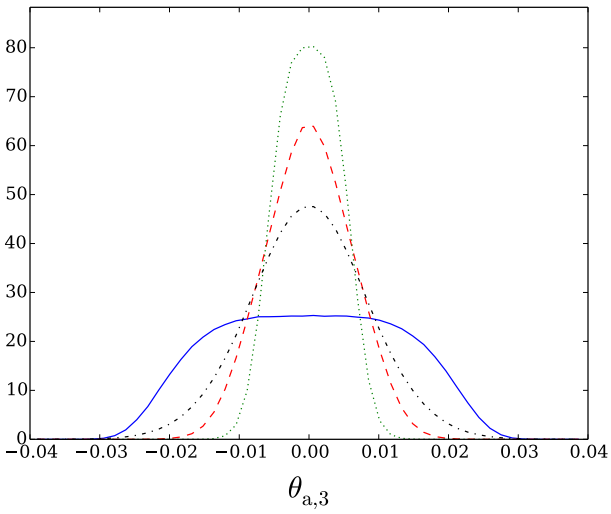

Coupled
Uncoupled
MTV
WL
t

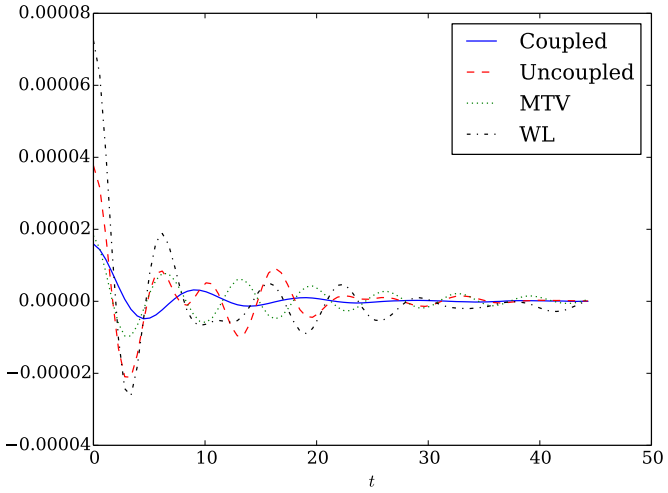

$\theta_{a,1}$

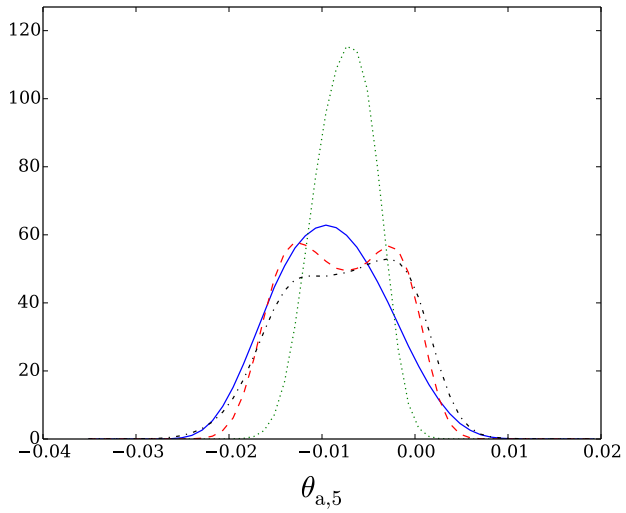

Coupled
Uncoupled
MTV
WL
t

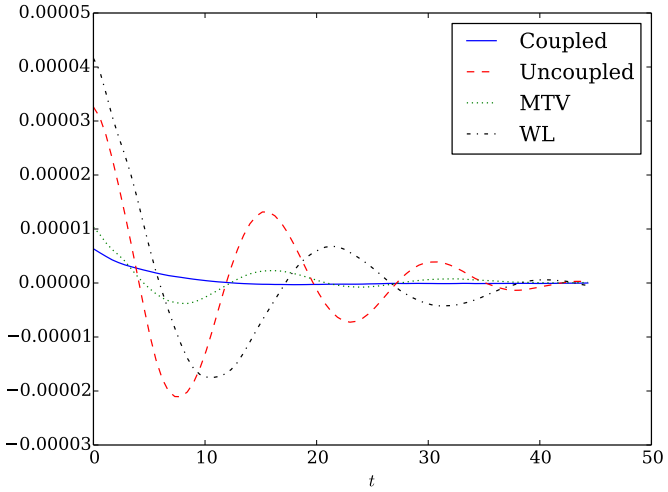

$\theta_{a,2}$

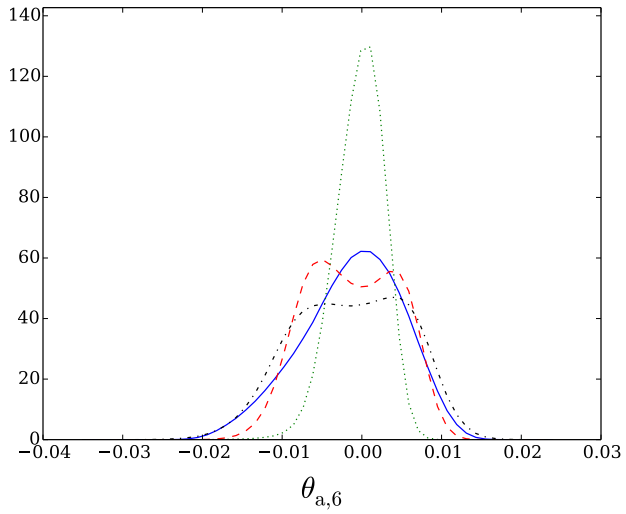

Coupled
Uncoupled
MTV
WL
t

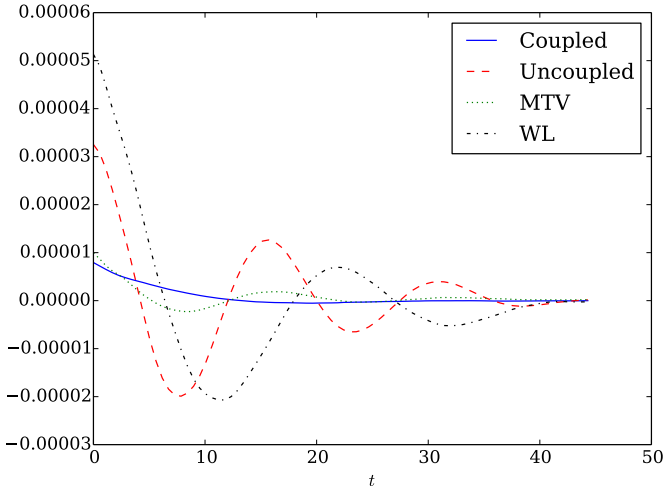

$\theta_{a,3}$

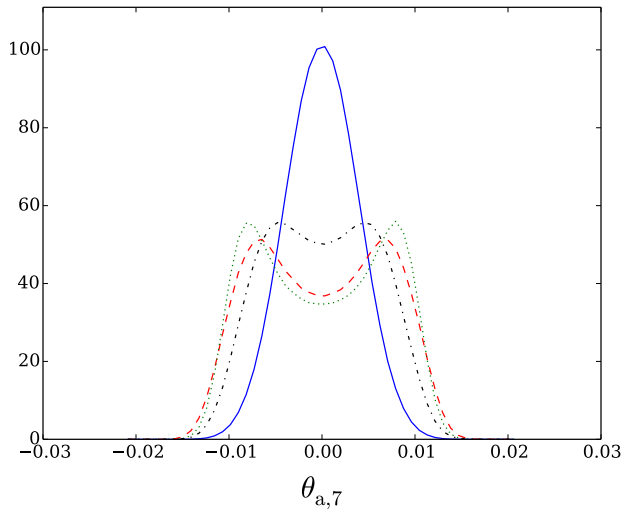

Coupled
Uncoupled
MTV
WL
t

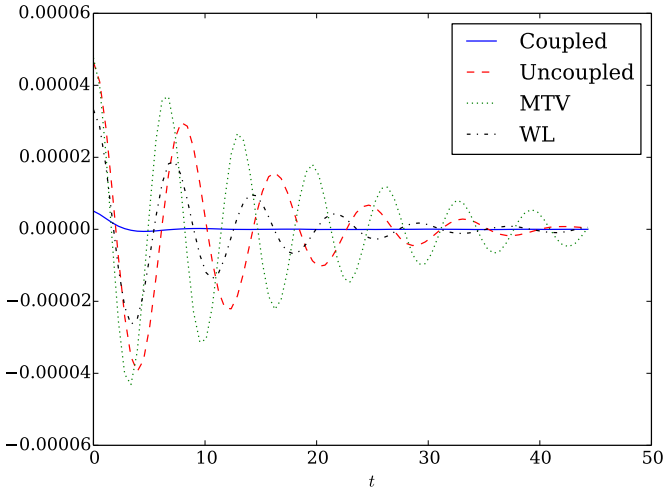

$\theta_{a,5}$

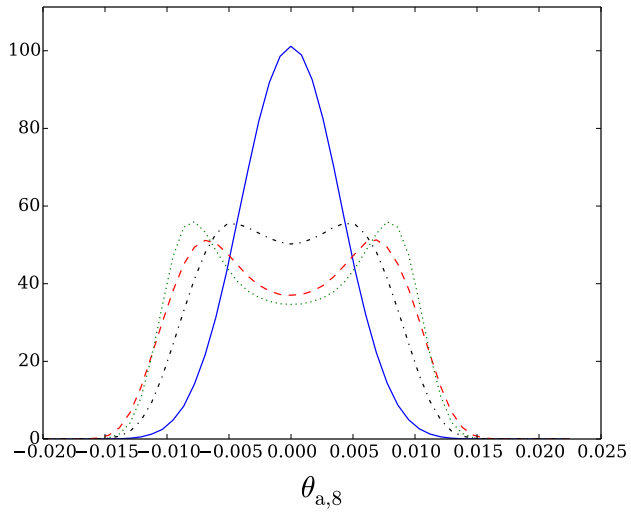

Coupled
Uncoupled
MTV
WL
t

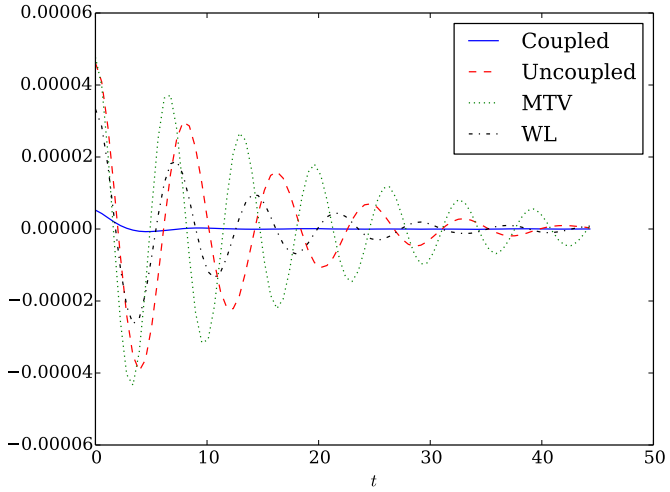

$\theta_{a,6}$


Coupled
Uncoupled
MTV
WL
t

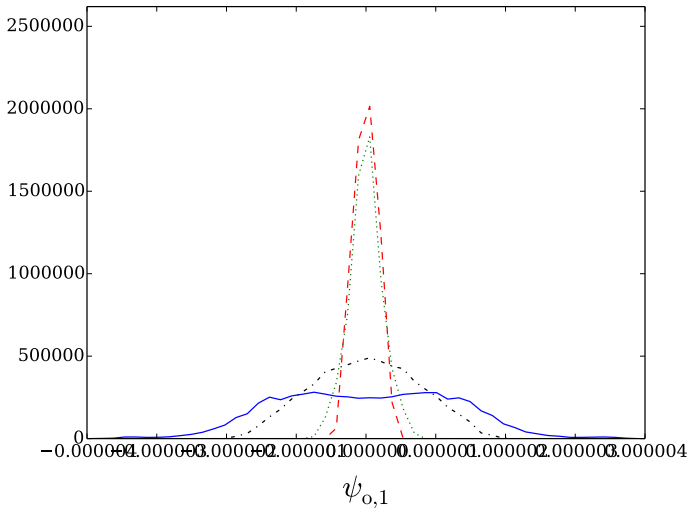

$\theta_{a,7}$

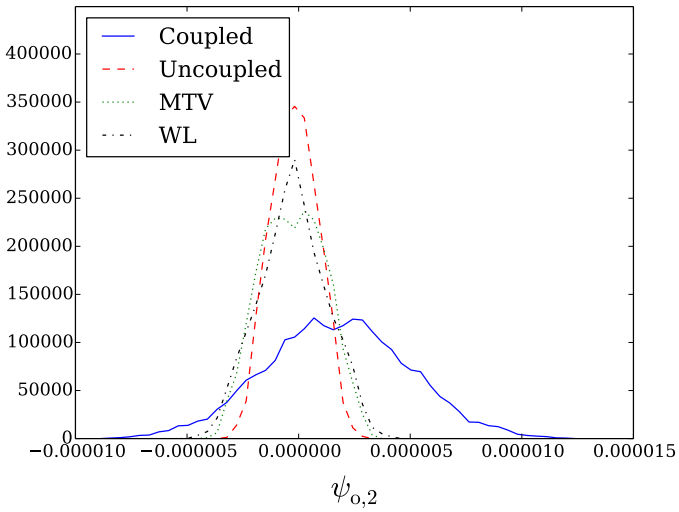

Coupled
Uncoupled
MTV
WL
t

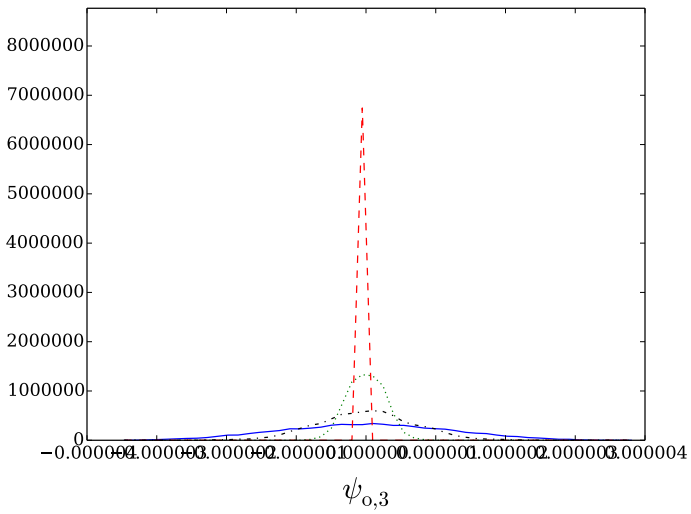


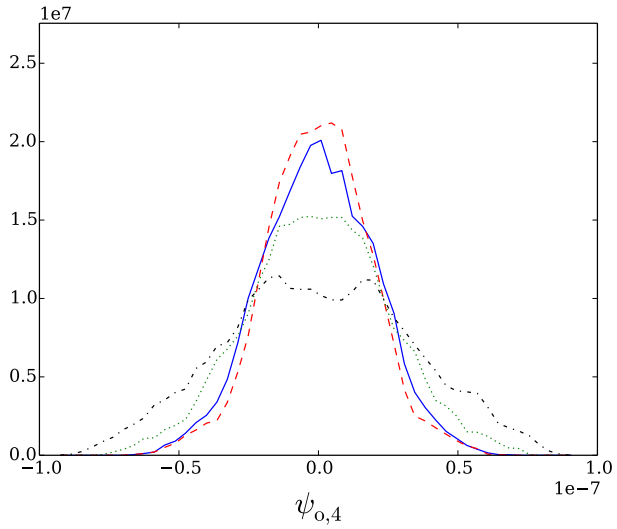


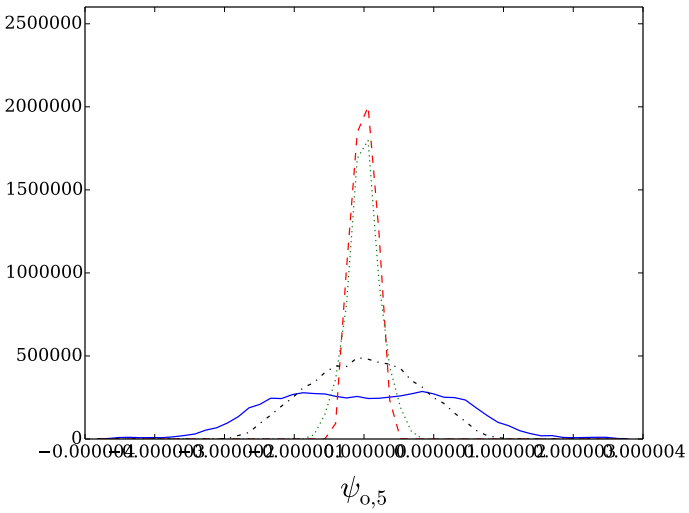
Oceanic variables Only the PDFs are available for these variables.



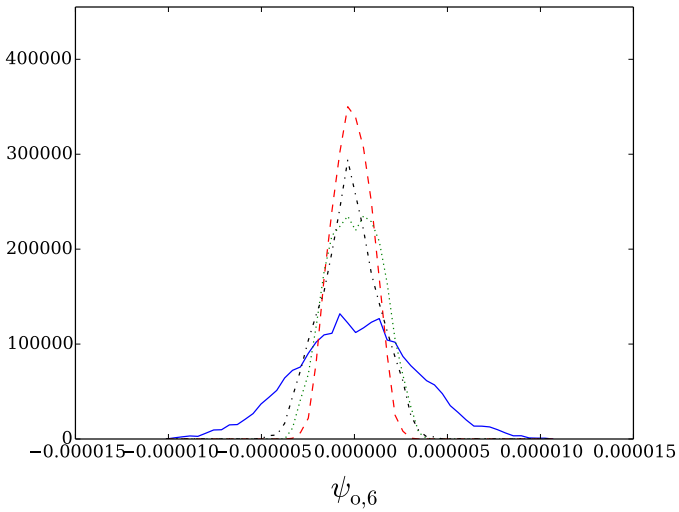




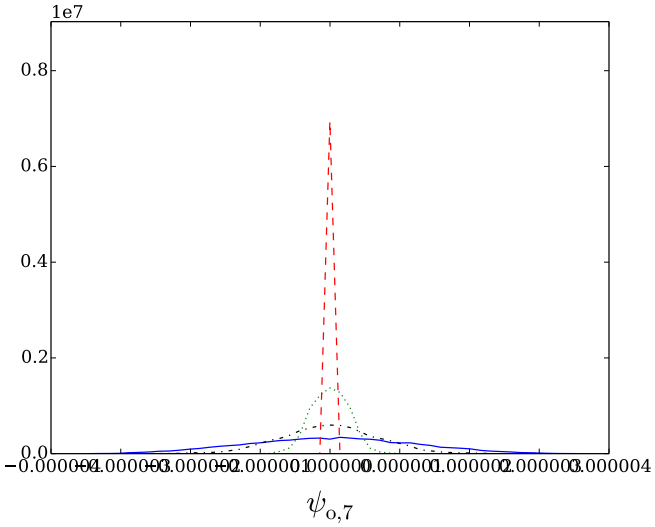




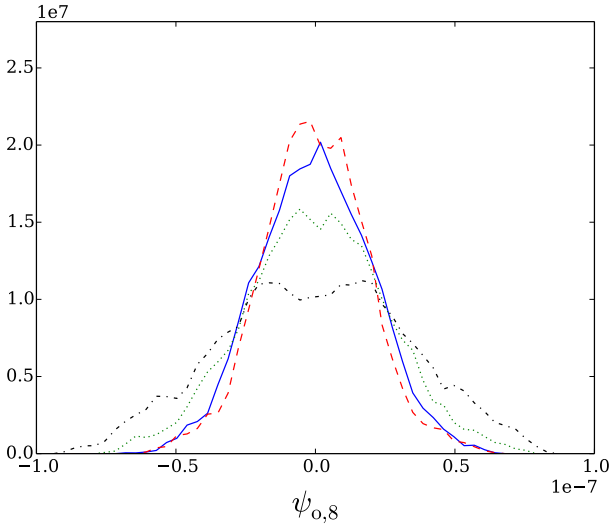
$\psi_{o,5}$



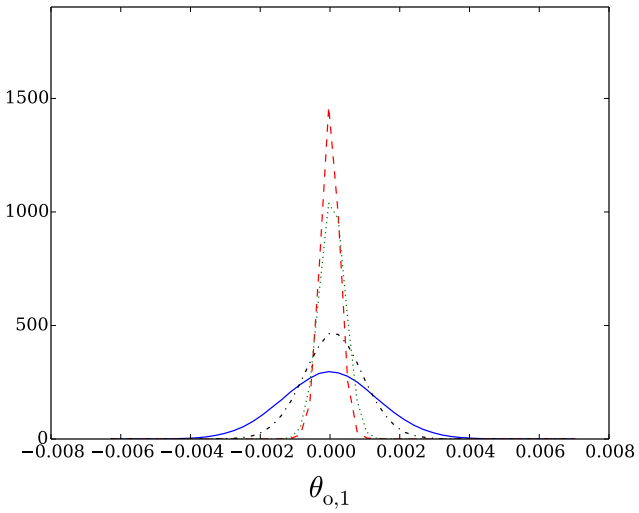
$\psi_{o,6}$

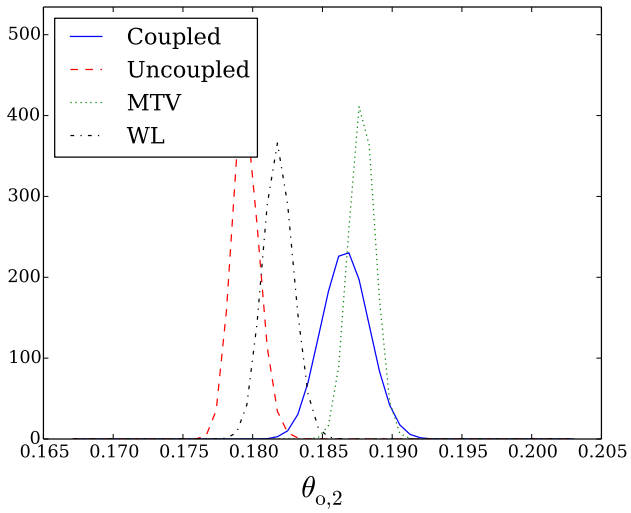


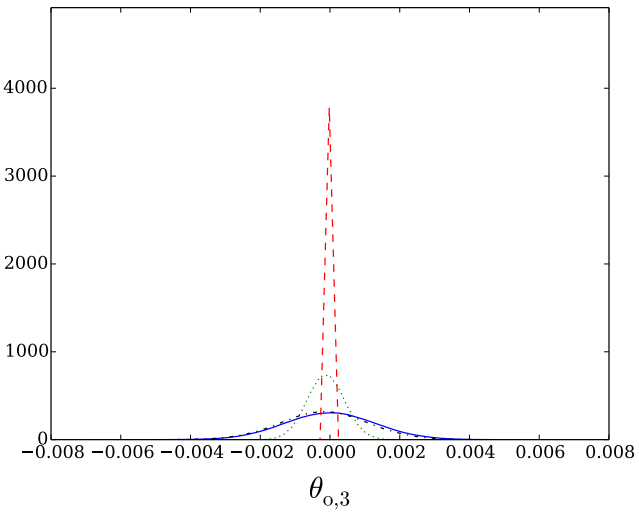
$\psi_{o,7}$

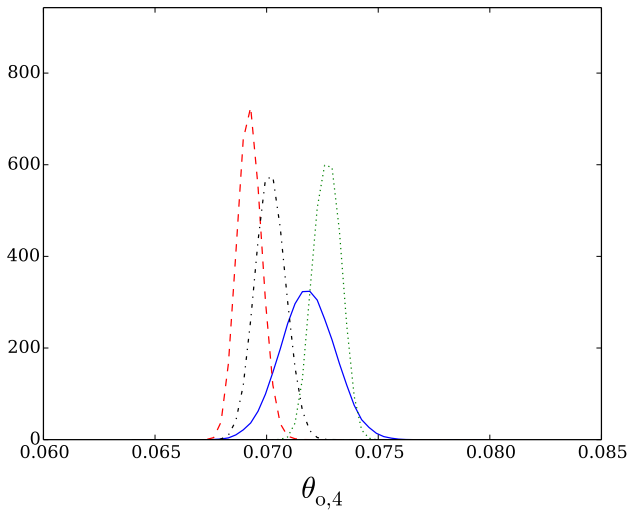


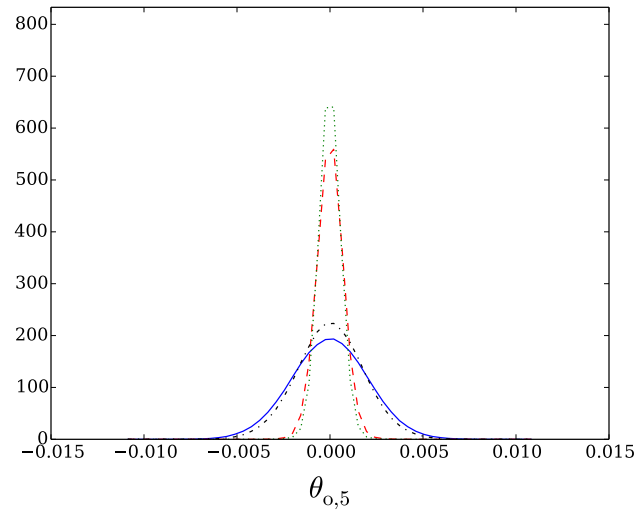
$\psi_{o,8}$

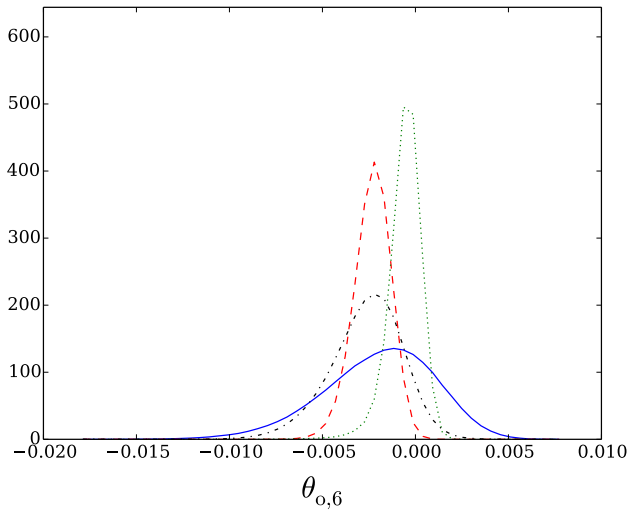

1500
1000
500
0
−0.008 −0.006 −0.004 −0.002 0.000 0.002 0.004 0.006 0.008
$\theta_{o,1}$

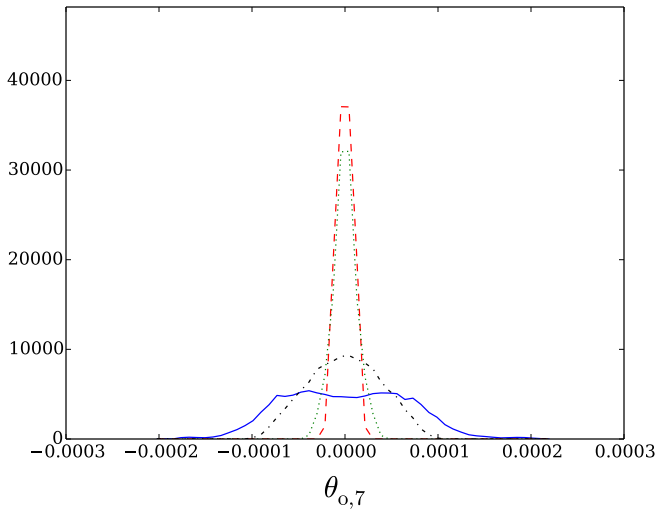

Coupled
Uncoupled
MTV
WL
500
400
300
200
100
0
0.165 0.170 0.175 0.180 0.185 0.190 0.195 0.200 0.205
$\theta_{o,2}$

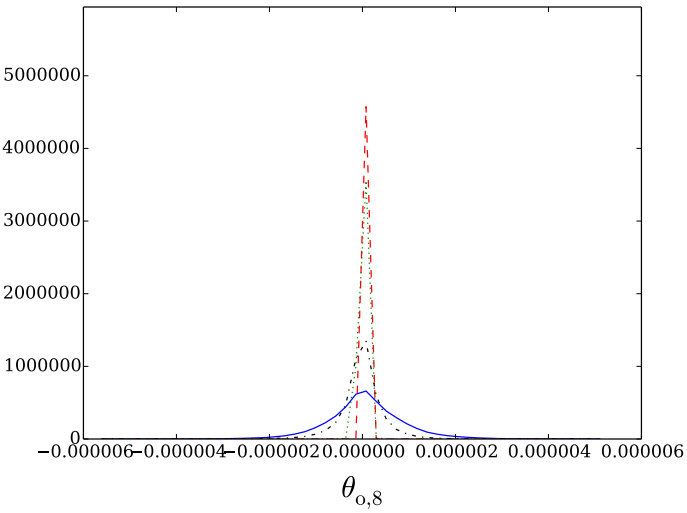
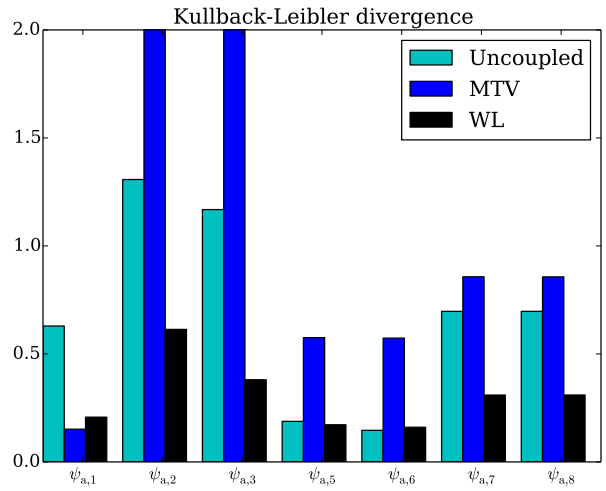
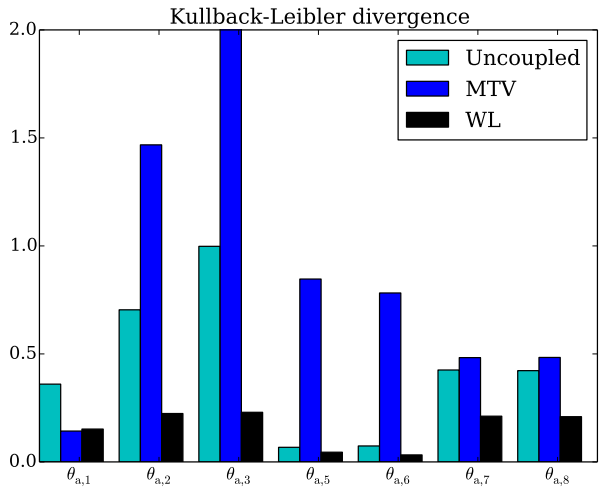
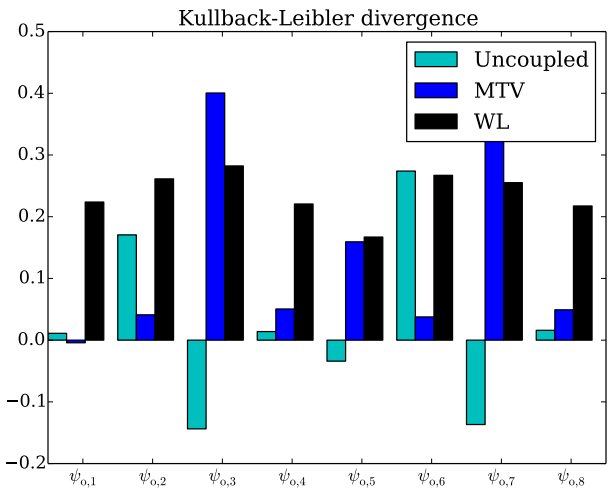
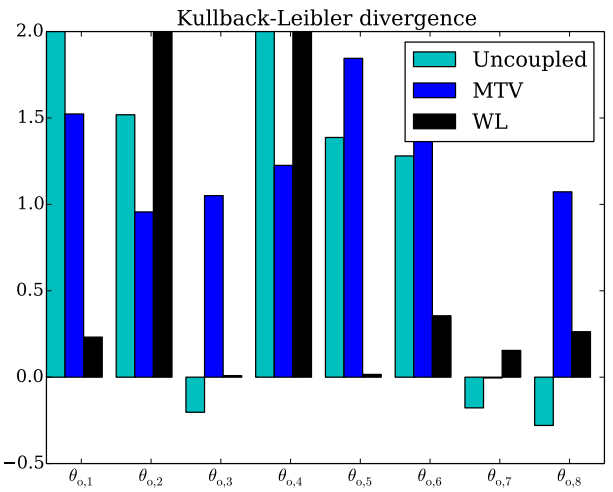

4000
3000
2000
1000
0
−0.008 −0.006 −0.004 −0.002 0.000 0.002 0.004 0.006 0.008
$\theta_{o,3}$


800
600
400
200
0
0.060 0.065 0.070 0.075 0.080 0.085
$\theta_{o,4}$


800
700
600
500
400
300
200
100
0
−0.015 −0.010 −0.005 0.000 0.005 0.010 0.015
$\theta_{o,5}$


600
500
400
300
200
100
0
−0.020 −0.015 −0.010 −0.005 0.000 0.005 0.010
$\theta_{o,6}$





3.2.2 Kullback-Leibler divergences