Data Assimilation in a high-resolution, sub-mesoscale regional model of Hawaii

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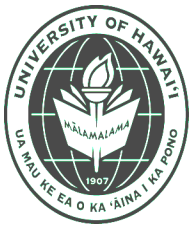
April 7, 2010

ROMS Workshop



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Objectives

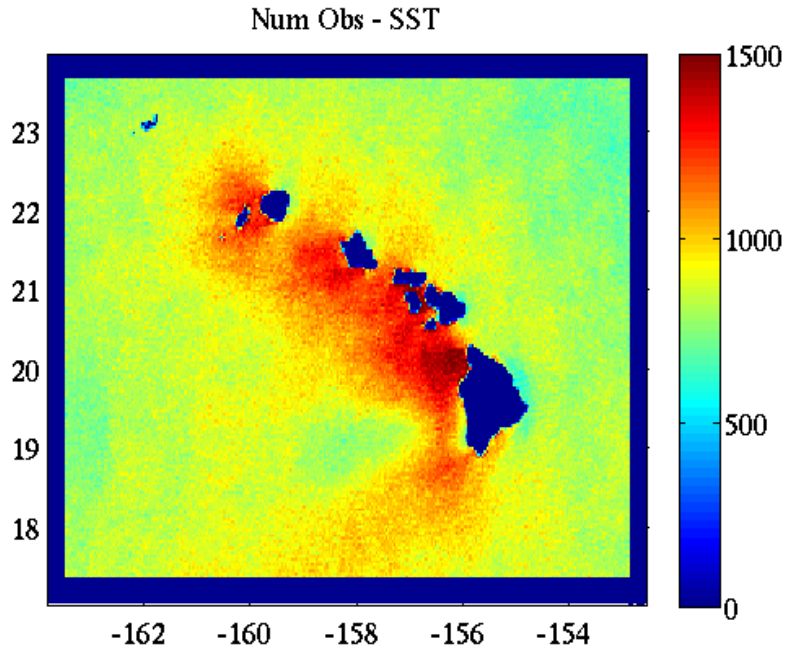
- Utilize IS4DVAR method to study circulation and dynamics around Hawaiian Islands
- Spin-up for near-realtime operational system (HIOOS)
  www.soest.hawaii.edu/hioos
- Evaluate assimilation system configuration
  - Obs/Model misfit
  - Overall Assimilation/NLM differences
  - Comparison with independent observations

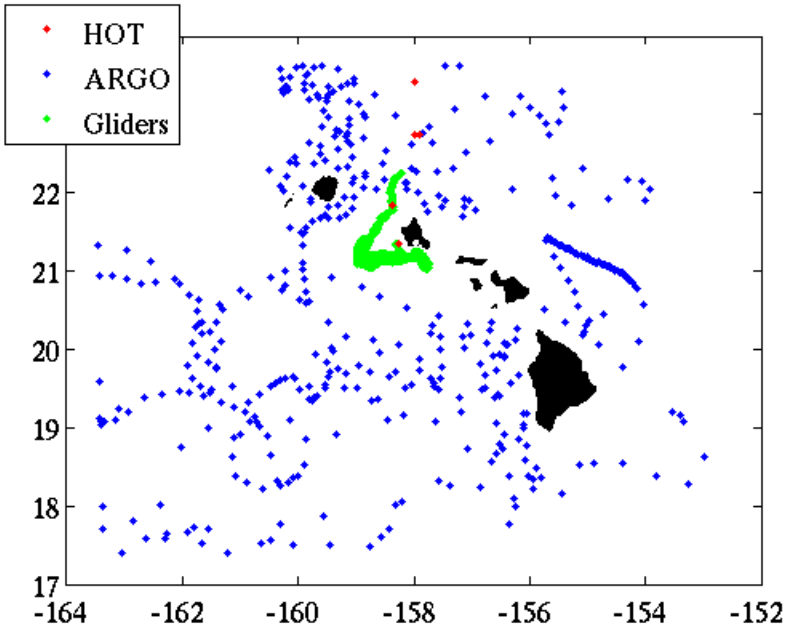
ROMS Configuration

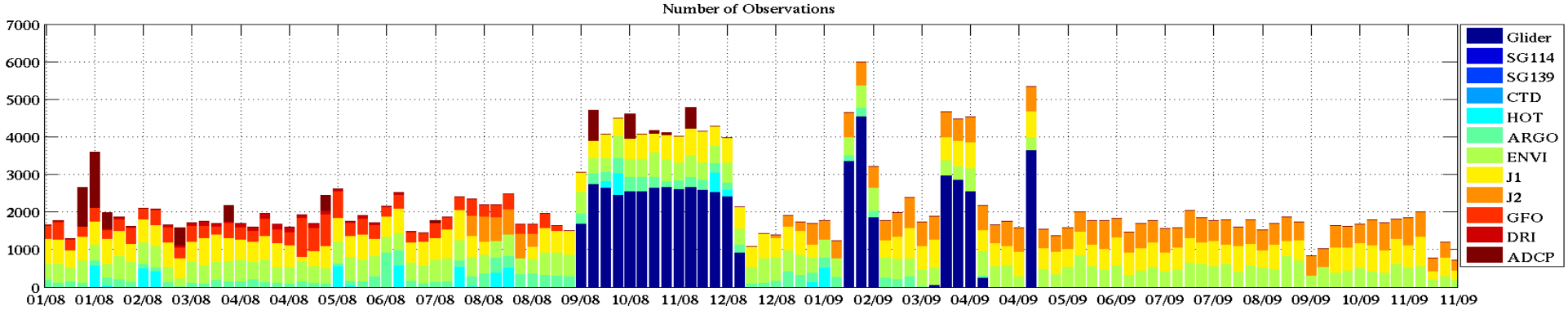
- 4 km horizontal resolution
- 30 sigma levels
- 4 open boundaries setup to conserve volume
- Boundary Conditions and Climatology
  - 1/8° global Naval Coastal Ocean Model (NCOM)
- Forcing
  - NCEP reanalysis with mm5 cora blend winds (NHI)
    - Jan 2008 to May 2009
  - Weather Research and Forecasting (WRF) Model
    - May 2009 to Dec 2009

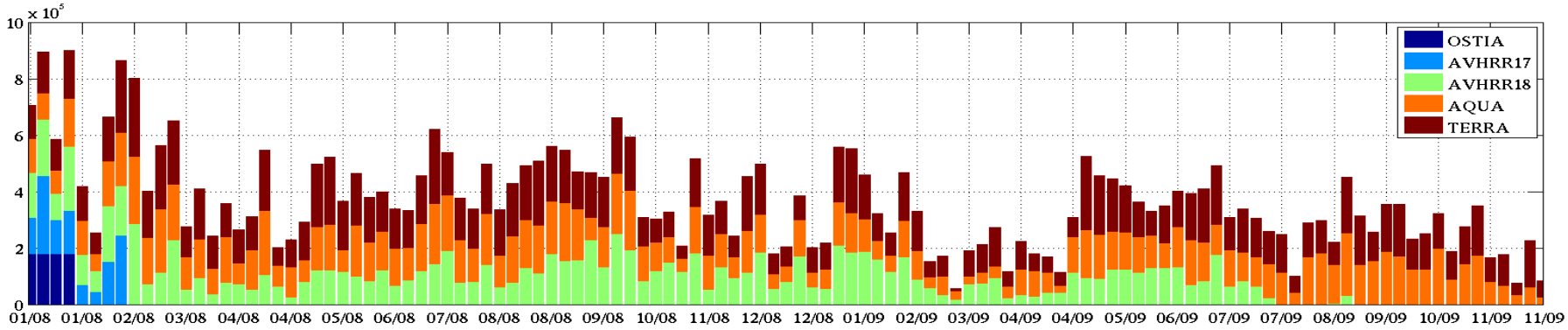
Observations

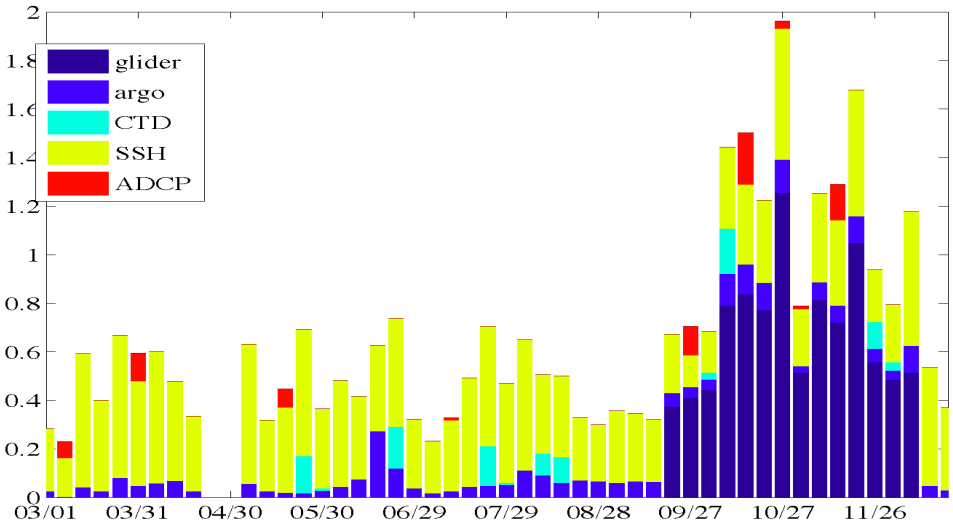
- Satellite Radiometry
  - Sea surface temperature (SST) - AVHRR-18, MODIS Aqua, MODIS Terra
  - LAC/HRPT 1.1 km resolution swath data
- Satellite Altimetry
  - Along-track Sea level anomalies (SLA) - Jason-1, Jason-2, Envisat and GFO
  - ~18 km resolution
  - AVISO does not release 1 Hz data in realtime
- Argo
  - Array of temperature/salinity free drifting profiling floats
- Gliders
  - Autonomous underwater vehicle
  - Temperature/salinity profiles
  - Short data sets due to ???
- Hawaii Ocean Time series (HOT) Cruises
  - CDT (conductivity, temperature, depth) profiles
  - ADCP (acoustic Doppler current profiler) velocity profiles
- Surface Drifters
  - Satellite tracked surface (15-m drogue) buoys estimate current velocity





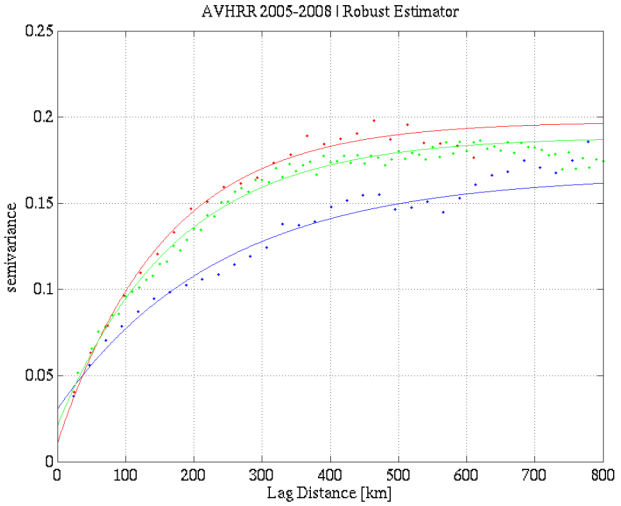

Number of Observations
7000
6000
5000
4000
3000
2000
1000
0
Glider
SG114
SG139
CTD
HOT
ARGO
ENVI
J1
J2
GFO
DRI
ADCP
01/08 01/08 02/08 03/08 04/08 04/08 05/08 06/08 07/08 08/08 08/08 09/08 10/08 11/08 12/08 12/08 01/09 02/09 03/09 04/09 04/09 05/09 06/09 07/09 07/09 08/09 09/09 10/09 11/09 11/09

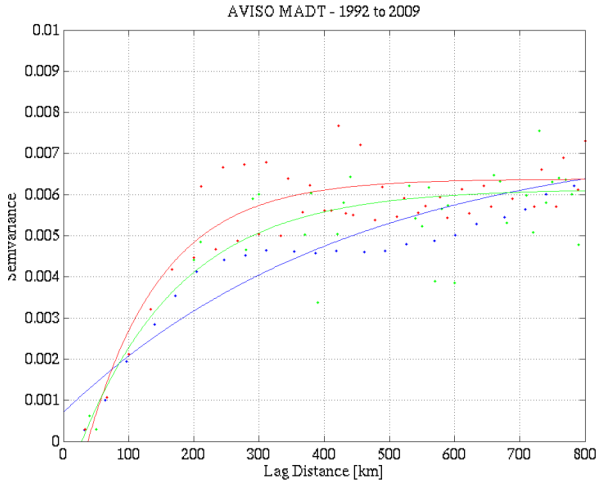

x 10^5
10
8
6
4
2
0
OSTIA
AVHRR17
AVHRR18
AQUA
TERRA
01/08 01/08 02/08 03/08 04/08 04/08 05/08 06/08 07/08 08/08 08/08 09/08 10/08 11/08 12/08 12/08 01/09 02/09 03/09 04/09 04/09 05/09 06/09 07/09 07/09 08/09 09/09 10/09 11/09 11/09

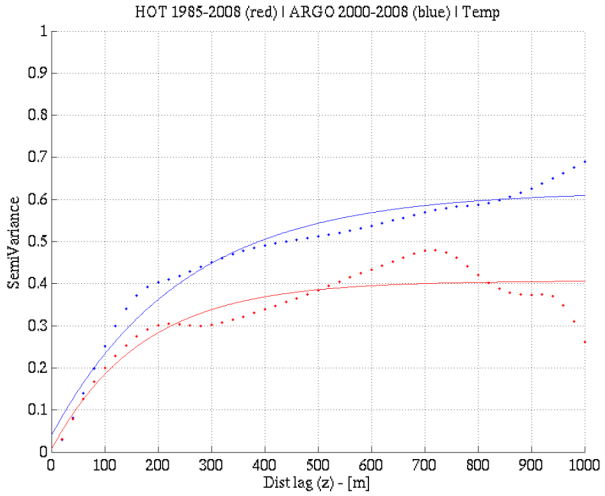

2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
glider
argo
CTD
SSH
ADCP
03/01 03/31 04/30 05/30 06/29 07/29 08/28 09/27 10/27 11/26

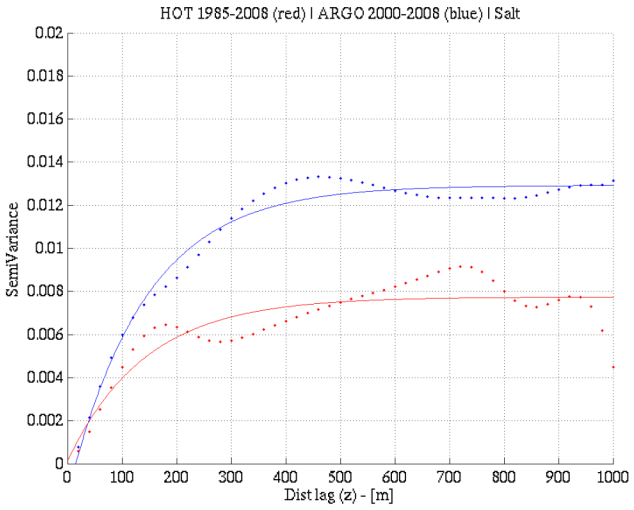
IS4DVAR Setup

- 6-year run forward model reference mean and variance of model state
- # of loops
  - Cycle 1-4
    - 1 outer loop and 50 inner loops
  - Cycle 5-8
    - 25 inner loops
  - Cycle 9-117
    - 20 inner loops
- Length scales
  - 200 km horizontal
  - 200 m vertical



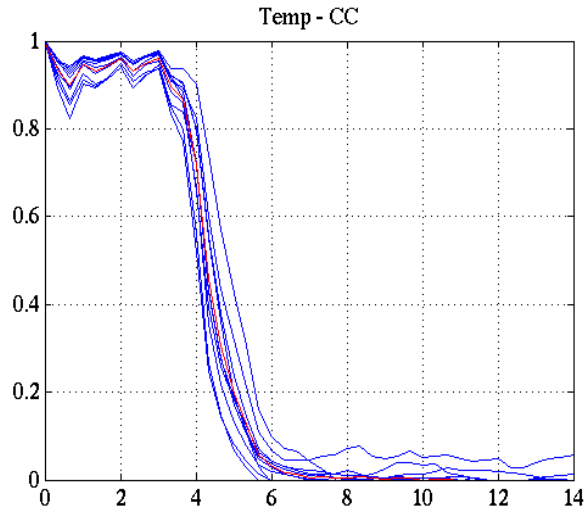


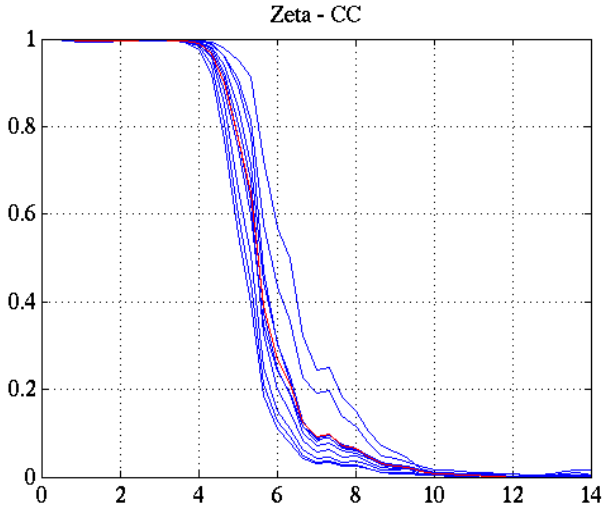




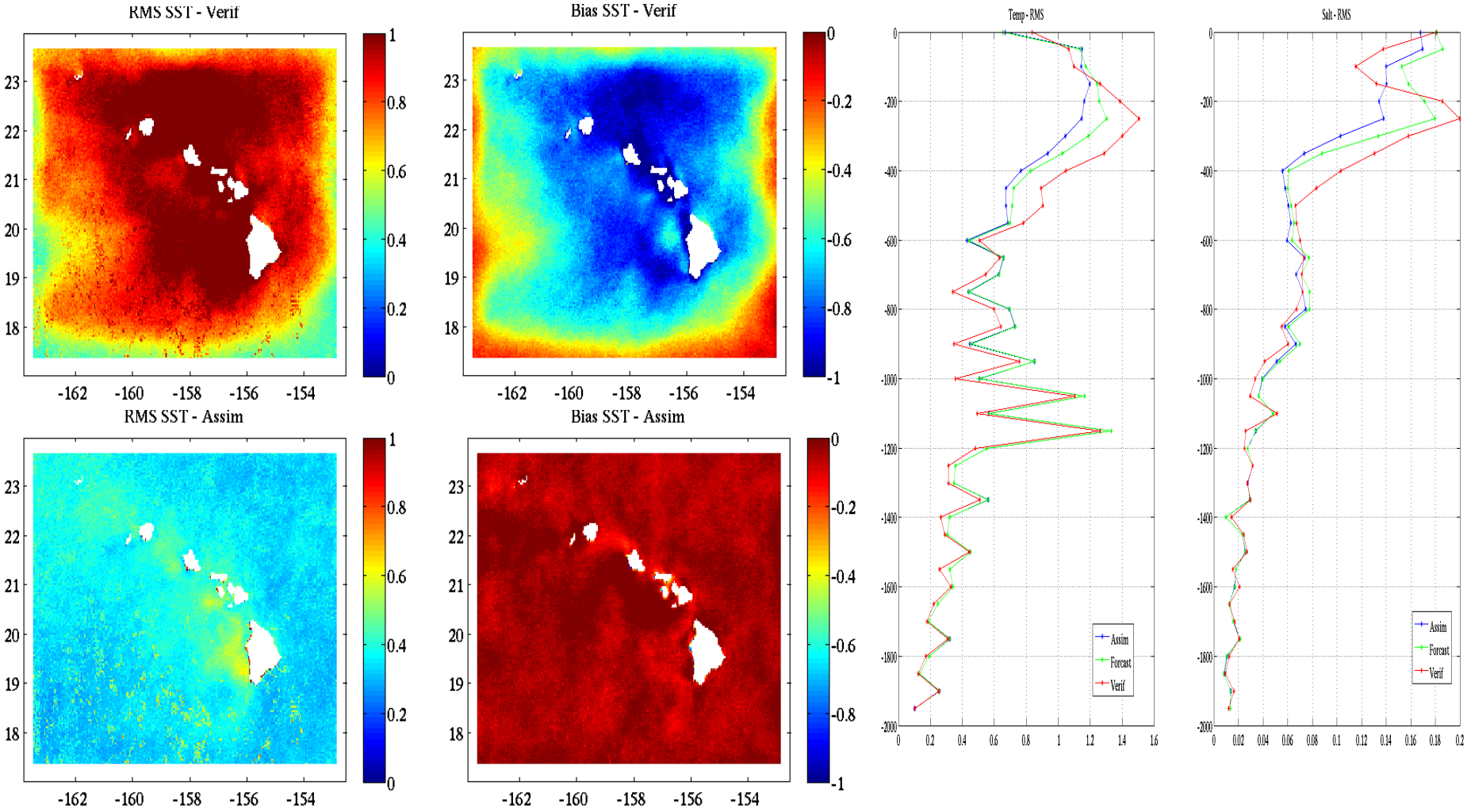
Tangent Linear Assumption

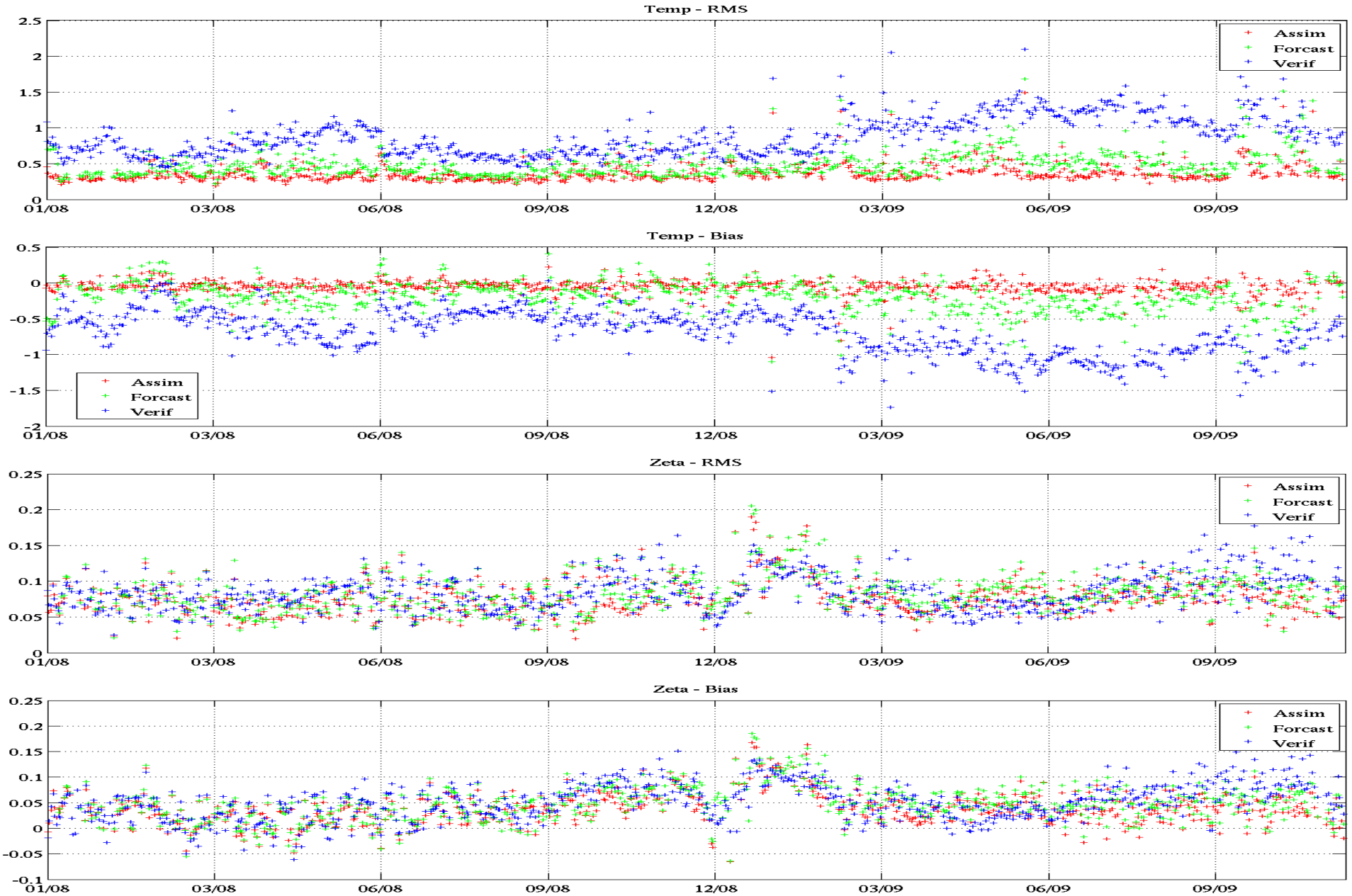
- 7-day assimilation cycle w/ 1-day overlap
- Test:
  - use MTLM and Gram-Schmidt orthogonalization to generate ensemble of perturbations to propagate through TLM and NLM
  - Correlation of NLM and TLM
- Result: 7-day runs suboptimal, however should invalidate assimilation



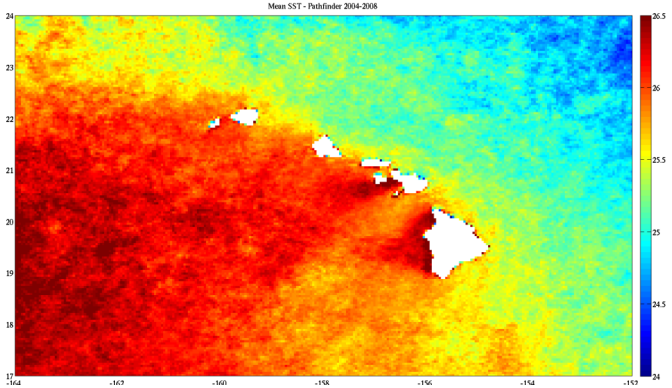


- Reduction of overall observation-model misfit by over 65%
- Reduction of SST RMSE by ~68%
- SSH RMSE reduction only ~9%
- At shallow depths (less than 100m) high assimilation RMSE in temperature and salinity compared to forward model
- In 150-500m reduced assimilation RMSE compared to forward model

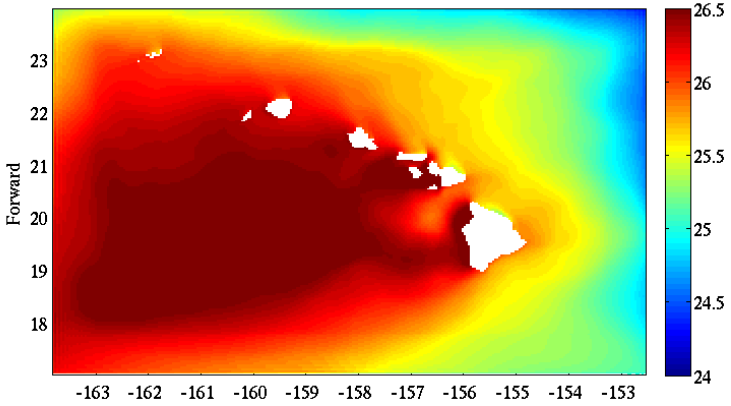


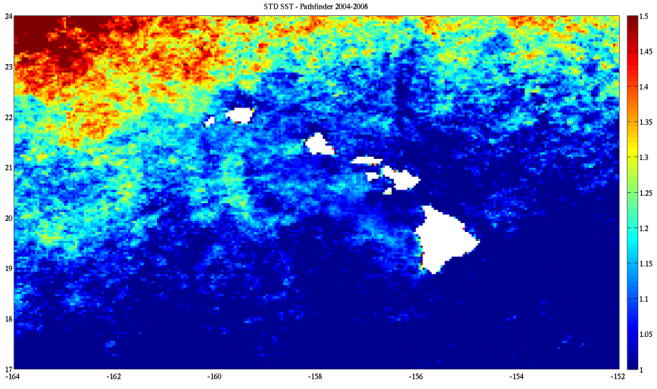


Time series of daily RMS differences and bias (obs – model) for SST and SSH.

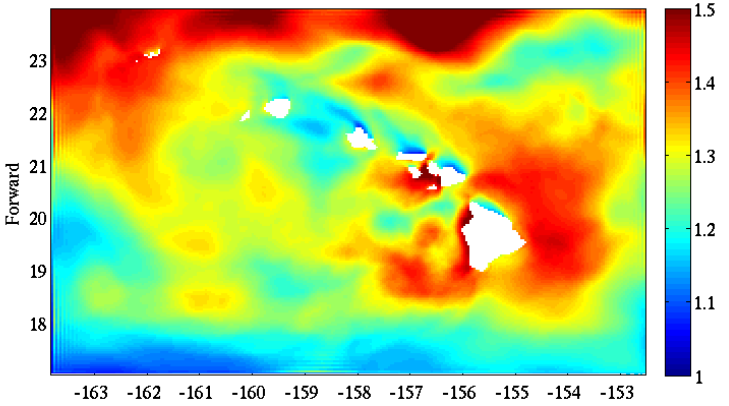


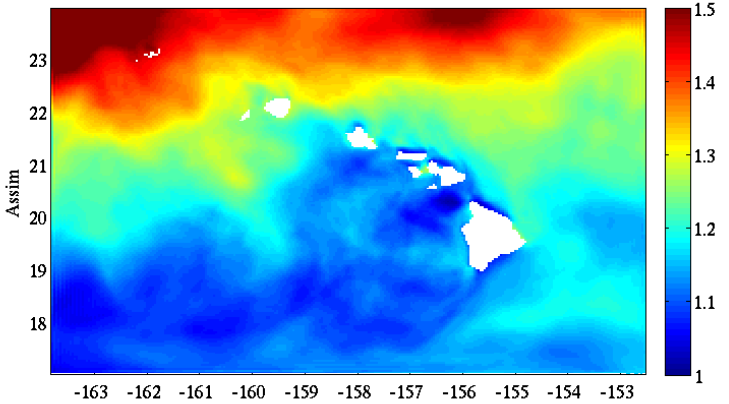
Mean SST

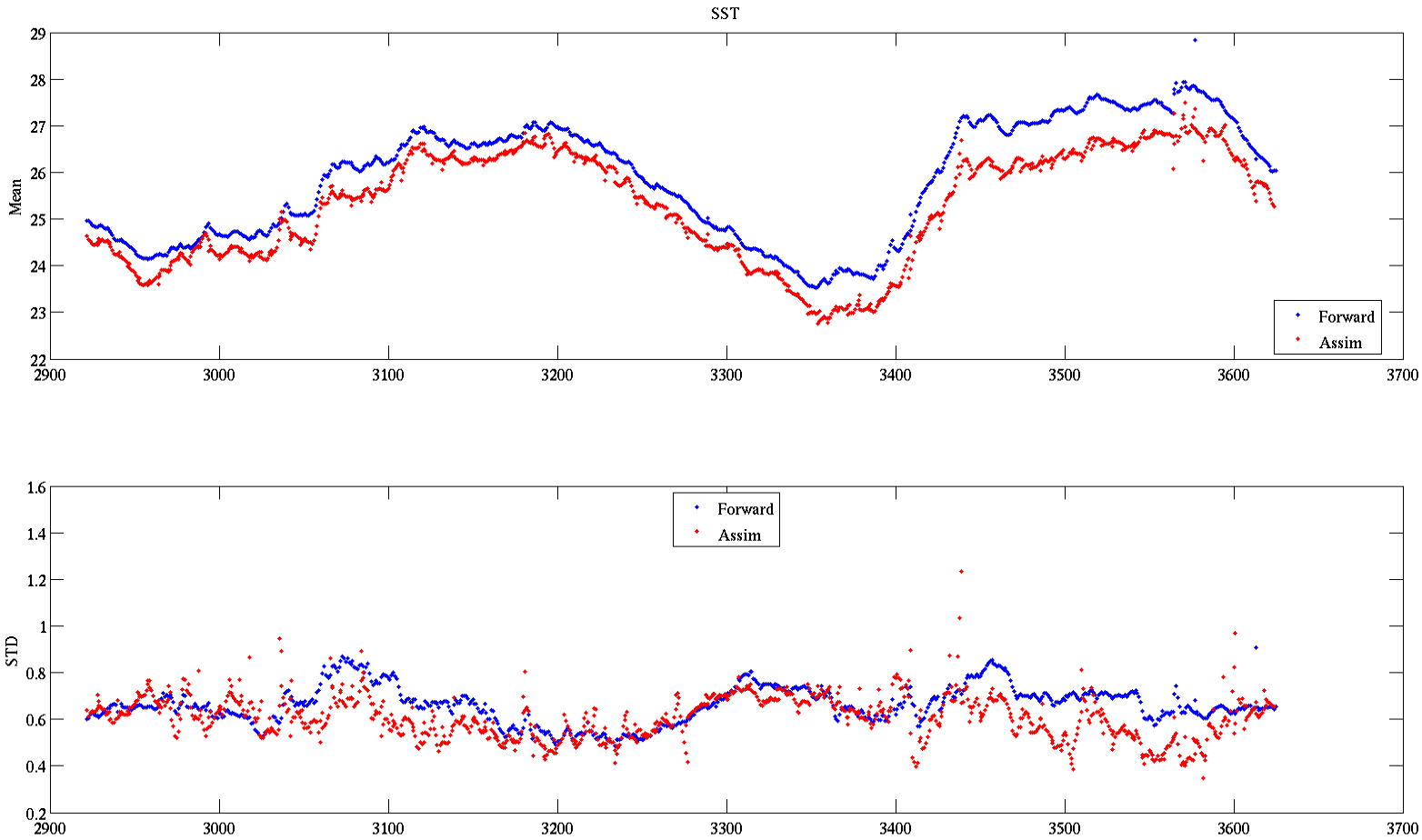


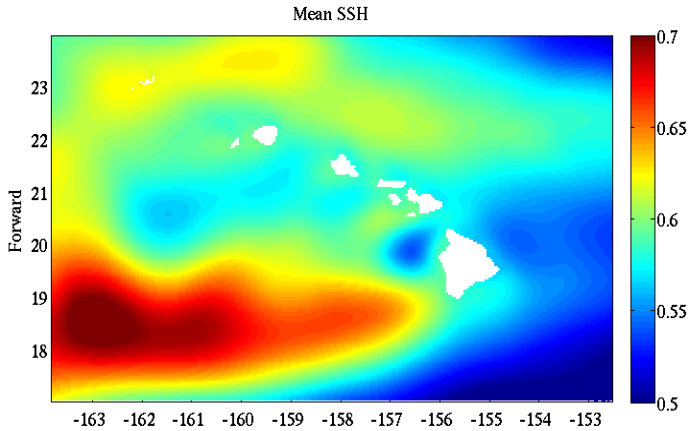


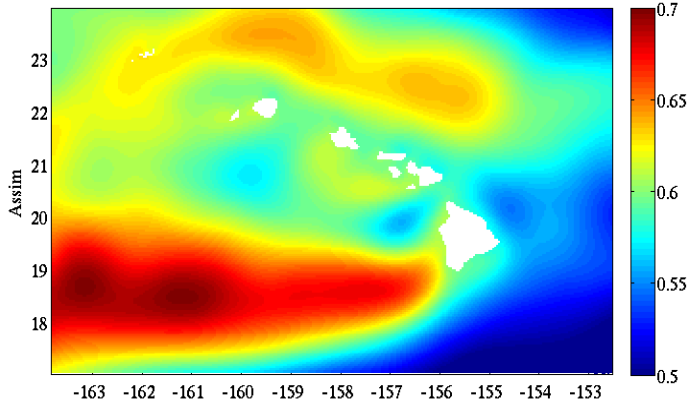
STD SST

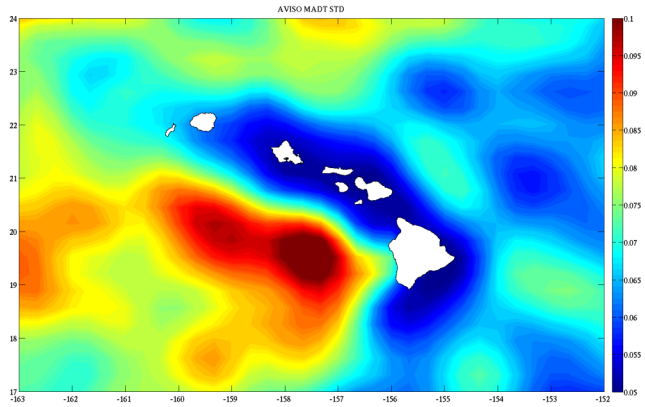


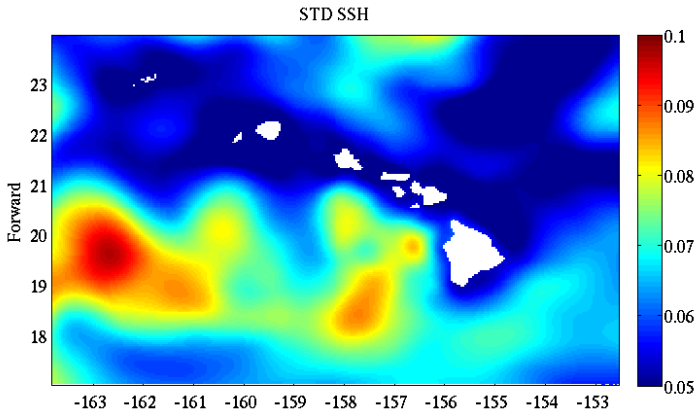


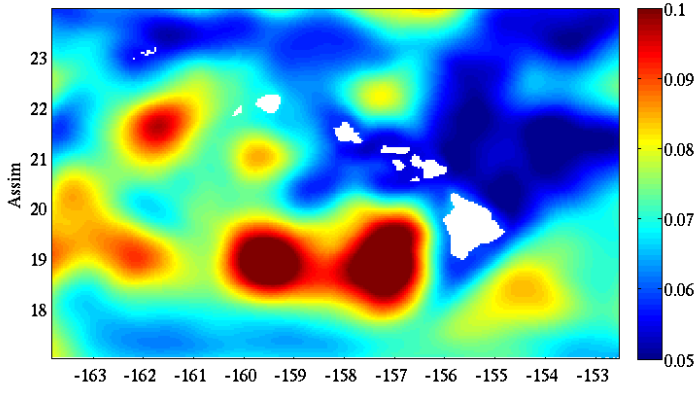

SST
Mean
29
28
27
26
25
24
23
22
2900
3000
3100
3200
3300
3400
3500
3600
3700
Forward
Assim
STD
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
2900
3000
3100
3200
3300
3400
3500
3600
3700
Forward
Assim

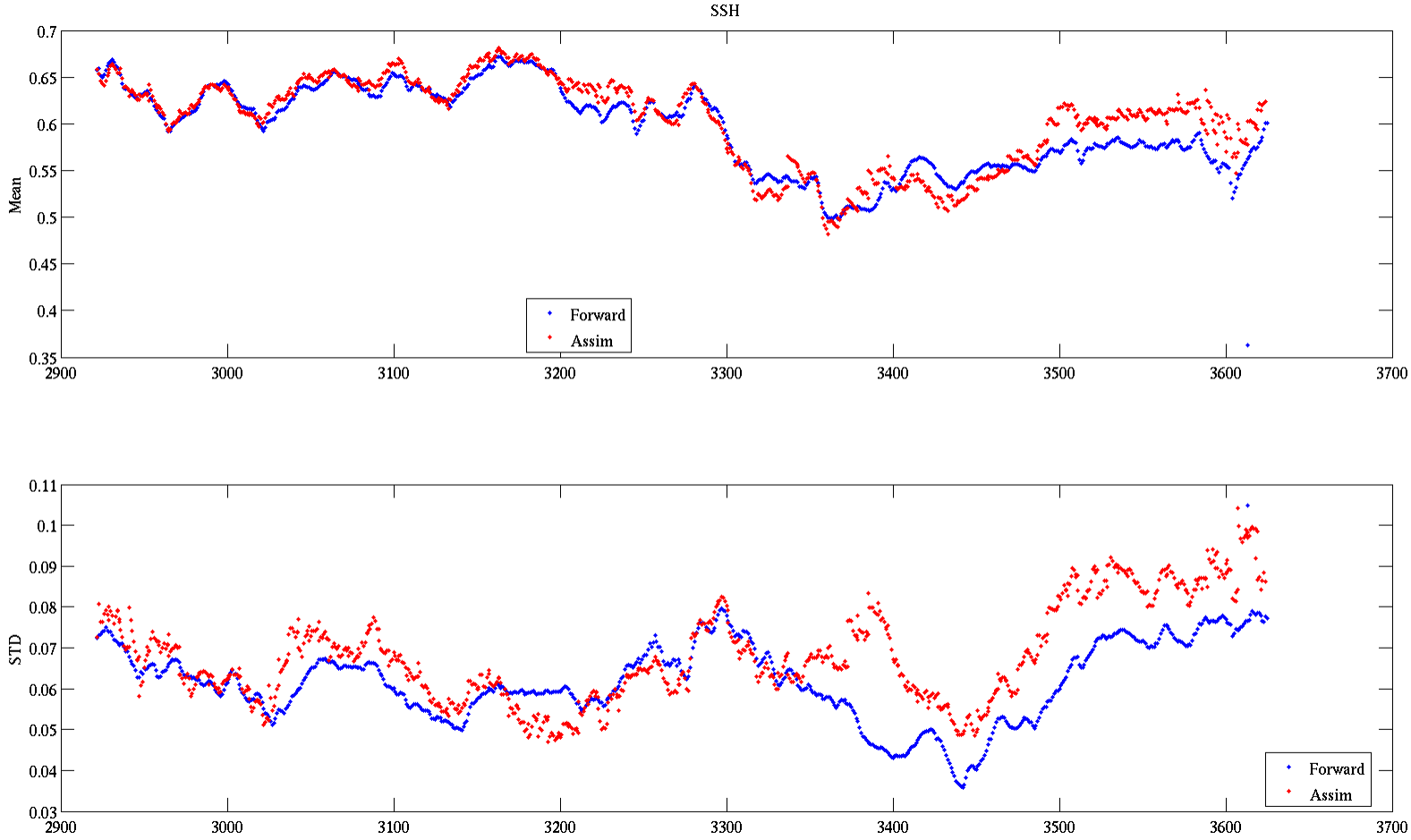

Mean SSH
Forward
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
0.7
0.65
0.6
0.55
0.5

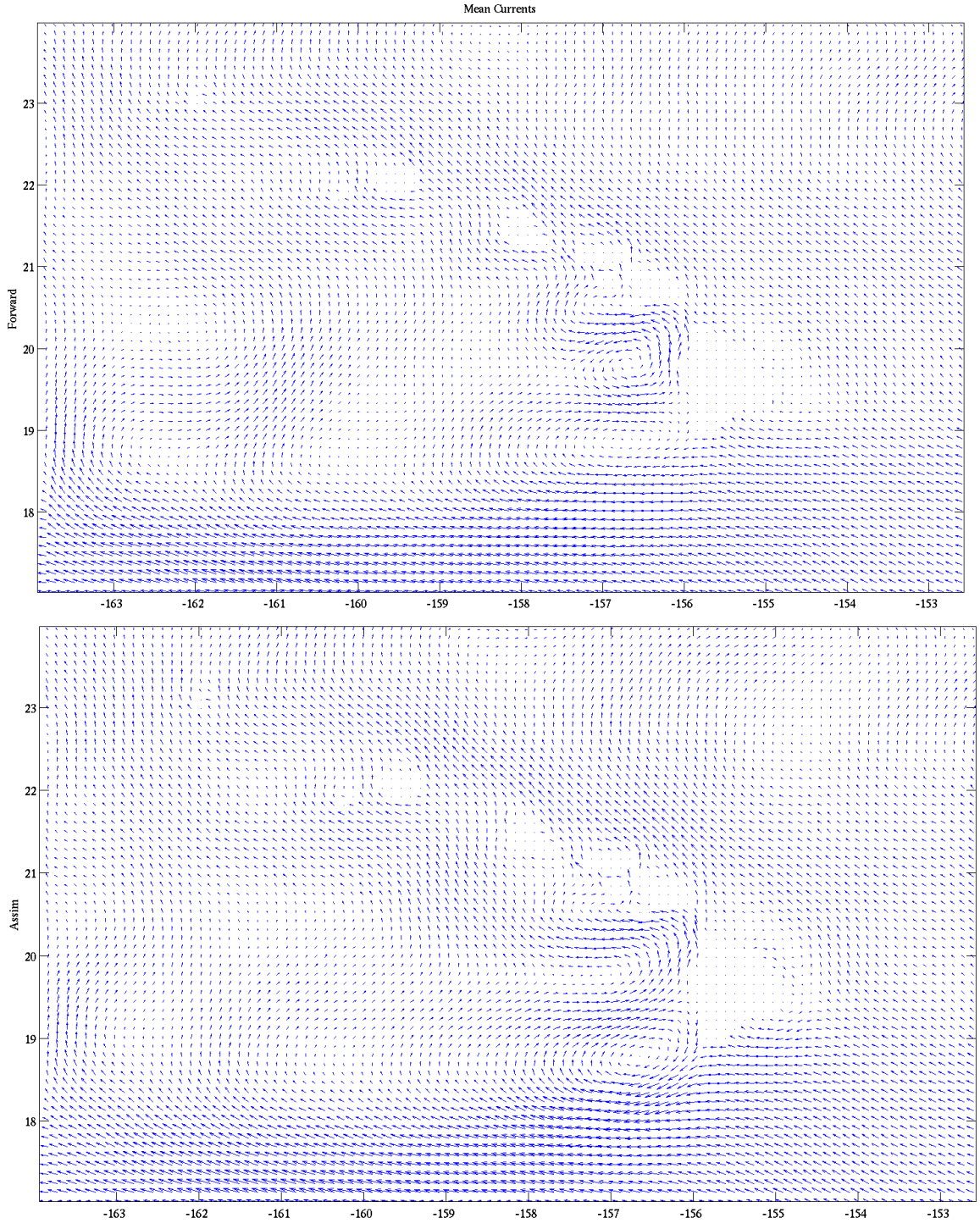

Assim
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
0.7
0.65
0.6
0.55
0.5

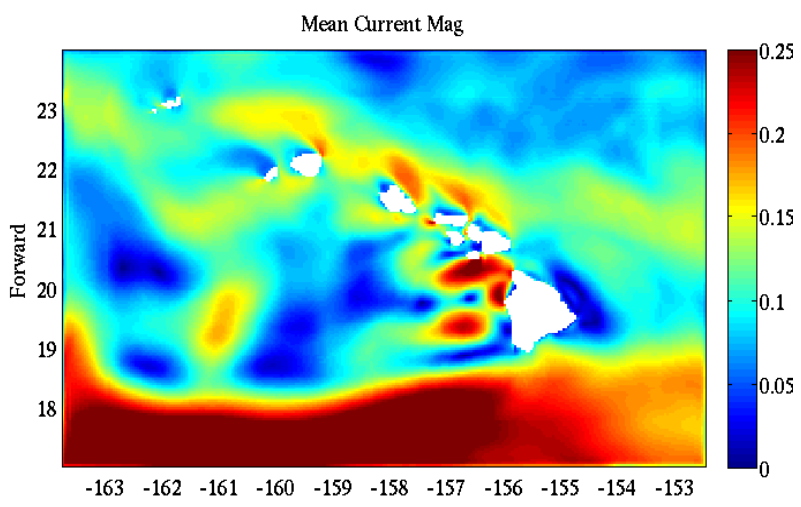

AVISO MADT STD


STD SSH
Forward
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
0.1
0.09
0.08
0.07
0.06
0.05


Assim
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
0.1
0.09
0.08
0.07
0.06
0.05


SSH
Mean
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
2900
3000
3100
3200
3300
3400
3500
3600
3700
Forward
Assim
STD
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
2900
3000
3100
3200
3300
3400
3500
3600
3700
Forward
Assim


Mean Currents
Forward
Assim
23
22
21
20
19
18
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153


Mean Current Mag
Forward
23
22
21
20
19
18
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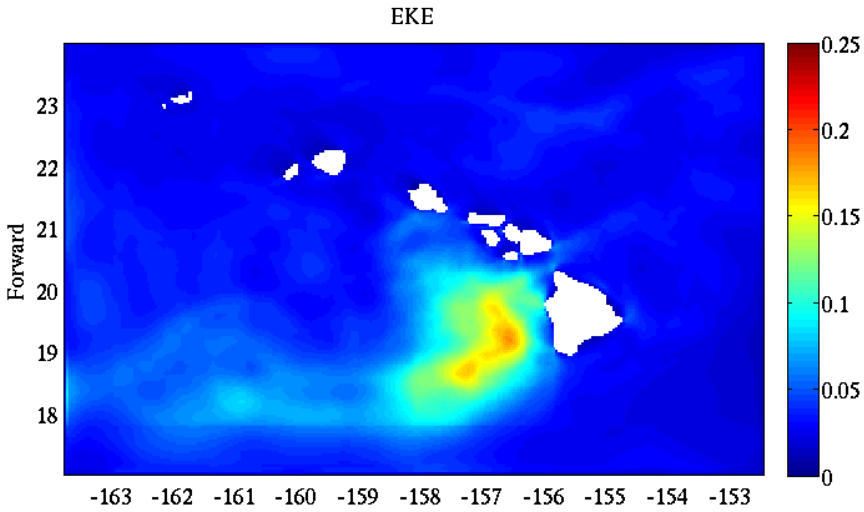
0.2
0.15
0.1
0.05
0


EKE
Forward
23
22
21
20
19
18
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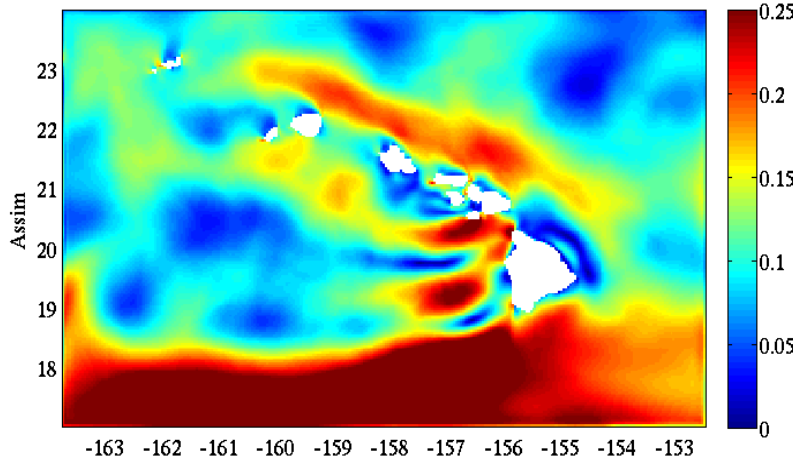
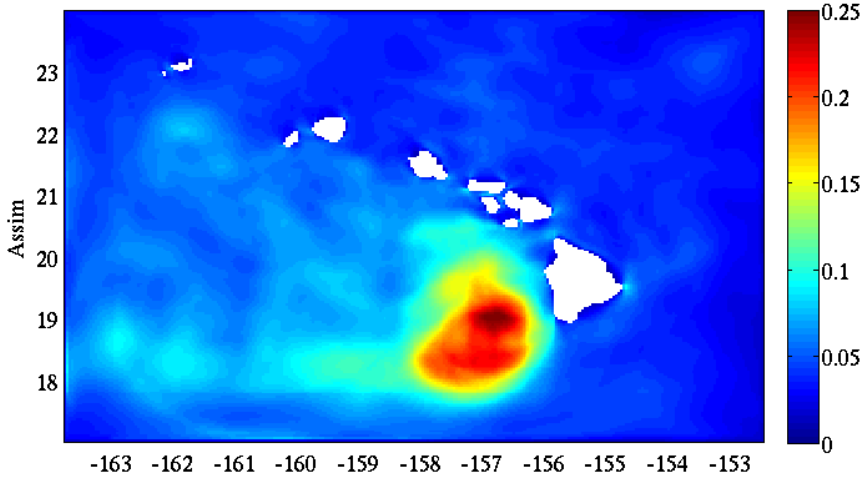
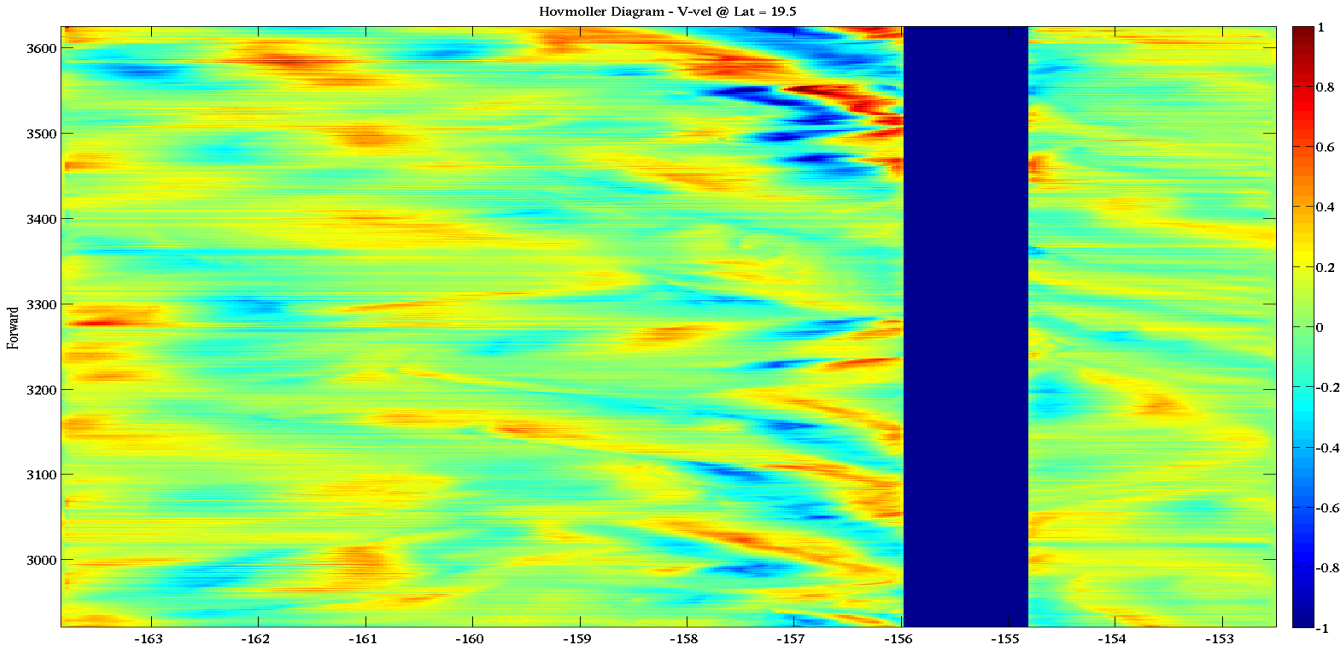
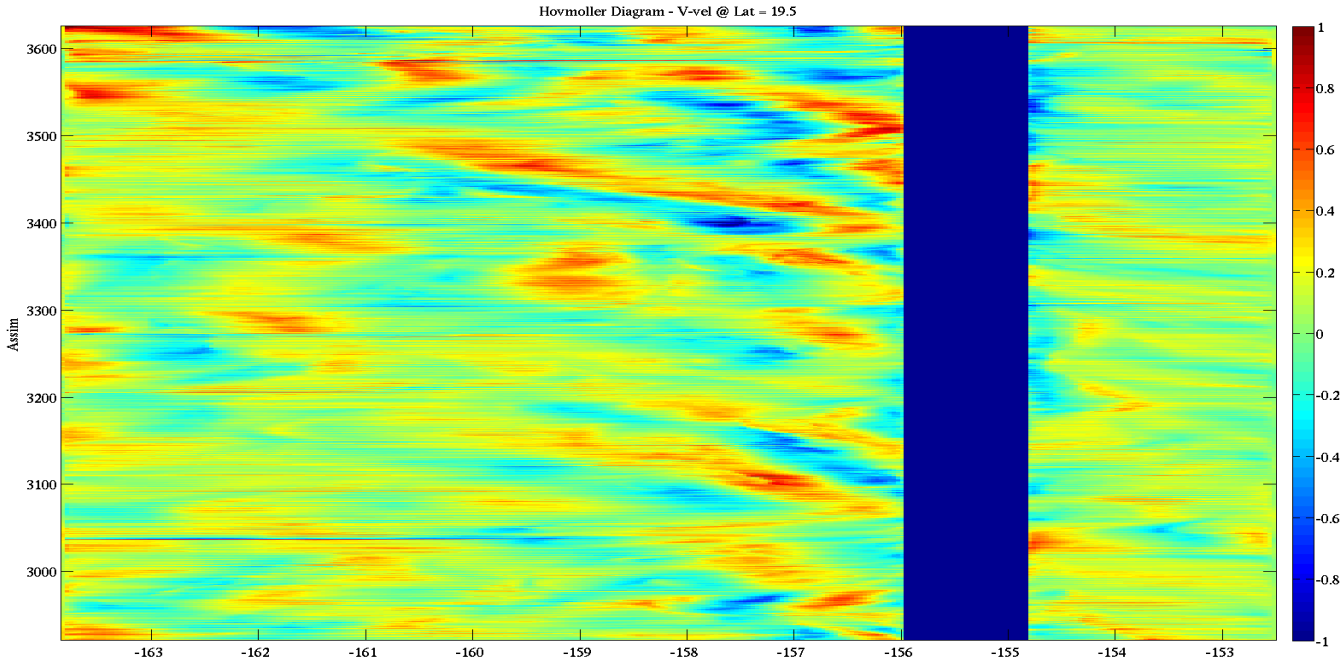
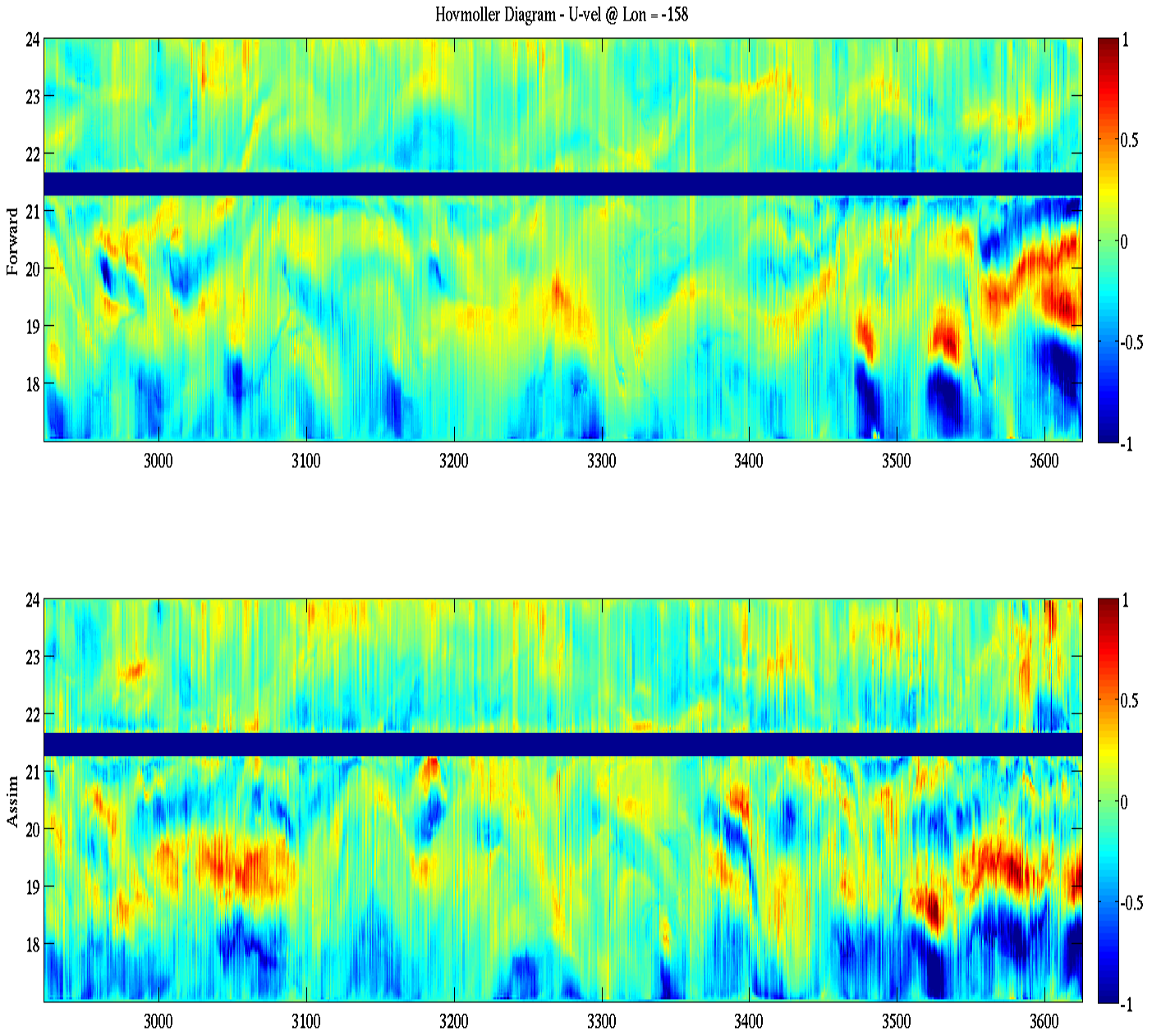
0.25
0.2
0.15
0.1
0.05
0

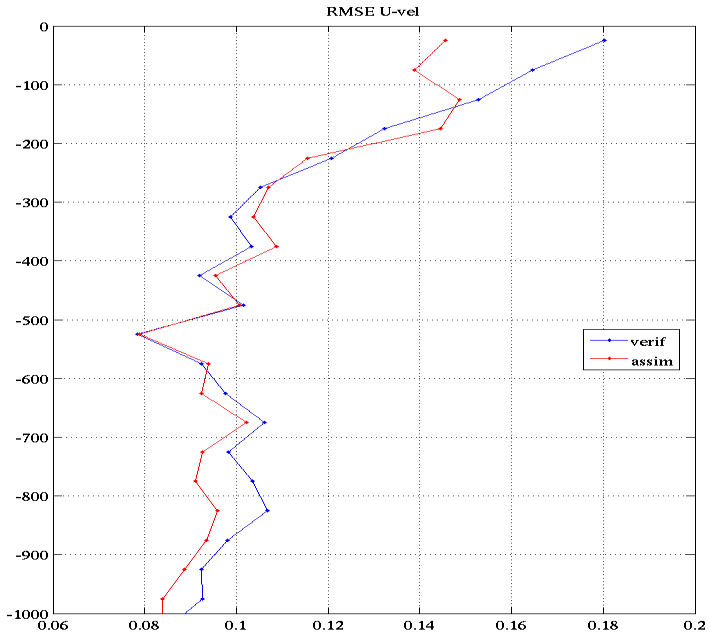

Assim
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
0.25
0.2
0.15
0.1
0.05
0

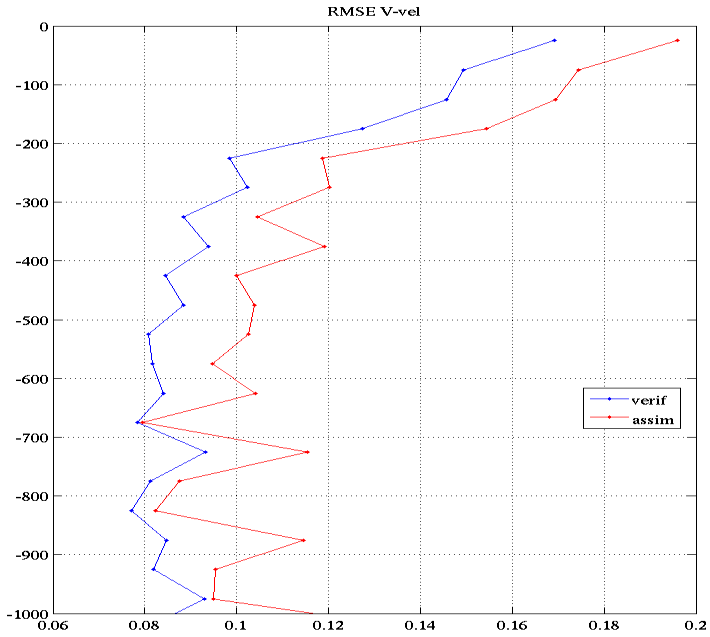

Assim
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
0.25
0.2
0.15
0.1
0.05
0

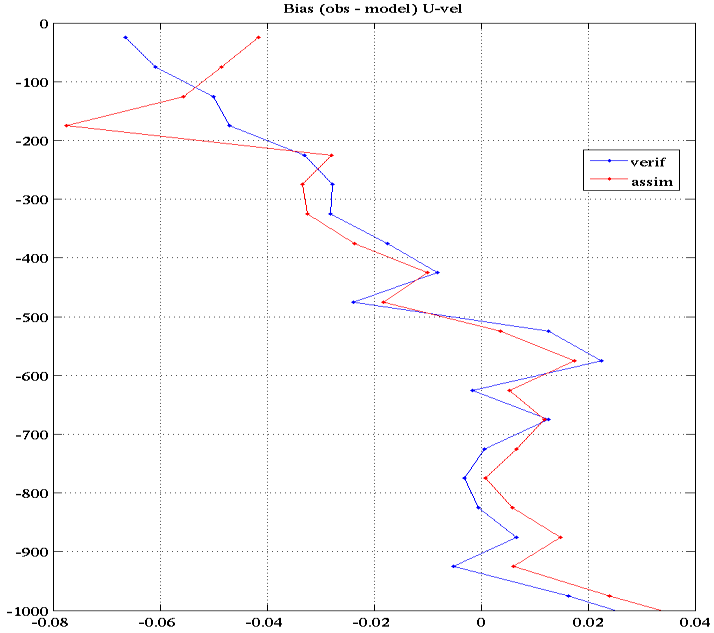

Hovmoller Diagram - V-vel @ Lat = 19.5
Forward
3600
3500
3400
3300
3200
3100
3000
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

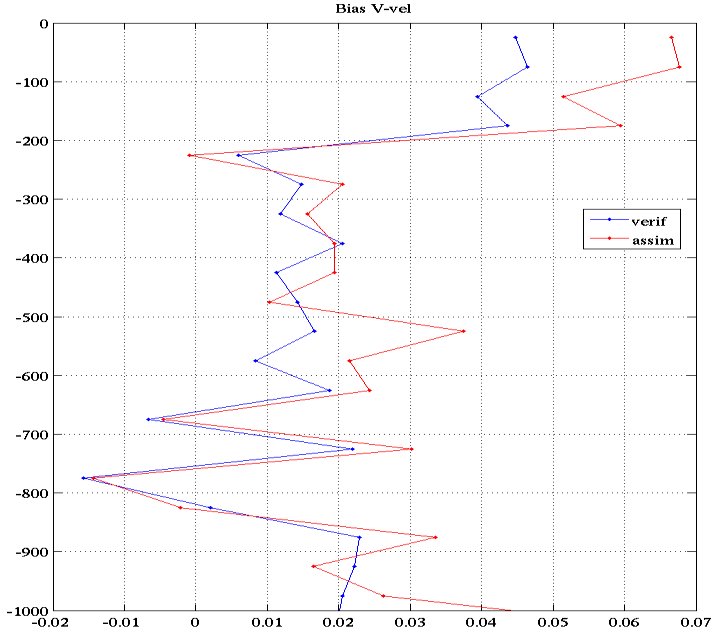

Hovmoller Diagram - V-vel @ Lat = 19.5
Assim
3600
3500
3400
3300
3200
3100
3000
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

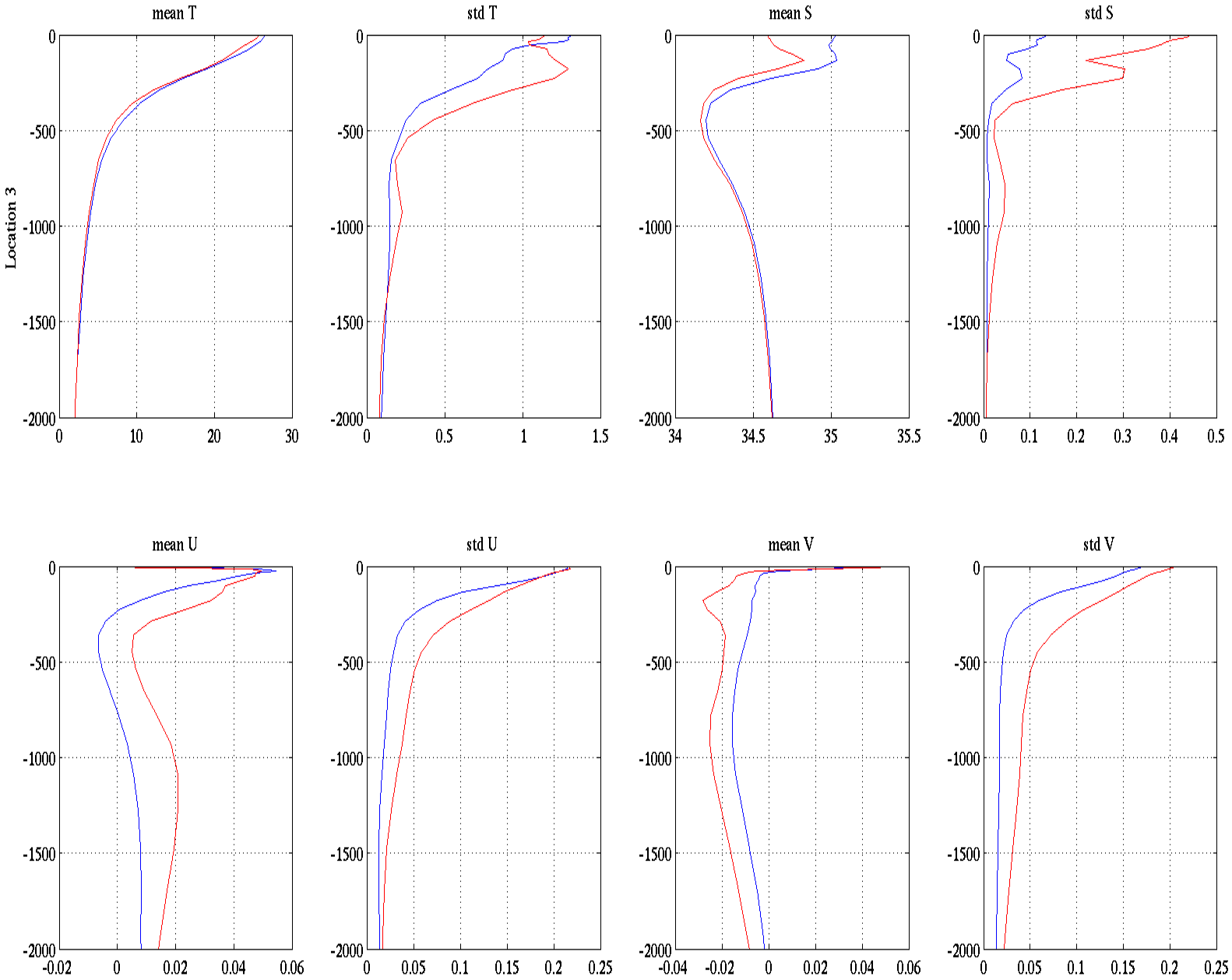

Hovmoller Diagram - U-vel @ Lon = -158
Forward
Assim
24
23
22
21
20
19
18
3000
3100
3200
3300
3400
3500
3600
1
0.5
0
-0.5
-1

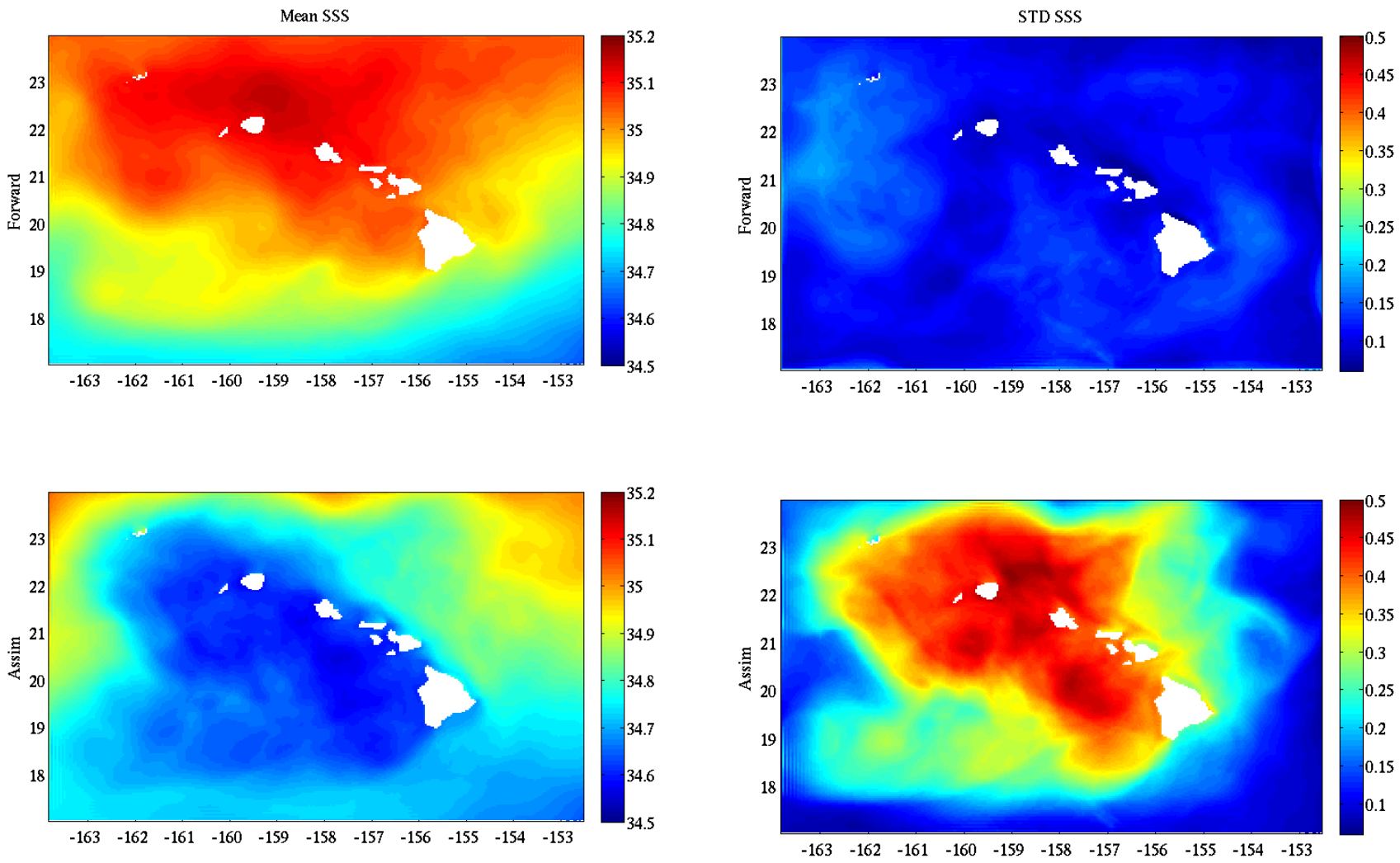

RMSE U-vel
verif
assim
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2

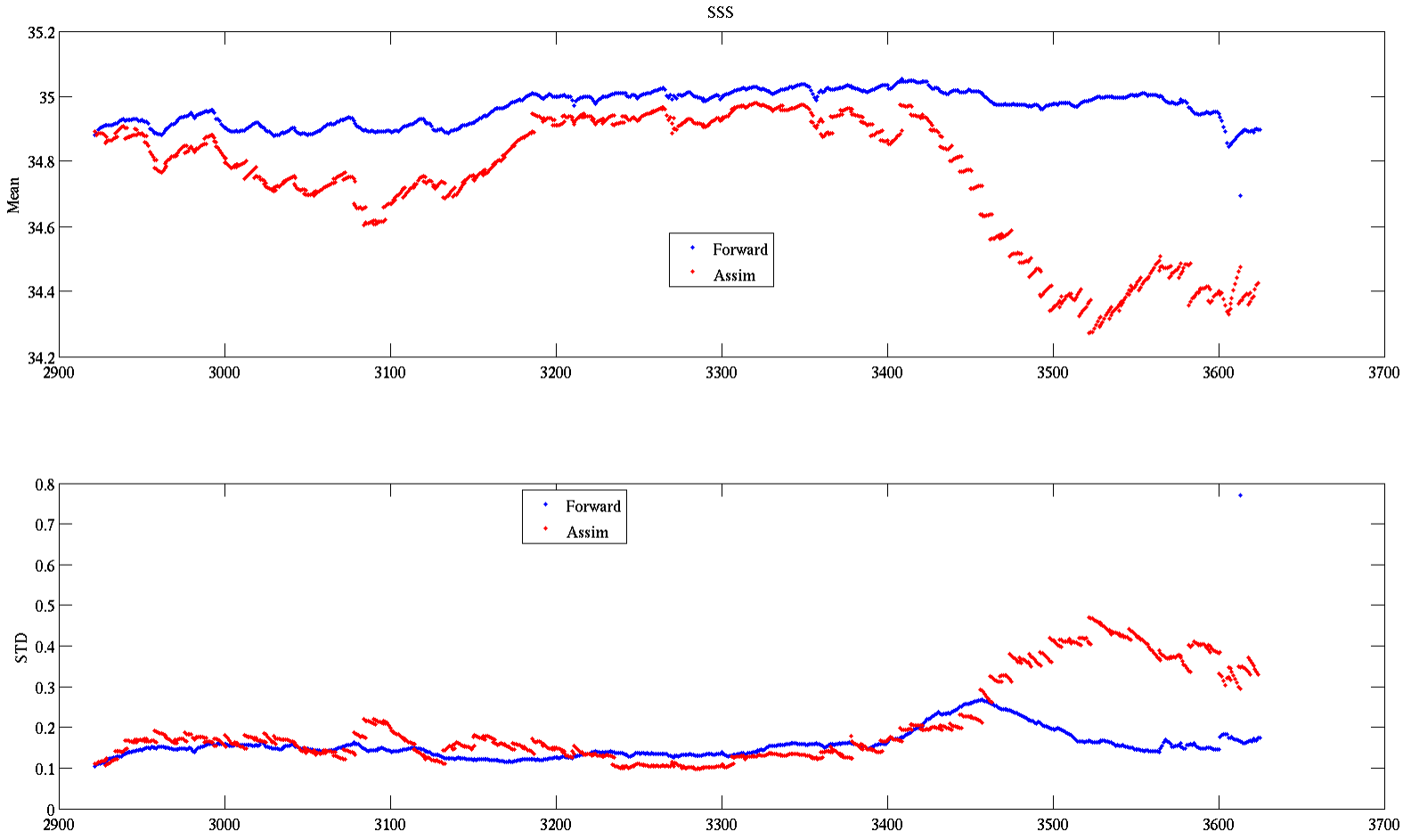

RMSE V-vel
verif
assim
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2

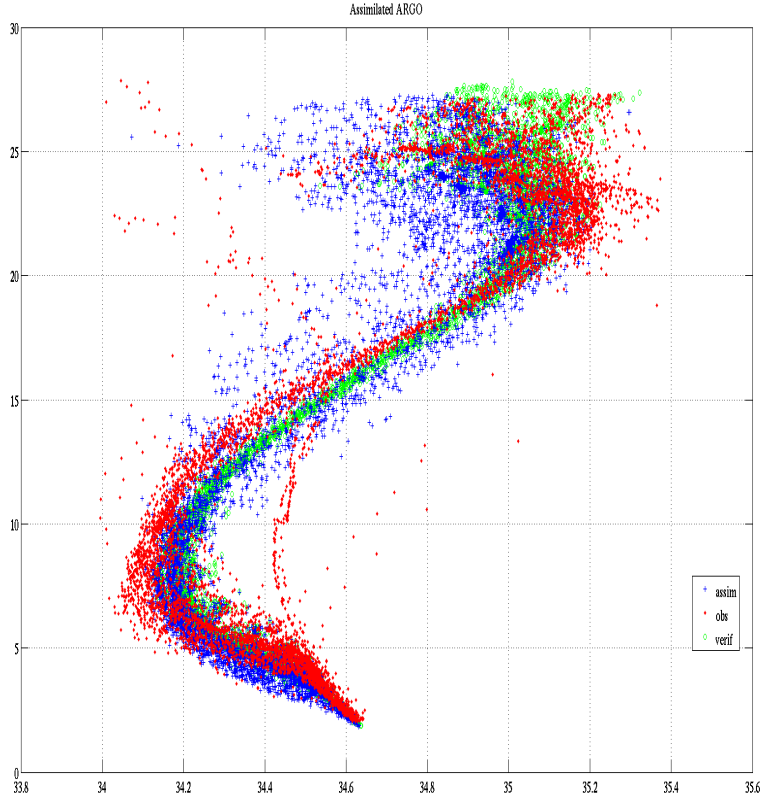

Bias (obs - model) U-vel
verif
assim
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04

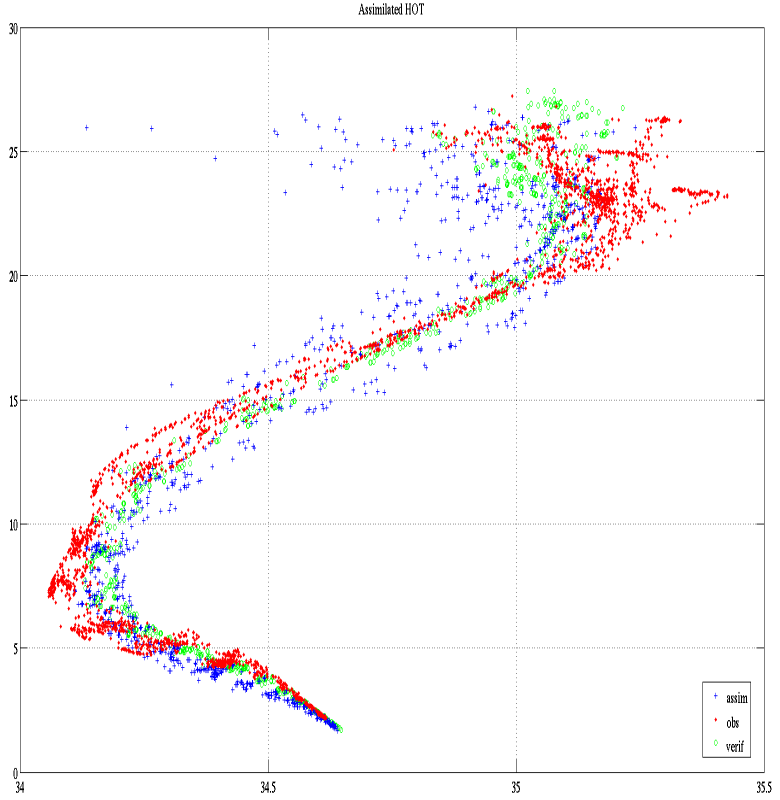

Bias V-vel
verif
assim
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07

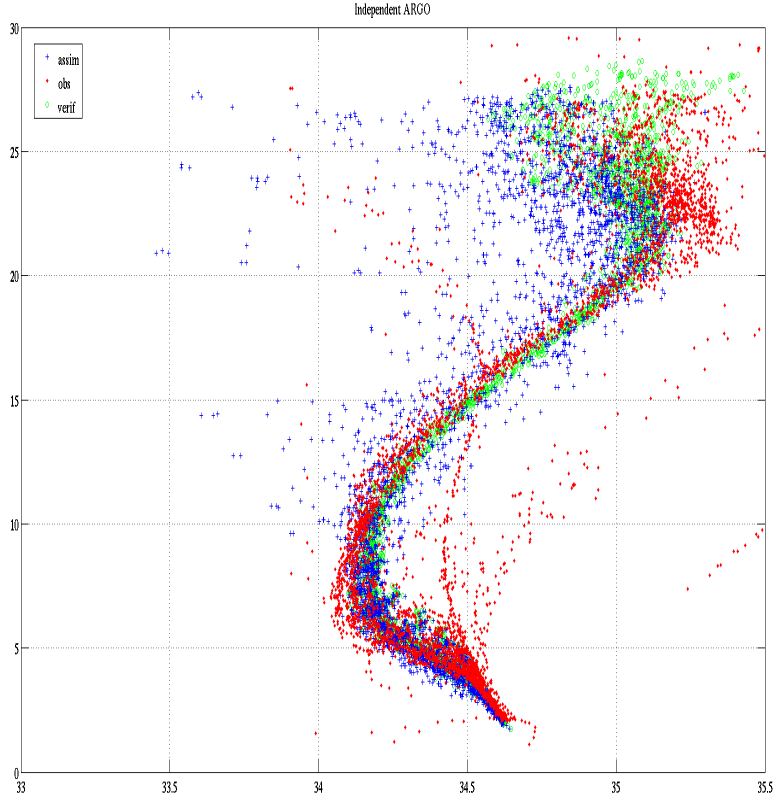

Location 3
mean T
std T
mean S
std S
mean U
std U
mean V
std V
0
-500
-1000
-1500
-2000
0
10
20
30
0.5
1
1.5
34
34.5
35
35.5
0.1
0.2
0.3
0.4
0.5
-0.02
0.02
0.04
0.06
0.05
0.1
0.15
0.2
0.25
-0.04
-0.02

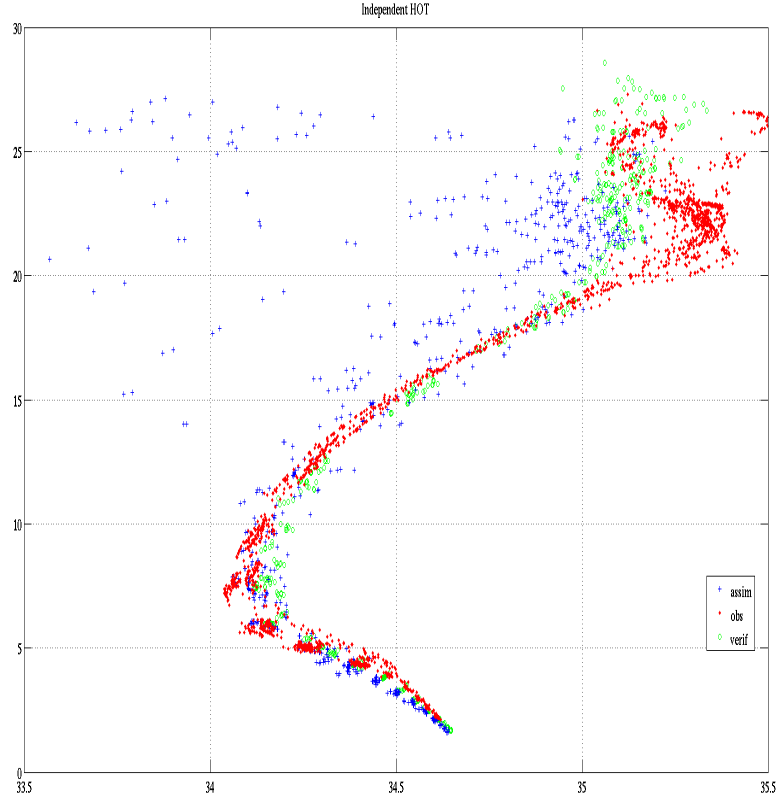

Mean SSS
STD SSS
Forward
Assim
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
35.2
35.1
35
34.9
34.8
34.7
34.6
34.5
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1

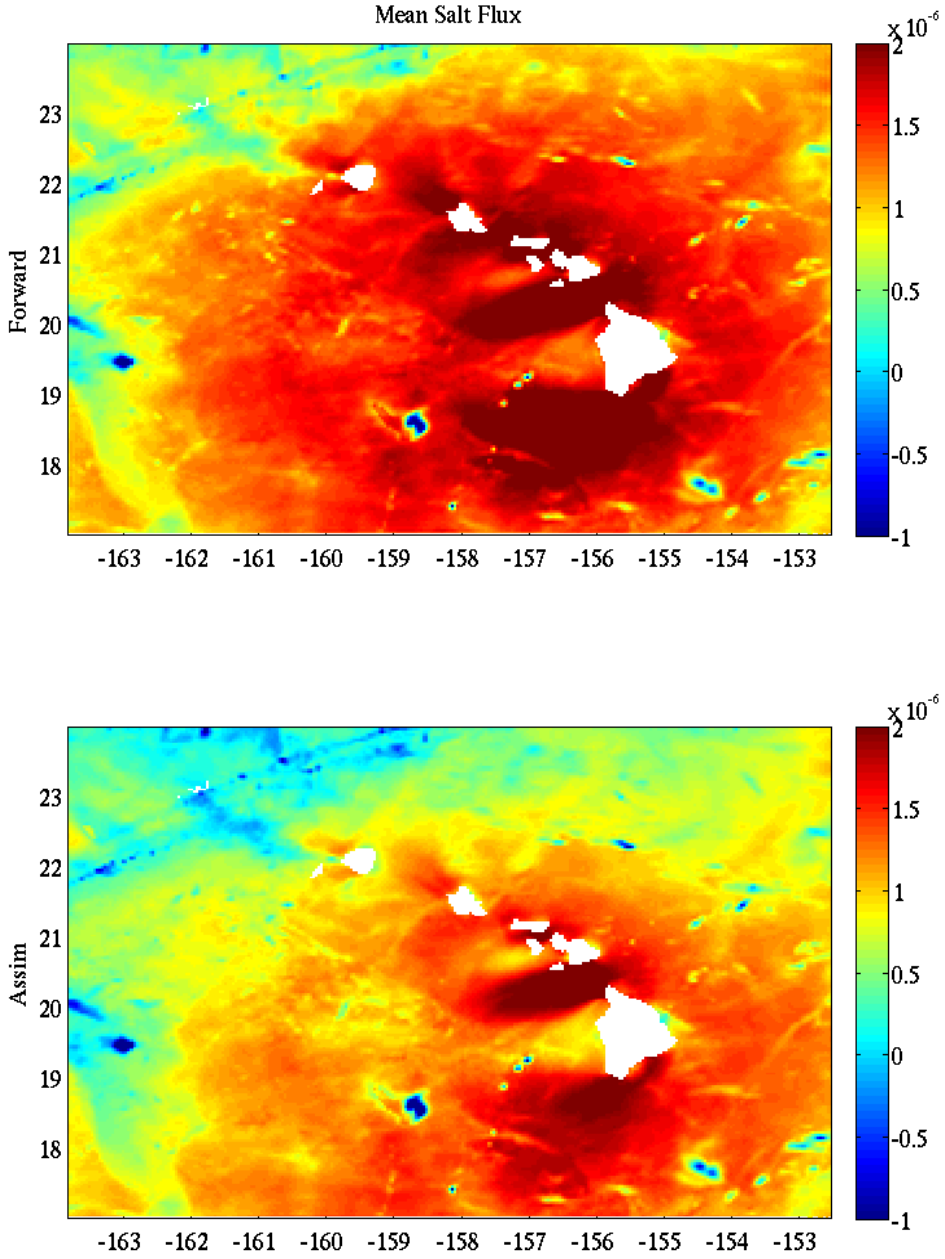

SSS
Mean
35.2
35
34.8
34.6
34.4
34.2
2900
3000
3100
3200
3300
3400
3500
3600
3700
Forward
Assim
STD
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Forward
Assim

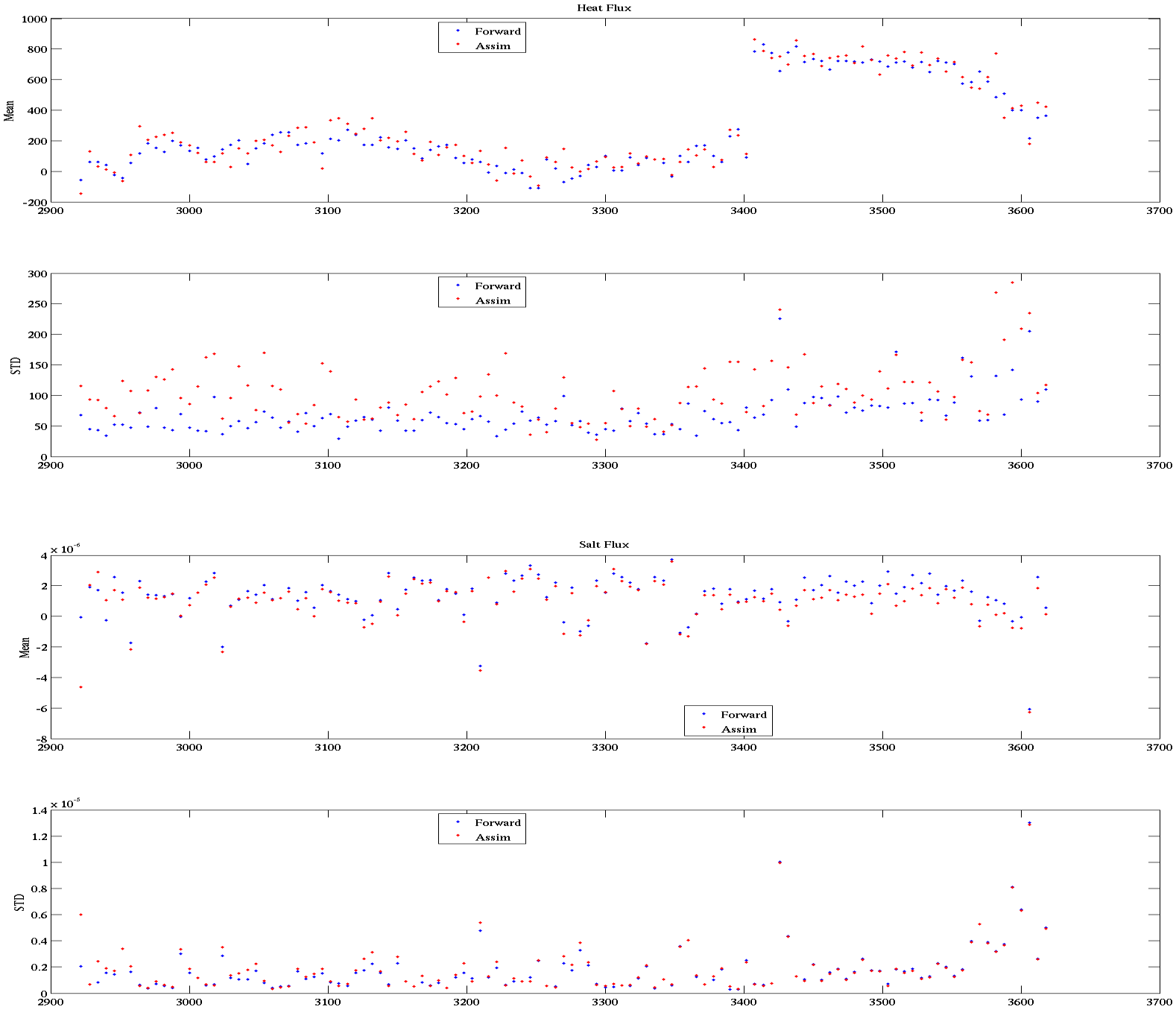

Assimilated ARGO
30
25
20
15
10
5
0
33.8
34
34.2
34.4
34.6
34.8
35
35.2
35.4
35.6
assim
obs
verif

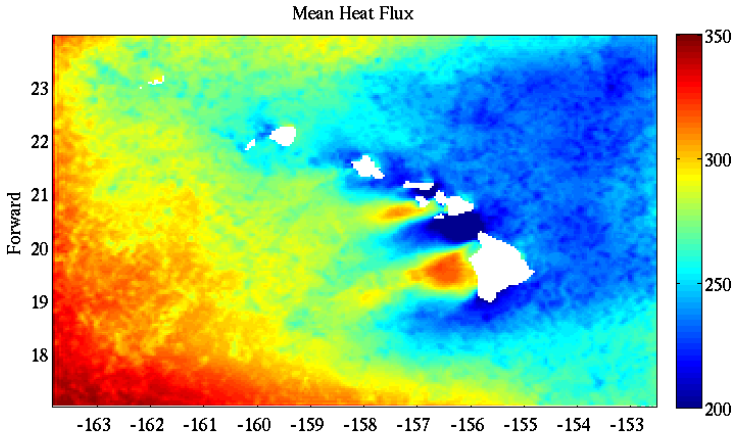

Assimilated HOT
30
25
20
15
10
5
0
34
34.5
35
35.5
assim
obs
verif

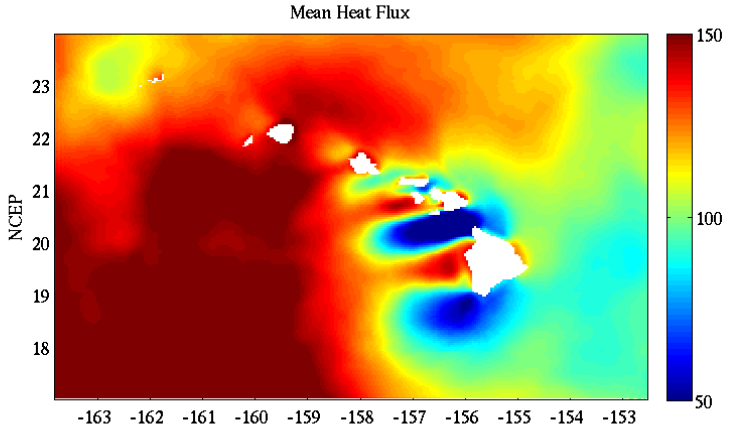

Independent ARGO
assim
obs
verif
30
25
20
15
10
5
0
33
33.5
34
34.5
35
35.5

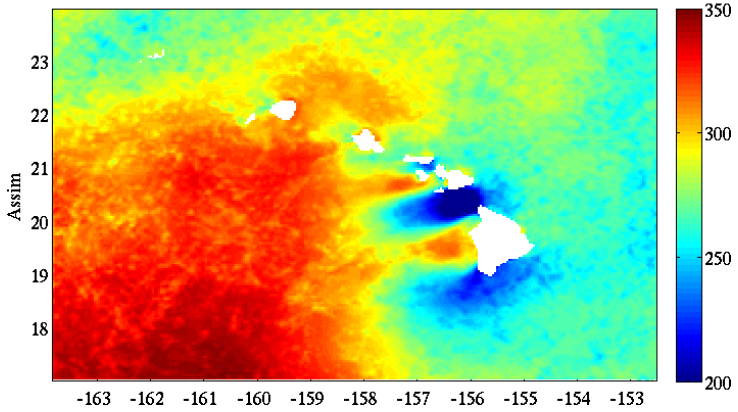

Independent HOT
assim
obs
verif
30
25
20
15
10
5
0
33.5
34
34.5
35
35.5

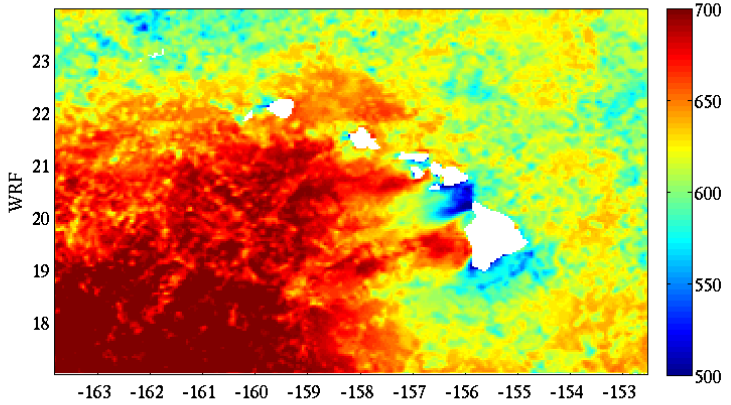

Mean Salt Flux
Forward
Assim
23
22
21
20
19
18
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153
x 10^-6
2
1.5
1
0.5
0
-0.5
-1

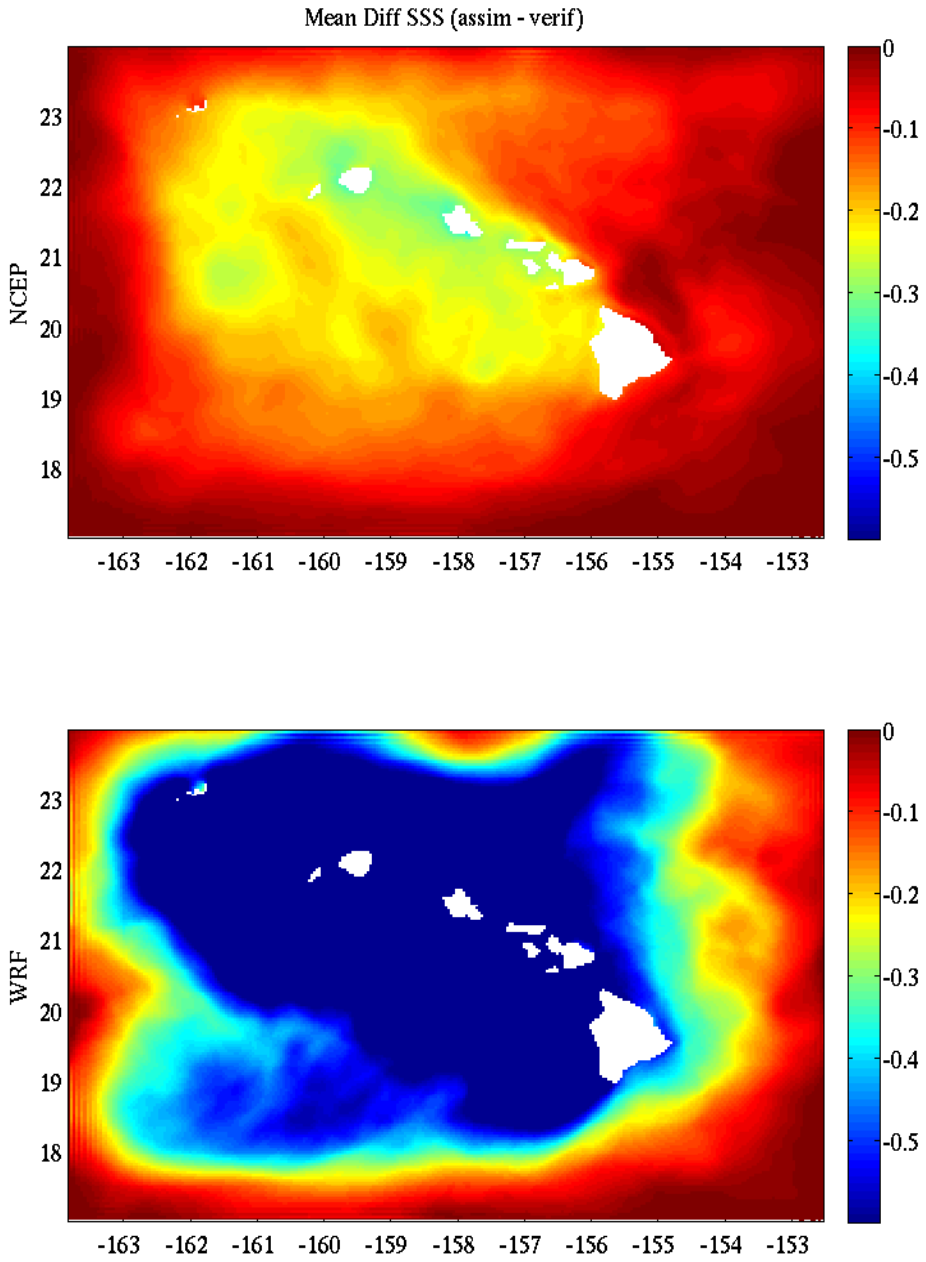

Heat Flux
Mean
Forward
Assim
STD
Forward
Assim
Salt Flux
× 10^-6
Mean
Forward
Assim
× 10^-5
STD
Forward
Assim

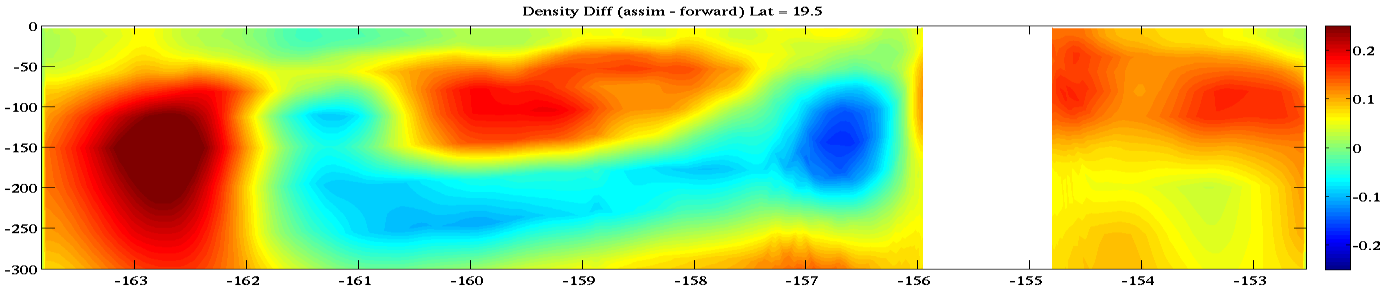

Mean Heat Flux
Forward
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
350
300
250
200

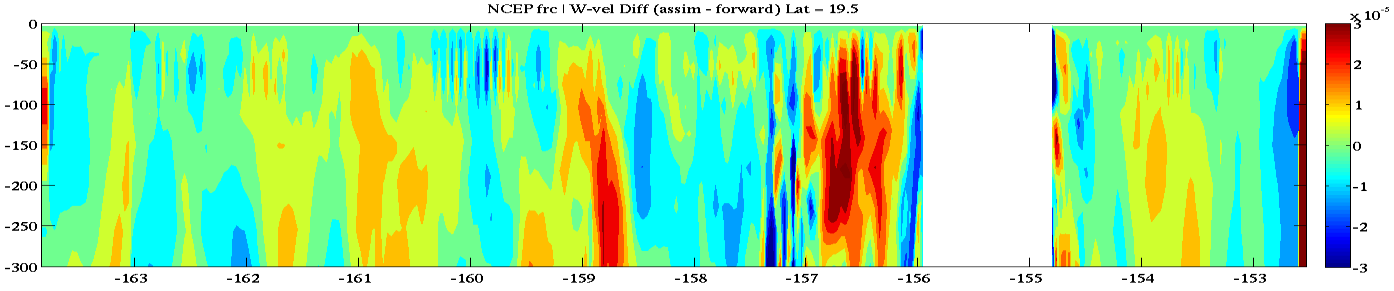

Mean Heat Flux
NCEP
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
150
100
50

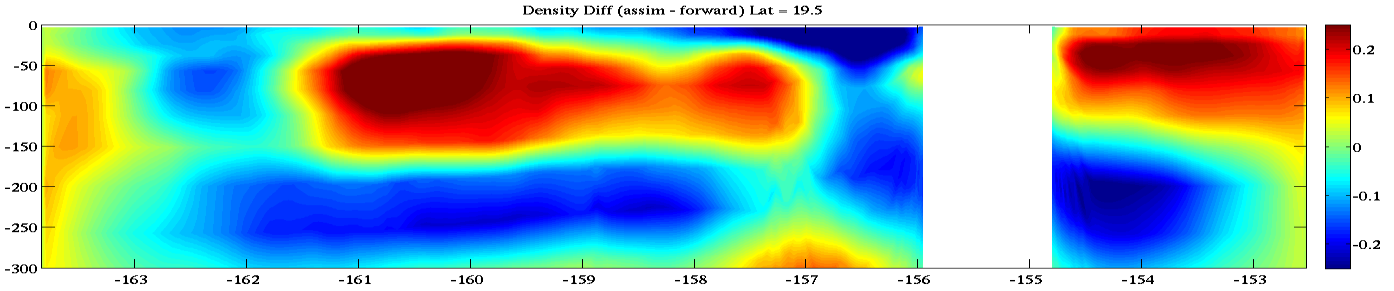

Assim
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
350
300
250
200

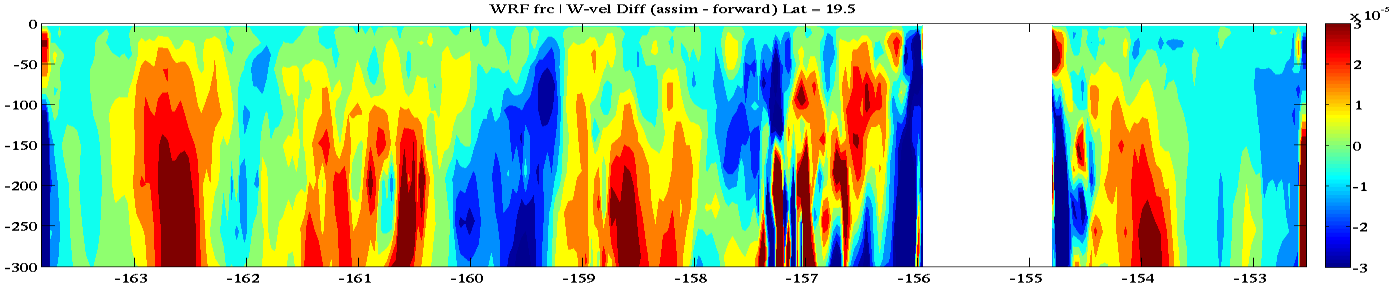

WRF
23
22
21
20
19
18
-163 -162 -161 -160 -159 -158 -157 -156 -155 -154 -153
700
650
600
550
500


Mean Diff SSS (assim - verif)
NCEP
WRF
23
22
21
20
19
18
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153
0
-0.1
-0.2
-0.3
-0.4
-0.5


Density Diff (assim - forward) Lat = 19.5
0
-50
-100
-150
-200
-250
-300
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153
0.2
0.1
0
-0.1
-0.2


NCEP frc | W-vel Diff (assim - forward) Lat = 19.5
0
-50
-100
-150
-200
-250
-300
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153
x 10^-5
3
2
1
0
-1
-2
-3


Density Diff (assim - forward) Lat = 19.5
0
-50
-100
-150
-200
-250
-300
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153
0.2
0.1
0
-0.1
-0.2


WRF frc | W-vel Diff (assim - forward) Lat = 19.5
0
-50
-100
-150
-200
-250
-300
-163
-162
-161
-160
-159
-158
-157
-156
-155
-154
-153
x 10^-5
3
2
1
0
-1
-2
-3

Future Work

- Switch to 1Hz PO.DAAC IGDR
- Test limiting number of SST obs
- Correct heat flux/hot bias
- Correct assimilation cycle length
- Introduce tides to system
- Obs impact study