Observations at 25.5ºN and 87ºW: Deepwater Currents in the Eastern Gulf of Mexico

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APPLETON

Characteristics of the GOM Basin

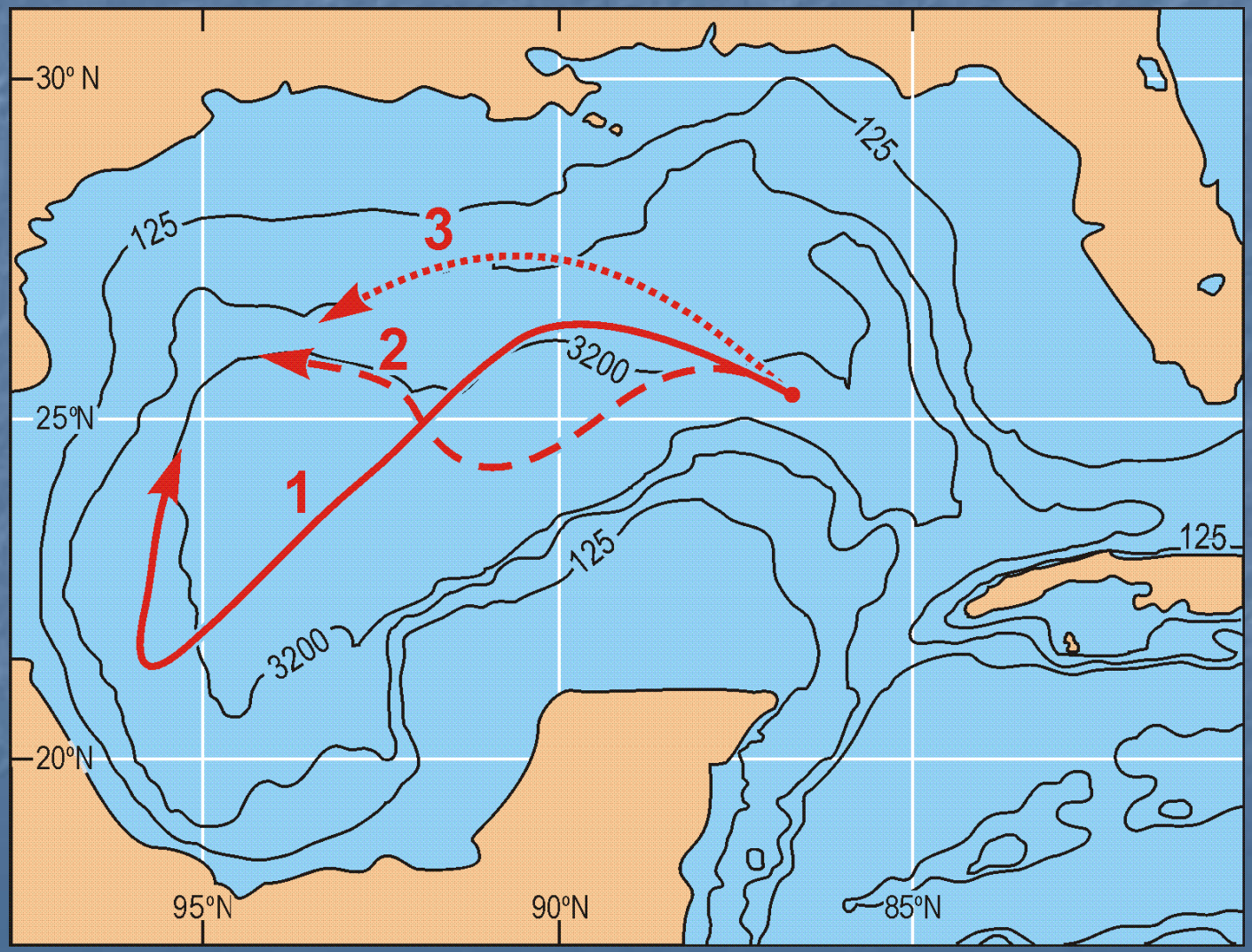
- Gulf of Mexico (GOM) is a semi-enclosed basin with maximum depths of 3400~3700m
- Sill depths at Yucatan Channel (~1900m) and at Florida Strait (~800m)
- Deep water below the sill depths, GOM is isolated

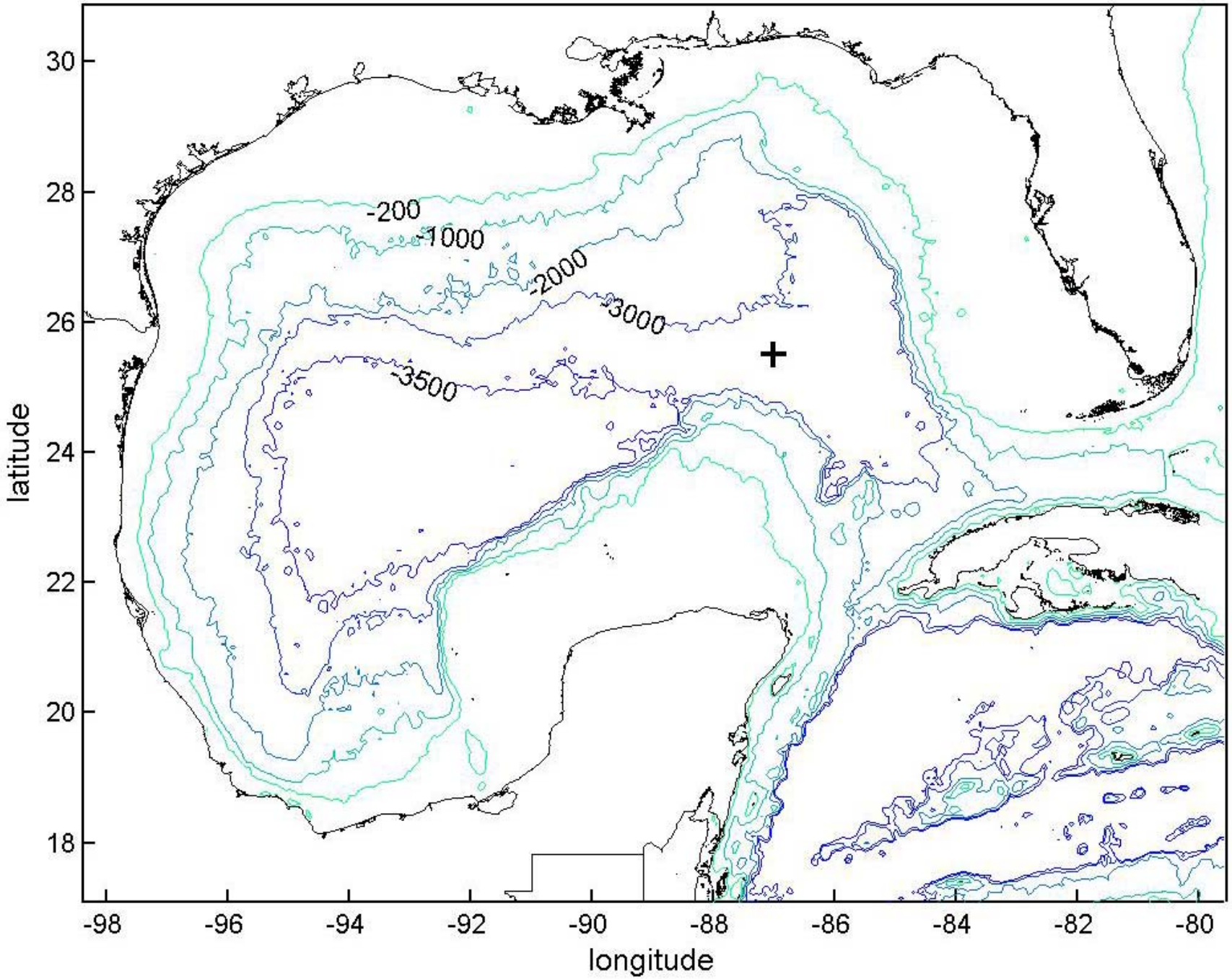
Characteristics of the Water Column within the GOM

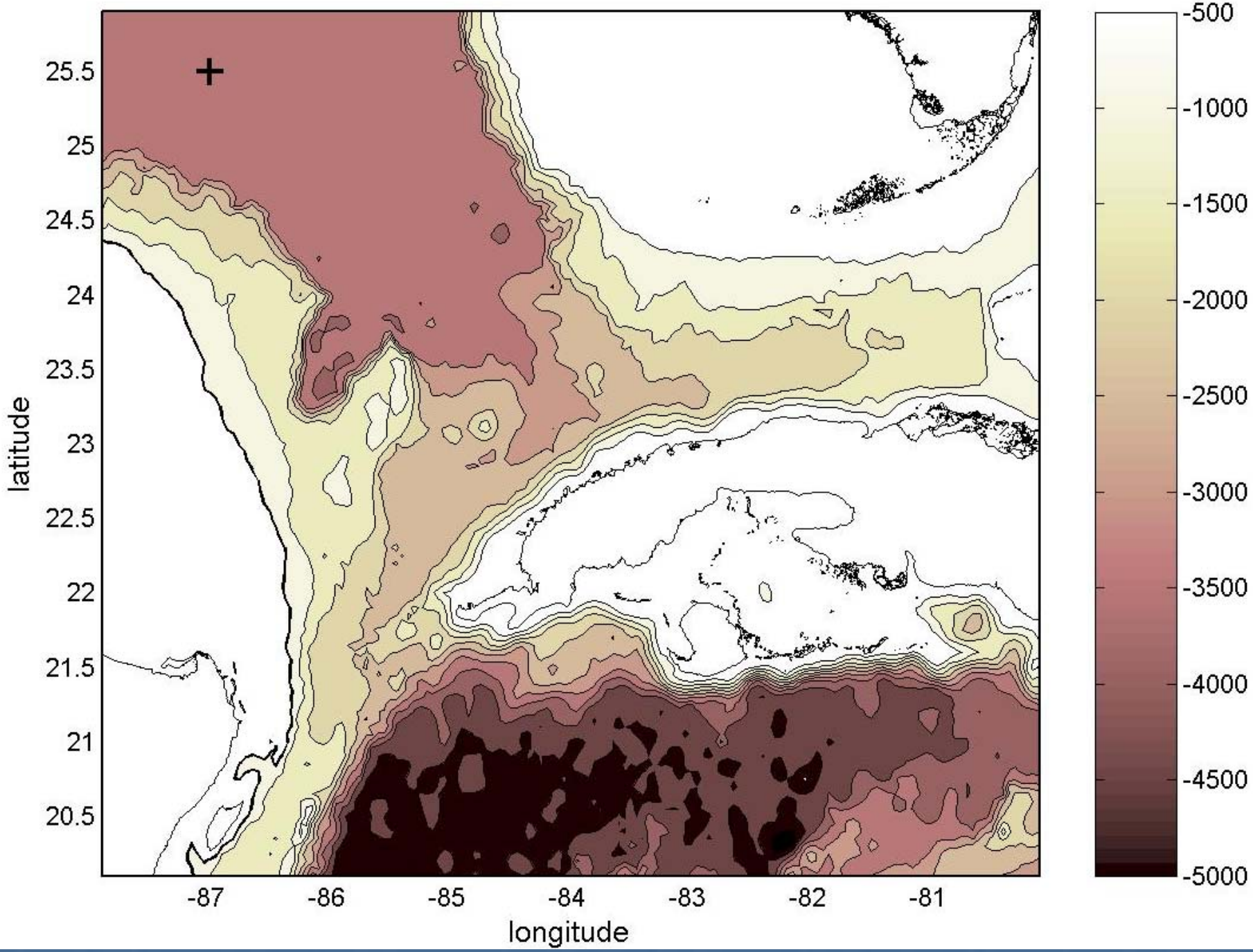
- The upper layer (~top 800 m) is dominated by the Loop Current (in the eastern basin) and the Loop Current Eddies (central and western GOM).
- Energetic cyclones and topographic Rossby waves have been observed in the deep water near the northern continental slope water region.
- Residence time in the deep GOM has been estimated to be relatively short (~100 years).
- Somehow, energy has to be transmitted vertically from the energetic upper layer to the deep water.

Selection of mooring site

3 types of trajectories of the Loop Current Rings identified by Vukovich and Crissman (1986)

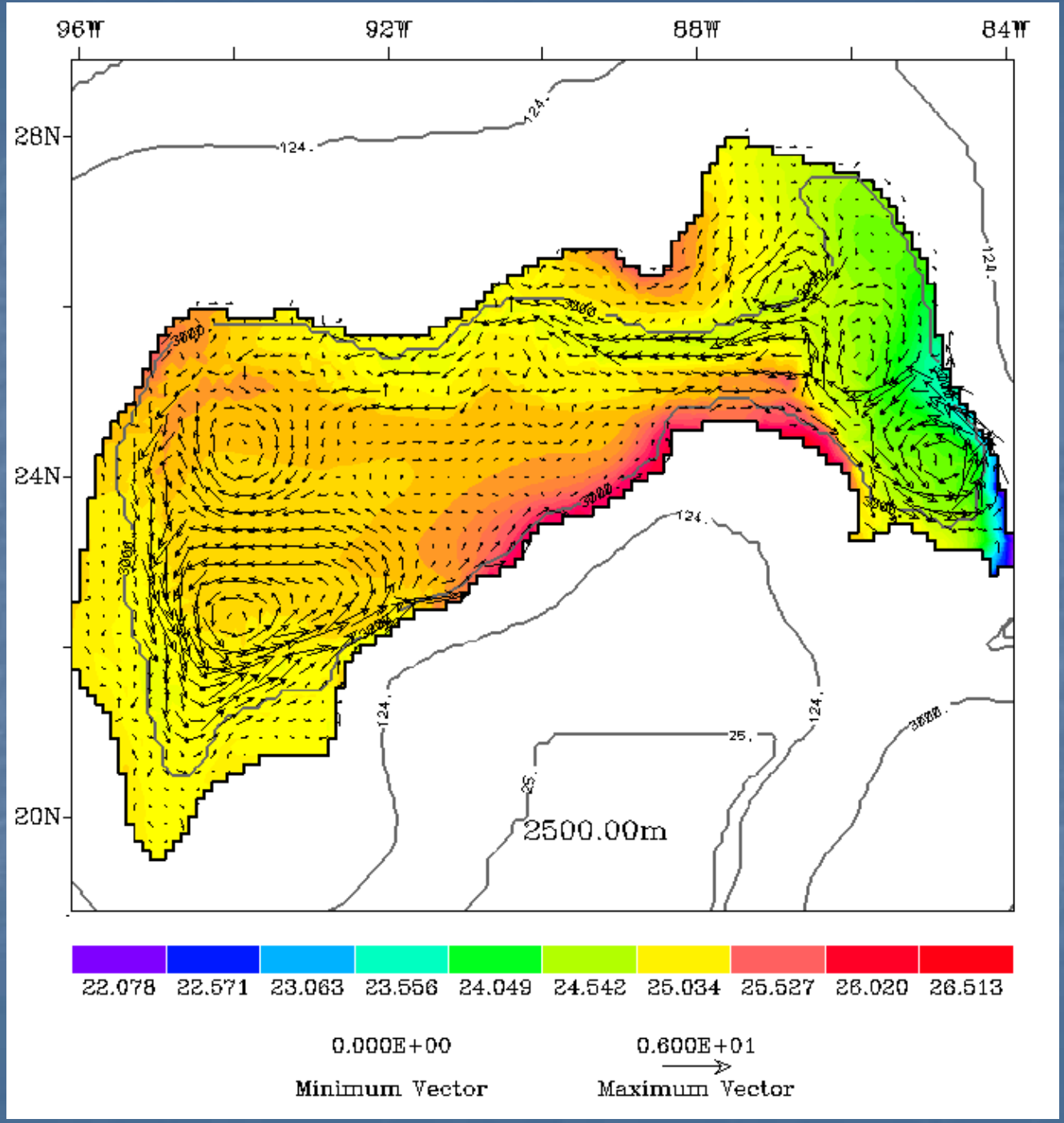


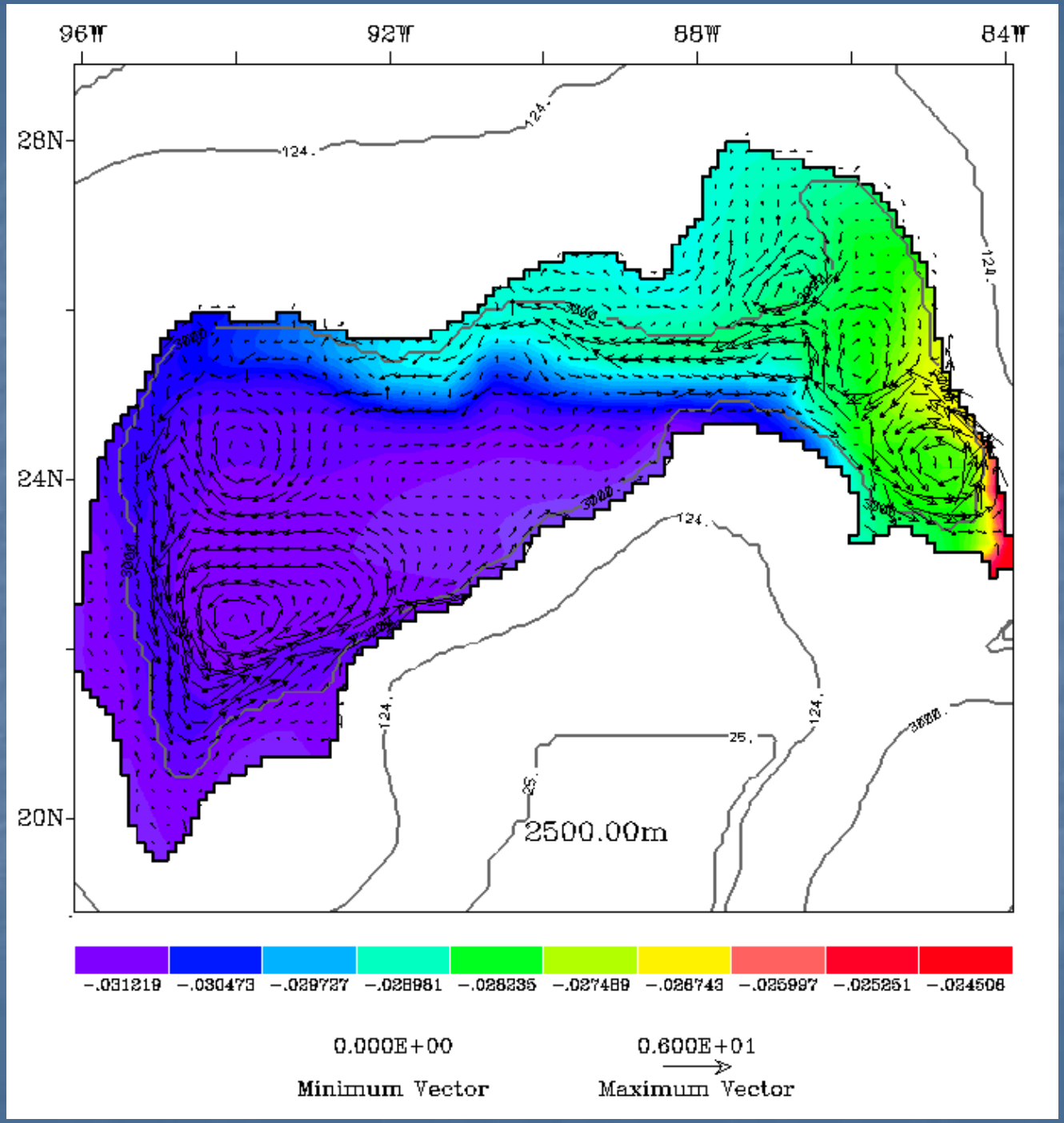

-200
-1000
-2000
-3000
-3500
latitude
longitude
30
28
26
24
22
20
18
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80


25.5
25
24.5
24
23.5
23
22.5
22
21.5
21
20.5
latitude
-87
-86
-85
-84
-83
-82
-81
longitude
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000

General Water Mass Properties in Deep Eastern GOM

- Counter-clockwise circulation of colder and saltier inflow from the Caribbean Sea (DeHaan and Sturges 2005)
- Spatial temperature and salinity gradients in the deep eastern GOM

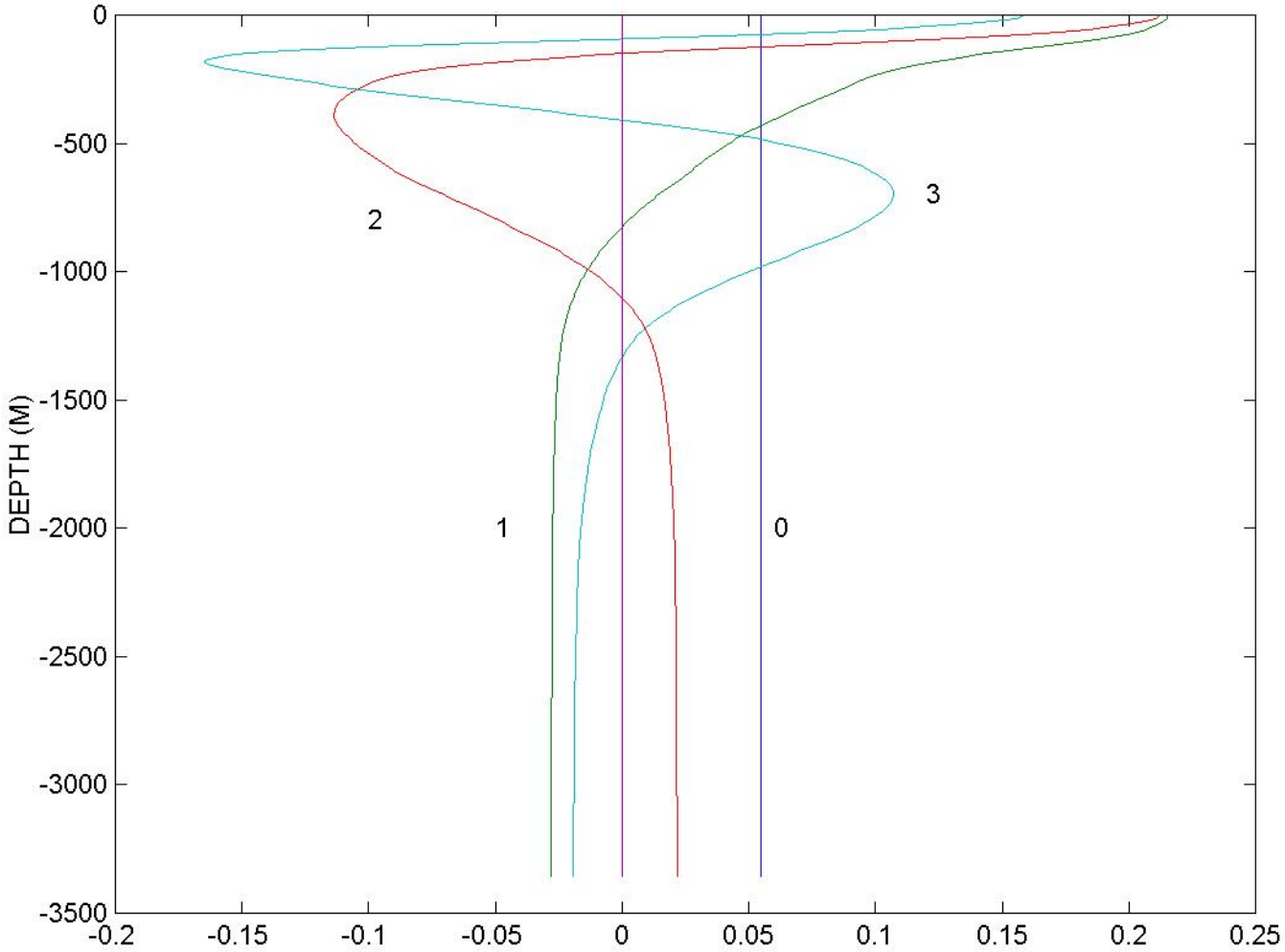

96W
92W
88W
84W
28N
24N
20N
124.
25.
2500.00m
22.078
22.571
23.063
23.556
24.049
24.542
25.034
25.527
26.020
26.513
0.000E+00
Minimum Vector
0.600E+01
Maximum Vector


96W
92W
88W
84W
28N
24N
20N
124.
25.
2500.00m
-.031219
-.030473
-.029727
-.028981
-.028235
-.027489
-.026743
-.025997
-.025251
-.024506
0.000E+00
Minimum Vector
0.600E+01
Maximum Vector

Deepwater Mooring at 87°W and 25.5^{o}N

- A single deep water mooring was deployed at 87°W and 25.5^{o}N (3356m).
- 2 ADCPs (at 140 m and at 3200 m) and 6Aandera RCM-9 current meters (155, 750, 1500, 2500, 3000 and 3200 m).
- Deployment 1: 31 May 2000 – 1 August 2001
- Deployment 2: 1 August 2000 – 3 June 2002
- Deployment 3: 19 April 2003 – 11 June 2004
- Deployment 4: 29 May 2005 – 15 June 2006

Dynamic Normal Modes at the Site



Summary

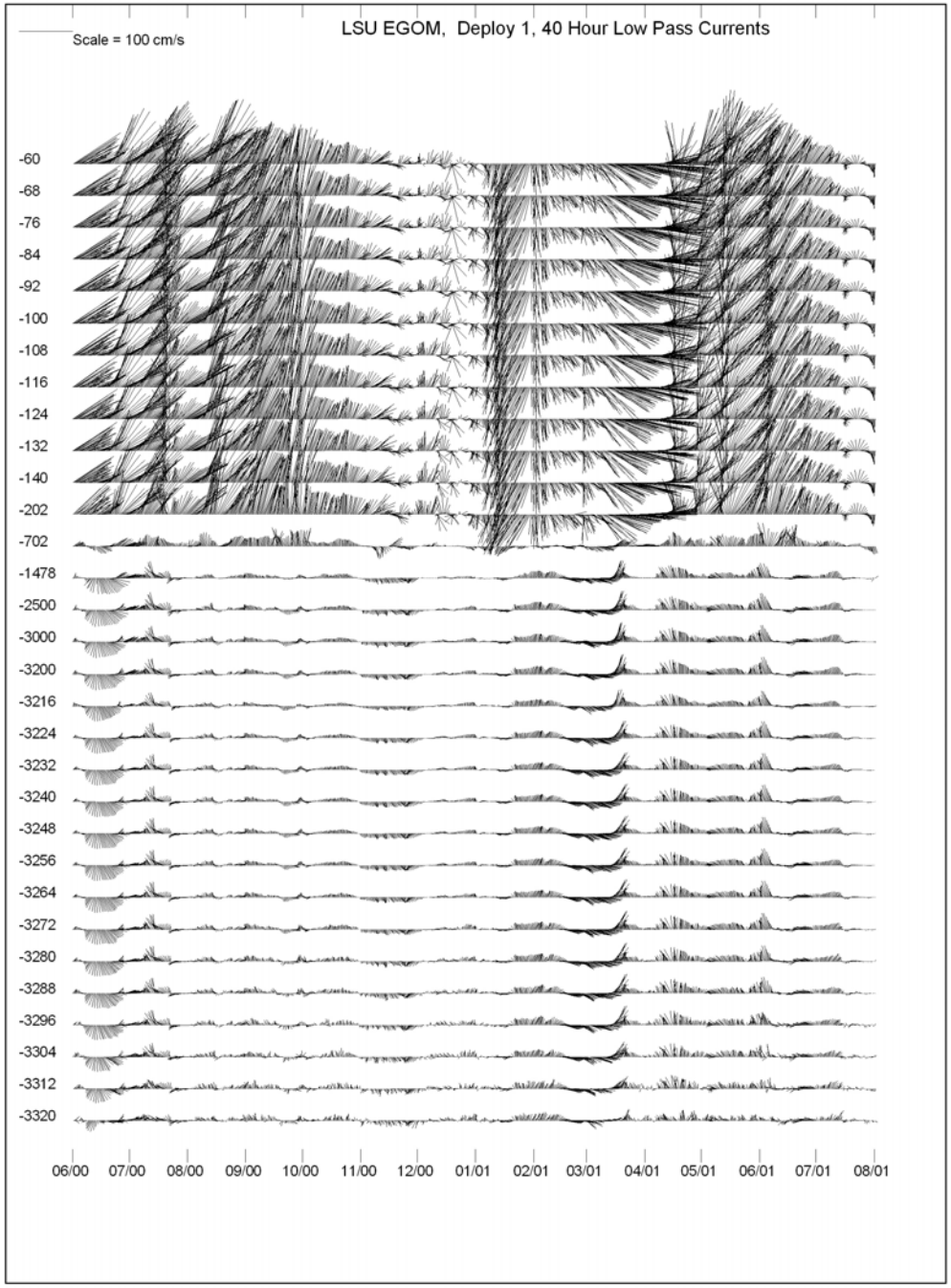
- Two-layer system is a good approximation.
- Generally, lower-layer (below ~800 m) currents are decoupled from the upper layer.
- Occasionally, some coherence between the two layers is established (e. g., during prominent northward penetration of the Loop Current prior to ring formation).
- Each deployment was different (LC in the eastern GOM is dominated by LC ring formation).

Upper-Layer Currents

- Dominated by the Loop Current with near-surface current magnitude exceeding 1.5 m/s.
- Dominant current direction changes depending on relative position of the Loop Current to the mooring.

Lower-Layer Current

- Vertically coherent in the lower-layer
- Decoupled from the upper-layer current
- Characterized by occasional energetic events (deep eddies?) with currents approaching 30 cm/s, and time-scales of 10~30 days. They appear to be accompanied by temperature and salinity variations.


LSU EGOM, Deploy 1, 40 Hour Low Pass Currents
Scale = 100 cm/s
-60
-68
-76
-84
-92
-100
-108
-116
-124
-132
-140
-202
-702
-1478
-2500
-3000
-3200
-3216
-3224
-3232
-3240
-3248
-3256
-3264
-3272
-3280
-3288
-3296
-3304
-3312
-3320
06/00
07/00
08/00
09/00
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02/01
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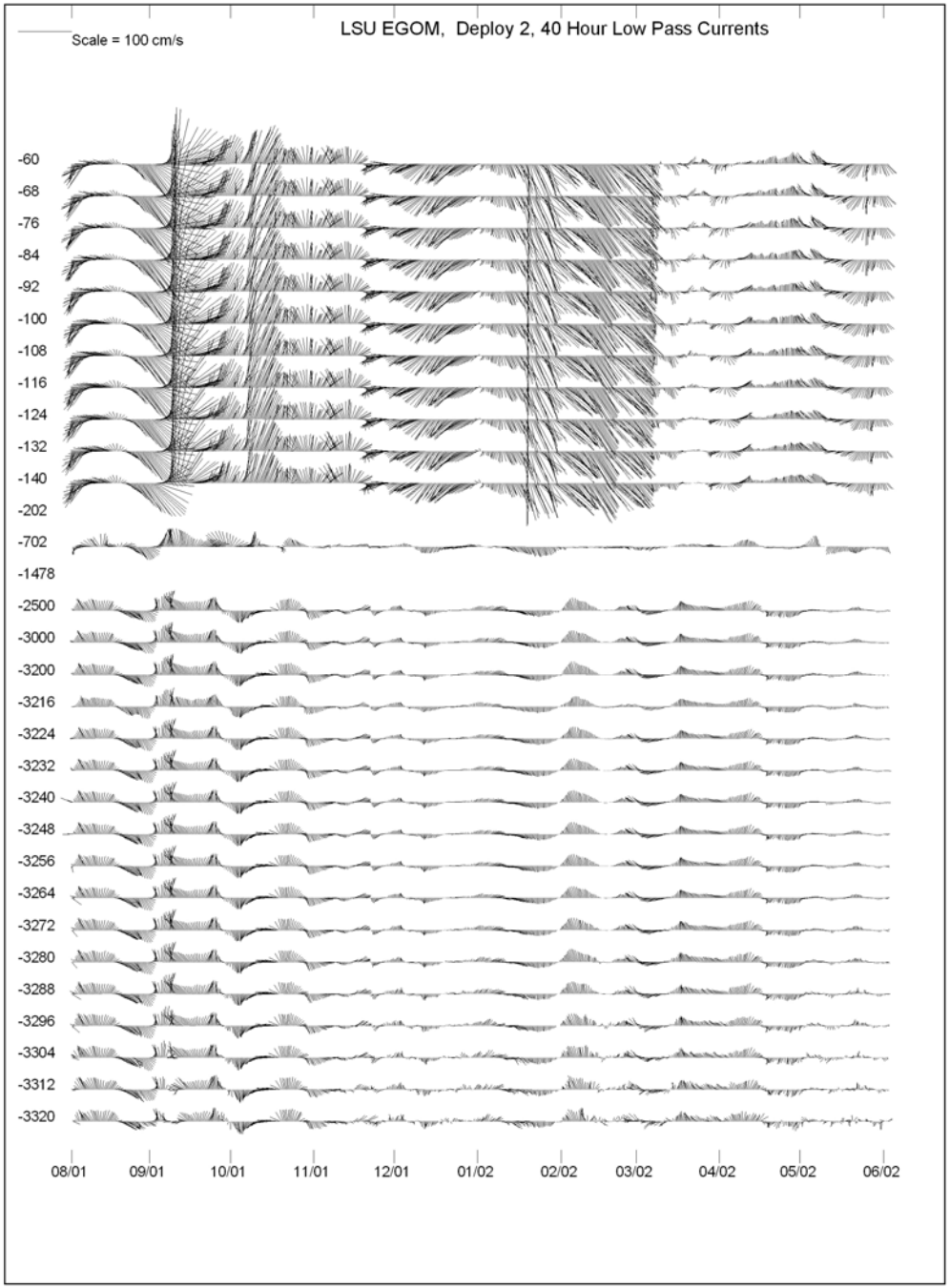
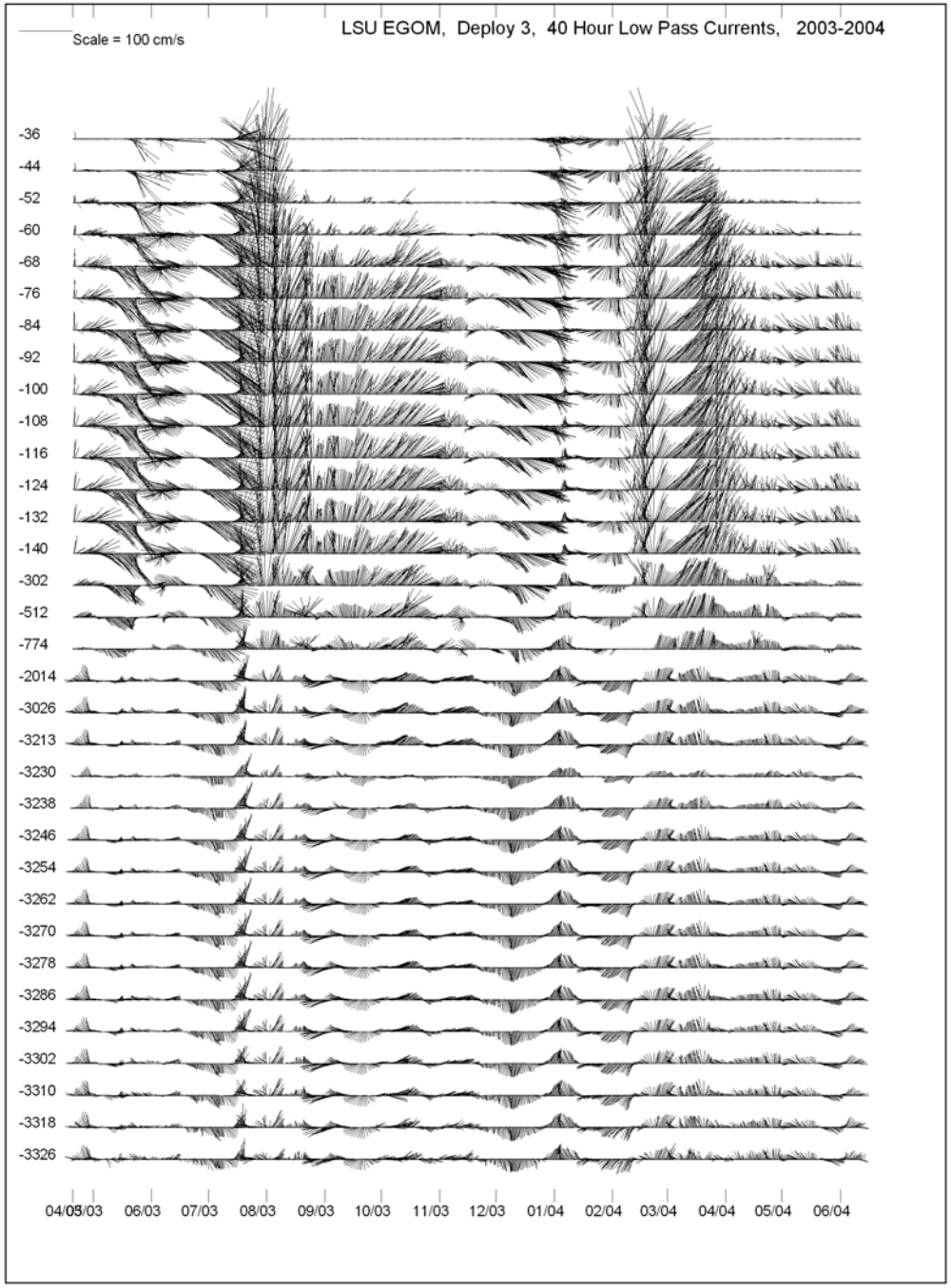
05/01
06/01
07/01
08/01


LSU EGOM, Deploy 2, 40 Hour Low Pass Currents
Scale = 100 cm/s
-60
-68
-76
-84
-92
-100
-108
-116
-124
-132
-140
-202
-702
-1478
-2500
-3000
-3200
-3216
-3224
-3232
-3240
-3248
-3256
-3264
-3272
-3280
-3288
-3296
-3304
-3312
-3320
08/01
09/01
10/01
11/01
12/01
01/02
02/02
03/02
04/02
05/02
06/02


LSU EGOM, Deploy 3, 40 Hour Low Pass Currents, 2003-2004
Scale = 100 cm/s
-36
-44
-52
-60
-68
-76
-84
-92
-100
-108
-116
-124
-132
-140
-302
-512
-774
-2014
-3026
-3213
-3230
-3238
-3246
-3254
-3262
-3270
-3278
-3286
-3294
-3302
-3310
-3318
-3326
04/03
05/03
06/03
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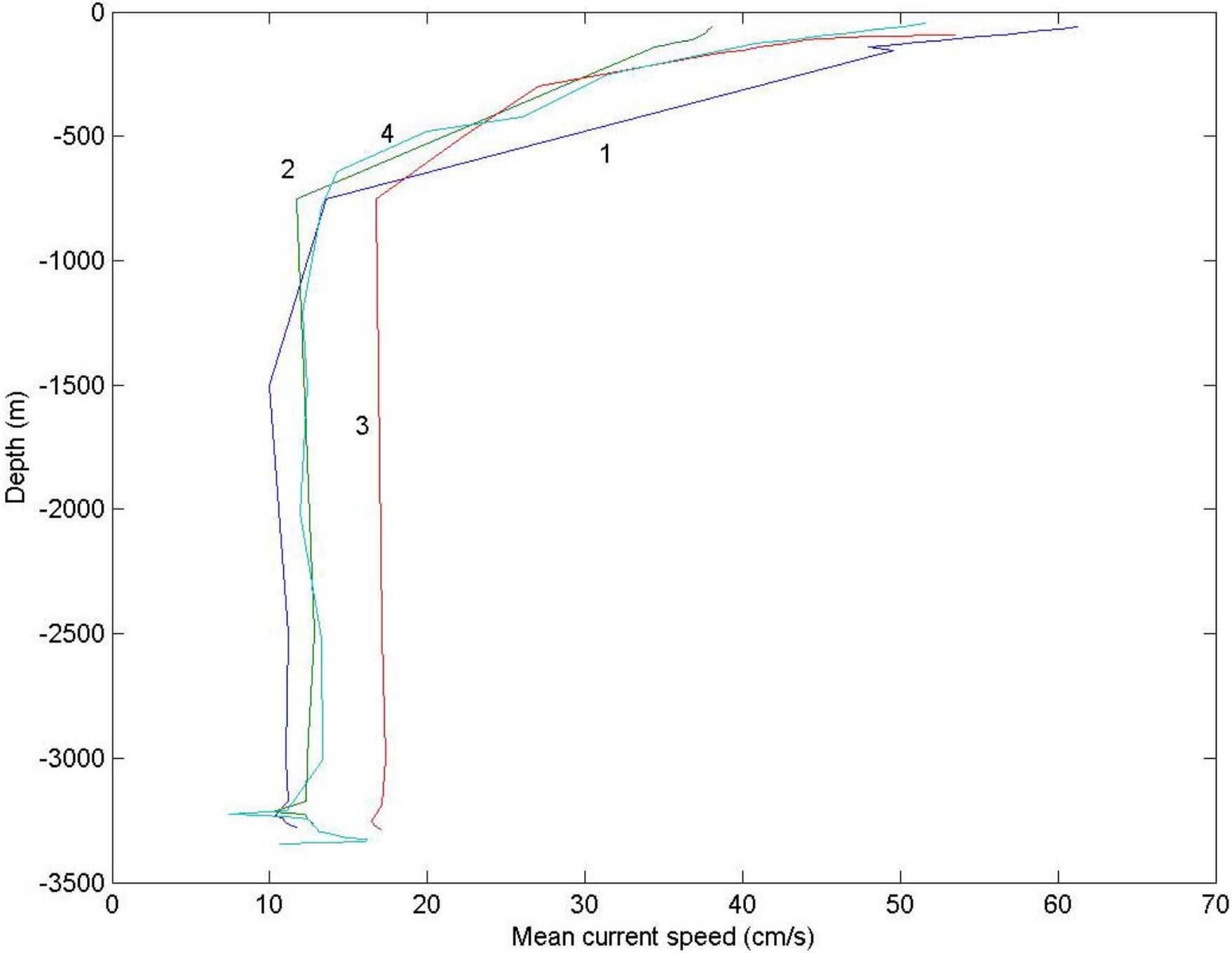
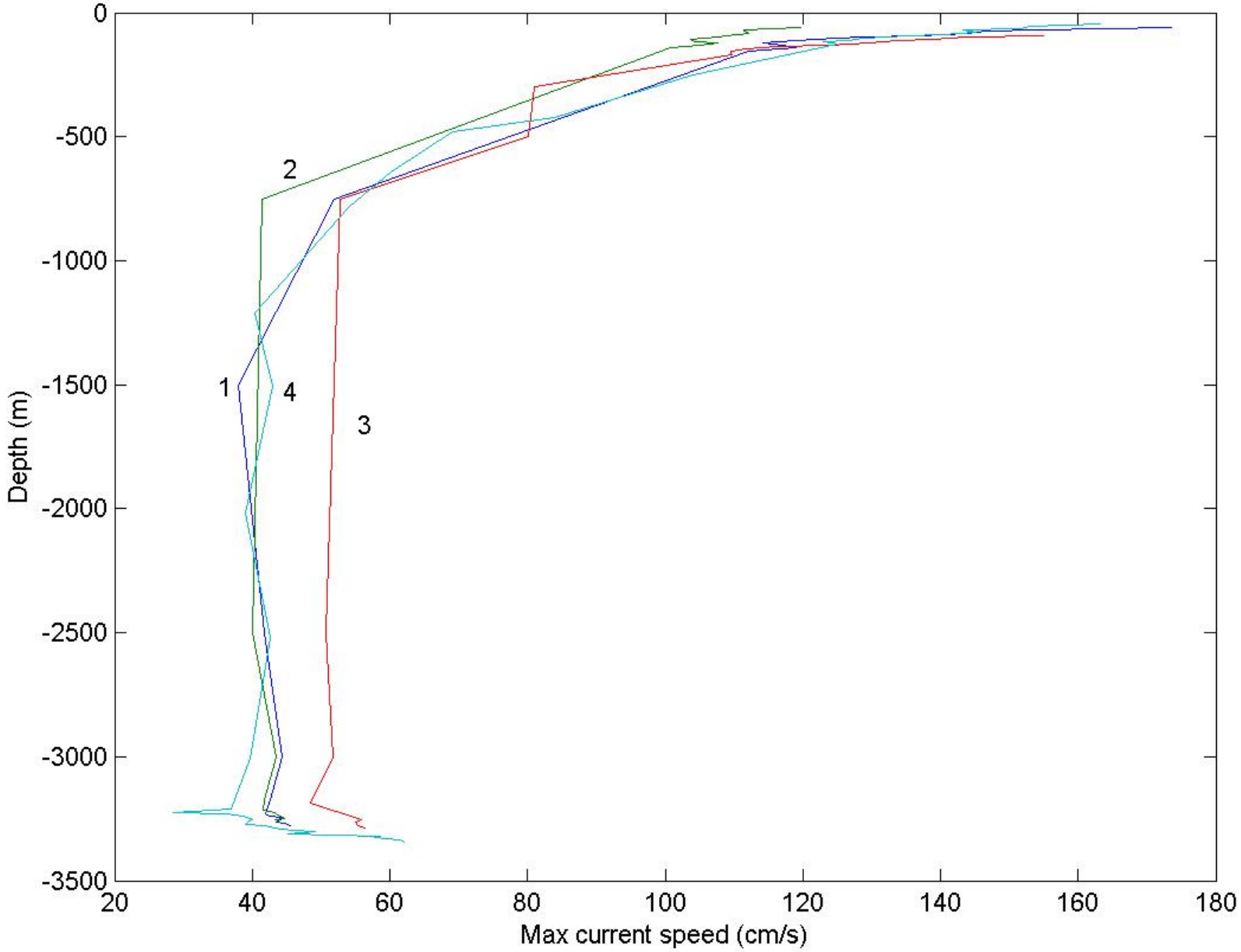
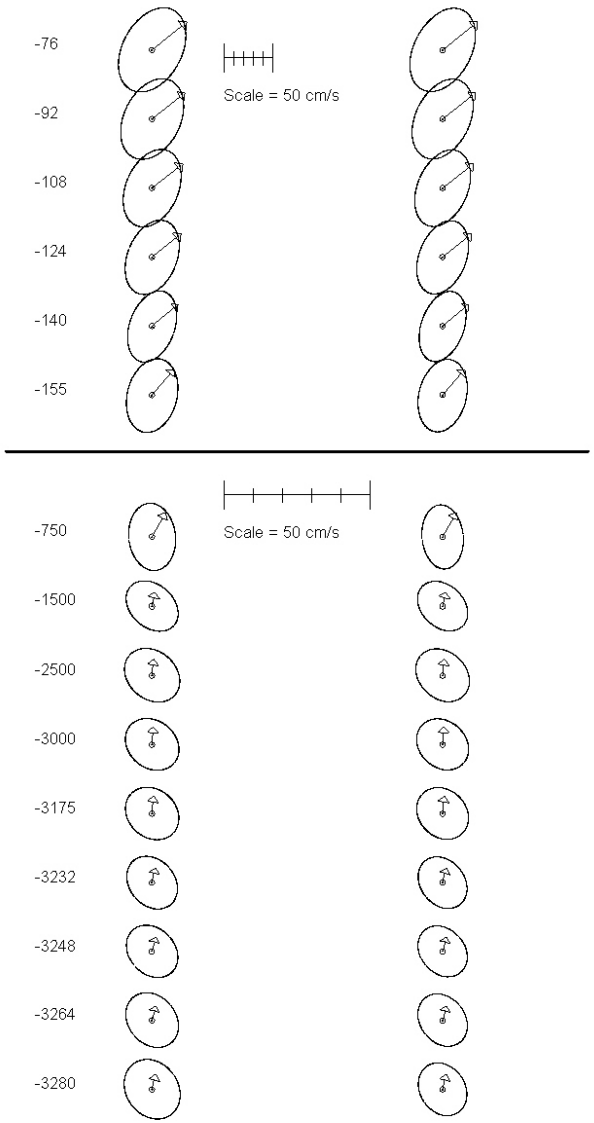
03/04
04/04
05/04
06/04


0
-500
-1000
-1500
-2000
-2500
-3000
-3500
Depth (m)
0
10
20
30
40
50
60
70
Mean current speed (cm/s)
1
2
3
4


0
-500
-1000
-1500
-2000
-2500
-3000
-3500
Depth (m)
20
40
60
80
100
120
140
160
180
Max current speed (cm/s)
1
2
3
4

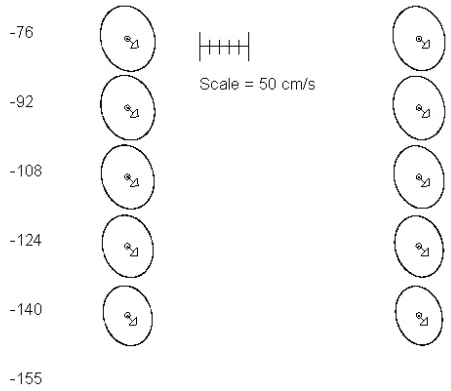
EGOM, Deep Gulf, Deploy 1, Raw Ellipise

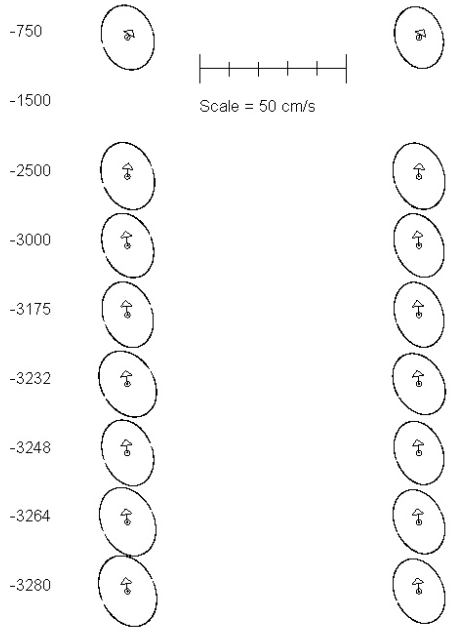
Raw currents 40 Hour Low Pass



EGOM, Deep Gulf, Deploy 2, Raw Ellipise

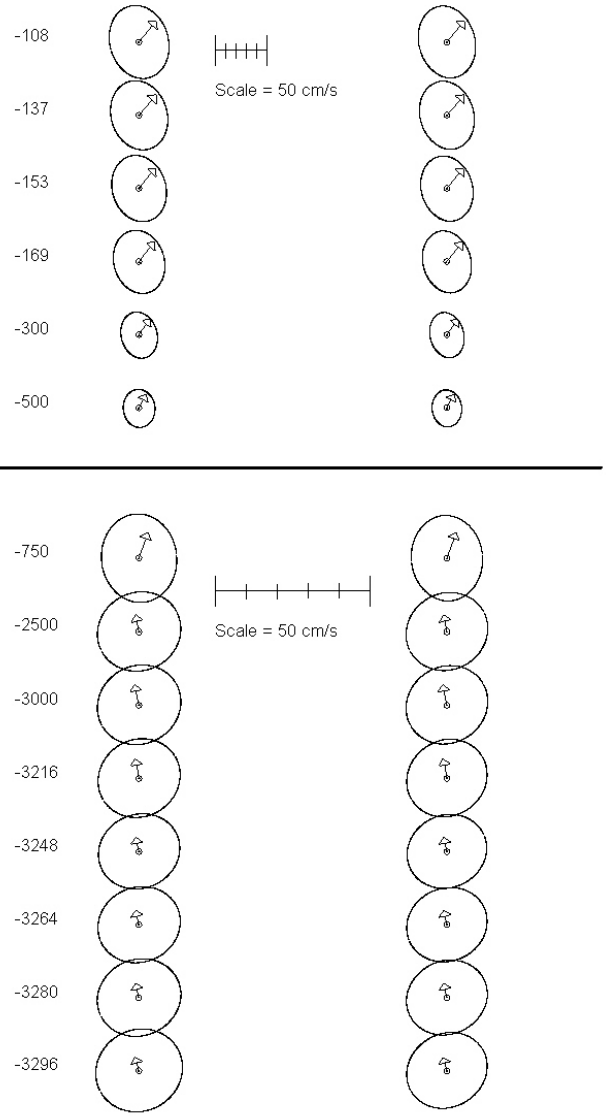
Raw currents 40 Hour Low Pass

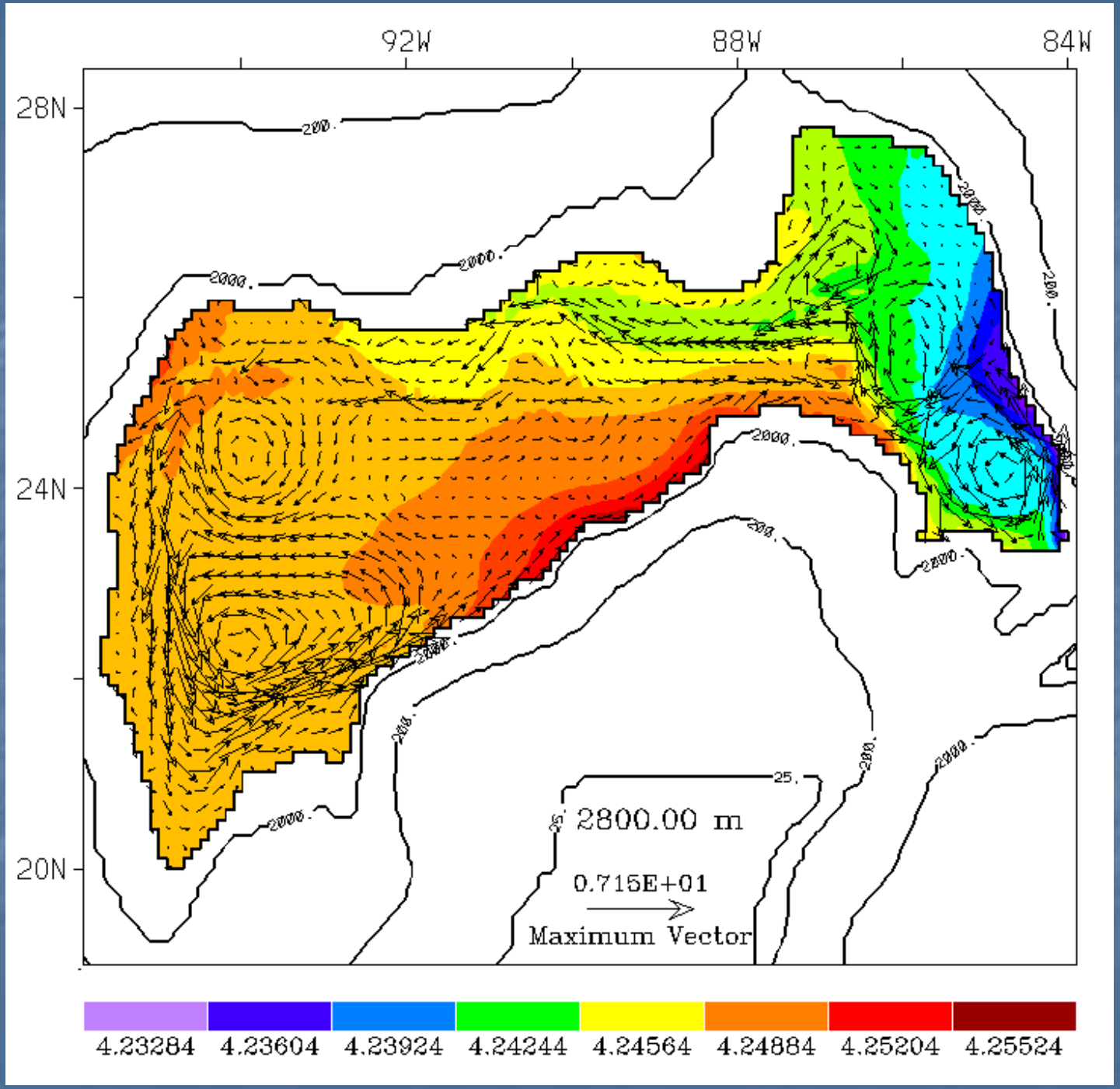


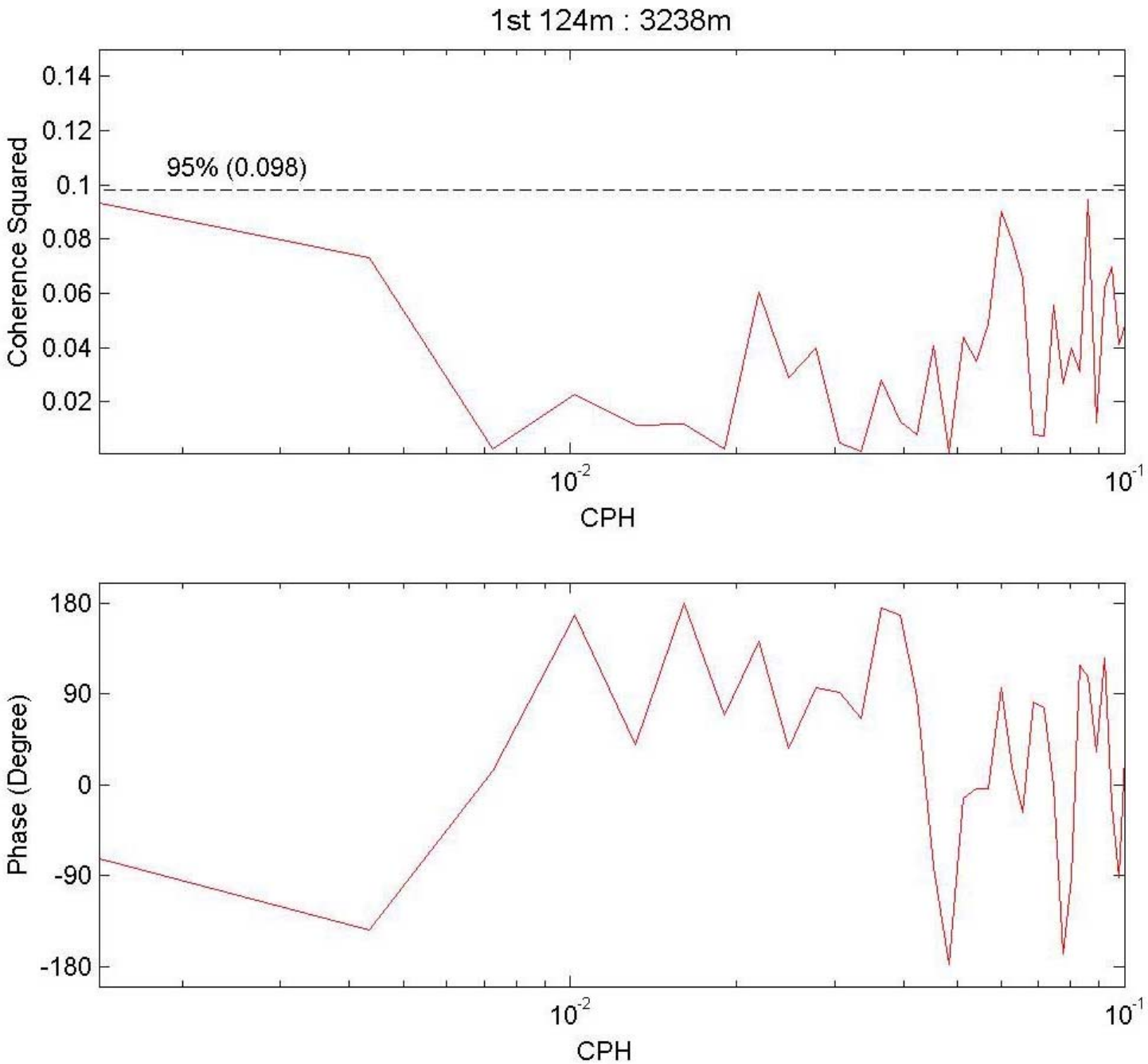


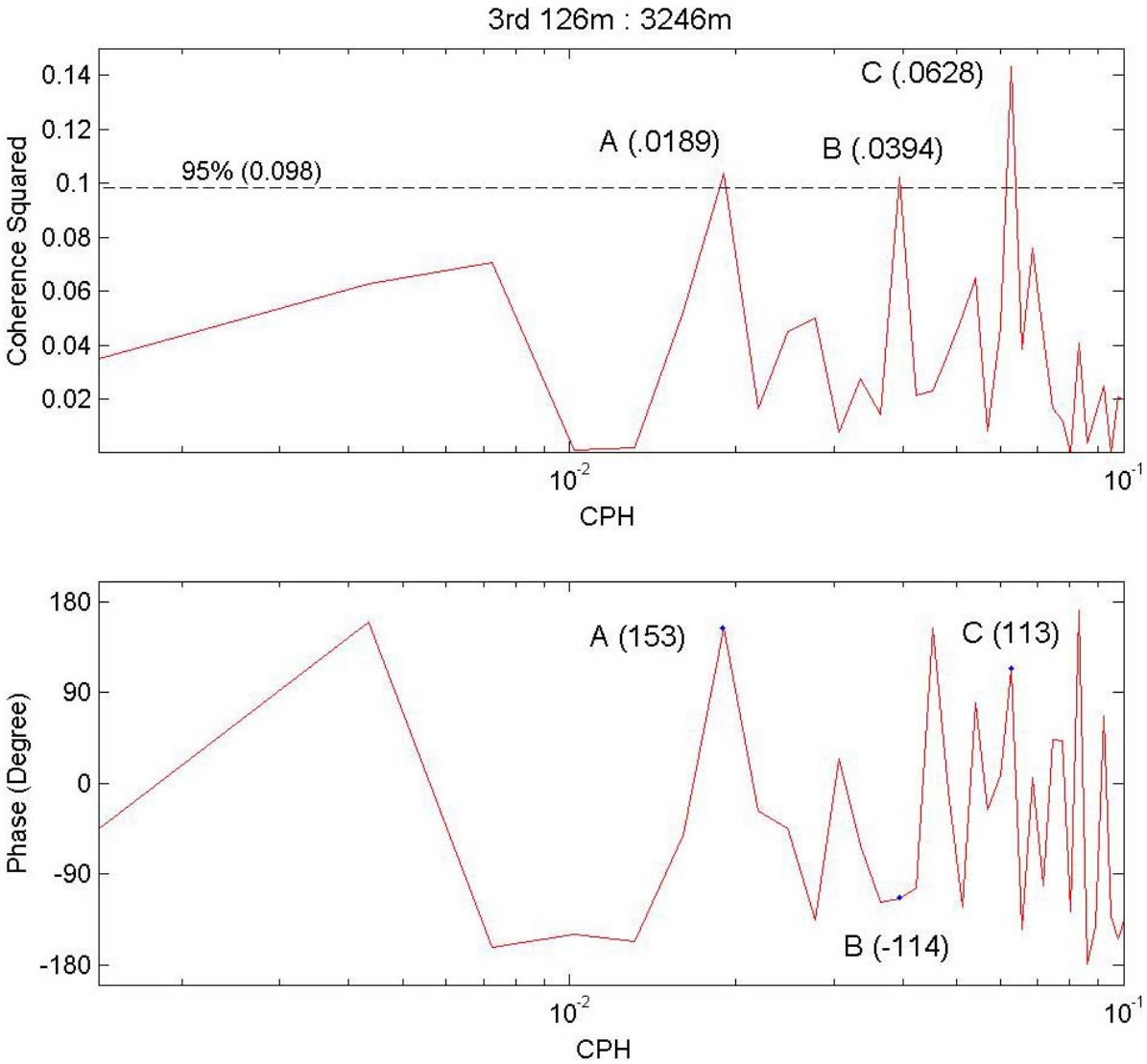
EGOM, Deep Gulf, Deploy 3, Raw Ellipise

Raw currents 40 Hour Low Pass




92W
88W
84W
28N
24N
20N
200.
2000.
25.
2800.00 m
0.715E+01
Maximum Vector
4.23284
4.23604
4.23924
4.24244
4.24564
4.24884
4.25204
4.25524

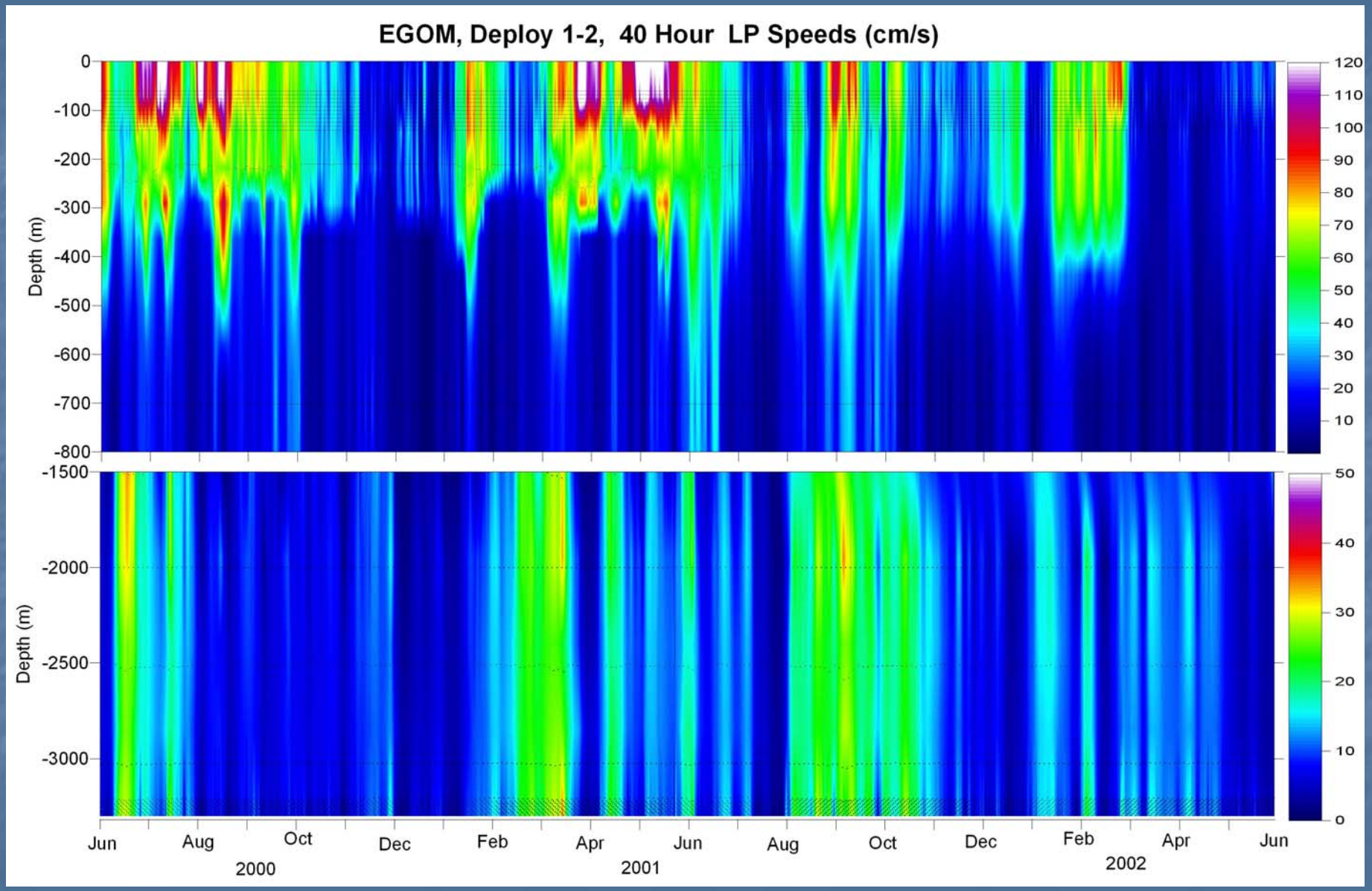

1st 124m : 3238m
Coherence Squared
0.14
0.12
0.1
0.08
0.06
0.04
0.02
95% (0.098)
10^{-2}
10^{-1}
CPH
Phase (Degree)
180
90
0
-90
-180
10^{-2}
10^{-1}
CPH

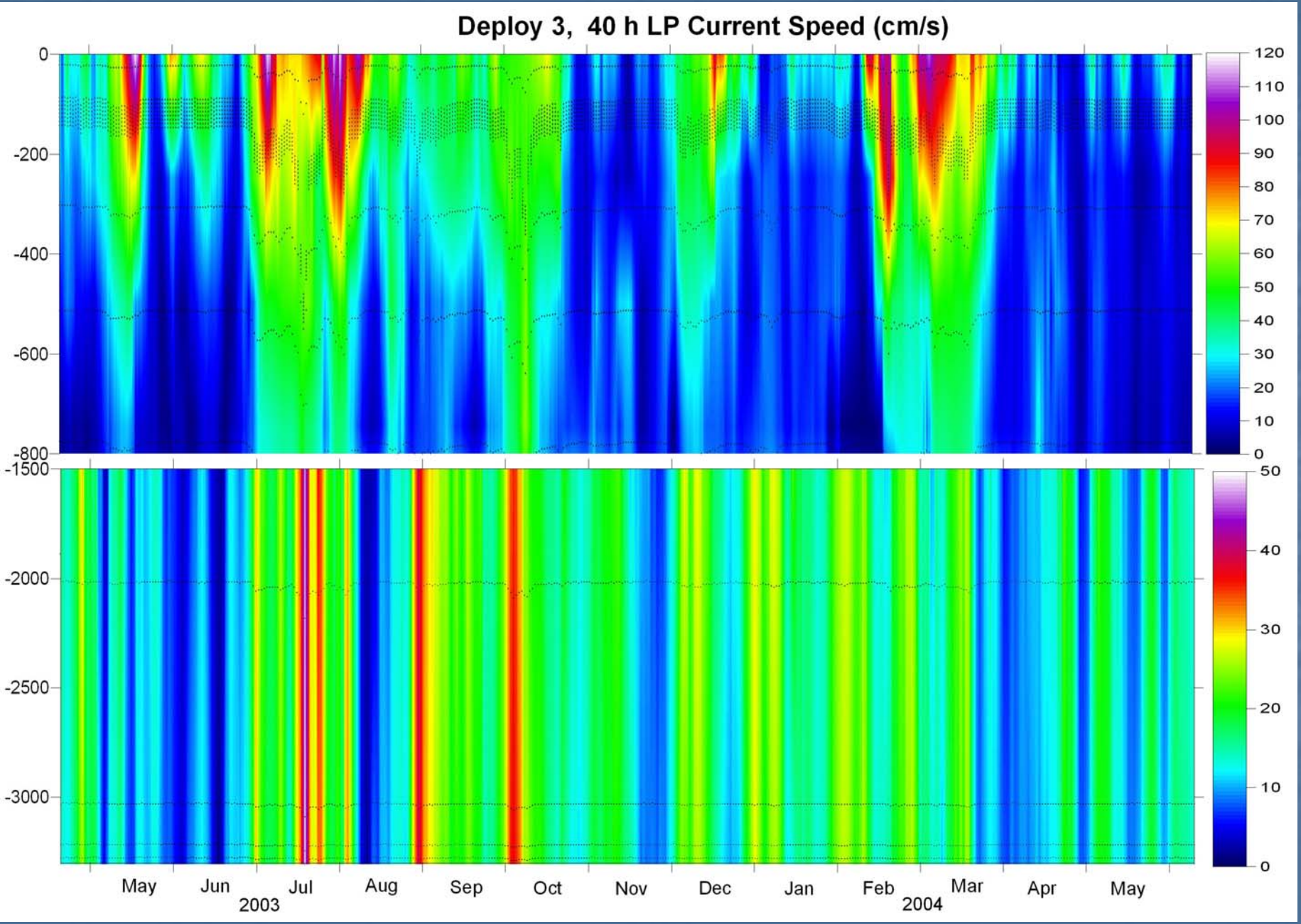


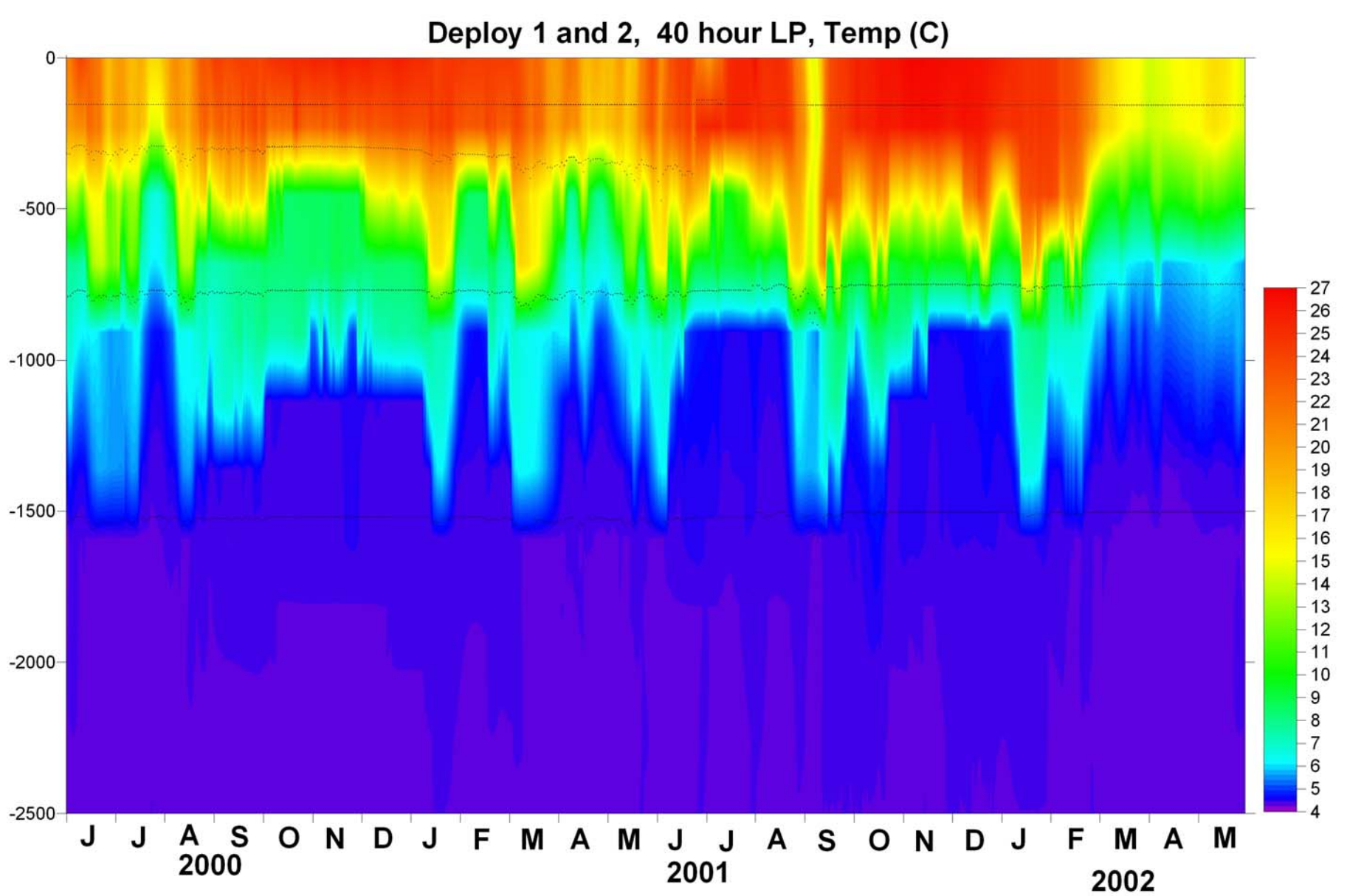
A (.0189) = 52.9 hrs

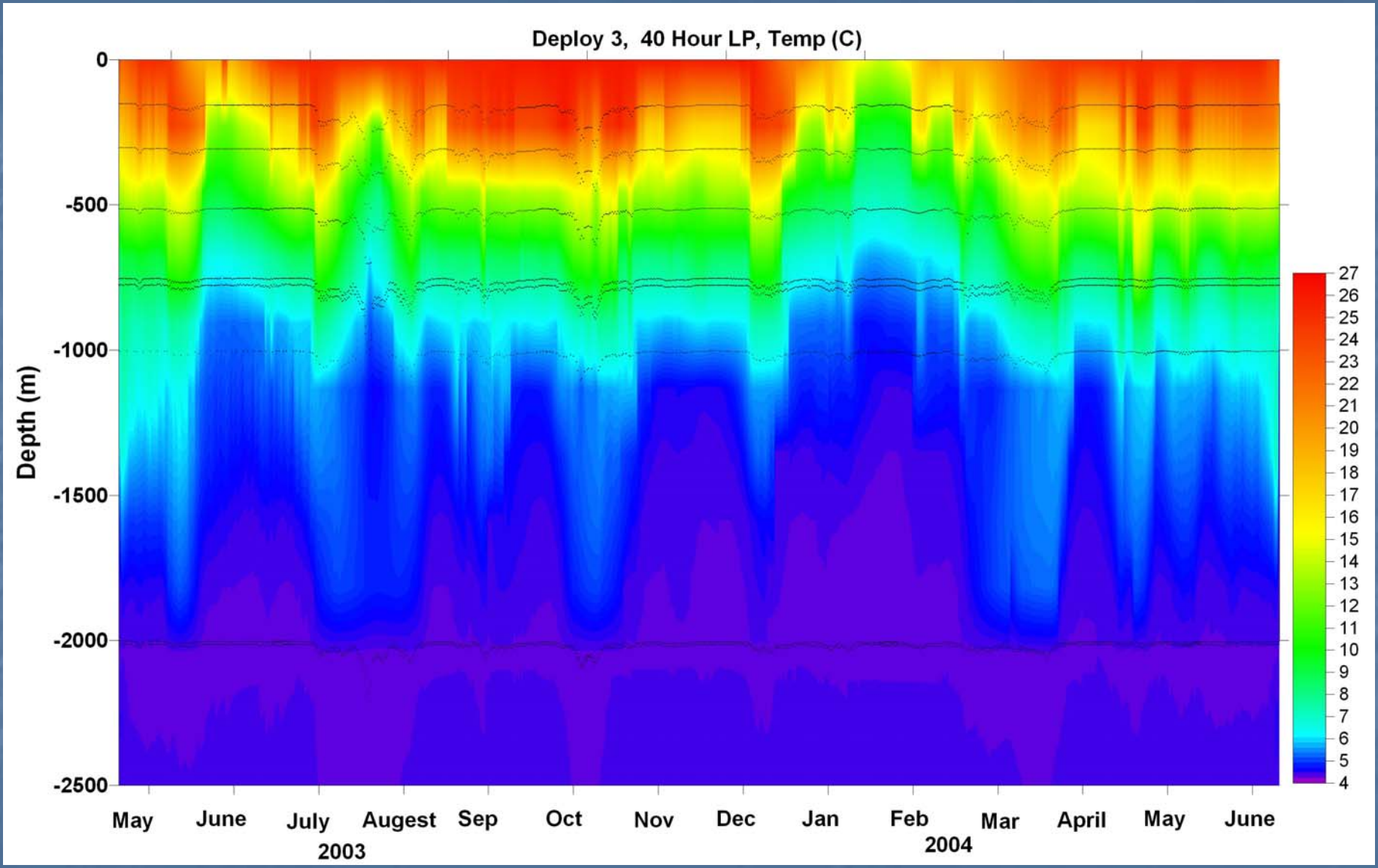
B (.0189) = 25.4 hrs

C (.0628) = 15.9 hrs


EGOM, Deploy 1-2, 40 Hour LP Speeds (cm/s)
Depth (m)
0
-100
-200
-300
-400
-500
-600
-700
-800
120
110
100
90
80
70
60
50
40
30
20
10
Depth (m)
-1500
-2000
-2500
-3000
50
40
30
20
10
0
Jun
Aug
Oct
Dec
Feb
Apr
Jun
Aug
Oct
Dec
Feb
Apr
Jun
2000
2001
2002

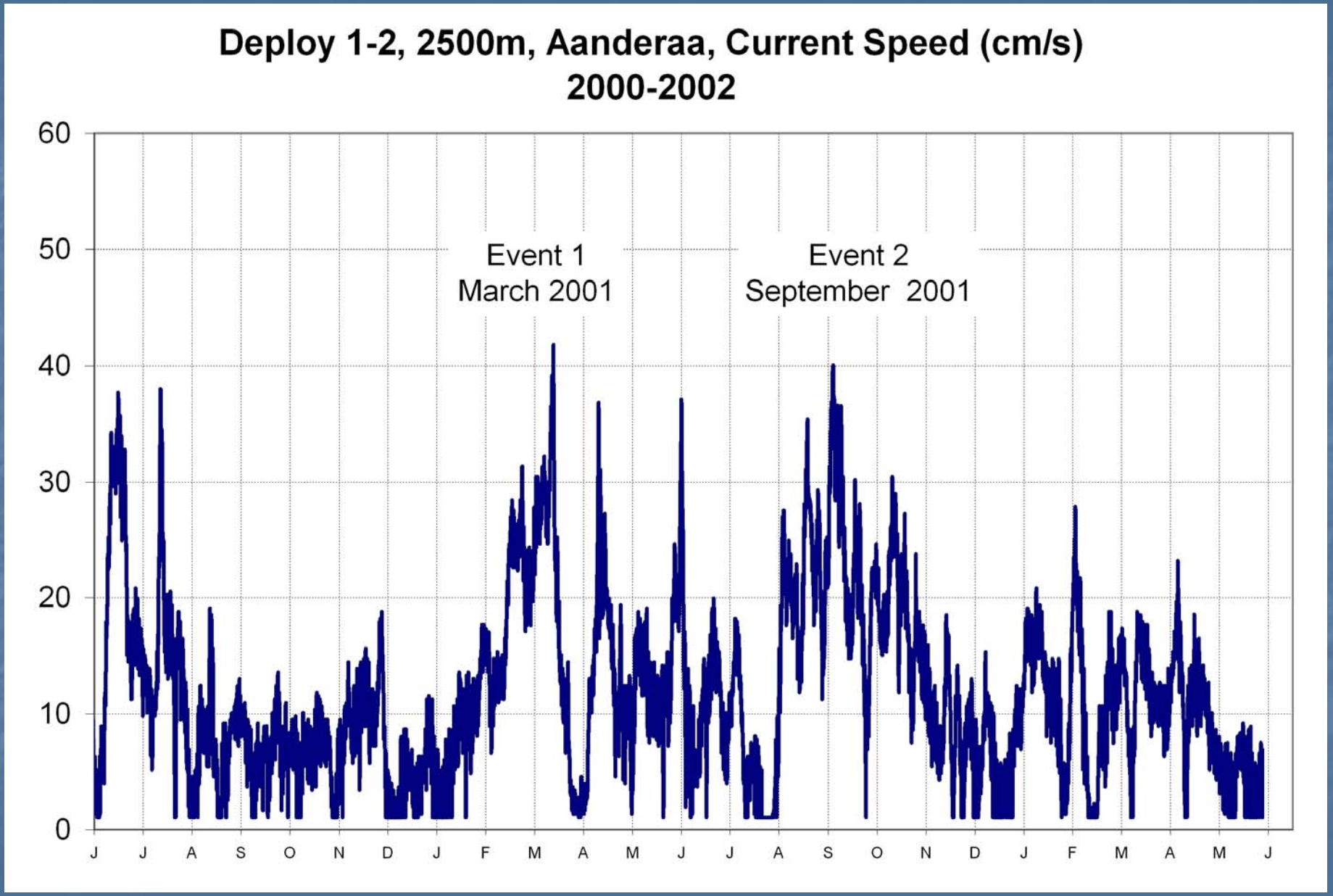

Deploy 3, 40 h LP Current Speed (cm/s)
0
-200
-400
-600
-800
-1500
-2000
-2500
-3000
120
110
100
90
80
70
60
50
40
30
20
10
0
50
40
30
20
10
0
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
2003
2004

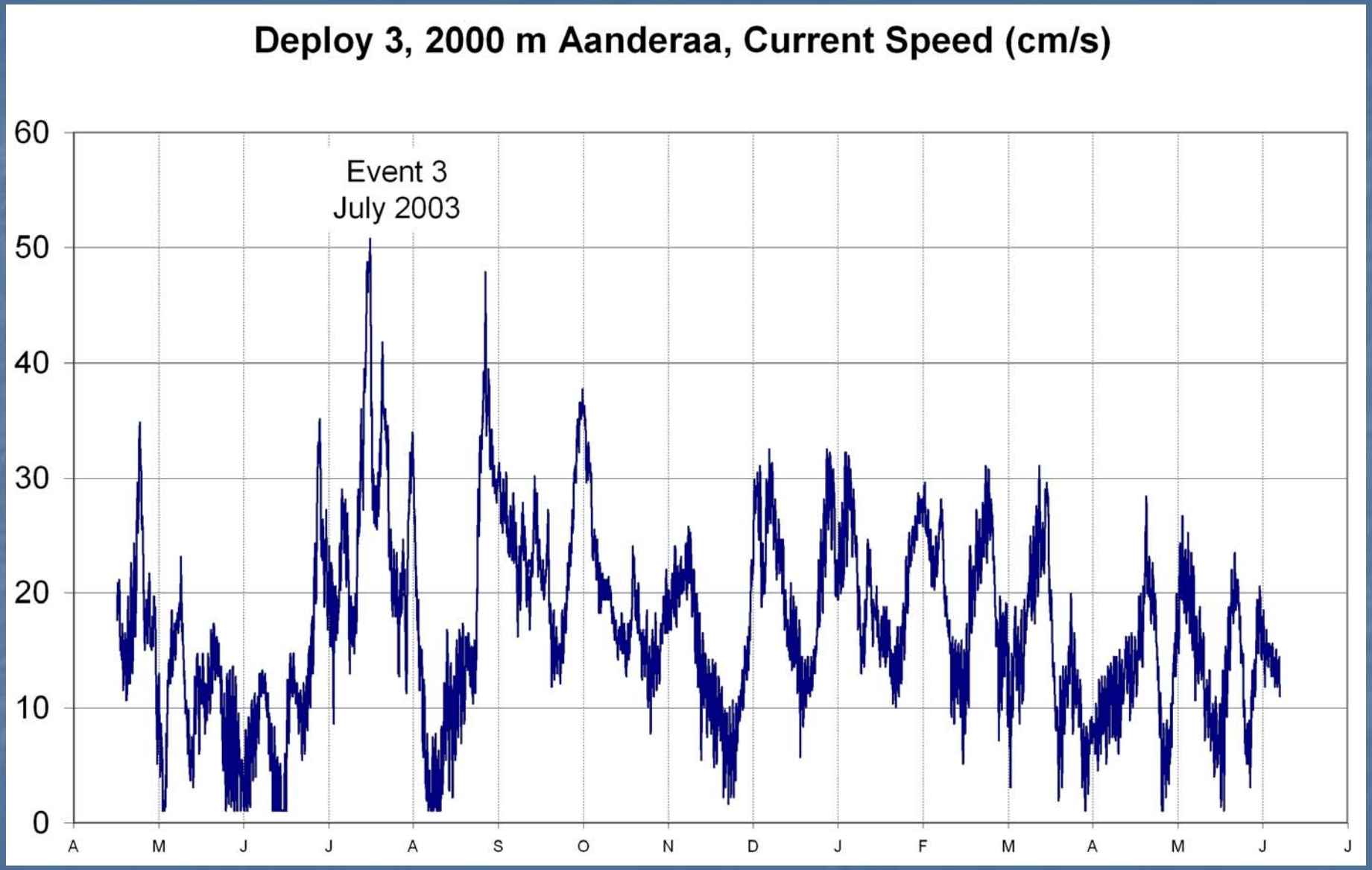

Deploy 1 and 2, 40 hour LP, Temp (C)
0
-500
-1000
-1500
-2000
-2500
J J A S O N D J F M A M J J A S O N D J F M A M
2000
2001
2002
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4

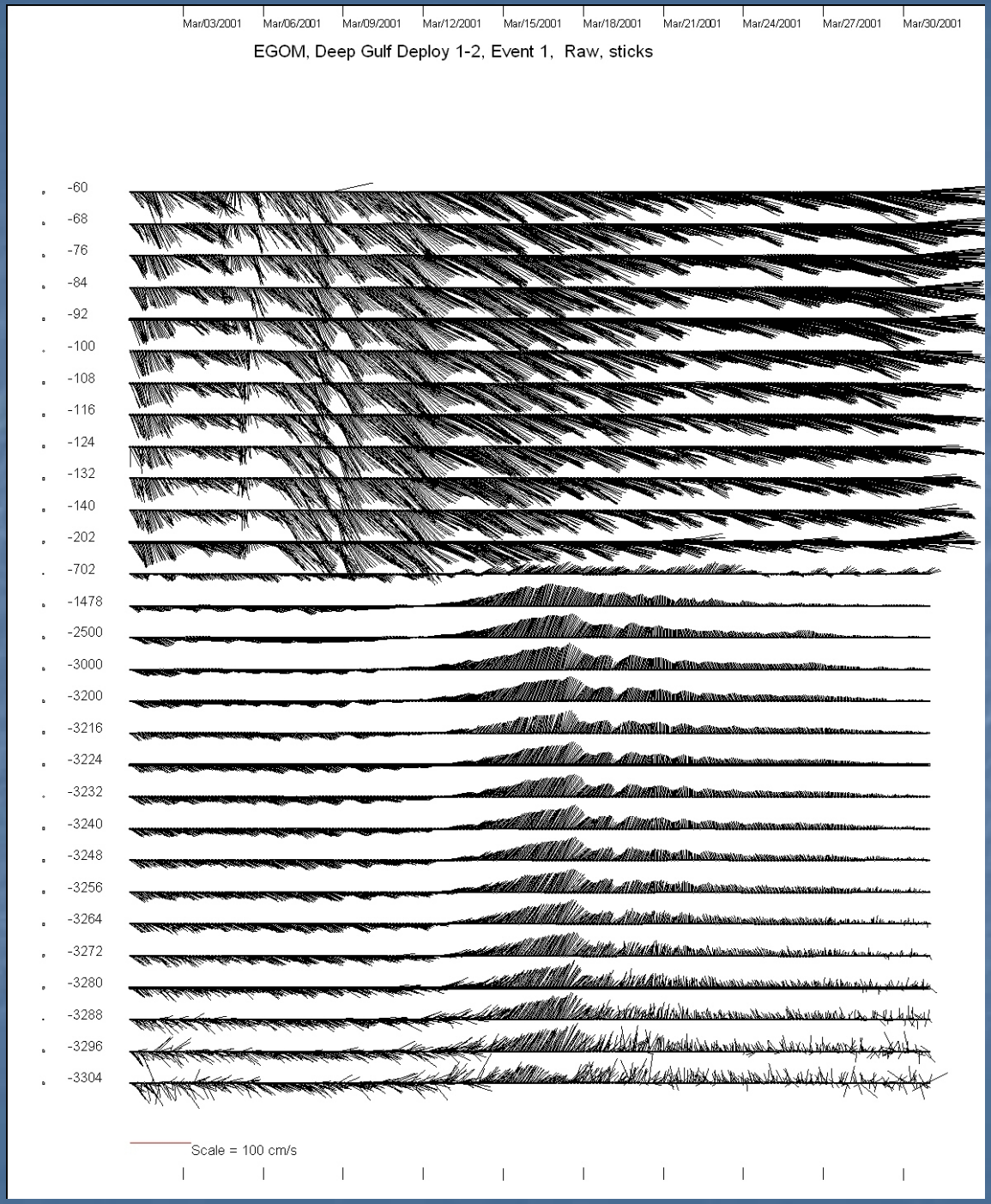

Deploy 3, 40 Hour LP, Temp (C)
Depth (m)
0
-500
-1000
-1500
-2000
-2500
May
June
July
Augest
Sep
Oct
Nov
Dec
Jan
Feb
Mar
April
May
June
2003
2004
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4

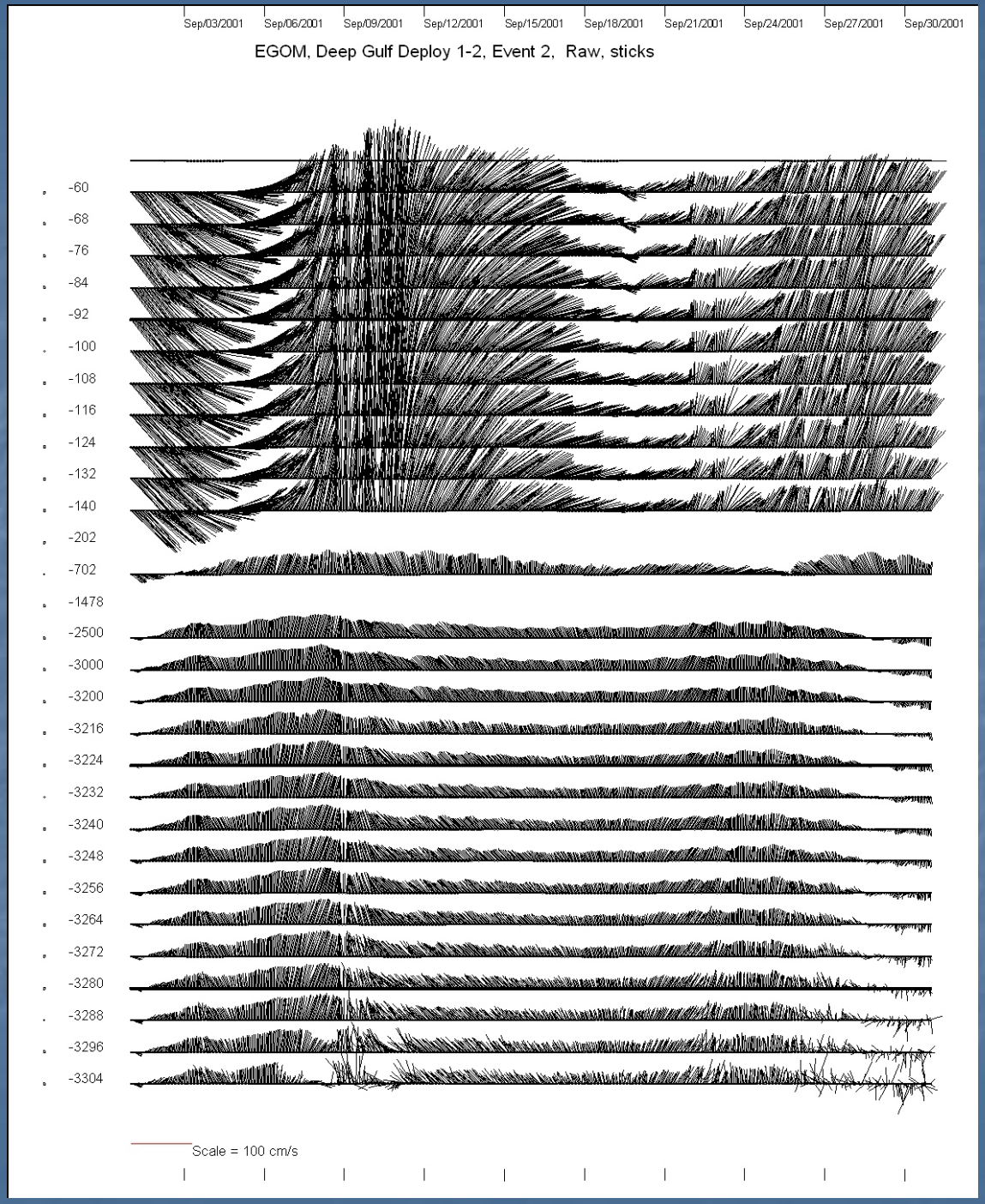
Deepwater Energetic Bursts Associated with the Formation of LCEs

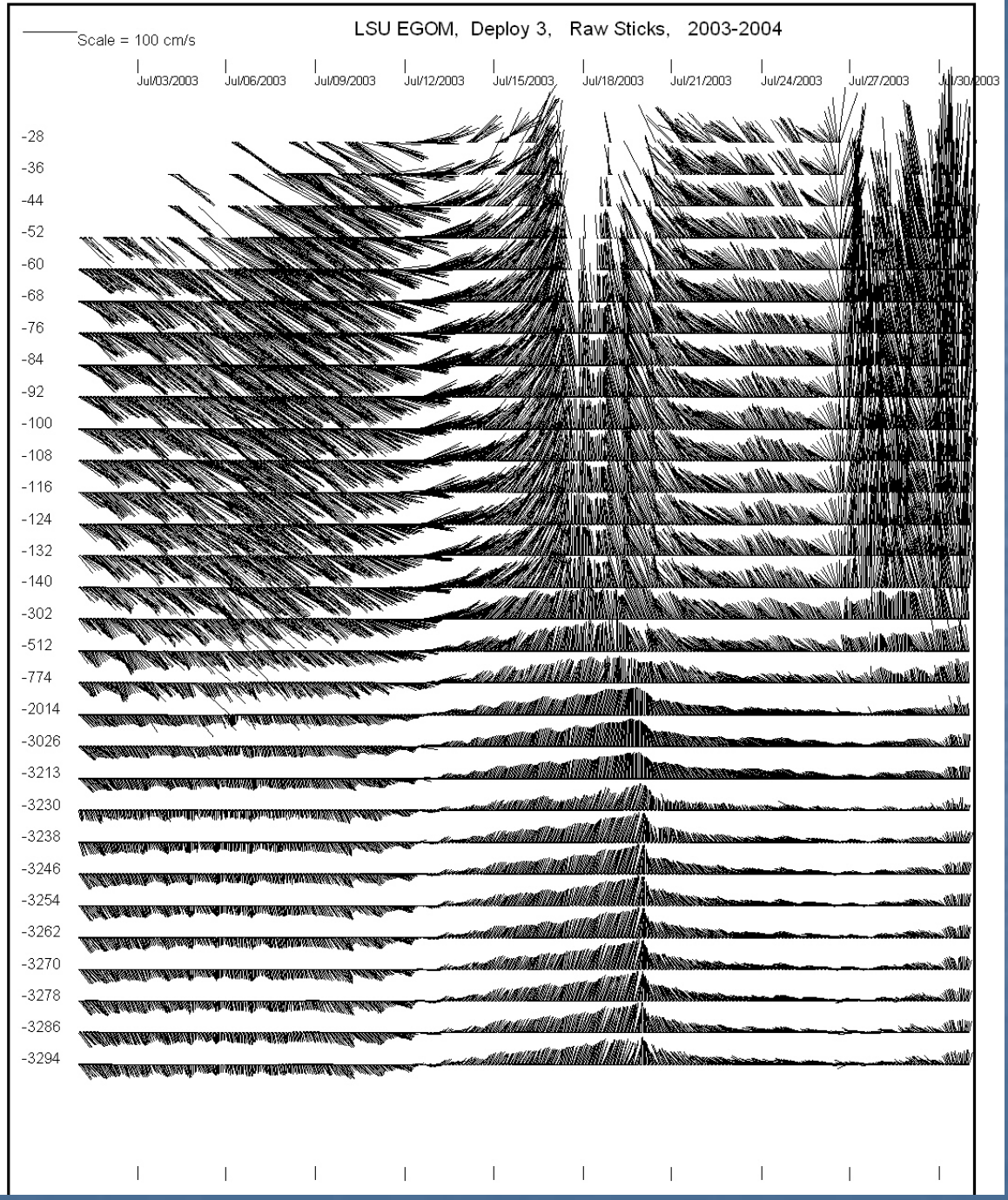
- Regardless of the upper-layer flow, strong northward flow, vertically coherent in the lower layer
- Characteristic time scale of 10~20 days
- Velocity scale of 40~50 cm/s
- Accompanied by temperature and salinity changes


Deploy 1-2, 2500m, Aanderaa, Current Speed (cm/s)
2000-2002
60
50
40
30
20
10
0
Event 1
March 2001
Event 2
September 2001
J J A S O N D J F M A M J J A S O N D J F M A M J


Deploy 3, 2000 m Aanderaa, Current Speed (cm/s)
Event 3
July 2003
60
50
40
30
20
10
0
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J


Mar/03/2001
Mar/06/2001
Mar/09/2001
Mar/12/2001
Mar/15/2001
Mar/18/2001
Mar/21/2001
Mar/24/2001
Mar/27/2001
Mar/30/2001
EGOM, Deep Gulf Deploy 1-2, Event 1, Raw, sticks
-60
-68
-76
-84
-92
-100
-108
-116
-124
-132
-140
-202
-702
-1478
-2500
-3000
-3200
-3216
-3224
-3232
-3240
-3248
-3256
-3264
-3272
-3280
-3288
-3296
-3304
Scale = 100 cm/s


Sep/03/2001
Sep/06/2001
Sep/09/2001
Sep/12/2001
Sep/15/2001
Sep/18/2001
Sep/21/2001
Sep/24/2001
Sep/27/2001
Sep/30/2001
EGOM, Deep Gulf Deploy 1-2, Event 2, Raw, sticks
-60
-68
-76
-84
-92
-100
-108
-116
-124
-132
-140
-202
-702
-1478
-2500
-3000
-3200
-3216
-3224
-3232
-3240
-3248
-3256
-3264
-3272
-3280
-3288
-3296
-3304
Scale = 100 cm/s


LSU EGOM, Deploy 3, Raw Sticks, 2003-2004
Scale = 100 cm/s
Jul/03/2003
Jul/06/2003
Jul/09/2003
Jul/12/2003
Jul/15/2003
Jul/18/2003
Jul/21/2003
Jul/24/2003
Jul/27/2003
Jul/30/2003
-28
-36
-44
-52
-60
-68
-76
-84
-92
-100
-108
-116
-124
-132
-140
-302
-512
-774
-2014
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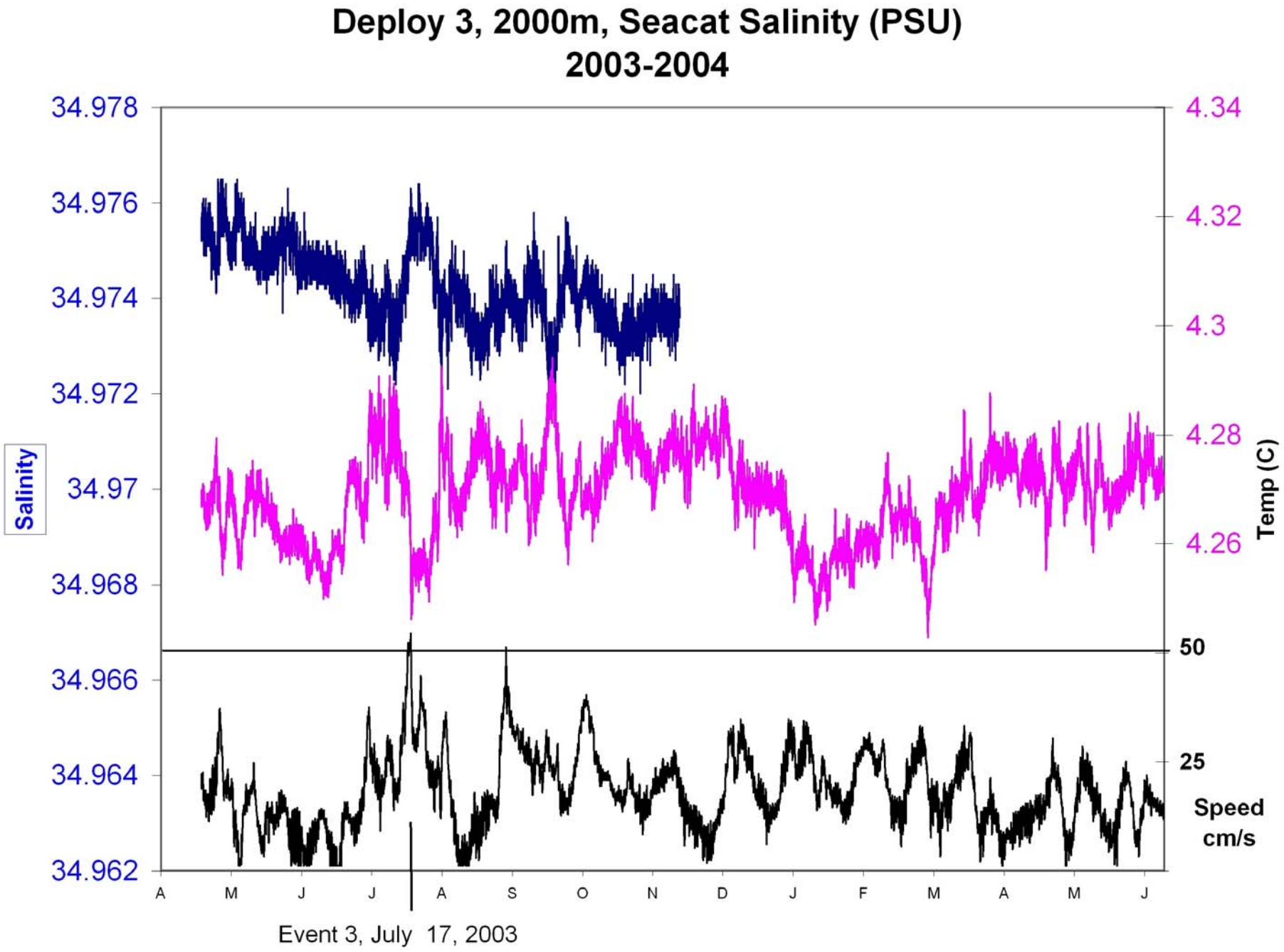
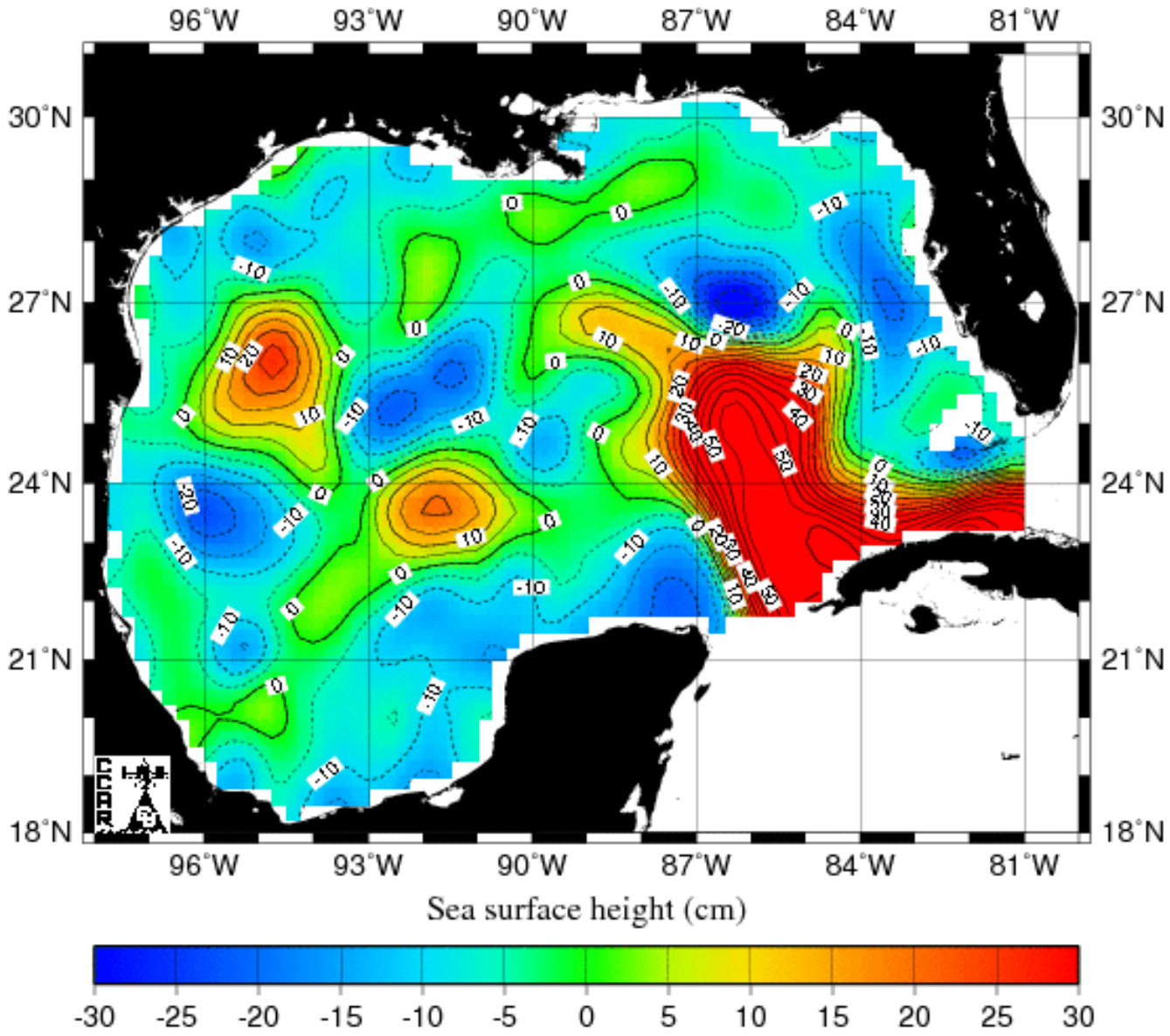
-3294

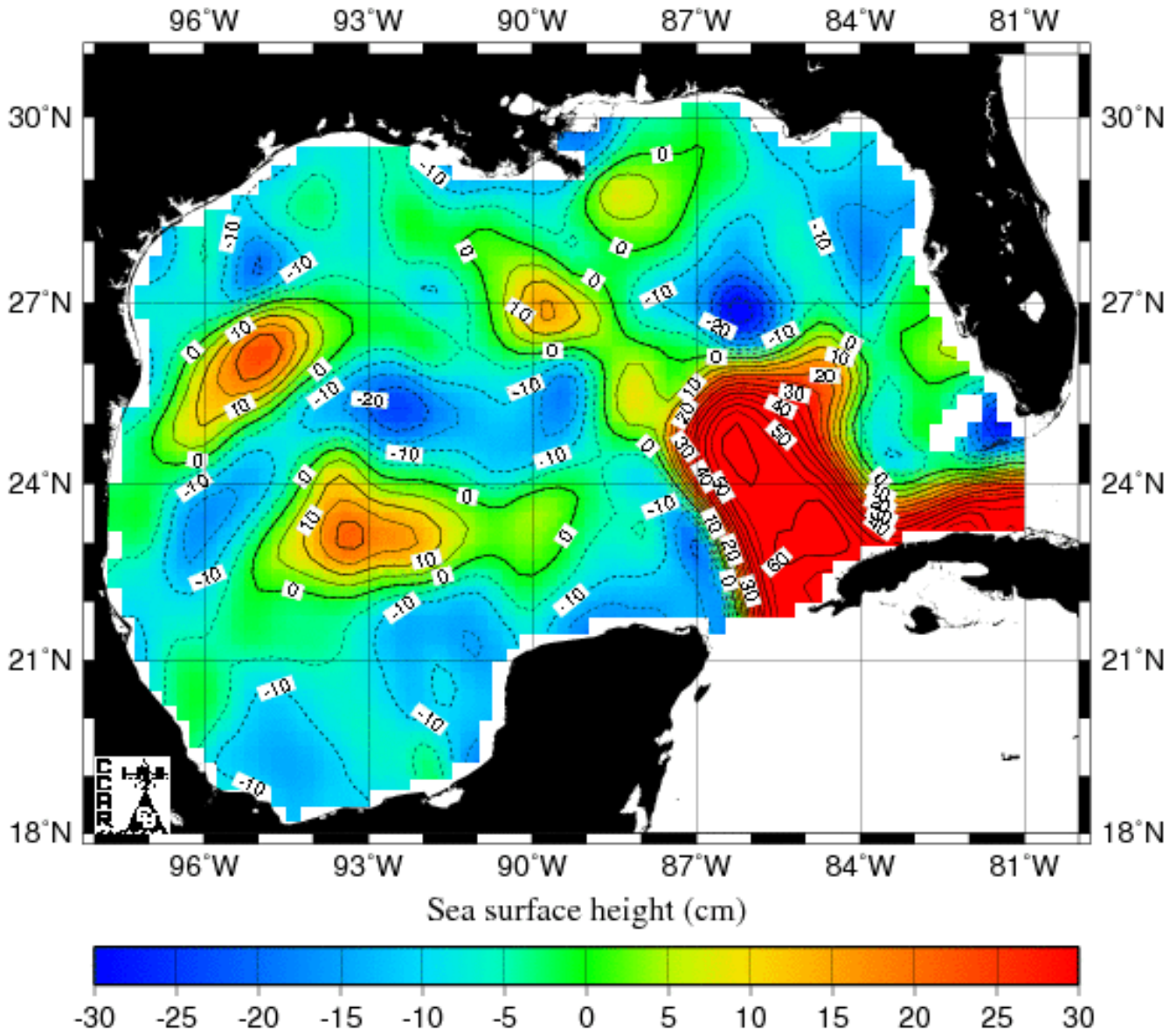

Deploy 3, 2000m, Seacat Salinity (PSU)
2003-2004
Salinity
34.978
34.976
34.974
34.972
34.97
34.968
34.966
34.964
34.962
4.34
4.32
4.3
4.28
4.26
Temp (C)
50
25
Speed
cm/s
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
Event 3, July 17, 2003

Deployments 1 & 2

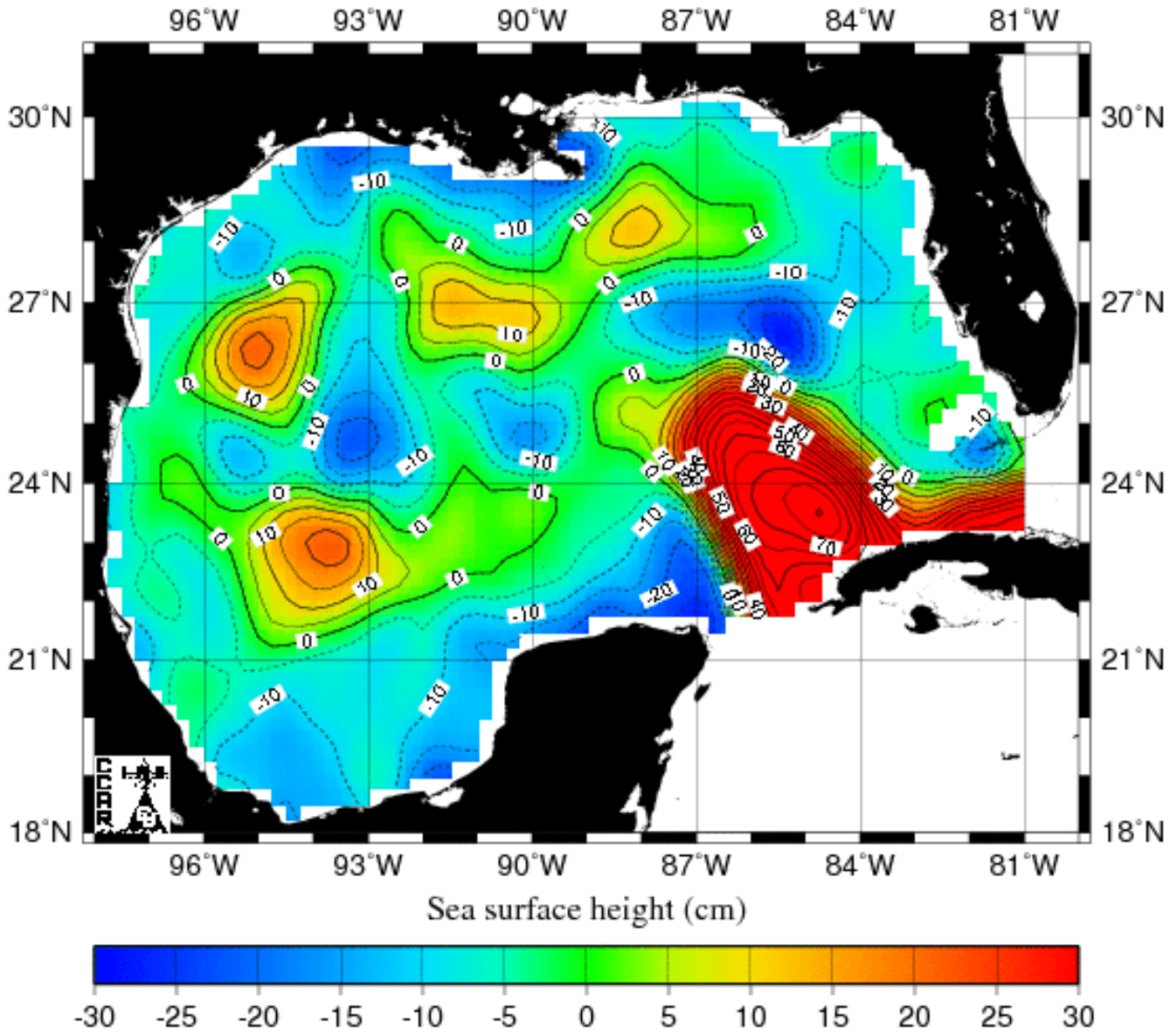
Historical Mesoscale Altimetry – 1 June 2000



Historical Mesoscale Altimetry – 1 July 2000



Historical Mesoscale Altimetry – 1 August 2000



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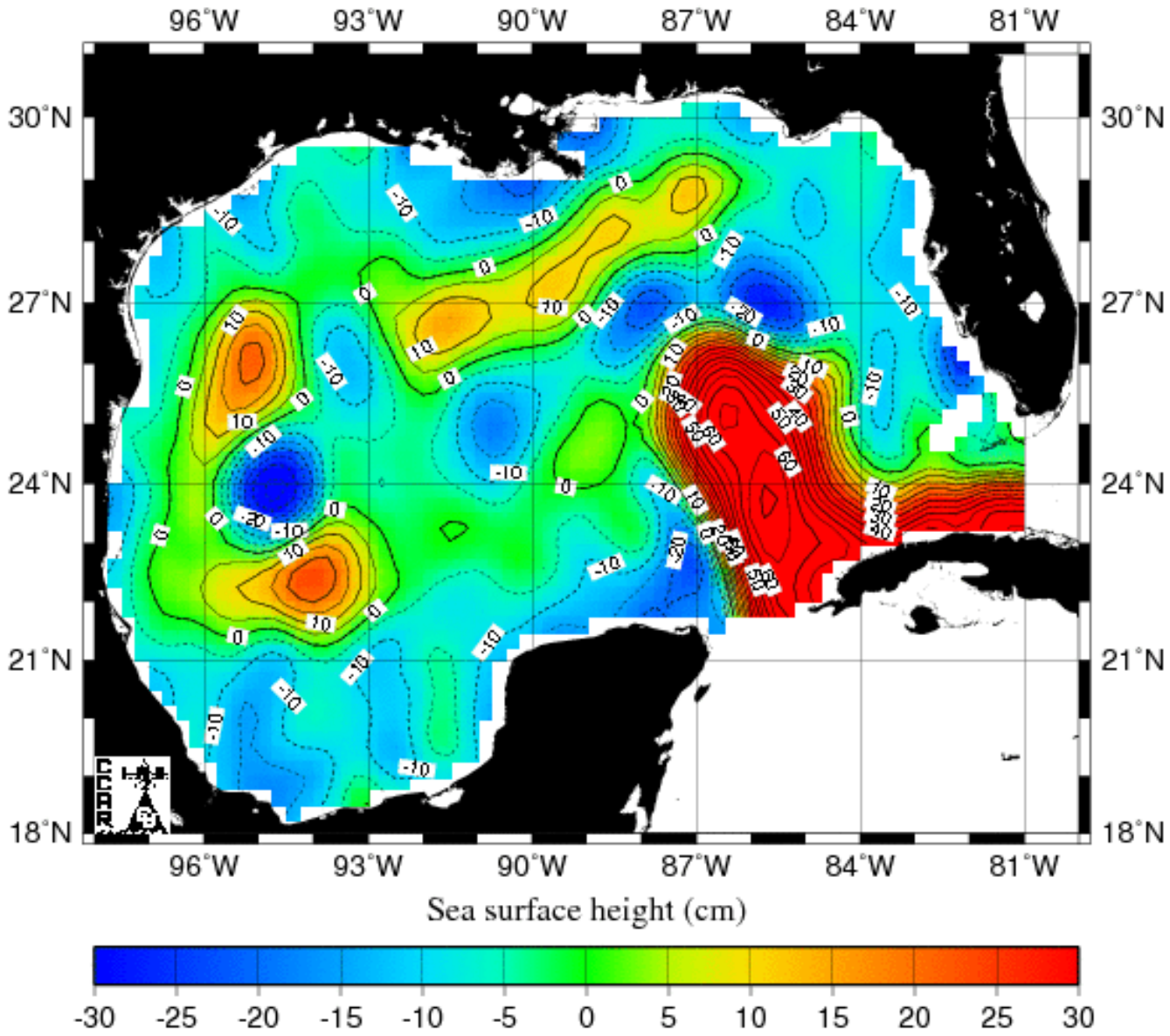
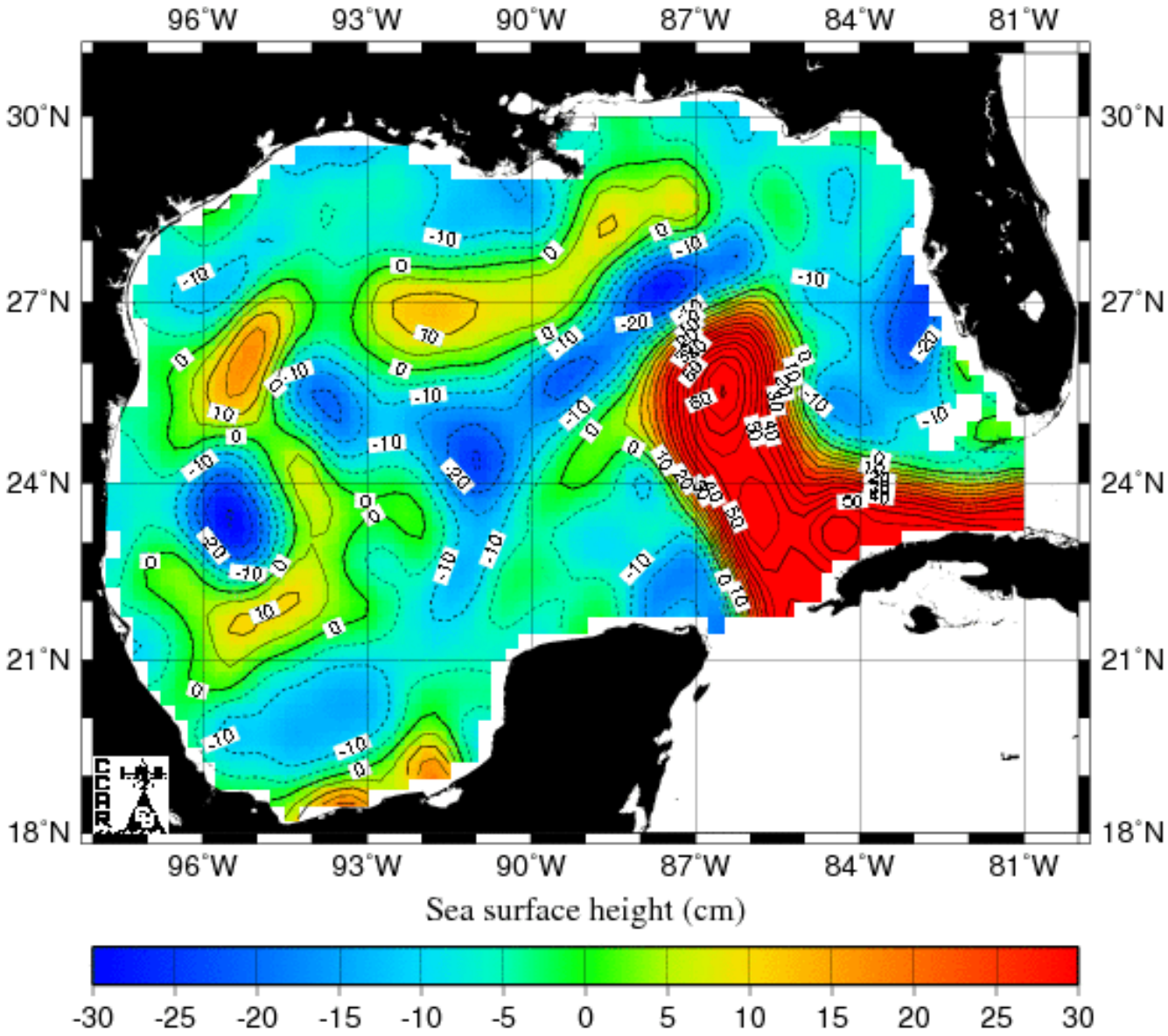
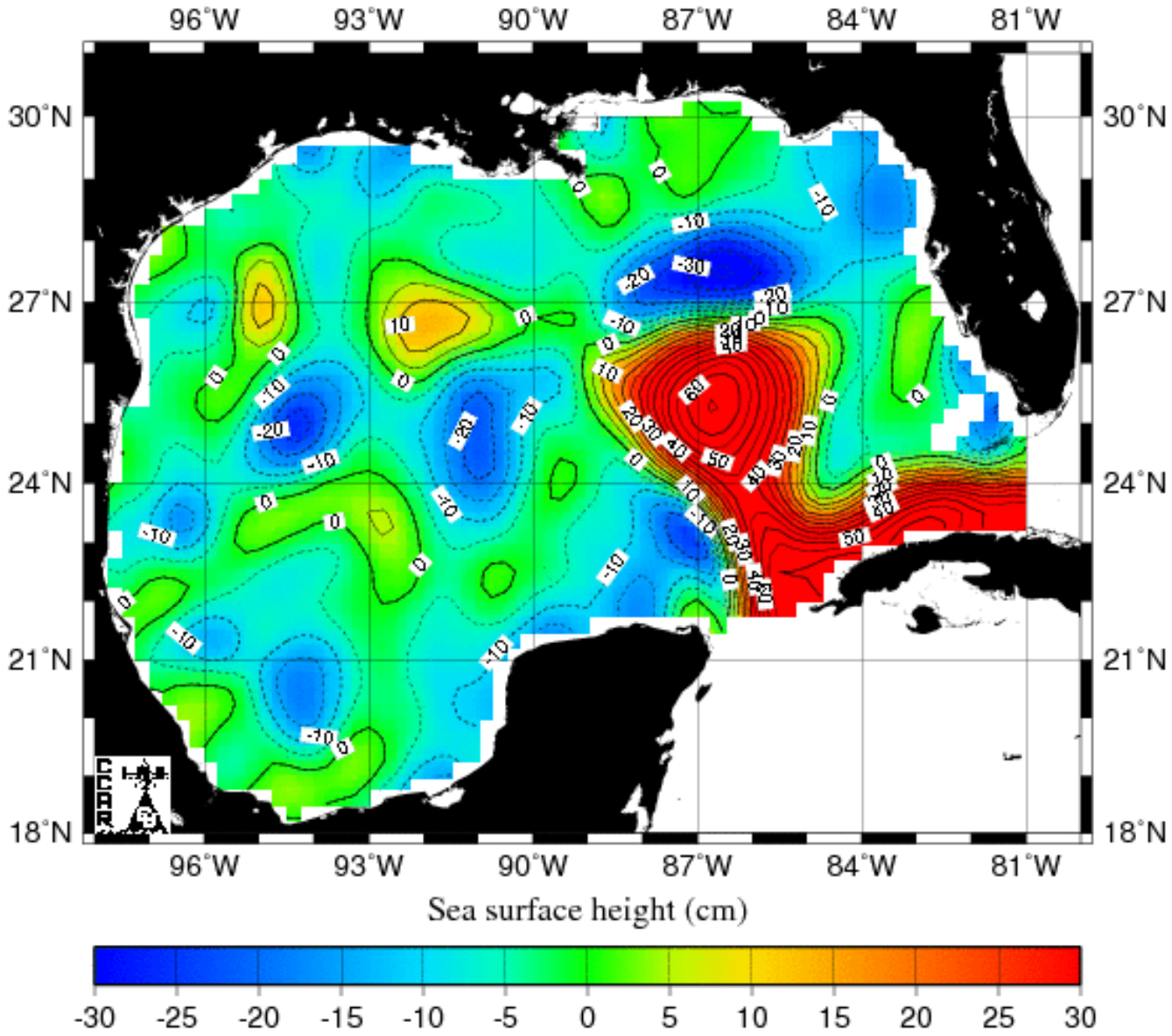


Historical Mesoscale Altimetry – 1 October 2000



Historical Mesoscale Altimetry – 1 November 2000



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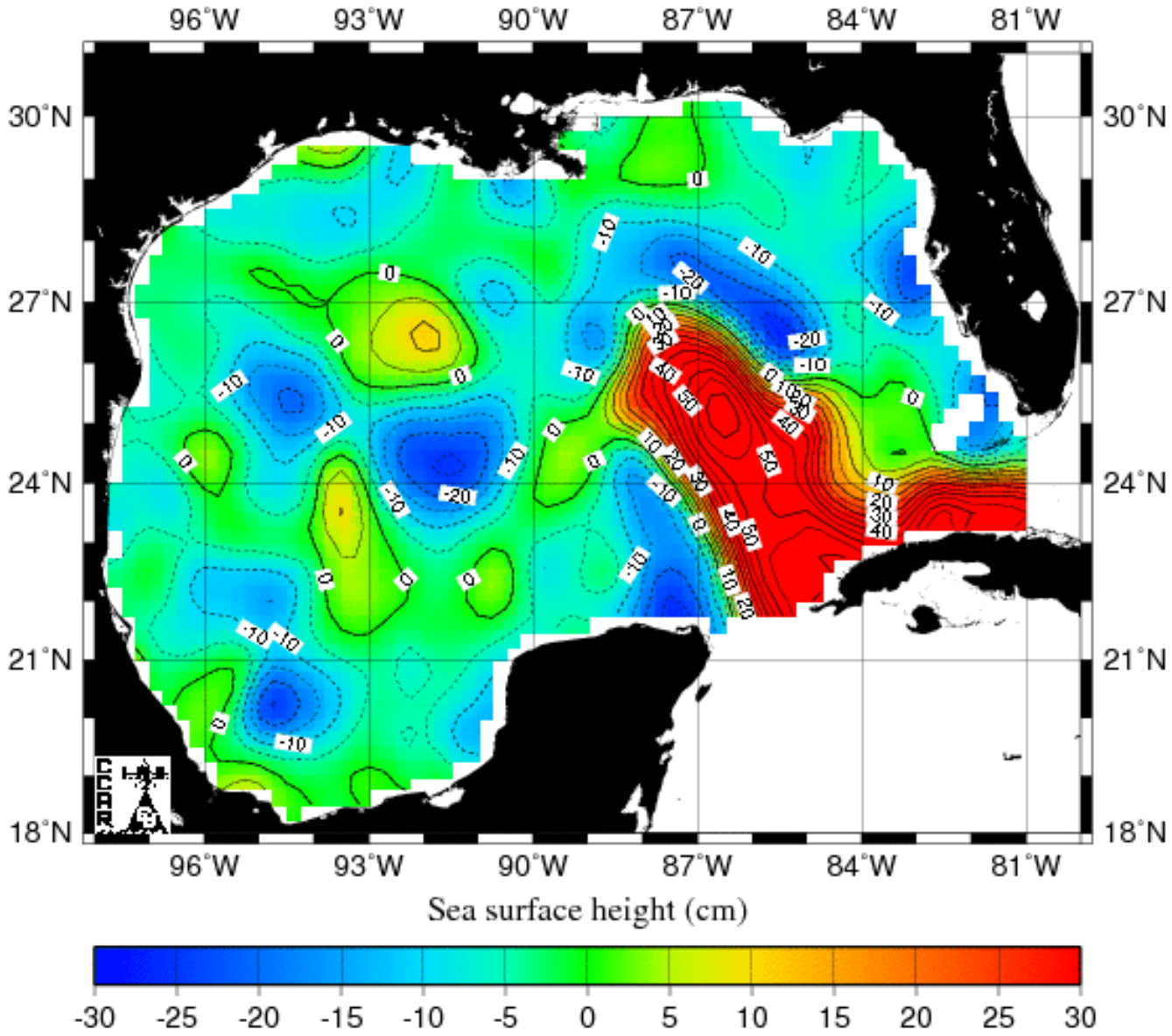

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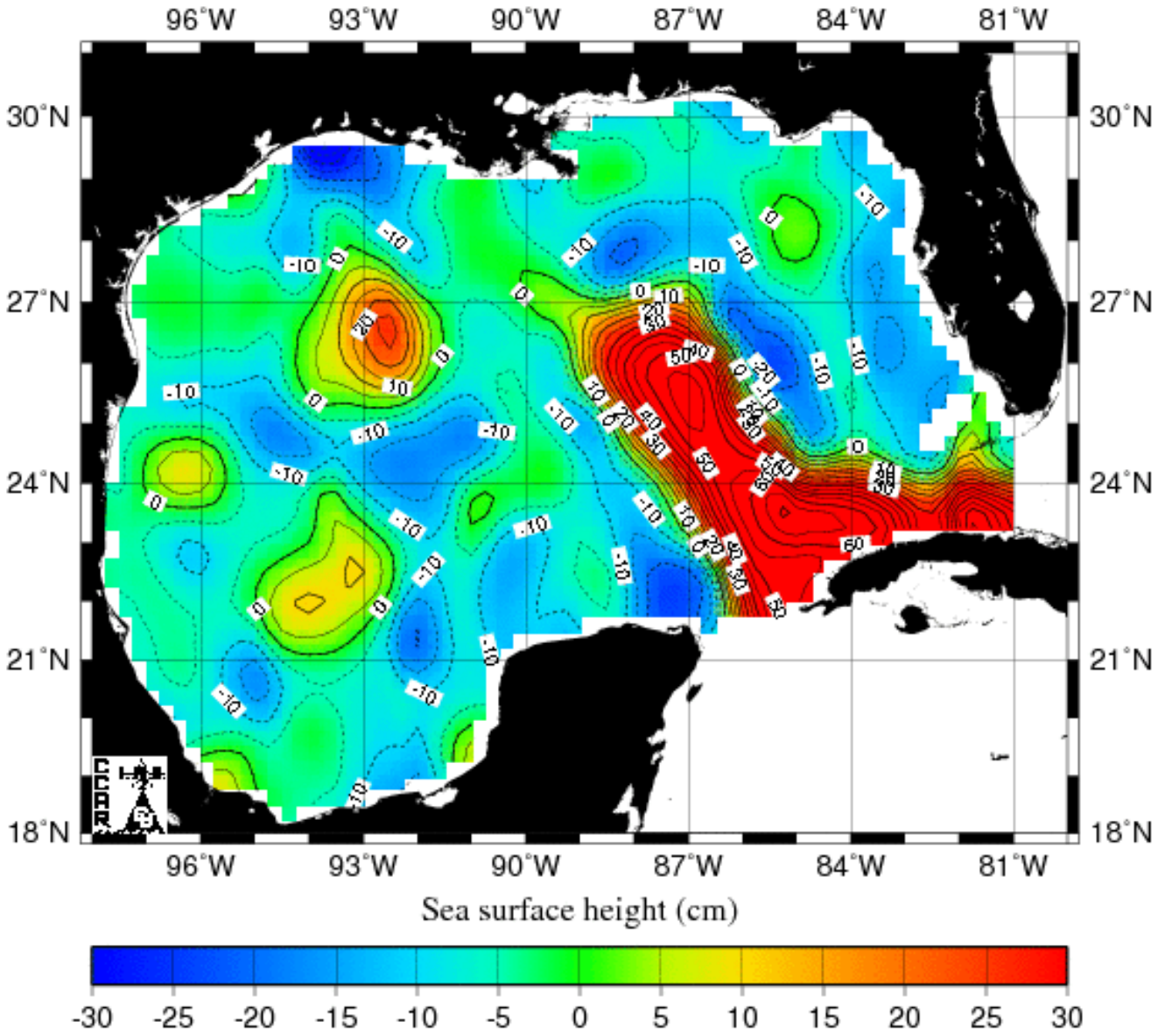

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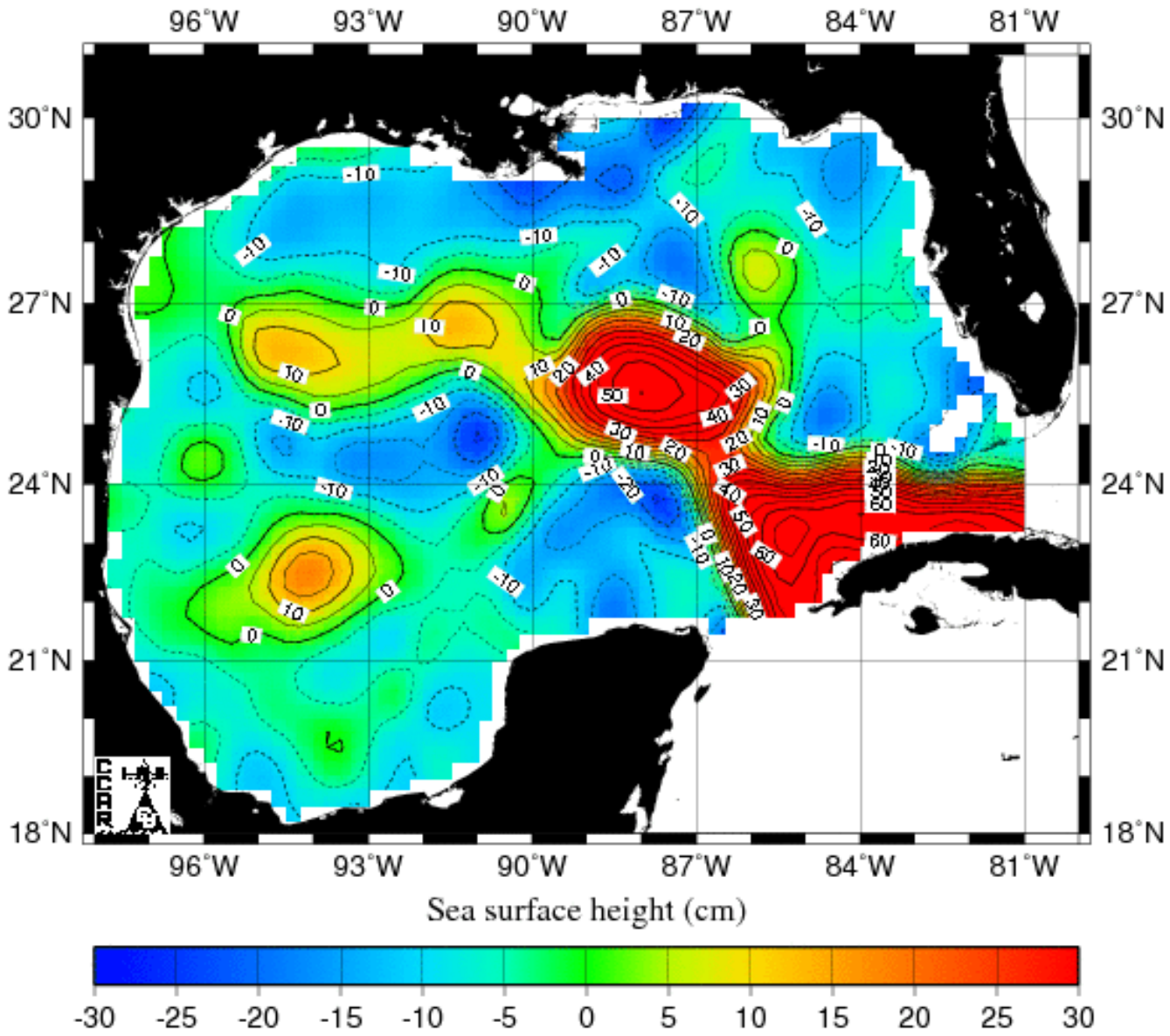

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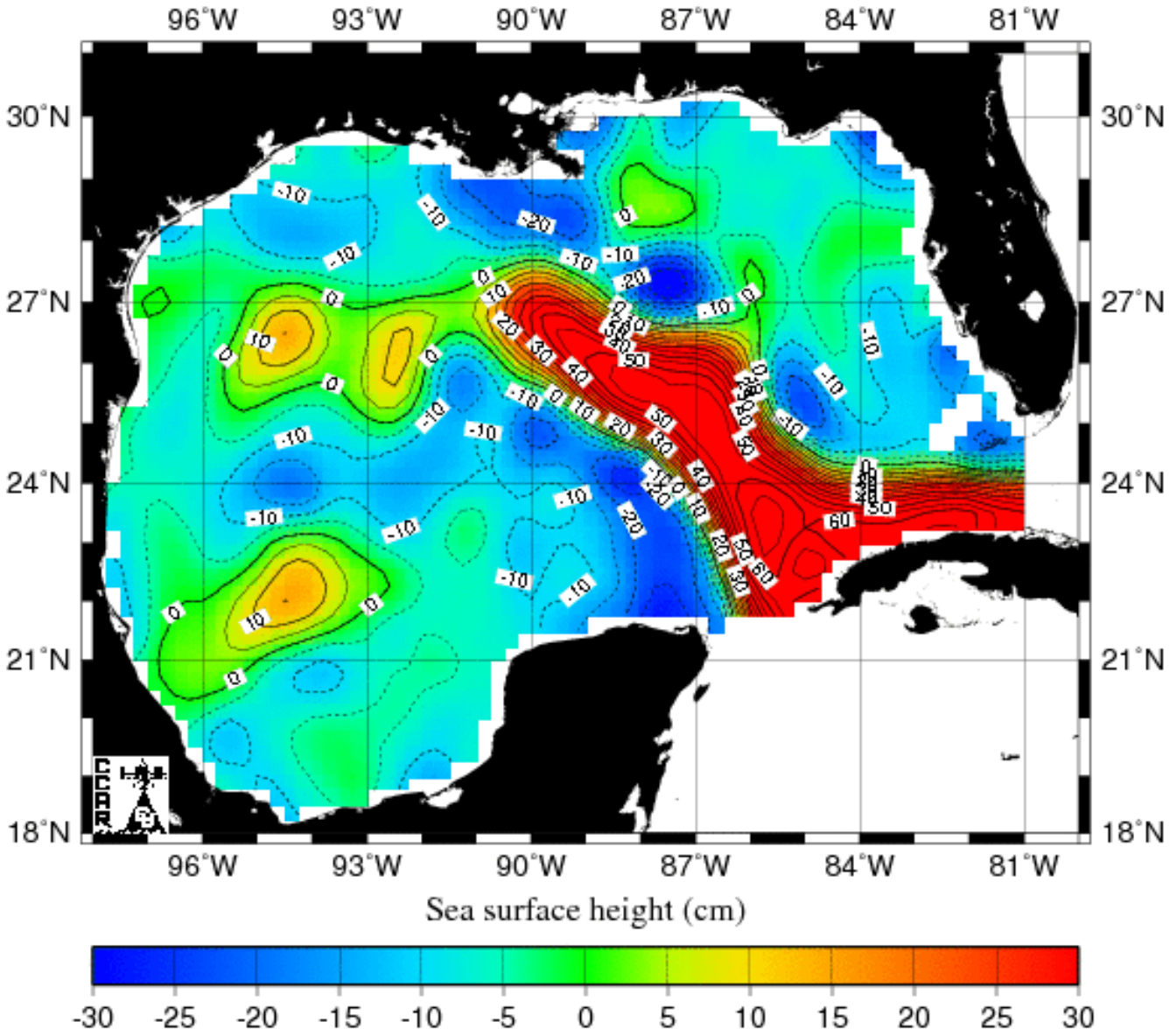

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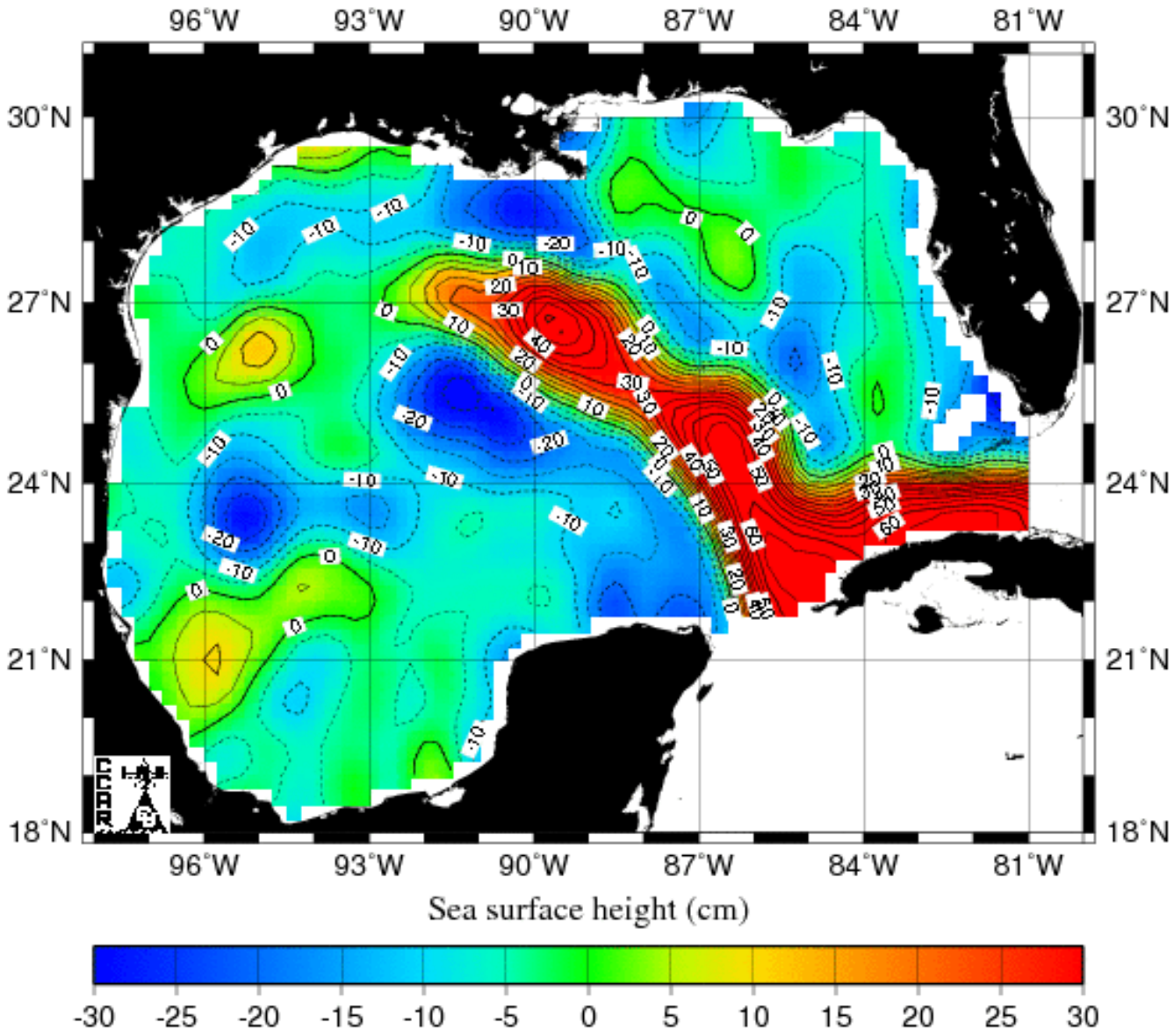

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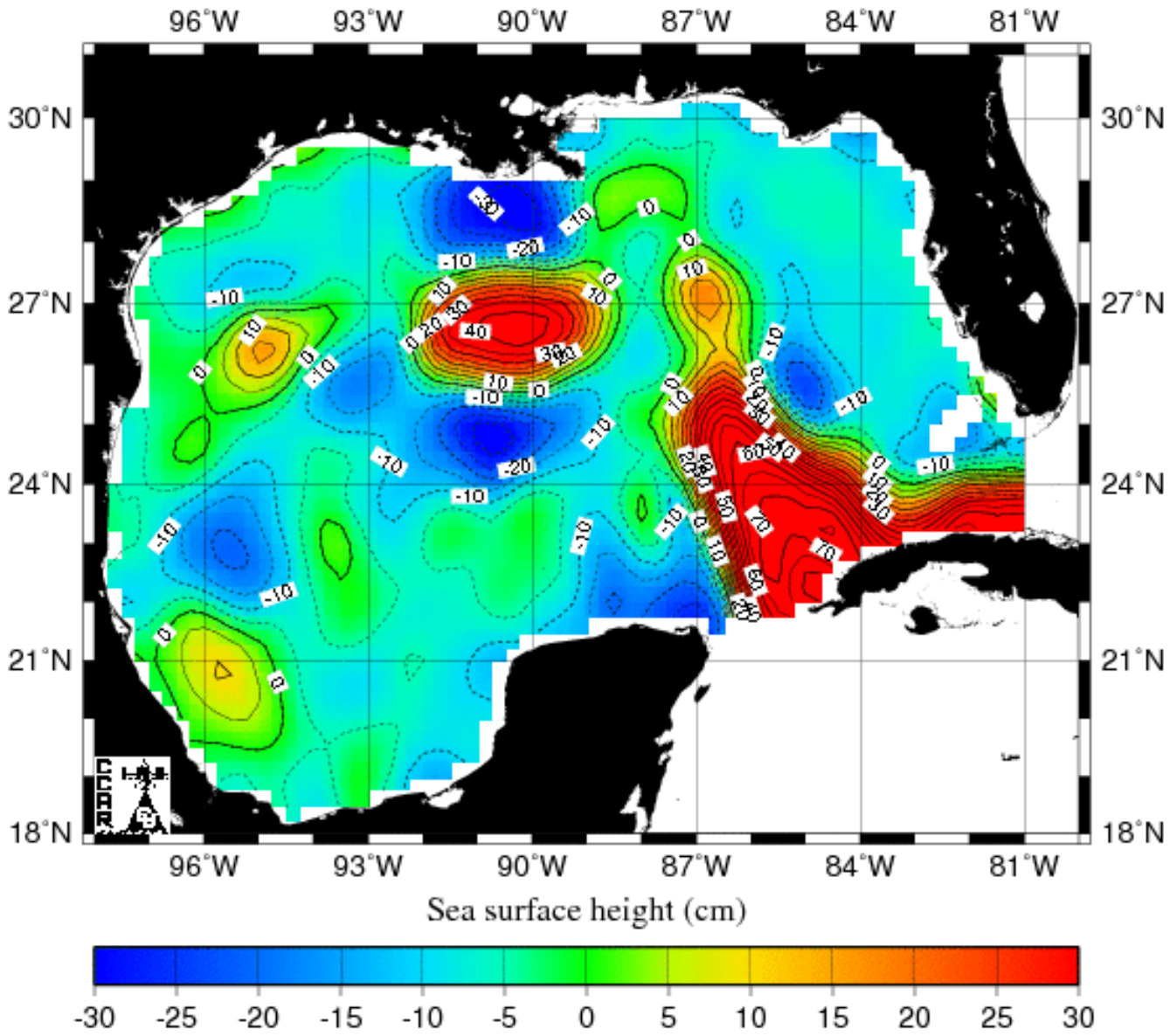

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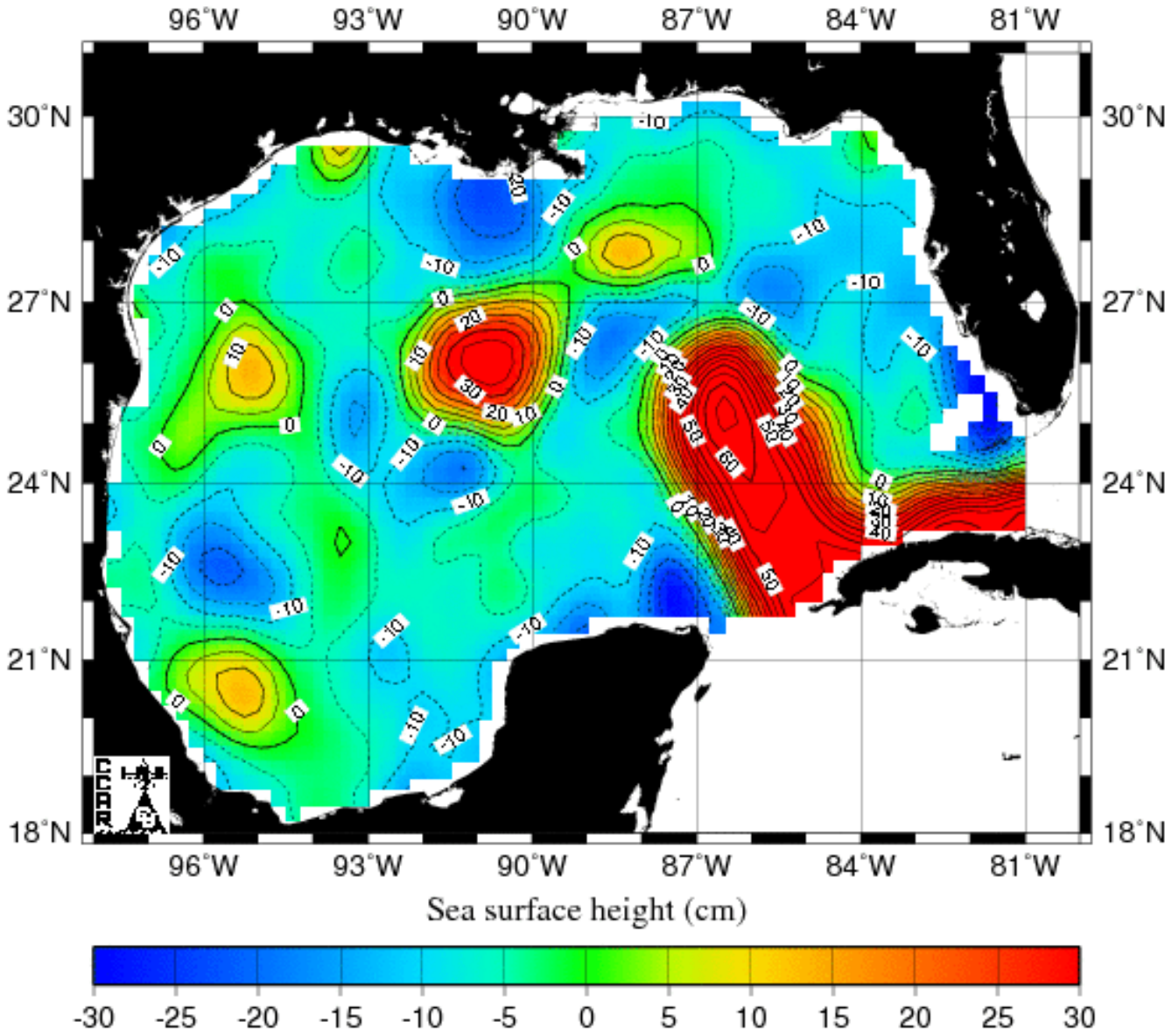

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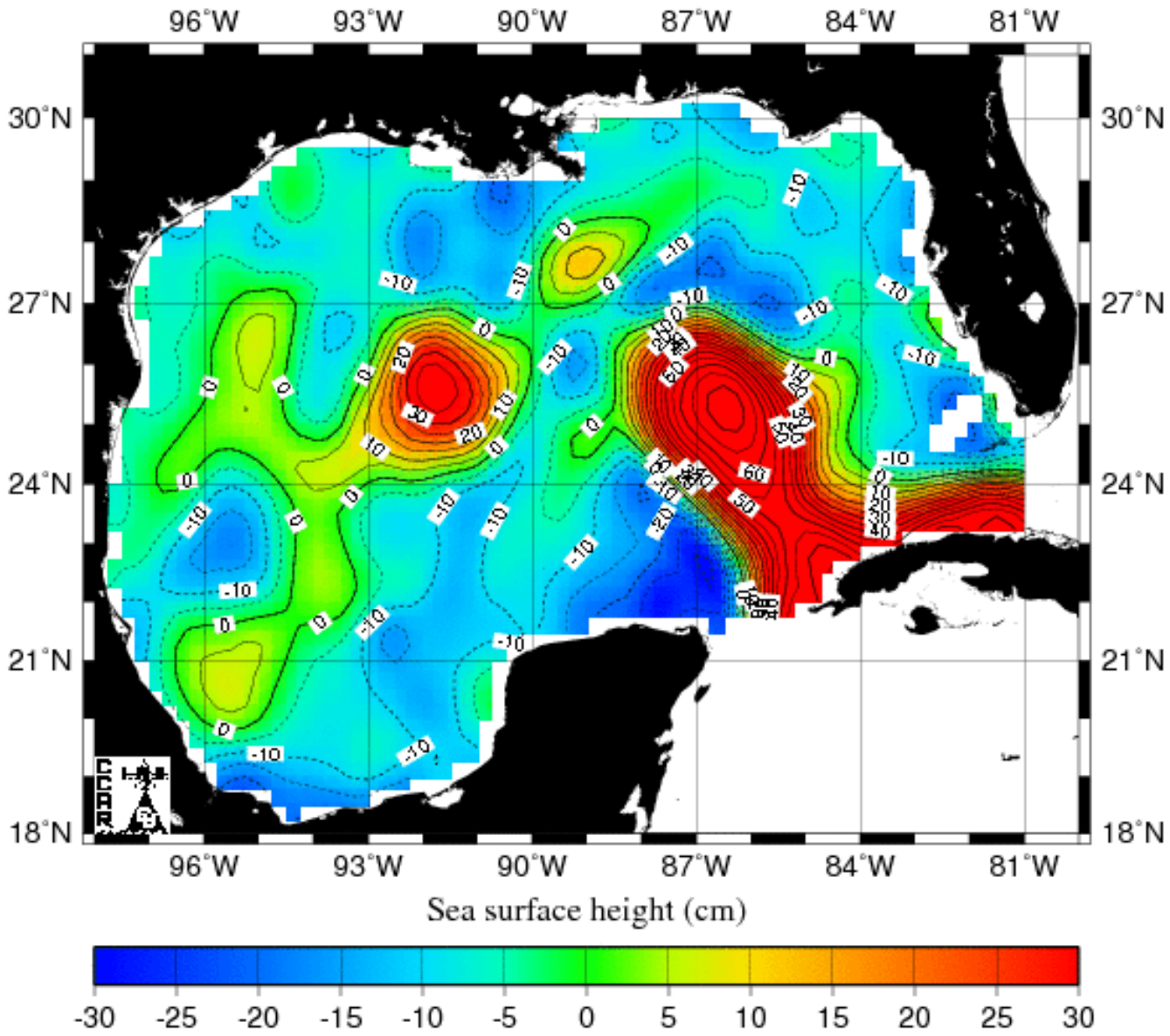

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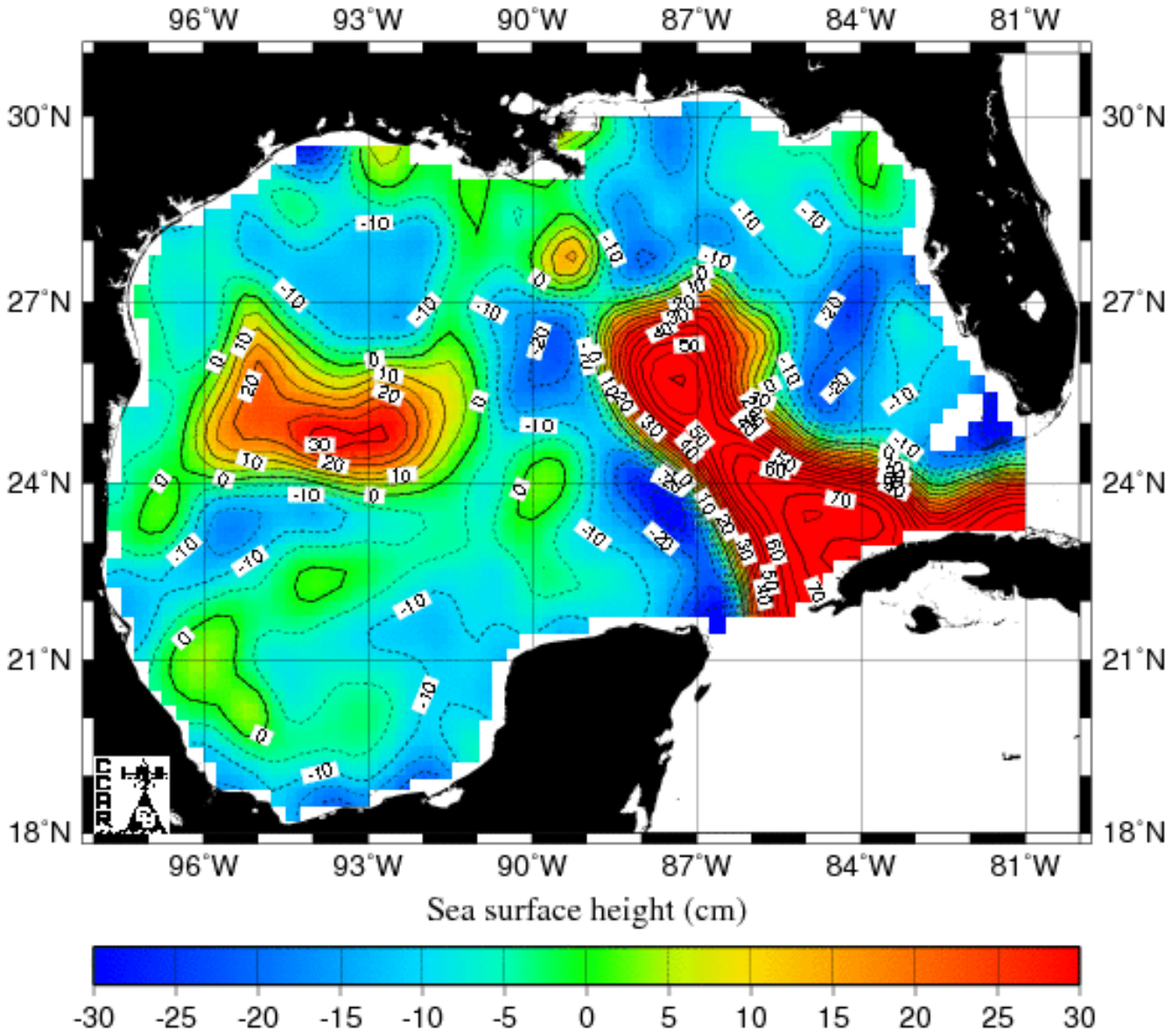

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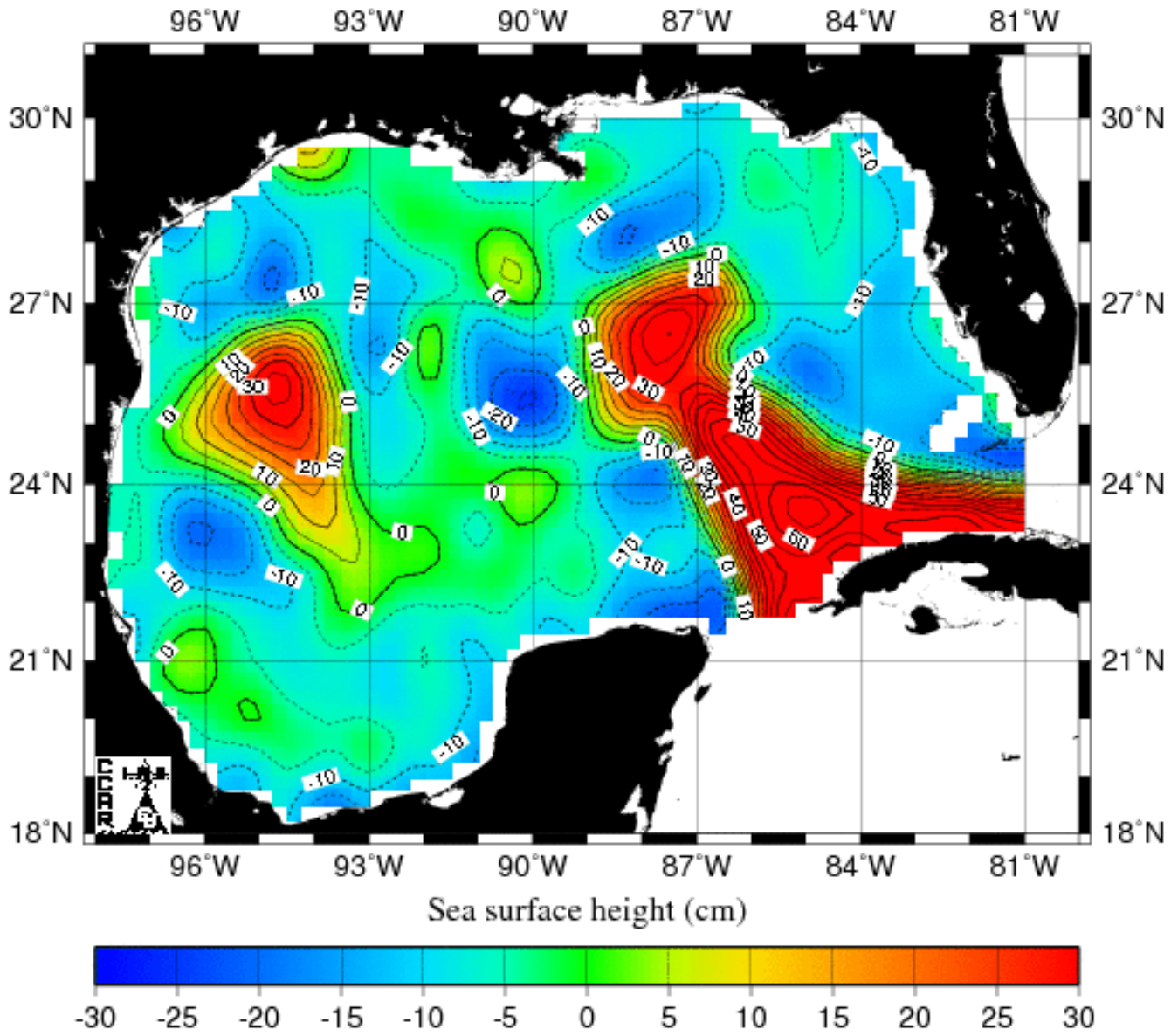

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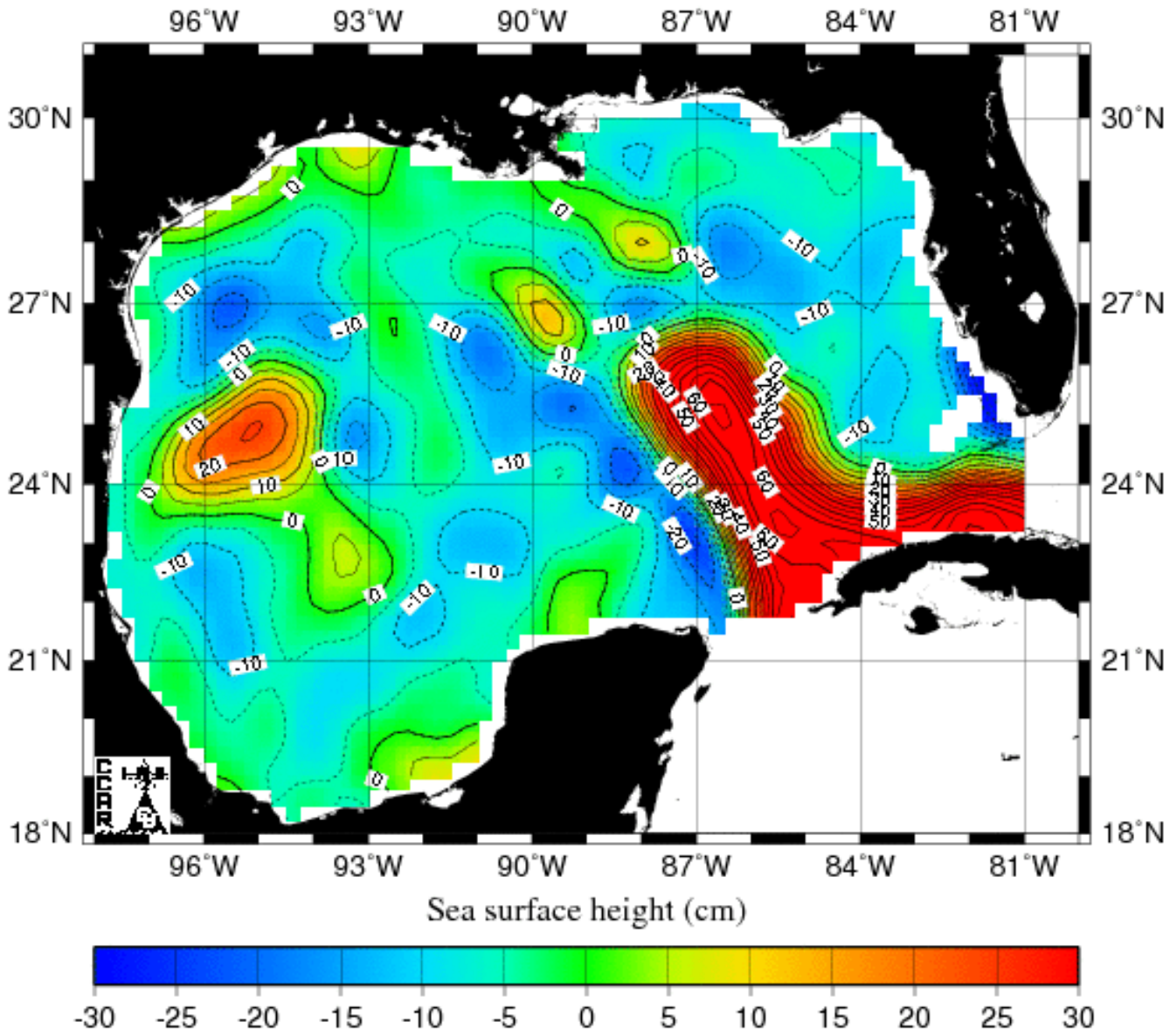

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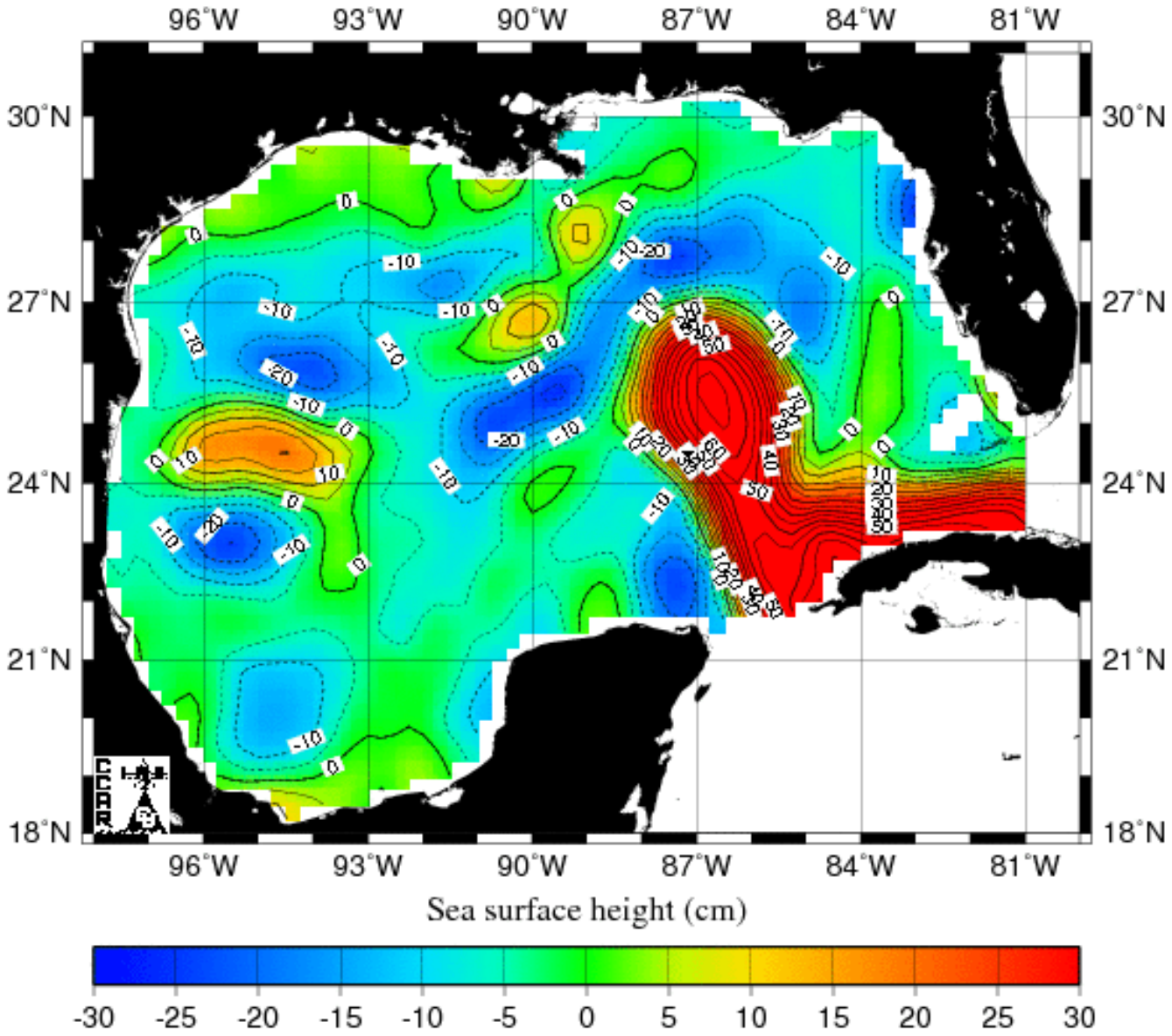

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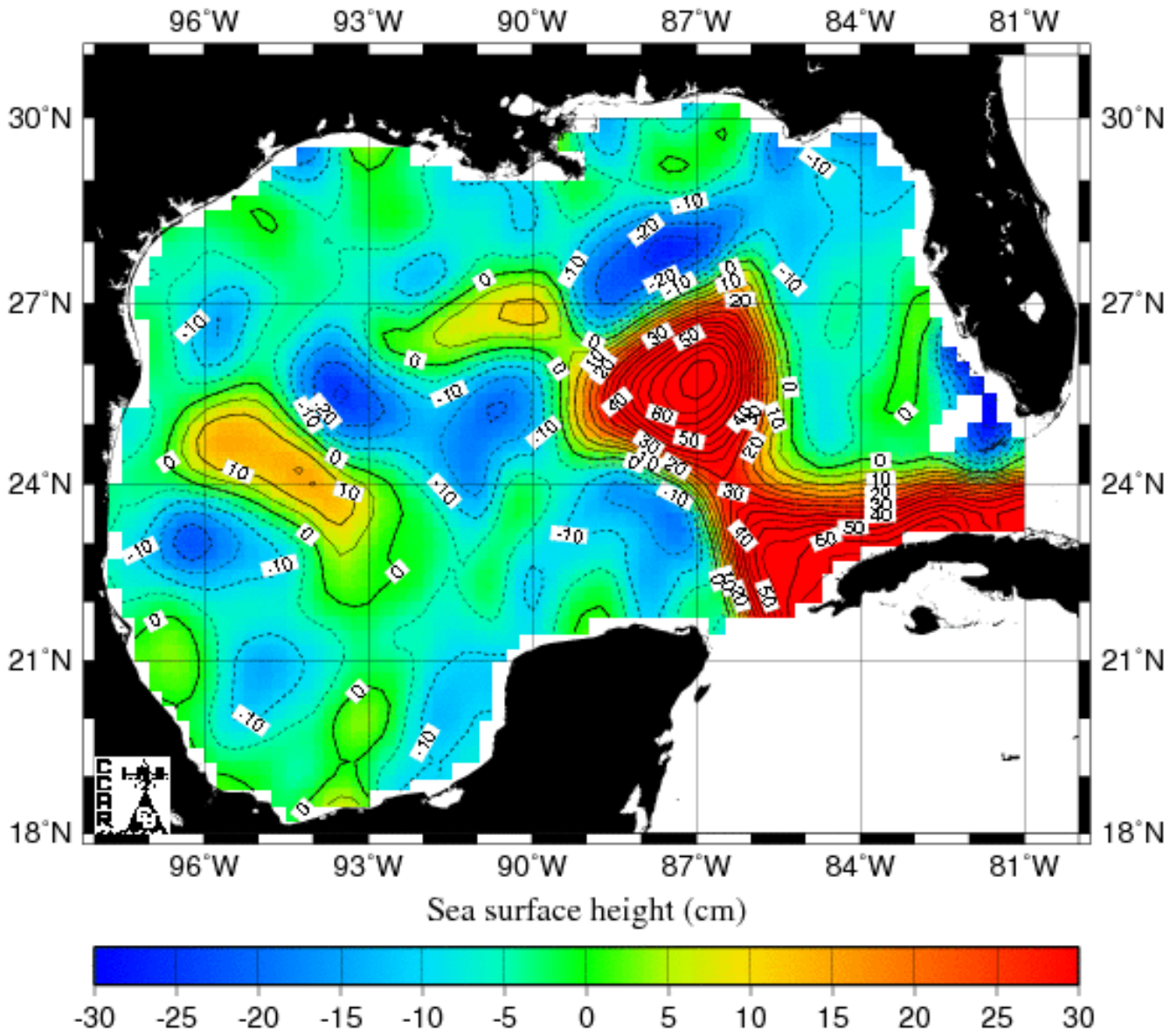
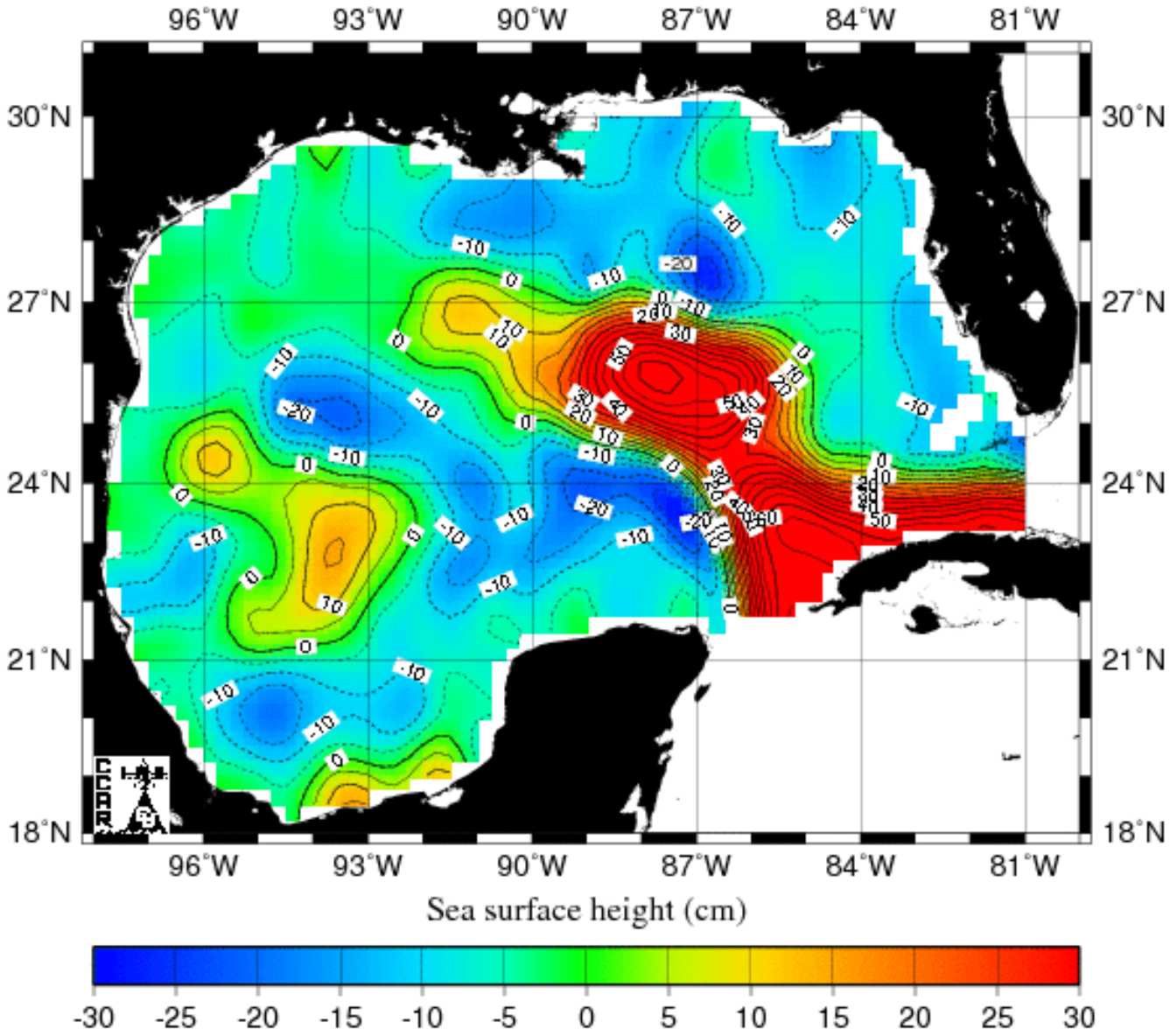


Historical Mesoscale Altimetry – 1 January 2002



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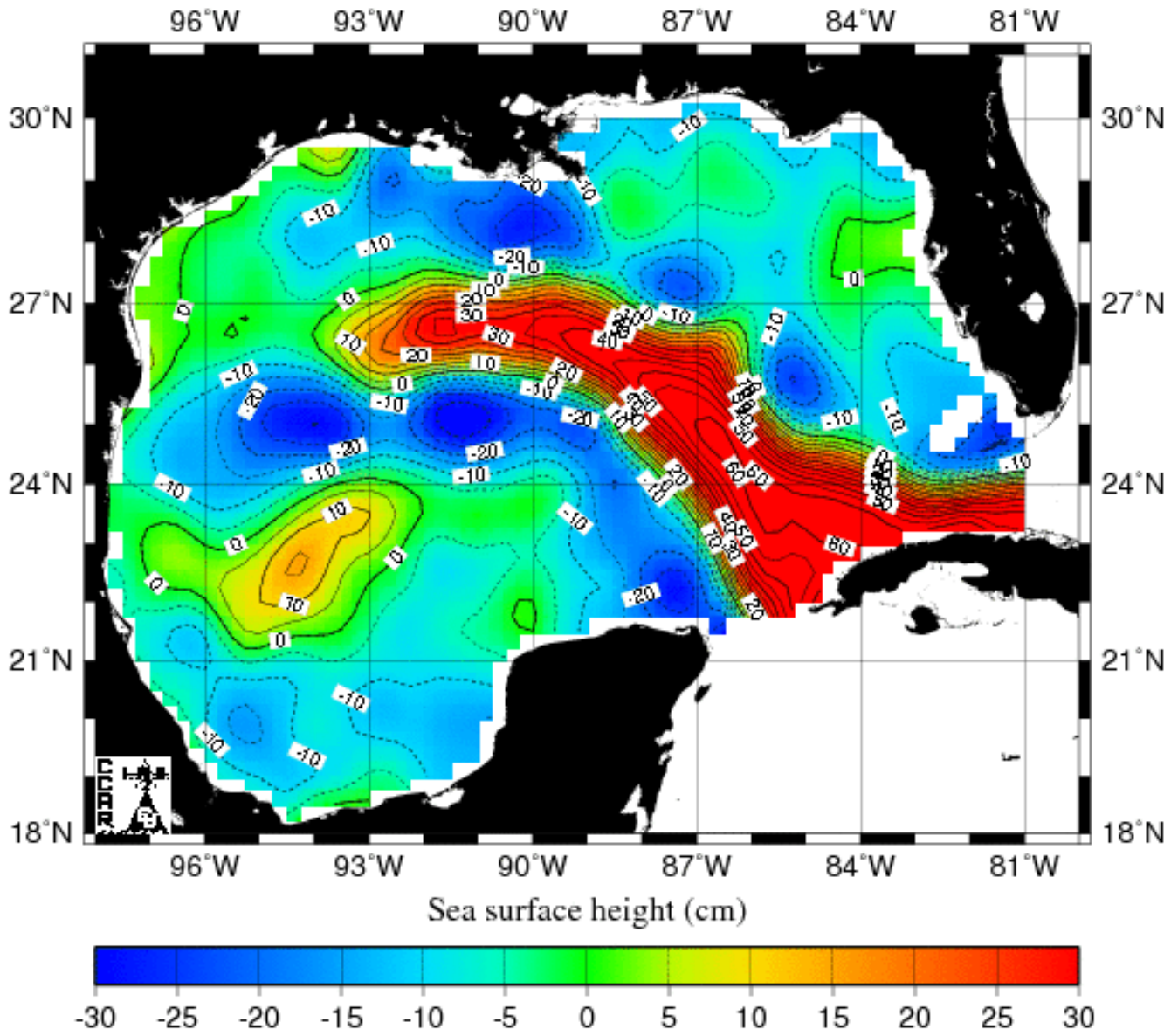

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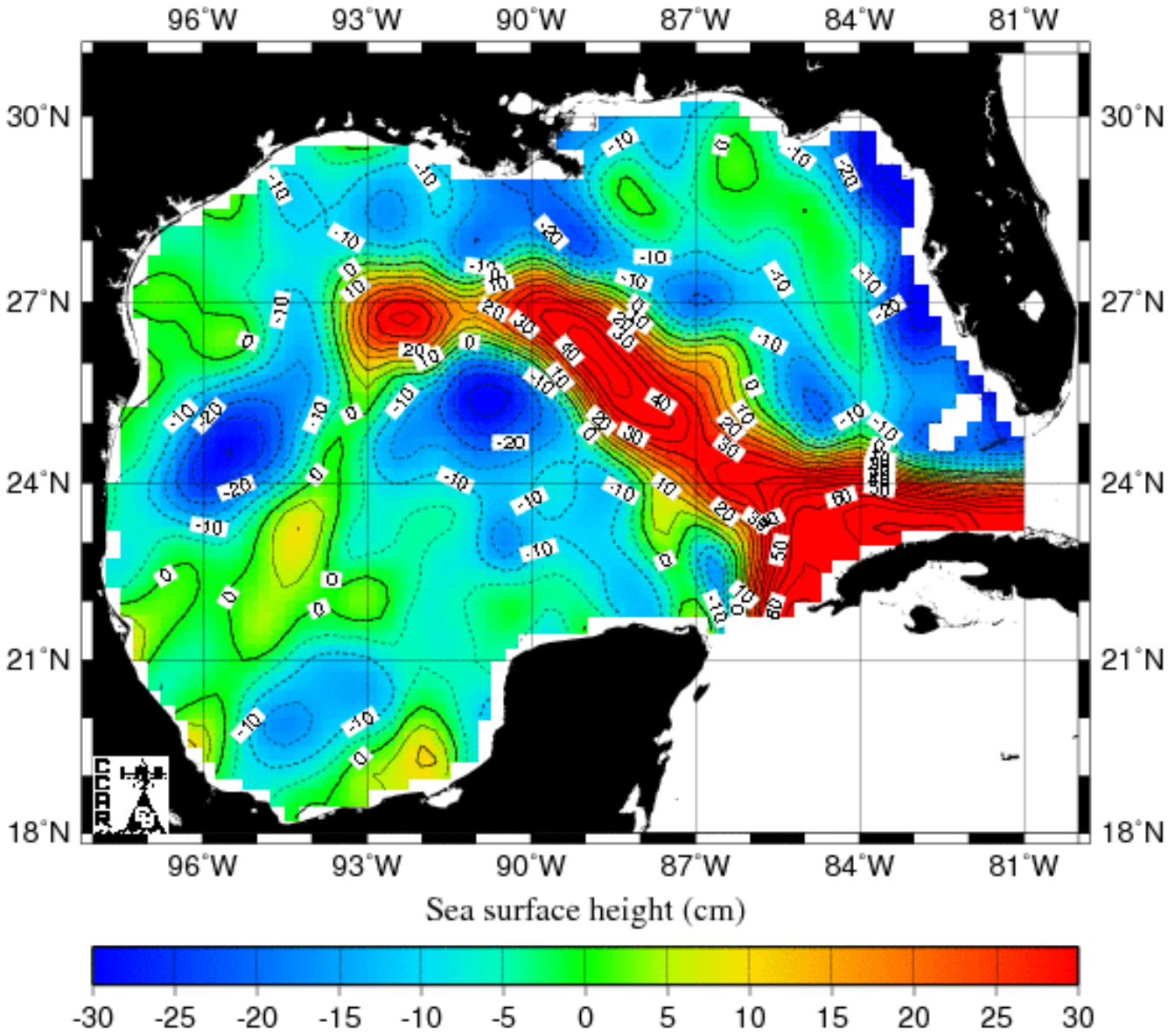
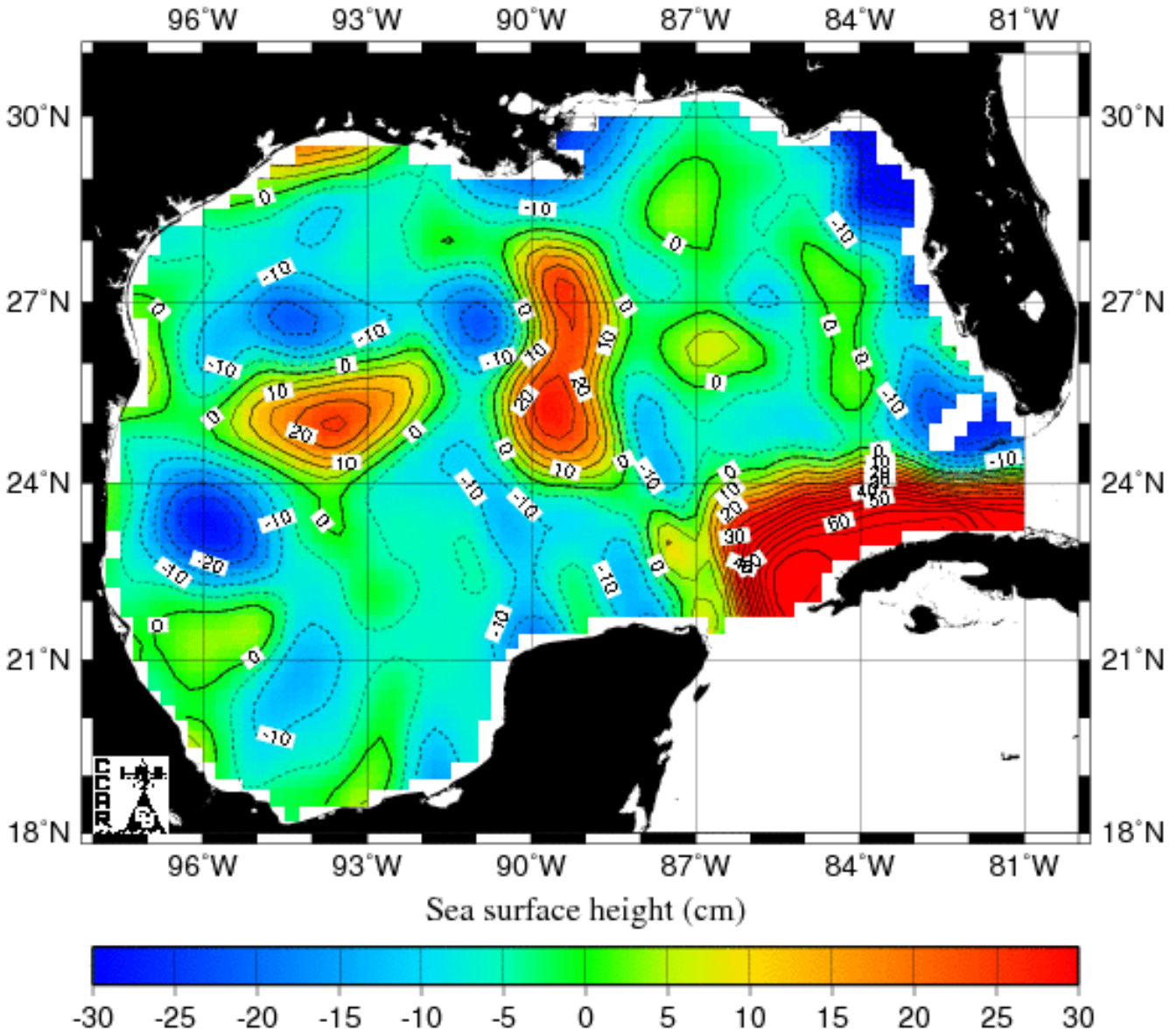


Historical Mesoscale Altimetry – 1 April 2002



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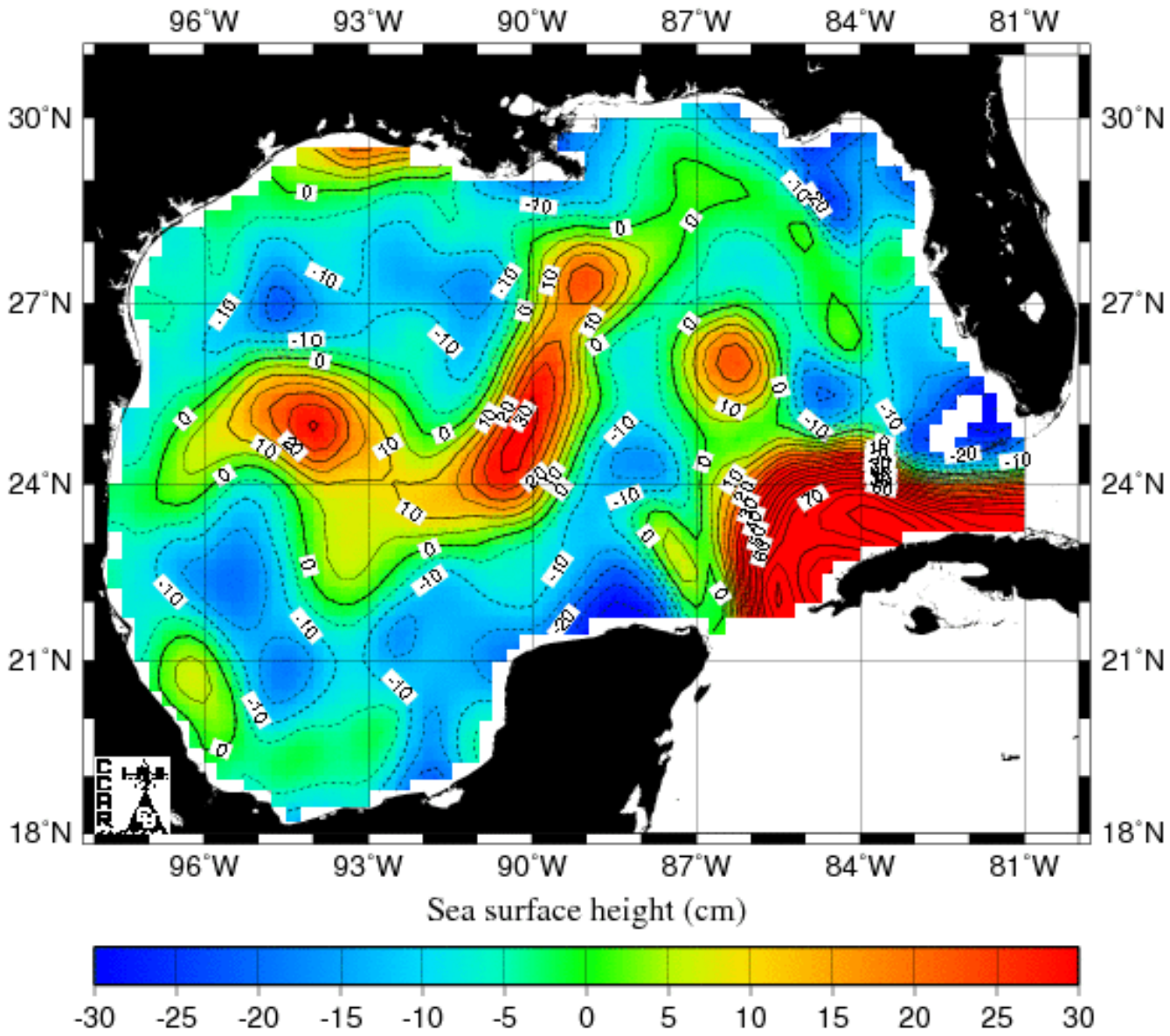
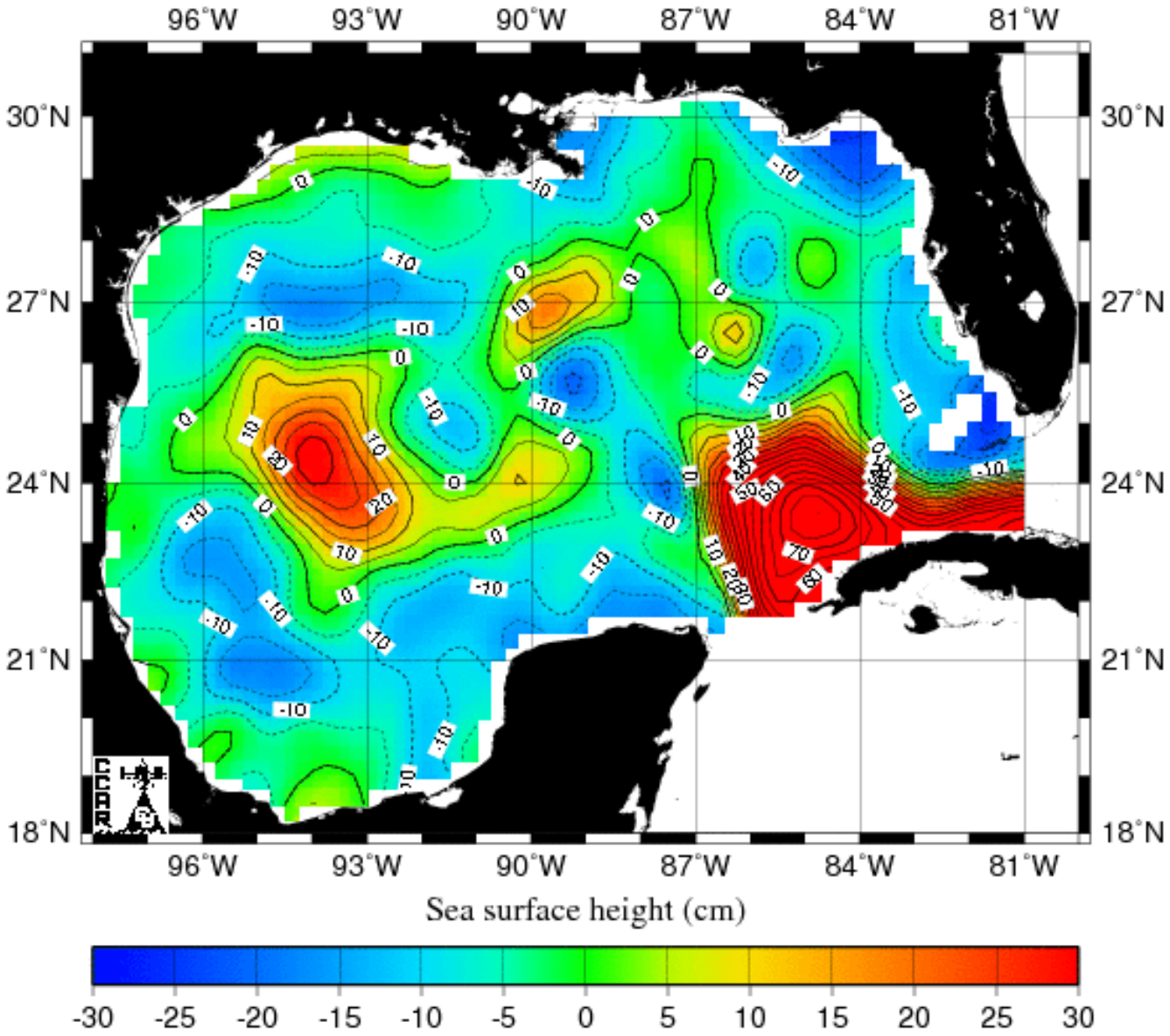
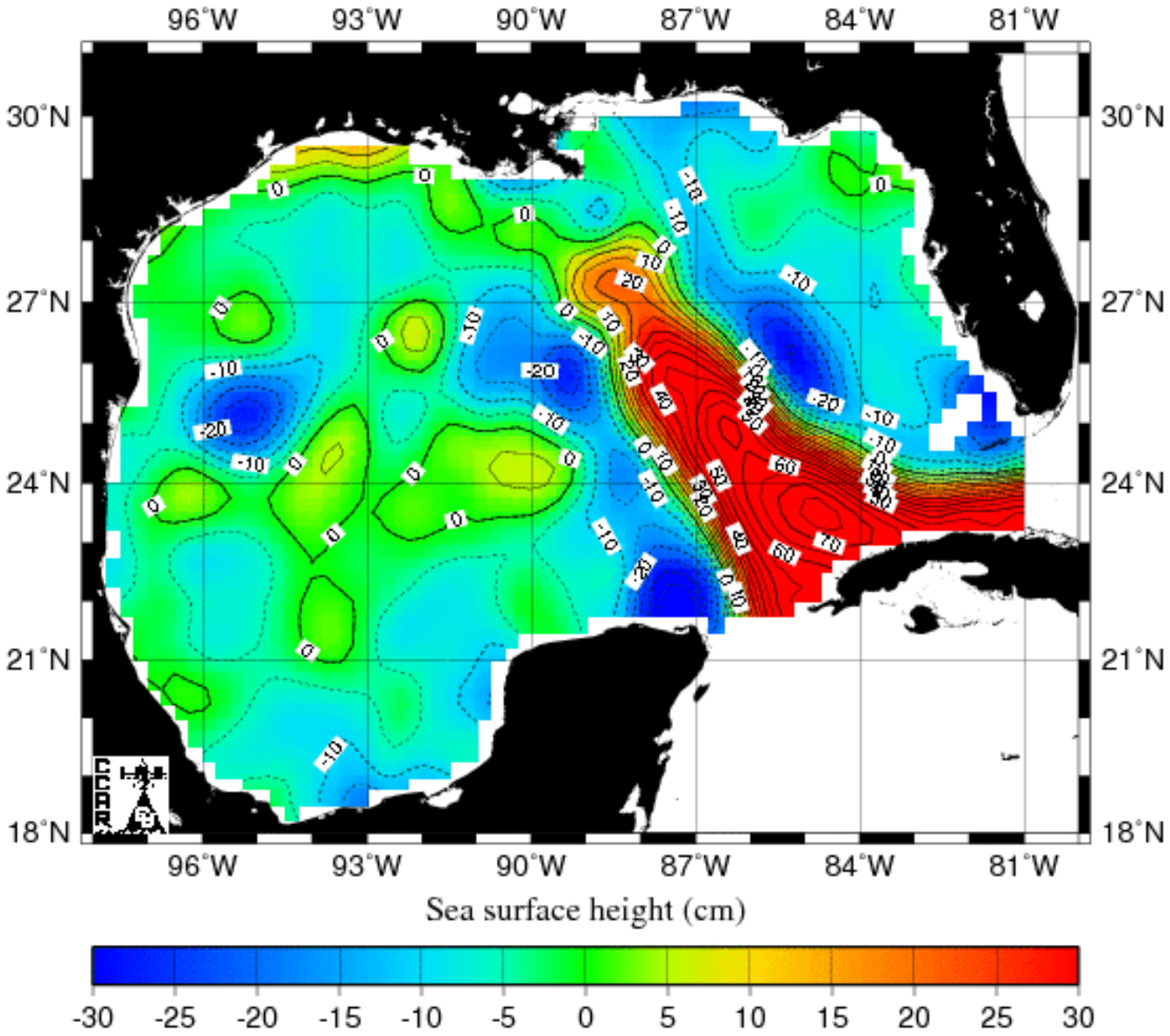


Historical Mesoscale Altimetry – 1 June 2002



Deployment 3

Historical Mesoscale Altimetry – 1 May 2003



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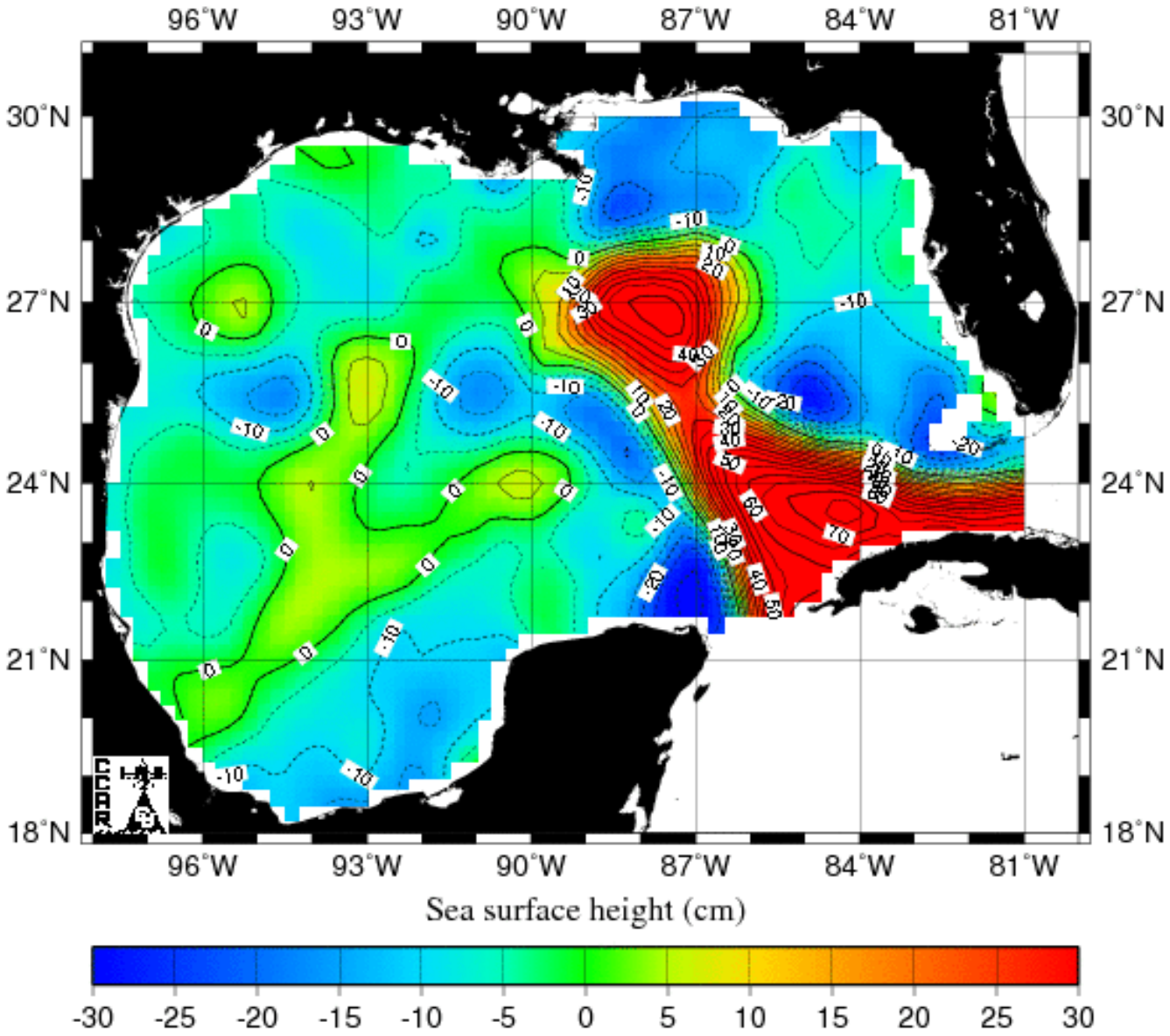

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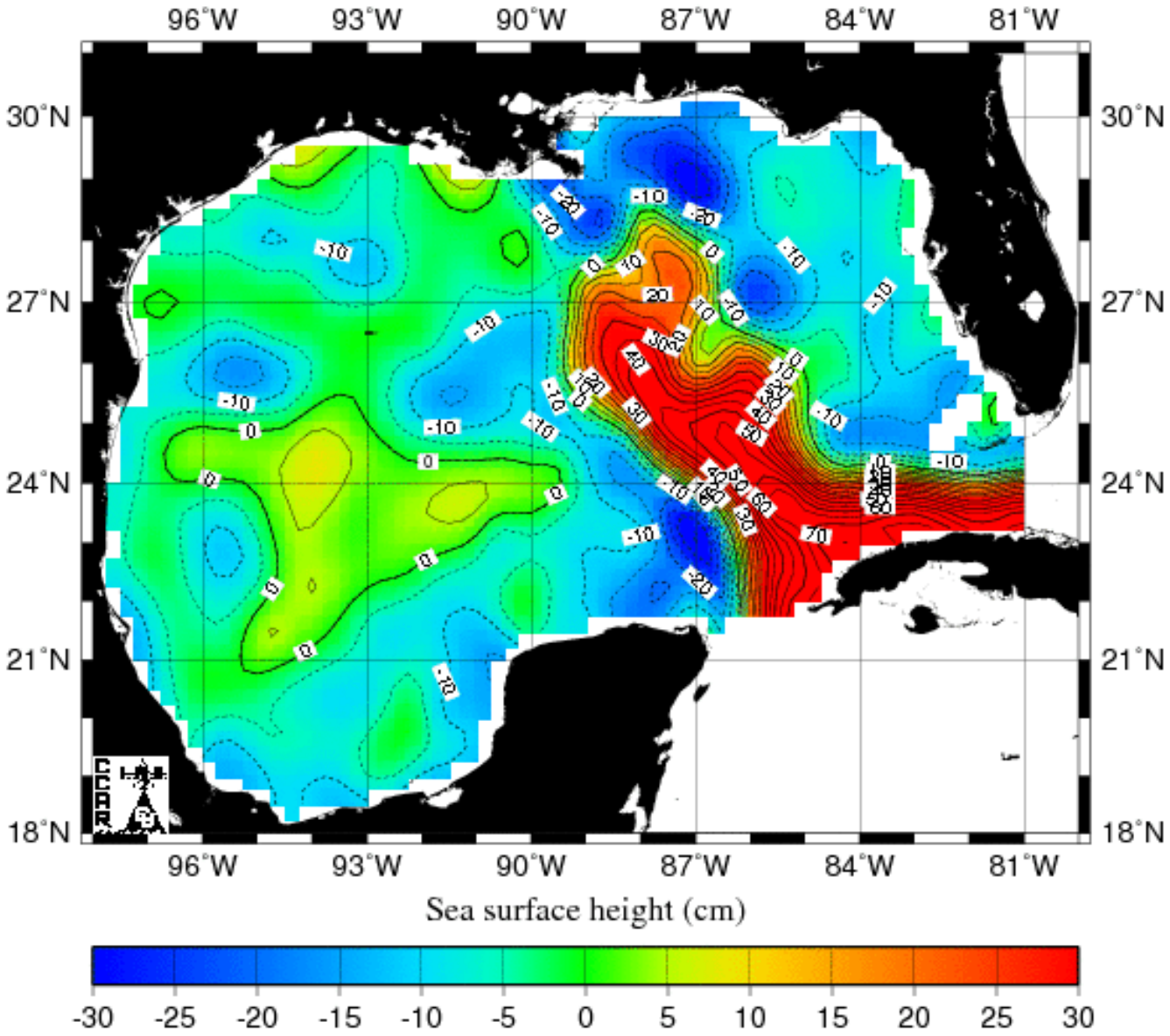

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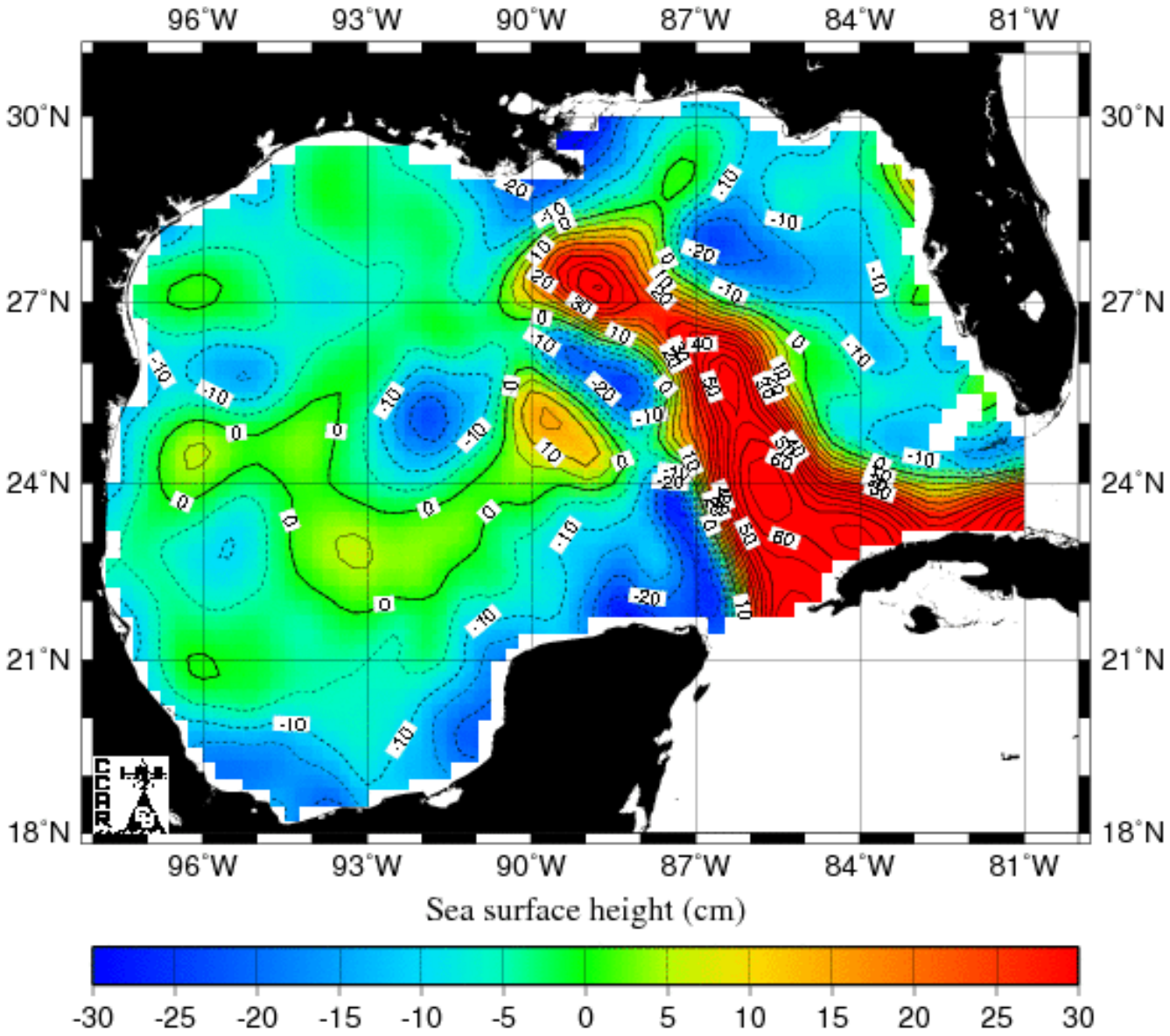

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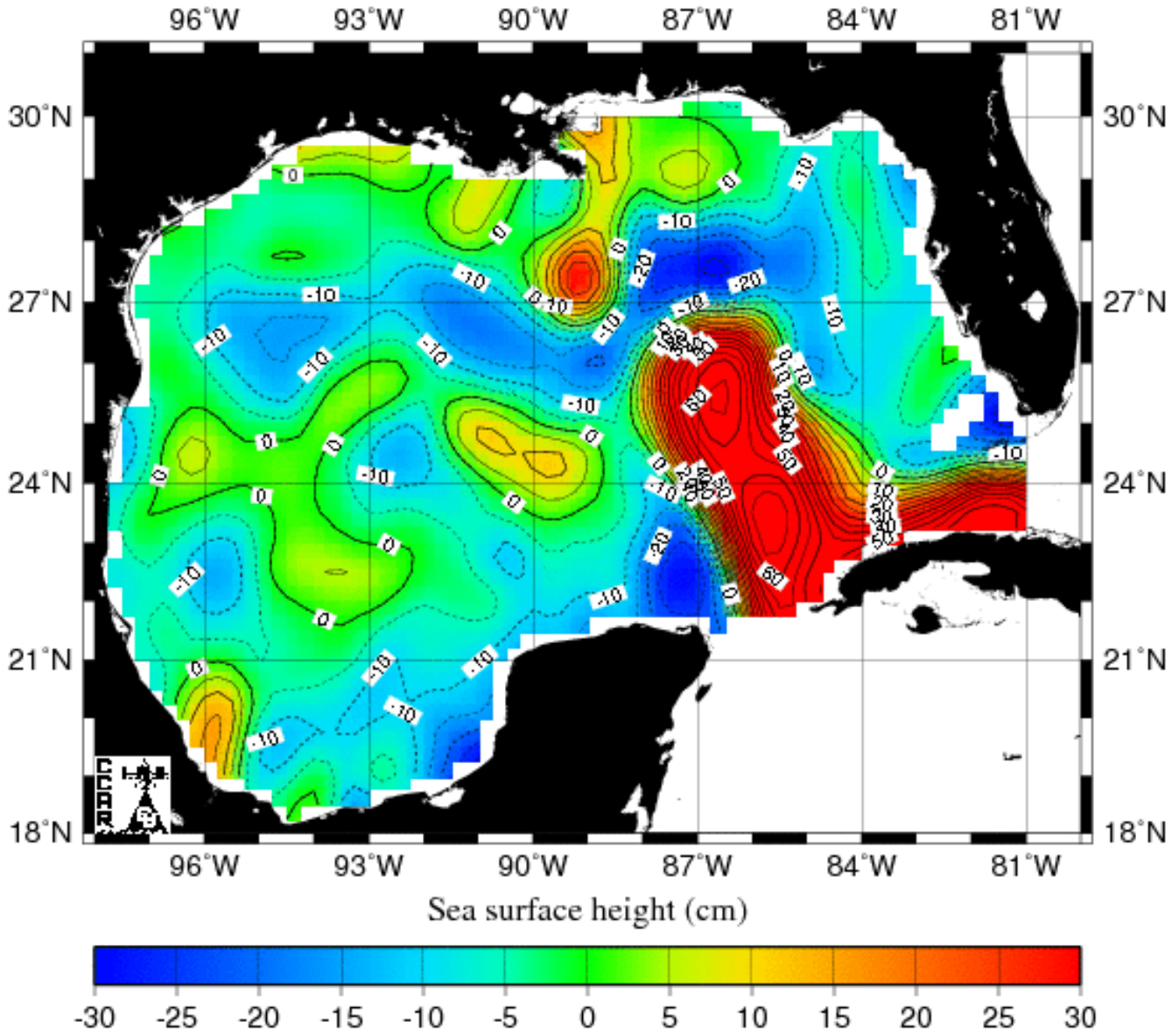

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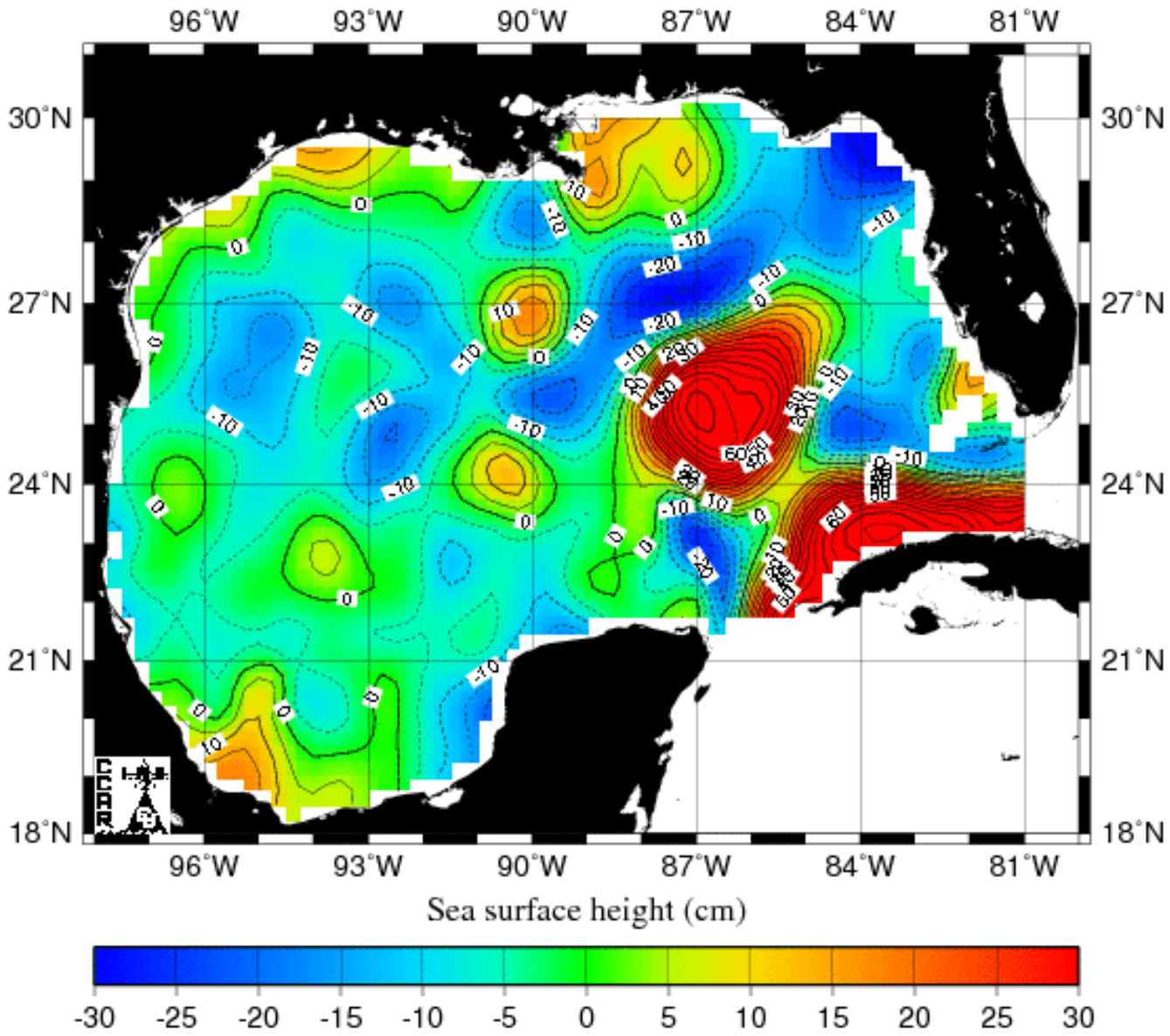

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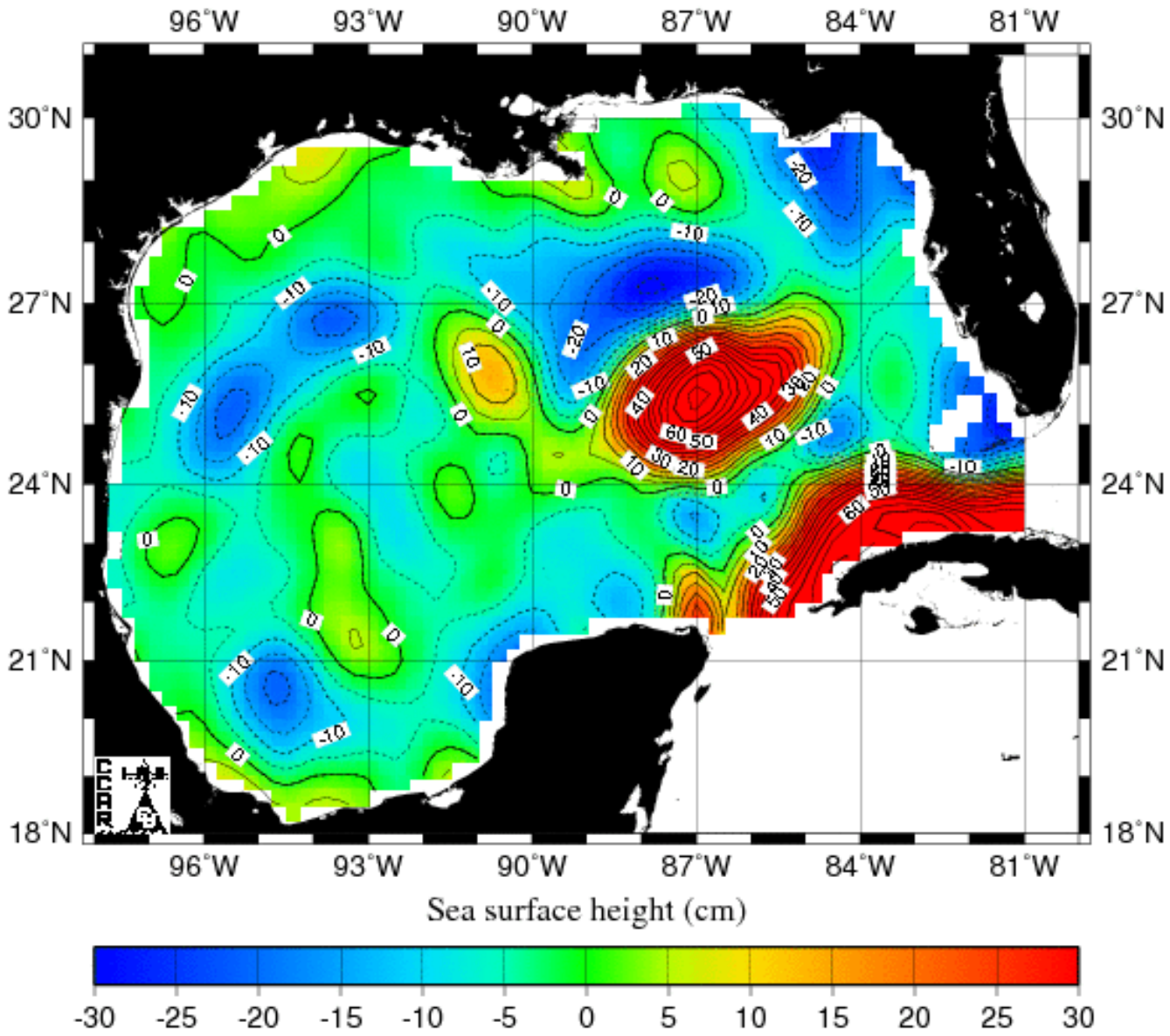

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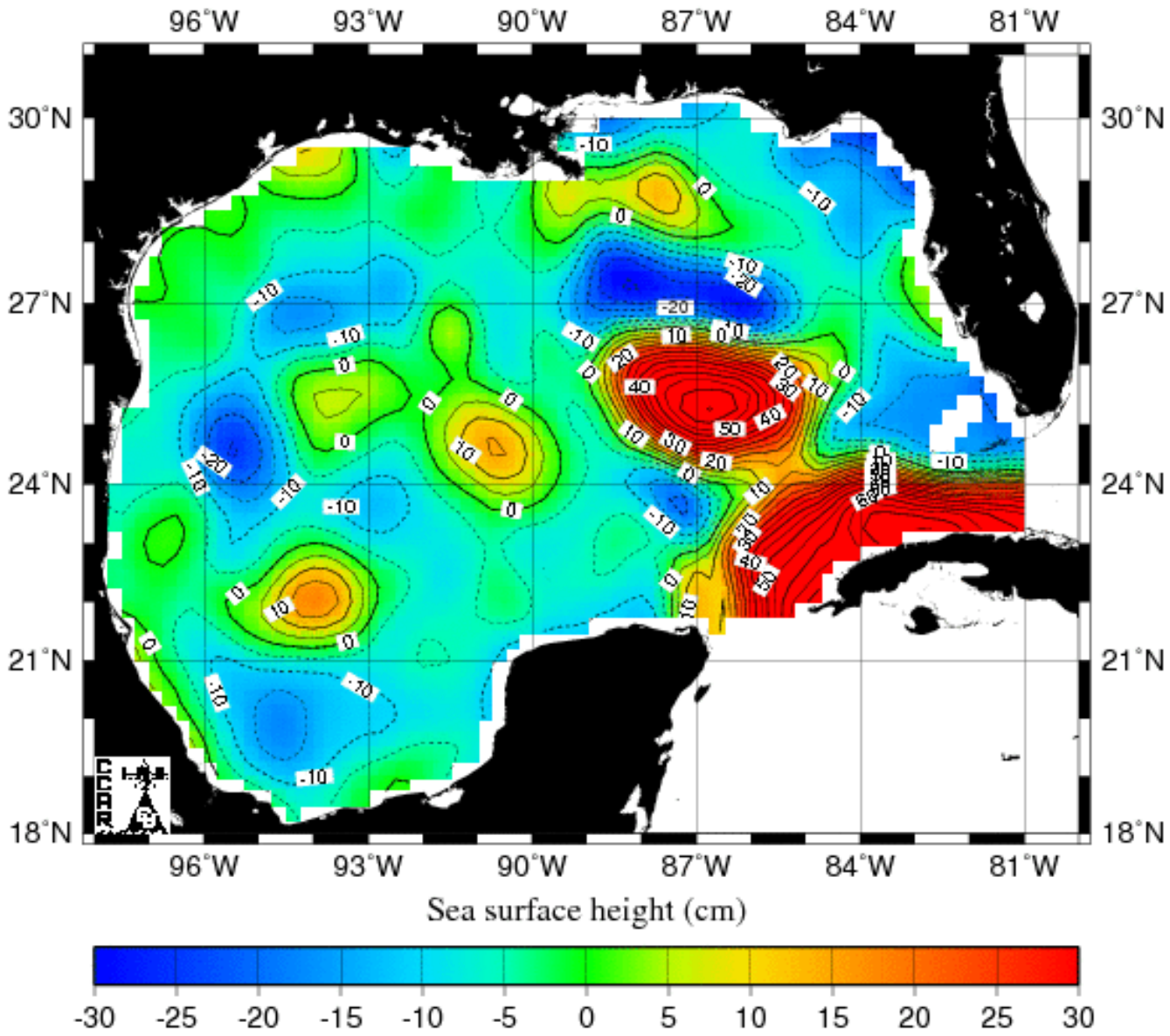

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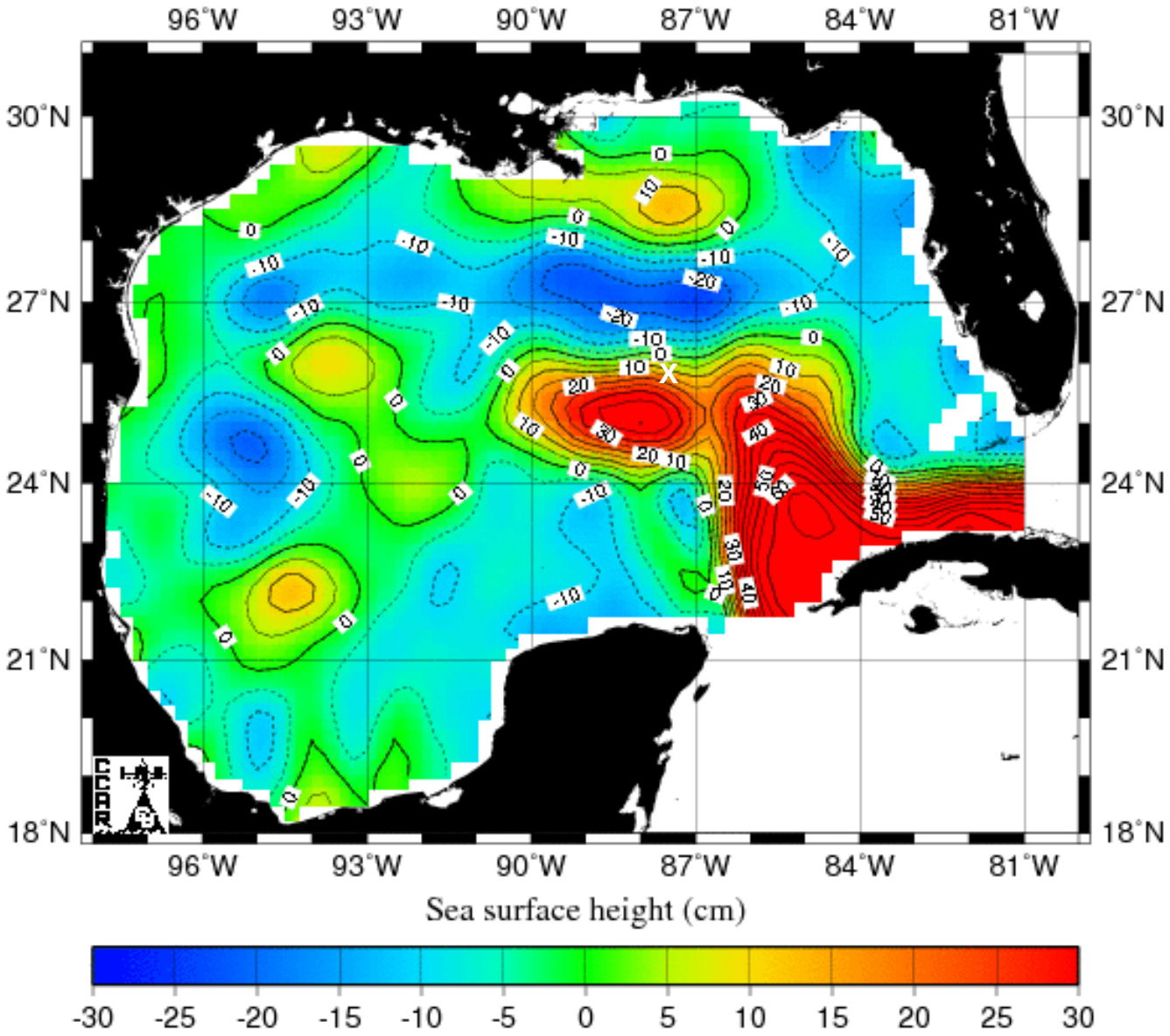

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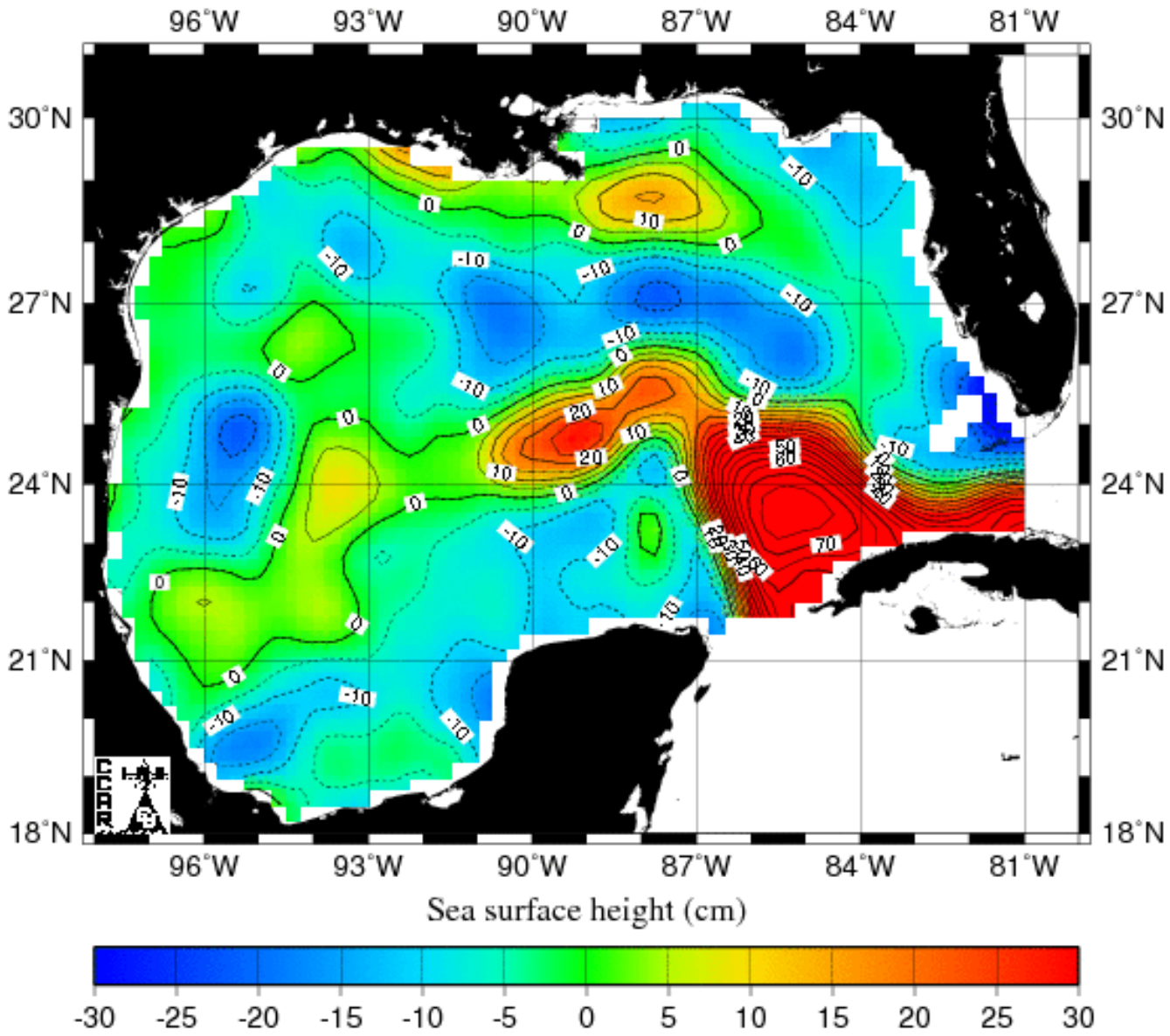

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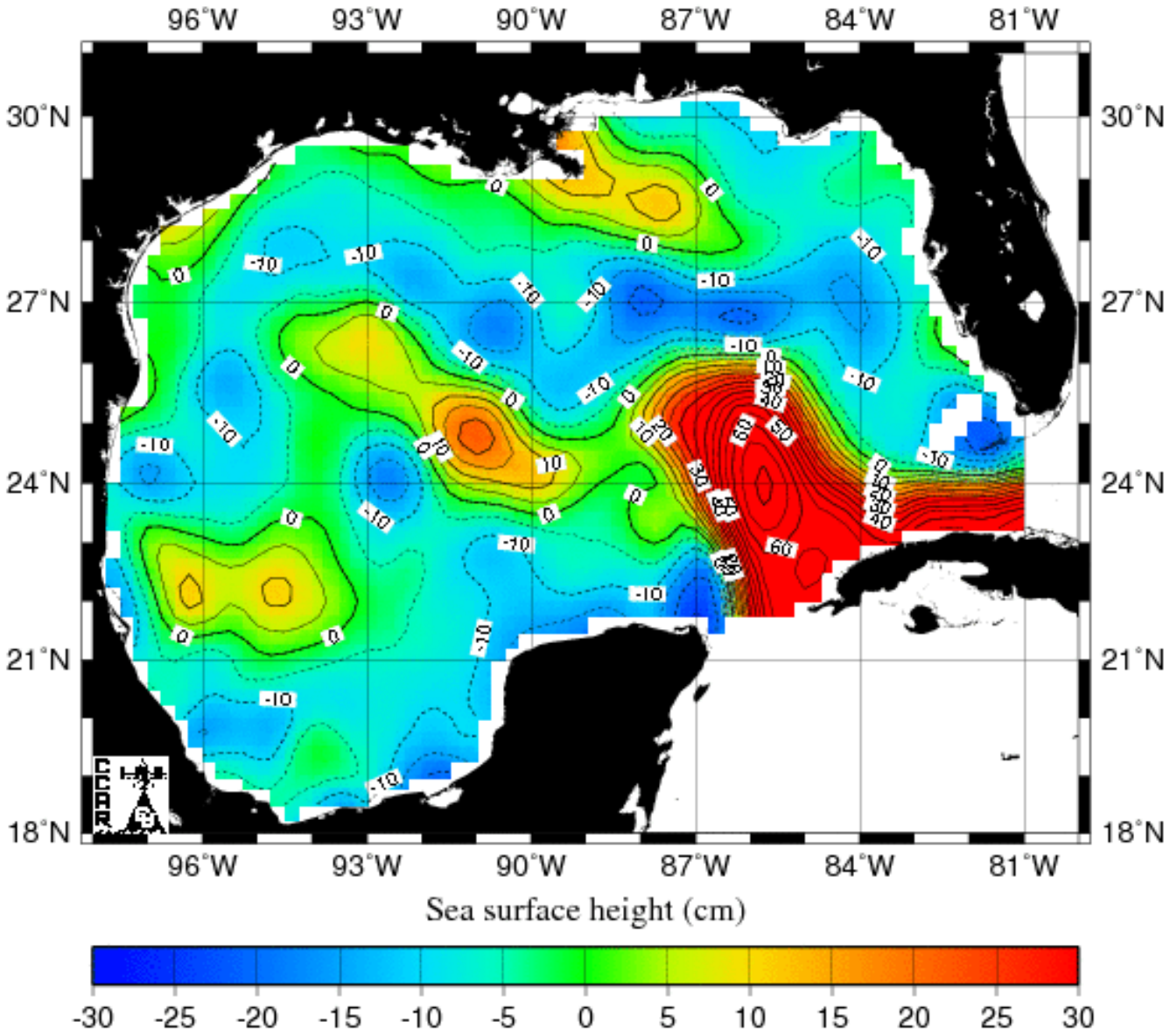

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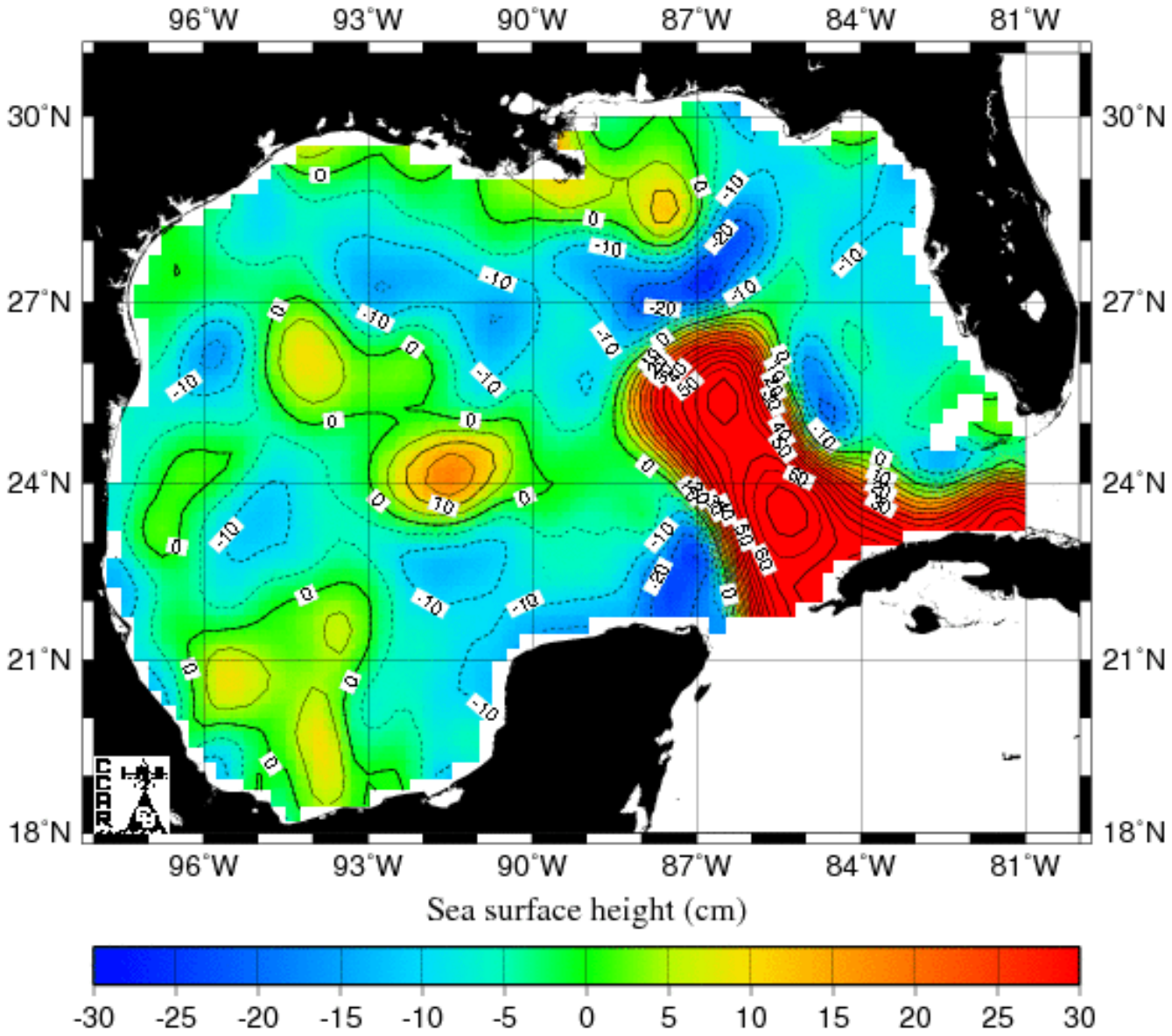

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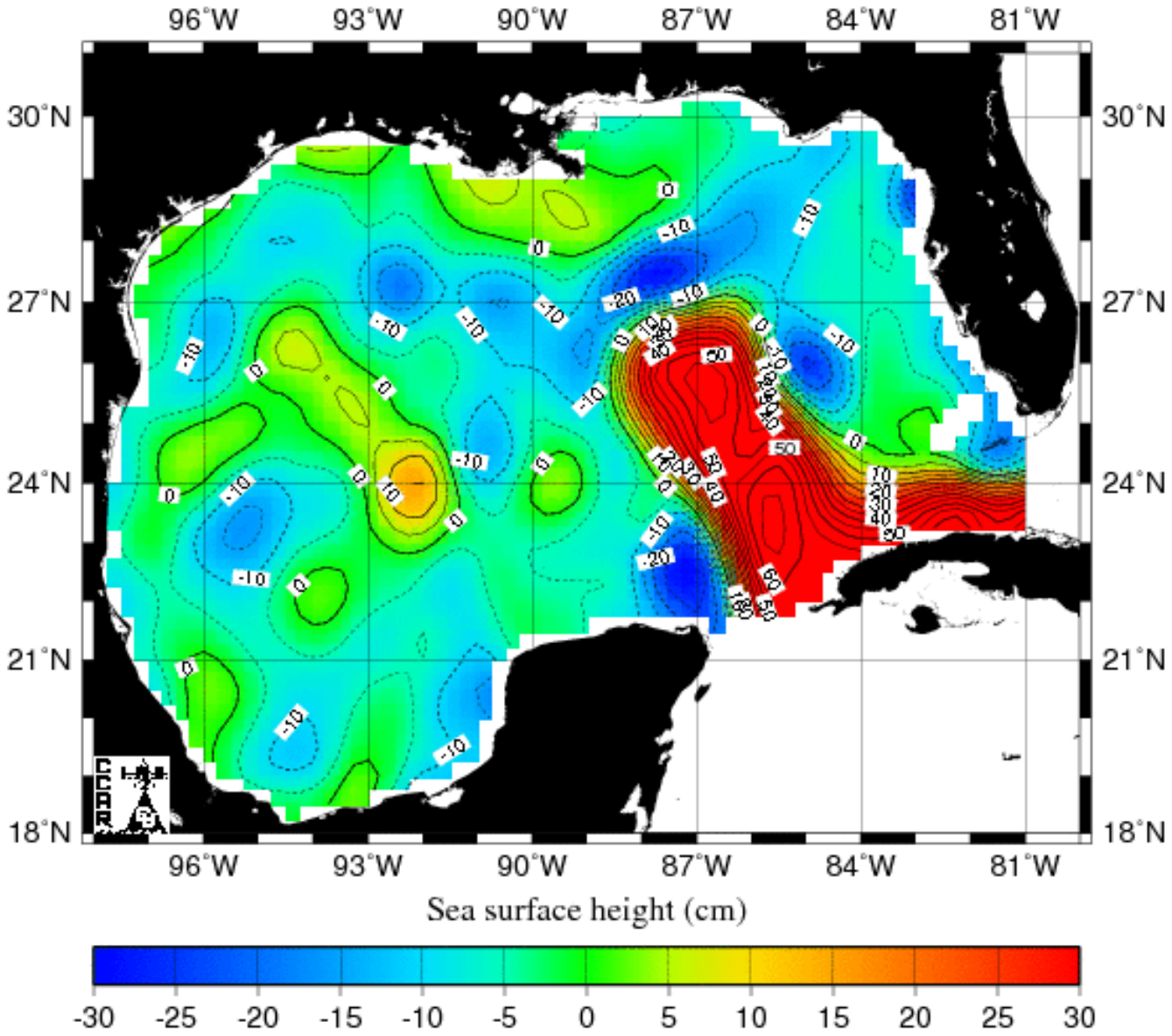

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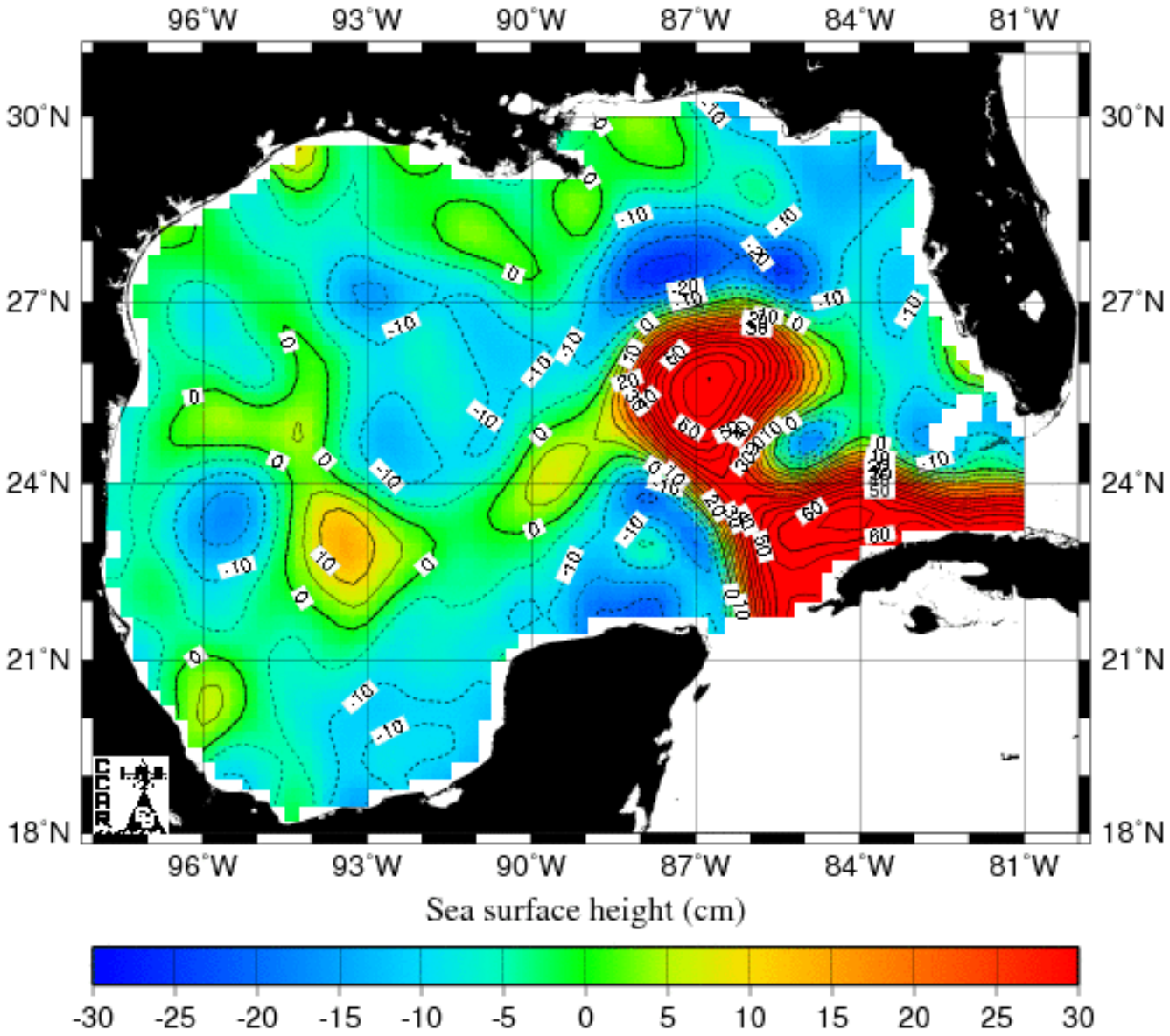

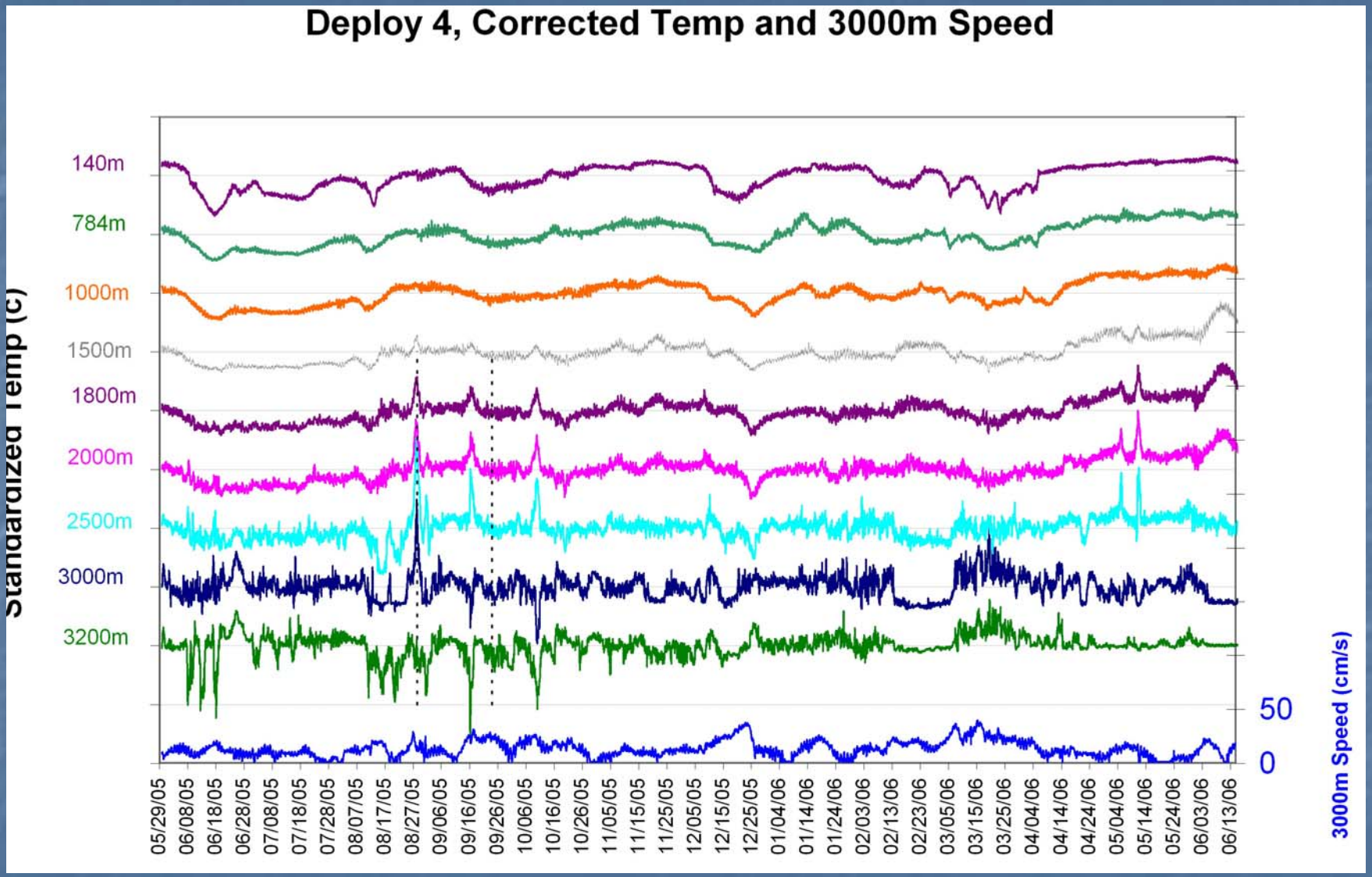
Deploy 4, Corrected Temp and 3000m Speed
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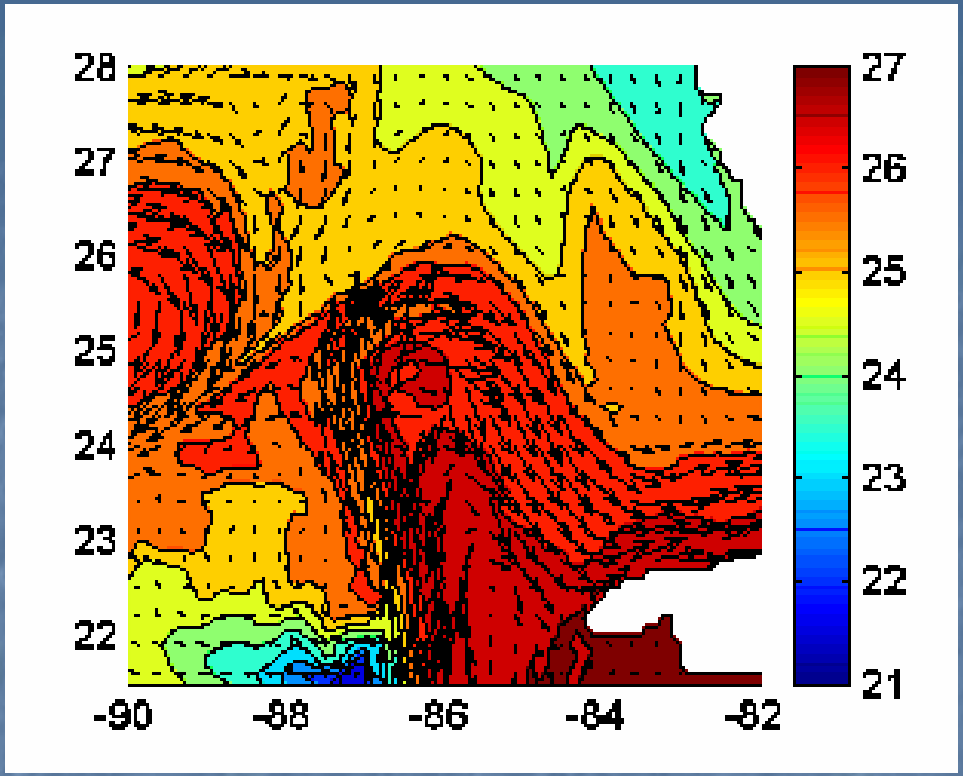
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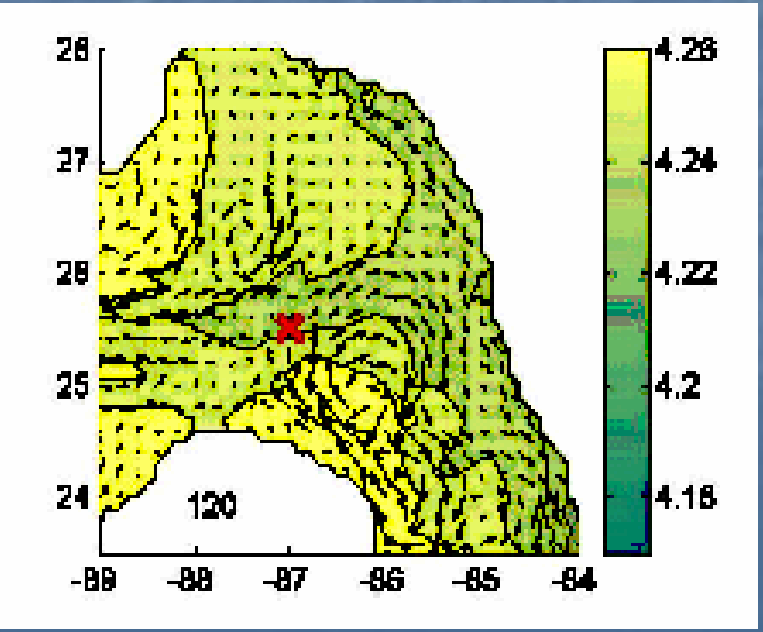
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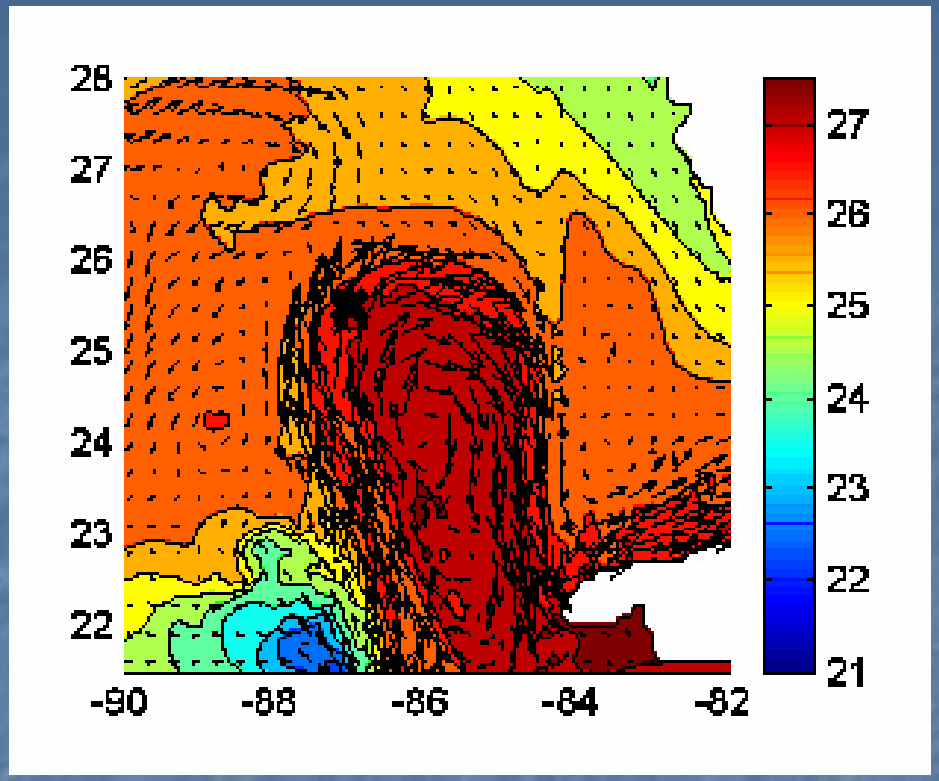
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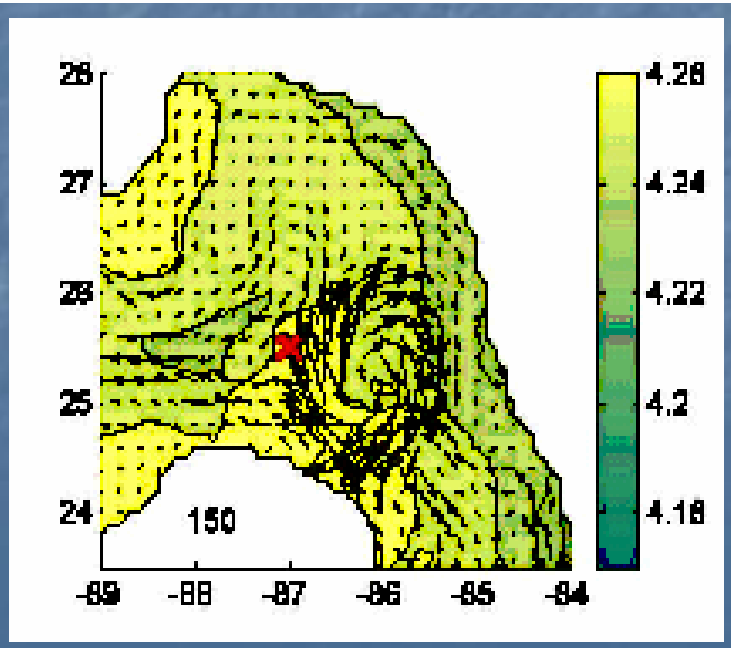
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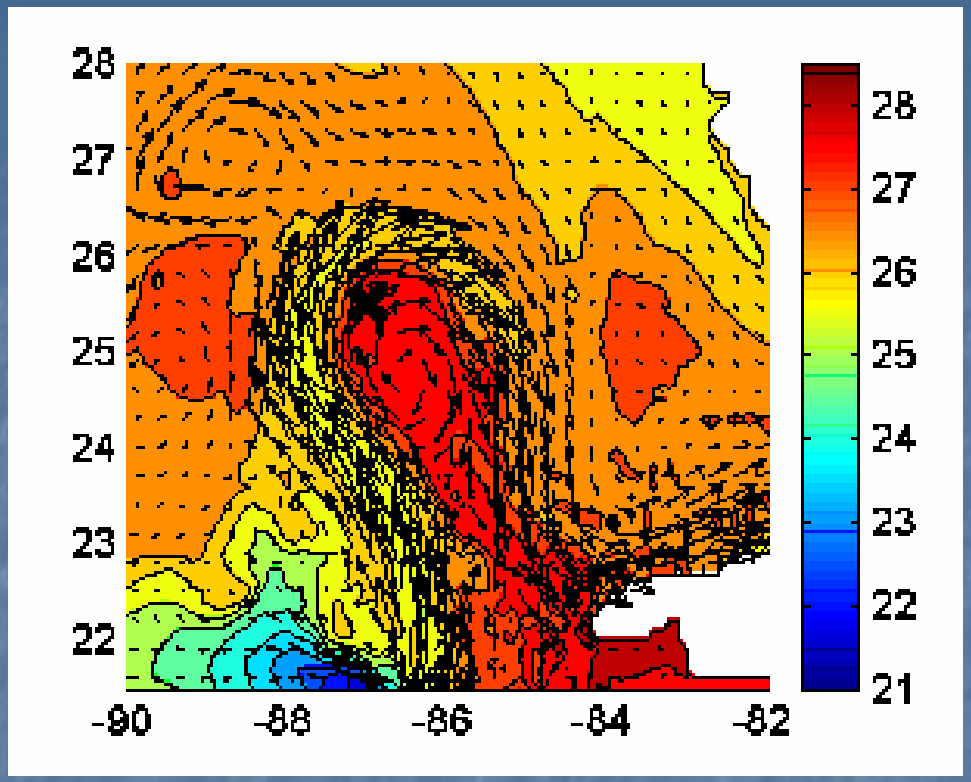
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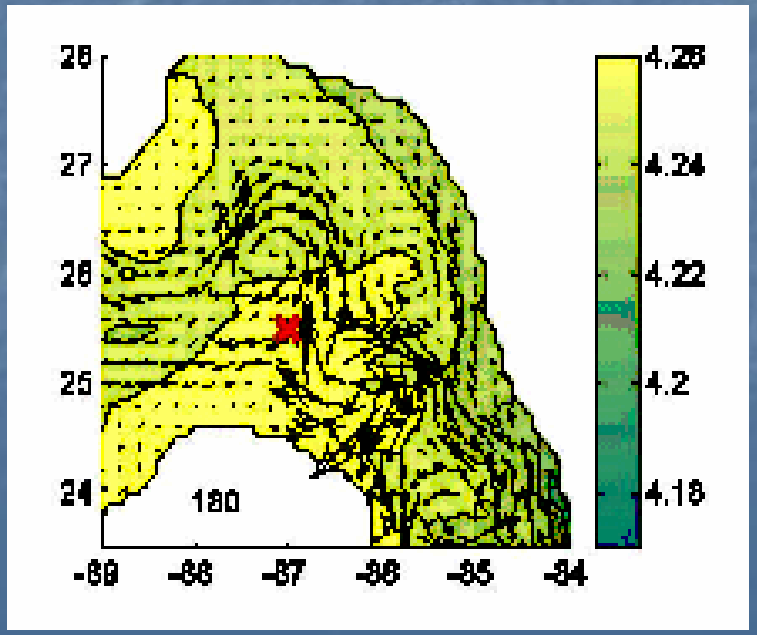
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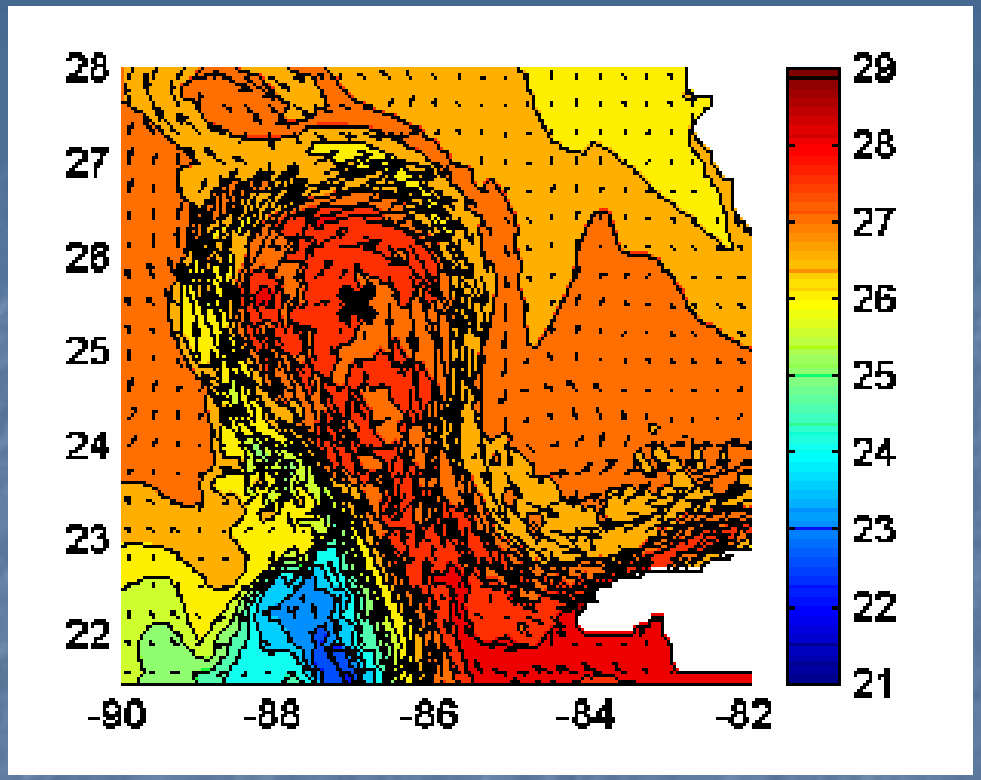
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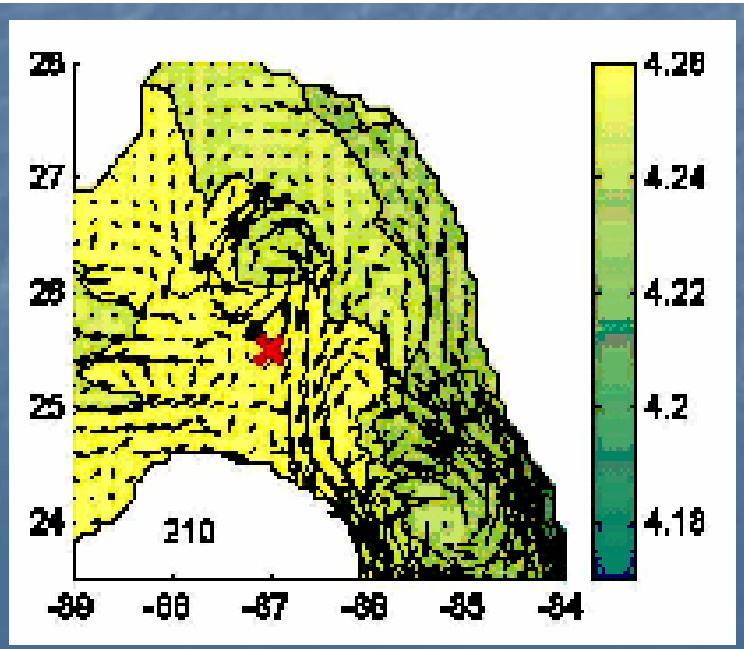
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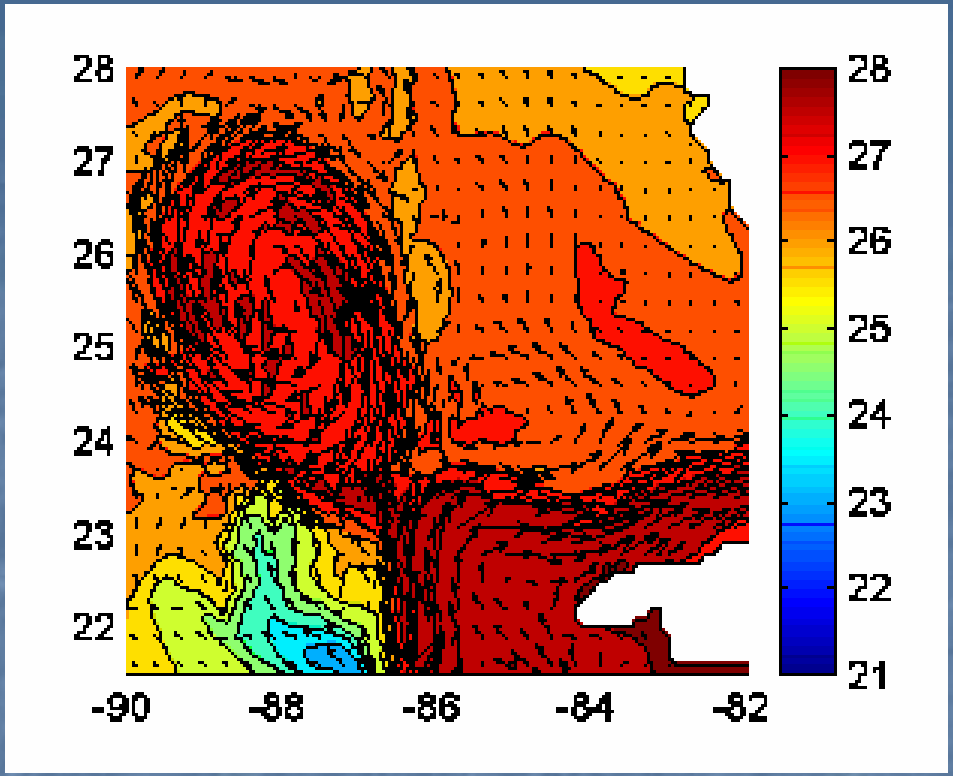
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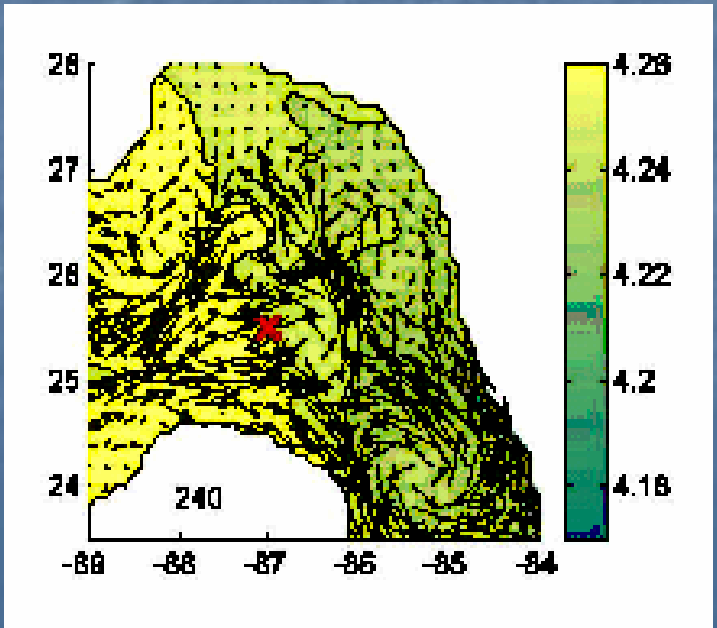
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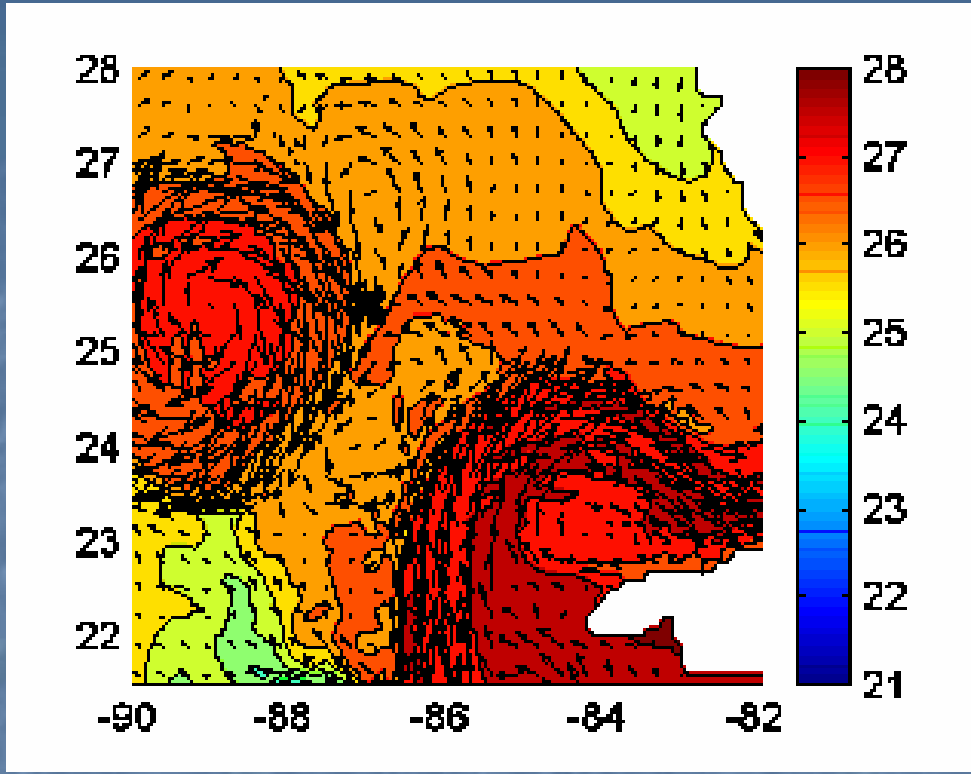
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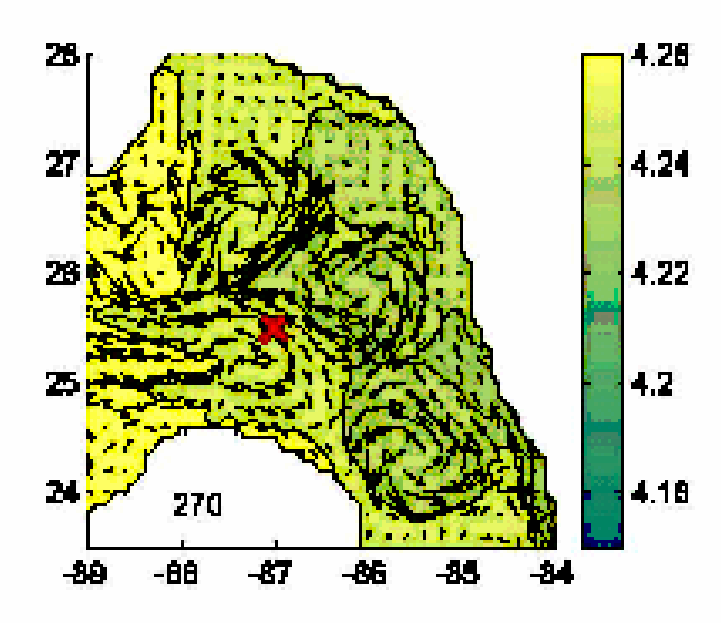
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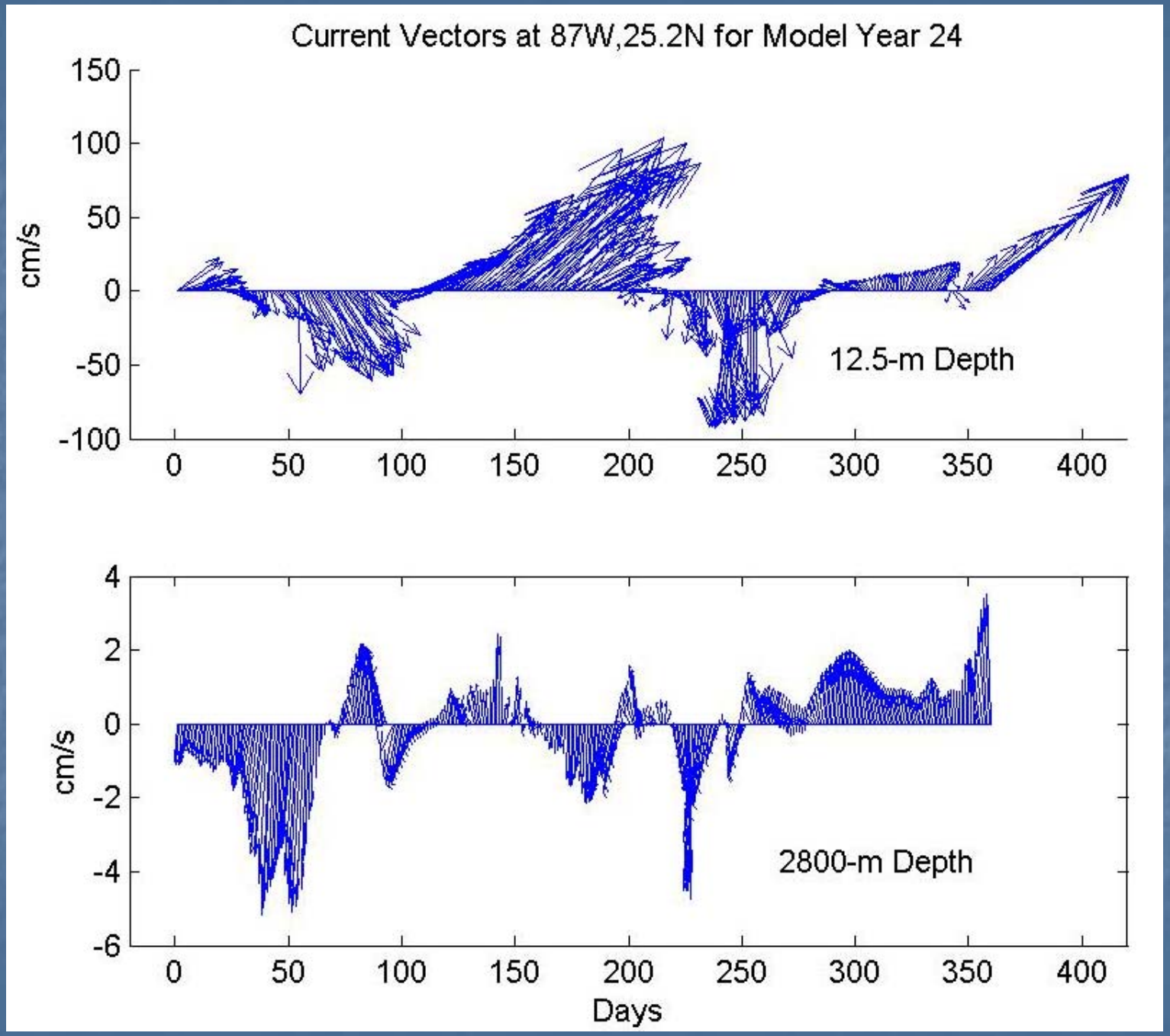
4.2
4.18


Current Vectors at 87W,25.2N for Model Year 24
150
100
50
0
-50
-100
cm/s
0
50
100
150
200
250
300
350
400
12.5-m Depth
4
2
0
-2
-4
-6
cm/s
2800-m Depth
Days

Summary

- Decoupling of upper- and lower-layer flow
- Northward surge in deepwater associated with the formation of LC rings
- Interannual shift in deepwater energy level
- Energetic events in deepwater are associated with T&S signal. What are they?
- T&S signal in deepwater show some depth dependency.

References

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