Satellite Altimetry use in Marine Forecasting at NOAA

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NOAA / National Weather Service

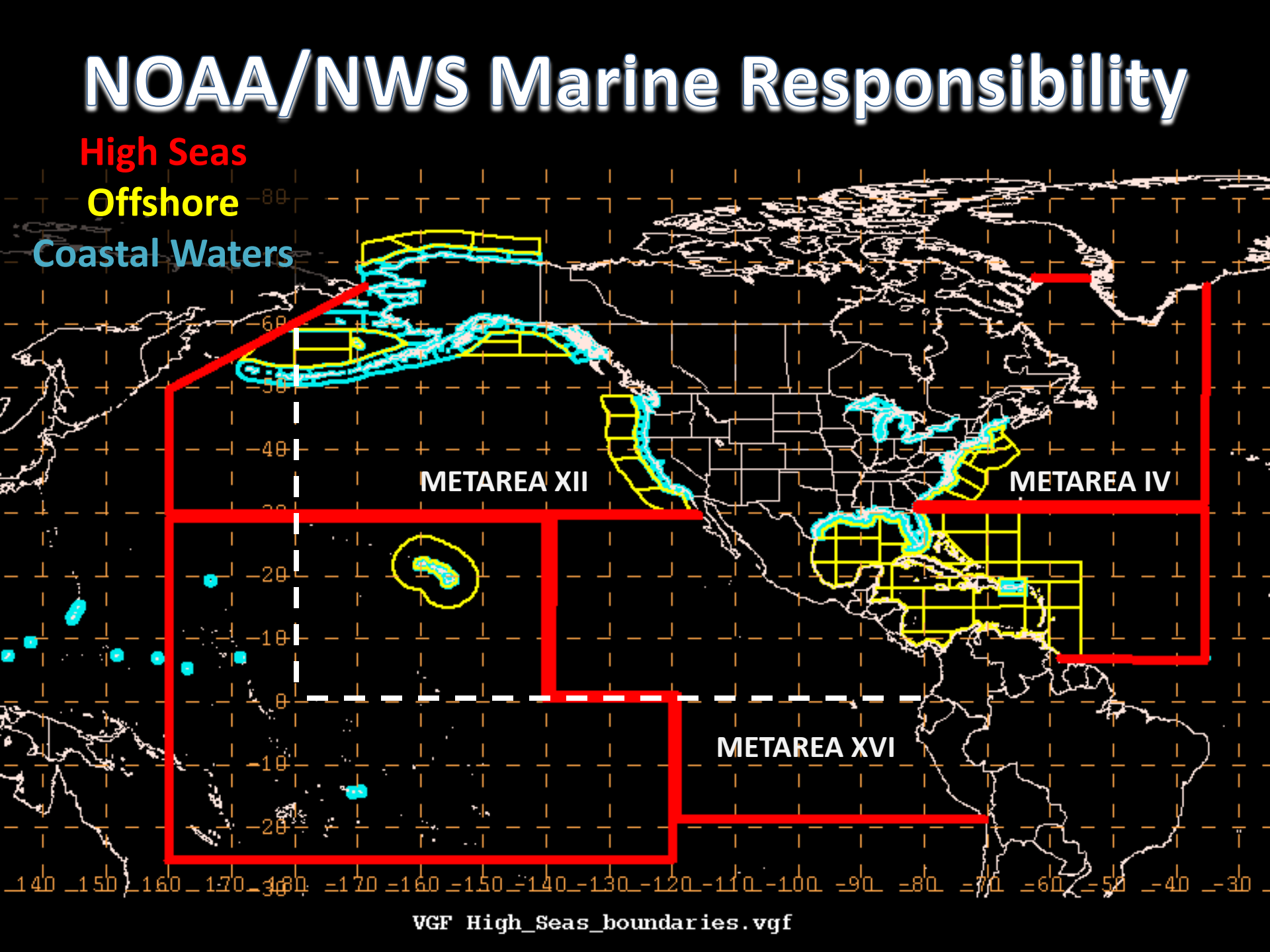
weather.gov

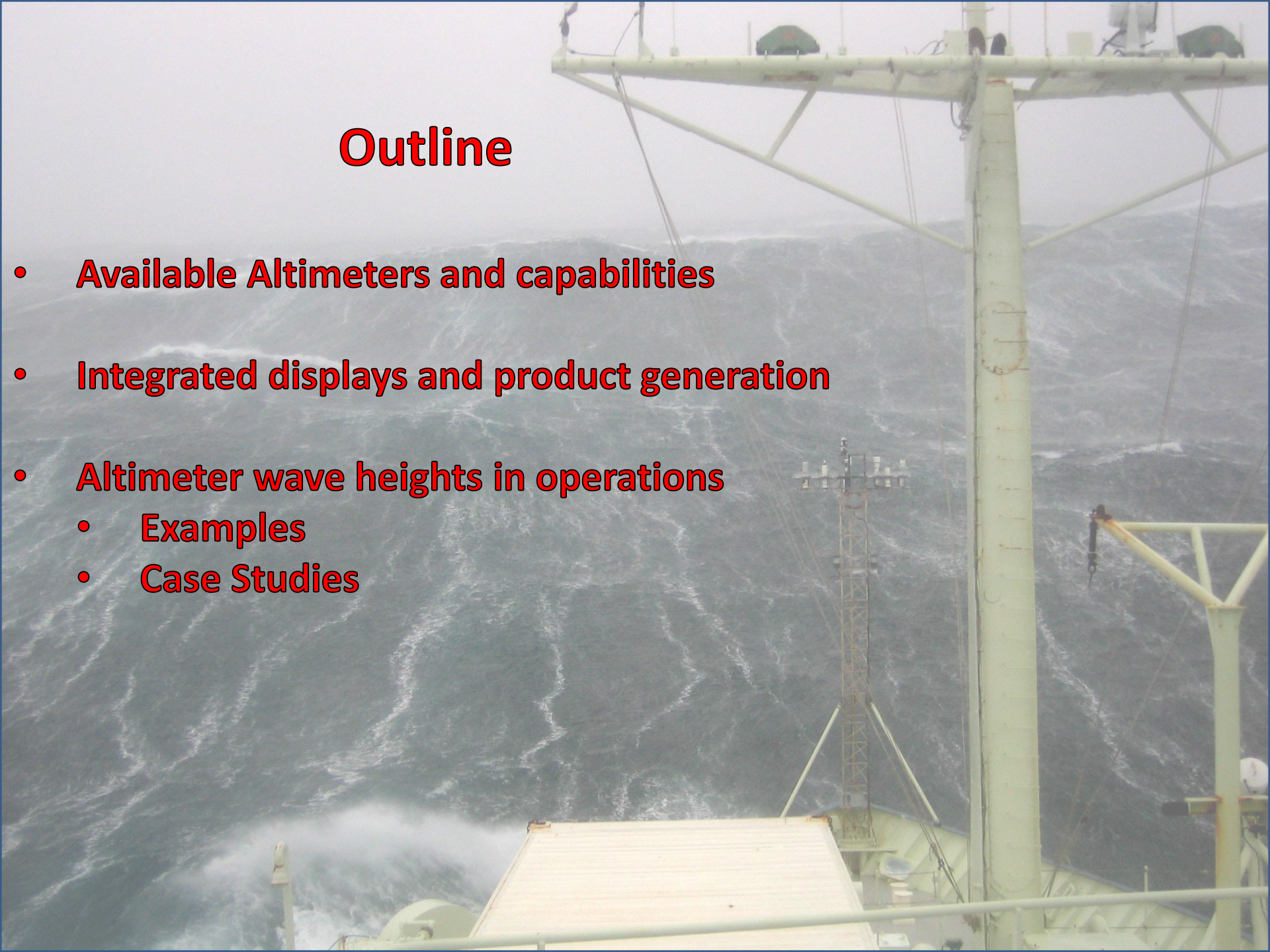
Ocean Prediction Center

www.opc.ncep.noaa.gov

Satellite Altimetry - EUMETSAT

NOAA/NWS Marine Responsibility

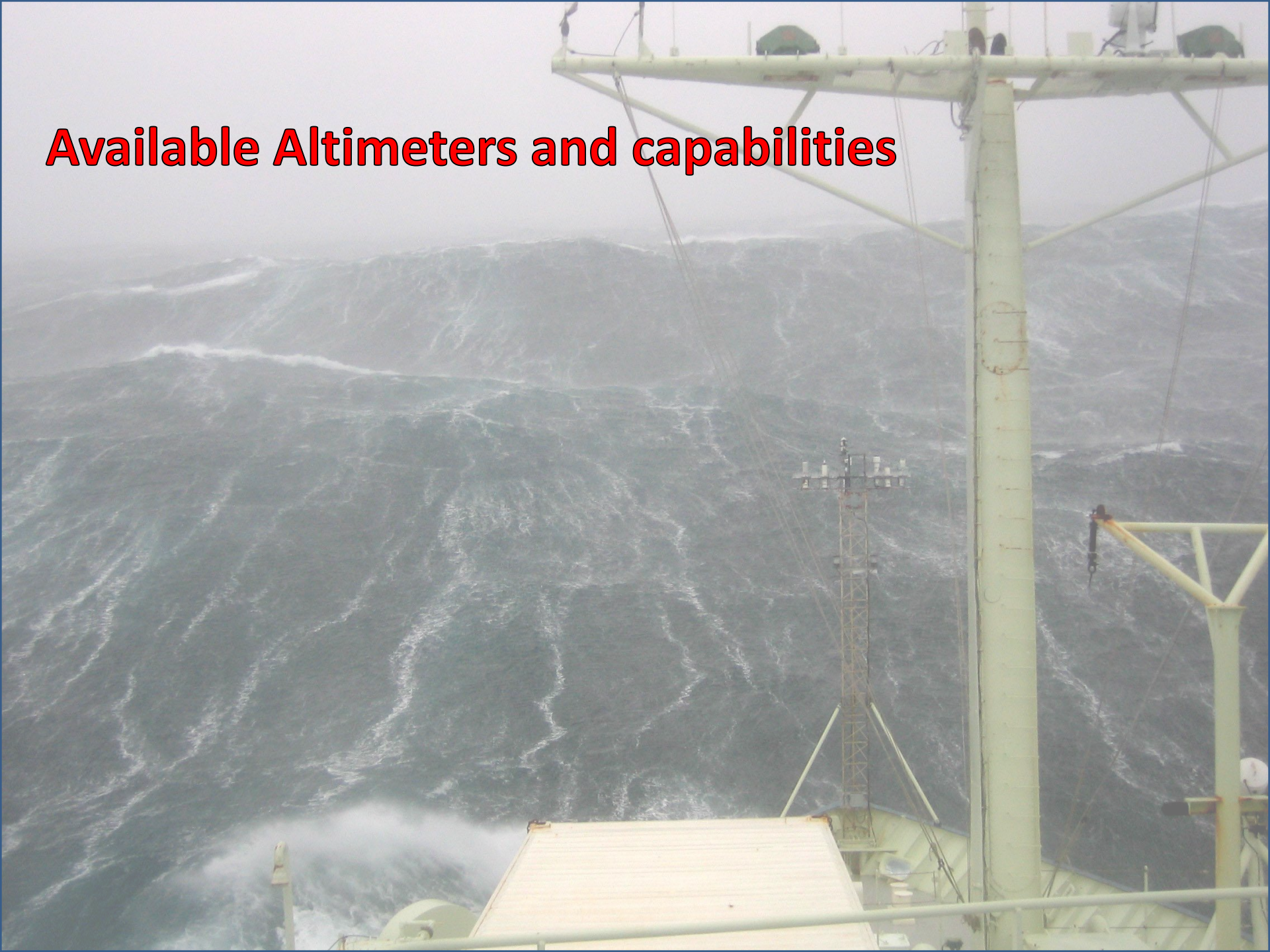




Outline

- Available Altimeters and capabilities
- Integrated displays and product generation
- Altimeter wave heights in operations
  - Examples
  - Case Studies

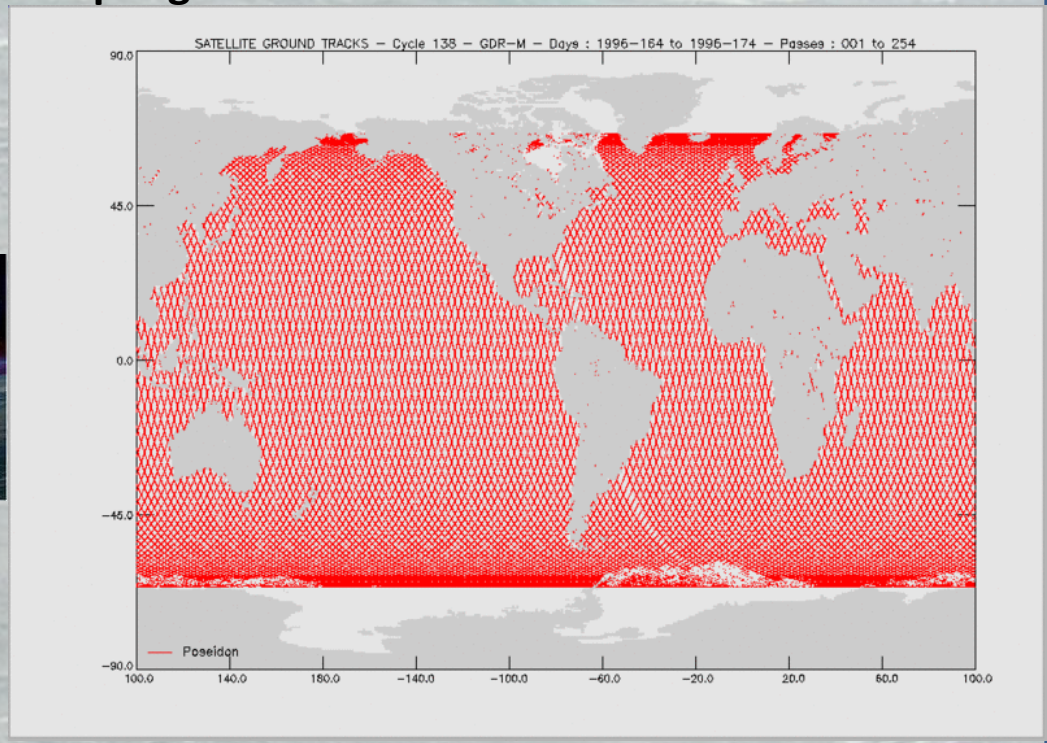
Available Altimeters and capabilities



OSTM / Jason-2

- **OSTM / Jason-2** - extend into the next decade the continuous climate record of sea surface height measurements begun in 1992 by the joint NASA/Centre National d'Etudes Spatiales (CNES) Topex/Poseidon mission and continued in 2001 by the NASA/CNES Jason-1 mission.
- **Parameters**
  - Sea Surface Height
  - Significant Wave Height
  - Wind speed
- **Applications** -
  - routing ships
  - improving the safety and efficiency of offshore operations
  - managing fisheries
  - forecasting hurricanes
  - monitoring river and lake levels.
- **Collaboration**
  - CNES
  - NASA
  - NOAA
- **Orbit**
  - **10 day repeat cycle**
  - **66 degree inclination orbit**
- **Launch – June 2008**

Sampling 1 hz ~ 6-7 km

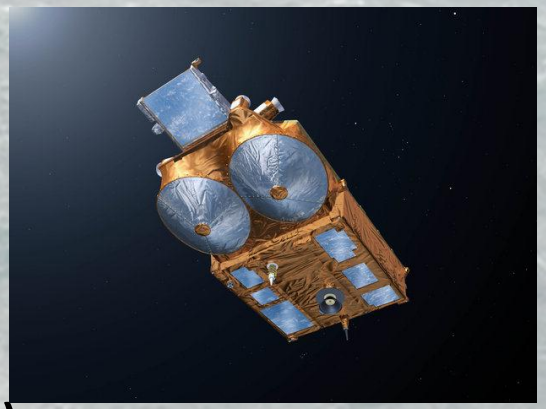


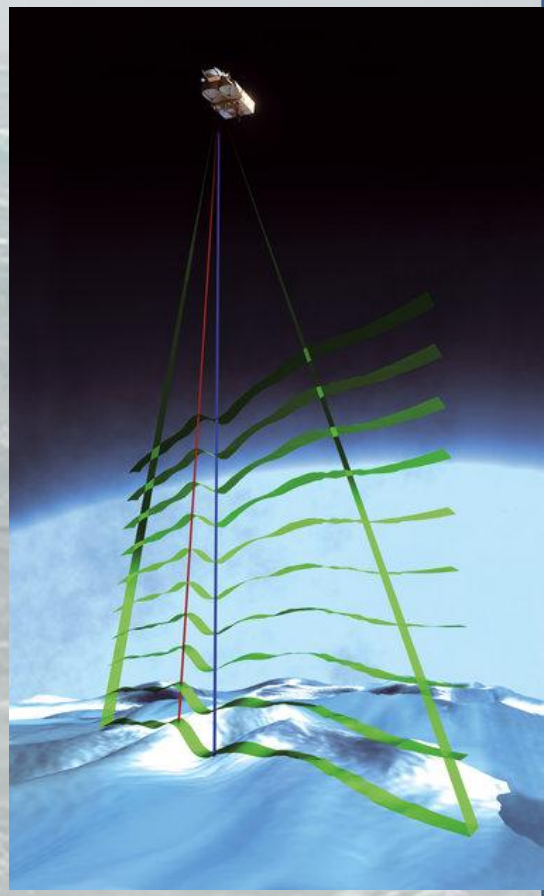
http://www.aviso.oceanobs.com/en/missions/current-missions.html
http://www.nasa.gov/mission_pages/ostm/overview/index.html#.UmUOjhzkt1Q

CryoSat-2

- **CryoSat-2 -** to measure ice thickness on both land and sea very precisely to provide conclusive proof as to whether there is a trend toward diminishing polar ice cover, furthering our understanding of the relationship between ice and global climate
- **Instrument**
  - SIRAL (SAR Interferometric Radar Altimeter)
- **Parameters**
  - Thickness of floating sea ice
    - annual variations can be detected.
  - Detect small changes to ice sheets
  - Sea Surface Height
  - Significant Wave Height
  - Wind speed
- **Applications**
  - Input to ocean models
- **European Space Agency (ESA)**
- **Orbit**
  - **369 days with 30 day sub-cycle**
  - **88 degree inclination orbit**
- **Launch – April 2010**

Sampling 1 hz ~ 6-7 km



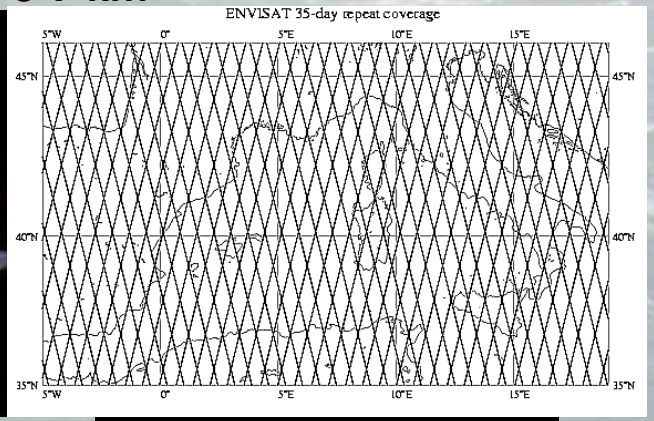


http://www.esa.int/Our_Activities/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers/CryoSat-2/Overview

Saral AltiKa

- **Saral AltiKa -** to carry out precise, repetitive global measurements of sea surface height for:
  - developing operational oceanography;
  - improving understanding of the climate and developing forecasting capabilities;
  - operational meteorology,
  - coastal, inland waters and ice applications.
- **Instrument**
  - AltiKA – Ka band radar altimeter (higher frequency than Ku band)
- **Parameters**
  - Thickness of floating sea ice
    - annual variations can be detected.
  - Detect small changes to ice sheets
  - Sea Surface Height
  - Significant Wave Height
  - Wind speed
- **Applications**
- for the meso-scale in open ocean,
- in coastal areas,
- for the seasonal forecast,
- for the climate studies.
- **CNES / ISRO**
- **Orbit – same as ENVISAT**
  - **501-pass, 35-day exact repeat cycle on a sun-synchronous orbit**
  - **98.55 degree inclination orbit**
- **Launch – February 2013**

Sampling 1 hz ~ 6-7 km



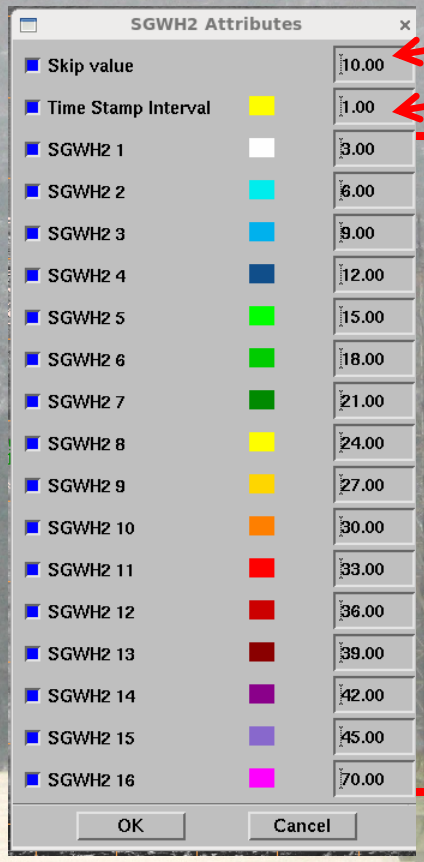
http://smsc.cnes.fr/SARAL/

Integrated Display / Product Capability

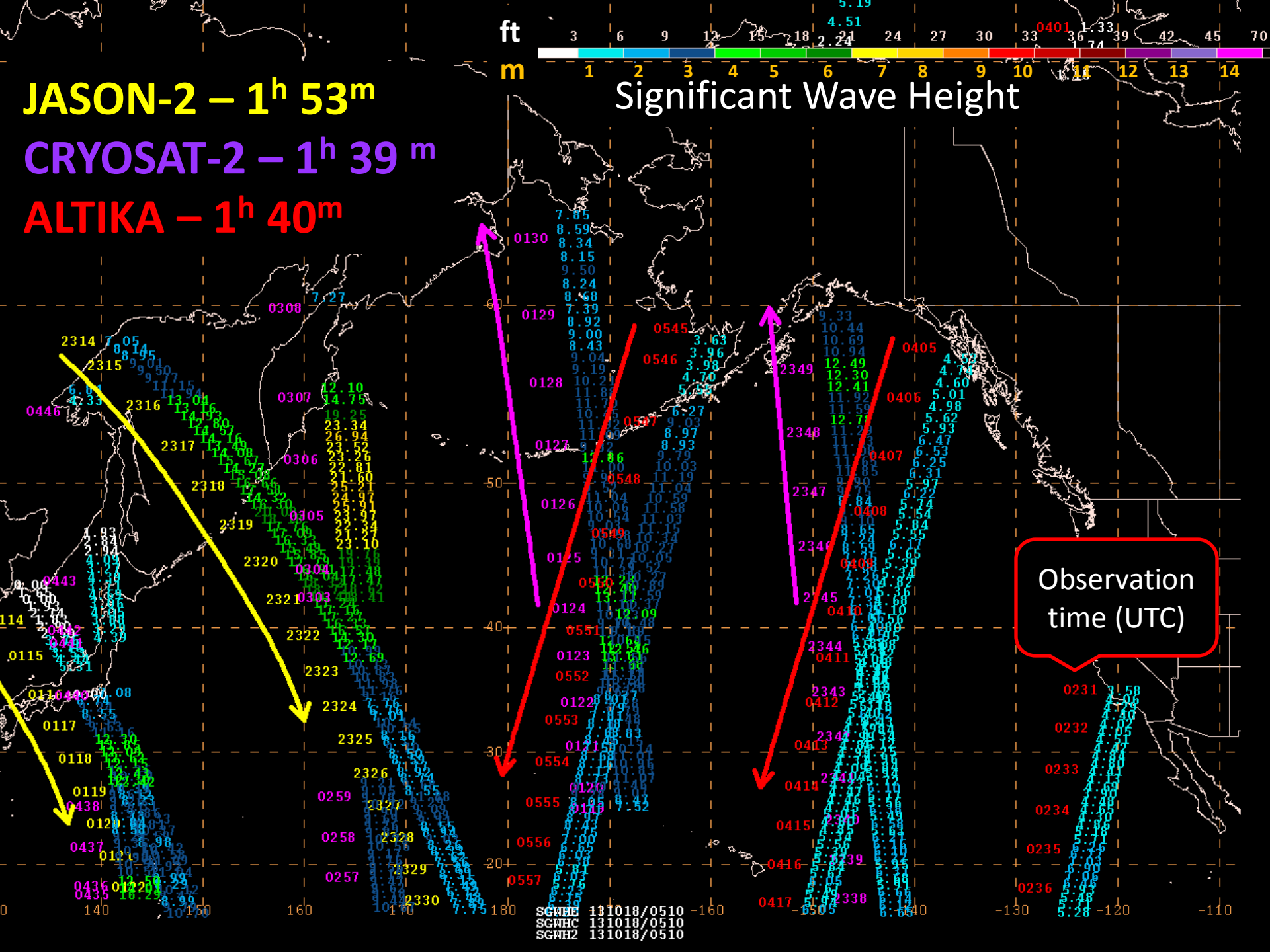
- GEMPAK based NAWIPS software
  - Moving to AWIPS II

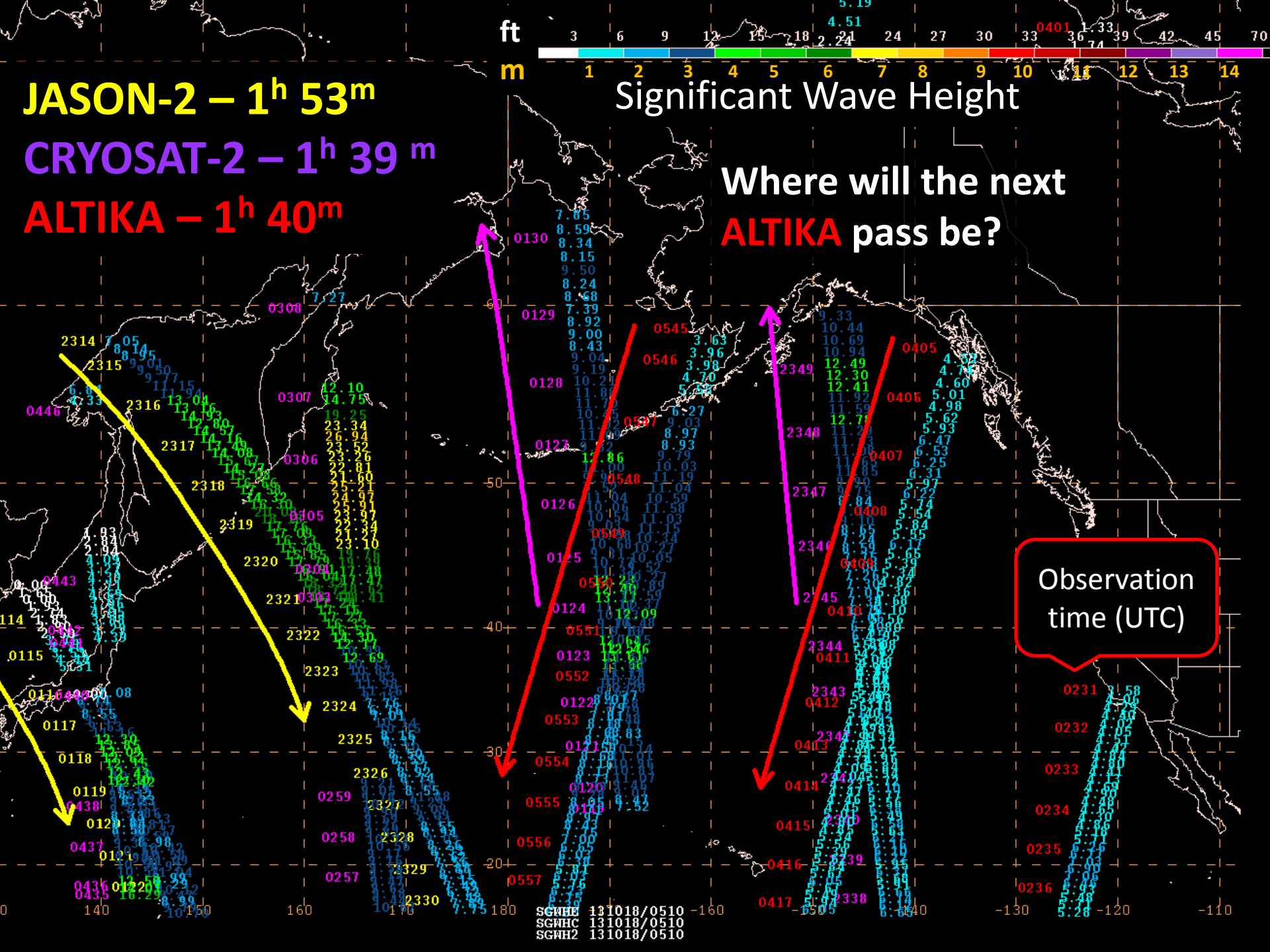
- Integrated data display
  - Numerical model output
  - Satellite imagery
  - Observations
    - Conventional
      - Surface
      - Upper air
    - Remotely sensed
      - Scatterometer
      - Altimeters
      - Lightning

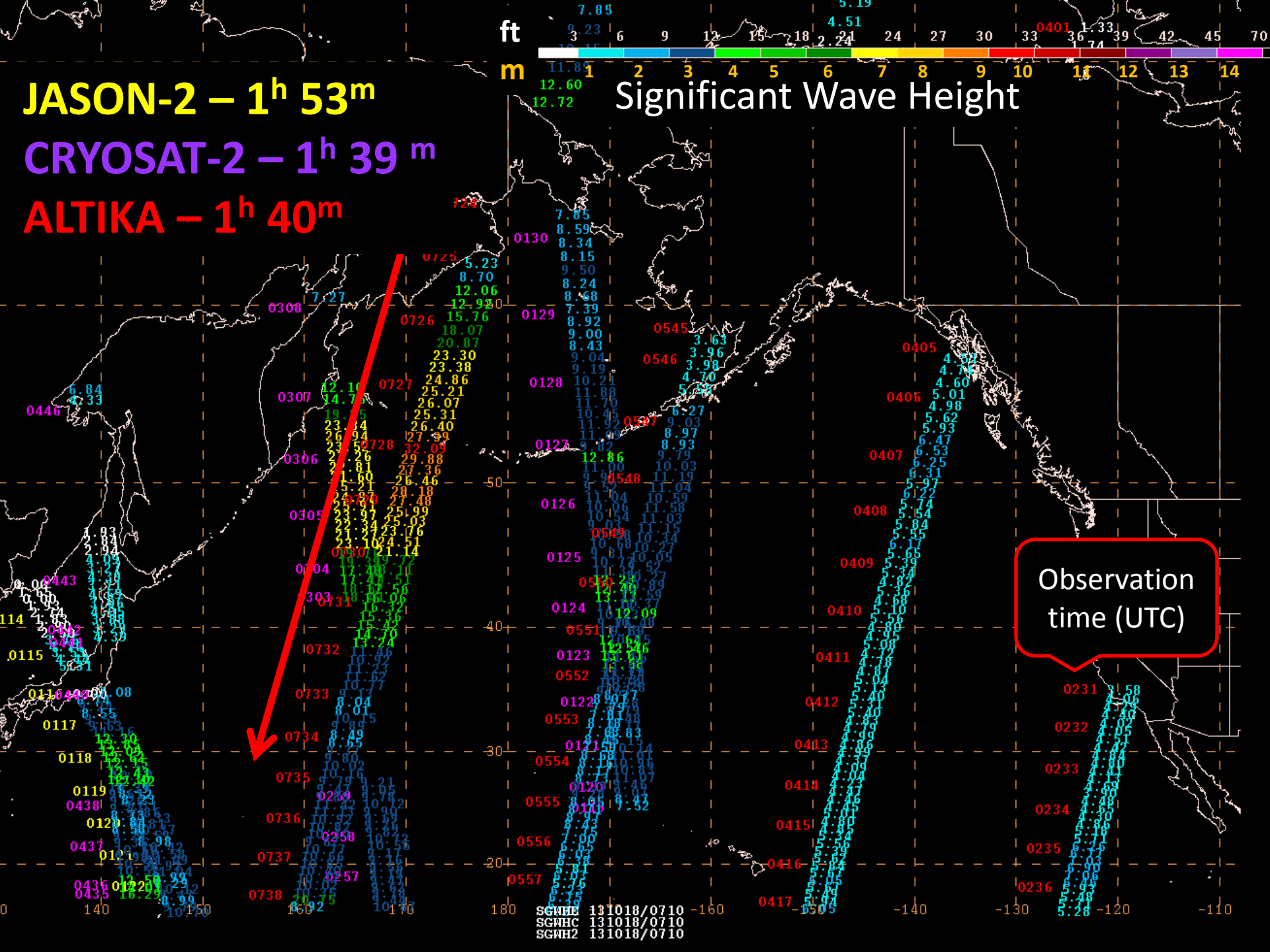
- Graphical Product Generation



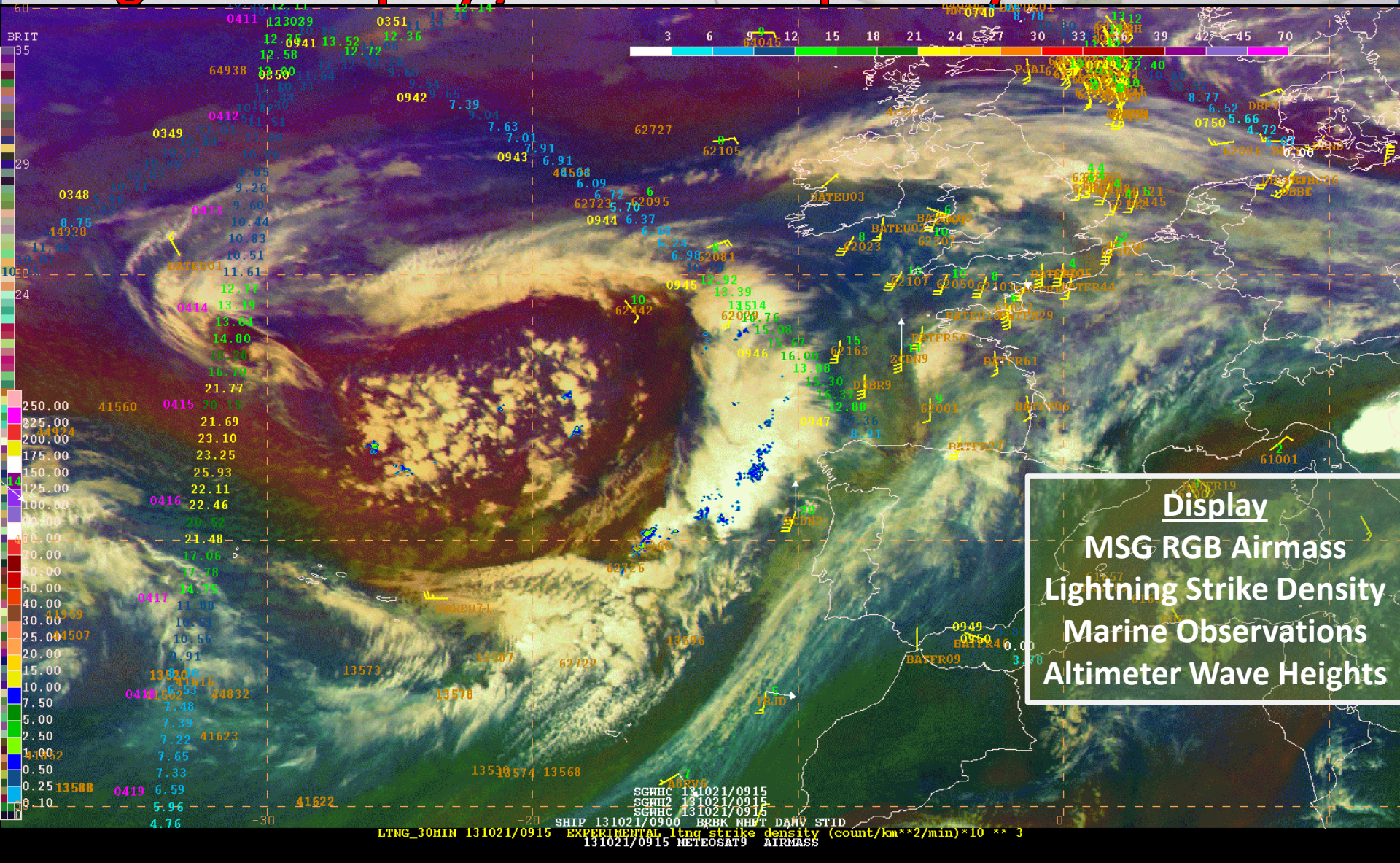
Edit Window
Plots every 10th value
Time stamp every minute
Color coded wave heights


JASON-2 – 1h 53m
CRYOSAT-2 – 1h 39 m
ALTIKA – 1h 40m
Significant Wave Height
ft
m
Observation time (UTC)
SGWHE 131018/0510
SGWHC 131018/0510
SGWH2 131018/0510

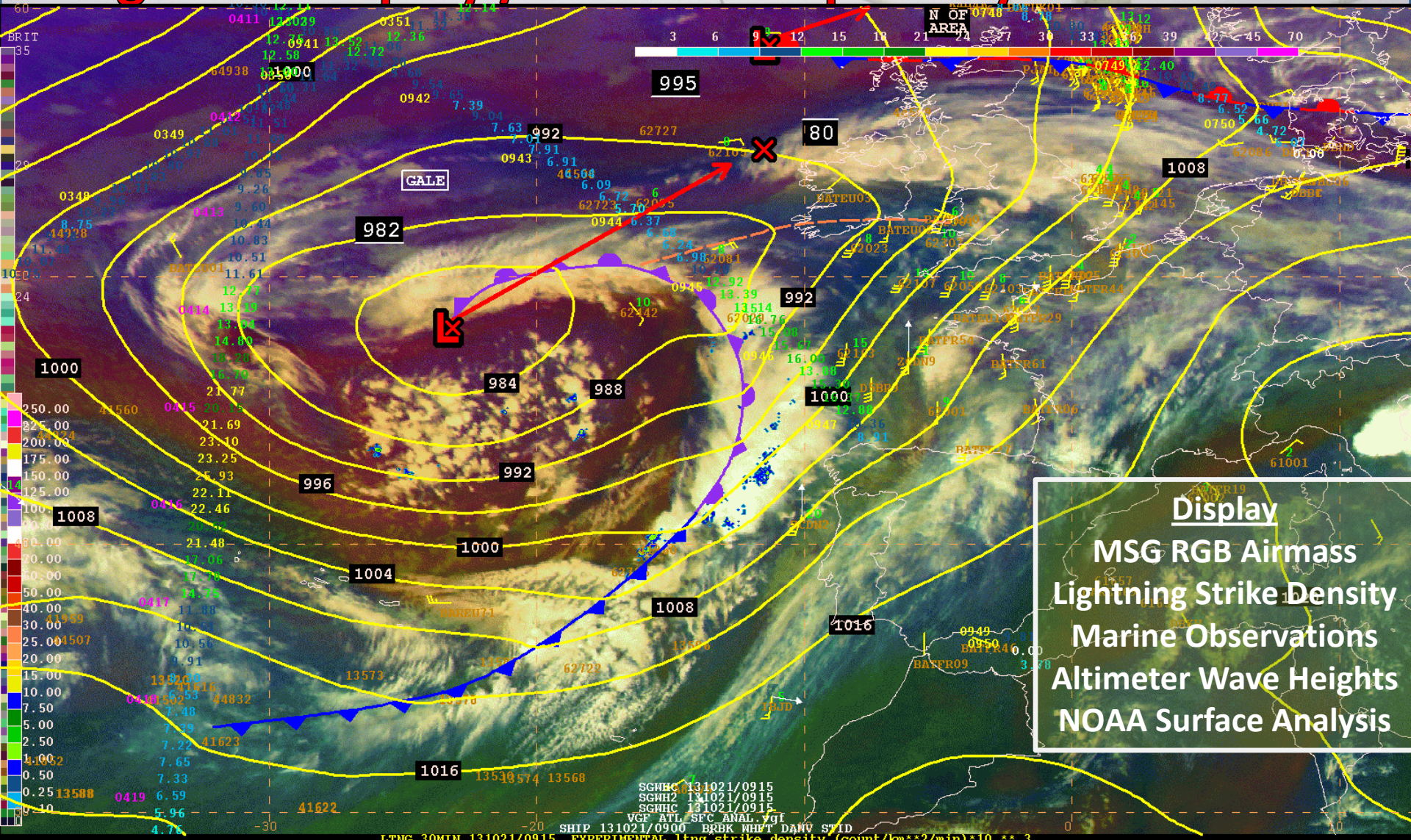

JASON-2 – 1h 53m
CRYOSAT-2 – 1h 39 m
ALTIKA – 1h 40m
Significant Wave Height
ft
m
Where will the next ALTIKA pass be?
Observation time (UTC)
SGWHE 131018/0510
SGWHC 131018/0510
SGWH2 131018/0510

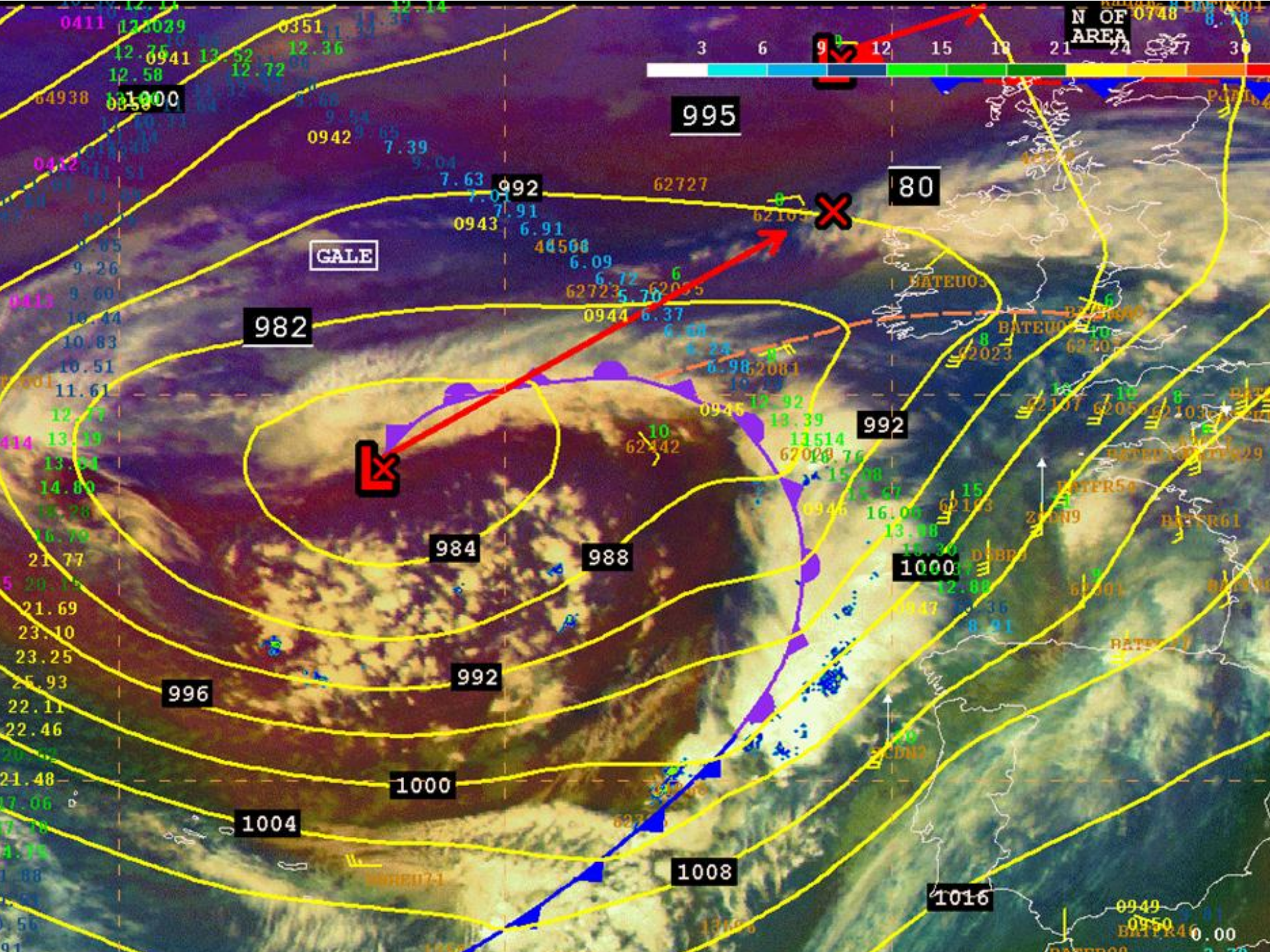

JASON-2 – 1h 53m
CRYOSAT-2 – 1h 39 m
ALTIKA – 1h 40m
ft
m
Significant Wave Height
Observation time (UTC)
SGWHE 131018/0710
SGWHC 131018/0710
SGWH2 131018/0710

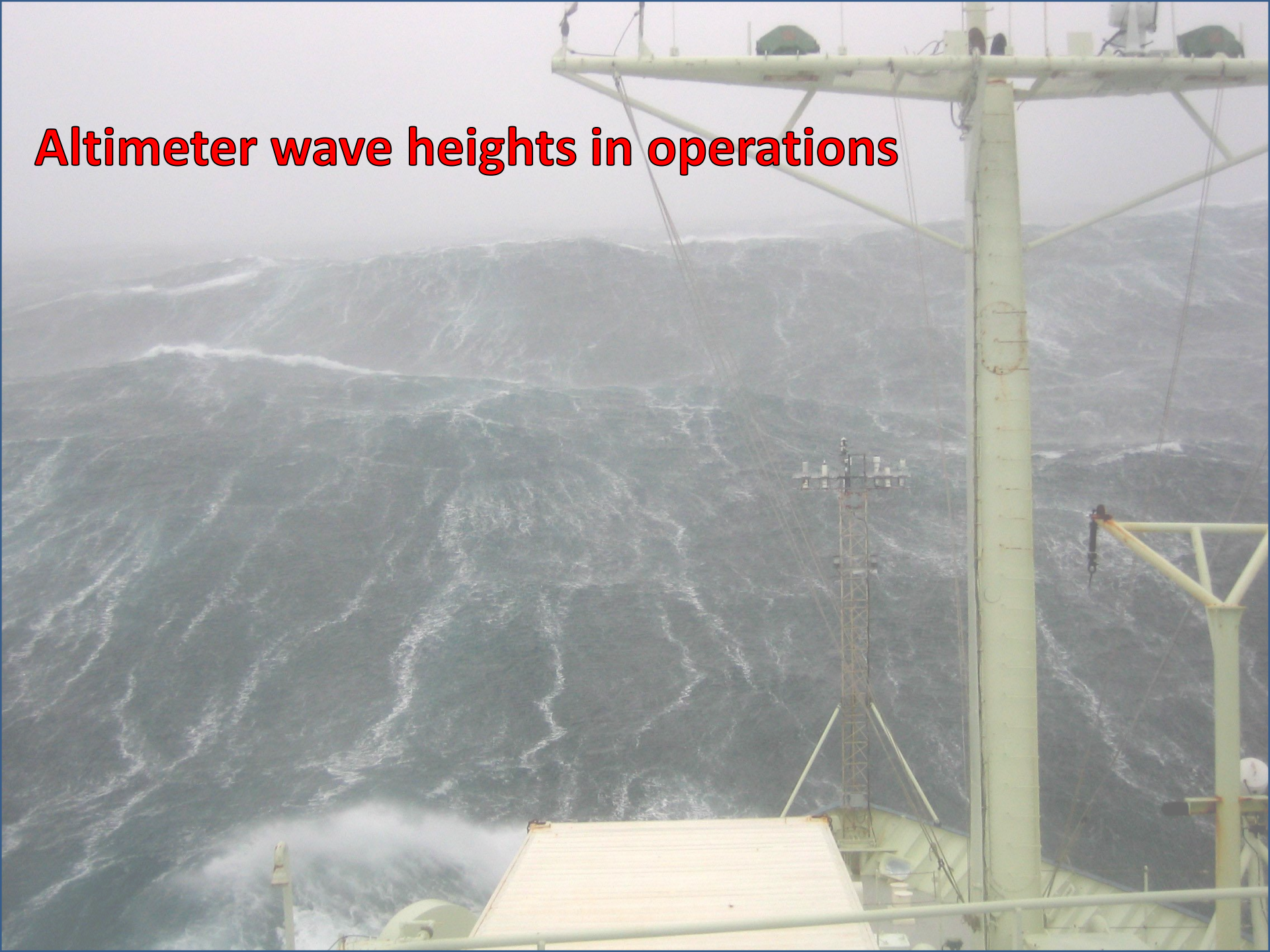
Integrated Display / Product Capability



Integrated Display / Product Capability

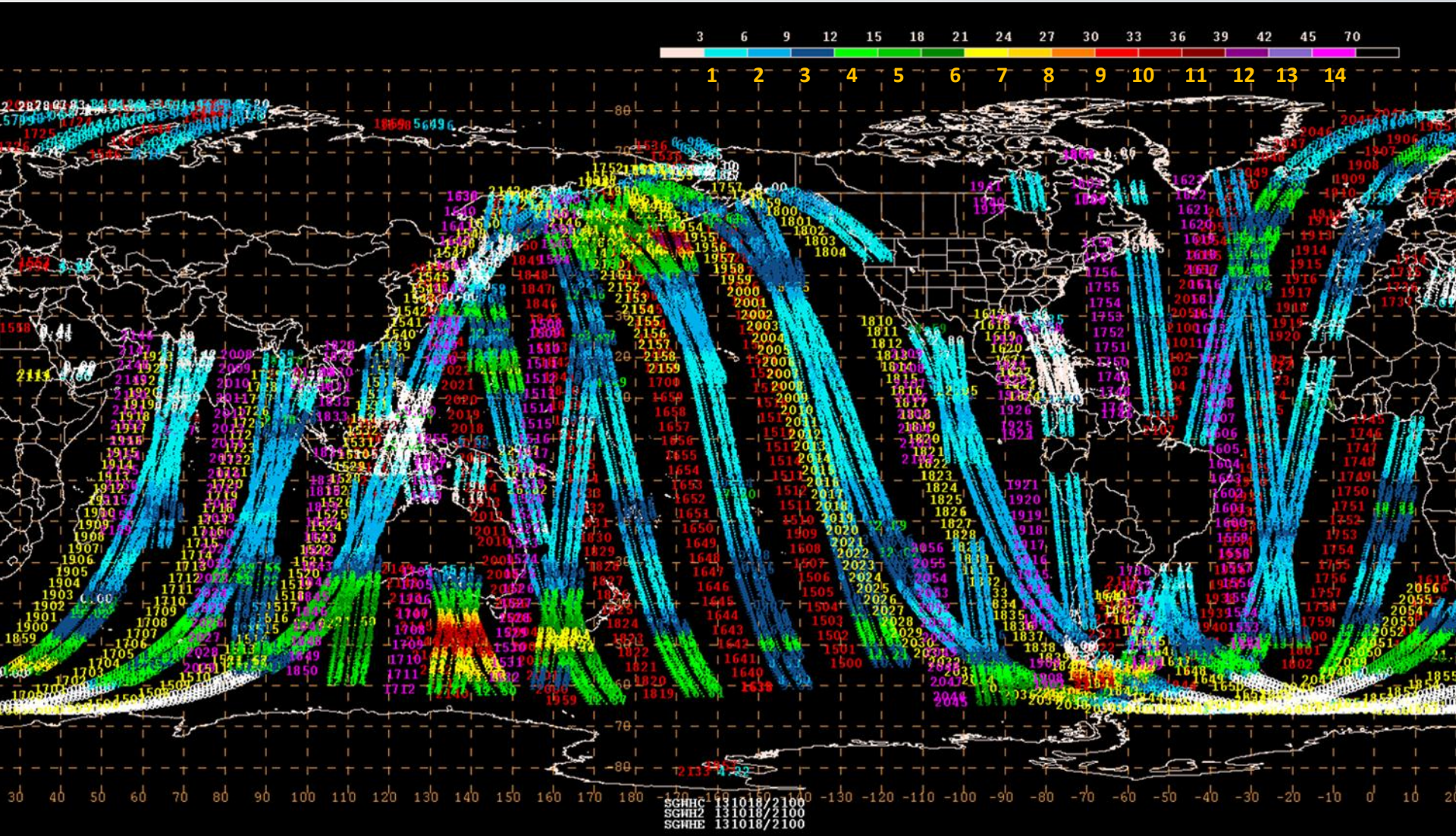



N OF AREA
3 6 9 12 15 18 21 24 27 30
995
80
992
GALE
982
992
984
988
1000
996
992
1000
1004
1008
1016


Altimeter wave heights in operations

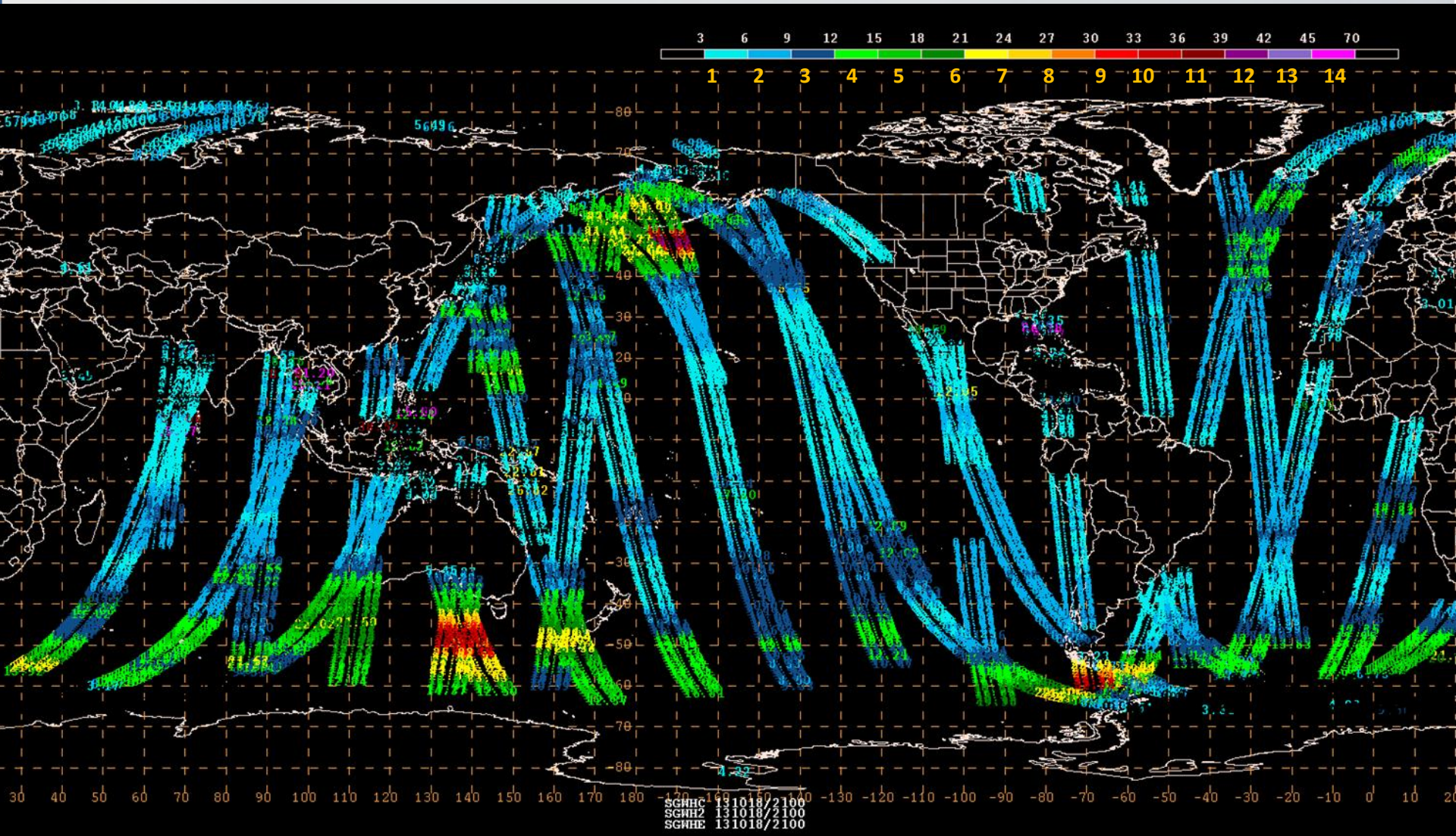
2100 UTC - 18 October 2013

6 hour collective of Altimeter wave heights



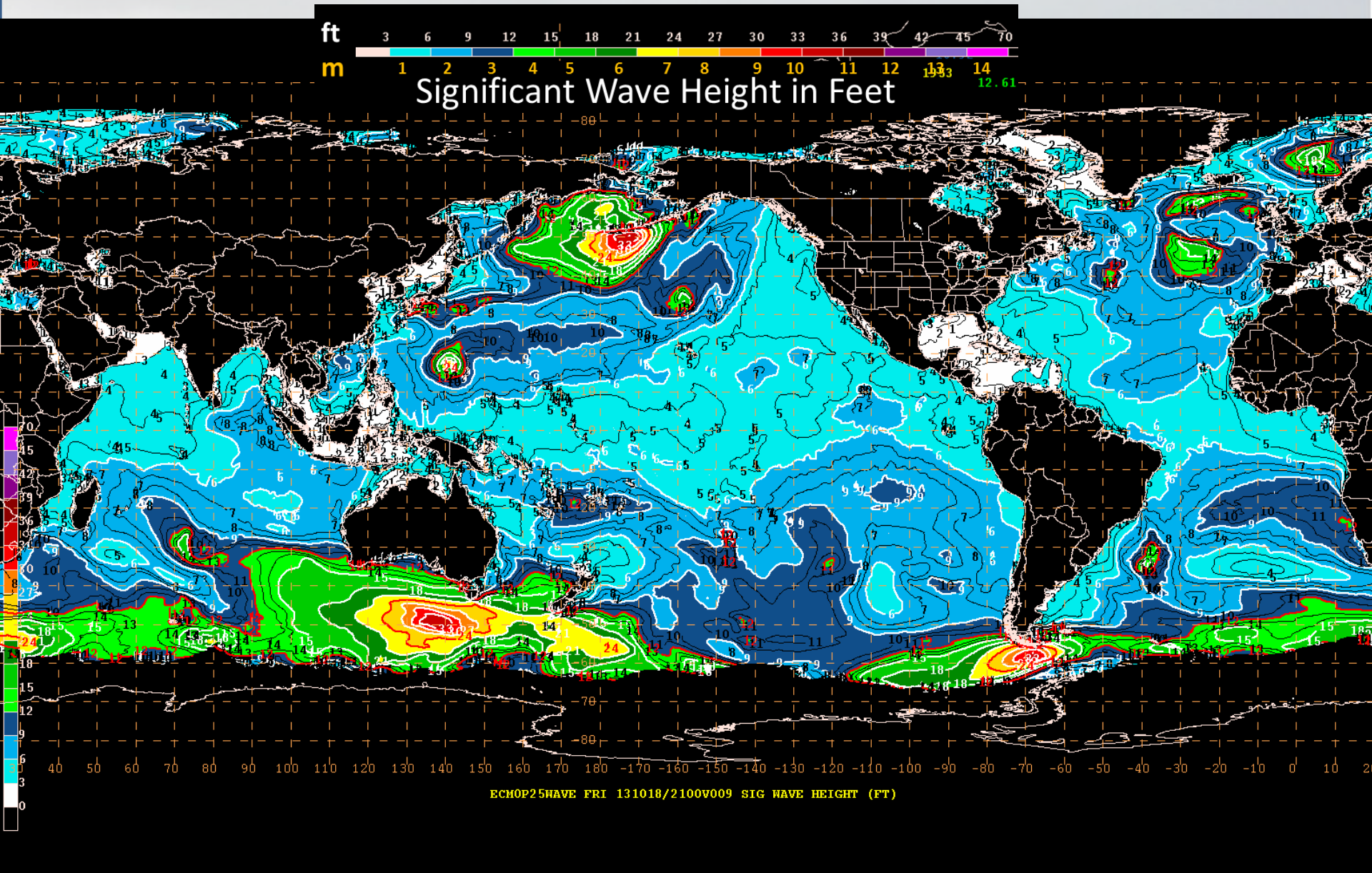
2100 UTC - 18 October 2013

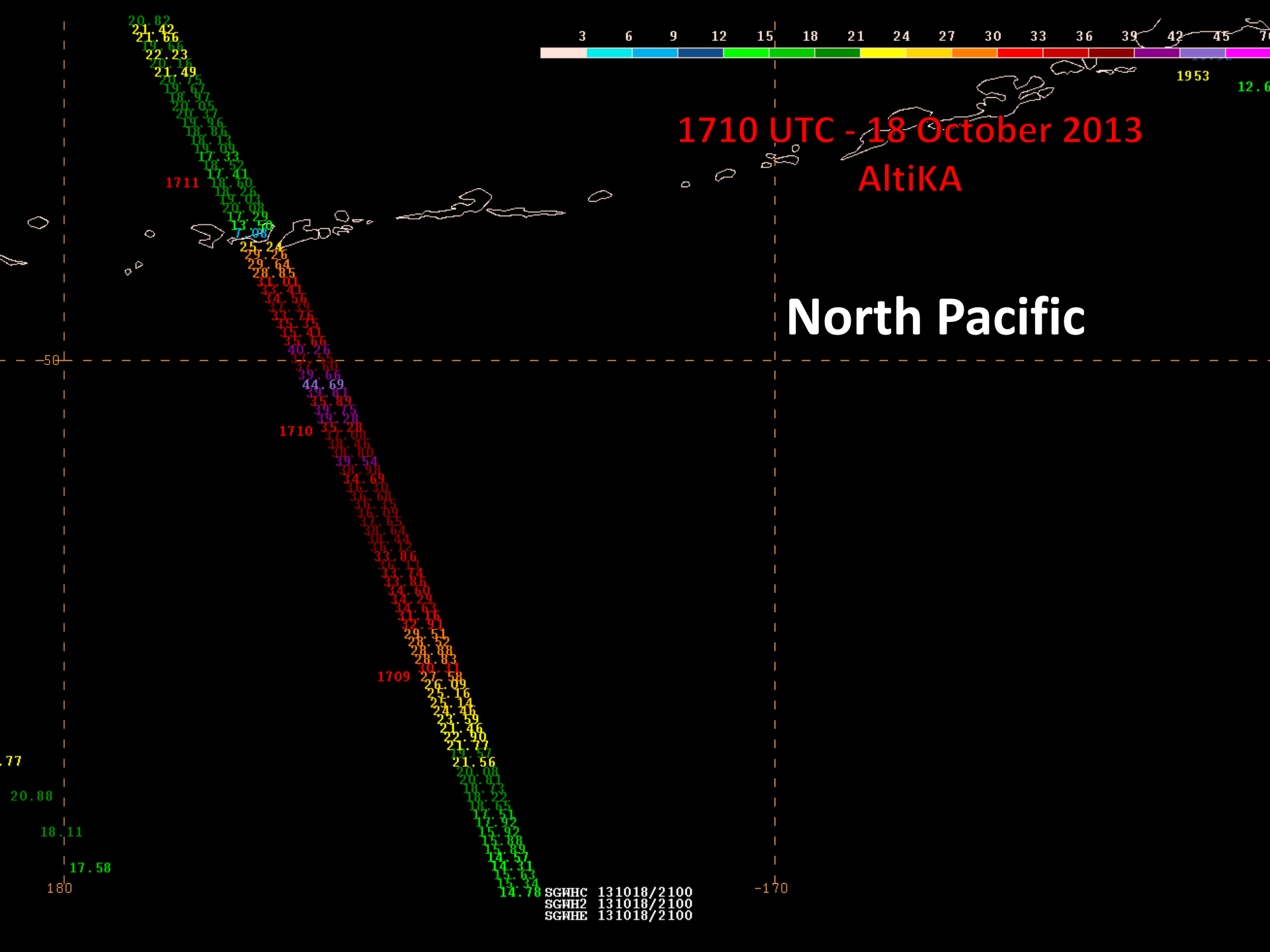
Where are the higher seas?

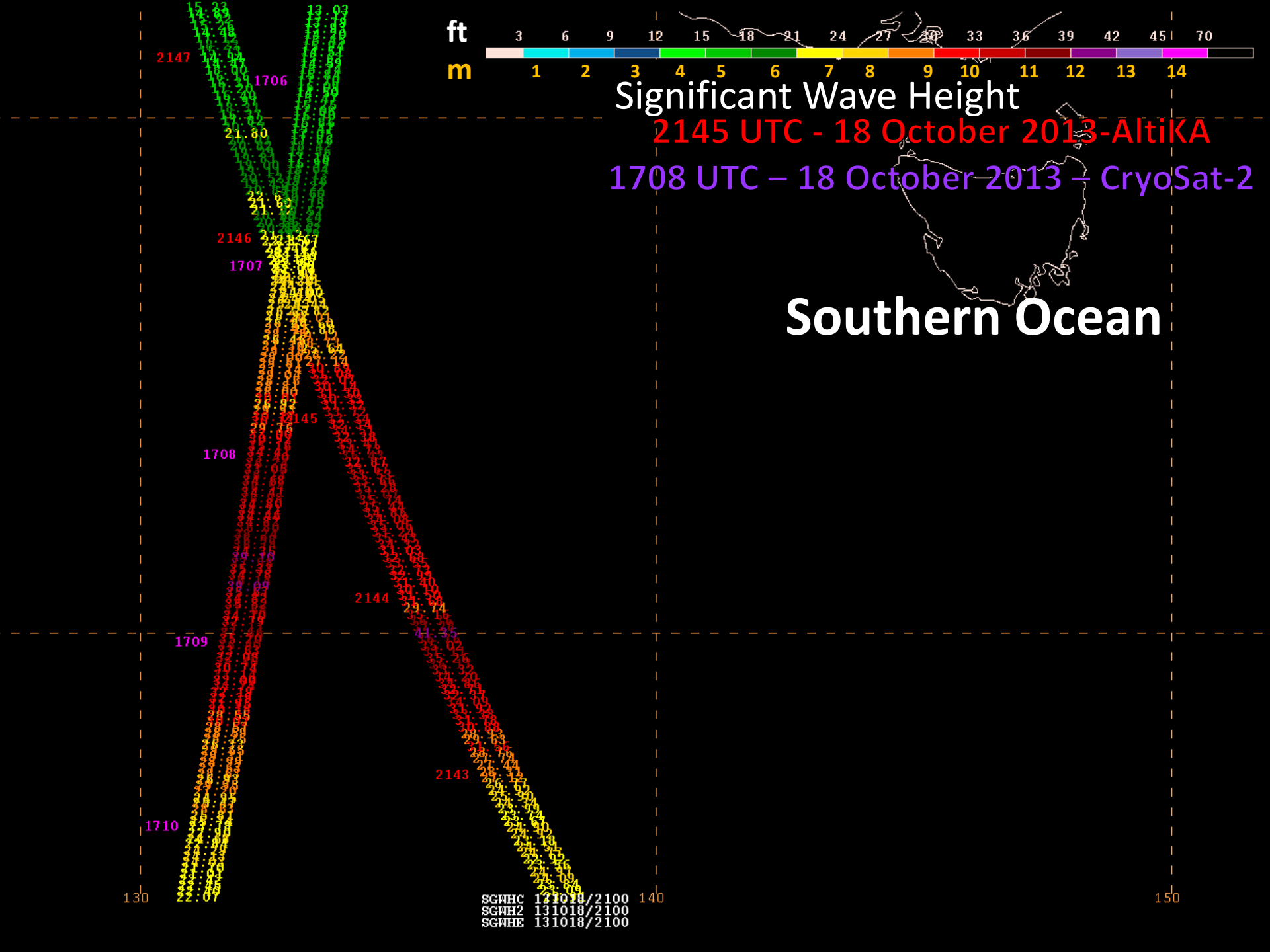


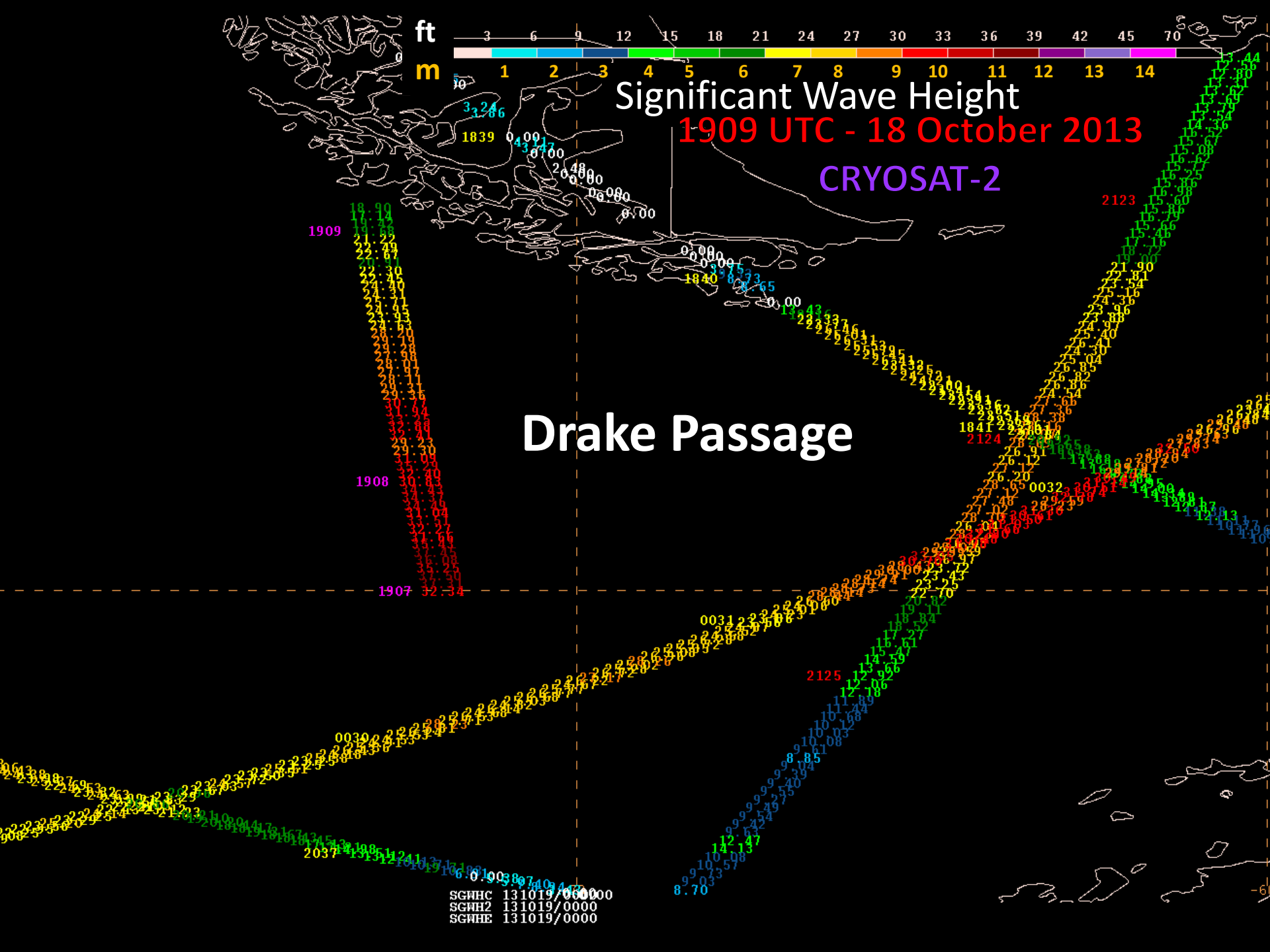
2100 UTC - 18 October 2013

ECMWF WAM 131018 f009



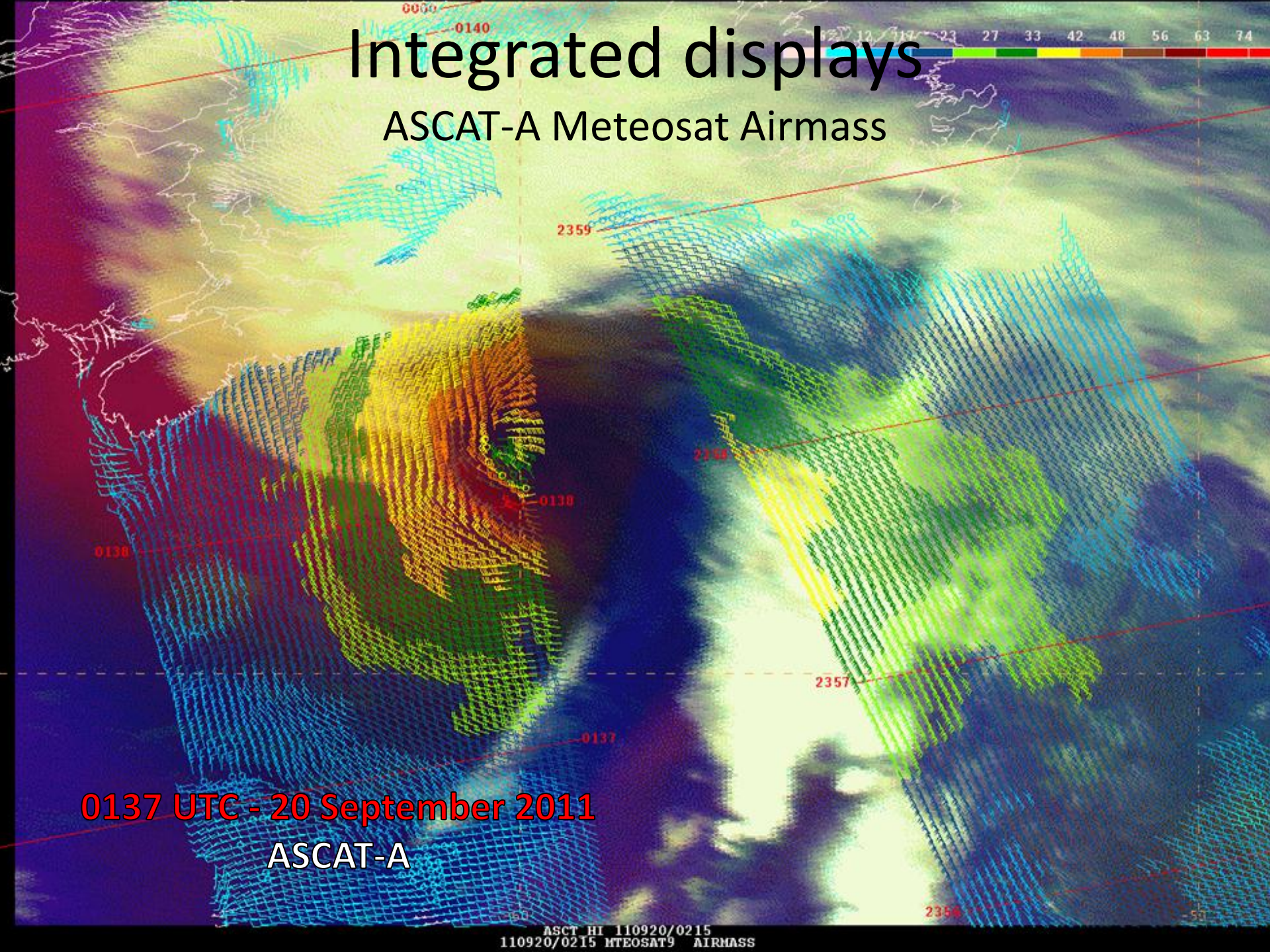

1710 UTC - 18 October 2013
AltiKA
North Pacific
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
1953
1711
1710
1709
50
180
-170
SGWHC 131018/2100
SGWH2 131018/2100
SGWHE 131018/2100


ft
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
m
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Significant Wave Height
2145 UTC - 18 October 2013-AltiKA
1708 UTC – 18 October 2013 – CryoSat-2
Southern Ocean
2147
1706
2146
1707
2145
1708
2144
1709
2143
1710
130
140
150
SGWHC 131018/2100
SGWH2 131018/2100
SGWHE 131018/2100


ft
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
m
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Significant Wave Height
1909 UTC - 18 October 2013
CRYOSAT-2
Drake Passage
SGWHC 131019/0000
SGWH2 131019/0000
SGWHE 131019/0000

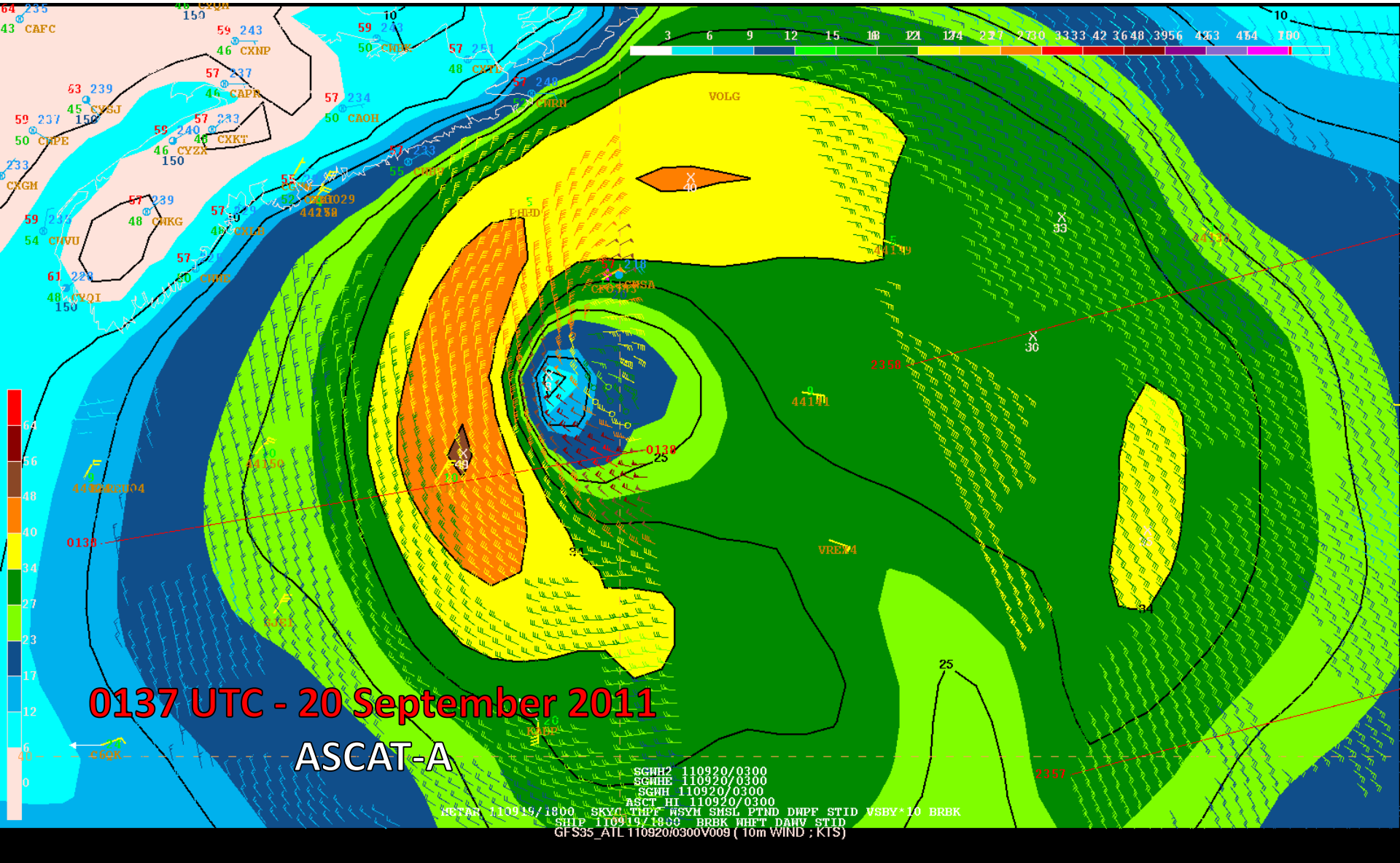
Integrated displays

ASCAT-A Meteosat Airmass



Integrated displays

ASCAT-A vs. GFS 201009191800 f009



Integrated displays

ASCAT-A vs. GFS 201009191800 f009

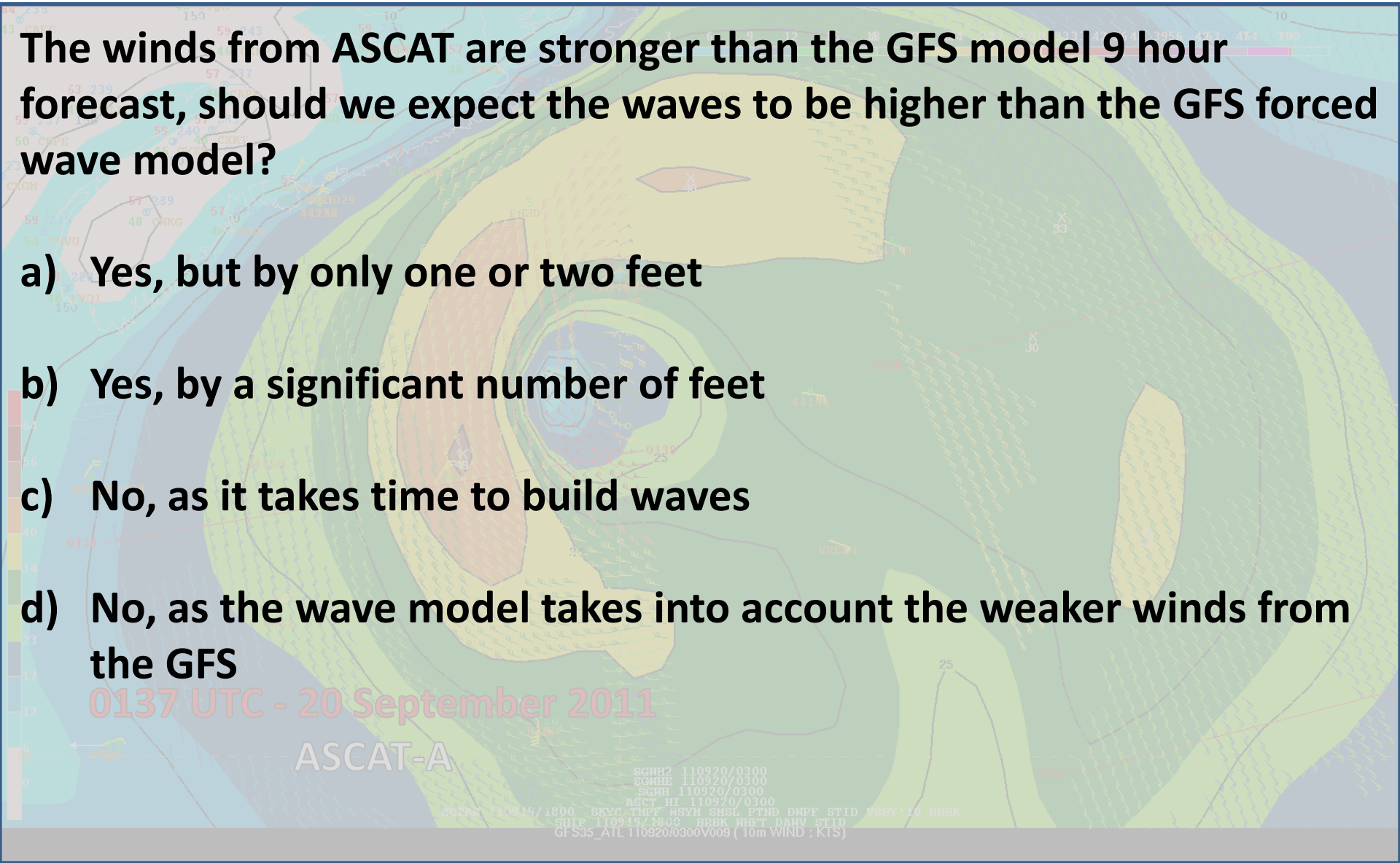
The winds from ASCAT are stronger than the GFS model 9 hour forecast, should we expect the waves to be higher than the GFS forced wave model?

a) Yes, but by only one or two feet

b) Yes, by a significant number of feet

c) No, as it takes time to build waves

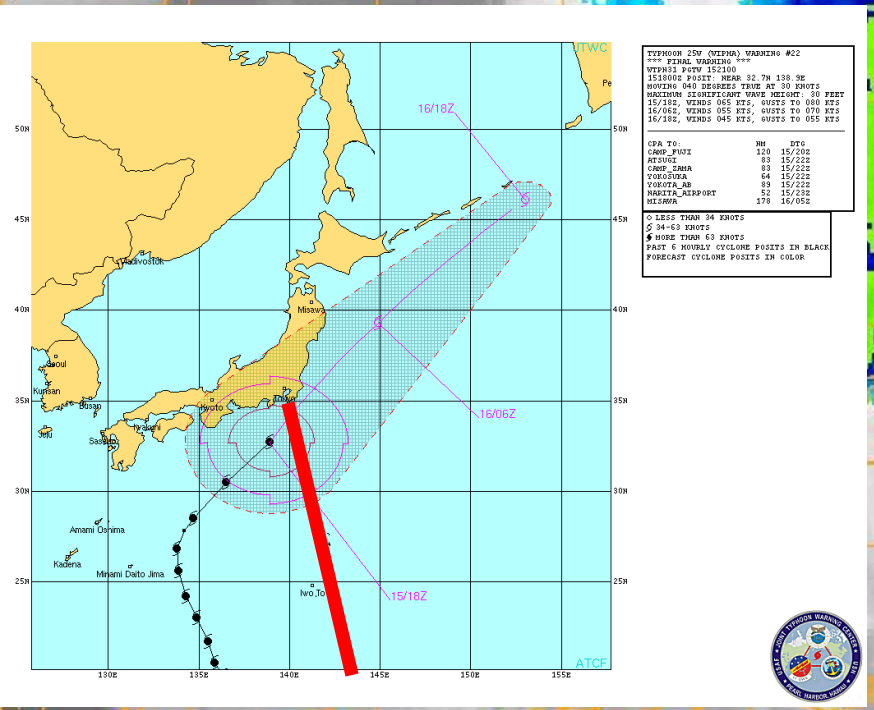
d) No, as the wave model takes into account the weaker winds from the GFS



Integrated displays

JASON1 vs. Multi-grid WAVEWATCH3

10/15/13 1800Z 25W WIPHA
10/15/13 2032Z MTSAT-2 IR



TYPHOON 25W (WIPHA) WARNING #22
*** FINAL WARNING ***
WTPN31 PGTW 152100
151800Z POSIT: NEAR 32.7N 138.9E
MOVING 040 DEGREES TRUE AT 30 KNOTS
MAXIMUM SIGNIFICANT WAVE HEIGHT: 30 FEET
15/18Z, WINDS 065 KTS, GUSTS TO 080 KTS
16/06Z, WINDS 055 KTS, GUSTS TO 070 KTS
16/18Z, WINDS 045 KTS, GUSTS TO 055 KTS

CPA TO:	NM	DTG
CRWP_FUJI	120	15/20Z
ATSUGI	83	15/22Z
CRWP_ZAMA	83	15/22Z
YOKOSUKA	64	15/22Z
YOKOTA_AB	89	15/22Z
NARITA_AIRPORT	52	15/23Z
MISAWA	178	16/05Z

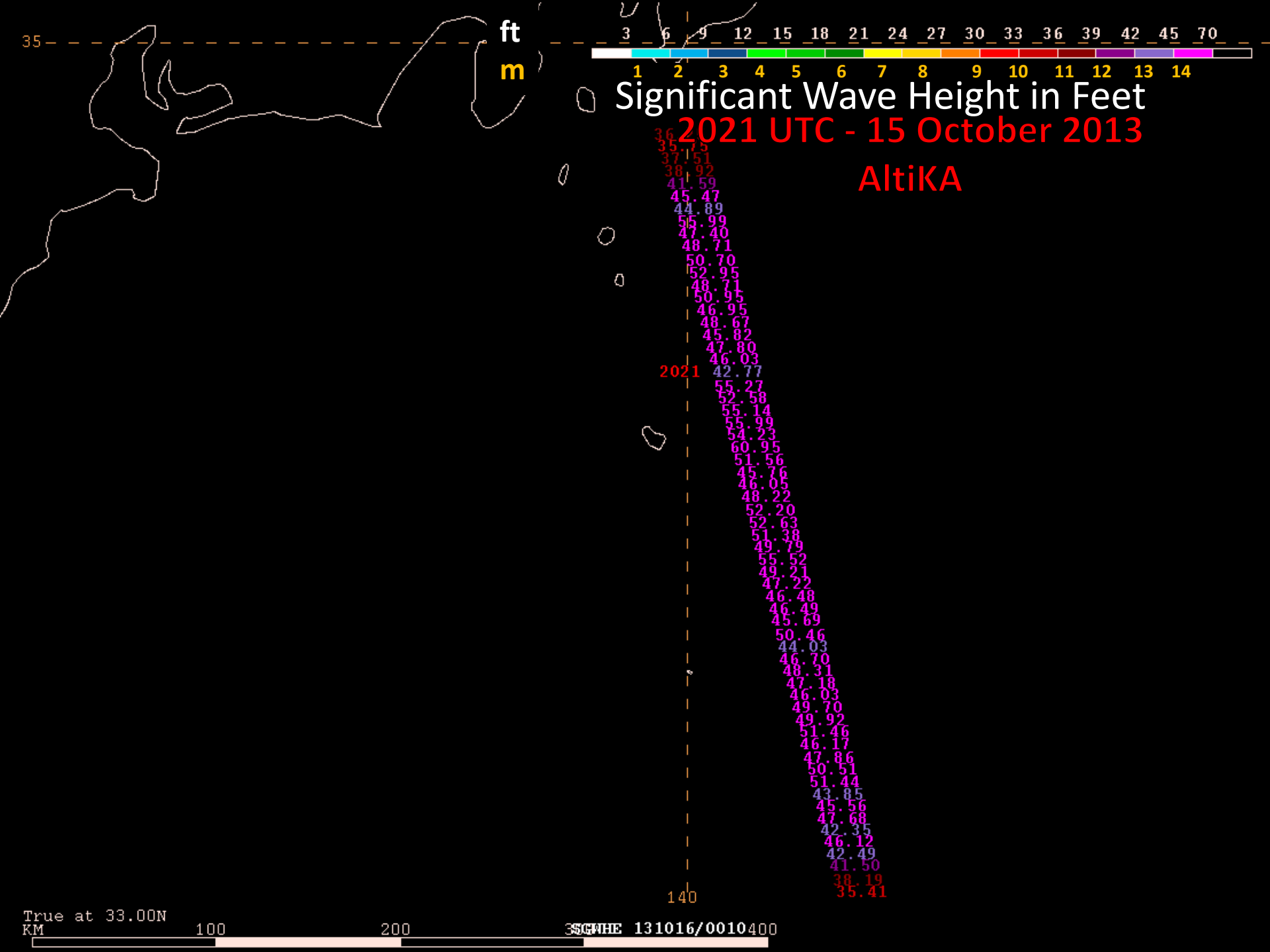
◇ LESS THAN 34 KNOTS
◯ 34-63 KNOTS
◆ MORE THAN 63 KNOTS
PAST 6 HOURLY CYCLONE POSITS IN BLACK
FORECAST CYCLONE POSITS IN COLOR

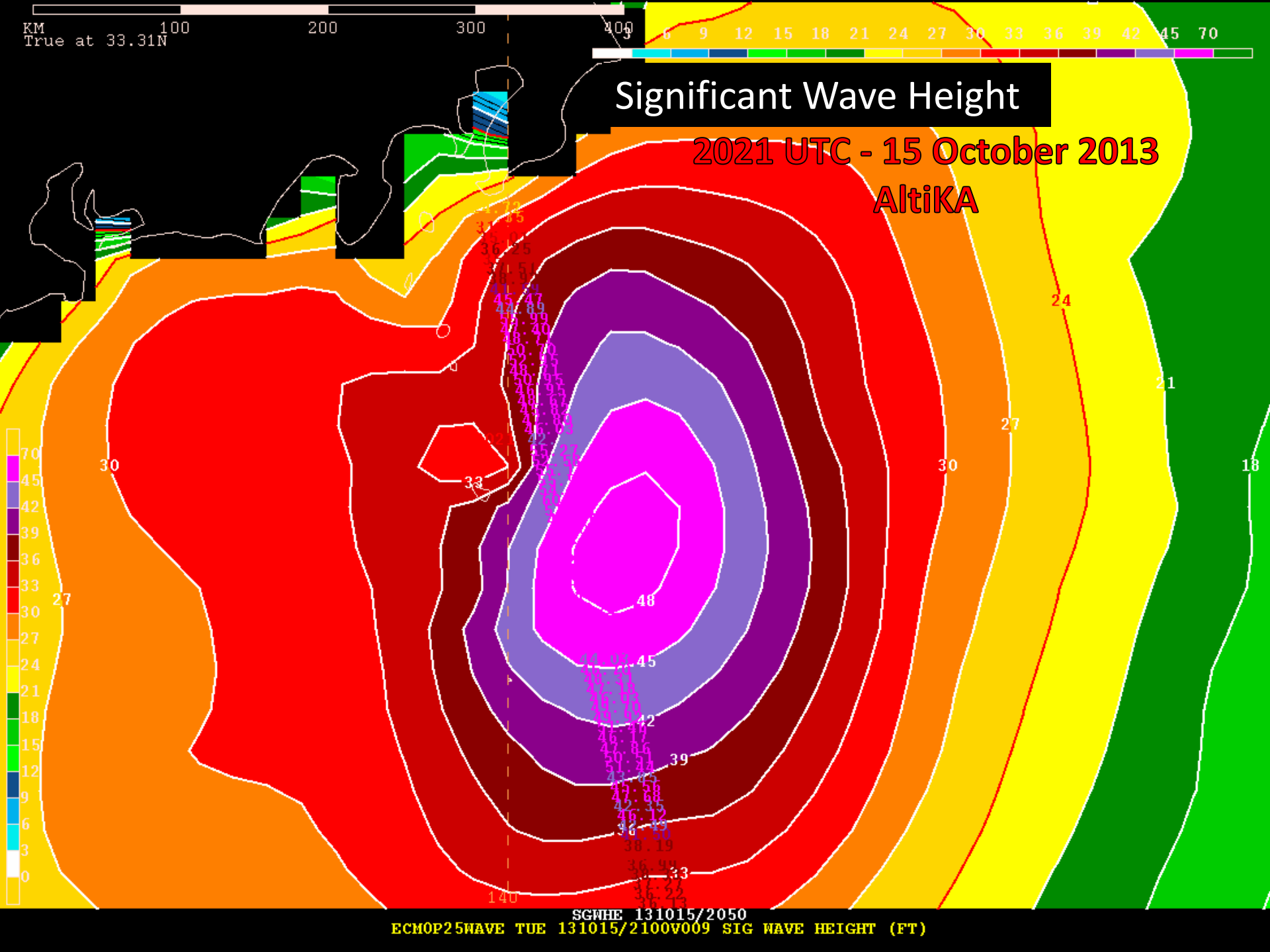
2021 UTC - 15 October 2013
AltiKA

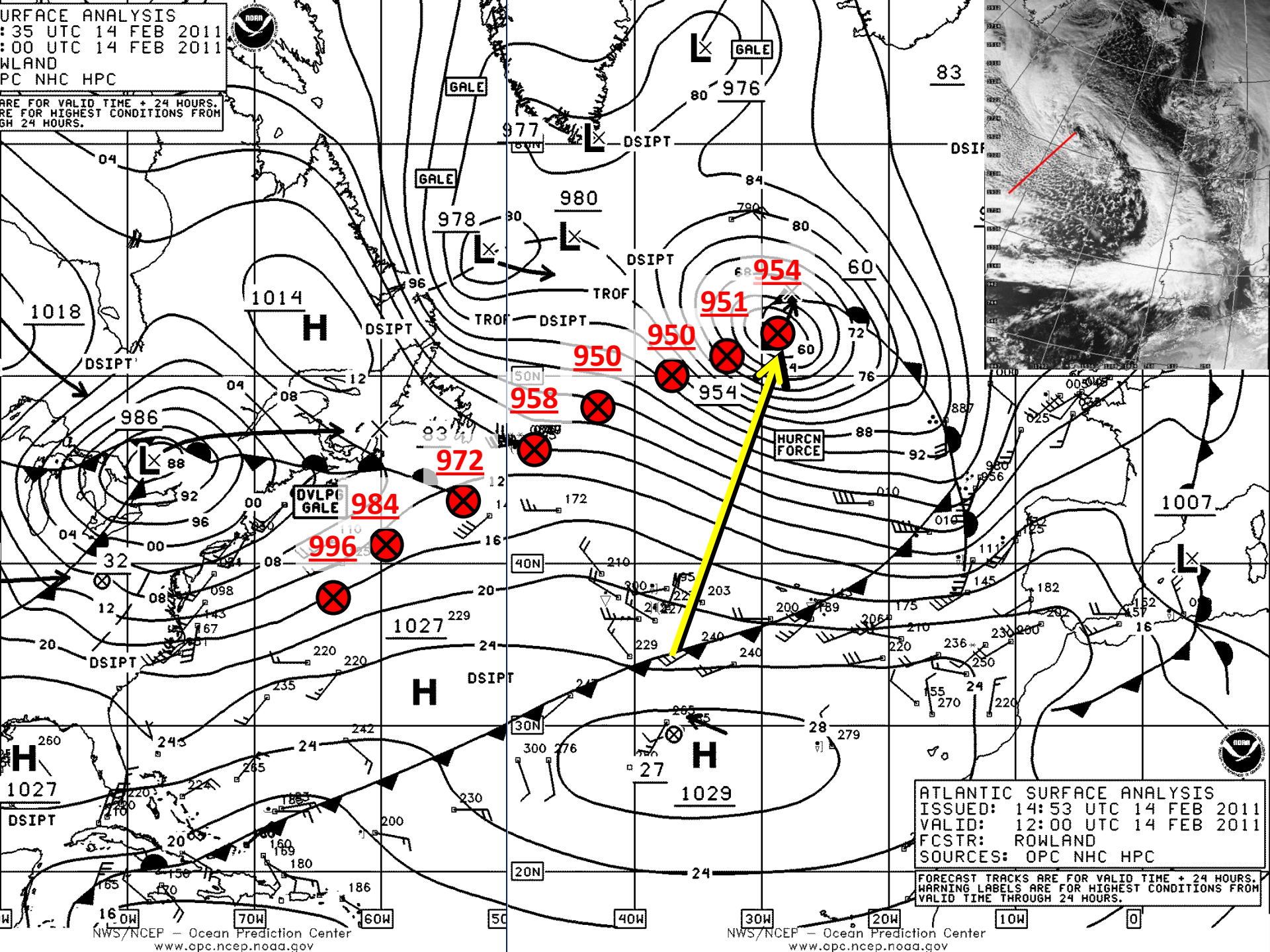
30 knots

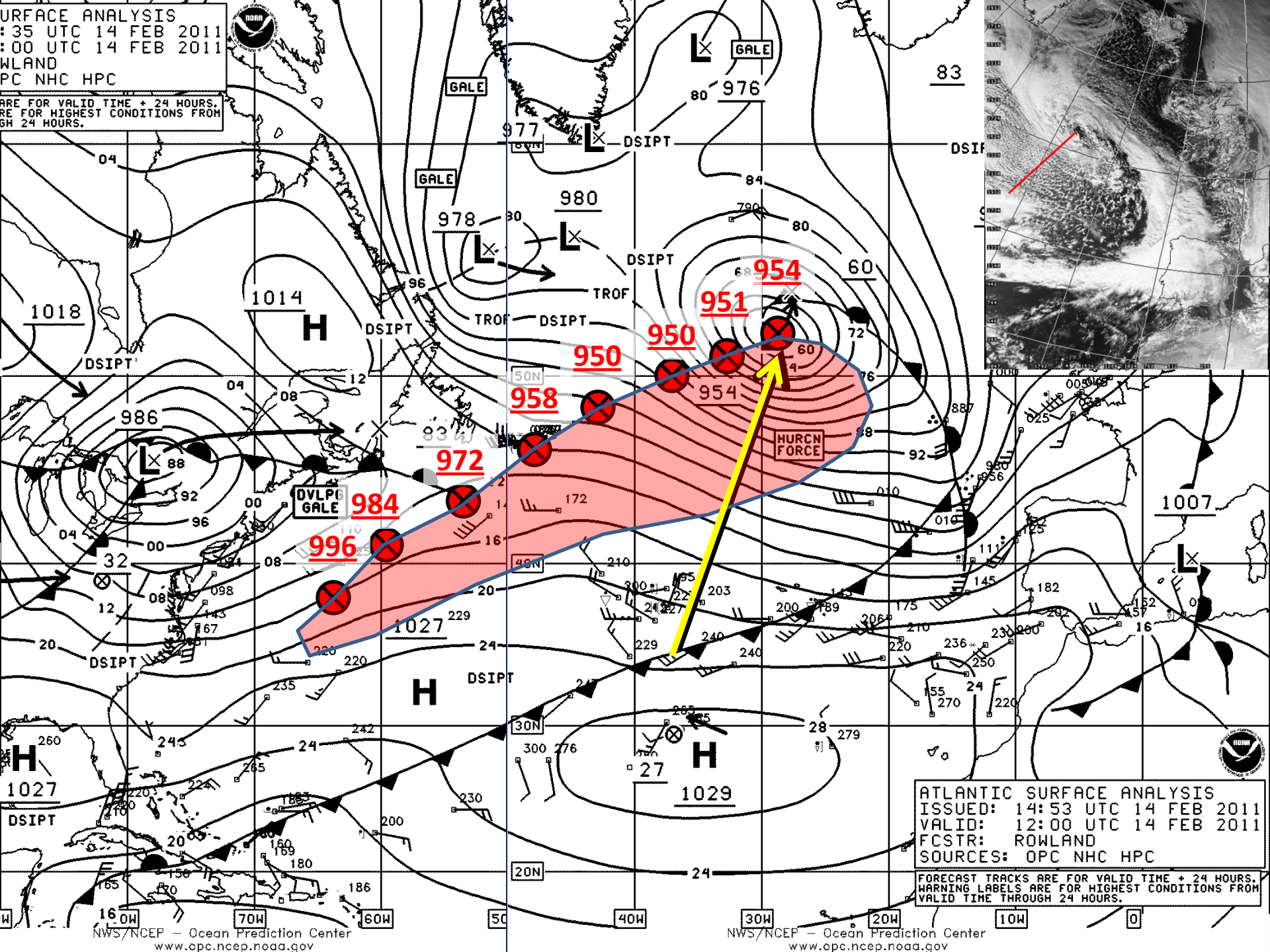
144E

30N


ft
m
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Significant Wave Height in Feet
2021 UTC - 15 October 2013
AltiKA
35
36.29
35.29
37.51
38.92
41.59
45.47
44.89
55.99
47.40
48.71
50.70
52.95
48.71
50.95
46.95
48.67
45.82
47.80
46.03
2021
42.77
55.27
52.58
55.14
55.99
54.23
60.95
51.56
45.76
46.05
48.22
52.20
52.63
51.38
49.79
55.52
49.21
47.22
46.48
46.49
45.69
50.46
44.03
46.70
48.31
47.18
46.03
49.70
49.92
51.46
46.17
47.86
50.51
51.44
43.85
45.56
47.68
42.35
46.12
42.49
41.50
38.19
35.41
140
True at 33.00N
KM
100
200
400
SGWHE 131016/0010


KM
True at 33.31N
100
200
300
400
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
Significant Wave Height
2021 UTC - 15 October 2013
AltiKA
70 45 42 39 36 33 30 27 24 21 18 15 12 9 6 3 0
SGWHE 131015/2050
ECMOP25WAVE TUE 131015/2100V009 SIG WAVE HEIGHT (FT)


URFACE ANALYSIS
:35 UTC 14 FEB 2011
:00 UTC 14 FEB 2011
WLAND
PC NHC HPC
ARE FOR VALID TIME + 24 HOURS.
RE FOR HIGHEST CONDITIONS FROM
GH 24 HOURS.
GALE
976
977
980
978
954
951
950
950
958
972
984
996
1018
1014
1027
1027
1029
986
1007
DSIPT
TROF
HURCN FORCE
DVLP GALE
50N
40N
30N
20N
ATLANTIC SURFACE ANALYSIS
ISSUED: 14:53 UTC 14 FEB 2011
VALID: 12:00 UTC 14 FEB 2011
FCSTR: ROWLAND
SOURCES: OPC NHC HPC
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM
VALID TIME THROUGH 24 HOURS.
NWS/NCEP — Ocean Prediction Center
www.opc.ncep.noaa.gov


URFACE ANALYSIS
:35 UTC 14 FEB 2011
:00 UTC 14 FEB 2011
WLAND
PC NHC HPC
ARE FOR VALID TIME + 24 HOURS.
RE FOR HIGHEST CONDITIONS FROM
GH 24 HOURS.
954
951
950
950
958
972
984
996
HURCN FORCE
GALE
DSIPT
TROF
1018
1014
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1029
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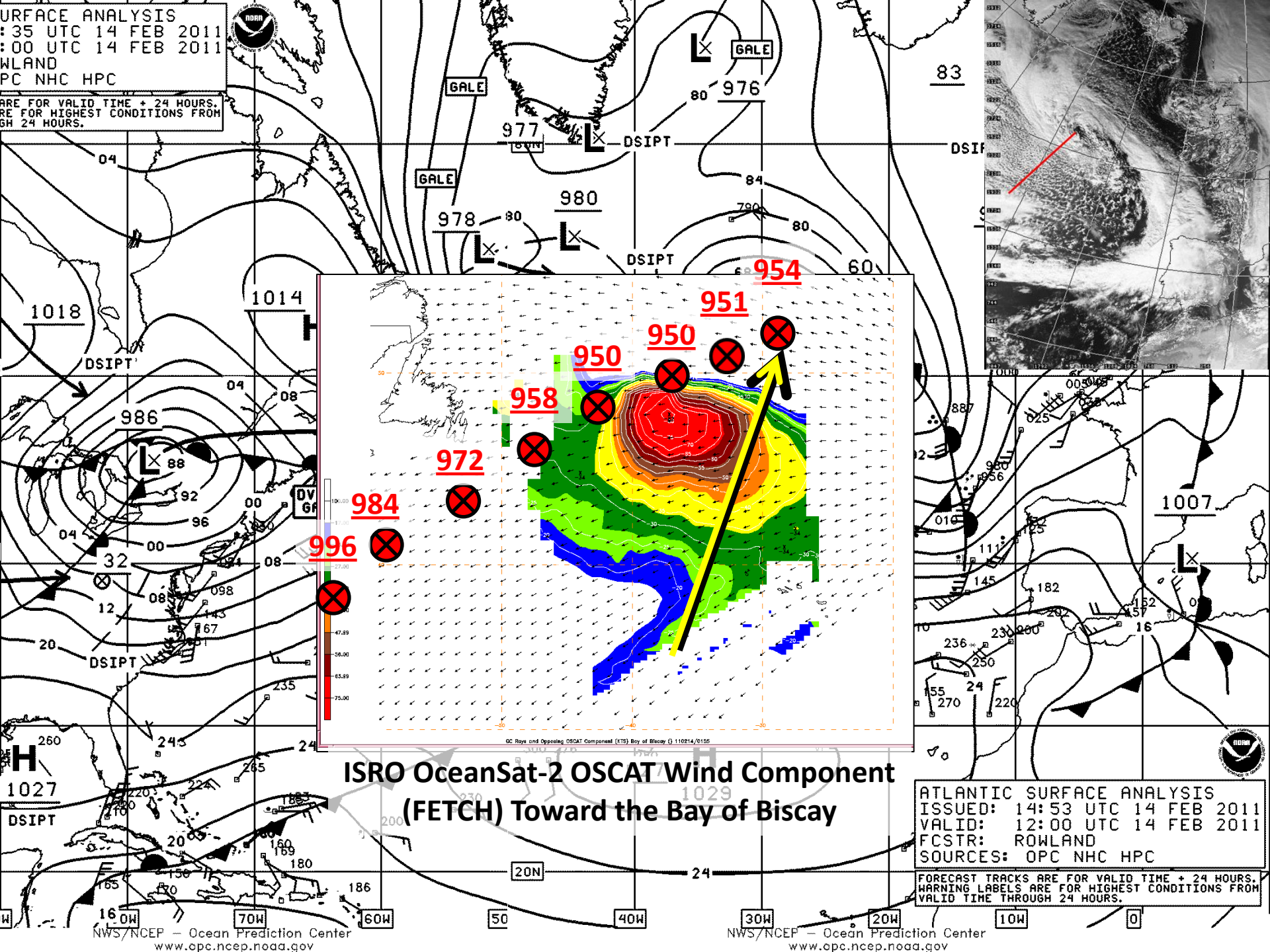
954
951
950
950
958
972
984
996
GALE
GALE
GALE
976
977
980
978
DSIPT
DSIPT
DSIPT
DSIPT
1018
1014
986
1027
1007
83
84
60
ISRO OceanSat-2 OSCAT Wind Component
(FETCH) Toward the Bay of Biscay
ATLANTIC SURFACE ANALYSIS
ISSUED: 14:53 UTC 14 FEB 2011
VALID: 12:00 UTC 14 FEB 2011
FCSTR: ROWLAND
SOURCES: OPC NHC HPC
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM
VALID TIME THROUGH 24 HOURS.
NWS/NCEP — Ocean Prediction Center
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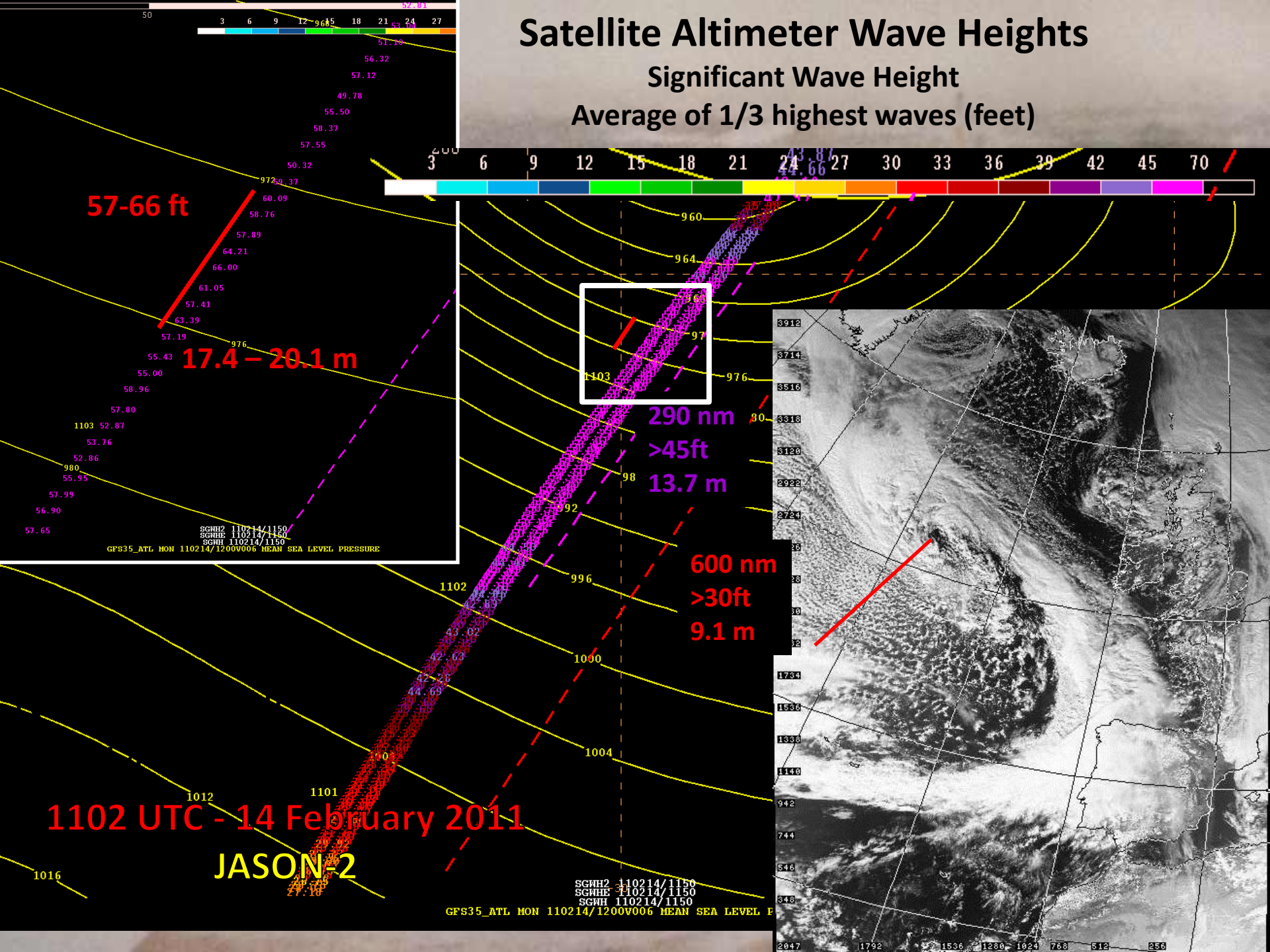
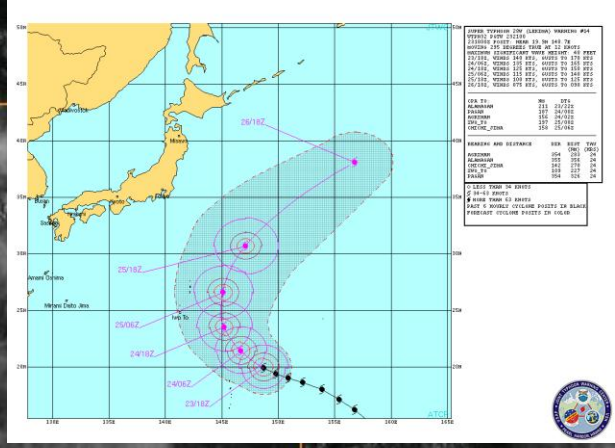
Satellite Altimeter Wave Heights

Significant Wave Height

Average of 1/3 highest waves (feet)



10/23/13 1800Z 28W LEKIMA
10/23/13 2130Z MTSAT-2 VIS

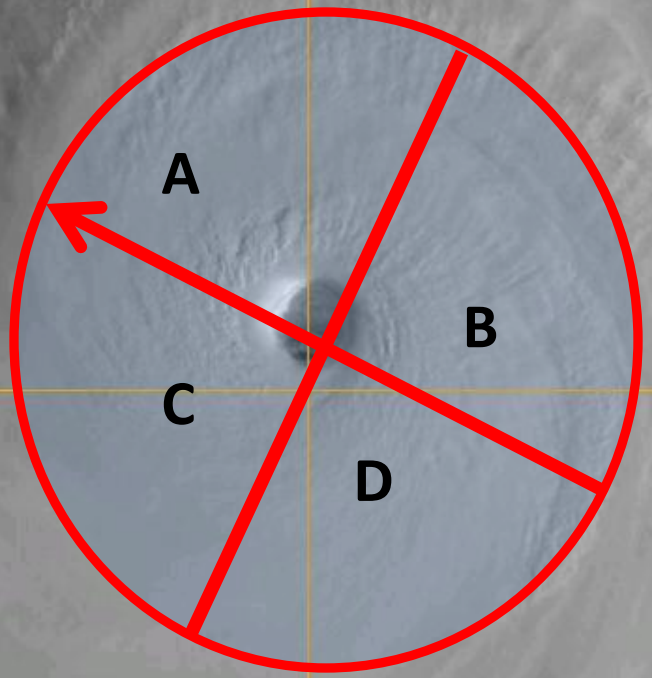


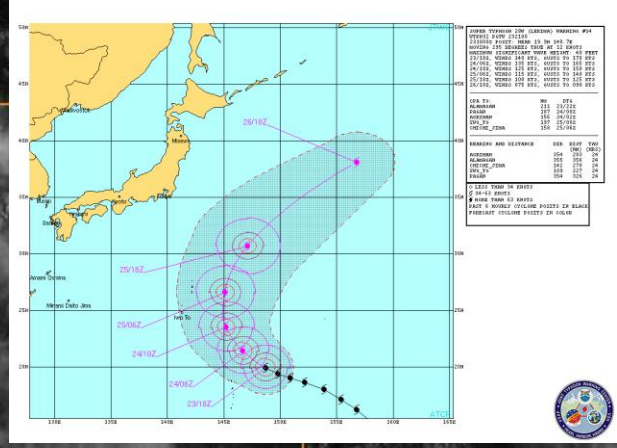
12 knots

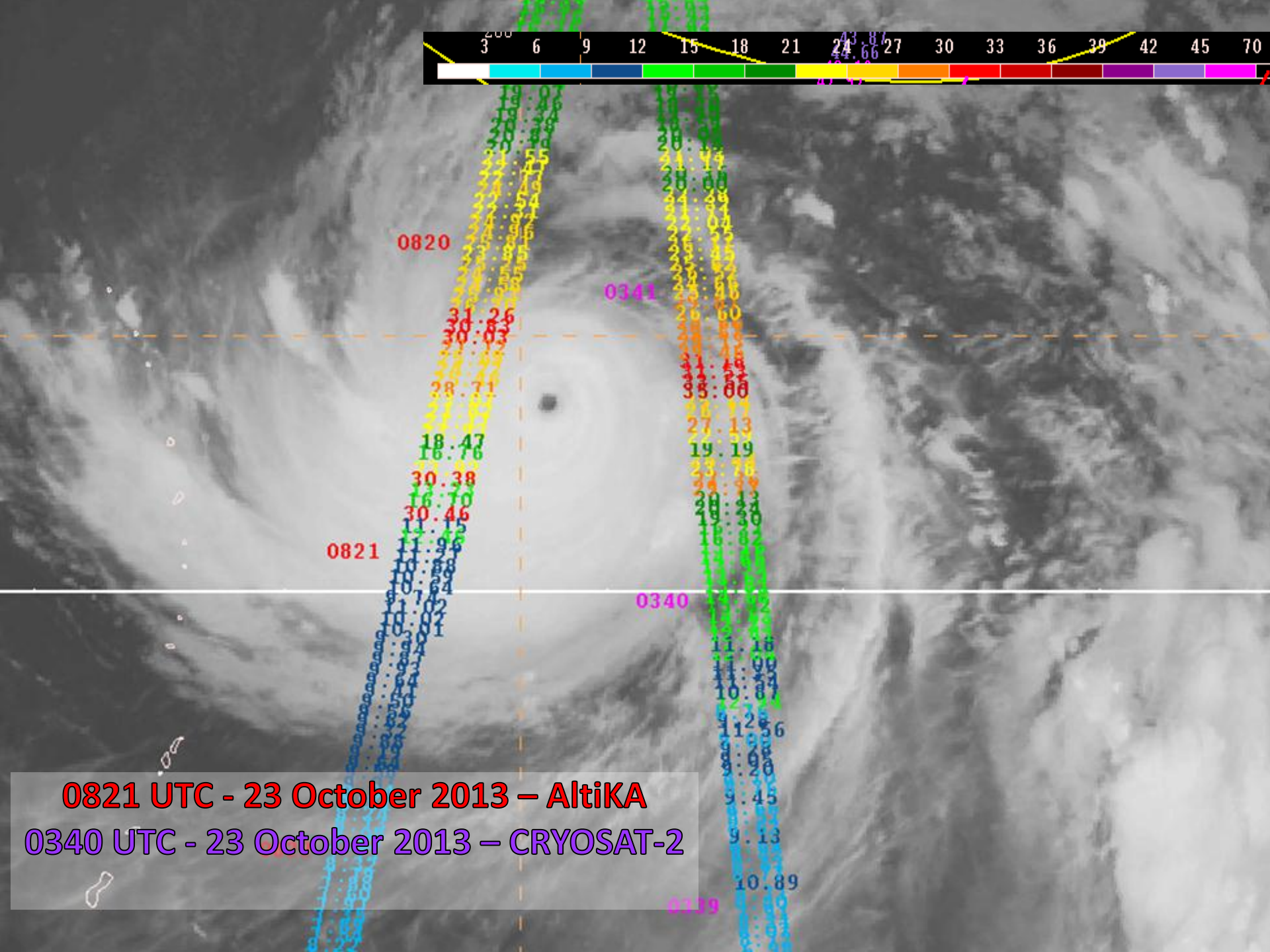
10/23/13 1800Z 28W LEKIMA
10/23/13 2130Z MTSAT-2 VIS

In which quadrants would you expect the highest waves?

1) A and C
2) A and B
3) B and D
4) C and D






3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
0820
0341
0821
0340
0239
0821 UTC - 23 October 2013 – AltiKA
0340 UTC - 23 October 2013 – CRYOSAT-2

AltiKa is a higher frequency (smaller wavelength radar) than JASON-2 and CRYOSAT-2, with that in mind, are the wave heights to the southwest of the eye real?

a) Yes, there are some sea mounts in that area

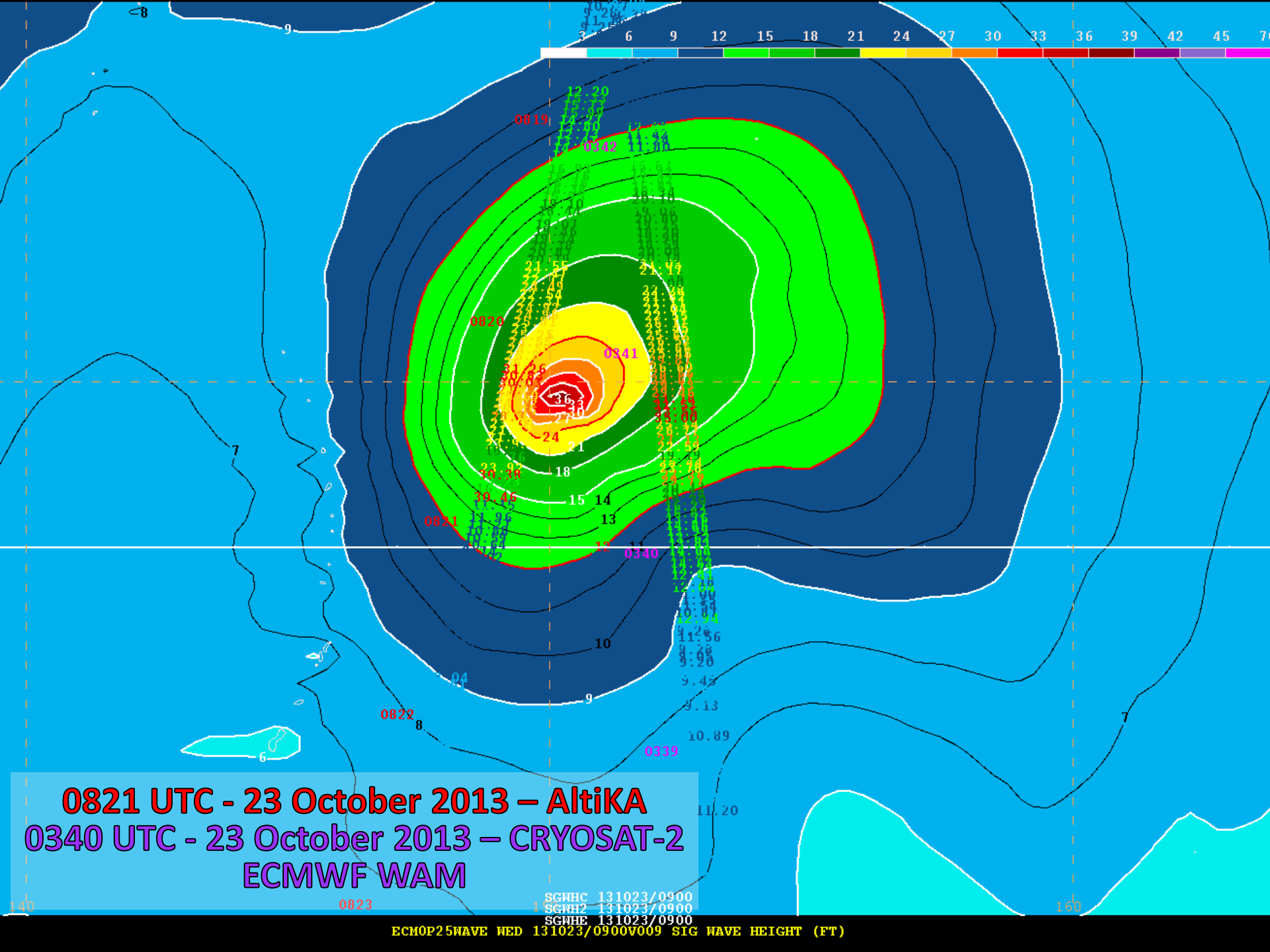
b) No, the altimeter radar signal is impacted by clouds

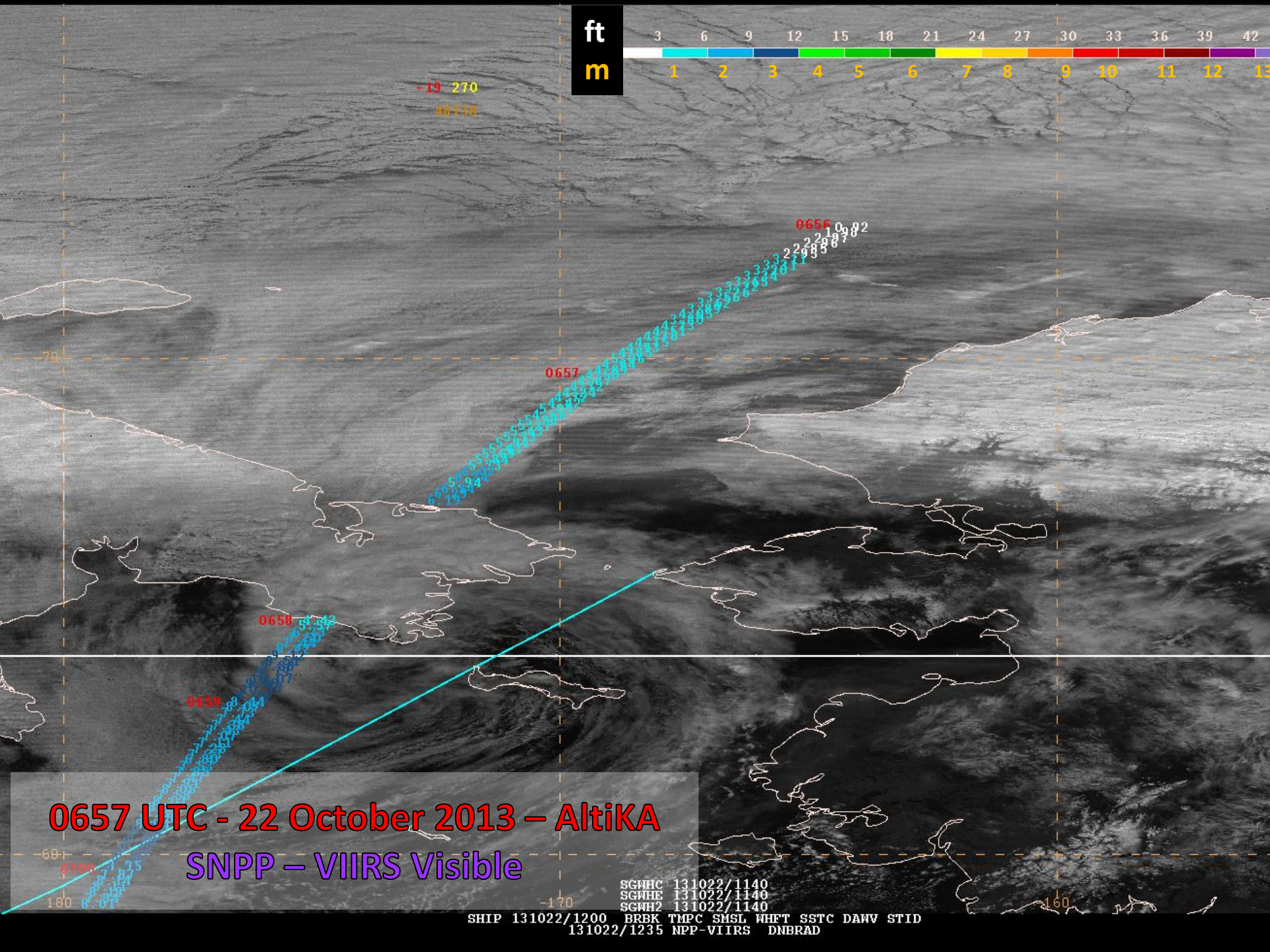
c) Yes, the radar is able to observe the high frequency differences in significant wave heights

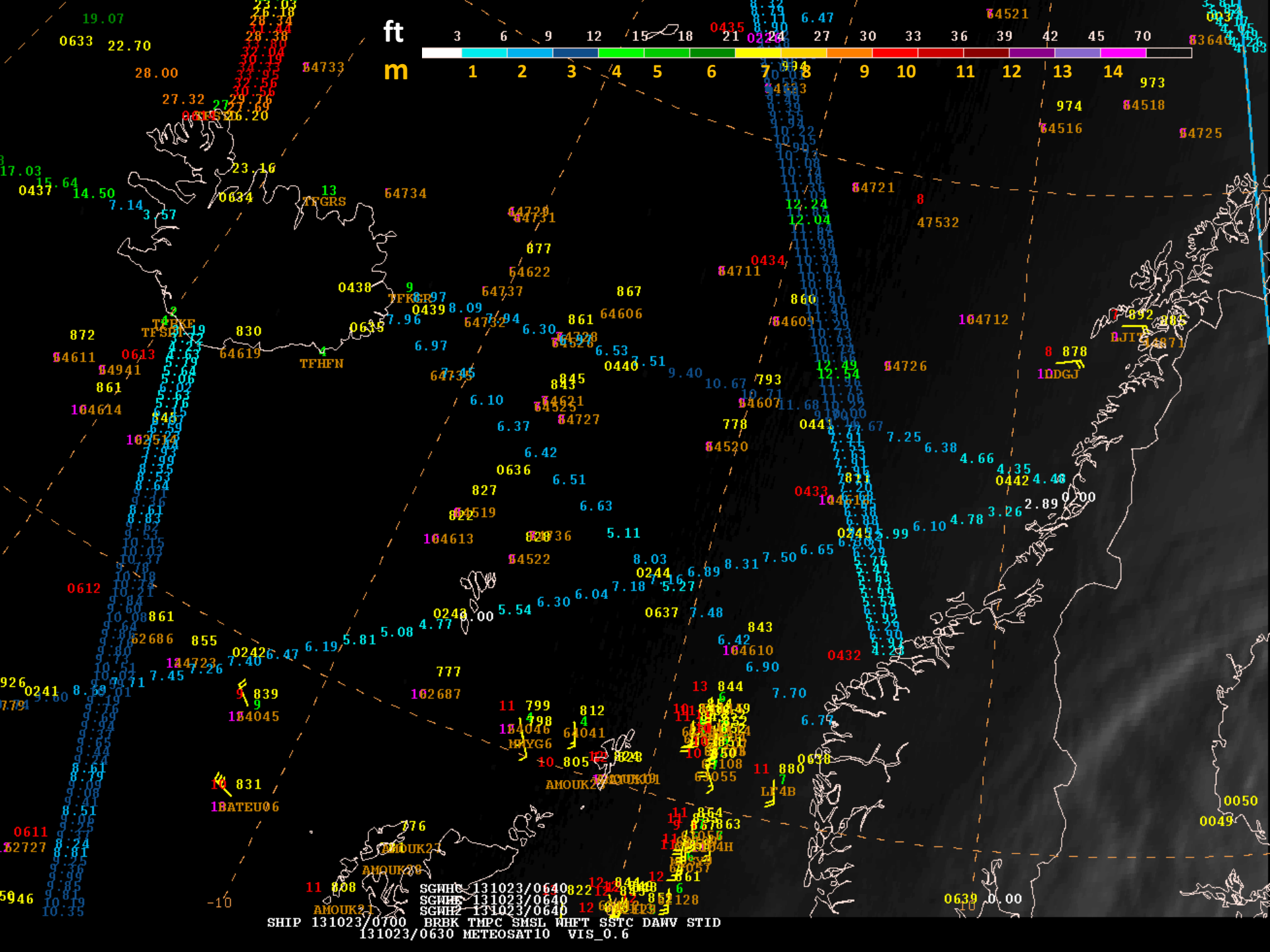
d) No, the altimeter radar signal is most likely impacted by heavy rain from a rain band

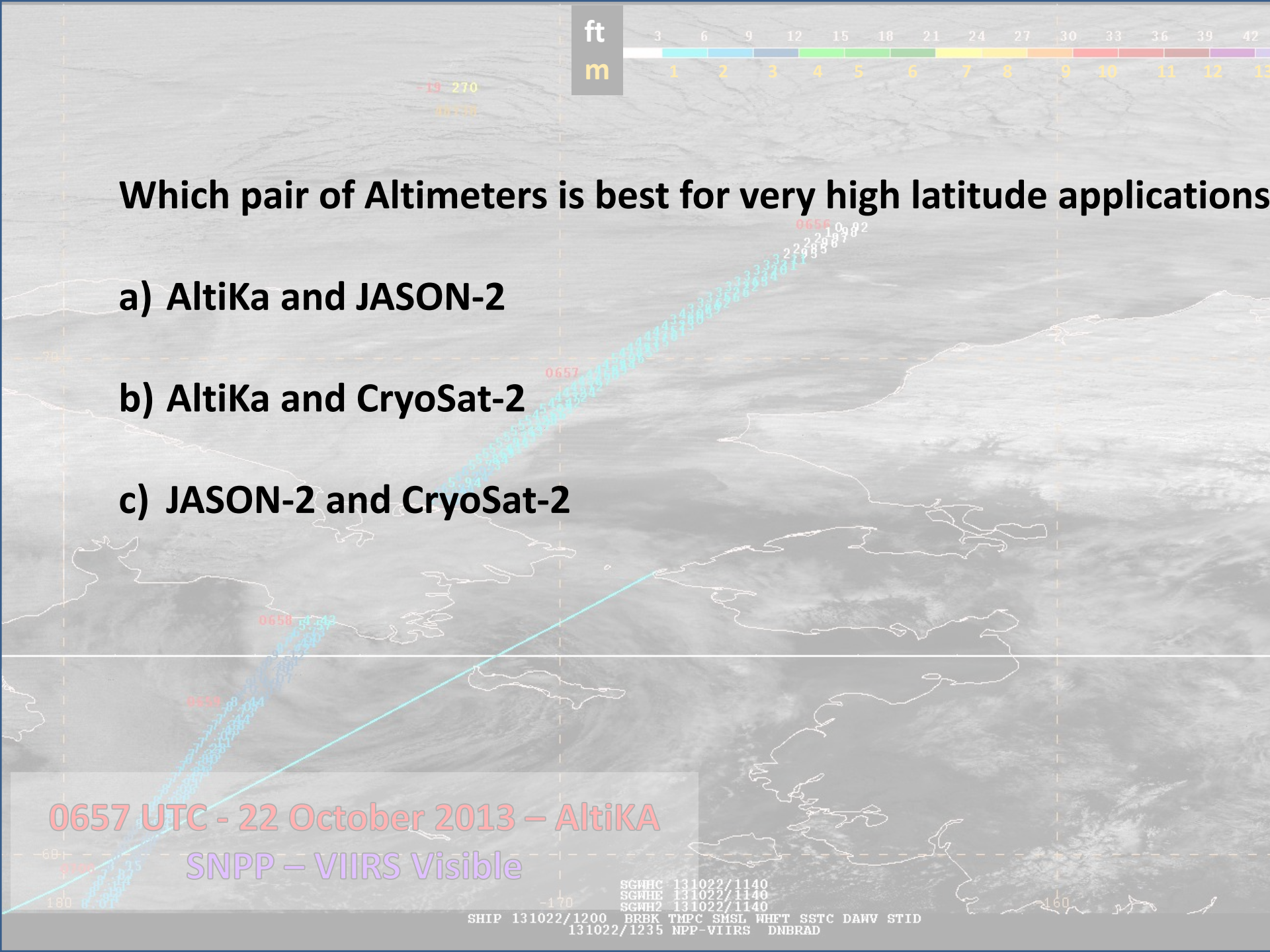
0821 UTC - 23 October 2013 – AltiKA

0340 UTC - 23 October 2013 – CRYOSAT-2


0821 UTC - 23 October 2013 – AltiKA
0340 UTC - 23 October 2013 – CRYOSAT-2
ECMWF WAM
SGWHC 131023/0900
SGWH2 131023/0900
SGWHE 131023/0900
ECMOP25WAVE WED 131023/0900V009 SIG WAVE HEIGHT (FT)


ft
m
3 6 9 12 15 18 21 24 27 30 33 36 39 42
1 2 3 4 5 6 7 8 9 10 11 12 13
0656
0657
0658
0659
0657 UTC - 22 October 2013 – AltiKA
SNPP – VIIRS Visible
SGWHC 131022/1140
SGWHE 131022/1140
SGWH2 131022/1140
SHIP 131022/1200 BRBK TMPC SMSL WHFT SSTC DAWV STID
131022/1235 NPP-VIIRS DNBRAD


ft
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
m
1 2 3 4 5 6 7 8 9 10 11 12 13 14
SGWHC 131023/0640
SGWHE 131023/0640
SGWH2 131023/0640
SHIP 131023/0700 BRBK TMPC SMSL WHFT SSTC DAWV STID
131023/0630 METEOSAT10 VIS_0.6

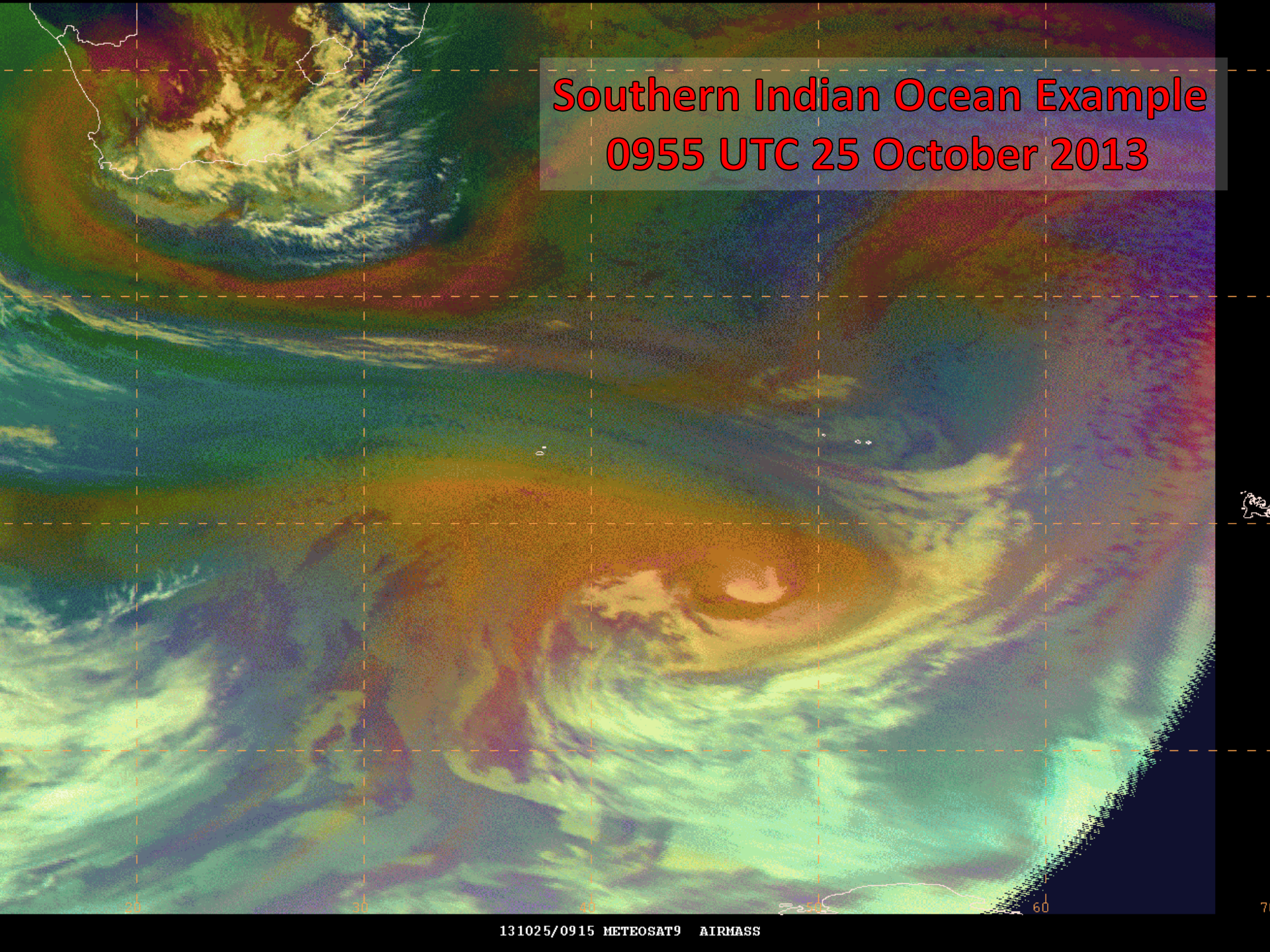


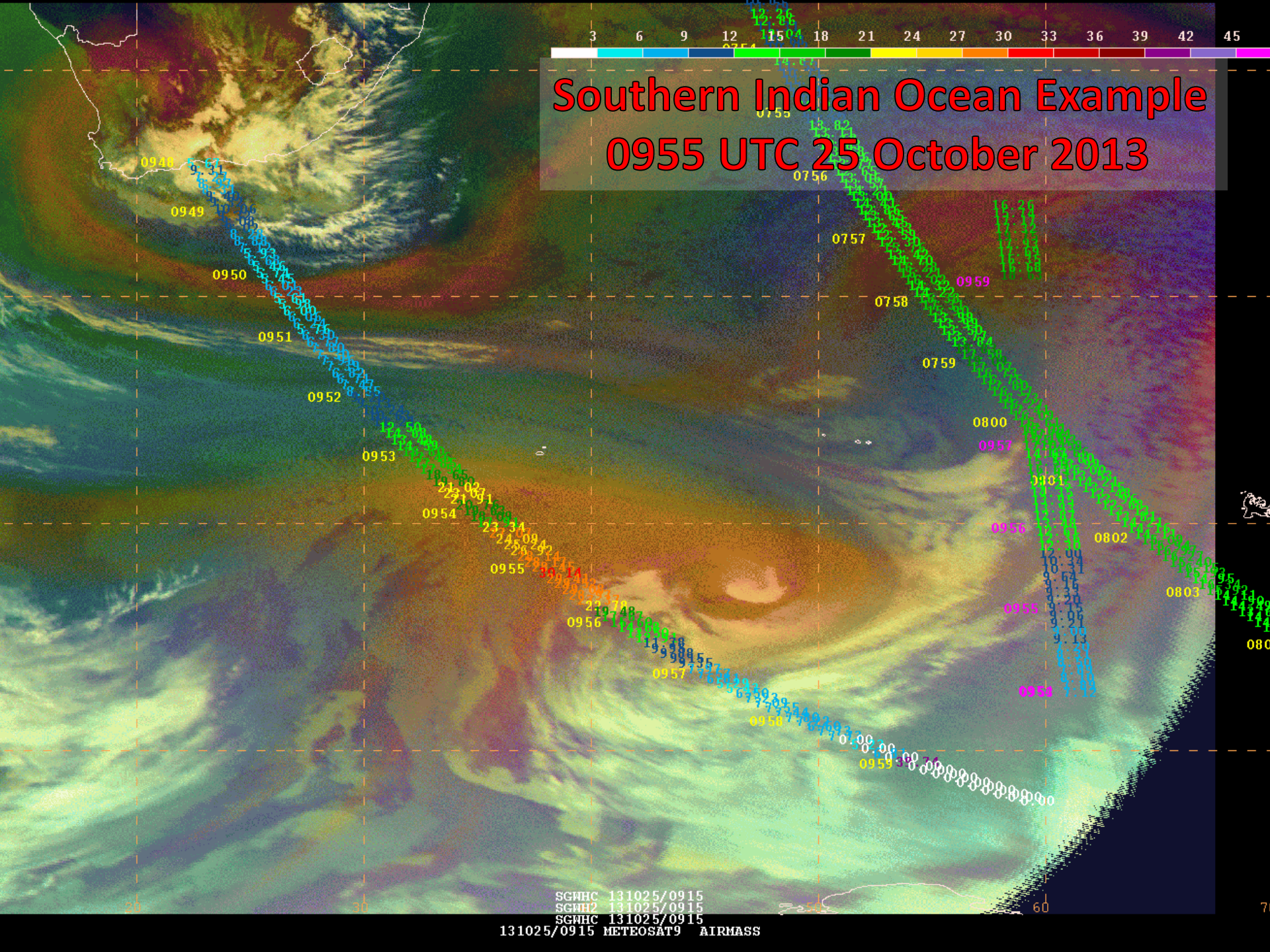
Which pair of Altimeters is best for very high latitude applications

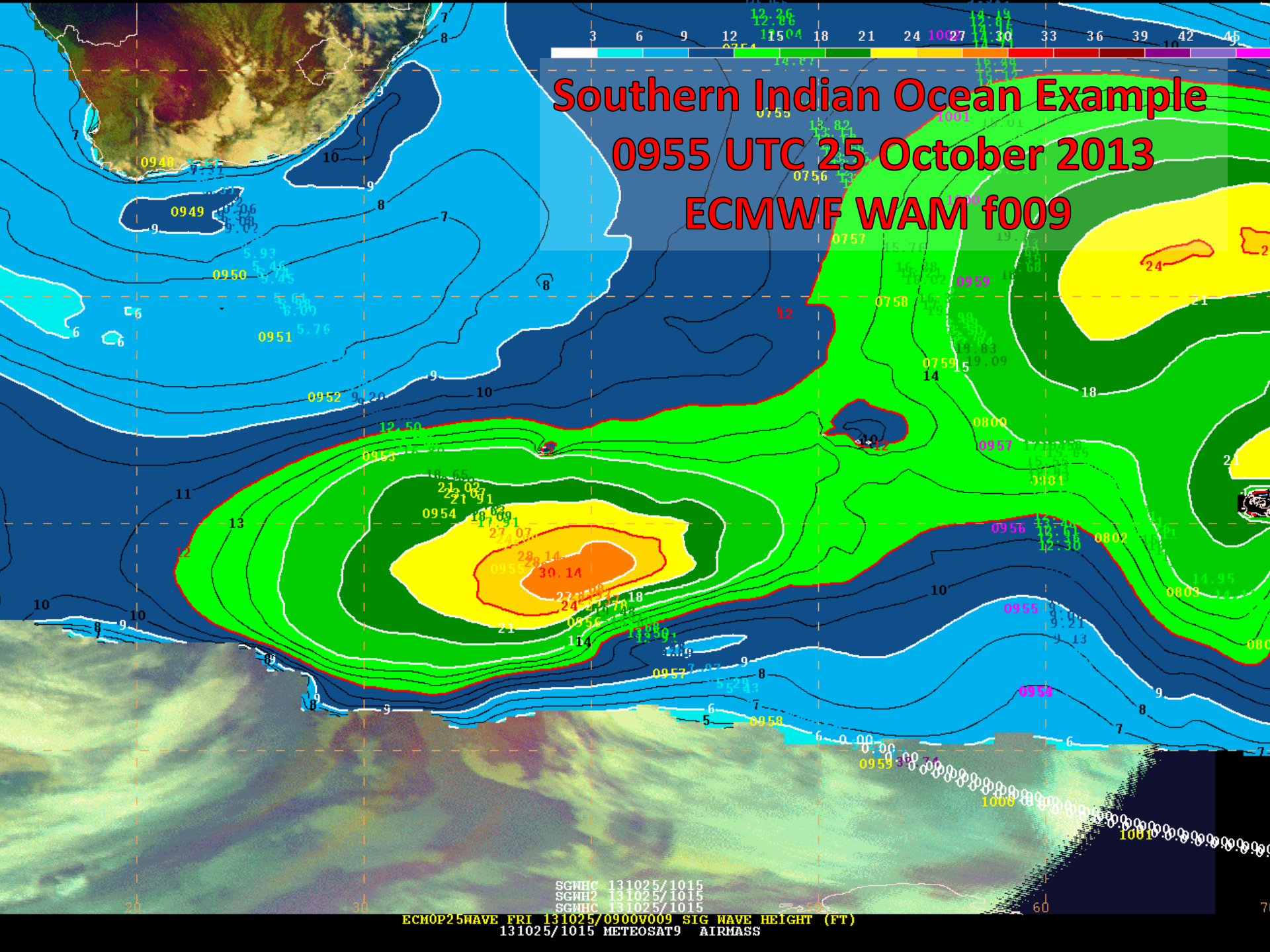
a) AltiKa and JASON-2

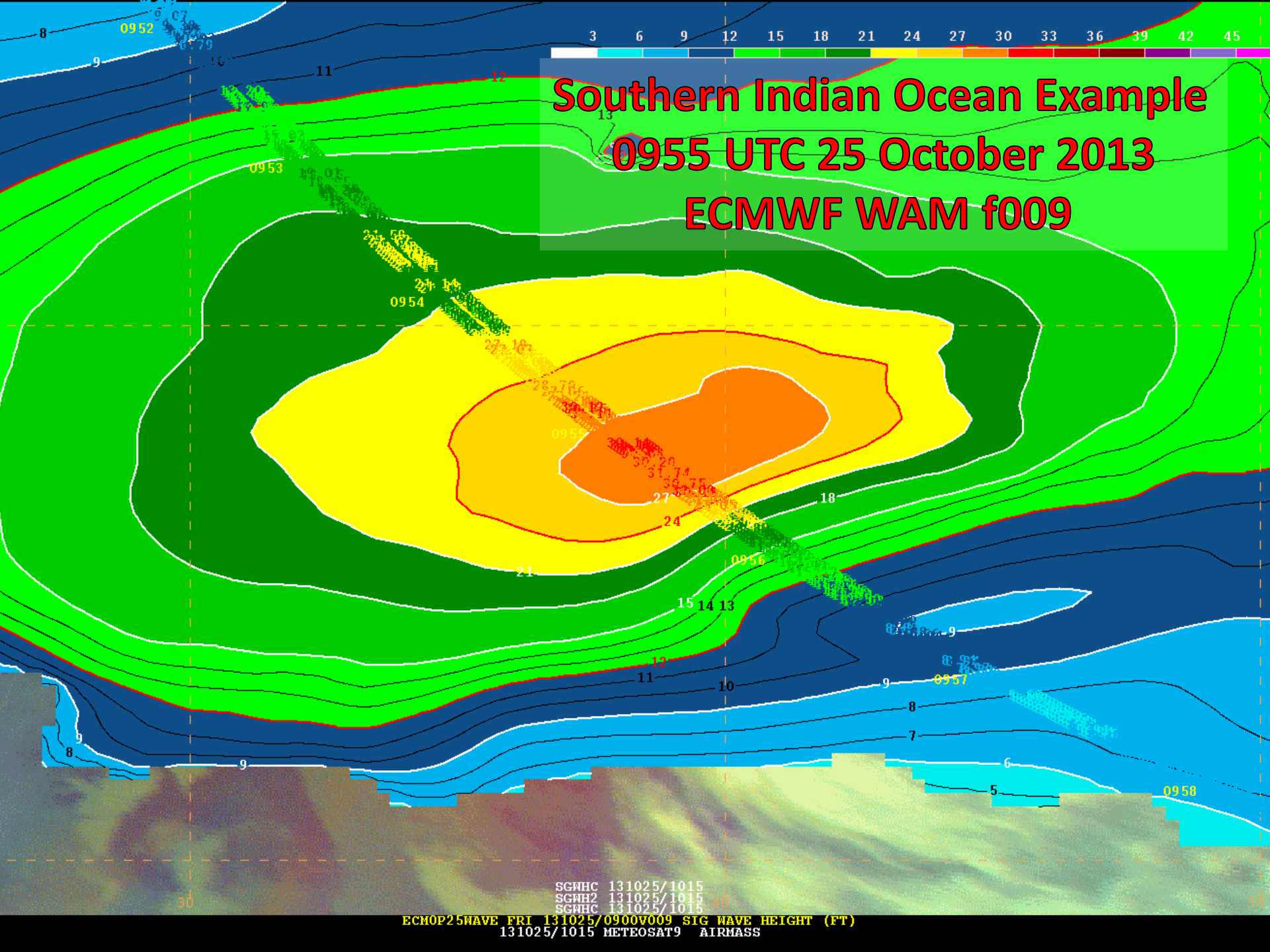
b) AltiKa and CryoSat-2

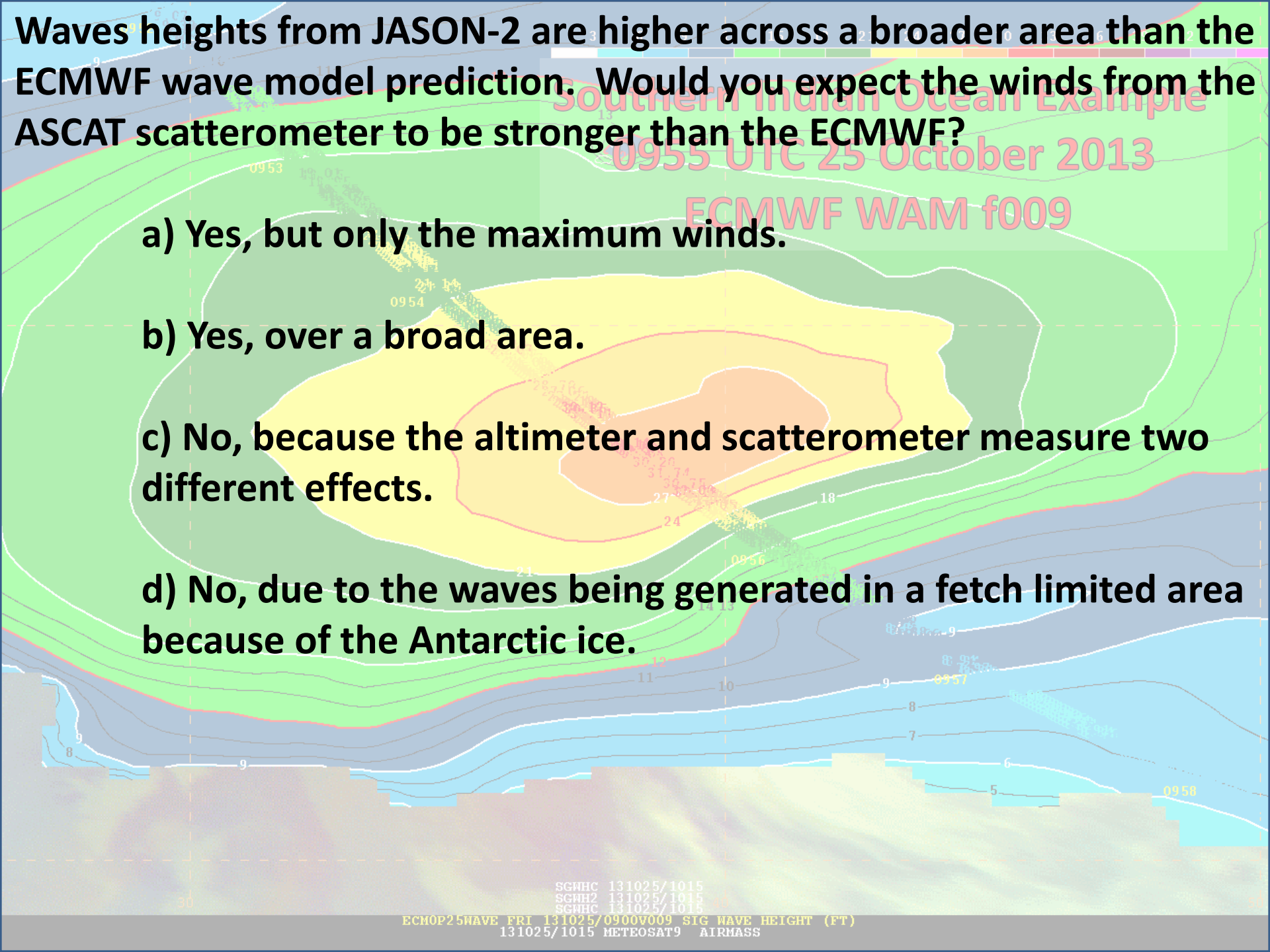
c) JASON-2 and CryoSat-2


Southern Indian Ocean Example
0955 UTC 25 October 2013
131025/0915 METEOSAT9 AIRMASS


Southern Indian Ocean Example
0955 UTC 25 October 2013
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
SGWHC 131025/0915
SGWH2 131025/0915
SGWHC 131025/0915
131025/0915 METEOSAT9 AIRMASS


Southern Indian Ocean Example
0955 UTC 25 October 2013
ECMWF WAM f009
SGWHC 131025/1015
SGWH2 131025/1015
SGWHC 131025/1015
ECMOP25WAVE FRI 131025/0900V009 SIG WAVE HEIGHT (FT)
131025/1015 METEOSAT9 AIRMASS


Southern Indian Ocean Example
0955 UTC 25 October 2013
ECMWF WAM f009
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
SGWHC 131025/1015
SGWH2 131025/1015
SGWHC 131025/1015
ECMOP25WAVE FRI 131025/0900V009 SIG WAVE HEIGHT (FT)
131025/1015 METEOSAT9 AIRMASS



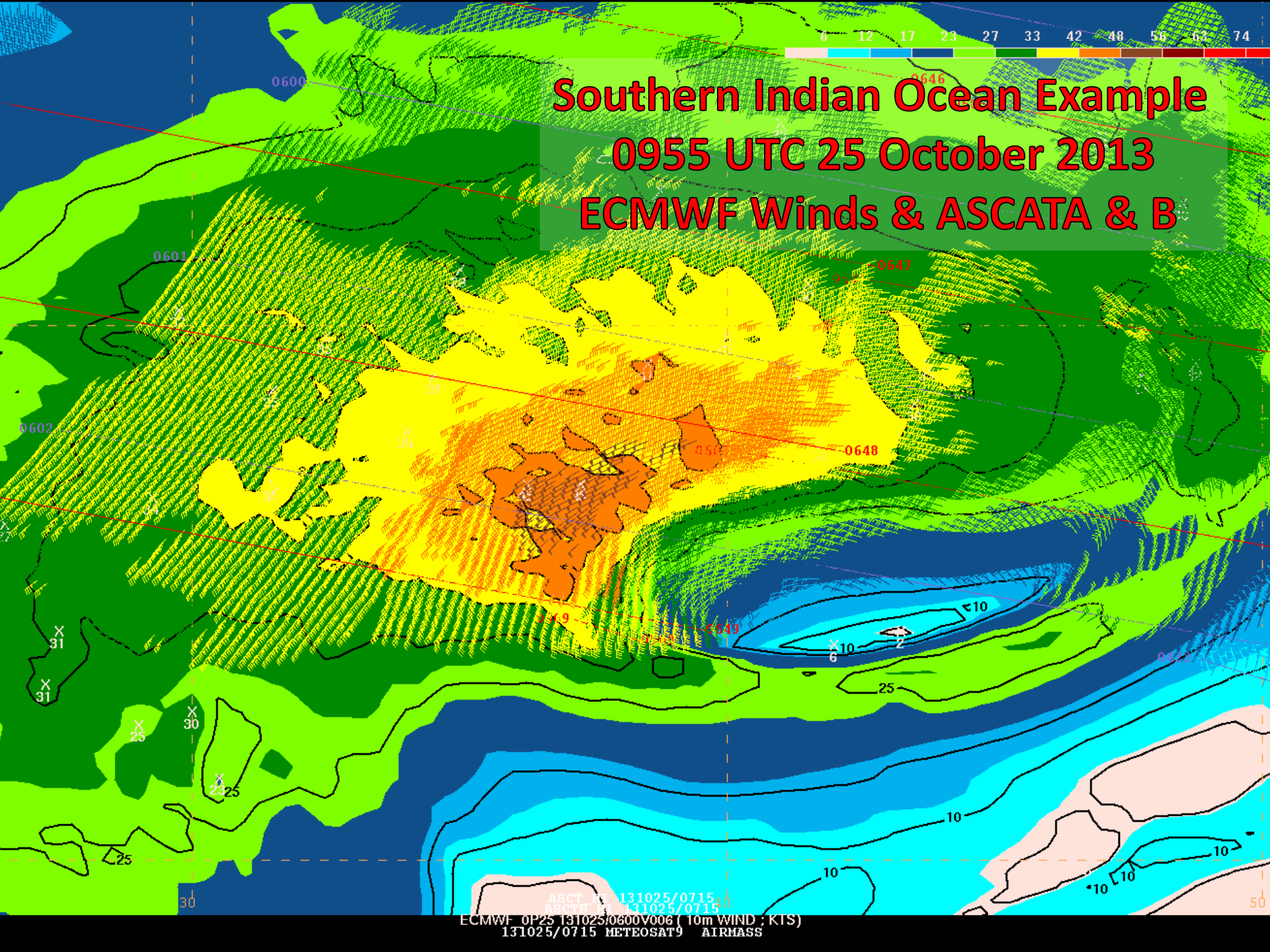
Waves heights from JASON-2 are higher across a broader area than the ECMWF wave model prediction. Would you expect the winds from the ASCAT scatterometer to be stronger than the ECMWF?

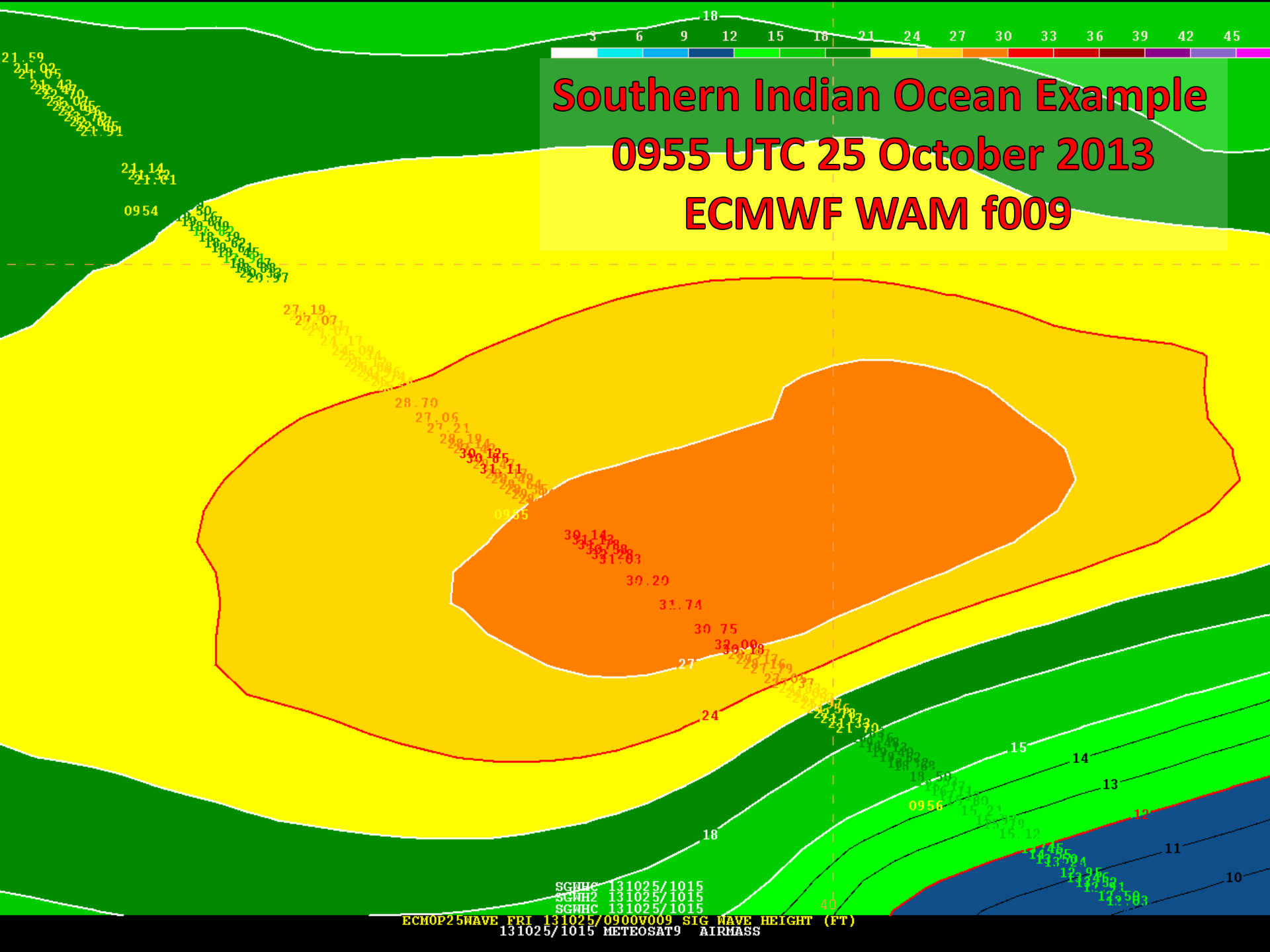
a) Yes, but only the maximum winds.

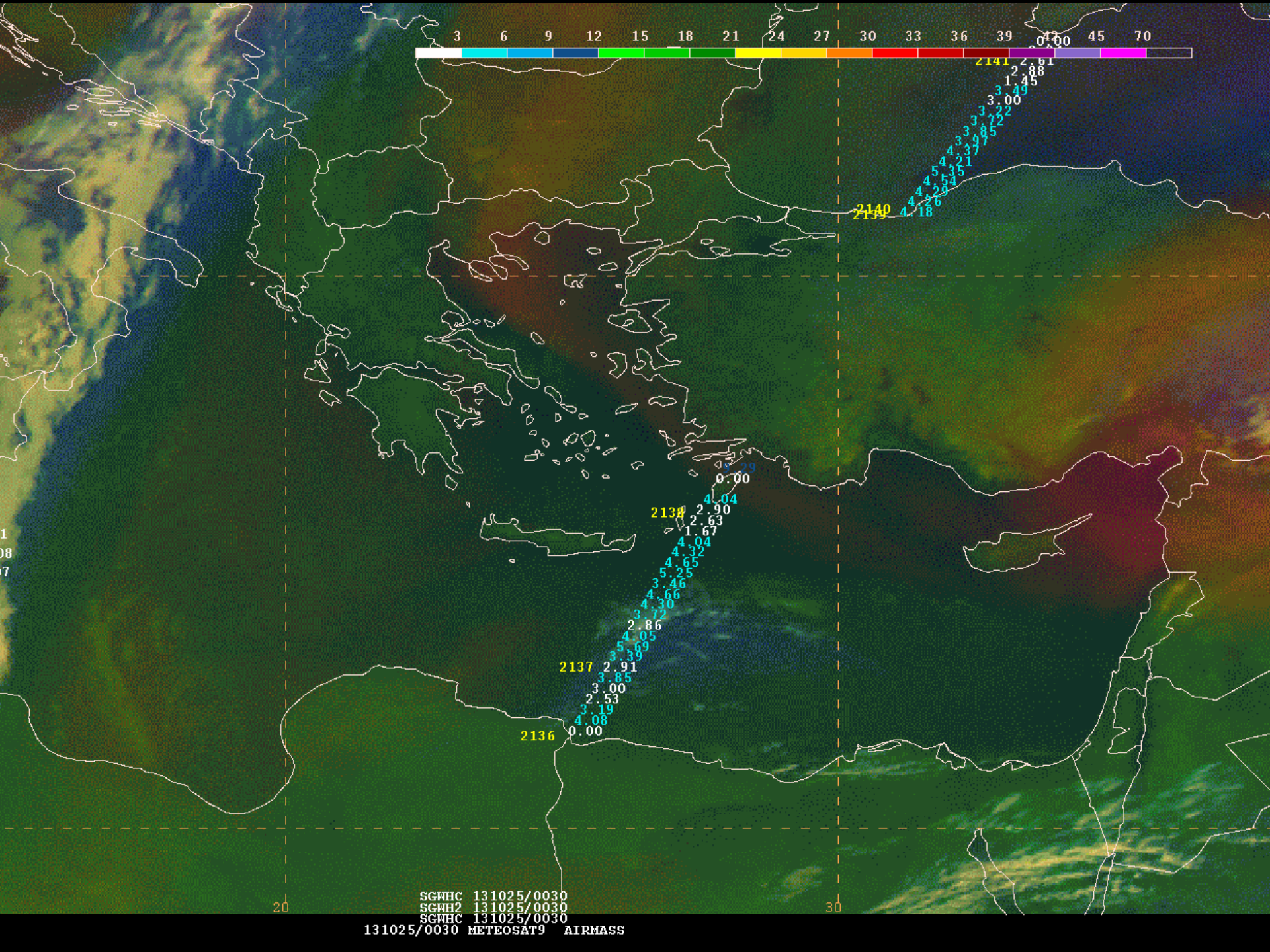
b) Yes, over a broad area.

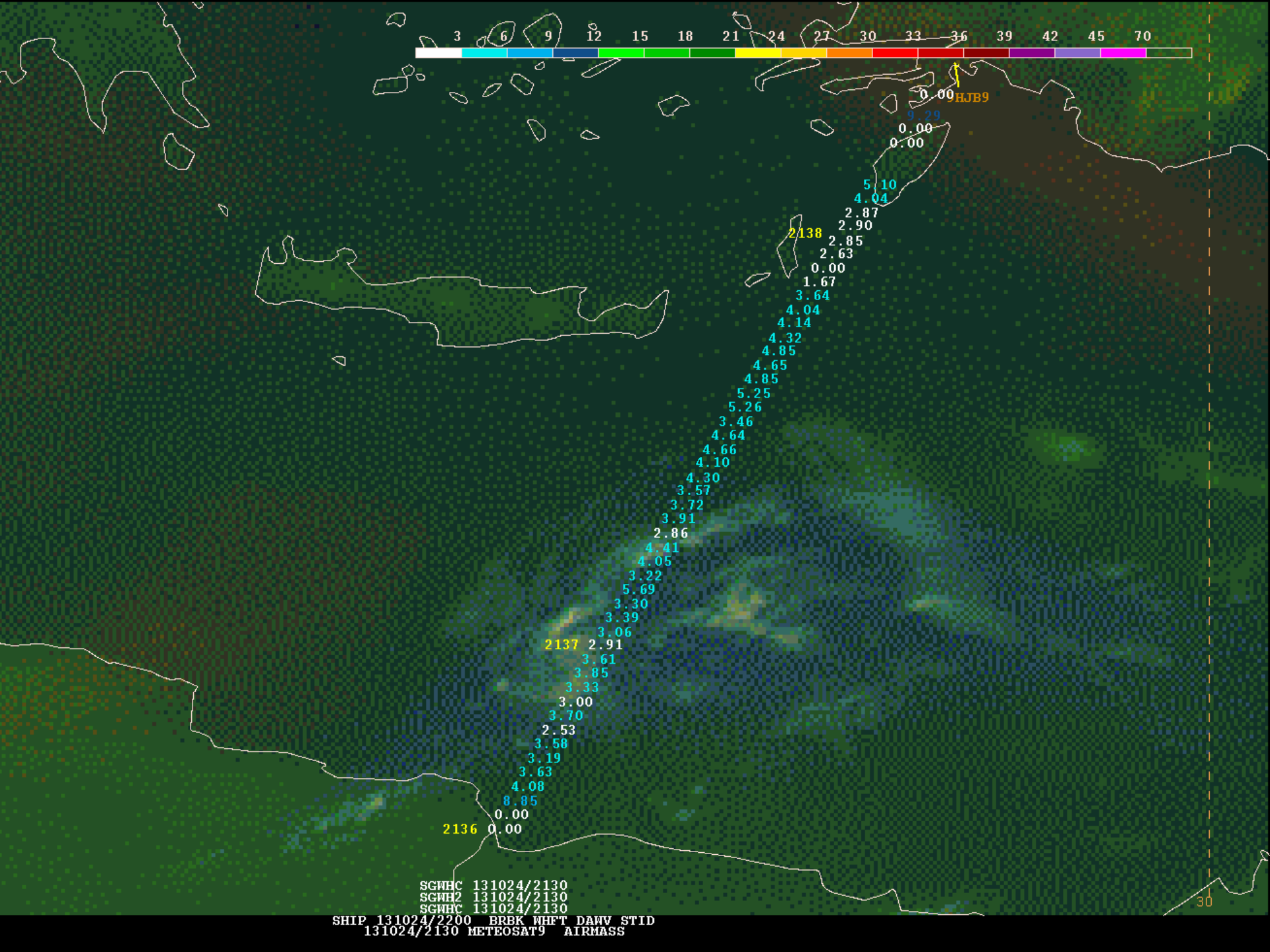
c) No, because the altimeter and scatterometer measure two different effects.

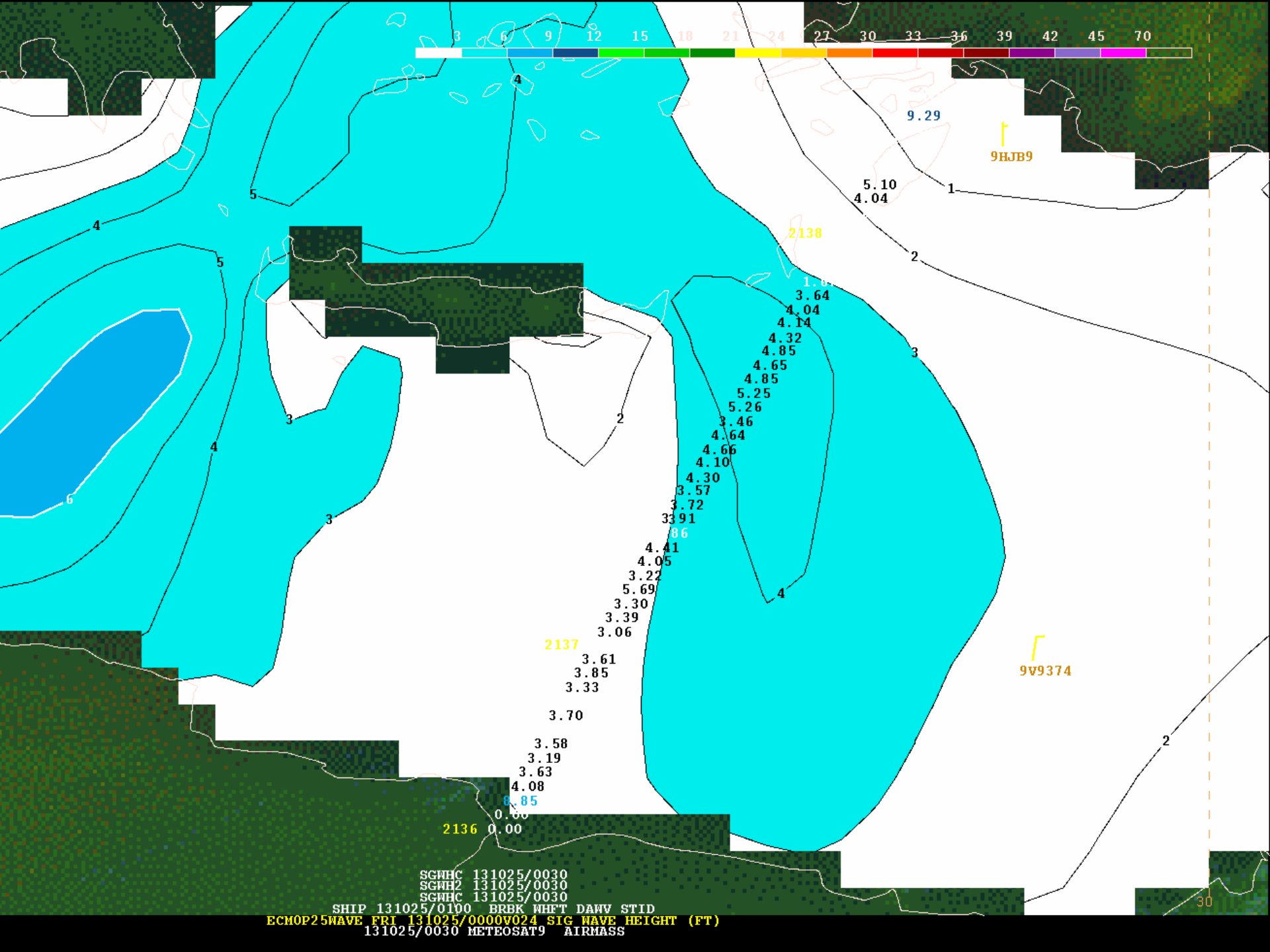
d) No, due to the waves being generated in a fetch limited area because of the Antarctic ice.

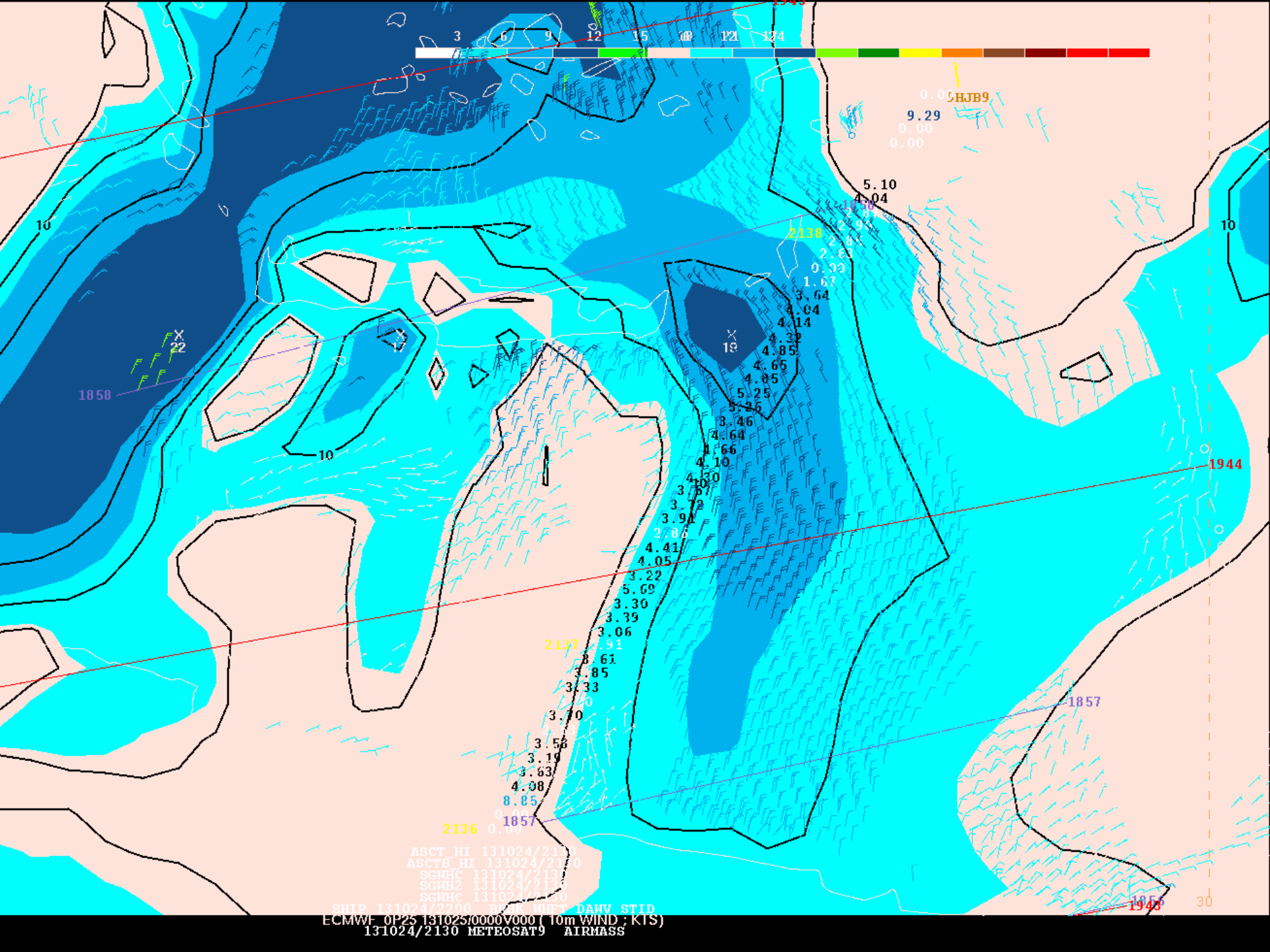

Southern Indian Ocean Example
0955 UTC 25 October 2013
ECMWF Winds & ASCATA & B
6 12 17 23 27 33 42 48 56 62 74
0600
0601
0602
0646
0647
0648
0649
10
25
30
ASCT A 131025/0715
ASCT B 131025/0715
ECMWF 0P25 131025/0600V006 (10m WIND : KTS)
131025/0715 METEOSAT9 AIRMASS

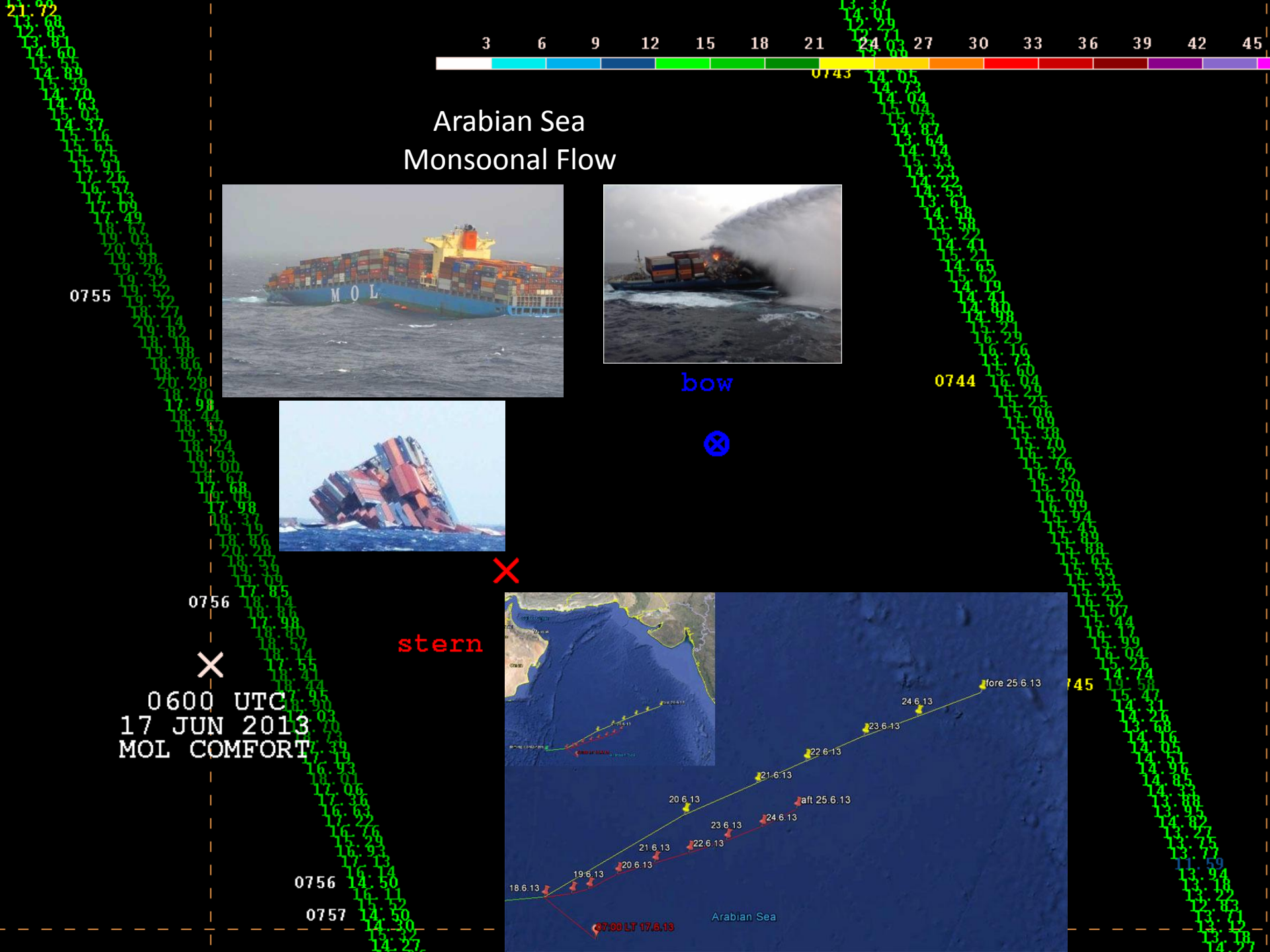

Southern Indian Ocean Example
0955 UTC 25 October 2013
ECMWF WAM f009
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
SGWHC 131025/1015
SGWH2 131025/1015
SGWHC 131025/1015
ECMOP25WAVE FRI 131025/0900V009 SIG WAVE HEIGHT (FT)
131025/1015 METEOSAT9 AIRMASS


3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
0.00
2141 2.61
2.88
1.45
3.49
3.00
3.22
3.72
3.85
3.97
4.37
4.21
5.35
4.54
4.29
4.26
2140
2139
4.18
0.00
4.04
2138 2.90
2.63
1.67
4.04
4.32
4.65
5.25
3.46
4.66
4.30
3.72
2.86
4.05
5.69
3.39
2137 2.91
3.85
3.00
2.53
3.19
4.08
2136
0.00
20
30
SGWHC 131025/0030
SGWH2 131025/0030
SGWHC 131025/0030
131025/0030 METEOSAT9 AIRMASS


3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
0.00 HJB9
9.29
0.00
0.00
5.10
4.04
2.87
2.90
2138 2.85
2.63
0.00
1.67
3.64
4.04
4.14
4.32
4.85
4.65
4.85
5.25
5.26
3.46
4.64
4.66
4.10
4.30
3.57
3.72
3.91
2.86
4.41
4.05
3.22
5.69
3.30
3.39
3.06
2137 2.91
3.61
3.85
3.33
3.00
3.70
2.53
3.58
3.19
3.63
4.08
8.85
0.00
2136 0.00
SGWHC 131024/2130
SGWH2 131024/2130
SGWHC 131024/2130
SHIP 131024/2200 BRBK WHFT DAWV STID
131024/2130 METEOSAT9 AIRMASS
30


3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 70
9.29
9HJB9
5.10
4.04
2138
3.64
4.04
4.14
4.32
4.85
4.65
4.85
5.25
5.26
3.46
4.64
4.66
4.10
4.30
3.57
3.72
3391
4.41
4.05
3.22
5.69
3.30
3.39
3.06
2137
3.61
3.85
3.33
3.70
3.58
3.19
3.63
4.08
8.85
0.00
2136 0.00
9V9374
SGWHC 131025/0030
SGWH2 131025/0030
SGWHC 131025/0030
SHIP 131025/0100 BRBK WHFT DAWV STID
ECMOP25WAVE FRI 131025/0000V024 SIG WAVE HEIGHT (FT)
131025/0030 METEOSAT9 AIRMASS


3 6 9 12 15 18 21 24
HJB9
9.29
0.00
0.00
5.10
4.04
2138
1.67
3.64
4.04
4.14
4.32
4.85
4.65
4.85
5.25
5.26
3.46
4.64
4.66
4.10
4.30
3.91
4.41
4.05
3.22
5.69
3.30
3.39
3.06
8.61
3.85
3.33
3.70
3.58
3.19
3.63
4.08
8.85
1857
1944
1858
10
22
19
2136
ASCT_HI 131024/2130
ASCTB_HI 131024/2130
SGWHC 131024/2130
SGWH2 131024/2130
SGWHC 131024/2130
ECMWF 0P25 131025/0000V000 (10m WIND ; KTS)
131024/2130 METEOSAT9 AIRMASS


3 6 9 12 15 18 21 24 27 30 33 36 39 42 45
Arabian Sea
Monsoonal Flow
bow
stern
0600 UTC
17 JUN 2013
MOL COMFORT
0755
0744
0756
0757
fore 25.6.13
aft 25.6.13
24.6.13
23.6.13
22.6.13
21.6.13
20.6.13
19.6.13
18.6.13
Arabian Sea

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COMET Training Module for JASON-2

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Summary

- Satellite altimeters provide near global coverage of significant wave height over varying repeat cycles

- Altimeters derive significant wave height over a 6 to 7 km length

- Altimeter wave heights are an excellent source to be used to :
  - Determine if a specific weather system is behaving as models have predicted
  - Observe conditions over data sparse areas
  - As a means to bias correct large scale biases in wave models
  - Complement other data sources such as
    - Buoy winds and waves
    - Scatterometer winds
    - Satellite imagery

  - Integrated displays with complimentary observations, imagery, and numerical model output are a very powerful tool to enhance forecaster awareness