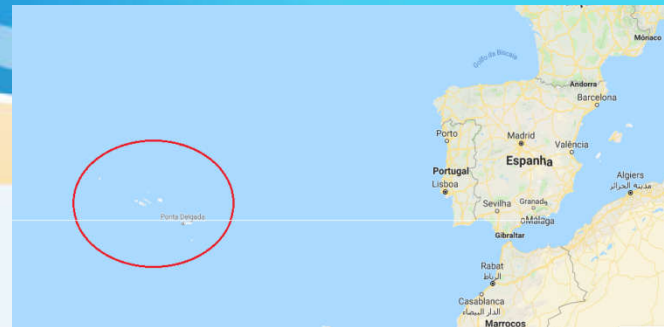


# Tropical and Extratropical cyclones in the Azores

08 November 2018

Eumetrain Marine Event Week



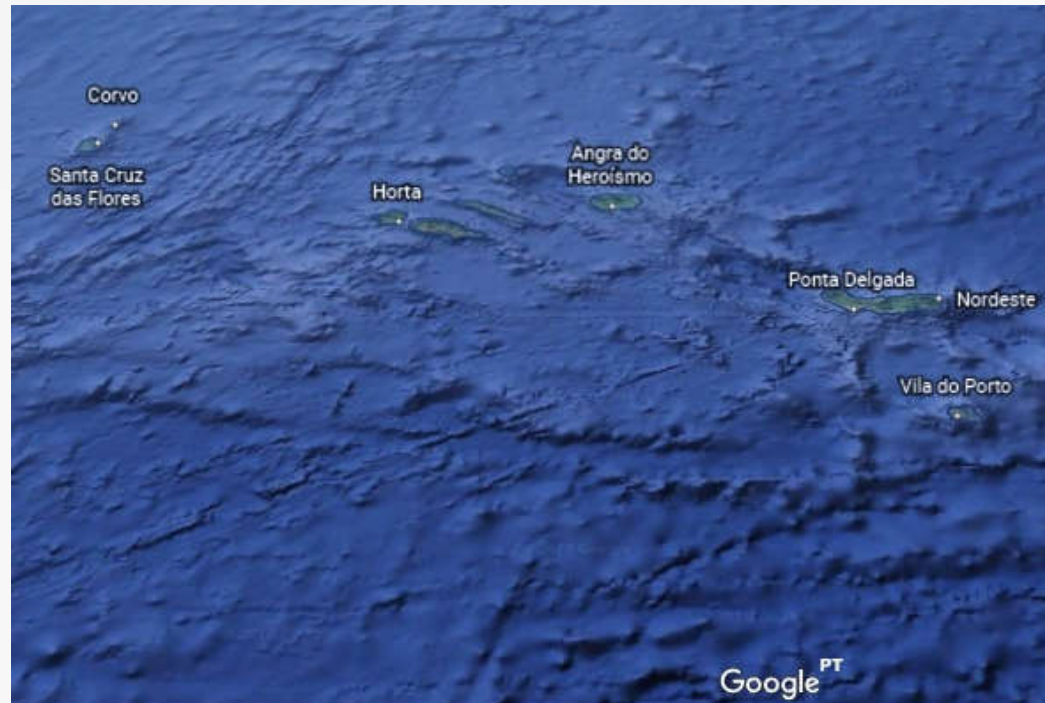
**Carlos Ramalho**

Instituto Português do Mar e da Atmosfera

(Portuguese Institute for Sea and Atmosphere)



- Due to the geographical ( $\sim 37^\circ \text{N}$ ,  $25^\circ \text{W}$ ) location of Azores this archipelago is occasionally affected by strong Extratropical cyclones and even by tropical cyclones.



- Extratropical cyclones are more frequent in winter and tropical cyclones occur mostly in September and October.
  1. Extratropical cyclone: 14 Dec 2015
  2. Tropical cyclones: Ophelia (2017) and Nadine (2012)



## Global Commercial Shipping Routes

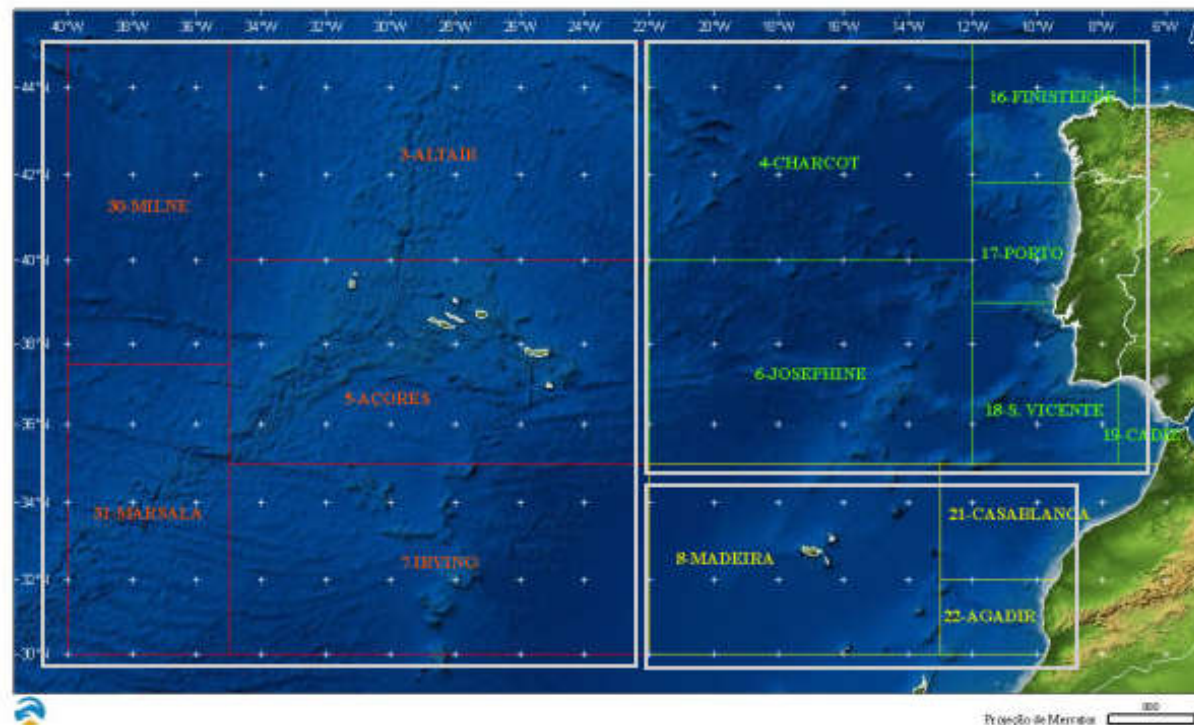




# Navigation forecast IPMA (Portuguese Institute for Sea and Atmosphere)

IPMA > Sea > Marine forecast

## Navigation forecastMarine



## Map bulletins METAREAs

[See map info](#)

## bulletins METAREAs

[Mainland zone](#)

[Arq. Madeira zone](#)

[Arq. Azores zone](#)

## bulletins under 20 miles

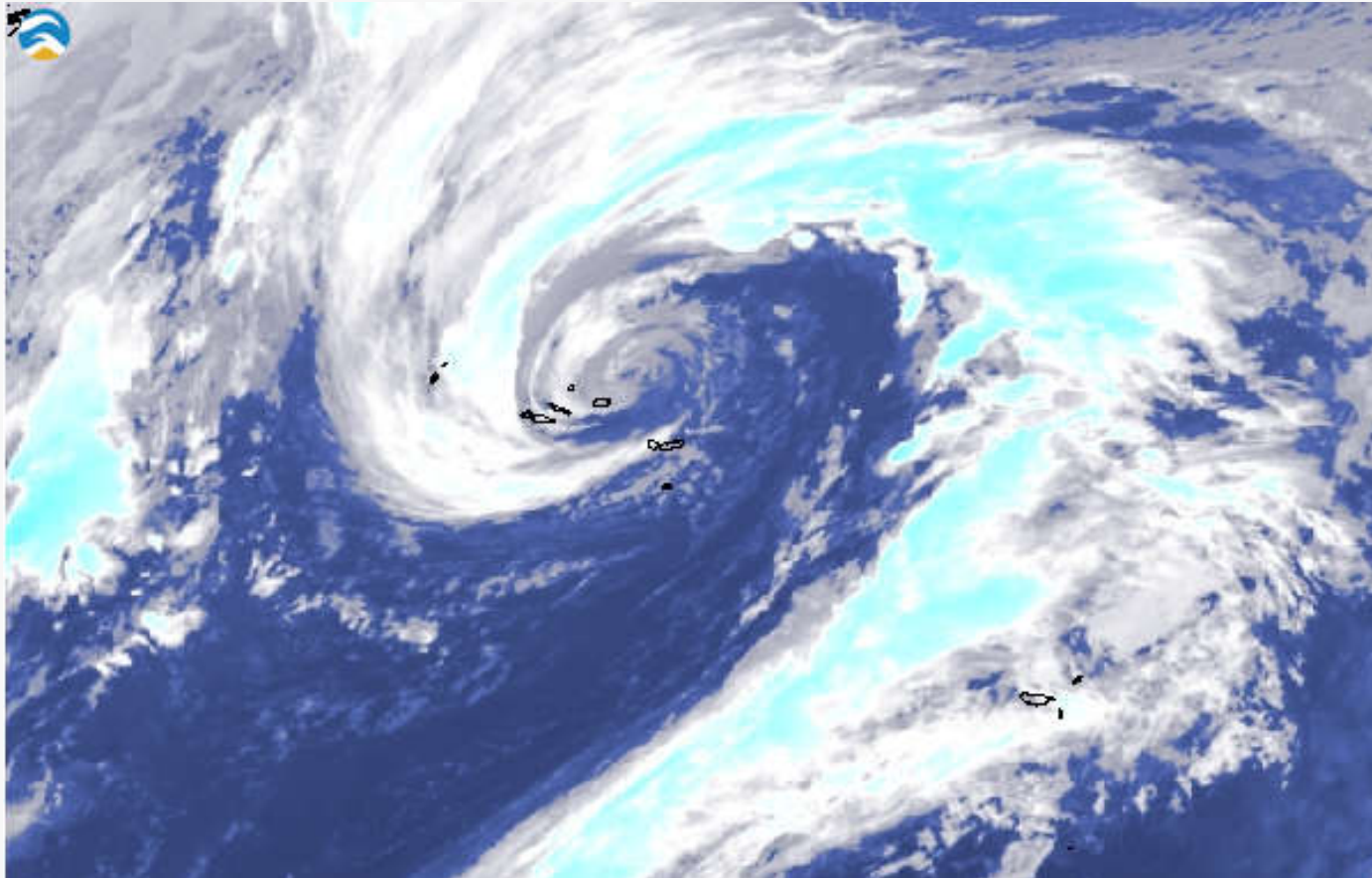
[Mainland zone](#)

[Arq. Madeira zone](#)

[Arq. Azores zone](#)



Case 1:  
Extratropical cyclone 14 December 2015





## Consequences

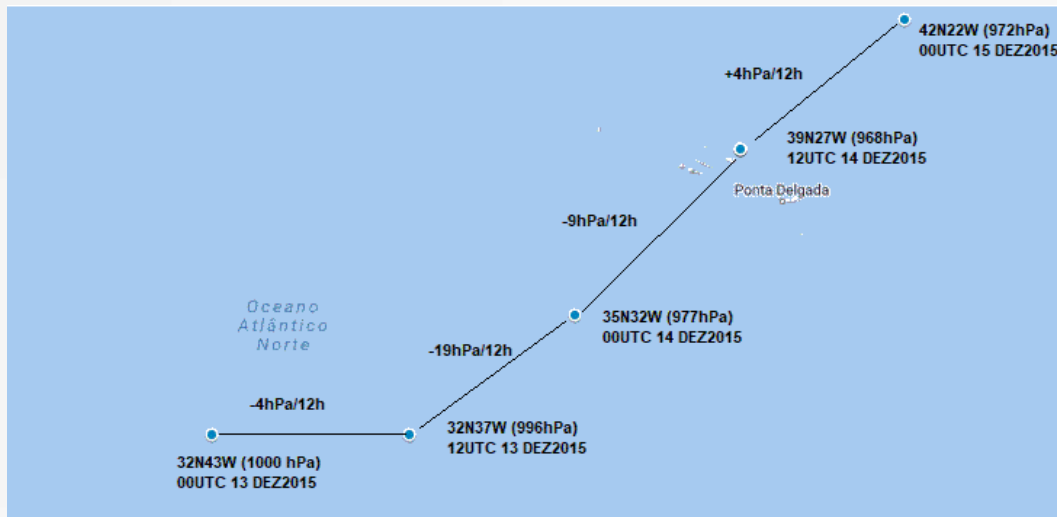


- 16 people lost their home and 4 injured in storm 146 incidents and 1 dead
- Destruction of the marine structure in Ponta Delgada (ships moved away from the port the day before – lesson learned from storm 25 dec 1995)



# Meteorological situation Summary

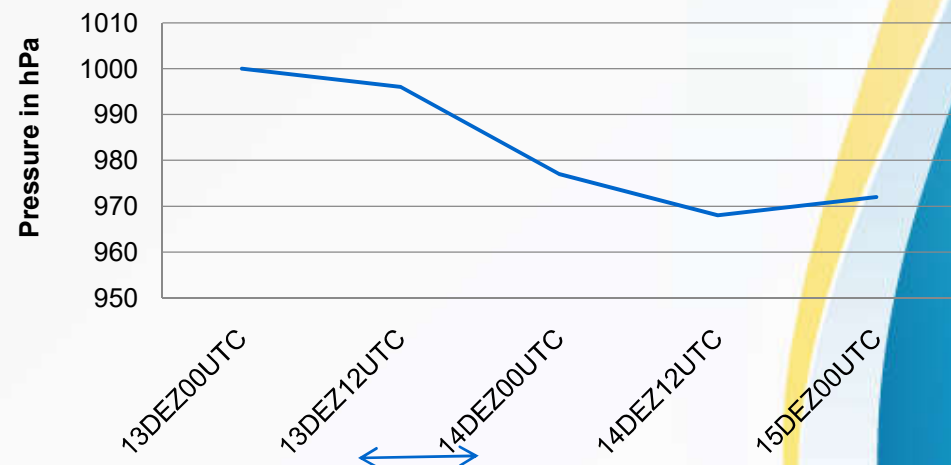
Path and m.s.l.p. variation (hPa)



Pressure variation in center of low (hPa)

Pressure in the center of the low (-28hPa/24h)

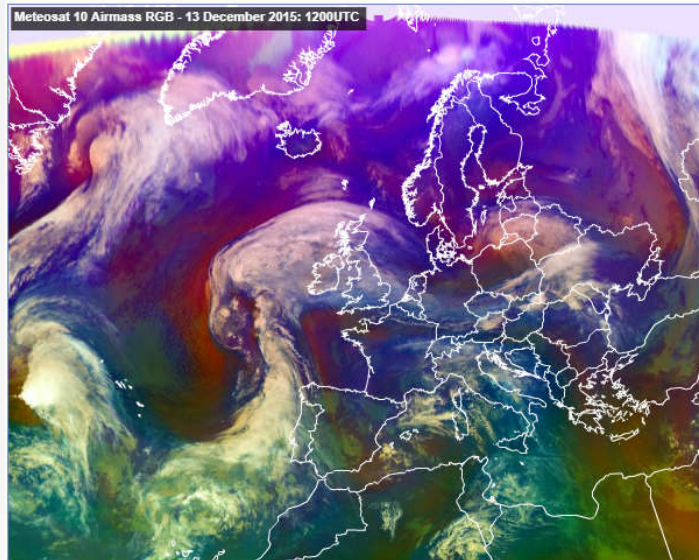
-19 hPa /12h  
12UTC 13Dec to 00UTC 14Dec)



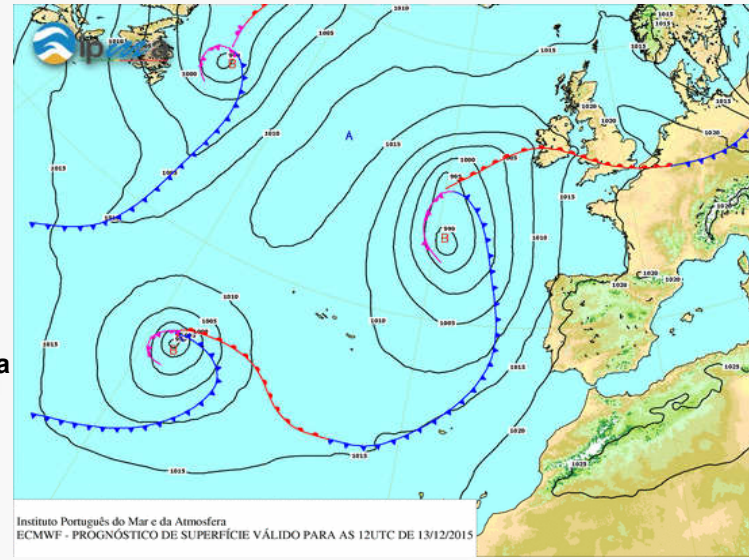


# ECMWF: European Center for Medium-Range Weather Forecast

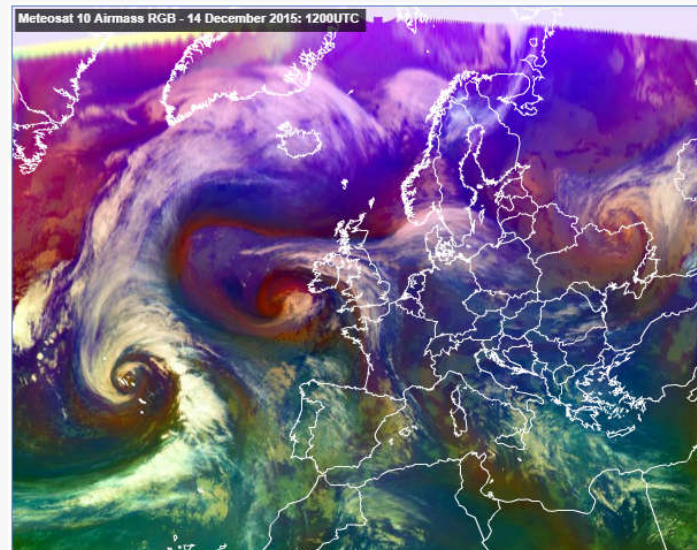
## Mean Sea Level Pressure and Meteosat 10 RGB



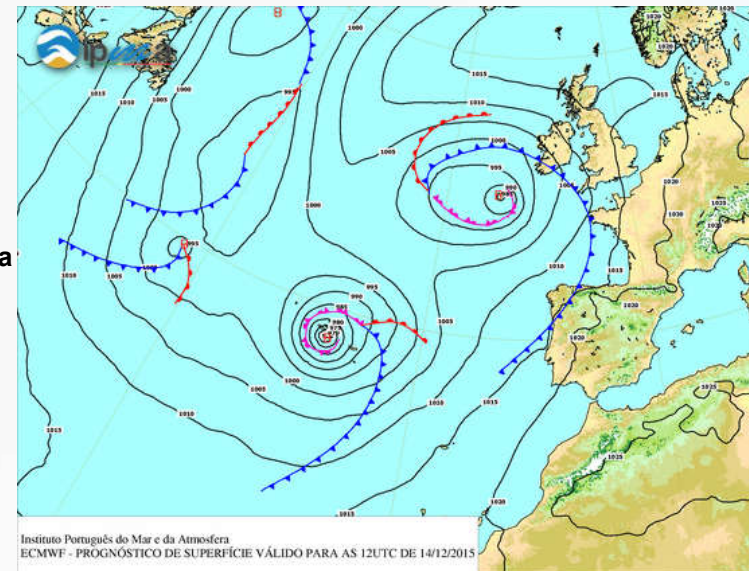
996hPa



-28hPa / 24 h



968hPa





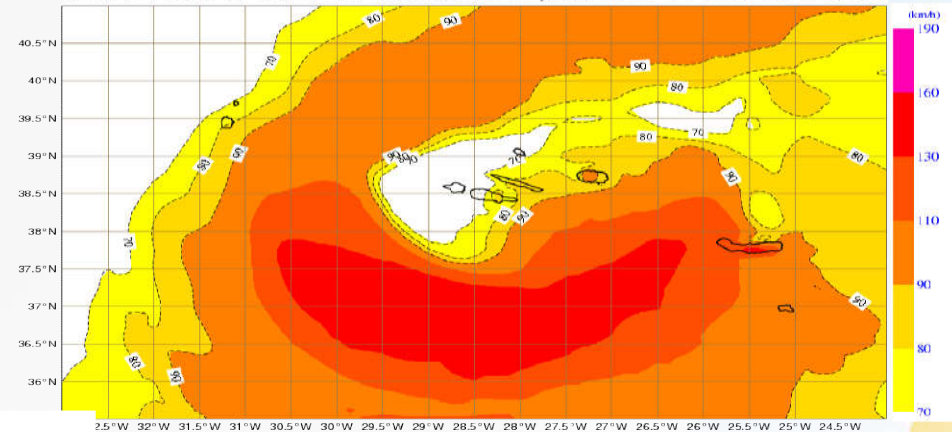
# FORECAST wind gust (km/h)

## ECMWF: European Center for Medium-Range Weather Forecast

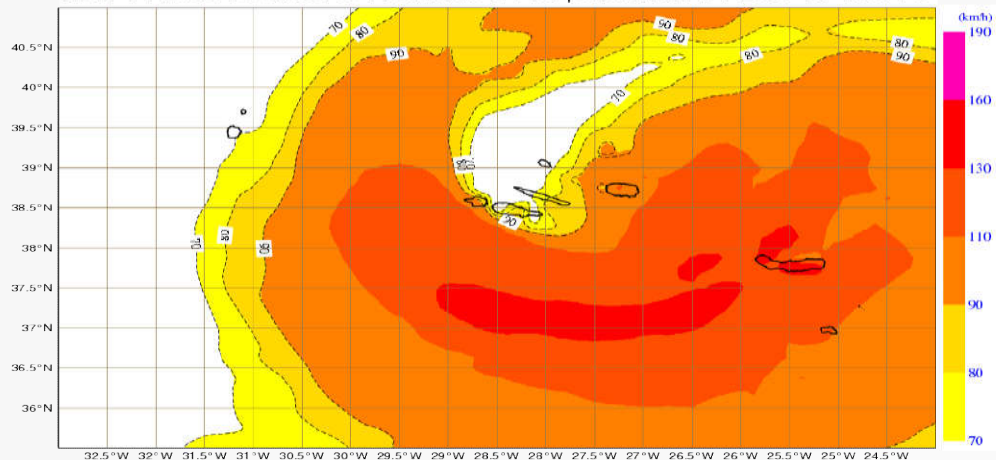
Maximum gust expected  
110 to 130 km/h between 09 and 12 UTC

Maximum gust expected 130 to 160 km/h  
between 12 and 15 UTC (São Miguel)

ECMWF: Rajada máxima a 10m nas últimas 3 horas ( $\text{km h}^{-1}$ )  
Mon 14 Dec 15 00UTC Previsão H+12 para Mon 14 Dec 15 12UTC



ECMWF: Rajada máxima a 10m nas últimas 3 horas ( $\text{km h}^{-1}$ )  
Mon 14 Dec 15 00UTC Previsão H+15 para Mon 14 Dec 15 15UTC

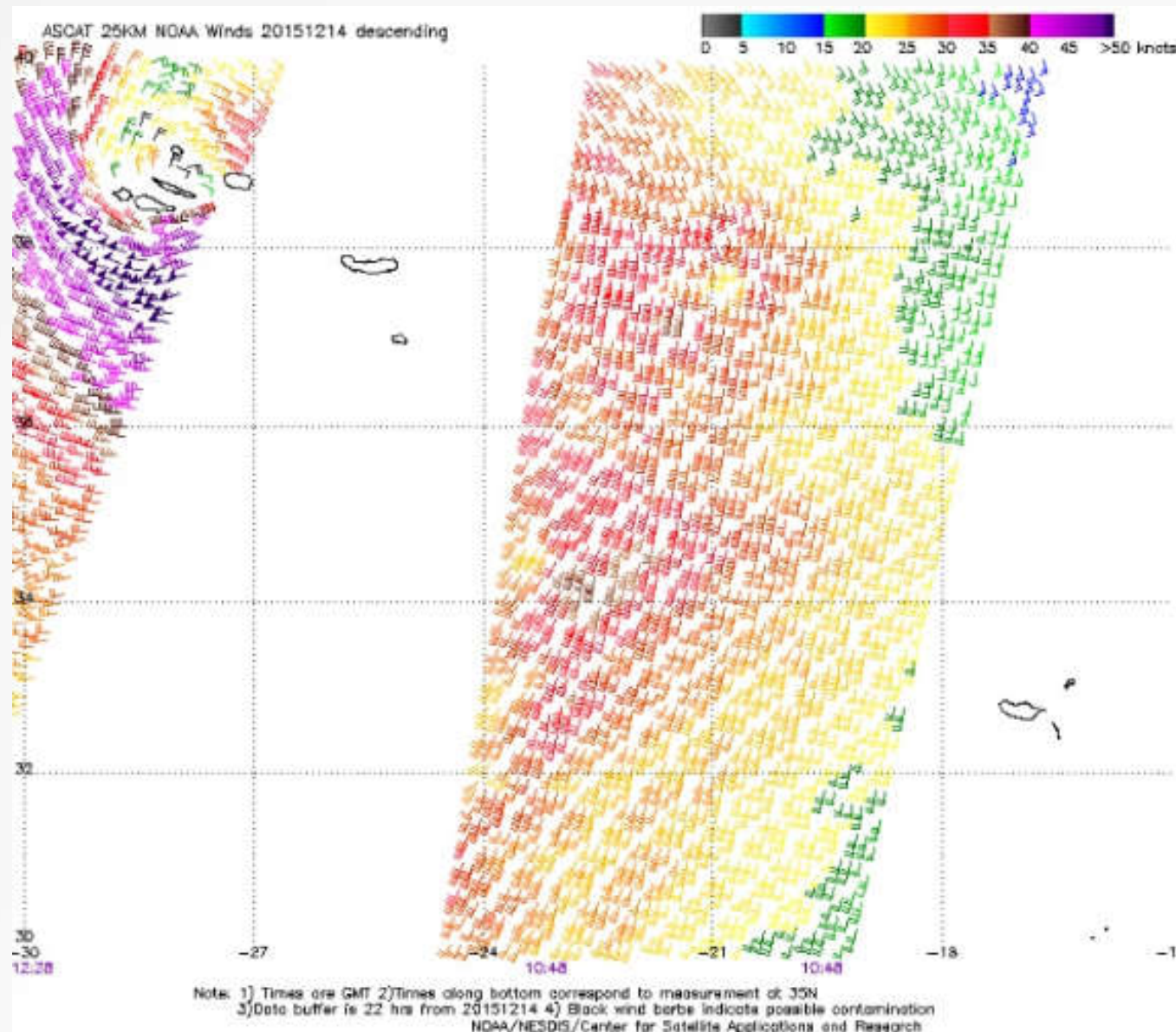


Maximum gust observed 141 km/h in  
São Miguel



# Advanced Scatterometer (ASCAT)

## 14 December 2015

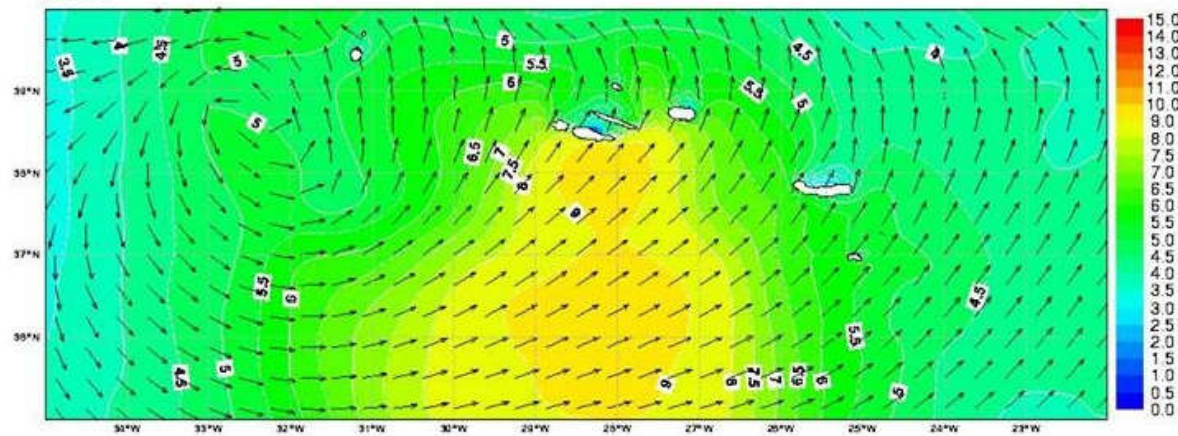




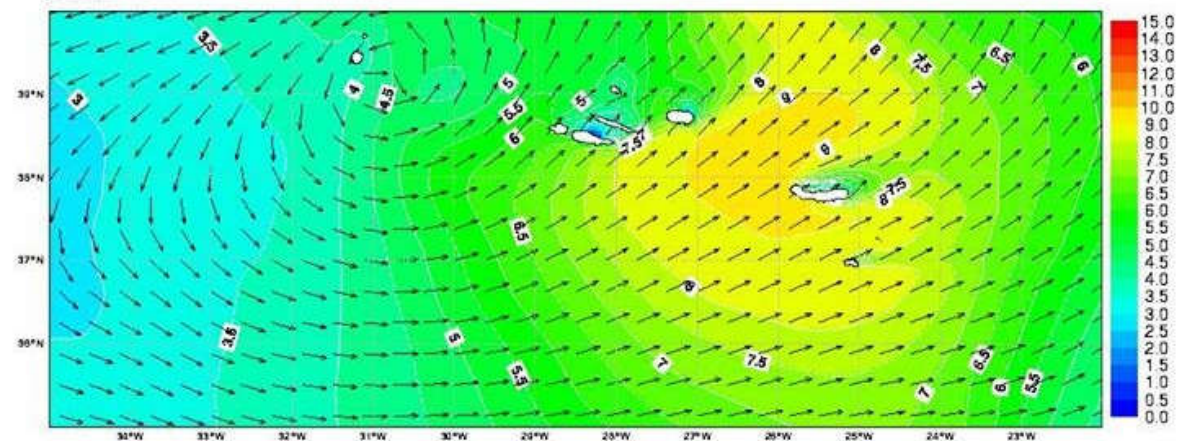
## FORECAST significant waves height (m) LAM (European Shelf Model)

3 days before: Significant wave height expected 8 to 10 m from SW in Central and Eastern islands.

Friday 11 December 2015 12UTC ECMWF Previsão H+078 para Monday 14 December 2015 18UTC  
Altura significativa (m) e direção média das ondas  
20413



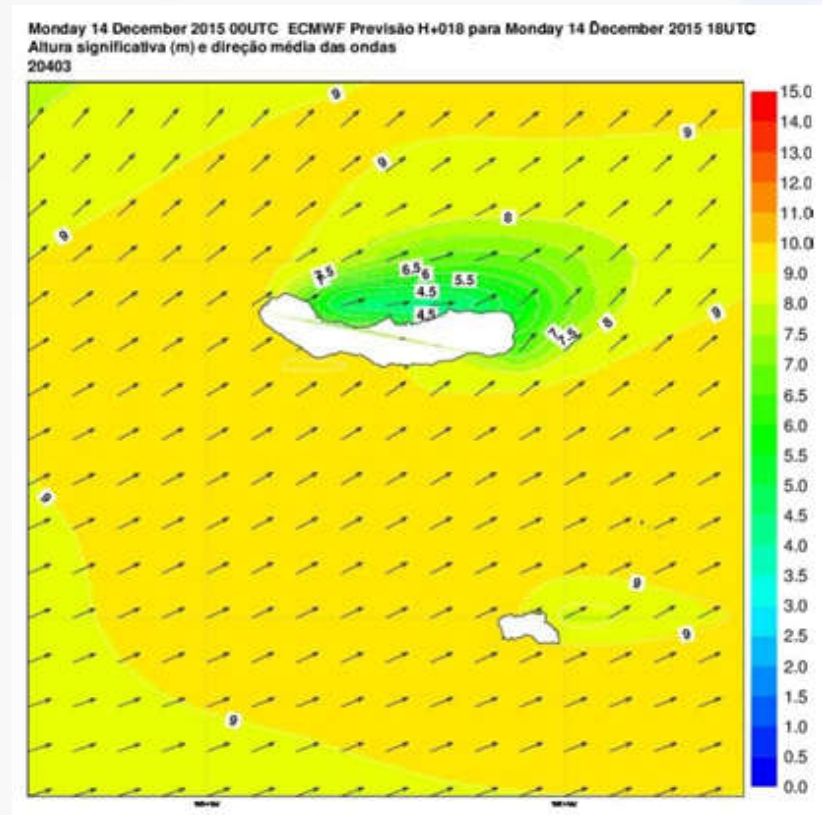
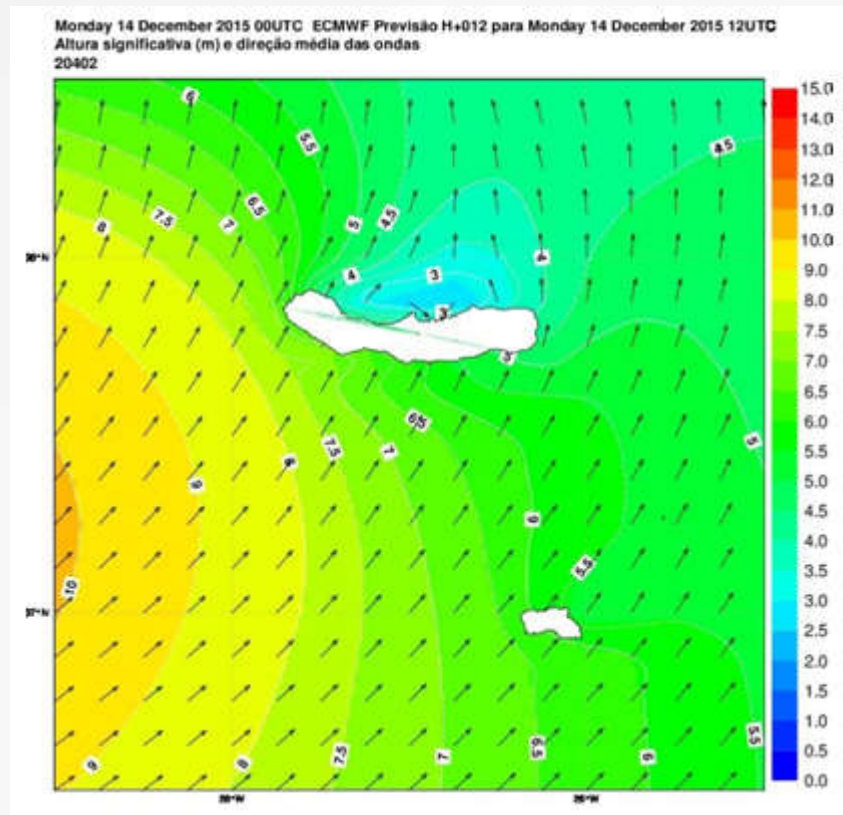
Friday 11 December 2015 12UTC ECMWF Previsão H+084 para Tuesday 15 December 2015 00UTC  
Altura significativa (m) e direção média das ondas  
20414





## FORECAST significant waves height (m) LAM (European Shelf Model)

Significant wave height expected 8 to 10 m from SW in Central and Eastern islands.

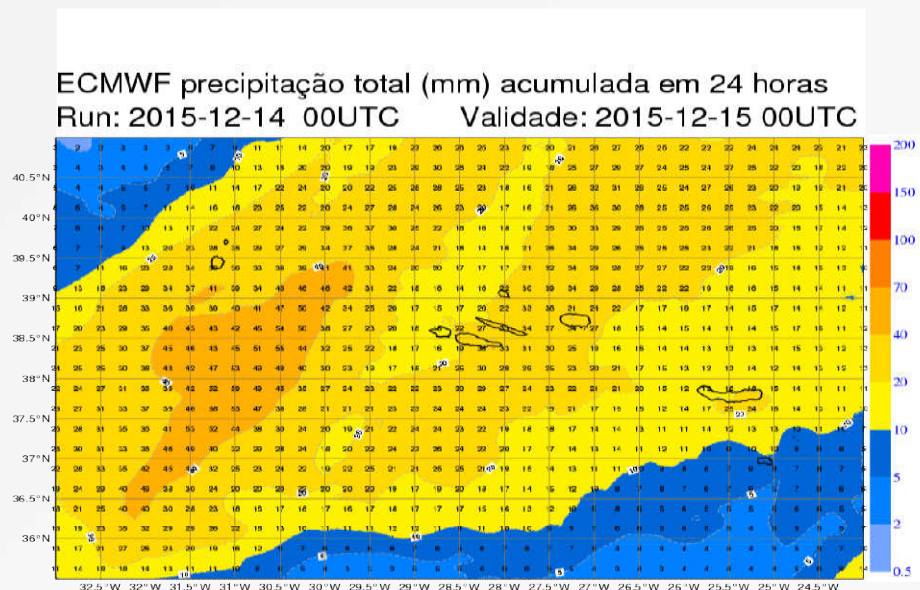


Significant wave height 8 m central and eastern islands  
(CLIMAAT: University of Azores buoys)

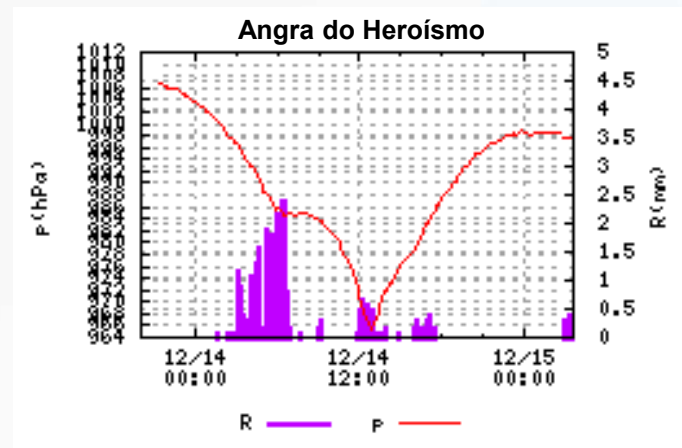
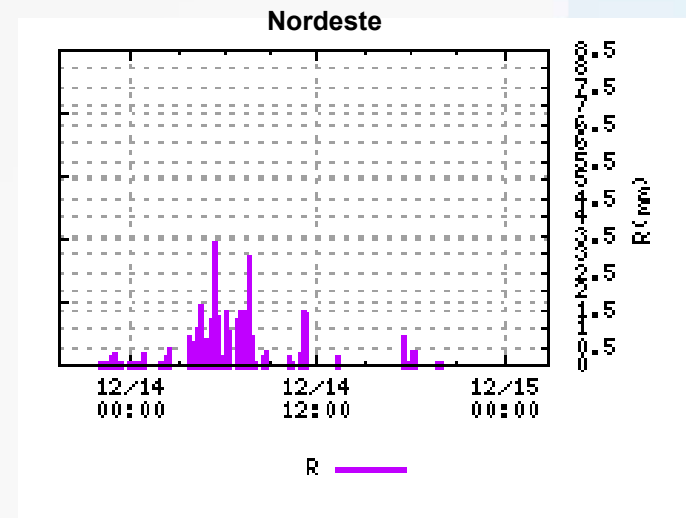


# FORECAST precipitation (mm)

## ECMWF:European Center for Medium-Range Weather Forecast



Expected precipitation 20 to 35 mm in 24h



m.s.l.p. Angra do Heroísmo 968 hPa



# 14 December 2015

## Final Notes

InfoSAM - Limites por grupo

Selecione grupo

Grupo Oriental	Limites para Grupo Central					
Grupo Central	Precipitação	[ 10 : 20 ]	[ 20 : 40 ]	> 40	mm/h	Milímetros numa hora
Grupo Ocidental		[ 25 : 40 ]	[ 40 : 60 ]	> 60	mm/6h	Milímetros em 6 horas
	Vento	[ 65 : 75 ]	[ 75 : 87 ]	> 87	km/h	
		[ 85 : 100 ]	[ 100 : 130 ]	> 130	km/h	
	Agit. Marítima	[ 6 : 7 ]	[ 7 : 9 ]	> 9	m	
		-- : --	-- : --	--	--	
	Trovoada	-- : --	-- : --	--	--	
	Calor	[ 28 : 29 ]	[ 29 : 31 ]	> 31	°C	Duração >= 48 horas
	Frio	[ 8 : 5 ]	[ 5 : 0 ]	< 0	°C	Duração >= 48 horas
	Neve	[ 0 : 1 ]	[ 1 : 5 ]	> 5	cm	Duração >= 48 horas e Cota >900 m
		[ 0 : 1 ]	[ 1 : 5 ]	> 5	cm	
	Nevoeiro	d)	e)	f)	--	d) Duração >= 48 horas
						e) Duração >= 72 horas
						f) Duração >= 96 horas

### Due to the weather warnings (wind):

- Schools and public services were closed
- Most of the private sector closed at lunch time
- Ships in Ponta Delgada port moved away



Forecast with ECMWF operational model was of foremost importance in this situation

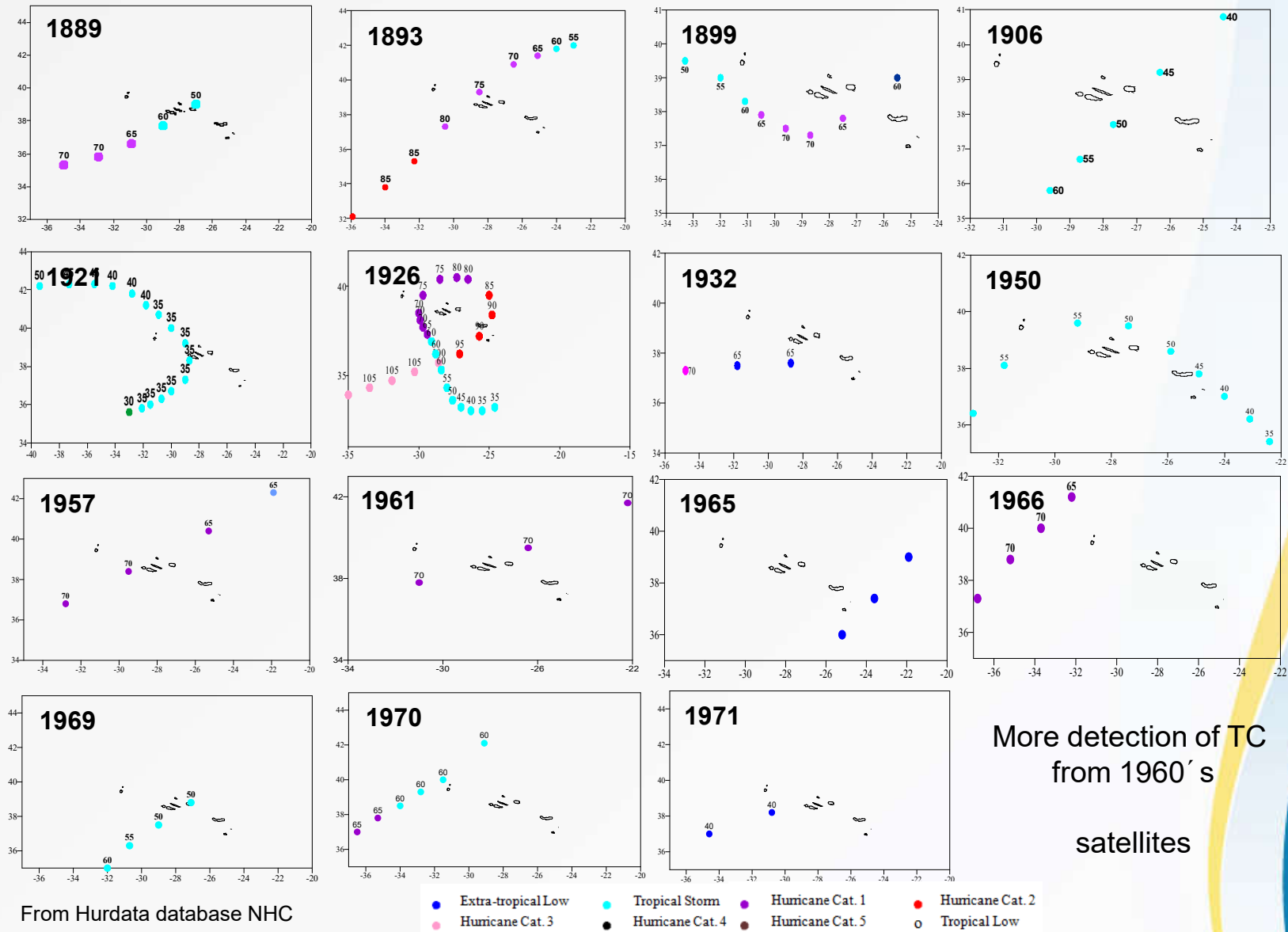


## Tropical cyclones in Azores





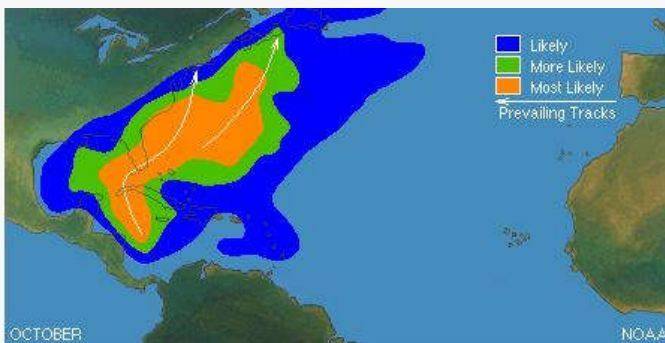
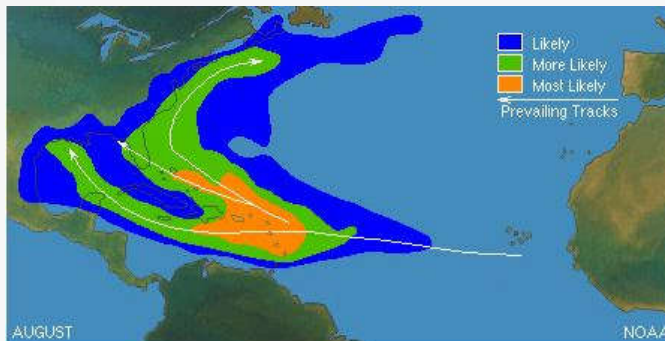
# Tropical cyclones in Azores



More detection of TC  
from 1960's  
satellites



## Prevailing tracks (month)

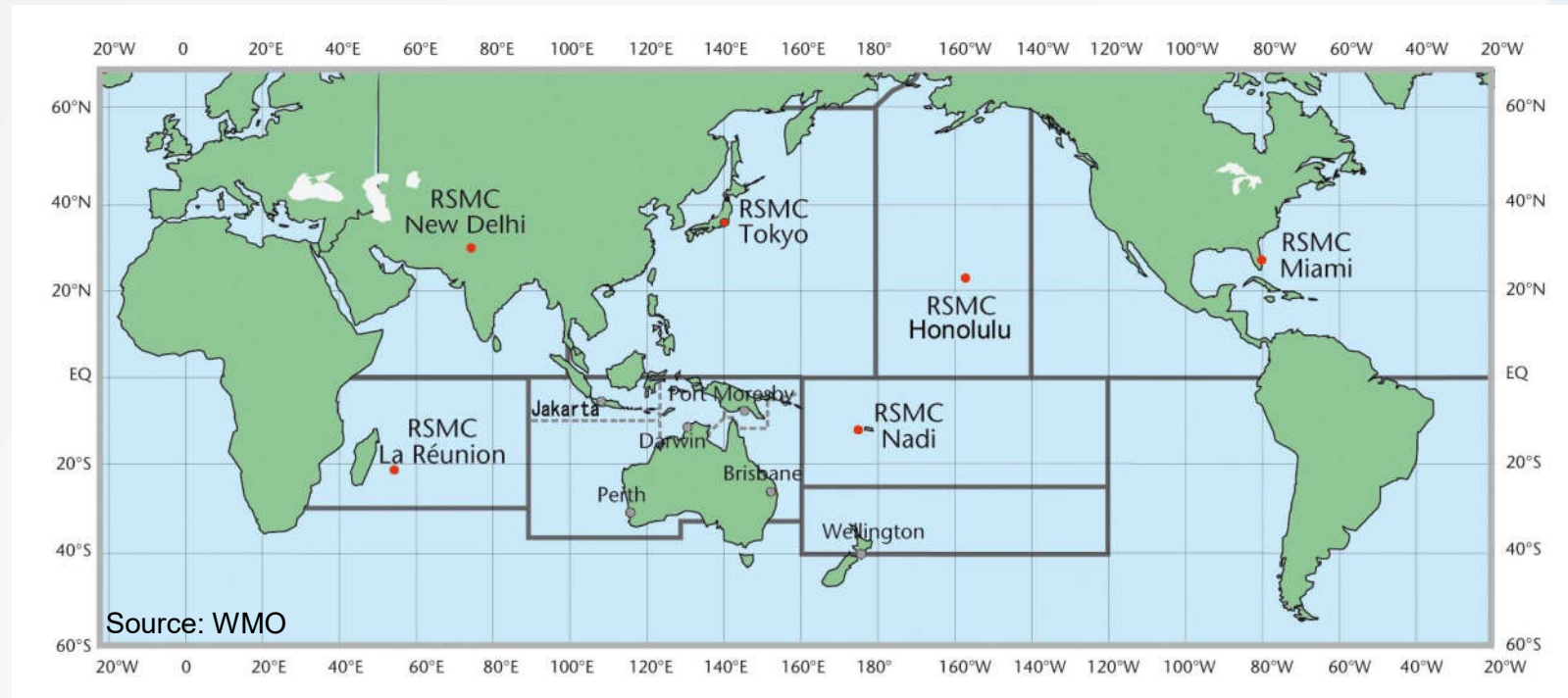


Azores: Occur mostly in September and October



## Tropical cyclone forecast

### Regional Specialized Meteorological Centres (RSMCs)



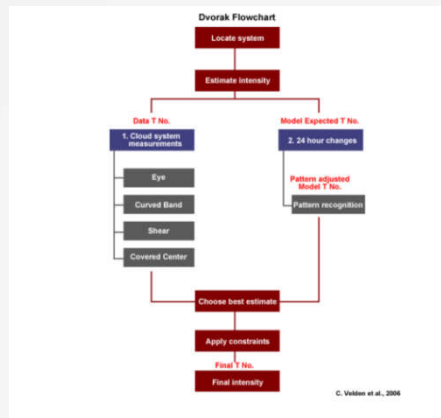
For the North Atlantic (Azores)

**RSMC Miami-Hurricane Center/NOAA/NWS National Hurricane Center, USA.**

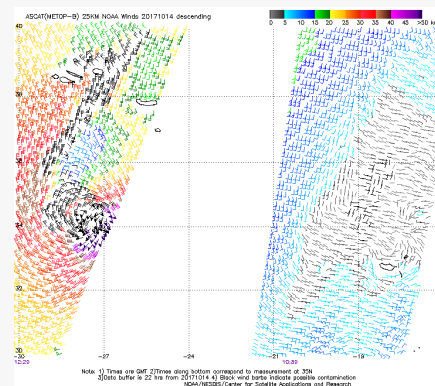


# National Hurricane Center techniques to estimate tropical cyclones intensity

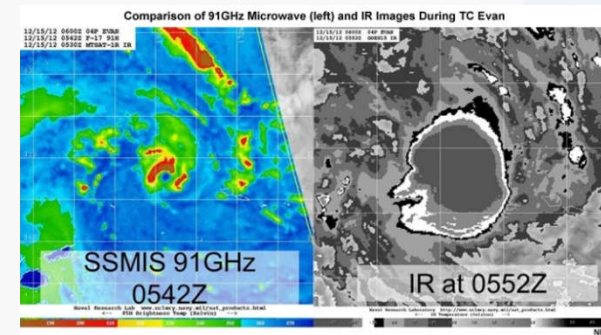
## Dvorak Technique



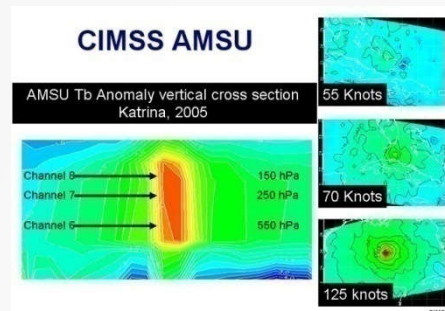
## Scatterometers



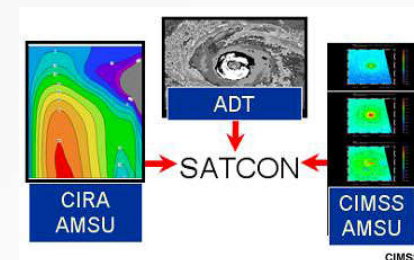
## Microwave Patterns



## Microwave Sounders

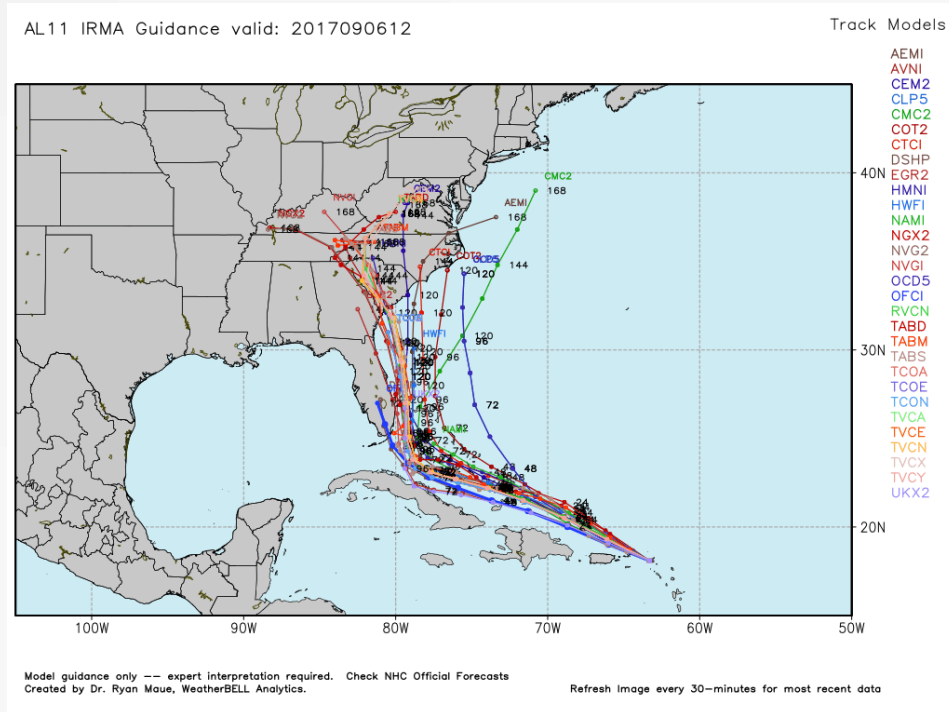


## SATCON





## Forecast intensity and path meteorological models



- Statistical:** Forecasts based on established relationships between storm-specific information (i.e., location and time of year) and the behavior of previous storms.

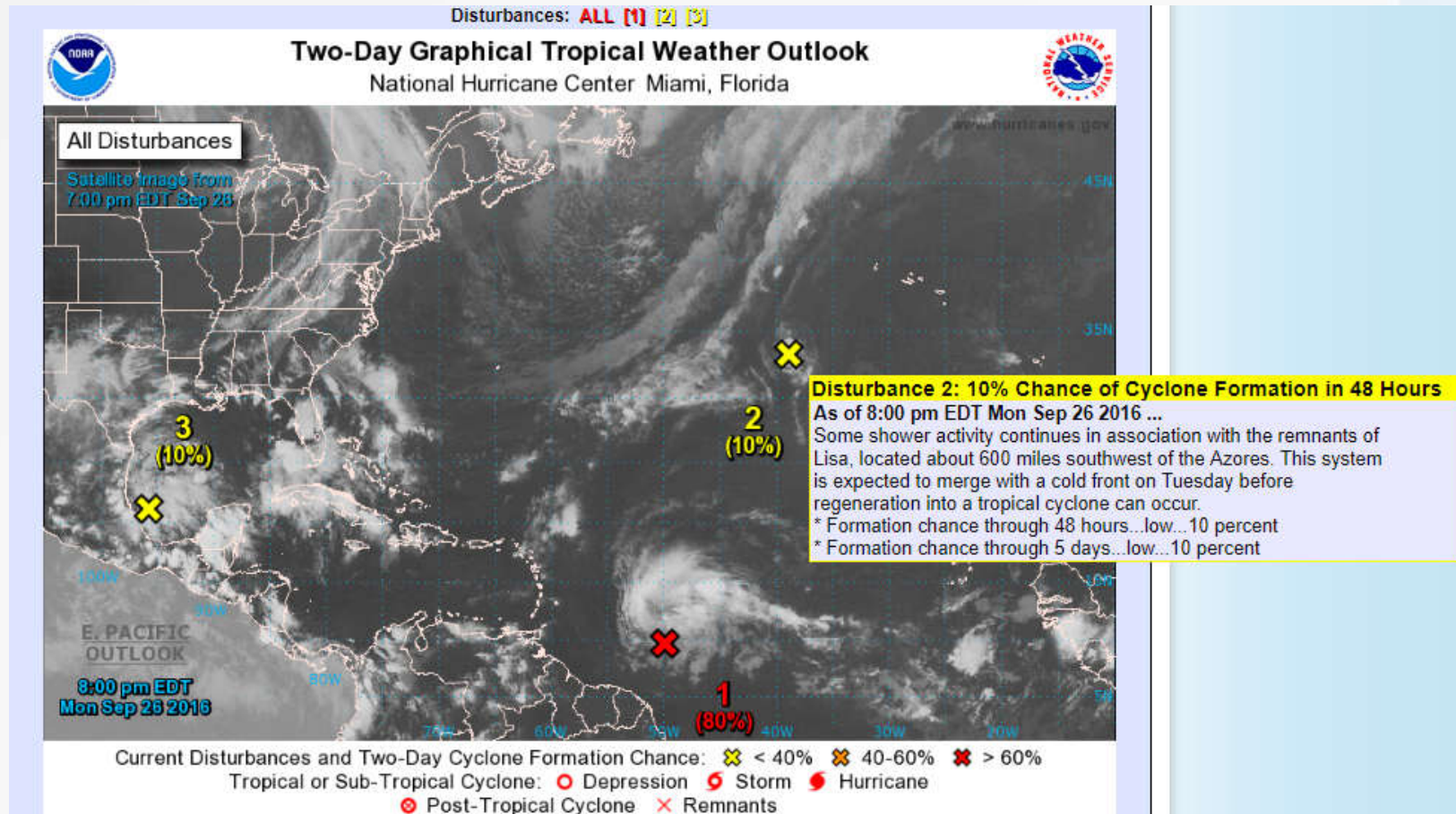
- Simplified dynamical :** Forecasts based on simplified dynamic representation of interaction with vortex and prevailing flow (trajectory)

- Consensus:** Based on multi-model or single-model ensembles

- Dynamical:** solve the three-dimensional physical equations of motion that govern the atmosphere.



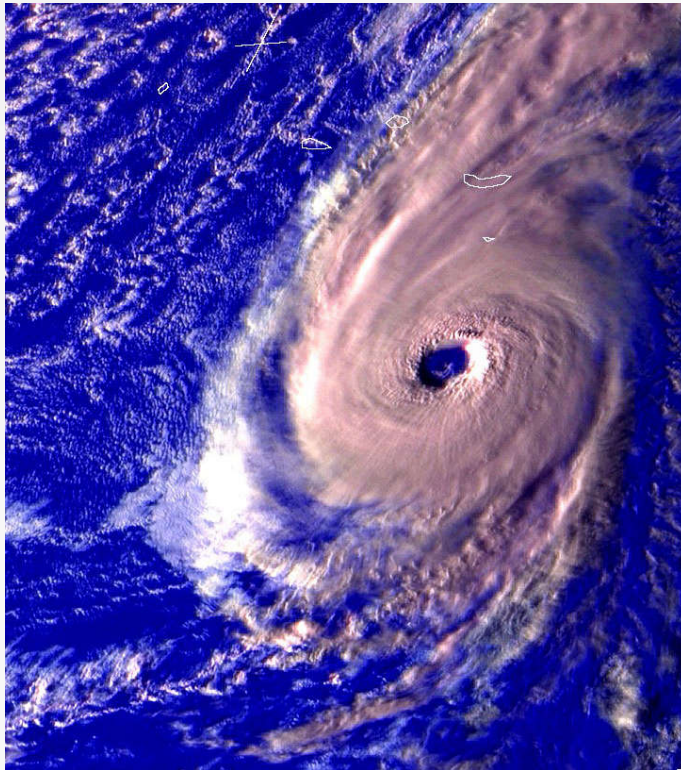
## The forecast rely mostly in information from NHC





# Case1

## Hurricane Ophelia (9-15 October 2017)



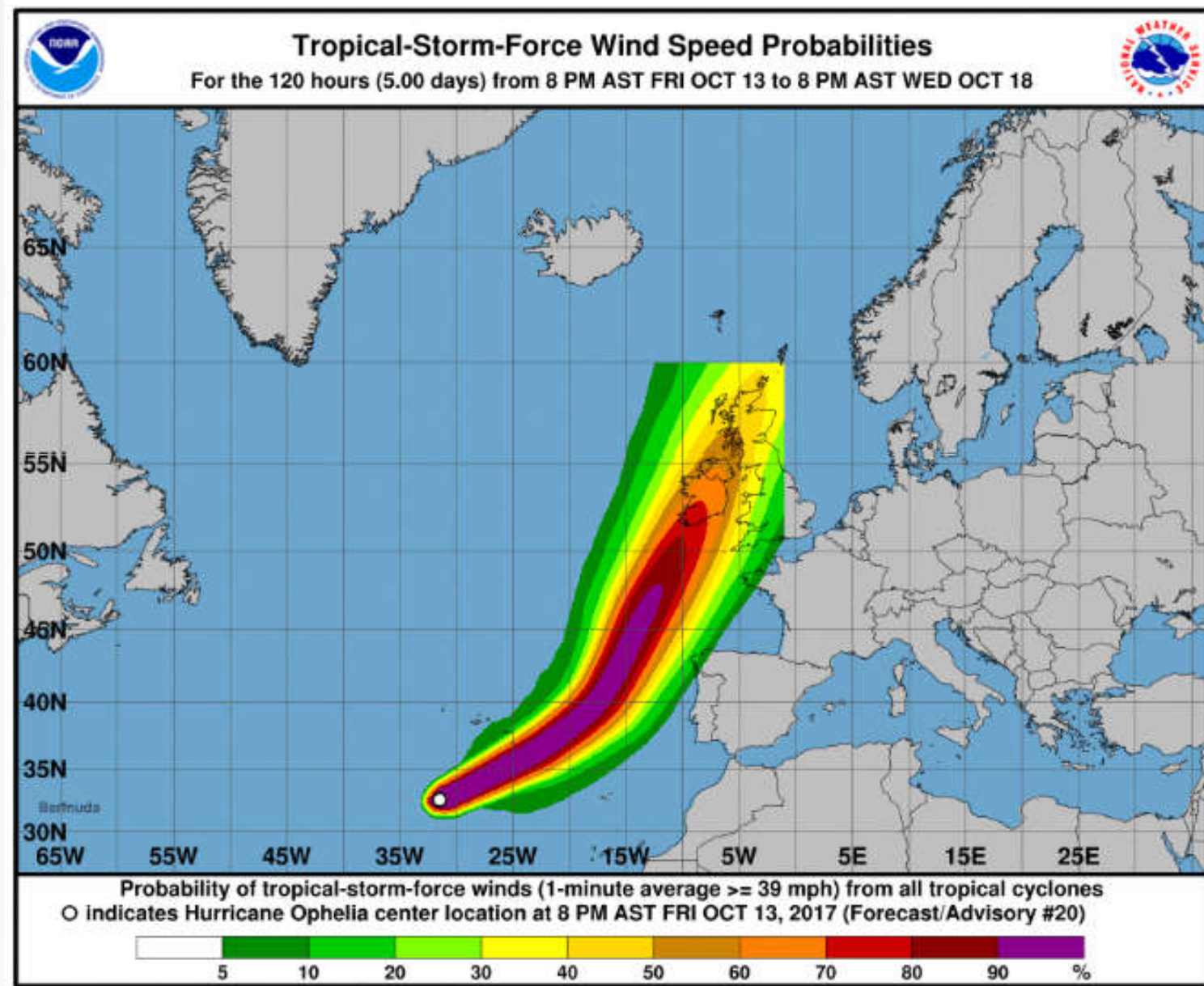
HRV image, tainted with values from the near infrared channels of Meteosat , at sunset on 14 October around 18:00 UTC, when the system passed south of Azores.

Category	Winds	Summary
1	74-95 mph 64-82 kt 119-153 km/h	Very dangerous winds will produce some damage
2	96-110 mph 83-95 kt 154-177 km/h	Extremely dangerous winds will cause extensive damage
3	111-129 mph 96-112 kt 178-208 km/h	Devastating damage will occur
4	130-156 mph 113-136 kt 209-251 km/h	Catastrophic damage will occur
5	157 mph or higher 137 kt or higher 252 km/h or higher	Catastrophic damage will occur

Category 3 hurricane: 178-208 km/h  
( Saffir-Simpson Hurricane Wind Scale)

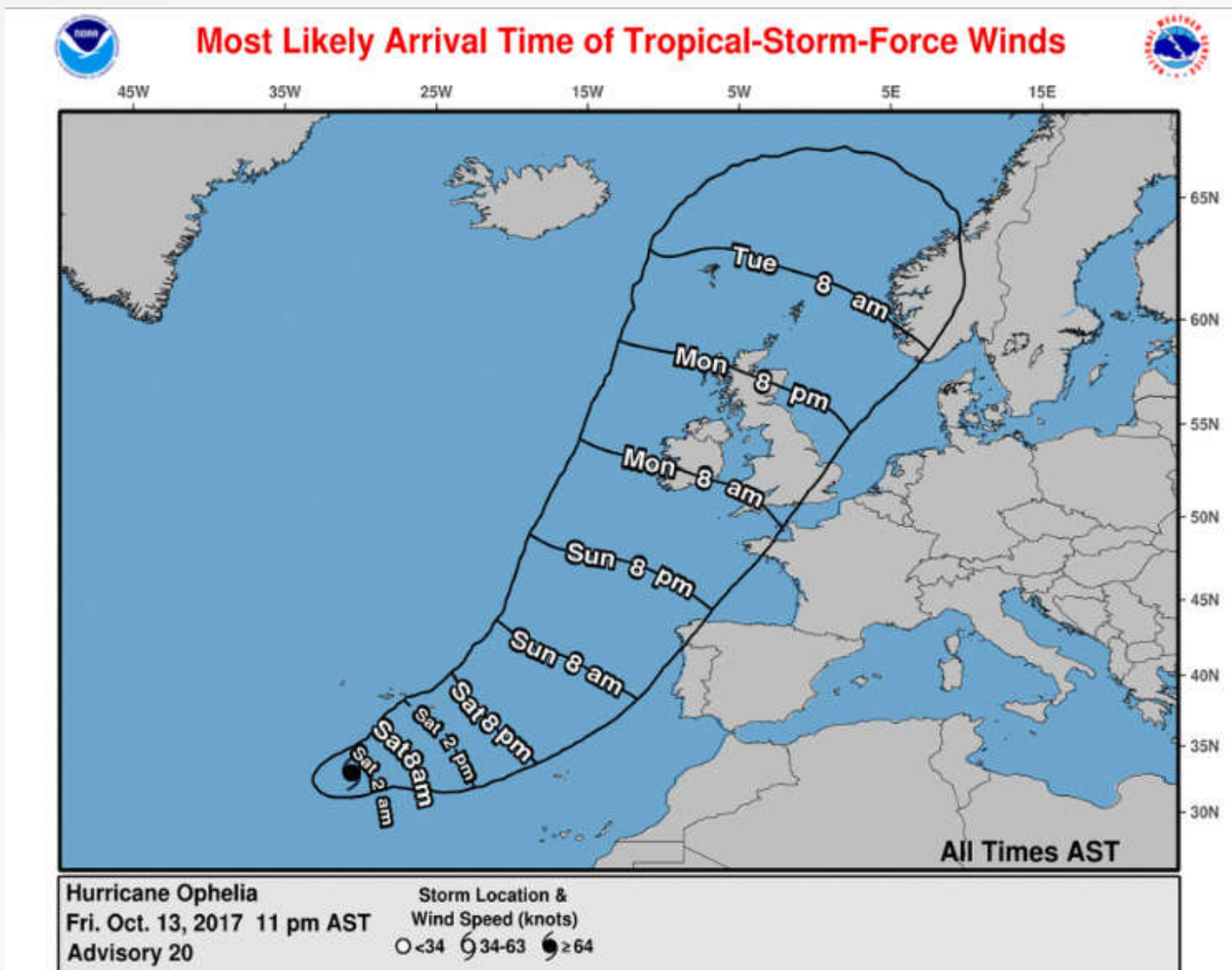


## Forecast (NHC)



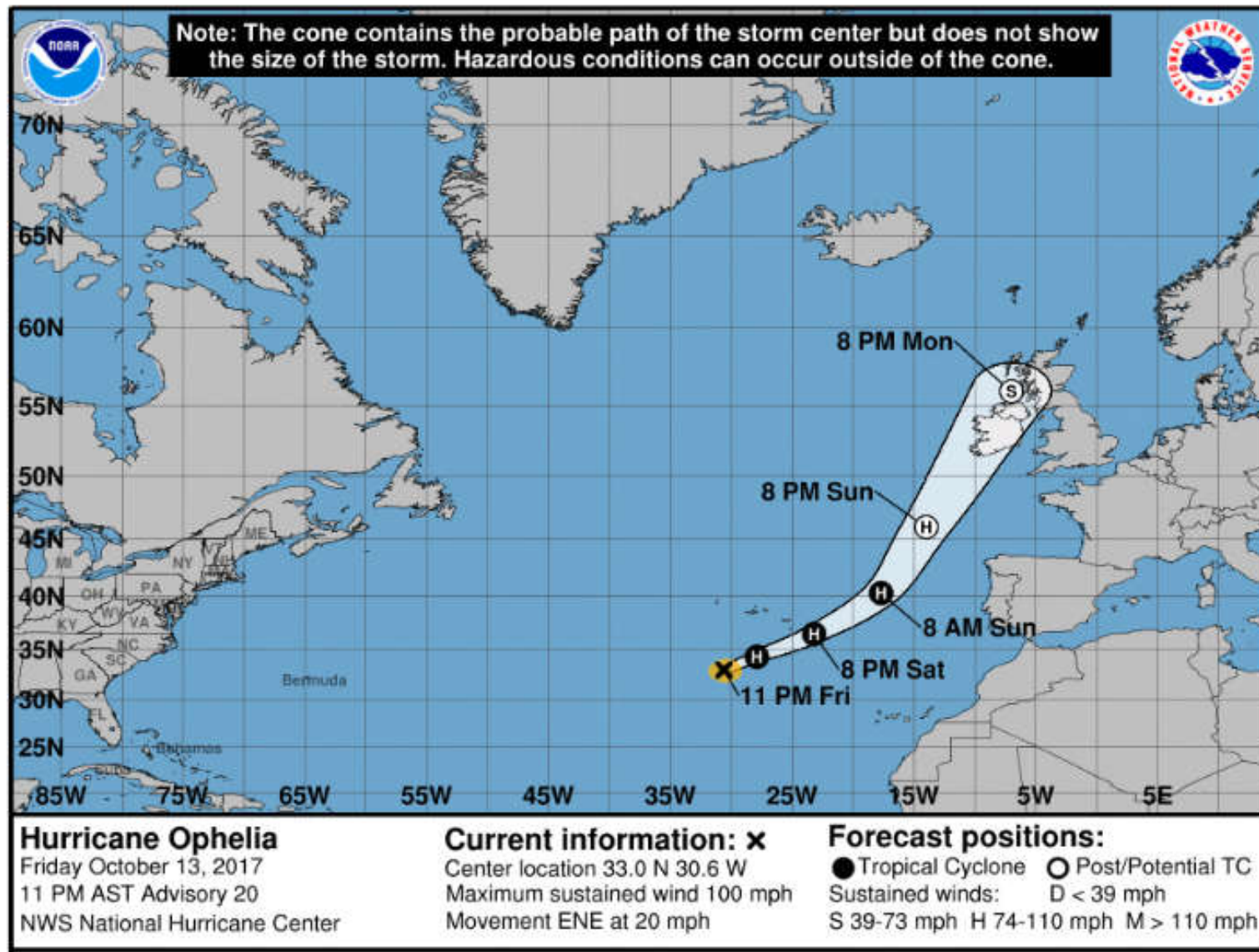


## Forecast (NHC)





## Forecast (NHC)





# Procedure in IPMA (Portuguese Institute for Sea and Atmosphere) for Azores



- High demand of information from public and media

- Tropical cyclone procedure was implemented in IPMA for Azores: Information for public, media and civil protection every 6 or 12 h (depending on the distance from the islands) .
- Update in IPMA webpage information (if needed).
- Voice record send to media by email.

**Comunicados IPMA**  
Comunicado válido entre 2017-10-09 16:28:00 e 2017-10-15 16:28:00

## CICLONE TROPICAL OPHELIA

13-10-2017

O I.P.M.A. informa que às 21h (hora dos Açores), o centro do ciclone Ophelia (categoria 2 na escala de Saffir-Simpson), localizava-se a 1150 km a SW dos Açores. O ciclone está praticamente estacionário contudo, nas próximas horas deverá voltar a deslocar-se para E/NE em direção ao arquipélago. De acordo com a previsão, existe uma probabilidade do ciclone condicionar o estado do tempo no grupo Oriental (com vento médio igual ou superior a 65 km/h) a partir das 12h (hora dos Açores) de sábado, 14 de outubro que em Santa Maria varia entre 50 a 70 % e em São Miguel entre 30 a 40 %. Nestas condições, prevê-se que a partir das 12h de sábado ocorra um agravamento do estado do tempo, com precipitação por vezes forte e acompanhada de trovoadas, vento com rajadas que em S. Miguel podem chegar aos 100km/h e em S. Maria poderão ultrapassar os 100km/h, e ondas que podem atingir os 6 metros de altura significativa.

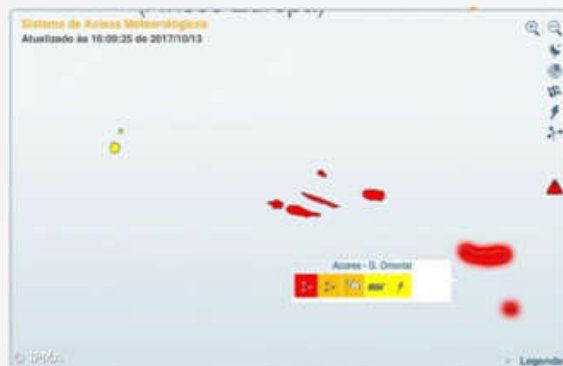
Quanto às ilhas dos grupos Ocidental, a partir desta madrugada, e devido a uma superfície frontal fria com atividade moderada a forte, prevê-se precipitação por vezes forte, podendo ser acompanhada de trovoadas. Esta situação estender-se-á às ilhas do grupo Central no sábado. Sugere-se o acompanhamento da evolução da situação meteorológica através da página do IPMA ([www.ipma.pt](http://www.ipma.pt)) e a obtenção de eventuais recomendações junto do Serviço Regional de Protecção Civil e Bombeiros dos Açores ([www.procv.azores.gov.pt](http://www.procv.azores.gov.pt)).

<http://www.ipma.pt/pt/otempo/comunicados/index.jsp>

- Location (ex: 150 km south of Terceira island)
- Movement (ex: to NE at 15 km/h)
- Intensity (ex: Category 1 in Saffir Simpson scale)
- Forecast (ex: winds from S 100 km/h gusting to 140 km/h)
- Time of arrival ( ex: Sunday morning ) - probabilities
- Warnings ( ex: red for wind and waves)



# Weather warnings



**AVISO METEOROLÓGICO**  
**Arquipélago dos Açores**

Comunicado N° 106 14.outubro.2017 02:19

Na sequência do comunicado anterior, acrescenta-se aviso amarelo de precipitação até às 12 horas de hoje para ilhas do grupo Oriental, mantendo-se os restantes avisos. Assim emite-se:

Grupo Oriental				
Cor	Aviso	Início	Fim	Texto
Vermelho	Precipitação	14.out 18:00	15.out 00:00	Precipitação FORTE.
Laranja	Precipitação	14.out 12:00	14.out 18:00	Precipitação FORTE.
Amarelo	Vento - Rajada Máxima	14.out 12:00	15.out 06:00	Vento médio superior a 65 km/h e rajadas até 100 km/h para S. Miguel e superiores a 100 km/h em S. Maria. Direção de sul (S) a rodar para norte (N).
Amarelo	Precipitação	14.out 02:20	14.out 12:00	Precipitação pontualmente FORTE.
Amarelo	Trovoada	14.out 12:00	15.out 00:00	Precipitação pontualmente FORTE.
Amarelo	Agitação Marítima	14.out 12:00	15.out 06:00	Ondas de sudoeste (SW) passando a noroeste (NW).
Grupo Central				
Cor	Aviso	Início	Fim	Texto
Vermelho	Precipitação	14.out 12:00	14.out 18:00	Precipitação FORTE.
Laranja	Precipitação	14.out 02:20	14.out 12:00	Precipitação FORTE.
Amarelo	Trovoada	14.out 02:20	14.out 18:00	

*Meteorologista)*  
Vanda Costa

## Hurricane OPHELIA

ZCZC MIATCPAT2 ALL  
TTAA00 KNHC DDHMM

### BULLETIN

Hurricane Ophelia Advisory Number 22  
NWS National Hurricane Center Miami FL AL172017  
1100 AM AST Sat Oct 14 2017

...OPHELIA BECOMES A RARE CATEGORY 3 HURRICANE SOUTH OF THE AZORES...

...THIS IS THE SIXTH MAJOR HURRICANE OF THE 2017 SEASON...

### SUMMARY OF 1100 AM AST...1500 UTC...INFORMATION

LOCATION...34.8N 26.6W

ABOUT 220 MI...355 KM S OF THE AZORES

MAXIMUM SUSTAINED WINDS...115 MPH...185 KM/H

PRESENT MOVEMENT...NE OR 55 DEGREES AT 25 MPH...41 KM/H

Hurricane-force winds extend outward up to 45 miles (75 km) from the center and tropical-storm-force winds extend outward up to 125 miles (205 km).

The estimated minimum central pressure is 960 mb (28.35 inches).

### HAZARDS AFFECTING LAND

WIND: Tropical-storm-force winds are possible throughout the Azores beginning this afternoon or tonight, primarily due to an approaching cold front.

RAINFALL: Ophelia is expected to produce total rain accumulations of 1 to 3 inches over the central and southeastern Azores through Saturday night.

### NEXT ADVISORY

Next complete advisory at 500 PM AST.

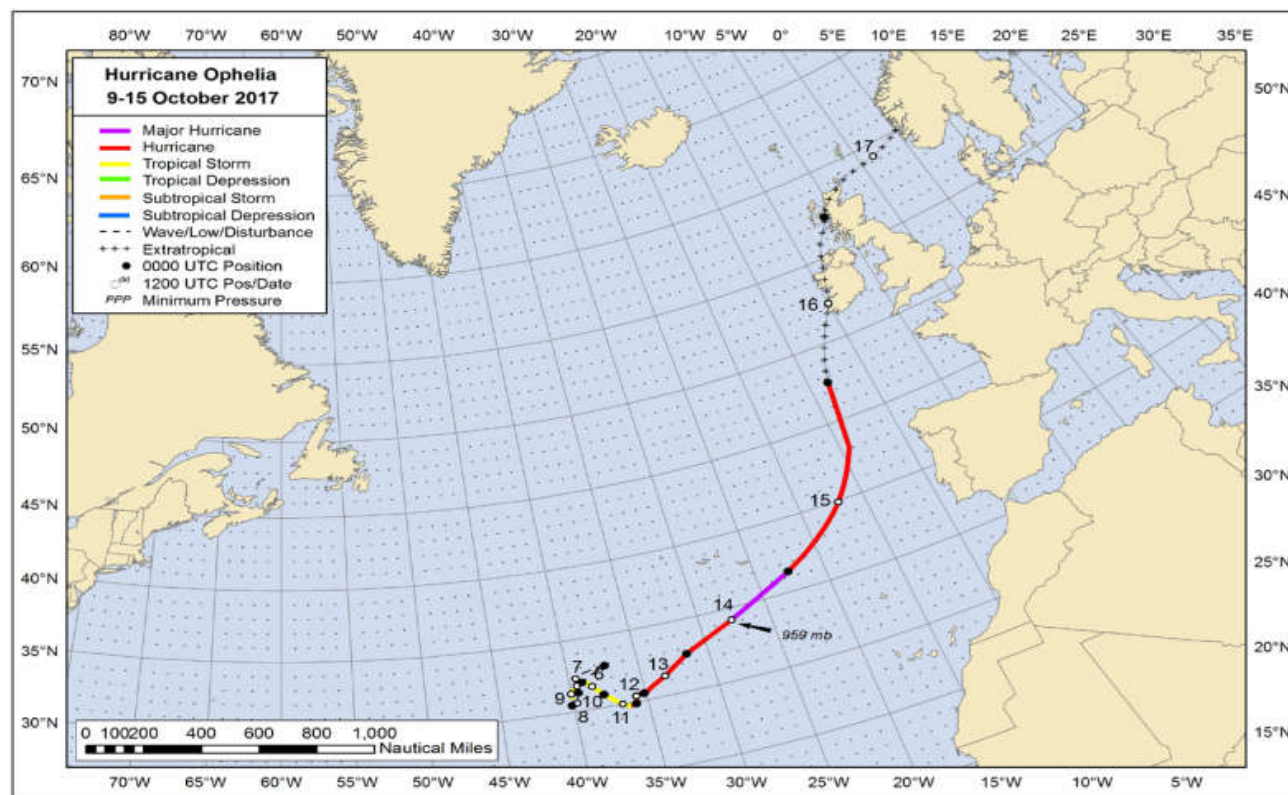
\$\$

Forecaster Avila

NNNN



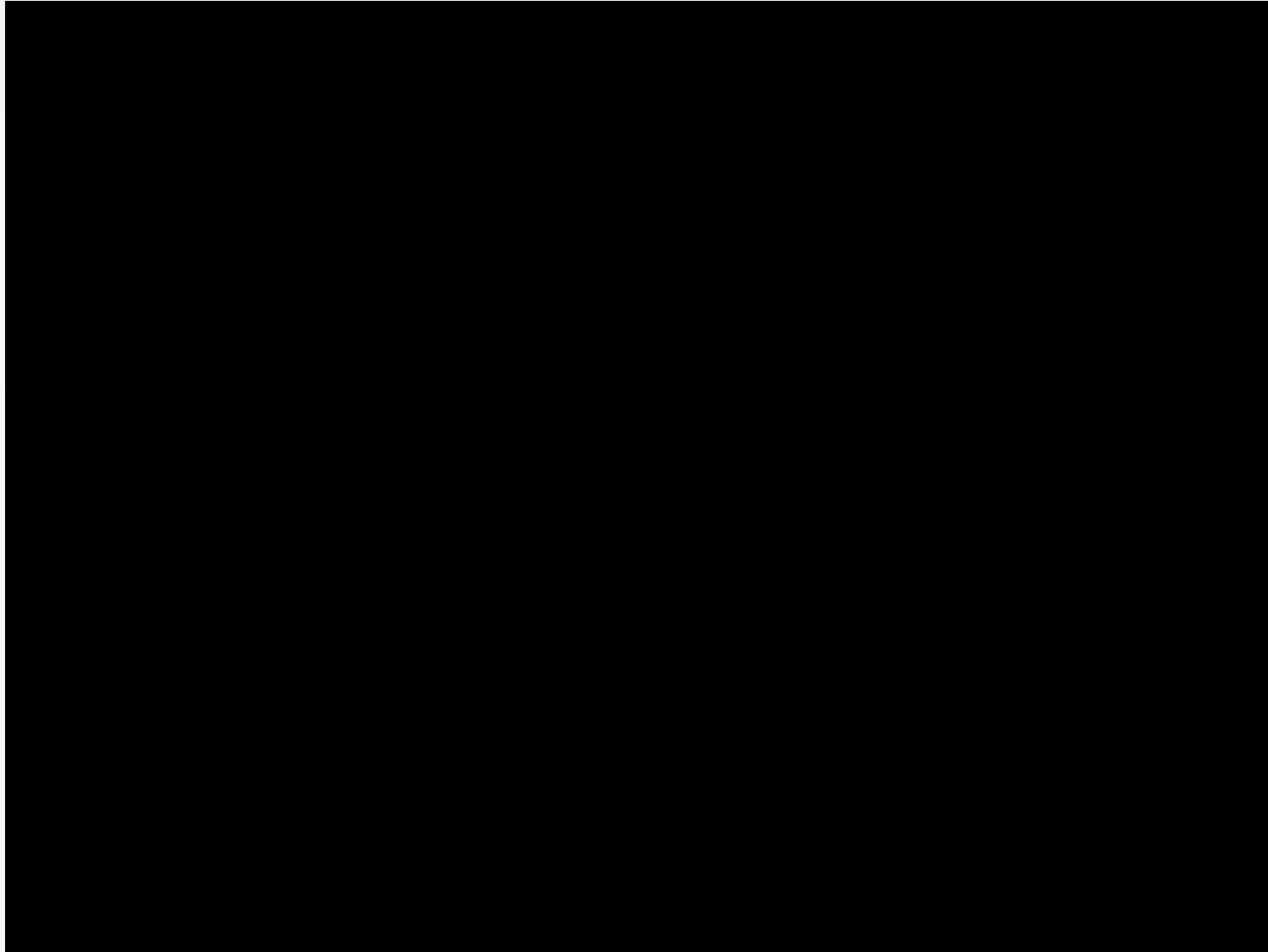
## Best track positions for Hurricane Ophelia, 9–15 October 2017. 16-17 October extratropical stage



The track during the extratropical stage on 16–17 October is partially based on analyses from the NOAA Ocean Prediction Center, Met Éireann (Irish National Meteorological Service), and the UKMET (United Kingdom Meteorological Office).

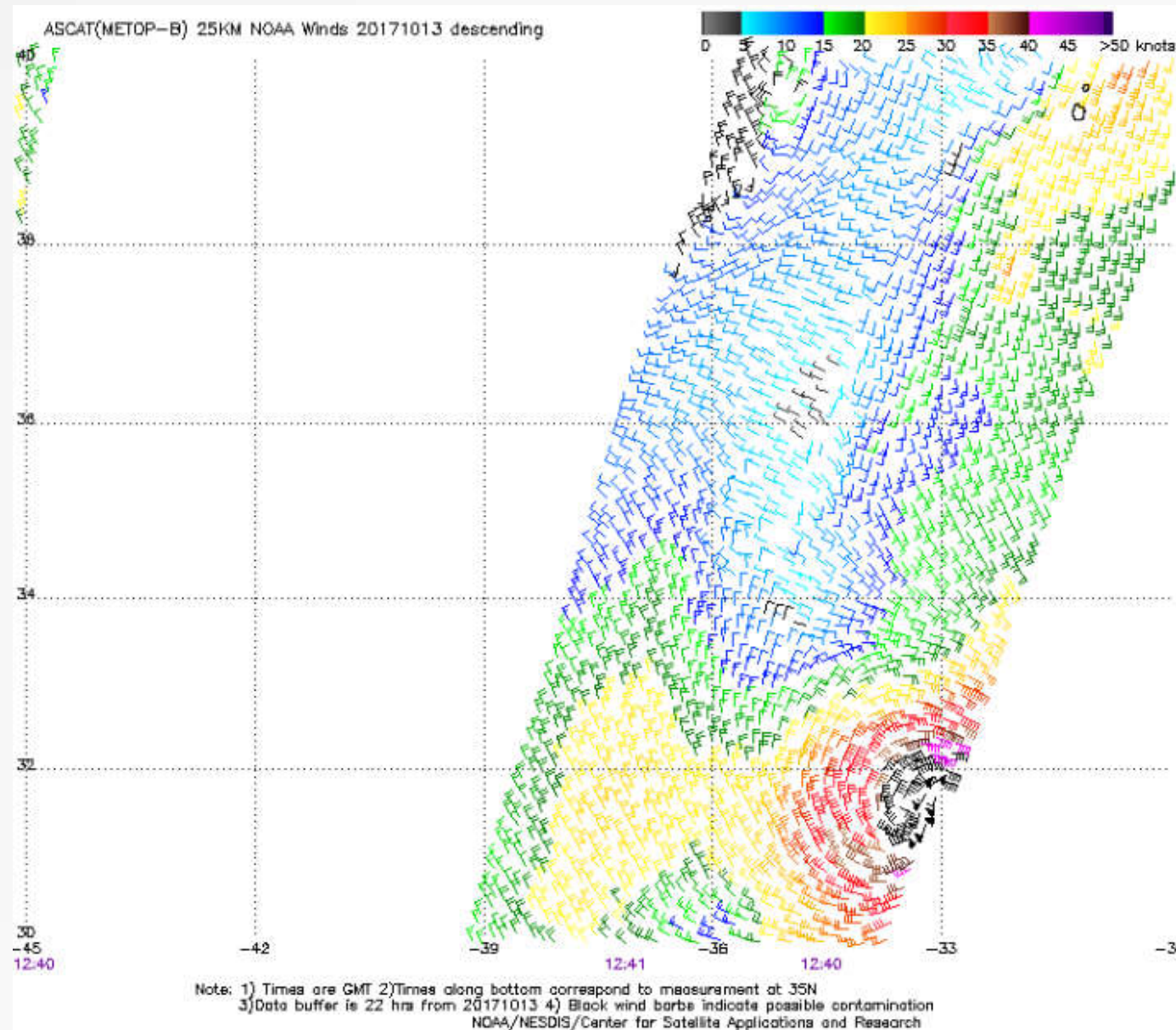


## Ophelia satellite 11-16 October



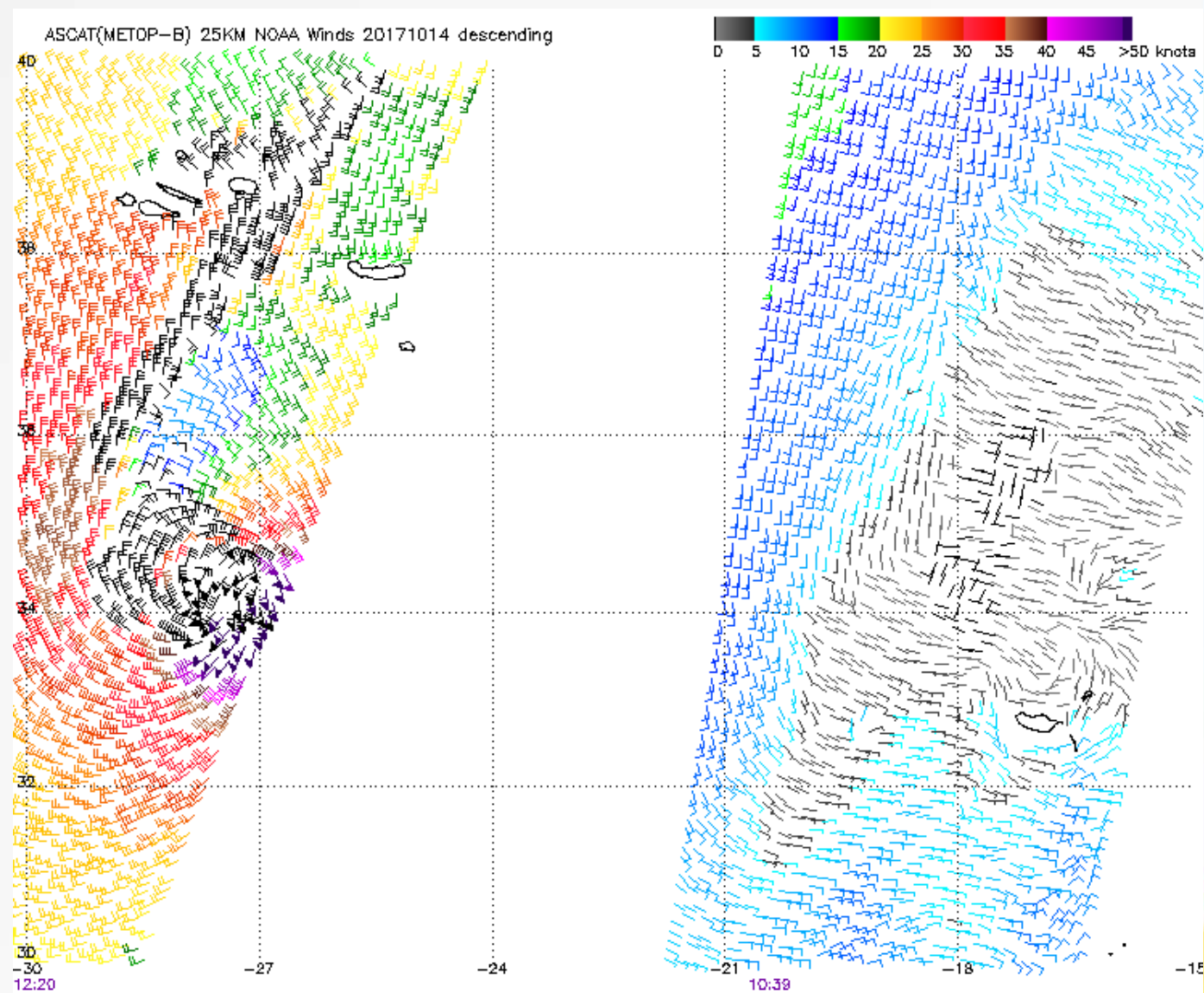


## Advanced Scatterometer (ASCAT)





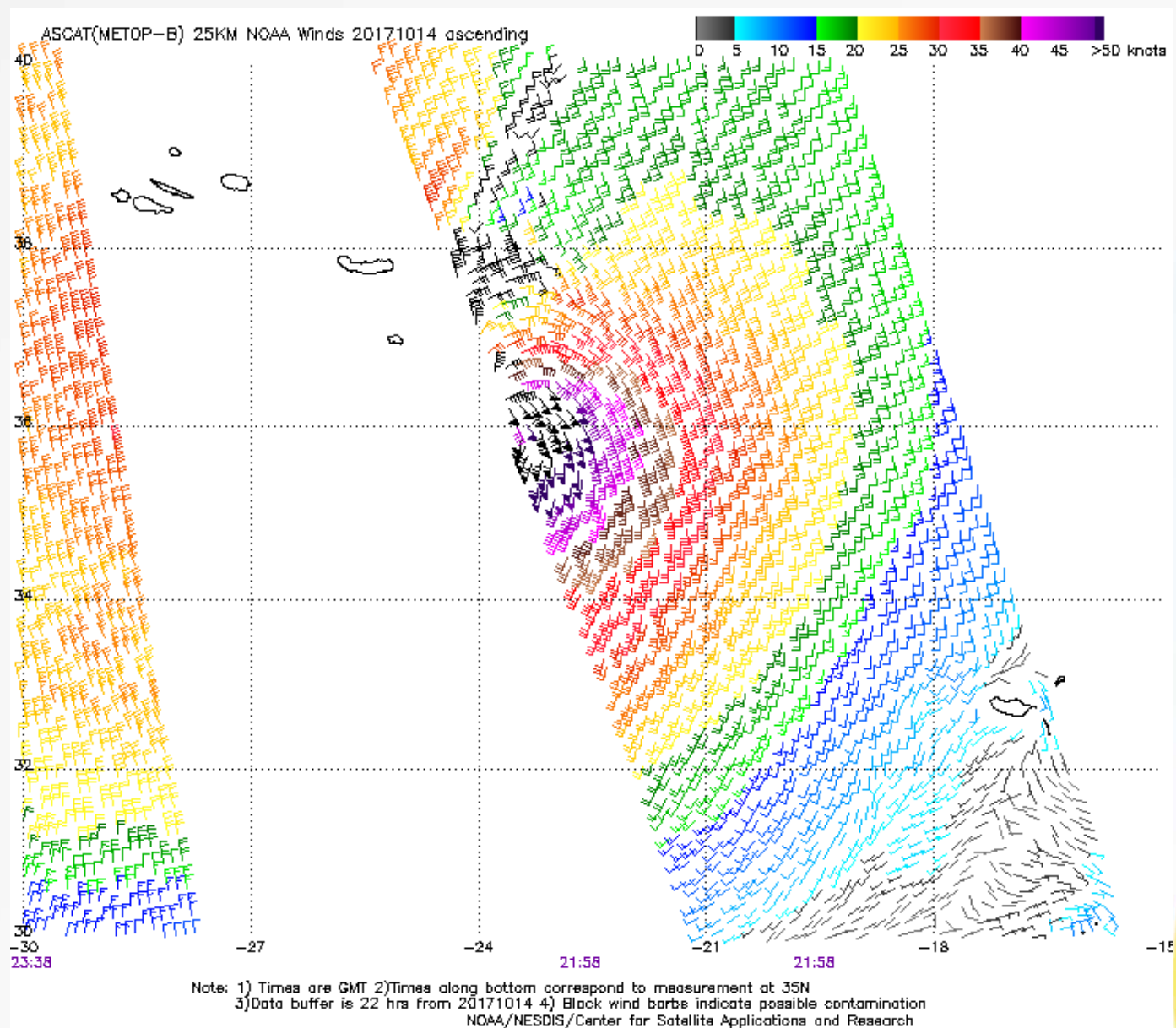
## Advanced Scatterometer (ASCAT)



Note: 1) Times are GMT 2) Times along bottom correspond to measurement at 35N  
 3) Data buffer is 22 hrs from 20171014 4) Black wind bars indicate possible contamination  
 NOAA/NESDIS/Center for Satellite Applications and Research

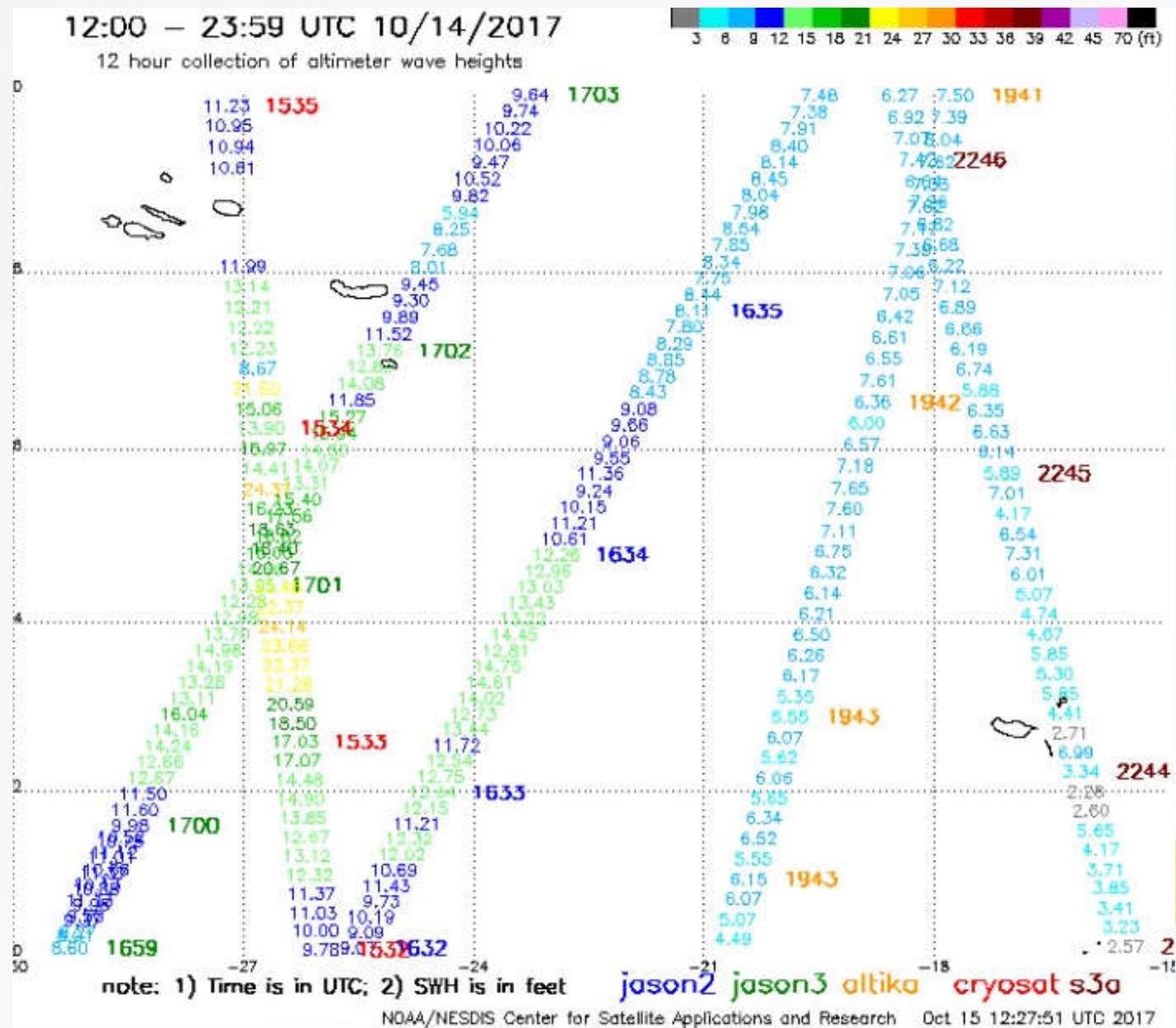


## Advanced Scatterometer (ASCAT)





## Altimeter (significant wave height)





# Observations

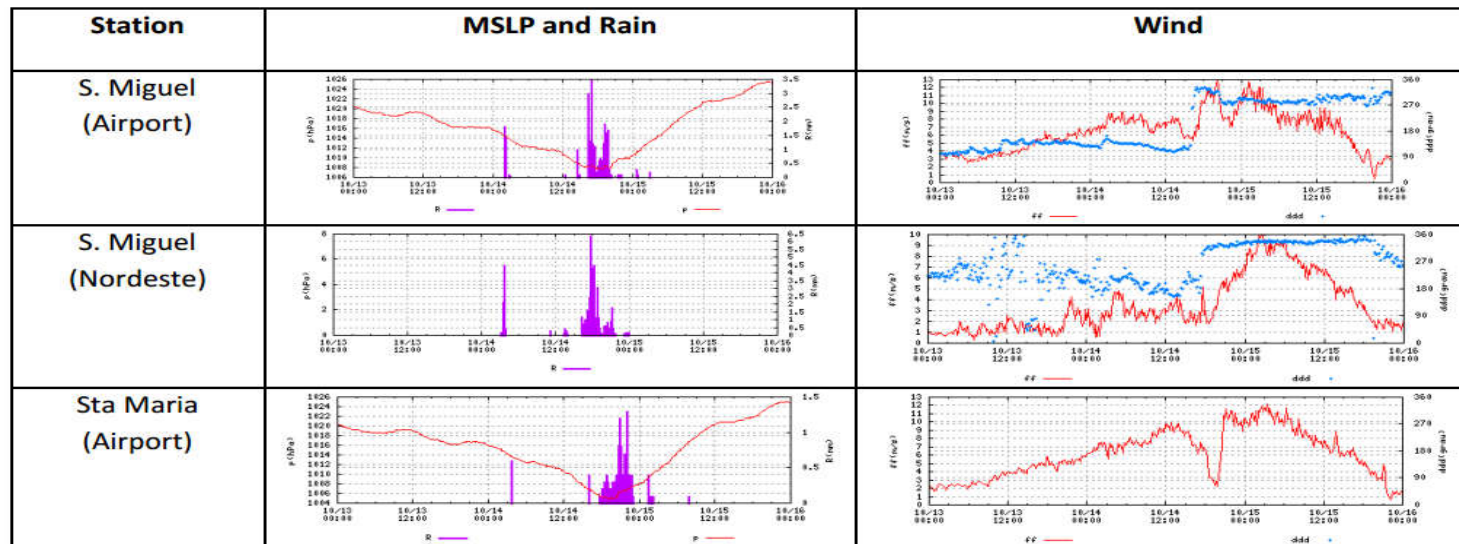
## POST-STORM COUNTRY REPORT

Country: PORTUGAL

Tropical Cyclone: Hurricane Ophelia

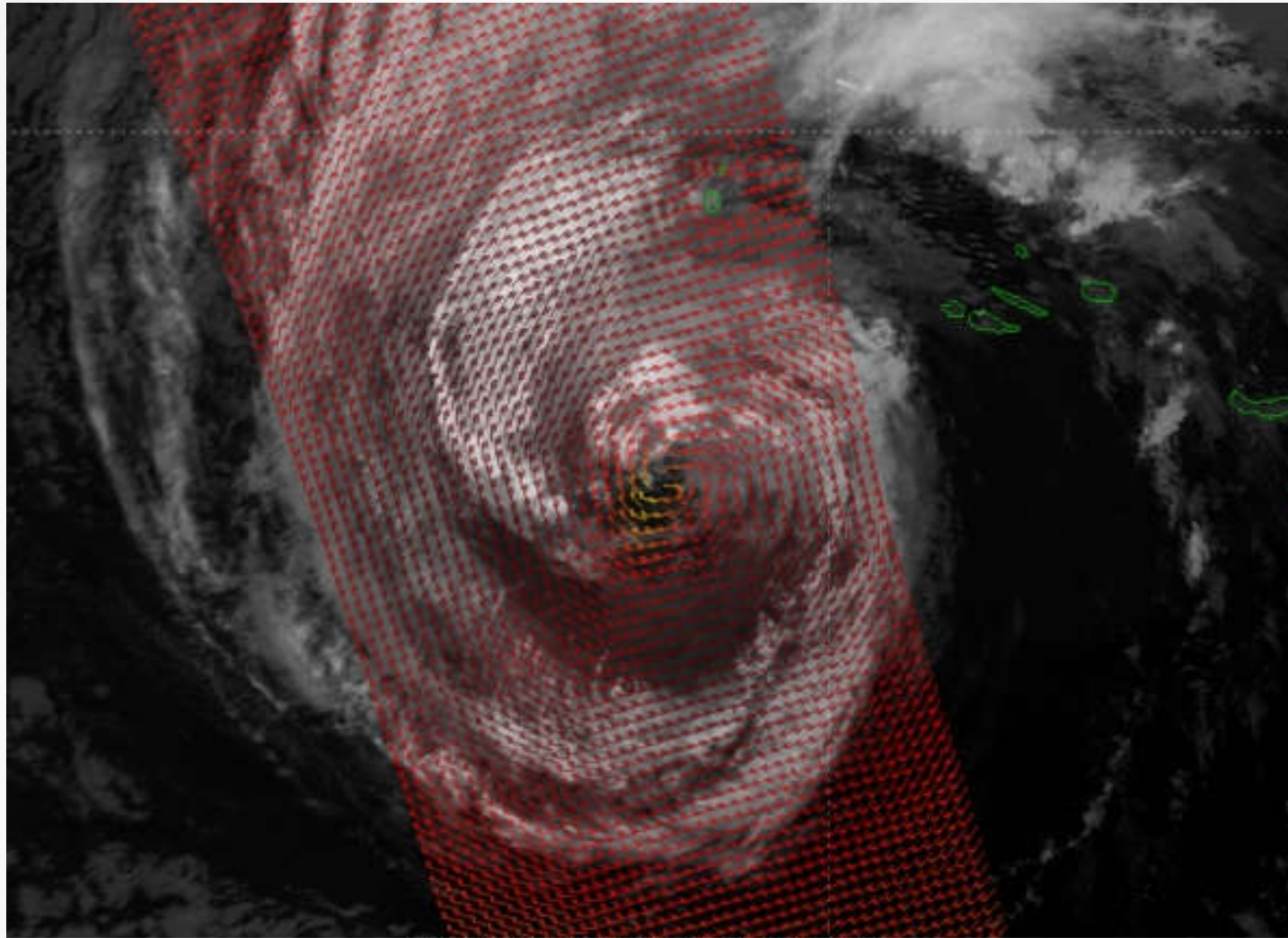
Date of data: From October 14 at 12UTC to October 15 12UTC, 2017 Date of issuance: October 20, 2017

Station	Maximum Sustained Wind			Maximum Wind Gust			Calm	Total Rainfall	Minimum SL Pressure	
	Direction	Veloc. kt (km/h) 10 min	Time (UTC)	Direction	Veloc. kt (km/h)	Time (UTC)	Time (UTC)	(mm)	Pressure (hPa)	Time (UTC)
08515 Sta Maria (Airport)	-	23(43)	03:20	-	37 (68)	04:20	-	14	1004.8	19:10
08512 S. Miguel (Airport)	NW	25(47)	20:10	WNW	39(72)	00:30	-	27	1007.7	17:40/18:30
08932 S. Miguel (Nordeste)	NW	19(36)	02:30	NW	35(65)	04:50	-	45	-	-





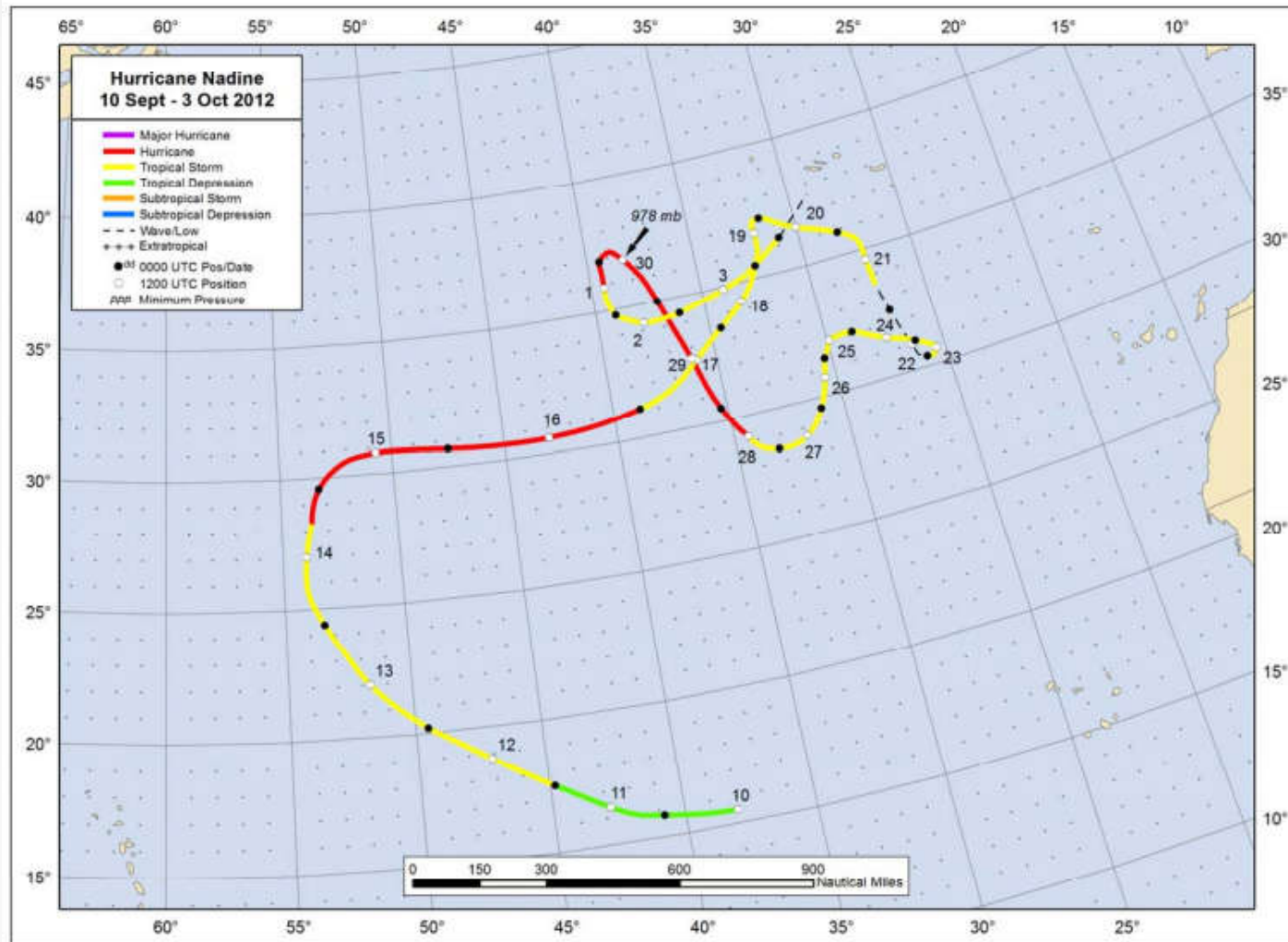
CASE 2 : Nadine 10 september – 3 october 2012  
(Azores in 20/21 Sep and 3 October)



ma AVHRR IR3.7 + ASCAT coastal wind - 2012-09-19 22:41UTC



## Best track positions for Hurricane Nadine 10 September – 3 October 2012

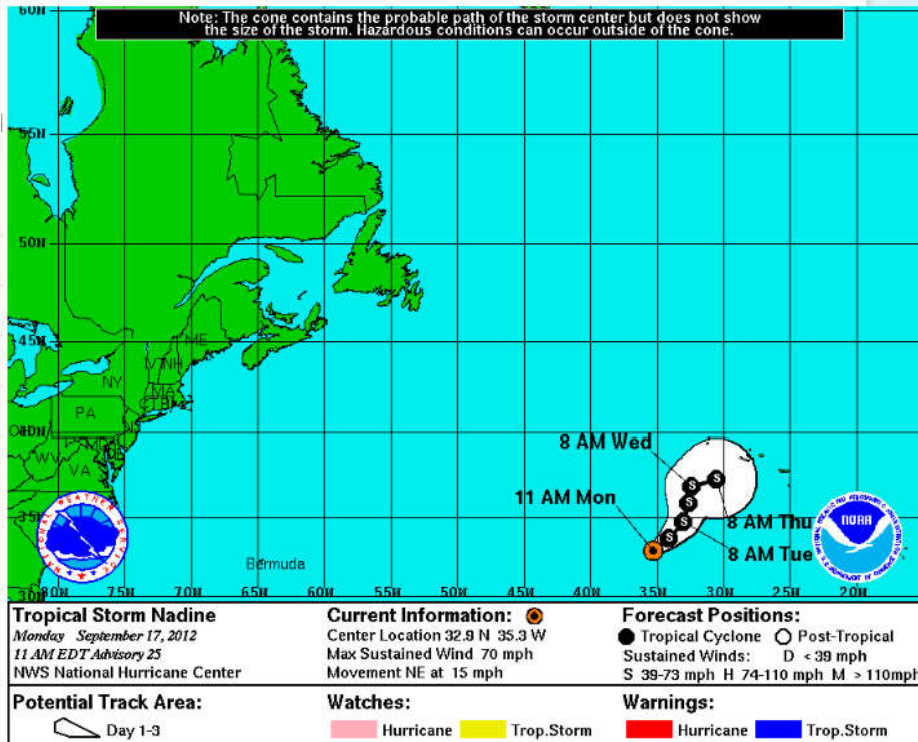


From NHC: Best track positions for Hurricane Nadine, 10 September – 3 October 2012.

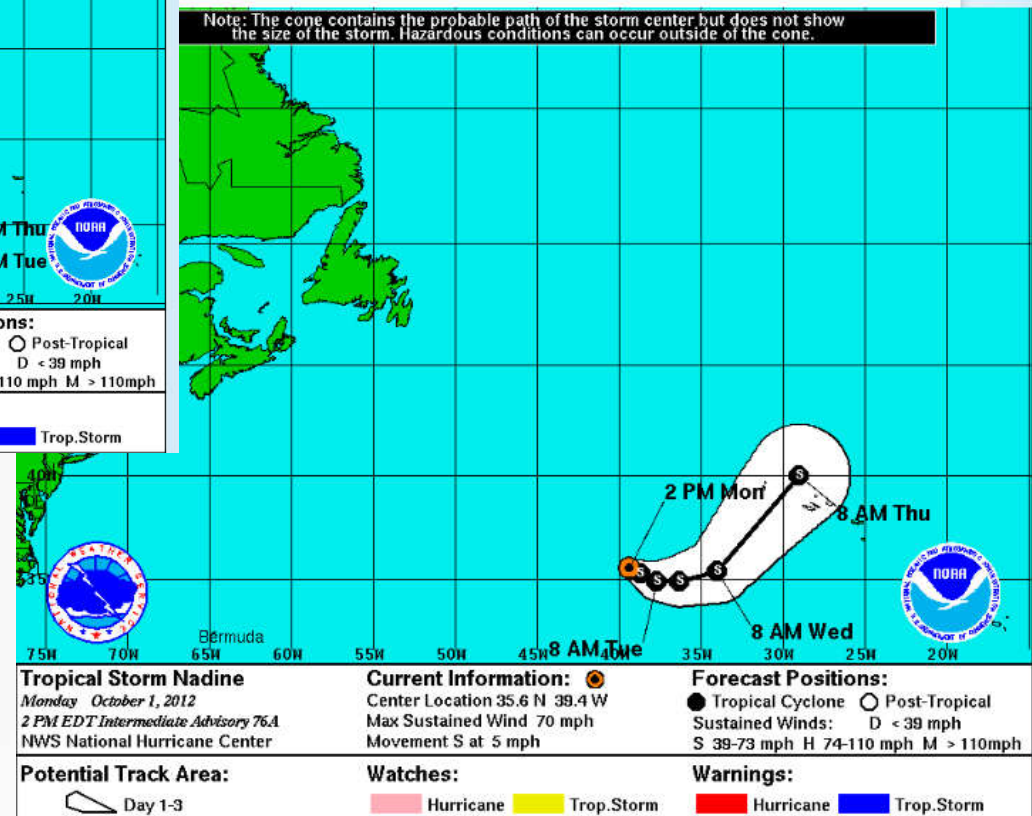


### 3-Day track forecast, uncertainty cone

#### NADINE Graphics Archive

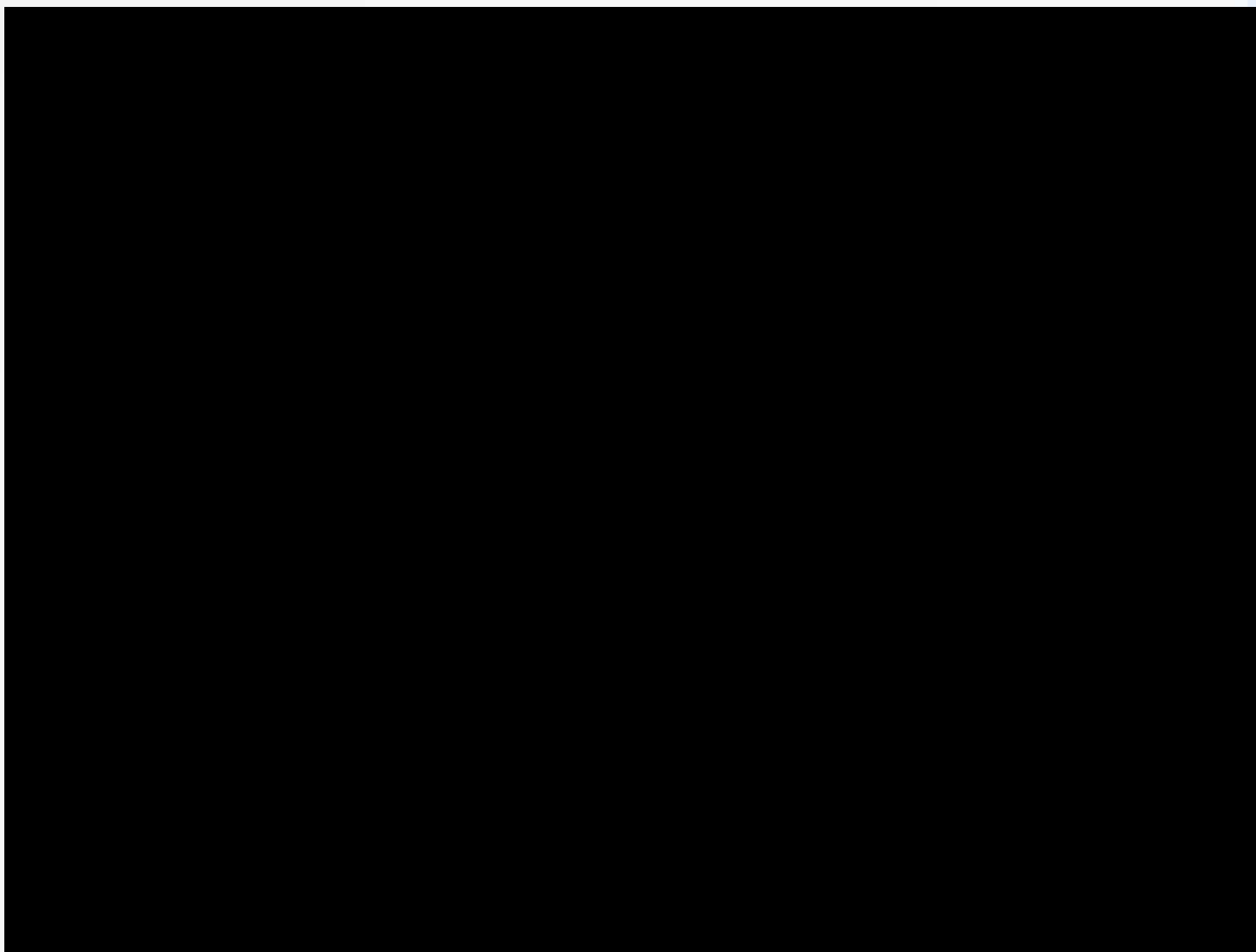


#### NADINE Graphics Archive



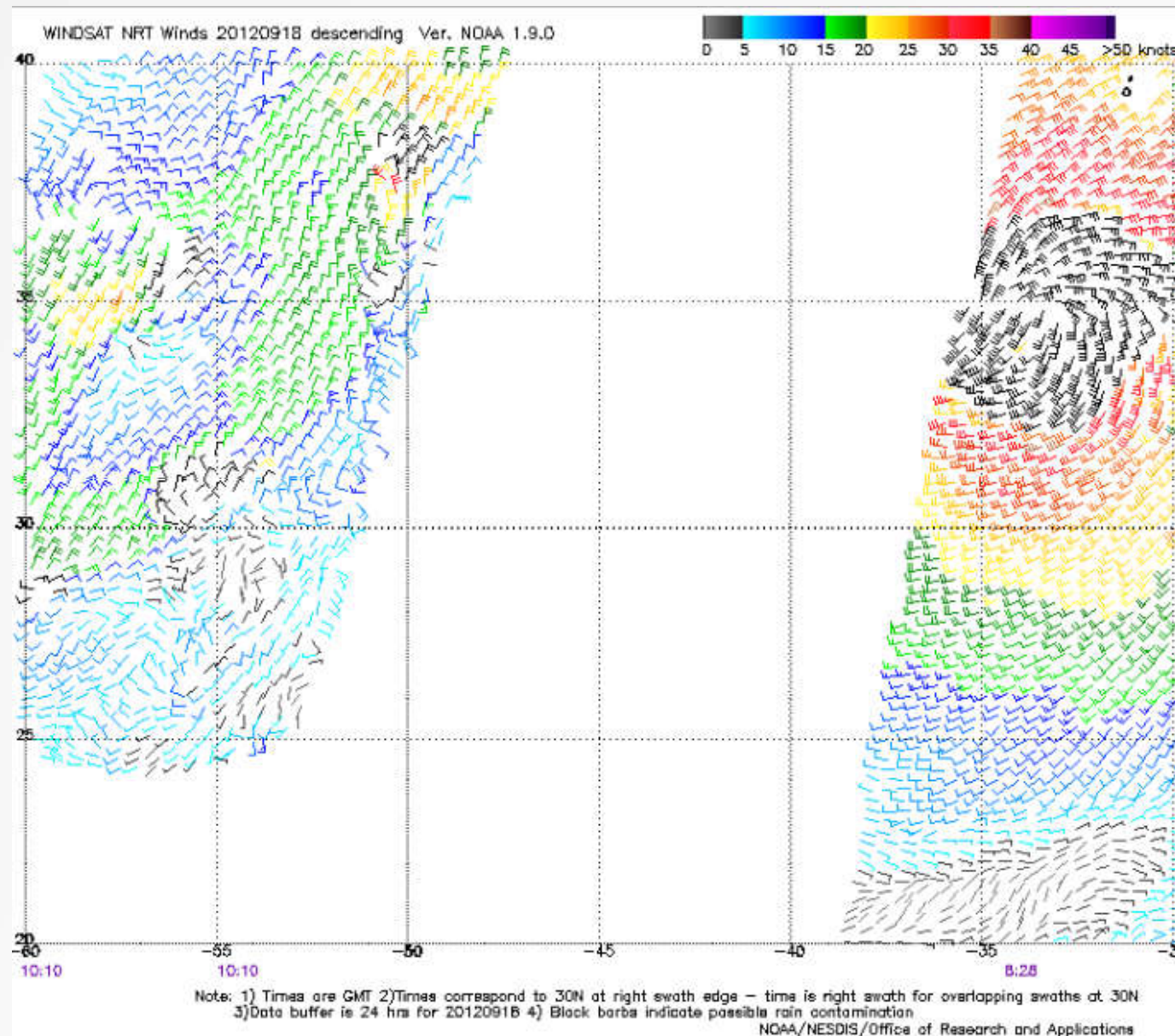


Nadine satellite (12 September to 04 October)



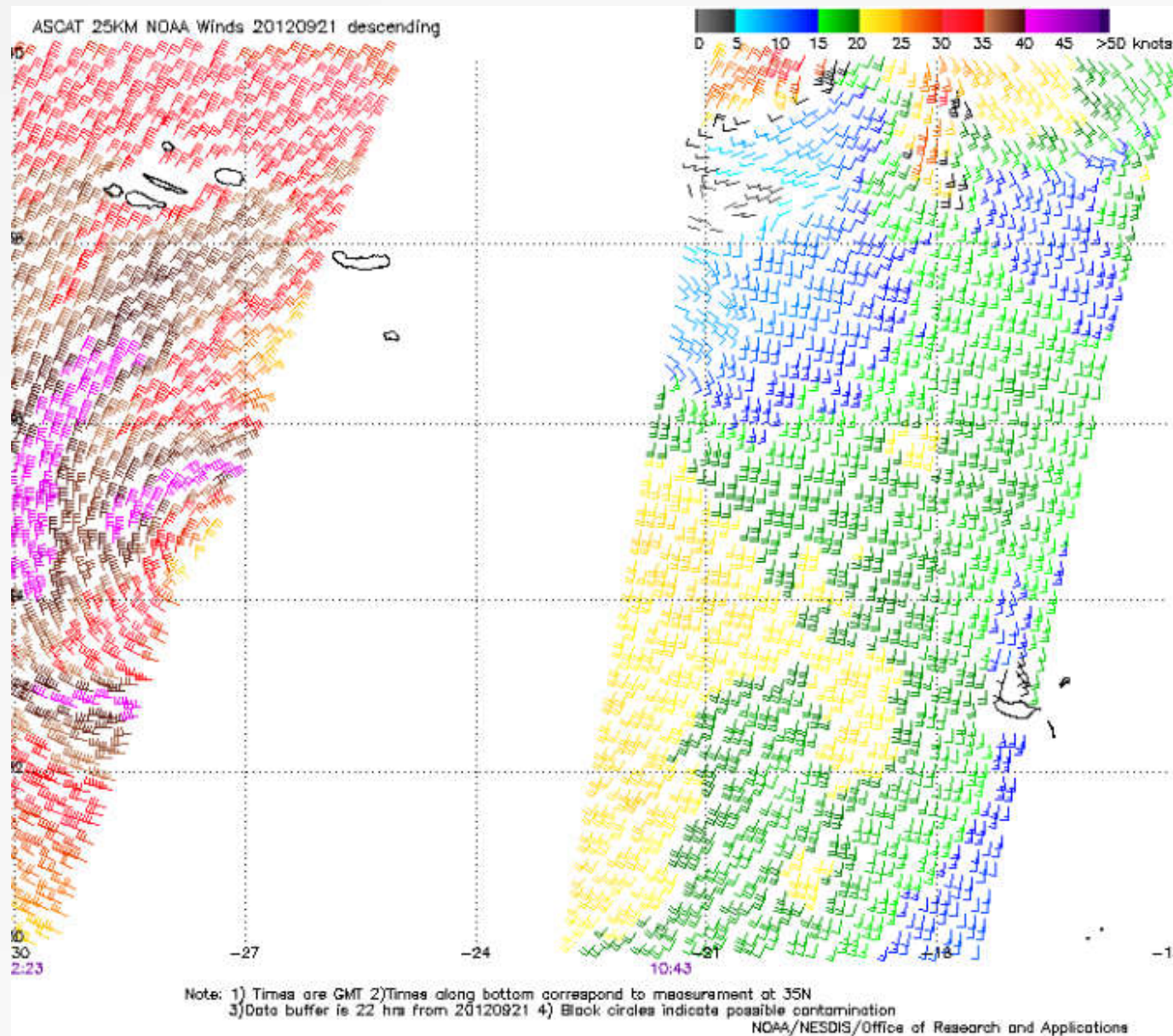


## Advanced Scatterometer (ASCAT)



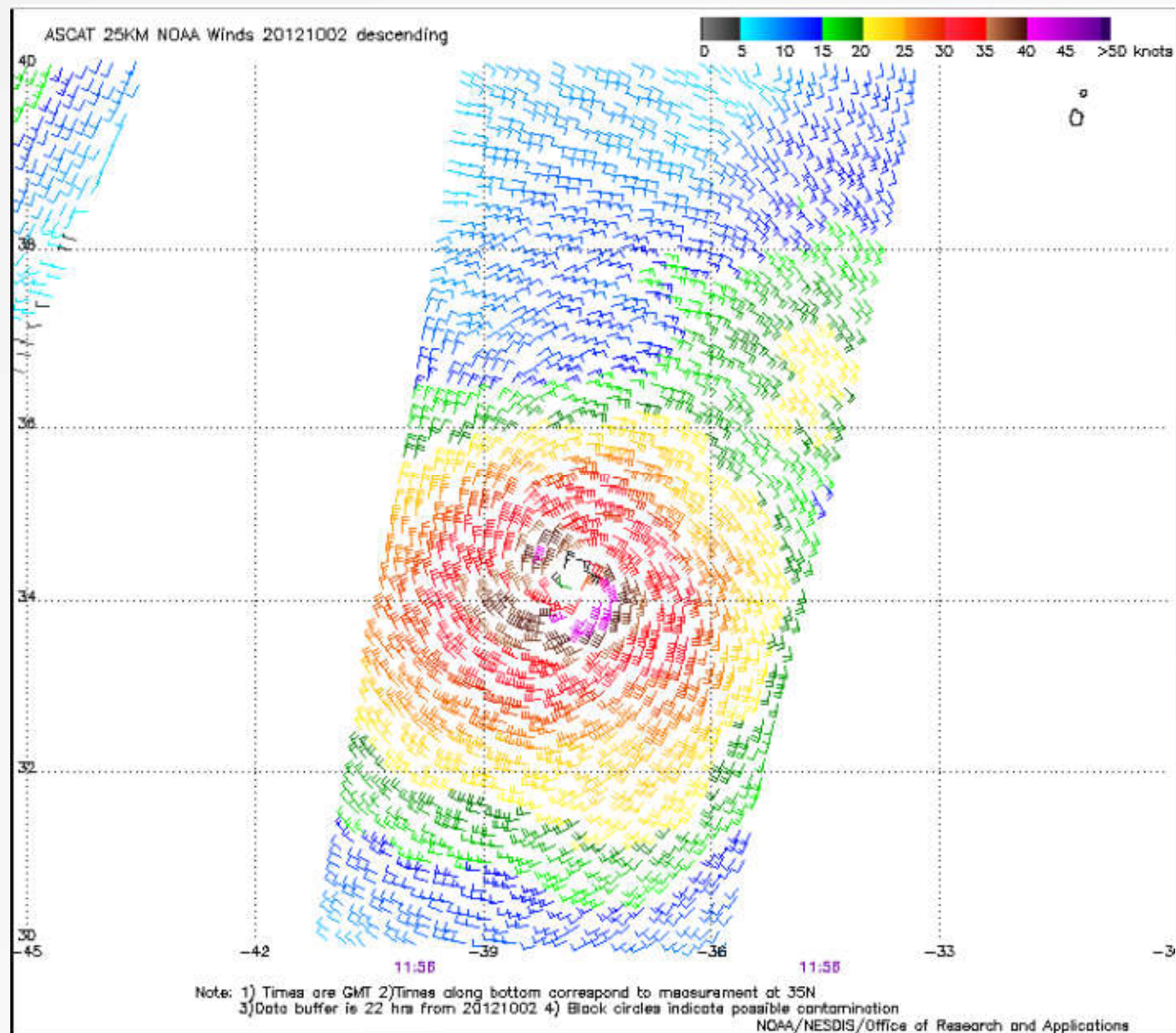


## Advanced Scatterometer (ASCAT)





## Advanced Scatterometer (ASCAT)





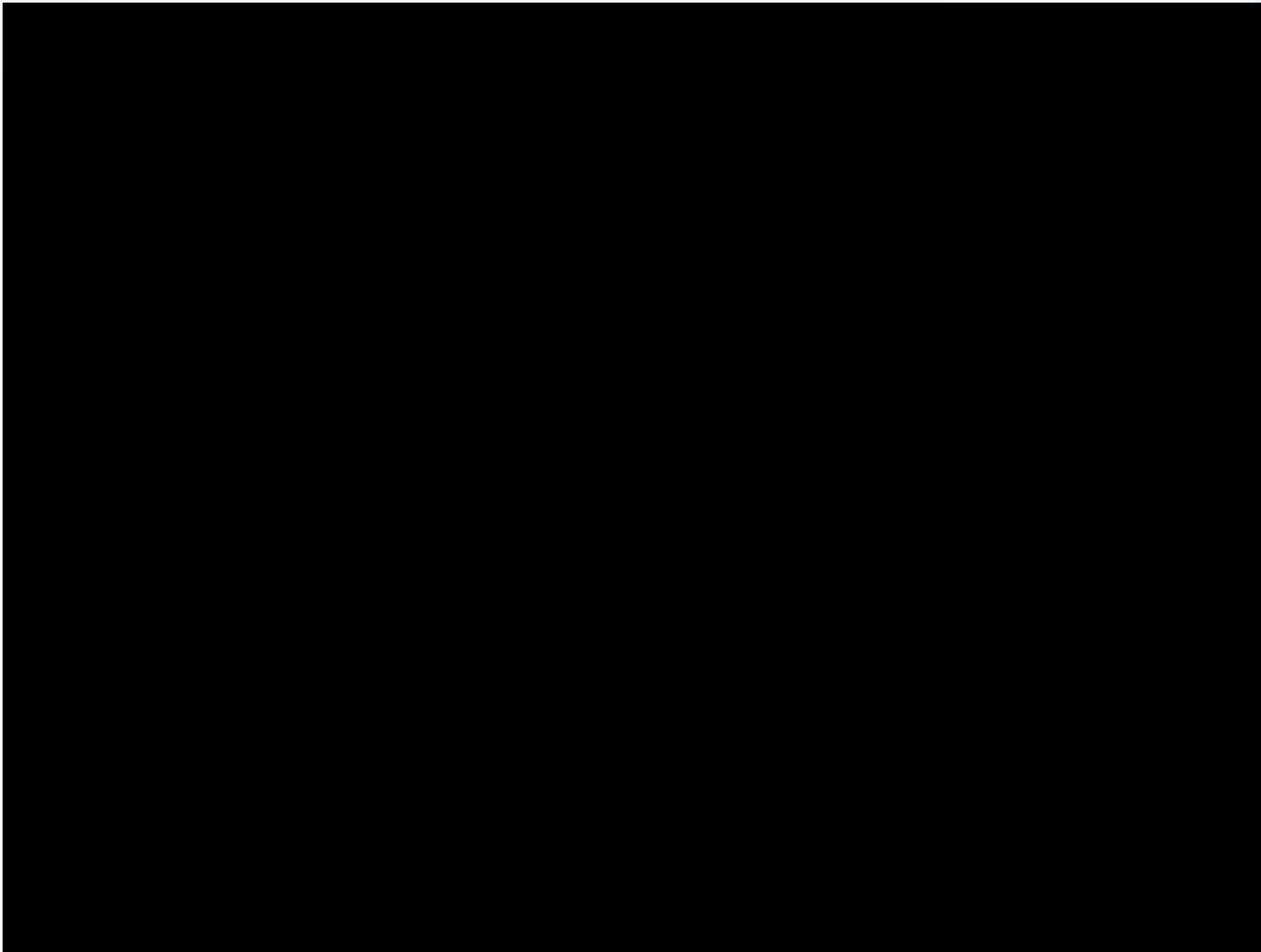
## Warning and watches issued for Azores (NHC)

Date/Time (UTC)	Action	Location
18 / 1000	Tropical Storm Watch issued	Islands of Flores and Corvo in the Northwest Azores
18 / 2100	Tropical Storm Watch discontinued	Islands of Flores and Corvo in the Northwest Azores
18 / 2100	Tropical Storm Warning issued	Azores Islands of Flores, Corvo, Faial, Pico, Sao Jorge, Graciosa, and Terceira
19 / 1500	Tropical Storm Warning issued	Azores Islands of Sao Miguel and Santa Maria
21 / 2100	Tropical Storm Warning discontinued	All
01 / 1500	Tropical Storm Watch issued	All of the Azores
02 / 0000	Tropical Storm Watch changed to Tropical Storm Warning	All of the Azores
04 / 1500	Tropical Storm Warning discontinued	All of the Azores

Watch and warning summary for Hurricane Nadine, 10 September – 3 October 2012.



## Surface wind field of tropical cyclone Nadine





## Observations in IPMA (Portuguese Institute for Sea and Atmosphere) meteorological stations

Island	Month/day	Maximum gust (km/h)
Faial	09/20	129
Terceira	09/20	108
	10/04	95
S. Jorge	09/20	101
	10/04	100
S. Miguel	09/22	101
	10/04	90





Thank you!