

Tropical Cyclone Report
Tropical Storm Grace
(AL092009)
4 – 6 October 2009

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Grace was a rare northeastern Atlantic Ocean tropical storm that formed near the Azores and moved northeastward toward the British Isles.

a. Synoptic History

Grace originated from a large extratropical low that formed along a cold front on 27 September about 410 n mi east of Cape Race, Newfoundland. The low occluded early on 28 September and moved southeastward and then eastward at about 12 to 14 kt over the next day. It slowed down briefly on 29 September but then accelerated toward the southeast and south on 30 September just to the west of the Azores. Beginning on 1 October, the low turned northeastward and began to make a counterclockwise loop across the central and western Azores while still associated with an occluded front. By 2 October, the structure of the low began to evolve as a 30-n mi radius of maximum winds developed and became separated from a broader area of maximum winds located 250 to 300 n mi from the center. For about a day and a half, the low produced only intermittent deep convection. Satellite imagery suggests that the warm sector of the cyclone wrapped entirely around the center of the low by 1800 UTC 3 October, leading to an erosion of the frontal structures near the cyclone's center. The low is estimated to have transformed into a tropical cyclone about 12 h later while centered over the western Azores about 115 n mi west of Lajes when deep convection became sufficiently organized and persistent. The "best track" chart of Grace's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1¹. The transition from extratropical low to tropical storm does not include a subtropical stage because the surface low had already separated from the upper-level low and had a small radius of maximum winds by the time the convection became organized and persistent enough to satisfy the definition of a tropical or subtropical cyclone.

Records indicate that no other cyclone has become a tropical storm as far northeast over the Atlantic Ocean as did Grace. However, it is important to note that prior to the beginning of routine Dvorak classifications in 1972—and before the advent of scatterometry—it would have been difficult to identify and assess the intensity of tropical cyclones in this part of the Atlantic basin.

¹ A digital record of the complete best track, including wind radii, can be found on line at <ftp://ftp.nhc.noaa.gov/atcf>. Data for the current year's storms are located in the *brk* directory, while previous years' data are located in the *archive* directory.

While passing through the Azores later on 4 October, Grace developed an eye-like feature surrounded by a ring of relatively deep convection, and began to strengthen. The cyclone accelerated eastward then northeastward over the northeastern Atlantic Ocean as it became embedded in deep-layer southwesterly flow, and it reached its estimated peak intensity of 55 kt around 0000 UTC 5 October. Figure 4 shows a visible image from METEOSAT-9 at 1400 UTC 5 October, when Grace is still estimated to have had maximum sustained winds of 55 kt. Moving north-northeastward at around 25 kt over increasingly colder water, Grace merged with a frontal boundary by 0600 UTC 6 October and become an extratropical low about 200 n mi west-southwest of Cork, Ireland. The small extratropical low moved east-northeastward over the Celtic Sea and dissipated by 0000 UTC 7 October as it approached Wales in the United Kingdom.

b. Meteorological Statistics

Observations in Grace (Figs. 2 and 3) include satellite-based Dvorak and Hebert-Poteat technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB) and UW-CIMSS intensity estimates from the Advanced Microwave Sounding Unit (AMSU). Data and imagery from NOAA polar-orbiting satellites, Defense Meteorological Satellite Program (DMSP) satellites, National Aeronautics and Space Administration (NASA) satellites, including TRMM, QuikSCAT, and Aqua, the U.S. Navy WindSat, and the EUMETSAT ASCAT were also useful in constructing the best track of Grace.

The estimated peak intensity of 55 kt from 0000 UTC to 1200 UTC 5 October is based on a blend of subtropical intensity estimates of 55 to 65 kt from TAFB, a Dvorak intensity estimate of 55 kt from SAB, and an estimate of 55 kt from a 0634 UTC 5 October QuikSCAT pass. While somewhat uncertain, the peak intensity has been set at the lower end of the range of intensity estimates since sea surface temperatures decreased to near 18.5°C along the path of Grace over that time period, and it is likely that an increasingly stable boundary layer prevented efficient mixing of strong winds aloft to the ocean surface. There are four CIMSS AMSU intensity estimates from around the time of peak intensity, but the data appear too noisy to be relied upon for the analysis.

The highest winds reported in the Azores were a sustained wind of 27 kt with a gust to 38 kt from Ponta Delgada on São Miguel Island and a sustained wind of 25 kt with a gust to 33 kt from the island of Santa Maria.

There was only one ship report of winds to tropical storm force while Grace was a tropical cyclone. A Liberian cargo ship, the *Cap Castillo* (call sign A8PI5), reported a sustained wind of 39 kt at 230° and a pressure of 997.8 mb at 0600 UTC 5 October, while located about 95 n mi south of the center of Grace.

c. Casualty and Damage Statistics

There were no reports of damage or casualties associated with Grace.

d. Forecast and Warning Critique

The genesis of Grace as a tropical cyclone was not expected. The precursor extratropical low was mentioned in the Tropical Weather Outlook (TWO) between 1800 UTC 1 October through 0600 UTC 2 October as it was moving northward across the central Azores, but it was explicitly stated that tropical or subtropical formation was not anticipated through the ensuing 48 h. Subsequent TWOs did not mention this system before the time that it is estimated to have become a tropical cyclone, largely due its unclimatological location for tropical cyclogenesis.

The average official forecast track errors for Grace were 57 and 83 n mi for the 12- and 24-h forecasts, respectively. These errors were higher than the average long-term track errors (which are 32 and 55 n mi, respectively) and were mainly the result of the official forecasts being too slow. Because only three 12-h forecasts and one 24-h forecast were made, a meaningful comparison of the track models is not possible.

The average official intensity errors for Grace were 3 and 0 kt for the 12- and 24-h forecasts, respectively. These errors were lower than the average long-term intensity errors (which are 7 and 11 kt, respectively). A meaningful comparison of the intensity models is also not possible due to the small number of forecasts.

Watches or warnings were not issued for the Azores since operational advisories and forecasts were initiated after Grace had moved east of those islands.

Table 1. Best track for Tropical Storm Grace, 4 – 6 October 2009.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
27 / 1800	46.0	43.2	995	55	extratropical
28 / 0000	45.3	42.9	994	50	"
28 / 0600	44.7	42.0	992	45	"
28 / 1200	44.0	40.3	992	45	"
28 / 1800	43.8	38.7	994	40	"
29 / 0000	43.6	37.1	996	40	"
29 / 0600	43.4	35.8	998	35	"
29 / 1200	42.9	35.3	1000	35	"
29 / 1800	42.3	35.2	999	35	"
30 / 0000	41.4	35.4	998	35	"
30 / 0600	40.3	35.3	997	35	"
30 / 1200	38.7	34.6	996	40	"
30 / 1800	37.4	33.2	995	40	"
01 / 0000	36.6	31.5	995	40	"
01 / 0600	36.7	29.7	995	40	"
01 / 1200	37.7	28.7	996	40	"
01 / 1800	38.6	28.5	996	40	"
02 / 0000	39.3	28.8	997	35	"
02 / 0600	39.7	29.4	997	35	"
02 / 1200	40.2	30.0	997	35	"
02 / 1800	40.9	30.4	996	40	"
03 / 0000	41.4	31.0	996	40	"
03 / 0600	41.4	31.9	996	35	"
03 / 1200	40.8	32.5	996	35	"
03 / 1800	39.9	32.3	995	40	low
04 / 0000	39.1	31.3	994	40	"
04 / 0600	38.5	29.5	993	40	tropical storm
04 / 1200	38.3	26.8	992	45	"
04 / 1800	38.8	23.9	991	50	"
05 / 0000	40.2	21.3	989	55	"
05 / 0600	42.0	19.0	988	55	"
05 / 1200	44.3	17.1	987	55	"
05 / 1800	46.6	15.5	986	50	"
06 / 0000	48.8	14.3	986	45	"
06 / 0600	50.0	12.7	989	40	extratropical
06 / 1200	50.4	10.6	993	35	"
06 / 1800	50.8	7.7	997	30	"
07 / 0000					dissipated
05 / 1800	46.6	15.5	986	50	minimum pressure
05 / 0000	40.2	21.3	989	55	maximum winds

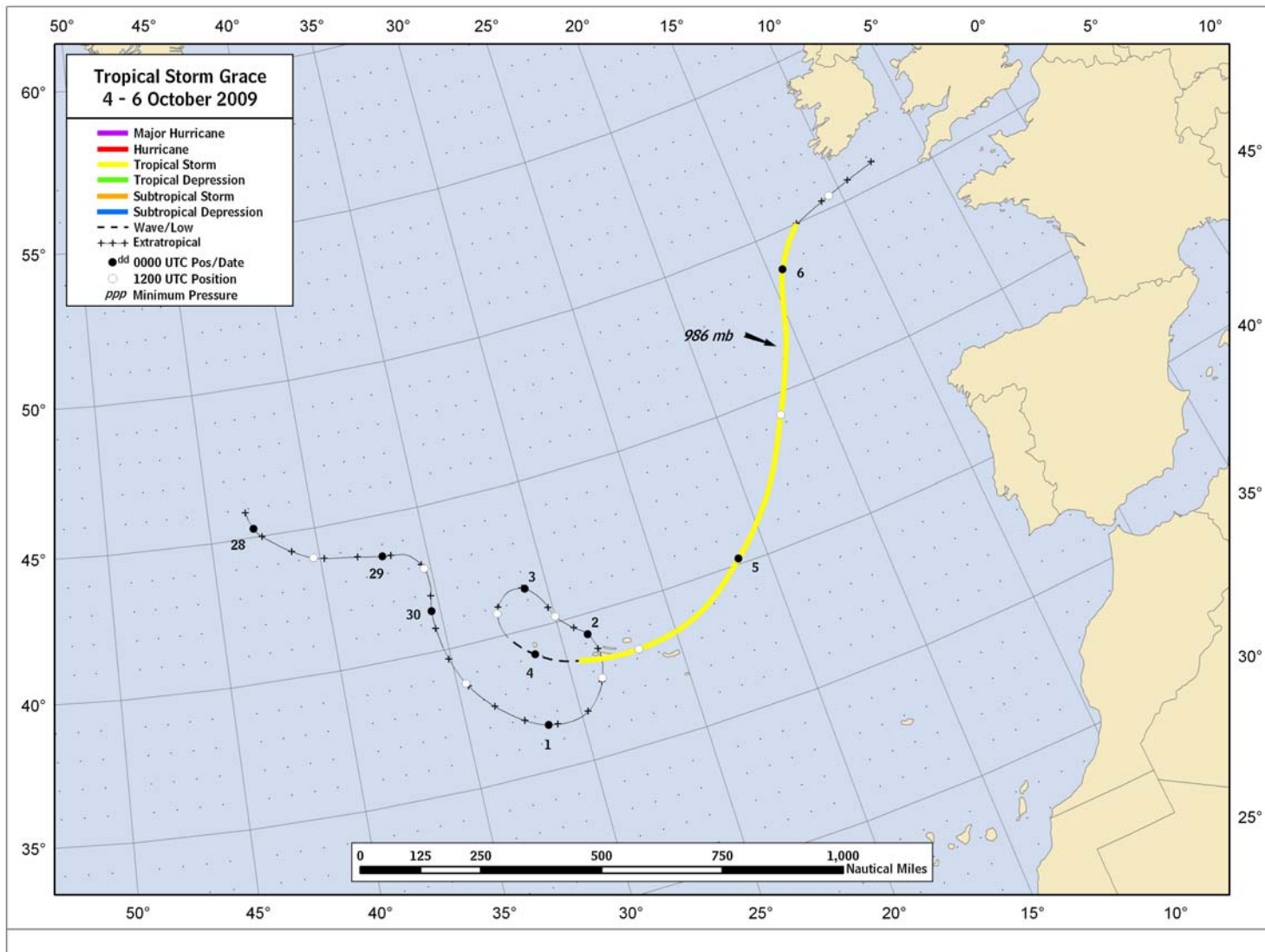


Figure 1. Best track positions for Tropical Storm Grace, 4 – 6 October 2009. Track during the extratropical stage is partially based on analyses from the NOAA Ocean Prediction Center.

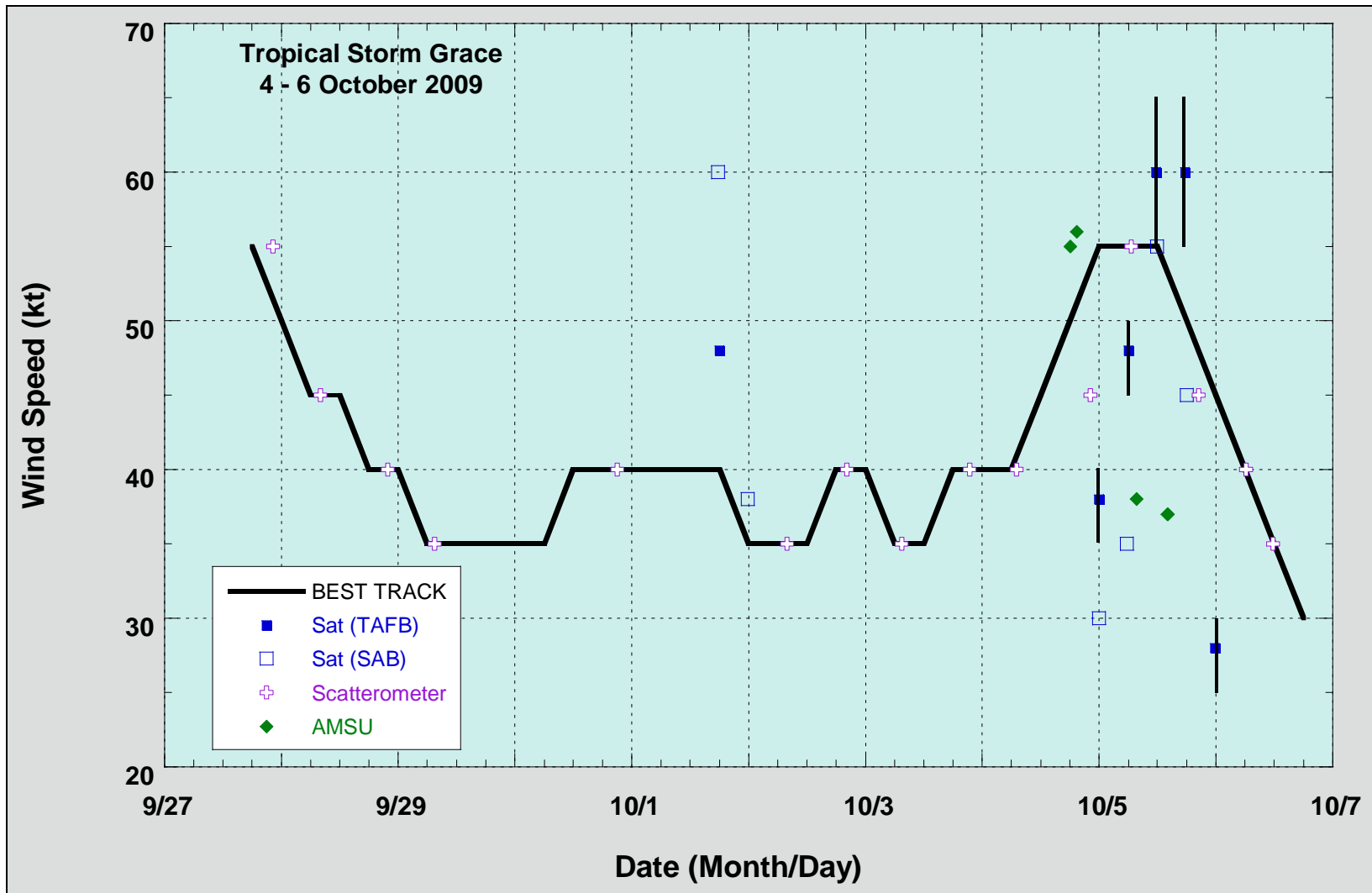


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Grace, 4 – 6 October 2009. Estimates during the extratropical stage are partially based on analyses from the NOAA Ocean Prediction Center. Subtropical satellite classifications are depicted as the mid-point of the Hebert-Poteat classification range (indicated by thin vertical bars). Dashed vertical lines correspond to 0000 UTC.

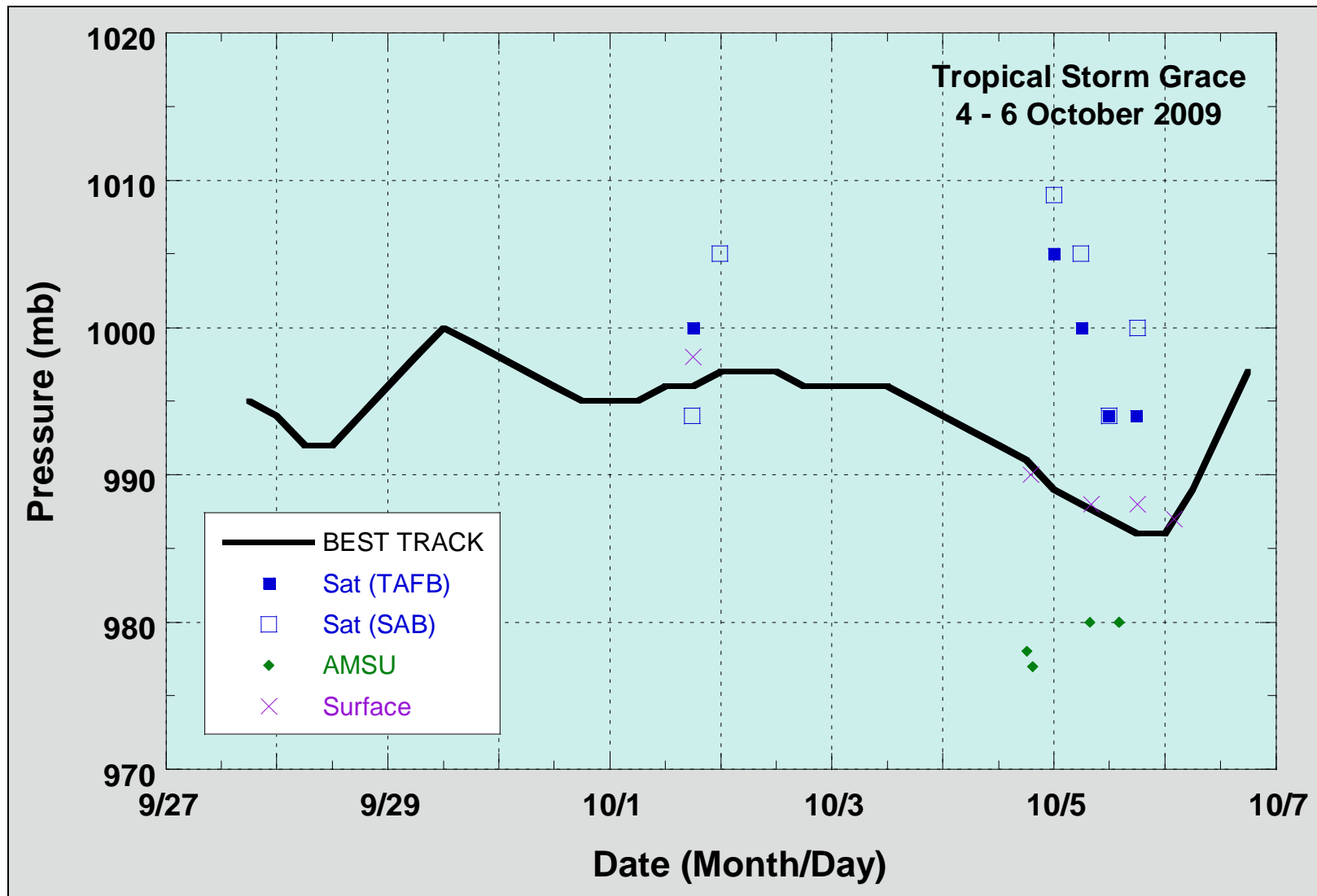


Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Grace, 4 – 6 October 2009. Estimates during the extratropical stage are partially based on analyses from the NOAA Ocean Prediction Center. Dashed vertical lines correspond to 0000 UTC.

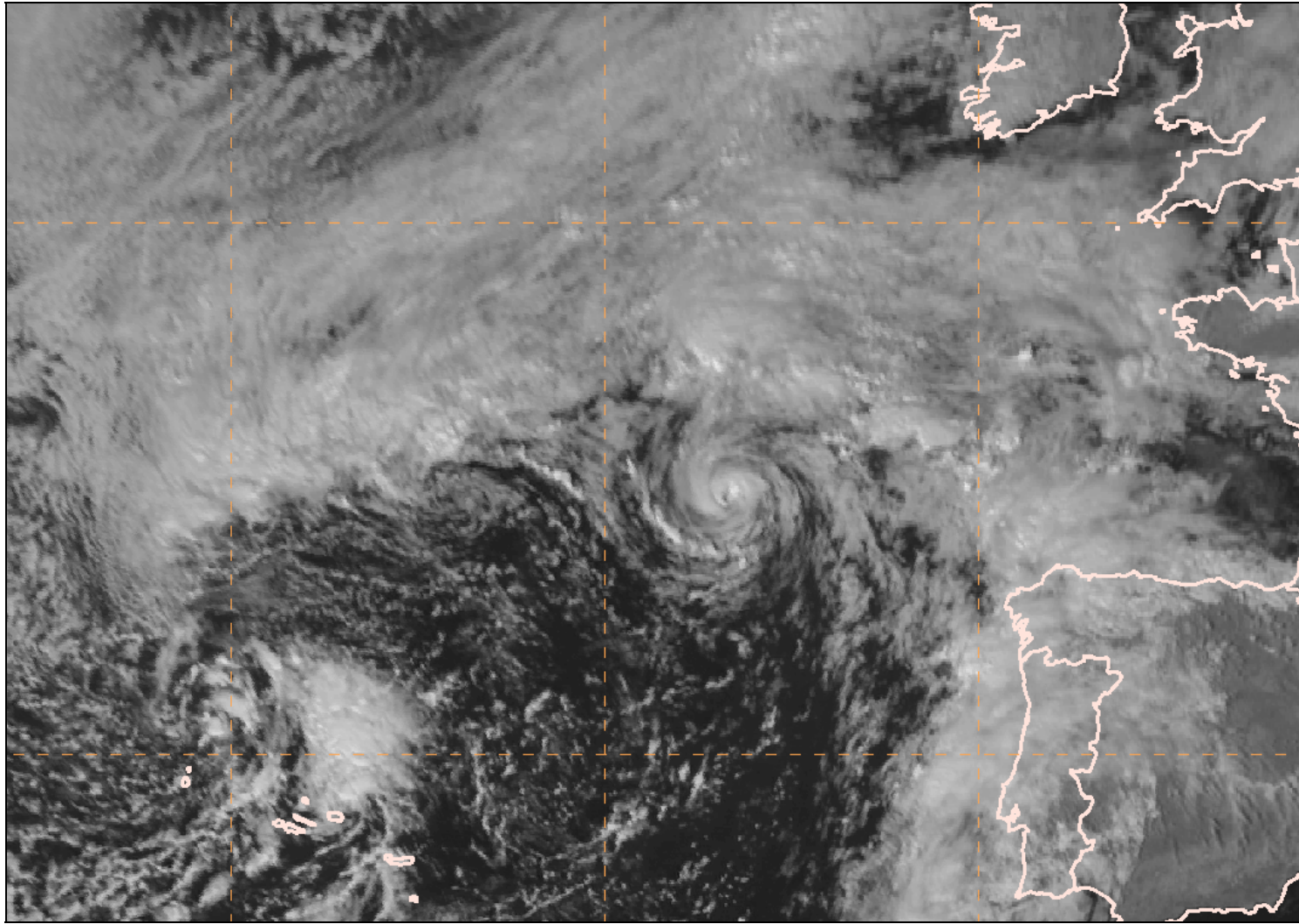


Figure 4. METEOSAT-9 visible image of Tropical Storm Grace at 1400 UTC 5 October 2009 as it was moving north-northeastward over the northeastern Atlantic Ocean between the Azores and the British Isles.