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World record rainfalls (72-hour and four-day accumulations) at Cratère
Commerson, Réunion Island, during the passage of Tropical Cyclone
Gamede

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1 **ABSTRACT**

2 The World Meteorological Organization (WMO) Commission for Climatology (CCI)
3 evaluation process is applied to two extreme rainfall records occurring at Cratère Commerson on
4 La Réunion Island during the passage of the major Tropical Cyclone (TC) Gamede for inclusion
5 into the WMO CCI World Weather and Climate Extremes Archive. In February 2007, TC
6 Gamede made two approaches to La Réunion Island as it traversed a rather complex path in the
7 Indian Ocean. Gamede's main feature was massive rainfall accumulation inland, with several
8 three- and four-day rainfall totals exceeding two meters. Specifically, an extreme rainfall rate of
9 3929 mm over 72 hours was recorded at Cratère Commerson, well above previous world record
10 of 3240 mm which had been measured at Grand-Ilet during TC Hyacinthe in 1980. Additionally,
11 the Cratère Commerson raingauge registered a rainfall total of 4869 mm over four days; also
12 well above the previous world record. The evaluation committee found consistent regional
13 rainfall measurements, reliable calibrated equipment, and correct recording procedures were
14 followed throughout the event. Problems with potential wind-induced measurement errors were
15 discussed but the committee consensus is that such errors tend to under- rather than over-
16 estimate rainfall accumulations. As shown by analysis of this event, the validation process for
17 the WMO CCI Weather and Climate Extremes Archive provides essential documentation and
18 certification for weather extremes across the world.

1 **1. Introduction**

2 A critical aspect of identifying climate change is the establishment and maintenance of
3 verifiable weather data of weather and climate extremes (Cerverny et al., 2007). Since reported
4 incidents of weather extremes are often used as indicators that the Earth’s climate is changing
5 and/or becoming more variable, confirmation of new weather extreme records should be
6 recognized as a high priority in the meteorology community. Although several countries across
7 the world have initiated weather and climate extremes committees (e.g., U.S. National Climate
8 Extremes Committee, see <http://www.ncdc.noaa.gov/oa/climate/monitoring/extremes/ncec.html>)
9 to identify, verify and archive weather extremes within their own borders, until recently similar
10 measures for documenting and archiving world weather extremes have not been established. In
11 2006, the World Meteorological Organization (WMO) Commission for Climatology (CCI)
12 appointed a Rapporteur on Climate Extremes to launch and maintain an official, unbiased list of
13 weather and climate extremes for the world and, additionally, to establish procedures for the
14 verification of future weather records.

15 Upon receipt of a new purported record, an ad hoc extremes committee is organized to
16 provide an expert and unbiased recommendation whether the extreme in question should be
17 added to the list. The committee consists of the President of the Commission for Climatology,
18 the Chair of the CCI Open Programme Area Group (OPAG) on Monitoring and Analysis of
19 Climate Variability and Change (the Rapporteur is part of this OPAG), and a representative of
20 the relevant Member State’s National Meteorological and Hydrologic Service as well as experts
21 in the appropriate meteorological phenomenon and observing instrumentation as required. The
22 committee may also consult with a wide variety of additional experts as the need arises. Based
23 on the available data from the event, the committee creates an evaluation and recommendation

1 for the Rapporteur of Climate Extremes, who then makes a judgment of the record's inclusion
2 into the WMO CCI World Weather and Climate Extremes Archive.

3 A critical aspect of the committee's evaluation process is to ascertain potential errors
4 arising in the recording of the purported weather extreme. For example, a recent report (Dhar
5 and Nandargi, 2006) indicated that on 10 June 2003 Cherrapunji, India, recorded a daily (24-
6 hour) rainfall total of 1840 mm, which would have been a new world record. However, upon
7 examination, an investigation conducted by Dr. Rupa Kumar Kolli at the request of the
8 Rapporteur proved that the published value was a misprint and that no 24-hour rainfall record
9 had been achieved at Cherrapunji for that date.

10

11 **2. Tropical Cyclone Gamede**

12 We detail in this paper the investigation of two possible new world record rainfall events
13 associated with the passage of a tropical cyclone in the South Indian Ocean. Recently, in
14 February of 2007, the major tropical cyclone, Gamede, made two approaches to the island of La
15 Réunion as it traversed a complex looping path in the Indian Ocean (Fig. 1). During the first
16 passage, at a distance slightly more than 200 km northwest of the island on Saturday, the 24th of
17 February 2007, winds first oriented from east-southeast veered progressively to east-northeast on
18 Sunday, the 25th of February. They were particularly strong in the highlands and over northern
19 and southern coasts. Heavy rains started over the island's main volcano (Piton de la Fournaise)
20 during the night from the 23th to the 24th, extending then progressively to the whole highlands.
21 Rainfall was more irregular at the coast, because of the succession of peripheral rain bands
22 associated with the whole system. Following this first passage, TC Gamede moved away along a
23 complicated trajectory involving two successive loops, and a prolonged stop on the evening of

1 Monday the 26th of February. Despite the distance (400 km) to the TC's center, storm conditions
2 over the island remained intense, with heavy rain continuing, especially in the highlands, and
3 strong winds blowing from the east-northeast.

4 During a second close passage, to within 250 km west of the island on Tuesday (27
5 February) evening, while the cyclone was moving south, winds turned from north-east to north-
6 north-east, and again strengthened over the highlands, so the western part of the island was hit in
7 its turn. Rainfall intensity decreased close to the coast, but remained heavy in the highlands. It is
8 only on morning of the 28th that conditions improved across the entire island as the system
9 moved away to the southwest.

10

11 **3. TC Gamede Precipitation over La Réunion**

12 The main feature of TC Gamede was a huge amount of rainfall inland, with several 3- and
13 4-day rainfall totals over two meters across the island (Table 1). Rainfall was not associated
14 with any extreme intensity peaks, but the cumulative totals over periods of 12 hours and more
15 reached remarkable, even exceptional levels in the high altitude sites of Salazie and Cilaos and
16 over the volcano (Figure 1).

17 It is important to note that the accumulated rainfalls mentioned in this chapter are
18 sometimes differing from the sums of daily totals appearing in Table 1, which correspond to
19 fixed time intervals starting and ending at 03UTC (07 local time). The accumulated rainfall
20 amounts mentioned in the table are the maximum running totals beginning at 01,02, to 23 hours
21 (all times mentioned are local time: UTC+4) over periods of 24, 48, 72, 96 hours.

22 Specifically, the highest of 24 hour rainfall amount of 1625 mm was recorded at Cratère
23 Commerson from 15h on the 24th to 15h on the 25th, which is somewhat less than the current

1 world record of 1825 mm measured at Foc-Foc during TC Denise in 1966 (Krause and Flood,
2 1997), while additional impressive amounts of 1489 mm (from 21h on the 24th to 21h on the
3 25th) and 1295 mm (from 23h on the 24th to 23h on the 25th) were measured at Hell-Bourg and
4 Bélouve, respectively. Even more impressively, over 48 hours, a rainfall total of 2463 mm at
5 Cratère Commerson was recorded from 07h on the 24th to 07h on the 26th, very close to the
6 world record of 2467 mm at Aurère during an unnamed TC (8-10 April 1958) (Holland, 1993).
7 Other extreme precipitation values included 2358 mm at Hell-Bourg over 48 hours (from 22h on
8 the 24th to 22h on the 26th) and 2185 mm at Bélouve (from 23h on the 24th to 23h on the 26th)
9 over the same time period.

10 Most importantly, an extreme rainfall of 3929 mm over 72 hours (from 16h on the 24th to
11 16h on the 27th) was recorded at Cratère Commerson and a rate of 3264 mm over the same time
12 period at Hell-Bourg (from 14h on the 24th to 14h on the 27th). Both of these values are well
13 above previous world record of 3240 mm over 72 hours which had been measured at Grand-Ilet
14 (see location Fig. 3) during tropical cyclone Hyacinthe in 1980 (Cervený et al., 2007; Krause and
15 Flood, 1997). Somewhat smaller, but still impressive rainfall totals of 2824 mm and 2321 mm
16 over 72 hours were recorded at Bélouve and Cilaos, respectively.

17 New world records associated with this event have also been established for rainfall totals
18 over a four-day interval. The Cratère Commerson raingauge registered a rainfall total of 4869
19 mm over four days while a rainfall amount of 3633 mm was recorded at Hell-Bourg. These two
20 values are well above previous world record of 3551 mm at Cratère Commerson during TC
21 Hyacinthe in 1980 (Cervený et al., 2007; Krause and Flood, 1997). Other high rainfall values
22 recorded on La Réunion during TC Gamede included 3139 mm at Bélouve and 2586 mm at
23 Cilaos.

1 Additionally, although these categories are not yet a part of the official WMO weather
2 and climate archive, new world records were also established for rainfall totals over 5, 6, 7, 8 and
3 9 days with respectively 4979 mm, 5075 mm, 5400 mm, 5510 mm and 5512 mm at this same
4 location (Cratère Commerson).

5 The Commerson station is located north of the volcano at 21°12.48' S and 55° 38.62' E
6 and is 2310 m above sea-level. It became operational on 1st January 1968. The local
7 environment of the station is very open, which is relatively unusual at La Réunion due to the
8 island's mountainous topography and vegetation. The instrumentation used to measure the
9 rainfall at this location was a Précis-Mécanique Tipping Bucket Raingauge, type 3020, (20 g
10 plastic buckets) with an aperture of 400 cm², installed at the site in May 2004.

11 Logs of maintenance and sensor calibration indicate that the raingauge had been
12 calibrated not long before the event (4 December 2006) and was rechecked on 9 January 2007.
13 Following the passage of TC Gamede, the raingauge was again examined on 10 April 2007. No
14 problems with calibration were discovered.

15 One of the critical missions of the ad hoc investigation committee was to ascertain if
16 there could be any anomalies in the manner in which data were collected. In this case, according
17 to the person responsible for the climatological network in La Réunion, there is no objective
18 reason to question measurements made at this site. The equipment was, and is, well protected
19 inside an impervious aluminium cylinder, and well fixed to the ground. Numerous studies have
20 demonstrated that wind induces a loss of precipitation measured by the raingauge (e.g., Chvila et
21 al., 2005; World Meteorological Organization 2006). Indeed, a comparison by one of the
22 committee members (Y. Boodhoo) of co-located wind shielded and non-shielded precipitation
23 measurements taken during the passage of TC Gamede at nearby Mauritius (Station Vacoas)

1 reveals that the shielded raingauge received more rainfall (11 mm over the course of 6 days from
2 February 21st to the 27th) in excess than its unshielded counterpart. Because the precipitation
3 gauge is not shielded, it is considered likely that the record values observed at Cratère
4 Commerson are conservative totals of the rainfall.

5 Tropical cyclones are affecting La Réunion Island from December to April, during the
6 hot season, with a maximum probability in January and February. Statistically, a significant
7 event is affecting the island every five to ten years, but it is not impossible to observe this type of
8 phenomena during two consecutive years (e.g. Colina in 1993, Hollanda in 1994). Over the 2-3
9 days when the cyclone generally affects La Réunion weather, typical rainfall range from 300 to
10 600 mm close to the coast, from 1000 to 1500 mm in the highlands (even much more in some
11 cases). Tropical cyclone precipitation always starts in the highlands of La Réunion as a result of
12 the extreme orography (70% of the island lies between altitudes from 400m to 3069m, see Fig.
13 3). At the end of a TC passage, again due to orographic uplift, precipitation tends to continue in
14 the highlands even as the lowland rains have stopped. Consequently, it is not surprising that the
15 highlands of the island recorded the greatest rainfall amounts (Figure 2). It is normal during
16 tropical cyclone passages for the Commerson site, which is at high elevation, to receive the
17 highest quantities of any observing site on the island (Table 1). In addition, because of its
18 geographical position, the orographic effect at Commerson is at a maximum, no matter what the
19 wind direction. This is not true for other stations in the highlands, where this orographic effect is
20 dependent on the wind direction.

21

22 **4. Summary and Conclusions**

1 In summary, a fairly even distribution of rain was observed over the four days for more
2 than half of the island stations and, on the 24th, the two highest sites, Commerson and
3 Bellecombe, received the greatest rainfall total with comparable values. On the 25th and 26th,
4 comparable daily rainfall rates were again observed at Commerson, Hell-Bourg and Bélouve.
5 On the 27th, rainfall rates were decreasing at stations in the northern half of the island, while
6 keeping the same order of magnitude in the southern half.

7 Even if one can question the behaviour of raingauges in such extreme conditions (a
8 general concern for verification of rainfall extremes), it appears that the observed record rainfalls
9 are indeed credible. Under strong winds, errors in tipping bucket raingauge measurements tend
10 to be underestimates rather than overestimates because of aerodynamic effects around the
11 instrument. However, it should be noted that the previous official world record rainfall values at
12 La Réunion (at Commerson for most of them) were recorded with the same type of raingauges.

13 Consequently, it was the recommendation of the committee and subsequent approval of
14 the Rapporteur, that two new world rainfall records have been established at La Réunion
15 associated with the passage of the intense TC Gamede. First, an extreme rainfall rate of 3929
16 mm over 72 hours as recorded at Cratère Commerson is now the new 72-hour world rainfall
17 total. Second, a new world rainfall record is established for the Cratère Commerson raingauge
18 when it registered a rainfall total of 4869 mm over a four-day period. These records are now a
19 part of the WMO World Weather and Climate Archive currently housed at <http://wmo.asu.edu/>

20 As the perception or the actual occurrence of more frequent extreme weather events
21 grows, the goal of WMO World Weather and Climate Extremes database is to archive and verify
22 extreme record events, such as the highest/lowest recorded temperatures and pressures on the
23 Earth, the strongest winds, the greatest precipitation (over different time intervals) as well as

1 records involving the world's most destructive storms, hurricanes and tornadoes. In the past,
2 without the existence of such an official designate to determine and maintain regional or world
3 records of extreme weather events, the critical supportive documentation needed to assess the
4 validity of a weather record event was often hard to find or simply did not exist. The WMO CCI
5 Extreme Weather and Climate Archive, together with the procedures for evaluating potential
6 new records, now provides the essential documentation and certification for weather extremes
7 across the world.

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10 *Acknowledgements:* The authors thank the members of WMO CCI Open Programme Area
11 Group (OPAG) on Monitoring and Analysis of Climate Variability and Change (see
12 http://www.wmo.int/pages/prog/wcp/ccl/index_en.html) for their support and input to the
13 formation of the Archive.

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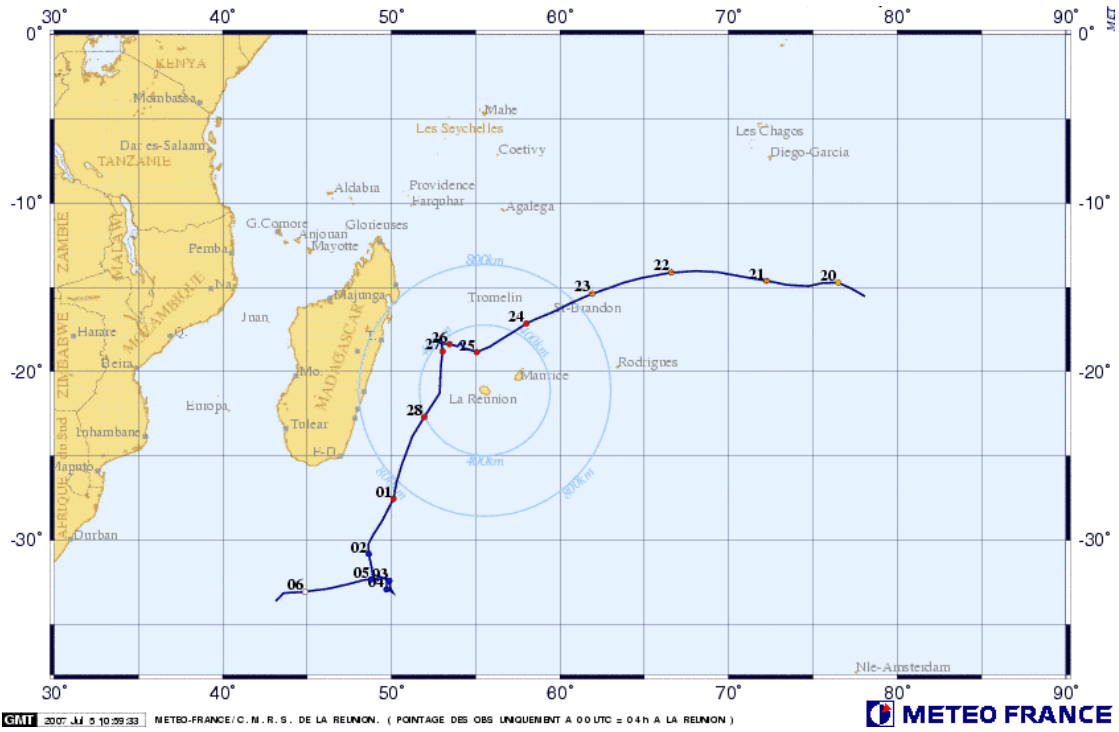
1 Table 1. One, two, three and four day maximum total rainfall accumulations (mm) for stations
 2 on La Réunion from 24-27 February 2007. As example, the 2-Day Total value is computed as
 3 the maximum of the totals for the 24-25, 25-26, 26-27 two-day periods. Four-day totals during
 4 the recent TC Diwa (2006), and TC Hyacinthe (1980) are given for comparison. Values in bold
 5 are record values for the given locations (stations having at least 30 years of data). A
 6 climatological day corresponds to a 24h period from 03UTC to 03UTC (07 local time) the day
 7 after.
 8

Station Name	Elev. (m)	City	Maximum Totals (mm)				TC Diwa	TC Hyacinthe
			1 Day	2 Days	3 Days	4 Days		
Les Avirons-Cirad	170	Les Avirons	45	88	102	130	117	340
Bras-Panon	480	Bras-Panon	172	280	391	471	774	
Ravine Citrons	487	Entre-Deux	225	427	610	714	458	
Pont-Mathurin	20	Etang-Sale	50	98	113	134	176	345
Piton-Bloc-Cirad	810	Petite-Ile	310	540	810	990	272	
Pl. Palmistes	1032	Pl. Palmistes	625	1122	1581	1932	1542	2151
Le Port	9	Le Port	93	174	220	246	171	639
Possession	9	La Possession	192	382	459	535	288	798
Dos D'Ane	915	La Possession	564	1116	1372	1603	980	1540
Aurère	940	La Possession	869	1569	2127	2680	1757	1759
Menciol	181	Saint-Andre	203	386	496	561	461	1002
Beauvallon	16	Saint-Benoit	102	178	270	321	422	891
St-Benoit	43	Saint-Benoit	118	192	266	309	550	973
Providence	138	Saint-Denis	153	269	378	448	312	1005
Chaudron	38	Saint-Denis	140	241	359	421	321	708
Pl. Chicots	1834	Saint-Denis	658	1238	1734	2124		
Commerson	2310	Saint-Joseph	1397	2463	3637	4869	2879	3551
La Crete-Cirad	650	Saint-Joseph	590	1071	1467	1830	882	1040
Carreau-Alfred	1380	Saint-Leu	150	259	385	478	518	1429
Piton St-Leu-Cirad	572	Saint-Leu	88	160	189	270	176	509
Les Makes	980	Saint-Louis	348	627	793	892	441	825
Tapage-Cirad	850	Saint-Louis	350	600	750	849	434	645
St-Paul-Cirad	186	Saint-Paul	187	369	451	519	305	1049
Bdn-Saint-Paul-Cirad	580	Saint-Paul	242	455	593	695	415	752
Ravine Cabris-Cirad	375	Saint-Pierre	173	295	338	434	236	741
Ligne-Paradis-Cirad	150	Saint-Pierre	164	193	249	345	167	605
Le Baril	115	Saint-Philippe	325	641	799	855	869	
St. Philippe	30	Saint-Philippe	207	331	420	455	756	540
Gillot-Aero	10	Saint-Marie	133	221	333	388	324	657
Bellecombe	2245	Sainte-Rose	1131	1615	2082	2331	1798	2587
Bagatelle	262	Sainte-Suzanne	174	324	474	534	503	849
Grand-Ilet	1185	Salazie	725	1311	1743	2083	2958	3485
Hell-Bourg	975	Salazie	1111	2172	3053	3633	2579	1746
Bélouve	1500	Salazie	1097	2004	2711	3139	2372	1700
Pl. Des Cafres	1560	Le Tampon	500	938	1342	1745	959	1586

Le Tampon- Cirad	786	Le Tampon	392	734	948	1220	561	754
Cilaos	1197	Cilaos	840	1550	2185	2586	1632	1643

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Fig. 1 : Trajectory of TC Gamede from 19 February to 6 March 2007. Red dots correspond to

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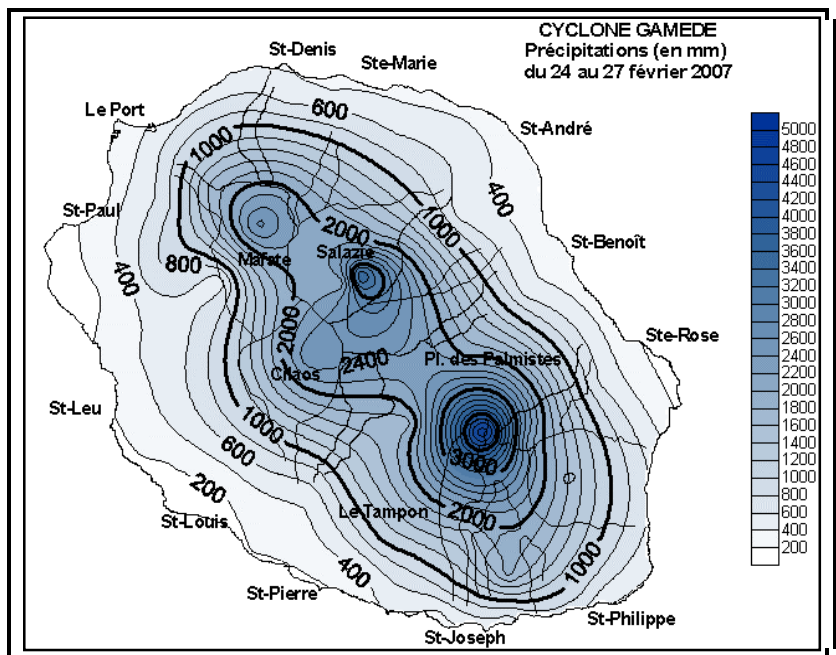
conditions of established tropical cyclone

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(from http://www.meteo.fr/temps/domtom/La_Reunion/#)

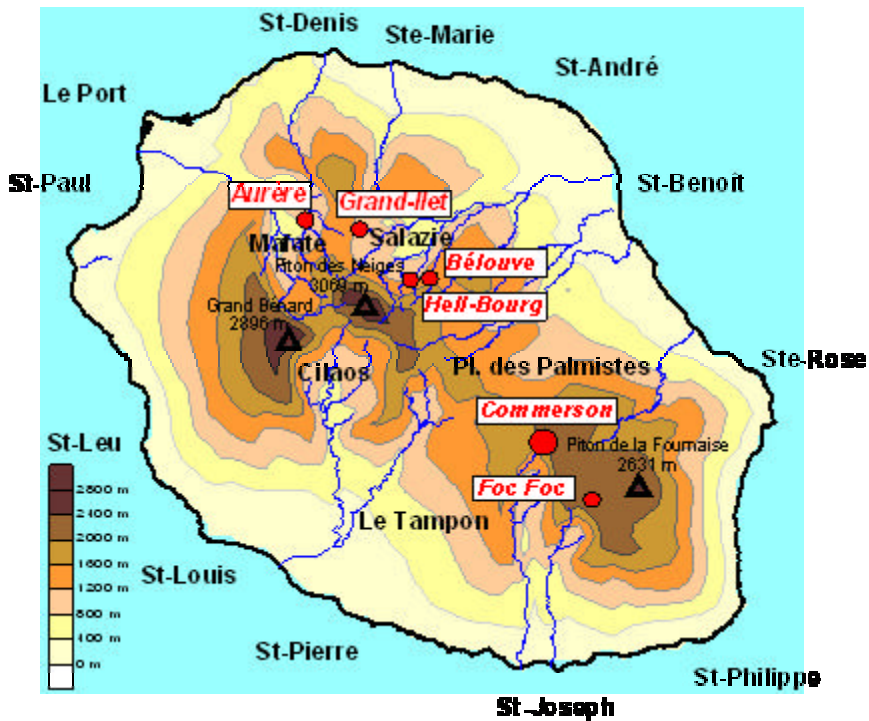
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Figure 2. Isohyet map of the 4-day precipitation accumulations (mm) for stations on La Réunion from 24-27 February 2007.

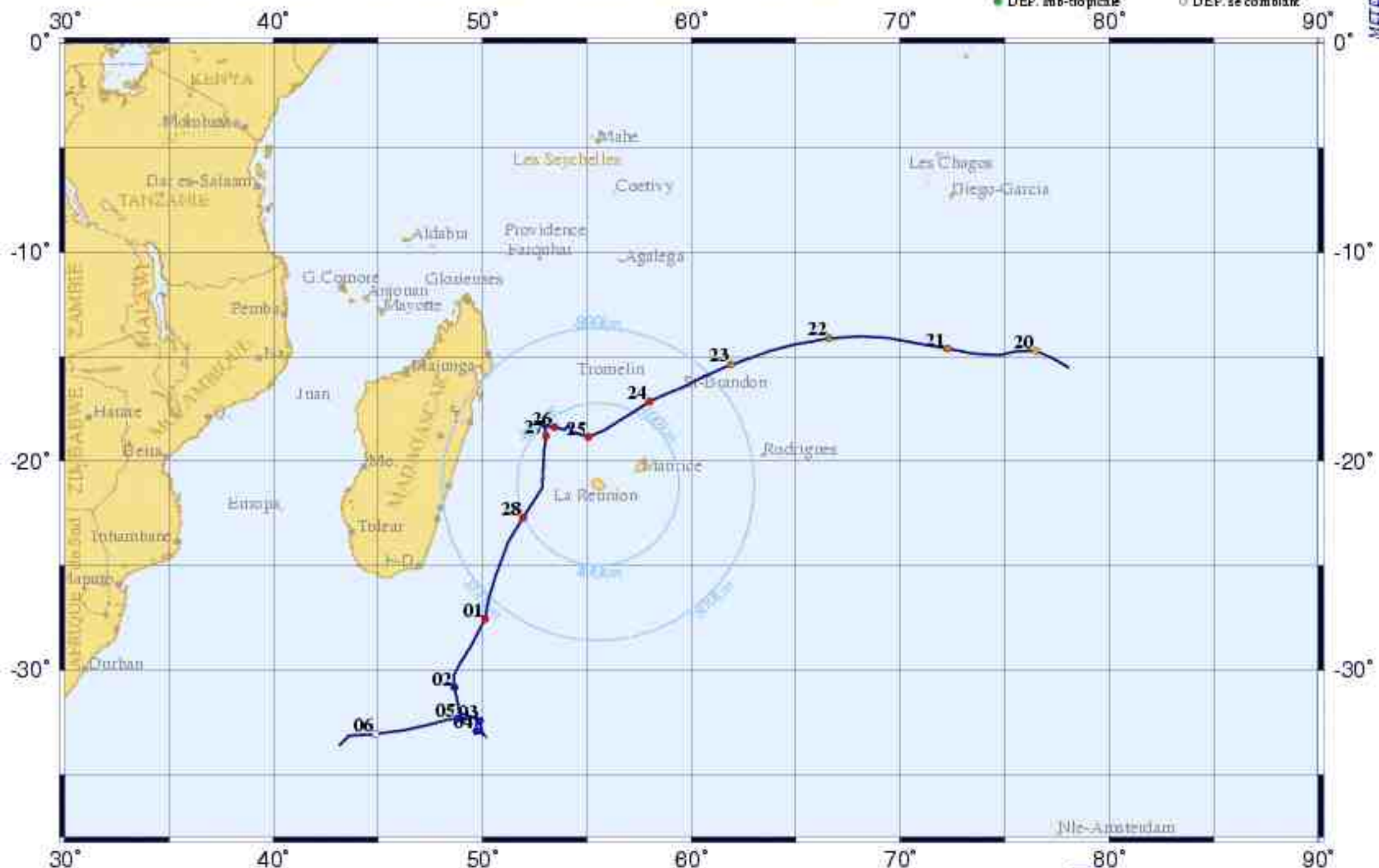


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Figure 3: Topographic map of La Réunion island

GAMEDE du 19/02/2007 au 06/03/2007

- CYCLONE tropical
- TEMPETE tropicale
- DEPRESSION ou Perturbation tropicale
- DEP. extra-tropicale
- DEP. sur terre
- DEP. sub-tropicale
- DEP. se comblant



CYCLONE GAMEDE
Précipitations (en mm)
du 24 au 27 février 2007

