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The Shipwreck of the Airship "Dirigibile Italia" in the 1928 Polar Venture: A Retrospective Analysis of the Ionospheric and Geomagnetic Conditions

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Abstract On 25 May 1928 the airship "Dirigibile Italia" during its return trip to the base in NyAlesund, after overflying the North Pole, shipwrecked on the ice-pack in a region at about 400 km northeast of Svalbard Islands. Survivors, by using a portable high frequency (HF) radio transmitter, tried unsuccessfully to send SOS messages and to establish a radio link with the ship "Città di Milano" of the Italian Navy, closely anchored at King's Bay. Only after 9 days of repeated radio-distress transmissions, a Russian radio amateur close to the town of Arkhangelsk about 1,900 km away was able to receive the messages launched by the survivors and raise the alarm. This paper aims at giving a retrospective analysis of the ionospheric and geomagnetic conditions of that epoch in order to explain the HF radio communications problems encountered by the survivors. The International Reference Ionosphere model has been applied, and early geomagnetic measurements have been evaluated, to come up with theories explaining the events. We assert the HF transmission difficulties were associated with the "radio silent" or "dead zones" associated with F-region propagation. These may have been exacerbated by solar and geomagnetically disturbed conditions of the days immediately following the airship wreck.

1. Introduction

The last decades of the 19th century and the first 40 years of the 20th century were characterized by an enormous interest for the exploration of the last uncharted territories of our planet. At the same time, the interest was high in the application of radio science and technology to communications, as well as in the conquest of the air with airplanes and airships.

More than 90 years have passed since the shipwreck of the airship "Dirigibile Italia," occurred in the 1928 polar venture. Those facts gave rise to discussions and controversies that, besides stealing the main pages of the newspapers of that time, reverberate still today (Sicolo, 2017). Specifically, the topic related to the high-frequency (HF) loss during flares and geomagnetic storms has been again recently emphasized by Frissell et al. (2019). Accordingly, we undertake a reconstruction of the space weather conditions characterizing that epoch, to try to further explain or confirm the hypotheses made about the HF radio communications difficulties encountered by the survivors. This is done resorting to recent ionospheric models and to an improved knowledge of the polar environment.

A short telling of the historical facts is provided in section 2 to define the radio communication problems. A retrospective analysis of the ionospheric and geomagnetic conditions in that epoch is given in section 3, which is the base of a critical discussion of all the radio links established by the survivors given in the last section.

2. The Historical Facts

Roald Amundsen, the Norwegian explorer who first reached the South Pole in 1912, overflew the North Pole in 1926 on board the airship "Norge," piloted in that venture by his designer Umberto Nobile, an Italian Air Force engineer. In those years, before the tragedy of the airship "Hindenburg" in 1937, the competition between airplanes and airships as media of transport was still a main issue. What motivated Umberto Nobile to plan a new expedition to the North Pole in 1928 was a mixture between the international competition in the new technologies and the possible exploration of unknown territories. The main targets were,
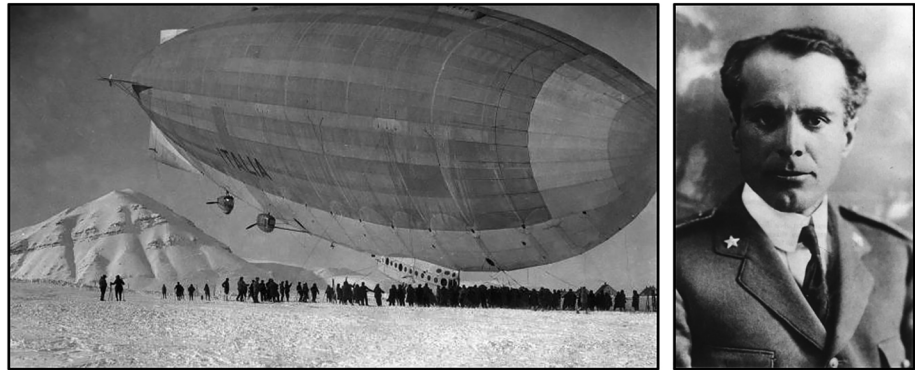
Figure 1. The airship "Italia" at NyAlesund and Umberto Nobile (courtesy of Irene Schettino Nobile).

however, the quest for potential unexplored emerged lands and the carrying out of several geophysical experiments, including a possibility to touch the iced surface of the Pole.

A new airship called "Italia," built by Umberto Nobile, left Milan on 15 April 1928 and arrived at King's Bay at Svalbard Islands on 5 May. The plan was to perform several explorative flights over the Arctic region and finally overfly the North Pole. Figure 1 shows Umberto Nobile and the airship "Italia." The "Dirigibile Italia" left NyAlesund, the small village close to King's Bay, on 23 May 1928, overflew the North Pole on 24 May and then retraced the route to get back to Svalbard Islands. At 10:35 UT of 25 May, under difficult weather conditions and when it was at about 400 km northeast of NyAlesund, the airship shipwrecked on the sea ice surface. Part of the cabin with nine surviving remained on the ice-pack, while unfortunately a tenth member was killed on the impact with the ice. Subsequently, the rest of the airship took off again with the other six crew members and disappeared for ever. The nine survivors took cover under a red tent, so the "Red Tent" became the historical name used to identify the event.

Luckily, an HF portable radio transmitter was available to the survivors of the Red Tent. The apparatus, called "Ondina 33," was originally designed to be used only for communications between the airship and members of the expedition during explorations on the ice-pack. The Ondina 33 was a prototype of a simple HF apparatus built by the naval arsenal of the Italian Navy in La Spezia harbor. It was able to generate a 5 W output over a range between 30 and 50 m (Solomon & Cala-Lazar, 2008). It was based on a project similar to that of many other battery-powered small transmitters, very popular among the radio amateurs of that epoch. It was made up by a Hartley Oscillator, a small Philips TB 0410 triode, a 16-ring spiral, an air capacitor, two small fix capacitors, and a voltage transformer from 12 to 300 V (Sicolo, 2017; Solomon & Cala-Lazar, 2008).

Just after the shipwreck, the radio operator Giuseppe Biagi started sending SOS messages to the ship "Città di Milano" of the Italian Navy anchored at King's Bay through a really precarious antenna system by using the 9.1 MHz radio frequency. Then, he moved the frequency to 9.4 MHz, being this frequency the one through which he listened (using a HF radio receiver Burndept MK4) to the news from the radio broadcasting station located in Rome (41.8°N, 12.5°E). The attempts to send a distress message were all unsuccessful, except for one uncertain episode. In fact, the ship "Città di Milano" was not able to receive those messages. On the other hand, although sporadically, messages sent by the ship equipped with a 10 kW HF transmitter were received from the Red Tent.

On 3 June 1928, 9 days after the crash, a young Russian radio amateur, Nicolaj Schmidt, was able to receive the SOS signal sent by the survivors and launch the alarm. He received the signal on the 9.4 MHz frequency with his home-made radio receiver, located in a small village close to Arkhangelsk (64.3°N, 40.3°E), a little town 1,900 km far from the Red Tent. Left side of Figure 2 shows the geographical positions and relative distances between the Red Tent, just after the shipwreck at the end of May 1928, and the ship "Città di Milano," the Russian town of Arkhangelsk, and Rome. Right side of Figure 2 shows both positions of the Red Tent at the end of May and at the end of June 1928 after drifting on the iced sea and the corresponding distances with the ship "Città di Milano." After this first contact, the communication between NyAlesund and the Red Tent was first occasional and then firm, also thanks to a reduction in the transmission frequency (see Table 1) due
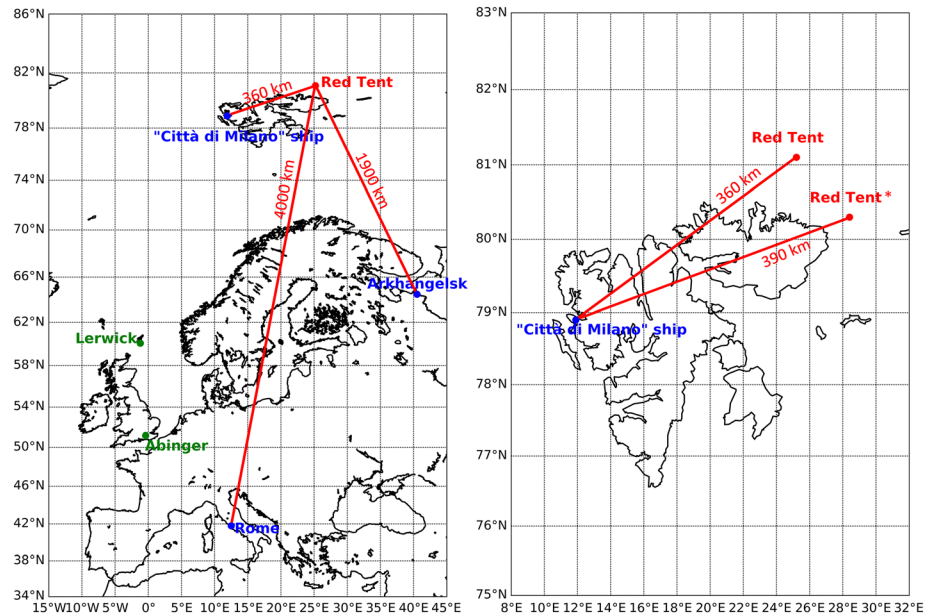
Figure 2. (Left) Geographical positions and relative distances between the Red Tent, just after the shipwreck at the end of May 1928, and the ship "Città di Milano," the Russian town of Arkhangelsk, and Rome. The position of Lerwick and Abinger geomagnetic observatories (see section 3.2 for further details) are shown in green. (Right) The approximate position of the Red Tent at the end of May 1928 just after the shipwreck and that at the end of June 1928 (Red Tent*) after drifting on the sea ice and corresponding distances with the ship "Città di Milano."

to a modification to the antenna. According to the memorial by Biagi (1929), the original antenna was a telescopic vertical oscillator. After damage due to the impact, the survivors rebuilt the antenna and subsequently lengthened it to reduce the frequency.

Finally, on 12 July 1928, after 48 days on the ice, survivors were reached and saved by the Russian icebreaker "Krassin." During the rescue operations, in a further tragedy, 15 rescuers died, among them the crew of a French airplane with the explorer Roald Amundsen onboard.

For a detailed and more recent report on the historical events, with a special regard to the radio communication aspects, see also the book (in Italian) by Sicolo (2017) and the complete list of references therein, the paper by Solomon and Cala-Lazar (2008), or the link https://en.wikipedia.org/wiki/AirshipItalia.

3. Ionospheric and Geomagnetic Conditions Characterizing the "Red Tent" Event

3.1. Ionospheric Environment

The first half of the past century was marked by the beginning of the exploration and the experimental investigation of the terrestrial ionosphere, mainly due to the development and dissemination of the wireless telegraph. The first transoceanic radio link was in fact realized by Guglielmo Marconi in 1901 (Brittain, 2004). Then, thanks to the first technological devices by Breit and Tuve (1926) and theoretical studies by Appleton (1928), systematic measurements gave a first realistic picture of both the vertical structure of the Earth's ionosphere and, more in general, about the radio propagation in an ionized medium. In those years, the theory of ionospheric refraction was consolidated by the formula of Appleton-Hartree (Appleton, 1928). The regular monitoring of the ionosphere started using the so-called ionosonde, a particular type of radar through which it is possible to estimate the electron density of the ionospheric plasma as a function of height. This had a decisive influence during and after the years of the Second World War due to long distance HF communications' needs for military purposes (Anduaga, 2009).

Finally, it was only after the International Geophysical Year in 1958 that Jones and Gallet (1960), by using the first computers handling a very large amount of observations, implemented a model capable to globally

Table 1
Concise Scheme of the Radio Links and Corresponding Radio Frequencies Characterizing the Red Tent Event (Sicolo, 2017)

Time and frequency used	Transmitter	Receiver	Quality of reception	Geomagnetic condition
25–31 May 1928 9.1 MHz 9.4 MHz	Red Tent	Ship "Città di Milano," NyAlesund	Only one uncertain radio link	Disturbed
25–31 May 1928 9.1 MHz	Ship "Città di Milano," NyAlesund	Red Tent	Sporadic and very disturbed	Disturbed
25–31 May 1928 9.4 MHz	Rome	Red Tent	Clear	Disturbed
3 June 1928 9.4 MHz	Red Tent	Arkhangelsk	Clear but sporadic	Quiet
After 6 June 1928 9.4 MHz	Red Tent	Ship "Città di Milano," NyAlesund	Clear but sporadic	Quiet
Early July 6.4 and 6.5 MHz (in transmission) 6.5 and 5.4 MHz (in reception)	Red Tent	Ship "Città di Milano," NyAlesund	Clear	Quiet

map the monthly median conditions of two important ionospheric characteristics: the critical frequency of the F2 layer (foF2) and the obliquity factor for a distance of 3,000 km (M(3000)F2), as a function of the hour of the day, the month of the year, and the solar sunspot number. This model was updated many times during the last decades, being adopted by the International Telecommunication Union as its standard, and included in the International Reference Ionosphere (IRI) model (Bilitza, 2018).

The polar ionosphere, however, poses serious challenges to radio propagation. Frequent large variations of foF2 under disturbed geomagnetic conditions, as well as the appearance of sporadic E (Es) layers (thin and dense layers of plasma, forming mostly between 90 and 130 km of altitude, that at high latitudes are prevalent at night), make it difficult to define a "quiet or normal ionosphere" in polar regions (Davies, 1990). So, monthly median values of the principal ionospheric characteristics predicted even by the most recent models may represent only partially, or even not at all, the real conditions of the high-latitude ionosphere (Cander, 2019; Hunsucker & Hargreaves, 2009). For instance, both Liu et al. (2007) using data from the Challenging Minisatellite Payload (CHAMP) satellite and Themens et al. (2014) using data from ionosondes showed that in the polar regions the IRI model sometimes fails to properly represent the ionospheric electron density. There is no doubt that this fact might in some way invalidate the ionospheric analysis shown in the following Figures 4 to 6, but, on the other hand, the corresponding discussion is rather consistent with the facts happened at that epoch.
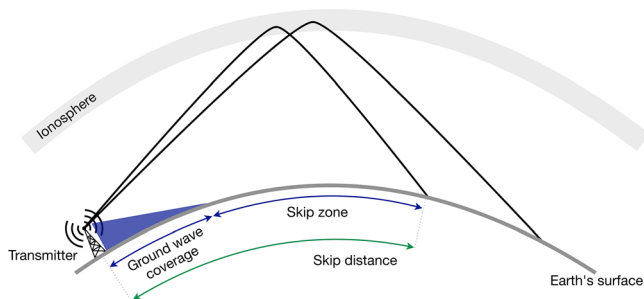

Figure 3. A sketch outlining both the skip distance (in green) and the skip zone (in blue). The skip distance is defined as the shortest distance between a transmitter and a receiver that will permit reception of radio waves (in black) of a specified frequency by one reflection from the ionosphere. The skip zone, also called silent zone or dead zone, is a region where a radio transmission cannot be received; it is the region between the point where the ground wave coverage (blue triangle) ends and the first point where the signal can be received, after being refracted back to the Earth's surface by the ionosphere.

Moreover, it is worth highlighting that the polar and auroral ionosphere profoundly affects the HF propagation at high latitudes. Related studies have shown that the HF propagation at high latitudes is determined by the location of the propagation path in relation to the intersections of the path with the auroral and polar D region and the E-region and F-region reflection points (Hunsucker & Hargreaves, 2009).

In principle, the frequencies to be used to perform a high-latitude and a midlatitude HF link are similar. At midlatitudes, the D region plays a secondary role in radio propagation acting primarily as an absorbing layer, reducing the strength of the signal but seldom preventing communications. Indeed, at midlatitudes, the main parameters of HF propagation are determined by the properties of the E and the F regions. On the contrary, at high latitudes, the ionization of D region may be significantly enhanced, thus making absorption considerably influential.

Specifically, there are two main phenomena characterizing high-latitude radio propagation disruption. One is the polar-cap absorption
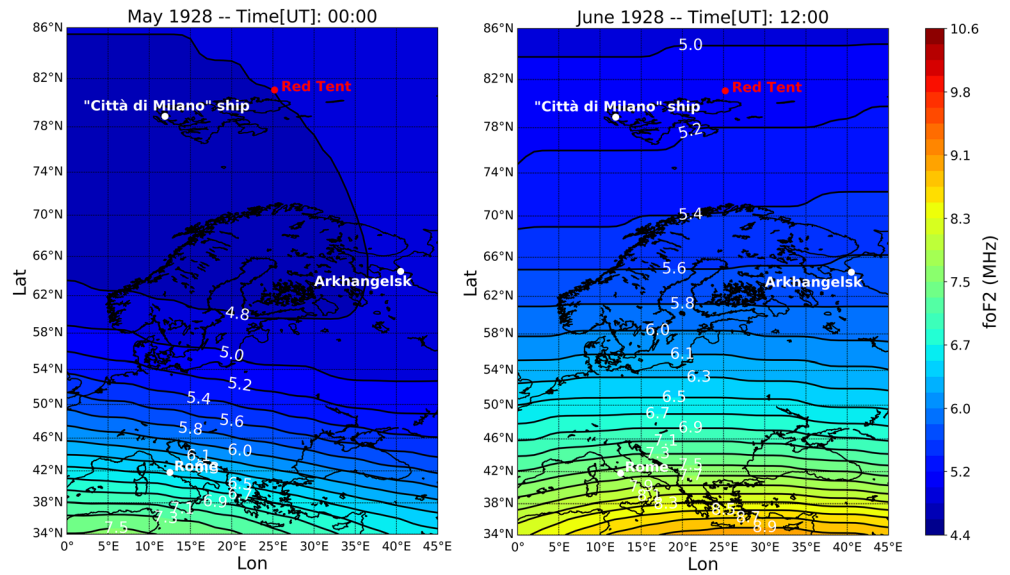
Figure 4. Maps of *f*oF2 (left) in May 1928 at 00:00 UT and (right) in June 1928 at 12:00 UT.

(PCA) caused by energetic protons emitted from the Sun, usually when major solar flares occur. When a PCA occurs, which is on average only about once per month in a year of high solar activity, the absorption may be very strong, leading to an HF blackout over a wide area. The other one is the auroral radio absorption, which occurs only in the auroral regions and is due to fluxes of energetic electrons that sporadically precipitate from the magnetosphere during periods of auroral activity. Differently from PCA, auroral absorption is more commonly confined to the auroral zones, and the corresponding amount of absorption does not rise to the intensity characterizing a PCA (Hunsucker & Hargreaves, 2009).

Of course, the behavior of the ionospheric characteristics and the space weather conditions able to influence the radio propagation parameters were not yet well known because no systematic observations were active at that time. Also, the problem of the skip distance, defined as the shortest distance between a transmitter and a receiver that will permit reception of radio waves of a specified frequency by one reflection from the ionosphere (see Figure 3), was well known by civil and military radio users, but only empirically.
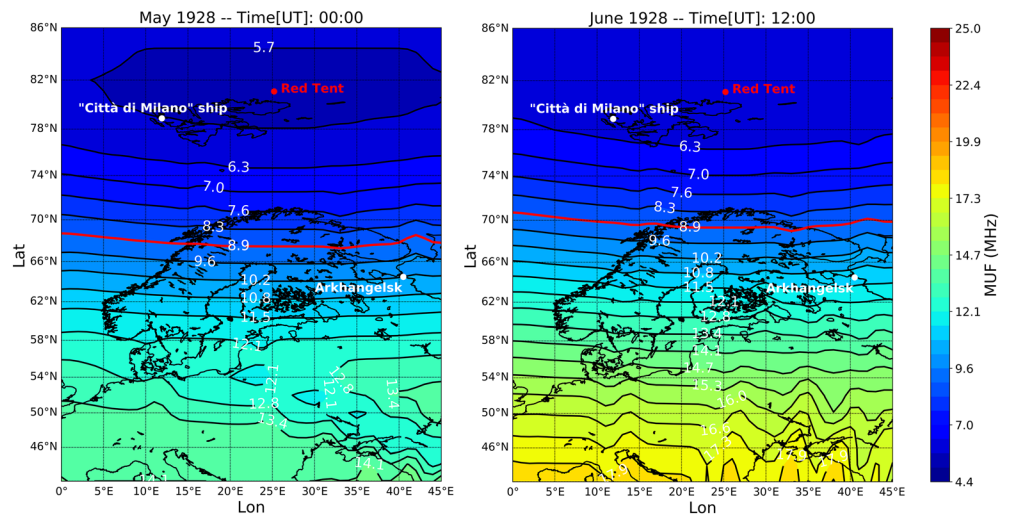

Figure 5. MUF values and corresponding skip distances for any potential radio frequency to be transmitted by the Red Tent in its first position (81.1°N, 25.2°W) (left) in May 1928 at 00:00 UT and (right) in June 1928 at 12:00 UT. The isoline of 8.9 MHz is highlighted in red.
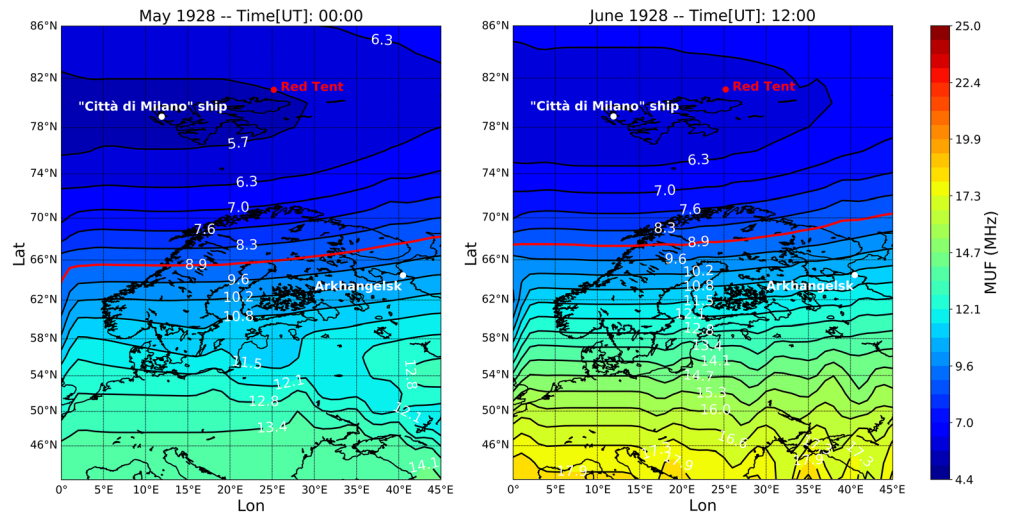
Figure 6. MUF values and corresponding skip distances for any potential radio frequency to be transmitted by the ship "Città di Milano" anchored at King's Bay close to NyAlesund (left) in May 1928 at 00:00 UT and (right) in June 1928 at 12:00 UT. The isoline of 8.9 MHz is highlighted in red.

A retrospective analysis of the radio propagation environment, along with the space weather conditions, is necessary to evaluate those radio propagation parameters that, in the days of the airship expedition, could have been influenced by solar activity and consequent geomagnetic disturbances. To this aim, the IRI model with the Comité Consultatif International des Radiocommunications (CCIR) model (1983) for the F2 peak representation has been applied at the continental scale. This allows performing the ionospheric mapping of foF2 and $M(3000)$F2 by using as input the solar activity index R_{12} taken from the Solar Influences Data Analysis Center website of the Royal Observatory of Belgium (http://sidc.oma.be/silso/datafiles).

Figure 4 shows, as examples, maps of foF2 for May 1928 at 00:00 UT and for June 1928 at 12:00 UT, respectively. They give a monthly median picture of the ionosphere that can be considered representative of a quiet ionosphere. However, the reflecting layer may behave differently day by day and hour by hour, especially at high latitudes and during disturbed geomagnetic conditions.

Given the grid maps of foF2 and $M(3000)$F2 over a definite area, it is possible to calculate the corresponding grid of the Maximum Usable Frequency (MUF) between a given point of transmission and every point of the area. From this grid it is also possible to draw the isoline of a given MUF which corresponds to the skip distance for that particular frequency (Zolesi & Cander, 2014, pp. 201–202). Consequently, the isoline highlights an area within which that particular frequency cannot be received by sky waves but potentially only by ground waves.

Figure 5 shows the isolines of MUF and corresponding skip distances for any potential radio frequency transmitted by the Red Tent in its first position (81.1°N, 25.2°E) at 00:00 UT in May 1928 and at 12:00 UT in June 1928. The isoline corresponding to 8.9 MHz is highlighted in red. Locations poleward of the 8.9 MHz isoline would not receive transmissions from the Red Tent transmitter. Locations equatorward of the isoline should have been able to receive the transmissions.

Differently, Figure 6 shows the isolines of MUF and corresponding skip distances for any potential radio frequency transmitted by the ship "Città di Milano" anchored at King's Bay (78.9°N, 11.9°E), close to NyAlesund, at 00:00 UT in May 1928 and at 12:00 UT in June 1928. In this case too the isoline corresponding to 8.9 MHz is highlighted in red.

It is worth highlighting that in Figures 4–6, the position of the Red Tent in June is the same as in May (that is the position identified as "Red Tent" in Figure 2). This is because the aim of these maps is to show the ionospheric conditions especially from the moment of the shipwreck to the early days of June; this in fact was the most agitated period from a HF communication point of view.
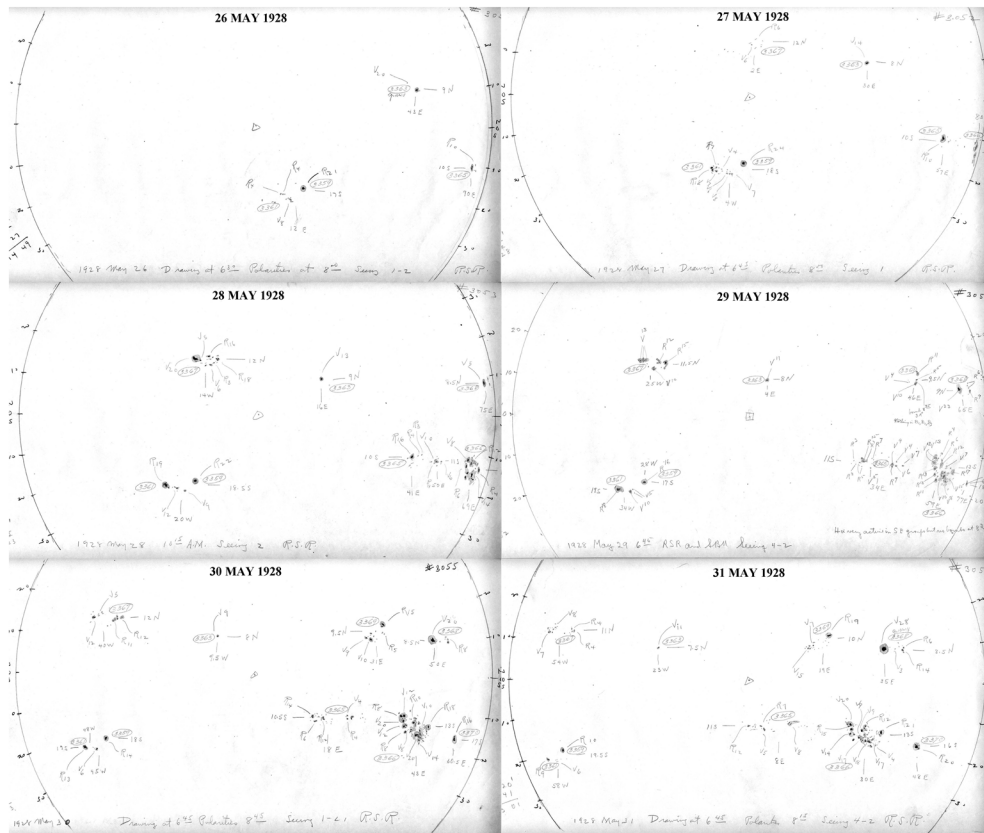
Figure 7. Sunspots drawings from Mount Wilson Observatory from 26 to 31 May 1928.

To complete the overview of all potential radio links, it is important to evaluate the radio wave path attenuation over the surface depending on the different positions of the Red Tent drifting on the ice-pack. Right side of Figure 2 shows the approximate positions occupied by the Red Tent during the early days after the shipwreck (81.1°N, 25.2°E) and during the last days of June 1928 (80.3°N, 28.4°E). In both cases the distances between the Red Tent and the ship "Città di Milano" over a surface composed by land, iced sea and mountains with peaks above 1,000 m, were about 350–390 km so that the attenuation of the radio signal was very high, presumably more than 100 dB (Halley, 1970).

3.2. Geomagnetic Environment

In polar areas the Earth's magnetic field is stronger than in other regions of the planet, since it is generated in the Earth's core and resembles the field produced by an ideal magnetic dipole, roughly coaxial with the Earth's rotation axis (see, for example, Lanza & Meloni, 2006). Moreover, the interaction occurring in the cusp regions between the solar wind particles and the Earth's atmosphere, as well as the intensification of the high-latitude current systems (e.g., auroral electrojets and field-aligned currents), affect significantly the geomagnetic field. Under conditions of high solar activity, disturbances in the solar wind significantly alter the electromagnetic state of the magnetosphere-ionosphere system. Under these conditions, the solar disk shows several active regions that may reasonably originate flares and/or coronal mass ejections triggering, as a consequence, geomagnetic storms (Kivelson & Russell, 1995). Figure 7 shows the sunspot drawings from Mount Wilson Observatory from 26 to 31 May 1928. This figure shows that both the number of single sunspots and the number of sunspot groups increased significantly since 26 May. It is therefore plausible that the survivors sent their first radio-distress transmissions during disturbed geomagnetic conditions.

A common way to support/discard a hypothesis of disturbed geomagnetic conditions is to resort to geomagnetic activity indices (Mayaud, 1980). To the purpose of establishing the local level of the geomagnetic field disturbance, the local K index (ranging from 1 to 9) is particularly suitable. To compute the local K index,
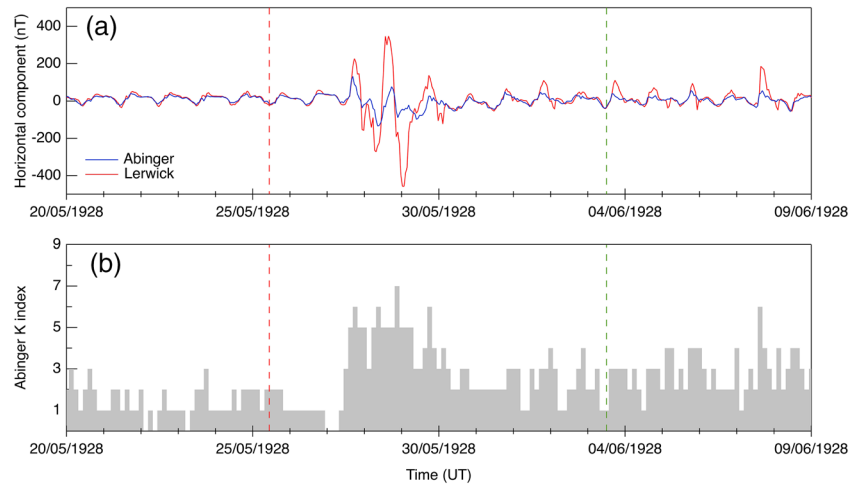
Figure 8. (a) Hourly means of the horizontal intensity (*H*) of the geomagnetic field as recorded in England at Abinger (blue) and in Scotland at Lerwick (red) magnetic observatories, from 20 May to 9 June 1928. To allow the comparison of the observations made at the two magnetic observatories, the *H* component average value has been removed from each time series. (b) Local K index estimated at Abinger. In both panels, the red vertical dashed line marks the moment of the disaster, while the green vertical dashed line marks the moment when the Russian radio amateur received the radio signal.

1-min geomagnetic field measurements made at ground observatories are needed. In 1928, however, only a few magnetic observatories were active in Northern Europe, among these Lerwick (60.1°N, 1.2°W) in Scotland was relatively close to the disaster area. Unfortunately, the local K index for Lerwick observatory is available only from January 1940, and for 1928 only hourly averaged geomagnetic data are available, thus making not possible to estimate the index. We recall that, for each 3-hr interval, the K index is estimated through the maximum fluctuation observed in the horizontal intensity with respect to a quiet day. This fluctuation is then translated into a value of the K index through a conversion table that varies from observatory to observatory so that levels of the K index should be about the same at all observatories. Based on this we can take advantage of the availability of the local K index estimated from another magnetic observatory located in England, south of Lerwick. This is Abinger (51.2°N, 0.4°W) observatory (the present Hartland observatory), whose K index values dates back to 1926. Note the position of Lerwick and Abinger observatories with respect to each other and to the Red Tent displayed in the left side of Figure 2.

Figure 8 displays, from 20 May to 9 June 1928, the hourly mean values of the horizontal component (*H*) for both Lerwick and Abinger observatories (panel a), together with the Abinger local K index (panel b). To better evidence and compare the behavior of *H* at the two observatories we have removed, from each time series, the average value of *H* estimated over the entire considered time interval. In Figure 8a, superimposed on an almost regular daily variation, periods of augmented magnetic activity fluctuations clearly emerge, especially starting on 27 May 1928. The different amplitude of the fluctuations recorded at the two observatories depends on their different latitude: As expected, fluctuations at Lerwick (red curve) are much larger than those at Abinger (blue curve). The red vertical dashed line indicates the time of the disaster (10:35 UT of 25 May 1928), while the green vertical dashed line indicates when the radio signal was received from the Russian radio amateur (3 June 1928). The level of the disturbance is quantified by the Abinger K index (Figure 8b) displaying that particularly disturbed geomagnetic conditions occurred between 27 and 29 of May 1928. Disturbance reached the highest level at 19:30 UT of 28 May 1928, with the K index equal to 7 indicating an ongoing severe geomagnetic storm. It is worth mentioning that to check for the real equivalence between the local K indices computed at Abinger and Lerwick, we have taken, for each observatory, a 6-month time series. The 6-month period has been chosen so that to be under conditions (of both instruments and K index computation procedures), as far as possible, close to those of 1928. So we considered the period with the earliest available K index values for Lerwick and characterized by a solar activity (in terms of sunspot number) close to that recorded during May/June 1928. The period satisfying these constraints corresponds to the first half of 1940, from 1 January to 30 June. We estimated the absolute value of the differences between the local K indices for Lerwick and Abinger and obtained that it is 0 in 56% of cases, 1 in 40%

of cases, 2 in 3% of cases, and 3 in the remaining 1% of cases. This confirms that the Abinger local K index well accomplishes the task of providing a rough but reliable estimate of the level of geomagnetic activity during the Red Tent event.

Accordingly, we argue that disturbed magnetic conditions starting a couple of days after the disaster were such that a strong ionospheric storm took place simultaneously to the magnetic storm.

4. Discussion and Conclusions

Table 1 shows a concise and reduced scheme of the many and complex radio links and frequencies used during the period of the Red Tent event (for more details, see Sicolo, 2017).

Since the shipwreck occurred on 25 May and before the 3 June, no radio signal on 9.1 MHz emitted by the transmitter of the Red Tent was received by the ship "Città di Milano" anchored close to NyAlesund, except for one uncertain episode mentioned above. However, survivors were able to listen to radio news of the broadcasting station of Rome, distant more than 4,000 km, working on 9.4 MHz. Moving to this frequency, on 3 June, their SOS message was received by the Russian radio amateur located in a village close to the town of Arkhangelsk, about 1,900 km away. Few days later, after 6 June, a disturbed and sporadic radio link was established between the ship and the Red Tent. In this period, the survivors of the Red Tent made several attempts to improve the efficiency of the transmitting apparatus, including the antenna system. At the beginning of July, they modified the antenna and reduced the frequency to 6.4 and 6.5 MHz in transmission and to 6.5 and 5.4 MHz in reception, so to obtain a finally stable radio link between the Red Tent and the ship.

From the maps of the skip distance shown in Figures 5 and 6, it is evident that, during quiet ionospheric conditions, the silent zone for the radio frequency 9.1 MHz and 9.4 MHz largely covers the Svalbard Islands. Therefore, the radio link via the ionospheric F region between the Red Tent and the ship "Città di Milano" at NyAlesund was impossible.

Differently, the village close to Arkhangelsk is in a geographical position able to receive signals from the Red Tent at a frequency higher than 9 MHz, even of weak intensity. At the same time, the radio frequency of 9.4 MHz, emitted by the high power broadcasting station in Rome could easily be received by the Red Tent.

Radio signals via ionosphere could be transmitted and received, even if not continuously, also by reflections from the sporadic E layer or due to an intense and temporary increase of the ionization caused by an increased geomagnetic activity (e.g., Cander, 2019). These phenomena, as well as the intrinsic day by day ionospheric variability, which is not represented by the monthly median conditions predicted retrospectively by the model here applied, might explain the few and sporadic radio links between the ship "Città di Milano" and the Red Tent. This hypothesis is further supported by common features of the geomagnetically disturbed high-latitude ionosphere (e.g., Hunsucker & Hargreaves, 2009; Kirkwood & Nilsson, 2000; Tsai et al., 2018): (i) a possible occurrence of large sporadic E layers and (ii) the occurrence of absorption phenomena.

Moreover, the radio propagation through a surface characterized by a mix of ice and ground, between the Red Tent and the ship "Città di Milano" that was more than 350 km away, was extremely difficult, if not completely impossible due to: the weak power transmitted (5 W), the unstable antenna system, and the high level of radio noise at NyAlesund. This radio noise was mainly due to industrial activities of the local coal mine industry but also to the radio communications established by many news agencies reporting the venture events. The inverse path from the ship to the Red Tent was very difficult, too. In fact, even though the ship was equipped with a 10 kW power transmitter, along the path there were mountains higher than 1,000 m.

Radio links of the Red Tent were however significantly affected mainly by skip distance issues and by space weather conditions, not fully known at that time, especially in polar regions. Specifically, according to Thomas et al. (2016), during summer and geomagnetic disturbed conditions, longer lasting ionospheric negative phase across all latitudes and local times are very likely. This could have played a key role in the early stage of tragedy by lowering, unbeknown to the survivors, values of frequencies that could be actually used.

In light of this, it is now clear that all the protagonists of that venture, both survivors and rescuers, faced huge difficulties with extreme courage and competence, including those related to radio communications that were at the beginning of their extraordinary technical evolution.

We finally conclude recalling that, due to both the complicated dynamics of the polar ionosphere and the limited dataset from polar sectors, the improvement of the high-latitude features of the IRI model is still an ongoing activity in IRI community (Bilitza & Reinisch, 2008). An additional possibility to further investigate the space weather environment during the "Dirigibile Italia" event could be to consider a high-latitude regional modeling approach as the E-CHAIM model proposed by Themens et al. (2017). Specifically, to generate MUF and skip distances maps, $M(3000)F2$ could be taken from IRI and $foF2$ from E-CHAIM.

As a last remark concerning the Red Tent event, we underline that the adverse space weather conditions did not play a role in this airship disaster, but rather played a crucial role in radio communications and so in the rescue delay. This is a history lesson that could replay during other explorations such as lunar or interplanetary travels, so possible communication issues due to disturbed space weather conditions must be taken in due consideration.

Data Availability Statement

In detail, Abinger and Lerwick hourly data have been downloaded from http://www.wdc.bgs.ac.uk/dataportal/, and Abinger K index values have been retrieved at http://www.geomag.bgs.ac.uk/data_service/data/magnetic_indices/k_indices.html. Grids used to generate maps of Figures 4–6 can be downloaded at https://drive.google.com/file/d/1HEPzM5Gj8DNbcLwOJtZxYcTxL0hbp6Qr/view?usp=sharing. Sunspot drawings from Mount Wilson have been downloaded from https://archive.org/details/mountwilsonobservatory?and%5B%5D=year%3A%221928%22&sort=titleSorter&page=2.

References

Anduaga, A. (2009). *Wireless and empire: Geopolitics, radio industry and ionosphere in the British Empire, 1918–1939* (p. 386). Oxford: Oxford University Press, pp. xxv+. ISBN: 978-0-19-956272-5. https://doi.org/10.1017/S0007087410000683

Appleton, E. V. (1928). Some notes on wireless methods of investigating the electrical structure of the upper atmosphere I. *Proceedings of the Physical Society*, *41*(1), 43–59.

Biagi, G. (1929). *Biagi racconta*. Milan, Italy: Ed. Mondadori. (in Italian)

Bilitza, D. (2018). IRI the international standard for the ionosphere. *Advances in Radio Science*, *16*, 1–11. https://doi.org/10.5194/ars-16-1-2018

Bilitza, D., & Reinisch, B. W. (2008). International reference ionosphere 2007: Improvements and new parameters. *Advances in Space Research*, *42*(4), 599–609. https://doi.org/10.1016/j.asr.2007.07.048

Breit, G., & Tuve, M. A. (1926). A test of the existence of the conducting layer. *Physical Review*, *28*(3), 554–575.

Brittain, J. E. (2004). Electrical engineering hall of fame: Guglielmo Marconi. *Proceedings Of IEEE*, *92*(9), 1501–1504. https://doi.org/10.1109/JPROC.2004.832946

Cander, L. R. (2019). *Ionospheric space weather*, *Springer Geophysics*. Switzerland: Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-319-99331-7_5

CCIR Atlas of Ionospheric Characteristics (1983). *Comité Consultatif International des Radiocommunications*, *Report* (Vol. 340). Geneva: International Telecommunications Union. ISBN: 92-61-01727-4.

Davies, K. (1990). *Ionospheric radio, IET Electromagnetic Waves Series 31* (p. 580). London, UK: Peter Peregrinus Ltd. ISBN: 978-0-86341-186-1.

Frissell, N. A., Vega, J. S., Markowitz, E., Gerrard, A. J., Engelke, W. D., Erickson, P. J., et al. (2019). High-frequency communications response to solar activity in September 2017 as observed by amateur radio networks. *Space Weather*, *17*, 118–132. https://doi.org/10.1029/2018SW002008

Halley, P. (1970). Propagation Des Ondes radioelectriques dans l'Environment Terrestre, Internal report of the Centre National D'Etudes des Telecommunications, Division des Previsions Ionospheriques.

Hunsucker, R. D., & Hargreaves, J. K. (2009). *The high latitude ionosphere and its effect on radio propagation*. Cambridge: Cambridge University. Press.

Jones, W. B., & Gallet, R. M. (1960). Ionospheric mapping by numerical methods. *Telecommunication Journal*, *12*, 260–264.

Kirkwood, S., & Nilsson, H. (2000). High-latitude sporadic-E and other thin layers—The role of magnetospheric electric fields. *Space Science Reviews*, *91*(3/4), 579–613.

Kivelson, M. G., & Russell, C. T. (1995). *Introduction to space physics*. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781139878296

Lanza, R., & Meloni, A. (2006). *The Earth's magnetism*. Berlin Heidelberg: Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-540-27980-8

Liu, H., Stolle, C., Watanabe, S., Abe, T., Rother, M., & Cooke, D. L. (2007). Evaluation of the IRI model using CHAMP observations in polar and equatorial regions. *Advances in Space Research*, *39*(5), 904–909. https://doi.org/10.1016/j.asr.2006.08.006

Mayaud, P.N. (1980). In *Derivation, meaning, and use of geomagnetic indices*, *Geophysical Monograph Series*, Vol. 22, P.N. Mayaud (Ed.), American Geophysical Union: Washington, USA. https://doi.org/10.1029/GM022

Sicolo, C. (2017). *Le onde smarrite della Tenda Rossa*. Sandit SRL: Albino (Bergamo), Italy. (in Italian) ISBN 978-88-6928-259-1.

Solomon, H. M., & Cala-Lazar, P. (2008). The role of radio in rescuing the survivors of the airship Italia. *Polar Research*, *27*(1), 73–74. https://doi.org/10.3402/polar.v27i1.6162

Themens, D. R., Jayachandran, P. T., Galkin, I., & Hall, C. (2017). The Empirical Canadian High Arctic Ionospheric Model (E-CHAIM): NmF2 and hmF2. *Journal of Geophysical Research: Space Physics*, *122*, 9015–9031. https://doi.org/10.1002/2017JA024398

Themens, D. R., Jayachandran, P. T., Nicolls, M. J., & MacDougall, J. W. (2014). A top to bottom evaluation of IRI 2007 within the polar cap. *Journal of Geophysical Research: Space Physics*, *119*, 6689–6703. https://doi.org/10.1002/2014JA020052

Thomas, E. G. H., Baker, J. B., Ruohoniemi, J. M., Coster, A. J., & Zhang, S.-R. (2016). The geomagnetic storm time response of GPS total electron content in the North American sector. *Journal of Geophysical Research: Space Physics*, *121*, 1744–1759. https://doi.org/10.1002/2015JA022182

Tsai, L., Su, S., Liu, C., Schuh, H., Wickert, J., & Alizadeh, M. M. (2018). Global morphology of ionospheric sporadic E layer from the FormoSat-3/COSMIC GPS radio occultation experiment. *GPS Solutions*, *22*(4), 118. https://doi.org/10.1007/s10291-018-0782-2

Zolesi, B., & Cander, L. R. (2014). *Ionospheric prediction and forecasting*, *Springer Geophysics*. Berlin Heidelberg: Springer Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-642-38430-1