BAMS-D-23-0063: Towards a South American High Impact Weather Reports Database

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ABSTRACT

Despite Southern South America being recognized as a hotspot for deep convective storms, little is known about the socio-environmental impacts of high impact weather (HIW) events. Although there have been past efforts to collect severe weather reports in the region, they have been highly fragmented among and within countries, sharing no common protocol, and limited to a particular phenomenon, a very specific region or a short period of time.

There is a pressing need for a more comprehensive understanding of the present risks linked to HIW events, specifically deep convective storms, on a global scale as well as their variability and potential future evolution in the context of climate change. A database of high-quality and systematic HIW reports and associated socio-environmental impacts is essential to understand the regional atmospheric conditions leading to hazardous weather, to quantify its predictability and to build robust early warning systems.

To tackle this problem and following successful initiatives in other regions of the world, researchers, national weather service members, and weather enthusiasts from Argentina, Brazil, Chile, Paraguay and Uruguay have embarked on a multi-national collaboration to generate a standardized database of reports of HIW events principally associated with convective storms and their socio-environmental impacts in South America. The goal of this paper is to describe this unprecedented initiative over the region, to summarize first results and to discuss the potential applications of this collaboration.

Significance Statement: The South American Meteorological Hazards and their Impacts Database represents a collaborative multi-national initiative aimed at systematically gathering data on high-impact weather events. Cross-border information exchange and collaborative efforts between national weather services, the academic sector, users and weather enthusiasts will improve multi-hazard impact-based forecasts and risk management strategies in the region.

INTRODUCTION

Many studies have recognized Southern South America (south of 15°S; Fig. 1) as a worldwide hot spot for strong deep moist convection (e.g.: Zipser et al. 2006; Romatschke and Houze 2010; Rasmussen and Houze 2011; Rasmussen et al. 2014; Prein and Holland 2018; Ribeiro and Bosart 2018; Bruick et al. 2019; Zhou et al. 2021). Environmental conditions here often favor the development of organized storms capable of producing severe weather hazards (i.e., hail, strong wind gusts, tornadoes). Several studies have analyzed the occurrence of severe storms in Argentina

(Altinger 1988; Matsudo and Salio 2011; Mezher et al. 2012; Kumjian et al. 2020; Trapp et al. 2020; Borque et al. 2020; Bechis et al. 2022; Veloso-Aguila et al. 2024), Brazil (Silva Dias 2011; Nascimento et al. 2014; Martins et al. 2017; Figueiredo et al. 2019; Ribeiro et al. 2019; Beal et al. 2020; Ferreira et al. 2022; Oliveira et al. 2022; Santos et al. 2023), Chile (Vicencio et al. 2021; Marin et al. 2021, Barret et al. 2020), and Uruguay (Durañona et al. 2019) based on ground reports of large hail, damaging winds, tornadoes and heavy precipitating events, but in general the information available has been limited and analyses have focused only on a individual country or localized areas.

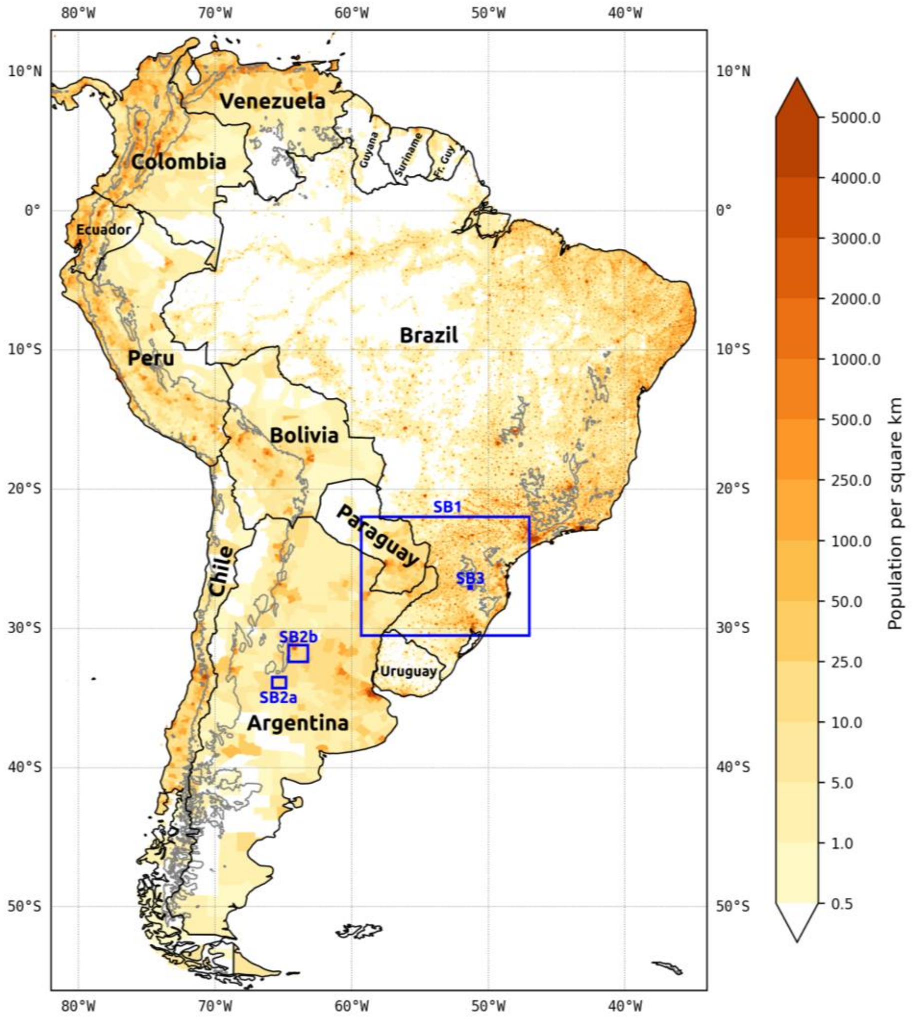

Fig. 1: Map of the region of interest analyzed in the present paper. Shading indicates the South America population density from the GPWv4-2020 dataset (Center for International Earth Science Information Network - CIESIN - Columbia University, 2018). In grey contour, the 1000 m topography from ETOPO-2022 (NOAA National Centers for Environmental Information 2022). Blue boxes indicate the domain of the Figures shown in the corresponding sidebars, SB1: No

borders. A widespread severe weather event (Fig. SB1), SB2: Fig. SB2.a and Fig. SB2.b corresponding to Encouraging Individuals to Accurately Report Natural Hazards: Giant Hail, and SB3: Tornadoes: the need for damage surveys (Fig. SB3).

In the last few years, as the recording and cataloging of hazards and their socio-environmental impacts have become a key element in the understanding of disaster risk, various initiatives have begun to catalog severe weather reports in different regions. Among successful initiatives can be mentioned the Severe Weather Database from National Centers for Environmental Information at National Oceanic and Atmospheric Administration (NOAA) in the USA, with reports since 1955 (www.ncdc.noaa.gov/IPS/sd/sd.html); the European Severe Weather Database (ESWD, Dotzek et al. 2009), that consists of reports from all European countries since the early 2000's, as well as historical reports, some dating back centuries; Northern Tornadoes Project in Canada focused on detecting and accurately assessing tornado occurrence (Sills et al 2020); among others. One example in Brazil is the initiative called *Plataforma de Registros e Rede Voluntaria de Observadores de Tempestades Severas* (PREVOTS, portuguese for Storm Spotting Network and Platform for Severe Weather Reports, x.com: @prevots_svr), which collects severe weather reports. Another example was implemented in Argentina during the Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations (RELAMPAGO) field campaign (Nesbitt et al. 2021) where reports and their socio-environmental impacts were collected during the warm season 2018-2019 in central Argentina by a group of students (x.com: @RELAMPAGO_edu). While these represent important initiatives to collect reports of hazardous weather events and their socio-environmental impacts, they are not part of a fully coordinated (nor standardized) effort to produce a true routinely updated database. The availability of a high-quality South American high impact weather (HIW) report database is essential for a large number of applications, such as: (a) understanding the atmospheric environments that lead the development, maintenance and decay of these events (e.g. Mezher et al. 2012; Lopes and Nascimento 2024); (b) evaluating and developing useful remote sensing proxies of intense convective storms and their associated hazards (e.g. Bang and Cecil, 2019; Ribeiro et al. 2019; Piscitelli et al 2021); (c) selecting environmental parameters for ingredients-based analysis of the meteorological situations favorable for these events (e.g. Brooks et al., 2003; Prein and Holland, 2018; Piscitelli et al. 2021; Glazer et al. 2021; Taszarek et al. 2021; Santos et al. 2023); (d) training artificial intelligence algorithms (e.g., McGovern et al. 2023); (e) forecast verification of convective hazards (e.g., Tsonevsky et al. 2018; Barras et al. 2019; Marsigli et al. 2021); (f) quantitative analysis of social and economic impacts of

HIW events (e.g., Púčik et al. 2019); (g) climate change baselines and trends (Groenemeijer et al. 2017).

An exemplary initiative is the "Early Warnings for All" initiative, spearheaded by the World Meteorological Organization (WMO 2022). This groundbreaking effort is focused on delivering advance warnings for a range of natural hazards, including heatwaves, storms, floods, and tsunamis. Numerous technology companies and governmental agencies have expressed keen interest in this undertaking, driven by the application of a broad spectrum of techniques, including advanced artificial intelligence models. However, what potential biases might arise in the calibration, validation and/or training of such systems when local ground truth information is scarce? What are the consequences on population and infrastructure due to incorrect forecast calibration and evaluation only possible on regions with data availability?

When users seek weather-related information, their primary concern often revolves around how the weather conditions will influence their day-to-day activities. For example, if a storm is forecast, they may want to know if there will be flooding, structural damage, power outages, etc. In these cases, the simple forecast of the storm becomes less relevant, as users are more concerned with the potential impact on their lives and property. Only recently have weather services turned their attention to this viewpoint, constituting a paradigm shift that requires a thorough understanding of the close and complex relationship between meteorological events and their associated impacts, taking into account the diversity of effects depending on location (Potter et al. 2018; Potter et al. 2021). Coordinated and methodical efforts to document this knowledge represent the most effective approach to uncovering the connections between significant meteorological events and their resulting socio-environmental and economic consequences. As a necessary complement to this multi-hazard impact-based forecasting approach, the WMO advocates for the establishment of records of meteorological events alongside their corresponding impacts (WMO 2020). The recording of hydro-meteorological events accompanied by socio-environmental implications has garnered substantial attention, with the DesInventar (desinventar.net) platform emerging as a pivotal source of information, endorsed by the United Nations Office for Disaster Risk Reduction since 1993. Serving as a central repository, it facilitates the gathering and scrutiny of data concerning a wide spectrum of natural hazards in tandem with their impact effects, primarily within the South American region, but this database is principally focused on widespread HIW events and not regularly updated.

The current lack of a unified database in South America remains an obstacle to improving our understanding of and building resilience towards HIW events, and in particular those associated with deep moist convection. To tackle this problem, researchers, national weather service members and weather enthusiasts from Argentina, Brazil, Chile, Paraguay and Uruguay have embarked on an multi-national collaboration to generate a standardized database of HIW reports and their impacts that is unprecedented in South America. This article presents the South American Meteorological Hazards and their Impacts Database (SAMHI, https://samhi.cima.fcen.uba.ar/), an effort based on long-lasting collaborations and friendships initiated during experimental field campaigns such as SALLJEX (Vera et al 2006), CHUVA (Machado et al 2014) and RELAMPAGO-CACTI (Nesbitt et al 2021, Varble et al 2021). For many years now, this community has recognized the need to unite and converge efforts, since HIW events know no borders. Building climatologies or analyzing case studies from the perspective of each individual country is insufficient to provide an integral understanding of HIW events. Following the expansion of the operational meteorological radar networks in the region, along with the launch of a new Geostationary Operational Environmental Satellites generation, the local weather community is presented with the significant challenge to effectively manage this information and translate it into multi-hazard impact-based forecasting and warning products.

THE DATABASE: DATA COLLECTION AND VERIFICATION

The South American members that are part of this initiative started building their respective databases at different times. However, in 2020, drawing inspiration from NOAA and ESWD, a virtual dialogue started during the COVID-19 pandemic, leading to the definition of a set of parameters aimed at comprehensively describing hazardous weather events and their socio-environmental impacts. All members agreed on standardizing the reports to contain:

- **Date and time of occurrence,** including a temporal uncertainty estimation ranging from 10 minutes to 24 hours.

- **Location** and spatial uncertainty estimation ranging from 100 m to 100 km. Administrative names and geographical coordinates can be selected from a list of cities, towns and neighborhoods extracted from the national geographical Institutes databases (Argentina, http://www.bahra.gob.ar/; Brazil, https://www.ibge.gov.br; Chile, https://www.bcn.cl; Uruguay, https://direcciones.ide.uy/swagger-ui.html), or they can be manually incorporated in case the location is not present in the database or for higher precision (i.e. to give specific coordinates within a city). All information is recorded although priority is given to the manually selected coordinates for dissemination purposes.

- **Source of the information**: social media, government agencies, newspaper, personal weather stations, storm spotters, among others.

- **Type of event:** the following events associated with deep moist convection are being recorded into the database: hail, tornado, wind gusts and lightning. All sizes of hail are included in the database. Severe wind gusts are only added to the database if there is either measured wind gust ≥ 80 km/h or wind damage. Though this threshold is lower than used by other initiatives, sometimes we observe wind damage associated with wind gusts around 80 km/h. A tornado report is only confirmed when a reliable picture/video is available. All locations with damage or visual observation of a tornado are included as reports, even if these reports are from the same tornado. A lightning report is included when an impact can be determined (i.e damage or disrupt activities, injured people, among others). The database also includes reports of storms and rainfall, particularly when they are linked to socio-environmental impacts (e.g., flood or flash flood). Other weather categories following the interest of aviation meteorology that have socio-economic impacts such as dust, fog, foehn wind, frost, ice, snow and blizzard are available. Additional categories of weather hazards can be incorporated in the future depending on member interests.

- **Socio-environmental impacts:** infrastructure damage including buildings, vehicles, trees, powerlines, urban infrastructure and services, agricultural or livestock activity. Information regarding direct implications to people's life, health and safety, such as injuries and deaths, and to the livelihood of the affected population can also be included. Impact categories were adapted and expanded from ESWD to the region.

- **Additional meteorological variables:** the database can host observed or estimated meteorological information such as hail size, total precipitation, precipitation type (solid or liquid), and wind intensity and direction. Tornadoes are not rated in the database due to existing resource constraints, and the available photos/videos are often insufficient to reliably estimate tornado categories. However, when information of reliable damage surveys is available, it is incorporated as an additional comment in the correspondent report.

- Optional description section open to any additional comments and possibility to upload pictures, especially important for estimating hail size and damage evaluation.

All information is collected through a web application featuring GraphQL API, developed and hosted by the Centro de Investigaciones del Mar y la Atmósfera (CIMA), Argentina. This interface provides

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tools for report validation and makes available the content of the database in different formats, including a display of the spatial distribution of the most recent events. Information is available upon request following the terms and conditions outlined on the website.

The reports are first logged in the database by users with a "RAW" quality-control flag, and then quality controlled. The quality control protocol by expert users includes the verification of the estimated time and spatial location of the report, along with the spatial and temporal uncertainty. Depending on their availability, satellite and weather radar data are used to verify and improve accuracy of localization in time and space. Once the report passes the quality control, a "VERIFIED" flag is assigned to it.

Partners of the SAMHI database are expected to be: national meteorological services, members of academia (universities, research institutes, among other agencies) and trained voluntary observers.

Presently, the number of reports contained in the database is close to 40,000 and includes all types of events described above. Fig. 2a-b shows the monthly number of reports associated with severe convective weather (hail, convectively induced wind gusts and tornadoes) for all the countries currently participating in the initiative. The Brazilian dataset (Fig. 2a) begins in June 2018 after a tornado outbreak in Southern Brazil on 11 June 2018, and it was built retrospectively to 1 June 2018. The initiative is fully volunteer and is embedded in the PREVOTS project. The Argentinean dataset (Fig. 2b) was initiated during the RELAMPAGO project in late 2018 to support the field campaign and continued after the intensive observation period ended. It is supported by the CIMA and the National Meteorological Service from Argentina (SMN, Servicio Meteorológico Nacional). In Uruguay (Fig. 2b), the dataset was built initially by *Datos de Tiempo Severo - Uruguay* (spanish for Severe Weather Data - Uruguay, x.com: @dts_uruguay) starting in August 2021, and now the National Meteorological Institute from Uruguay (INUMET, Instituto Uruguayo de Meteorología) supports the initiative. The Paraguayan dataset (Fig. 2b) began in 2022 and is maintained by volunteers from *Registro de Eventos de Tiempo Severo en Paraguay* (RETSPY, Spanish for Severe Weather Event Reports in Paraguay). The database encompasses a range of significant events. It begins with the inaugural report from the PREVOTS initiative and delves into the comprehensive reports from the RELAMPAGO campaign. Notable among these is the thorough analysis of the "Chilean Tornado Outbreak" that occurred in late May 2019. The collaboration from SMN includes Luciano Vidal's reports from the warm season 2019-2020 and SMN's Meteorology and Society information including relevant impact information. Coordinated reporting in the database by CIMA

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and SMN is initiated in August 2021, and reports from Uruguay and Paraguay are incorporated in August 2021 and June 2022 respectively from weather enthusiasts. Socio-environmental impacts (Fig. 2.c) started to be collected during RELAMPAGO in Argentina, while in 2021 the information acquired significant value given the decision of the SMN to envision a transition to multi-hazard impact-based forecasting and warnings.

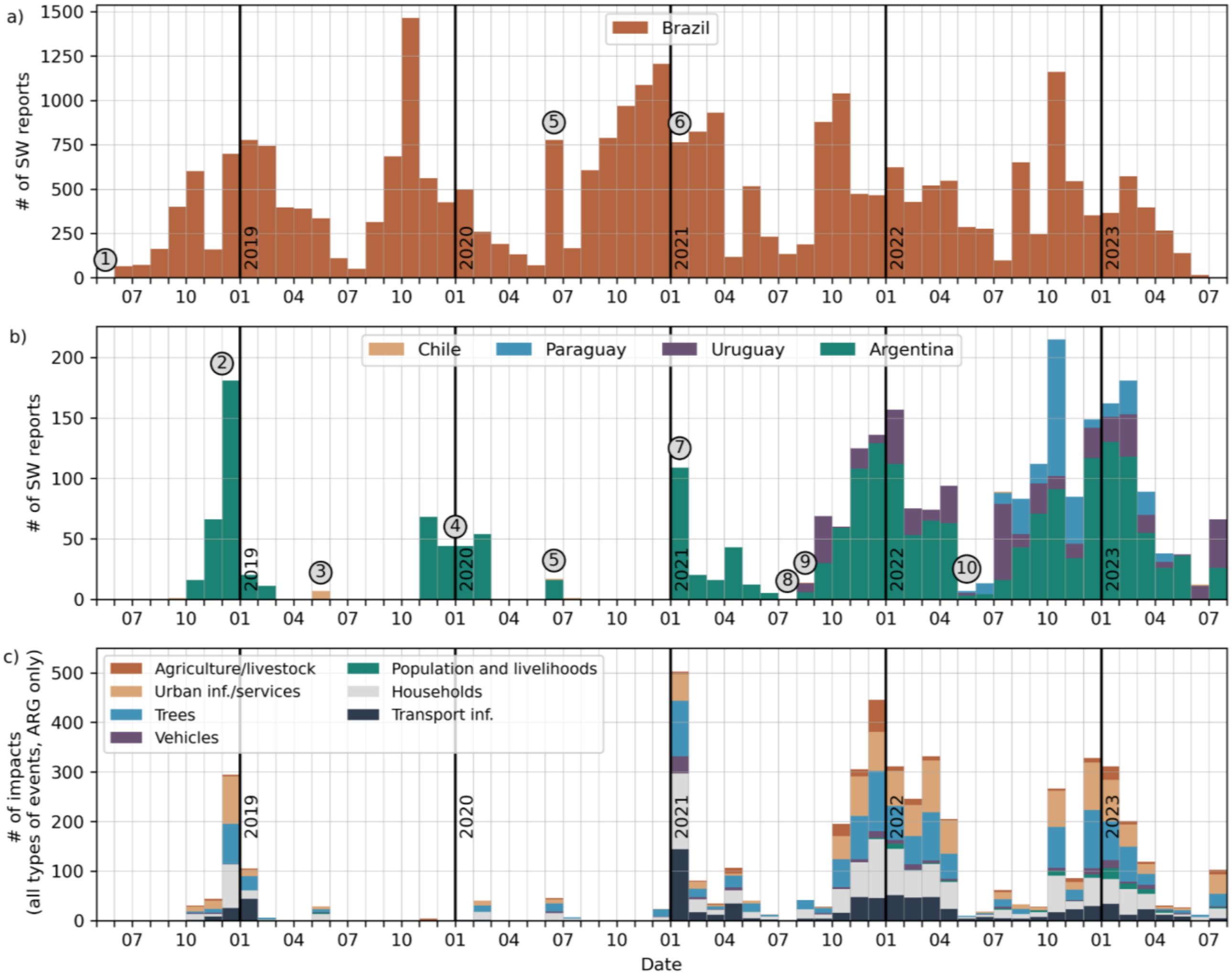

Figure 2: a) Number of severe storm reports in Brazil per month since 2018; b) Idem a) for Argentina, Chile, Paraguay and Uruguay; c) Number of reported impacts by category in Argentina over the same period, considering all event types available in SAHMI database. Note vertical data scaling has different intervals along the three panels. Circles indicate relevant milestones for the database: 1) PREVOTS first report; 2) RELAMPAGO field campaign reports; 3) the "Chilean tornado outbreak"; 4) reports generated by Luciano Vidal at SMN; 5) the 30 June 2020 severe weather outbreak; 6) PREVOTS started to gather only hail reports with known sizes and/or associated with damage; 7)

SMN - Meteorology and Society department starts reporting; 8) Beginning of coordinated reporting in the database by CIMA and SMN; 9) First report from Uruguay; 10) First report from Paraguay.

Fig. 3 shows all severe weather reports (hail, wind gusts and tornadoes) available in the SAMHI database from 2018 up to July 2023 (Fig. 3a) and prior to that date (Fig. 3b). All reports after 2018 in Fig. 3 are associated with a convective storm that is evident in either radar or satellite data. Reports are predominant over south-central Brazil, north-central Argentina, Uruguay and Paraguay, but a large number of events can also be observed in northern Patagonia, Central-Southern Chile as well as the Amazon region. Uninhabited regions, identifiable in Fig. 1, are correlated with regions with no reports in Fig. 3. Severe convective reports total to 5,545 including tornadoes (Fig. 3c), large hail (greater than or equal to 2 cm, Fig. 3d) and wind gusts (greater than or equal to 80 km/h and/or associated with damage, Fig. 3e) between 2018 and July 2023. In addition to the reports collected in near-real time, there is a continuous effort to integrate into the SAMHI pre-2018 records (Fig. 3b). This includes the daily hail occurrence reports gathered from traditional surface stations affiliated with the SMN and the National Agricultural Technology Institute in Argentina. These records, which date back to 1908, were analyzed by Mezher et al. (2012). Tornado and severe storm reports in Argentina since 1930 reported by Altinger de Schwarzkopf (1988) and Balbi and Barbieri (2017) are also included, as well as HIW events from Uruguay and Brazil (Lopes and Nascimento 2024). In addition, the Chilean tornado database, maintained by researchers in the Department of Geophysics at the University of Chile, with reports going as far back to 1554 will also be included in the SAHMI database. Many retrospective activities are undertaken to enhance the database, such as conducting newspaper research at the National Library or photo search at the Digital Library of Argentinean National Archives. Similar efforts are currently underway in Brazil regarding the documentation of pre-2018 tornado events reported in the scientific literature (e.g., Silva Dias 2011), media clippings, and Civil Defense reports (Lopes and Nascimento 2023). These efforts involve the digitization of historical reports, thereby enriching the database's content and accessibility.

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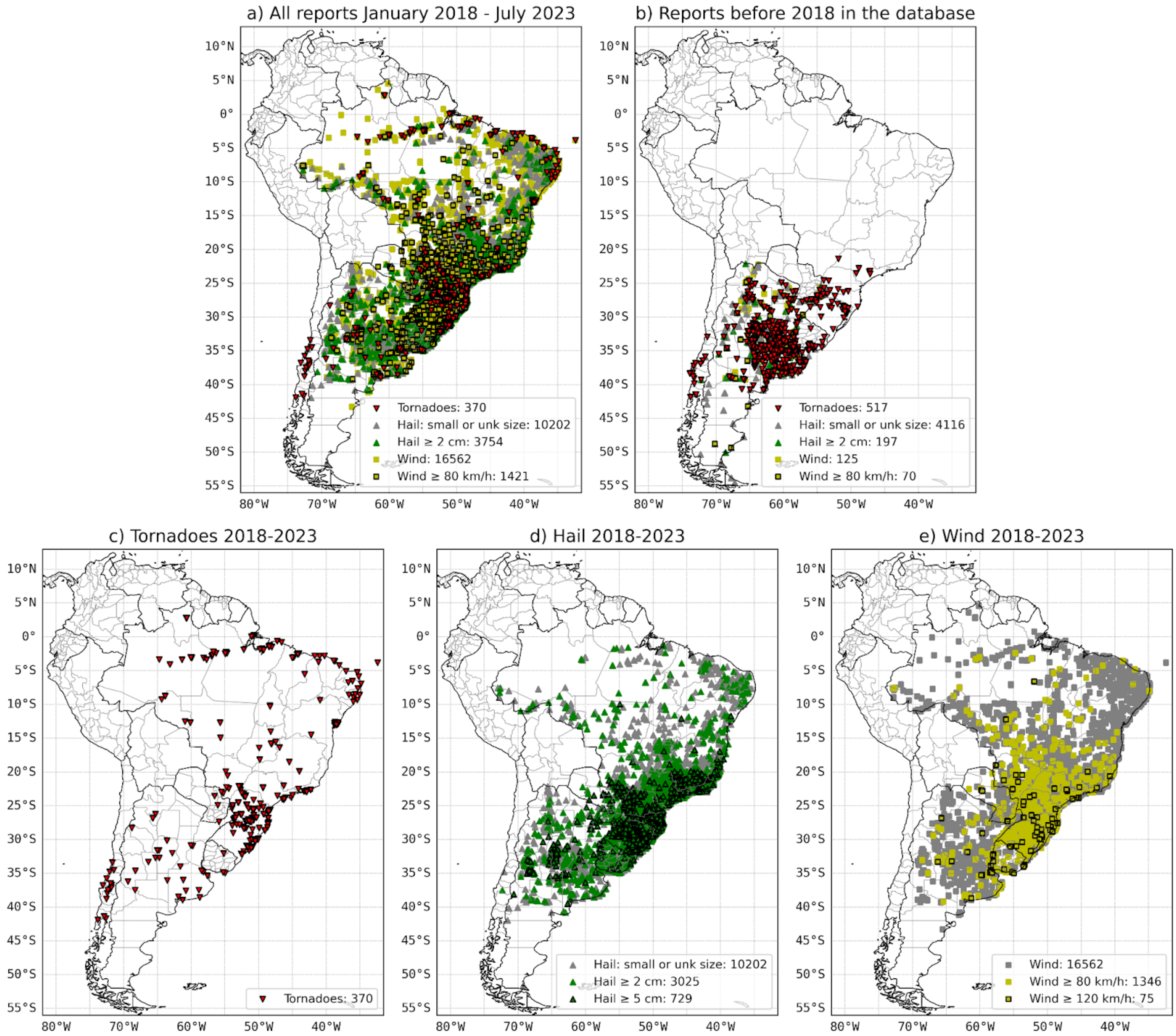

Figure 3: Geographical distribution of all the severe weather reports in the SAHMI database. a) All the categories since 2018, b) all the categories before 2018, c) tornadoes (including waterspouts), d) hail and e) damaging wind gusts.

FUTURE CHALLENGES

Databases containing information about HIW and their effects are uncommon in many regions (Golding et al. 2022), access to them is mostly restricted, and observation protocols often differ among databases. To avoid propagating such issues, we believe that the construction, maintenance and verification of the SAMHI database is a fundamental component for understanding the physical processes leading to HIW events, validation of severe weather remote sensing tools, numerical modeling verification, development of locally calibrated early warning systems, and possibly a vast array of innovative products on the horizon, driven by the rapid advancement of artificial intelligence techniques.

The **major challenge** in this endeavor is to identify the institution(s) that can maintain leadership in this initiative, since long-standing endeavors cannot rely on a few individuals. These institutions play a crucial role in fostering engagement across the entire community, establishment and maintenance of reporting standards and data sharing policies. Moreover, these institutions should actively collaborate with information providers, including emergency managers and volunteer networks, while advocating for high-quality reports from partners and consistency in the database throughout the years.

The **database sustainability** hinges on the active participation of a broad and diverse community that recognizes the value of the information for their specific needs. Several actions will be taken to boost the number of high-quality reports, especially in areas with large temporal and spatial gaps. One way to achieve this goal is to get elementary school students and weather enthusiasts directly involved with the reporting processes. We are currently in the process of creating multiple tools to simplify this involvement (i.e chatbot, training courses, educational material, among others). Pursuing the active participation of students and weather activists has the potential to improve weather awareness. We are also working towards involving emergency managers to report directly to the database and opening a discussion about their needs as potential users of multi-hazard impact-based forecasts and warnings. This latter point is important as the inherent design of the SAMHI API allows enhancing data access to end users like emergency managers.

It is imperative to actively engage national weather services across South America that are currently not involved with the SAMHI database to contribute to it, enabling the assessment of cross-border risks that have the potential to impact their respective nations. In pursuit of this goal, meetings were organized with the WMO Regional Office III in 2022 and new actions will be implemented in 2024.

In the coming years, a crucial challenge will be securing the necessary financial resources to ensure the project's long-term sustainability. To achieve this goal, the team must develop a comprehensive plan and deliver a compelling pitch to potential investors or donors. With this in mind, an annual in-person meeting will be organized to address these challenges and build strategies for the future.

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Data availability statement.

The information available in this paper is based on data accessible upon request at: https://samhi.cima.fcen.uba.ar/

SIDEBAR 1: No borders: A widespread severe weather event.

Some extreme events often account for a large number of reports on a single day. On 30 June 2020, a quasi-linear convective system (QLCS) caused hundreds of reports in southern Brazil, northeastern Argentina and southern Paraguay (Fig. SB1). This event can be classified as a serial derecho (Johns and Hirt 1987) based on the wind reports. This QLCS occurred in an environment with strong synoptic scale forcing for ascent, very intense wind shear, and was followed by explosive cyclogenesis off the coast of Southern Brazil. This event underlines the critical importance of having an integrated severe storm reports database in order to effectively characterize large-scale convective systems that traverse international borders.

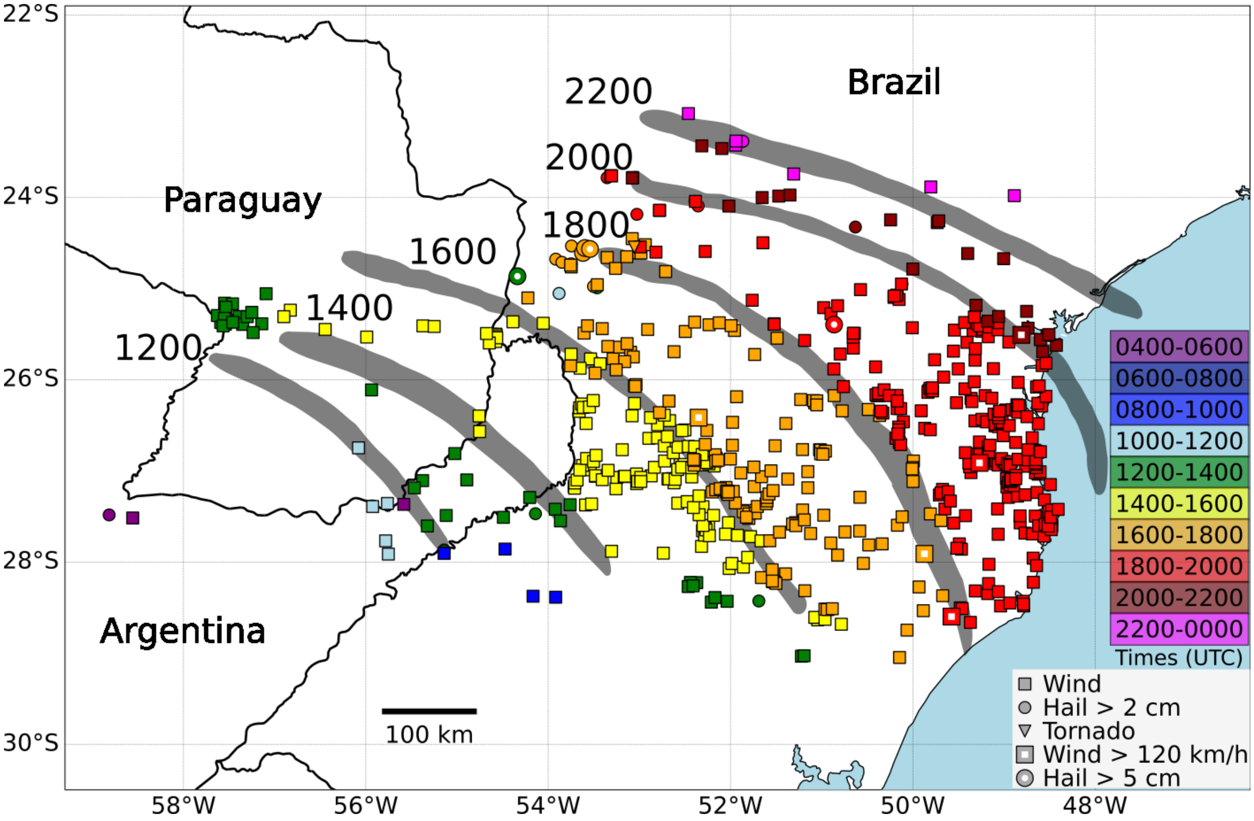

Figure SB1: Reports from Brazil, Argentina and Paraguay between 0400 UTC 30 June and 0000 UTC 01 July 2020. Most reports were caused by a quasi-linear convective system. There were 592 wind reports (5 measured wind gusts > 120 km h^{-1}), 91 hail (5 reports of hail > 5 cm size) and 1 tornado. Gray areas denote the approximate location of the 50-dBZ area every 2 hours based on radar imagery.

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SIDEBAR 2: Encouraging Individuals to Accurately Report Natural Hazards: Giant Hail.

Severe hail events (diameter larger than 2 cm) are frequent in South America. Their magnitudes are illustrated by two cases shown in Fig. SB2. On 22 February 2019 (left), the database holds several reports along the track of a storm as it moved northeast towards Córdoba, Argentina as evidenced by the progression of reports and their associated pictures (Fig. SB2). On 27 January 2023 (right), one of the largest hail diameters was reported in the SAHMI database in Villa Mercedes (San Luis, Argentina). This storm resulted in one fatality, numerous injuries, and substantial infrastructure damage, amplifying its impact as it coincided with a well-attended summer festival (see Figs. SB2.d-f). Table SB1 below shows some of the data fields that were recorded into the database that are relevant for these two hail events to illustrate what the database looks like. For both cases, the photographic evidence from social media and digital newspapers allowed the determination of the location and time of the event, and to estimate the corresponding maximum hail dimensions. Both these cases rank among the reports with the largest hail dimensions (> 10 cm). The maximum hail size was estimated considering the standard size of an adult human hand but the absence of other reference objects or a ruler introduces uncertainty in the hail diameter estimation. Providing training in simple reporting techniques to weather enthusiasts, emergency managers, and the general public can be the decisive factor in transforming a mere crowd-sourced post into valuable data for numerous tools and applications.

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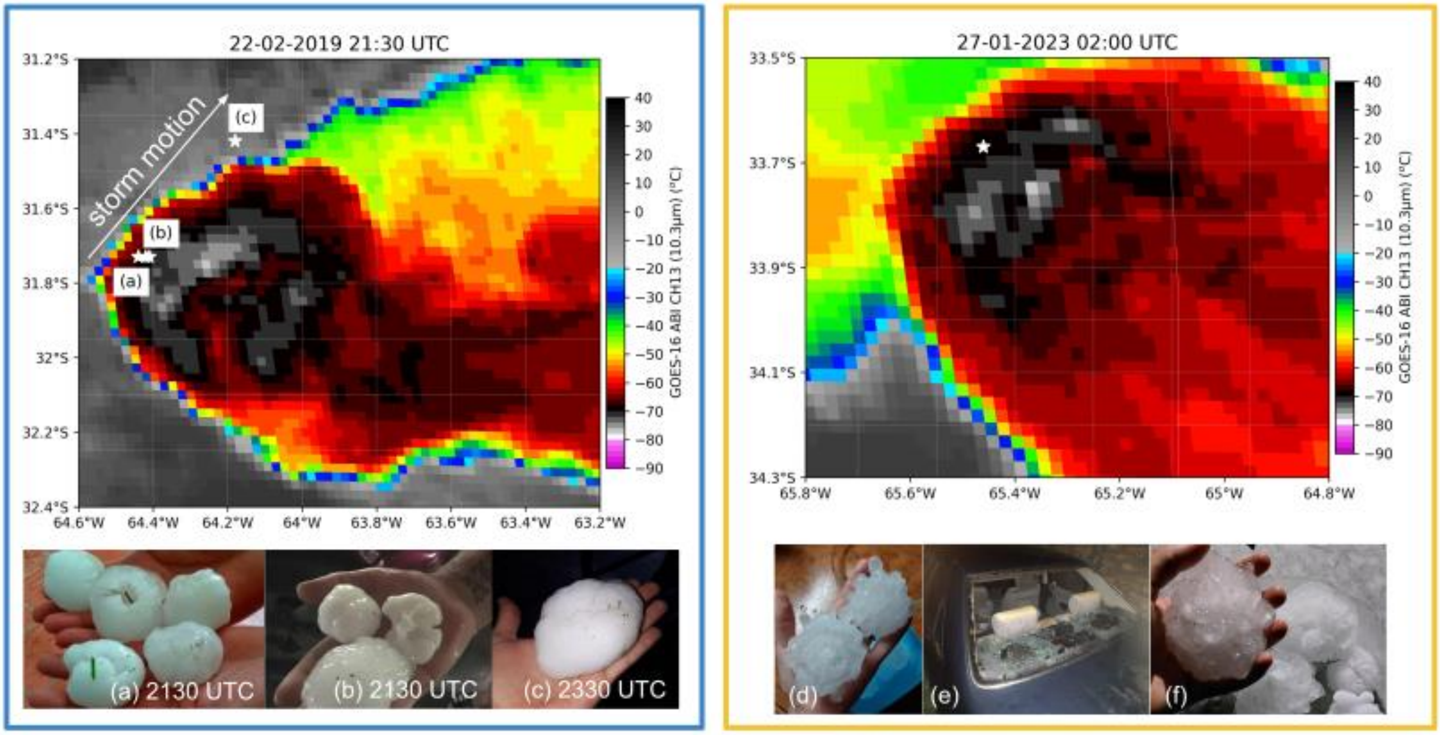

Figure SB2: GOES-16 ABI 10.3µm brightness temperatures observed over Argentina during two different convective storms at 2130 UTC 22 February 2019 (left) and 0200 UTC 27 January 2023 (right). Hail report locations are shown by white stars, and photographs of hailstones are shown below each map. The images were posted in the following links: (a) http://tinyurl.com/2x7ydhkp, (b) http://tinyurl.com/2bdxt7je, (c) http://tinyurl.com/mr3vcyr2, (d) http://tinyurl.com/v7tuam69, (e) http://tinyurl.com/mvkuswdm, (f) http://tinyurl.com/3vdtncnt.

Data Quality	References	Event Type	Images	Source	Country	City	Lat/Lon	Spatial Uncertainty	Time	Temporal Uncertainty	Max. Diam	Impacts
Verified	http://tinyurl.com/2x7ydhkp	HAIL	1	News	ARG	Villa Los Aromos	-31.734 / -64.439	10 km	2019-02-22 T21:30:00.000Z	10 min	7 cm	
Verified	http://tinyurl.com/2bdxt7je	HAIL	1	News	ARG	Anisacate	-31.726 / -64.414	10 km	2019-02-22 T21:30:00.000Z	10 min	8 cm	
Verified	http://tinyurl.com/mr3vcyr2	HAIL	1	Social media	ARG	Córdoba	-31.434 / -64.154	1 km	2019-02-22 T23:30:00.000Z	10 min	5 cm	
Verified	http://tinyurl.com/v7tuam69	WIND HAIL STORM	1	News	ARG	Villa Mercedes	-33.674 / -65.462	1 km	2023-01-27 T01:55:00.000Z	30min - 1hr	10 cm	Waterlogged street/avenue/route(s) General damage to home(s)

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												Self-evacuation Injured and/or with health problems Cancellation of commercial, economic and/or labor activities with material losses Damaged motorcycle(s), car(s) or small vehicles (general) Car(s) dented, with broken windshield or glass Damaged tree(s) Broken or overturned tree (s) Power outage
Verified	http://tinyurl.com/3vdtncnt	WIND HAIL STORM	2	News	ARG	Villa Mercedes	-33.674 / -65.462	1 km	2023-01-27 T01:55:00.000Z	30min - 1hr	10 cm	Waterlogged street/avenue/route(s) Roof(s) destroyed or blown off Self-evacuation Injured and/or with health problems Dead Cancellation of commercial, economic and/or labor activities with material losses Damaged motorcycle(s), car(s) or small vehicles (general) Car(s) dented, with broken windshield or glass Damaged tree(s) Broken or overturned tree (s) Damaged or destroyed power transmission line Power outage

Table SB1: Data records in the actual database for the reports shown in Figure SB2. Database holds other data fields that are not shown in the table for clarity.

SIDEBAR 3: Tornadoes: the need for damage surveys.

On 14 August 2020, multiple tornadoes occurred in southern Brazil. One member of the PREVOTS team was able to assess the post-storm damage in the following day and compile detailed information about the areas affected by tornadoes (Fig. SB3). Damage indicators and radar signatures were used to distinguish tornado damage from straight-line wind damage. For at least 50 years there has been some information about tornado damage reporting in South America, a work championed by Dr. Altinger (Altinger de Schwarzkopf, 1988), and now there is an emerging interest for these assessments to evolve into a standard practice within the national weather services of South America. This evolution is driven by the recognition that damage evaluation plays a pivotal role in the disaster management cycle, contributing significantly to risk reduction and preparedness efforts. Occasionally, remote sensing can be used to determine tornado damage to vegetation and confirm tornado reports, but field surveys enable a much more accurate assessment and help improve remote sensing algorithms calibration and verification.

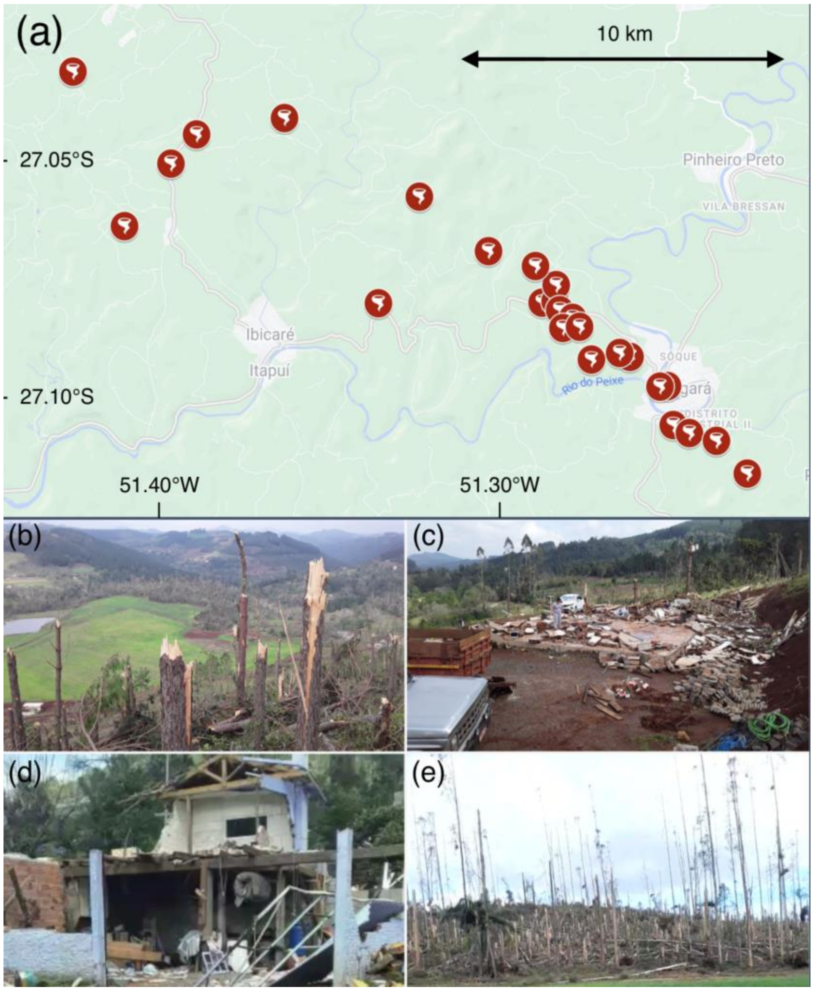

Figure SB3: (a) Tornado reports on 14 August 2020 in Santa Catarina state, southern Brazil (map source: Google Maps). (b-d) Photos of the damage associated with tornadoes (pictures courtesy of Vitor Goede, used with permission).

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