Center for Disaster Management and Risk Reduction Technology

Super Cyclonic Storm 02B „Phailin“

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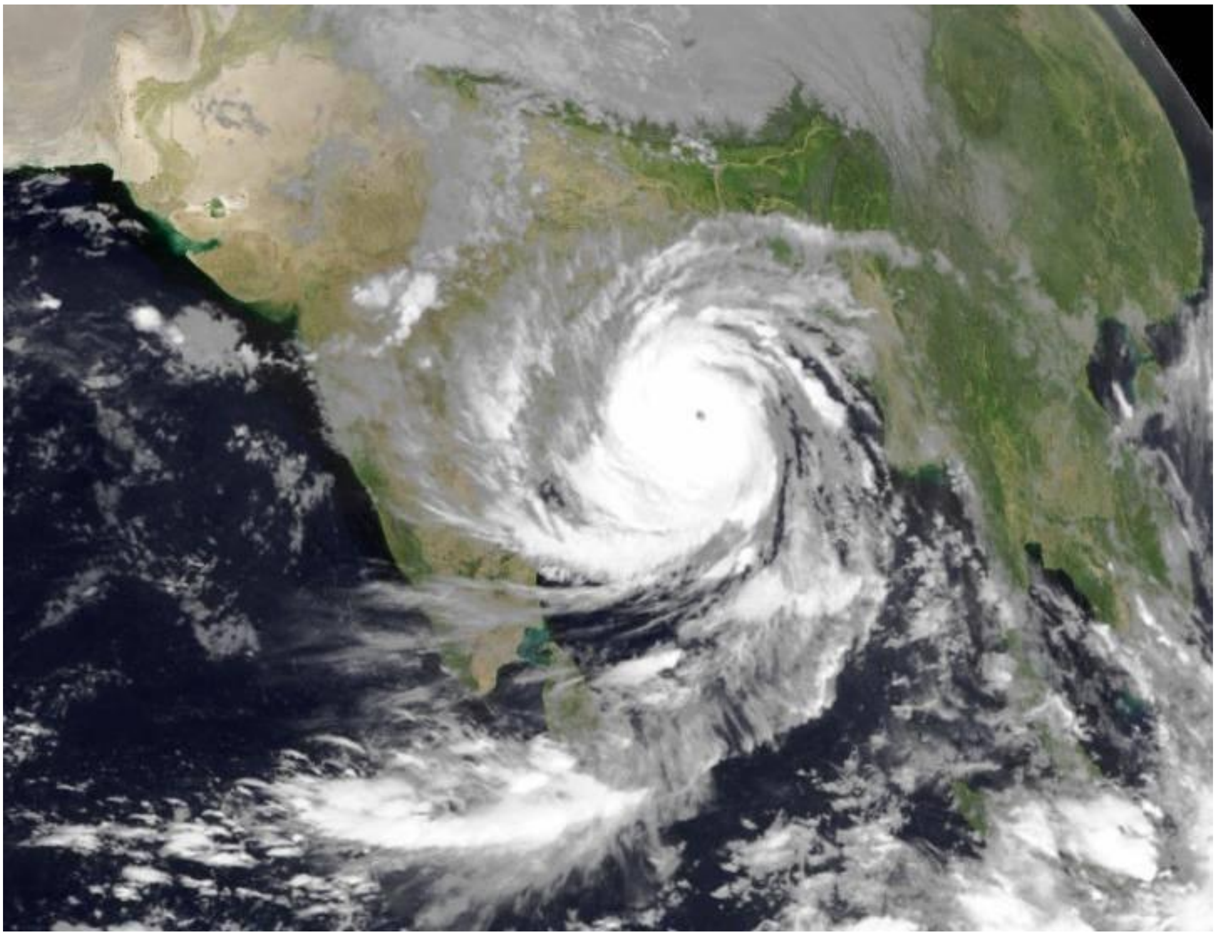
Report 2

24 October 2013



Satellite image with Super cyclone *Phailin* over the Bay of Bengal, October 11, 2013, 21 UTC
Image credit: fvalk.com / Eumetsat

Content

1 Hazard Information

1.1 Summary

At the beginning of the second decade of October 2013 a very strong cyclone developed over the Bay of Bengal. Super cyclone 02B *Phailin* showed average wind speeds of up to 259 km/h making the storm a category 5 cyclone, the highest category according to the Saffir-Simpson hurricane scale. *Phailin* became one of the strongest tropical cyclones ever recorded over the North Indian Ocean. *Phailins* track led towards the northeast of India, where the tropical cyclone in the federal state of Odisha made landfall and caused enormous damage.

PHAILIN – Super cyclonic Storm over Bay of Bengal
➢ Date: October 09-13, 2013 ➢ Maximum 1 min-sustained winds: 140 kt (259 kph) ➢ Maximum wind gusts: 170 kt (315 kph) ➢ Category 5 (according to Saffir-Simpson Hurricane Scale) ➢ Lowest pressure in storm center: 910 hPa on October 10-11, 2013 ➢ Landfall: October 12, 2013, 15:45 UTC, near Gopalpur (Odisha) ➢ Storm surge: up to 3.5 m (according to media reports) ➢ Maximum significant wave height: > 50 ft (15 m) ➢ *Phailin* was one of only 4 category 5 cyclones over Bay of Bengal ➢ Unexpected intensity (by most forecast models) ➢ Rapid development within 24 hours from tropical storm into cat 4 cyclone

1.2 Evolution of tropical cyclone *Phailin*

Phailin originated from a tropical disturbance that moved westward over the Andaman Sea. On October 9, 2013, the cloud complex formed a closed cyclonic circulation near the archipelago of the Andaman and Nicobar Islands and then intensified into a tropical storm. At 12 UTC the mean wind speed was 40 kt (74 kph) and on the Andaman islands thunderstorms brought heavy rain already. At this time, many forecast models were in agreement that the tropical storm would made its way during the following days over the Bay of Bengal into a west-northwesterly direction and heading for the east coast of India. The numerical weather models predicted only a moderate intensification and the system should arrive as a category 1 tropical cyclone named Phailin at the Indian mainland. But on October 10, 2013, the tropical storm strengthened unexpectedly and almost unprecedented rapid into a fully developed category 5 tropical cyclone east of the Andamans.

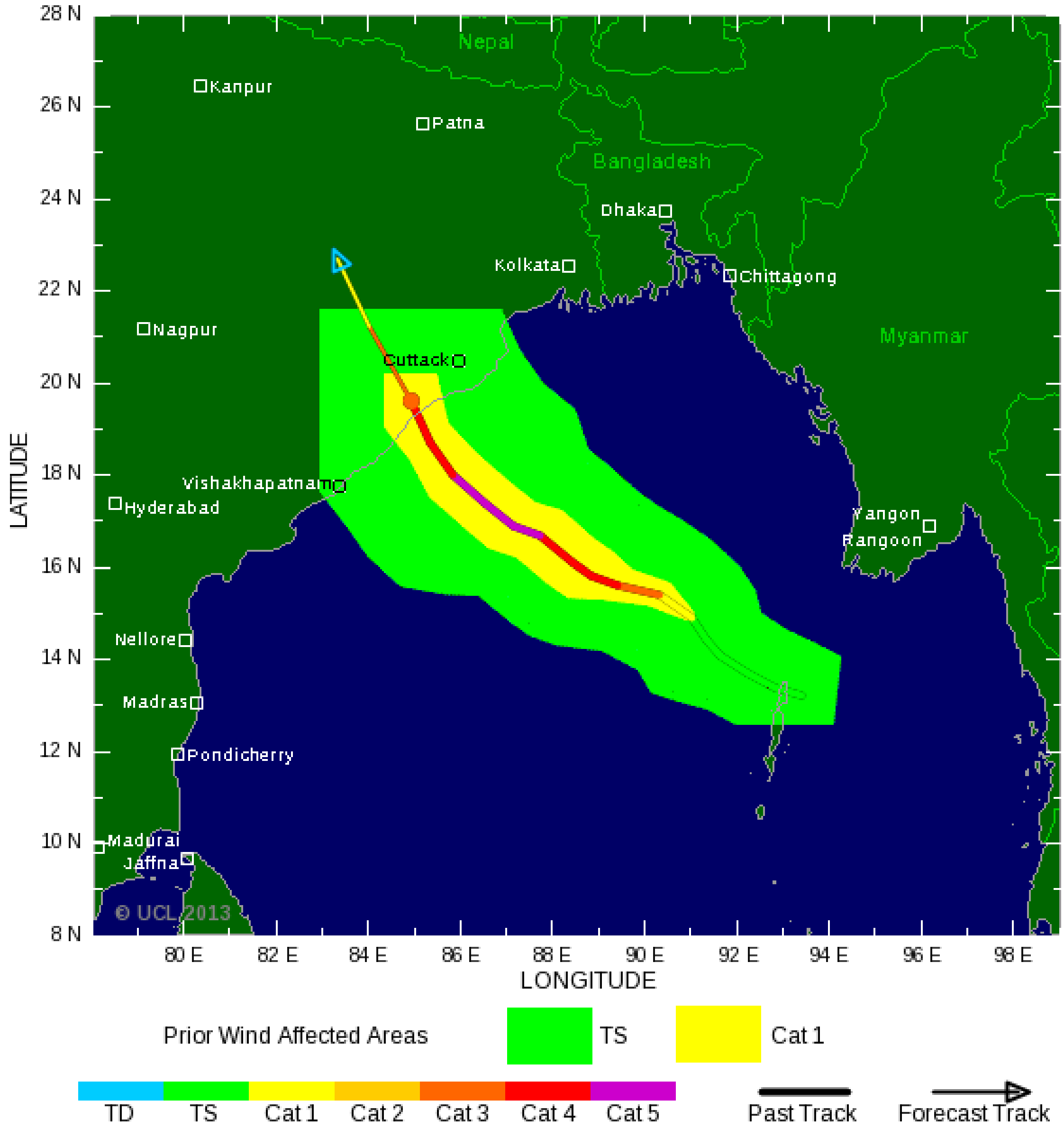


**Figure 1: Track of Super Cyclone *Phailin* (October 09-13, 2013) and the associated storm force (green) and hurricane force (green) winds.
Image Credit: tropicalstormrisk.com**

The mean wind speed on October 10, 2013, 00 UTC, was 55 kt (102 kph). only 24 hours later they had increased to 135 kt (250 kph). Thus, within only one day the tropical storm grew into a category 4 tropical cyclone, which is the second highest category according to the Saffir-Simpson hurricane scale.

With sea surface temperatures between 27 and 30°C the upper water layers of the Bay of Bengal provided enough latent heat. These values were close to the long term average in that area.

In addition, the wind shear between the upper and lower troposphere was weak enough (about 25 kph) and the tropical cyclone could evolve and keep its vital symmetric structure.

1.3 Record low central pressure of Phailin

Phailin showed its maximum intensity between October 11, 12 UTC, and October 12, 00 UTC in the middle of the Bay of Bengal. With maximum 1 min-sustained winds of 140 kt (259 kph) and gusts as strong as 170 kt (315 kph) *Phailin* was classified as category 5 super cyclone. *Phailin* equaled the typhoon Usagi, which was previously the world's strongest tropical cyclone of the 2013 season over the western Pacific. According to satellite observations (NOAA) *Phailin* had a minimum central pressure of 910 hPa on October 10 and 11, one of the lowest pressures ever observed in the territory of the North Indian Ocean. However, these observations are uncertain as buoy measurements and reconnaissance flights are not available in the region for verification. The Joint Typhoon Warning Center (JTWC) issued a minimum central pressure of 914 hPa, and the number of 918 hPa was given by the Naval Research Laboratory (NRL) .

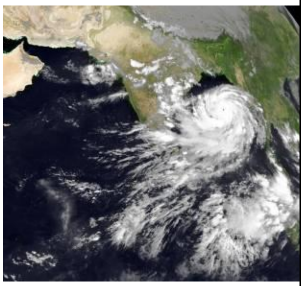
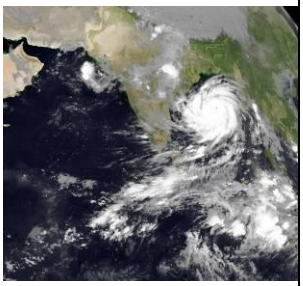
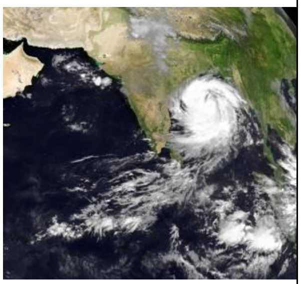
1.4 Landfall of Phailin

Shortly before landfall the tropical cyclone interacted with the India mainland and began to weaken due to the dwindling energy source (warm ocean waters) and increasing friction effects.

On October 12, 2013, the center of *Phailin* crossed the coastline at 15:45 UTC south of the city of Brahmapur in the Indian federal state of Odisha. At that time *Phailin* still was a category 4 cyclone. The mean wind speeds taken from satellite observations were about 120 kt (222 kph). The weather station in Gopalpur observed a gust of 185 kph at the storms northern eyewall. Before the weather station failured at 17:10 UTC, a minimum air pressure of 937.4 hPa was measured. After landfall, the former super cyclone weakened rapidly into a category 2 tropical cyclone. *Phailin* moved into a northerly direction towards the Himalaya and on October 13, the cyclone was identified only as a tropical depression over the North East of India.

1.5 Phailin on satellite images

During its maximum intensity *Phailin* had an enormous extent. On satellite images (see Figure 2) the outer cloud bands are spiraling as far as over Sri Lanka and the southern tip of India in the south and over northern Bangla Desh and even the Himalaya at the northern edge of the storm. The storms circulation covered nearly the entire Bay of Bengal and affected an area with roughly 2500 km in diameter. The storm center, the eye, is clearly visible until landfall indicating the symmetrical structure and strength.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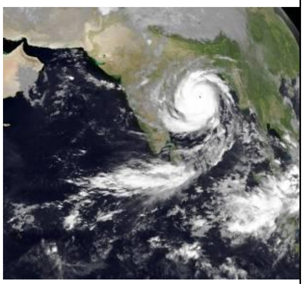		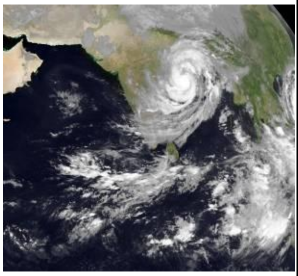	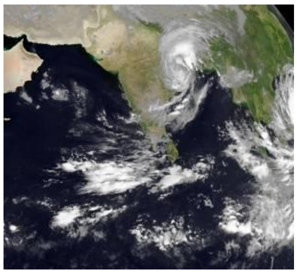
12.10.2013, 0:00 UTC	12.10.2013, 9:00 UTC	12.10.2013, 18:00 UTC	13.10.2013, 3:00 UTC

Figure 2: Satellite images VIS/IR.
Image credit: F. Valk / EUMETSAT

1.6 Heavy Precipitation, wind, storm surge and wave height

In most cases tropical cyclones are accompanied by heavy precipitation and rain amounts easily in excess of 500 mm. The rain amount and the rain pattern depend on the propagation speed of the storm system, its intensity and extension, and the topography of the affected area. In mountainous and rugged terrain rain might be enhanced to amounts of even more than 1000 mm (e.g. Taiwan, Philippines, Reunion).

Phailin delivered a lot of rain but no exceptional high amounts. In Banki (Odisha) a rain amount of 381 mm fell within 24 hour on October 13. On the same day there were 305 mm at Balimundali (Odisha) and 198 mm in Itchapuram (Andhra Pradesh) 198 mm. On October 9, heavy thunderstorms that were associated with the tropical storm Phailin while crossing the Andamans, brought 336 mm at Maya Bandar within 24 hours.

Table 1: 24-hour rainfall totals in India (left). Precipitation characteristics (daily values and sum October 12 -14) at single stations in India. Data source: IMD (India Meteorological Department)

Station India	Date	Rain/24 h
Banki (Odisha)	13.10.	**381 mm**
Long Islands (Andamanen)	09.10.	**337 mm**
Maya Bandar (Andamanen)	09.10.	**336 mm**
Balimundali (Odisha)	13.10.	**305 mm**
Itchapuram (Andhra Pradesh)	13.10.	**198 mm**

Station India	12.10.	13.10.	14.10.	Rain/72 h
Shyamakhunta-Agro (Odisha)	8 mm	167 mm	102 mm	**277 mm**
Bhubaneswar-Agro (Odisha)	60 mm	168 mm	4 mm	**232 mm**
G.Udayagiri-Agro (Odisha)	20 mm	243 mm	1 mm	**264 mm**
Khurdah (Odisha)	57 mm	169 mm	6 mm	**232 mm**
Bokaro (Jharkhand)	-	57 mm	151 mm	**208 mm**

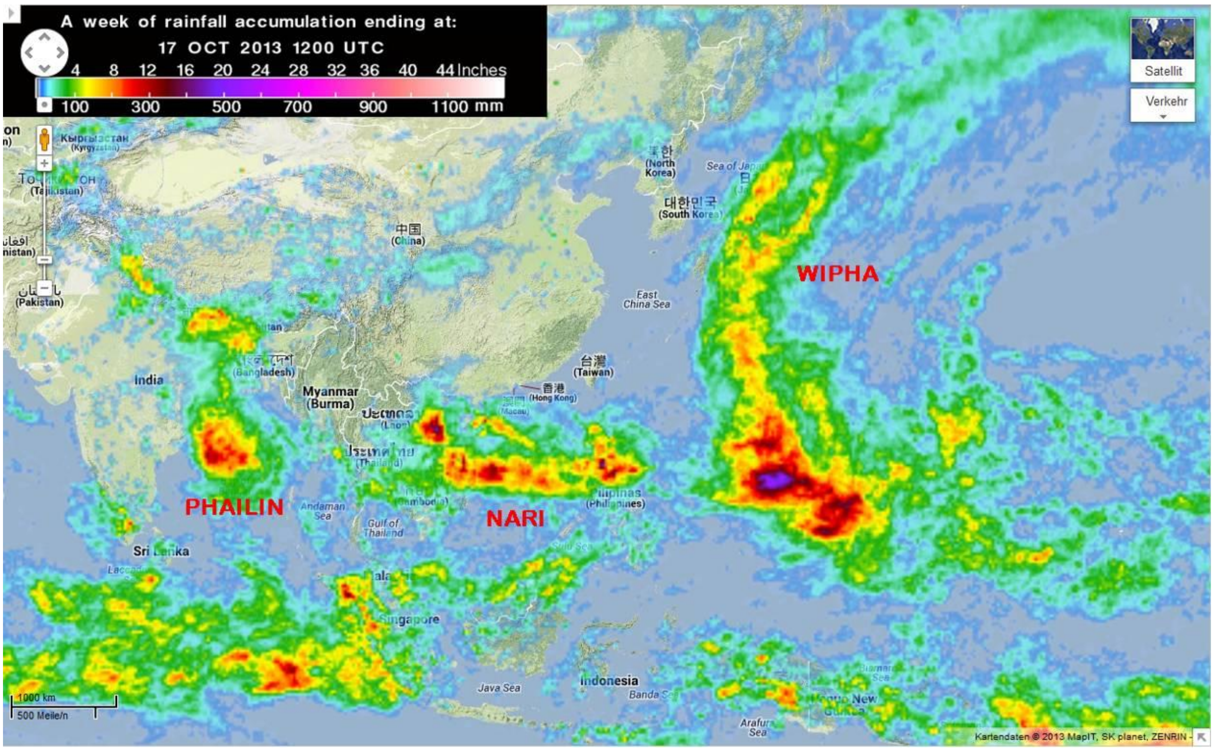

Figure 3: Accumulated rain amount (October 11-17, 2013, 12 UTC).
Data source: TRMM (Tropical Rainfall Measuring Mission)

Figure 3 above shows the accumulated rain amount between October 11 and 17 over the eastern Indian Ocean and the western Pacific. During this week, three storm systems left their paths in the rain pattern. The rain information was derived from satellite data as gathered by the Tropical Rainfall Measuring Mission (TRMM) of the NASA. Most of Phailins rain fell over the Bay of Bengal. However, along its inland track from the coast of Odisha towards the Himalayan mountains in the Indian federal states of Jharkand and Bihar Phailin released notable rain amounts around 100 to 250 mm. Much more rain was associated with the passage of Nari (landfall in Vietnam) and Wipha. The latter was responsible for Japans sixth-highest rain amount ever recorded within 24 hours: 822 mm in Oshima.

The maximum wind gusts (see section 1.3) exceeded 300 kph (315 kph) while Phailin was classified as a category 5 super cyclone. At this time the JTWC specified the maximum significant wave height in the open waters of the Bay of Bengal with 54 ft (16 m). Approaching the coastline the cyclone kept its wind gusts well above 200 kph.

Along the coast of Odisha, storm winds piled up a storm surge which penetrated some several hundred meters into the coastal hinterland. According to the Times of India and the BBC, the storm surge was up to 3 meters high, forecasts saw the highest storm surge of about one meter around the town of Gopalpur.

2 Disaster Profile

2.1 History of tropical cyclones over the North Indian Ocean and classification of "Phailin"

Whereas over the west Pacific Ocean usually several category 5 cyclones develop every year, such strong tropical cyclones are much less common over the North Indian Ocean. *Phailin* was the first super cyclone in the Indian Ocean since 2007 and a maximum mean wind speeds of 140 kt (259 kph) made the storm to one of the strongest ever observed in this area. Only *Gonu* in 2007 was a stronger cyclone (145 kt, 269 kph).

The last similarly strong tropical cyclone in the Bay of Bengal occurred in late October 1999, when the large *1999 Odisha Cyclone* also came along with mean wind speeds of 140 kt (259 kph) and a minimum central pressure of 912 hPa. The *1999 Odisha Cyclone* was the first cyclone that was titled as "Super cyclone" by the Indian Meteorological Service (IMD). When making landfall, this cyclone had mean wind speeds of 135 kt (250 kph) exceeding those of *Phailin* by 15 kt. The *Odisha Cyclone* fell ashore 160 km further north than *Phailin* and was accompanied by a 5.9-meter storm surge and caused 9,658 deaths making this storm ranking 4th on the list of deadliest cyclones in India in the last 100 years. Other category 5 tropical cyclones in the North Indian Ocean were *Sidr* in 2007 and the *1991 Great Bangladesh cyclone.*

26 out of the worlds 35 deadliest tropical cyclones raged in the regions around the Bay of Bengal. 42% of all fatalities caused by tropical cyclones refer to Bangla Desh, 27% to India. In November 1977 14,204 people lost their lives, as the *Andhra Pradesh Cyclone* made landfall just a little bit south of where *Phailin* hit the Indian mainland. Most devastating was the great *Bohla Cyclone* in November 1970, that went ashore in Bangladesh (former East Pakistan). The *Bohla Cyclone* caused a storm surge with a height of more than 10 feet in the Ganges delta and claimed 300,000-500,000 human lives.

2.2 Use of twitter messages for rapid assessment

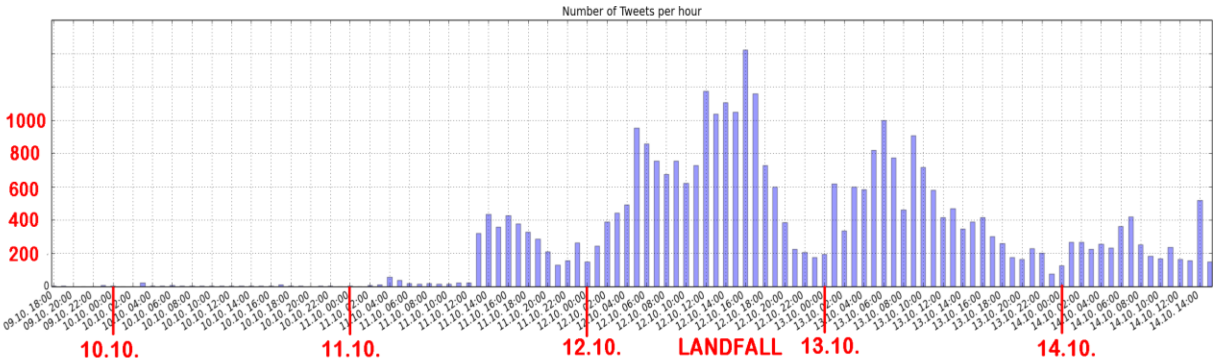

Figure 4: Number of tweets per hours containing one of the keywords "phailin" and "cyclone" from October 9, 18 UTC, until October 14, 16 UTC.

Image Credit: CEDIM

To get local, detailed, and up-to-date information about the behavior of the cyclone and its impact, Twitter messages (tweets) with various keywords such as cyclone, phailin, shelter, storm or power outage have been recorded.

Figure 4 illustrates the number of tweets per hour containing one or both of the keywords "phailin" and "cyclone". *Phailin* got much attention from the day before making landfall on October 11, nearly 1,500 tweets were written during the hour of landfall at October 12, 16 UTC, and also during the day after landfall *Phailin* was very present.

3 Loss and Damage Analysis

3.1 Summary

PHAILIN – Super cyclonic Storm over Bay of Bengal - India
➢ Flooding and landslides in the interior of Odisha and Andhra Pradesh, as well as in the states of Jharkhand, Bihar and Chhattisgarh ➢ Storm surge along the coasts of Odisha and Andhra Pradesh ➢ Over 12 million people affected ➢ More than 18,000 villages in 20 districts hit by cyclone ➢ More than 250,000 houses partially or fully damaged ➢ Crop areas with an accumulated size > 600,000 hectares destroyed ➢ At least 46 fatalities ➢ > 1,500,000 people evacuated / brought into safety ➢ Power outages in > 3,000 villages

The tropical cyclone Phailin left enormous damage in India. While in the coastal areas of the federal states of Odisha and Andhra Pradesh fierce winds and a storm surge were the main problem, torrential rainfall caused flooding and landslides in the interior of Odisha and Andhra Pradesh, as well as in the states of Jharkhand, Bihar and Chhattisgarh.

Over 12 million people have been affected by cyclone Phailin in Odisha and Andhra Pradesh state respectively. The number of disaster-hit villages across 20 districts has risen to more than 18,000. The worst affected districts in Andhra Pradesh state are

Visakhapatnam and Srikakulam districts, and in Odisha state Ganjam, Barhampur, Puri, and Khurdha districts.[1]

More than 250,000 houses have been either partially or fully damaged, and countless trees have been uprooted. Crop areas with an accumulated size of more than 600,000 hectare have been destroyed.[2] Phailin caused widespread power outages and cut off water supply. Main highways have been affected by uprooted trees, eroded streets and congestion. The railway infrastructure suffered severe damages and more than 165 trains were cancelled. Service at Biju Patnaik airport in Bhubaneswar was disrupted and the majority of flights were cancelled on 12 October.

At least 46 people died - a small number, compared to similarly strong events in the past. Due to one of the largest evacuations in Indian history the storm event didn't cause more fatalities. The Indian Meteorological Service (IMD) issued warnings days ahead of Phailins landfall, so more than 1.5 million people were brought into safety in Odisha and Andhra Pradesh.[3]

3.2 Infrastructure

3.2.1 Energy supply and telecommunication systems

The Indian power ministry stated that cyclone Phailin has caused substantial damage to local power transmission lines in the coastal districts of Odisha and Andhra Pradesh. In several districts power supply has been switched off by the authorities.[4] In the district Ganjam, Odisha, more than 3,000 villages have been affected by the black out.[5] To high tension wires and power generation units no damages have been reported. More than 7,000 telephone towers have been destroyed, but most of them have been restored within two days. In the mean time, telecommunication operators have shared their infrastructure to provide a mobile network.[6]

3.2.2 Road infrastructure and traffic

Vehicle movement on National Highway 5, which connects Kolkata to Chennai and runs along the Eastern coast, came to a standstill on 12 October. Trucks and cars

[1] http://www.ifrc.org/docs/Appeals/13/MDRIN013drefOU1.pdf

[2] http://www.ifrc.org/docs/Appeals/13/MDRIN013drefOU1.pdf

[3] http://www.ifrc.org/docs/Appeals/13/MDRIN013drefOU1.pdf

[4] http://www.business-standard.com/article/current-affairs/phailin-caused-huge-damage-to-power-infrastructure-ministry-113101400531_1.html

[5] http://www.livemint.com/Politics/naS1OfEY0PssPpyes5Xl3H/Survivors-of-Cyclone-Phailin-return-home-to-destruction.html?facet=print

[6] http://www.howabi.com/viewNews.aspx?TID=N1381676292480&hl=Cyclone+Phailin+live+Steps+to+rebuild+damaged+infrastructure+begin

could be seen lined up along the highway since all movement towards the cyclone area had been restricted by the state administration.[7] After the landfall of Phailin countless streets were blocked due to thousands of transmission towers along the highways and uprooted trees everywhere. Many vehicles have toppled by strong winds and suffered severe damages.[8] Although, most main connections have been restored, clearance of debris on the roads and rebuilding of eroded streets is still ongoing.

3.2.3 Railway infrastructure and traffic

The railway infrastructure has suffered extensive damage. Signaling equipment and towers have been uprooted, and there was widespread damage to platforms and stations.[9] As a precautionary measure, more than 165 trains to the coastal areas of Odisha, Andhra Pradesh and West Bengal have been cancelled. With trains being cancelled in wake of cyclone Phailin, Indian railways suffered estimated losses worth Rs 15 crore[10] (~1.8 million Euro), about Rs 12 crore (~1.4 million Euro) on account of passenger train and ticket cancellation alone.[11] The busy Howrah-Puri link was already restored on 16 October, but restoration work on other links is continuing.

3.2.4 Airports and air traffic

Biju Patnaik airport in Bhubaneswar was closed on 12 October and all flights, except Air India flight from Delhi and Mumbai, have been cancelled.[12] The airport reopened one day later. Air India Ltd. resumed its flights schedule on 15 October and all flights of private airlines are operating without changes.

3.3 Damage to critical facilities (schools, hospitals, ports, harbors, etc.)

The department of school and mass education in Odisha stated as per preliminary report that cyclone Phailin has damaged more than 5,500 educational institutions, causing a damage of more than Rs 250 crore (~30 million Euro). More than 4,500 elementary schools, 1,000 high schools and five teacher-training institutions have

[7] http://www.thehindu.com/news/national/phailin-disrupts-rail-road-traffic/article5228492.ece

[8] http://ibnlive.in.com/news/cyclone-phailin-live-death-toll-rises-to-17/428085-62-127.html

[9] http://articles.economictimes.indiatimes.com/2013-10-16/news/43107046_1_flood-situation-odisha-relief-work

[10] 1 crore is equivalent to 10 Million

[11] http://www.dnaindia.com/india/1903218/report-cyclone-phailin-leaves-23-dead-man-made-disaster-kills-90

[12] http://www.thehindubusinessline.com/industry-and-economy/logistics/bhubaneswar-airport-closed/article5228314.ece

been damaged.[13]

Paradip port, one of the largest ports in India, has been cut off for several days since two connecting roads caved in and there was no access to the 10-km long channel to the port. Three days after Phailin hit the coast, cargo handling, vessel movement and rail movement have resumed.[14]

4 Framework for loss and future risk reduction (FORIN Questions) / Additional Sections

4.1 Information Gap Analysis

The chart below (Figure 6) is the result of an analysis of the information produced within the first 4 days following landfall. The information was obtained from ReliefWeb (http://reliefweb.int/disaster/tc-2013-000133-ind), and was retrieved as it was released. All information obtained was categorized under the headings listed on the left side of the graph. Three types of information have been identified (right of the graph) as Basic Data, Analysis, and Root Causes. 'Basic Data' is purely factual and makes up the majority of the information. 'Analysis' consists of information which results from review of this basic data.

It consists of predictions and warnings, as well as identification of levels of needs met or outstanding. 'Root Causes' refers to information which identifies why aspects of the disaster occurred. For example, the low casualties observed in the aftermath of Cyclone *Phailin* was identified as being the result of a good warning system and excellent coordination between agencies which successfully evacuated almost one million people prior to landfall.

This type of information is very important to disaster risk reduction activities, which attempt to learn from past failures and success by understanding the root causes of each.

The Basic Data is quantified by reviewing how much is produced and how fast each piece of information is provided. Therefore, each of the who, what, where, and when type information, unique to each category, is measured based on how fast it is produced. The Analysis information is also quantified in this way but with a more forgiving time-scale as it will understandably take a little longer to produce. The Root Causes are quantified using only the amount of information, as the timing of this information is not relevant to the immediate disaster response. The dotted line represents the highest potential value of the information produced under each category, being very fast and containing all required information. Therefore, the solid

[13] http://articles.timesofindia.indiatimes.com/2013-10-17/india/43143663_1_odisha-school-and-mass-education-kitchens

[14] http://articles.economictimes.indiatimes.com/2013-10-16/news/43107046_1_flood-situation-odisha-relief-work

bars are percentages of the total potential and the dotted areas indicate where the information gaps are.

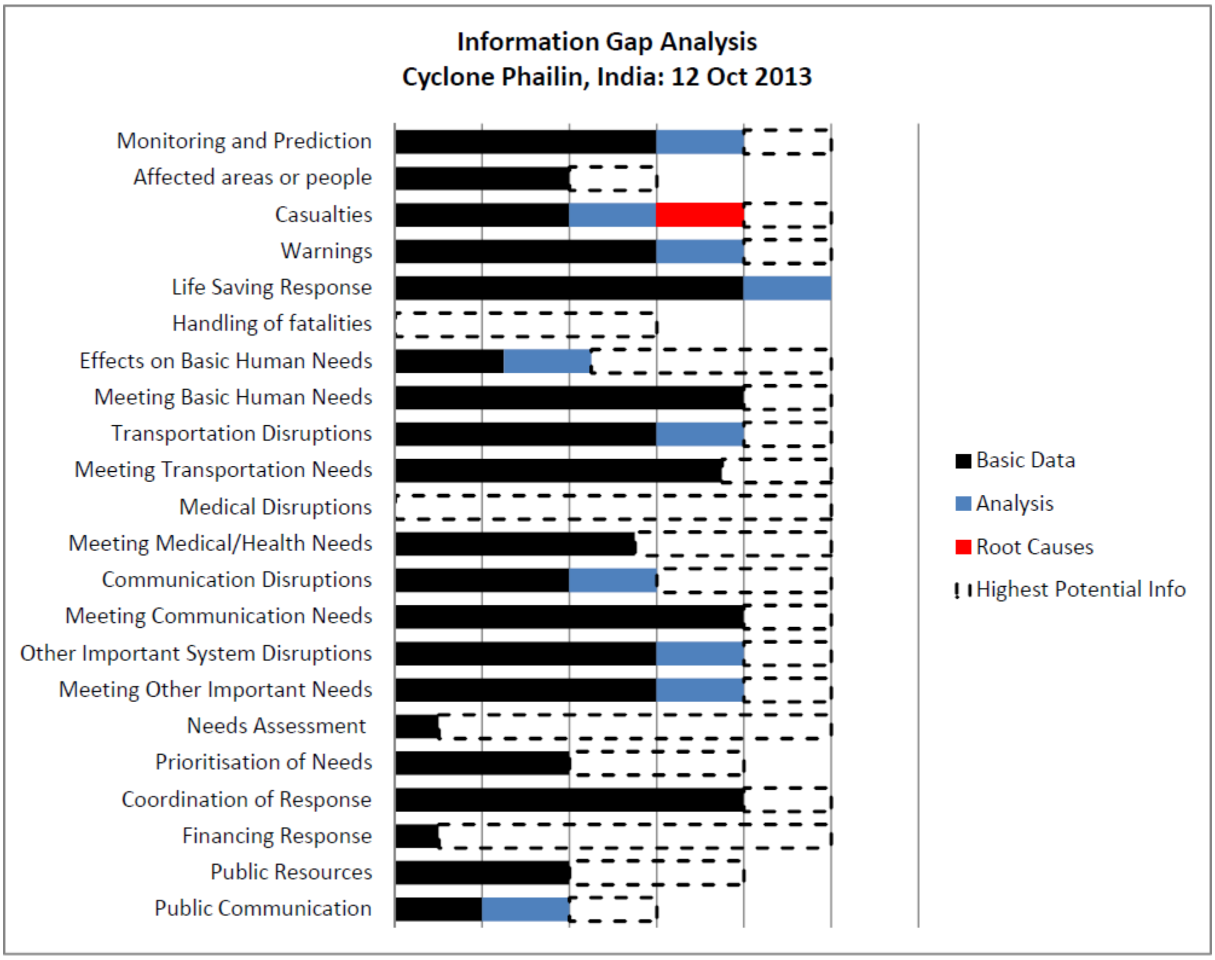

Figure 5: Information Gap Analysis of Super Cyclone *Phailin*, India

Image Credit: CEDIM

5 List of abbreviations

CEDIM FDA	CEDIM Forensic Disaster Analysis
CEDIM	Center for Disaster Management and Risk Reduction Technology
FDA	Forensic Disaster Analysis
FORIN	Forensic Disaster Investigations (IRDR Working Group)
GDACS	Global Disaster Alert and Communication System
GFZ	Helmholtz-Zentrum Potsdam – Deutsches GeoForschungsZentrum Helmholtz Centre Potsdam – German Research Centre for Geosciences
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmBH

IfGG	Institute for Geography and Geoecology, KIT Institut für Geographie und Geoökologie, KIT
IIP	Institute for Industrial Production, KIT Institut für Betriebslehre und Industrielle Produktion, KIT
IKET	Institute for Nuclear and Enegery Technologies, KIT Institut für Kern- und Energietechnik, KIT
IMK	Institute for Meteorology and Climate Research, KIT / Institut für Meteorologie und Klimaforschung, KIT
IMK-TRO	IMK – Troposphere Research, KIT IMK – Forschungsbereich Troposphäre, KIT
IPF	Institute of Photogrammetry and Remote Sensing, KIT Institut für Photogrammetrie und Fernerkundung, KIT
IRDR	Integrated Research on Disaster Risk
IWW	Institut für Wirtschaftspolitik und Wirtschaftsforschung, KIT
KatInfo	Helmholtz KatInfo
KIT	Karlsruhe Institute of Technology Karlsruher Institut für Technologie
Section 1.5	Section 1.5 Geoinformatics, GFZ Sektion 1.5 Geoinformatik
Section 2.1	Section 2.1 Earthquake Risk and Early Warning, GFZ Sektion 2.1 Erdbebenrisiko und Frühwarnung, GFZ
Section 2.4	Section 2.4 Seismology, GFZ Sektion 2.4 Seismologie, GFZ
Section 2.6	Seismic Hazard and Stress Field, GFZ Erdbebengefährdung und Spannungsfeld, GFZ
Section 5.4	Section 5.4 Hydrologie, GFZ Sektion 5.4 Hydrologie, GFZ
TMB	Institute for Technology and Management in Construction, KIT Institut für Technology und Management im Baubetrieb, KIT

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