Asia Wind Energy Association

IN PARTNERSHIP WITH

StormGeo

AWEA WEBINAR SERIES 2020 - TECHNICAL SESSION

Managing Weather Risks for Offshore Wind Projects in Asia-Pacific

SPEAKERS:

GARD HAUGE
Chief Data Officer - Stormgeo

ANNA HILDEN
Global Industry Manager Offshore Wind - Stormgeo

ANTONI THERATTIL
Forecast Manager - Stormgeo

TUESDAY, 15 SEPTEMBER 2020 - 3 PM SGT

Asia Wind Energy Association

The Asia Wind Energy Association was established in December 2016 to become the leading trade association for the wind energy sector in Asia Pacific.

The association acts as the regional platform for all wind power industry stakeholders to collectively promote the best interests of the wind power sector.

The Asia Wind Energy Association is supported by a wide variety of stakeholders from the offshore and onshore wind industry.

Information

Asia Wind Energy Association

www.asiawind.org

@asiawindenergy

Asia Wind Energy Association

(65) 6679 6071

membership@asiawind.org

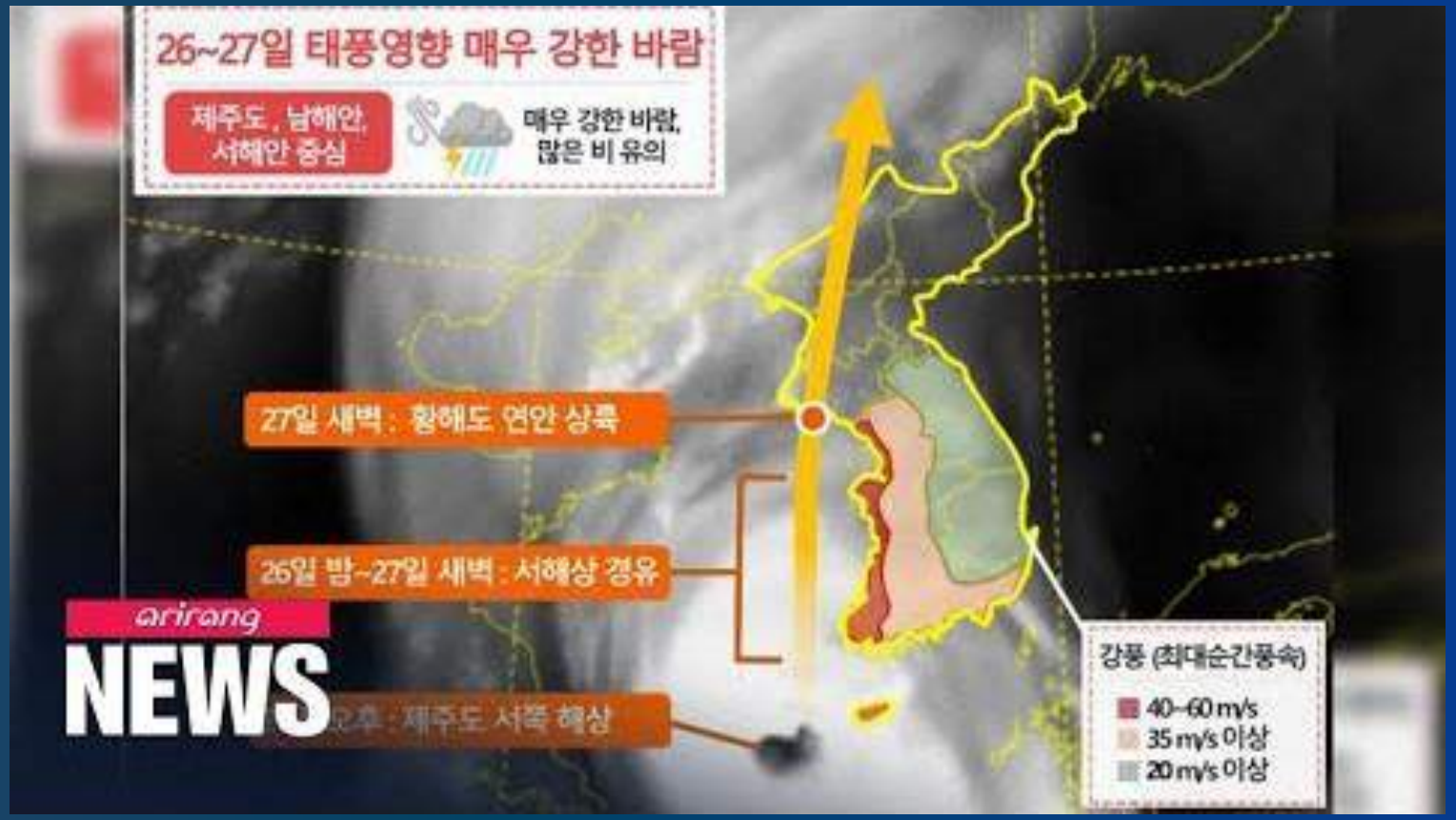
CapitaGreen - Level 24
138 Market Street, Singapore 048946

Asia Wind Energy Association Corporate Partners

Asia Wind Energy Association Corporate Members

Asia Wind Energy Association Partner Organizations

Managing Weather Risks for Offshore Wind Projects in Asia-Pacific


26~27일 태풍영향 매우 강한 바람
제주도, 남해안, 서해안 중심
매우 강한 바람, 많은 비 유의
27일 새벽 : 황해도 연안 상륙
26일 밤~27일 새벽 : 서해상 경유
arirang
NEWS
강풍 (최대순간풍속)
40~60 m/s
35 m/s 이상
20 m/s 이상

Anna Hilden

Global Industry Manager Offshore Wind
StormGeo

With over a decade of industry experience, Anna provides advanced meteorological services to clients in the renewable energy sector for safer and more efficient offshore operations. With a background of working in meteorology, as well as experience from a leading wind turbine OEM, Anna is well placed to find the right services for our clients in the renewable energy sector. She has experience from all parts of the value chain, from programming through project and product management, through to sales. Anna co-ordinates StormGeo's offshore wind team, providing clients in offshore wind with services for wind forecasting, helicopter logistics, and metocean forecasting – contributing to safer and more efficient offshore operations.

Antoni Therattil

Forecast Manager
StormGeo

With over three decades of experience in the Asian Oceans and weather, Antoni joined StormGeo 12 years ago and is the Forecast Manager for Asia Pacific, Middle East & Africa. Qualifications in MSc Maths, MSc Meteorology, PgDip Oceanography, and Naval Meteorologist and Oceanographer (served as the Joint Director of Meteorology and Oceanography).

Gard Hauge

Chief Data Officer
StormGeo

Leads an agile team focused on growing existing and future business areas for StormGeo. Holds a strong technology and analytic background with a focus on how weather and data science influences people and complex decisions. An expert in understanding how weather influences complex operations and how advanced services can help to safeguard critical operations.

Managing Weather Risks for Offshore Wind Projects in Asia-Pacific

AWEA Webinar Series 2020 – Technical Session

Asia Wind Energy Association

StormGeo

Navigate tomorrow – today

Speakers:

Gard Hauge

Chief Data Officer, StormGeo

Nina Winther-Kaland

Research Director, StormGeo

Anna Hilden

Global Industry Manager

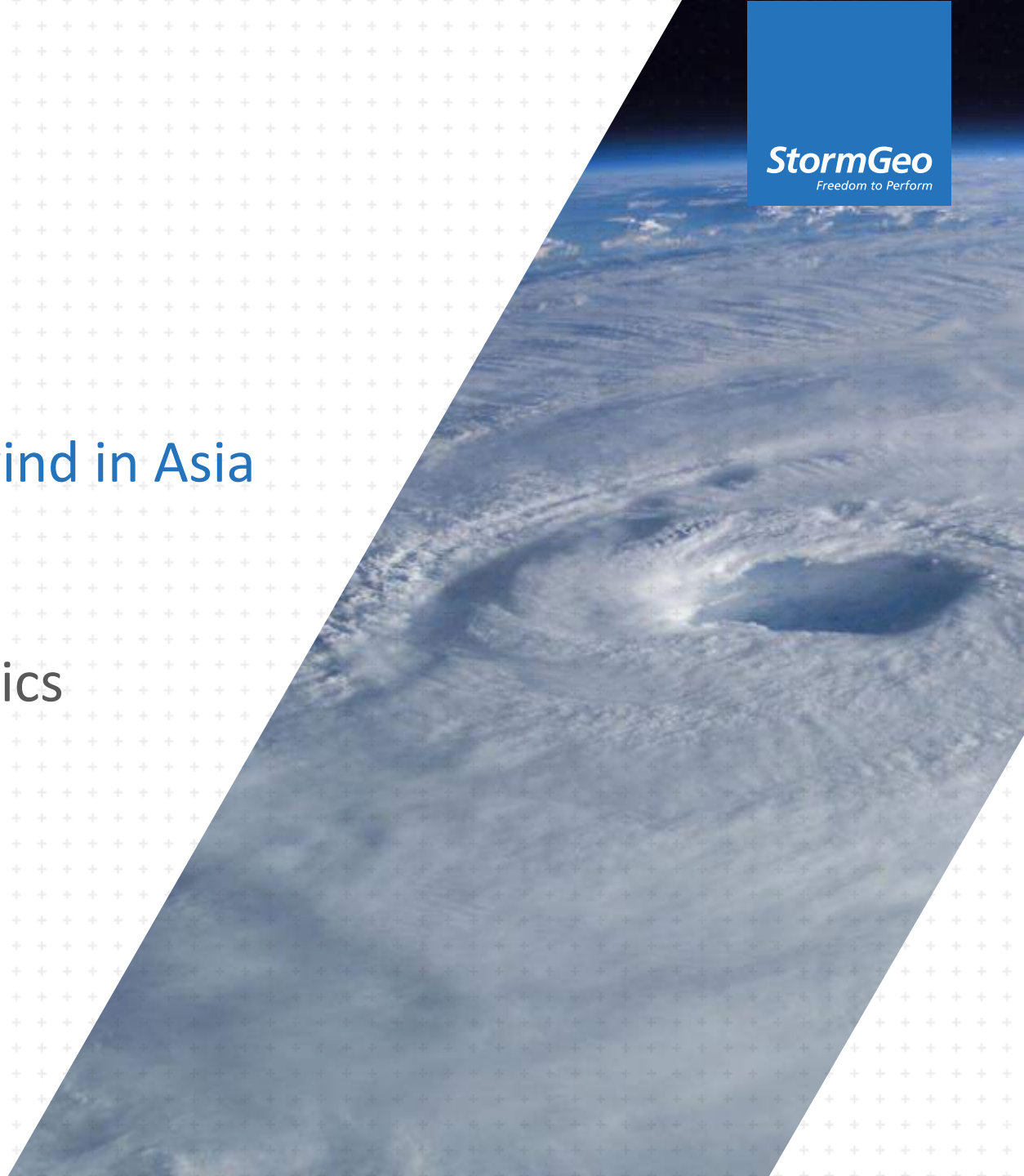
Offshore Wind, StormGeo

Antoni Therattil

Forecast Manager, StormGeo

// Outline

- StormGeo – a short introduction
- Weather challenges for offshore wind in Asia
- Typhoons and tropical storms
  – climatology and characteristics
- Recent systems
- StormGeo decision support tools



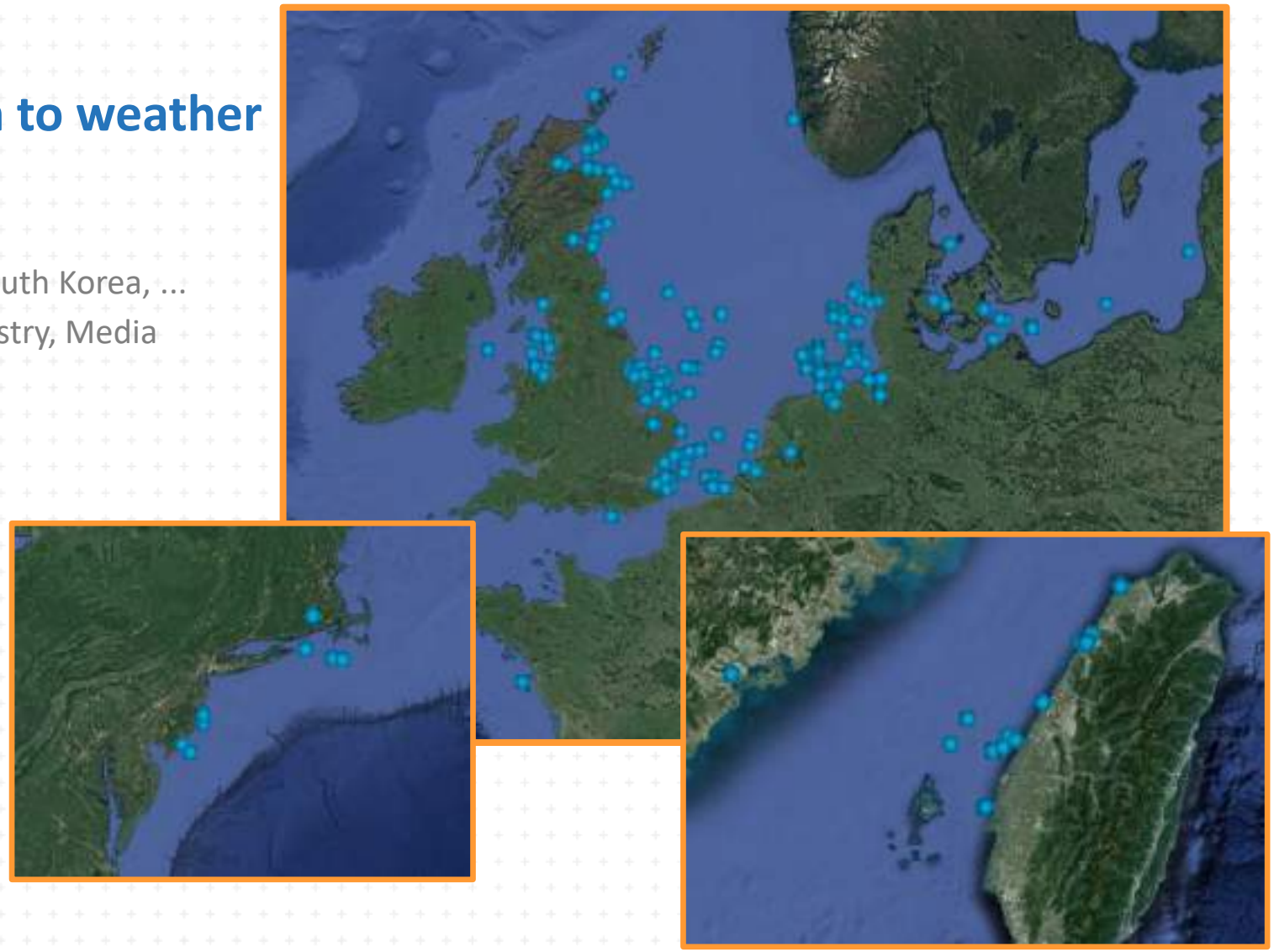
// StormGeo – a short introduction

StormGeo – weather information to weather sensitive industries worldwide

- // Established 1997
- // 24 offices in 19 countries - China, Japan, South Korea, ...
- // Shipping, Oil&Gas, Renewables, Cross Industry, Media
- // 24/7/365

Offshore wind at StormGeo

- // More than 100 project references
- // Europe, Asia, USA
- // Metocean and tropical forecasting
- // Finescale modelling
- // Wind resource modelling



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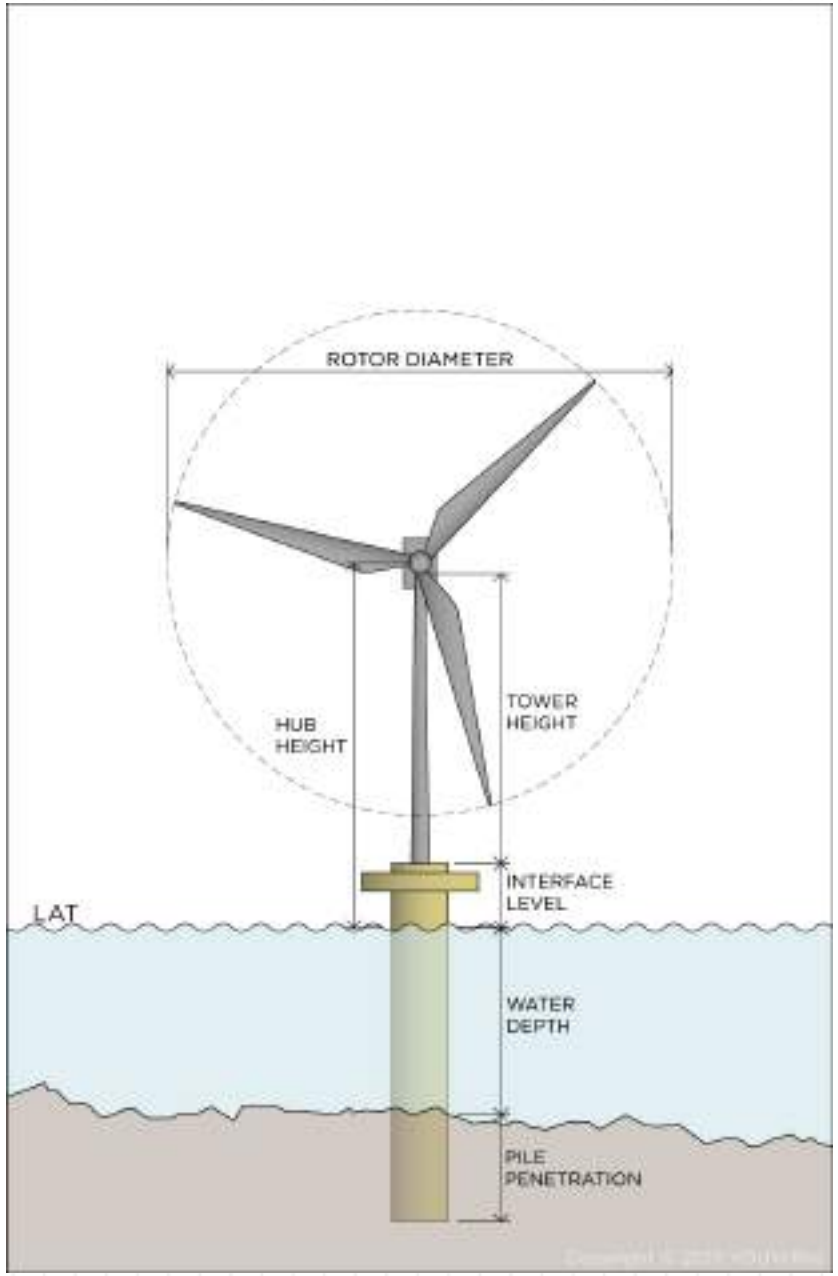

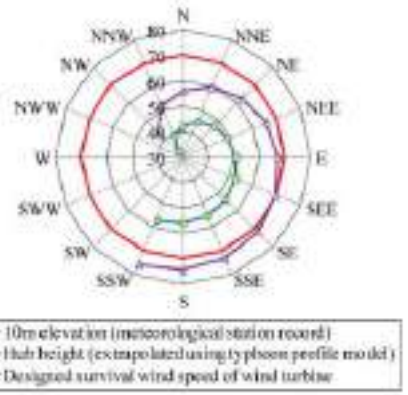

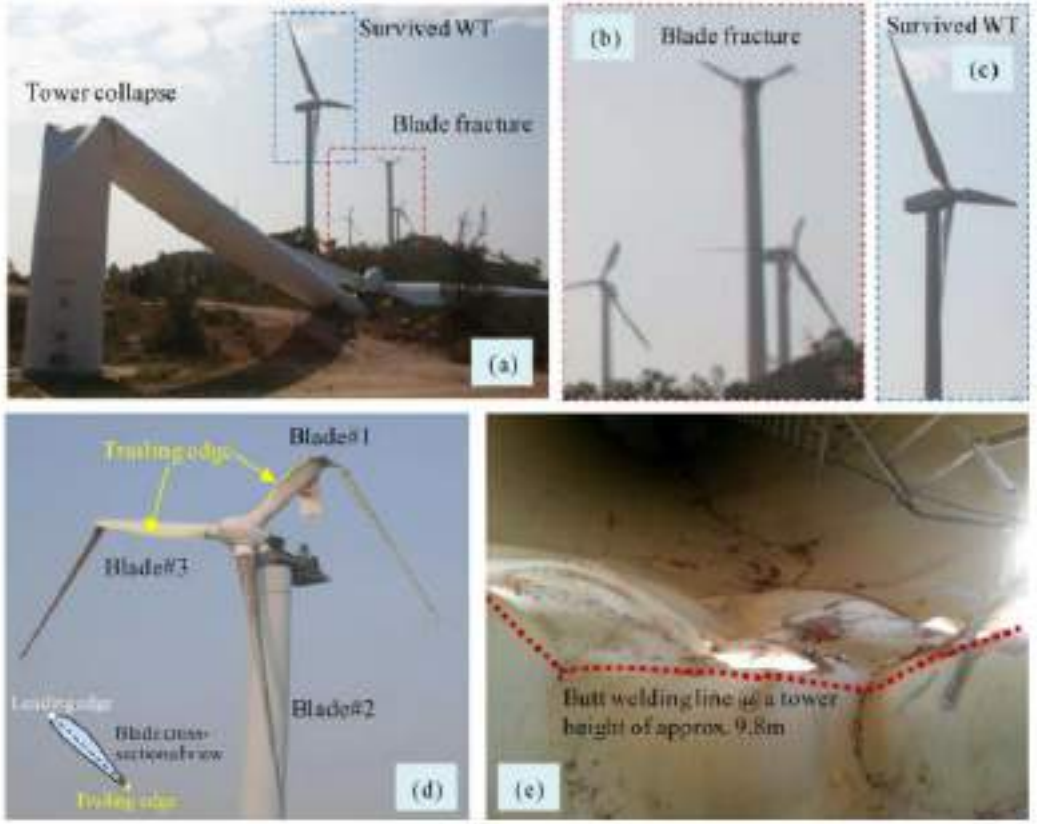

Representative structural failure of wind turbines caused by Usagi. (a) Typical failure in the wind farm. (b) Blade fracture. (c) Survived WT with different blade pitches (d) WT with abnormal pitch angles. (e) Local buckling of tower at shell wall thickness transition region.

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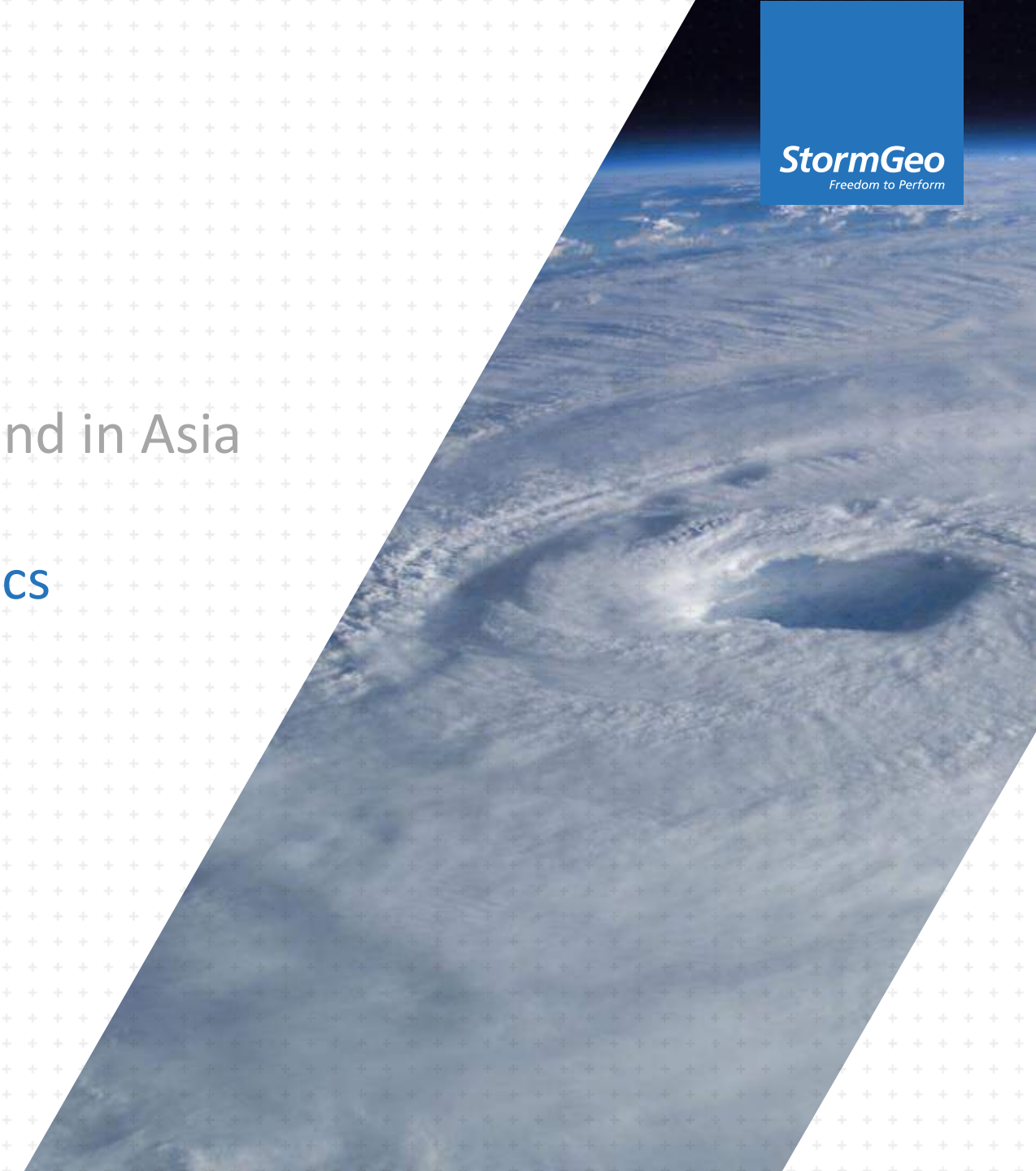
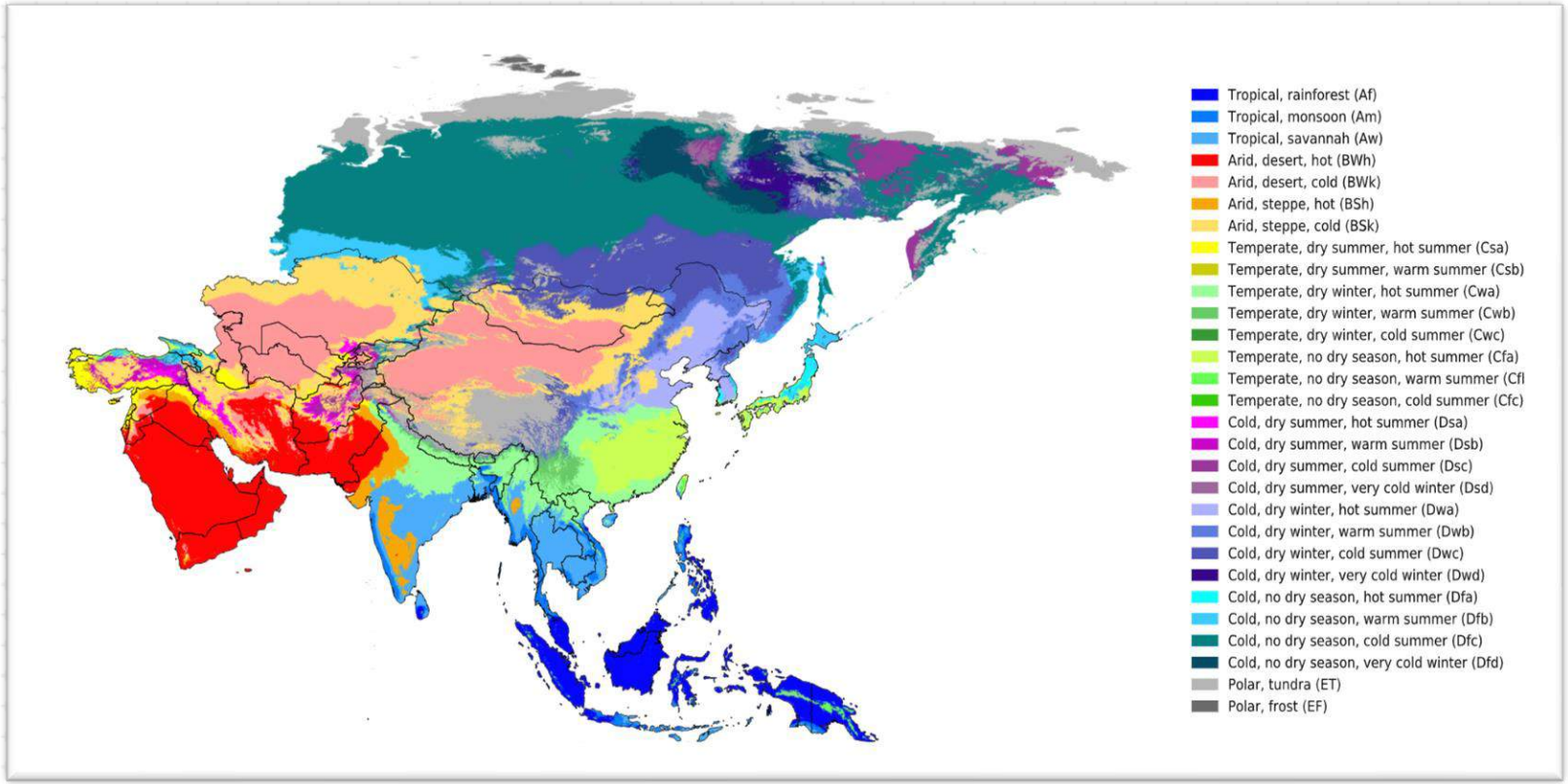




Latest IPCC assessment report:

Extreme weather events are increasing in Asia

- Heat waves
- **Extratropical and tropical cyclones**
- Droughts
- Intense rainfall
- Thunderstorms
- Snow avalanches
- Dust storms

1st	2nd	3rd
A (Tropical)	f (Rainforest)	
	m (Monsoon)	
	w (Savanna, Dry winter)	
	s (Savanna, Dry summer)	
B (Arid)	W (Desert)	
	S (Steppe)	
		h (Hot)
		k (Cold)
C (Temperate)	w (Dry winter)	
	f (No dry season)	
	s (Dry summer)	
		a (Hot summer)
		b (Warm summer)
		c (Cold summer)
D (Continental)	w (Dry winter)	
	f (No dry season)	
	s (Dry summer)	
		a (Hot summer)
		b (Warm summer)
		c (Cold summer)
		d (Very cold winter)
E (Polar)	T (Tundra)	
	F (Eternal frost (ice cap))	

// Tropical cyclones

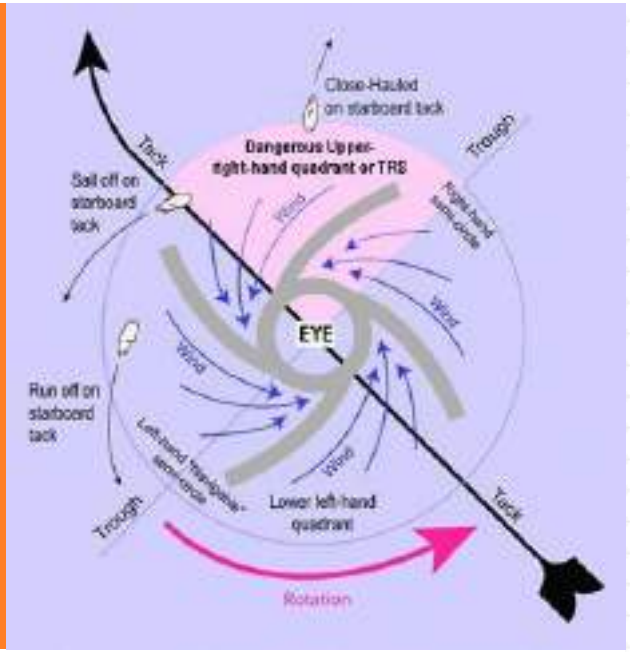
- Among the costliest types of natural disaster
- Climate models: Increase in extreme rainfall and winds associated to these events most parts of Asia.
- Disruption to transportation, energy, and telecommunication
- Coastal erosion, increasing the risk of assets along coastlines
- Flooding increases the probability of landslides and mudslides, affecting transportation infrastructure and power lines.

  - sufficiently warm sea surface temperatures
  - atmospheric instability
  - high humidity in the lower to middle levels of the troposphere
  - enough Coriolis force to sustain a low pressure center
  - a preexisting low level focus or disturbance, and low vertical wind shear.

➢ While these conditions are necessary for tropical cyclone formation, they do not guarantee that a tropical cyclone will form.

IMD Tropical Cyclone Strength Classification

Wind speed (3-min) Knots (km/h)	Category	Saffir–Simpson Scale Hurricane
<27 (<51)	Depression	TROPICAL DEPRESSION
28-33 (52-61)	Deep Depression	TROPICAL DEPRESSION
34-47 (62-87)	Cyclonic Storm	TROPICAL STORM
48-63 (88-117)	Severe Cyclonic Storm	CATEGORY 1 - 2 HURRICANE
64-119 (118-221)	Very Cyclonic Storm	CATEGORY 3 - 4 HURRICANE
<120 (<222)	Super Cyclonic Storm	CATEGORY 5 MAJOR HURRICANE



List of Western Pacific tropical cyclone names

List	Contributing nation													
	Cambodia	China	North Korea	Hong Kong	Japan	Laos	Macau	Malaysia	Micronesia	Philippines	South Korea	Thailand	United States	Vietnam
1	Damrey	Haikui	Kirogi	Yun-yeung	Koinu	Bolaven	Sanba	Jelawat	Ewiniar	Maliksi	Gaemi	Prapiroon	Maria	Son-Tinh
	Ampil	Wukong	Jongdari	Shanshan	Yagi	Leepi	Bebinca	Pulasan	Soulik	Cimaron	Jebi	Krathon	Barijat	Trami
2	Kong-rey	Yutu[nb 1]	Toraji	Man-yi	Usagi	Pabuk	Wutip	Sepat	Mun	Danas	Nari	Wipha	Francisco	Lekima[nb 2]
	Krosa	Bailu	Podul	Lingling	Kajiki	Faxai[nb 3]	Peipah	Tapah	Mitag	Hagibis[nb 4]	Neoguri	Bualoi	Matmo	Halong
3	Nakri	Fengshen	Kalmaegi	Fung-wong	Kammuri[nb 5]	Phanfone[nb 6]	Vongfong	Nuri	Sinlaku	Hagupit	Jangmi	Mekkhala	Higos	Bavi
	Maysak	Haishen	Noul	Dolphin	Kujira	Chan-hom	Linfa	Nangka	Saudel	Molave	Goni	Atsani	Etau	Vamco
4	Krovanh	Dujuan	Surigae	Choi-wan	Koguma	Champi	In-fa	Cempaka	Nepartak	Lupit	Mirinae	Nida	Omais	Conson
	Chanthu	Dianmu	Mindulle	Lionrock	Kompasu	Namtheun	Malou	Nyatoh	Rai	Malakas	Megi	Chaba	Aere	Songda
5	Trases	Mulan	Meari	Ma-on	Tokage	Hinnamnor	Muifa	Merbok	Nanmadol	Talas	Noru	Kulap	Roke	Sonca
	Nesat	Haitang	Nalgae	Banyan	Yamaneko	Pakhar	Sanvu	Mawar	Guchol	Talim	Doksuri	Khanun	Lan	Saola

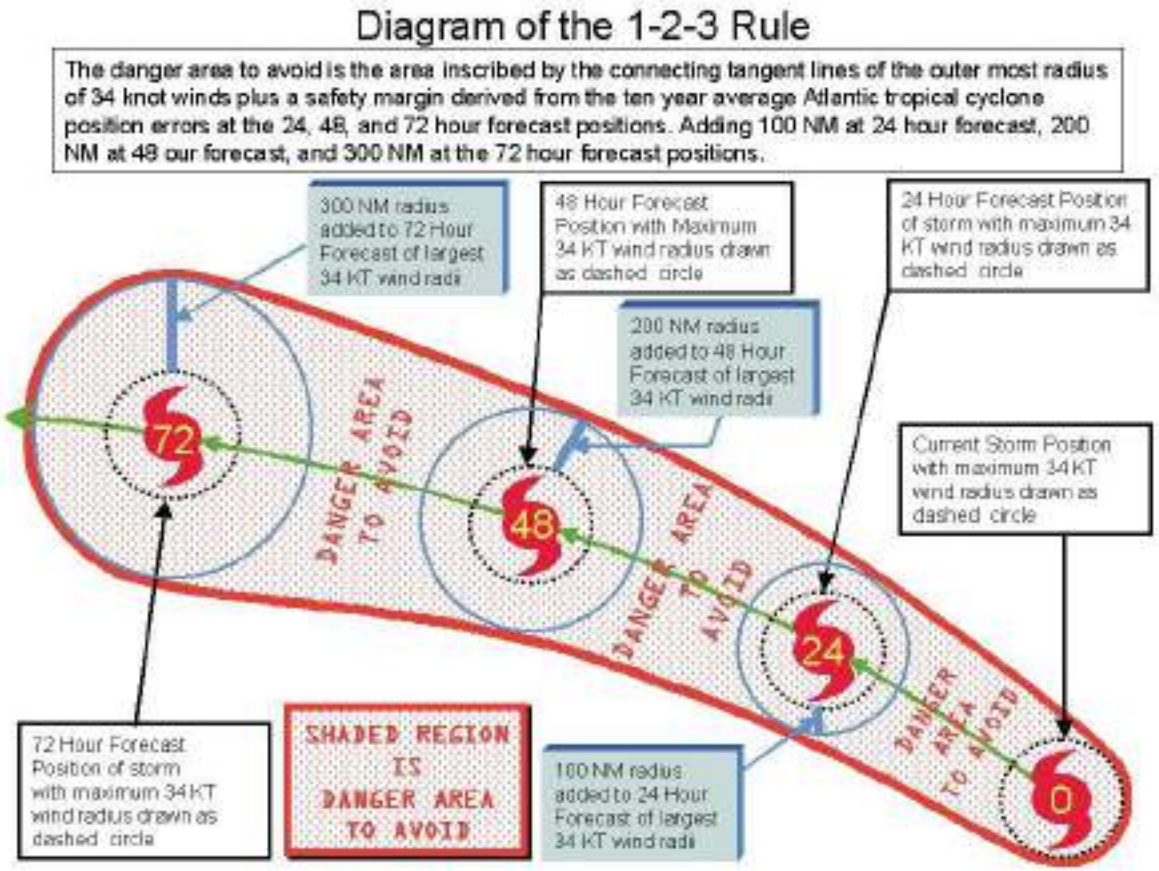
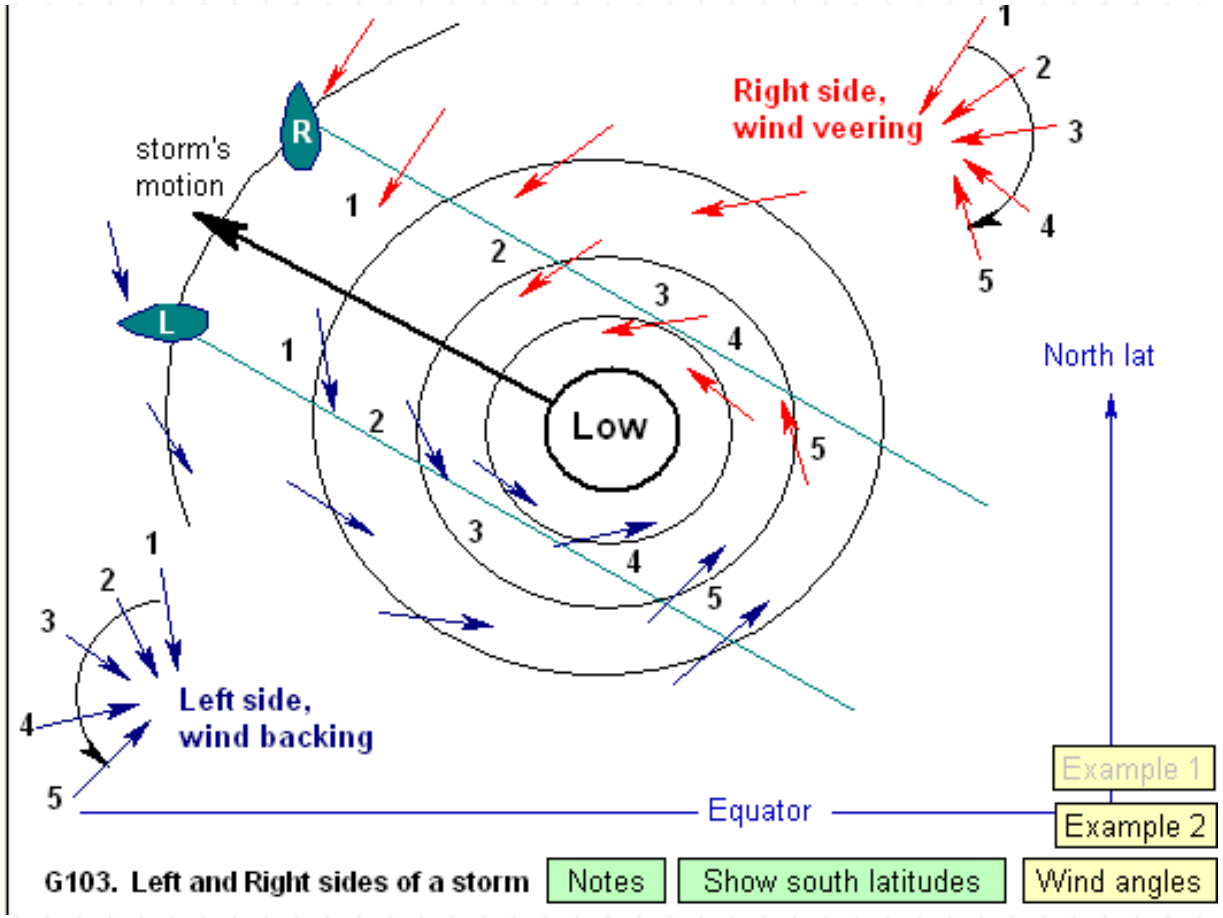
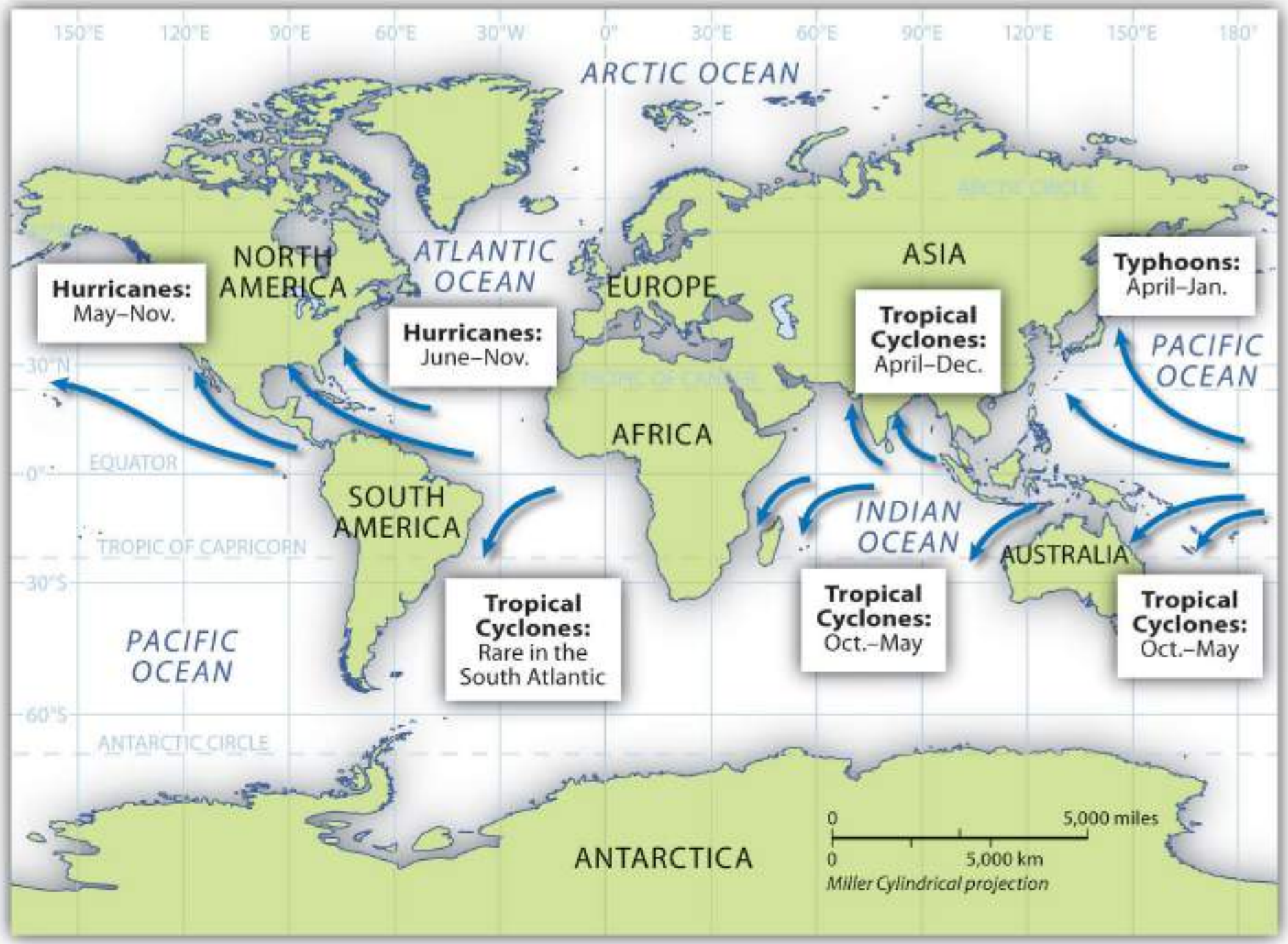


Diagram of the 1-2-3 Rule
The danger area to avoid is the area inscribed by the connecting tangent lines of the outer most radius of 34 knot winds plus a safety margin derived from the ten year average Atlantic tropical cyclone position errors at the 24, 48, and 72 hour forecast positions. Adding 100 NM at 24 hour forecast, 200 NM at 48 our forecast, and 300 NM at the 72 hour forecast positions.
300 NM radius added to 72 Hour Forecast of largest 34 KT wind radii
48 Hour Forecast Position with Maximum 34 KT wind radius drawn as dashed circle
24 Hour Forecast Position of storm with maximum 34 KT wind radius drawn as dashed circle
200 NM radius added to 48 Hour Forecast of largest 34 KT wind radii
Current Storm Position with maximum 34 KT wind radius drawn as dashed circle
72
48
24
0
DANGER AREA TO AVOID
DANGER AREA TO AVOID
DANGER AREA TO AVOID
72 Hour Forecast Position of storm with maximum 34 KT wind radius drawn as dashed circle
SHADED REGION IS DANGER AREA TO AVOID
100 NM radius added to 24 Hour Forecast of largest 34 KT wind radii

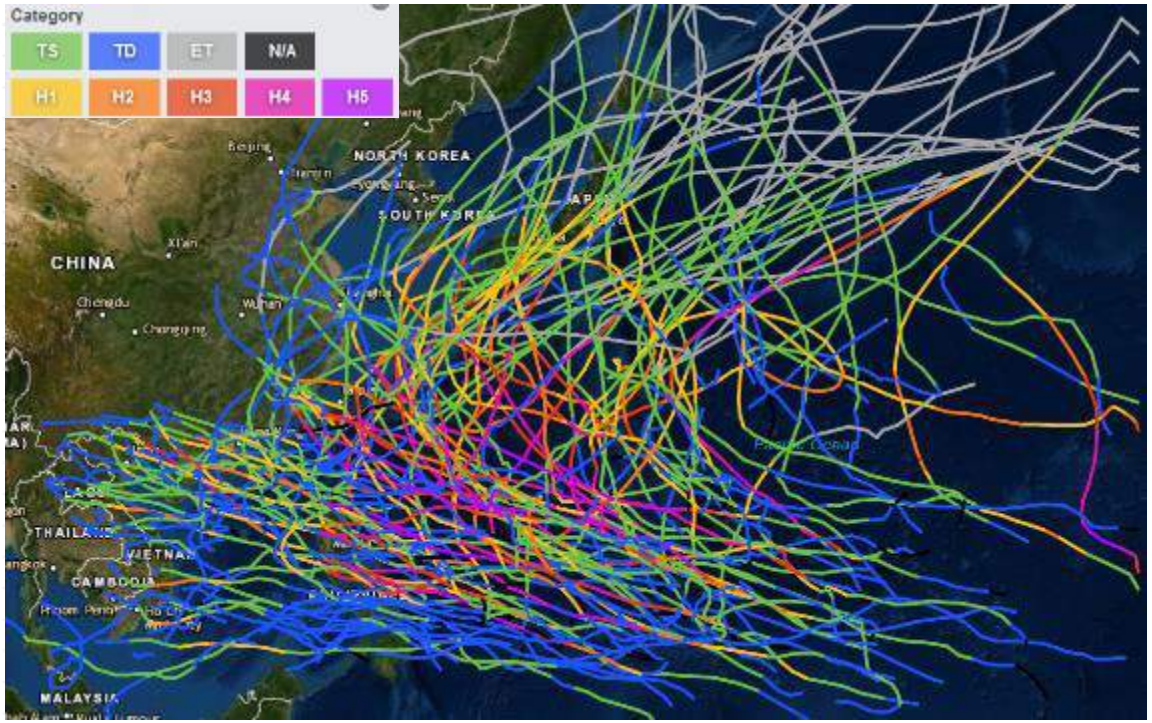

storm's motion
R
L
Low
Right side, wind veering
Left side, wind backing
1
2
3
4
5
North lat
Equator
Example 1
Example 2
G103. Left and Right sides of a storm
Notes
Show south latitudes
Wind angles

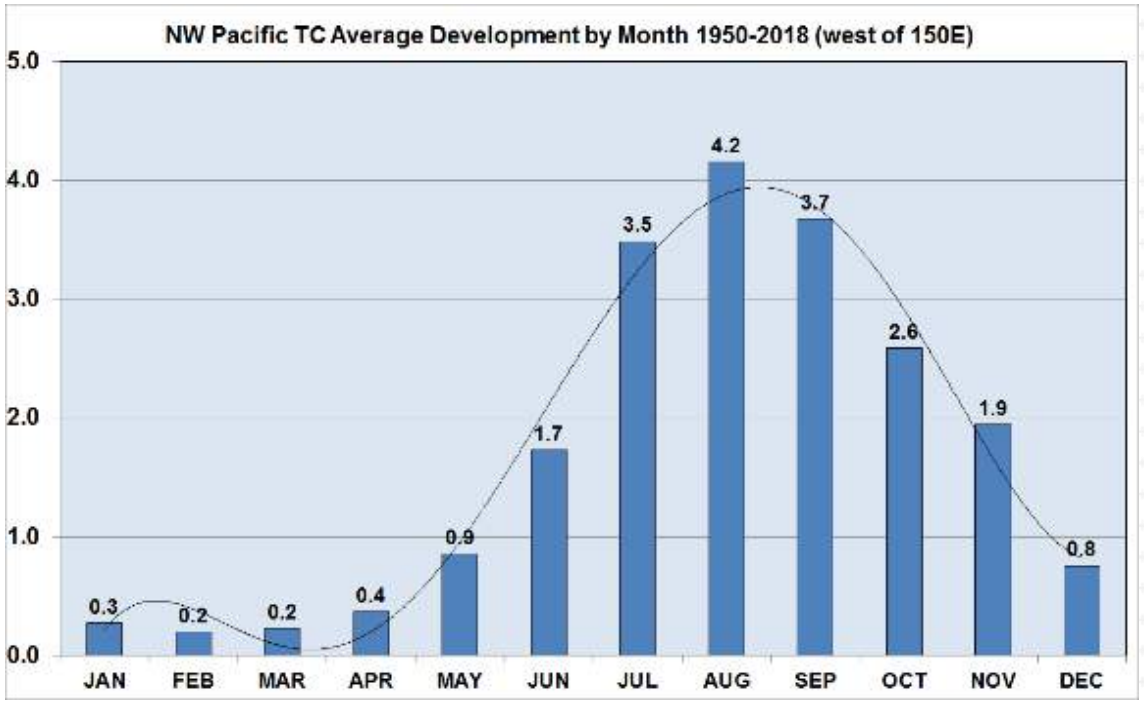


StormGeo
Freedom to Perform

NW Pacific – the world's most active tropical cyclone basin

- 161 named tropical cyclones last 5 years
- Activity peaks in August but tropical cyclones can occur in any month





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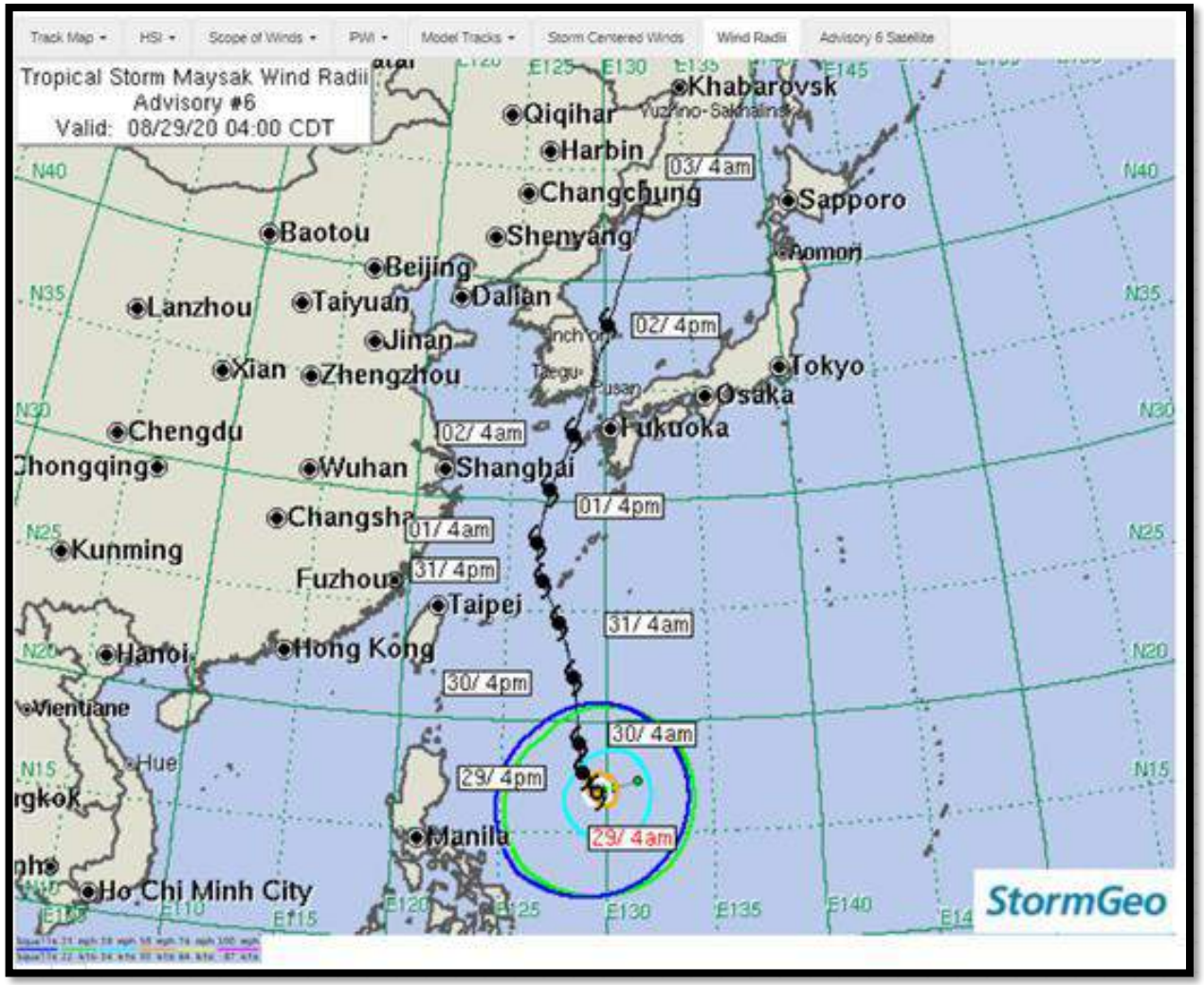
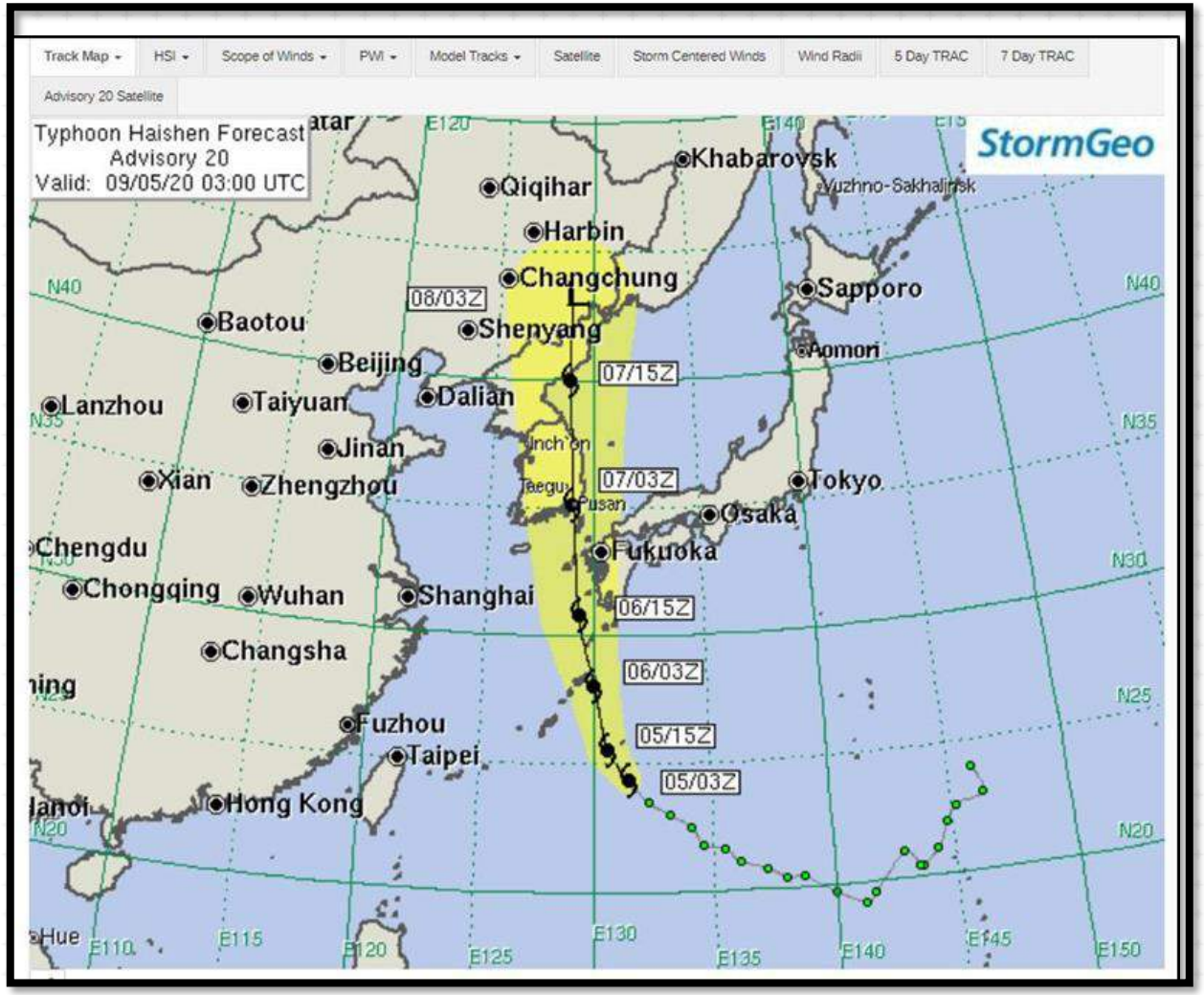

Track Map
HSI
Scope of Winds
PWI
Model Tracks
Storm Centered Winds
Wind Radii
Advisory 6 Satellite
Tropical Storm Maysak Wind Radii
Advisory #6
Valid: 08/29/20 04:00 CDT
Khabarovsk
Qiqihar
Yuzhno-Sakhalinsk
Harbin
03/ 4am
Changchung
Sapporo
Baotou
Shenyang
Aomori
Beijing
Lanzhou
Taiyuan
Dalian
02/ 4pm
Jinan
Xian
Zhengzhou
Tokyo
Osaka
Chengdu
02/ 4am
Fukuoka
Chongqing
Wuhan
Shanghai
01/ 4pm
Changsha
01/ 4am
Kunming
31/ 4pm
Fuzhou
Taipei
31/ 4am
Hanoi
Hong Kong
30/ 4pm
Vientiane
30/ 4am
Hue
29/ 4pm
29/ 4am
Manila
Ho Chi Minh City
StormGeo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Satellite
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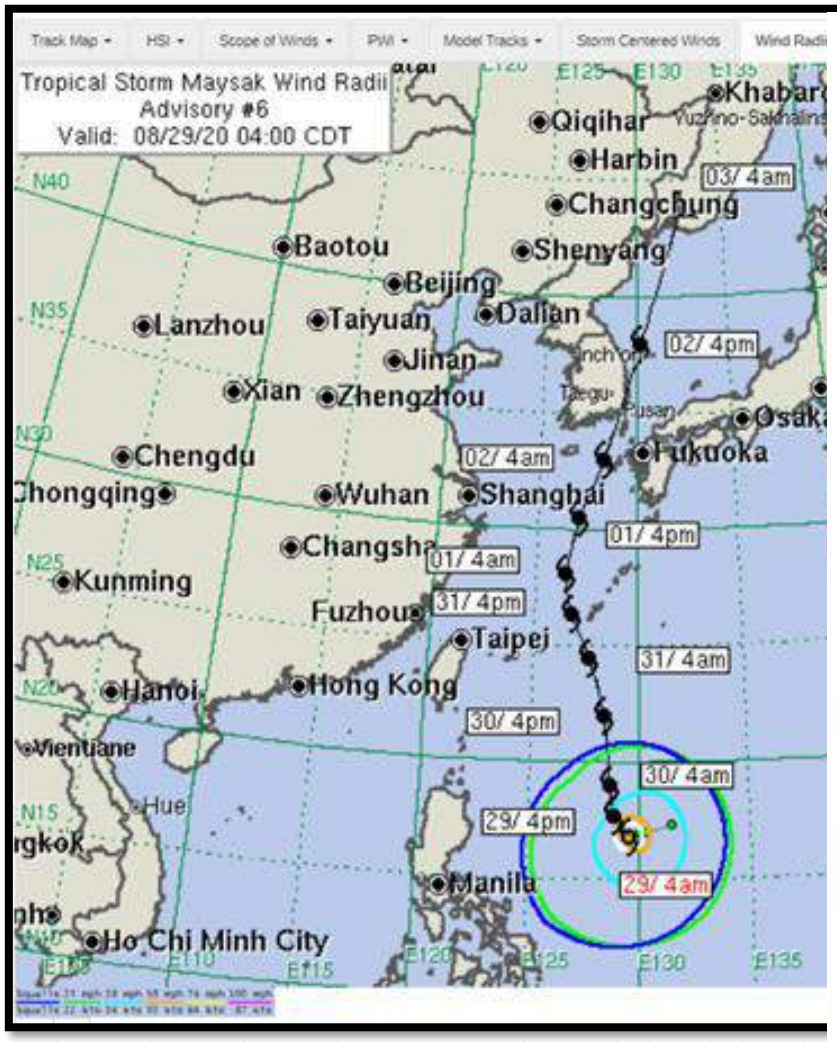
Wind Radii
5 Day TRAC
7 Day TRAC
Advisory 20 Satellite
Typhoon Haishen Forecast
Advisory 20
Valid: 09/05/20 03:00 UTC
StormGeo
Khabarovsk
Qiqihar
Yuzhno-Sakhalinsk
Harbin
Changchung
08/03Z
Sapporo
Baotou
Shenyang
Aomori
Beijing
07/15Z
Lanzhou
Taiyuan
Dalian
Jinan
Xian
Zhengzhou
07/03Z
Tokyo
Osaka
Chengdu
Fukuoka
Chongqing
Wuhan
Shanghai
06/15Z
Changsha
06/03Z
Fuzhou
05/15Z
Taipei
05/03Z
Hong Kong
Hue



Video
https://vimeo.com/457735519/e222697da6

MarineTraffic
@MarineTraffic

5 facts about the Gulf Livestock 1

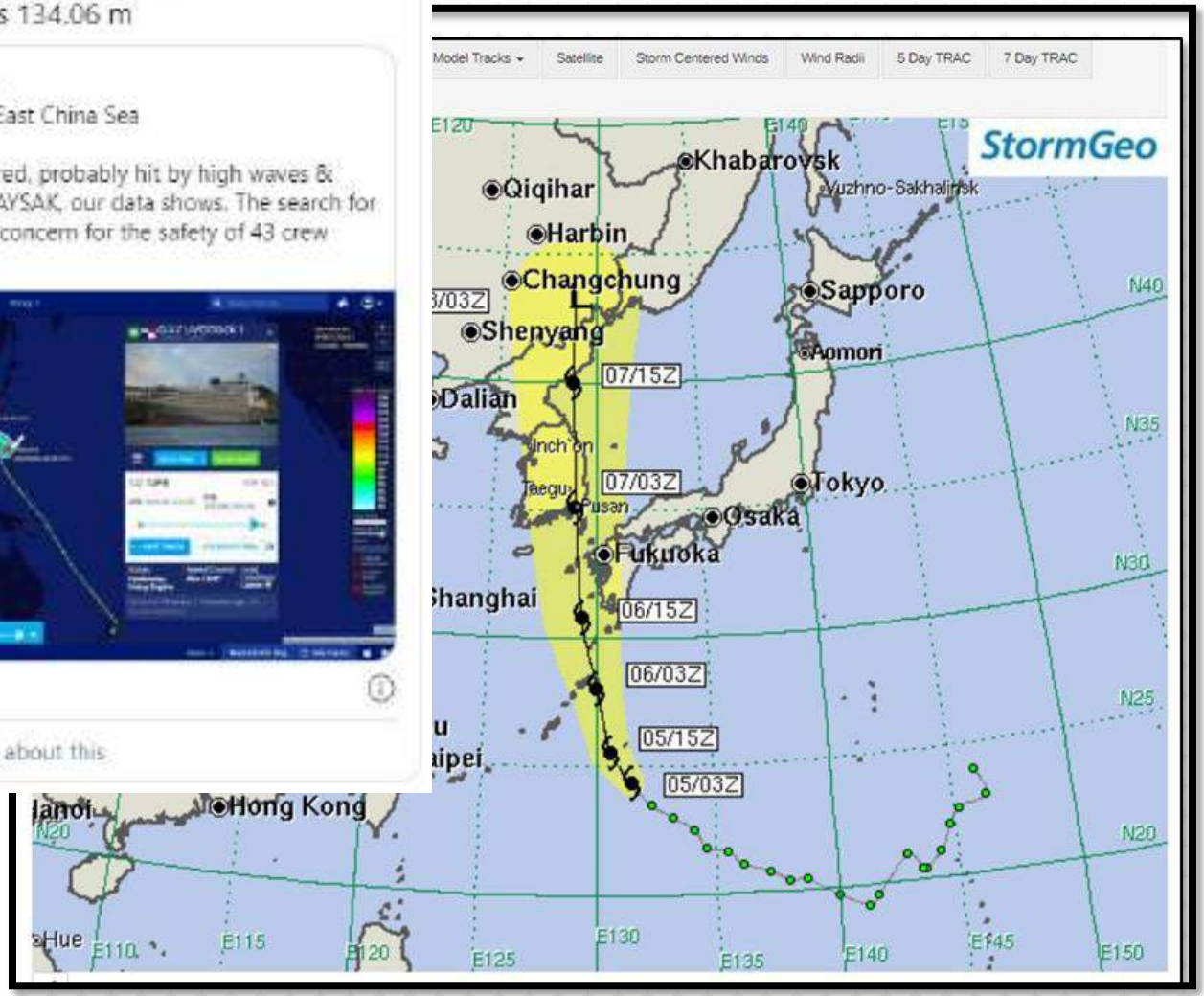
-Last position received via AIS was 48 hours ago
-Recent port calls before Napier: Gladstone & Manila
-This was the 1st time she made this journey in 2020
-Distance travelled: approx 35,000 NM this year
-The ship was built in 2002 & is 134.06 m

MarineTraffic @MarineTraffic
Livestock carrier goes missing in the East China Sea

The GULF LIVESTOCK 1 has disappeared, probably hit by high waves & strong winds caused by typhoon #MAYSAK, our data shows. The search for the livestock carrier in load began as concern for the safety of 43 crew onboard rises

12:43 PM · Sep 3, 2020

35 28 people are Tweeting about this



StormGeo Offshore Weather Service

Home | Asset Overview | Site Forecast | Tides | Hourly Tide Tables | Currents | TropicsWatch

ImpactWeather Storm Archive

2020

Atlantic	Arabian Sea	Bay of Bengal	East Pacific	ea	South Indian Ocean	South Pacific	West Pacific
Arthur	2	Amphan	One-e	Ona	Blake	Tino	Vongfong
Bertha	Nisarga		Amanda		Claudia	5	Nuri
Cristobal			Boris		Diane	Uesi	7
Dolly			Four-e-rmo		Esther	Vicky	Sinlaku
Edouard			Four-e		Damien	Wasi	Hagupit
Fay			Cristina		Francisco	Gretel	Jangmi
Gonzalo			Six-E		Gabekile	Harold	Mekkhala
Hanna			Seven-E		Esther		10
Isaias			Douglas		Ferdinand		Higos
Ten			Elida		5		Bavi
Josephine			Ten-E		Herold		Maysak
Kyle			Fausto		Irondro		
Laura			Genevieve		Jeruto		
Marco			Hernan		6		
Omar							
Nana							

Tropical Depression 23

31/08/2020 8:58 UTC

Current Location	24.5N, 146.0E
Geographic Reference	900 miles south-southeast of Tokyo, Japan
Movement	South-southwest at 5 mph
Max Winds	35 mph gusting to 45 mph
Current Radius of Tropical Storm-Force Winds	0 miles
Max Predicted Radius of Tropical Storm-Force Winds	140 miles
Organizational Trend	Increasing
Forecast Confidence	Average
Estimated Central Pressure	1005 mb

StormGeo Advisory 1

Key Points

1. Tropical Depression 23 will likely be a large and strong typhoon when it reaches Japan this weekend.
2. Destructive winds, tidal surges, and heavy rainfall are expected.

Our Forecast

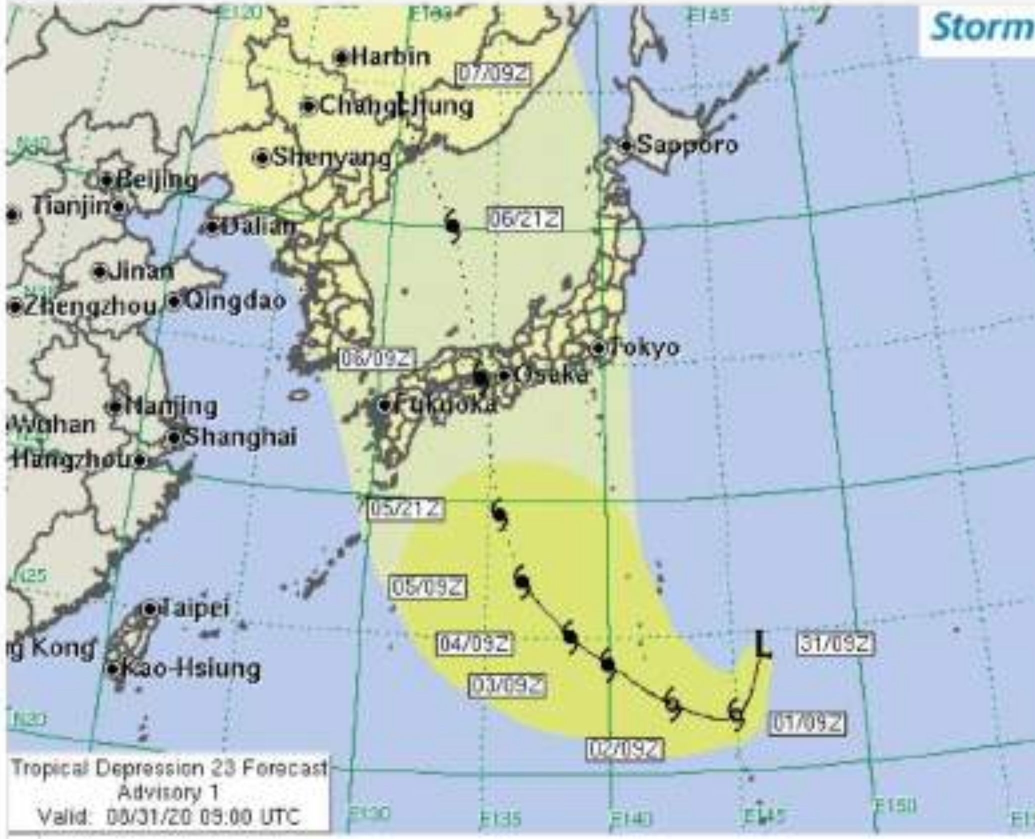
Disturbance 23 has been upgraded to a tropical depression by the Japanese Meteorological Agency. Conditions are forecast to be favorable for intensification over the next several days. The depression will likely become a tropical storm over the next 24 hours, and a typhoon by Thursday. As for the track, a motion towards the southwest is expected into tomorrow, with a turn more towards the northwest likely occurring by Wednesday. The northwestward motion should continue through the weekend taking the system across Japan. The latest model guidance is indicating that the system will be a large and strong typhoon by this time. After impacting Japan, the typhoon is expected to transition into an extratropical cyclone by the time it reaches northeastern China next Monday.

Our next advisory will be issued by 1500 UTC.

Meteorologist: Justin Penuelas

Track Map | HS | Scope of Winds | PW | Model Tracks | Satellite | Storm Centered Winds | Wind Radii | 5 Day TRAC | 7 Day TRAC

Advisory 1 Satellite



Typhoon Haishen

05/0300Z 2.5N UTC

Current Location	34.3N, 132.9E
Geographic Reference	405 miles South of the southern tip Kyushu
Movement	Northeast at 9 mph
Max Winds	105 mph gusting to 184 mph
Current Radius of Tropical Storm Force Winds	519 miles
Max Predicted Radius of Tropical Storm Force Winds	345 miles
Organizational Trend	Temporarily Decreasing
Forecast Confidence	Average
Estimated Central Pressure	939 mb

StormGeo Advisory 20

Key Points

1. Haishen is significantly larger than previously analyzed.
2. Severe impacts are expected for the Ryukyu Islands.
3. Destructive winds, tidal surges, and heavy rainfall are expected to occur for western Kyushu and western South Korea.

Our Forecast

Haishen is somewhat weaker based upon recent satellite estimates. Winds are now estimated at 140 mph. However, satellite data indicates that Haishen is significantly larger than we previously analyzed. Winds of tropical storm force extend more than 300 miles from the center. Winds are likely at tropical storm force now over the Ryukyu Islands. There could be a little intensification during the next 12 to 24 hours. Winds could be 150 mph when Haishen moves through the Ryukyu Islands. Thereafter, gradual weakening is expected as it passes near western Kyushu and moves into Korea. Winds at the expected Korean landfall are forecast to be 105 mph. Rapid weakening is expected after landfall, along with a transition into an extratropical storm.

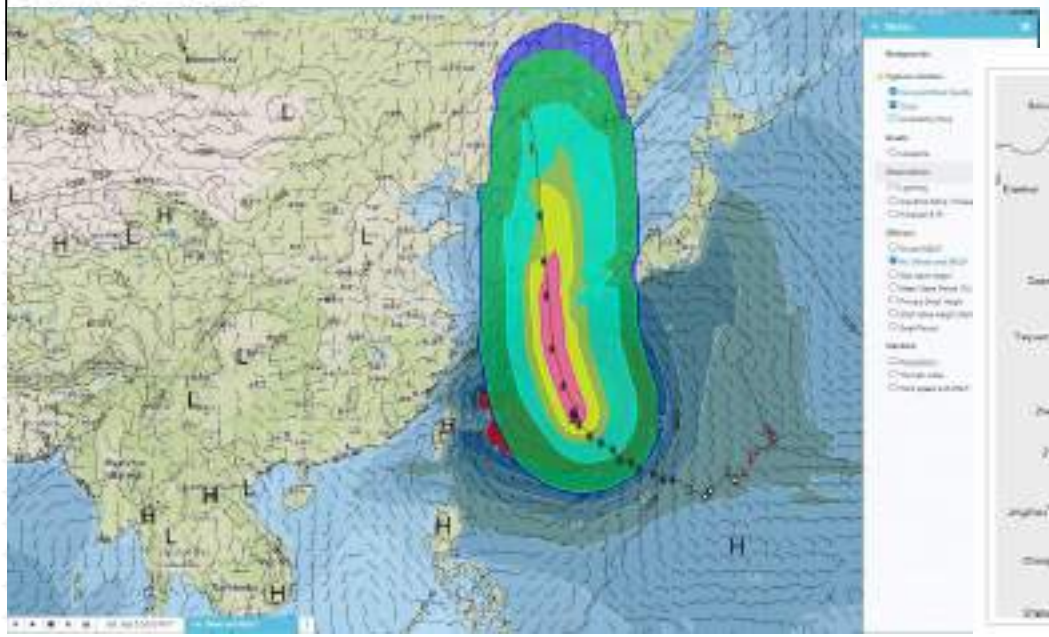
There remains a very high risk of major flooding for the Korean Peninsula due to the recent passage of Maysak.

Expected Impacts on Land

Ryukyu Islands
Significant wind and tidal surge damage is likely for the Ie Island and northern Ryukyu Islands. Flash flooding and mudslides are also likely.

Western Kyushu
Significant damage from wind and tidal surge is likely. In addition, some damage due to flash flooding and mudslides is likely.

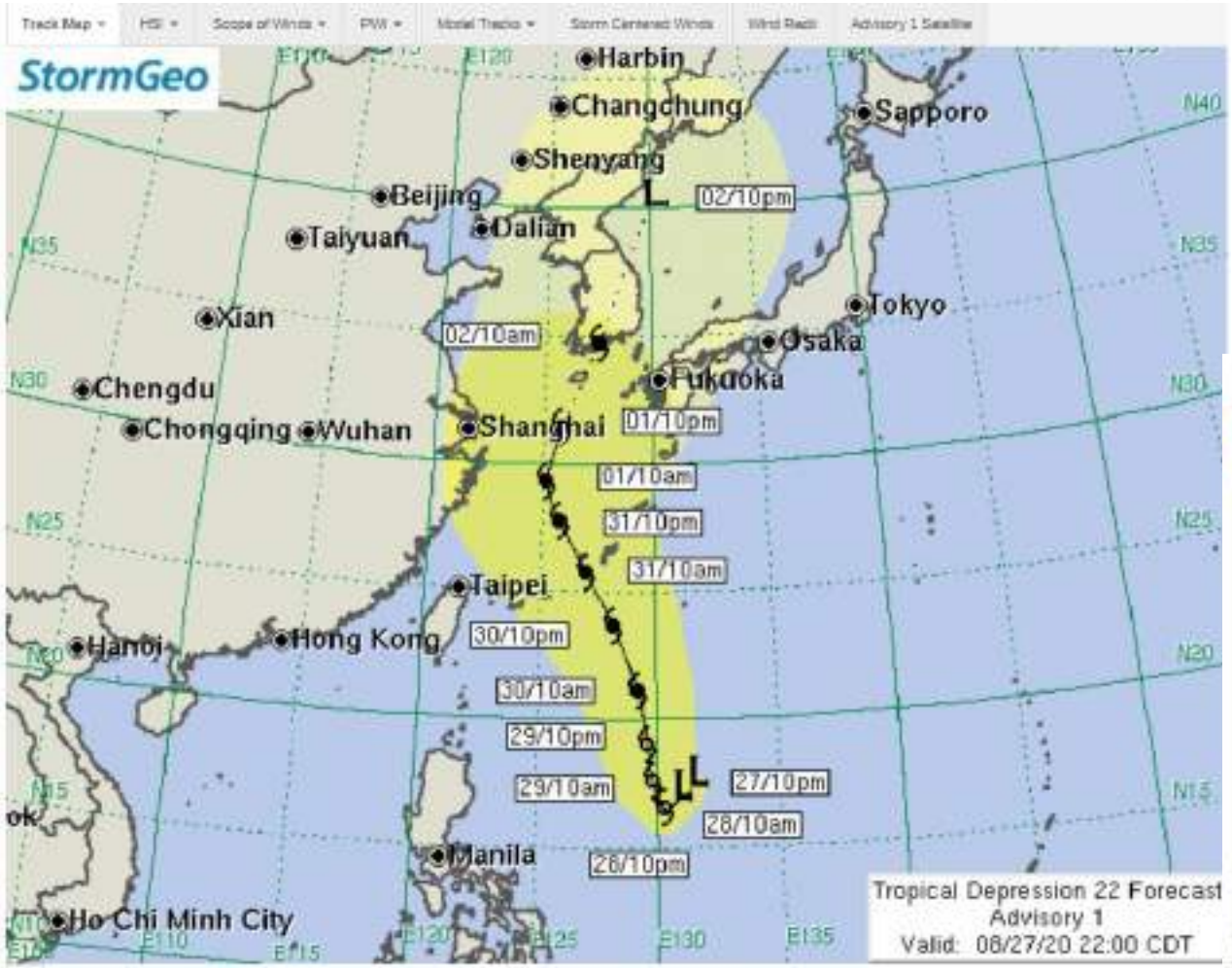
Korea
Any already occurring issues as a result of the previous wind from Maysak and rain may be exacerbated by another round of heavy rainfall and strong, damaging winds from Haishen. Severe inland flooding that results in widespread damage is possible.

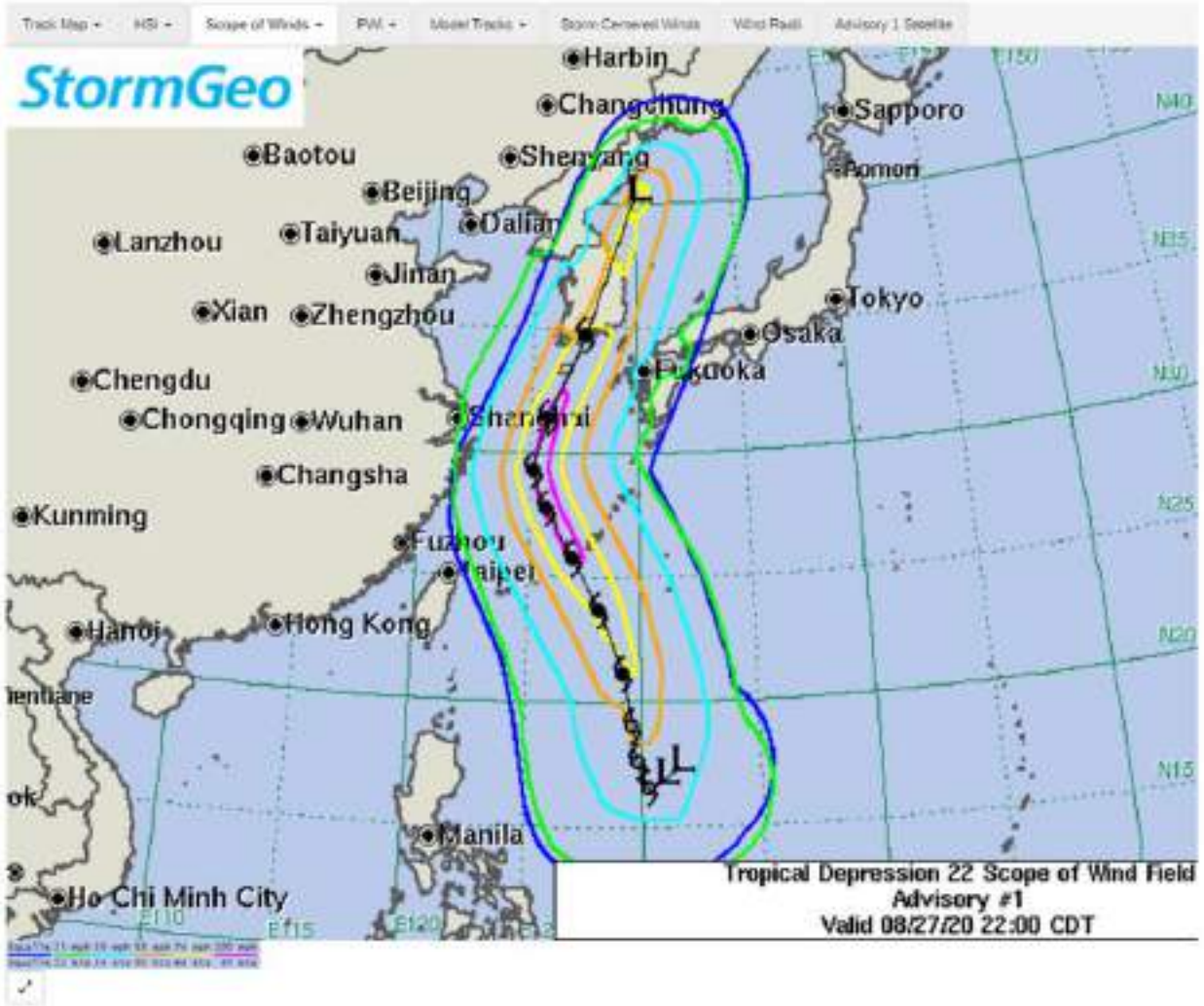


StormGeo
Freedom to Perform

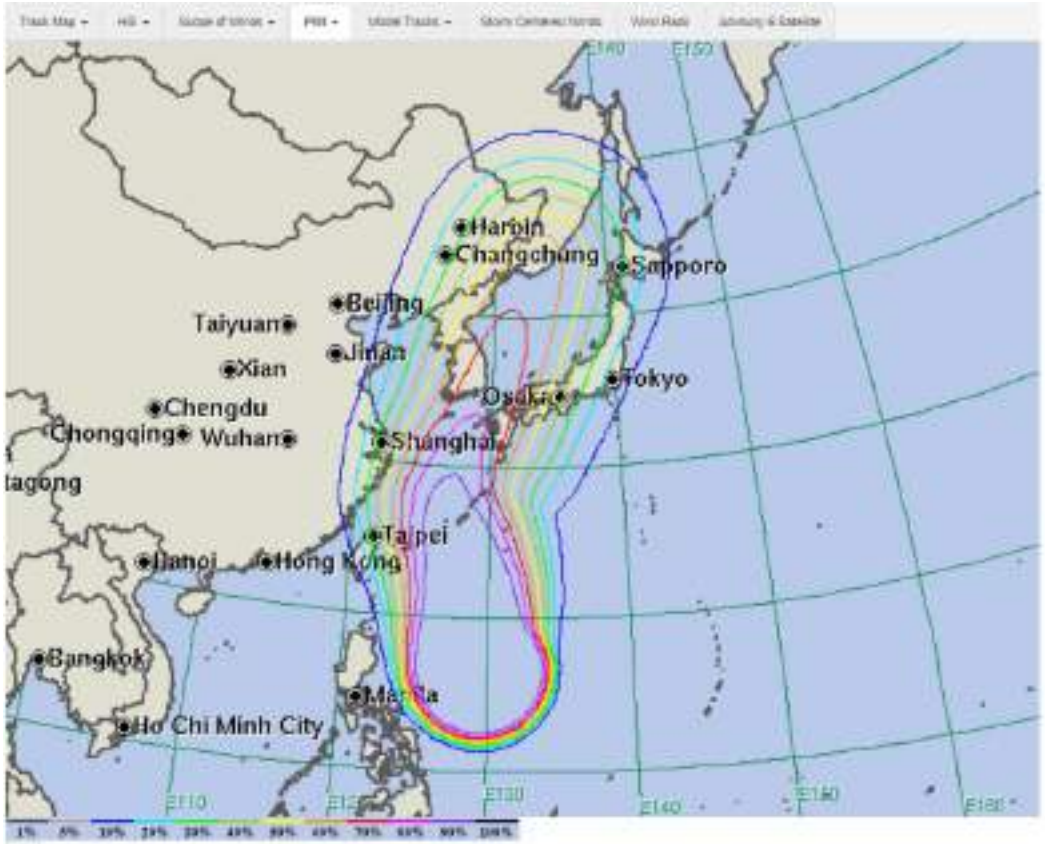
StormGeo

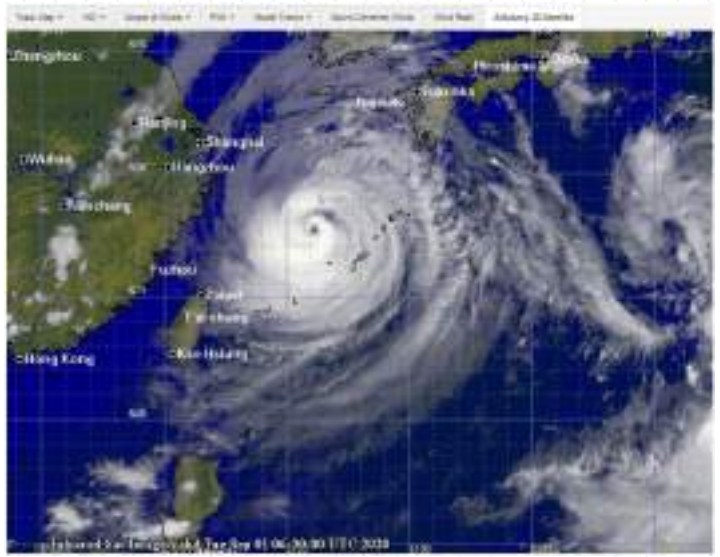
Typhoon Haishen



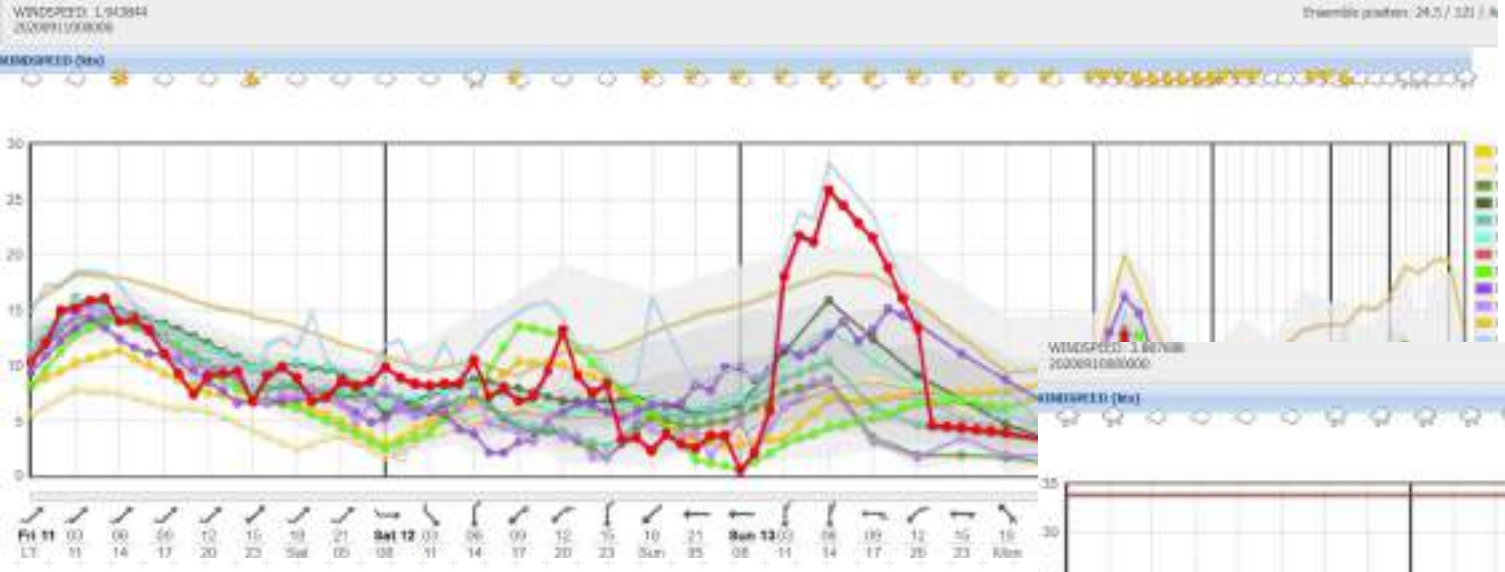


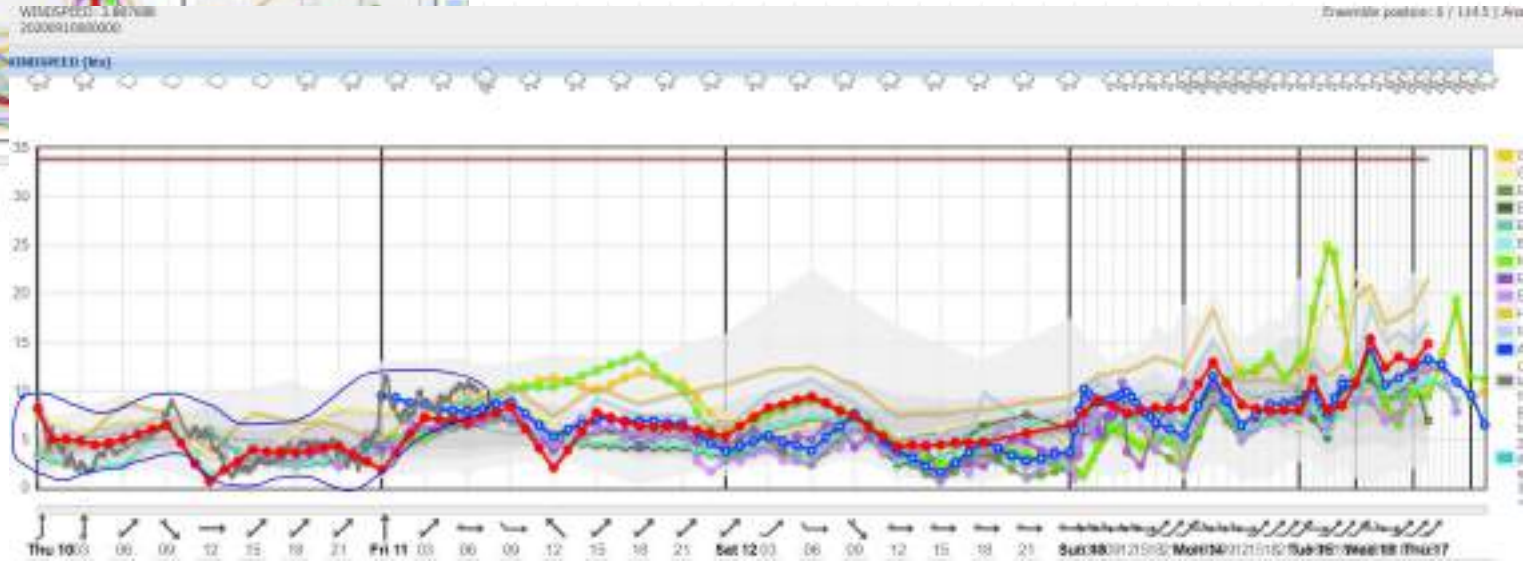
StormGeo
Freedom to Perform

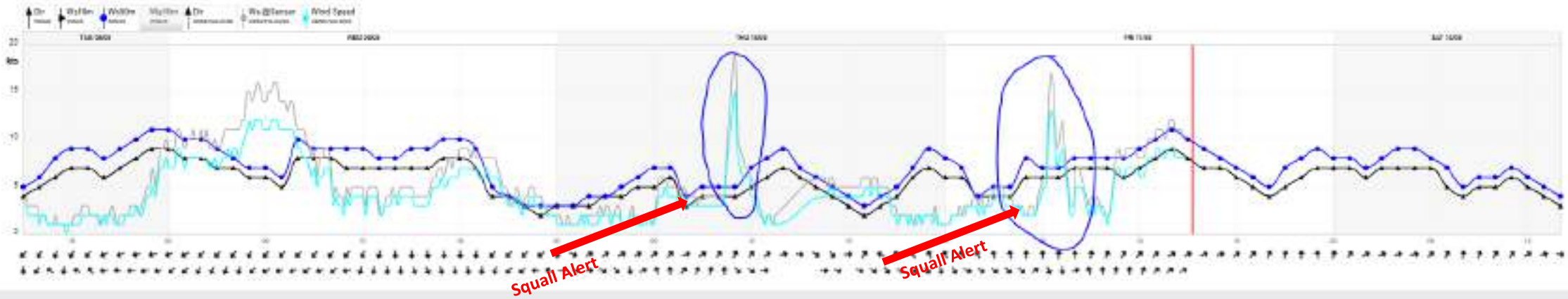


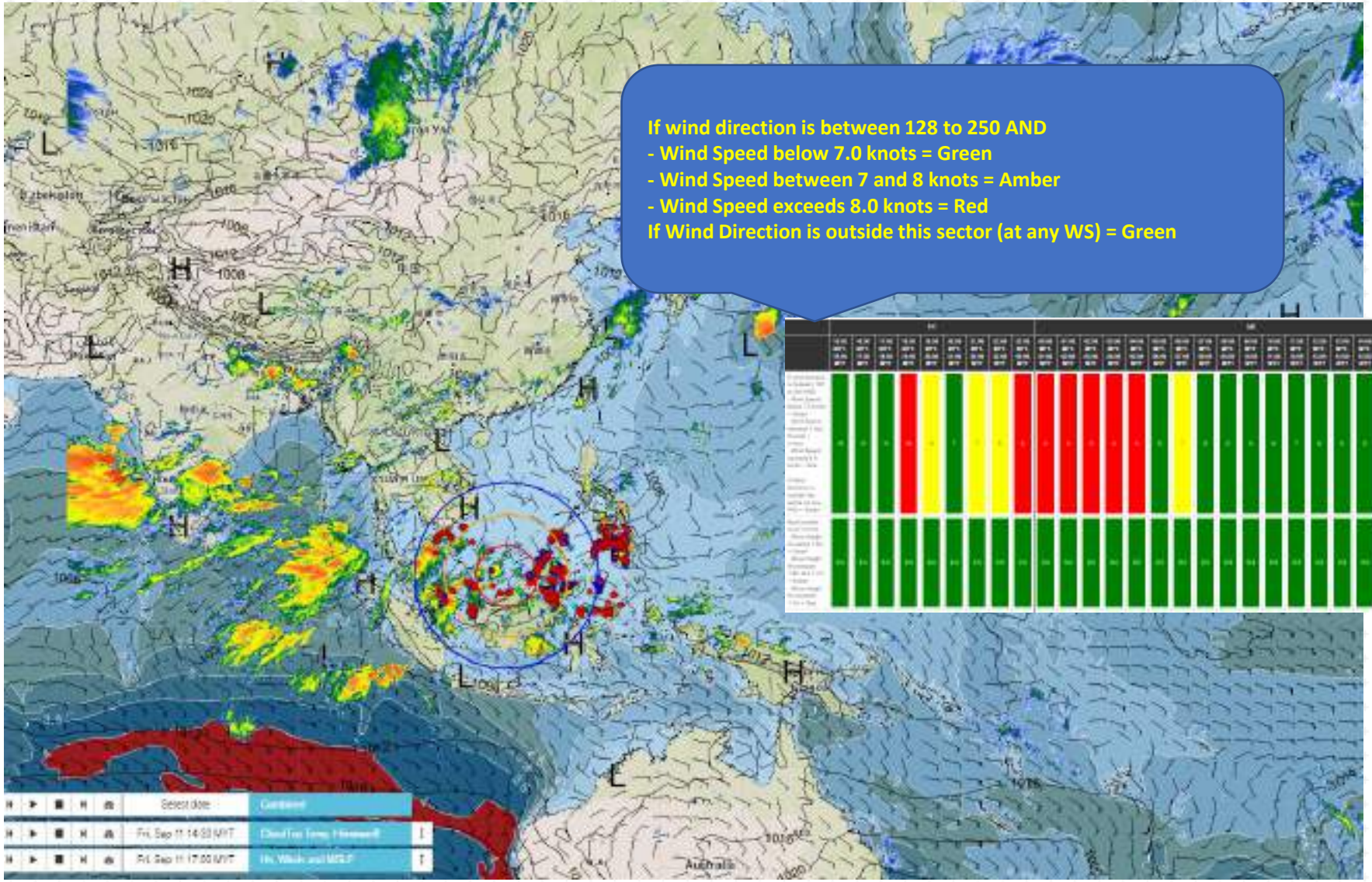


StormGeo
Freedom to Perform






Squall Alert
Squall Alert


If wind direction is between 128 to 250 AND
- Wind Speed below 7.0 knots = Green
- Wind Speed between 7 and 8 knots = Amber
- Wind Speed exceeds 8.0 knots = Red
If Wind Direction is outside this sector (at any WS) = Green

// Outline

- StormGeo – a short introduction
- Weather challenges for offshore wind in Asia
- Typhoons and tropical storms
  - climatology and characteristics
- Recent systems
- **StormGeo decision support tools**

// Decision support 1/4

Storm Advisory -

up to 7 days ahead

Tropical Storm Hagupit

8/2/2020 10:07 PM GMT+2

Current Location	25N, 123.1E
Geographic Reference	87 nautical miles east of Taipei, T
Movement	Northwest at 10 kts
Max Winds	60 kts gusting to 75 kts
Current Radius of Tropical Storm-Force Winds	74 nautical miles
Max Predicted Radius of Tropical Storm-Force Winds	78 nautical miles
Organizational Trend	Increasing
Forecast Confidence	Average
Estimated Central Pressure	990 mb

StormGeo Advisory 9

Our Forecast

Tropical Storm Hagupit continues to strengthen. It will pass north of Taiwan over the next few hours. We think it will b typhoon while passing to the north of Taiwan. Landfall is forecast to occur in eastern China late Monday as a strong t the center moves inland, it should quickly weaken to a remnant low pressure area. The primary concern will be heav flooding on the east side of the storm.

The heaviest squalls and strongest winds will be located on the north and east side of the track, so impacts across n Taiwan Strait should be minimal.

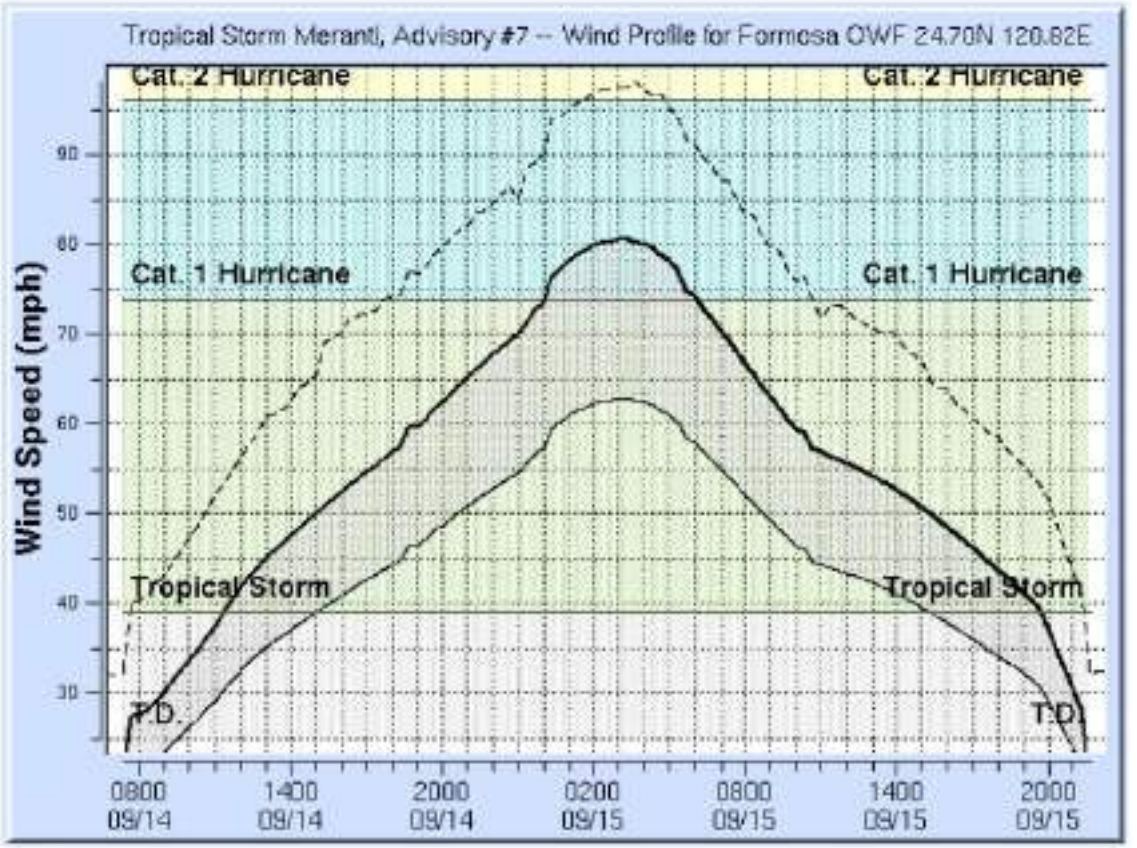
Our next advisory will be issued by 0300 UTC.

Meteorologist, Cameron Self

// Decision support 2/4

Site Forecast – details the effects of a storm at your site

- // Wind
- // Waves – *via coupling to metocean forecast*
- // Precipitation
- // Storm surge
- // Flooding



TROPICSWATCH

Tropical Storm Meranti, Advisory #7 Site Forecast for Formosa OWF, Formosa OWF 24.70N 120.82E

Valid: 11:00 PM CST 10 Sep, 2016

Discussion: Tropical Storm Meranti is expected to strengthen into a 140 mph typhoon before making landfall on southern Taiwan Wednesday. The highest winds and heaviest squalls will occur across central and southern Taiwan. Some heavy squalls and tropical storm force winds are possible across northern Taiwan on the current forecast track.

On our current track, the Hsinchu City would experience winds of 60-75 mph and isolated squalls with winds gusts to 90 mph on Wednesday. This would result in widespread power outages and minor damage to structures.

General Rainfall Amounts:
Rainfall totals may possibly reach the 4-6 inch range on our current track. This would result in widespread flooding of streets.

cted First Onset and Duration of Sustained Winds

ate / Time	Duration	End Date / Time
732 CST	37 hours, 56 minutes	15/2128 CST
114 CST	32 hours, 34 minutes	15/1948 CST
820 CST	16 hours, 17 minutes	15/1037 CST
359 CST	6 hours, 11 minutes	15/0611 CST

Point of Closest Approach of Center:
20 CST – 48 miles at Azimuth 260.0 degrees (SW)

Current Storm Distance and Direction

	Direction
	Azimuth 120 degrees (SE)

// Decision support 3/4

Trigger Report – ties in with your Emergency Response Plan

- // Issued as soon as new alert level reached
- // Explains what triggered new alert level
- // States expected time to next alert level

StormGeo
Control in a changing environment

TROPICSWATCH

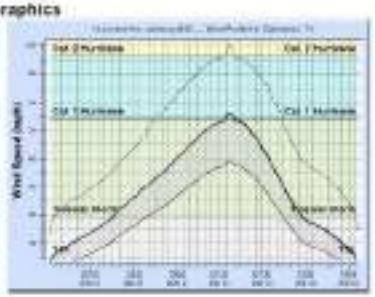
Site Triggers Report for Your Location – Hurricane Ike Adv. #38
Generated: Wednesday, September 10th 2008 4:47pm CDT

Current Conditions	
Location	24.4N/88.2W
Movement	WNW @ 8 mph
RPA Status	Positive
Winds	100mph
Current HSI	20 (12/8)
Current Indicated Phase	Preparation

Forecast Conditions	
Max Forecast Winds	135mph
Max Forecast HSI	32 (17/16)
Hrs to Next Trigger Point	6hrs
Estimated Next Phase	Evacuation
	10:45pm Wed Sep 10th

Forecast Track, Scope of Winds & Wind Profile Graphics





Note: Hours remaining is calculated from the time the report was generated

Wind Field Forecast and Worst-Case Arrival Times at Your Location

	Forecast ETA			Worst-Case ETA		Probability of Wind Impact	
Wind Field	Hrs. Until Arrival	Arrival Time/Date	Duration	Hrs. Until Arrival	Arrival Time/Date	Value	Trend
39mph	42	12th 9:32am CDT	27hrs 39min	35	12th 2:35am CDT	70%	+11%
58mph	50	12th 5:57pm CDT	14hrs 28min	42	12th 9:59am CDT	49%	+9%

Response Decision Guidance: If Max Forecast HSI > 25, consider accelerating response actions

Phase	Trigger Parameter	Trigger Reached?	Estimated Hours Remaining and Time When Next Will be Reached
1	RPA+	Yes	-
Awareness	WCS39 < 72hrs and PWI58 > 20%	Yes	-
Stand-by	WCS39 < 60hrs and PWI58 > 25%	Yes	-
Decision	FTA39 < 48hrs and PWI58 > 30%	Yes	-
Preparation	FTA39 < 45hrs and PWI58 > 30%	Yes	
Evacuation	FTA39 < 36hrs	No	6hrs 10:45pm Wed Sep 10th
Post Event	Sustained winds fall below 39mph	No	69hrs 1pm Sat Sep 13th

Forecast and Worst-Case Arrival Times at Your Location

ETA		Worst-Case ETA		Probability of Wind Impact	
Date	Duration	Hrs. Until Arrival	Arrival Time/Date	Value	Trend
CDT	27hrs 39min	35	12th 2:35am CDT	70%	+11%
CDT	14hrs 28min	42	12th 9:59am CDT	49%	+9%

nce: If Max Forecast HSI > 25, consider accelerating response actions

Parameter	Trigger Reached?	Estimated Hours Remaining and Time When Next Will be Reached
PA+	Yes	-
and PWI58 > 20%	Yes	-
and PWI58 > 25%	Yes	-
and PWI58 > 30%	Yes	-
and PWI58 > 30%	Yes	
< 36hrs	No	6hrs 10:45pm Wed Sep 10th
s fall below 39mph	No	69hrs 1pm Sat Sep 13th

Predicted Conditions for Your Facility

ide of Ike's track may average in the 5-10 inch range, with some areas receiving as much as 10-15
Saturday afternoon.
within about 1-2 hours of the center crossing the coast early Saturday morning. The surge will extend
as coast for 60-80 miles. If Ike strikes in the Matagorda Bay area, then the surge at the beach between
reach 9-12 feet, and up to 14-16 feet in northern Matagorda Bay. If Ike strikes just west of Freeport as
port area could reach 12-16 feet. A strike near Freeport could put a surge of 18-25 feet into Galveston

General	30 miles southwest of Freeport Texas early Saturday morning as a borderline Category 3-4 hurricane. Once inland, Ike should turn northward and begin to accelerate off to the north and northeast on Saturday afternoon and Sunday.

// Decision support 4/4

StormGeo
Freedom to Perform

Our TropicsWatch team is there for you

- // Call or email anytime 24/7/365 to discuss potential threats to your assets or operations
- // Schedule a conference call with one of our specialists

// Concluding remarks

// Tropical cyclones can affect offshore wind farm assets and operations severely

// Detailed and accurate weather forecasting essential for managing the risks

// StormGeo's Advisories provide detailed guidance up to 7 days ahead

// Site Forecasts and Trigger Reports enable rational decision making before and during storms

// 24/7 hotline to TropicsWatch team ensures optimal expert support throughout event

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Forecast Manager (MENA & Asia Pacific)
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Anna Hilden
Meteorologist M.Sc.
Global Industry Manager Offshore Wind
anna.hilden@stormgeo.com

// Thank you!

Best chance of above-normal impacts into Japan/Korea and farther south through the Philippines to Vietnam

StormGeo
Freedom to Perform

30-yr Average

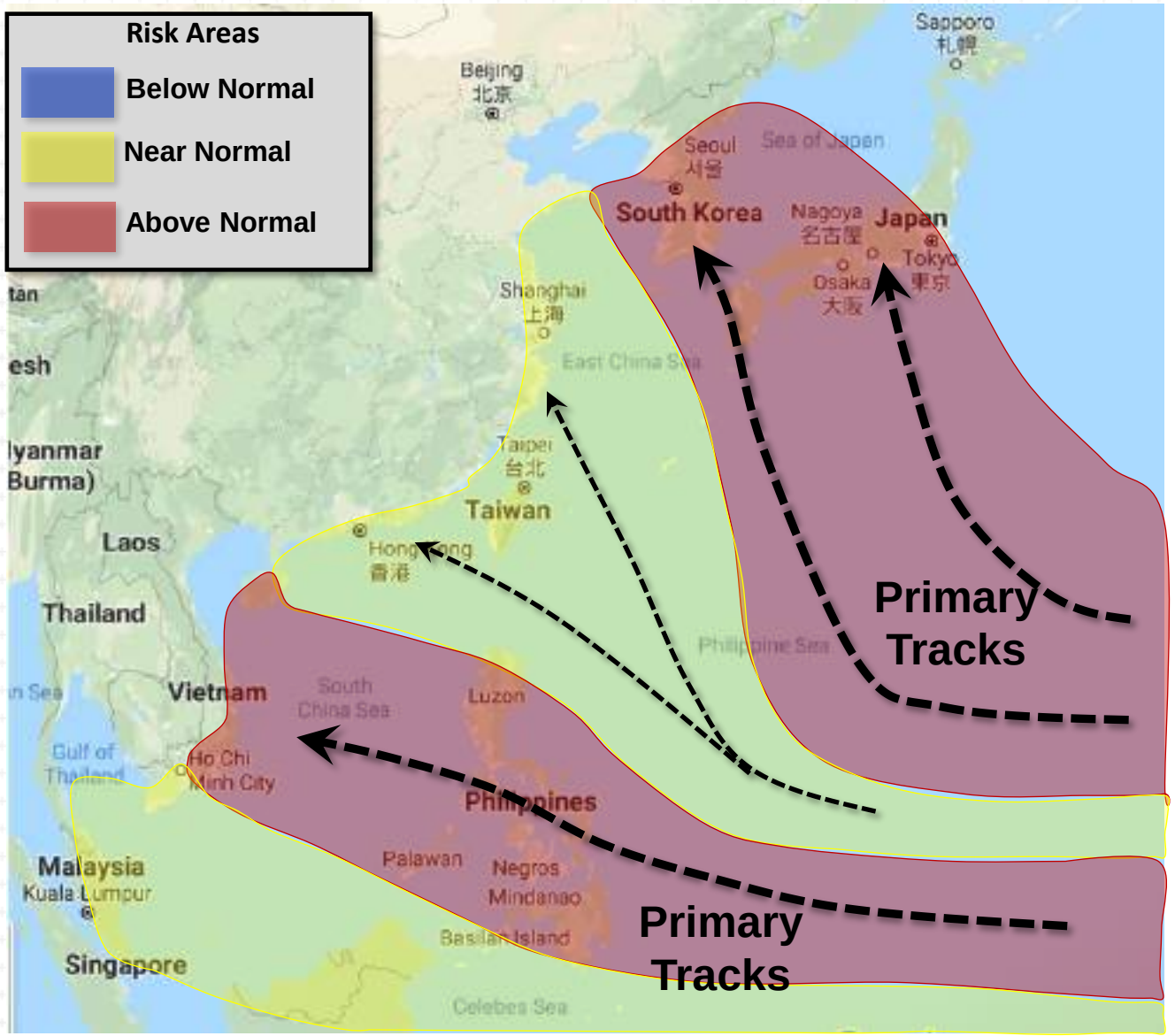
26 Named Storms

13 Typhoons

2020 Forecast

28 Named Storms (+)

15 Typhoons (+)



Safer and more efficient wind farms with advanced weather analytics

StormGeo
Navigating tomorrow - today

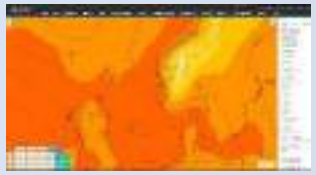
Gard Hauge, PhD
CTO StormGeo

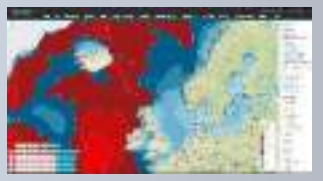
Dr Nina Winther-Kaland, PhD
Research Director StormGeo

StormGeo has more than 20 years of experience in handling of complex big data optimized for advanced decision support

StormGeo
Navigating tomorrow - today

Observations → Global scale models → Regional models → 24-7 Operations → Visualization

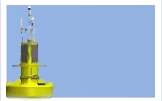




Global and local


3rd Party data


Synop


Buoy


Aircraft


Vessel data


Radar

Data Engineering and processing

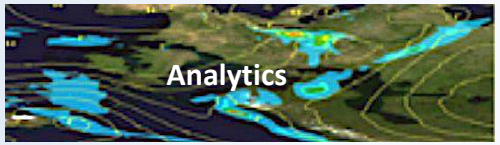
Level 1 models (StormGeo Predictions)

9-25 km resolution	0.1-9 km resolution
ECMWF	WRF, SWAN
GFS FOAM NORKYST TOPAS	

Level 2 models (StormGeo ML / AI)

- Deep Learning Forecast Improvemetns
- Vessel analytics and performance
- Response modelling
- Environmental impact modelling

Interaction and Customer Engagements




Production/ Delivery Systems

---- INFRASTRUCTURE & DATA ARCHITECTURE ----

Products & Services

SHIPPING

OCEAN

ENERGY MARKETS

TERRA

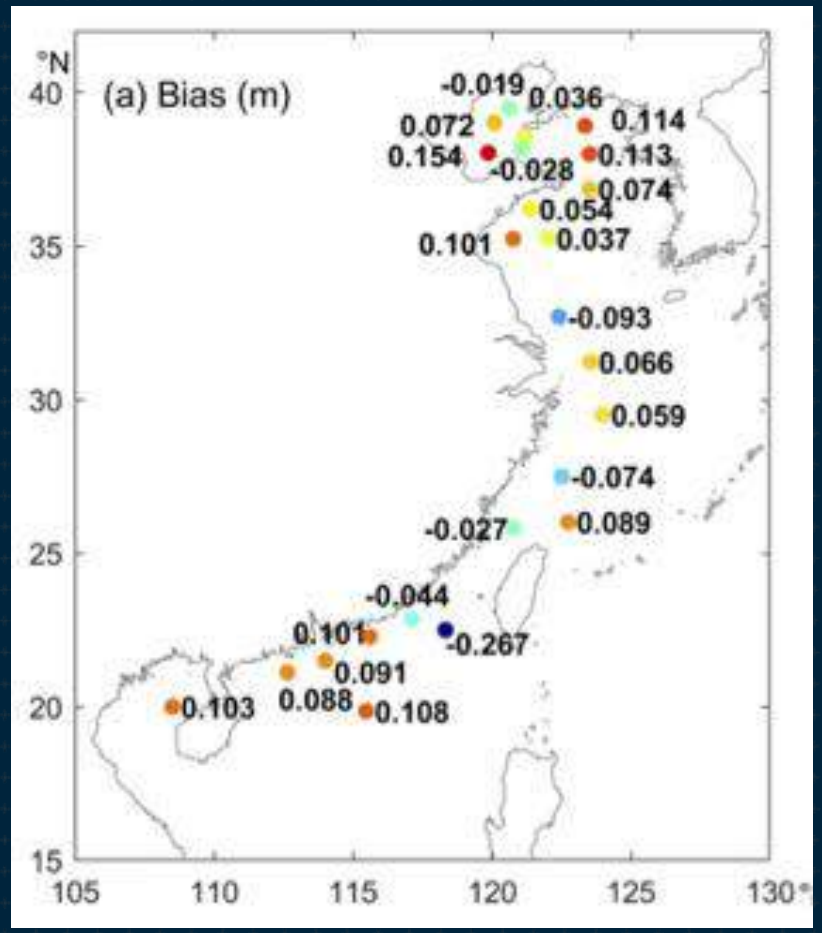
MEDIA

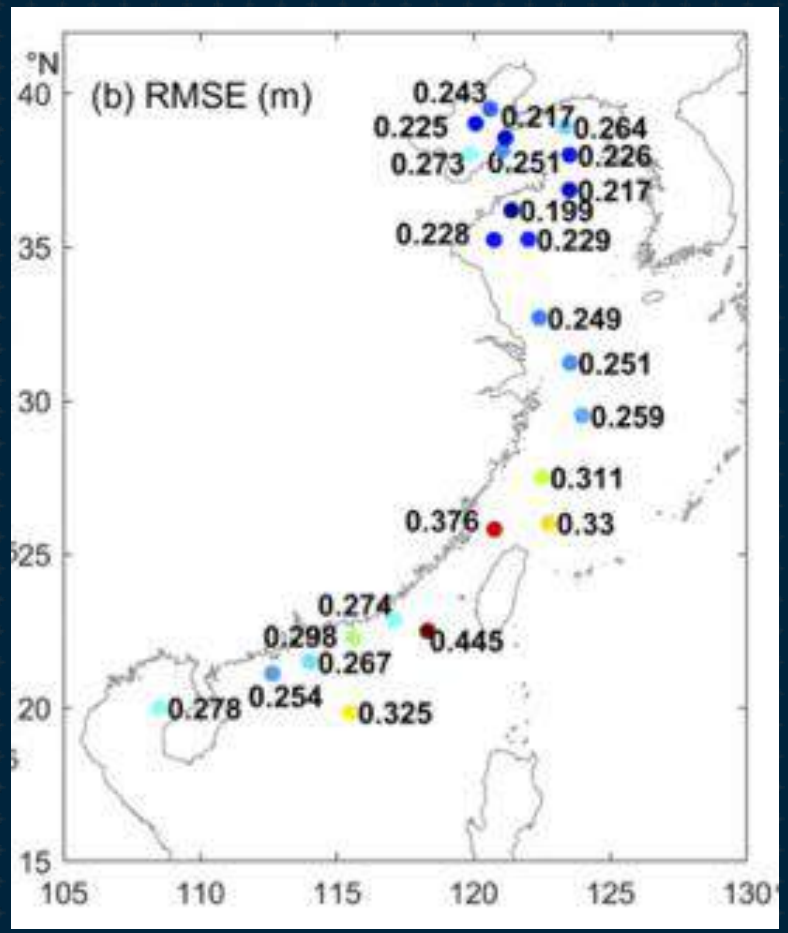
Weather Insights

Performance of global wave model

Global scale ECMWF model has quality challenges in the Taiwan strait

StormGeo
Navigating tomorrow - today





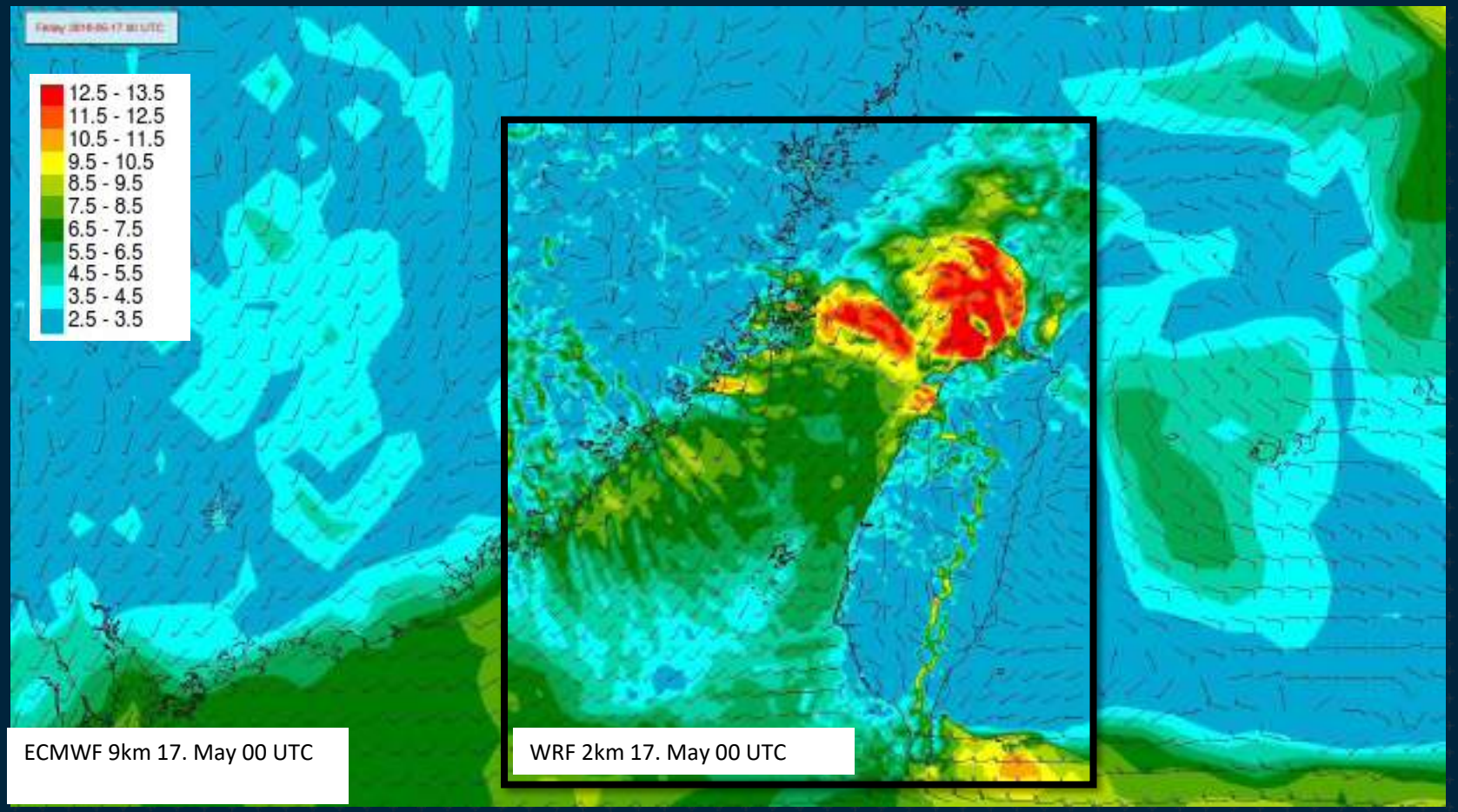
Forecasting quality is challenged by

- the complex sea state generated by two seasonal monsoons with prevailing wind directions from northeast and southwest depending on season. A mix of wind sea and swell systems, contributing to a wide range of wave ages from very young waves to mature waves.
- AND, lack of observations in the area to calibrate the models

Wang et al. 2019: Comparison of ECMWF significant wave height forecast in the China sea with buoy data

WRF improves accuracy and skill on short term wind predictions

StormGeo
Navigating tomorrow - today



- Boundary and initial conditions from ECMWF operational global forecast
- 36 vertical levels
- Hourly model output

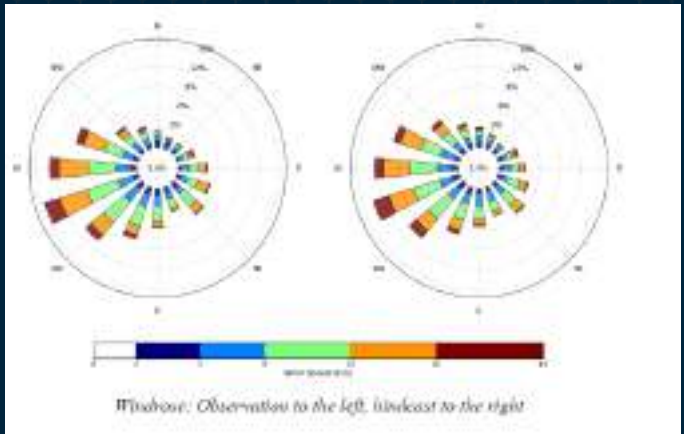
// Finescale hindcast modelling

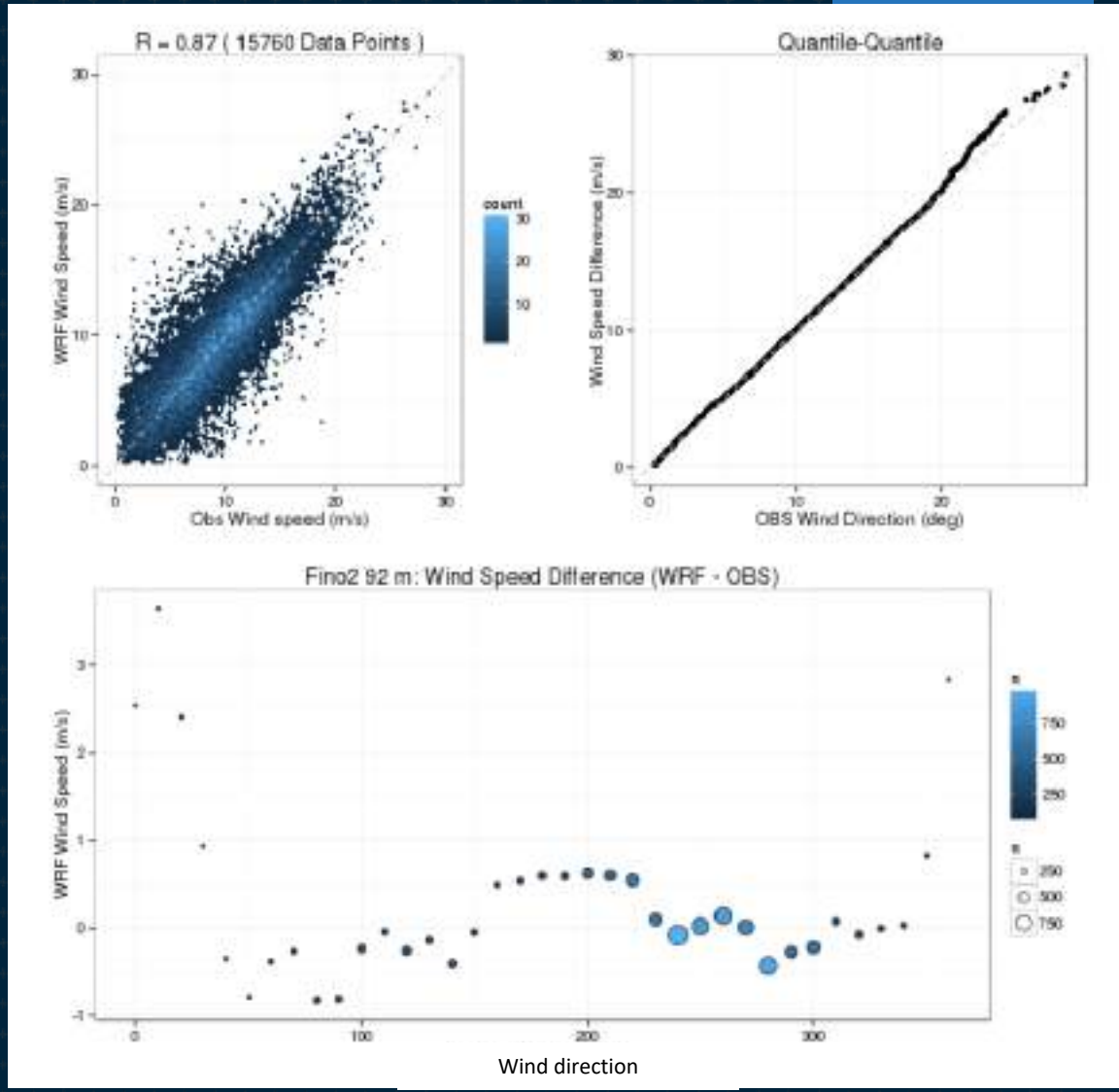
StormGeo
Navigating tomorrow - today

***StormGeo* - modelling experts since 2003**

- Dedicated in-house modelling specialists
- Hybrid Infrastructure (in-house + cloud) - scalable
- Global coverage
- 1-5 km resolution (typically)
- Independently validated by 3rd-party experts

World-class data for wind resource screening and assessment





WRF 1 km vs FINO2 92 m, 2 years of data

// Data Science in StormGeo

StormGeo
Navigating tomorrow - today

Public & Private | **Processing, Cleaning and Integration** | **Interaction and Customer Engagements**

3rd Party data

Synop

Buoy

Aircraft

Ship data

Radar

DeepStorm

Data Lake

Data Engineering

Ingestion

Cleaning of Data & Quality control

Integration

Public Data Sources

Private Data sources

UNSUPERVISED LEARNING

SUPERVISED LEARNING

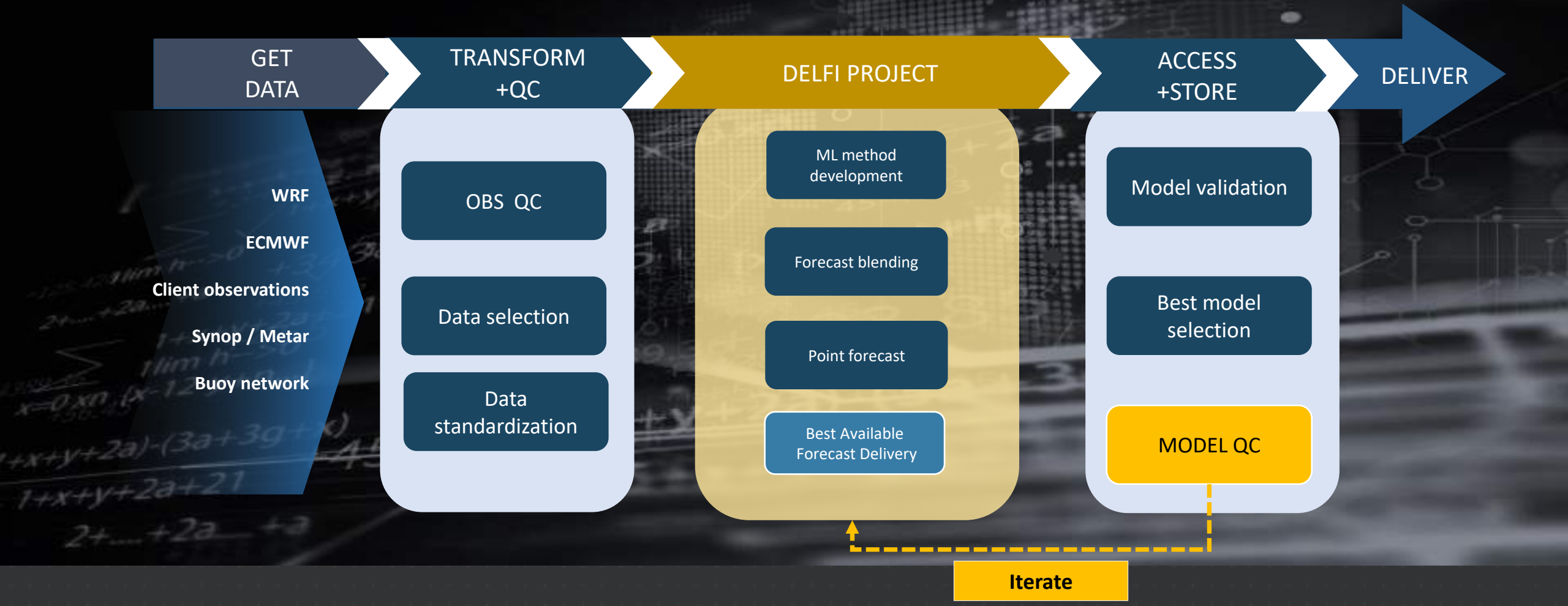
MACHINE LEARNING

REINFORMCEMENT LEARNING

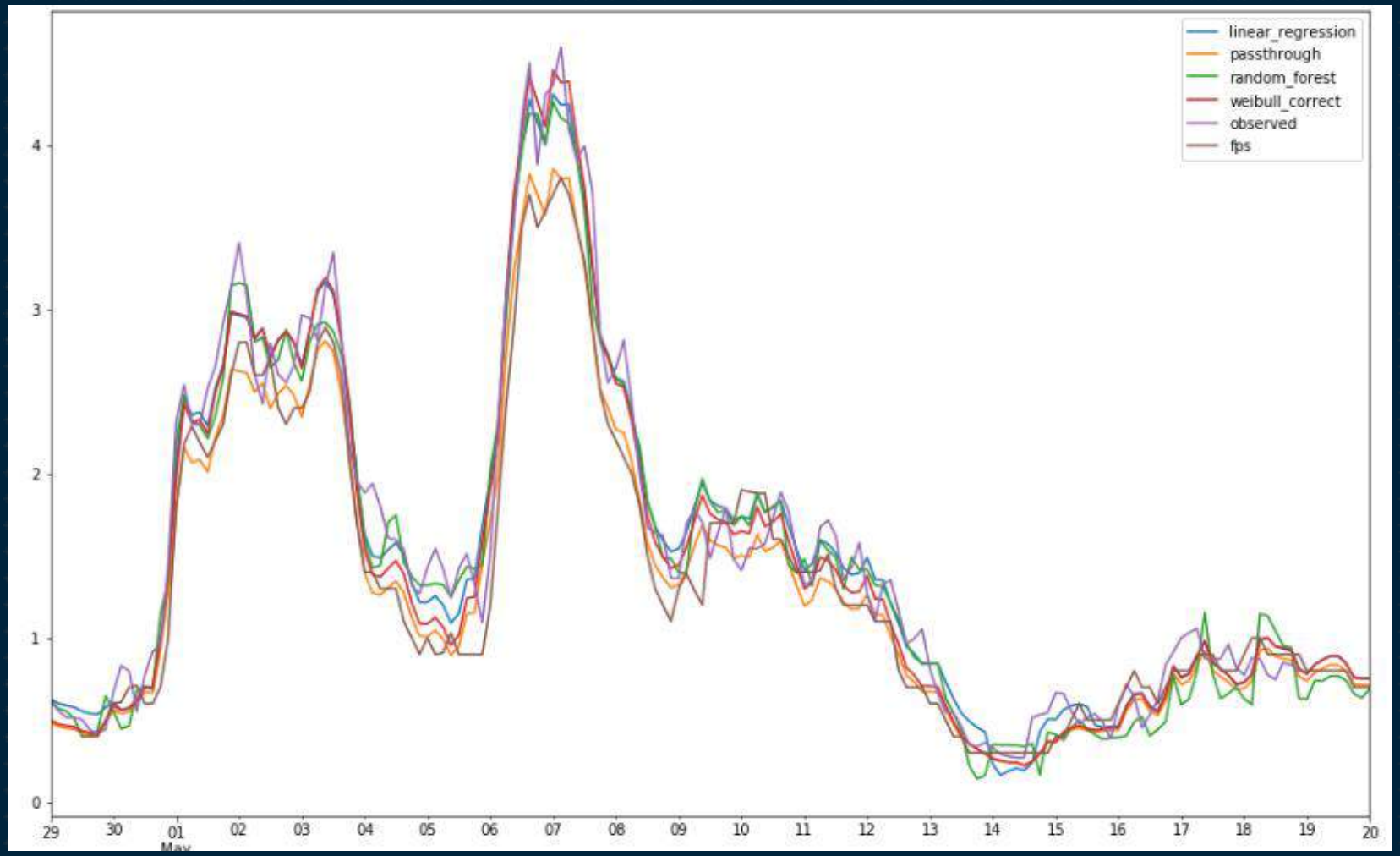
- Data and how you connect your data to internal and external sources is critical for success
- Data science is a team effort that requires different skillsets across the team for successful algorithm development.
- 80 % to 90 % of is spent gathering and cleaning the data NOT building algorithms and models. Revising system to improve this.

DEep Learning Foredasting Improvements – DELFI
a ML framework to improve predictive skill

StormGeo
Navigating tomorrow - today



Changhua location – test of different ML approaches



StormGeo base forecast

ME	0.21
MAE	0.23

Linear regression

ME	0.01
MAE	0.14

Random forrest

ME	0.05
MAE	0.17

Weibull correction

ME	0.06
MAE	0.15

Training data: 20.11.2018 - 20.04.2019
Test data: 29.04.2019 - 20.05.2019

Forecast improvement using ML for 100 meter winds

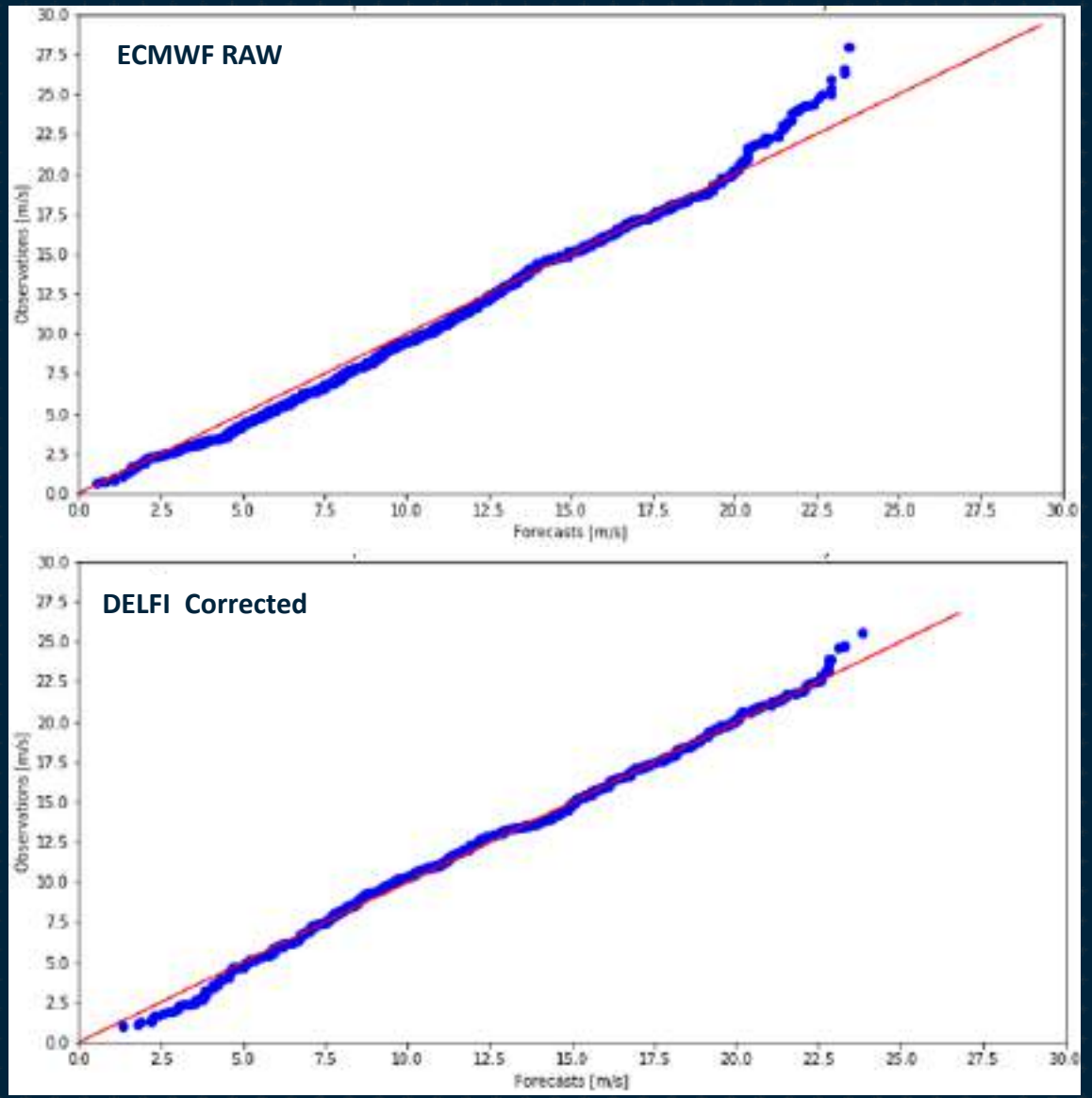
StormGeo
Navigating tomorrow - today

SET-UP:

- Based on wind turbine observations and ECMWF hourly, 0.1˚ forecasts
- Inputs 2-m temperature and 10-m and 100-m zonal and meridional wind speeds and directions to
  output 90-m and 99-m wind speeds

RESULTS:

- Weibull correction improved the upper level winds forecast even with limited observations available

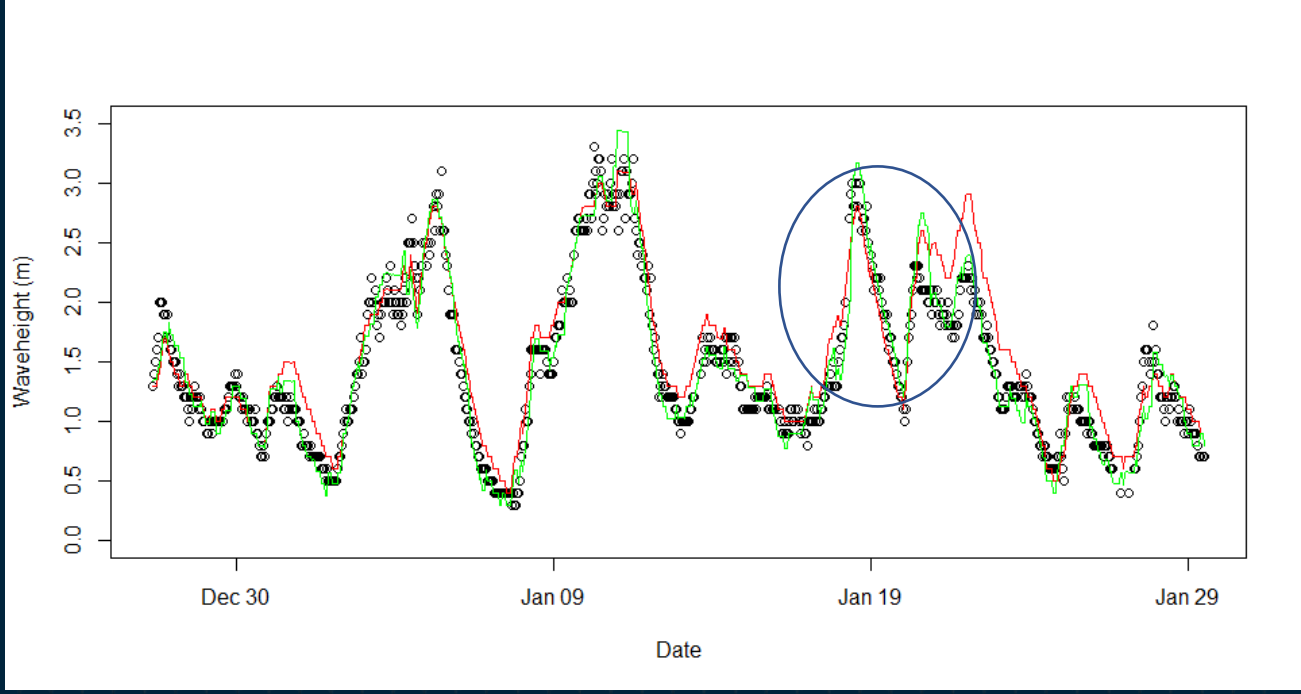


More advanced models reduces errors more that simple models if suficcient observations are available

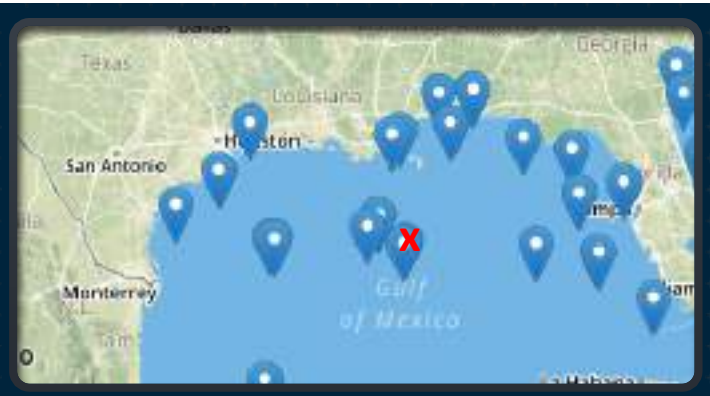
StormGeo
Navigating tomorrow - today

- The graph shows the improvements that can be achieved for one particular location by taking the persistence of model-errors into account.

- This is an ARIMA model, and the improvement in MAE compared to raw EC is about 25%, while the improvement of linear regression for this location was < 10%.



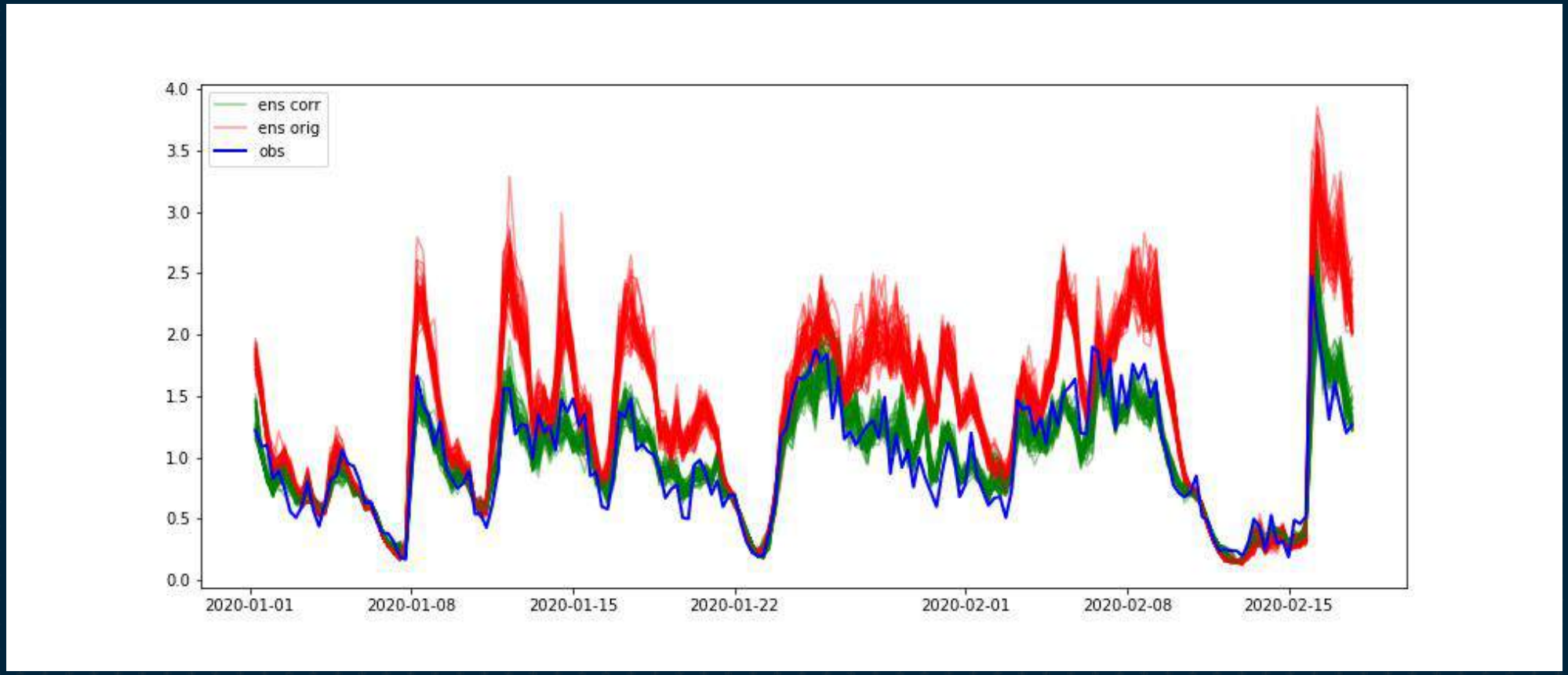
Obs – black
EC raw model – red
DELFI ARIMA - green



ENSEMBLE FORECAST to account for uncertainty

ML approach to bias correct individual ensemble members

StormGeo
Navigating tomorrow - today



Calibration of ensemble allows for better estimation of uncertainties during critical operations

Summary

StormGeo
Navigating tomorrow - today

- Observations are key to improve forecast quality
- StormGeo forecast system consist of a mix of global models, local area models and machine learning methods
- Knowledge about our clients operating limits is of high importance

Asia Wind Energy Association

IN PARTNERSHIP WITH

StormGeo

AWEA WEBINAR SERIES 2020 - TECHNICAL SESSION

Managing Weather Risks for Offshore Wind Projects in Asia-Pacific

Q & A Session

Question 1

What is your forecast for typhoons for the rest of the year?

Question 2

Are developers in Asia-Pacific aware of the weather risks?

Question 3

Have you already seen weather related damages in Asia-Pacific?

Question 4

Do you expect typhoon intensity to increase due to climate change?

Question 5

Does ENSO have any direct relation with predicting a cyclone/ typhoon? For example, for an El Nino year can we expect more cyclones in a region?

Question 6

Out of the four main offshore wind markets (China, Taiwan, Japan and South Korea) which is the most affected by weather related issues?

Question 7

When do you (Stormgeo) typically get engaged by wind farm developers / operators? (Pre-construction, during construction, after commissioning)?

Question 8

Do you have a view on weather conditions for upcoming offshore wind developments in Vietnam and Australia?

Question 9

How do you combine your great know-how with earthquake (Tsunami) risks?

Question 10

Could the Site Forecast service be used to assist generate a financial model acceptable to Lenders ?

Question 11

Do you (Stormgeo) have a public online tools to evaluate the project site belongs to storm surge or typhoon or other natural perils?

Question 12

Do you see weather events hindering the development of the offshore wind industry in APAC?


Asia Wind
Energy Association
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AWEA WEBINAR SERIES 2020 - TECHNICAL SESSION
Managing Weather Risks for Offshore Wind Projects in Asia-Pacific

Closing

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Upcoming Webinars

Asia Wind Energy Association

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Managing Weather Risks for Offshore Wind Projects in Asia-Pacific

Thank You!