Impact-based Forecasting and Risk-based Warning of Typhoon-Induced Gale and Torrential Rainfall

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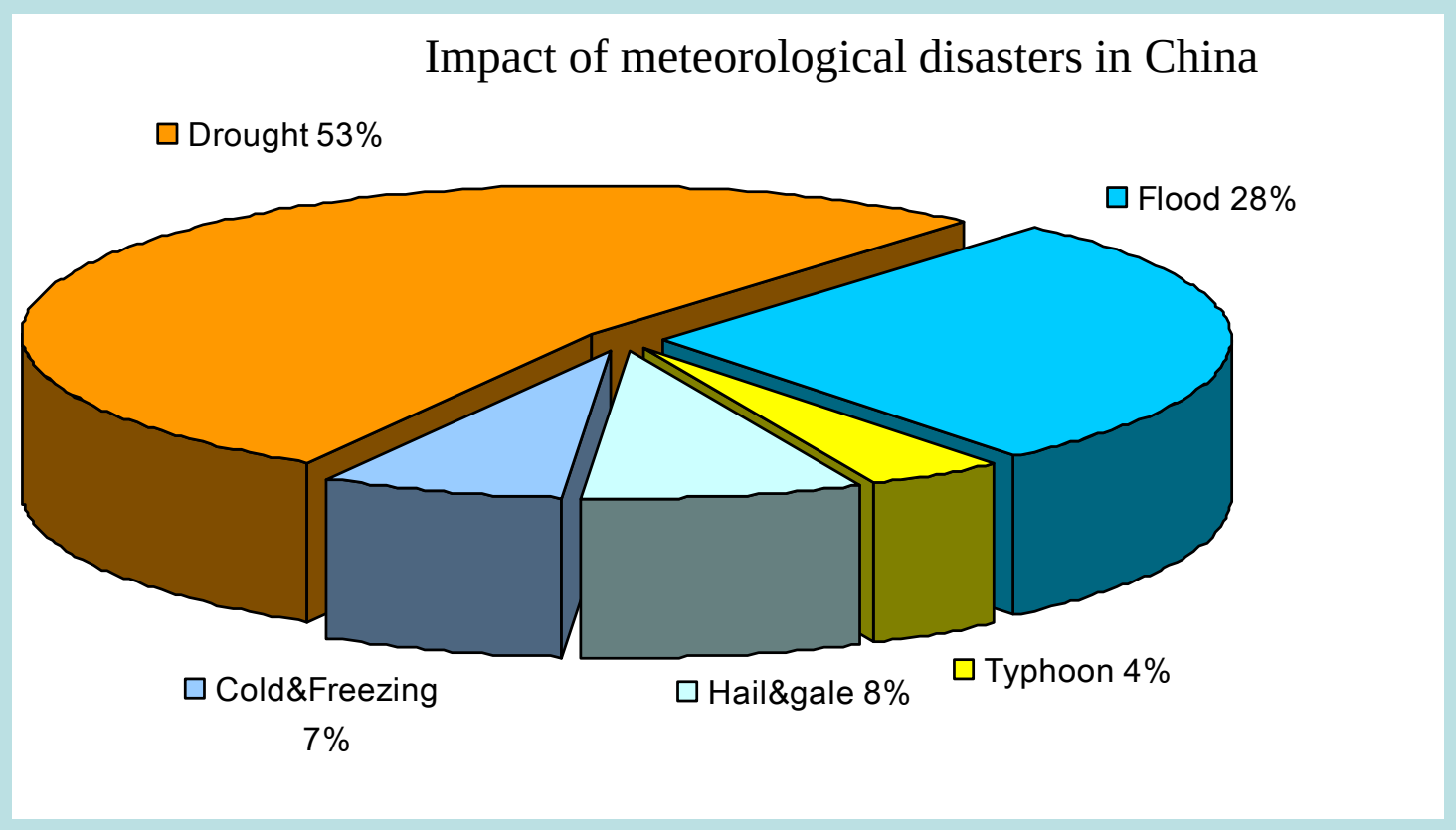
Contents

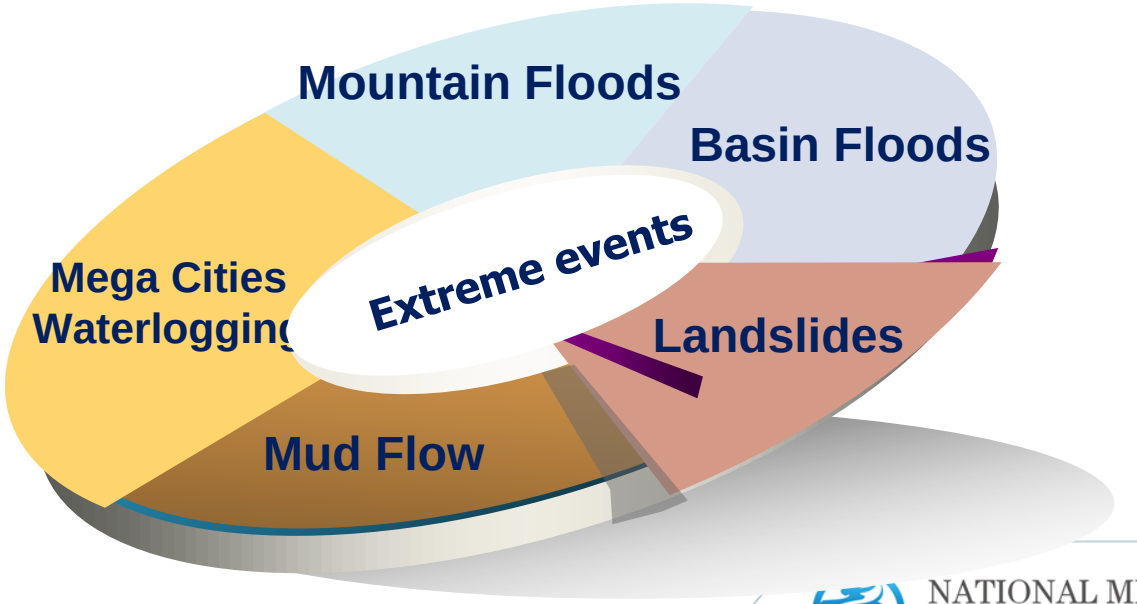
Characteristics of Typhoon Impact in China

Study on the factors of Typhoon disaster shows that the coefficient of factors for casualties is 0.59 by torrential rainfall and 0.75 by gale, while for the economic loss it is 0.71 by torrential rains and 0.62 by gale.



Increasing Risks of Meteorological Hazards

- **Rainstorm: River and mountain floods caused 2/3 of the total death toll related to meteorological hazards, and 70% or 80% of the total economic losses.**
- **Gale: Destroy the large public facilities, result in peoples' life loss and injury, bring troubles to traffics and communication, induce capsizing, and destroy crops and fruit trees.**



CMA Typhoon Track Forecast performance

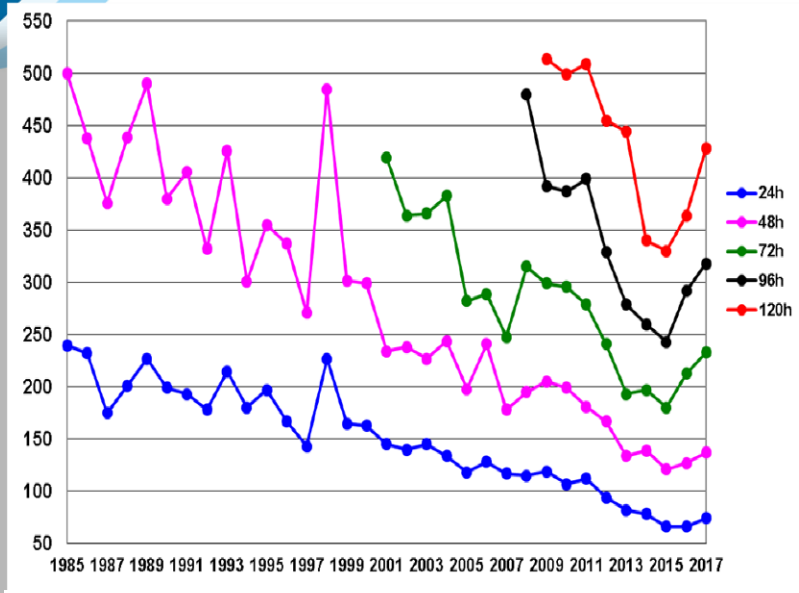


Fig1.24-120h typhoon track forecast errors for CMA

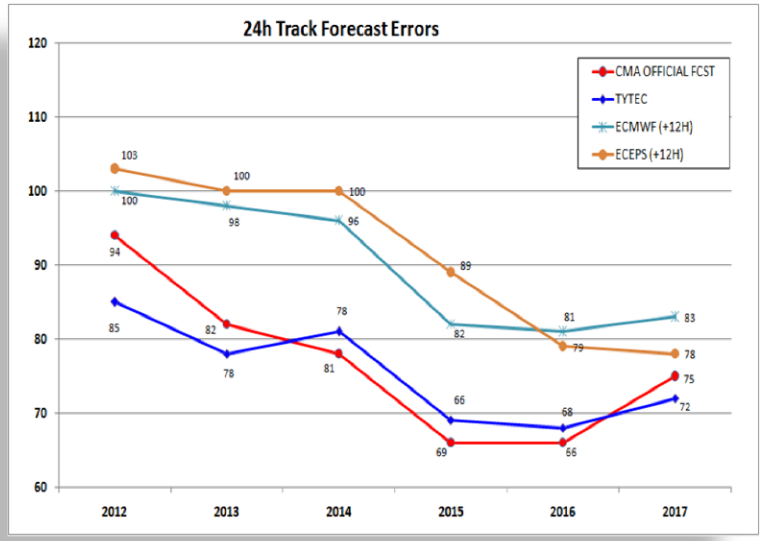


Fig2. 24h typhoon track forecast errors for TYTEC and ECMWF

Since 1985, CMA official typhoon track forecast errors for 24-120h decreases significantly. Typhoon track forecast errors for 24h is 50 percent less than 20 years ago.

TYTEC (Typhoon Track Ensemble Correction):

Principle: select some best-performance members based on the newest observation, the mean of the selected members is better than the ensemble mean.

Keys: The optimal selected members

How to determine the weights for different ensemble models.

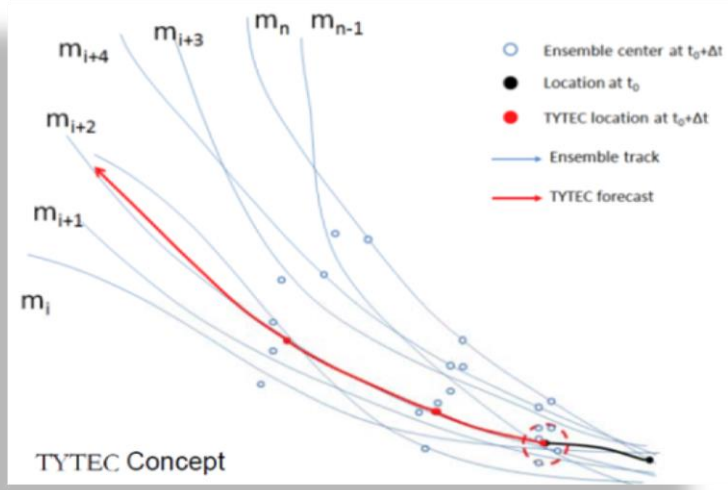


Fig3. TYTEC Concept forecasts developed by CMA forecasters.

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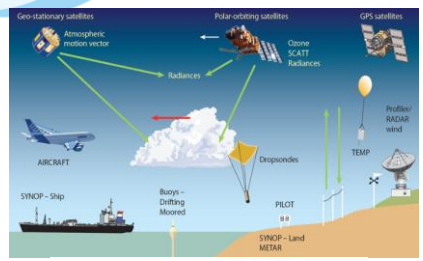
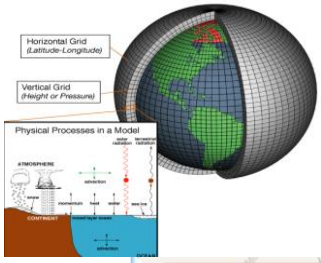
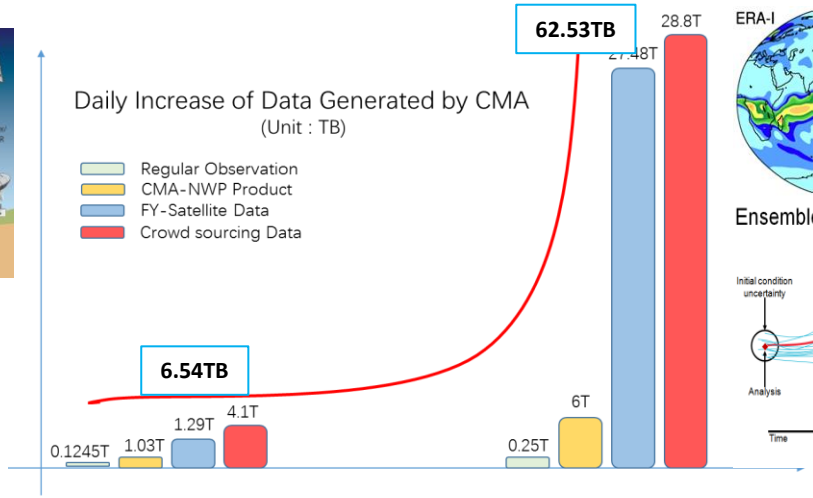
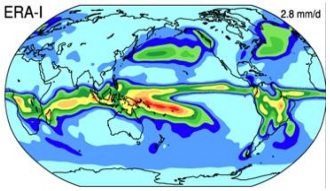
Smart-grid forecast

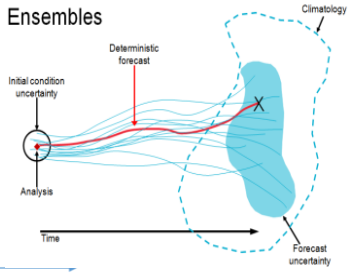
(5×5km domestic and 10 ×10km global (0-14days)

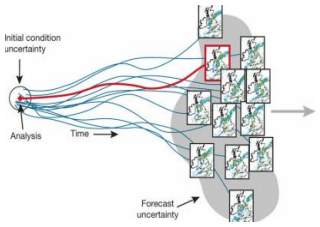


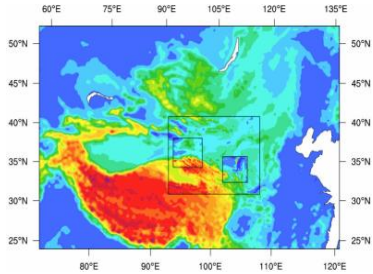






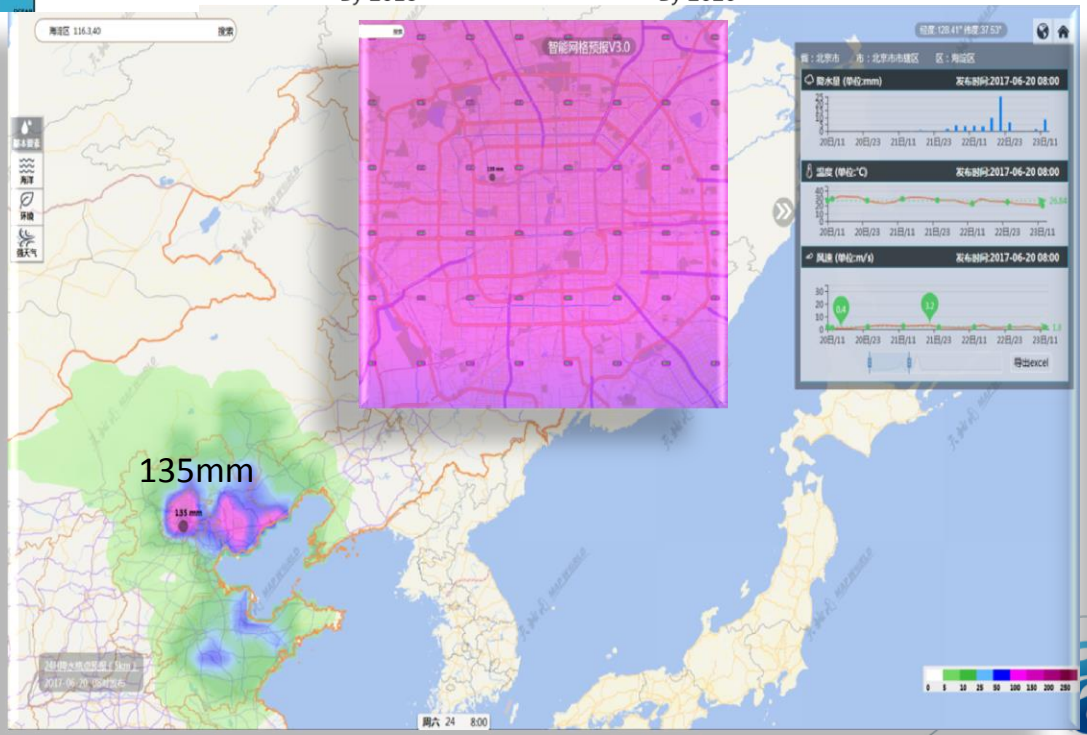






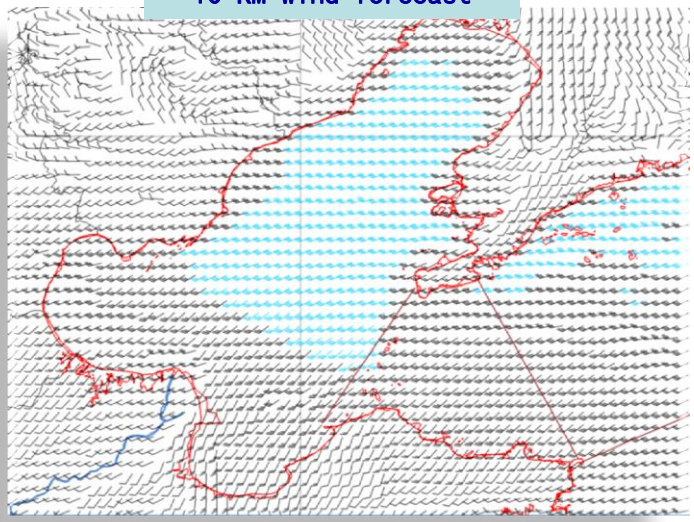
By 2015

By 2020

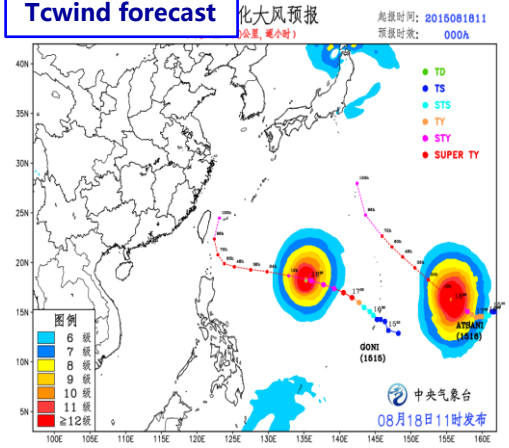


Developing smart-grid forecast of gust wind with 10KM resolution

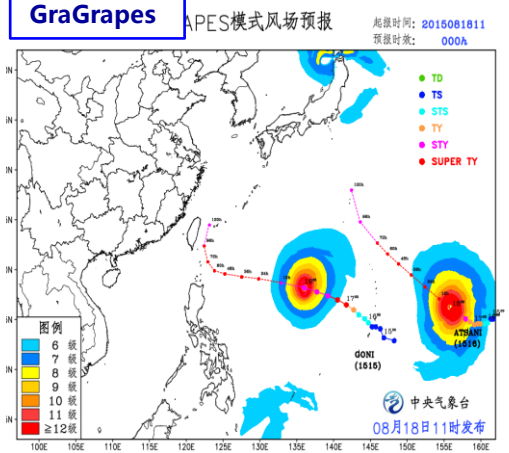
10 KM wind forecast



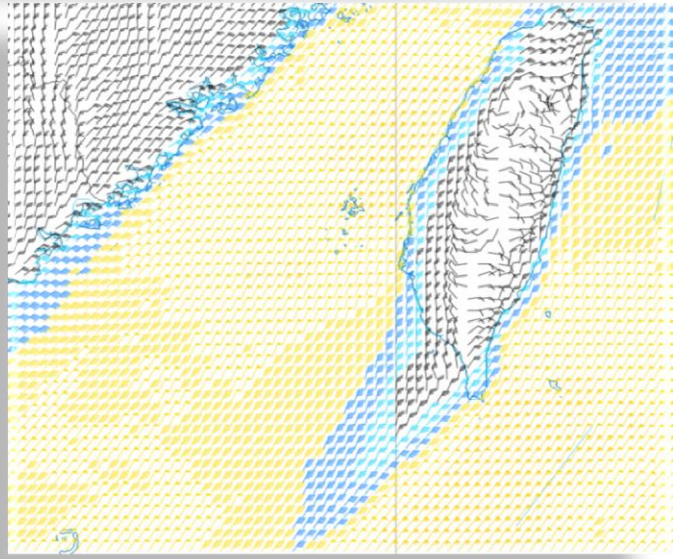
Tcwind forecast



GraGrapes



Tc wind and precipitation forecast technology



- Based on ocean observation and regression statistical methods, we have developed forecast-observation equations to make correction of model data, and to forecast winds with resolution of 10Km for the N Pacific and the N Indian Ocean

- Moving the typhoon intelligence in model forecast to the position of subjective forecast, the intensity of the mode typhoon was corrected to the same as the subjective strength forecast.

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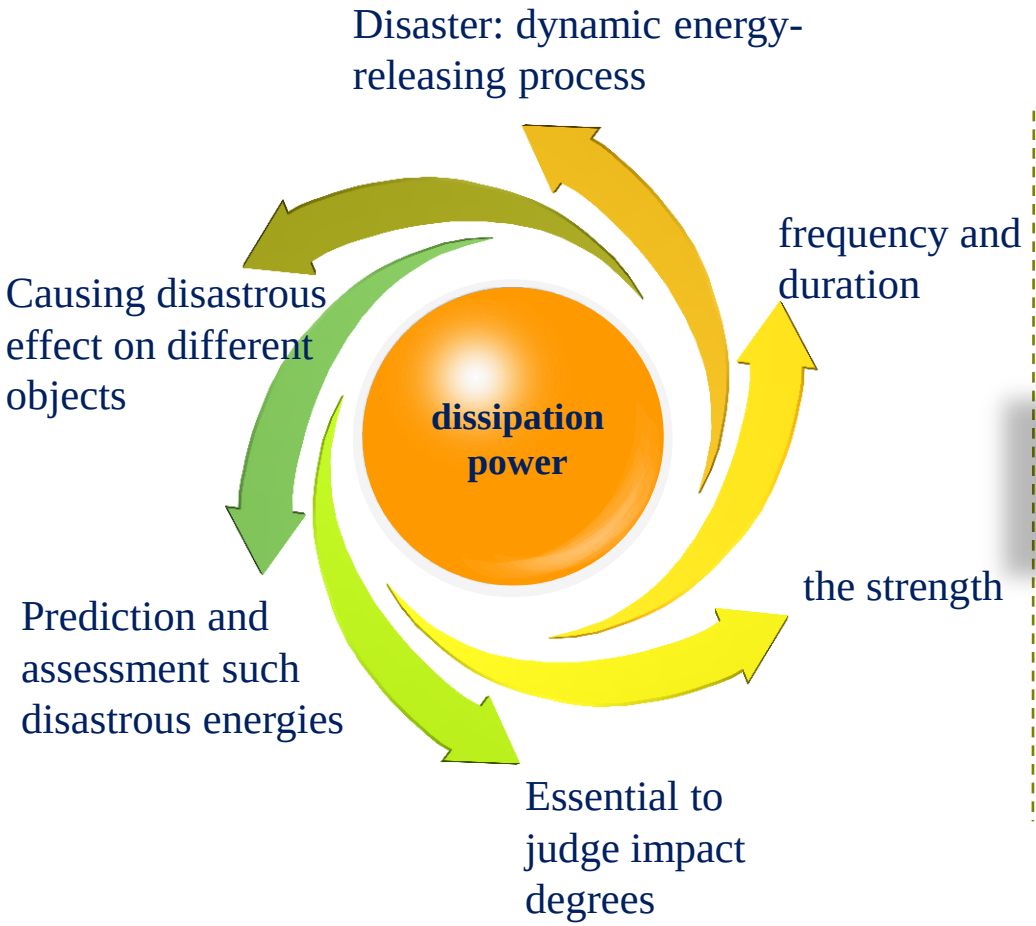
Contents

2.Study on collapsing force of typhoon

the Index of Potential destructiveness (PDI)



- Based on concept of dissipation power, Emanuel proposed the Index of Potential destructiveness (PDI)
- PDI considers the strength, frequency and duration of typhoon

$$PD = 2\pi \int_0^{\tau} \int_0^{r_0} C_D \rho |V|^3 r dr dt$$

- r is the radius of typhoon
- r_0 is the radius of typhoon outer boundary
- ρ is the air density
- C_D is surface drag coefficient
- V is wind speed.

Study on collapsing force of typhoon

$$\mathrm{PD} = 2\pi \int_0^{\tau} \int_0^{r_0} C_{\mathrm{D}} \rho |\mathrm{V}|^3 r \mathrm{d}r \mathrm{d}t$$

If ρ and C_D are constants in different tropical cyclones, the main contribution to *PD* is from the maximum wind speed circle. Potential damage capability of tropical cyclones can be simply expressed by PDI (Power Dissipation Index):

$$\mathrm{PDI} = \int_0^{\tau} V_{\max}^3 \mathrm{d}t$$

where $V_{\max}$ represents maximum wind speed near the typhoon centre,τ is the duration of tropical cyclone.

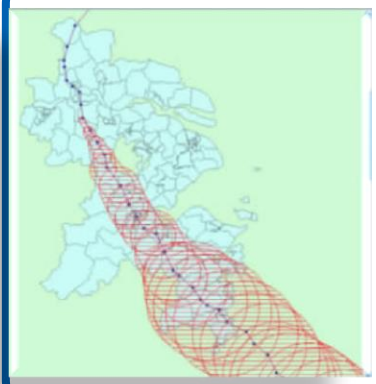
Impact-based assessment process to collapsing force of typhoon

Track, intensity Duration,Vmax circle

instantaneous dissipation kinetic energy

Risk level

Intensity



Energy

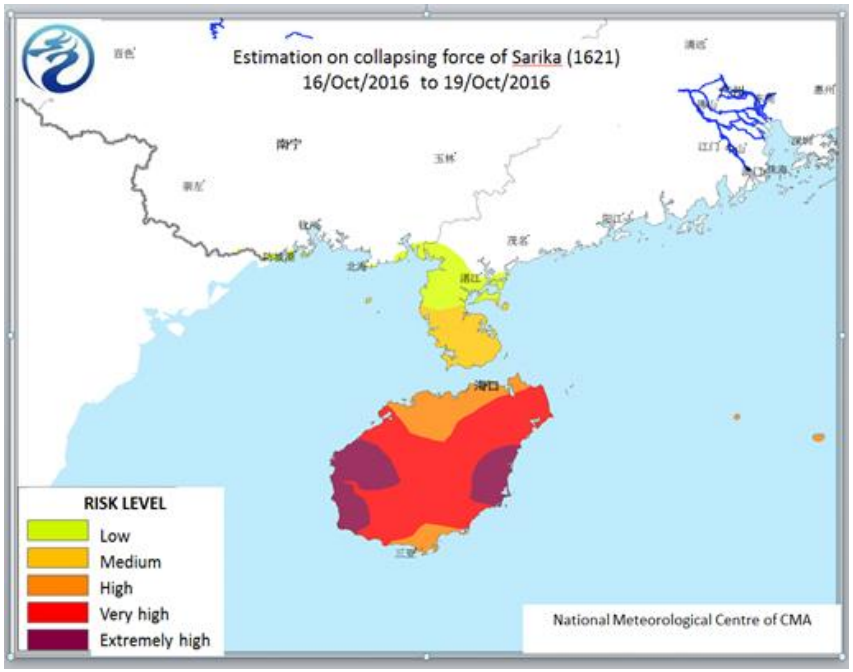
- hourly wind from Grapes-TYM and Tcwind
- Characteristics of the disaster-bearing body
- Output daily grided collapsing force of typhoon gale

Risk

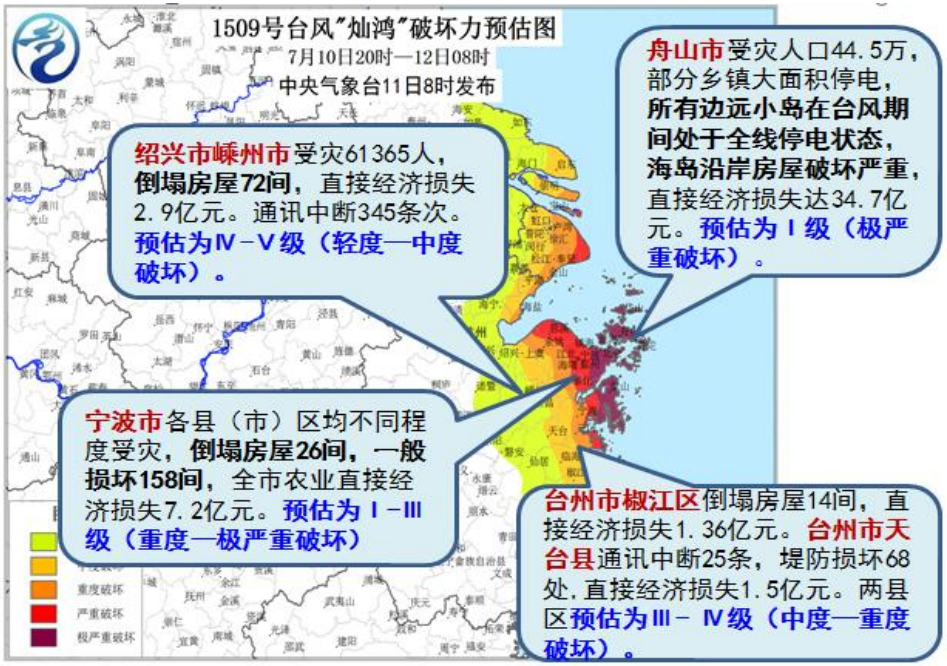
- Extremely
- Very serious
- Serious
- Medium
- Low

Impact-based forecast verification

- Cases verification from 2015 to 2016 showed that the house could be collapsed or damaged when risk of collapsing force in coastal area reached degree of extremely serious, very serious or serious.
- As a comprehensive index,the collapsing force of typhoon gale can destroy the large public facilities, result in peoples' life loss and injury, bring troubles to traffics and communication, induce capsizing, and destroy crops and fruit trees.



Estimation verification on collapsing force of Sarika (1621)



Estimation verification on collapsing force of CHAN-HOM (1509)

Contents

3.Impact of typhoon on low-rise buildings

The correlation coefficient between number of building's collapse and the deaths is 0.8 or more.

In free flow

Closed House

a house on the windward side

a house on the leeward side

eddy effect

The force diagram of the house under various conditions of Typhoon

- Influenced by eddy effect of air pressure, the windward wall suffering great air pressure will lead to house sharply shaking.
- The upright air flowing over the roof of the house cause suction power, also along side and leeward walls will be impacted by suction power.

3.Impact of typhoon on low-rise buildings

a.Study of method

The accumulated wind pressure can be got from the following formula:

$$AWP = \int_0^{\tau} \frac{V_{\max}^2}{2\rho} dt$$

$V_{\max}^2$ indicates the hourly instantaneous maximum wind speed.

τ means impact duration of typhoon.

ρ is air density.

$$\rho = \frac{P}{R_d T}(1 - 0.378 \times 0.622 \times q)$$

The accumulated wind pressure can reflect the strength of strong wind force and its impact duration

3.Impact of typhoon on low-rise buildings

Questions : how much of the wind pressure can lead to house collapsing and how strong is the acting force that can cause the risk for load-bearing walls of low-rise buildings?

b. Algorithm of designing wind load of main walls

When calculating the main stressed structure, the characteristic value of wind load can be expressed by:

$$W_k = \beta_{gz} \mu_s \mu_z W_0$$

The formula is derived from the *Specifications of Building Structural Load of China* (GB 50009-2012))

β_{gz} is coefficient of instantaneous wind at the height of Z

μ_z is variation coefficient of wind pressure by height

W_0 is basic wind pressure (kN/m^2)(V_{max} of 10 min for 50 year frequency)

μ_s is shape coefficients of wind load

β_{gz} μ_z can be get from ground roughness table.

Design wind load of main walls: $\varpi = r_w W_k$

r_w is partial coefficient for the loads which takes 1.3 in case of standard value more than 4kN/m^2 and takes 1.4 in other conditions.

This is cited from the *Specification of Building Structural Load of China* (GB 50009-2012).

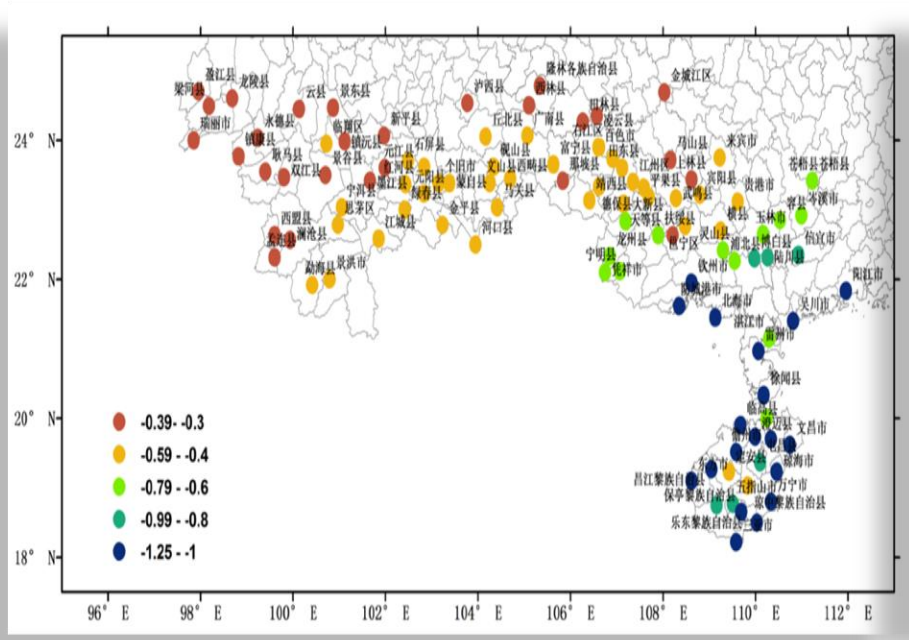


Fig1.Distribution of designed wind load of main walls (kN/m^2)

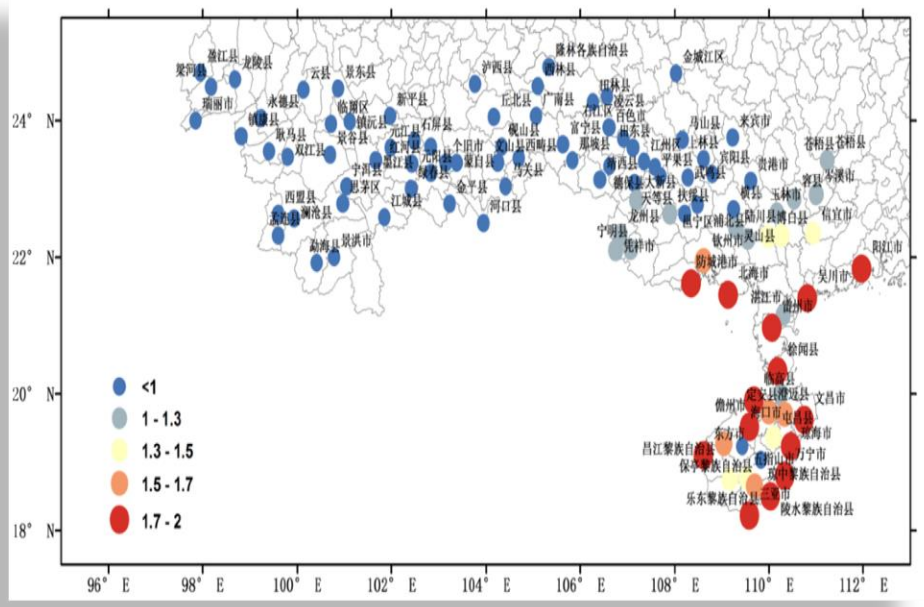
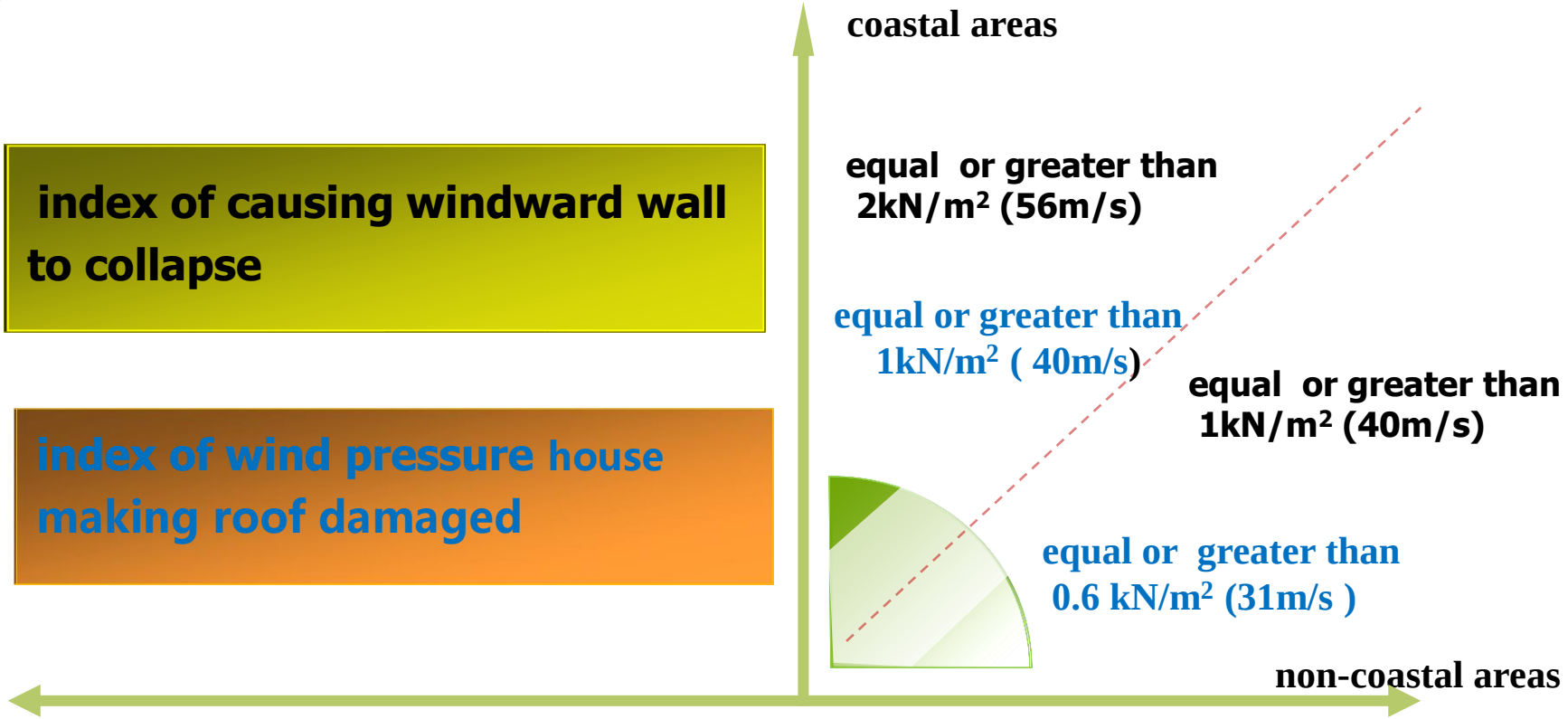


Fig2.Distribution of designed wind load of windward wall (kN/m^2)

index of causing windward wall to collapse

index of wind pressure house making roof damaged



The calculation results show that the typhoon gale can make house roof damaged and windward wall to collapse

3.Impact of typhoon on low-rise buildings

b. Damage index of typhoon gale for low-rise buildings

The damage index for low-rise building is derived from *CDI*, which is calculated by:

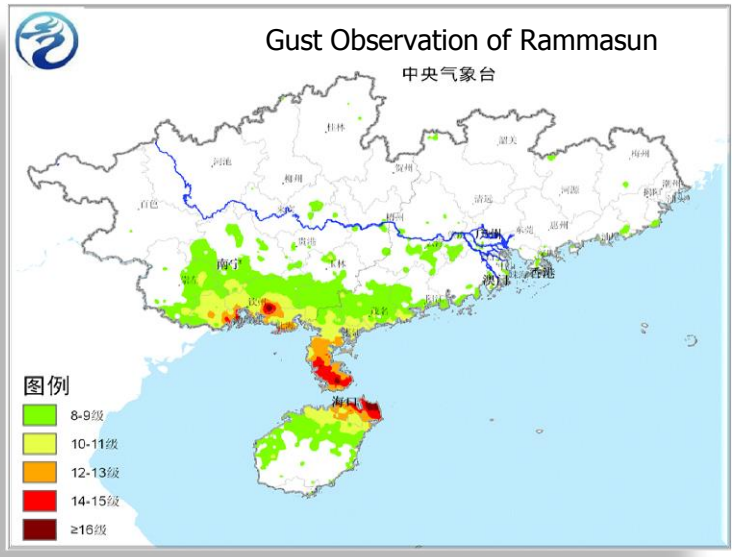
$$CDI = \int_0^{\tau} (wp - |\varpi|)\ dt$$

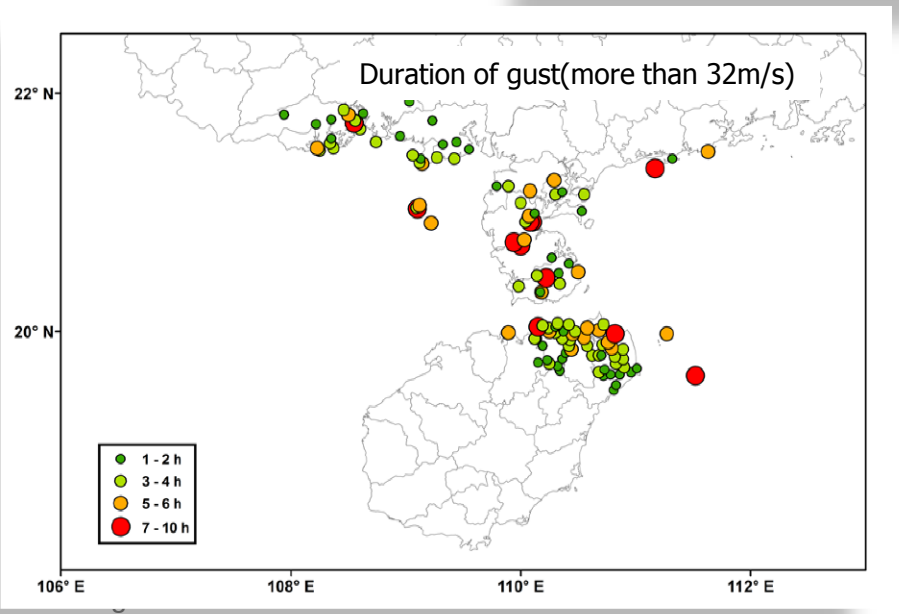
$$(wp - |\varpi|) > 0$$

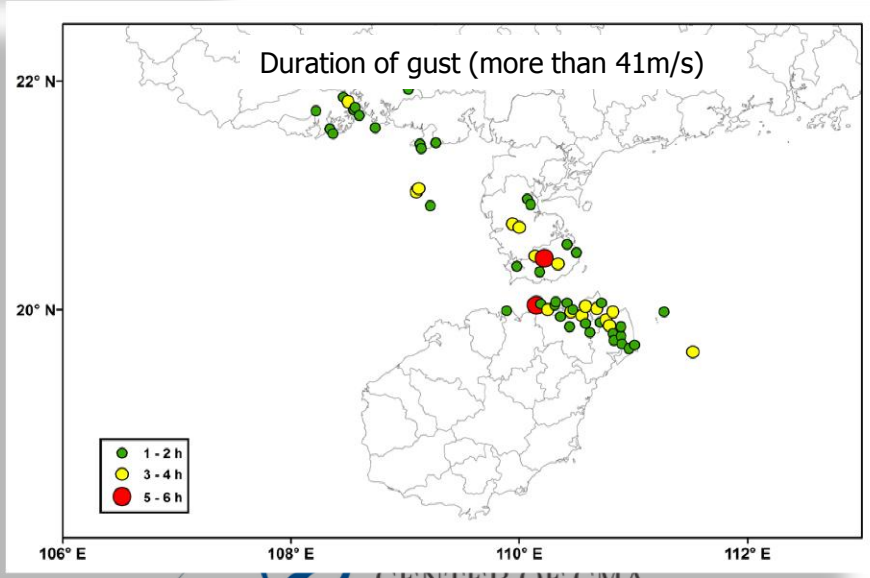
Suppose that the designed wind load of bearing wall is the maximum wind pressure that the wall can bear. Then, the house collapse could take place when wind pressure is higher than the designed wind load.

3.Impact of typhoon on low-rise buildings

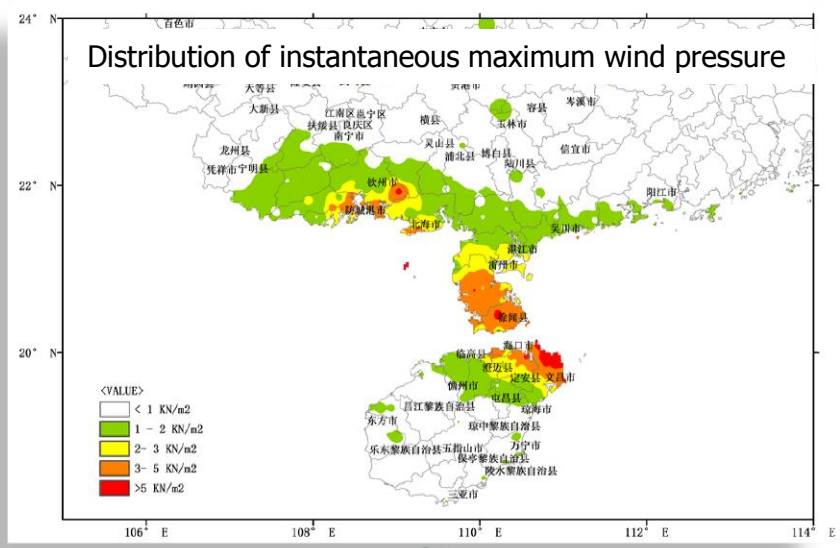
C. Case of Rammasun (1409)







3.Impact of typhoon on low-rise buildings



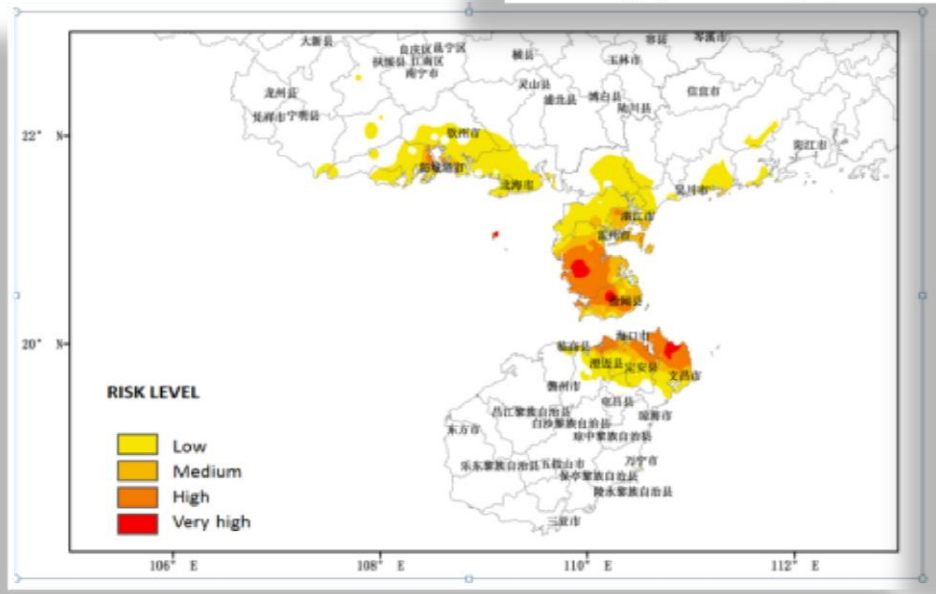


Fig1. Damaged risk index for low-rise building induced by Rammasun (1409)

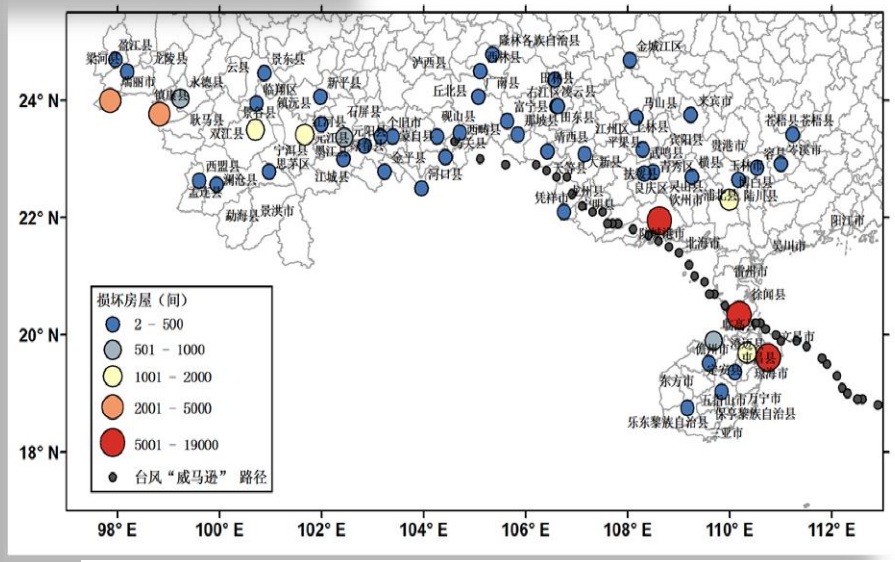


Fig2. The number and distribution of damaged houses under impact of Rammasun (1409).

3.Impact of typhoon on low-rise buildings

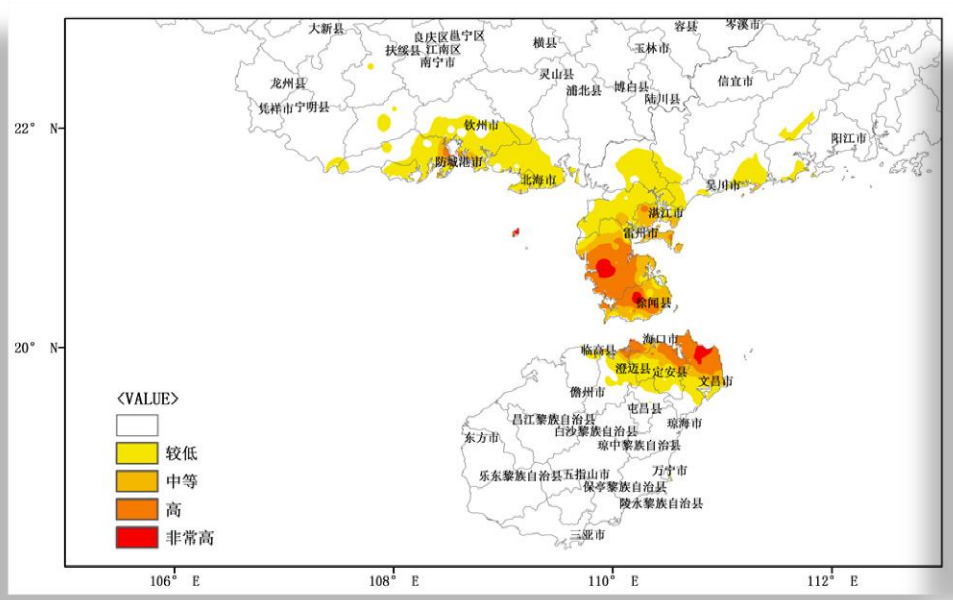


Fig1. Collapsed risk index for low-rise building induced by Rammasun (1409)

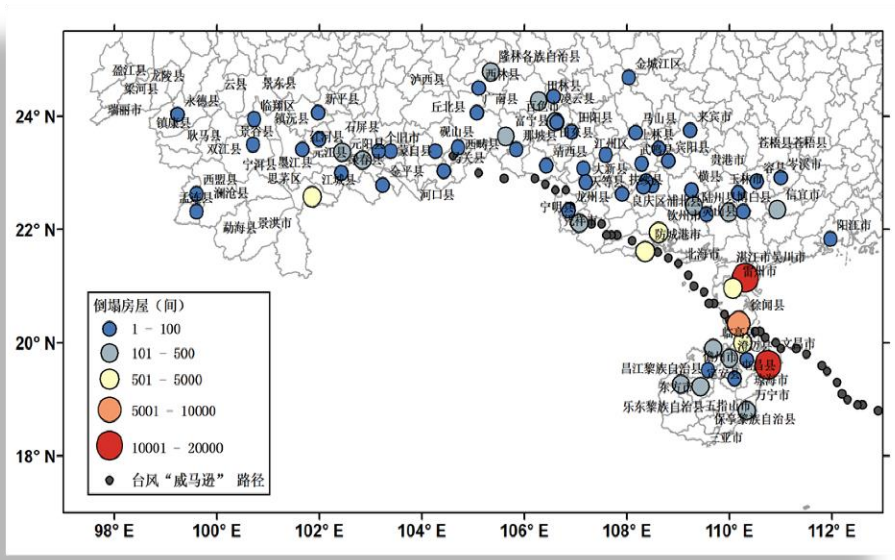
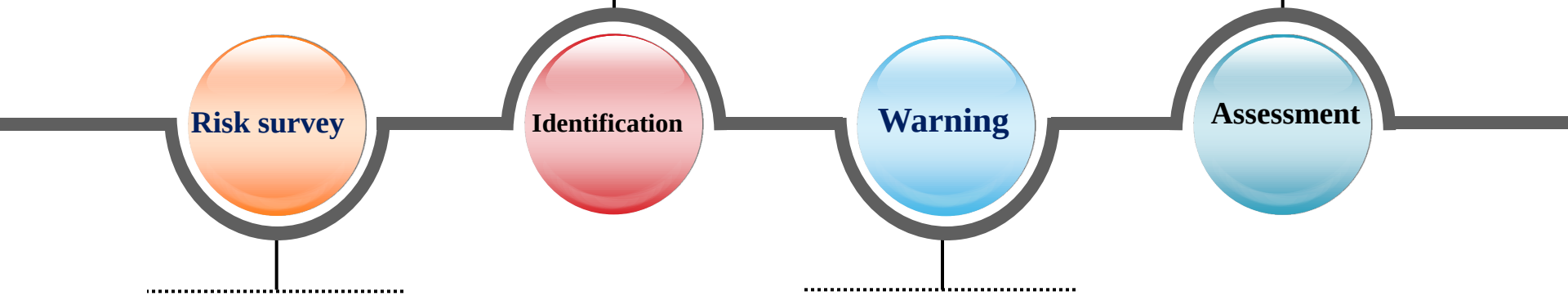


Fig2. The number and distribution of collapsed houses under impact of Rammasun (1409).

Contents

CMA has put risk assessment and risk-based warning of meteorological disaster as key priorities of public meteorological service. An operational system of risk-based warning covered



Totally, 1,160,000

- 2190 counties
- 5860 river basins
- 17759 flash flood sites
- 12438 mud flow sites
- 53589 landslide sites

Thresholds of Disaster

- rainfall duration
- 48h, 24h, 12h
- 6h, 3h and 1h

Four risk levels

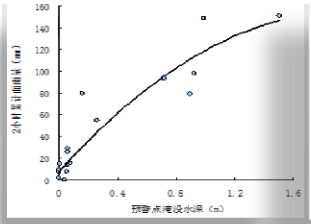
- blue (low risk)
- yellow (medium risk)
- orange (high risk)
- red (extremely high risk)

Based on meteorological forecast and historical loss data

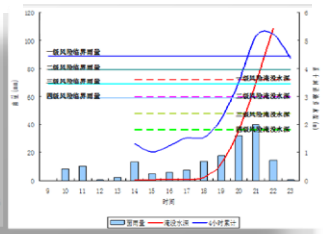
- spatial coverage
- depth
- inundation duration
- possible losses

Methodology

Relationship of Submerged Depth with Rainfall

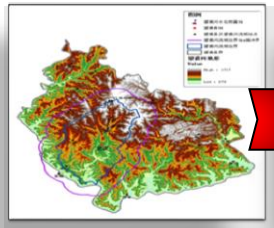


Different levels of rainfall thresholds

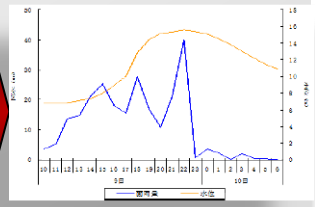


1.Modeling

Water Level Obsevation

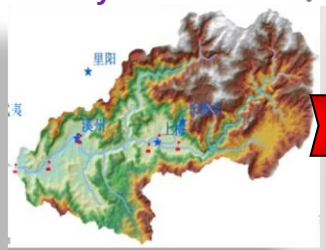


Hourly water level and rainfall



3.Statistics

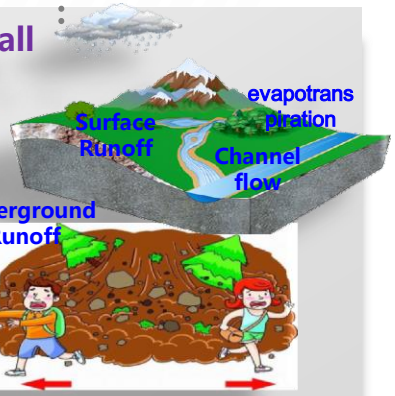
Target Mountain Valleys



Similar Mountain Valleys

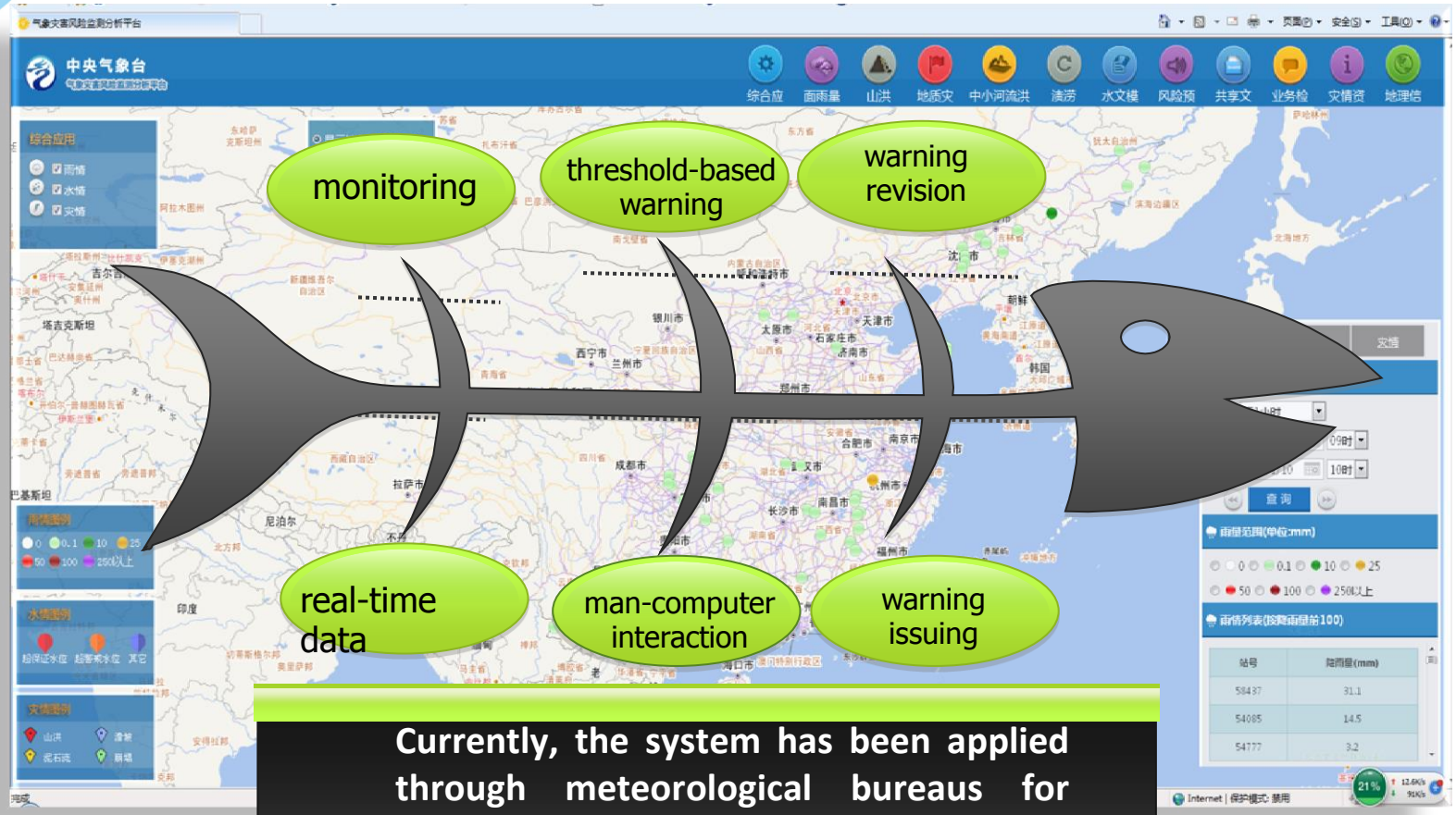
2.Analogy

Rainfall



4.Hydrological Model

Operational System

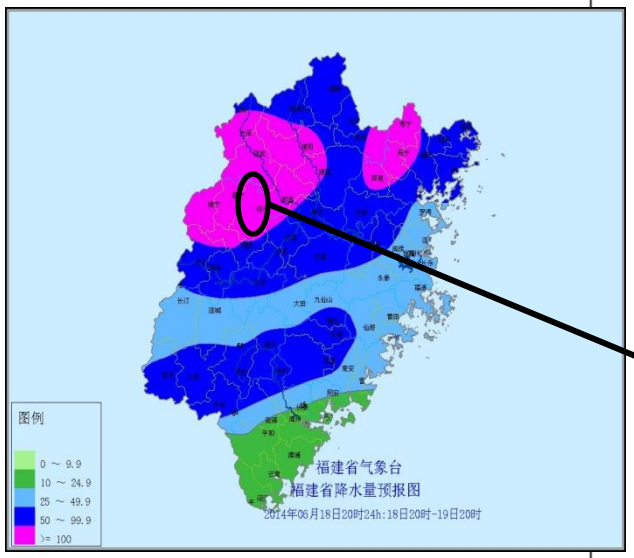


Currently, the system has been applied through meteorological bureaus for more than 300 cities and 2000 counties within 31 provinces

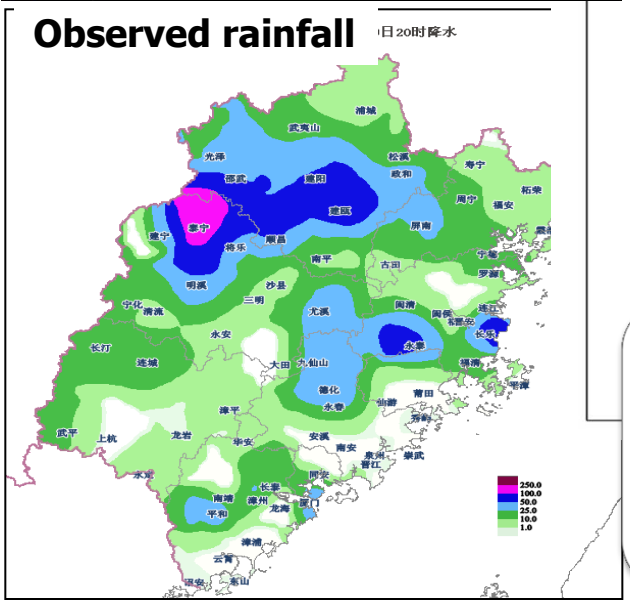
Real-time services of risk-based warning have been carried out at national, provincial, city, and county levels. Geological hazard warning is jointly disseminated by the Ministry of Land Resources and CMA. Flash flood warning is jointly disseminated by Ministry of Water Resources and CMA. The production, correction and dissemination of the warning products are the responsibilities of the meteorological services.

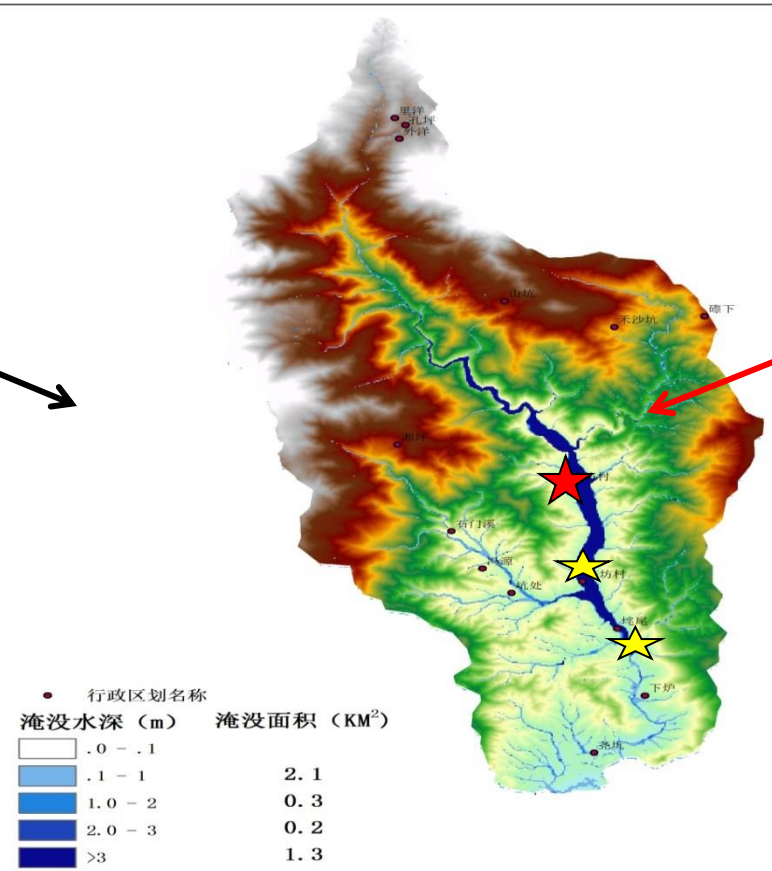
CASE 1: MOUNTAIN FLOOD WARNING FOR TOWNSHIP (Fujian Provence)

Predicted rainfall on June 19, 2014

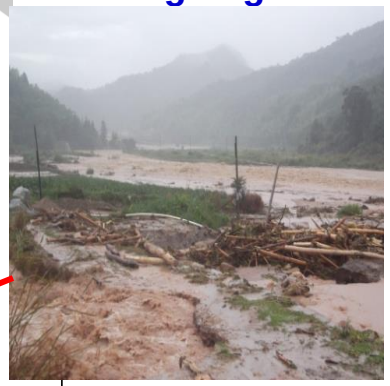


Observed rainfall





Flood in Dengfangxi

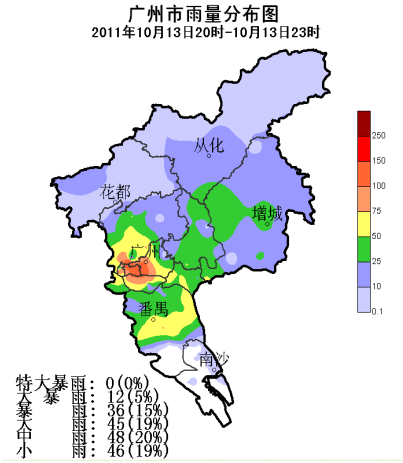


Flood Depth: 1.8m
Rainfall: 92mm
Affected Villages: 3
Dengfang
Chawei
Chenfang

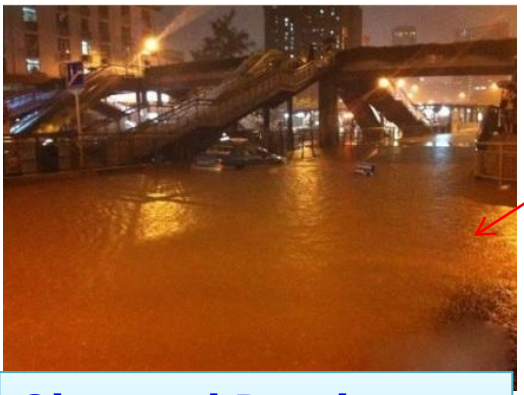
Warning Issued by Local Met Office

- **Risk Warning: Level -1**
- **Warning Delivery: SMS**
- **Emergency Actions: 121 people were evacuated. No casualties reported.**

CASE 2: URBAN WATERLOGGING RISK WARNING (Megacity, Guangzhou)



Observed submerging depth at Jinan University: 100cm
Predicted depth: 126cm

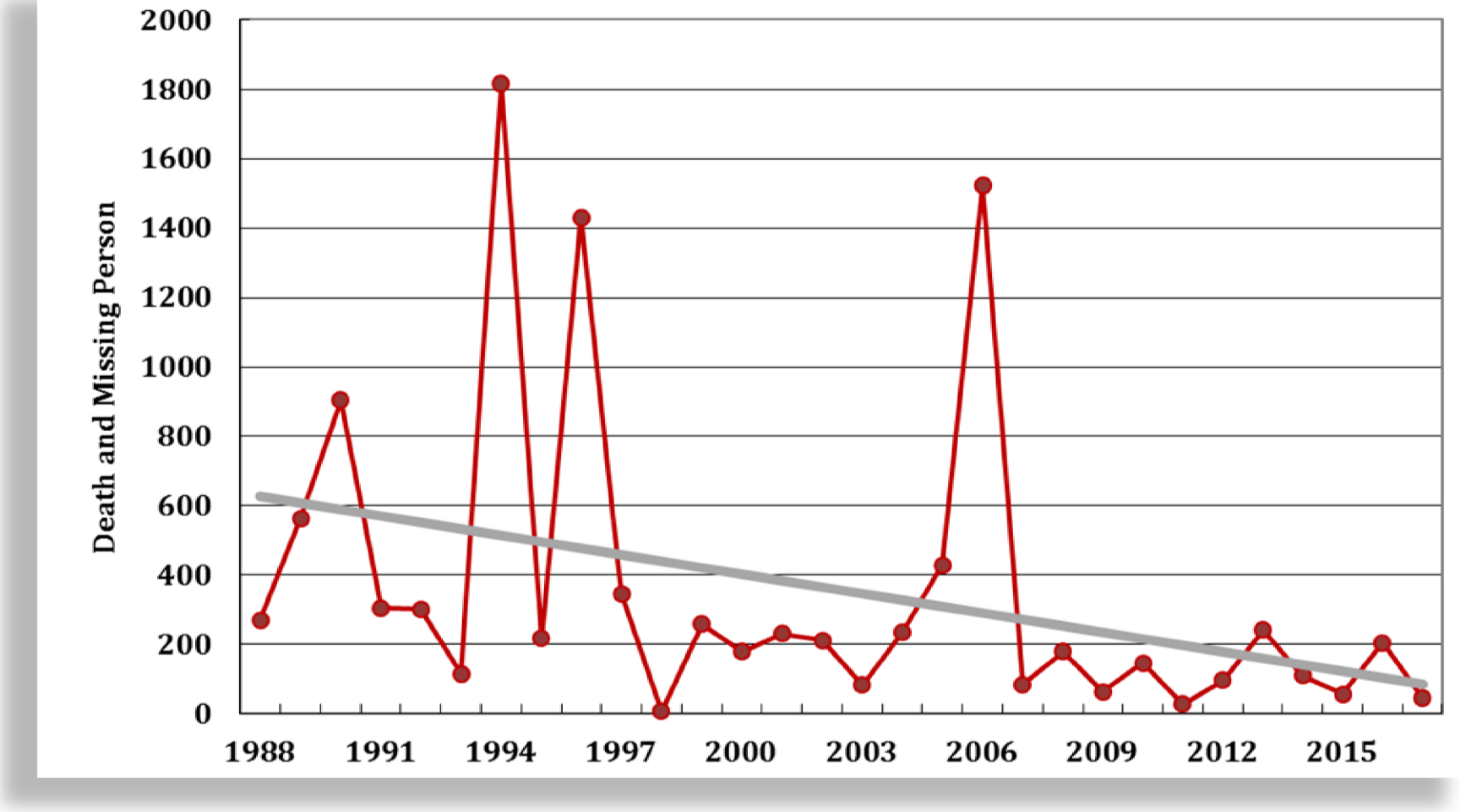


Observed Depth at Gangding: 60cm
Predicted Depth: 76cm

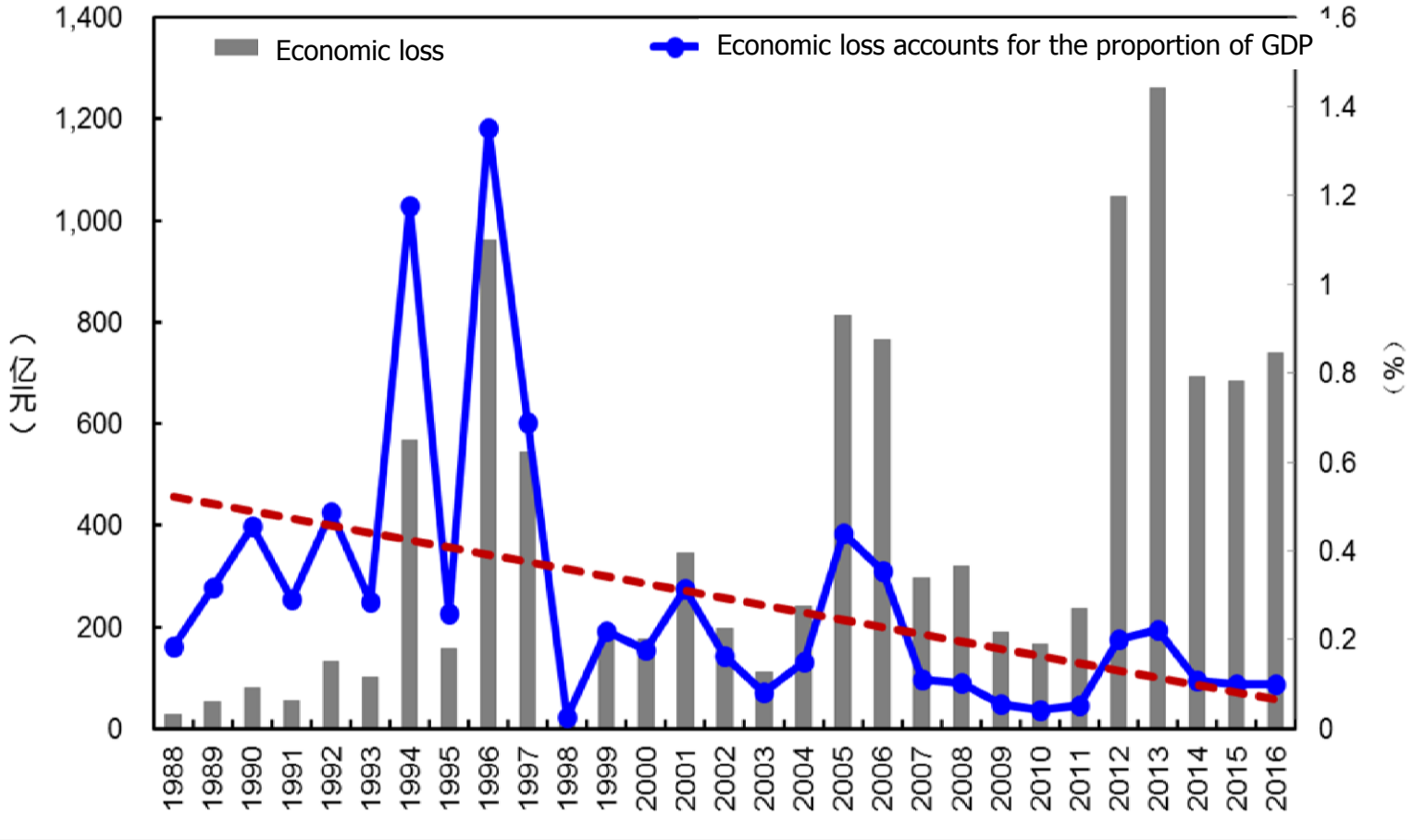
Observed Depth of Tianhe Road: 70cm
Predicted Depth: 86cm

The Accuracy of urban waterlogging warning for depth ≥20CM reached 76%.

Death and missing person of typhoon related disasters from 1988 to 2017.



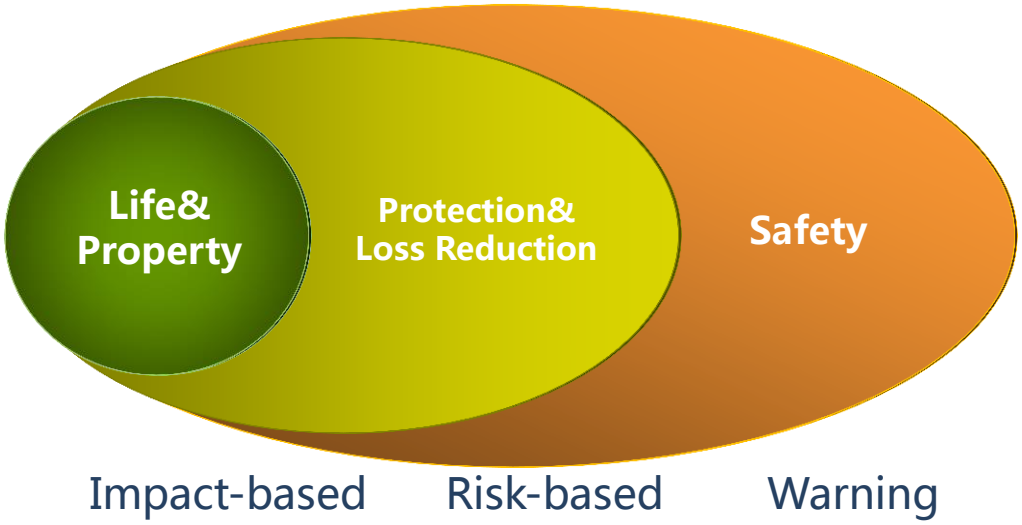
The economic loss caused by the typhoon showed a significant declining trend in the proportion of GDP of China.



NATIONAL METEOROLOGICAL CENTER OF CMA

Discussions

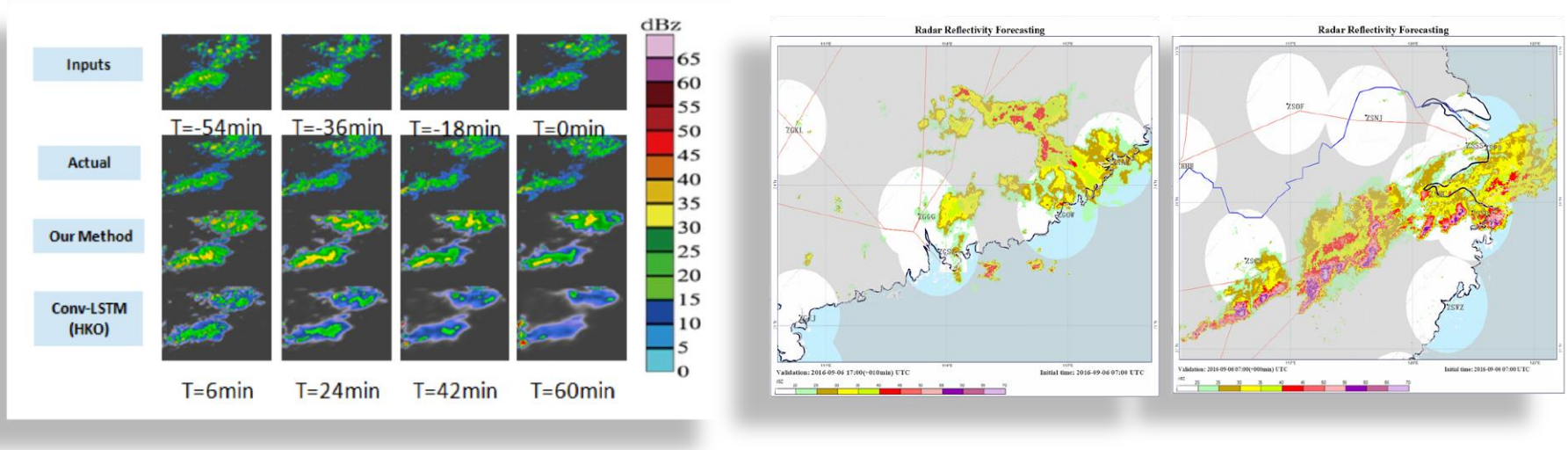
We have done effect work on impact-based forecast and risk-based warning of Typhoon. Government in China make great efforts to typhoon disasters prevention and reduction. But we are still confronted with some challenges and opportunities.



Discussions

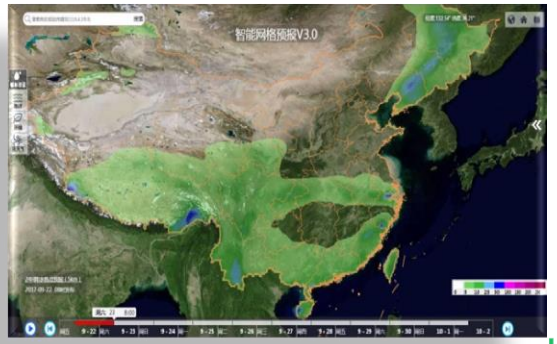
1.Development Opportunities of AI and its application in weather forecast.

- Identify extremely weather with deep learning techniques.
- Deep convolution neural network for short time precipitation forecast
- Typhoon Track Ensemble Correction

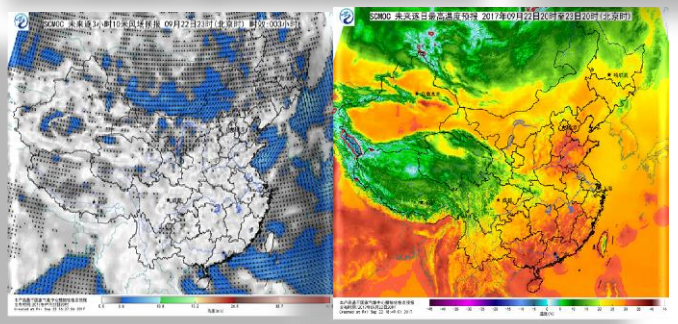


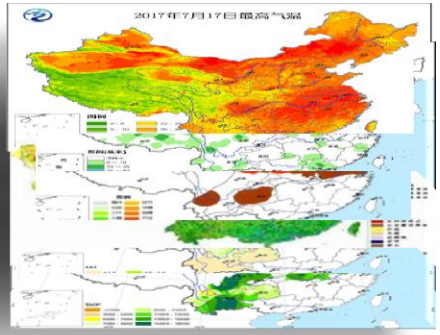
Deep convolutional neural networks for short time precipitation forecast
(From Tsinghua University and CMA)

2. Development Opportunities of BIG data application impact-based forecast and risk-based warning.

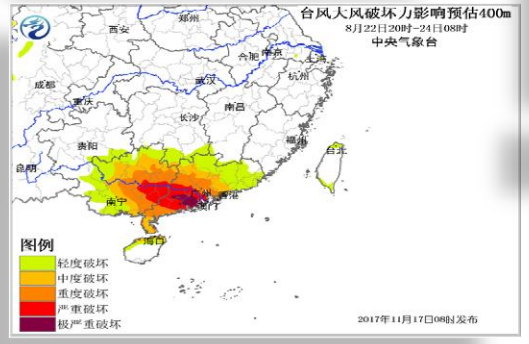


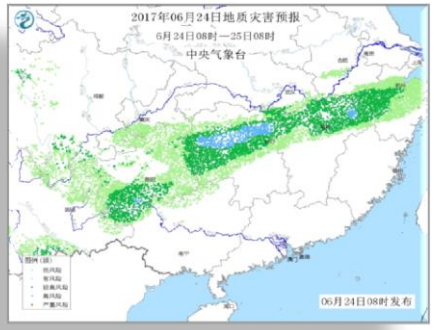
Smart -grid forecast





Impact-based forecast





Risk-based warning

Developing partnership and cross-disciplinary information sharing, access to sufficient information on hazardous factors, exposure and vulnerability; full understanding of the formation and development of hazards

3. Improving forecast accuracy

- **Improving accuracy of quantitative precipitation forecasts and gale to support reliable hazard risk warnings fulfilling specific needs**

- **Developing high resolution models, and nowcasting, ensemble probability techniques to improve NMHSs' capability on heavy rainfall and gale forecast.**

Thank you for your attention!