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FIFTEENTH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE
THE JOINT 2025 FENGYUN SATELLITE USER CONFERENCE

Dynamics of typhoon characteristics, risks and resilience in Coastal China

Presenter: George Darko

Supervisor: Prof. Shuoben Bi

Nanjing University of Information Science and Technology

School of Law and Public Administration,

History of Science and Technology



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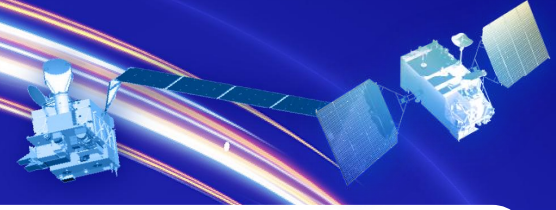
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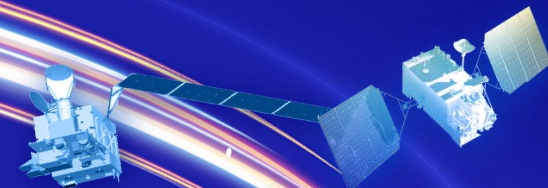
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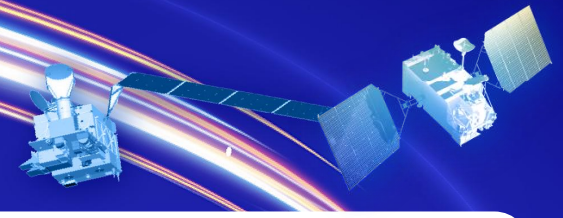


INTRODUCTION



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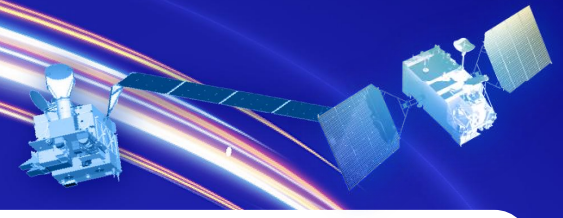
STATEMENT OF THE PURPOSE

- ❖ The Geographical location of China on the Western shores of the North Pacific ocean makes her more prone to storm of variably high intensity
- ❖ China Meteorological Administration (CMA) and Hong Kong Observatory (HKO) have been highly active in tracking tropical cyclones in real time to boost mitigation and resilience.
- ❖ Records from 2024 indicated temperature anomaly compared to pre-industrial averages has peaked at a monthly average of 1.57°C above baseline levels which affirms the warming effects of greenhouse gases and short-term climate patterns like El-Niño.
- ❖ Global warming highly impact typhoons behavior, intensity and frequency serving as energy for typhoons. Rise of ocean temperature give strength to high intensity typhoons and even more category 4 and 5 storms whose landfalls and impacts have extended to new areas recently.
- ❖ The historical data suggests that the impact of typhoons on socioeconomic systems cannot be underestimated and therefore encourages more studies into this phenomenon



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OBJECTIVES OF THE STUDY

OVERALL OBJECTIVE

Carry out an assessment of risk and resilience to the characteristics of typhoon storm surges in coastal China

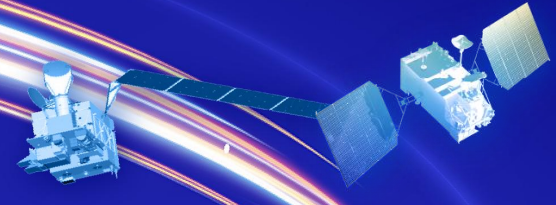
SPECIFIC OBJECTIVE

- ❖ Visualizing the categories of typhoon storms that made landfall over China area of responsibility from 1973 to 2023 with GIS and the Gantt Chart.
- ❖ Conduct historical trend assessment of typhoon storms and their characteristics using Sen Slope +Mann Kendal test and a hybrid EMD-SVM methods of typhoons over coastal China from 1979 to 2025
- ❖ Evaluate risks impacts of typhoon storms on socioeconomic variables and livelihoods over coastal China
- ❖ Investigate model approaches adapted and enhanced to strengthen resilience while minimizing impact of recurrent storms in China



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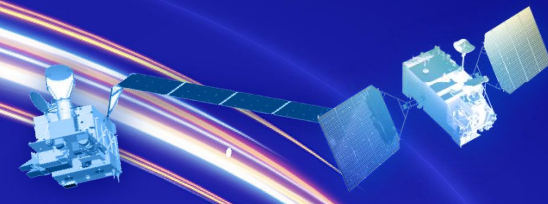


STUDY AREA AND DATA

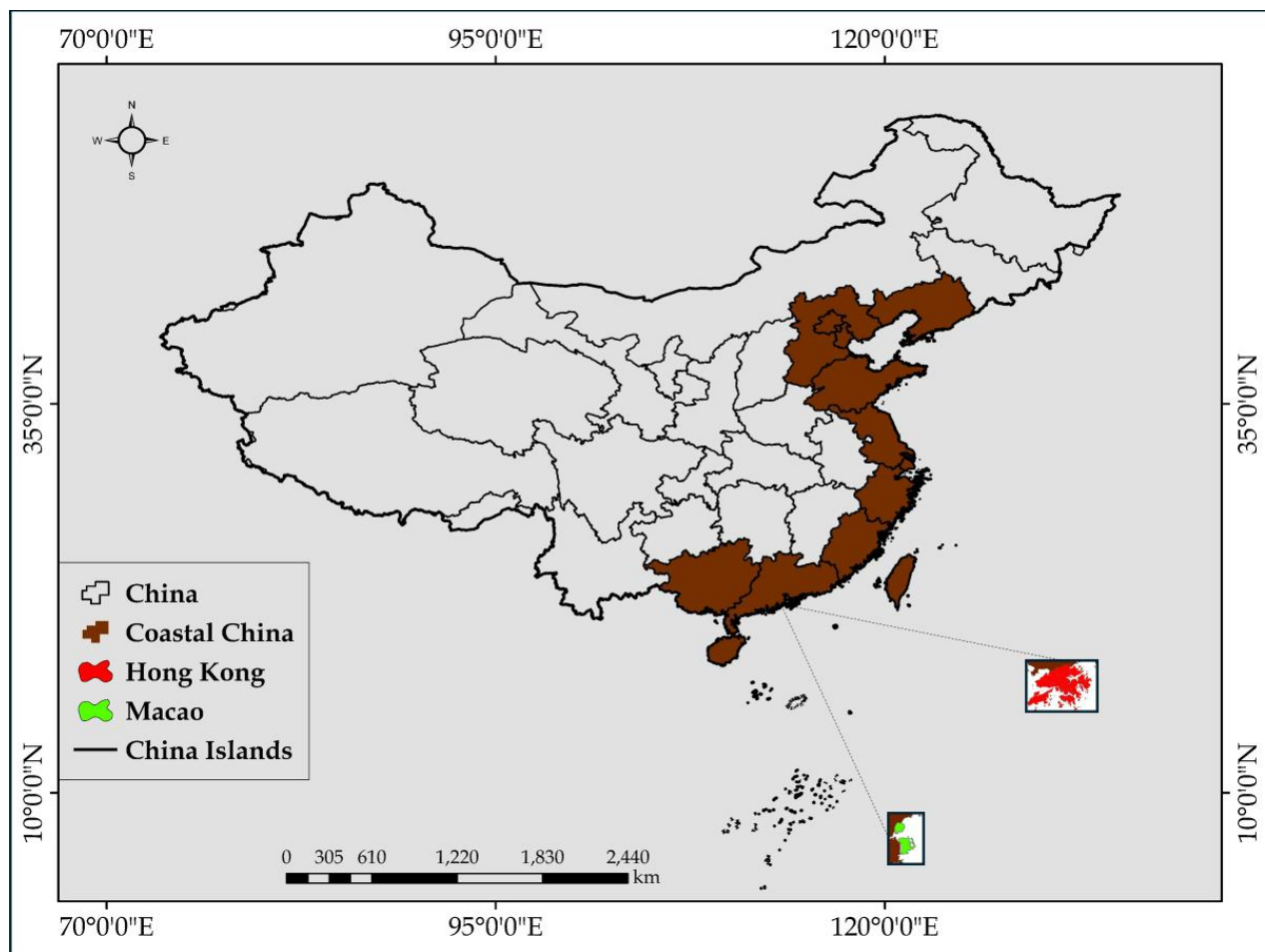


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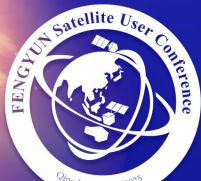
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OVERVIEW OF THE STUDY AREA

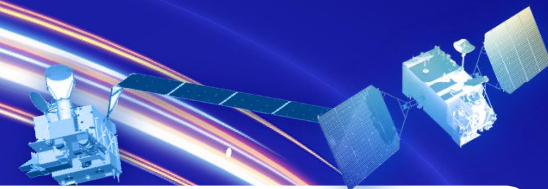


- ❖ China is situated in Eastern Asia on the western shore of the Pacific Ocean
- ❖ Covers an area of 9.6 million Km²
- ❖ Coastline stretching over 14,000 km from Bohai gulf in the north to Beibu Gulf in the South
- ❖ Has more than 5,000 islands (Taiwan & Hainan are the largest)
- ❖ Diversity of climates across China, from tropical in the south to cold temperate monsoon climate in the north and alpine in the west
- ❖ Developed country

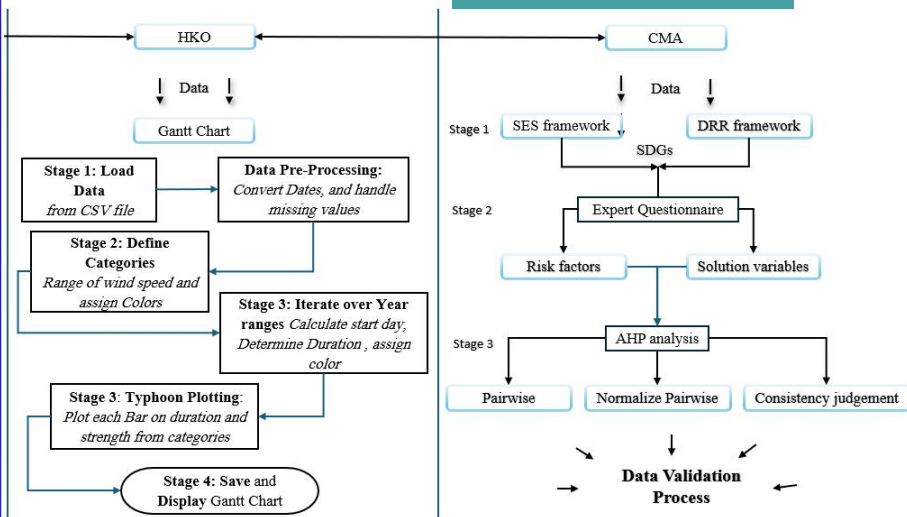


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Plan & Workflow



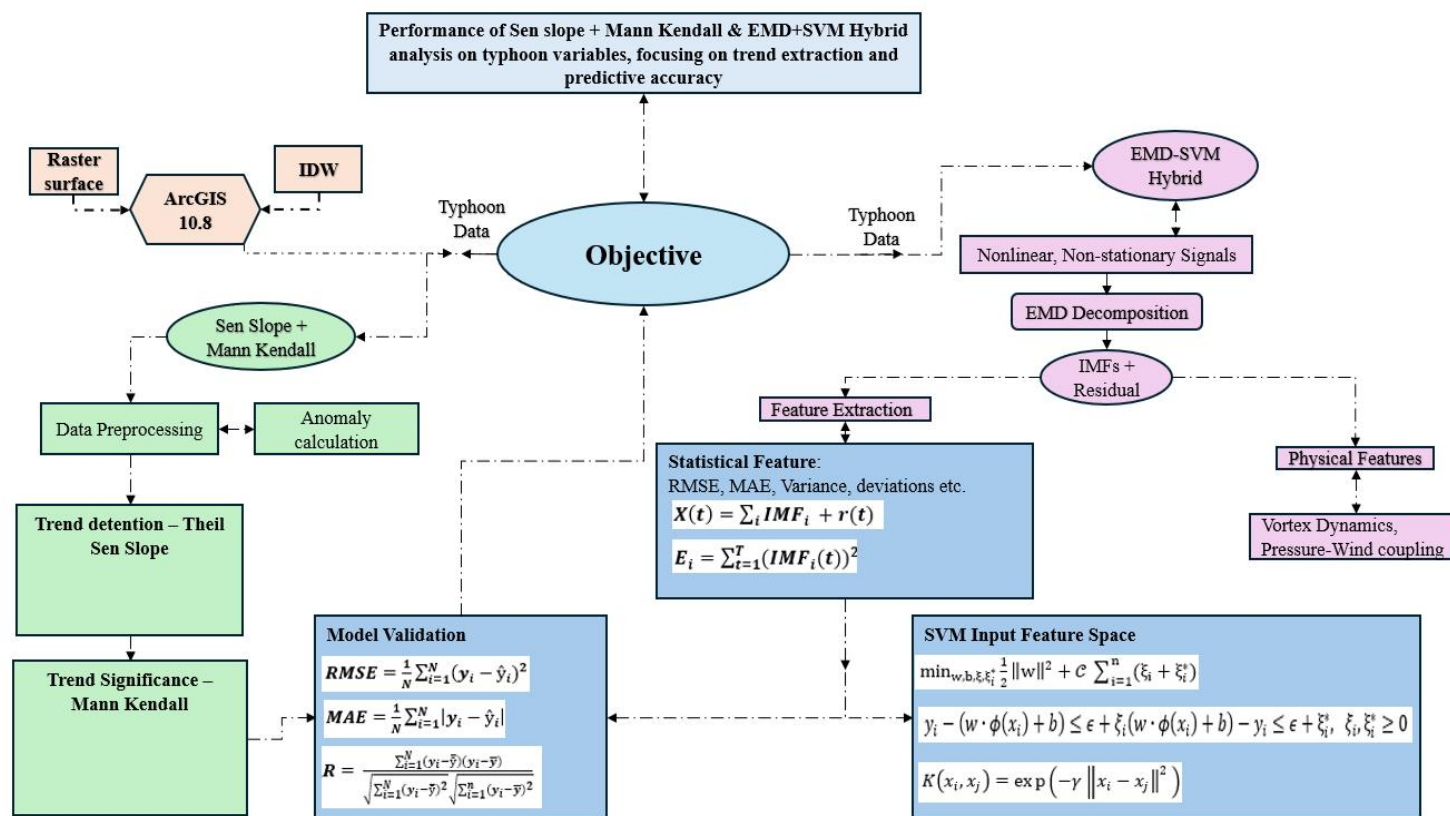
• CMA / HKO (Ground observational Wind speed and precipitation)

Data

➤ China Statistical Yearbook (2023):
Socio-economic data

Expert Questionnaire

➤ NOAA, NCEP/DOE Reanalysis II (wind speed, Precipitation, Pressure, Temperature)





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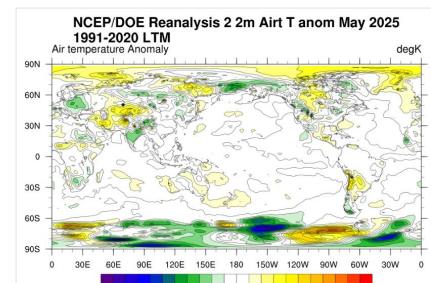
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DATA SOURCES

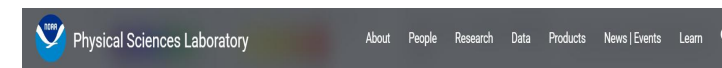


NCEP/DOE Reanalysis II

NCEP-DOE Reanalysis 2 is an improved version of the NCEP Reanalysis I model that fixed errors and updated parameterizations of physical processes.



SPECIFICATIONS	
DESCRIPTION	
USAGE & CITATION	
SOURCE & REFERENCES	
VARIABLES	
Air Temperature	Air temperature
Convective Precipitation Rate	Divergence
Downward Longwave Radiation Flux	Downward Solar Radiation Flux



Download and Plot Data

u-wind

+ / -

Variable Statistic Level TimeScale Options

U-wind

u-wind

45 U-wind Individual Obs 10 m 4x Daily

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/Datasets/ncep.reanalysis2/gaussian_grid/uwnd.10m.gauss.1983.nc

Geopotential height	Ground Heat Flux
Ice Concentration	Land-sea mask
Latent Heat Net Flux	Maximum Temperature
Mean Sea Level Pressure	Meridional Gravity Wave Stress
Minimum Temperature	Momentum Flux, u-component
Momentum Flux, v-component	Omega (dp/dt)
Orography	Potential Evaporation Rate
Precipitable Water Content	Precipitation Rate
Pressure	Relative Humidity
Relative humidity	Sensible Heat Net Flux
Skin Temperature	Specific Humidity
Temperature	Total cloud cover
U-wind	Upward Longwave Radiation Flux
Upward Solar Radiation Flux	V-wind

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Climate datasets

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2001-2010

1951-1960

1901-1950

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国家统计局编

Compiled by National Bureau of Statistics of China

CHINA STATISTICAL YEARBOOK 2023

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中文版

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- 1-1 Division of Administrative Areas in China (End of 2022)
- 1-2 Aggregate Indicators on National Economic and Social Development and Growth Rates
- 1-3 Composition Indicators on National Economic and Social Development
- 1-4 Proportion and Efficiency Indicators on National Economic and Social Development
- 1-5 Number of Corporate Units by Sector
- 1-6 Number of Corporate Units by Three Strata of Industry and Type of Institutions and Region (2022)
- 1-7 Numbers of Corporate

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In pics: Ligustrum flowers attracted bees and butterflies

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Current Weather

Update at 00:00

HKO

↓ 27°C ↑ 32°C

27.8°C

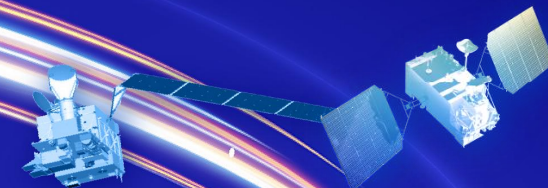
88%

Innovate with Science, Serve with Heart



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Removing Errors

Analytic Hierarchical Process (AHP) for Expert Questionnaire

- consistency ratio
 $CR \leq 0.1$ (10%) for acceptable consistency
 $CR = \frac{CI}{RI}$
- Geometric Mean for combining the multiple experts' judgement across all participants using the formula:

$$\tilde{a}_{ij} = \left(\prod_{k=1}^n a_{ij}^{(k)} \right)^{1/n}$$

$a_{ij}^{(k)}$ represents the judgement from expert and k for criteria i against j .

Chinese National Standard for grade of tropical cyclones

Description label	Storm description	Maximum sustained wind speed
Weaker than Tropical depression or unknown intensity		
Lowest Intensity	TD	Tropical Depression
	TS	Tropical storm
	STS	Severe Tropical Storm
	TY	Typhoon
	STY	Severe Typhoon
	Super TY	Super Typhoon
Highest Intensity		
		10.8-17.1 m/s; i.e. Beaufort scale 6-7
		17.2-24.4 m/s; i.e. Beaufort scale 8-9
		24.5-32.6 m/s; i.e. Beaufort scale 10-11
		32.7-41.4 m/s; i.e. Beaufort scale 12-13
		41.5-50.9 m/s; i.e. Beaufort scale 14-15
		> 51.0 m/s; i.e. Beaufort scale >16

- Model Validation Process:
Observed vs Simulated data
measurements

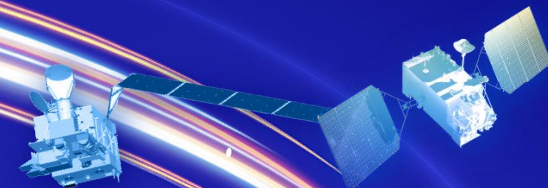
China Statistical Yearbook 2023

- nominal values adjusted for inflation to obtain real values using:
 - ✓ deflation method
 - $Real\ value = \frac{Nominal\ Value}{Price\ Index} \times 100$
 - ✓ Consumer Price Index (CPI) provided by the National Bureau of Statistics of China
 - $Real\ Economic\ Loss_{base\ year} = \frac{Norminal\ Economic\ Loss_{year}}{CPI_{year}} \times 100$



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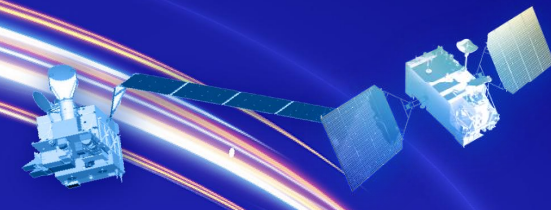


RESULTS

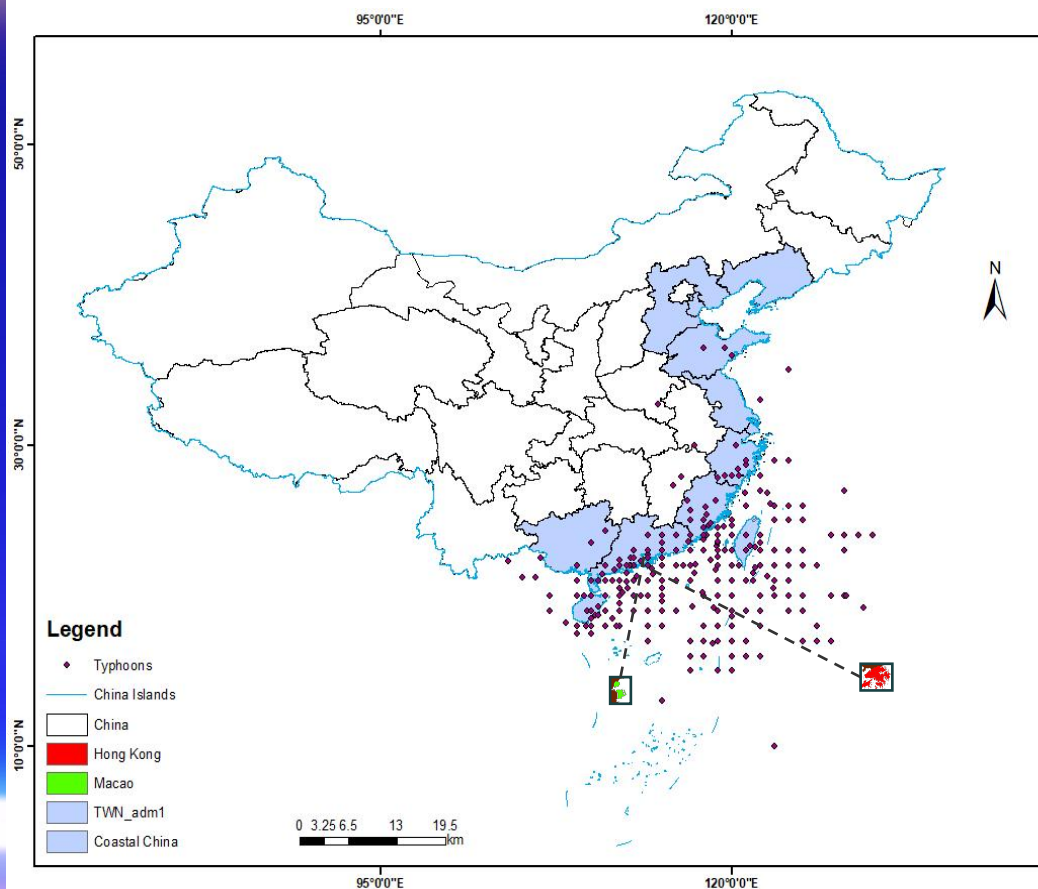


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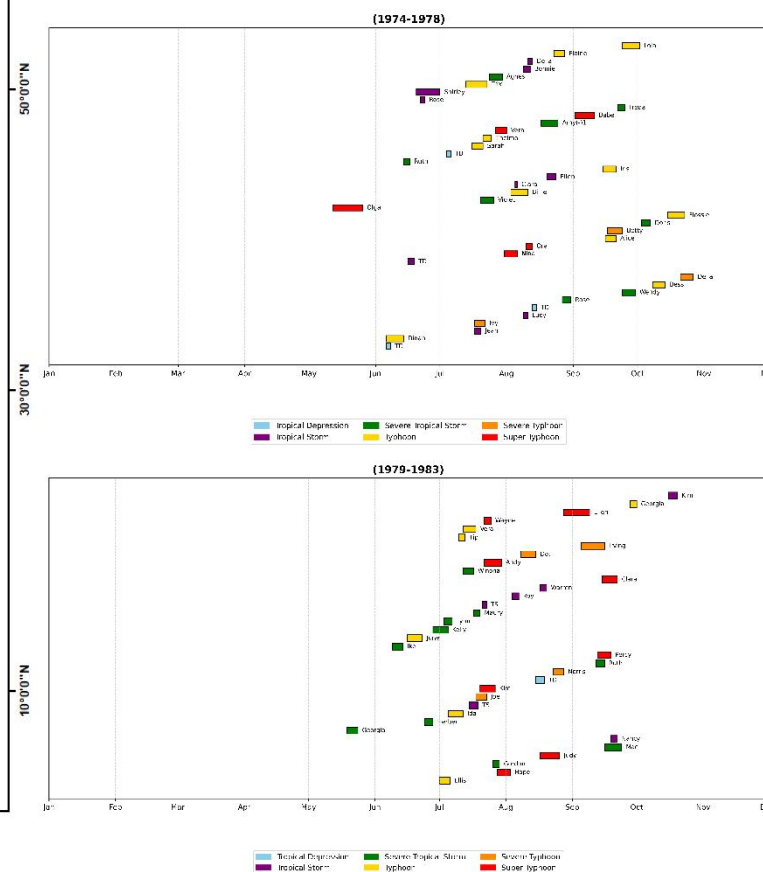


Landfall Tropical Cyclones



- Total of **425 tropical cyclones** of variable intensity made landfall on coastal China

- **13 Super Typhoons (SuperTY)** category

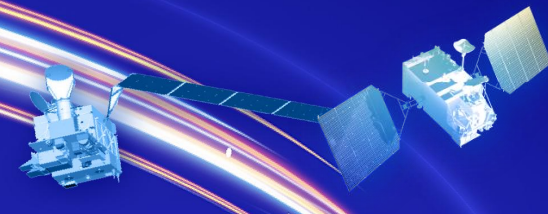


- **46 Severe Typhoon (STY)** category
- **130 Typhoon (TY)** category
- **188 TCs** made landfall in Guangdong Province (including storms making more than one landfall)
- **98 TCs** made landfall in Taiwan (including storms making more than one landfall)
- **85 TCs** of variable intensity made landfall in Fujian

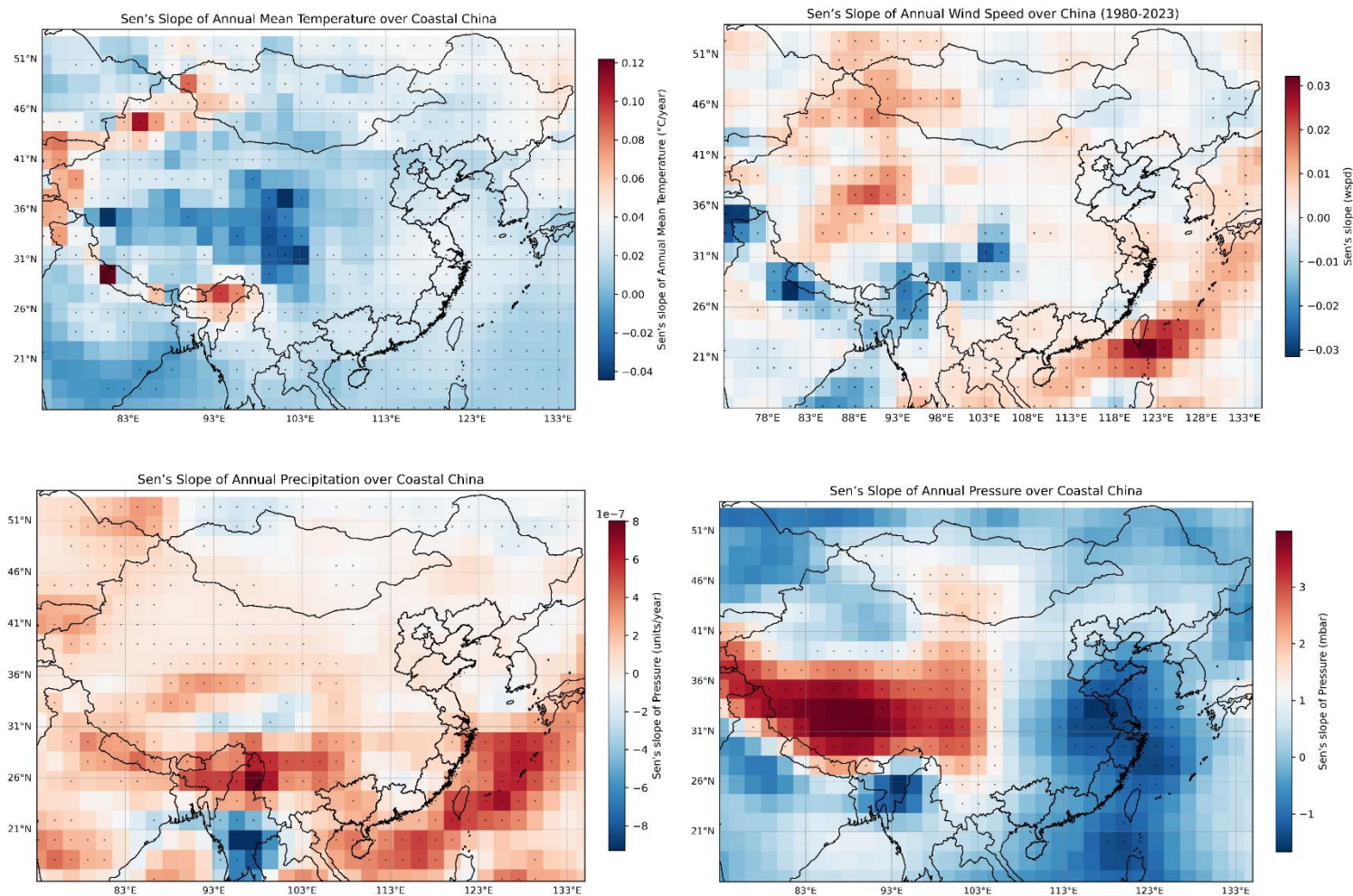


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Trend Detection – Sen Slope + Mann Kendall Test



➤ Temperature

- weak cooling trends over coastal China linked to ocean-atmosphere heat exchange process
- significant upward trend of $+0.029\text{ }^{\circ}\text{C}$ per year, equivalent to approximately $1.3\text{ }^{\circ}\text{C}$ of warming since 1979.
- This warming enhances ocean atmosphere heat exchange, increasing the potential intensity of typhoons through greater latent heat supply.

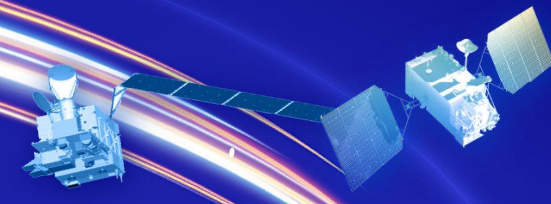
➤ Wind speed

- exhibit positive anomalies dominating along sections of the eastern Chinese coast and the East China Sea highlighting strengthened wind speeds, that are consistent with intensification of monsoonal circulation and typhoon-associated wind fields.
- displays a nearly stable trend of $+0.001\text{ m/s}$ per year suggesting that large-scale circulation has not undergone substantial long-term shifts; however, this stability does not preclude stronger storm-related gusts, which are often decoupled from mean background winds

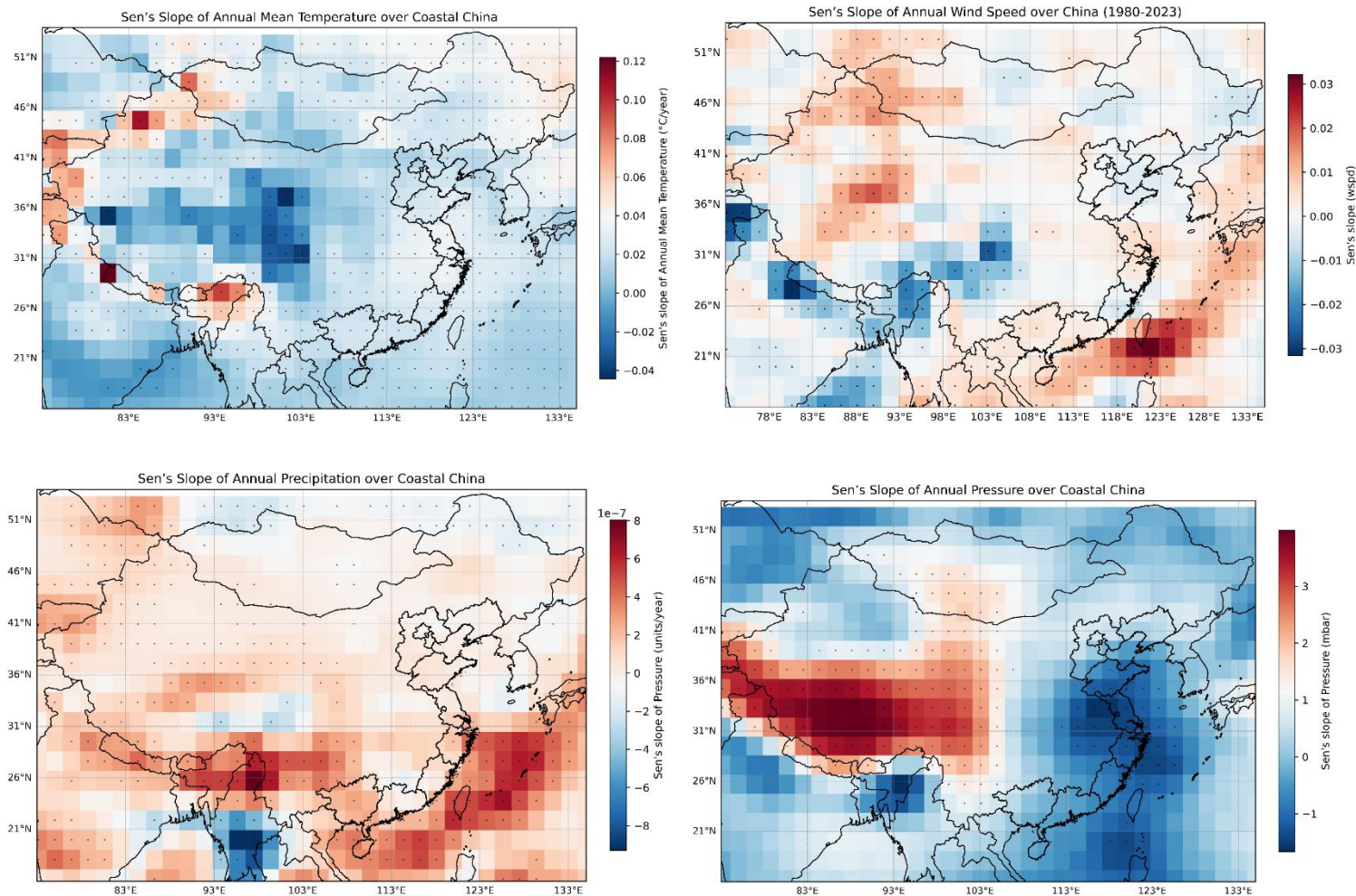


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Trend Detection – Sen Slope + Mann Kendall Test



➤ Precipitation

- patterns show pronounced increases in southern and southeastern China
- enhanced rainfall along China's southeastern seaboard, influenced by landfalling typhoons and strengthened summer monsoon moisture transport.
- no clear monotonic increase but is characterized by pronounced interannual variability, with several extreme peaks linked to typhoon-driven rainfall. This variability underscores the episodic nature of flood risks in the region

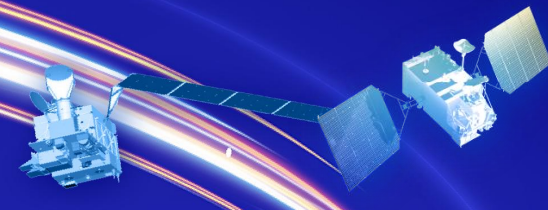
➤ Pressure

- exhibits a dipole pattern.
- southeastern coastal China shows strong pressure declines reflecting weakening surface pressure systems, that facilitates the intensification of cyclonic activity and enhance vulnerability to typhoons and other extreme events.
- mean sea level pressure exhibits a steady decline of – 0.013 mbar per year, reflecting a background state increasingly conducive to cyclonic activity and lower central pressures during storm events

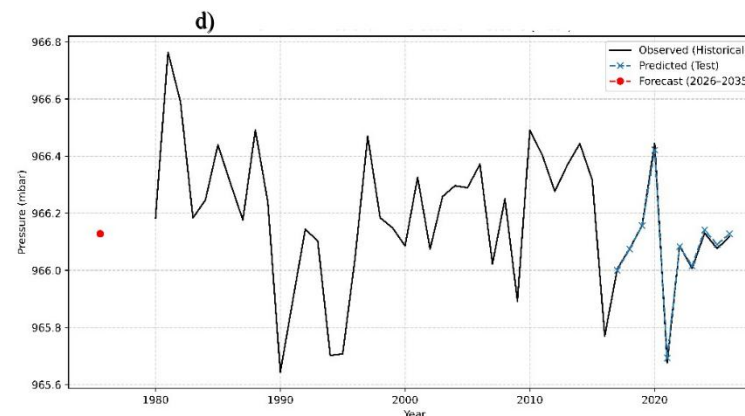
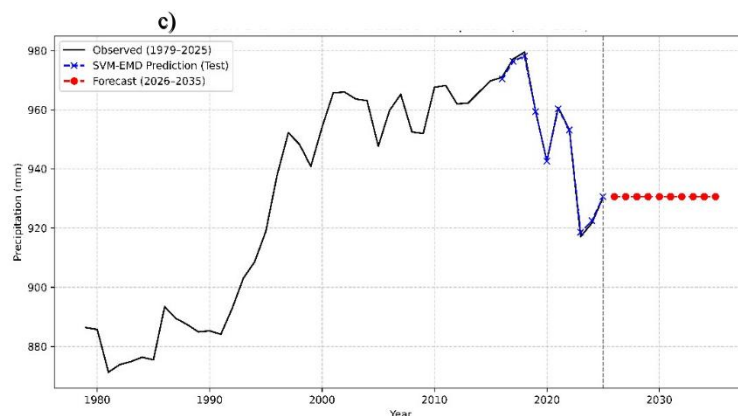
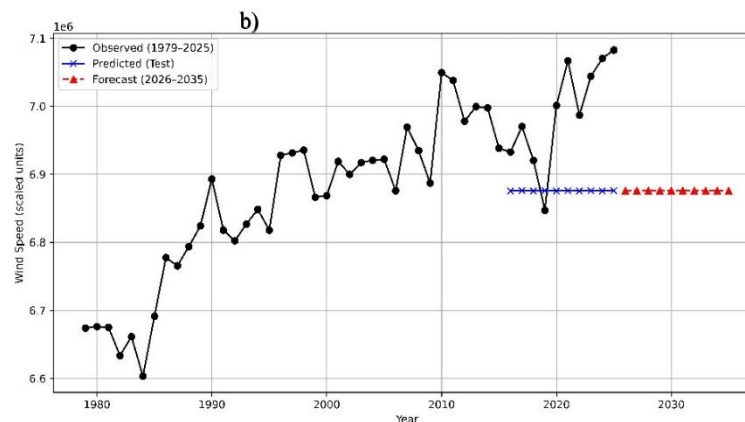
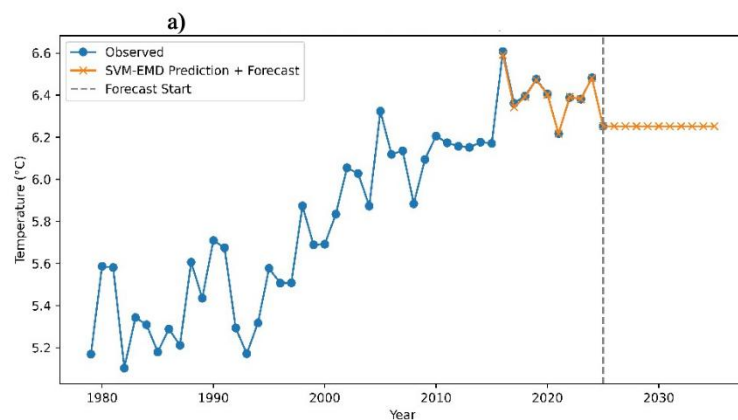


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EMD -SVM Hybrid Observed and Prediction 1979-2025

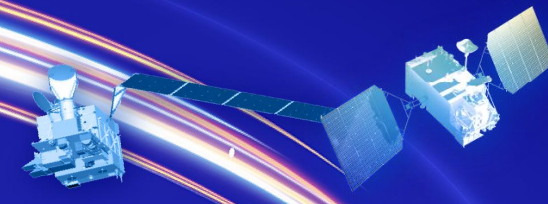


- **Panel (a) - Temperature** exhibited a consistent upward trend (1979-2025).
- **Panel (b) - Wind speed** displayed a long-term increase with substantial interannual variability.
- **Panel (c) - Precipitation**, characterized by strong fluctuations, reflecting episodic wet and dry cycles. Although precipitation proved more challenging to predict, the model adequately captured observed variability, and forecasts suggest stabilization at slightly reduced values relative to the historical mean
- **Panel (d) - Pressure** indicates atmospheric pressure exhibited no significant long-term trend but considerable short-term fluctuations



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Observed and Prediction Through 2035

Temperature (°C)			Wind speed (m/s)			Precipitation (mm)			Pressure (mbar)		
Year	Obs	Pred	Year	Obs	Pred	Year	Obs	Pred	Year	Obs	Pred
2016	6.61	6.59	2016	6.93	6.93	2016	970.9	970.4	2016	966.0	966.0
2017	6.36	6.34	2017	6.97	6.97	2017	977.2	976.3	2017	966.1	966.1
2018	6.40	6.39	2018	6.92	6.92	2018	979.5	978.2	2018	966.2	966.2
2019	6.48	6.47	2019	6.85	6.85	2019	959.4	959.4	2019	966.5	966.4
2020	6.41	6.40	2020	7.00	7.00	2020	942.6	942.6	2020	965.7	965.7
2021	6.22	6.22	2021	7.07	7.06	2021	960.8	960.4	2021	966.1	966.1
2022	6.39	6.39	2022	6.99	6.98	2022	953.3	953.2	2022	966.0	966.0
2023	6.38	6.38	2023	7.04	7.04	2023	917.2	918.6	2023	966.1	966.1
2024	6.48	6.48	2024	7.07	7.06	2024	921.7	922.5	2024	966.1	966.1
2025	6.25	6.25	2025	7.08	7.08	2025	930.4	930.6	2025	966.1	966.1
2026		6.25	2026		7.08	2026		930.6	2026		966.1
2027		6.25	2027		7.08	2027		930.6	2027		966.1
2028		6.25	2028		7.08	2028		930.6	2028		966.1
2029		6.25	2029		7.08	2029		930.6	2029		966.1
2030		6.25	2030		7.08	2030		930.6	2030		966.1
2031		6.25	2031		7.08	2031		930.6	2031		966.1
2032		6.25	2032		7.08	2032		930.6	2032		966.1
2033		6.25	2033		7.08	2033		930.6	2033		966.1
2034		6.25	2034		7.08	2034		930.6	2034		966.1
2035		6.25	2035		7.08	2035		930.6	2035		966.1

Model performance

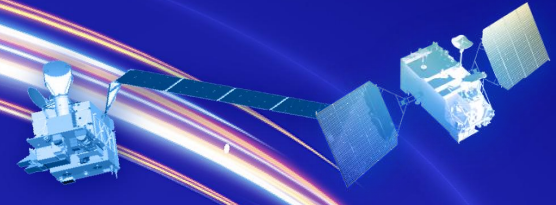
Variable	RMSE	MAE	R ²	Best Params.	
Temperature (°C)	0.008	0.005	0.994	<i>C</i>	100
				ϵ	0.01
				γ	0.01
Wind Speed (m/s)	0.004	0.004	0.996	<i>C</i>	100
				ϵ	0.01
				γ	0.01
Precipitation (mm)	0.075	0.057	0.999	<i>C</i>	100
				ϵ	0.01
				γ	0.01
Pressure (mbar)	0.012	0.009	0.996	<i>C</i>	100
				ϵ	0.01
				γ	0.01

- Trends were well captured by the EMD-SVM Hybrid model, and forecasts suggest a continued increase through 2035
- The EMD-SVM Hybrid model reproduced all variability effectively



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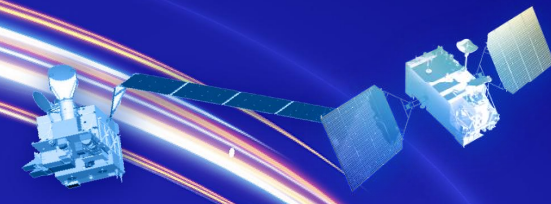


TCs IMPLICATION ON COASTAL CHINA

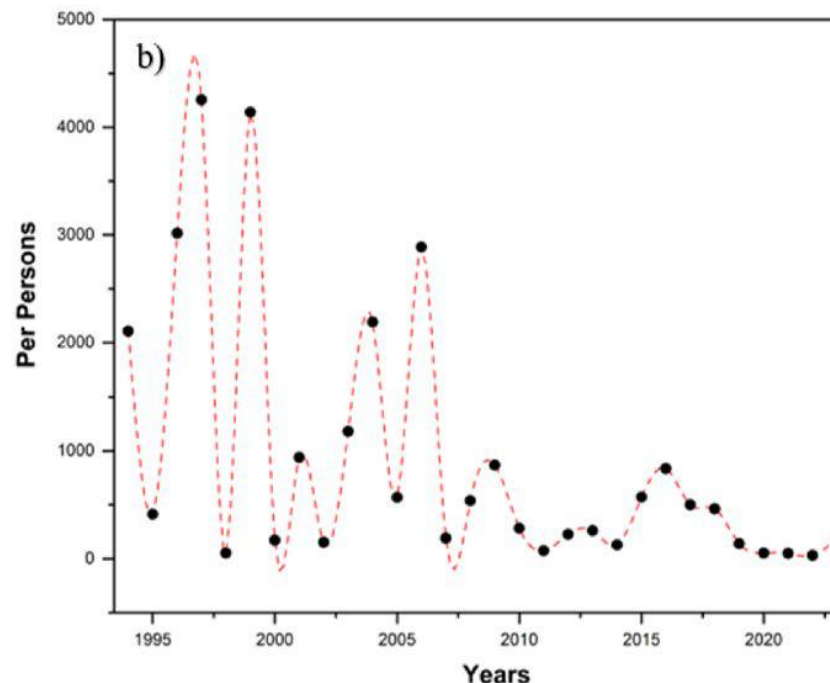
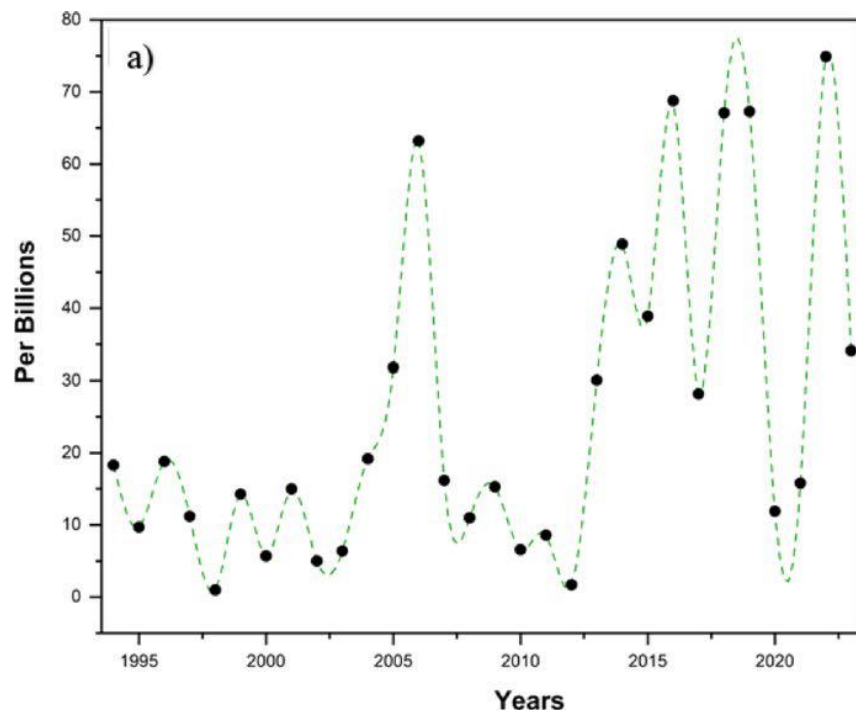


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TCs Impact on Coastal China



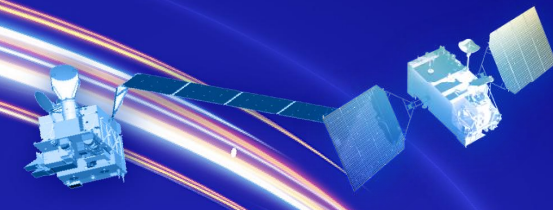
- **Direct Economic Loss (a)** exhibits an increasing trends compared to a declining deaths, missing and injured (b) from 1994 to 2023
- This suggests improved disaster management that reduces loss of life but not necessarily property damage

- **Severe typhoon Fred (1994)**
 - speed of 51.4 m/s, caused a total of 1069 casualties including deaths, missing and injured while having a direct economic loss estimated at 7.5 billion RMB (\$1.028 billion)
- **Typhoon Sally (1996)**
 - wind speed of 51.4 m/s inflicted very serious damages on western Guangdong and Guangxi causing at least 2270 deaths including injured and missing while greatly impacted communication, transport, electricity and water supplies
- **Typhoon Winnie (1997)** associated with heavy rain, flooding, and landslides resulted in over 2494 casualties including deaths, injured and missing
- **2016 and 2022** reflected the highest direct economic losses of 68.8 billion yuan (\$9.5 billion) and 74.9 billion yuan (\$10.27 billion) respectively

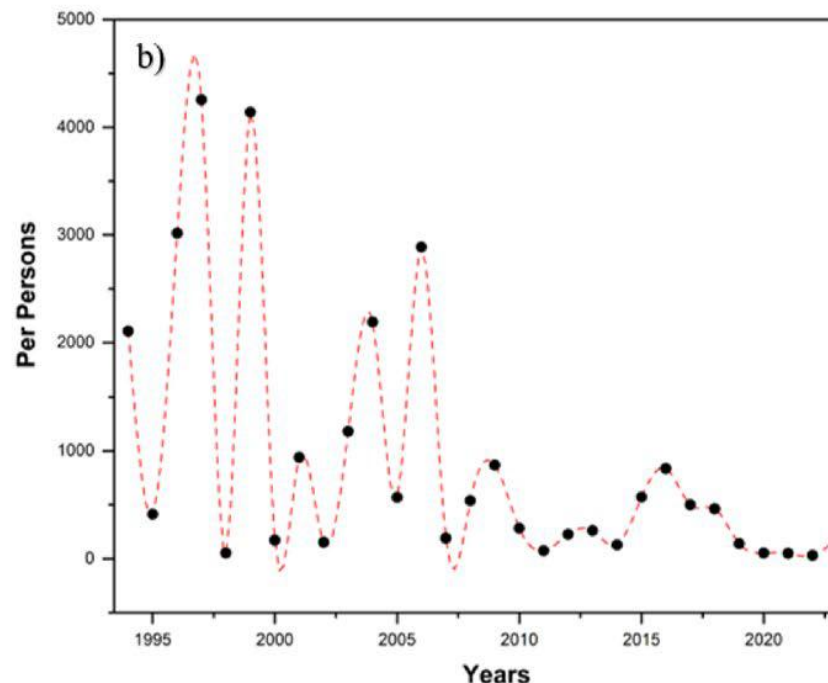
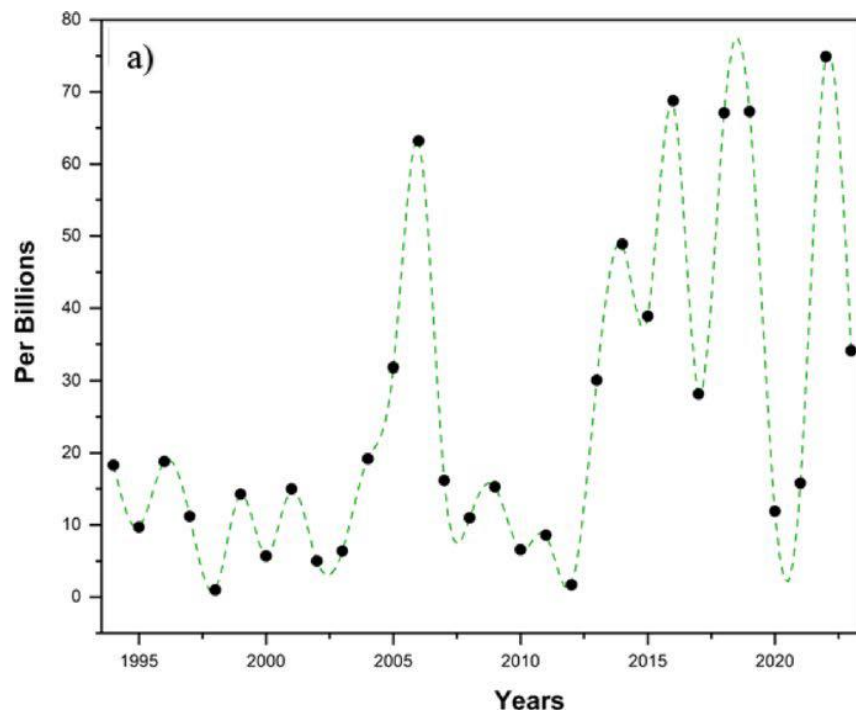


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TCs Impact on Coastal China



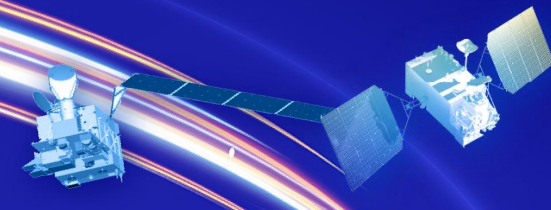
- **Direct Economic Loss (a)** exhibits an increasing trends compared to a declining deaths, missing and injured (b) from 1994 to 2023
- This suggests improved disaster management that reduces loss of life but not necessarily property damage

- **Super Typhoon Meranti (2016)** alone recorded direct economic losses ranging from approximately 1.7 billion yuan to over 11.7 billion yuan representing up to 46.2% of the year total
- **Tropical Cyclones** in 2018 affected nearly 32 million people in 22 provincial regions of China, with 80 people dead, millions evacuated, and a direct economic loss of over 67 billion yuan
- TCs impacts on natural and artificial defence systems: total of 76 cases of damages in 2022 to seawalls and revetment spanning a length of 52 km, at a DEL of over 2.4 billion yuan across coastal China



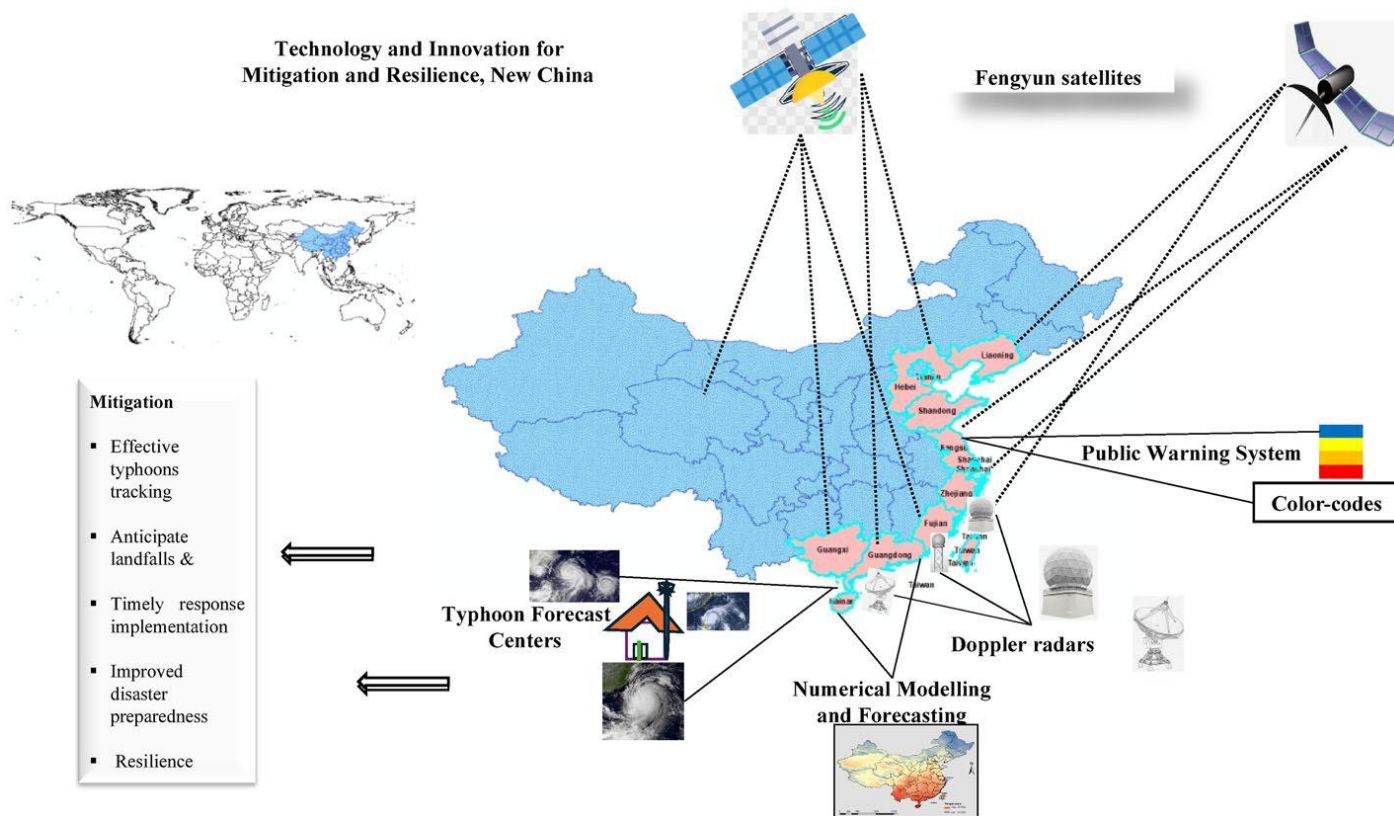
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Resilience

Technology and Innovation for
Mitigation and Resilience, New China



➤ Strengthened infrastructure

- the building construction sector employed a little over 12 million persons per year from 1980 to 2000 resulting in an average output of 412 billion yuan however, the proceeding years (2001–2022) saw a spike of an average of 44.1 million persons employed per year.
- In 2022 alone, the national total construction output was estimated at over 30 trillion yuan of which output from the coastal areas of China amounted to 14.3 trillion yuan (46.4% of the national total) and Jiangsu province recorded the highest output at 13% of the national total output

➤ Improved observation and early warning systems

- China Meteorological Administration as of 2018, had established an extensive observation network of 198 weather radars, over 2500 national observation stations, more than 60,000 Automatic Weather Stations (AWSs), and Fengyun-series meteorological satellites

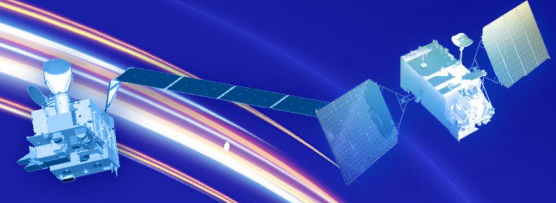
➤ Adaptation Justice in Coastal China e.g.

- Collaborative disaster risk reduction initiatives in Fujian Province
- The Adaptive Governance for Coastal Sustainability program in Guangdong Province



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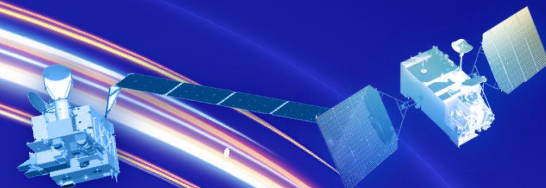
Recommendations

- ☐ The research findings are as a result of a merge between atmospheric science data of typhoons and economic data relating to the social sciences and encourages similar in-depth interdisciplinary study of natural occurrences that directly impact societies and human life
- ☐ The interdisciplinary nature of this study has a positive impact on community-based early warning systems (EWS) and their effectiveness which is a measure of both forecast performance and social uptake
- ☐ There is the need to revise existing models for asset protection while reducing loss of property



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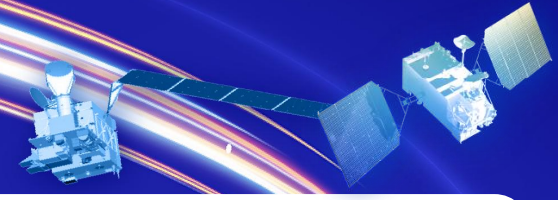
Q & A
sessions

*THANK
YOU !!!*



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