Interaction between tropical cyclone and southwesterly monsoon

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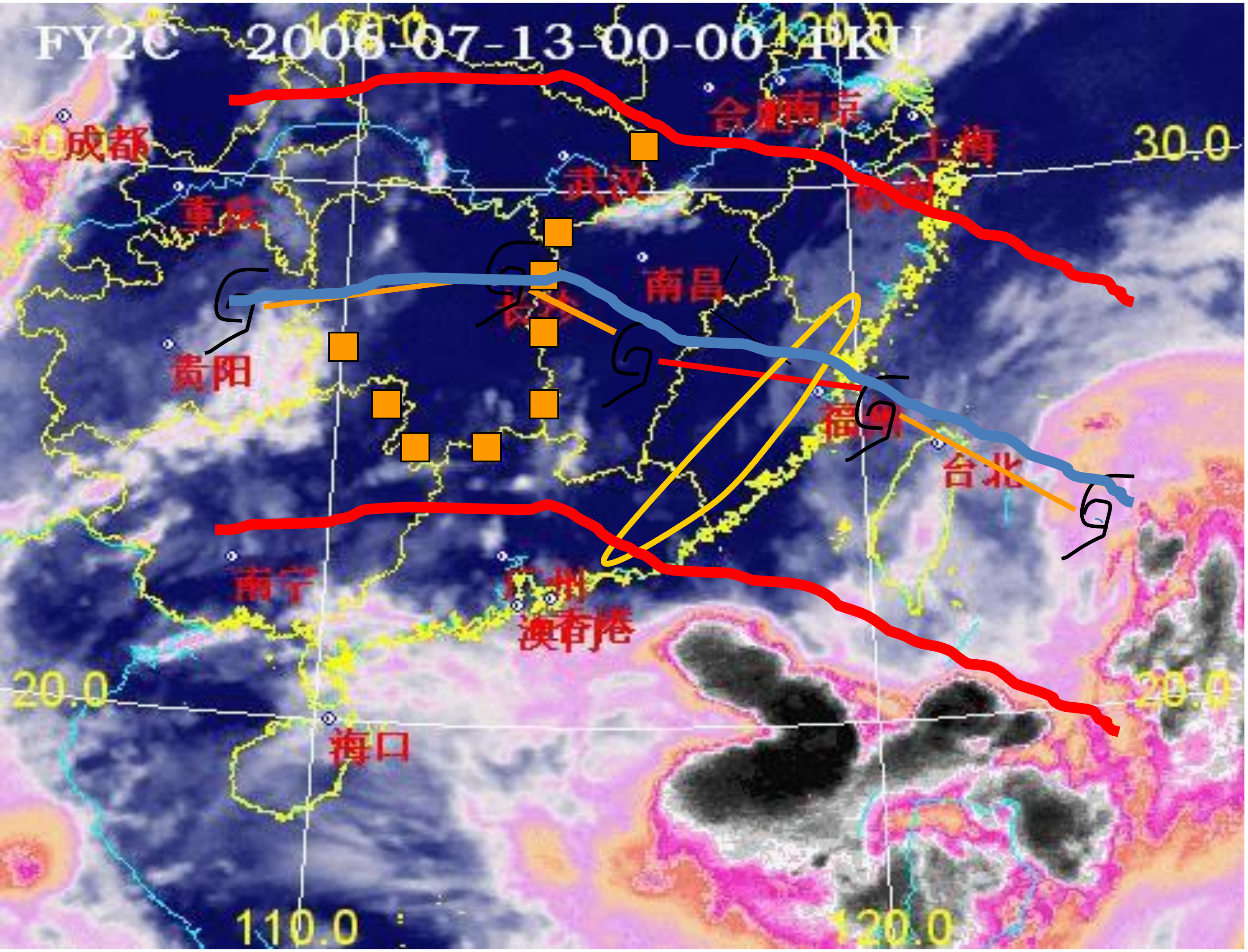
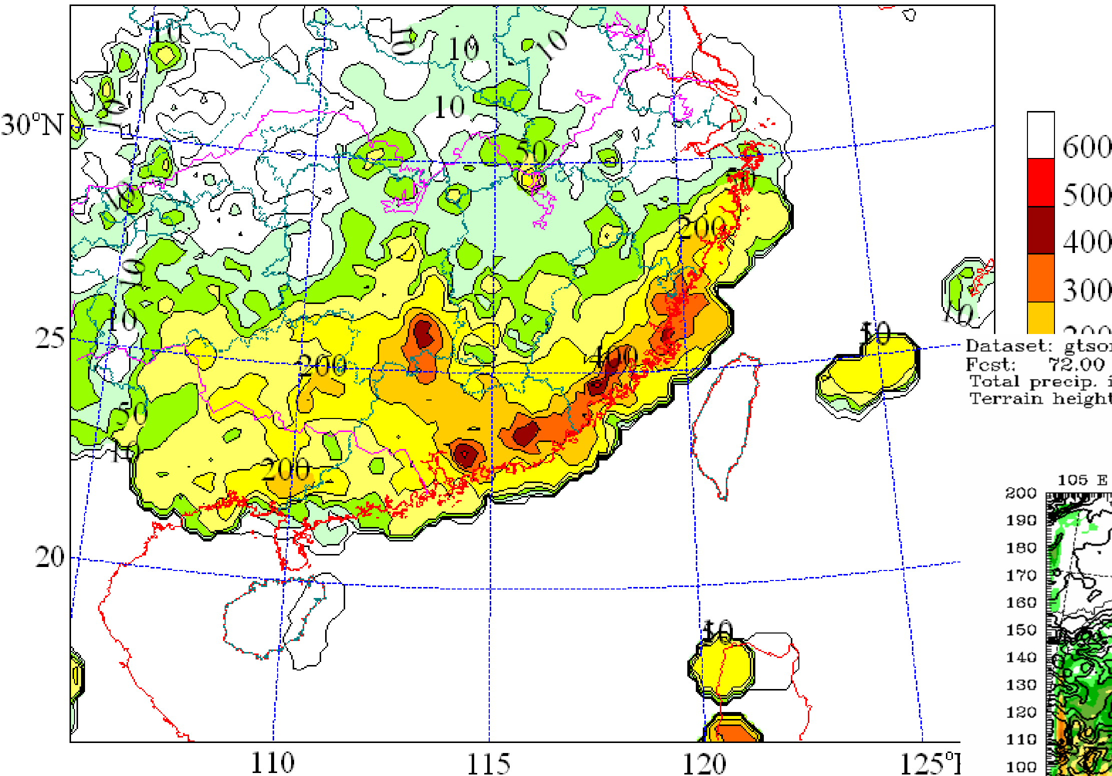
Roving seminar Dec 2010 Thailand

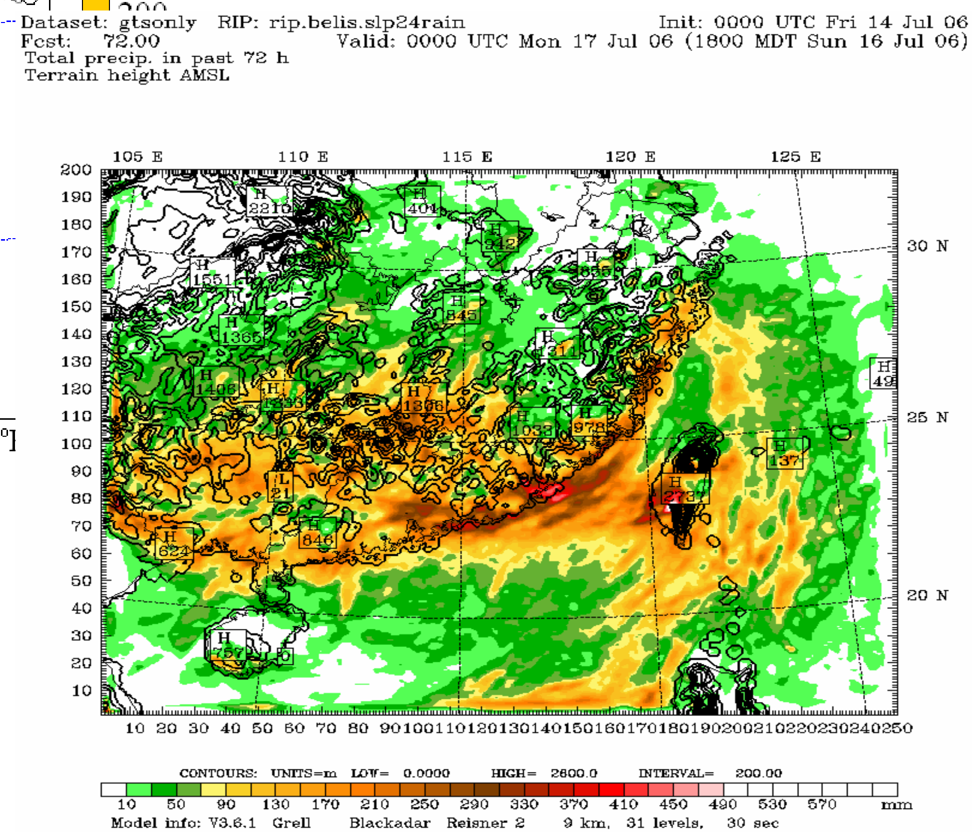
Satellite FY 2C IR observation



1953-2006
Bilis 路径南北5个经纬度内的登陆热带气旋共有30个

Rainfall Comparison between observation & MM5-9km simulation





Rainfall Reinforcement Associated with Landfalling Tropical Cyclones in Mainland China (Dong et. al. 2010)

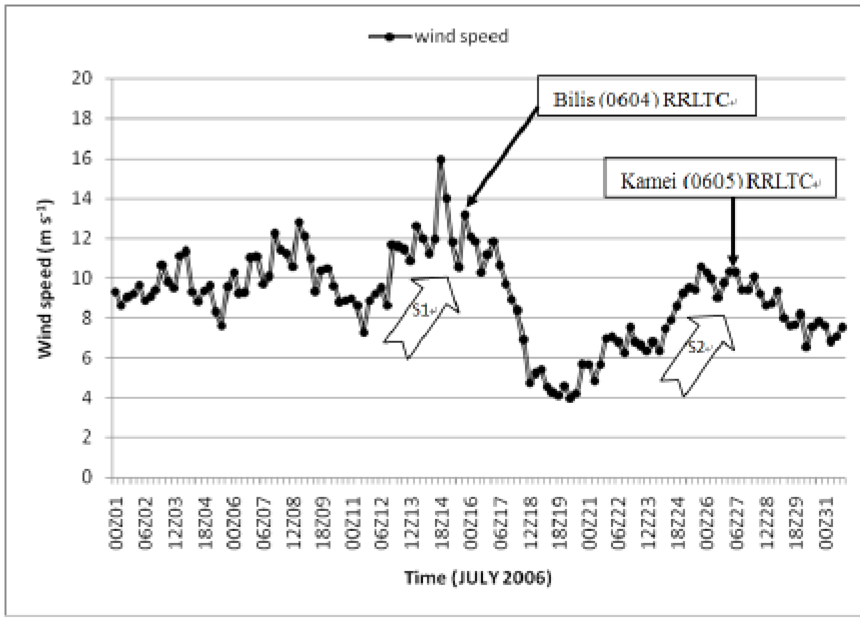
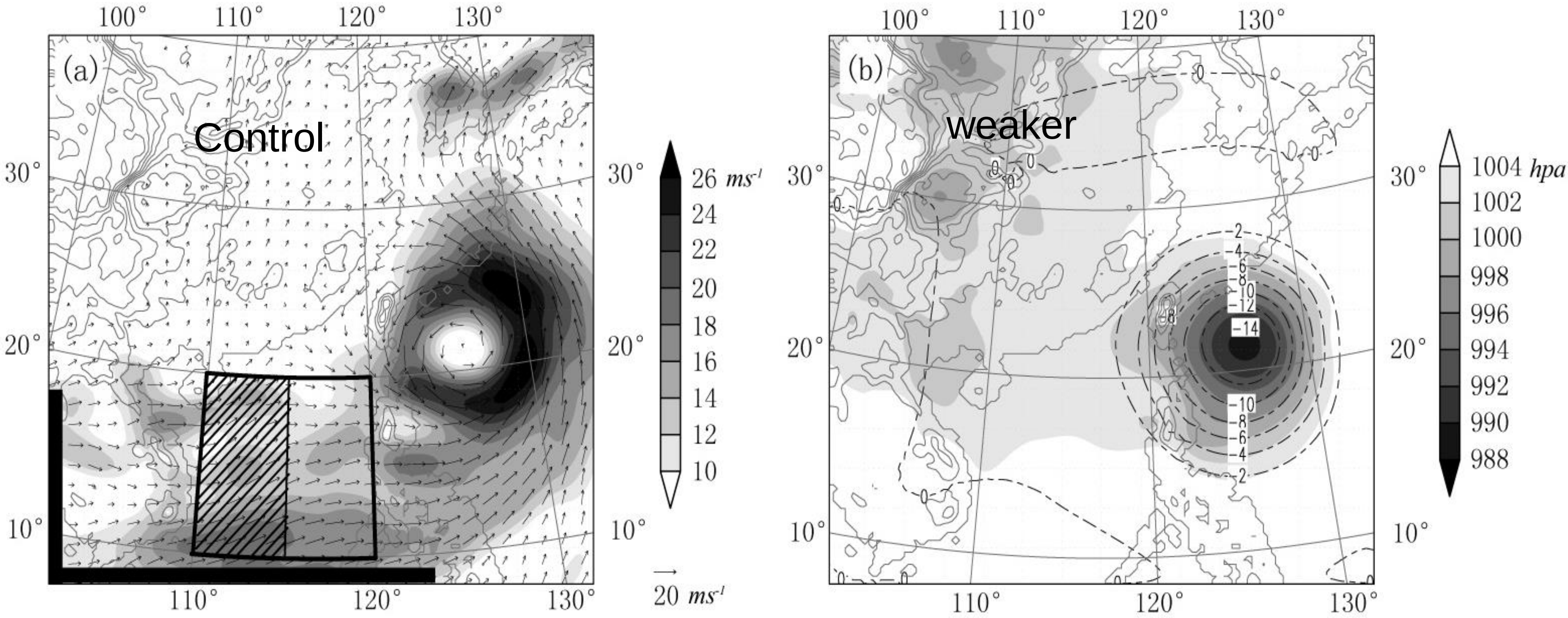
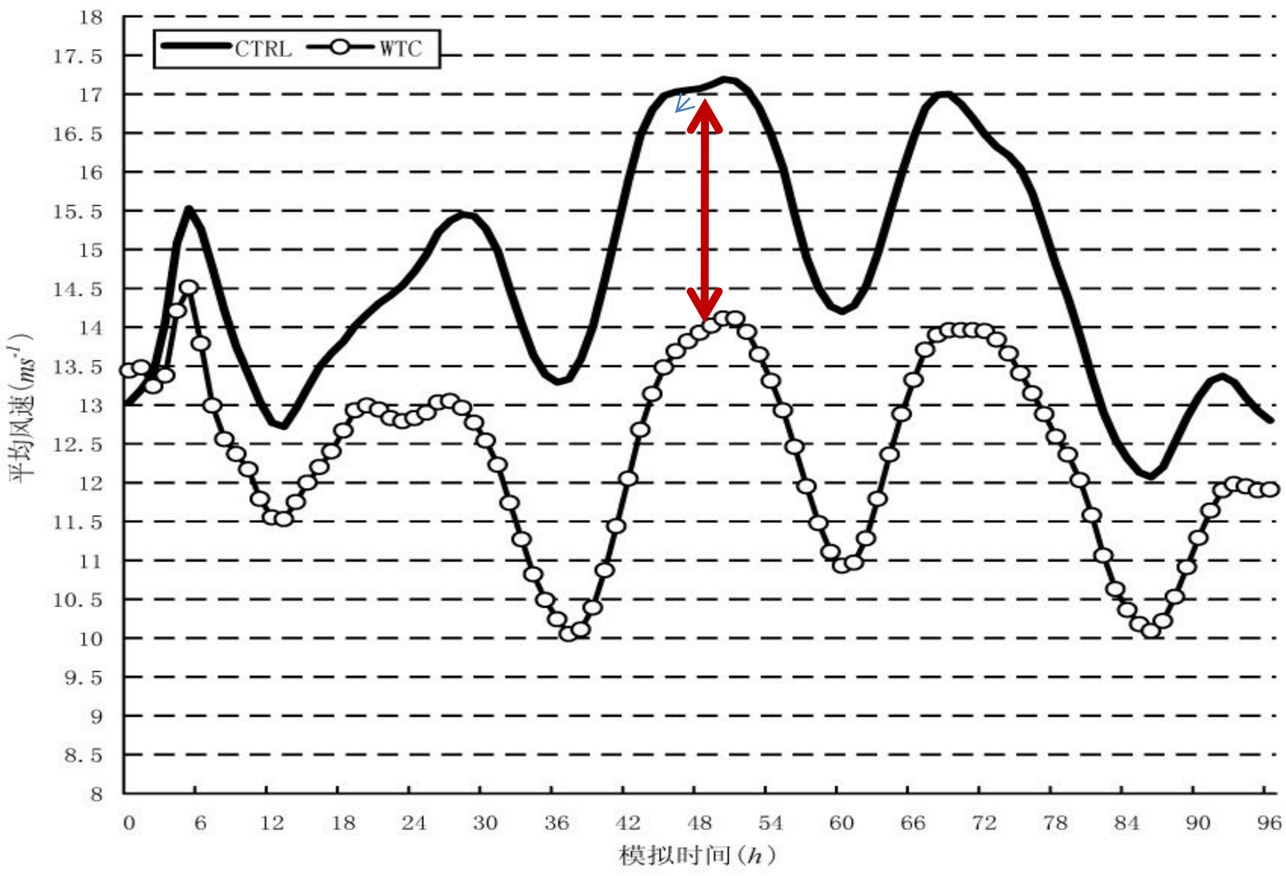


FIG. 17: Monsoon (unit: m s^{-1}) variation during July 2006. The wind speed is an area mean of total wind over the northern South China Sea (105-120E, 10-20N) at 850hPa. Open arrows with label S1 and S2 respectively denote monsoon surges during Bilis (0604) and Kamei (0605) affecting China.

Initial field of sensitive experiment



Comparison 850 hPa wind speed over SCS of control and weaker TC run



3-4 m/s difference

Momentum budget

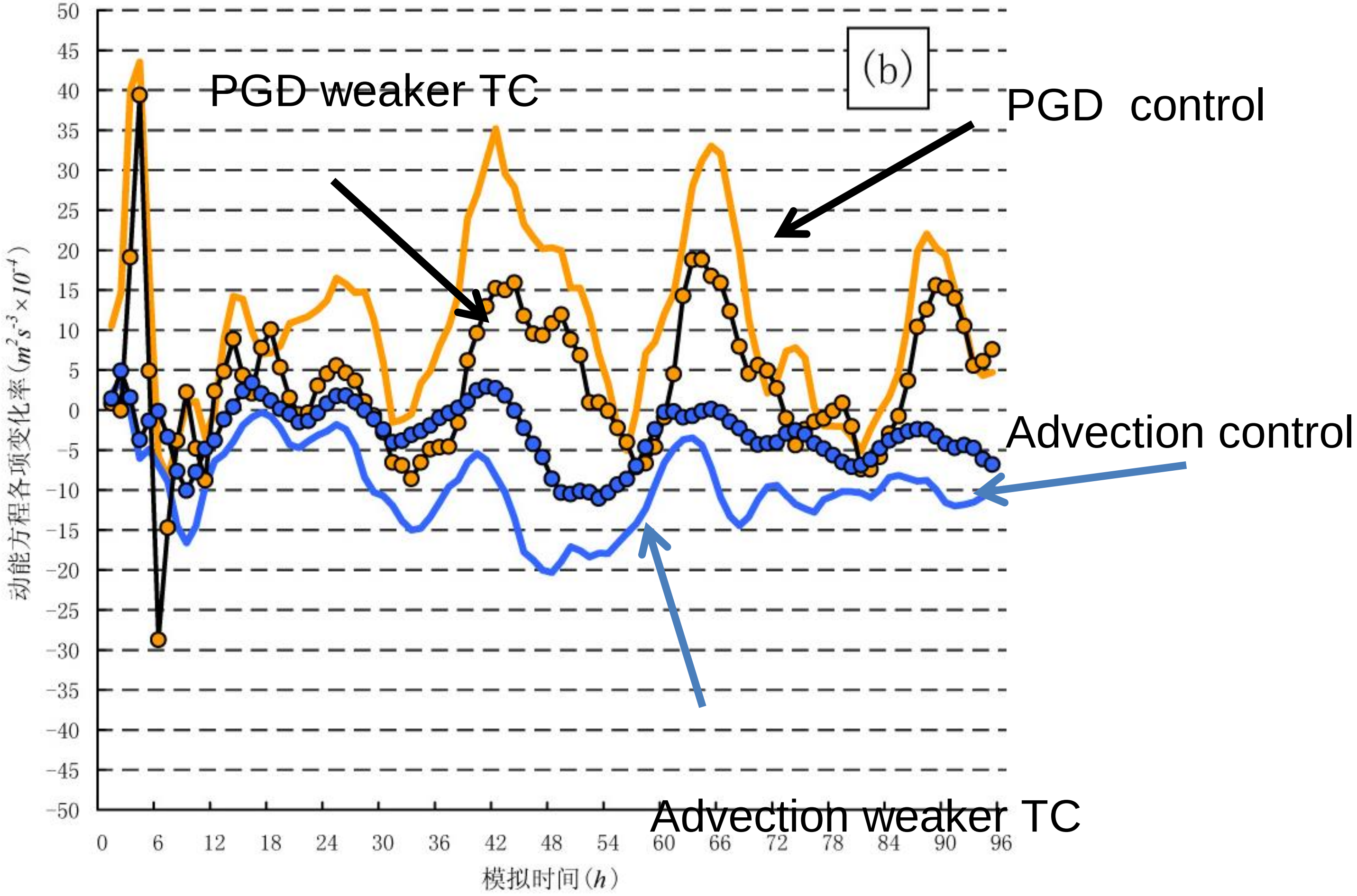
$$\frac{\partial k}{\partial t} = -\boldsymbol{V} \cdot \nabla k - \omega \frac{\partial k}{\partial p} - \boldsymbol{V} \cdot \nabla \quad \Phi$$

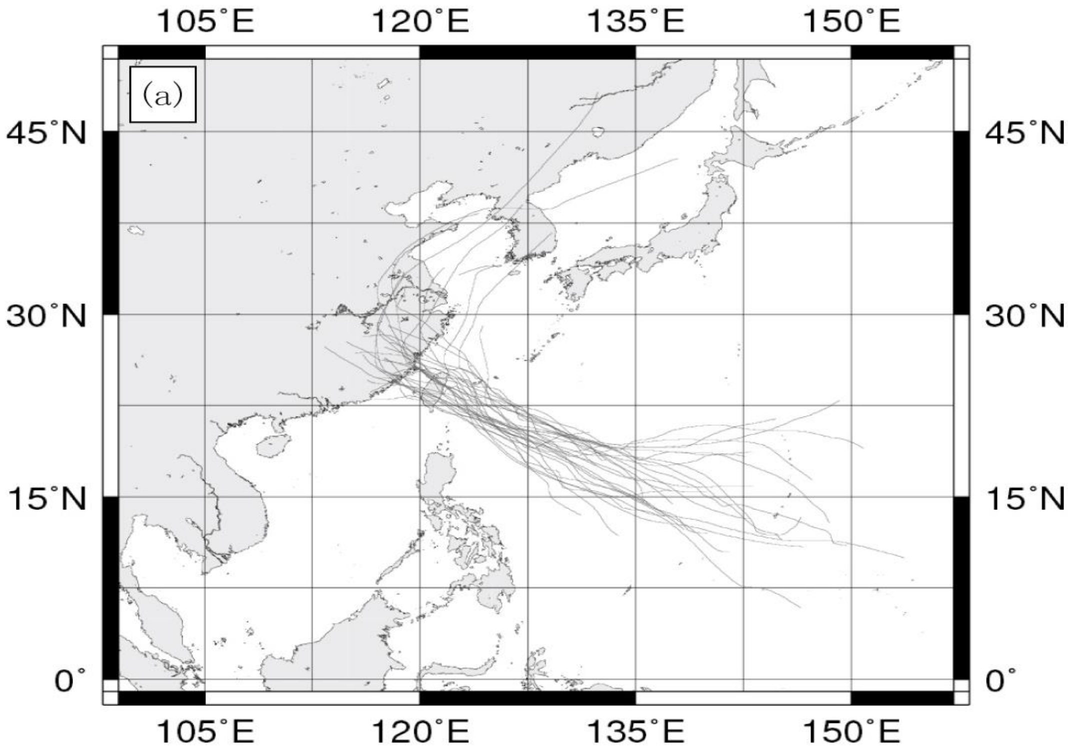
$$\text{(I)} \qquad \text{(II)} \qquad \text{(III)}$$

advection

Pressure gradient force

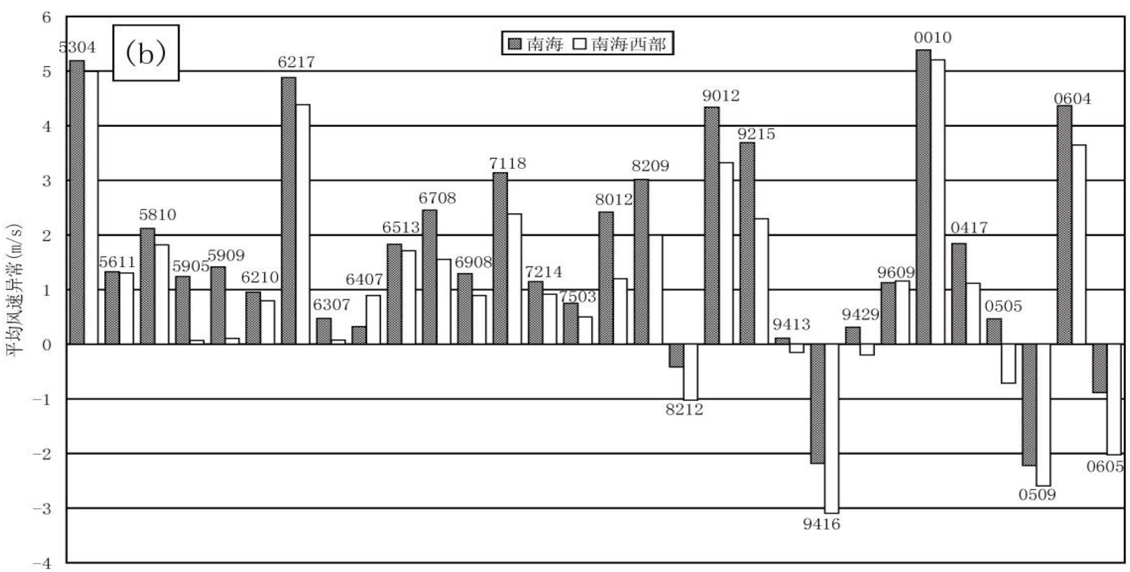
Momentum budget comparison between control and weaker TC run



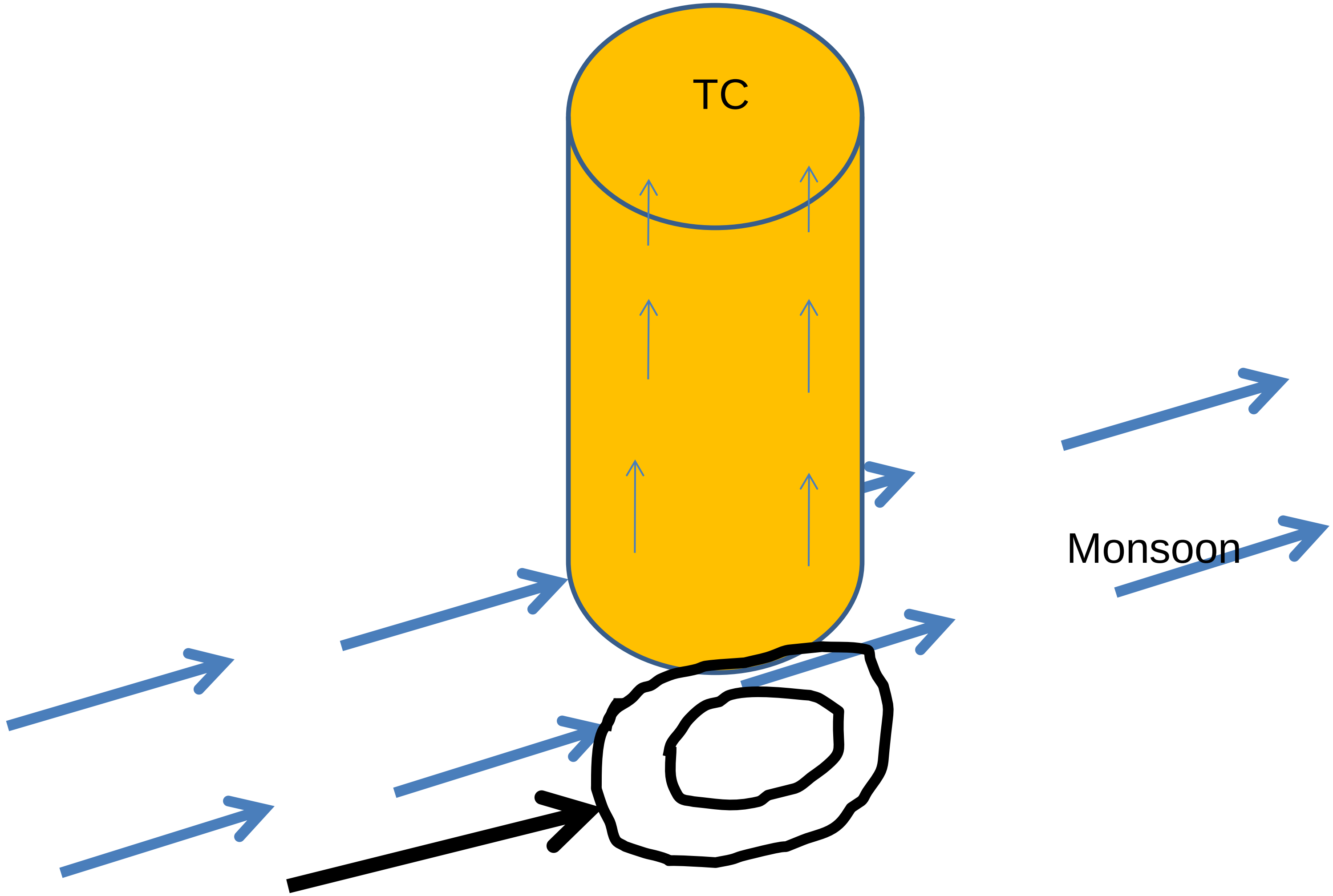


30 typhoons with
similar track with Bilis

Mesoscale convection systems accompanied with tropical cyclone landfall would enhance the pressure gradient force in low atmosphere above South China Sea Region, which would lead to intensification of the low level jet in summer monsoon.



from 1950 to 2009, 80% of the tropical cyclone activities accompany with positive low level wind speed anomaly in South China Sea .


TC
Monsoon

Rainfall Reinforcement Associated with Landfalling Tropical Cyclones in Mainland China (Dong et. al. 2010)

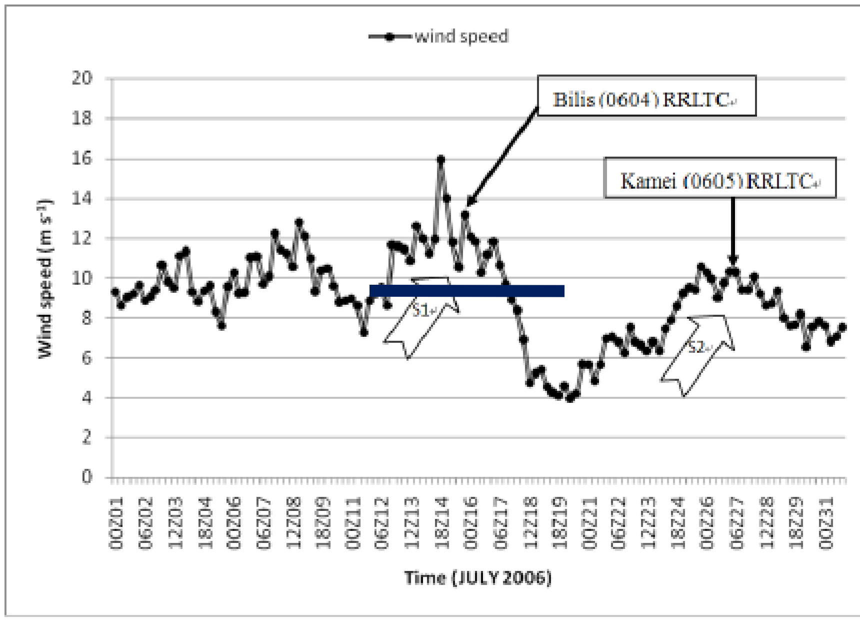


FIG. 17: Monsoon (unit: m s^{-1}) variation during July 2006. The wind speed is an area mean of total wind over the northern South China Sea (105-120E, 10-20N) at 850hPa. Open arrows with label S1 and S2 respectively denote monsoon surges during Bilis (0604) and Kamei (0605) affecting China.

*Study on the **potential impact** of landfall TC in China*

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Collaborator: Qing Wei , Lianshou Chen and Zhanpeng Dai

Roving seminar Dec 2010 Thailand

Motivation

- Landfall TCs are high-impact weather systems in China.
- Prediction of TC economic loss are based on the statistics using intensity observed, forecasting track in China
- ***How to predict the potential impact, especially economic impact before TC landfall is still not clear.***
- **Heavy rainfall, strong wind and storm surge** are associated with TCs and make loss of life and damage to properties

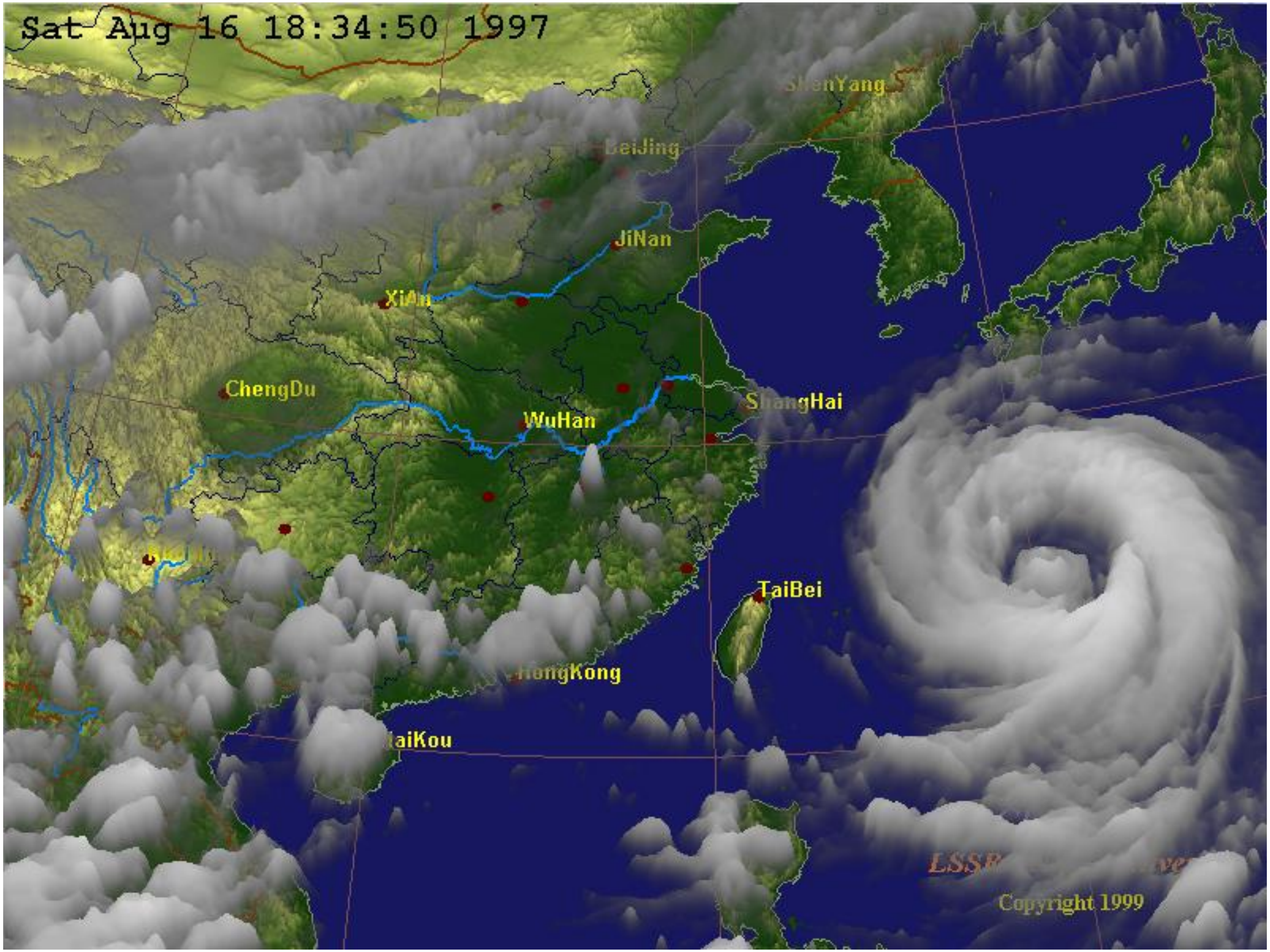
Motivation

- **Strong Wind**

$$PDI = \int_0^{\tau} V_{\max}{}^3 dt$$

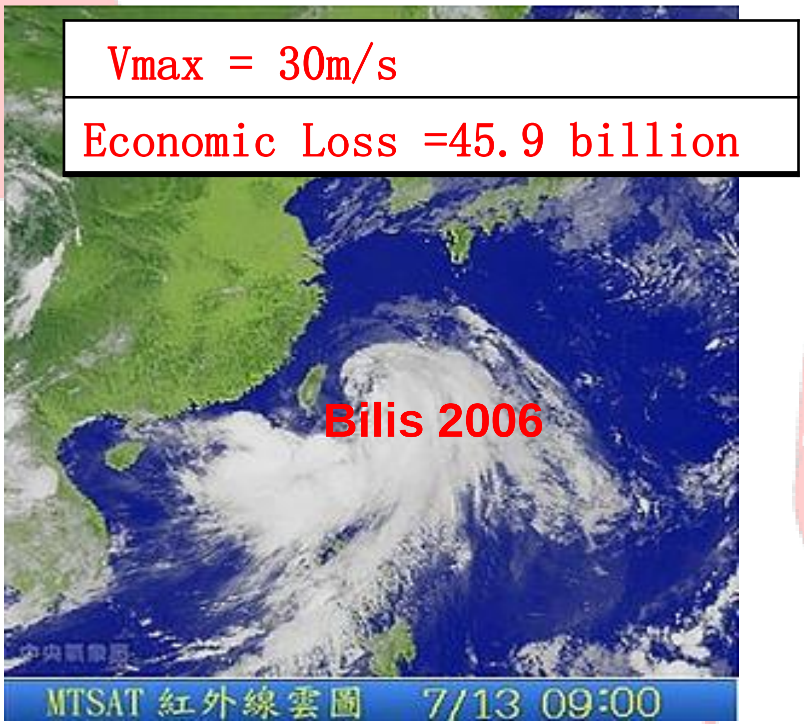
Size is ignored

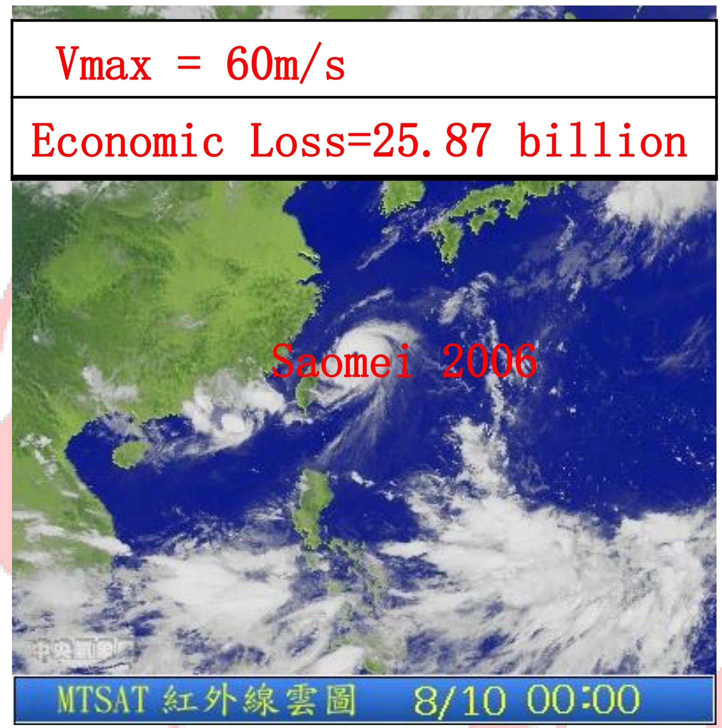
- **Heavy rainfall** $\neq$ **strong wind**


Sat Aug 16 18:34:50 1997
BeiJing
JiNan
XiAn
ChengDu
WuHan
ShangHai
TaiBei
Copyright 1999

Motivation

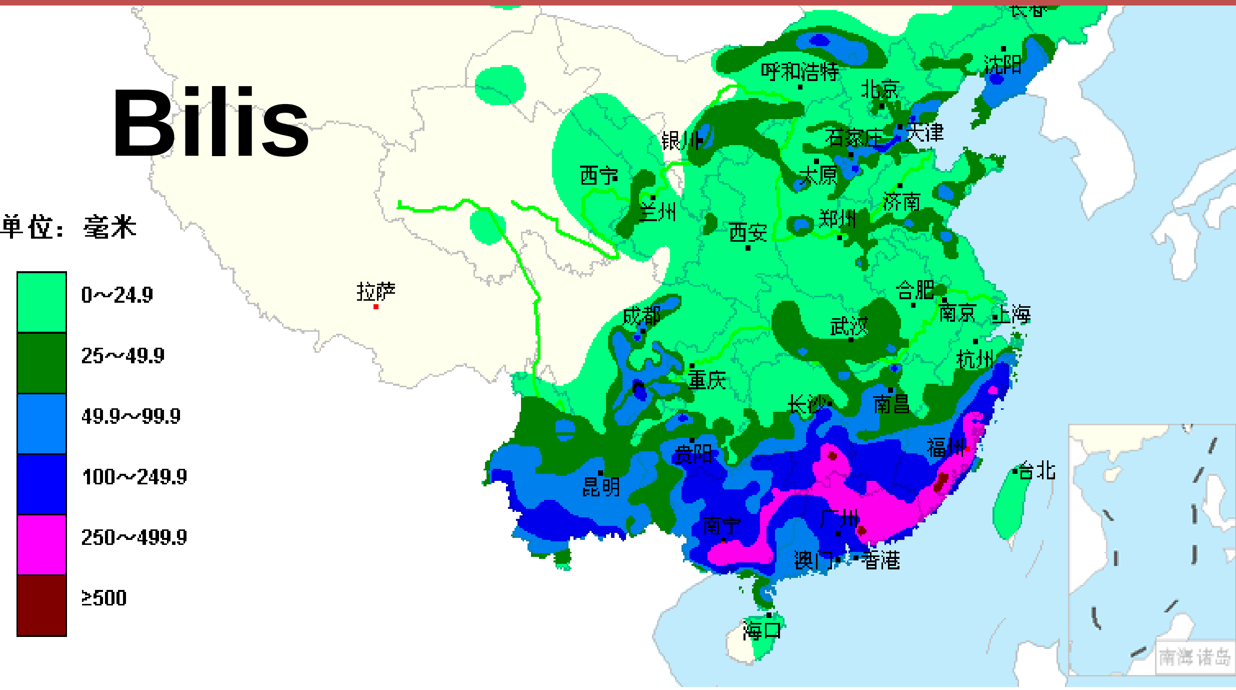
There are 2 landfall TCs that make imposing impact to China in 2006.

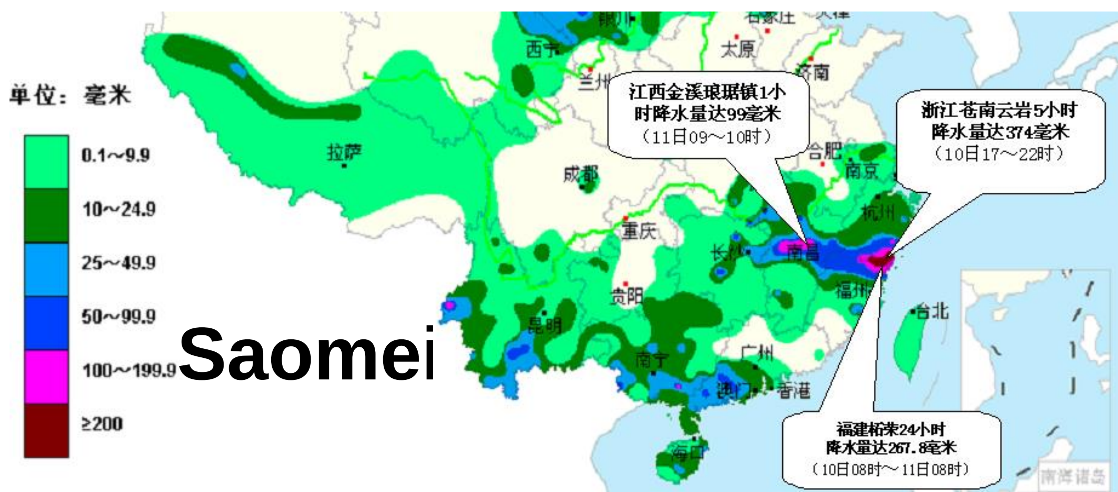


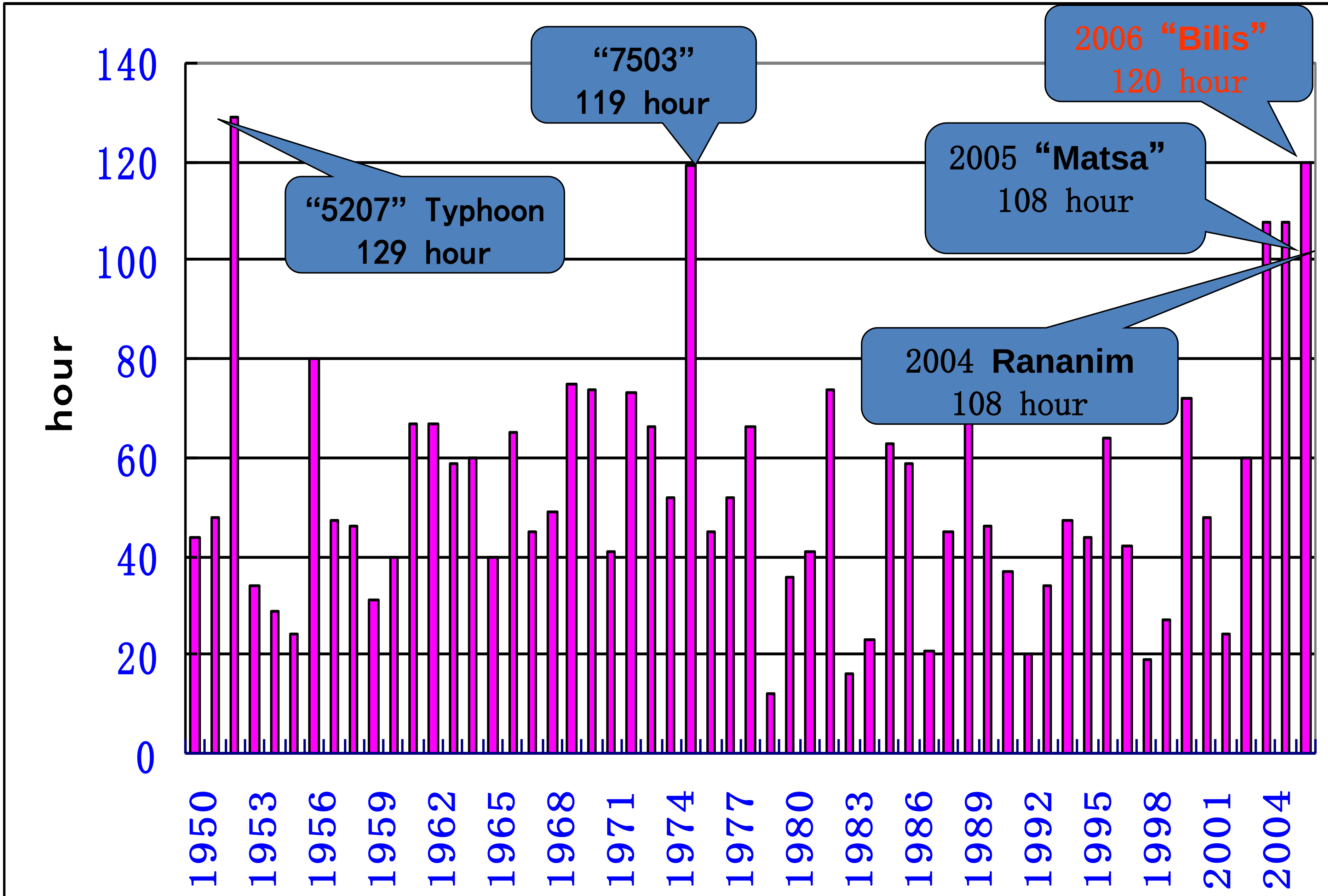


Why tropical storm Bilis made the highest economic loss in 50 years in China.

Total rainfall during “Bilis” & “Saomei” landfall

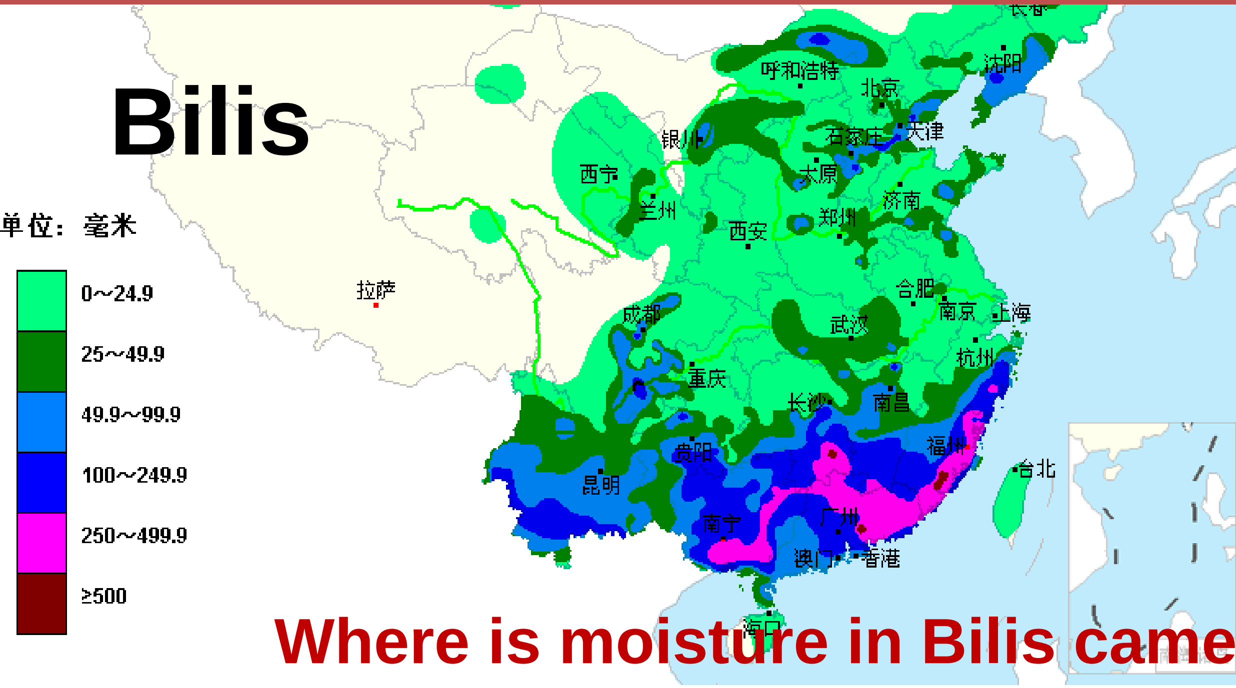




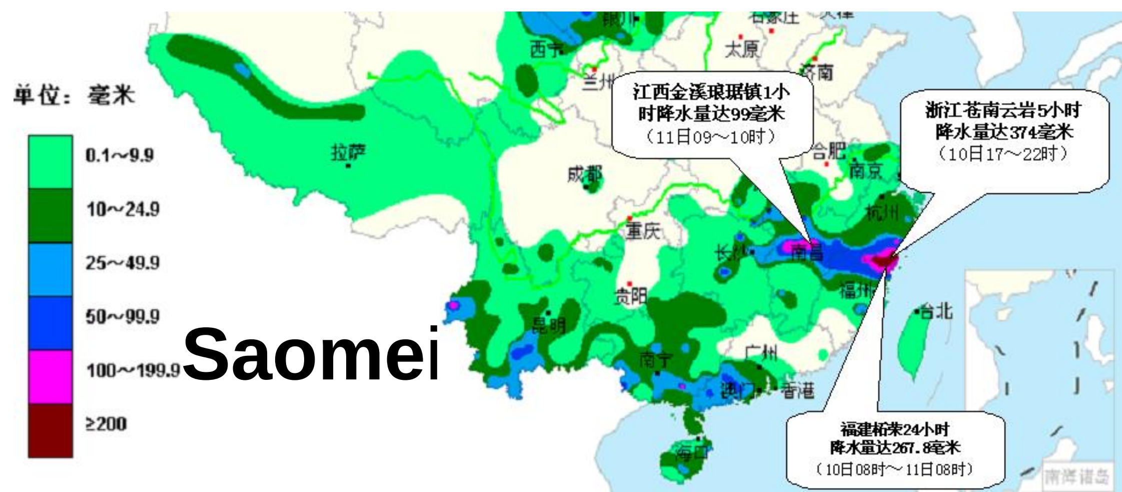


The inland duration of landfalling TC in China

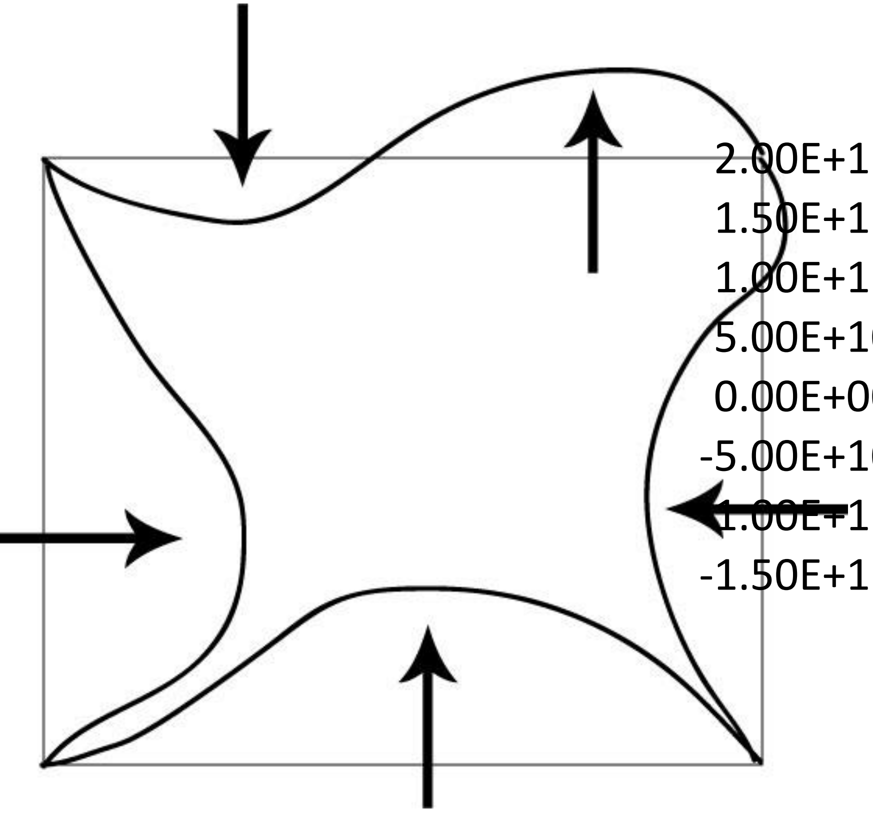
Total rainfall during “Bilis” & “Saomei” landfall

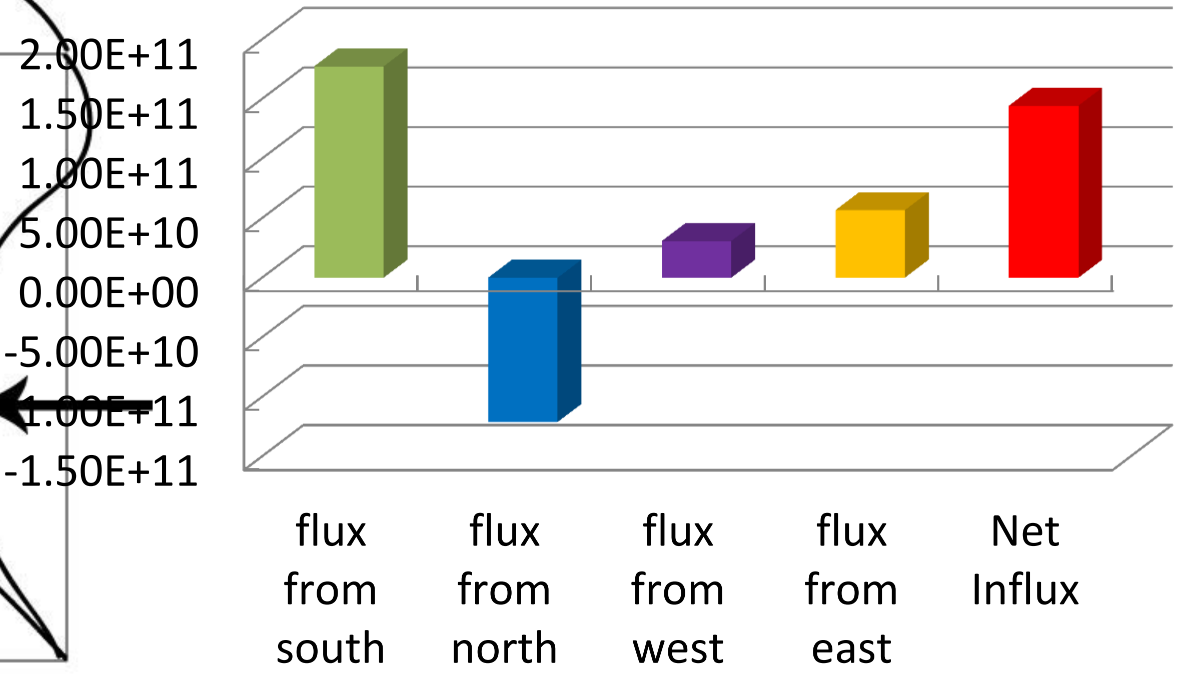


Where is moisture in Bilis came from?



Moisture Budget using 3-day simulation of MM5



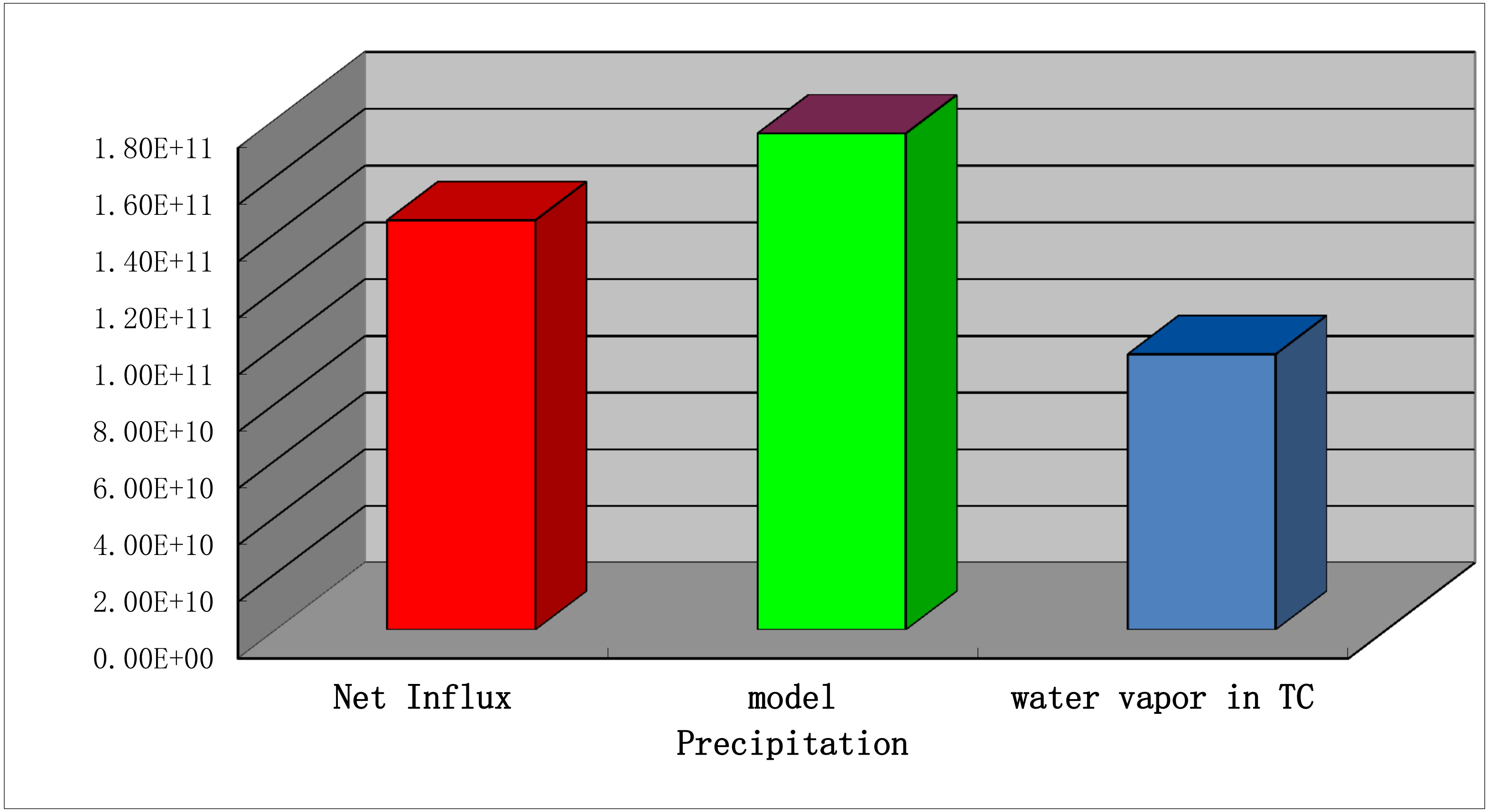


- Q is water vapor mixing ratio, V is wind velocity

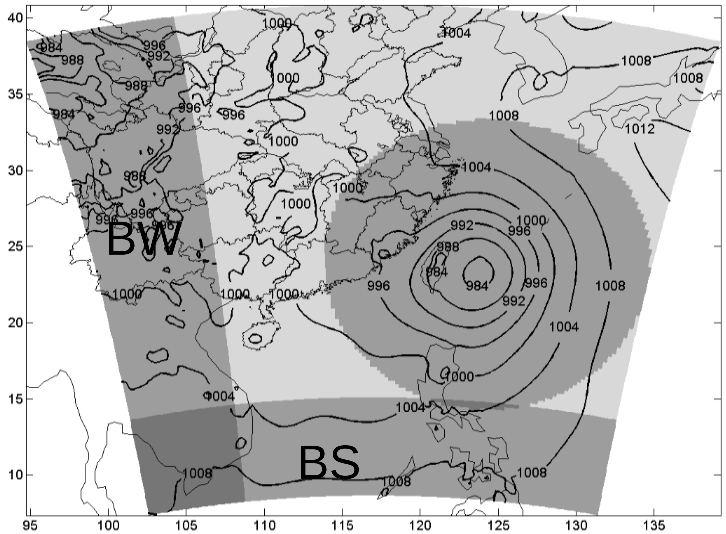
$$\text{flux} = \int\int\int qVdpdtdx$$

Net Influx : precipitation: water vapor inside TC before landfall

3 : 4 : 2



Moisture Sensitive Simulation



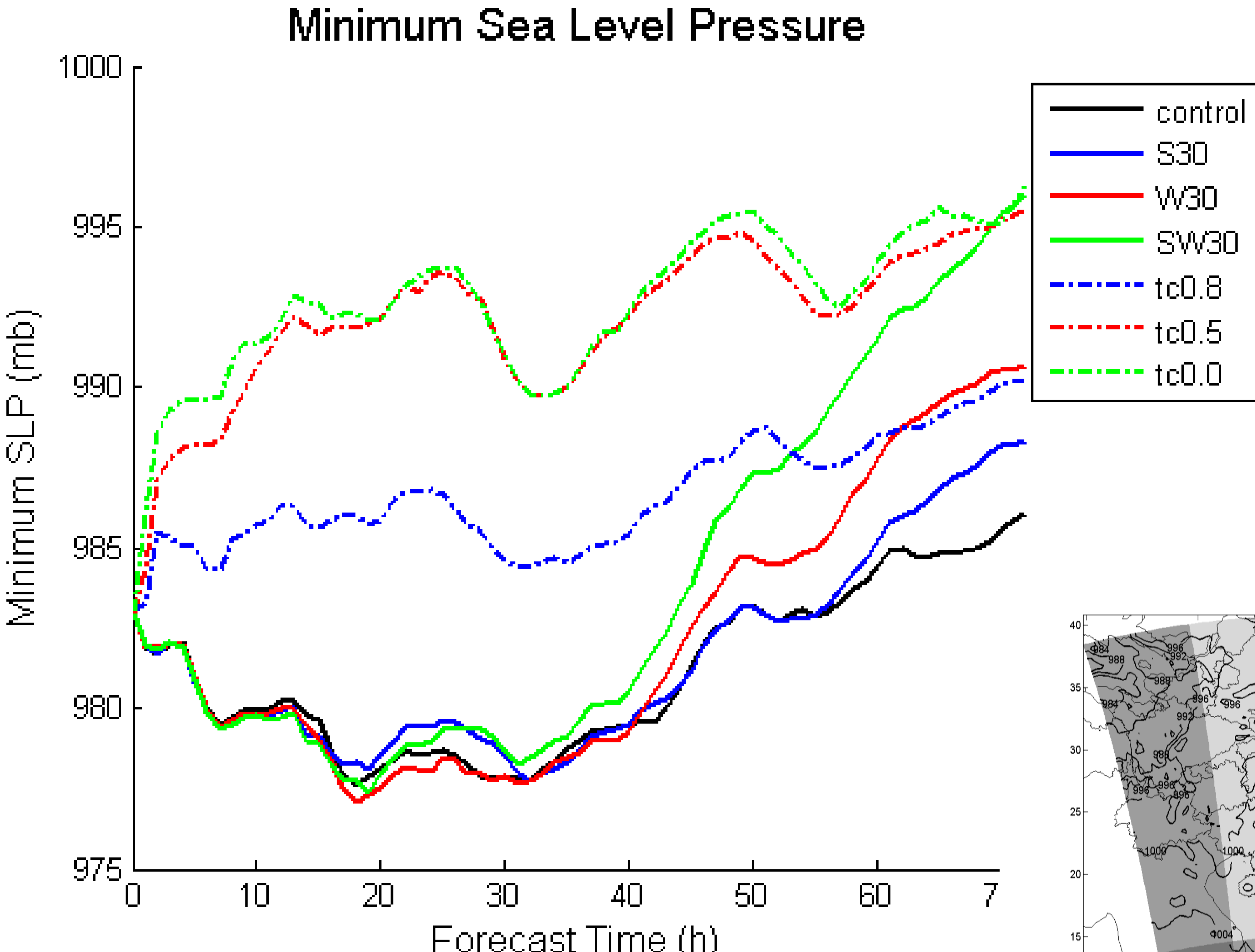
- Group A moisture of TC

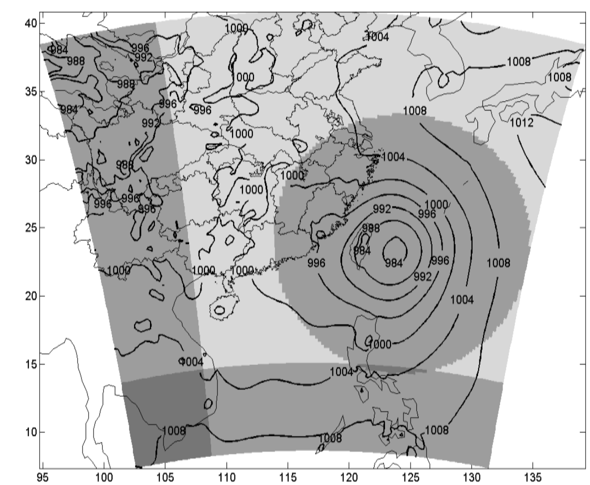
$$Q' = \begin{cases} Q \cdot \left[\beta + (1-\beta)\frac{r}{R}\right], & r < R \\ Q, & r \geq R \end{cases}$$

- control
- Tc0.8 0.8 Qv
- Tc0.5 0.5 Qv
- Tc0.0 0

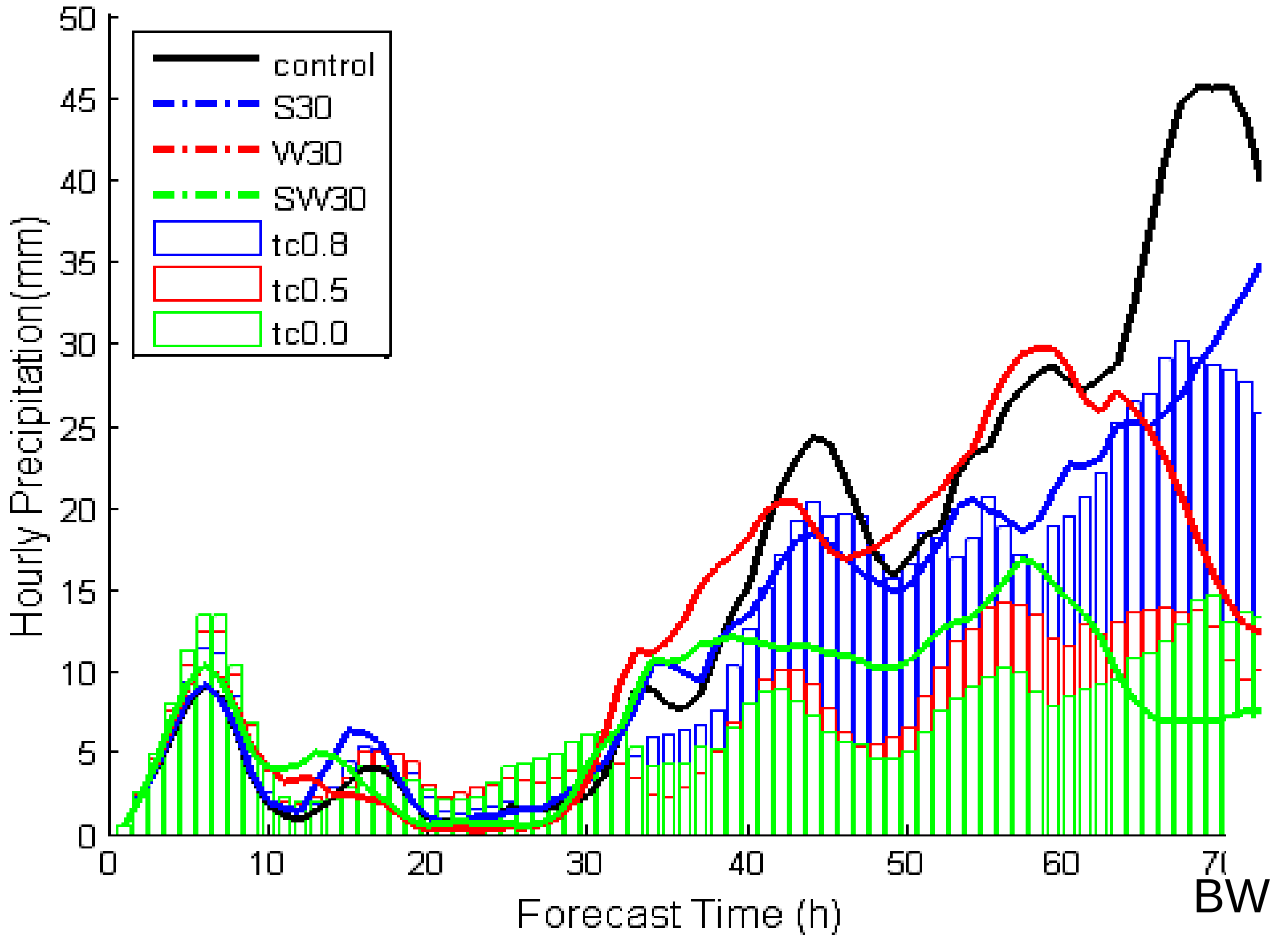
- Group B
- Control
- BS-S30 Qv are set to 0 for initial field and lateral boundary condition
- BW-W30
- BSW –SW30

intensity of sensitive simulation

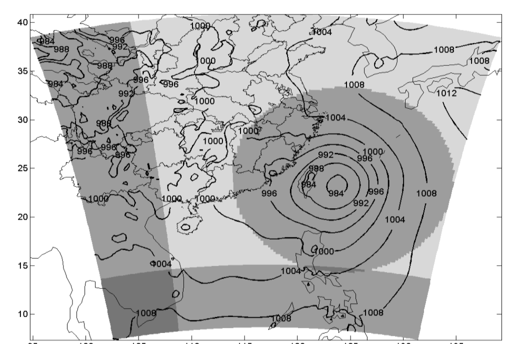




Total precipitation of sensitive simulation



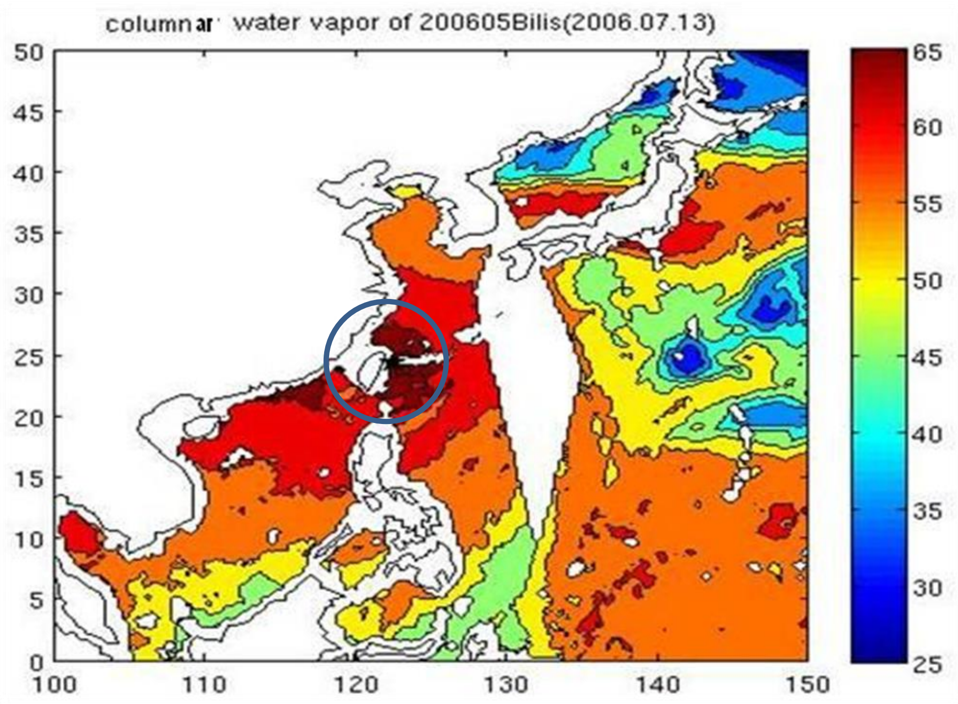
BW



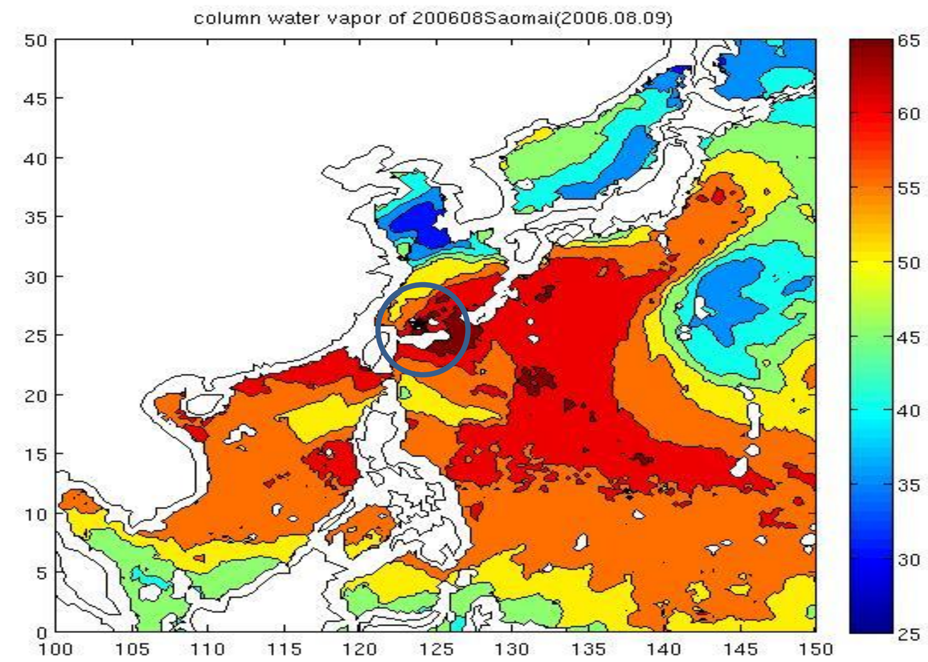
BS

Comparison of radius and CWV between Bilis 2006 and Saomei 2006

CWV：columnar water vapor



Bilis 2006



Saomei 2006

R = 509.3km
Total CWV=69013.26mm

R = 333.36km
Total CWV=28302.87mm

Data (30 landfall TCs from 2001 to 2007)

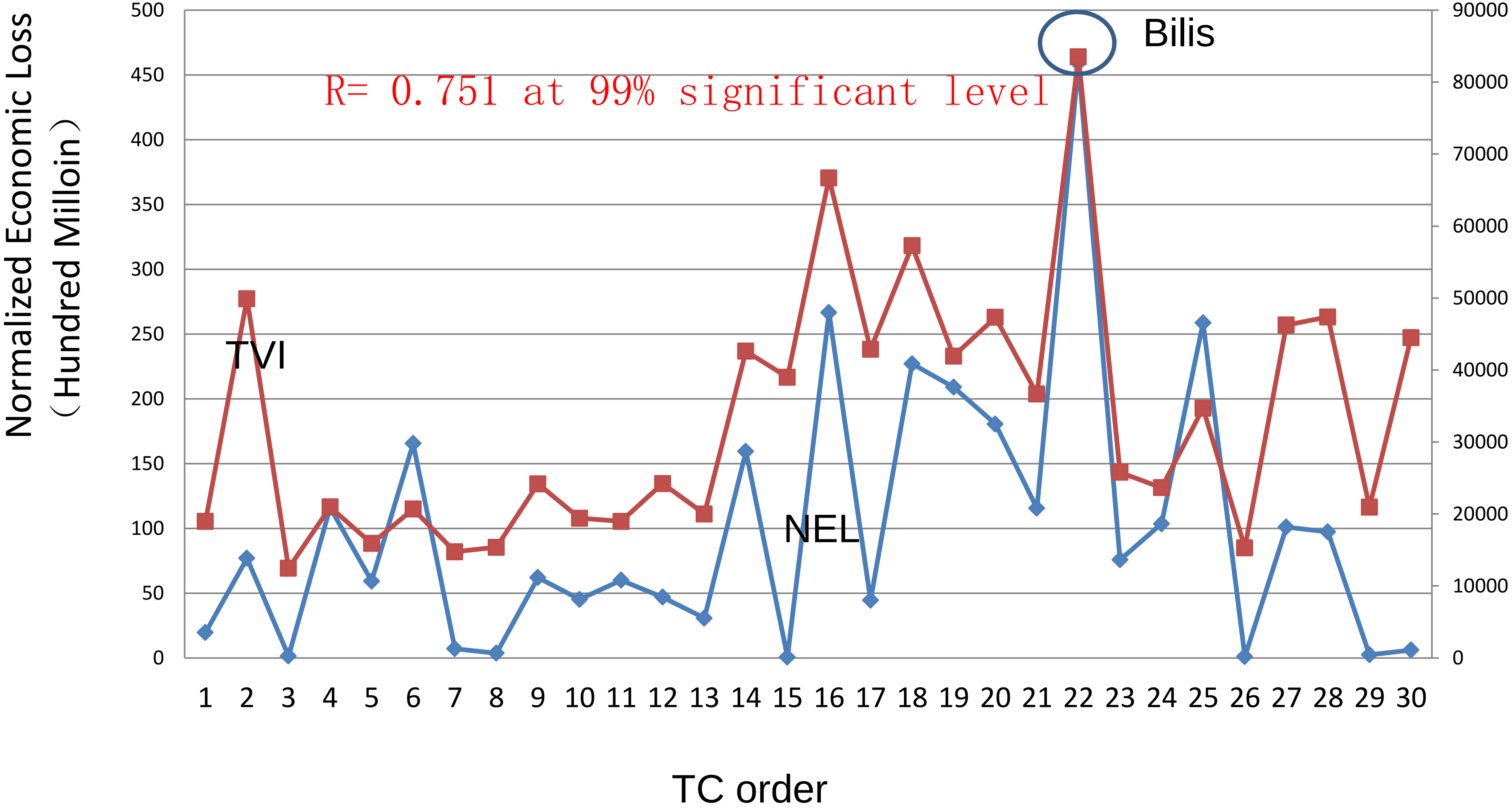
- **The economic loss of TCs obtained from the Ministry of Civil Affairs and be normalized using the inflation and GDP from 2001 to 2007 http://www.econstats.com**
- **Total column water vapor derived from SSM/I satellite observation http://www.ssmi.com/ssmi/ssmi_description.html**
- **QuickScat sea surface wind velocity over the ocean http://www.ssmi.com/qscat/qscat_browse.html**
- **CMORP（Climate prediction center MORPHing method） precipitation data with 3-h interval http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html**
- **Best track and radius of TCs from JTWC（Joint Typhoon Warning Center）**

TC order	Time	Name	NEL	V max	Rank Vmax	Radius
1	200107	Yutu	19.59	41.2	11	250.02
2	200108	Toraji	76.92	38.6	12	407.44
3	200118	Nari	1.33	15.4	28	203.72
4	200215	Kammuri	116.15	23.1	22	259.28
5	200217	Vongfong	59.25	18	25	222.24
6	200219	Sinlaku	165.5	46.3	9	259.28
7	200221	Hagupit	7.07	18	25	222.24
8	200308	Goni	3.63	33.4	16	222.24
9	200309	Imbudo	62.04	46.3	9	277.80
10	200310	Morakot	45.19	33.4	16	250.00
11	200312	Krovanh	59.95	36	14	250.02
12	200315	Dujuan	46.88	64.3	3	287.06
13	200323	Nepartak	30.71	33.4	16	259.28
14	200505	Haitang	159.36	59.2	4	370.00
15	200508	Washi	0.59	18	25	351.88

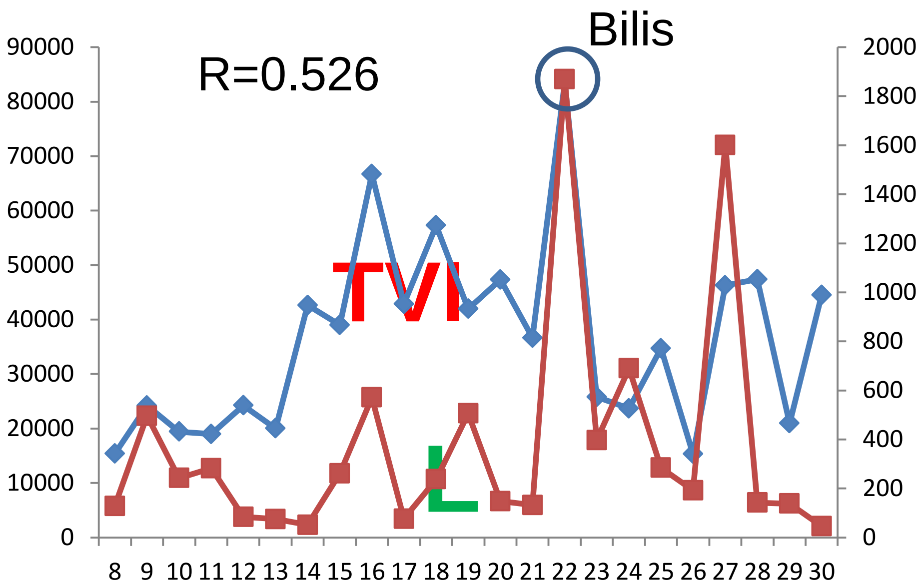
TC order	Time	Name	NEL	V max	Rank Vmax	Radius
16	200509	Matsa	266.68	38.6	12	463.00
17	200510	Sanvu	44.5	30.9	19	370.00
18	200513	Talim	227.07	56.6	7	444.00
19	200515	Khanun	209.03	56.6	7	379.25
20	200518	Damrey	180.5	30.9	19	407.00
21	200519	Longwang	115.45	61.7	3	370.40
22	200606	Bilis	459.11	23.1	22	509.30
23	200607	kaemi	75.71	30.8	19	287.06
24	200608	Prapiroon	103.52	23.1	22	277.80
25	200610	Saomei	258.73	72	1	333.36
26	200703	Toraji	1.02	7.7	30	222.24
27	200709	Sepat	100.95	59.1	4	388.92
28	200713	Wipha	97.36	59.1	4	388.92
29	200714	Francisco	2.44	10.3	29	259.28
30	200715	Lekima	6.04	36	14	379.66

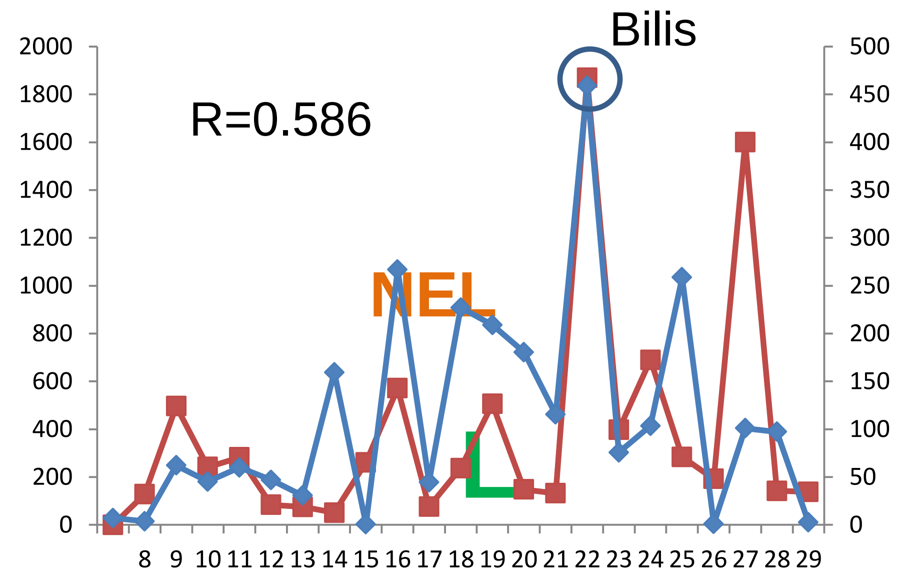
Correlation between TVI and Nomolized economic loss

$$TVI = \sum_{i=1}^{n} CWV_i$$



Physical Mechanism between TVI(before landfall) and Normalized Economic Loss



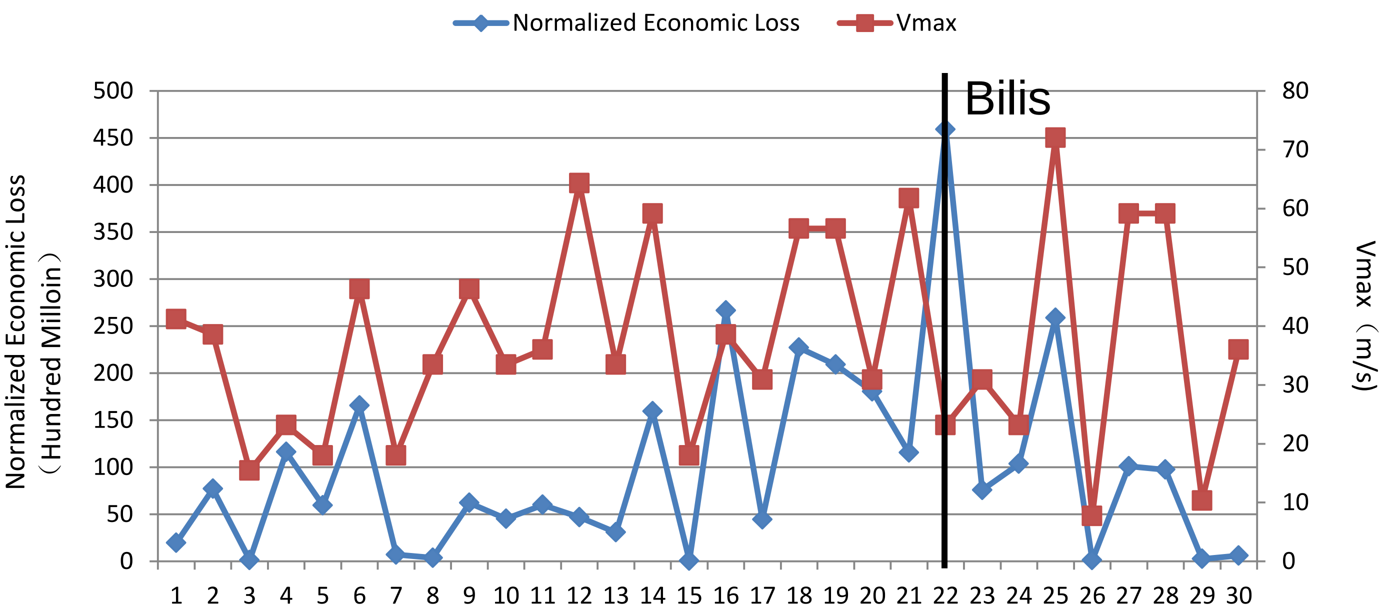


$$L = \sum_{i=1}^{m} \sum_{t=1}^{n} l_{i,t} \qquad l_{i,t} = \begin{cases} 1 & 10mm \geq x_{i,t} \geq 5mm \\ 2 & 20mm > x_{i,t} \geq 10mm \\ 3 & x_{i,t} > 20mm \end{cases}$$

x is the accumulated TC precipitation at a given grid point in every 3 hour (CMOPH) over land;
n is the total observed times of precipitation（8 times in a day）
m is the number of grid point with TC precipitation in a given time.

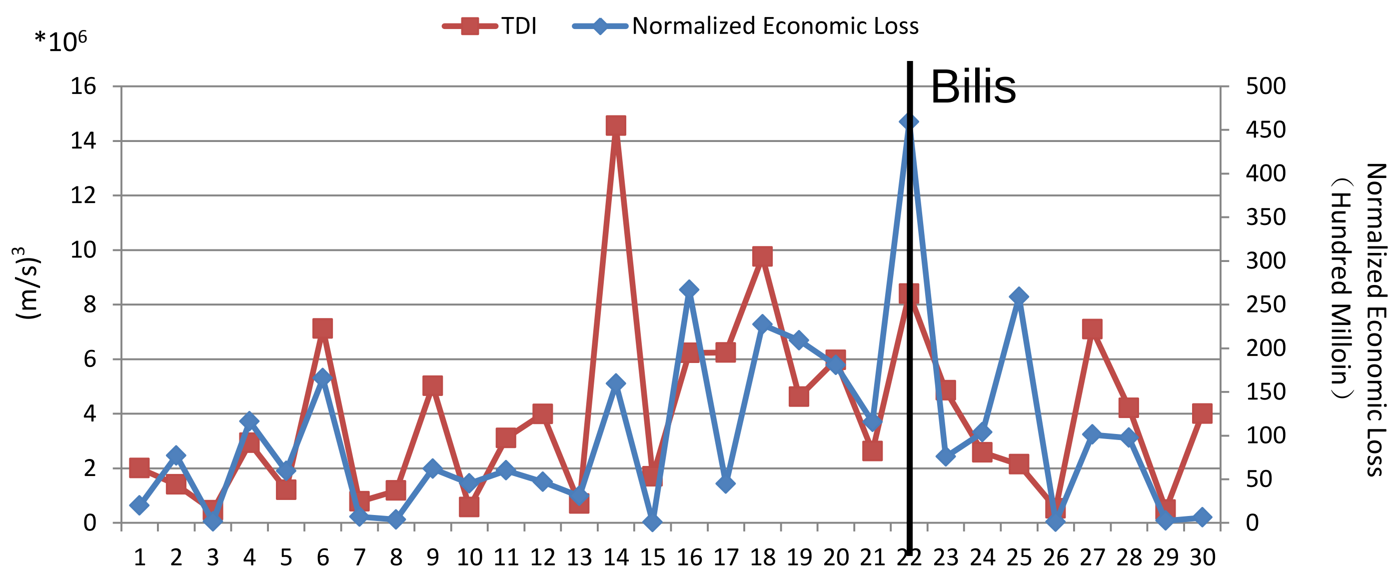
Correlation between Vmax (TDI) and economic loss

Vmax
(R=0.345)



$$TDI = \sum_{i=1}^{n} V_i^3$$

R=0.59



Impact Index (TVI and TDI)

$$I = 1.499 * 10^{-6} TVI * L + 6.657 * 10^{-6} TDI - 49.732$$

Correlation between I and economic loss :

R=0. 769 at 99% significant level

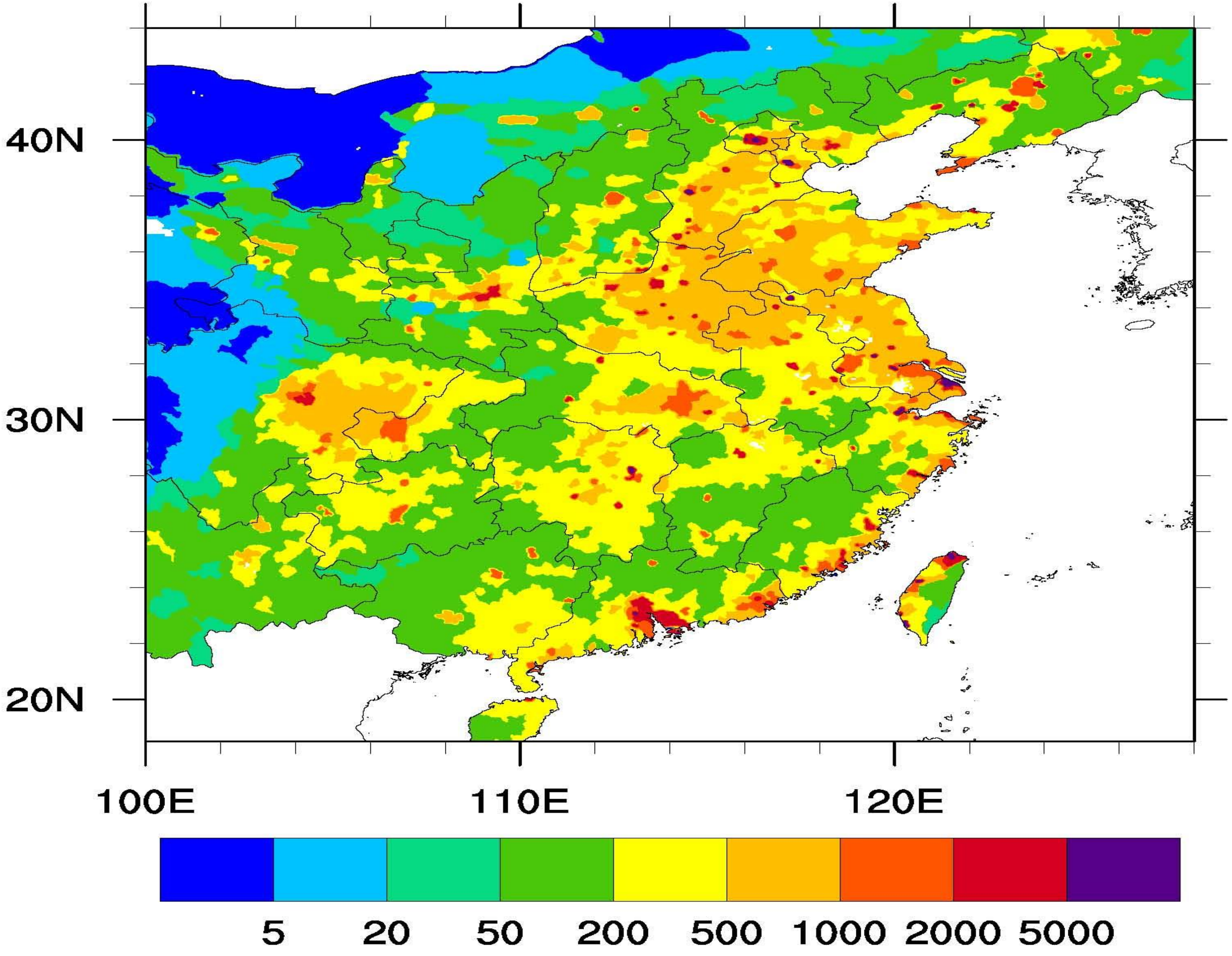
5 categories are classified using system cluster analysis scheme.

300＜I	**categories 5**
200＜I≤300	**categories 4**
120＜I≤200	**categories 3**
60＜I≤120	**categories 2**
I≤60	**categories 1**

TC order	Time	Name	NEL	V max	Rank Vmax	Radius	TVI 10^4	Impact Index	Rank Impact	Grade
1	200107	Yutu	19.59	41.2	11	250.02	1.89	34.77	22	1
2	200108	Toraji	76.92	38.6	12	407.44	4.99	146.85	9	3
3	200118	Nari	1.33	15.4	28	203.72	1.24	0.02	30	1
4	200215	Kammuri	116.15	23.1	22	259.28	2.10	48.56	20	1
5	200217	Vongfong	59.25	18	25	222.24	1.59	18.05	26	1
6	200219	Sinlaku	165.5	46.3	9	259.28	2.07	75.33	16	2
7	200221	Hagupit	7.07	18	25	222.24	1.47	10.90	29	1
8	200308	Goni	3.63	33.4	16	222.24	1.54	15.83	27	1
9	200309	Imbudo	62.04	46.3	9	277.80	2.42	74.53	17	2
10	200310	Morakot	45.19	33.4	16	250.00	1.94	27.00	25	1
11	200312	Krovanh	59.95	36	14	250.02	1.90	42.21	21	1
12	200315	Dujuan	46.88	64.3	3	287.06	2.42	67.76	18	2
13	200323	Nepartak	30.71	33.4	16	259.28	2.00	30.03	24	1
14	200505	Haitang	159.36	59.2	4	370.00	4.26	207.01	4	4
15	200508	Washi	0.59	18	25	351.88	3.90	107.91	12	2

TC order	Time	Name	NEL	V max	Rank Vmax	Radius	TVI 10^4	Impact Index	Rank Impact	Grade
16	200509	Matsa	266.68	38.6	12	463.00	6.67	241.85	2	4
17	200510	Sanvu	44.5	30.9	19	370.00	4.29	152.62	8	3
18	200513	Talim	227.07	56.6	7	444.00	5.73	229.96	3	4
19	200515	Khanun	209.03	56.6	7	379.25	4.19	138.36	11	3
20	200518	Damrey	180.5	30.9	19	407.00	4.73	167.52	6	3
21	200519	Longwang	115.45	61.7	3	370.40	3.67	105.20	13	2
22	200606	Bilis	459.11	23.1	22	509.30	8.35	319.40	1	5
23	200607	kaemi	75.71	30.8	19	287.06	2.58	79.39	15	2
24	200608	Prapiroon	103.52	23.1	22	277.80	2.37	56.24	19	1
25	200610	Saomei	258.73	72	1	333.36	3.47	94.67	14	2
26	200703	Toraji	1.02	7.7	30	222.24	1.53	11.28	28	1
27	200709	Sepat	100.95	59.1	4	388.92	4.63	170.95	5	3
28	200713	Wipha	97.36	59.1	4	388.92	4.74	156.02	7	3
29	200714	Francisco	2.44	10.3	29	259.28	2.10	32.14	23	1
30	200715	Lekima	6.04	36	14	379.66	4.45	143.76	10	3

Population density in China in 2000
(Unit: person per square km)



summary

Total water vapor inside TC
Total destructive index inside TC

} before TC landfall has significant correlation with the economic loss {

R=0.743
R=0.59

Landfall TCs with higher TVI would bring heavier rainfall, and make more economical loss over land in China.

TC impact index is defined as a function of TVI and TDI. The correlation between TC impact index and economical loss are significant(r=0.769).

Suggestions

To WMO or government

TC wind intensity warning is not enough in our operational systems, TC rainfall intensity and TC radius warning should be included

To Scientist

We need pay more attention to moisture data, since moisture is energy of TC and may affect the inland duration and rainfall of TC. Moisture has less degree of dynamical constraint than temperature, wind and other variables in data assimilation.

Real Time forecast of Impact Index of MORAKOT 2009

2009 08

MORAKOT

Index: 472

Grade: 5

05-Aug-2009

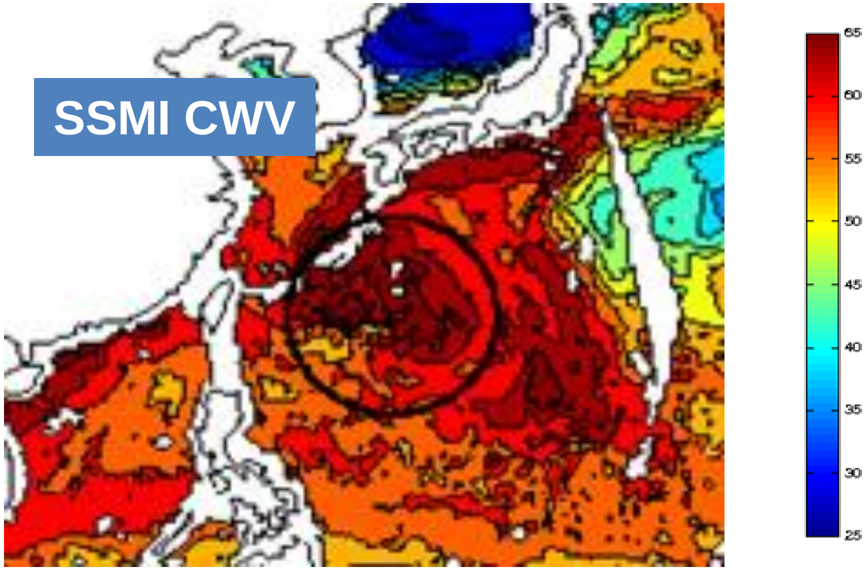
(Before landfall)

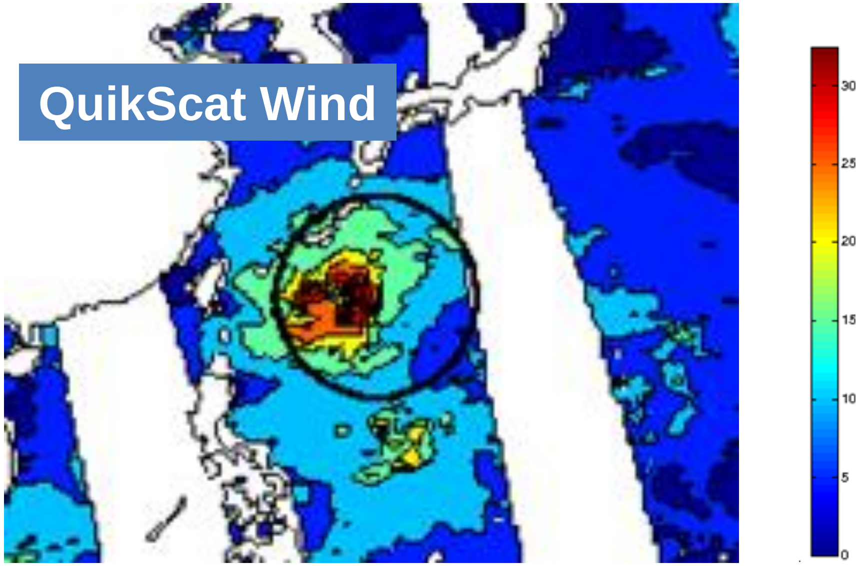
2006 04

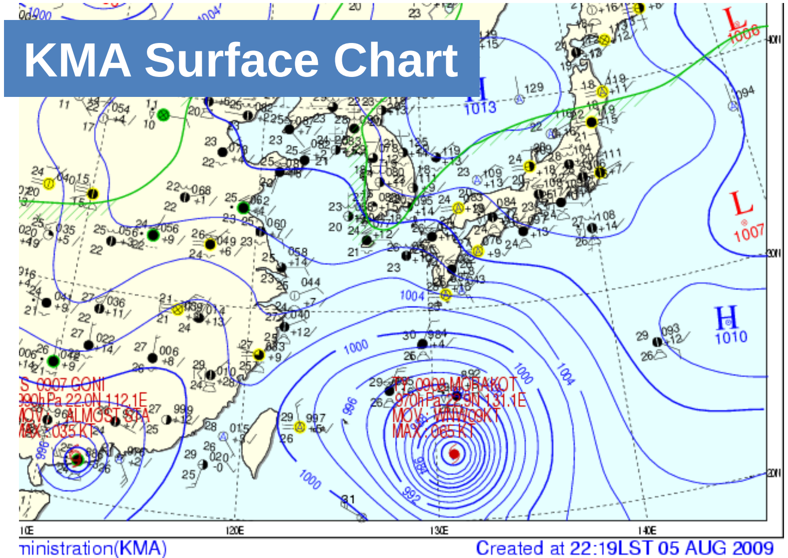
BILIS

Index: 319

(Before landfall)







Thanks