Application of numerical model on extreme weather and environmental studies

Chuan-Yao Lin

Research Center for Environmental Changes, Academia Sinica, Taiwan

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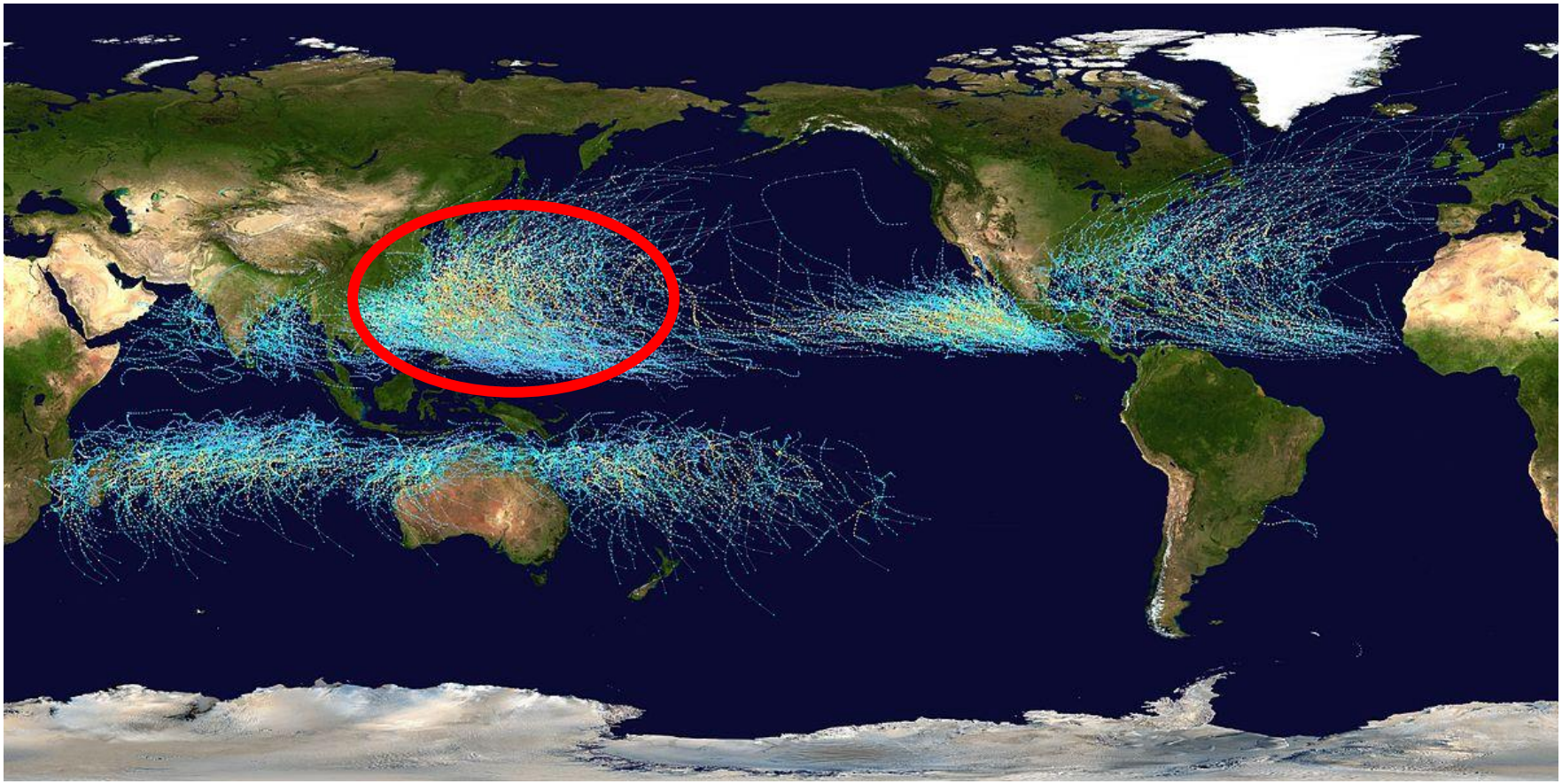
Introduction



Tracks of all tropical cyclones which formed worldwide between 1985 and 2005.

(from Joint Typhoon Warning Center)

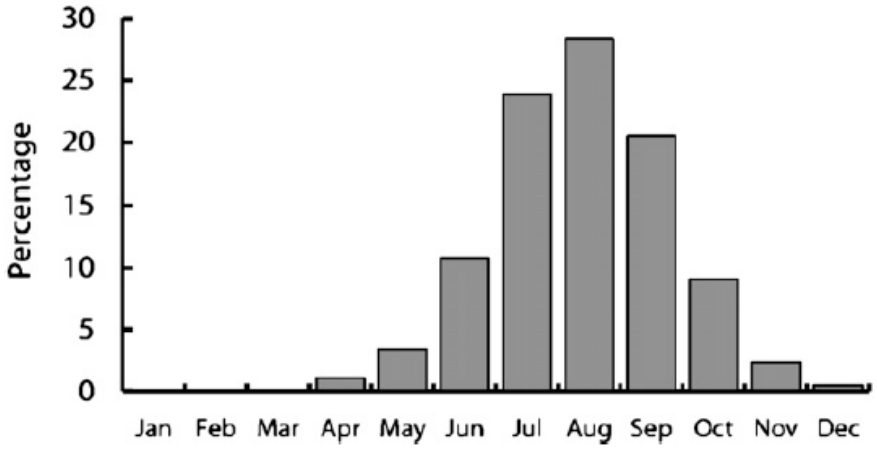
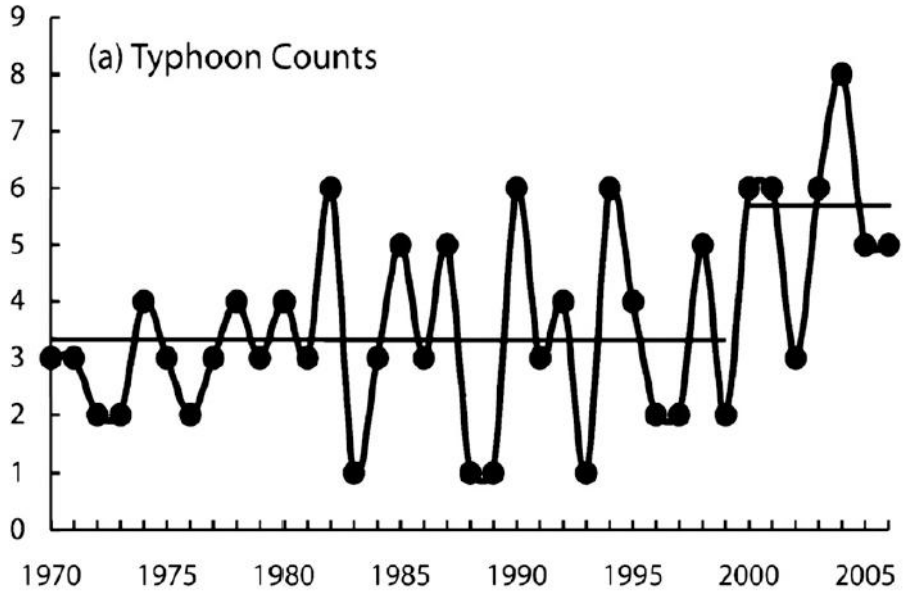


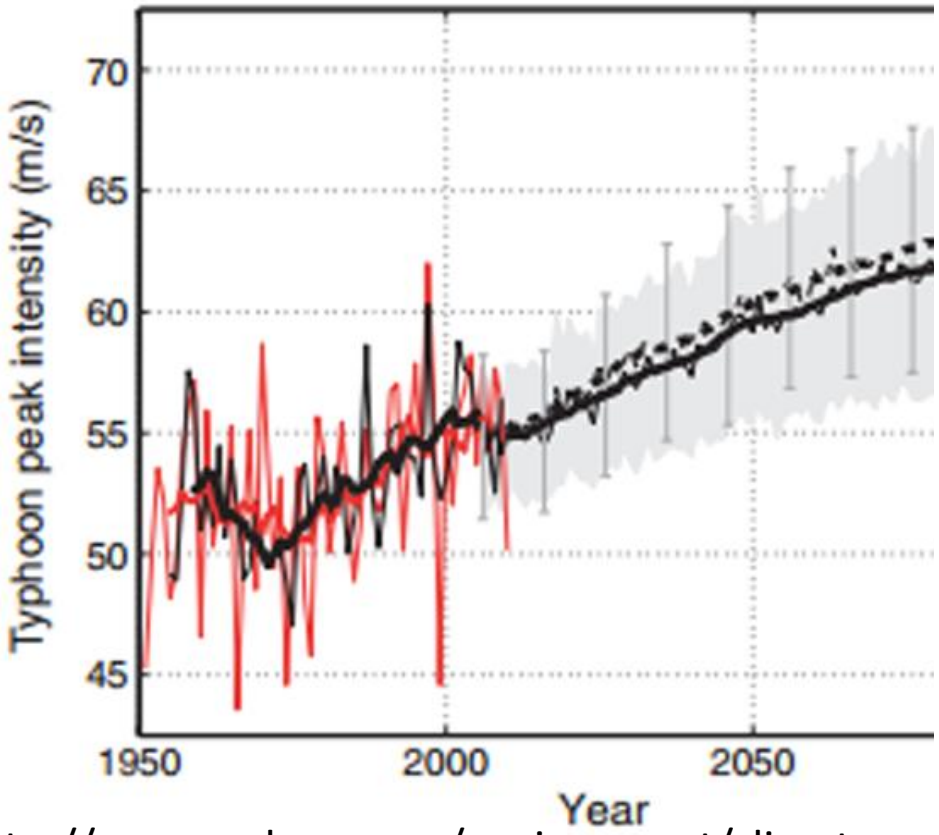
FIG. 2. Monthly percentage of typhoons impacting Taiwan averaged over the period of 1970–2006.

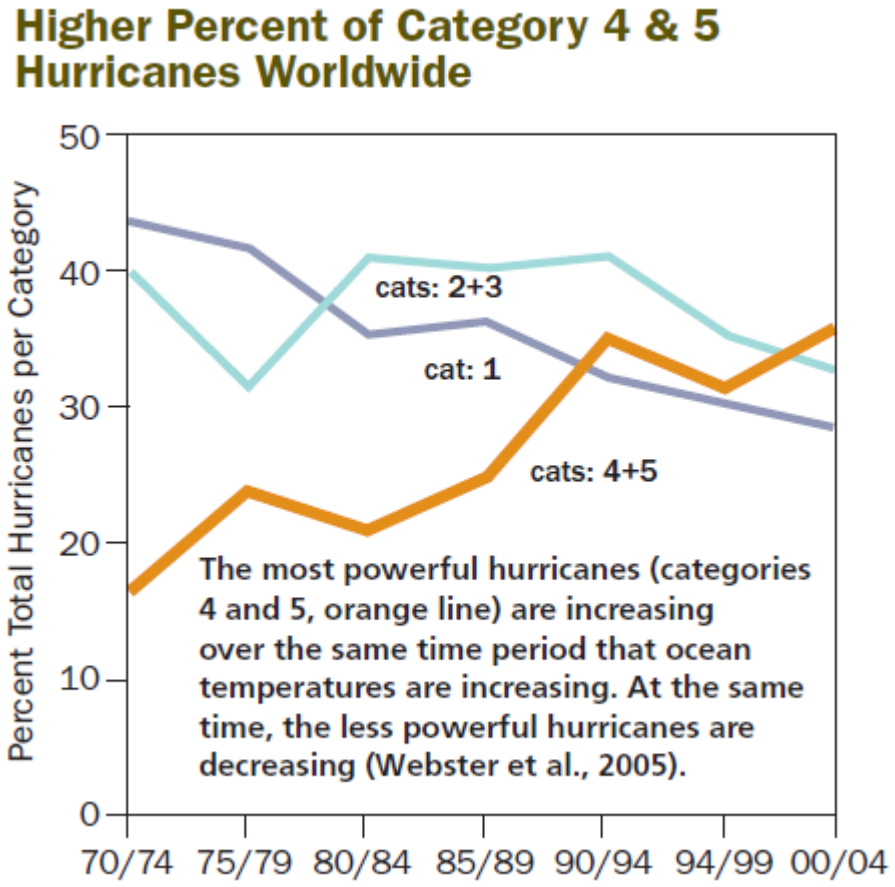


Time series of seasonal (JJASO) **typhoon numbers passing the vicinity of Taiwan from 1970 to 2006** as complied by the Central Weather Bureau. The vicinity was defined as21–26N, 119–125E.

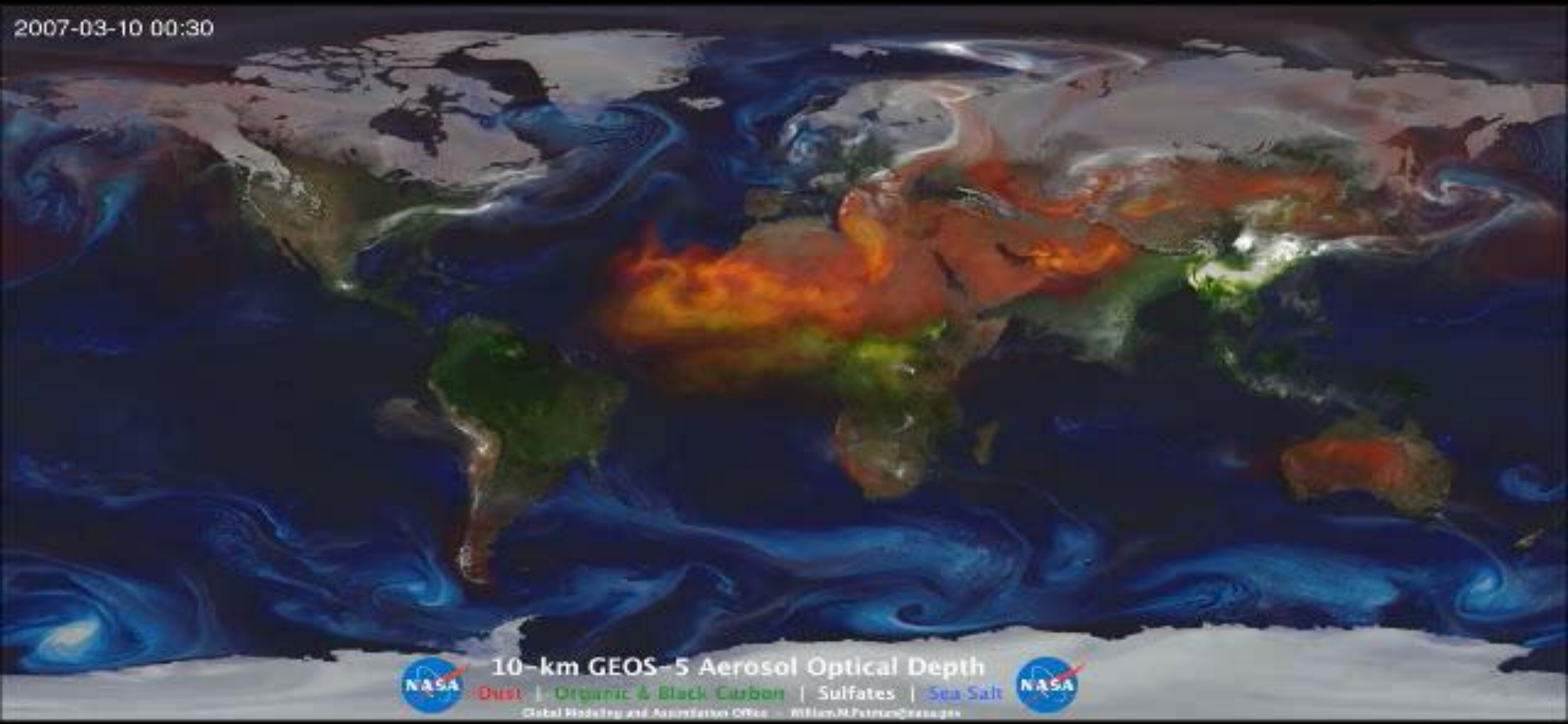
(Tu et al. 2009)

Future Warming and Typhoon

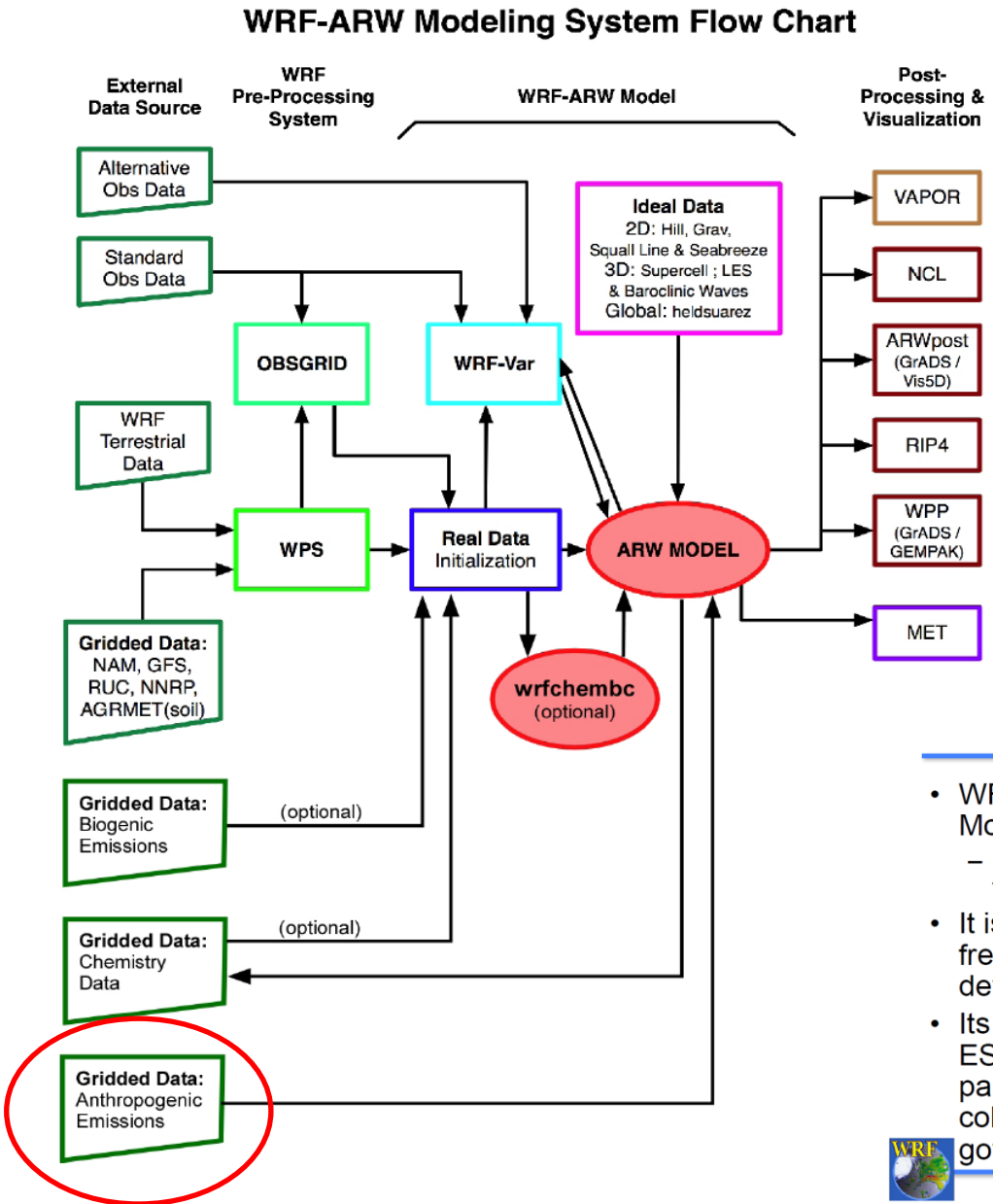




http://www.smh.com.au/environment/climate-change/super-typhoons-to-increase-in-strength-with-climate-change-researchers-find-20150529-ghcbfs.html


2007-03-10 00:30
10-km GEOS-5 Aerosol Optical Depth
Dust | Organic & Black Carbon | Sulfates | Sea Salt
NASA
NASA

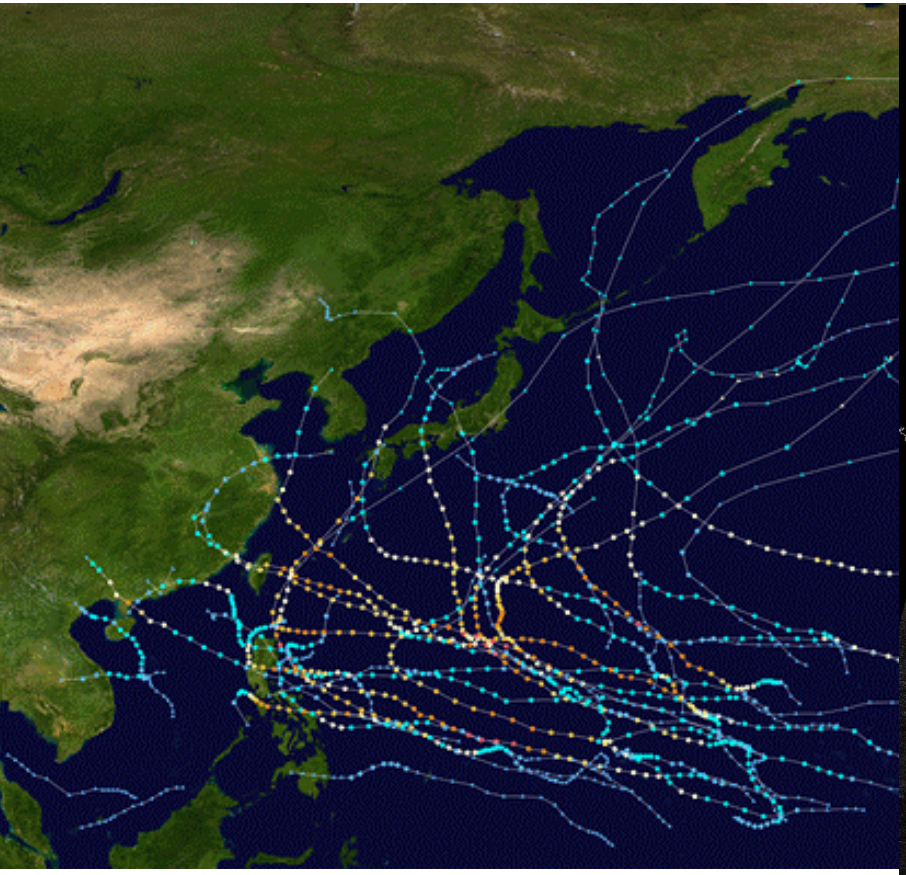
Model:WRF/WRF-Chem



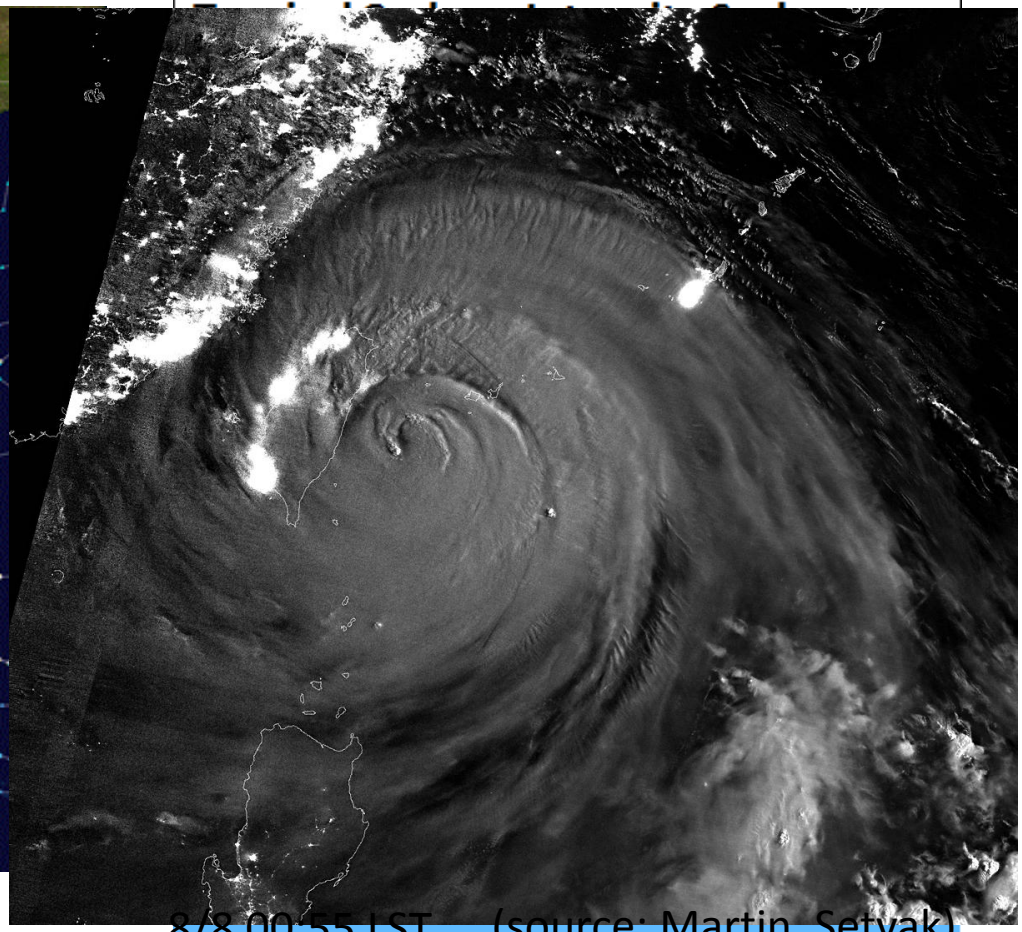
What is WRF?

- WRF: Weather Research and Forecasting Model
  - Used for both research and operational forecasting
- It is a supported "community model", i.e. a free and shared resource with distributed development and centralized support
- Its development is led by NCAR, NOAA/ ESRL and NOAA/NCEP/EMC with partnerships at AFWA, FAA, DOE/PNNL and collaborations with universities and other government agencies in the US and overseas

Storm tracks in 2015



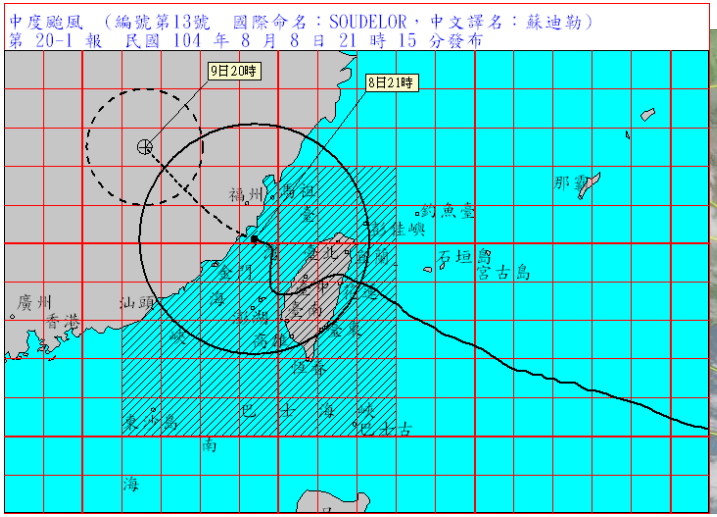
Typhoon Soudelor

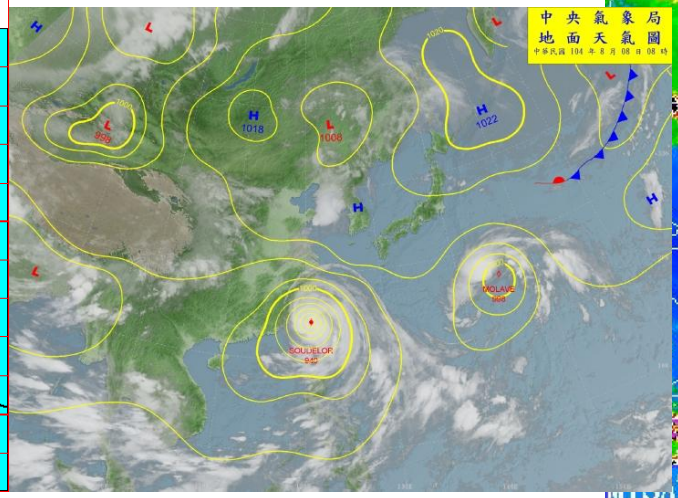


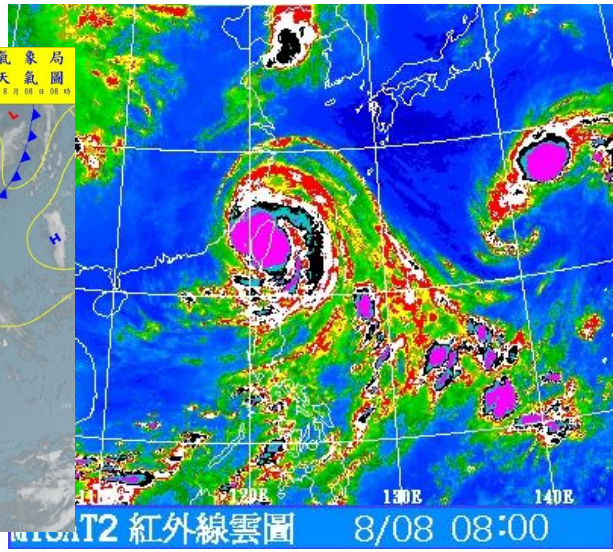
8/8 00:55 LST (source: Martin Setvak)

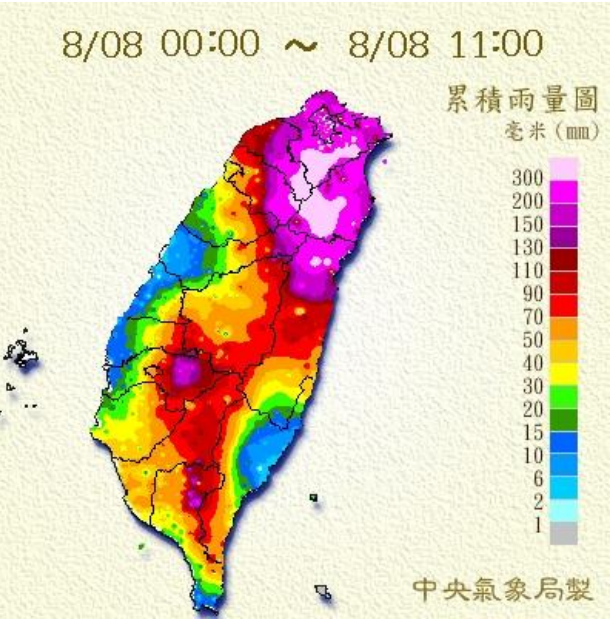
with peak winds at 180 mph (290 kph), according to the Joint Typhoon Warning Center.

中時電子報
chinatimes.com


中度颱風 （編號第13號 國際命名：SOUDELOR，中文譯名：蘇迪勒）
第 20-1 報 民國 104 年 8 月 8 日 21 時 15 分發布
9日20時
8日21時
福州
釣魚臺
那霸
石垣島
宮古島
廣州
香港
汕頭
巴士海峽
巴士古
東沙島
南
海


中央氣象局
地面天氣圖
SOUDELOR
MOLAVE


120E
130E
140E
紅外線雲圖
8/08 08:00


8/08 00:00 ～ 8/08 11:00
累積雨量圖
毫米（mm）
300
200
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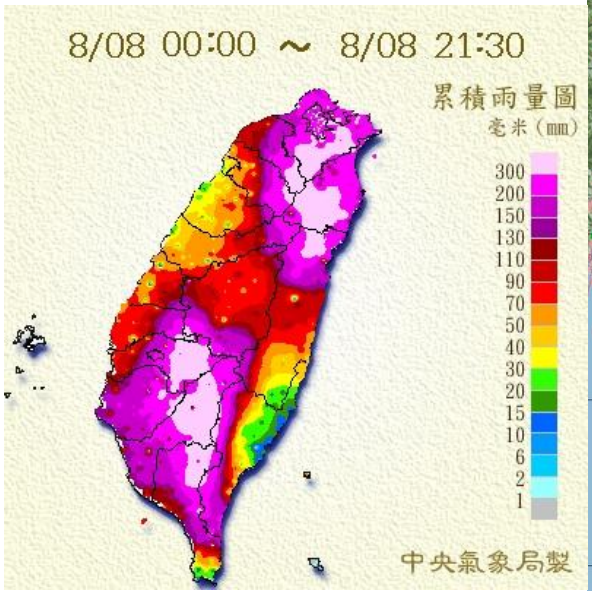
2
1
中央氣象局製


8/08 00:00 ～ 8/08 21:30
累積雨量圖
毫米（mm）
300
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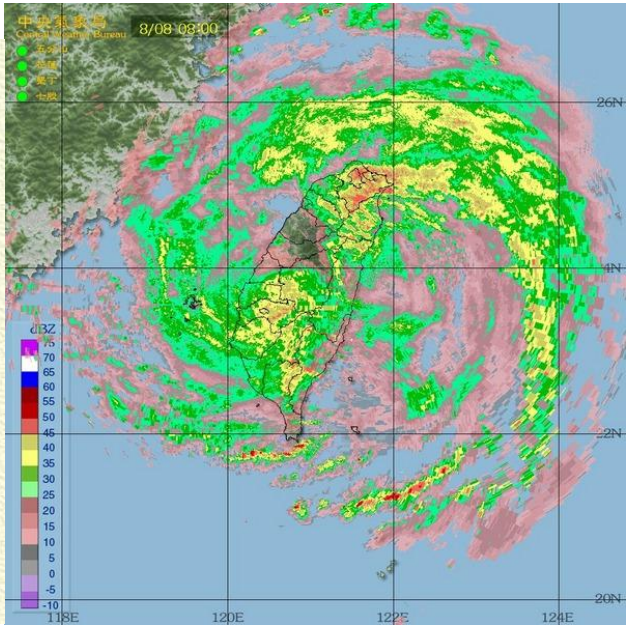
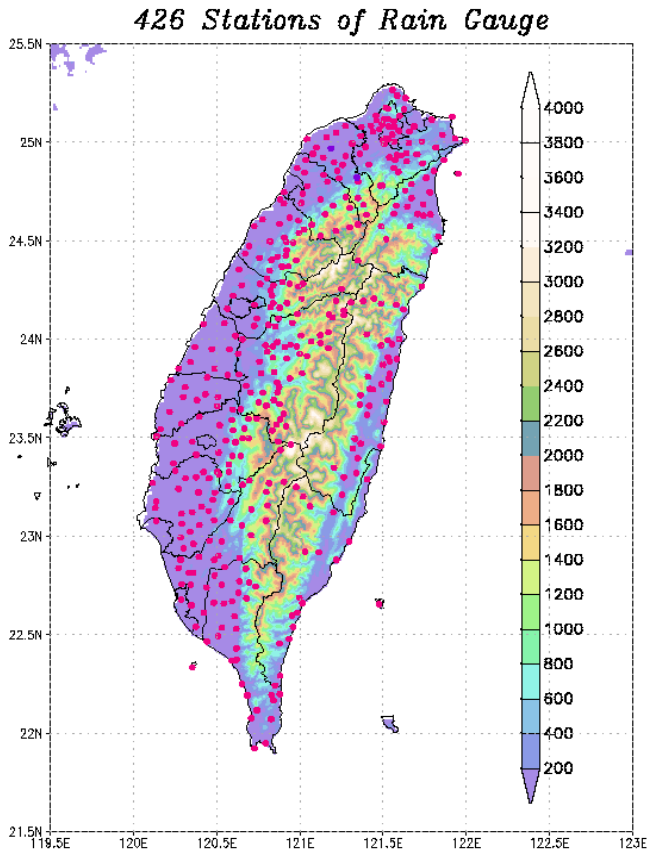
中央氣象局製


8/08 08:00
dBZ
26N
20N
118E
120E
122E
124E

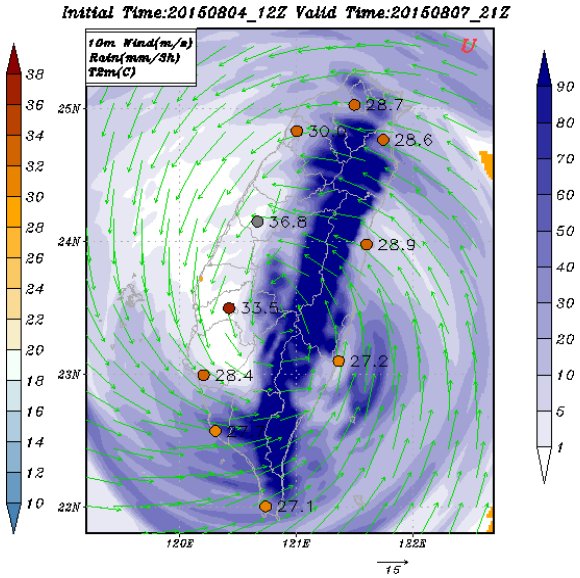
How good can we simulate (predict) typhoon ?

- I.C., B.C. and resolution :the forecasting of track, intensity
- dynamic of Typhoon circulation and their interaction with the Taiwan terrain
- mesoscale wind and precipitation distribution



Initial condition impacts on landfall simulation

08/04-12Z



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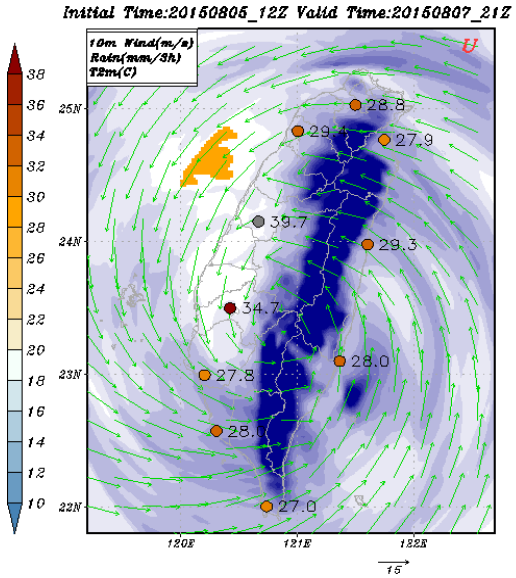

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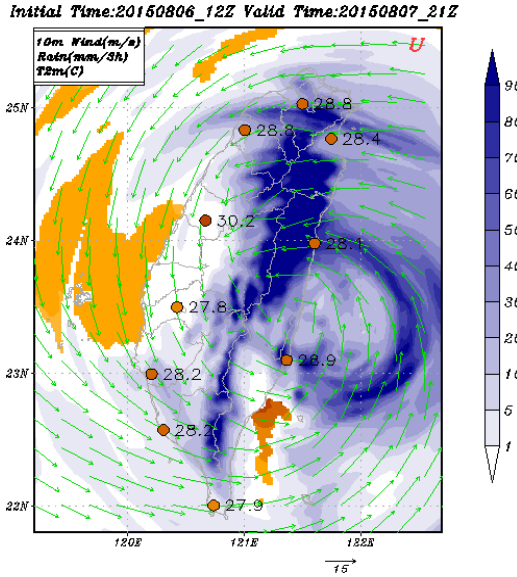

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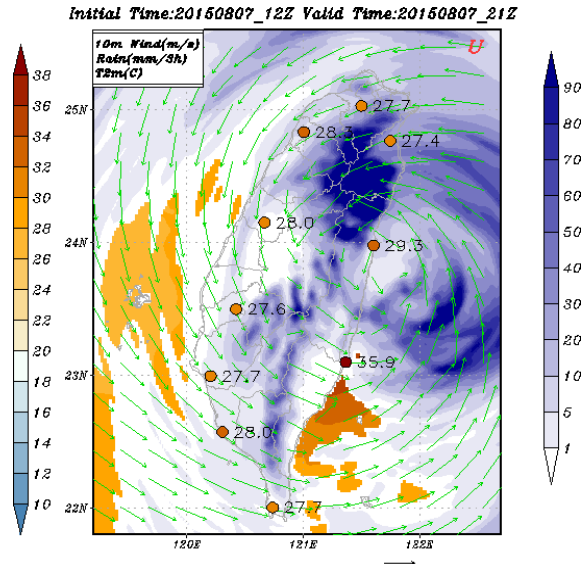
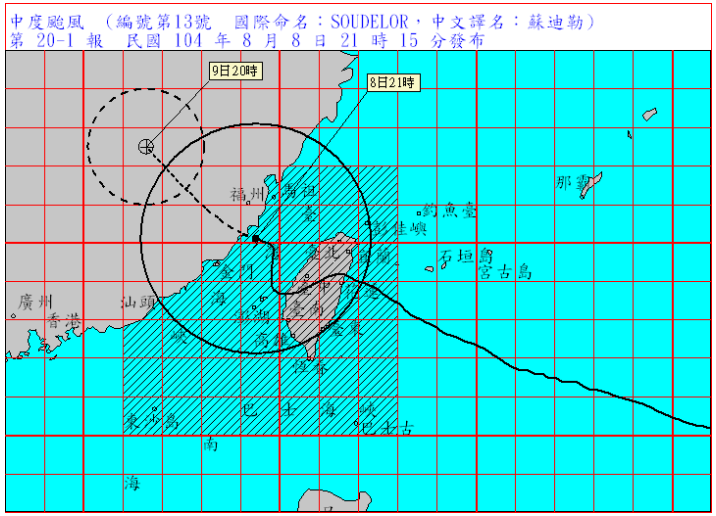
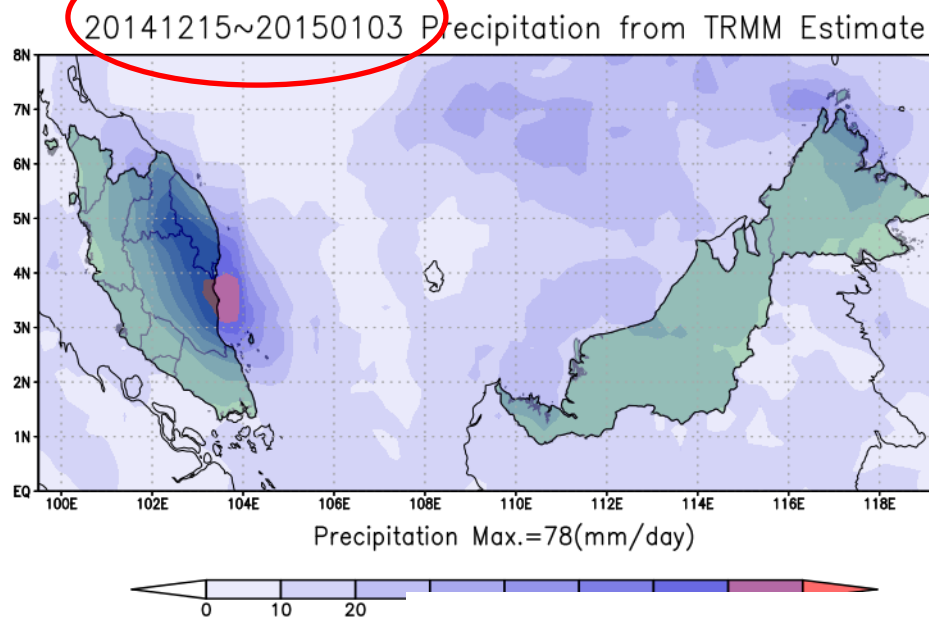
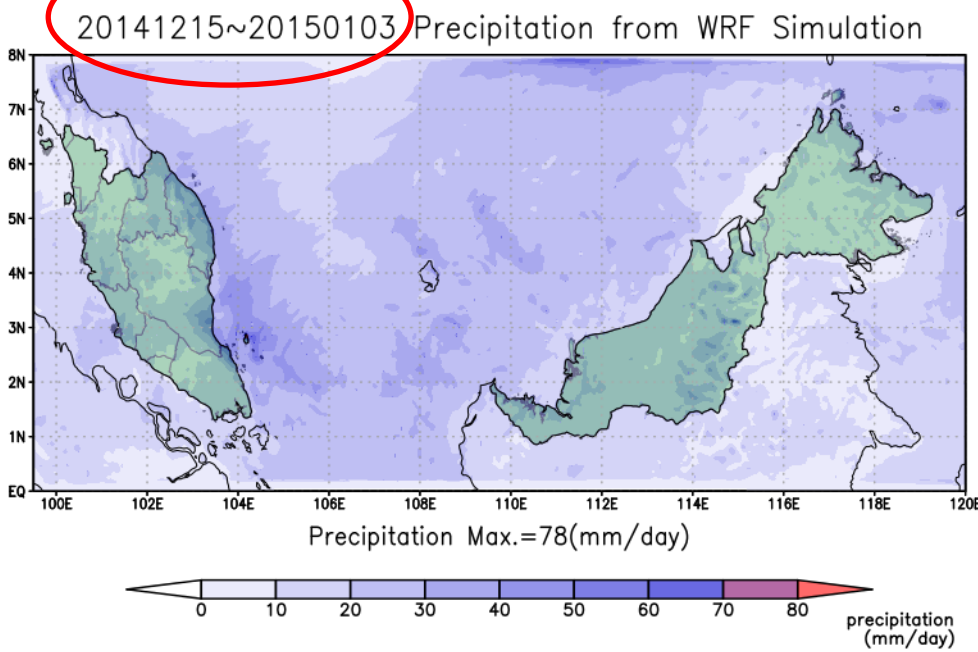


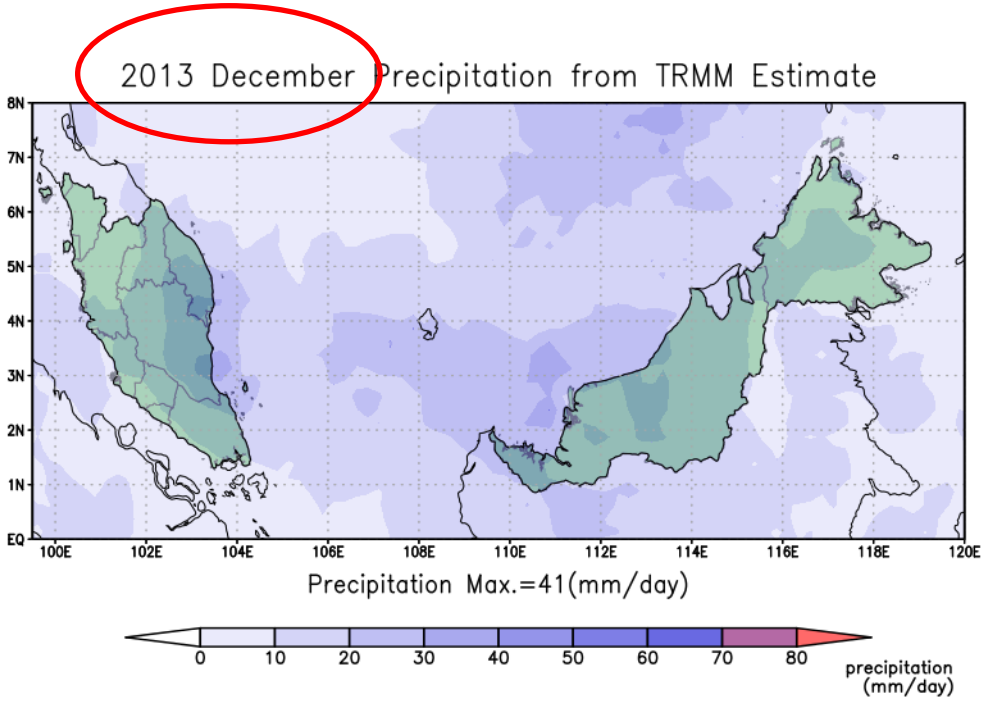


Flooding in Malaysia (2014-2015)

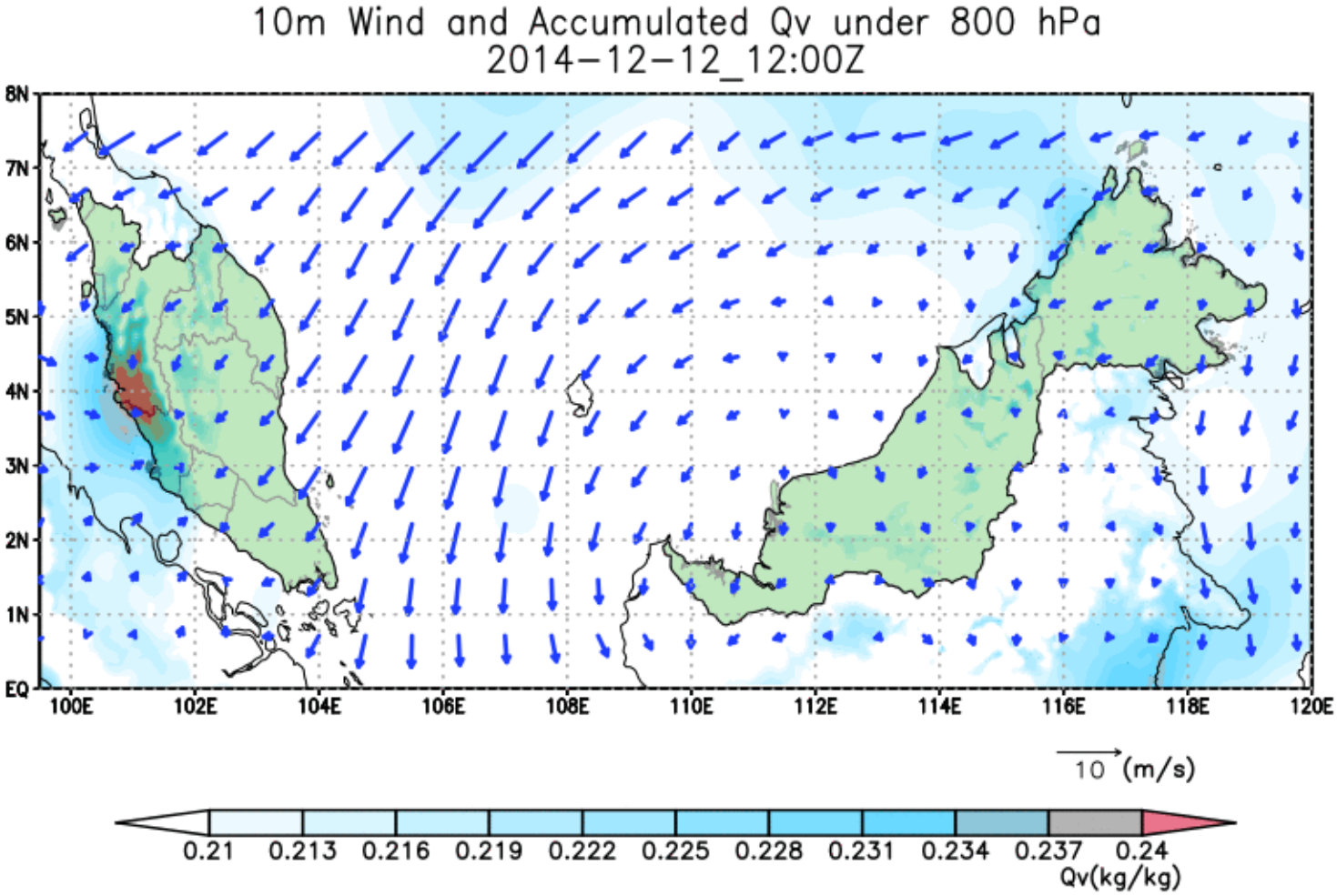
As part of the northeast monsoon,[4] heavy rains since 17 December forced 3,390 people in Kelantan and 4,209 people in Terengganu to flee their homes.[5] Several Keretapi Tanah Melayu(KTM) intercity train services along the East Coast route were disrupted on 18 December following the floods.[6] On 20 December, the area of Kajang, Selangor, was also


20141215~20150103 Precipitation from TRMM Estimate
8N
7N
6N
5N
4N
3N
2N
1N
EQ
100E
102E
104E
106E
108E
110E
112E
114E
116E
118E
Precipitation Max.=78(mm/day)
0
10
20


20141215~20150103 Precipitation from WRF Simulation
8N
7N
6N
5N
4N
3N
2N
1N
EQ
100E
102E
104E
106E
108E
110E
112E
114E
116E
118E
120E
Precipitation Max.=78(mm/day)
0
10
20
30
40
50
60
70
80
precipitation
(mm/day)


2013 December Precipitation from TRMM Estimate
8N
7N
6N
5N
4N
3N
2N
1N
EQ
100E
102E
104E
106E
108E
110E
112E
114E
116E
118E
120E
Precipitation Max.=41(mm/day)
0
10
20
30
40
50
60
70
80
precipitation
(mm/day)

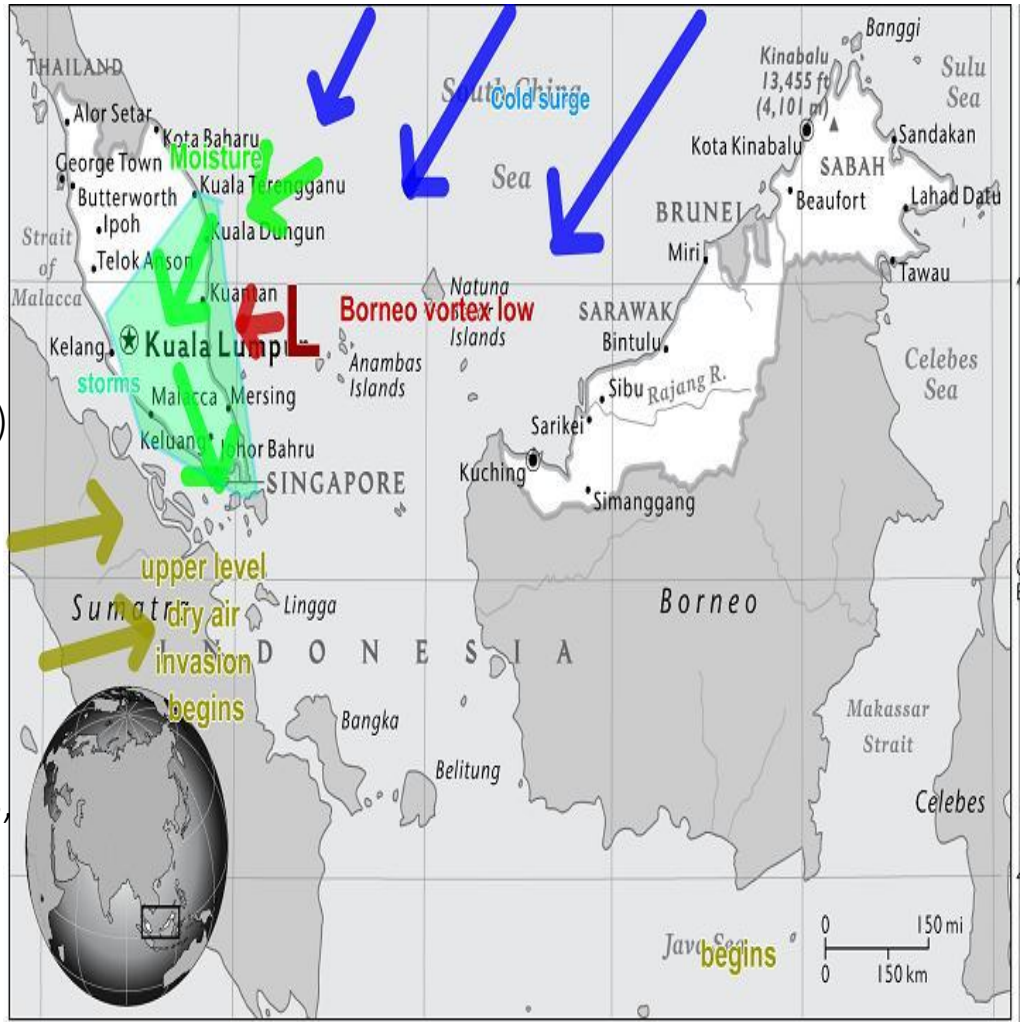
(20 days)



The **2014–15 Malaysia floods** hit Malaysia from 15 December 2014 – 3 January 2015. More than 200,000 people affected while 21 killed on the floods.[1] This flood have been described as the worst floods in decades

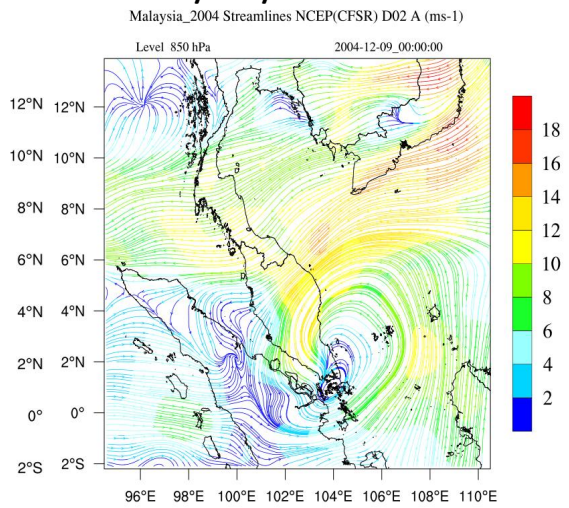
- This area is subjected to significant largescale and mesoscale interactions
  - **Topographic feature :** distribution of deep convection (Chang et al, 2005)
  - **northeasterly cold surges** dominate the low-level circulation patterns (Zhang et al. 1997)
  - Quasi–stationary **Borneo vortex** (Johnson and Houze, 1987; Chang et al. 2003, Chang et al. 2005, Juneng et al. 2007)
  - Madden-Julian Oscillations **(MJO):** (Madden and Julian, 1972)

on intra-seasonal time scales peak amplitude during boreal winter over the Maritime Continent

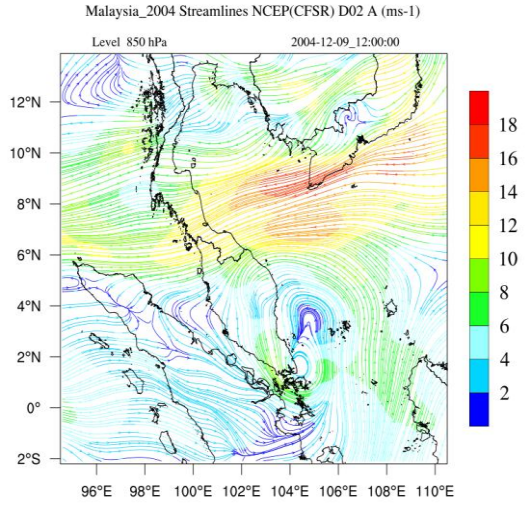


Preliminary Results in 2004 flooding Case

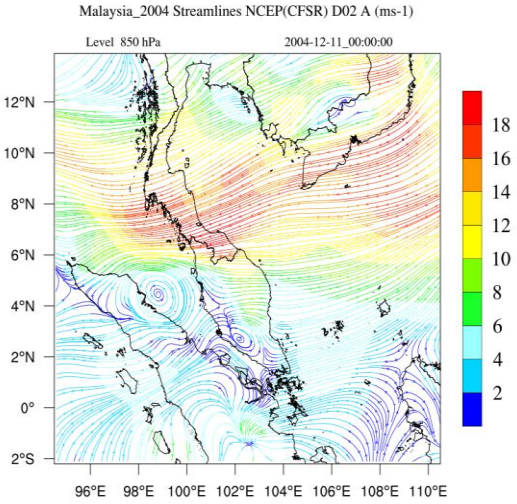
2004/12/09 00UTC



2004/12/09 12UTC



2004/12/11 00UTC



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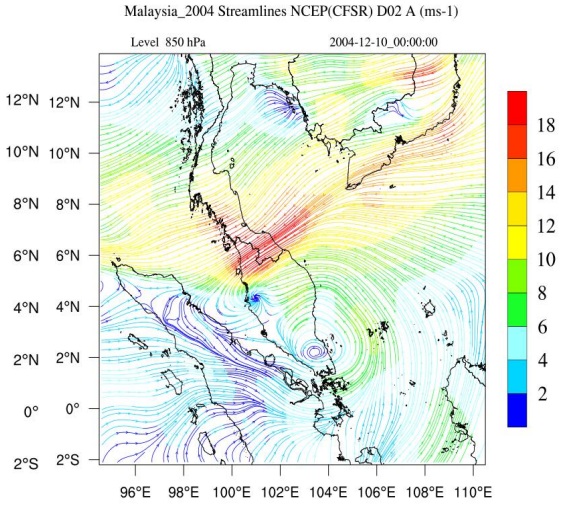
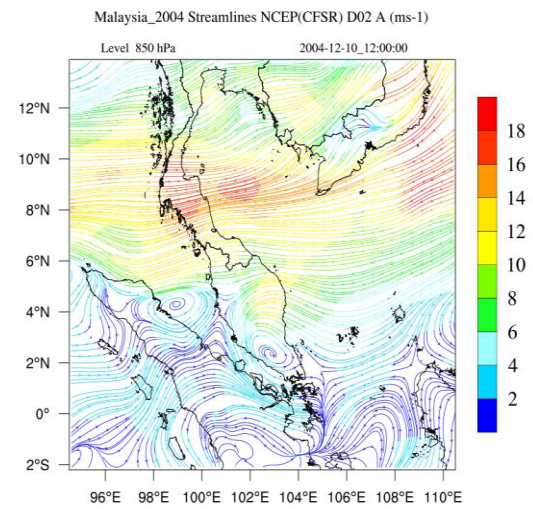
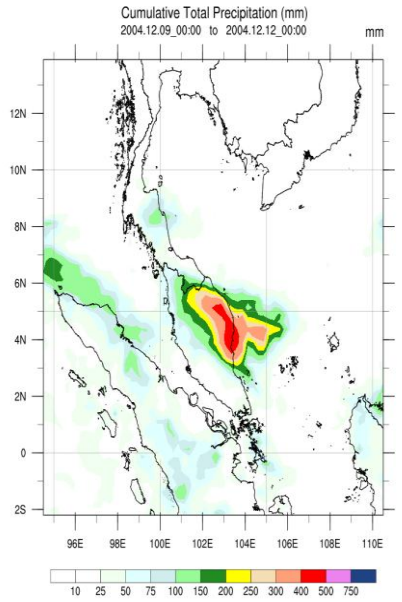


2004/12/10 12UTC



Domain 02 - Simulation > Dec 09-12 | Accumulaton Rainfall

TRMM Data



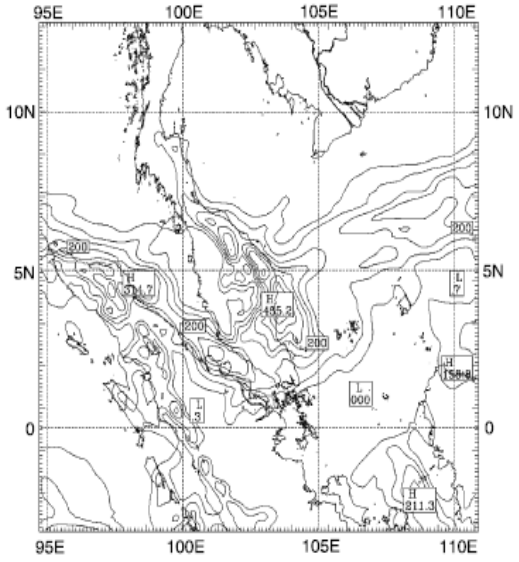
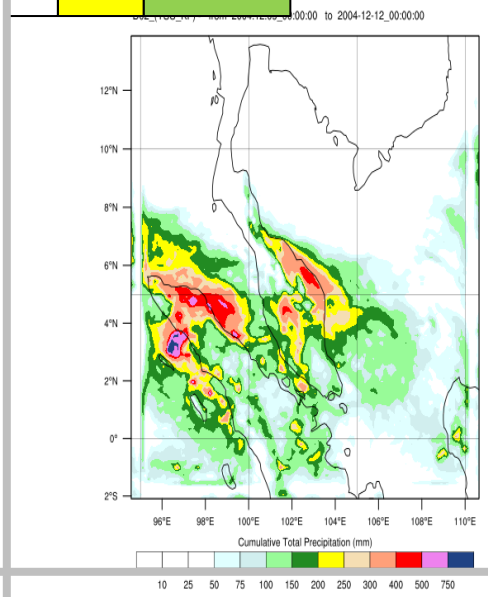
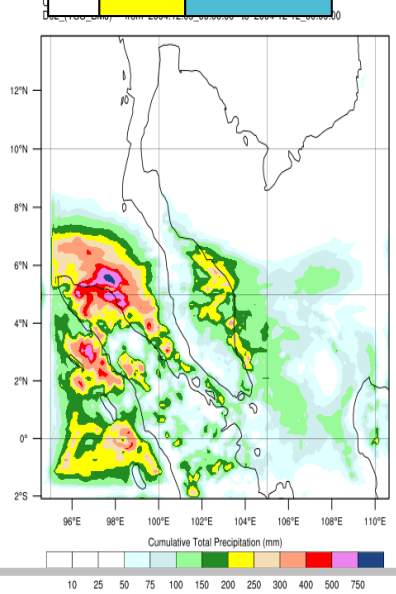


Fig. 7. 72 h accumulated rainfall simulated by the CTRL model run (Juneng et al. 2007)

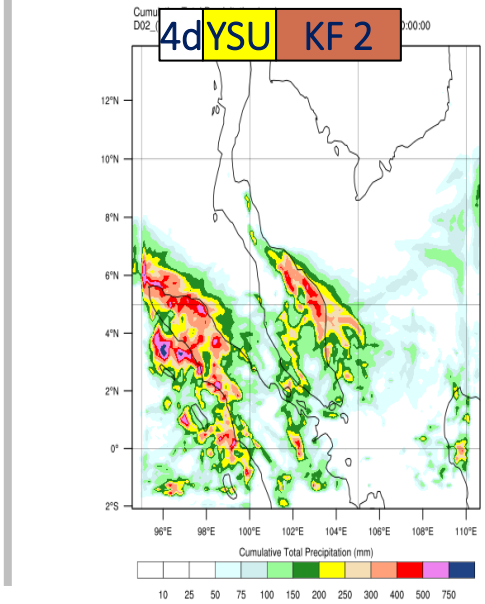
4a YSU KF



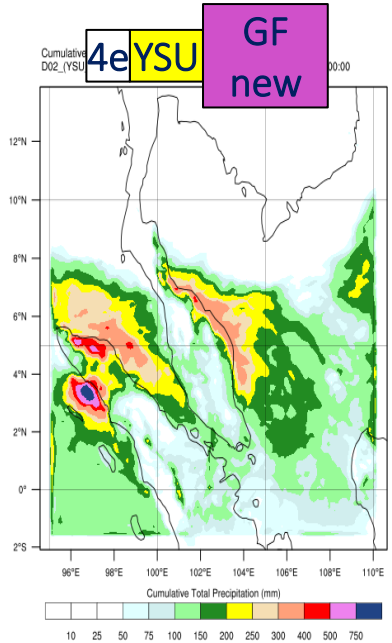
4b YSU BMJ



4d YSU KF 2



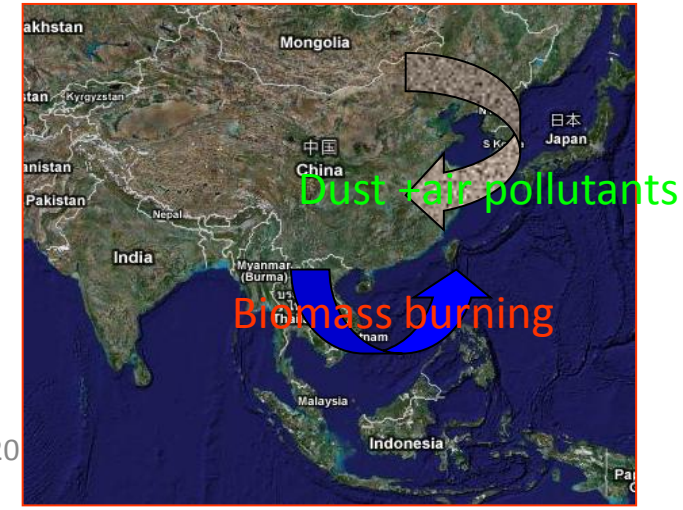
4e YSU GF new

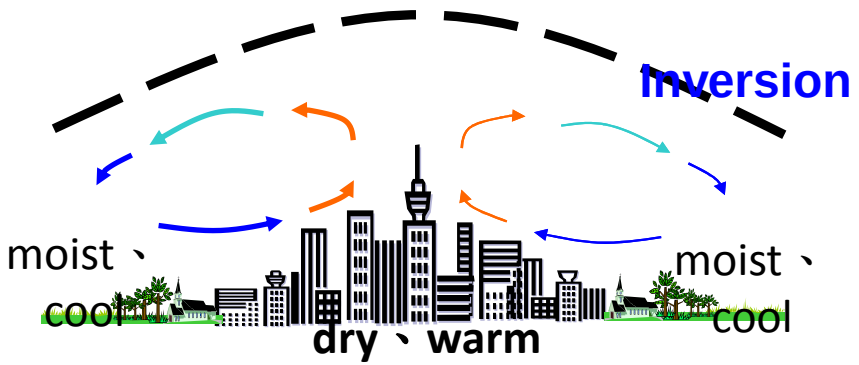


Environmental Research Topics

Environmental Research Topics

- **Long-range transport of air pollutants to Taiwan**
  - **Asian dust and air pollutants from China**
  - **Impact of Biomass burning pollutants from Indochina**
- **UHI effect and urban pollution**
- **Regional climate change and Heatwave; air quality**





UHI effect

Atmos. Chem. Phys., 12, 271–285, 2012
www.atmos-chem-phys.net/12/271/2012/
doi:10.5194/acp-12-271-2012
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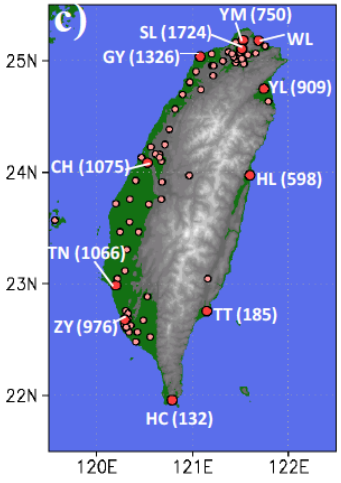
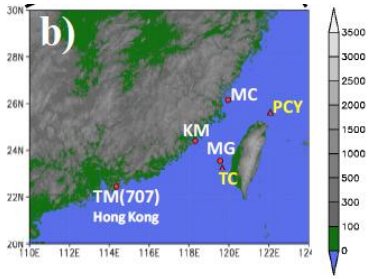
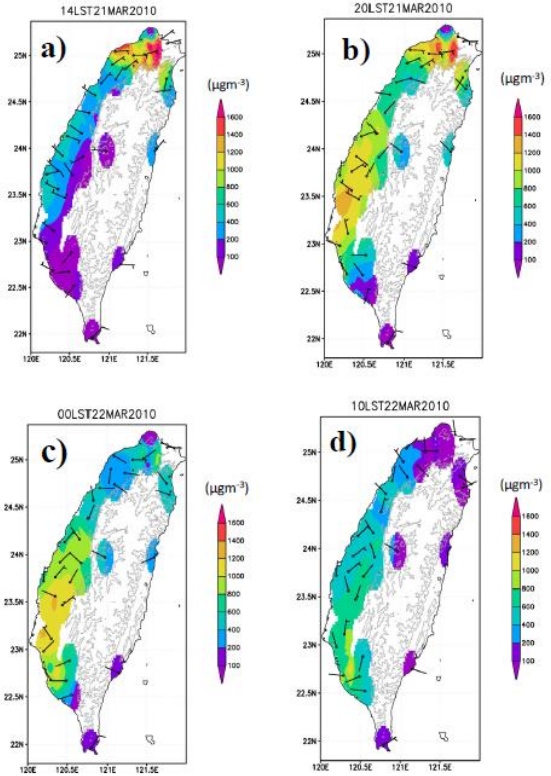
Atmospheric Chemistry

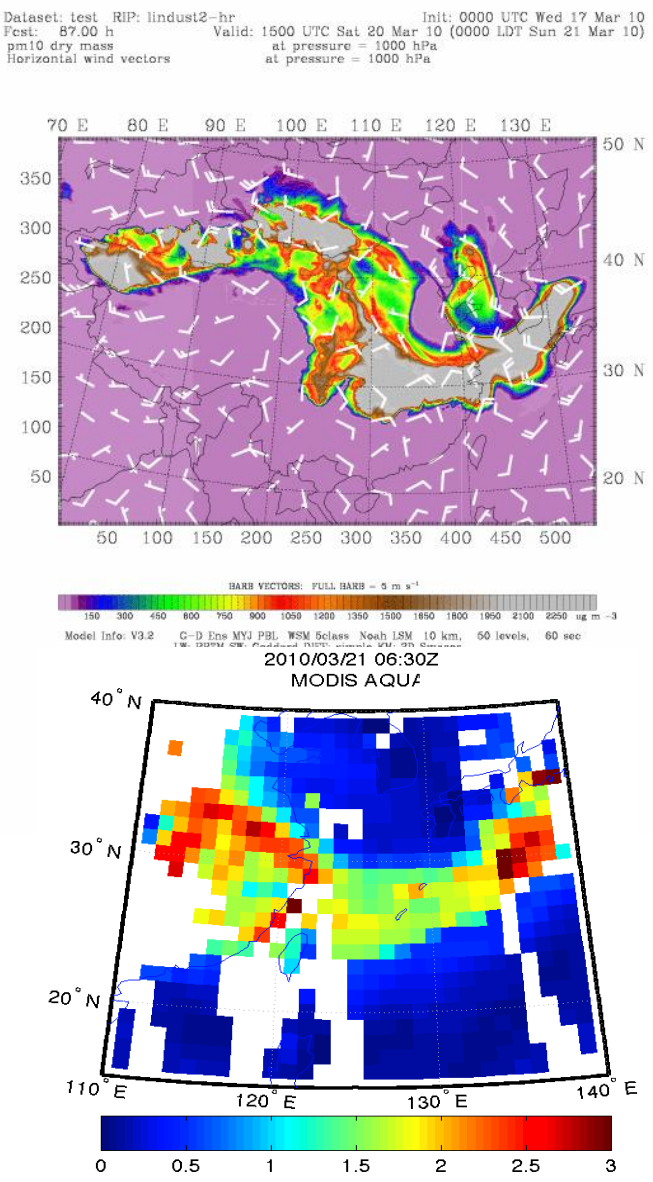
The impact of channel effect on Asian dust transpo a case in southeastern Asia

C.-Y. Lin[1], Y.-F. Sheng[1], W.-N. Chen[1], Z. Wang[2], C.-H. Kuo[3], W.-C. Chen[1], and T. Yan









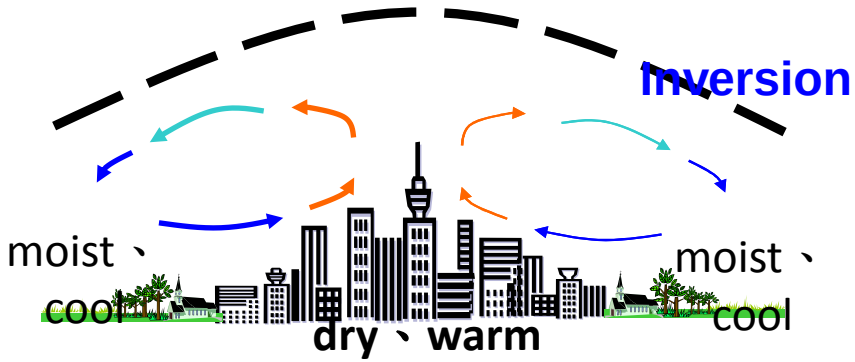
Model: WRF/Chem, 10 km resolution

Research Topics

- **Long-range transport of air pollutants to Taiwan**

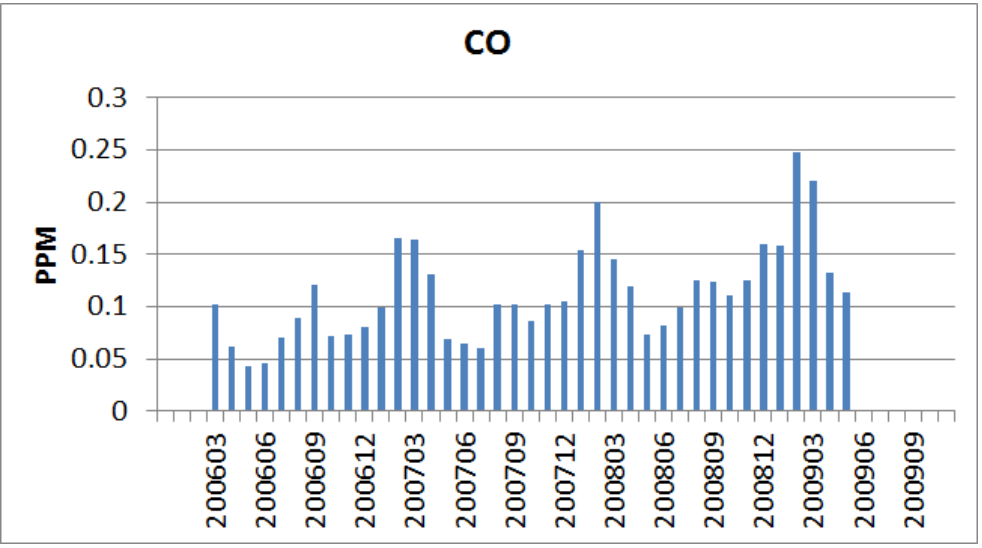
  Asian dust and air pollutants from China

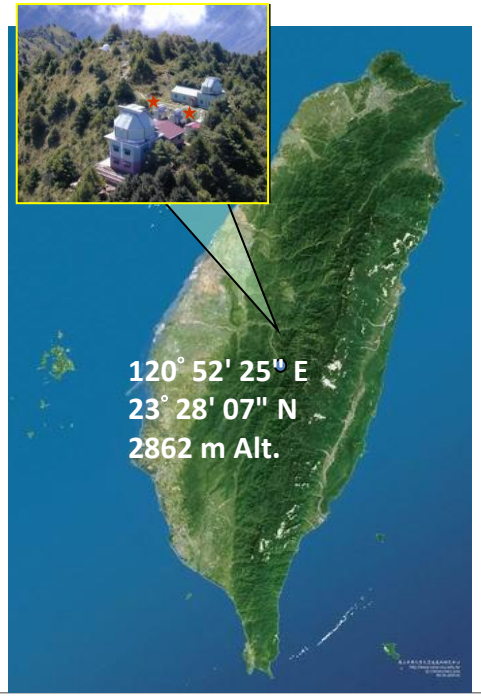
  Impact of Biomass burning pollutants from Indochina

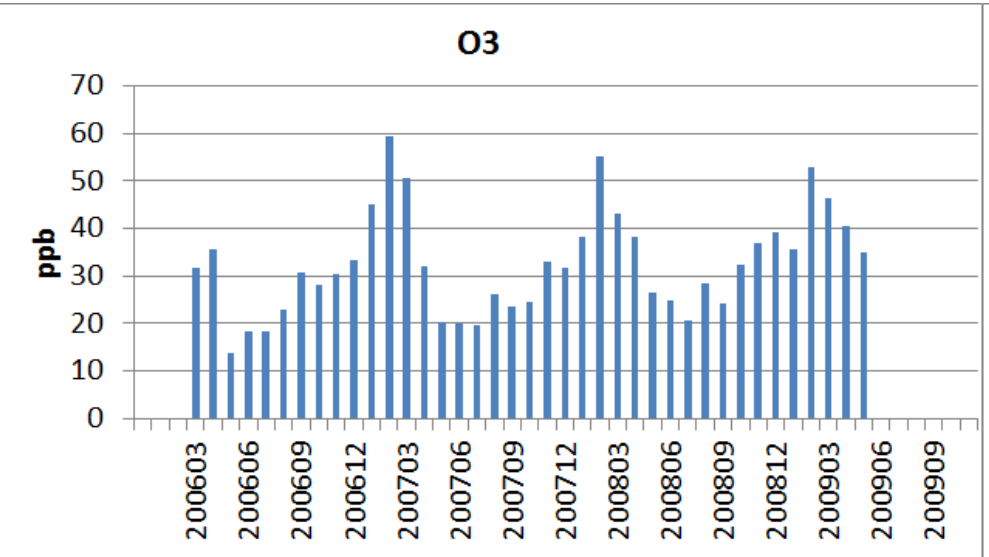


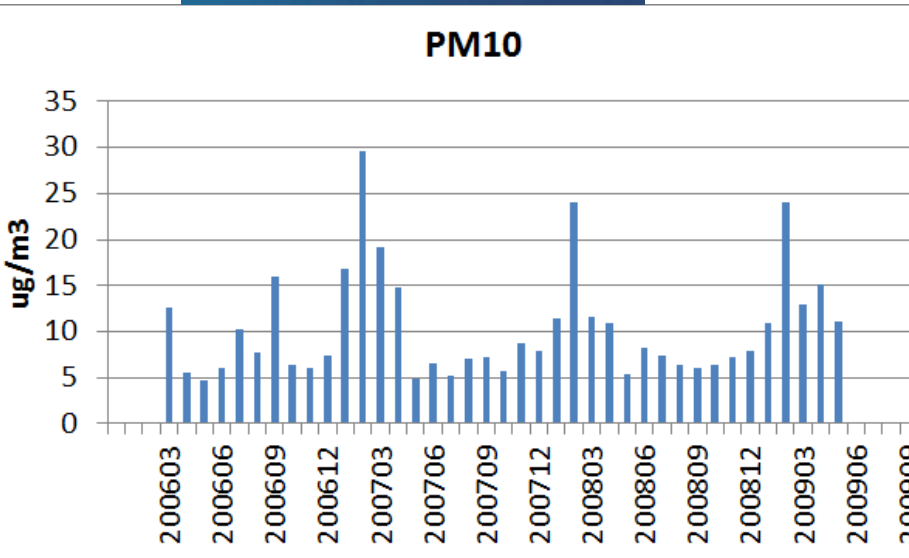
UHI effect

Seasonal variation of CO, O3 and PM10 at LuLin Mountain station (2006-2009)





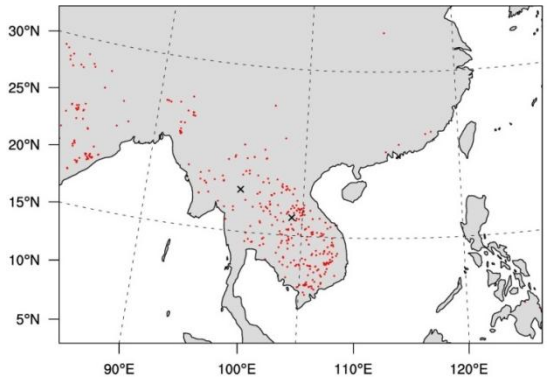


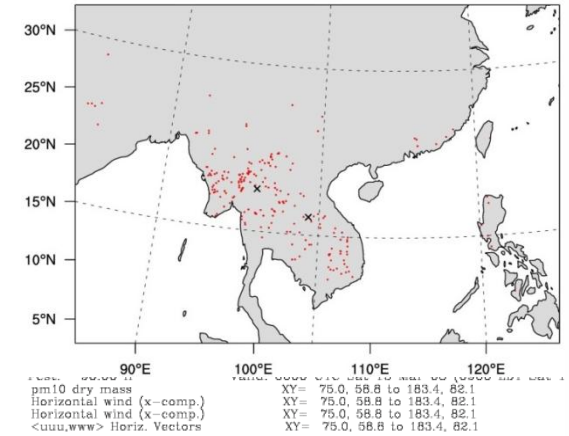


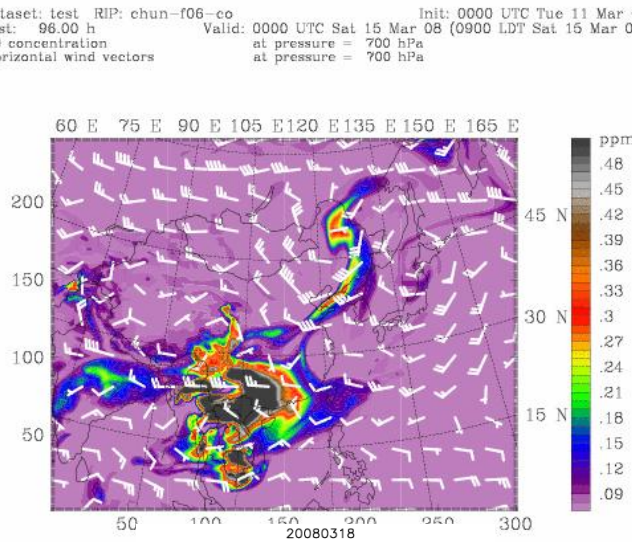
Tellus SERIES B CHEMICAL AND PHYSICAL METEOROLOGY

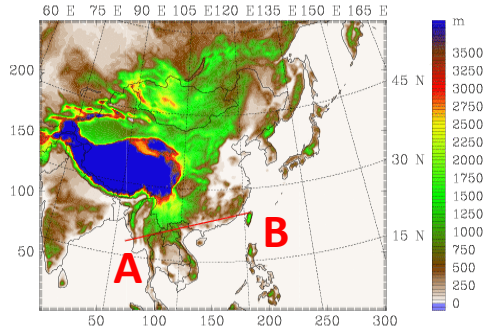
Modelling of long-range transport of Southeast Asia biomass-burning aerosols to Taiwan and their radiative forcings over East Asia

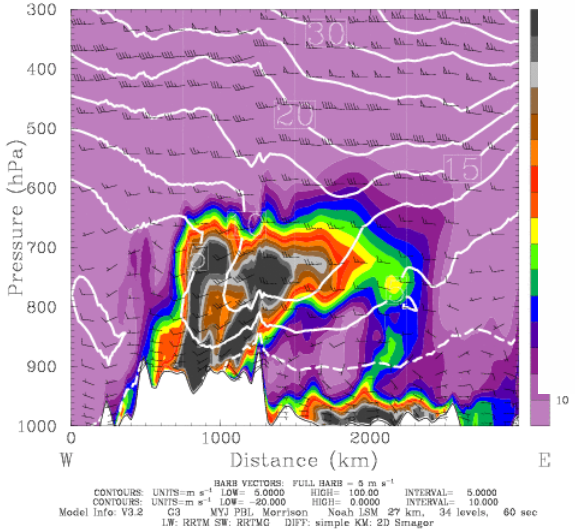
By CHUAN-YAO LIN[1]*, CHUN ZHAO[2], XIAOHONG LIU[2,3], N
WEI-NEI CHEN[1], [1]*Research Center for Environmental Changes, Acaden*

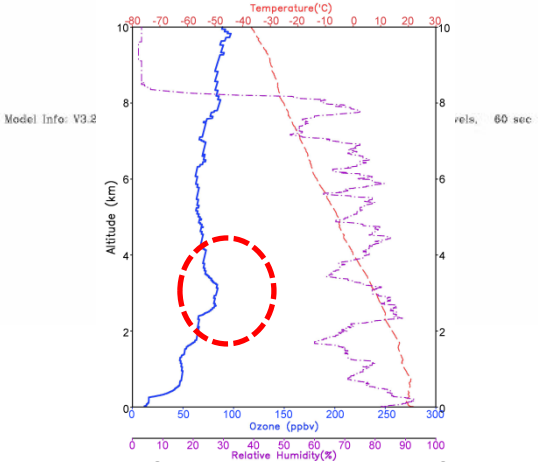






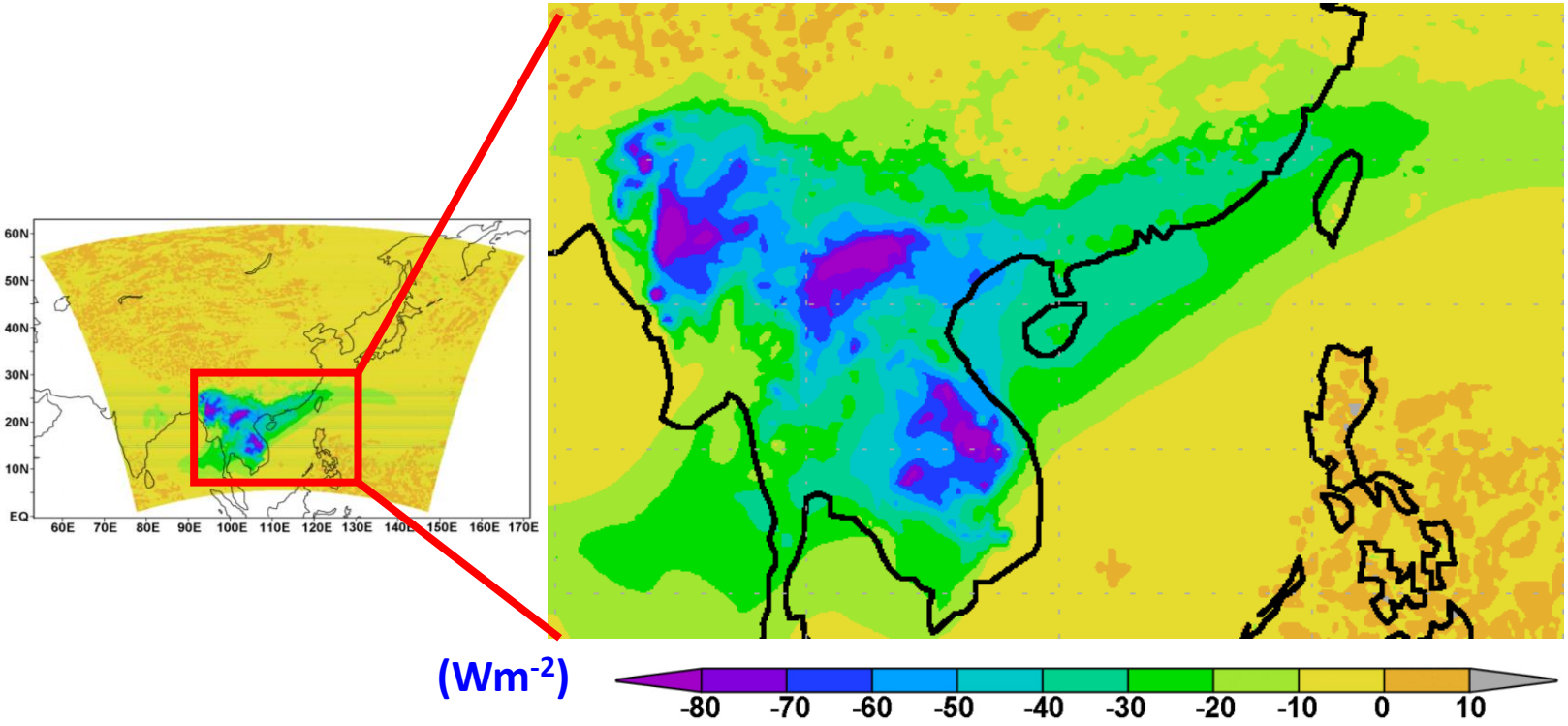






Model: WRF/Chem,
15 km resolution

Difference of downward shortwave flux at surface (biomass burning emission turn on and off)



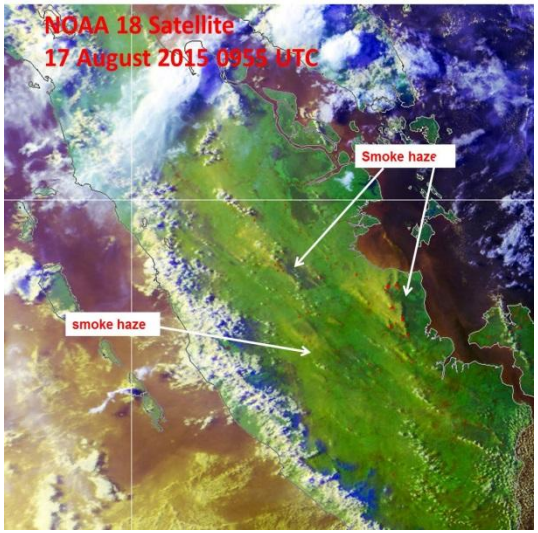
Average reduction in shortwave radiation fluxes at ground surface simulated with and without biomass-burning emission during 15-18 March, 2008 (unit W m^{-2}).

(Lin et al. 2014)

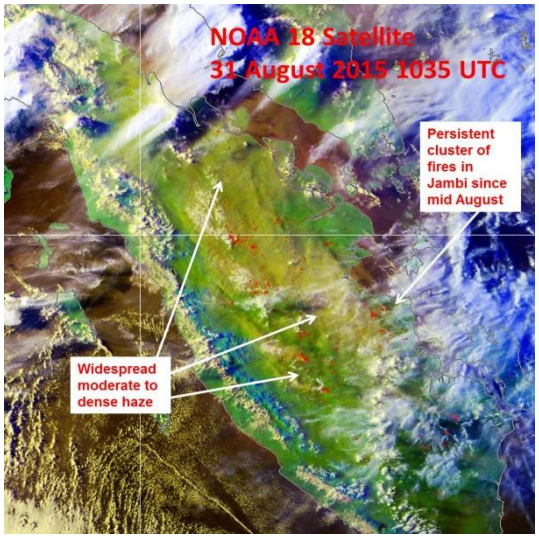
South East Asia haze 2015

The haze affected Indonesian from at least late June, to the end of October, turning into an international problem for other countries in September.

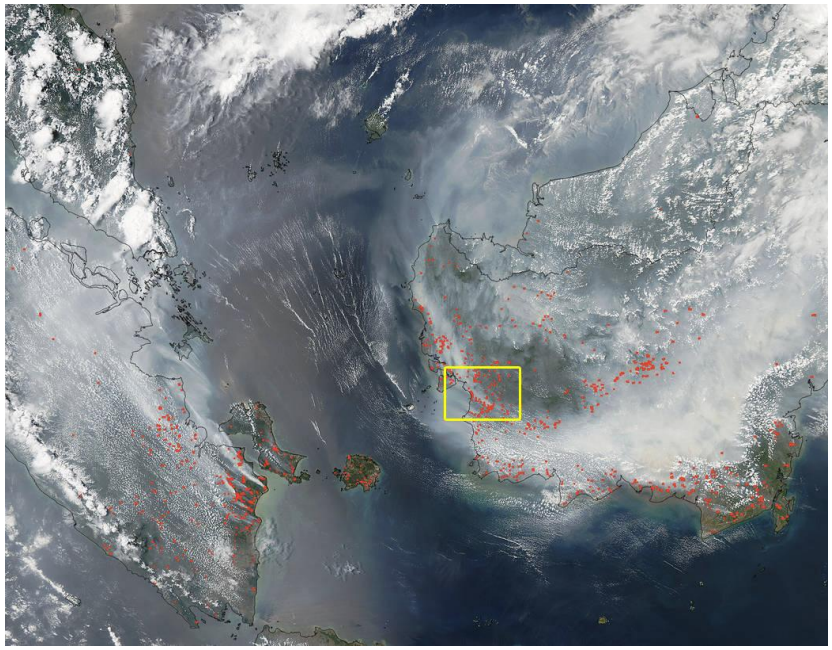
https://zh.wikipedia.org/wiki/



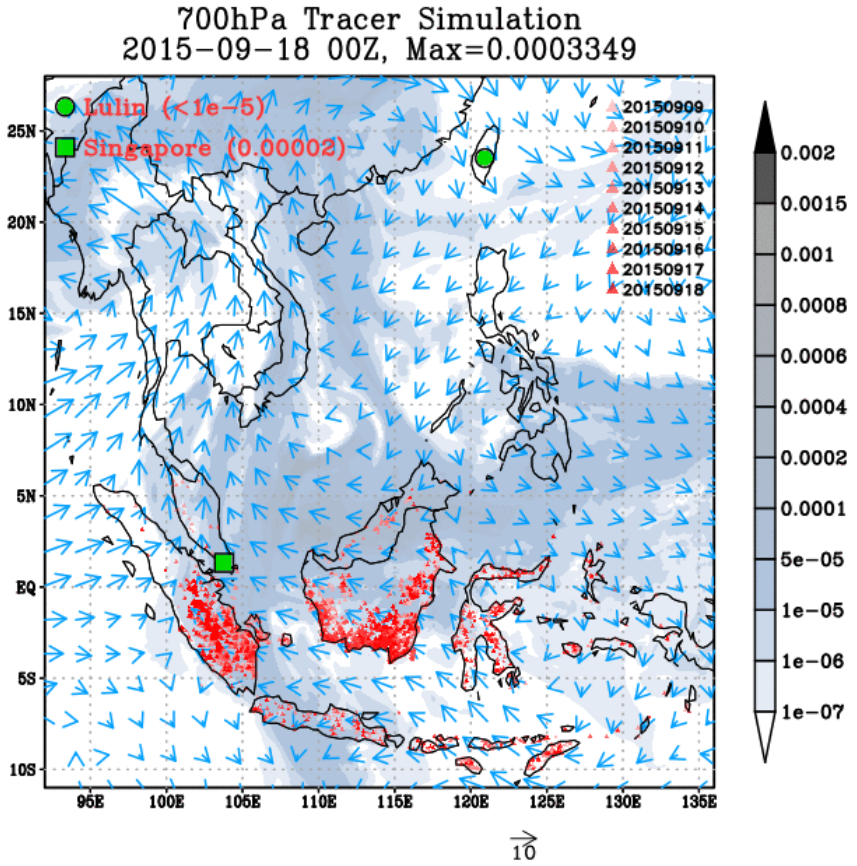
NOAA-18 satellite picture on 29 August 2015 shows deterioration of smoke haze situation in Kalimantan

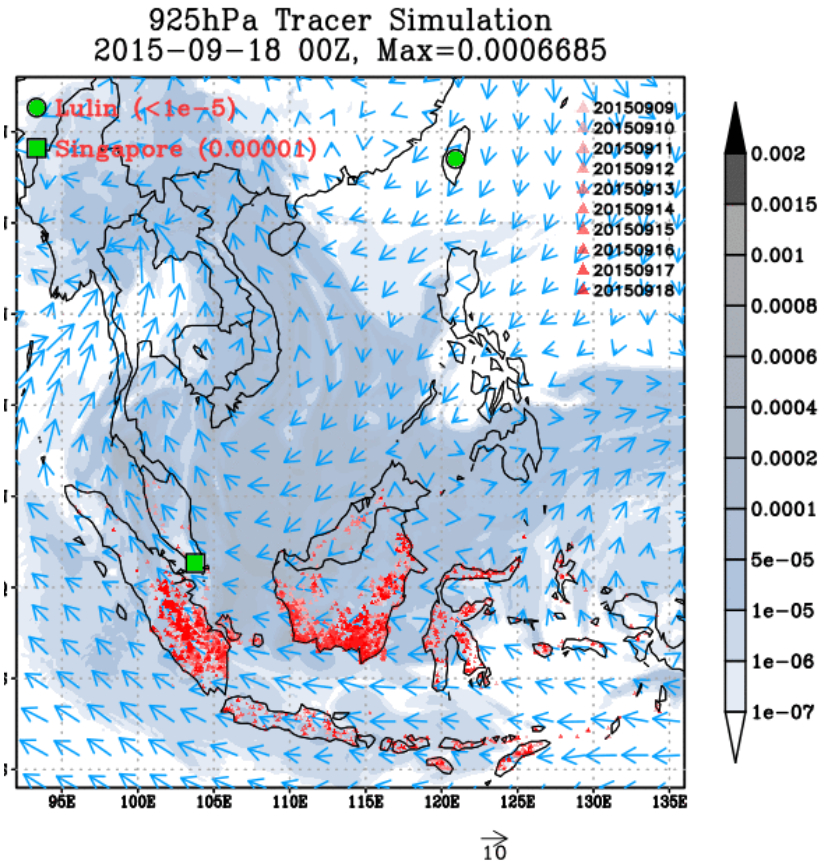


NOAA-18 satellite picture on 31 Augusts 2015 shows widespread smoke haze from Sumatra spreading into the Strait of Malacca.



NASA's Aqua satellite collected this natural-color image with the Moderate Resolution Imaging Spectroradiometer, MODIS, instrument on September 22, 2015.

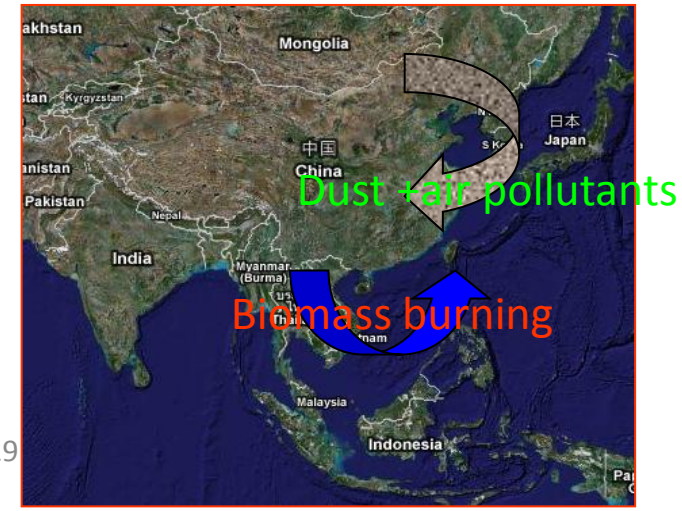


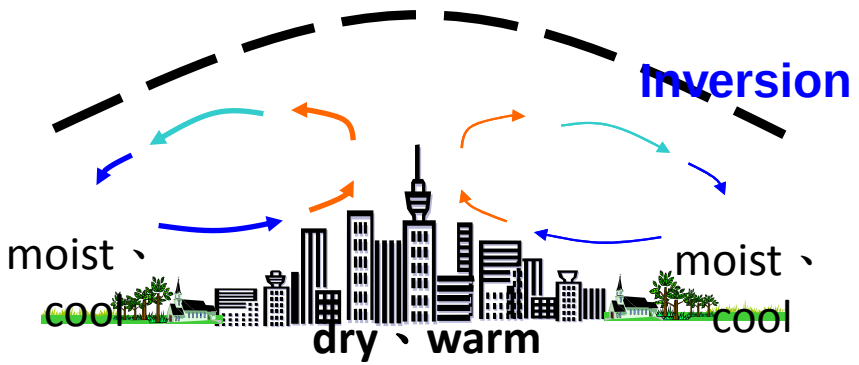


Resolution: 10 km

Research Topics

- Long-range transport of air pollutants to Taiwan
  - Asian dust and air pollutants from China
  - Impact of Biomass burning pollutants from Indochina
- **UHI effect and urban pollution**
- **Regional climate change and Heatwave; air quality**





UHI effect

Percentage urban and location of urban agglomerations with at least 500,000 inhabitants, 2014

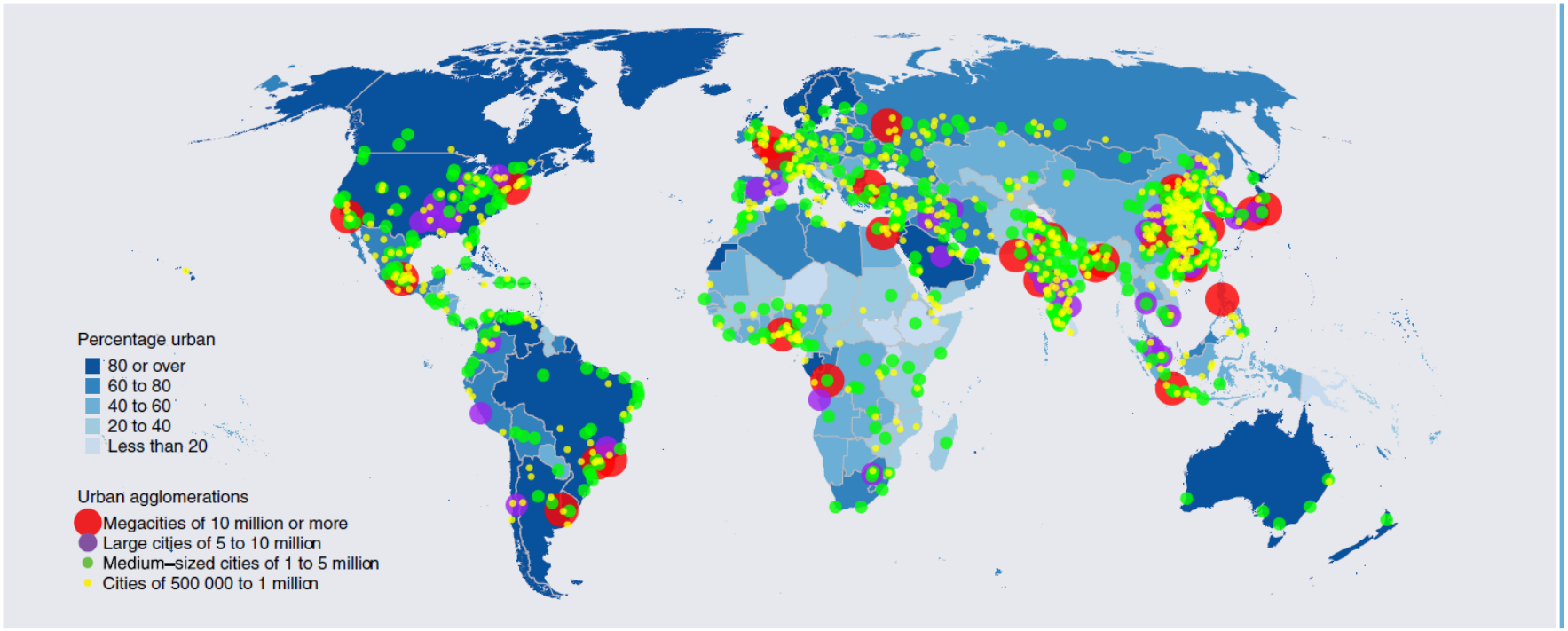
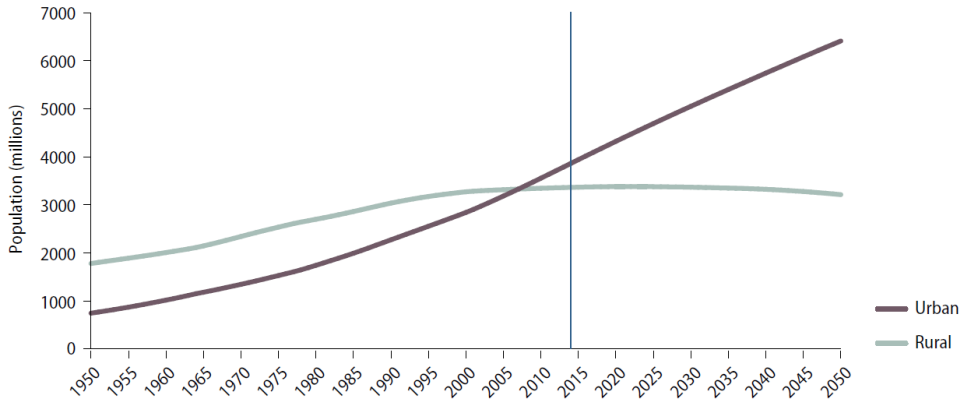


Figure 2.

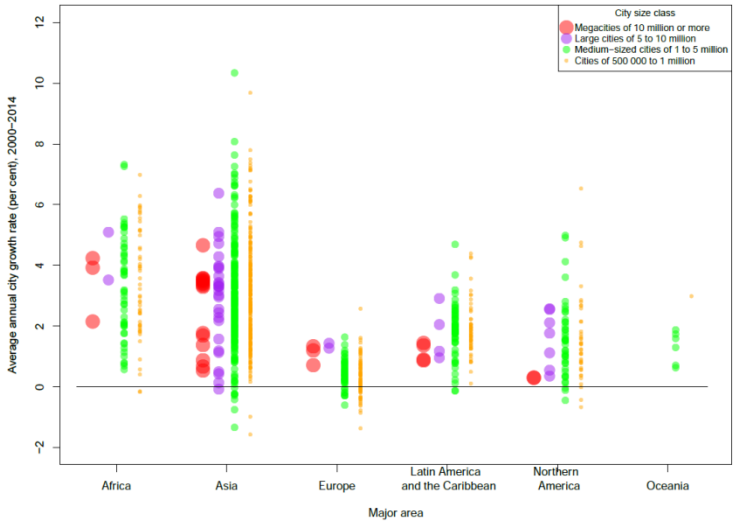
Urban and rural population of the world, 1950–2050



United Nations (2014)

A majority of the world's population lives in urban areas

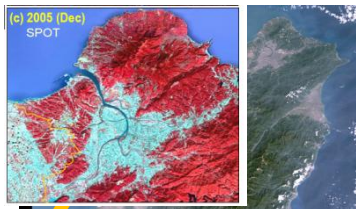
The world's fastest growing cities are in Africa and Asia



Cross scale modeling system: From regional to urban scale (WRF-UCM)

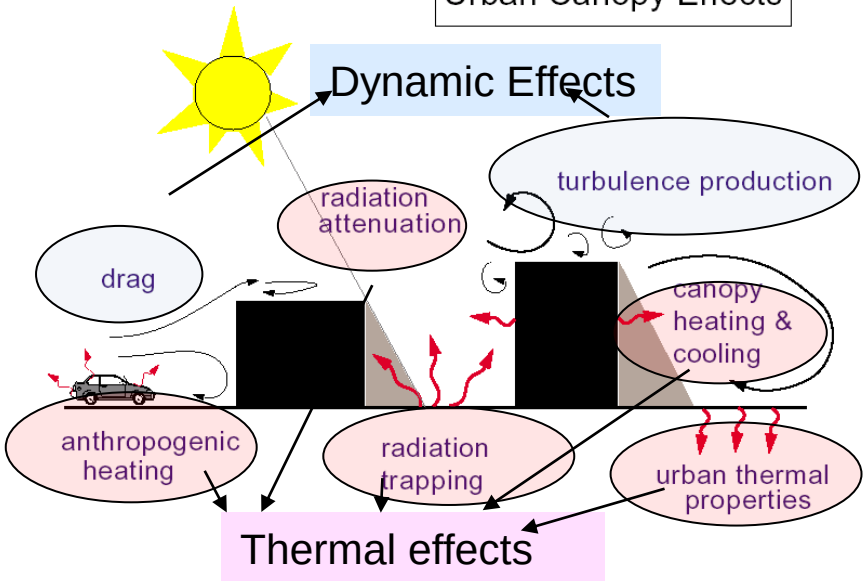
Regional scale

Local scale

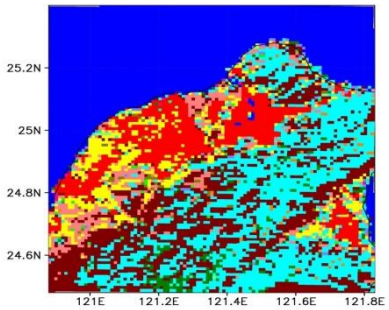


Urban scale

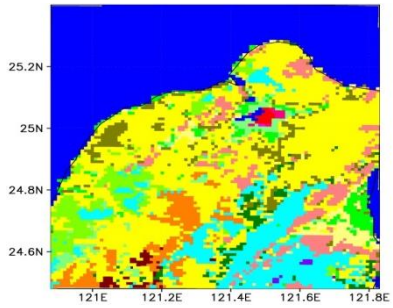
Urban Canopy Effects



WRF-Noah UCM model study the summer thunderstorm

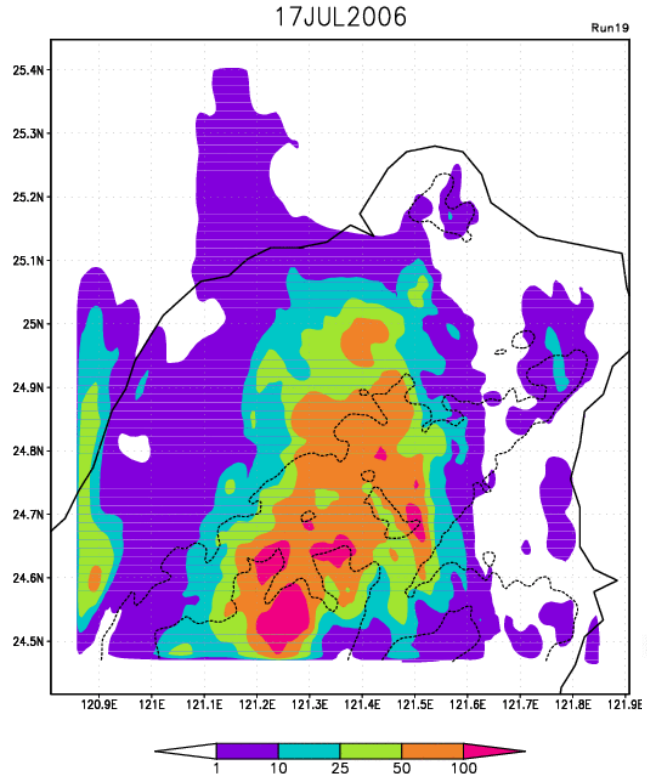


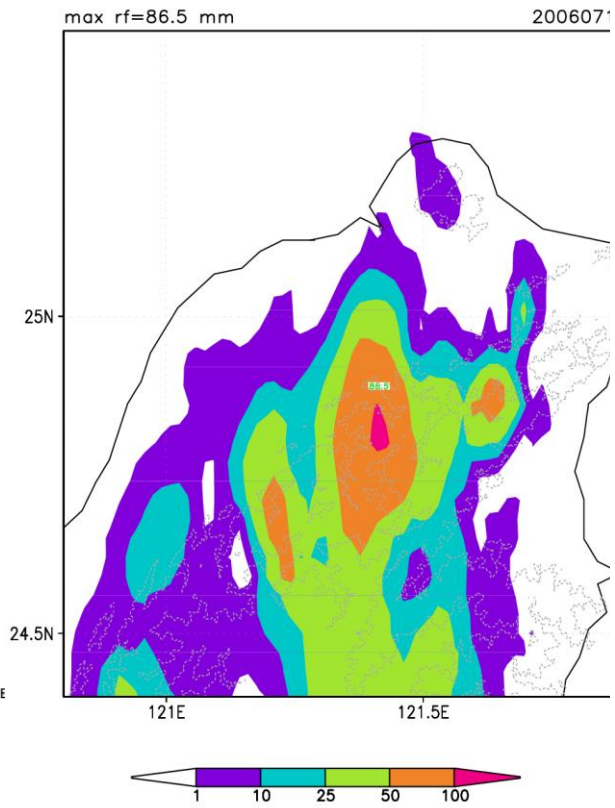
MODIS

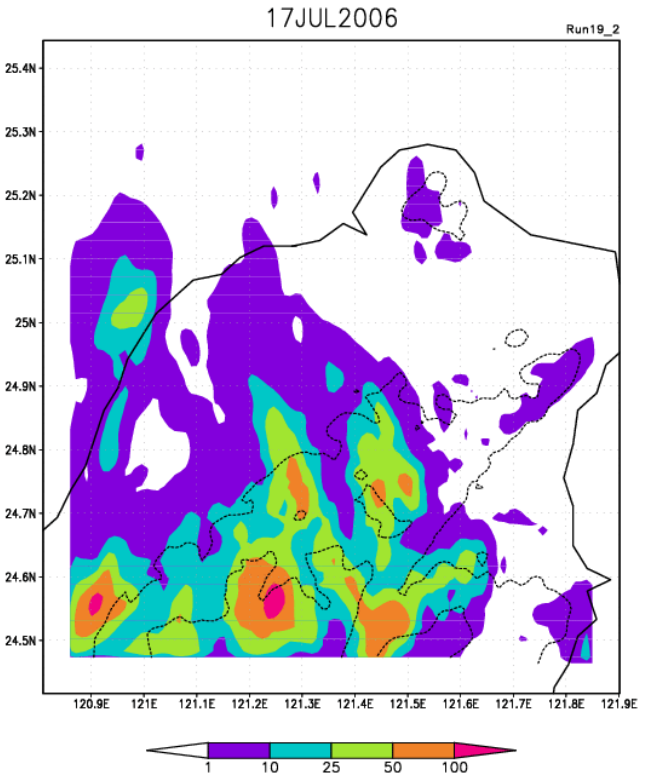


Original
WRF-USGS

Observation







(Lin et al. 2011, JAMC)

Atmos. Chem. Phys., 16, 1809–1822, 2016
www.atmos-chem-phys.net/16/1809/2016/
doi:10.5194/acp-16-1809-2016
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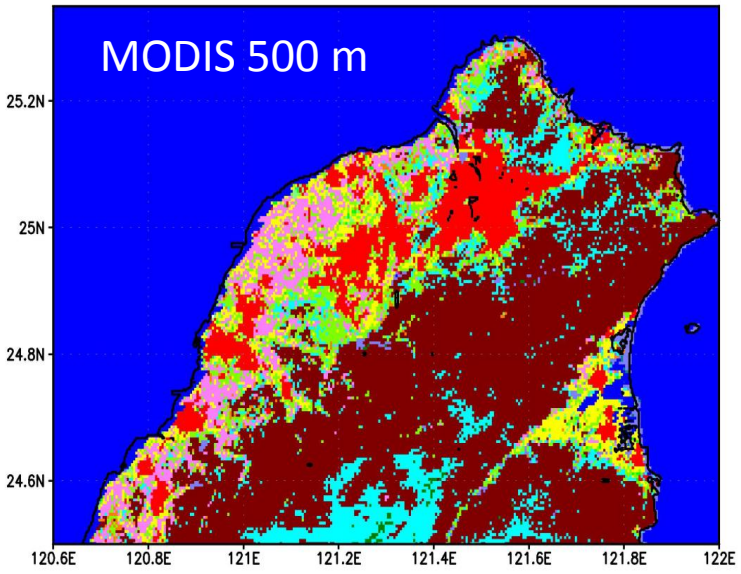
Atmospheric Chemistry and Physics Open Access EGU

Impact of an improved WRF urban canopy model on diurnal air temperature simulation over northern Taiwan

Chuan-Yao Lin[1], Chiung-Jui Su[1], Hiroyuki Kusaka[2], Yuko Akimoto[2], Yang-Fan Sheng[1], Jr-Chuan Huang[3], and Huang-Hsiung Hsu[1]

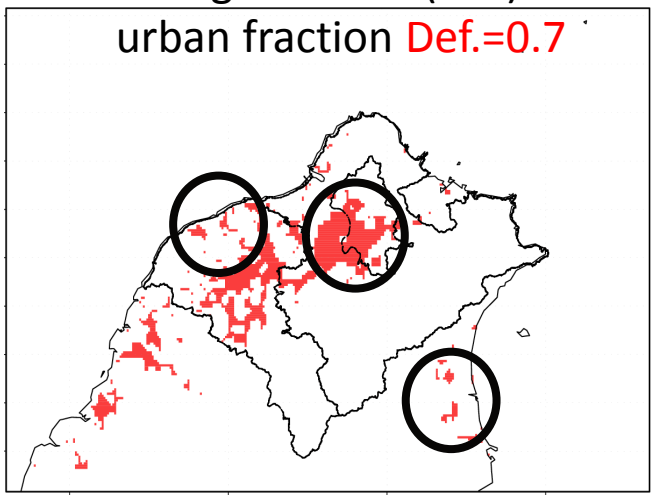
[1]Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan
[2]Graduate school of Life and Environmental Sciences, and Center for Computational Sciences, University of Tsukuba, Tsukuba, Japan
[3]Department of Geography, National Taiwan University, Taipei, Taiwan

MODIS Land use classification in Taiwan



urban
DryInd Crop.
Irrg. Crop.
Mix. Dry/Irrg. C.P.
Crop./Grs. Mosaic
Crop./Wood Mosc
Grassland
Shrubland
Mix Shrb./Grs
Savanna
Decis. Broadlf.
Decis. Needlf.
Evergrn. Braodlf.
Evergrn. Needlf
Mixed Forest
Water bodies

Original UCM (1-D)



1km resolution, generated from100 m resolution from National Land Surveying and Mapping Center.

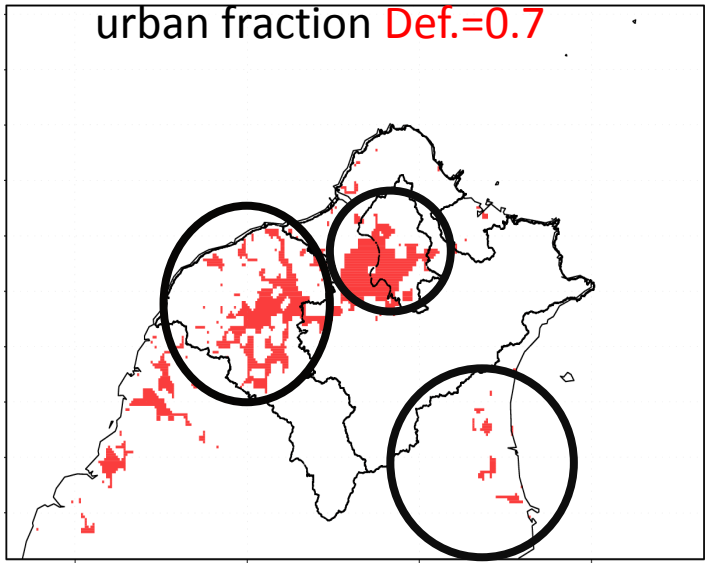
2-D Urban Canopy Model (UCM) model -Urban Fraction

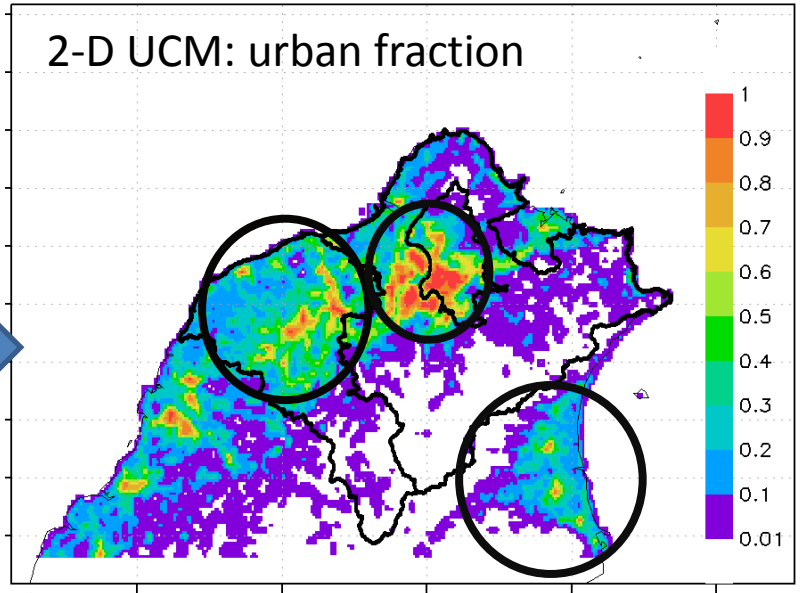
- **Original UCM :**

  Urban Fraction is fixed, for instance 0.7, or given in three types of urban

- **2-D UCM :**
  - 2-D urban fraction : generated from 100 m resolution from National Land Surveying and Mapping Center.

Original UCM (1-D)
urban fraction Def.=0.7





（1km resolution）

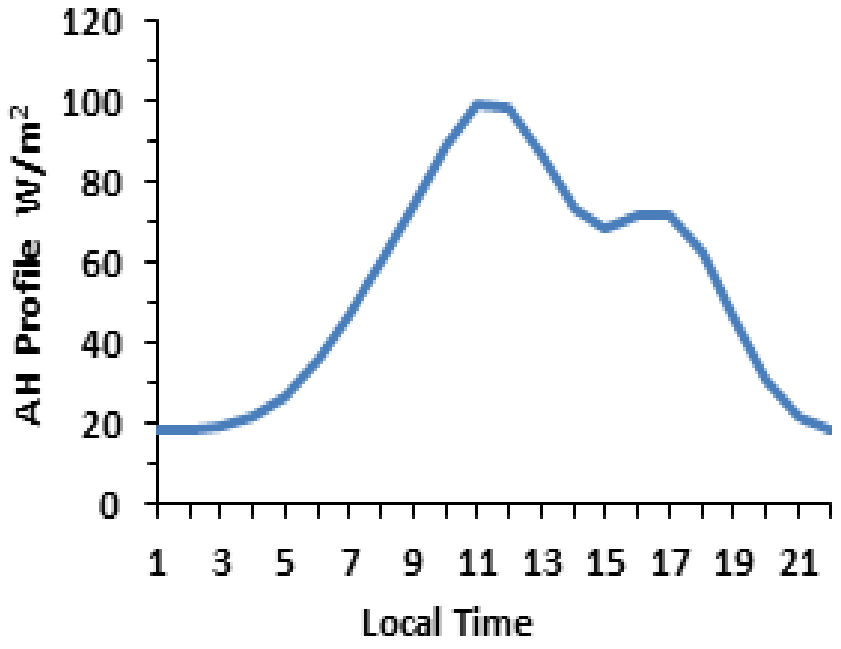
(Lin et al. 2016 ACP)

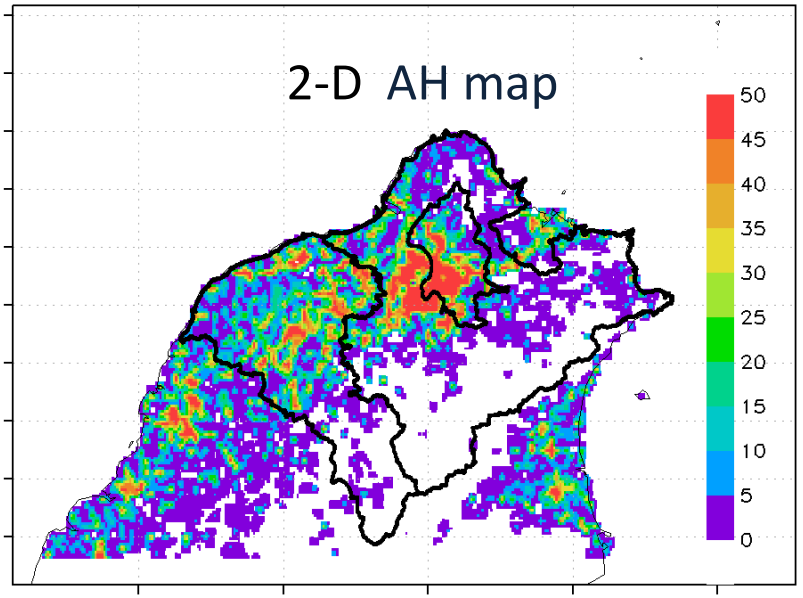
2-D Urban Canopy Model (UCM) model -Anthropogenic heat

- **Original UCM :**

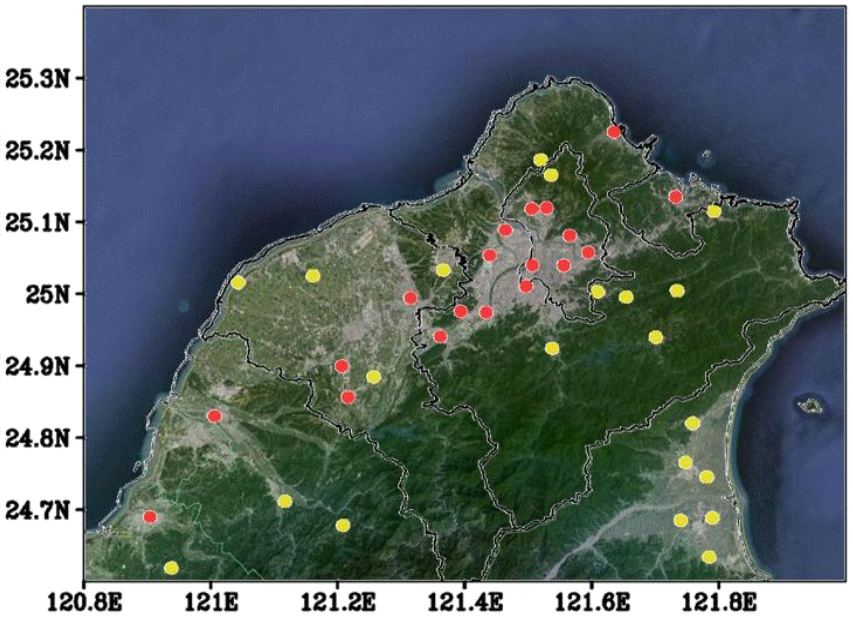
  Anthropogenic heat(AH) is fixed, for example, 50W/m²

- **2-D UCM :**
  - **Anthropogenic Heat**
    - **2-D anthropogenic heat is generated from 100 m resolution of building density (2006),**
    - **The maximum AH value is *50 W/m²*.**

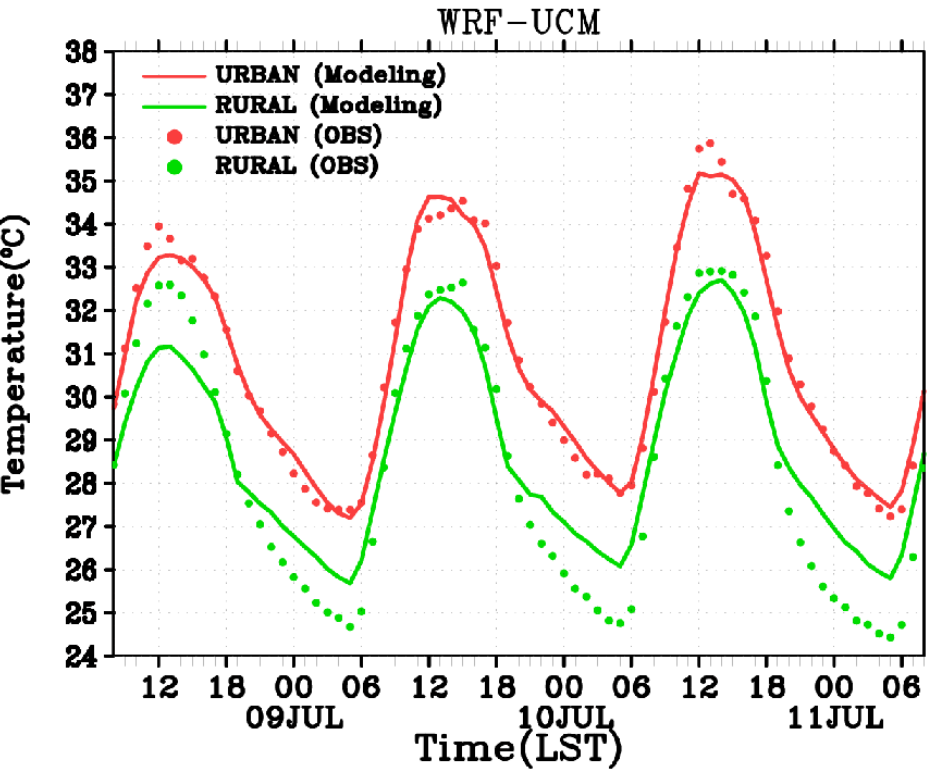


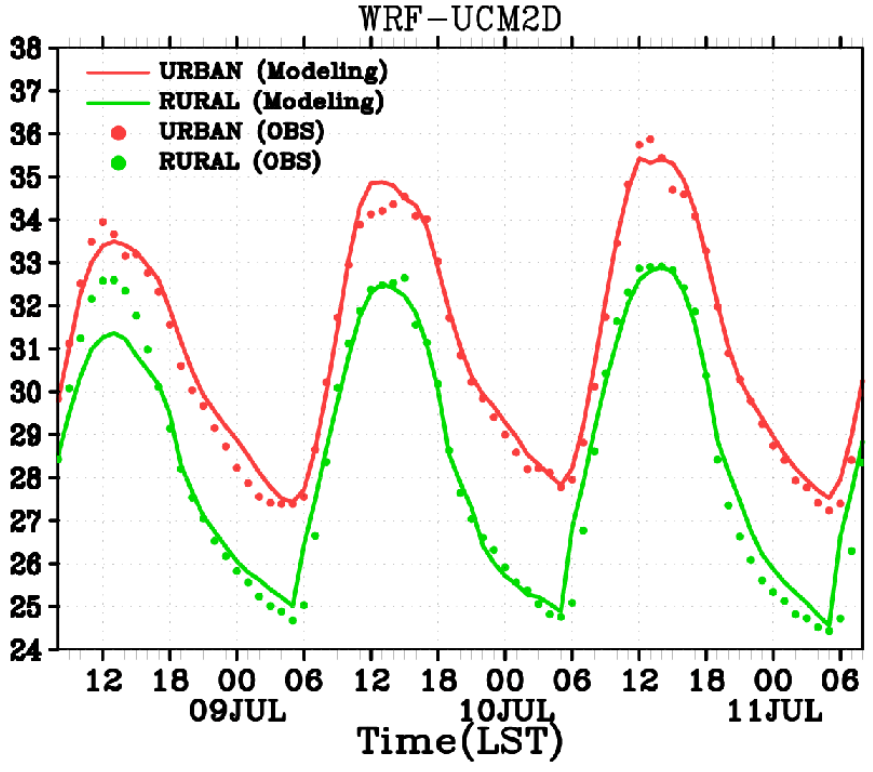


resolution）



Urban (red dots)
Non-urban (yellow dots)





Future Climate projection

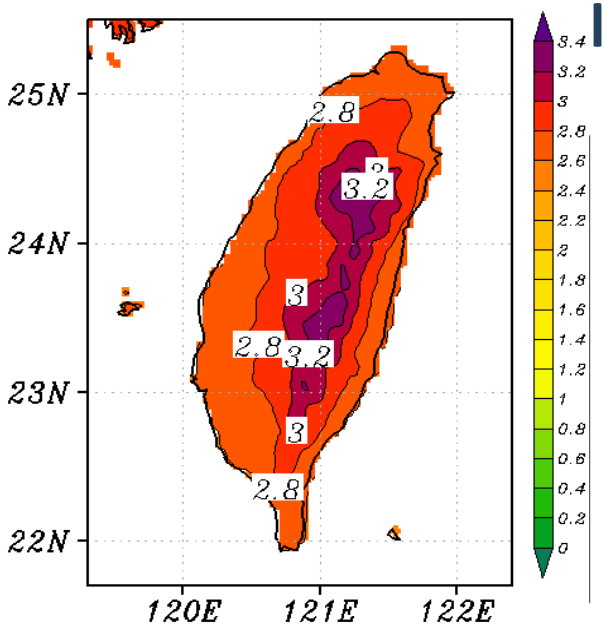
INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (2014)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/joc.4118

RMetS
Royal Meteorological Society

Altitudinal and latitudinal dependence of future warming in Taiwan simulated by WRF nested with ECHAM5/MPIOM

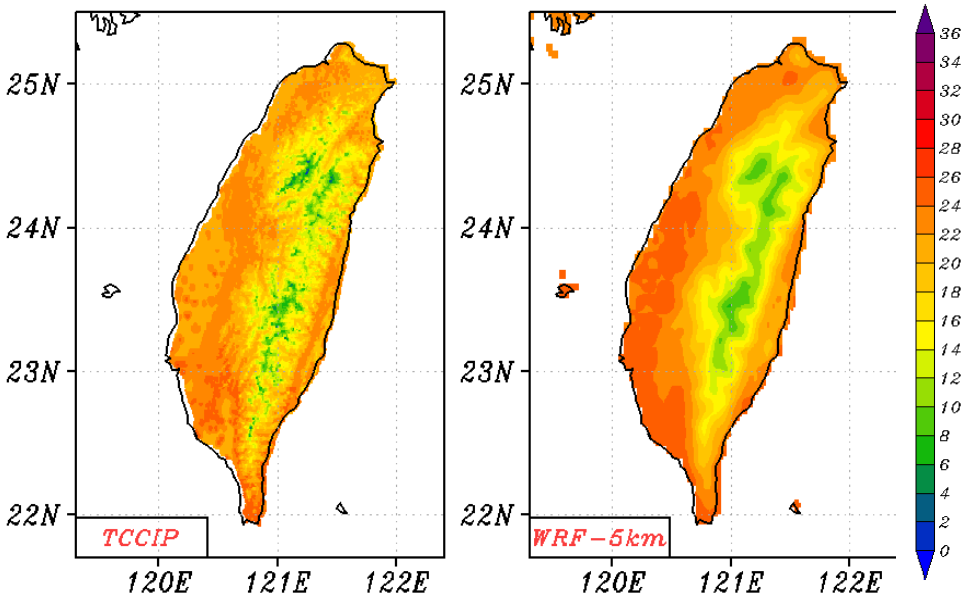
Chuan-Yao Lin,[a]* Ying-Jea Chua,[a] Yang-Fan Sheng,[a] Huang-Hsiung Hsu,[a] Chao-Tzuen Cheng[b] and Yi-Yin Lin[b]

ECHAM5-WRF, A1B scenario



(2075-2099)-(1979-2003)

l evaluation and simulation results:

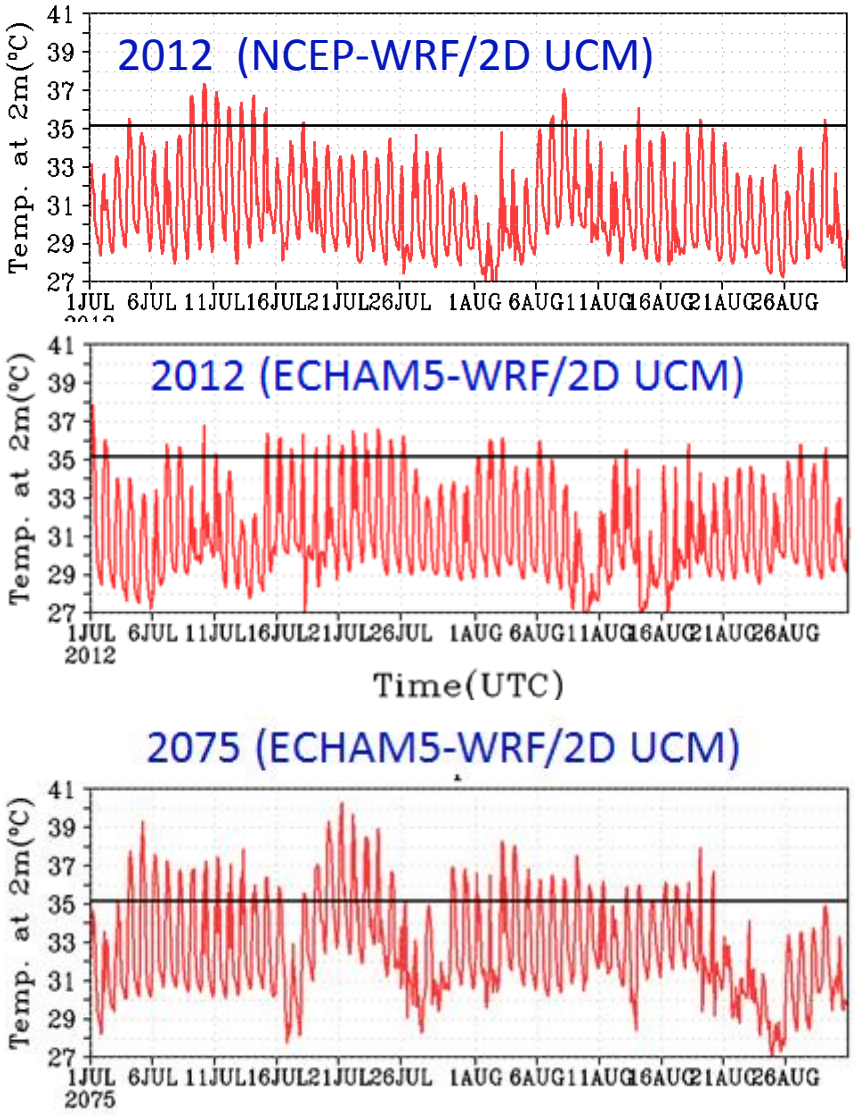


1979-2003

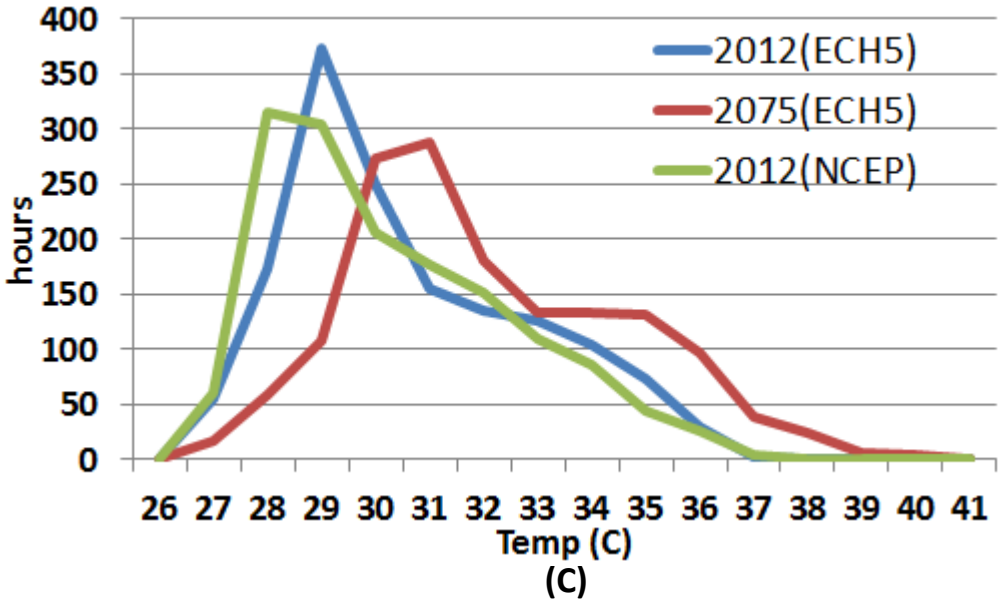
Future Heat Wave projection:

Summer (Jul. and Aug.)

air Temperature in 2012 and 2075



	2012 NCEP	2012 ECH5	2075 ECH5
Daytime mean Temp.	31.67	32.00	33.45
Nighttime mean Temp.	29.25	29.45	31.11
DTR	2.42	2.55	2.34
>=35.2℃ total hours	62	87	267



Earth and Planetary Science Letters 319-320 (2012) 9–14

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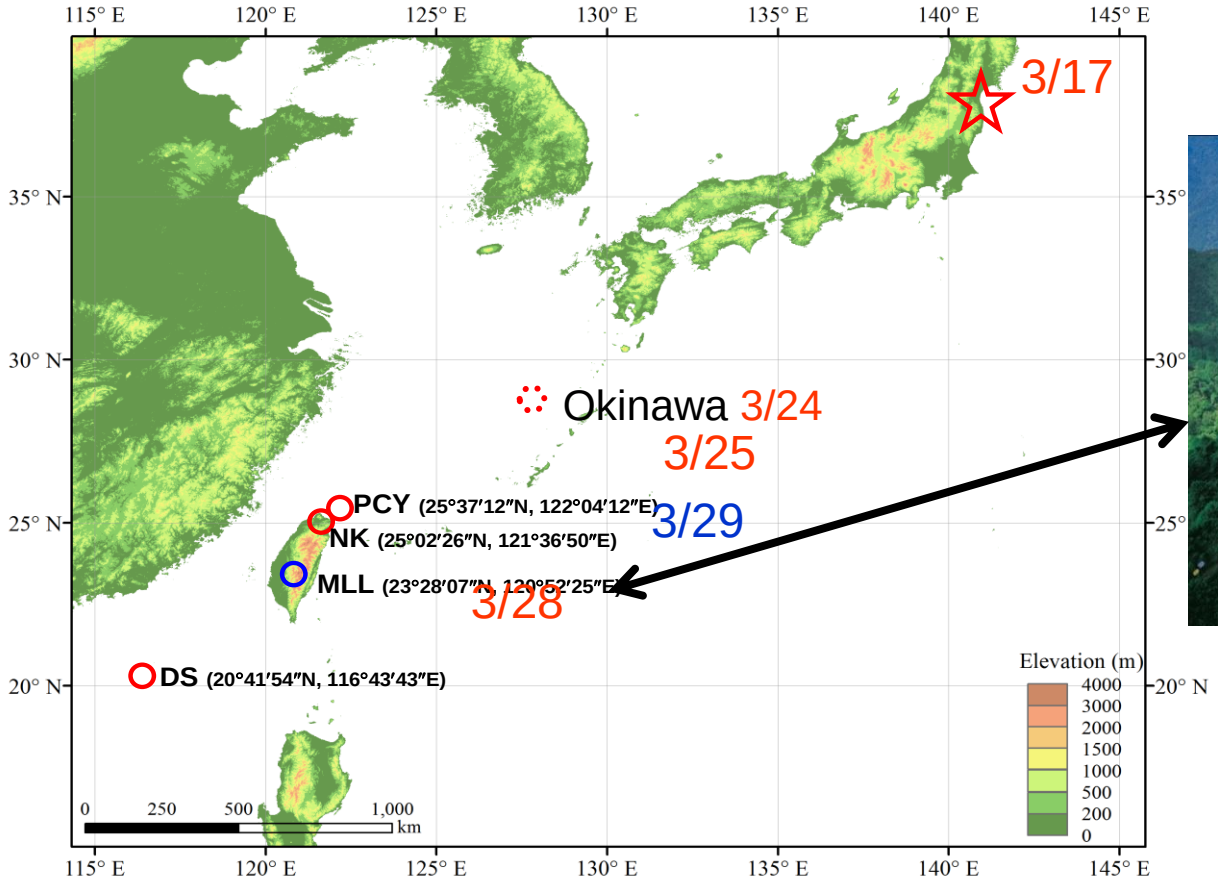
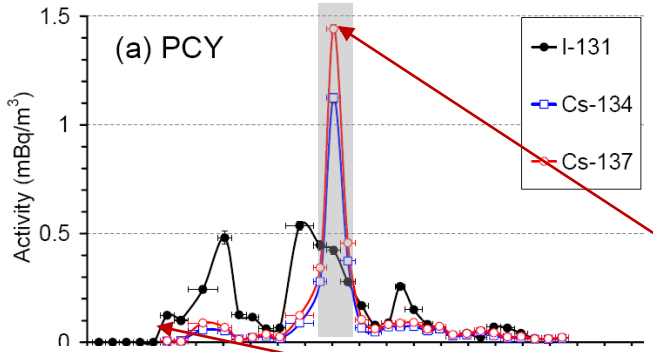
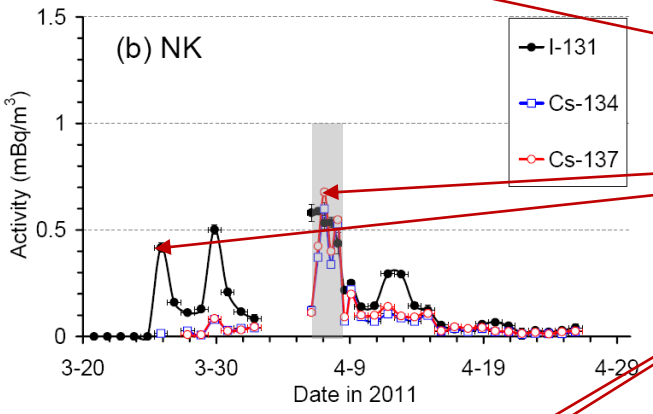
journal homepage: www.elsevier.com/locate/epsl

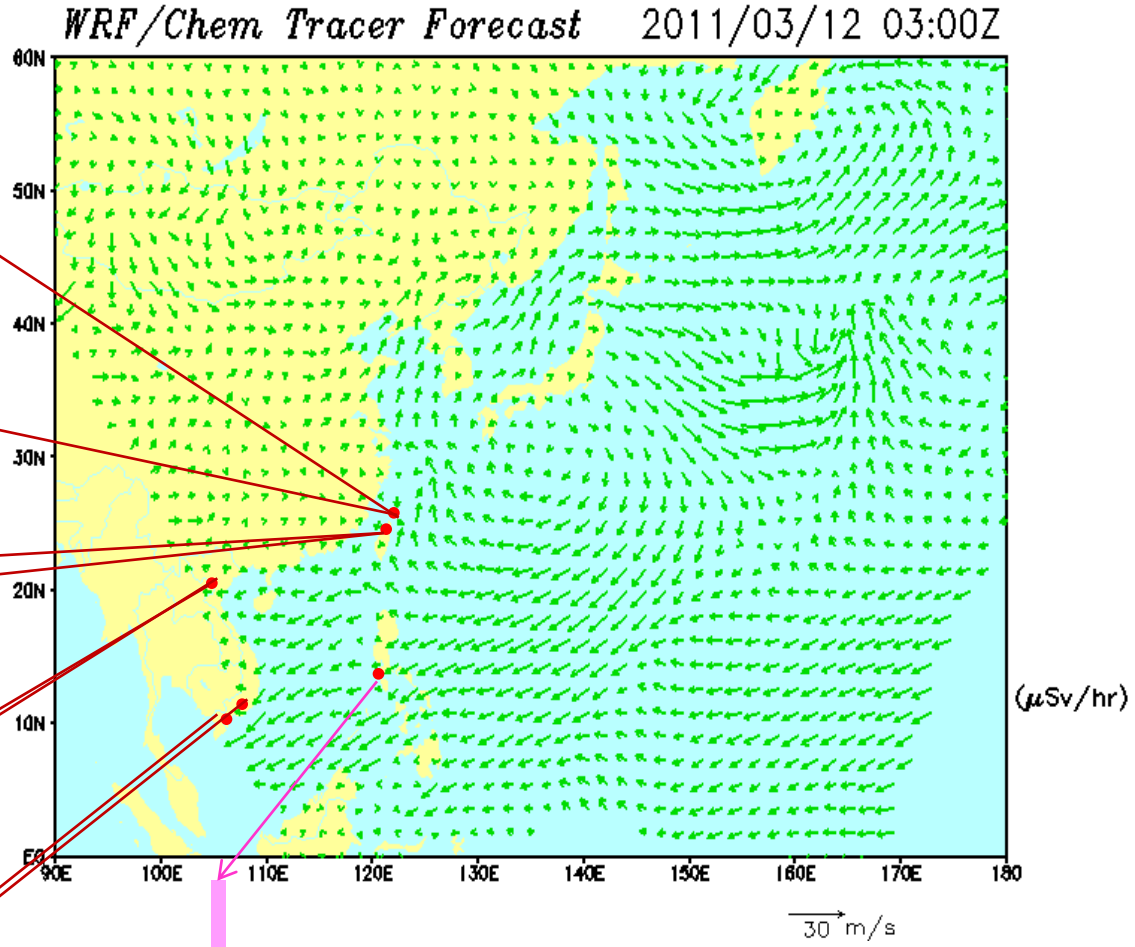
Fukushima-derived fission nuclides monitored around Taiwan: Free tropospheric versus boundary layer transport

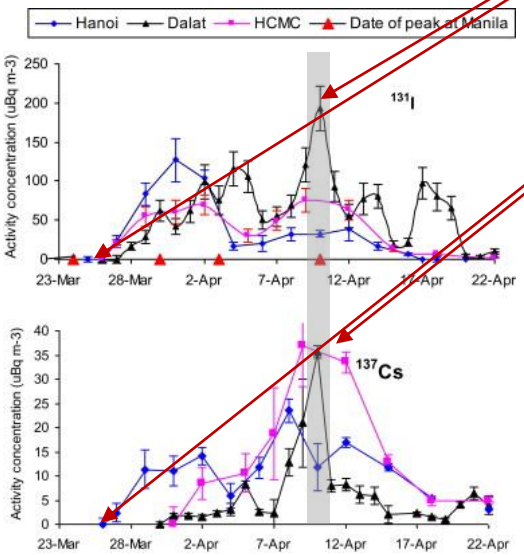
Chih-An Huh [a,*], Shih-Chieh Hsu [b], Chuan-Yao Lin [b]

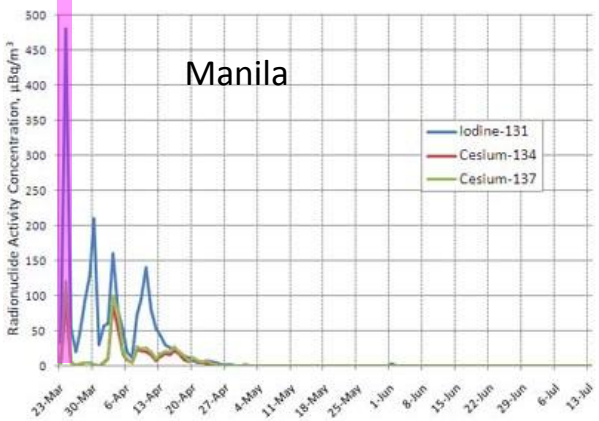



(a) PCY
I-131
Cs-134
Cs-137
Activity (mBq/m3)
1.5
1
0.5
0


(b) NK
I-131
Cs-134
Cs-137
Activity (mBq/m3)
1.5
1
0.5
0
3-20
3-30
4-9
4-19
4-29
Date in 2011


WRF/Chem Tracer Forecast 2011/03/12 03:00Z
60N
50N
40N
30N
20N
10N
EQ
90E
100E
110E
120E
130E
140E
150E
160E
170E
180
(μSv/hr)
30 m/s


Hanoi
Dalat
HCMC
Date of peak at Manila
131I
137Cs
Activity concentration (uBq m-3)
23-Mar
28-Mar
2-Apr
7-Apr
12-Apr
17-Apr
22-Apr


Manila
Iodine-131
Cesium-134
Cesium-137
Radionuclide Activity Concentration, μBq/m3

Thank you !!!!

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www.atmos-chem-phys.net/11/345/2011/
doi:10.5194/acp-11-345-2011
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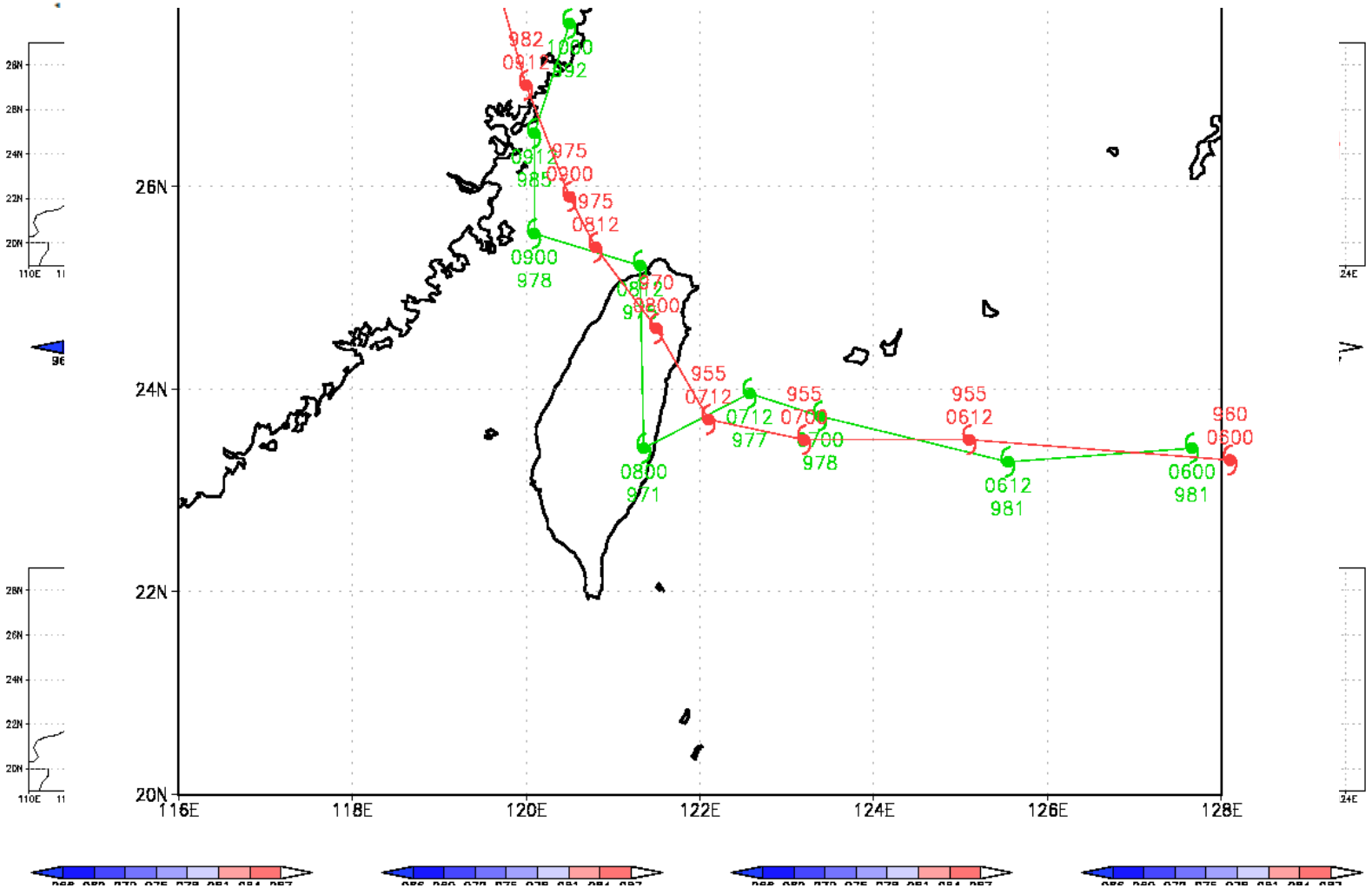
Atmospheric Chemistry and Physics

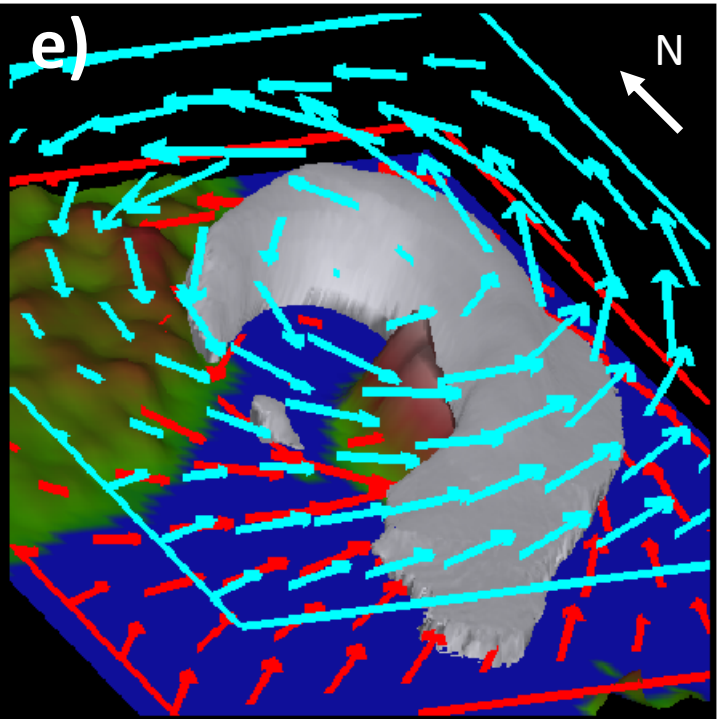
Mesoscale processes for super heavy rainfall of Typhoon Morakot (2009) over Southern Taiwan

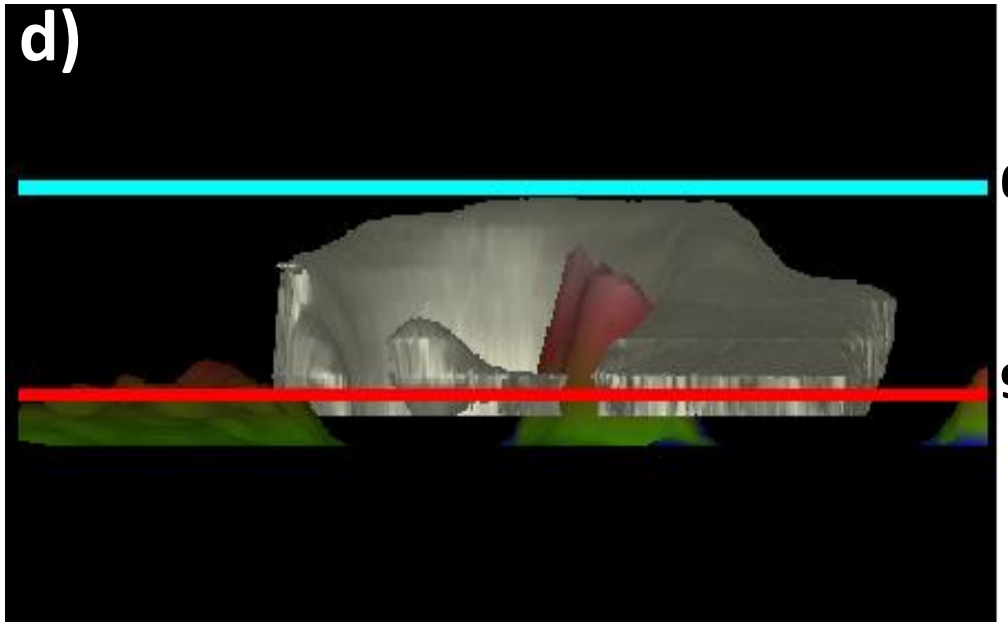
C.-Y. Lin[1], H.-m. Hsu[2], Y.-F. Sheng[1], C.-H. Kuo[3], and Y.-A. Liou[4]

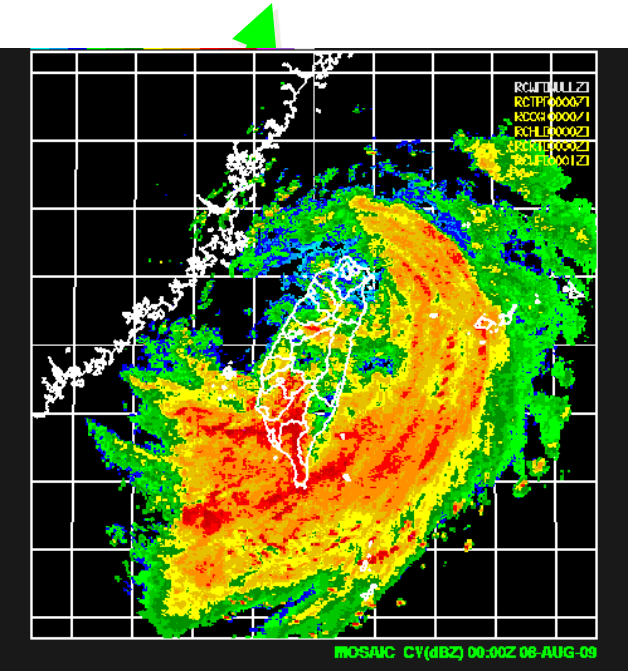


Typhoon Morakot (2009)

■ Massive deep landsliding Caused by Morakot





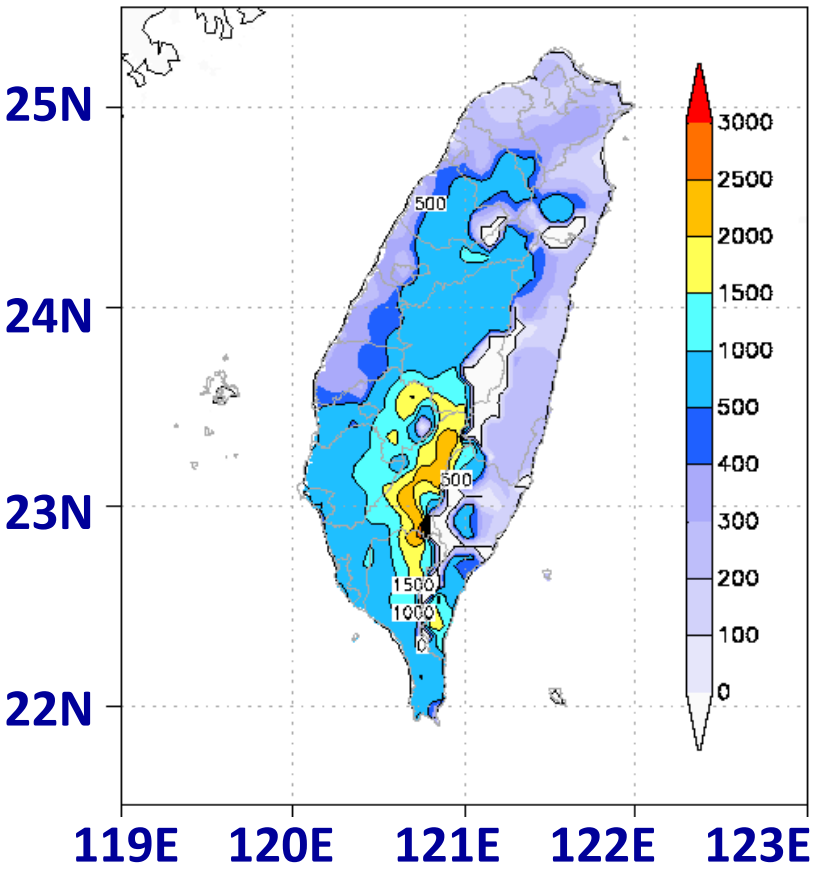


(d) A northwest-southeast vertical perspective views for depth by VIS5D for the moisture flux at 00:00 UTC 8 August taken from the direction of the arrow in (e) The grey shading is the moisture flux surface of 550 g/kg m/s.

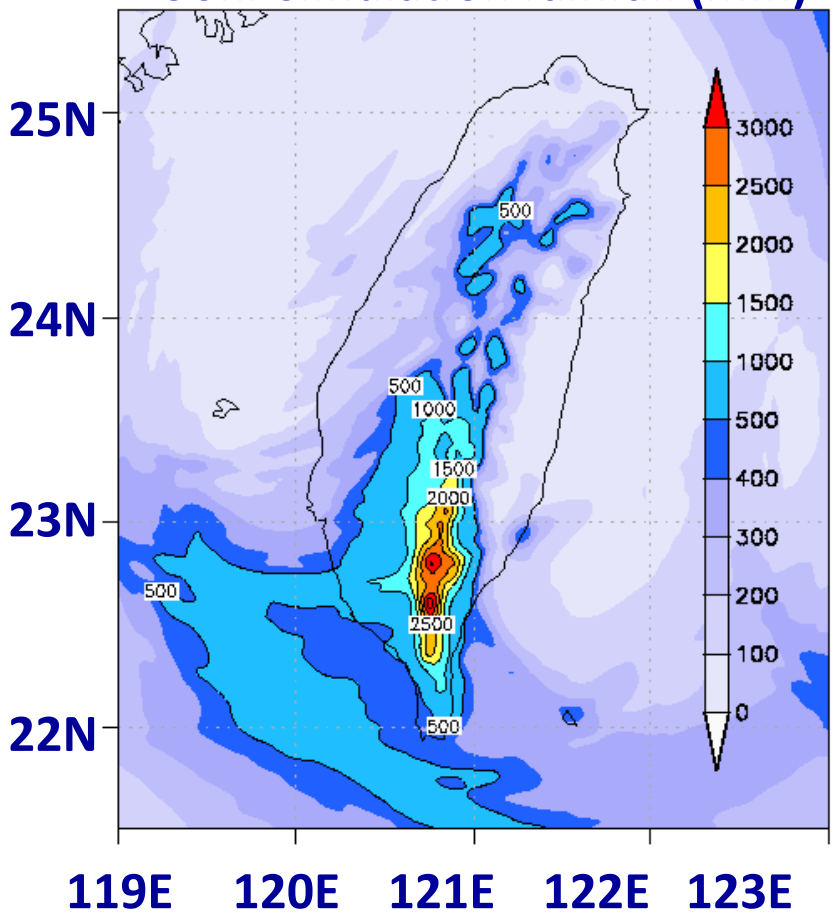
(e) Three-dimensional perspective views by VIS5D for the moisture flux at 00:00 UTC 8 August. The blue (red) arrow represents the wind field at 650 hPa (925 hPa). The grey shading is the moisture flux surface of 550 g/kg m/s.

(Lin et al. 2011, ACP)

96 hrs observation rainfall (mm)



WRF (3km)
96hr simulation rainfall (mm)



(Lin et al. 2011, ACP)