Overview of Hong Kong Observatory (HKO), R&D and Severe Weather Nowcasting in Hong Kong

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Hong Kong Observatory
17 July 2012

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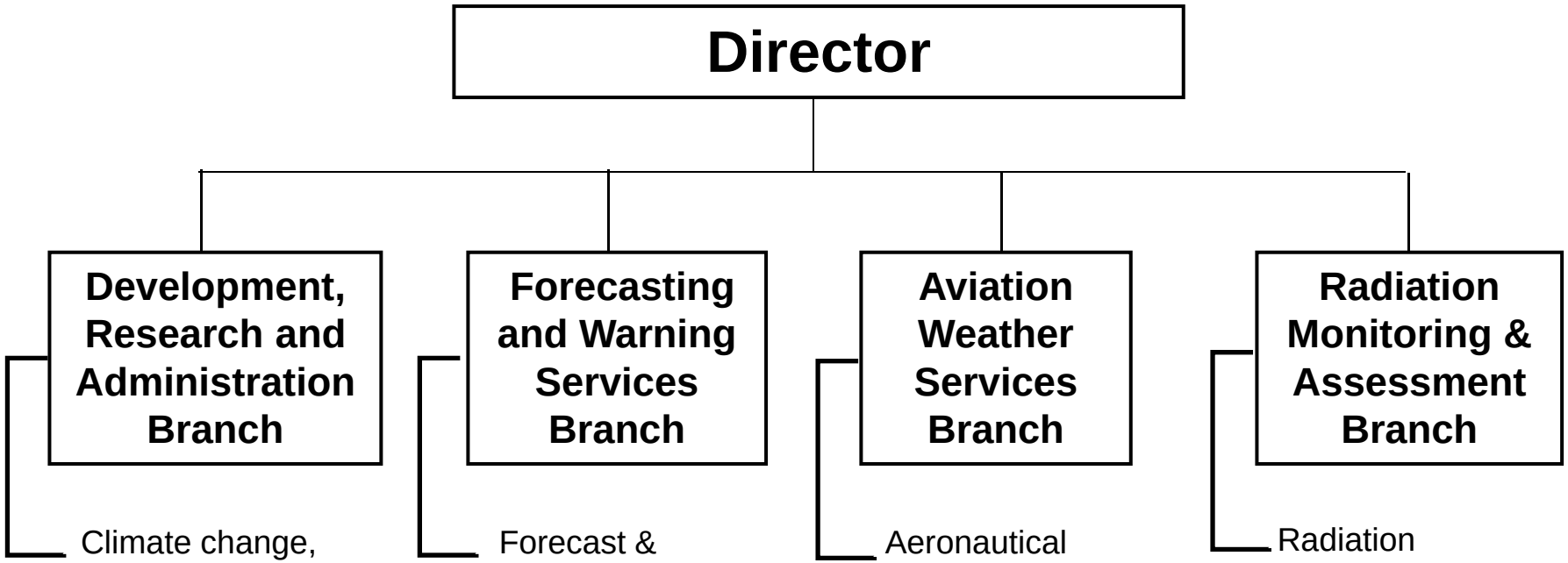
Structure of HKO



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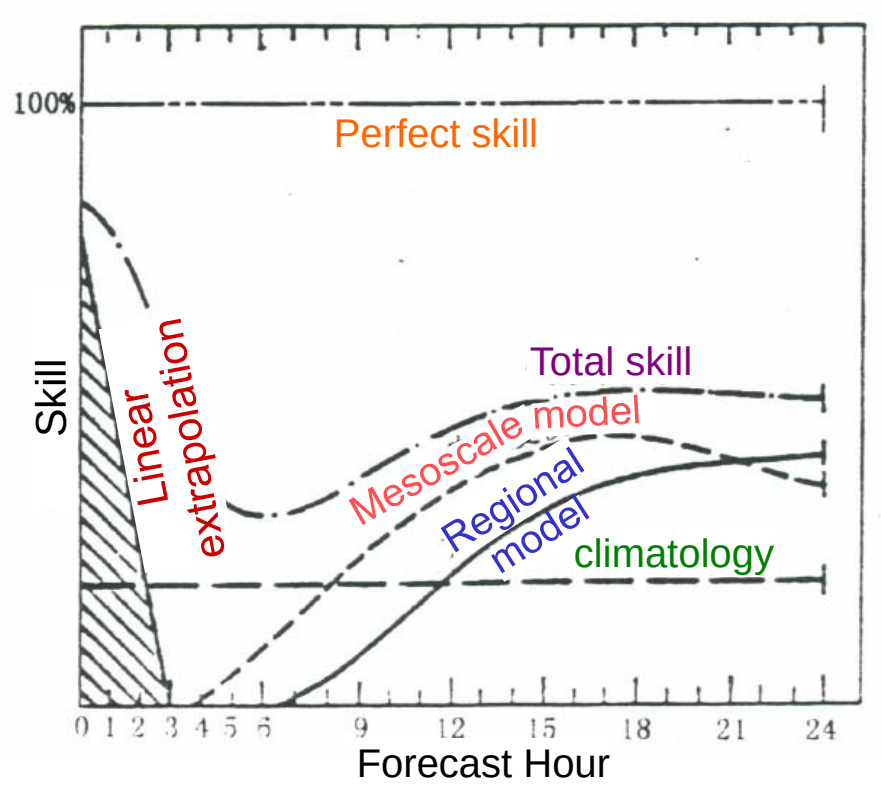
Weather forecasting

- Nowcast (0 - 6 h)
- Very short-range (=< 12 h)
- Short-range (12-72 h)
- Medium-range (3-10 days)
- Extended-range (10-30 days)
- Long-range (>30 days)



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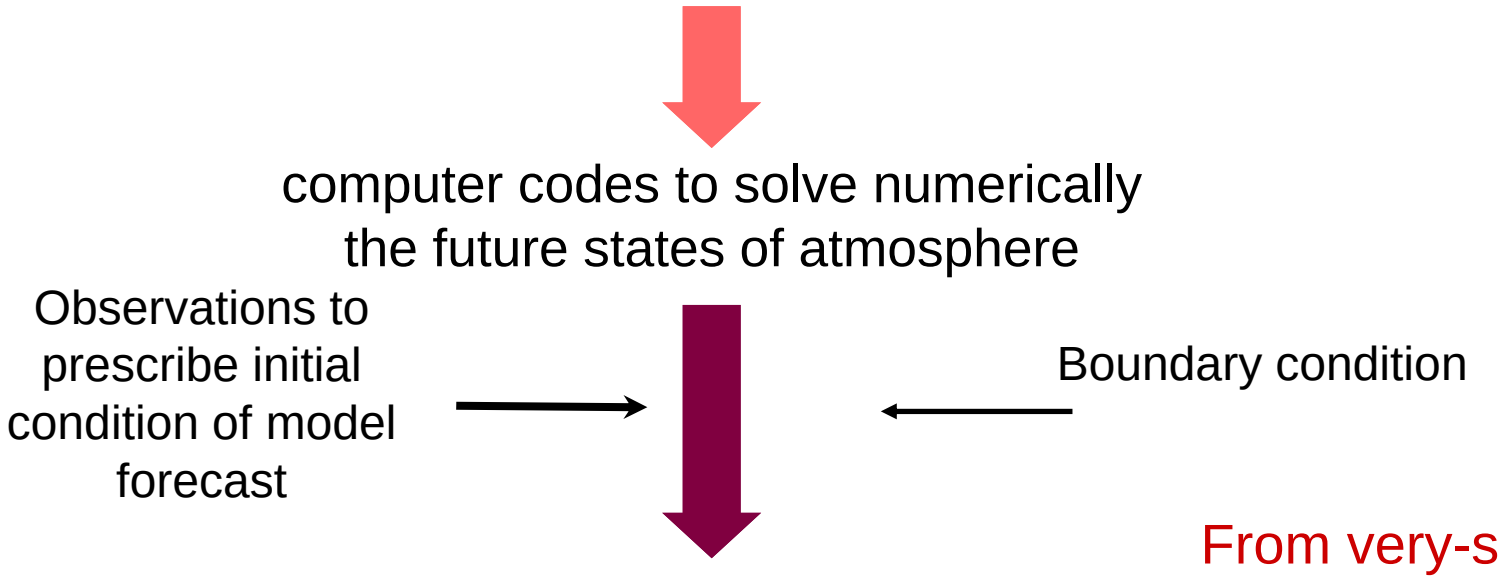
Numerical Weather Prediction (NWP) Model

Governing equations of the atmosphere
(including land-surface processes, ocean coupling, etc ...)



Prediction of wind, temperature, pressure, humidity, cloud amount, ...

From very-short-range to long-range forecasts

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NWP Model Process

- NWP is an initial value problem

time step

$$X_{n+1} = X_n + \Delta t \times F(X, t)$$

dynamics and physics

state of atmosphere in next time step

current state of atmosphere

pressure gradient force, vertical acceleration, radiation, cloud process, energy exchange between atmosphere and land/sea surface ...

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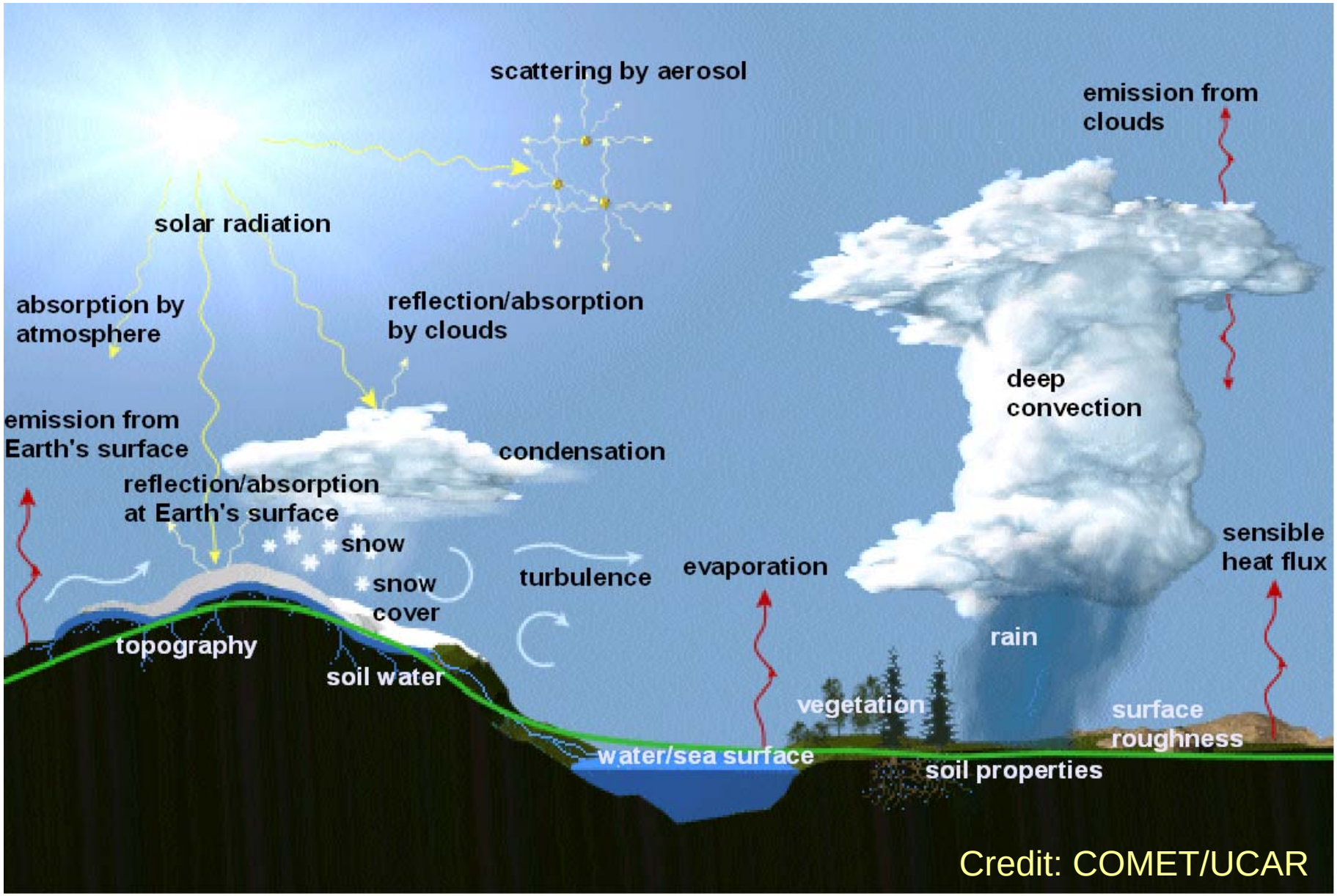
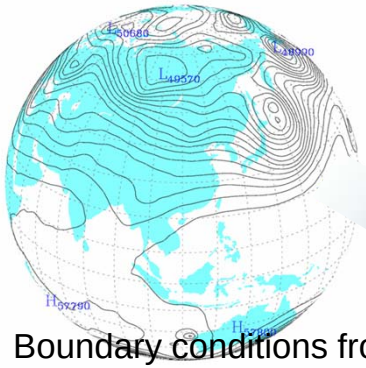
Physical Processes in NWP models

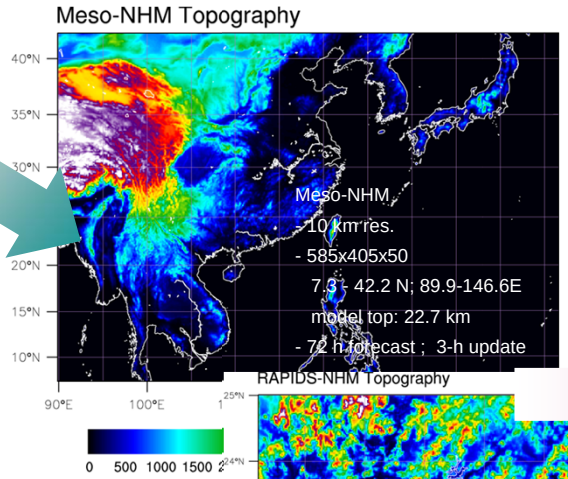


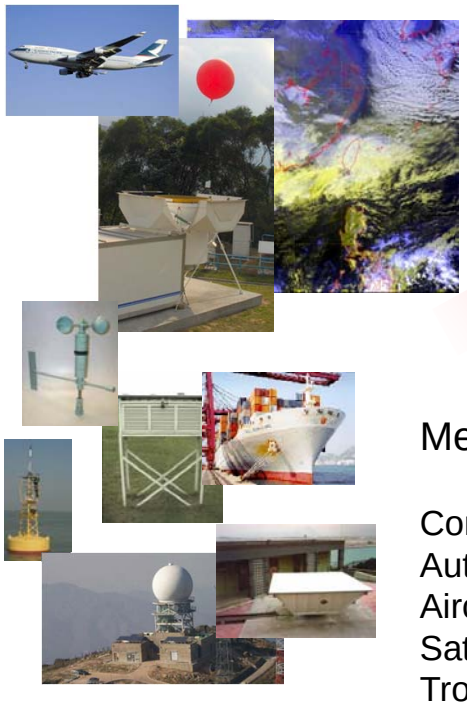
Operational Mesoscale NWP Model system at HKO



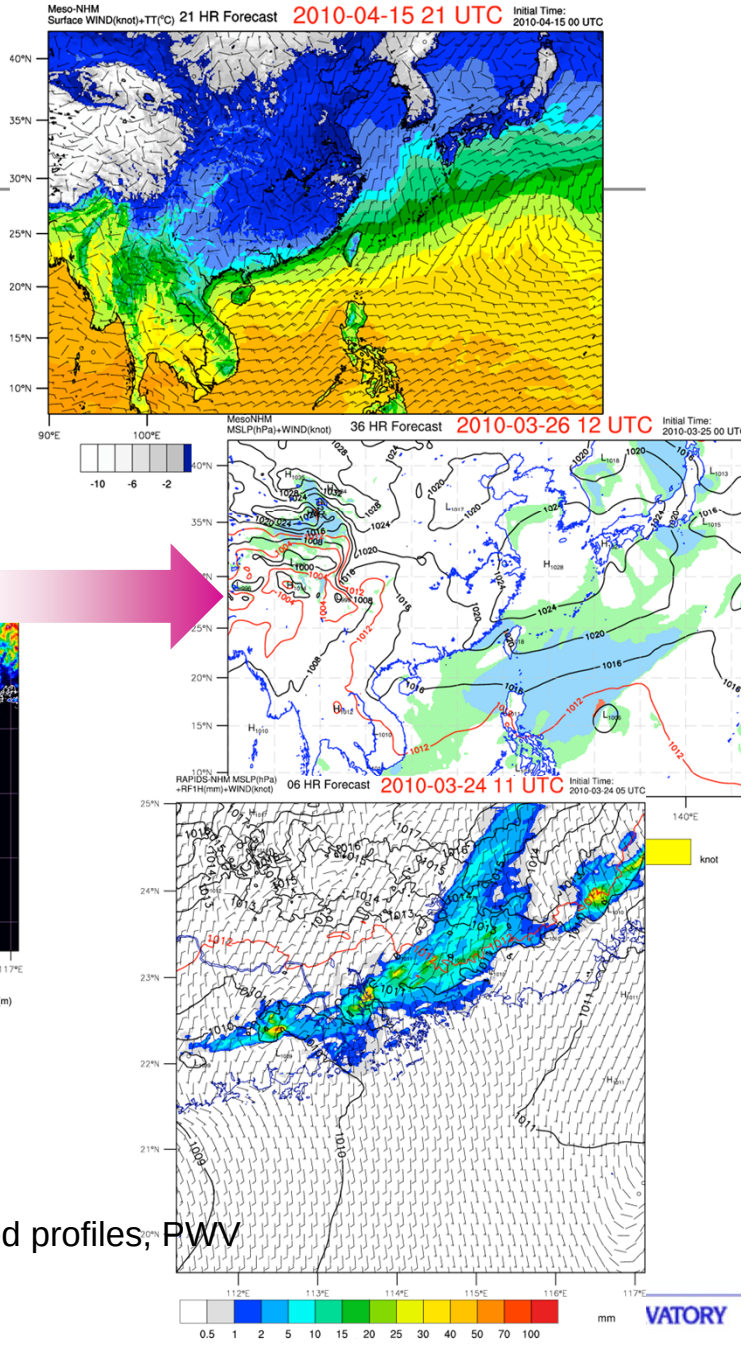
Boundary conditions from global models

Two regional domains of the Non Hydrostatic Model (NHM)





Data Assimilation System



Meteorological Observations

Conventional
Automatic weather stations (HK and Guangdong)
Aircraft
Satellite - cloud motion wind, temperature retrieved profiles, PWV
Tropical cyclone bogus data
Radar

Nowcasting

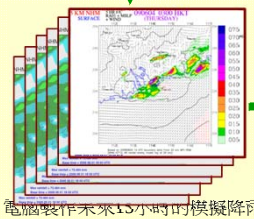
- Observation-based
  - Weather radar data
  - Automatic weather station data
  - Lightning data
- Conceptual models
- Empirical models
- Rapid updating mesoscale numerical model

Short-range Warning of Intense Rainstorms and Localized Systems (SWIRLS)

電腦模擬大氣物理過程
Computer Simulation of Physical Processes in the Atmosphere

遙感及常規天氣觀測資料
Remote-sensing and conventional weather observation data

高分辨率風暴模式，直接模擬未來15小時雨雲的演變過程
High-resolution storm model to directly simulate the evolution of precipitating clouds up to 15 hours ahead

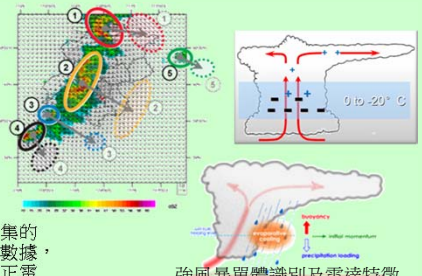


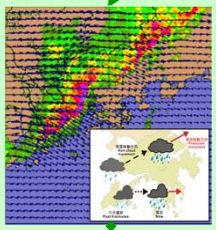
電腦製作未來15小時的模擬降雨預測圖
Forecast rainfall maps for the next 15 hours based on computer simulation

雷達追蹤、分析及預測
Radar Tracking, Analysis and Forecast

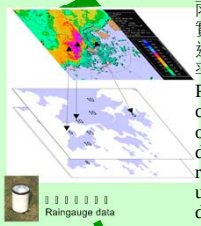
「小渦旋」臨近預報系統
SWIRLS Nowcasting System

「小渦旋」特別版 Special Editions of SWIRLS

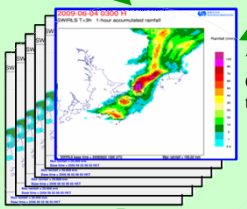




利用雷達自動追蹤及估計雨帶的移動路徑
Automatic tracking and prediction of rainband movement from radar



利用密集的雨量站數據，實時訂正雷達探測降雨率
Real-time calibration of radar-detected rainfall rate using the dense raingauge network



電腦製作未來1至6小時的雷達降雨預測圖
Computer-generated forecast rainfall maps up to 6 hours ahead based on radar

強風暴單體識別及雷達特徵分析
Cell identification and radar signature analysis for severe storms

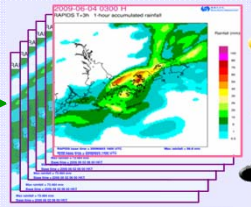
電腦製作狂風、閃電、冰雹及大雨預測圖
Computer-generated forecast map of squalls, lightning, hail and heavy rain

臨近預報產品及服務
Nowcast Products & Services

支援國際盛事
In support of Important International Events

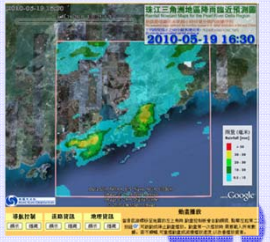
支援雷暴警告系統
In support of Thunderstorm Warning System

支援暴雨及相關警告系統
In support of Rainstorm and Related Warning Systems



融合雷達臨近預報及電腦模擬結果的未來1至6小時雨量預測圖
Forecast rainfall maps up to 6 hours ahead blended from radar nowcast and computer simulation results

「珠三角」降雨臨近預測圖在天文台網站公開發放
Public dissemination of nowcast rainfall maps for the Pearl River Delta region via HKO Internet website



降雨預測資料透過四維立體地圖展示
Forecast rainfall information visualized with 4-dimensional map of the globe

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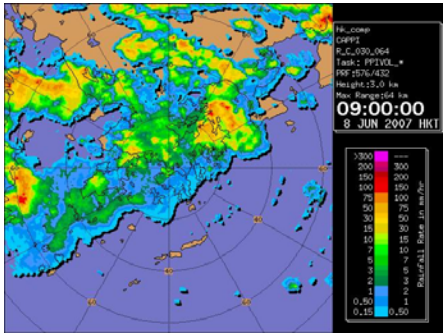
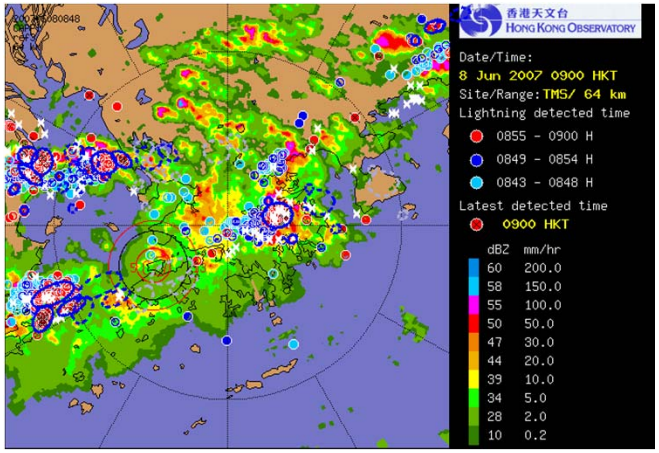
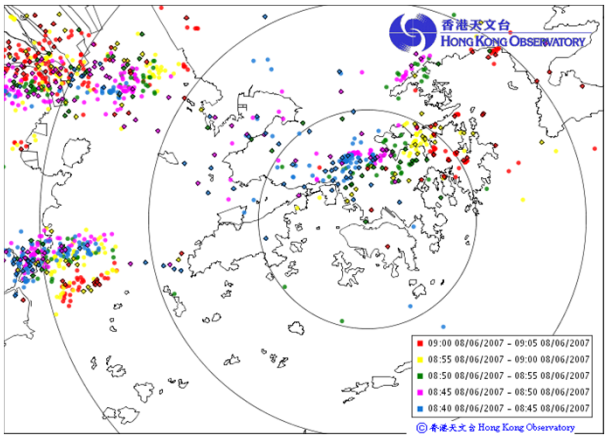
Airport Thunderstorm and Lightning Alerting System (ATLAS)

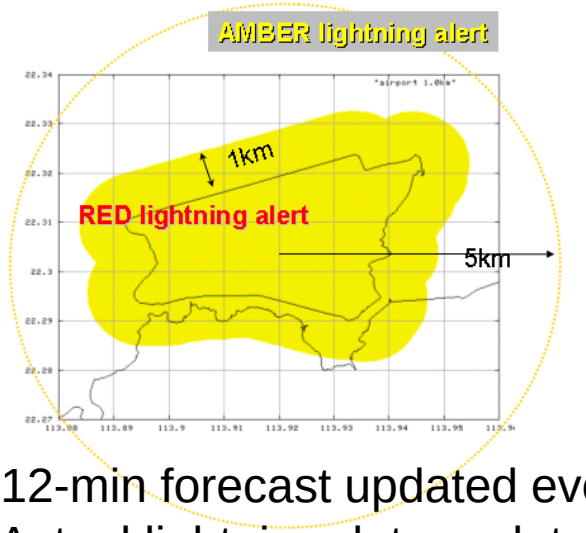


Radar derived TREC winds





Lightning data



- 12-min forecast updated every min
- Actual lightning data updated every sec

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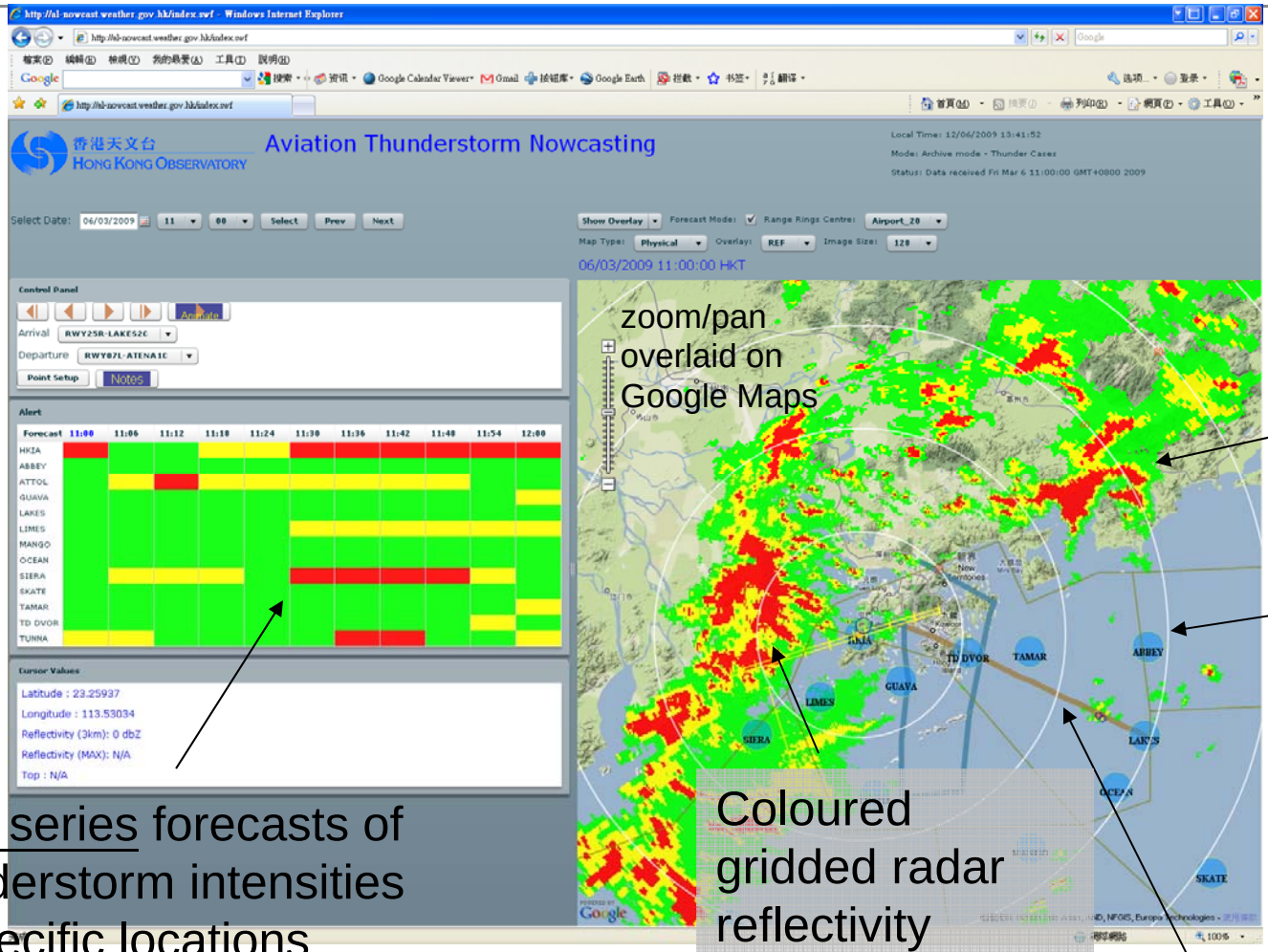
Aviation Thunderstorm Nowcasting System (ATNS)



- 1-h forecast updated every 6 min

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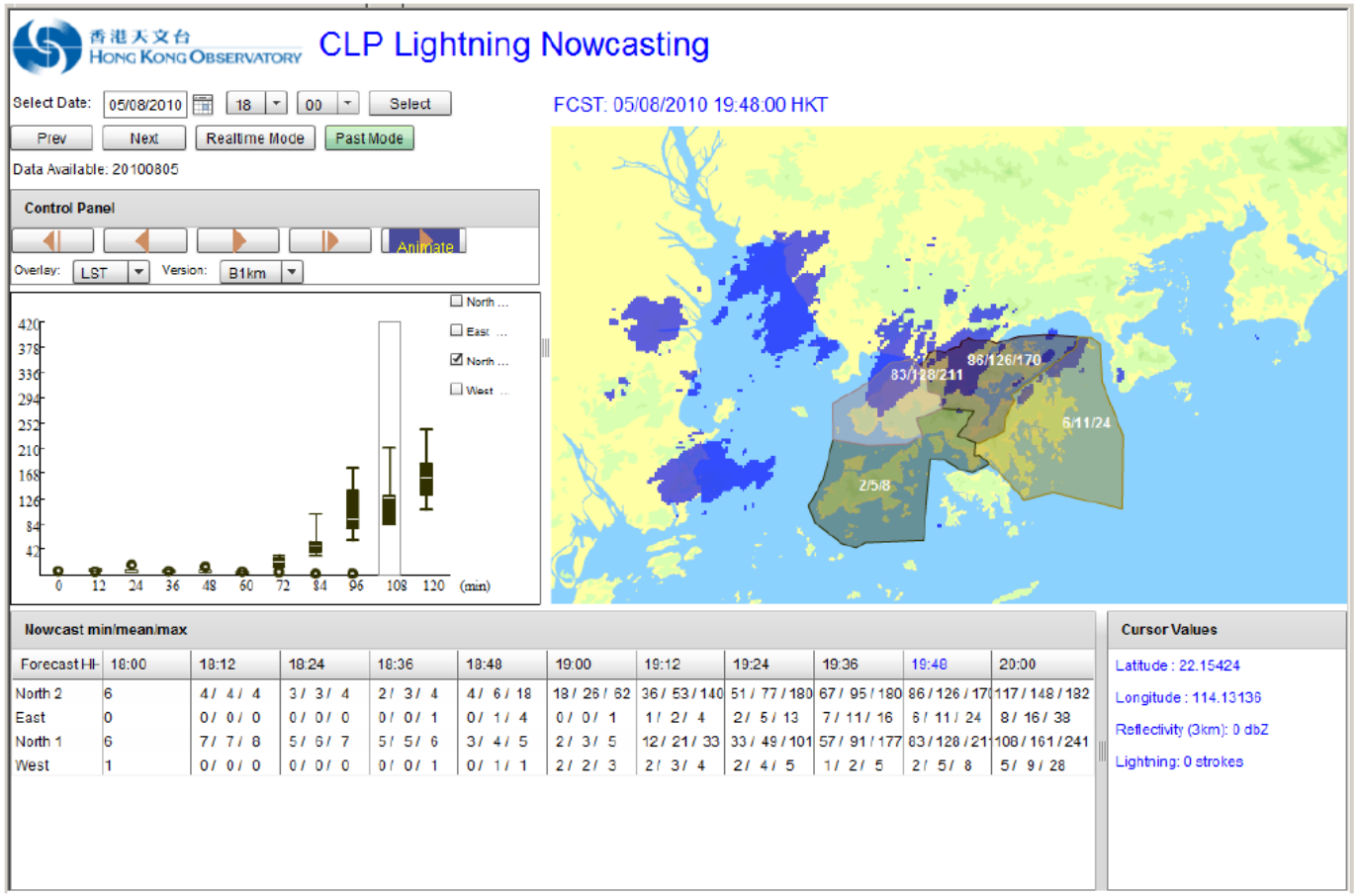
CLP Lightning Nowcasting System



Forecast Hr	18:00	18:12	18:24	18:36	18:48	19:00	19:12	19:24	19:36	19:48	20:00
North 2	6	4 / 4 / 4	3 / 3 / 4	2 / 3 / 4	4 / 6 / 18	18 / 26 / 62	36 / 53 / 140	51 / 77 / 180	67 / 95 / 180	86 / 126 / 170	117 / 148 / 182
East	0	0 / 0 / 0	0 / 0 / 0	0 / 0 / 1	0 / 1 / 4	0 / 0 / 1	1 / 2 / 4	2 / 5 / 13	7 / 11 / 16	6 / 11 / 24	8 / 16 / 38
North 1	6	7 / 7 / 8	5 / 6 / 7	5 / 5 / 6	3 / 4 / 5	2 / 3 / 5	12 / 21 / 33	33 / 49 / 101	57 / 91 / 177	63 / 128 / 211	108 / 161 / 241
West	1	0 / 0 / 0	0 / 0 / 0	0 / 0 / 1	0 / 1 / 1	2 / 2 / 3	2 / 3 / 4	2 / 4 / 5	1 / 2 / 5	2 / 5 / 8	5 / 9 / 28

- No trend (realtime)
  - http://192.168.13.74/clpn1/clp_nomap.swf
- Linear trend (case)
  - http://192.168.13.75/clpn_trend/clp_nomap.swf
- Nonlinear trend (case)
  - http://192.168.13.74/clpn2/clp_nomap.swf

- 2-h forecast updated every 6 min
- 48 ensemble members : 16(multi-scale TREC winds) x 3(no/linear/non-linear intensity change based on lightning intensity)

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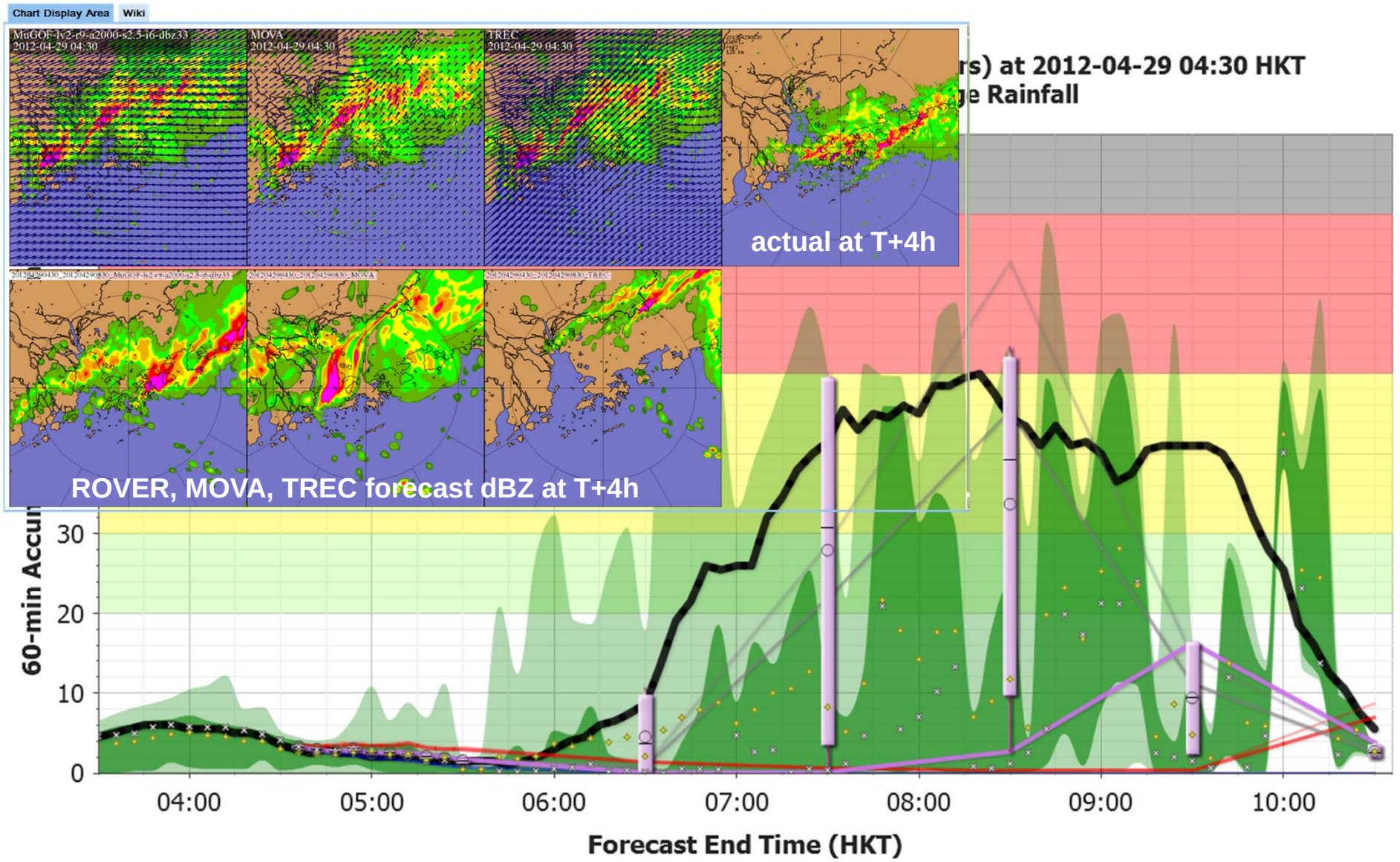
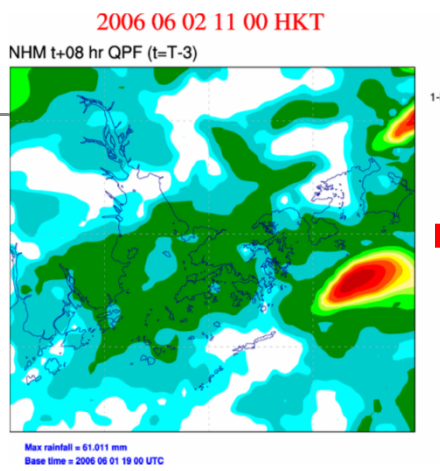
Ensemble Approach to Nowcasting

- To assess how close or how far the forecast is deviated from the actual rainstorm status (i.e. forecast uncertainty)
- To predict rainfall distribution and hence occurrence of rainstorms in the form of probability distribution
  - instead of deterministic “yes/no” signal
- Method: conduct multiple runs of the nowcasting system each to start with slightly different initial conditions and forecast configurations
  - for motion: by perturbing parameters of the radar-echo tracking algorithm
  - for intensity: from past rainstorm statistics

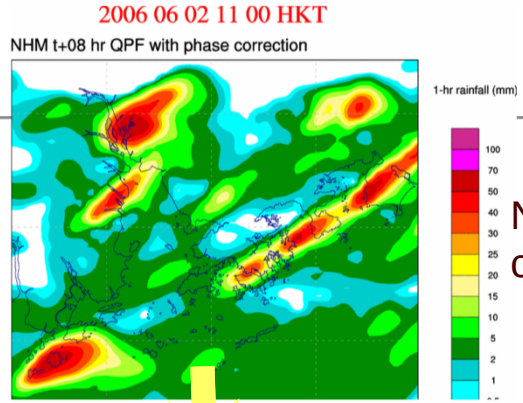
Case: Red Rainstorm on 29 April 2012



Nowcasting + NWP

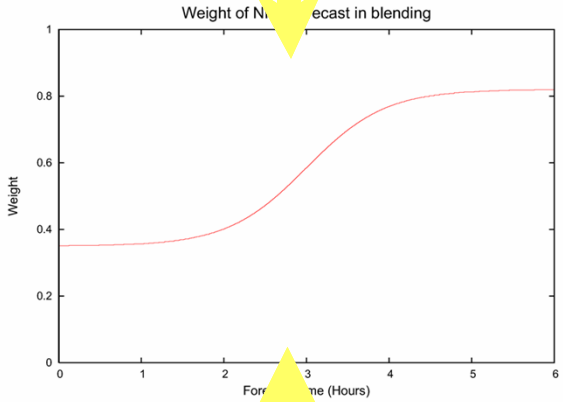


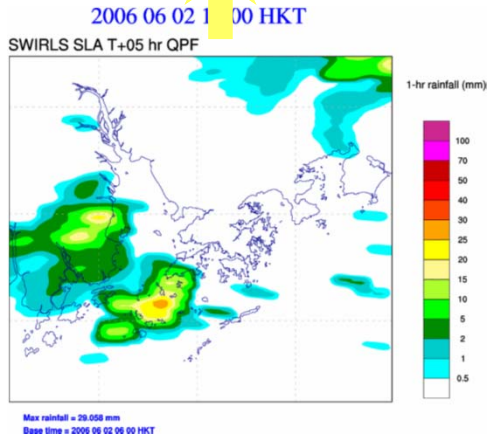
NHM QPF



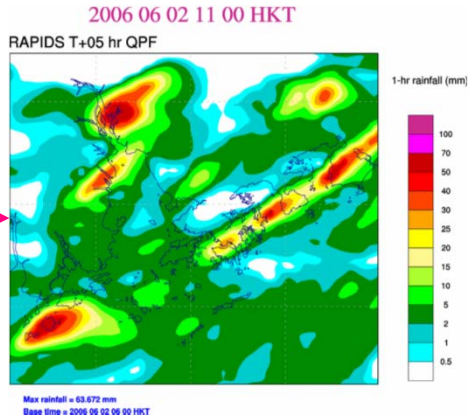
Very-short range forecast

NHM QPF with phase correction





SWIRLS Nowcast



RAPIDS (Rainstorm Analysis and Prediction Integrated Data-processing System) QPF

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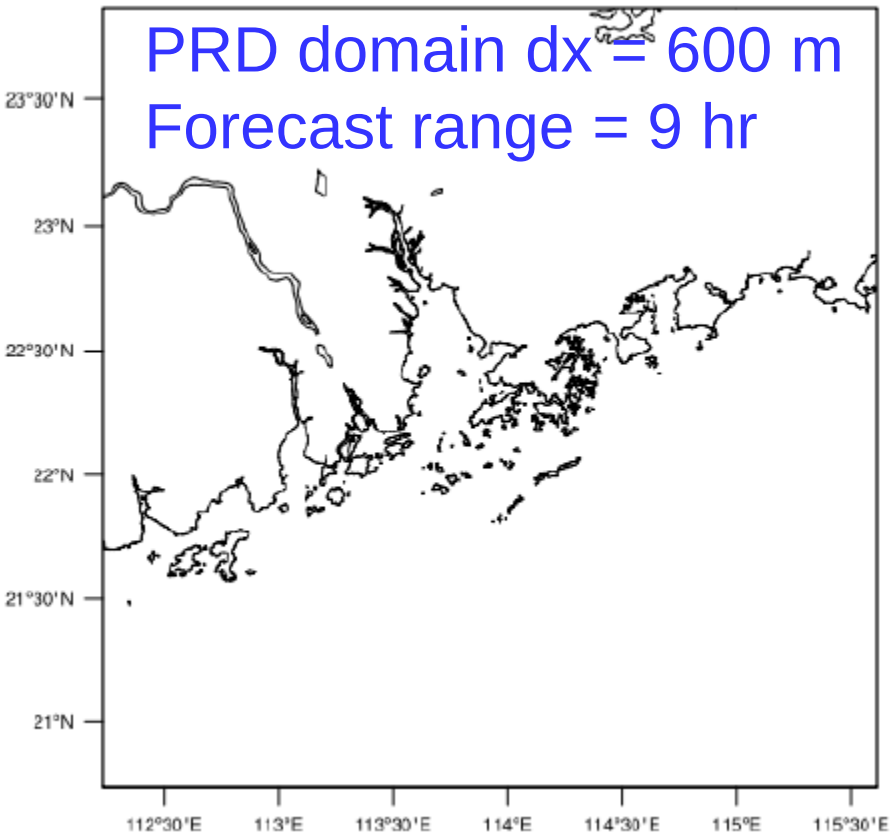
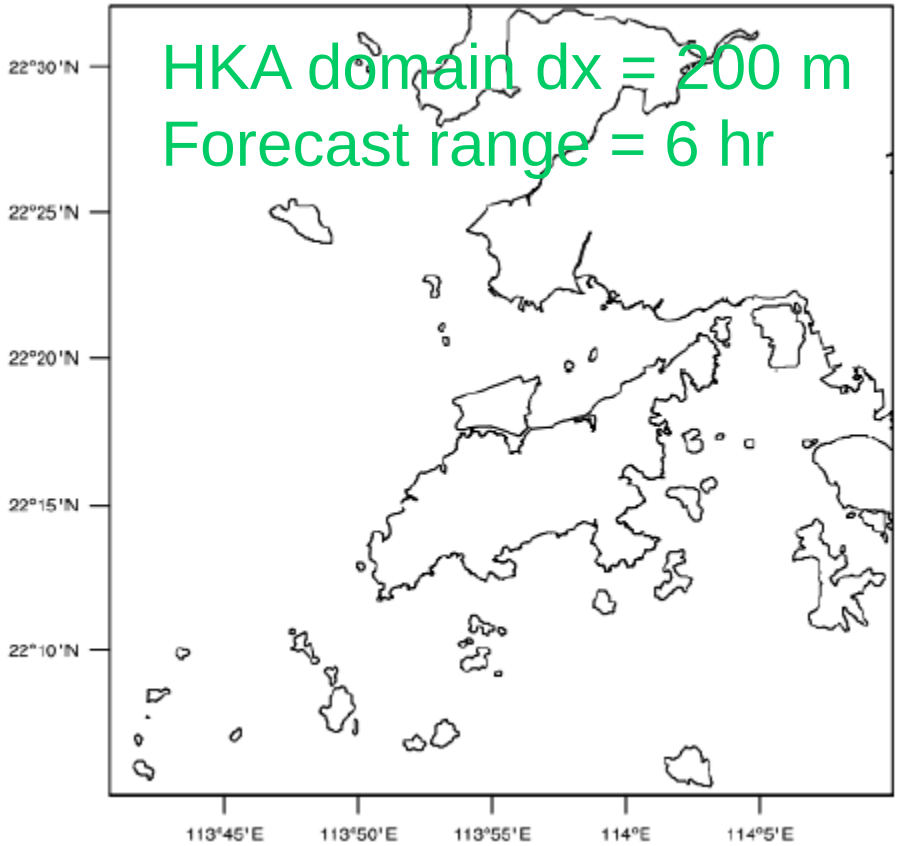
Aviation Model (AVM)





- Update frequency = 1 hr
- Initial and boundary conditions: NHM

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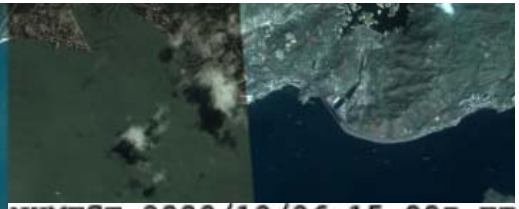
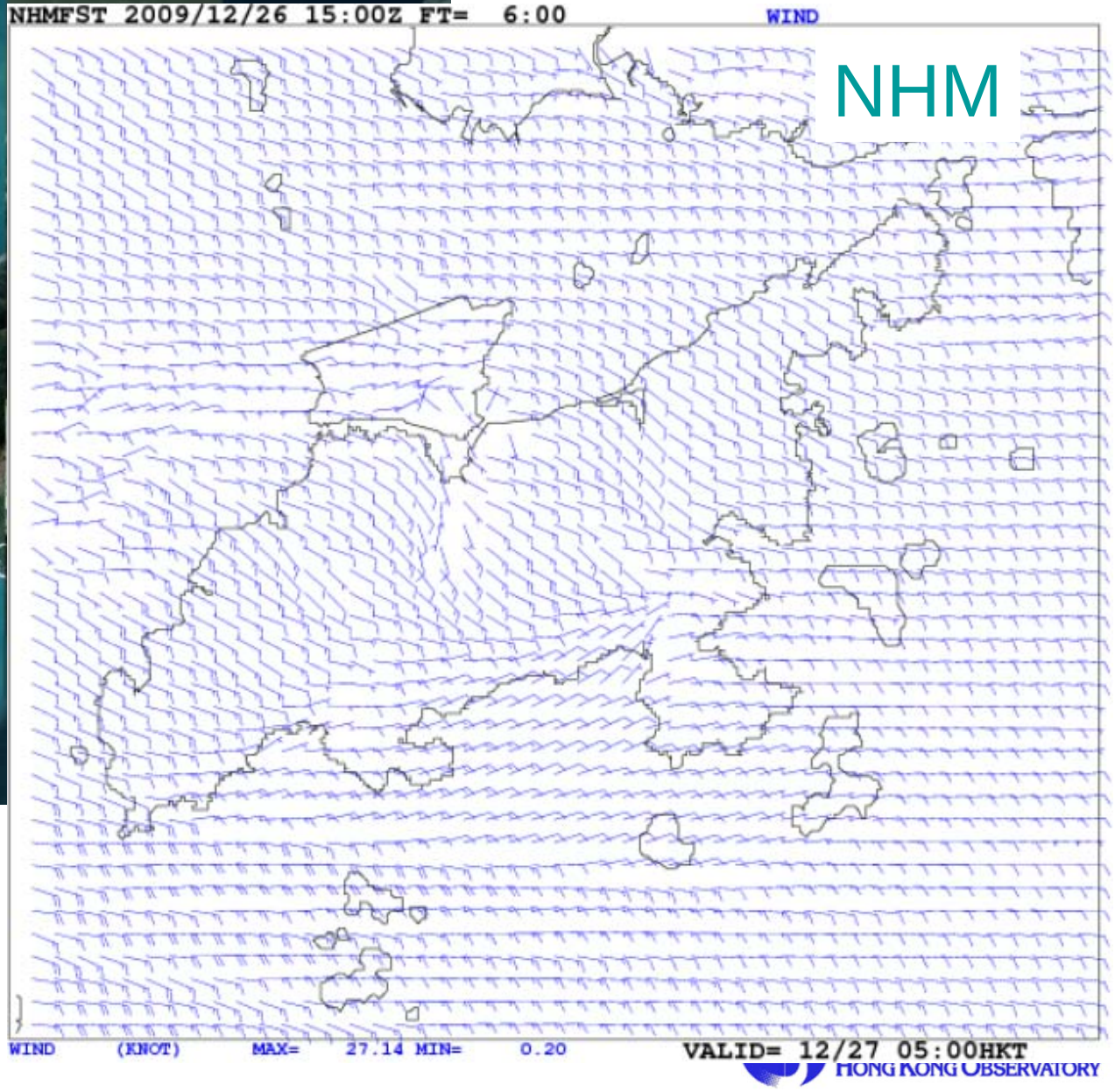
Dec 27, 2009 5:02 am
SSC
R2E
R2C
R2W
CLK
R1E
S1E
R1C
R1W
A1E
SLW
CT3
SSW
CT4
TOI
NLS
NGP
TFA
PKA




NHMFST 2009/12/26 15:00Z FT= 6:00
WIND
NHM
WIND (KNOT) MAX= 27.14 MIN= 0.20
VALID= 12/27 05:00HKT
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Targets of AVM

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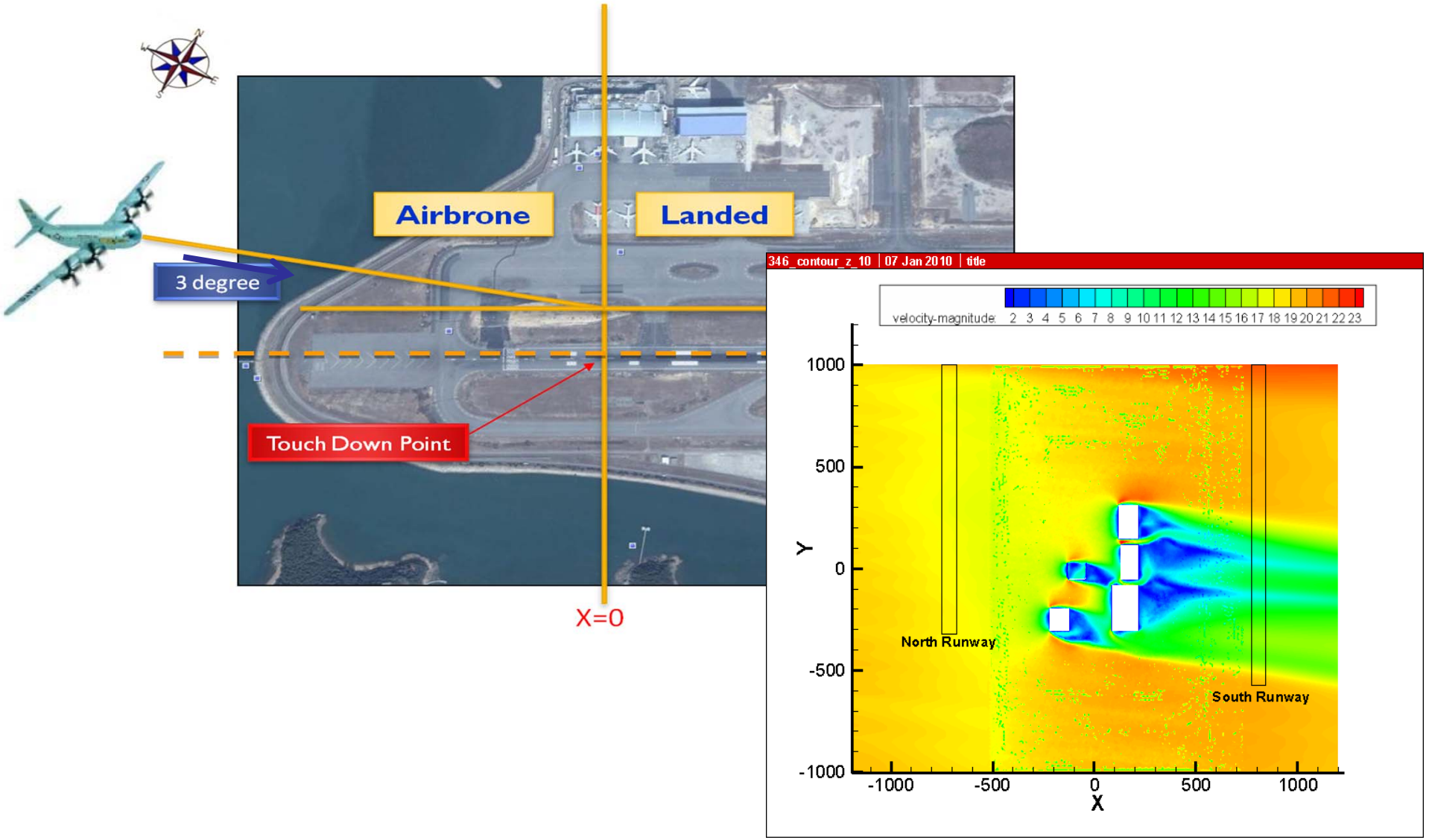
Computational Fluid Dynamics (CFD) modeling to evaluate building effect on low-level winds



Climate Forecast

- Climate prediction
  - Seasonal
  - Monthly

- Projections of future climate
  - Temperature
  - Rainfall
  - Sea level

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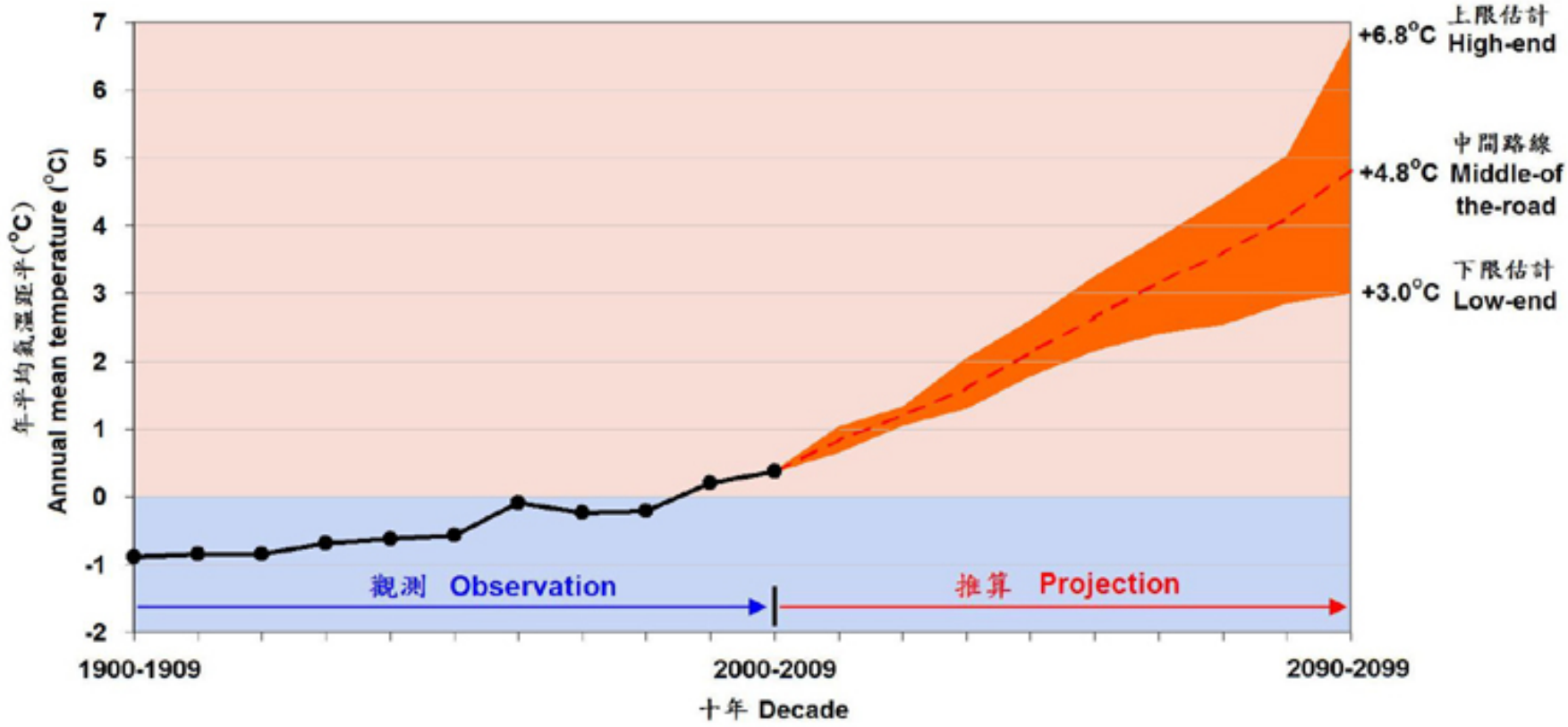
Past and projected annual mean temperature anomaly for Hong Kong (based on IPCC AR4 annual mean projection data)



Note *: there are uncertainties in the model simulation for the future climate, depending on the future forcing emission scenarios, local urbanization effect , the model characteristics/performance, etc.*

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Past and projections of rainfall Hong Kong

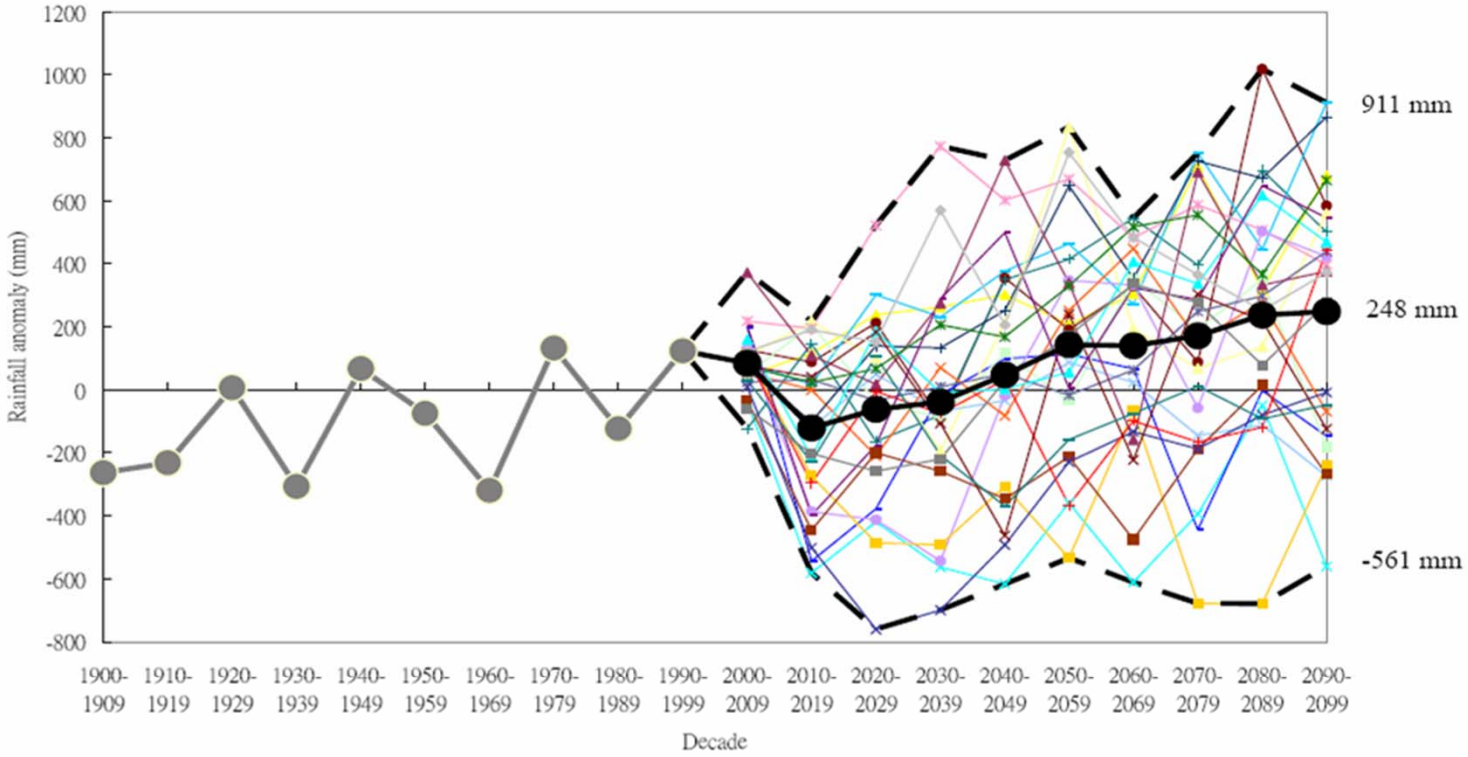

Figure 5. Projected changes in mean annual rainfall in Hong Kong based on different models for all three scenarios (i.e. A1B, A2 and B1). The rainfall change is with reference to the 1980-99 average of 2324 mm. The dark line joining the black dots denotes the average of the multi-model ensemble mean of the three emission scenarios (see Figure 4). For the decade 2000-2009, actual observations for 2000-2007 and projected values for 2008-2009 are used.

Note *: there are uncertainties in the model simulation for the future climate, depending on the future forcing emission scenarios, local urbanization effect , the model characteristics/performance, etc.*

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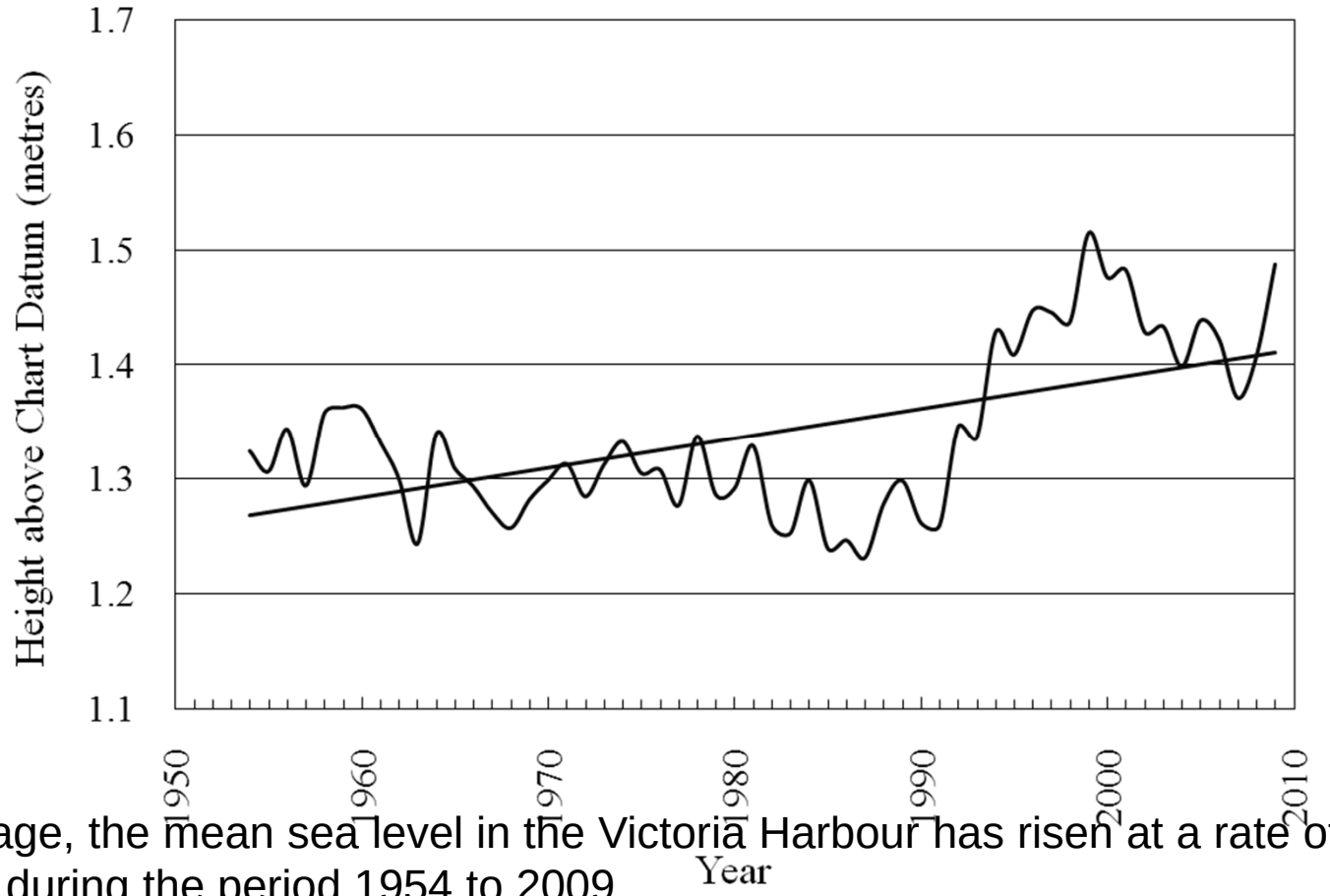
Sea level in Hong Kong



On average, the mean sea level in the Victoria Harbour has risen at a rate of 2.6 mm per year during the period 1954 to 2009.

In the long run, likely to be close to the global average, rising by 0.18 to 0.59 m at the end of 21st century relative to 1980-1999 according to IPCC AR4.

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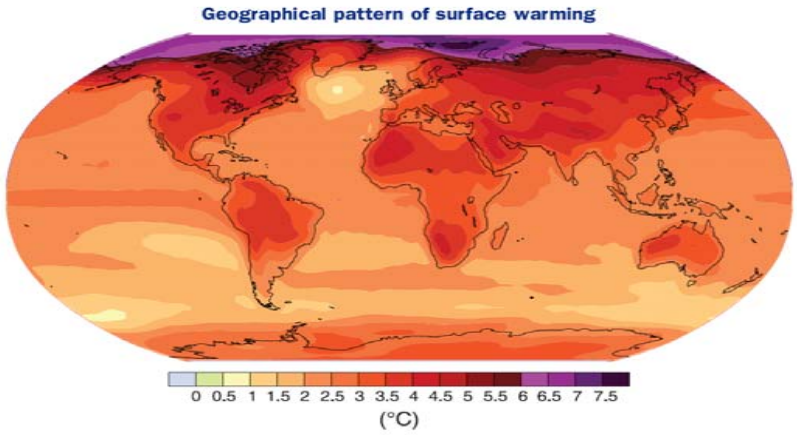
Global climate projections

Global Climate Models /
General Circulation Models (GCMs)

Human factors
(Greenhouse gas, aerosols,
and land surface changes, etc.)

Future climate



Intergovernmental Panel on Climate Change (IPCC)

- multi climate model experiment – 23 models used in IPCC Fourth Assessment Report (AR4) in 2007
- different greenhouse gas emission scenarios

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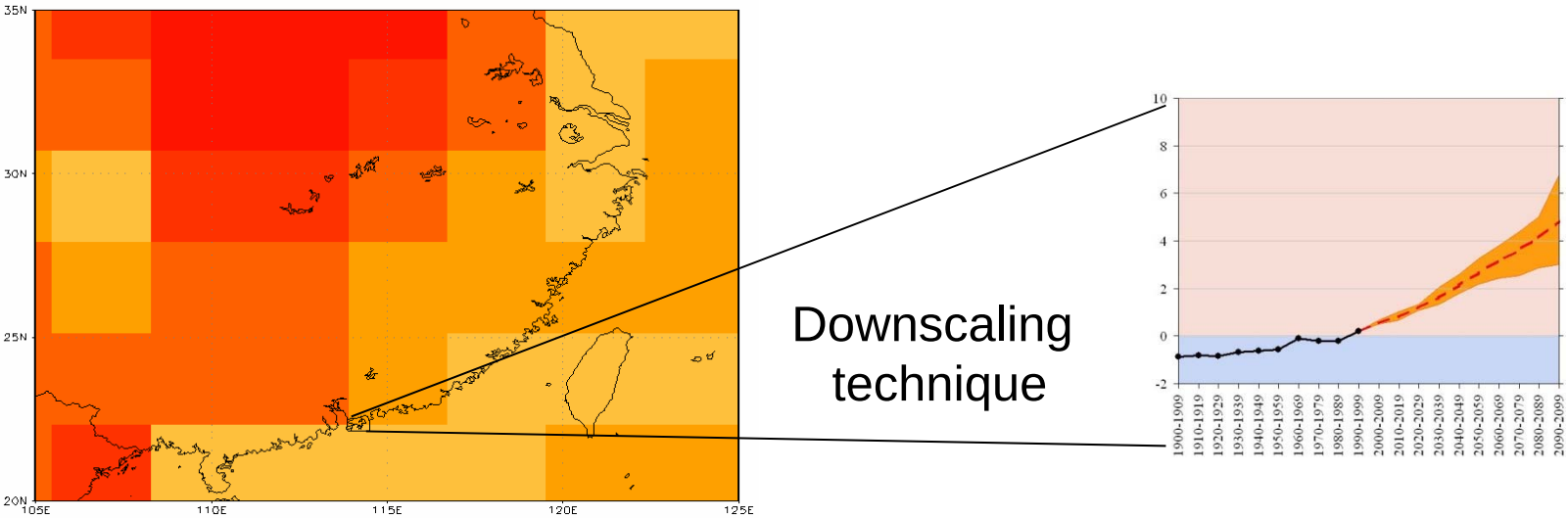
Statistical / Dynamical Downscaling of GCM



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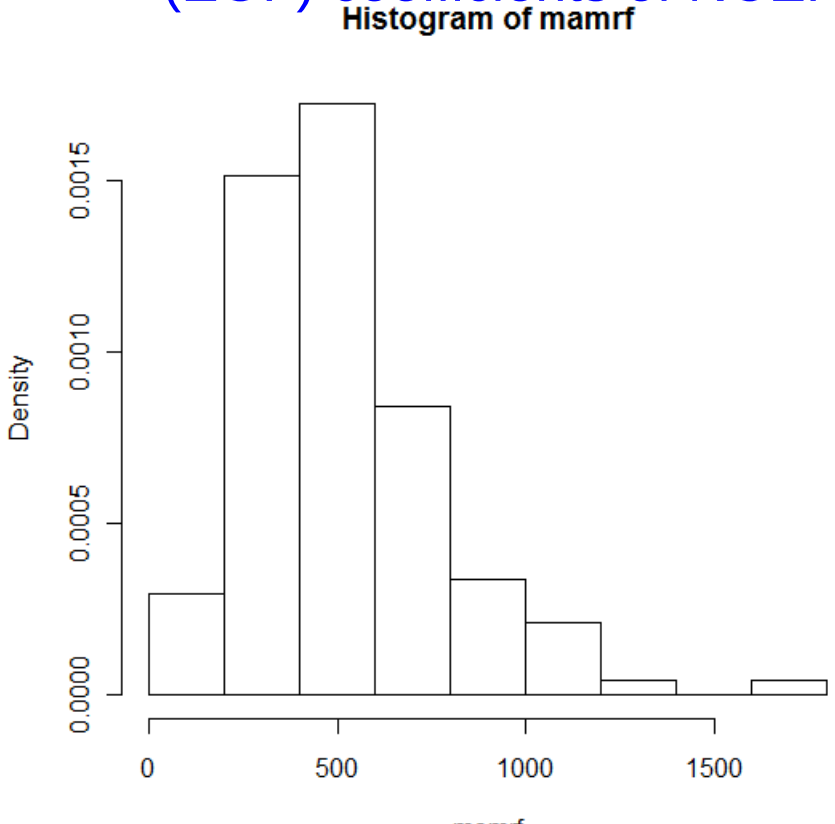
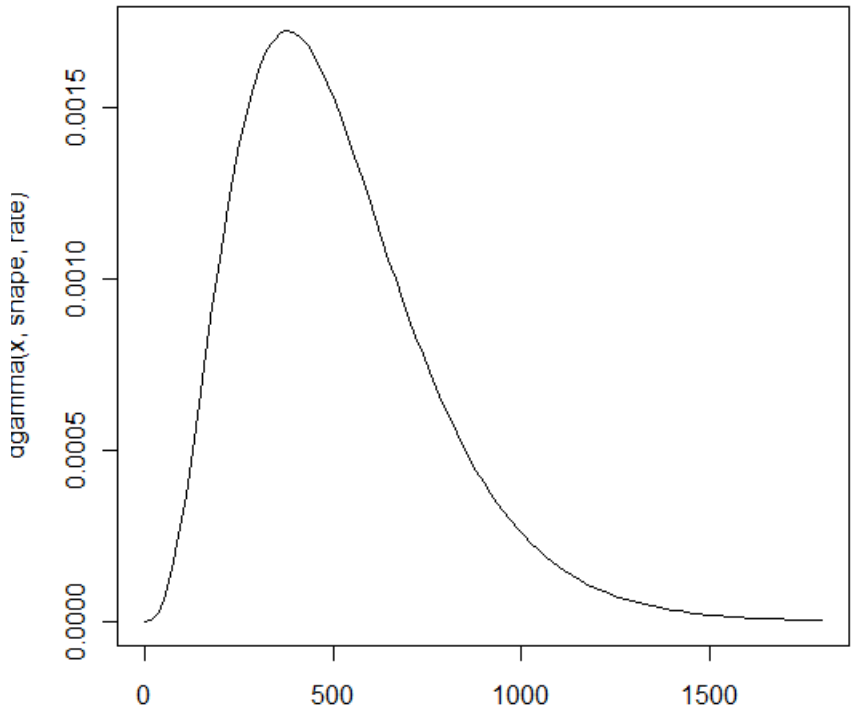
Statistical Downscaling

Annual rainfall forecast

Gamma Regression Model using Empirical Orthogonal Function (EOF) coefficients of NCEP Climate Forecast System data



HKO Mar-May rainfall (1884-2009)



Gamma Regression Model (parameters estimated from HKO data)

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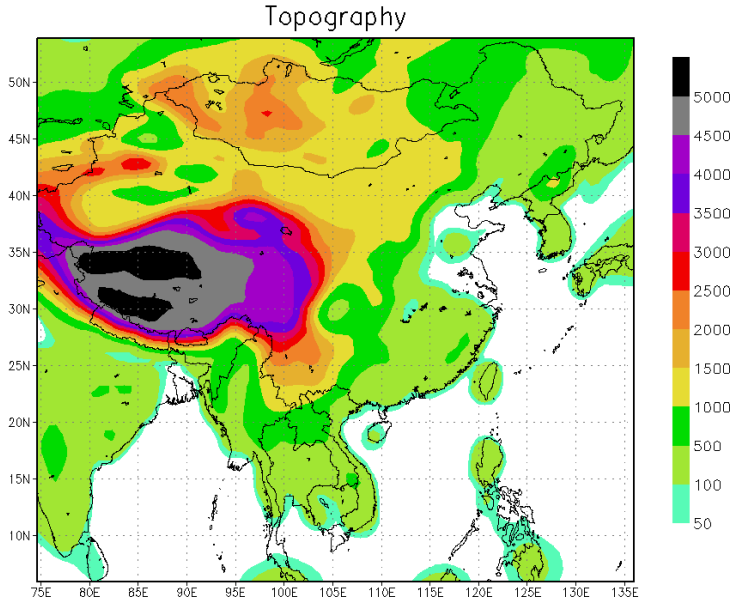
Dynamical Downscaling

HKO Global-Regional Climate Model

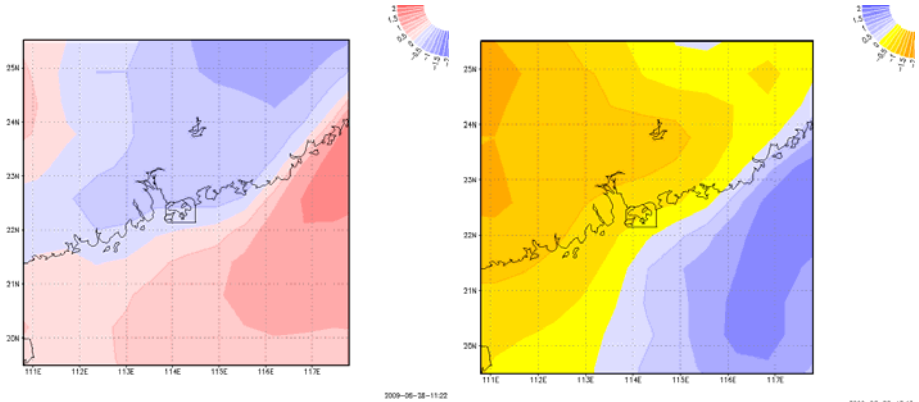
- Adapted from Experimental Climate Prediction Centre (ECPC) in 2006
- Global model – T62(~200 km), 28 levels
- Regional model – 60 km, 28 levels



Initial condition : NCEP/NCAR re-analysis or NCEP GFS output

Boundary condition : NCEP SST forecast

Regional climate model forecast charts



Temperature anomaly forecast

Red: +ve anomaly (above normal temperature)
Blue: -ve anomaly (below normal temperature)

Rainfall anomaly forecast

Blue: +ve anomaly (above normal rainfall)
Orange: -ve anomaly (below normal rainfall)

Unit expressed in standard deviation
±0.5 being classified as near normal

Temperature and rainfall anomalies (every 3 months)

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High Performance Computers in HKO

CRAY SV1

16 CPU

8GB RAM

19.2 GFLOPS

IBM SP

44 CPU

25 GB RAM

66 GFLOPS

IBM Regatta

32 CPU

48 GB RAM

140.8 GFLOPS

Galactic SuperBlade

60 CPU

60 GB RAM

432 GFLOPS

NICE

186 CPU

2,120 GB RAM

7,700 GFLOPS

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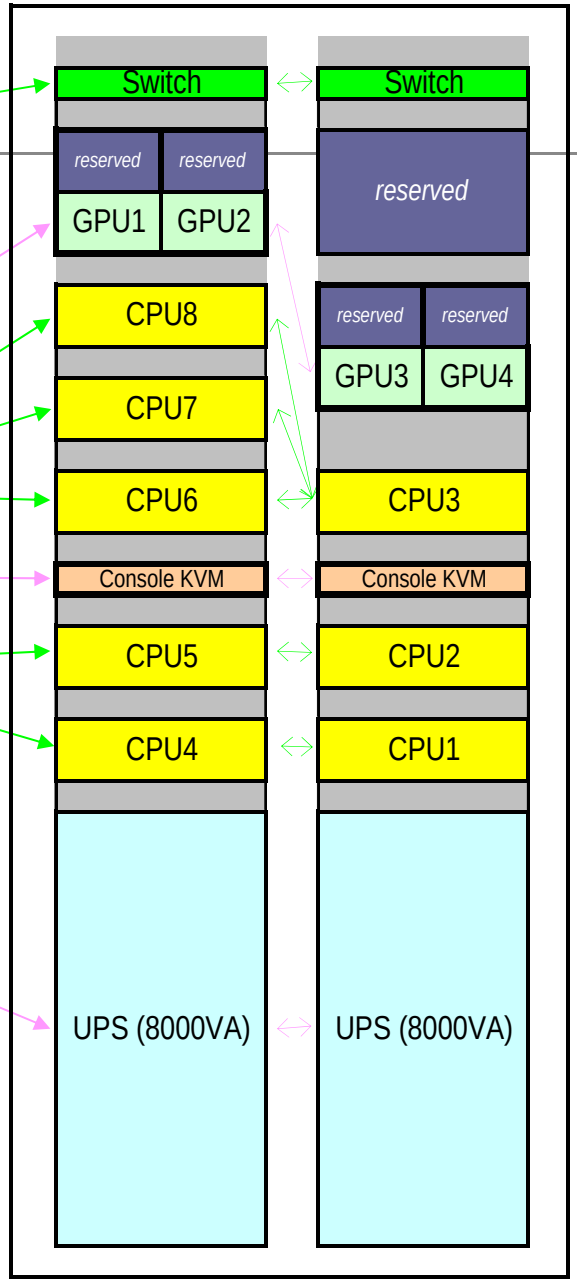
Operational Nowcast Server for HKO Nowcasting System

Physical locaton: L/G F, HKOHQs



Legend

CPU servers
1 for SWIRLS-2, 1 for co-Kriging, 1 for I/O, 1 for f/c verification, 4 for ensemble trial

~ 1.3 Tera-FLPOS

CPU+GPU servers
2 for ensemble R&D, 2 for QPE/QPF R&D

~ 6.8 Tera-FLPOS

GB Ethernet Switch to intranet

Console keyboard-video-mouse kit

Uninterruptible Power Supply

space reserved for future expansion

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Thank You

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