Typhoon simulation with the 20 km mesh global spectral model on the Earth Simulator

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And Kyosei 4 Group

Kyousei 4 Research Project

- Numerical experiments on the Earth Simulator

20 km global model	1-5 km cloud resolving model
Effects of global warming on typhoons and hurricanes by time slice experiments	Effects of global warming on heavy rainfall and heavy snowfall by time slice experiments

Contribution to the IPCC-AR4, and
government policies on the global environment

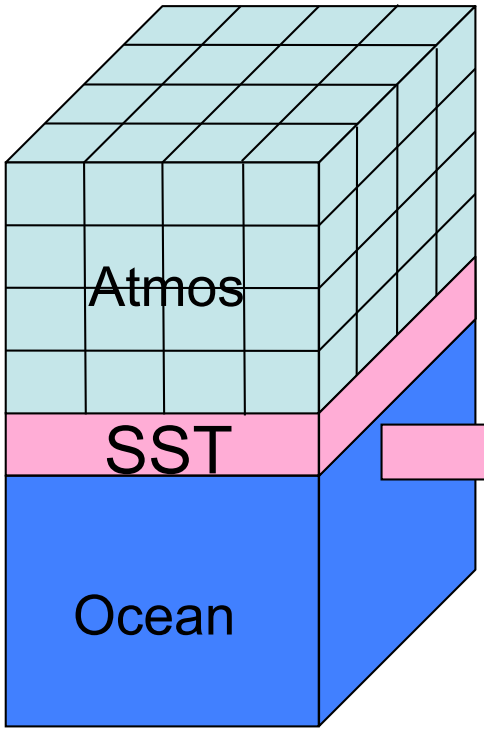
The Time Slice Experiment

Global warming experiment by CGCM

Time slice experiment by the 20 km mesh high Resolution AGCM

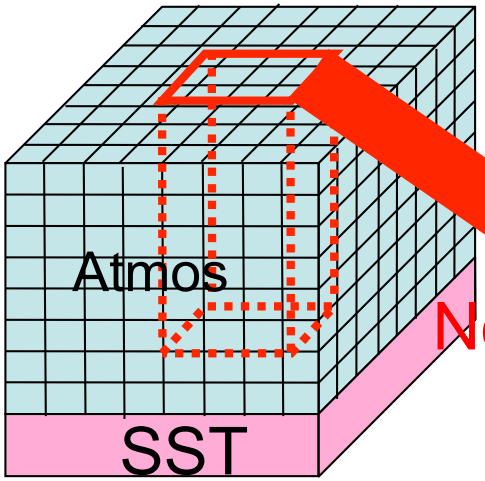
Time slice experiment by 5km high resolution regional model

270km mesh AGCM

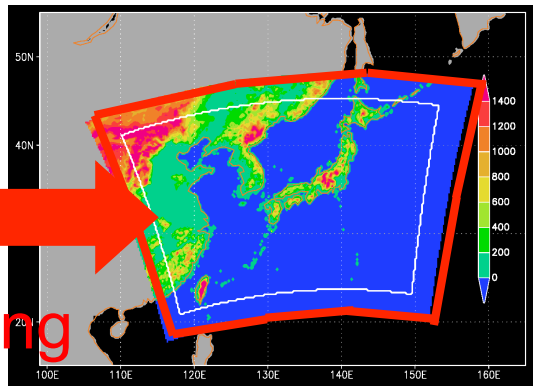


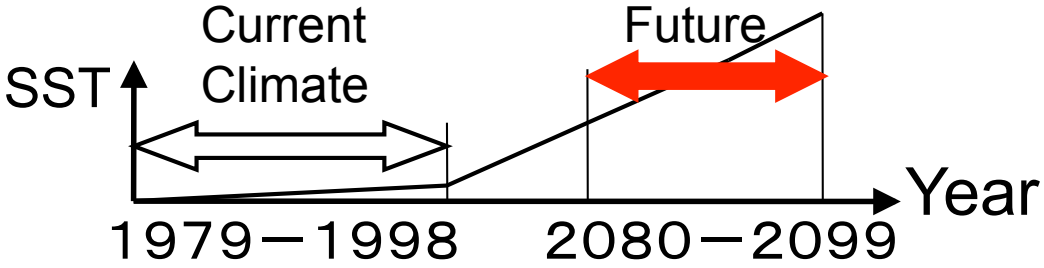
200−50km mesh global Ocean model

Simulated SST

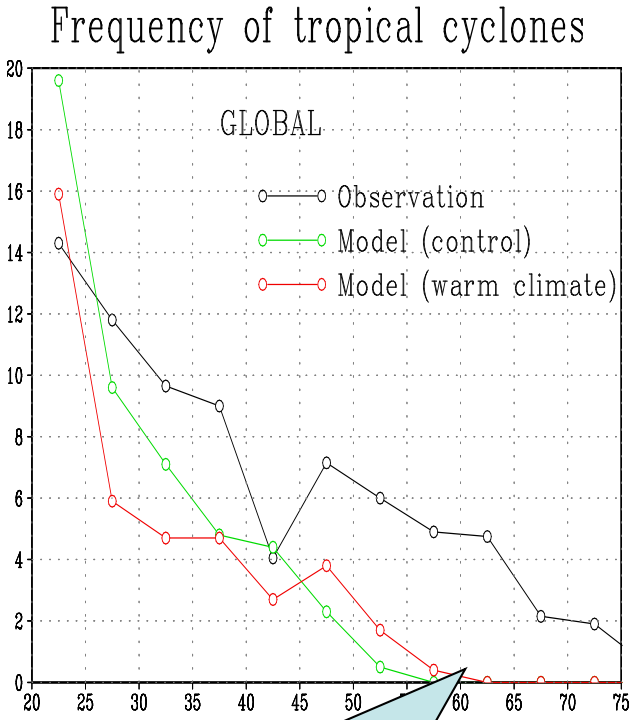


Nesting

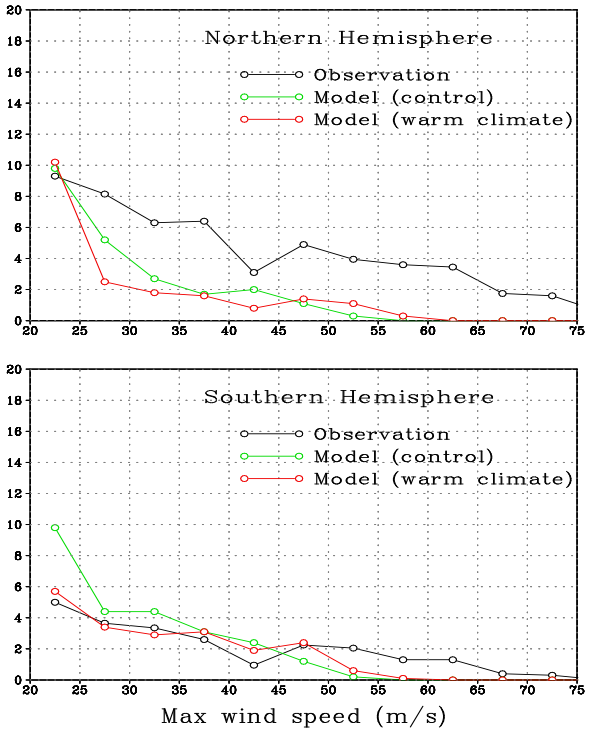




Tropical Cyclones in Warm Climate



counted when its intensity is maximum.
/fwindm20.gsp 2004-08 Jun Yoshimura



Frequency: Each TC is
clpc134: ~/UU/TL959/tc2/

In the case of warmer climate
TC's number will be decreased.
Stronger TCs will be generated.

Dr. Yoshimura will show this later

Purpose and Motivation

Are those time slice experiments reliable?

Are typhoons predictable with the model?

↓

Lets verify its typhoons predictability with short range forecasts.

Bottom Line

Our 20km mesh AGCM can simulate

Typhoon Position

Typhoon Strength

Heavy Rainfall

more realistically than JMA operational 60km mesh GSM.

A Problem in short range forecasts

- Initialization (NNMI) becomes impractical when horizontal resolution is increased.

	Vertical Mode(KByte)		Holizontal Mode(MByte)	
	Eigen Value	Eigen Vector	Eigen Value	Eigen Vector
T106L40	0.31	25.00	0.44	31.60
T213L40	0.31	25.00	1.76	251.00
TL319L40	0.31	25.00	3.92	837.27
TL511L60	0.47	56.25	10.02	3423.38
TL959L60	0.47	56.25	35.19	22535.25

22Gbyte!!

- Introduction of New Initialization Scheme

Vertical mode Initialization（Bourke and McGregor 1983）

Horizontal Mode Separation is not required→ computational efficiency

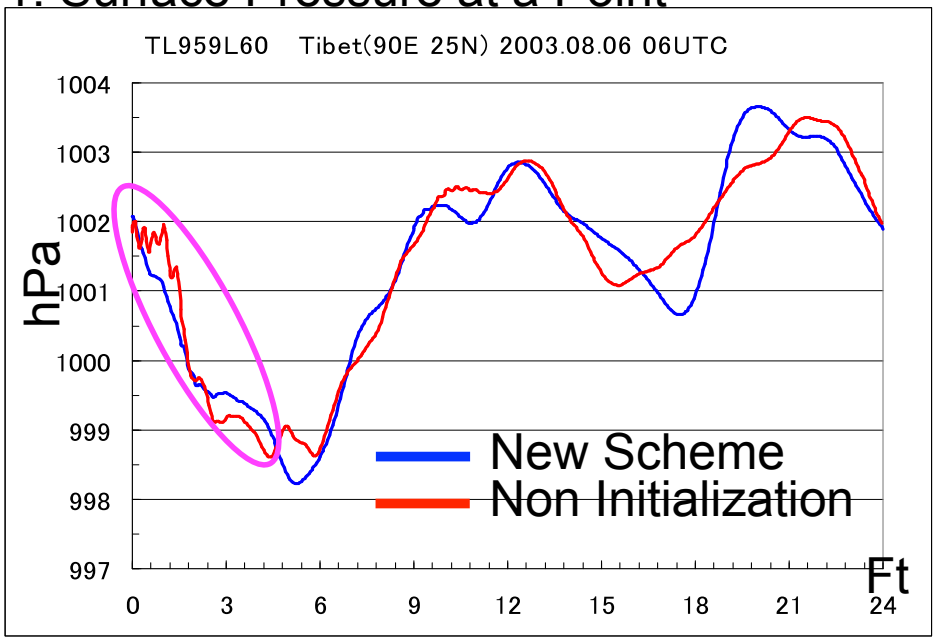
Incremental NMI（Ballish et al. 1992)

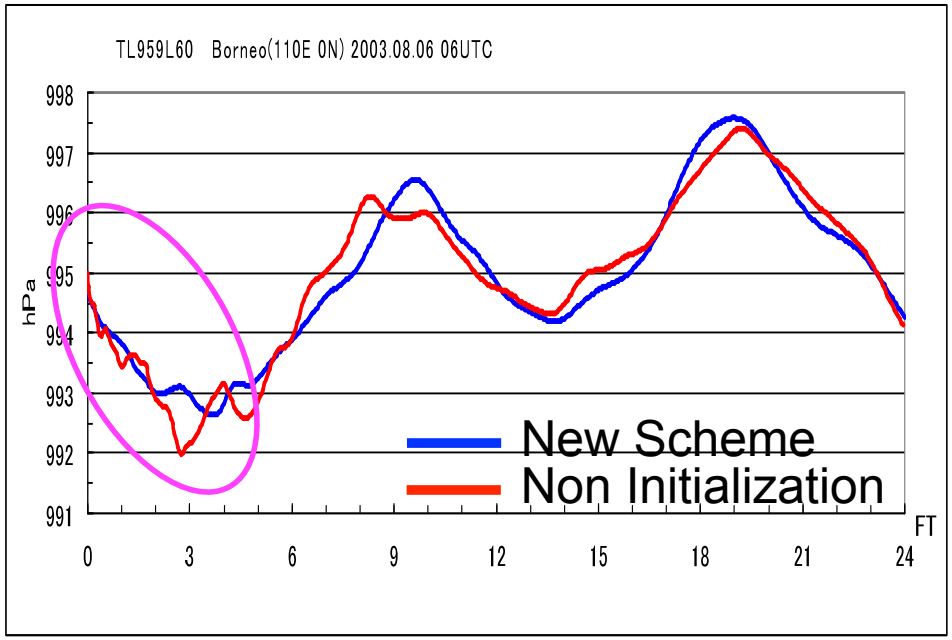
Support Vertical mode Initialization assumption

Refinement of tidal mode

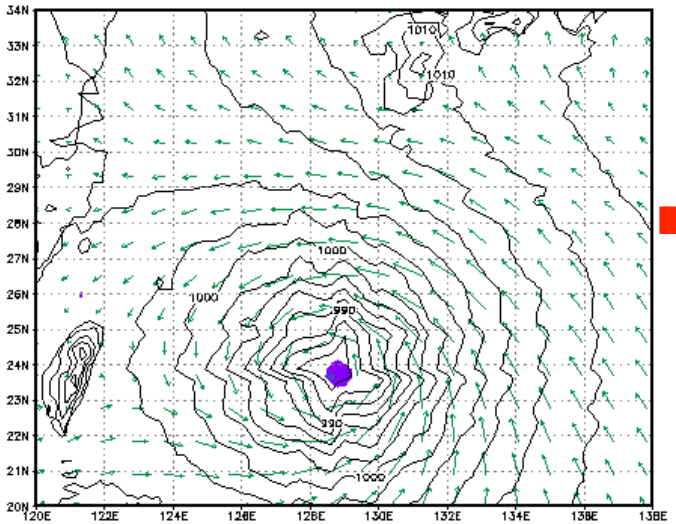
Results of the New Initialization

1. Surface Pressure at a Point

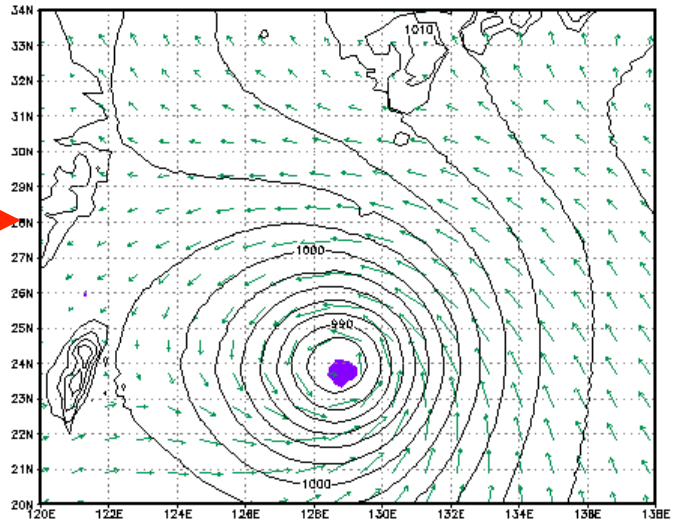




2. Two Dimensional Surface Pressure Distribution



Non Initialization



New Scheme

TL959L60

2003 08 06 06 UTC Initial

By the Earth Simulator

Short Range Typhoon Forecasts

- Model

  20 km mesh global climate model (TL959L60)

- Comparison

  Model: JMA operational global spectral model (GSM;T213L40,60km mesh)

  Truth: Regional Specialized Meteorological Center (RSMC) Best Track Data

- Target typhoons to be predicted

Typhoon	Integration term
DIANMU(T0406)	2004061312-2004062112 8days
MAEMI(T0314)	2003090600-2003091318 8days
ETAU(T0310)	2003080306-2003080906 6days
HALONG(T0207)	2002070800-2002071612 9days

- Initial data

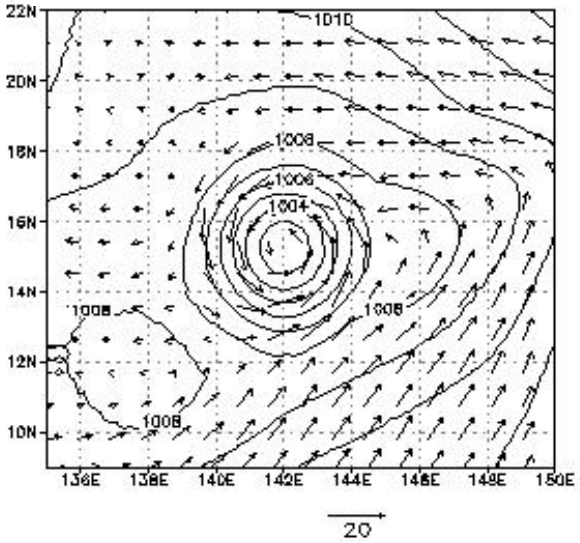
  ・JMA 60km mesh analysis was used by Interpolating into 20km mesh

  ・Forecast-Forecast Cycle by the new initialization scheme

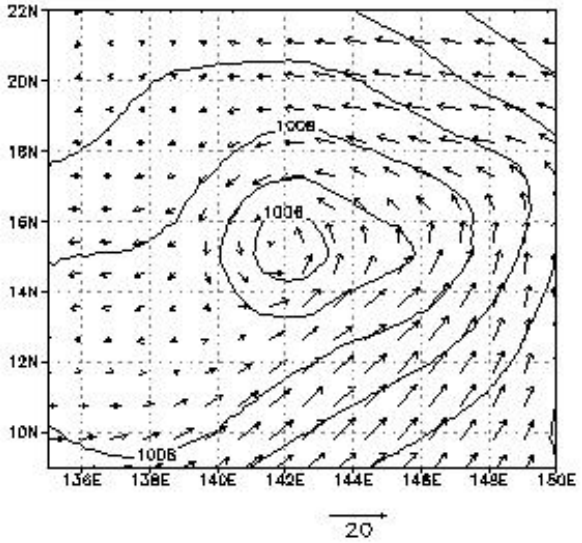
Typhoon Bogus

PSEA,WIND 200309060OUTC INIT FT=000

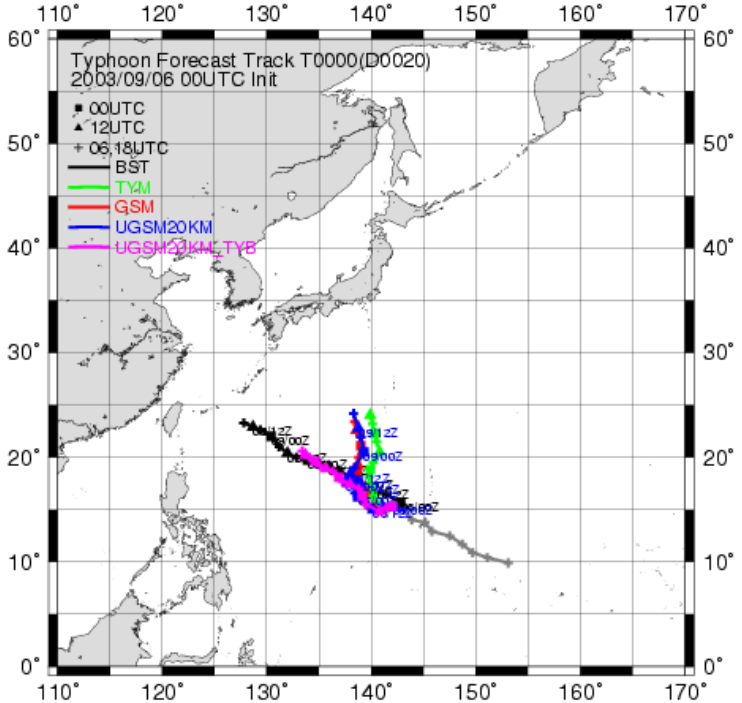
With Typhoon Bogus

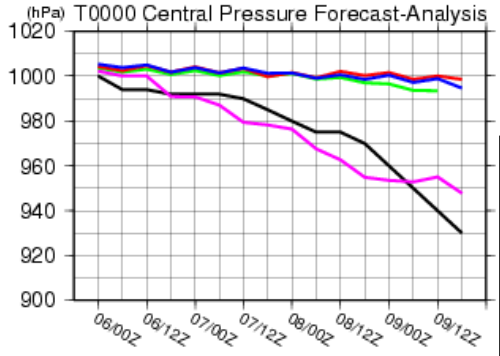


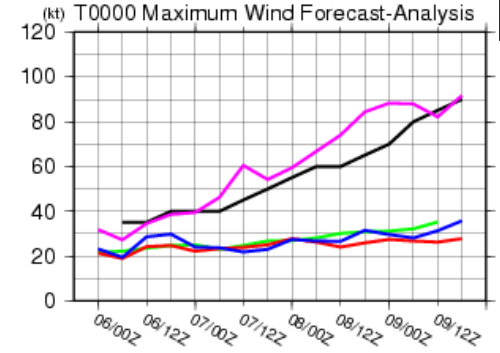
W/O Bogus



T0000(D0020) Typhoo





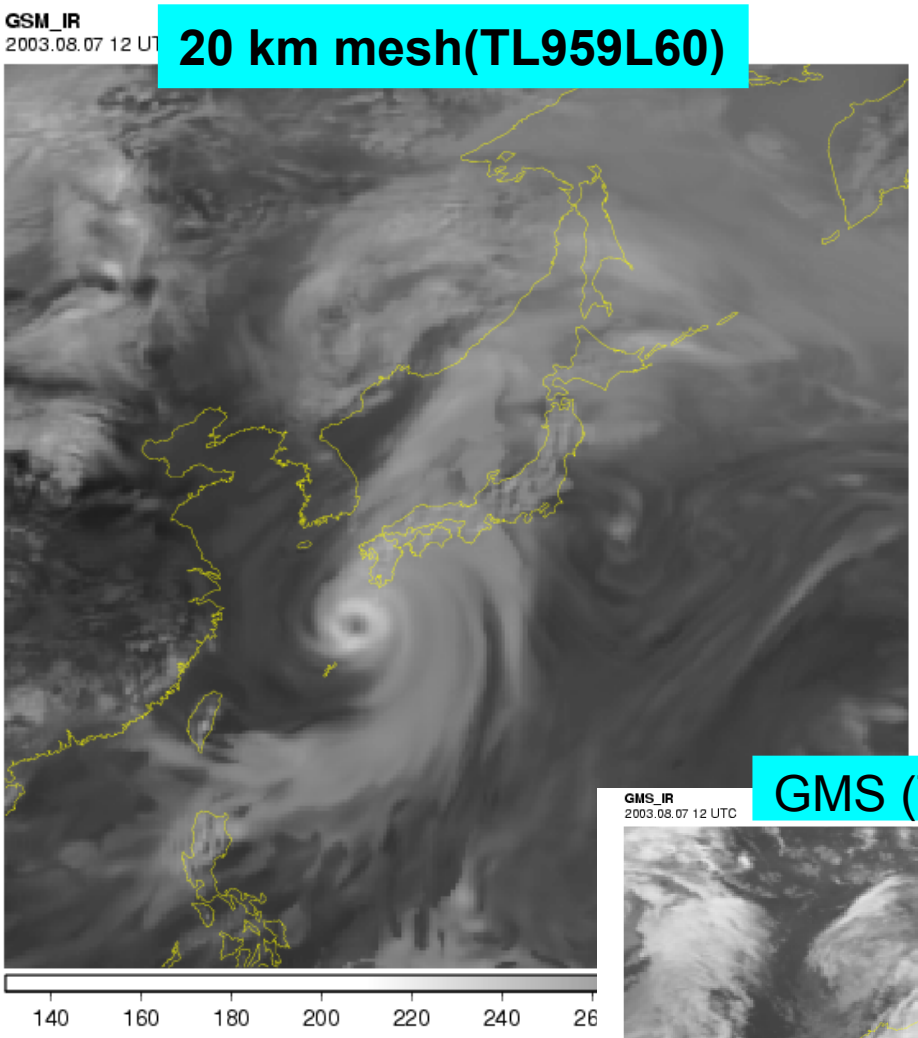


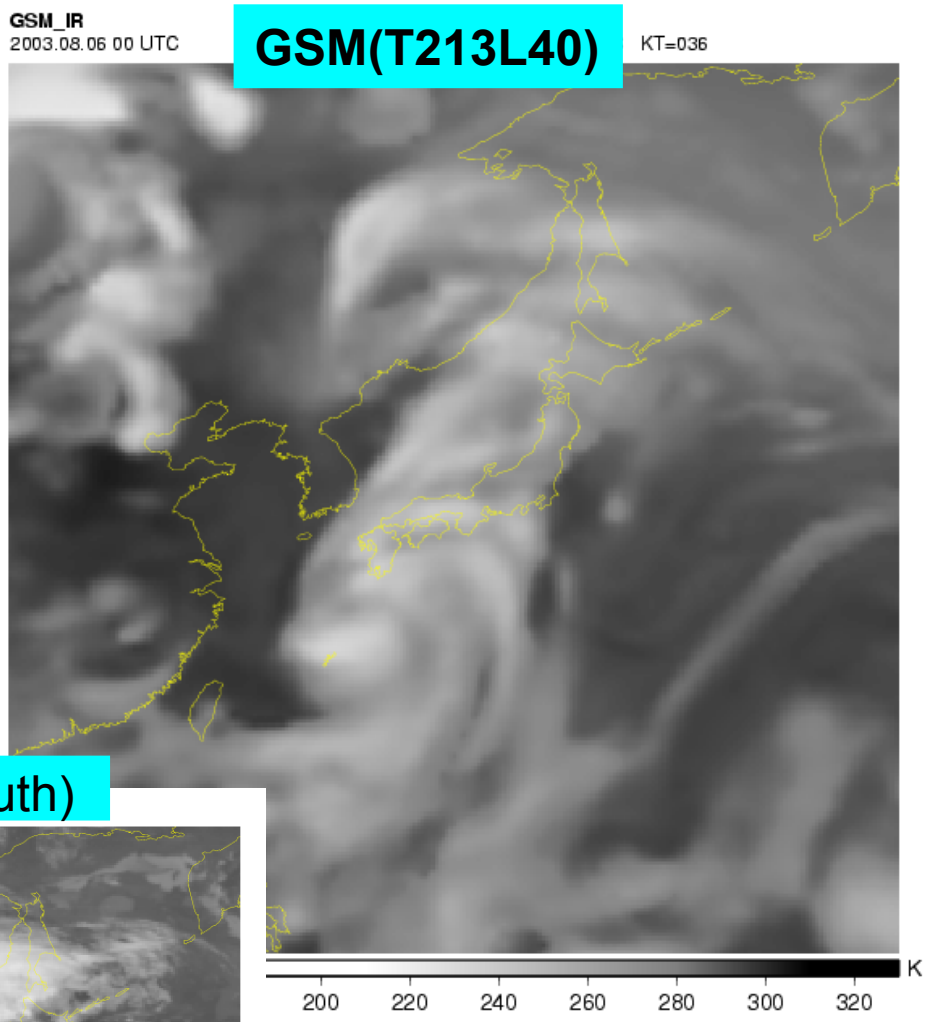
GSM(60km mesh)

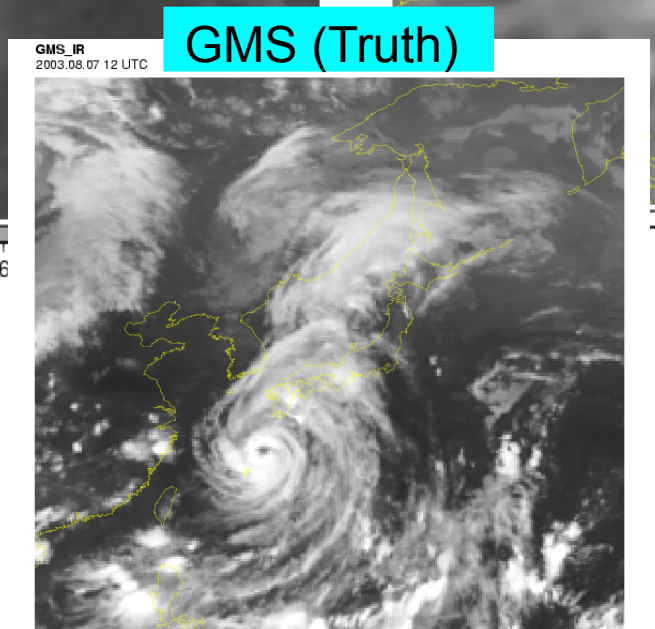
20km mesh (With Bogus)

20km mesh (W/O Bogus)

An Example of Typhoon Simulation







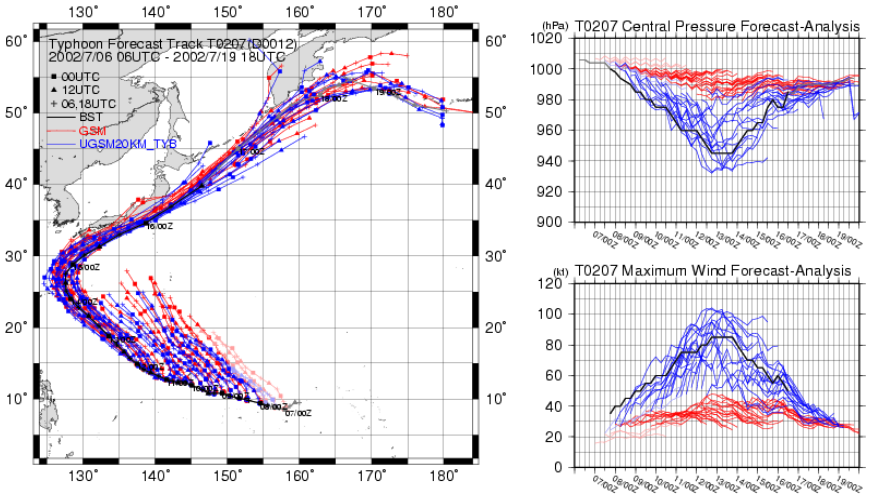
Infrared image

2003 08 07 12 Initial

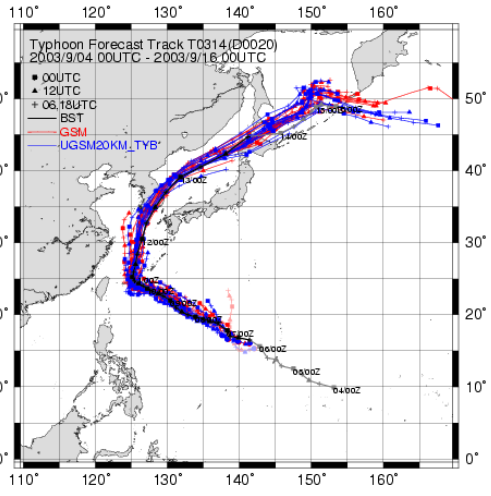
FT=36

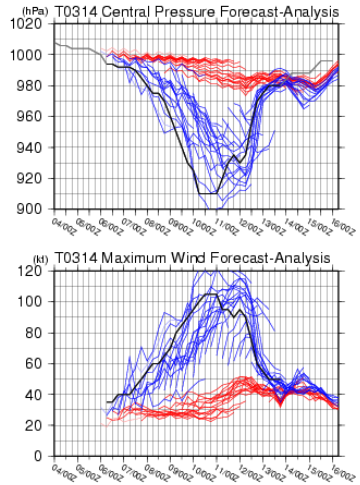
Typhoon Position and Strength

T0207(D0012) Typhoon Forecast and Analysis (Track and Intensity)

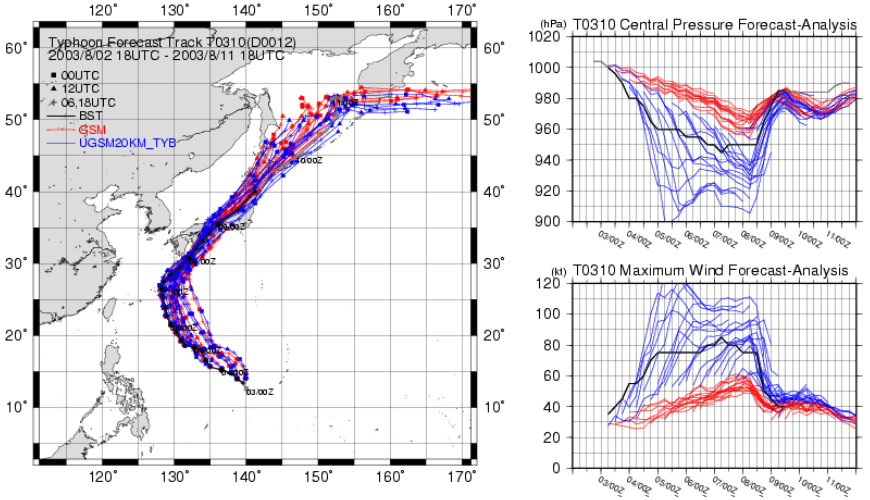


T0314(D0020) Typhoon Forecast and Analysis (Track and Intensity)

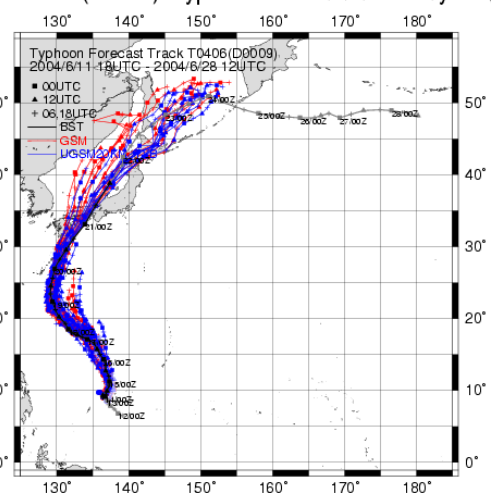


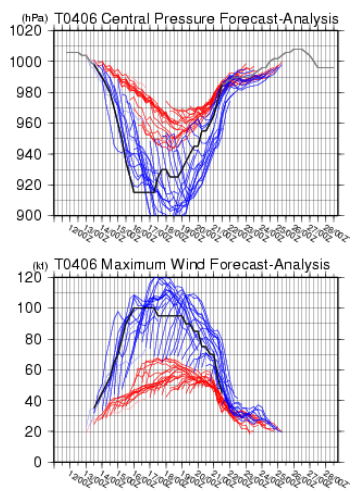


T0310(D0012) Typhoon Forecast and Analysis (Track and Intensity)



T0406(D0009) Typhoon Forecast and Analysis (Track and Intensity)

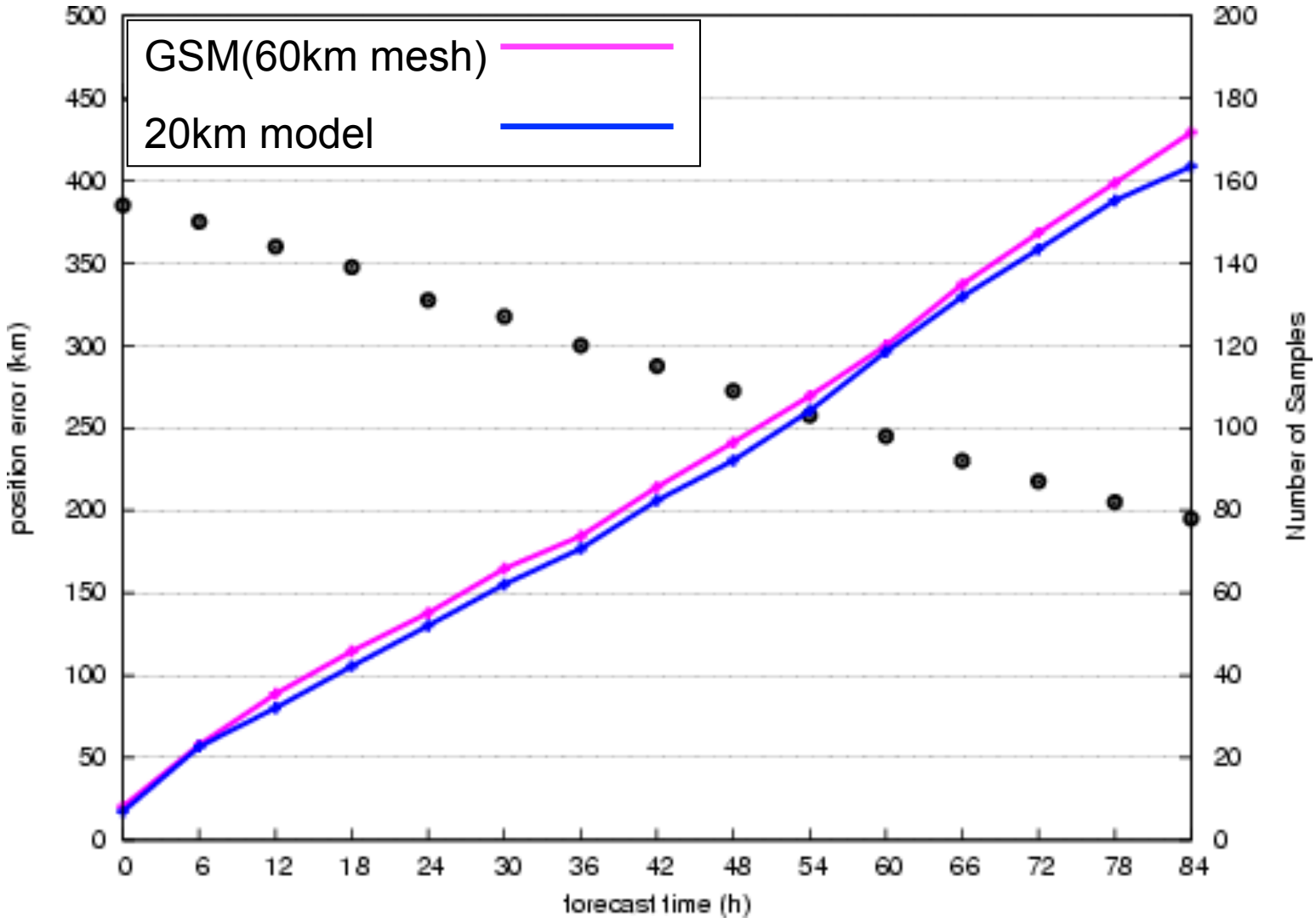




GSM(60km mesh)

20km mesh model

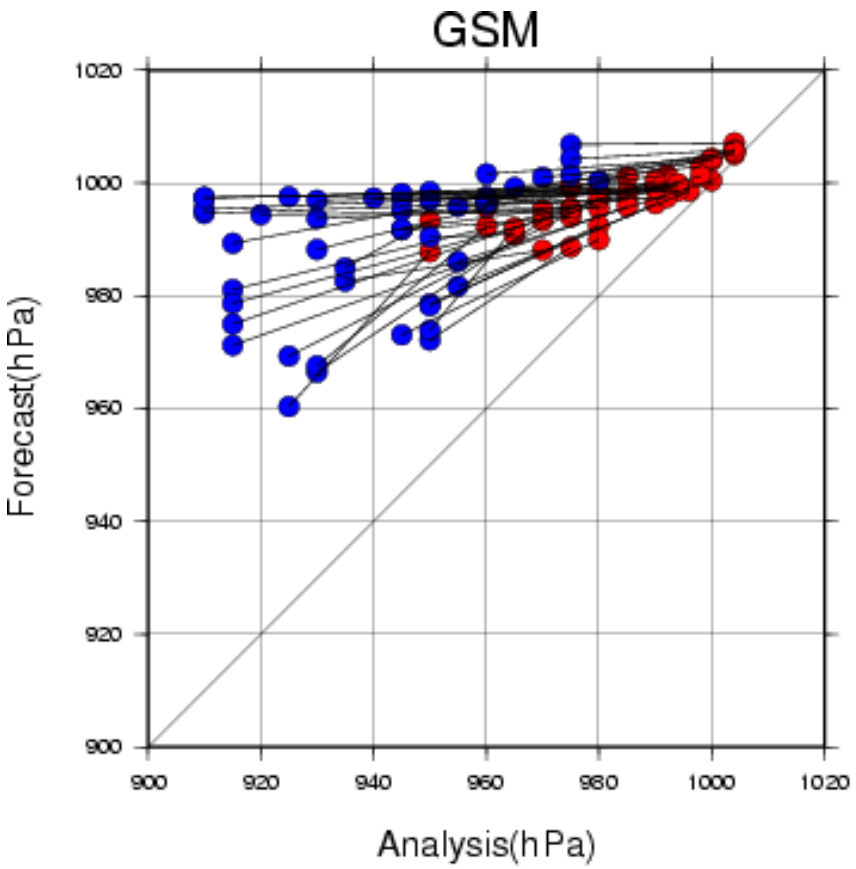
Typhoon Position Error

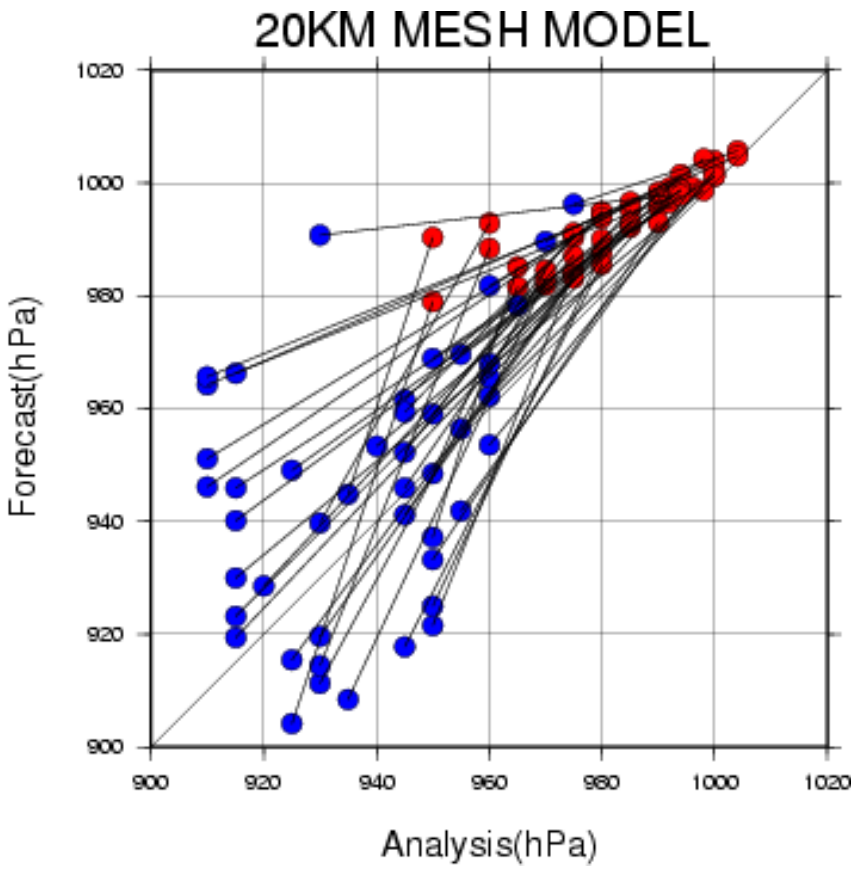


Intensifing Tendency

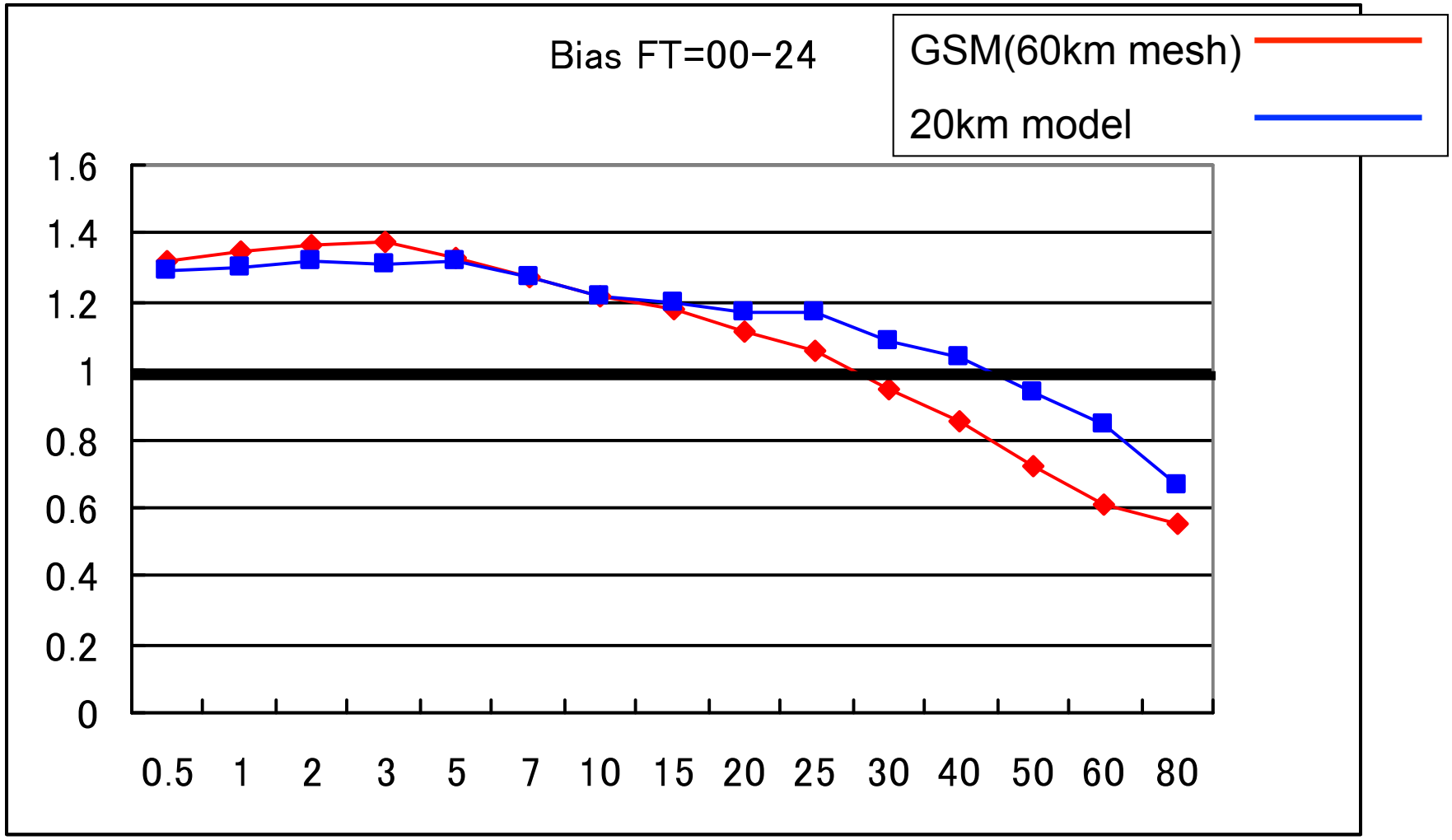
FT=0

FT=72





Precipitation Bias Score



Verification Period : 18 days (same as typhoon forecast period)

Area : Japan

Observation : AMeDAS (Automated Meteorological Data Acquisition System)

Summary

Typhoon simulations in a forecast mode

-Our high resolution AGCM can simulate position and intensity of typhoons more realistically than a lower resolution JMA GSM.

A new initialization scheme

-computationally effective for high resolution model

-succeeded in removing spurious gravity wave

20 km mesh global climate model and GSM

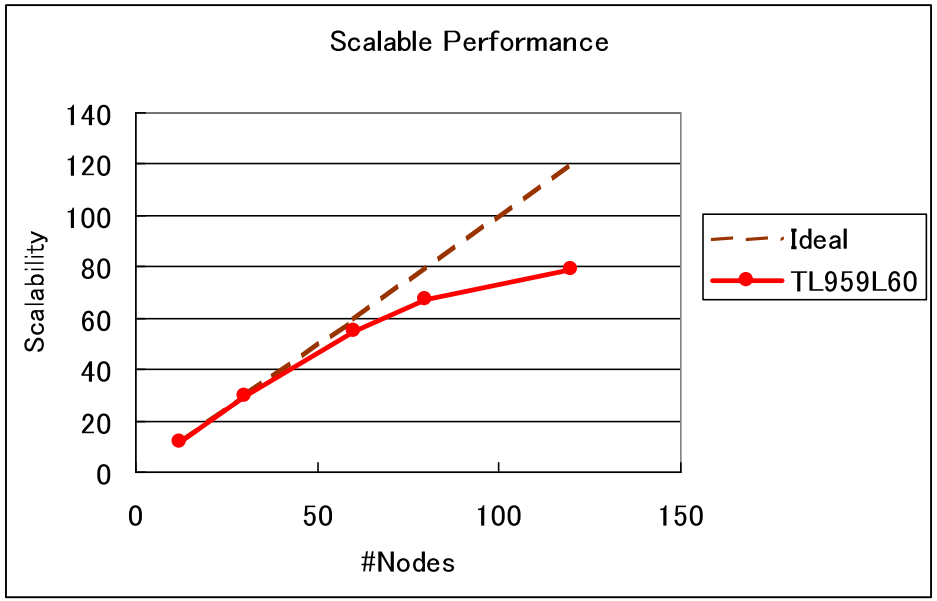
	20 km mesh global climate model	Global Spectral Model (GSM)
Horizontal Grids	1920x 960	640 x 320
Vertical Layers	60	40
Truncation Wave	TL959	T213
Grid Spacing	20km	60km
Top Layer Pressure	0.4hPa	
Dynamical frame	Semi-Lagrangian scheme	Eulerian scheme
Radiation Process	Shiata et al. (1999) Solar (every hour) Infrared (3 hourly)	
Precipitation Process	Prognostic Arakawa-schubert Large-scale condentation Prognostic cloud water content	
Gravity wave drug	Iwasaki et al (1989)	
Land surface	Simple Biosphere(SiB) model	
PBL and surface fluxes	Mellor-Yamada level 2 Moni-Obukhov similarity	

20 km mesh global climate model

- MRI/JMA unified global model
  - Based on the JMA global spectral model (GSM0103)
  - Semi-Lagrangian advection scheme
  - Fortran90 coding style
  - Radiation process : MRI-version or NPD-version
  - Prognostic Arakawa-Schubert, Large-scale condensation
  - Prognostic cloud water content
  - Mellor-Yamada level2, Monin-Obukhov similarity
  - Gravity wave drag (Long wave, short wave)
  - Simple Biosphere (SiB)

Computational Performance

- Execution Time : 24-Hours forecast on the ES
  - TL959L60 : 6min (with 60-nodes)
    - 35% of Peak Performance



  - Legendre transform : W2G 6.8Gflops/cpu, 85%
    G2W 7.6Gflops/cpu, 95%