Overview of the Center for Computational Sciences

Summary of Activities for 2008 to 2013

Division of Global Environmental Science

Atmospheric Science Group

Hiroshi L. Tanaka

(Group Leader)

Group Member

- Hiroshi L. Tanaka, Prof. CCS Staff (Since 2004)
- Hiroyuki Kusaka, Assoc. Prof. CCS Staff (Since 2006)
- Hiroaki Ueda, Affiliated Prof. University of Tsukuba
- Yasutaka Wakazuki, Affiliated Asst. Prof. U. Tsukuba
- Researchers in CCS : Drs. Akimoto, Ikeda, (Terasaki)

Graduate Student in CCS:

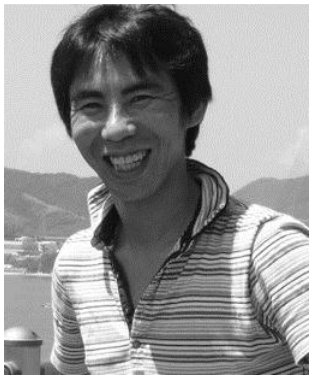
DC: (7) Kondo, Aizawa, Yamagami, Koshiba, Katoh, Doan, Nishi

MS:(10) Umino, Kino, Baba, Kudoh, Kuno, Fujita, and others

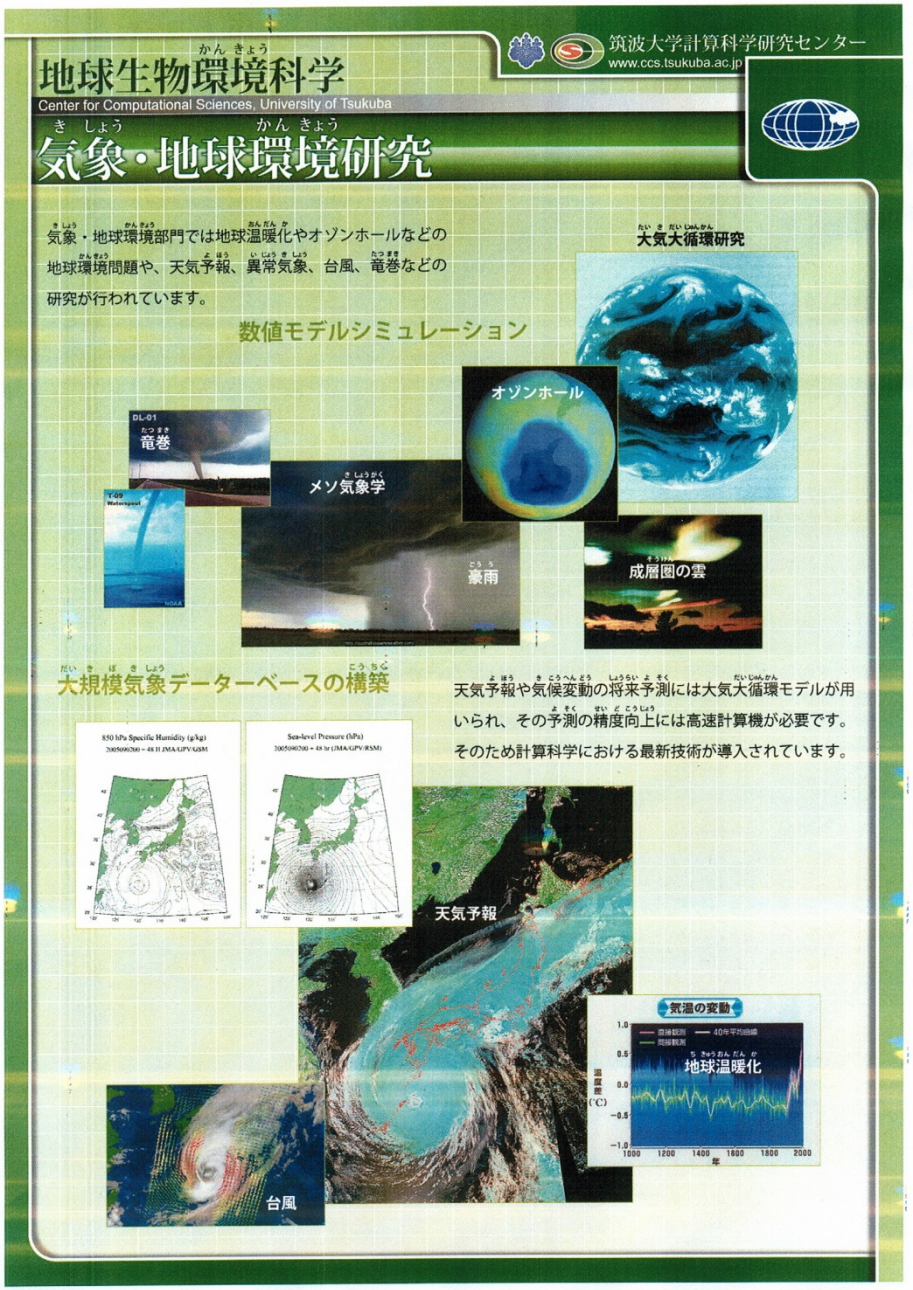
Tanaka

Kusaka

Ueda



Wakazuki



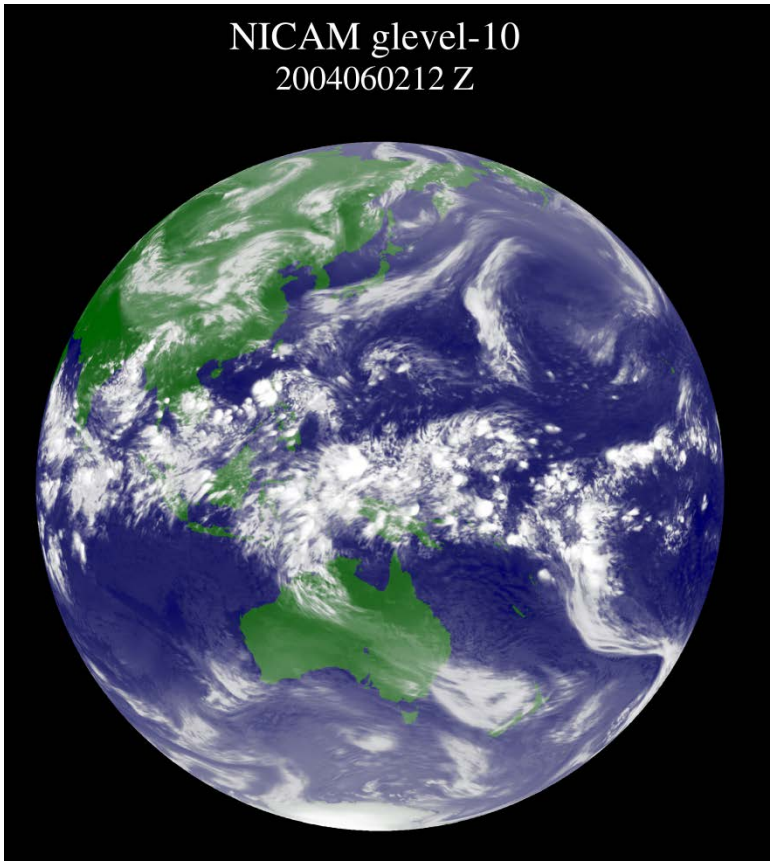
Research activity (H.L. Tanaka)

- General circulation of the atmosphere
- Global warming and Arctic Oscillation
- Global warming and tropical circulation
- Global spectral energetics
- Blocking and abnormal weather
- Dynamics of baroclinic waves

Research activity (H. Kusaka)

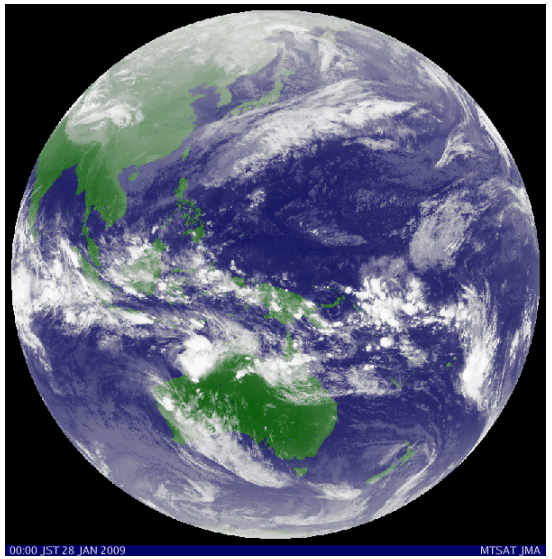
- Regional modeling using WRF
- Urban climate modeling
- Meso-scale precipitation system
- GPS and data assimilation
- Surface heat budget and radiation
- Real-time regional prediction system

General Circulation Model: NICAM



NICAM 7 km grids

GMS Observation



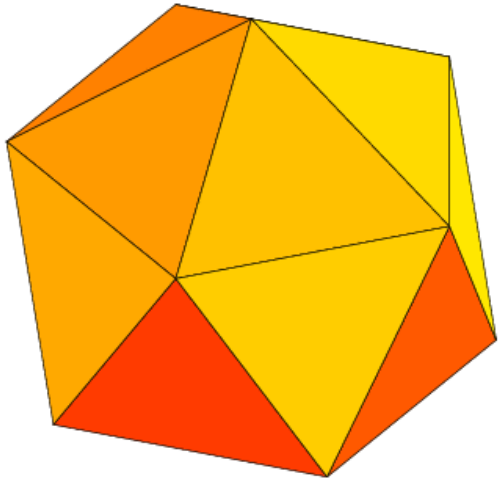
NICAM

by T2K-Tsukuba

Original Icosahedron

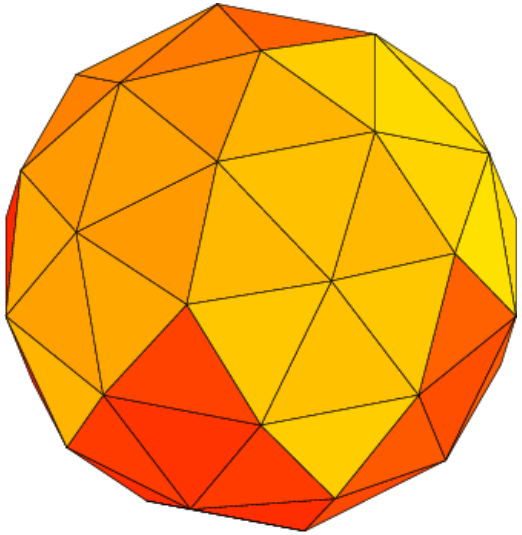
Satoh et al. AORI

Glevel-0

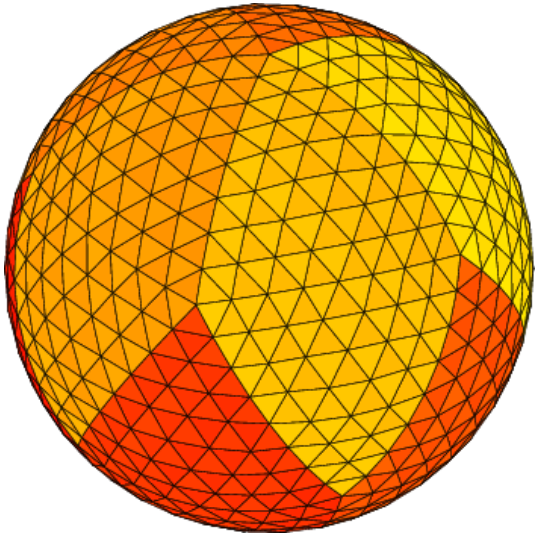


Glevel-5: Δx=250km
Glevel-6: Δx=120km
Glevel-7: Δx= 60km
Glevel-8: Δx= 28km
Glevel-9: Δx= 14km
Glevel-10: Δx= 7km
Glevel-11: Δx=3.5km

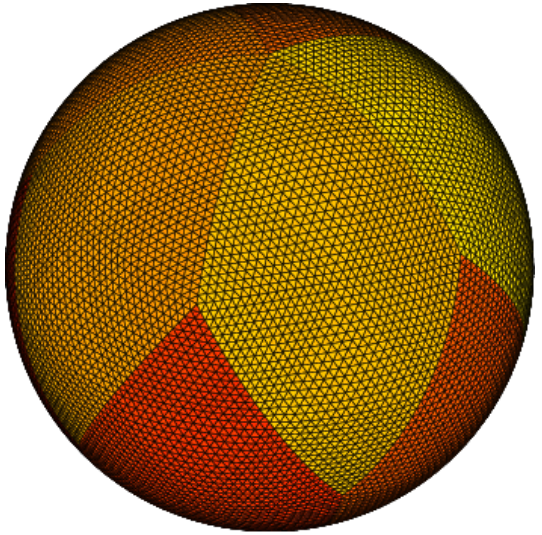
Glevel-1



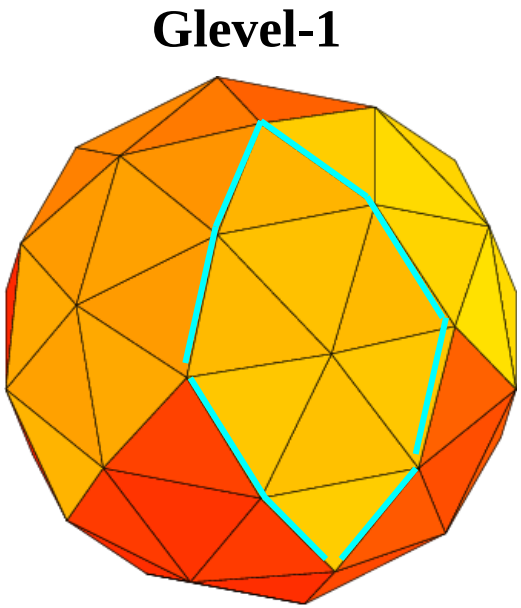
Glevel-3



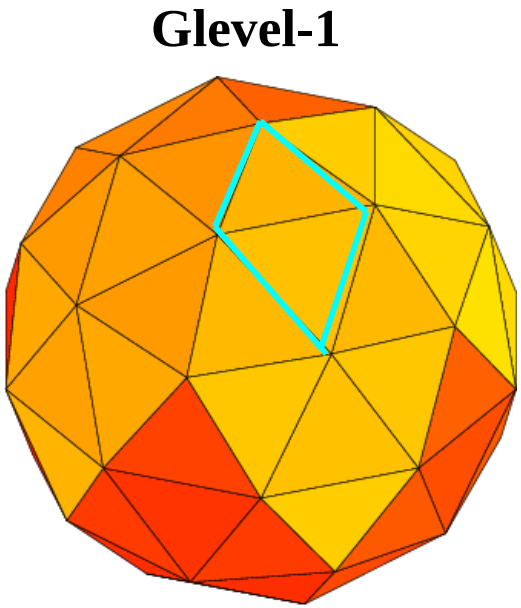
Glevel-5



Non-hydrostatic AGCM: NICAM



Rlevel-0



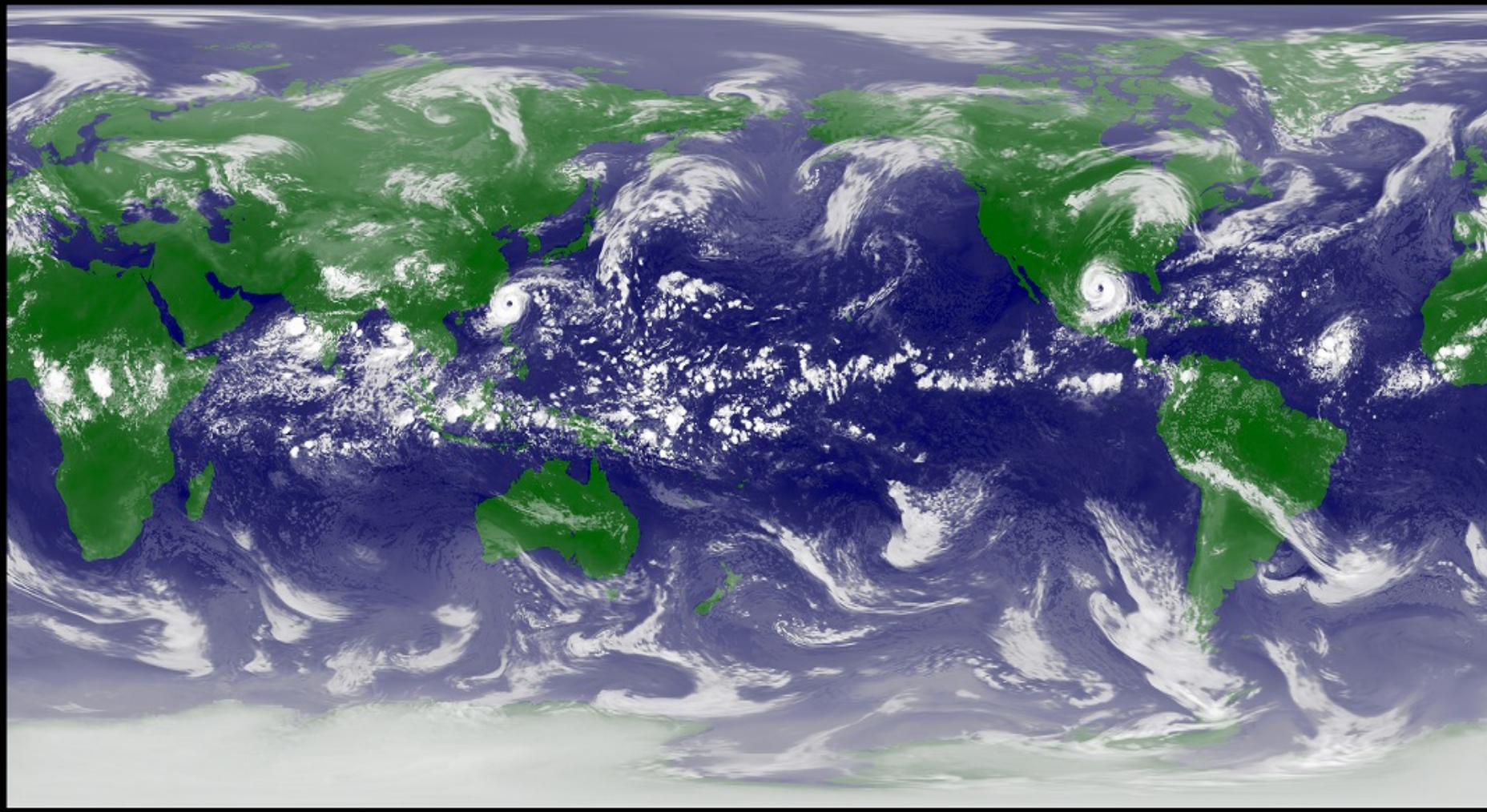
Rlevel-1

Level region

- Rlevel-0 : 10
- Rlevel-1 : 40
- Rlevel-2 : 160
- Rlevel-3 : 640
- Rlevel-4 : 2560

- Two triangles makes one region
- Computing region changes by Rlevel

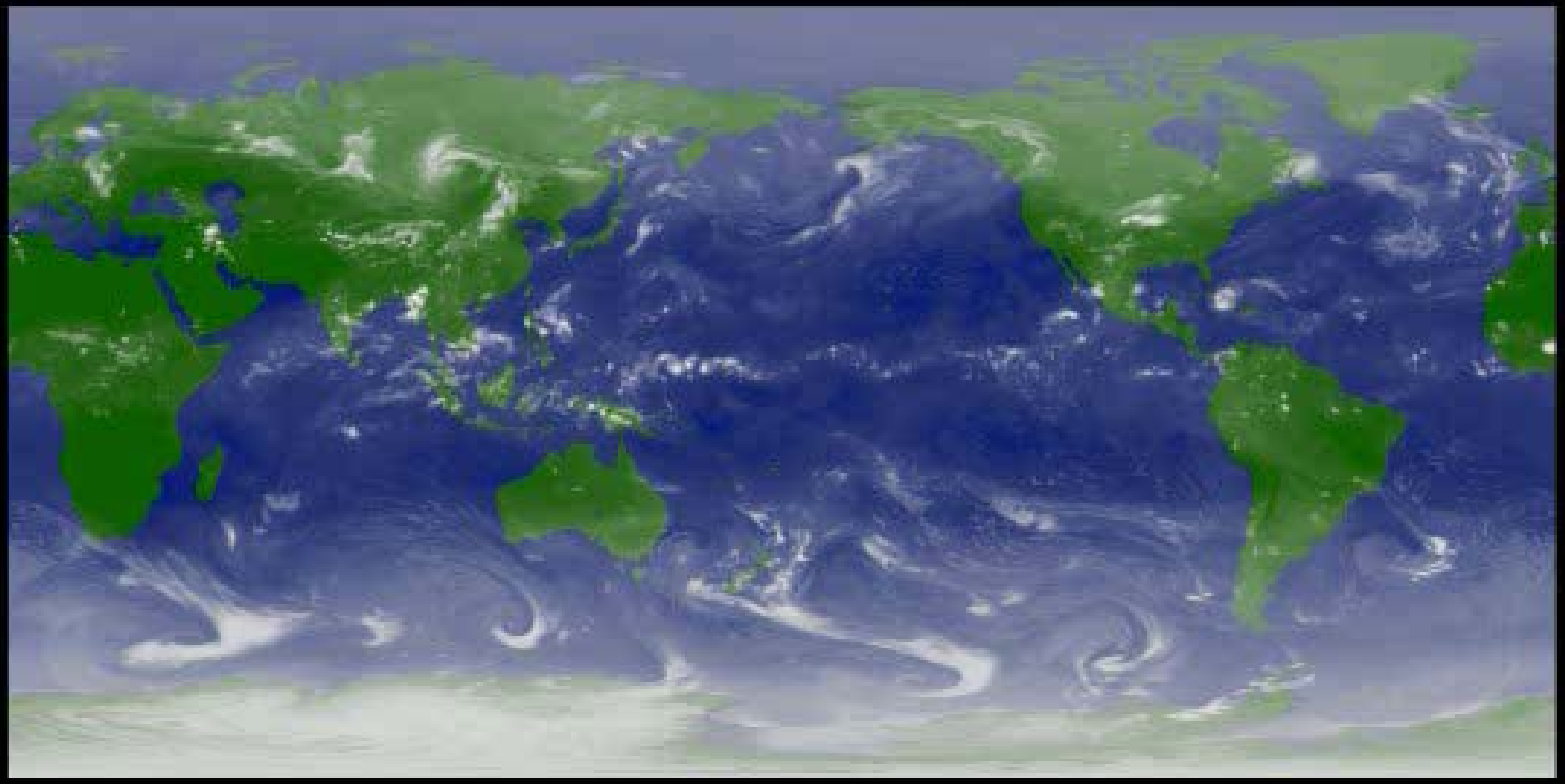
Numereical Simulation of Arctic and Tropical Cyclones Using NICAM Installed at CCS Tsukuba



Typhoon Sinlaku and Hurricane Ike in 2008

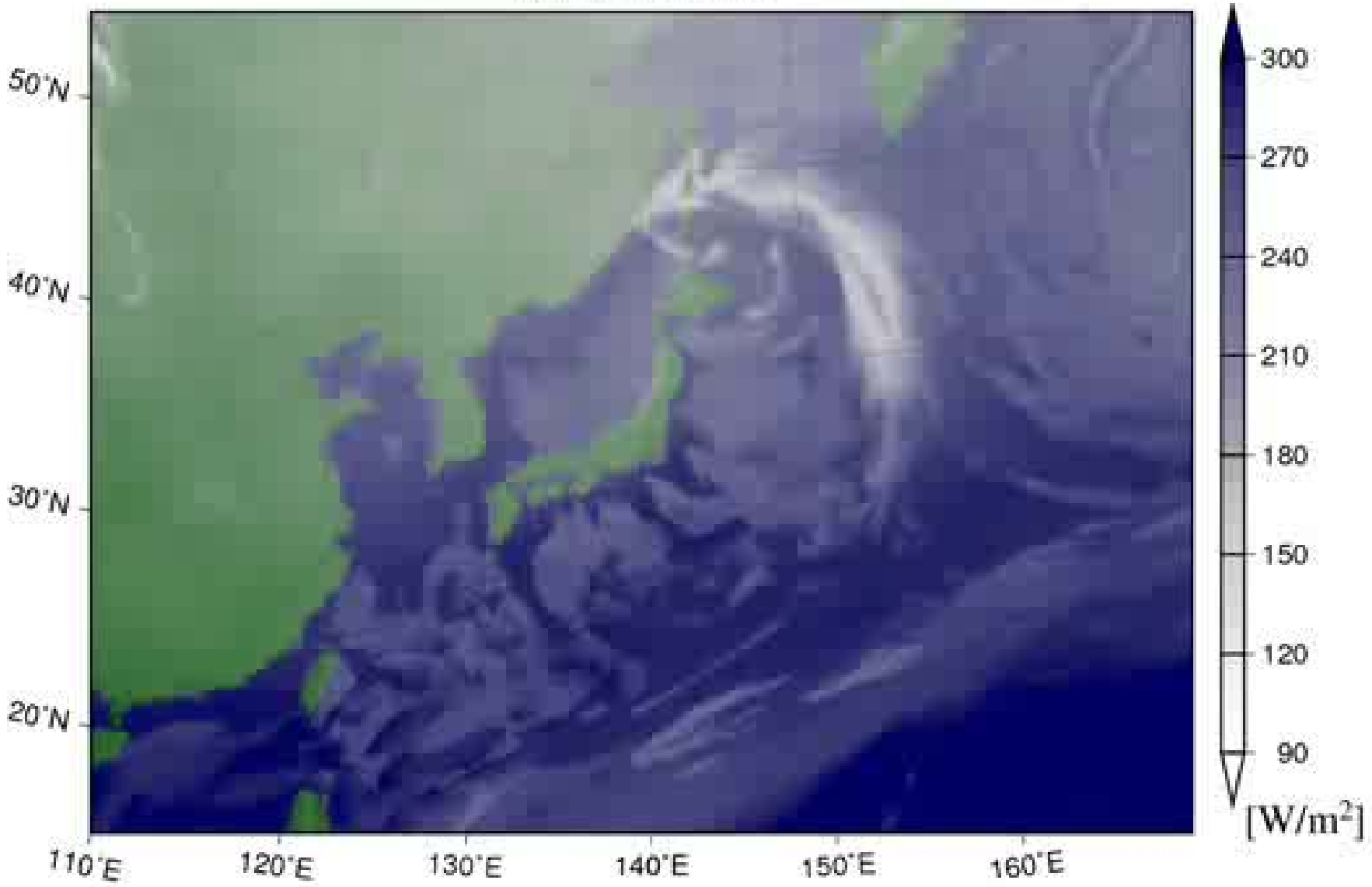
NICAM glevel-10

20080908l2 Z



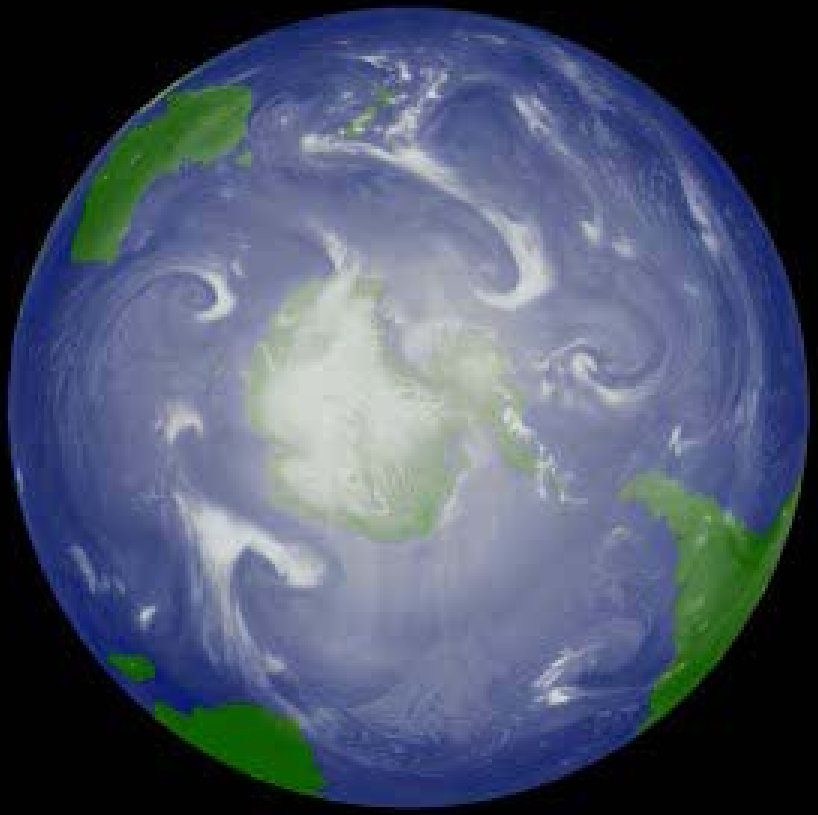
NICAM gl-10 IR (JAPAN)

2009011512 Z

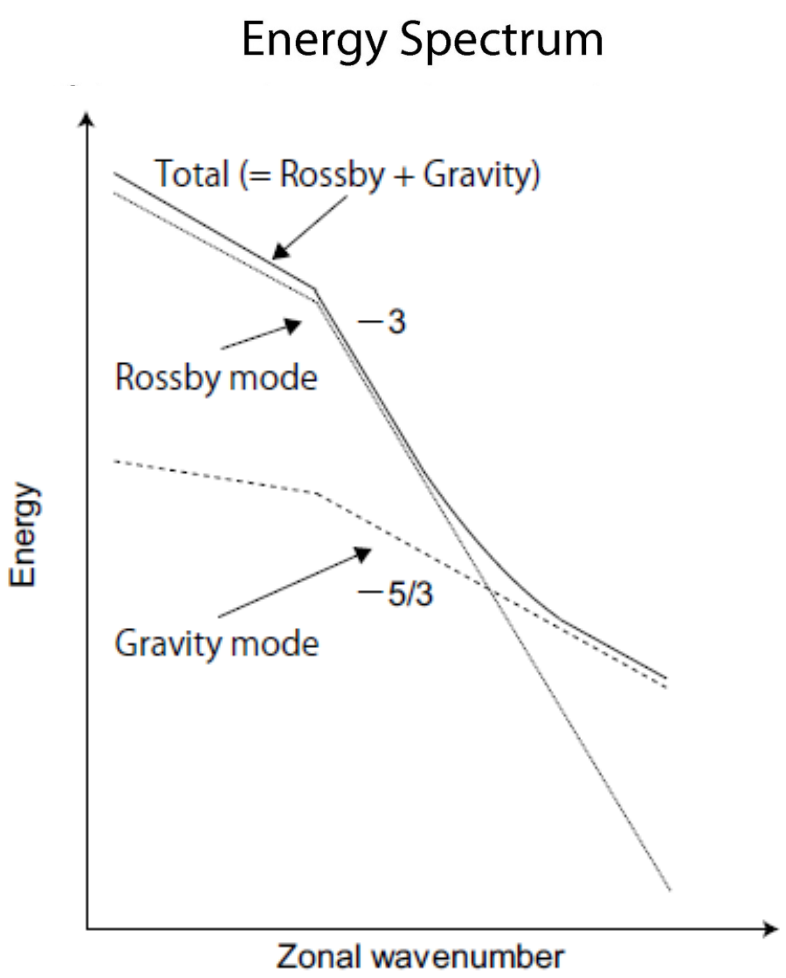


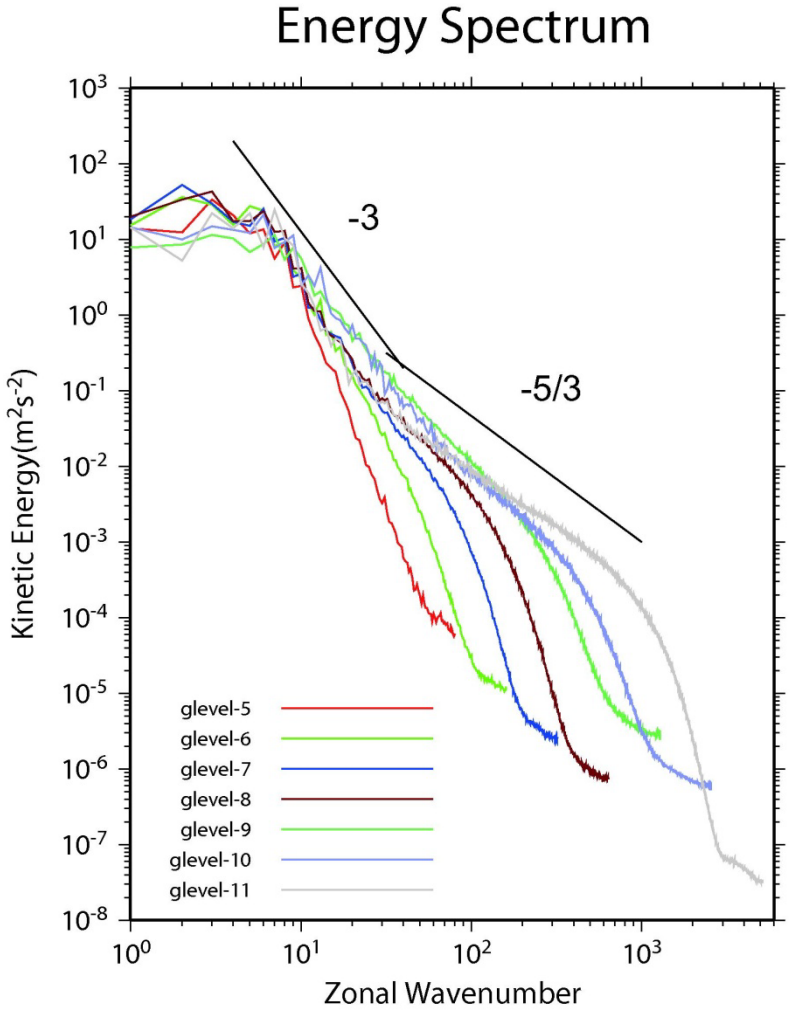
NICAM glevel-10
2009011512 Z

NICAM glevel-10
2008090812 Z



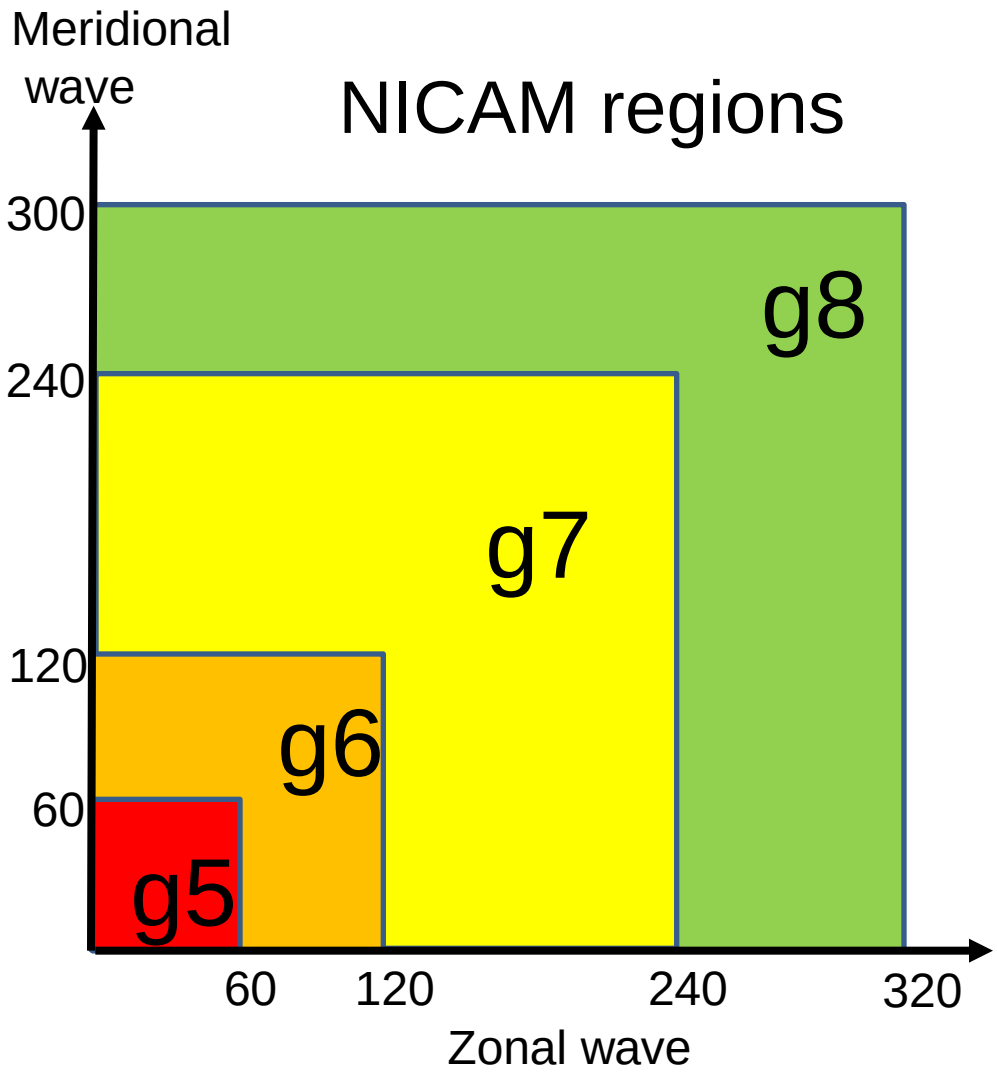
Global Energy Spectrum of NICAM
Normal mode energetics analysis

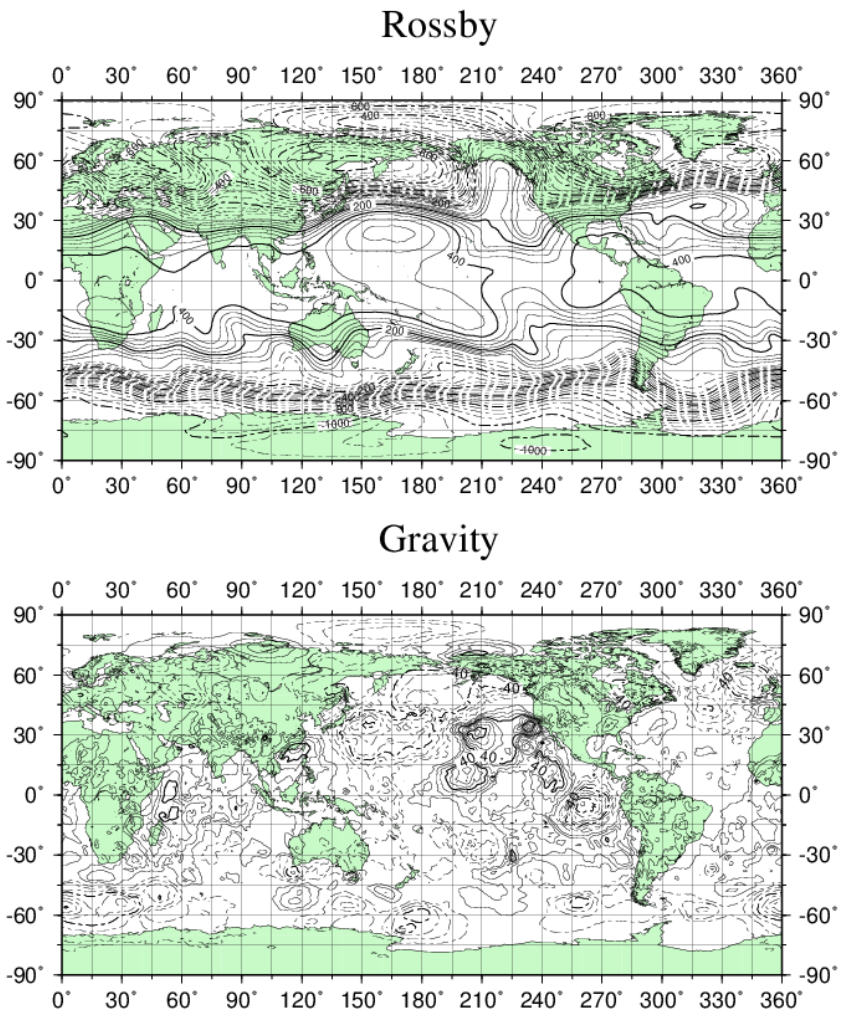




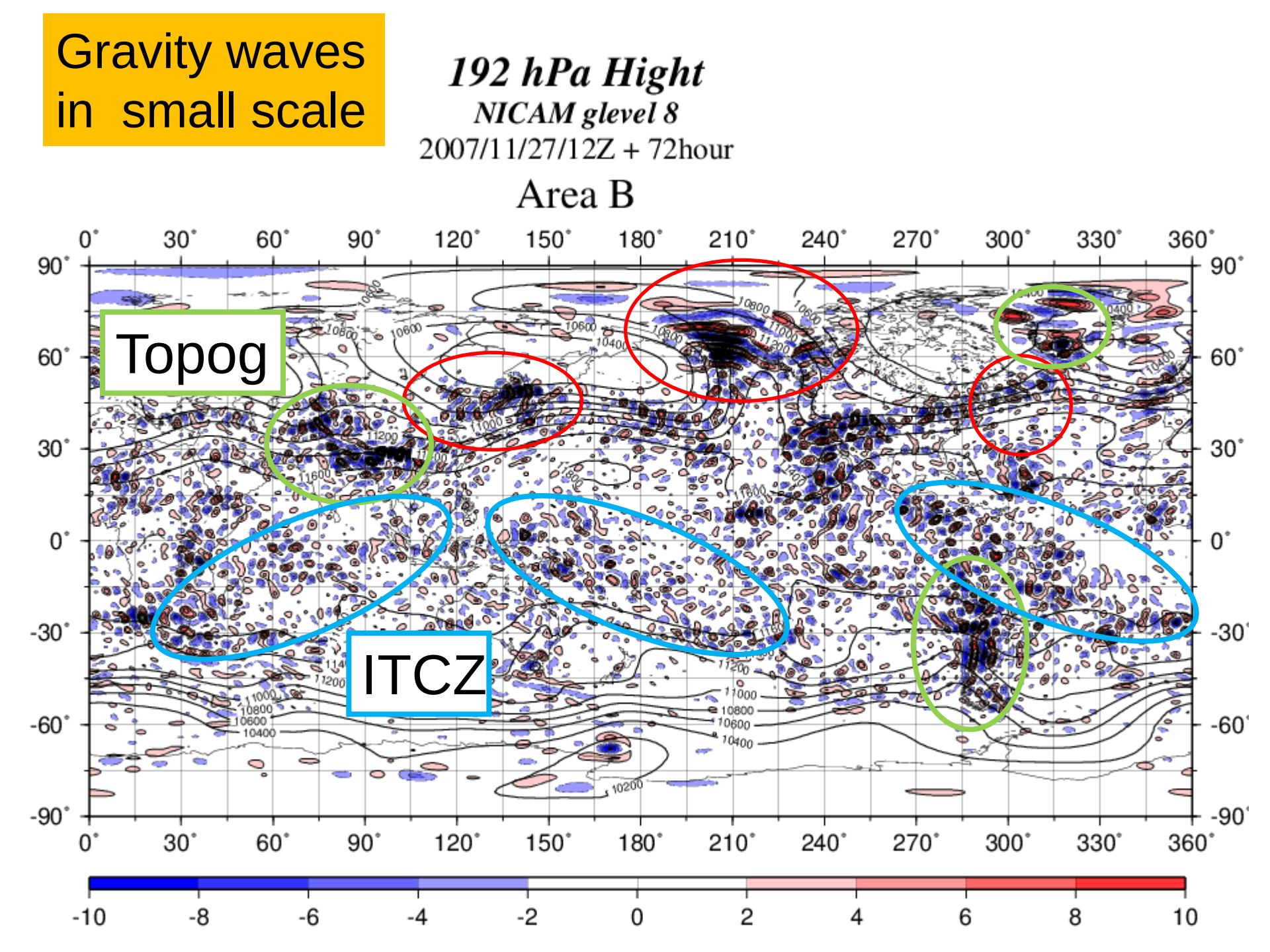
(Terasaki, Tanaka, and Satoh 2009, SOLA)

Rossby wave world and gravity wave world



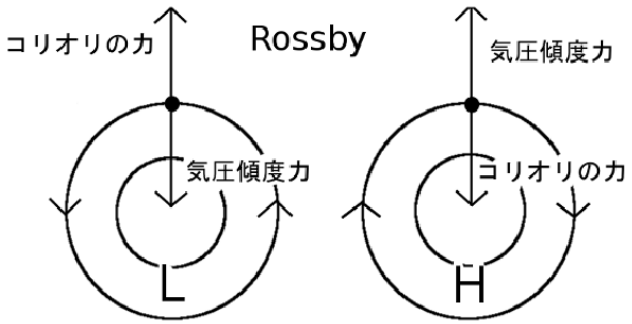


Gravity waves in small scale

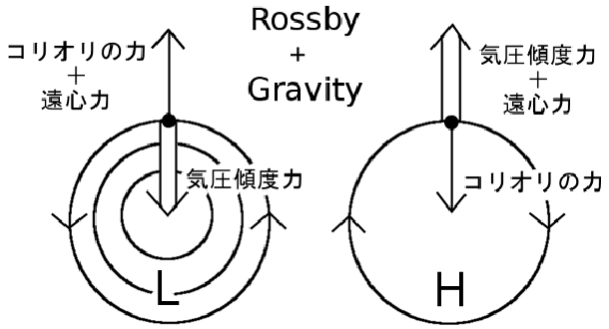


Gravity waves in large scale

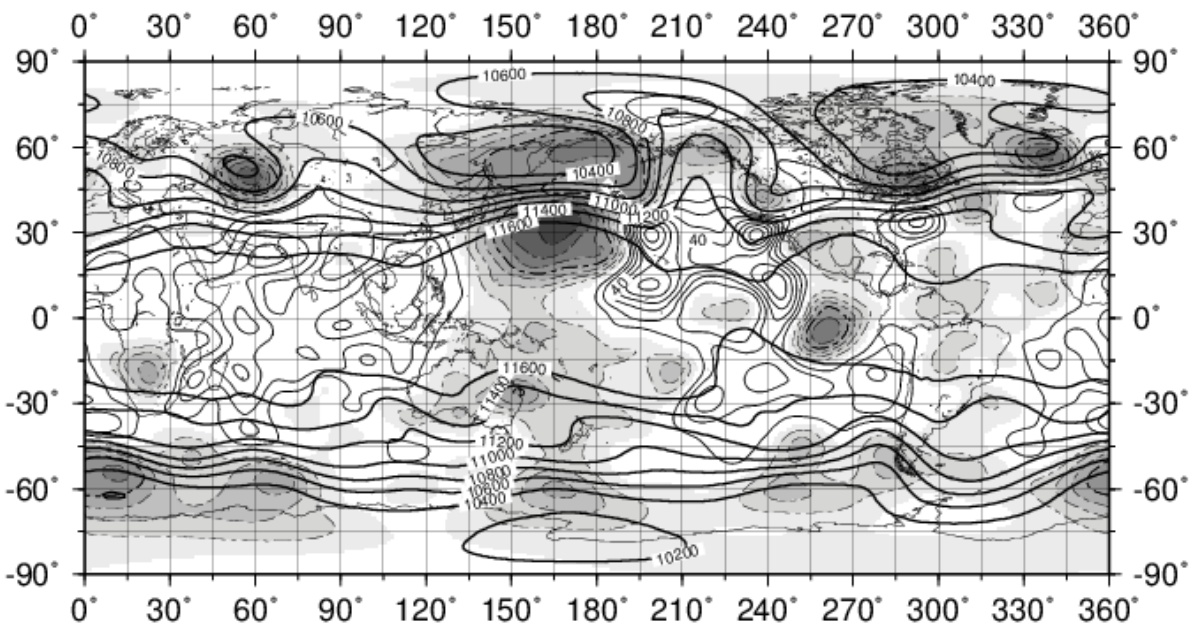
Geostrophic wind



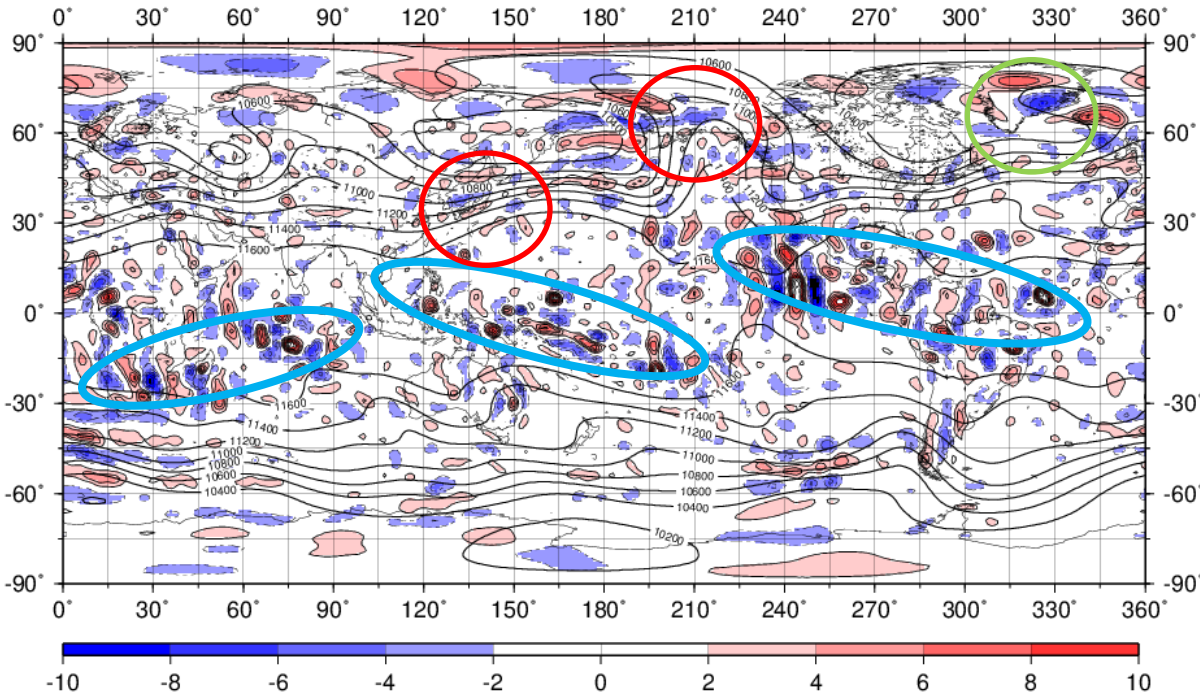
Gradient wind



Area A1

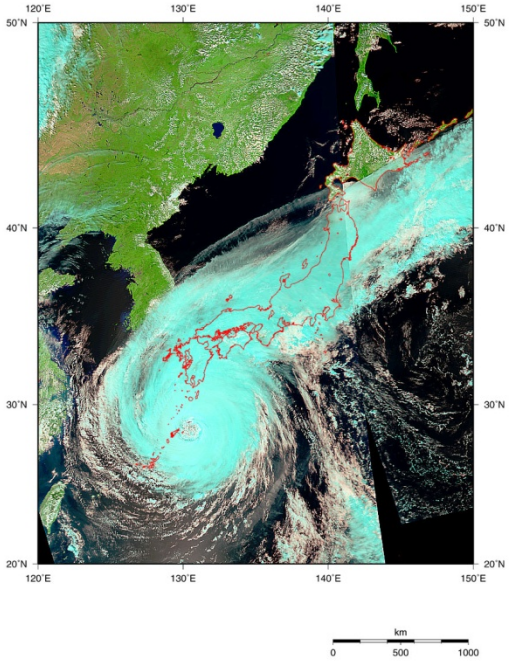


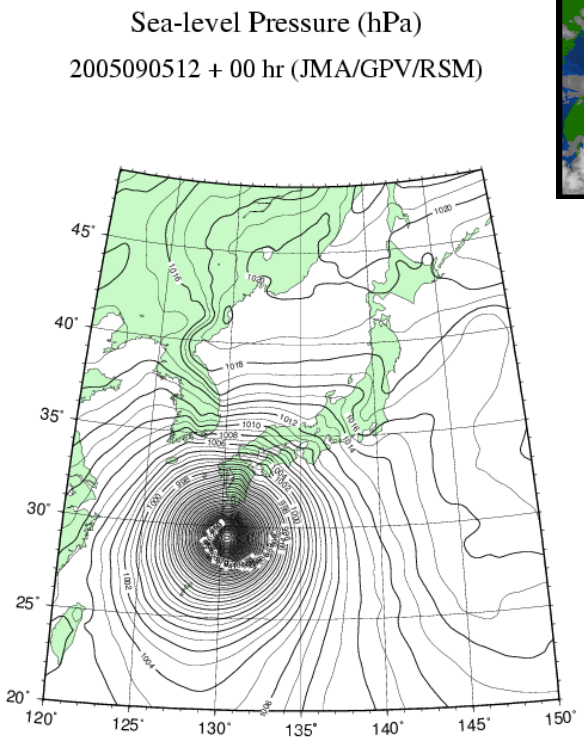
Area A2

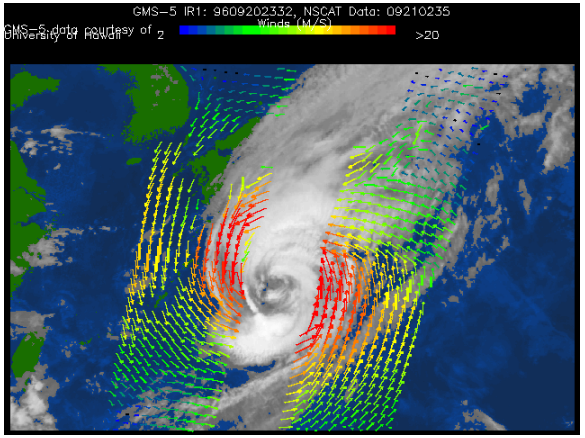


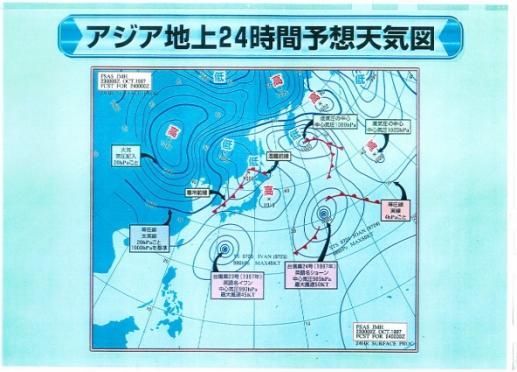
Tropical Cyclone

- Life cycle of Typhoon



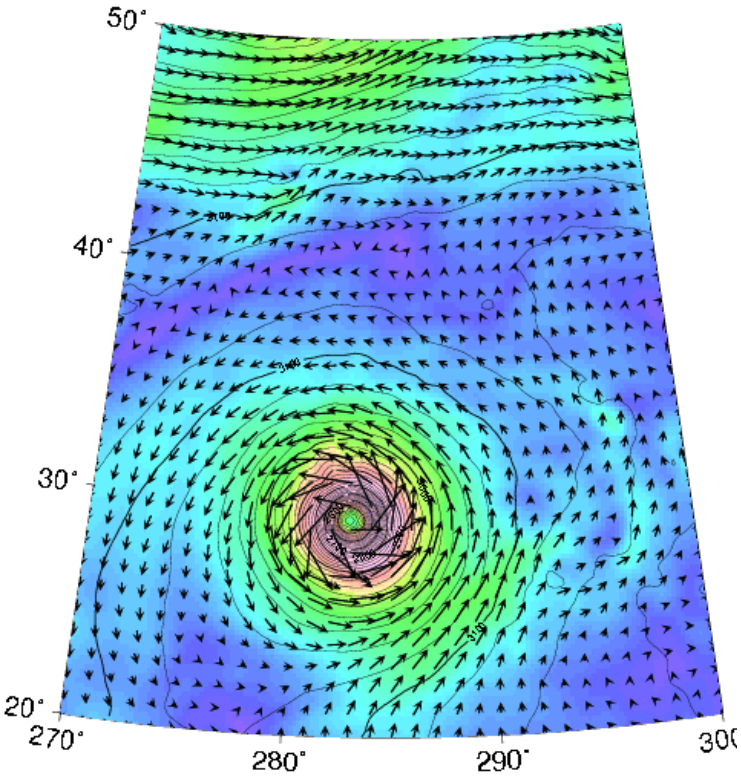




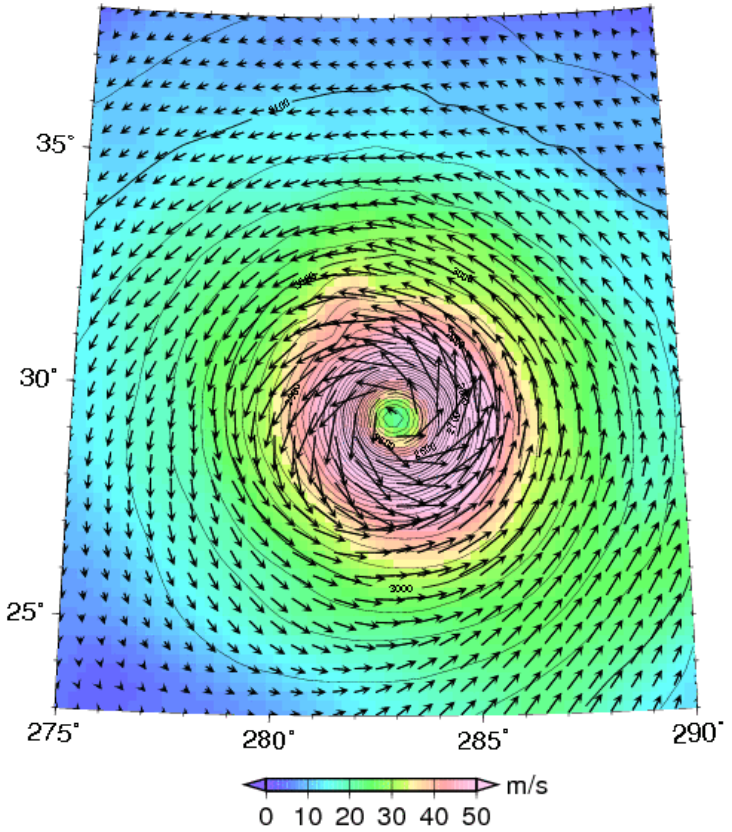


Tropical Cyclones

NICAM gl-8
Height (m) and Wind (m/s) at 700 hPa
2008070500Z+78HR

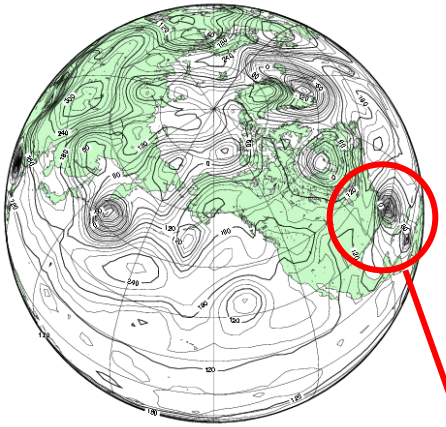


NICAM gl-8
Height (m) and Wind (m/s) at 700 hPa
2008070500Z+78HR

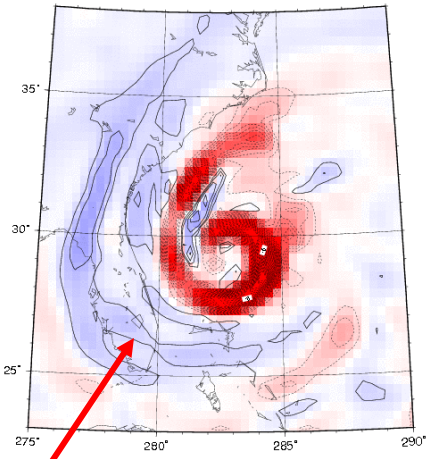


Tropical cyclone

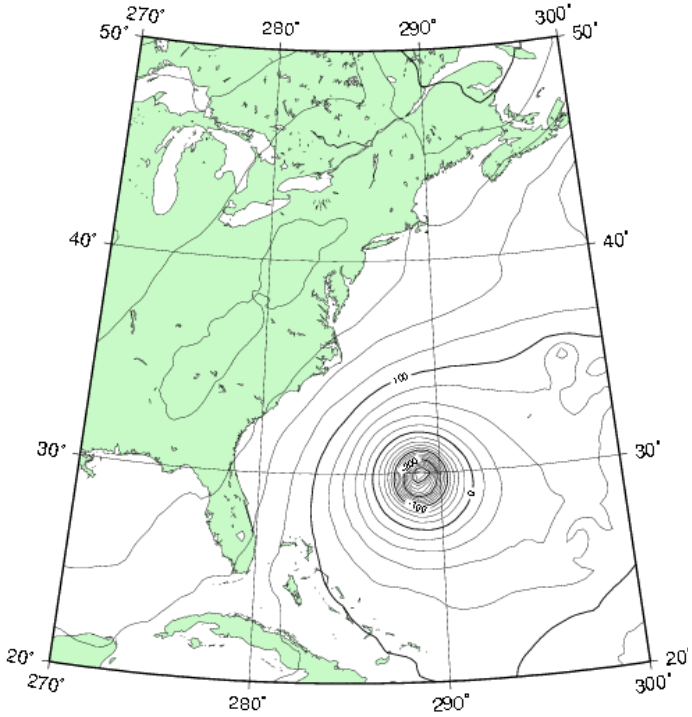
NICAM 28km model 21 day integration starting from June 21, (PACS-CS 256PE)



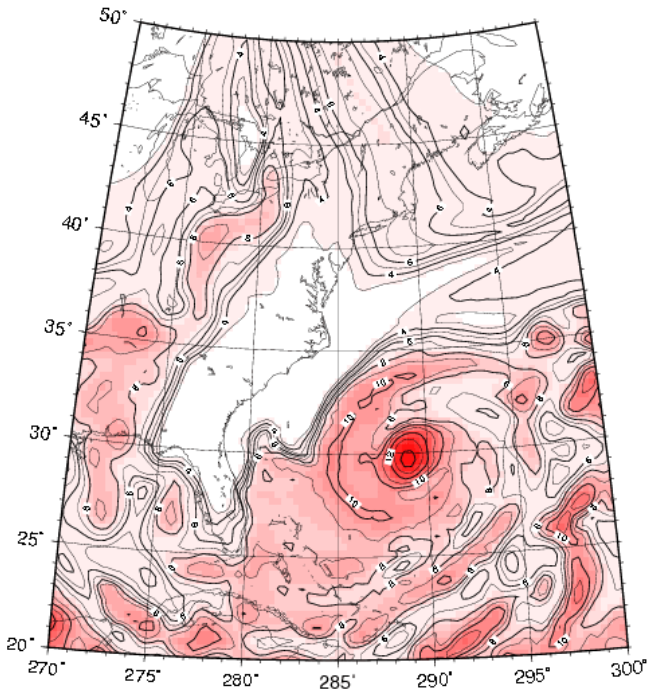
Global



Omega



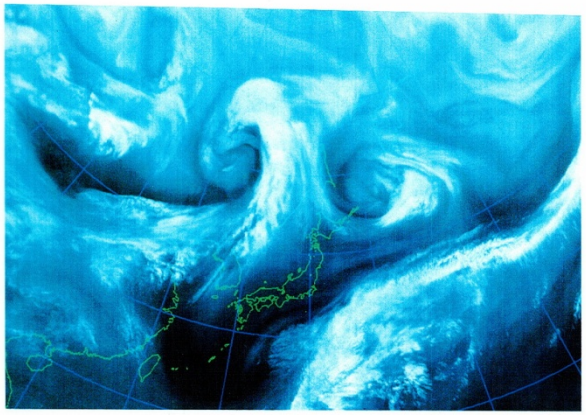
SLP

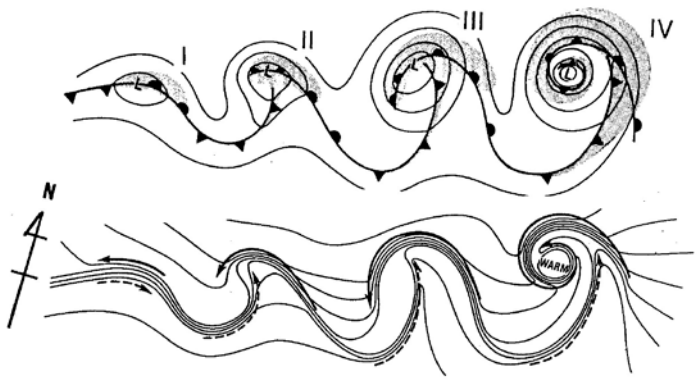


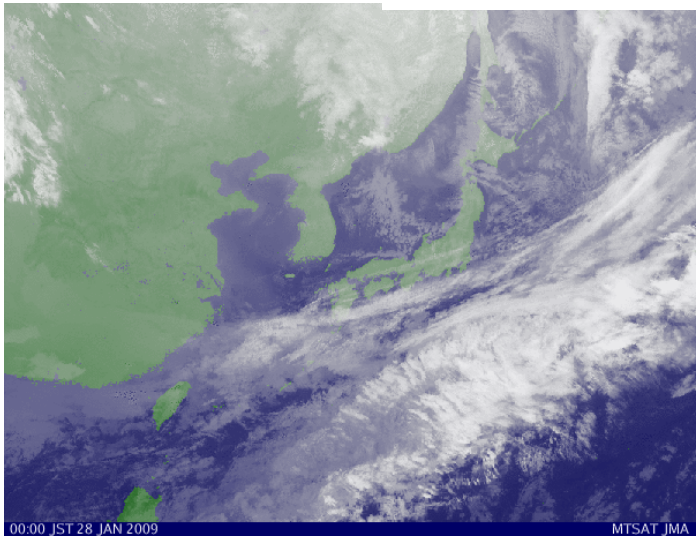
Humidity

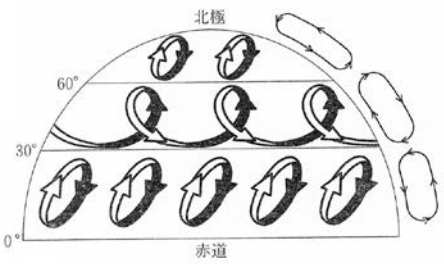
Extra-tropical Cyclones

- Life cycle
- Warm and cold fronts









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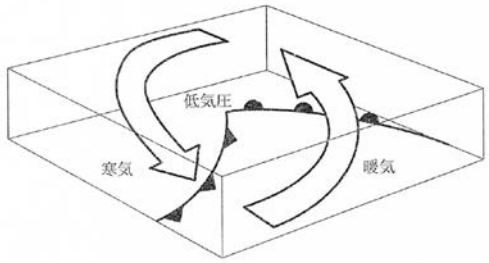
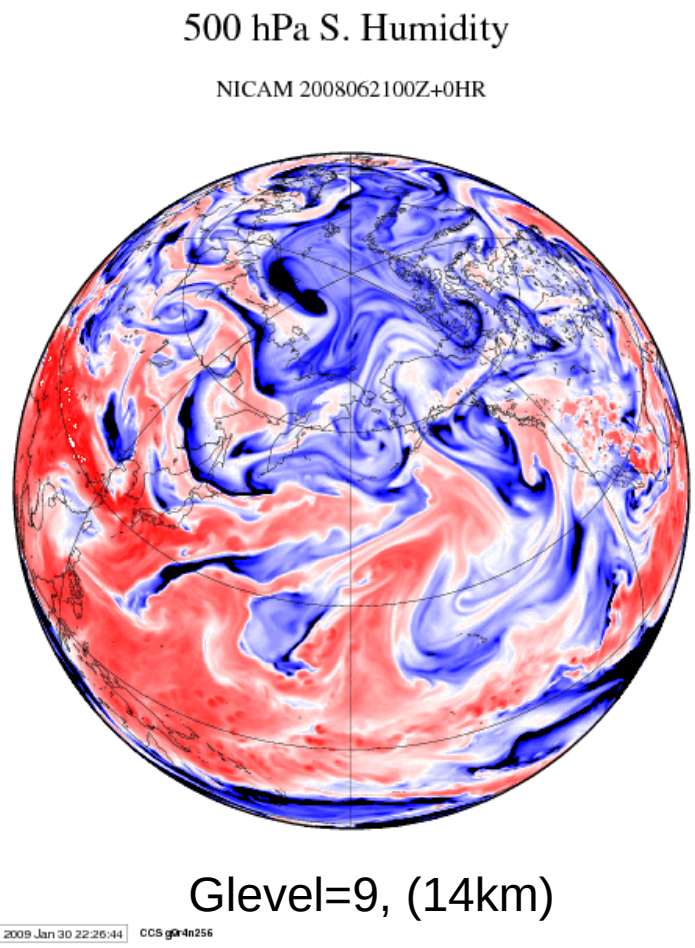
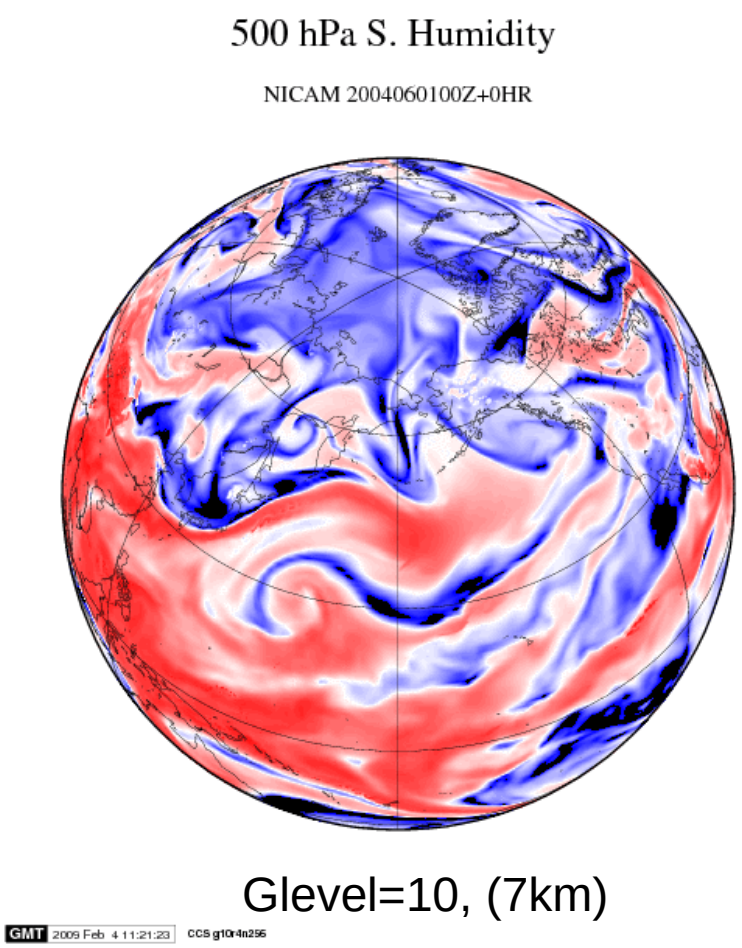


Water vapor in NICAM



Glevel=9, (14km)

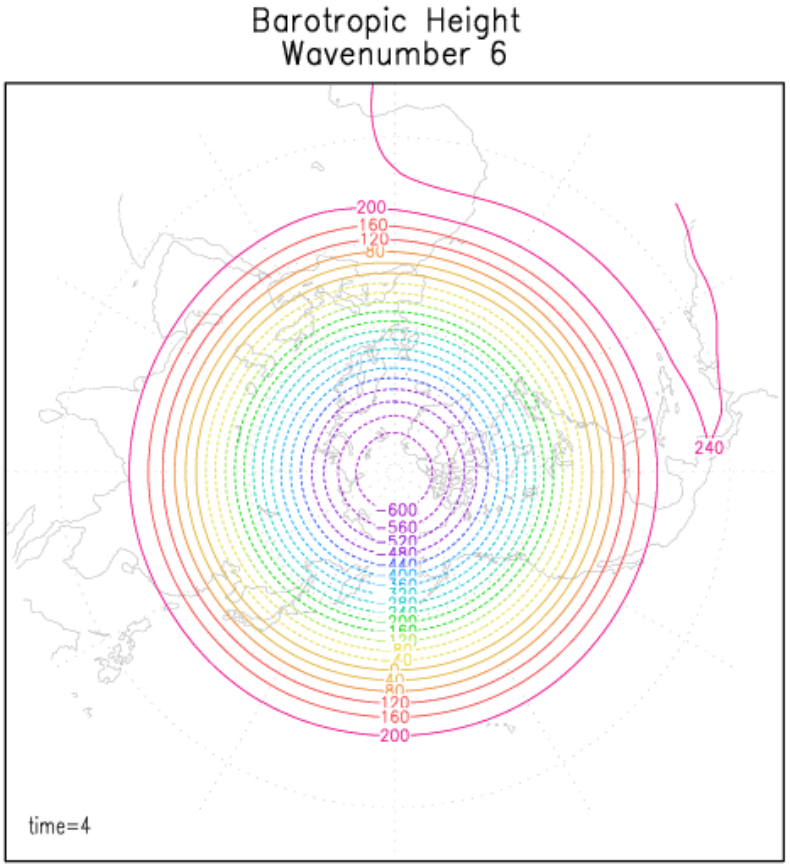


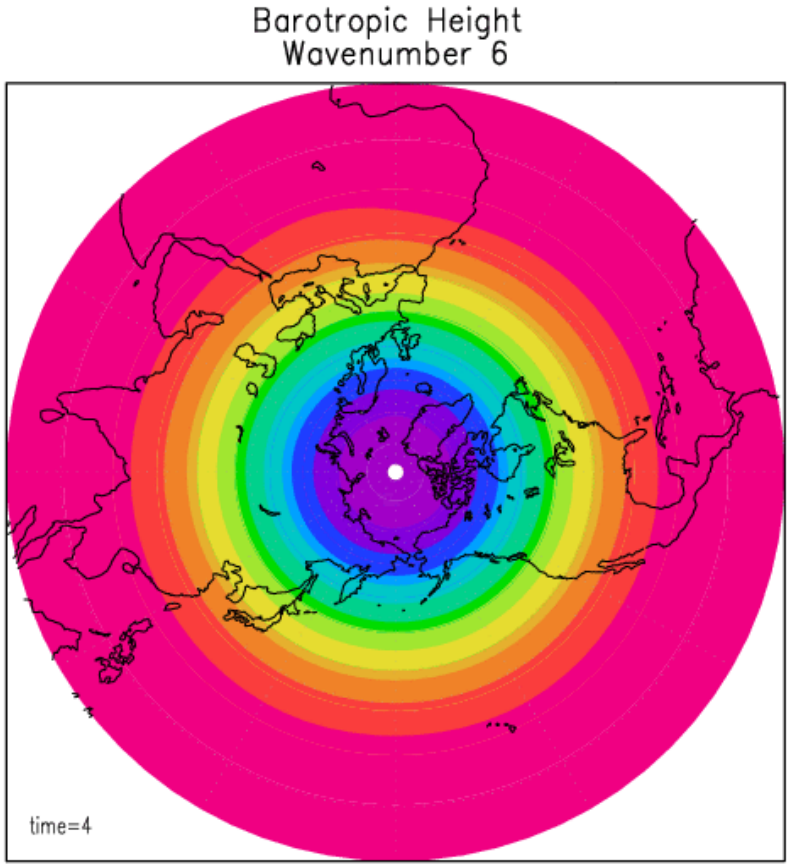
Glevel=10, (7km)

Up-scale energy cascade

Rossby wave breaking for n=6

Growth rate × 1.7

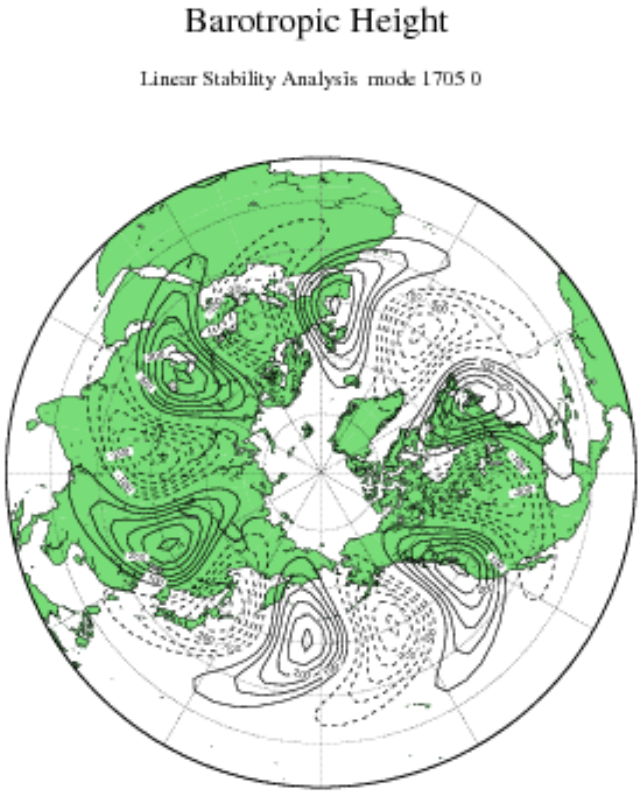




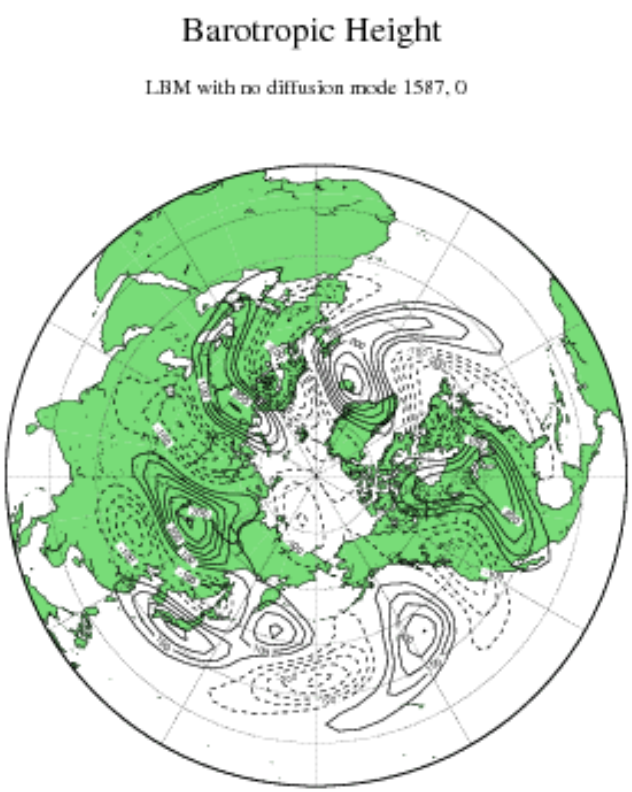
2009-01-13-09:04

Baroclinic instability

Zonal basic state

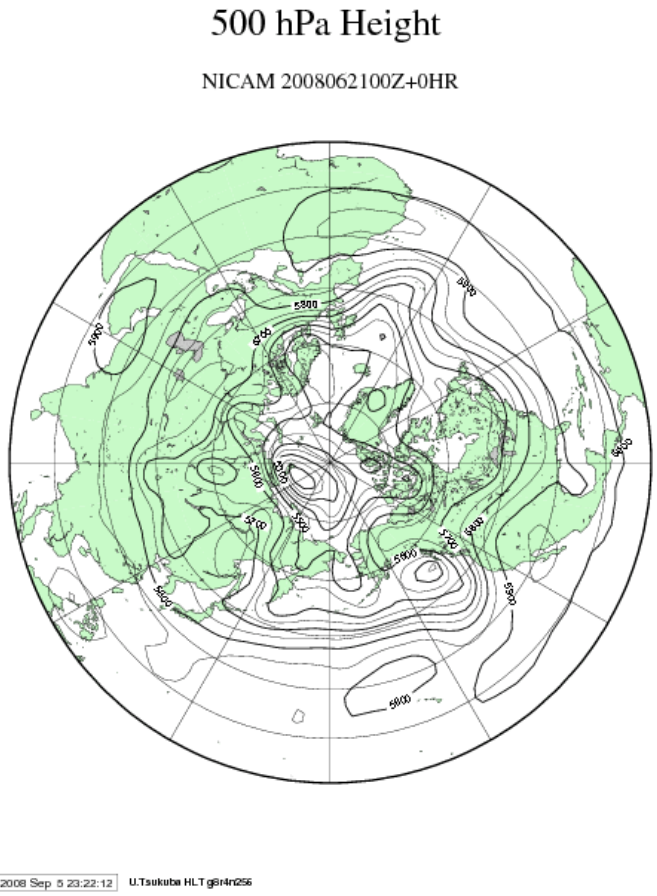


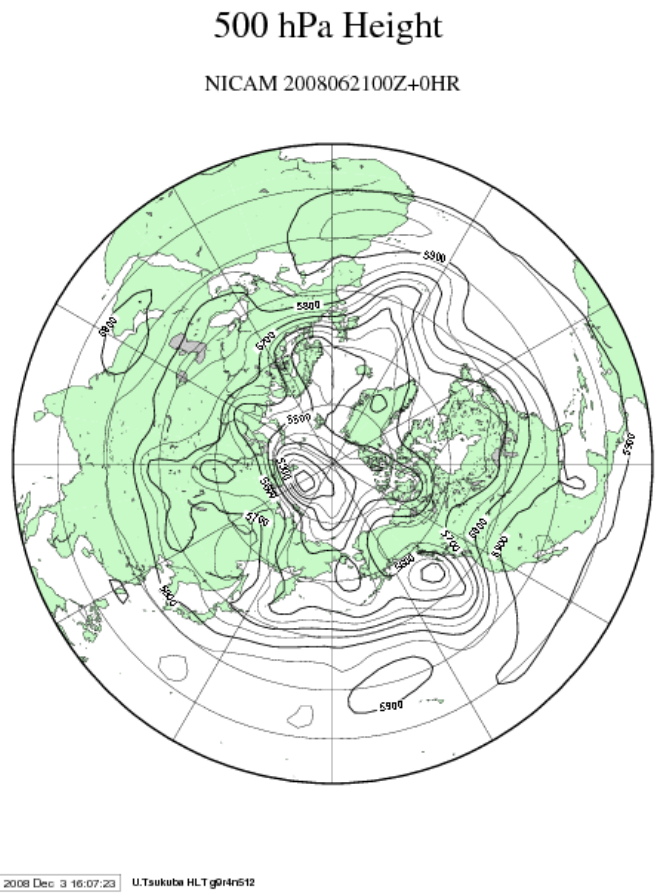
3D basic state



Arctic Cyclones SLP

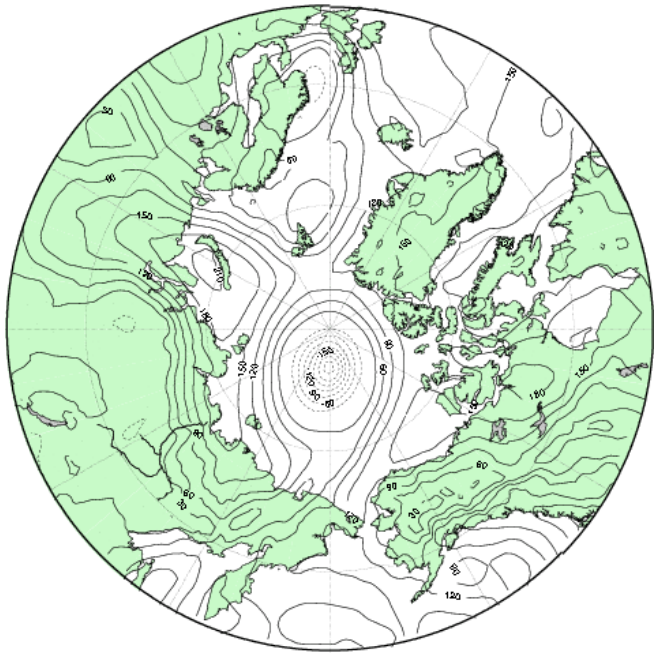
10 day integration starting
From June 21, 2008
NICAM gl8 and gl9 rl02-n512



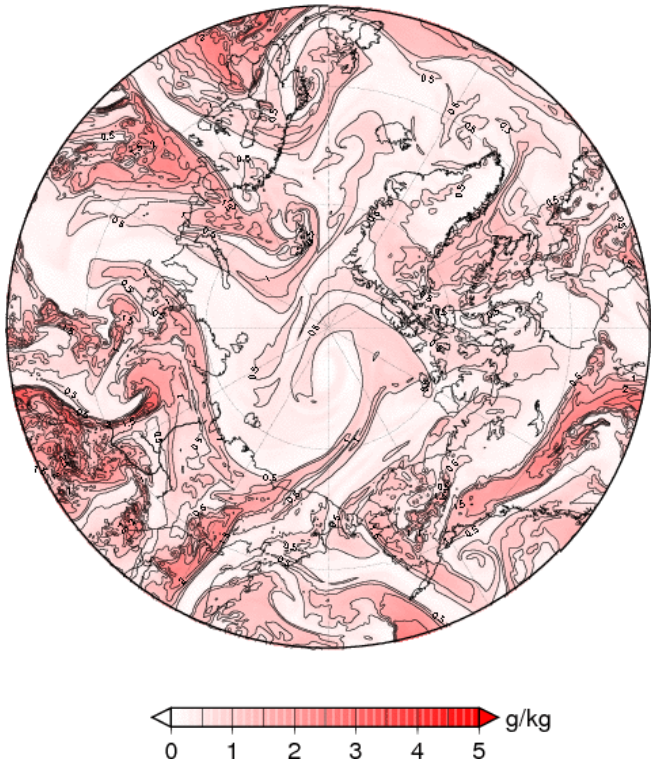


SLP and humidity

NICAM gl-9
1000 hPa Height
2008062100Z+48HR

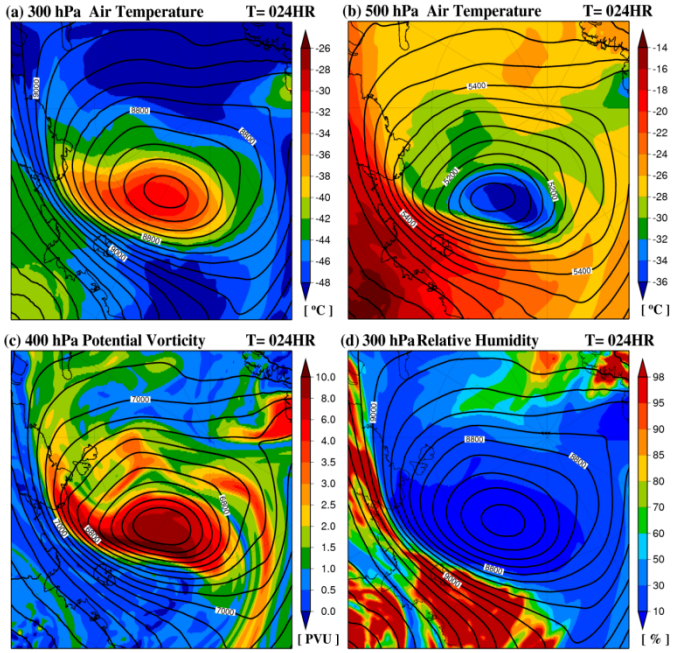


NICAM gl-9
500 hPa S. Humidity
2008062100Z+48HR

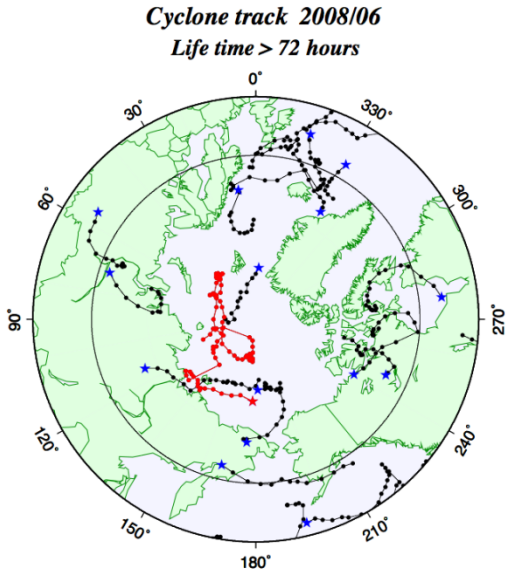


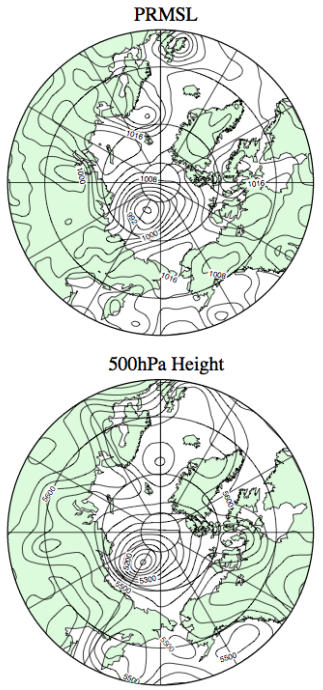
NICAM glevel-9
2008062100 Z

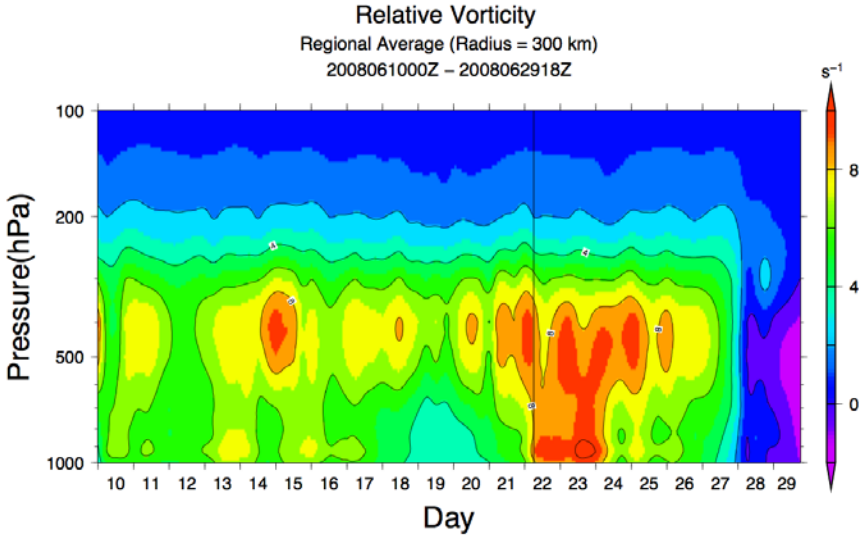
Arctic Cyclone in JRA-25 and NICAM

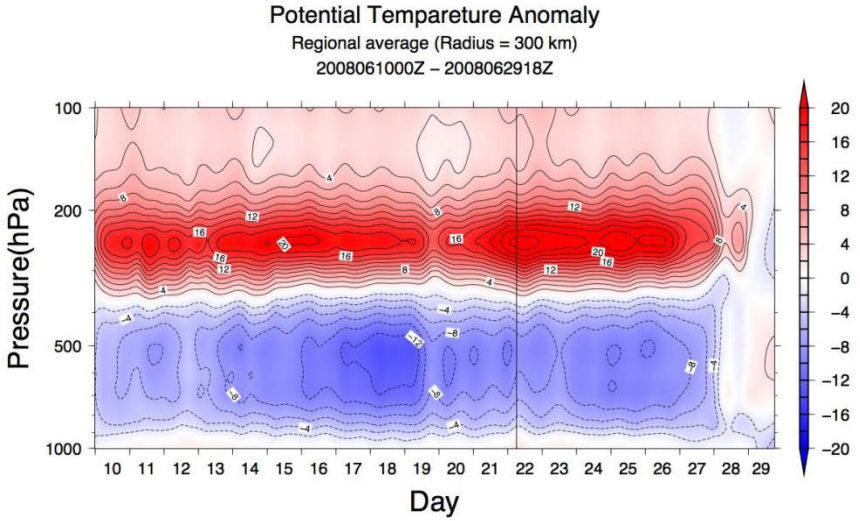


Tanaka and Yamagami 2012

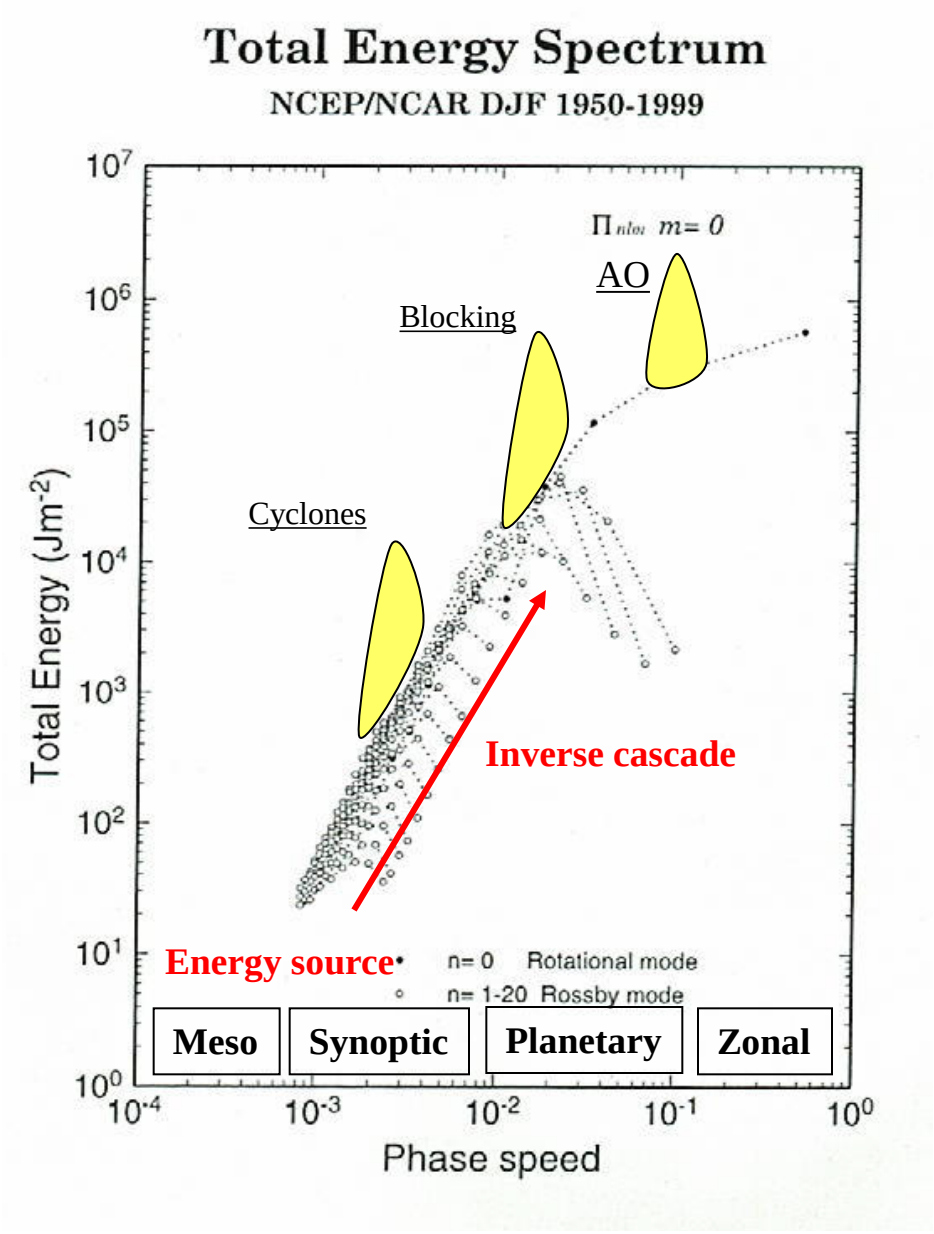


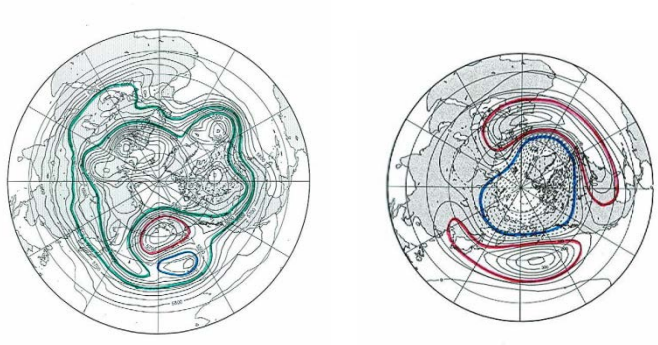


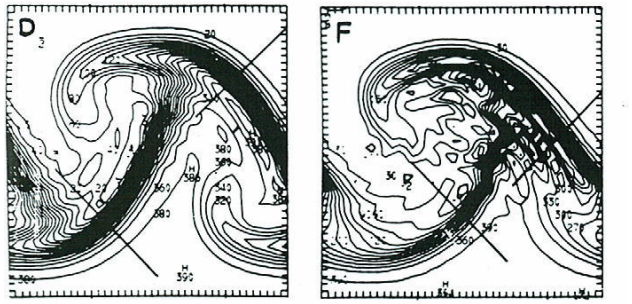




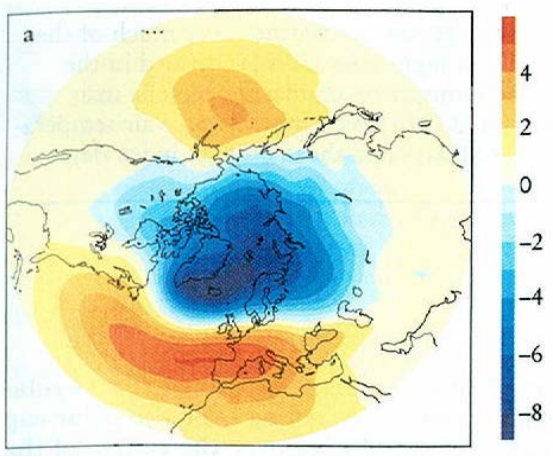
Low-frequency variability of the atmosphere

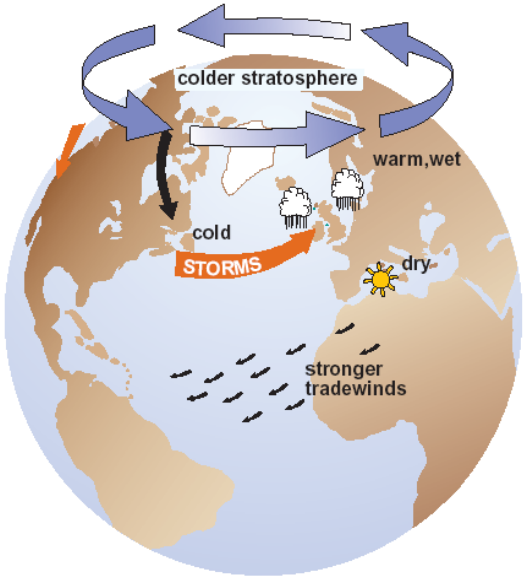


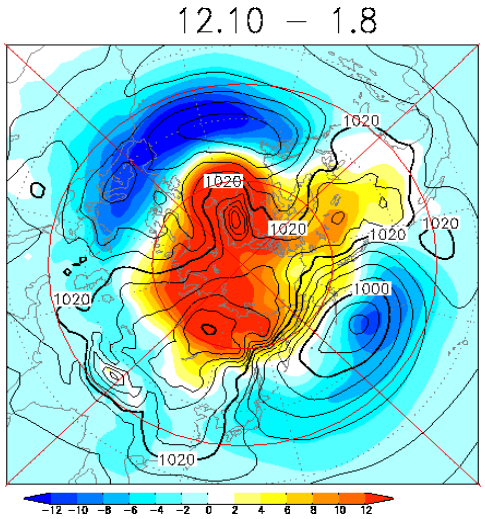




Global warming and Arctic Oscilation



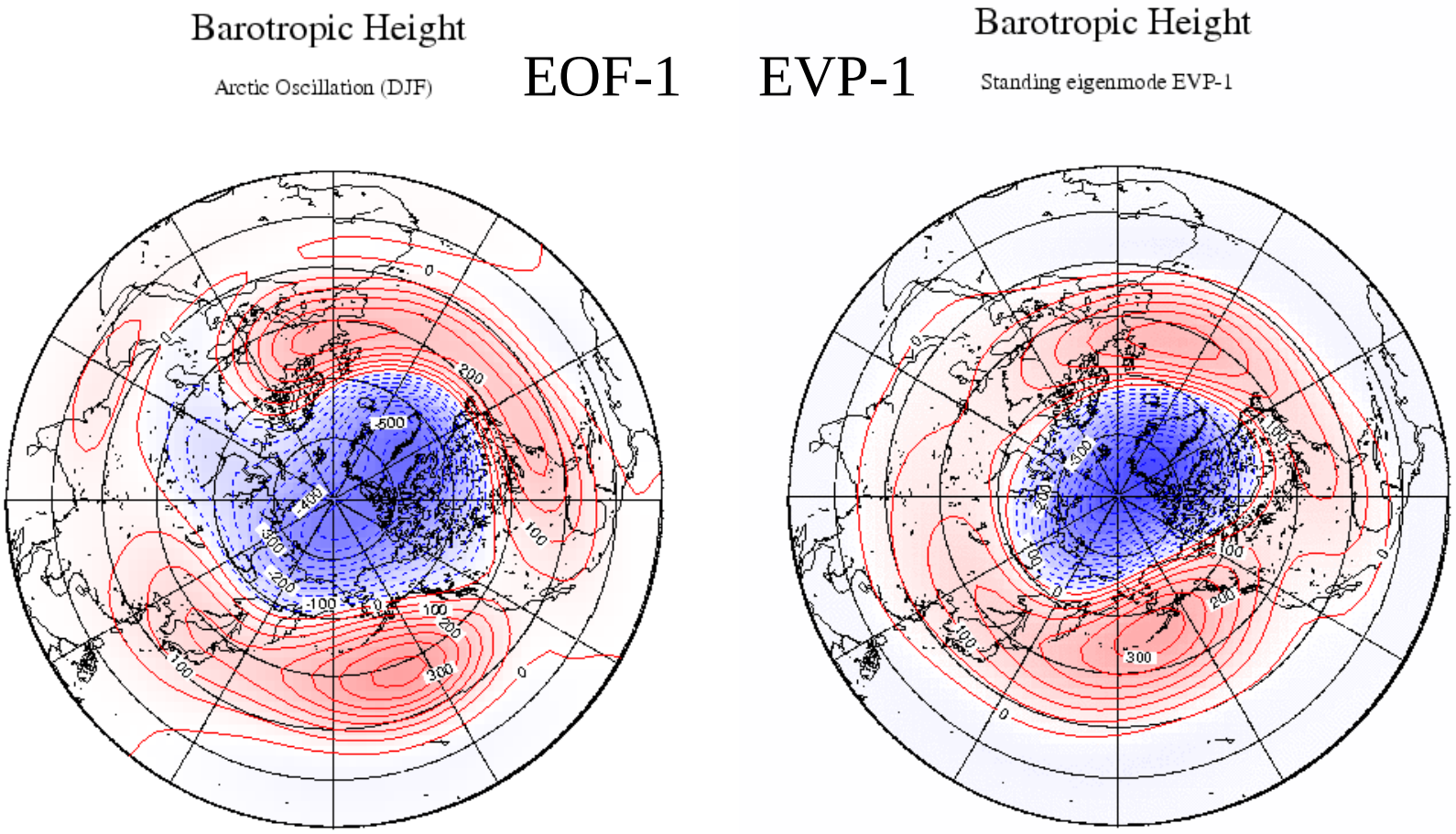




Arctic Oscillation
Singular eigenmode theory

AO (DJF)

Eigenmode



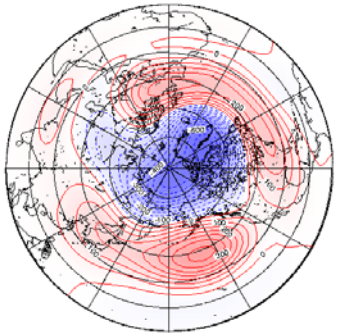
AOI Equation for AO Index

3D Spectral Primitive Equation

$$\frac{dw_i}{d\tau} + i\sigma_i w_i = -i\sum_{j=1}^{K}\sum_{k=1}^{K} r_{ijk} w_j w_k + s_i$$

Time change L N F

AO eigen vector



Definition : $\mathrm{AOI} = \langle w_i', z_i \rangle$

AO is obtained as EOF-1 of the time series data of the state variable w_i

AOI Equation

$$\frac{d\langle w_i', z_i\rangle}{dt} = \langle -i\sigma_i w_i' - i\sum_{jk} r_{ijk}(\overline{w_k} w_j' + \overline{w_j} w_k'), z_i\rangle + \langle -i\sum_{jk} r_{ijk} w_j' w_k' - i\sum_{jk} r_{ijk}\overline{w_j' w_k'}, z_i\rangle + \langle f_i', z_i\rangle$$

Time change of AOI

Linear term

Non-linear term

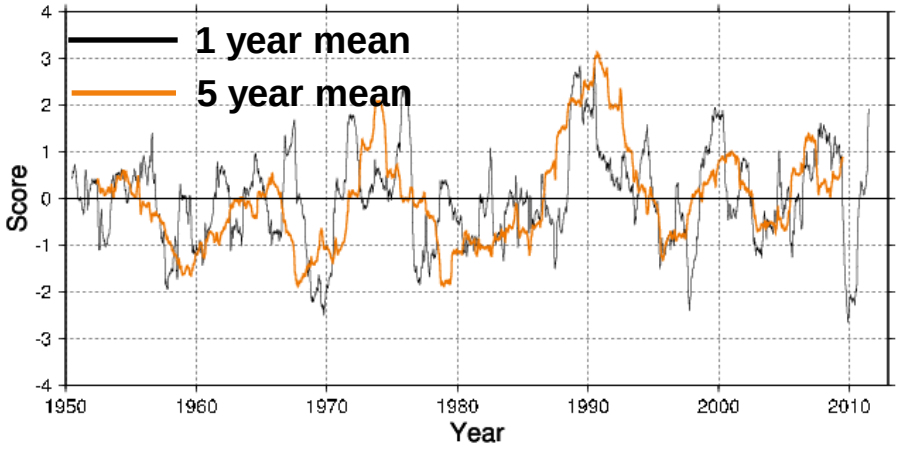
Forcing

AOI equation enables us to analyze the dynamical cause of the AO

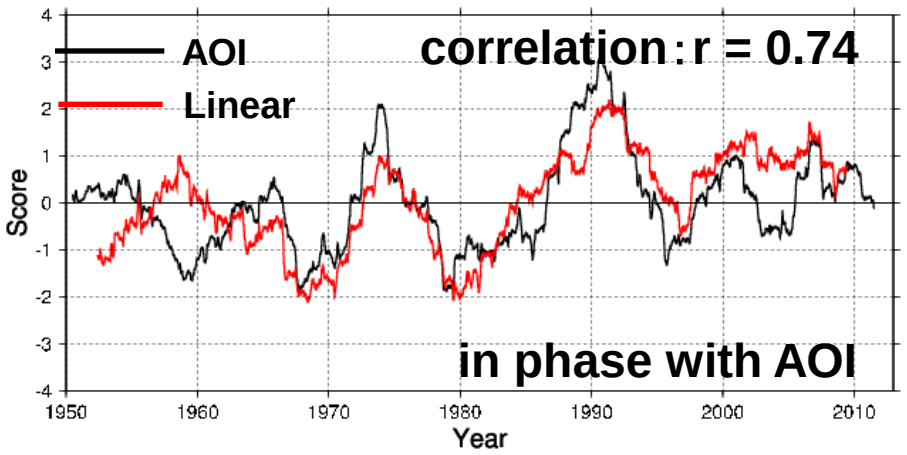
Results of time series for each term

AOI an AOI equation terms for 1950 to 2012 by NCEP

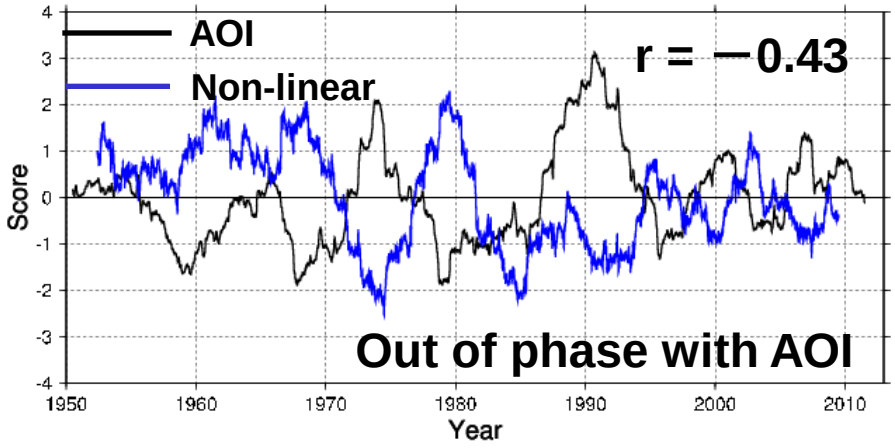
AOI



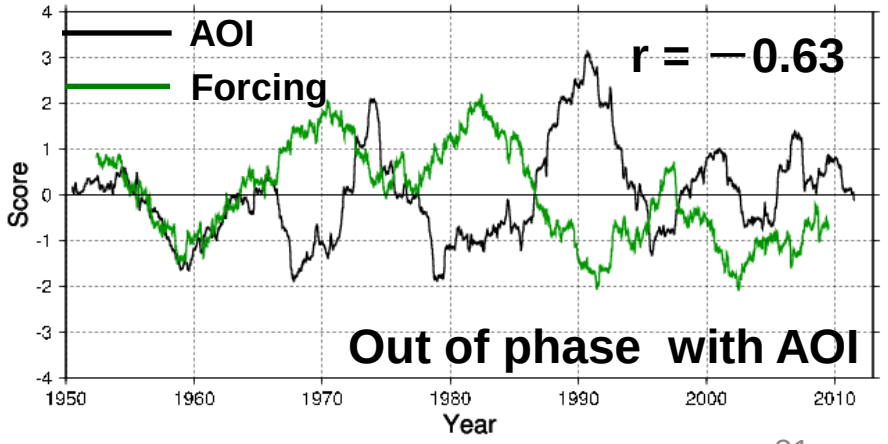
Linear term



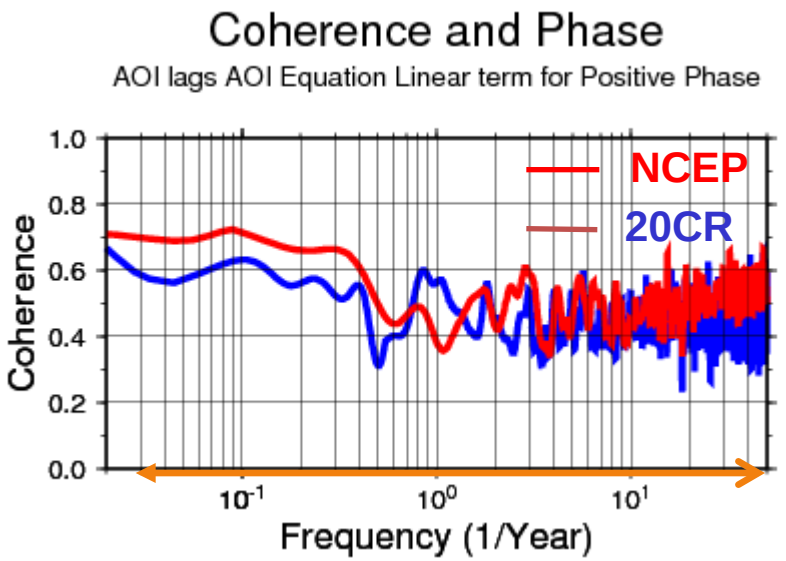
Nonlinear term

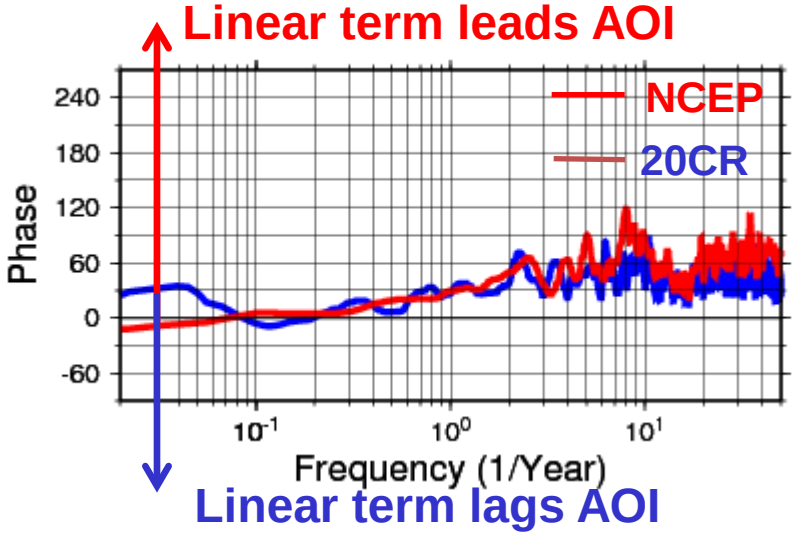


Force term



Cross-spectral analysis of time series





$$\frac{d(AOI)}{dt} = \boxed{L} + N + F$$

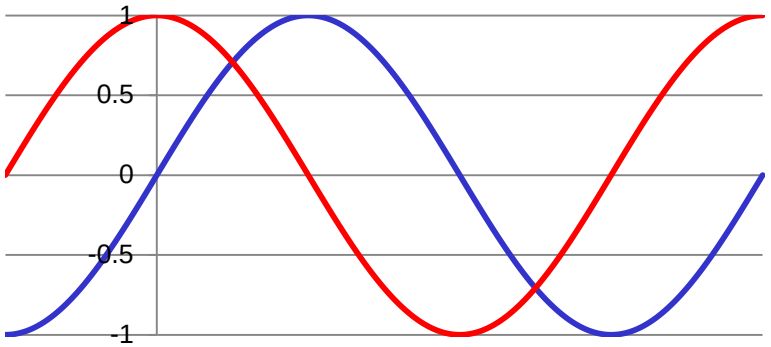
- **AOI and Linear Term**

Coherence 0.4~0.6 is high

Low-frequency: L is in phase

High-frequency: L leads AOI by 90°

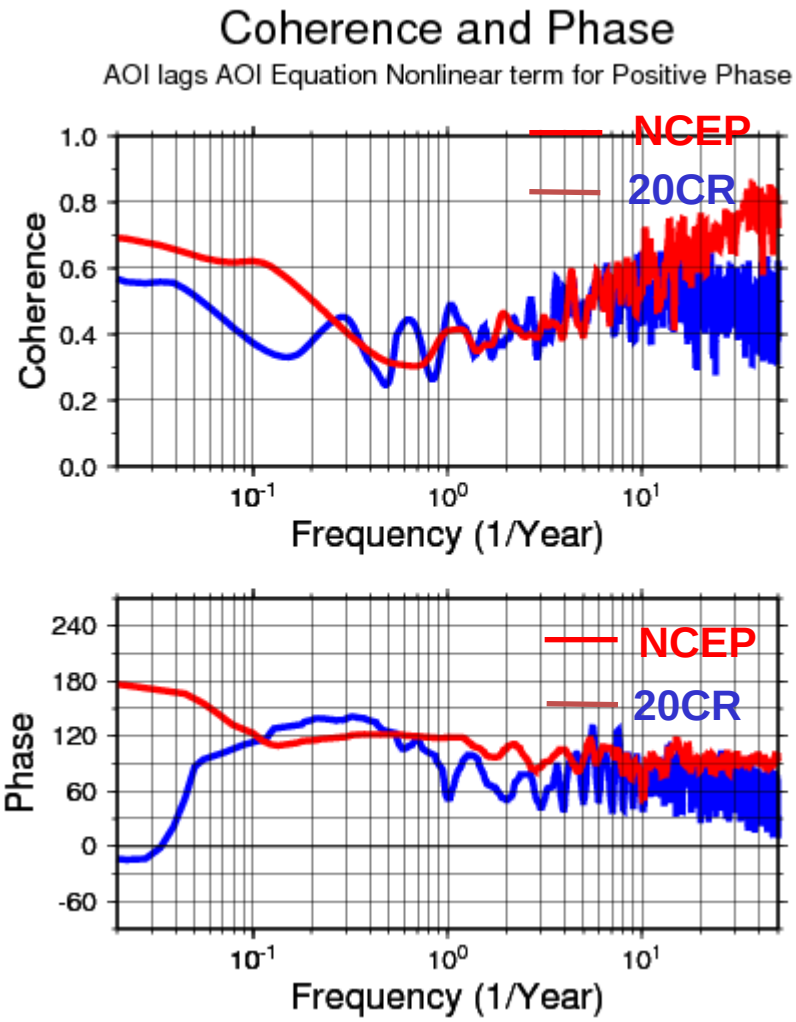
EVP of Linear term : $Az_i = \lambda z_i$



Leads ← → Lags

Cross-spectral analysis of time series

$$\frac{d(AOI)}{dt} = L + \boxed{N} + F$$

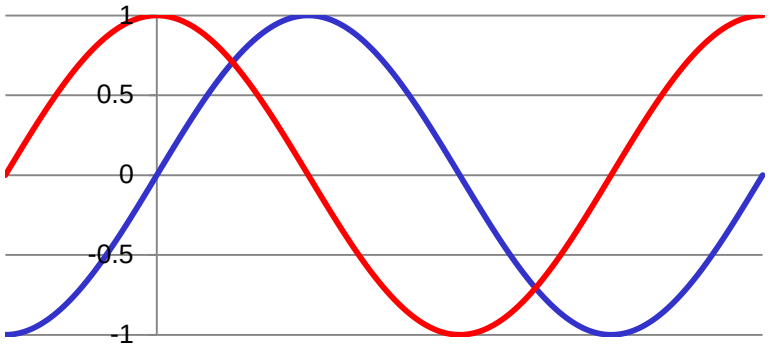


- **AOI and Non-linear Term**

Coherence 0.4~0.8 is very high

Low-frequency: N is out of phase

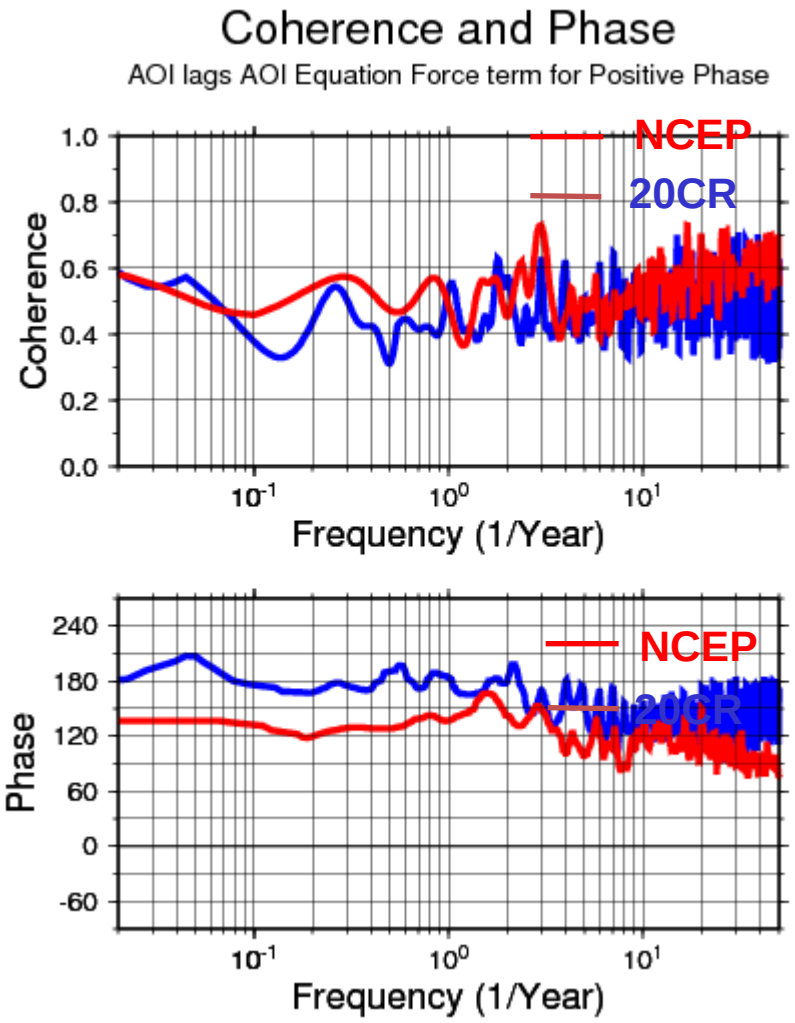
High-frequency: N leads AOI by 90˚



Leads ← → **Lags**

Cross-spectral analysis of time series

$$\frac{d(AOI)}{dt} = L + N + \boxed{F}$$

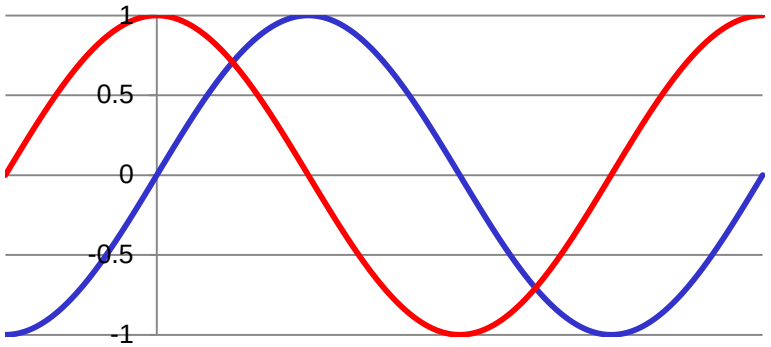


- **AOI and Forcing Term**

Coherence 0.4~0.6 is high

Low-frequency: F is out of phase

High-frequency: F leads AOI by 90°



Leads ← → **Lags**

Research in General Circulation

- General circulation of the atmosphere
- Global warming and tropical circulation
- Arctic Oscillation as natural variability
- Arctic cyclone and tropical cyclone
- Spectral energetics using normal modes
- Blocking and abnormal weather
- Dynamics of baroclinic waves

End
Thanks