

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, Koshihara, Katoh, Doan, Nishi
MS:(10) Umino, Kino, Baba, Kudoh, Kuno, Fujita, and others



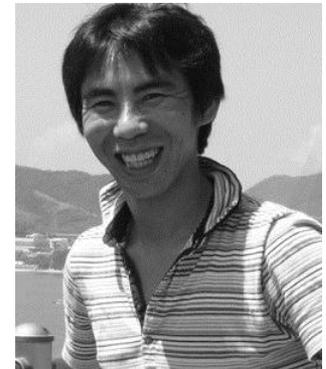
Tanaka



Kusaka



Ueda



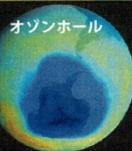
Wakazuki



気象・地球環境部門では地球温暖化やオゾンホールなどの地球環境問題や、天気予報、異常気象、台風、竜巻などの研究が行われています。

数値モデルシミュレーション

大気大循環研究



オゾンホール



メソ気象学



DL-01

竜巻

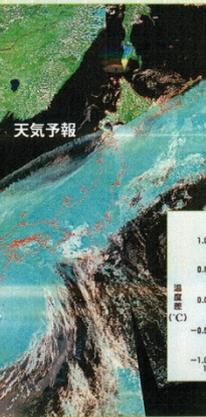
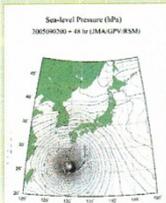
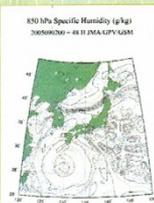
豪雨



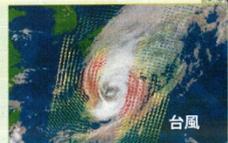
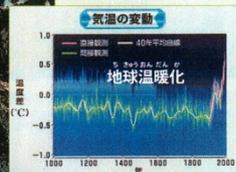
成層圏の雲

大規模気象データベースの構築

天気予報や気候変動の将来予測には大気大循環モデルが用いられ、その予測の精度向上には高速計算機が必要です。そのため計算科学における最新技術が導入されています。



天気予報



台風

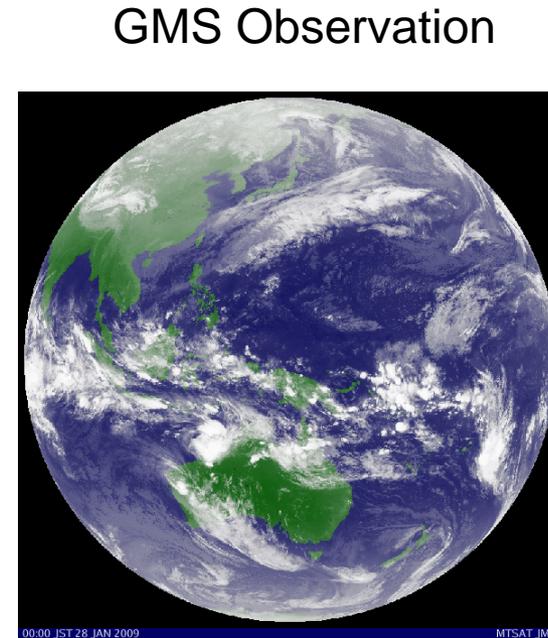
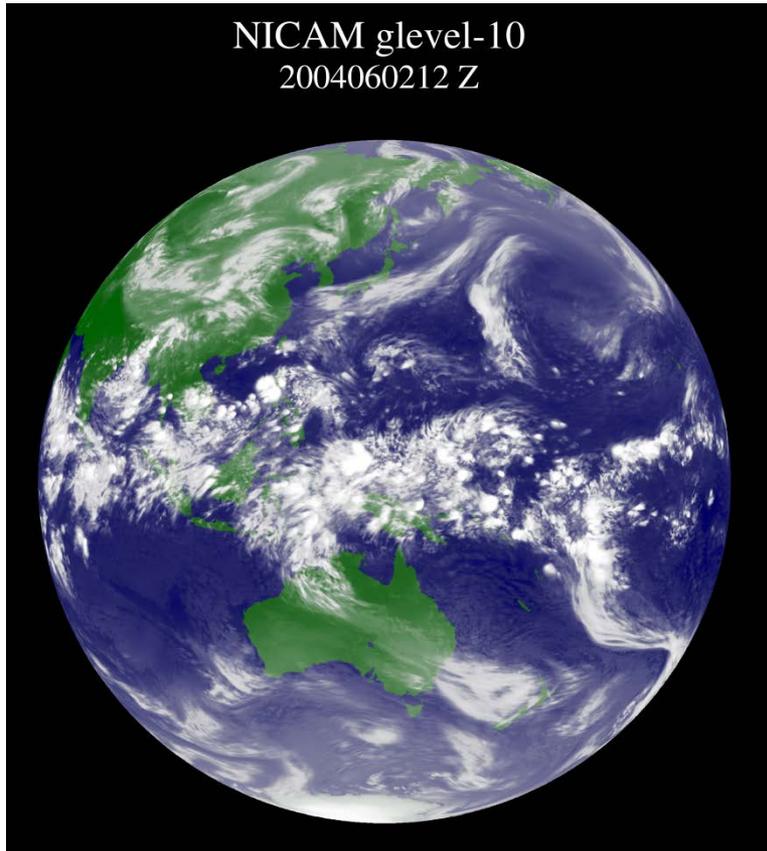
Research activity (H.L. Tanaka)

- 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

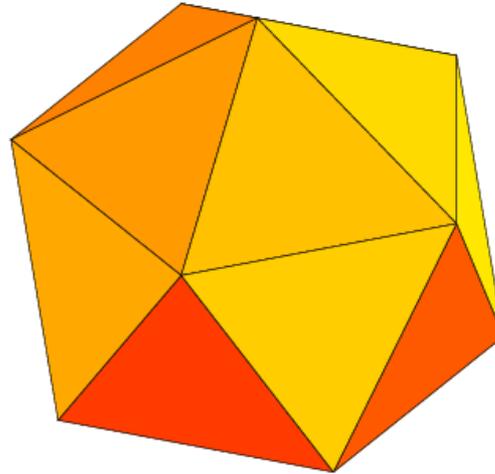
NICAM

by T2K-Tsukuba

Original Icosahedron

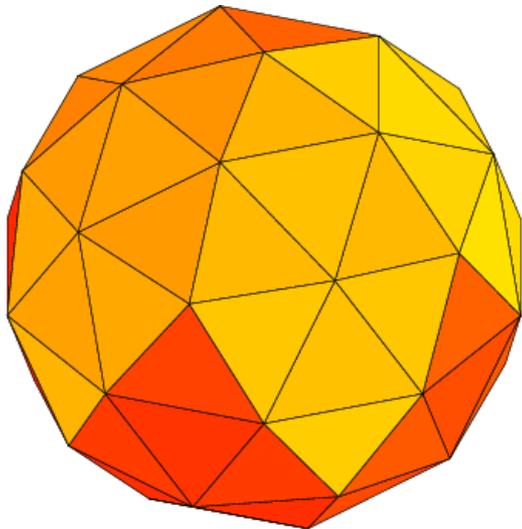
Satoh et al. AORI

Glevel-0

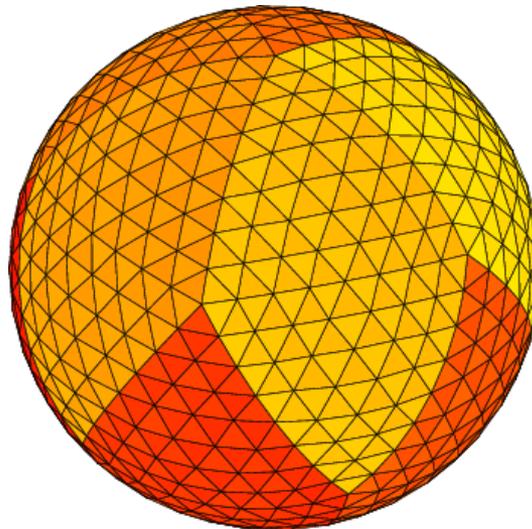


- Glevel-5: $\Delta x=250\text{km}$
- Glevel-6: $\Delta x=120\text{km}$
- Glevel-7: $\Delta x=60\text{km}$
- Glevel-8: $\Delta x=28\text{km}$
- Glevel-9: $\Delta x=14\text{km}$
- Glevel-10: $\Delta x=7\text{km}$
- Glevel-11: $\Delta x=3.5\text{km}$

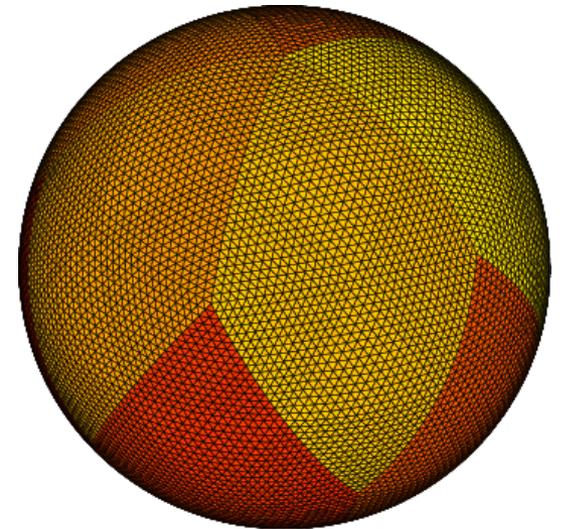
Glevel-1



Glevel-3

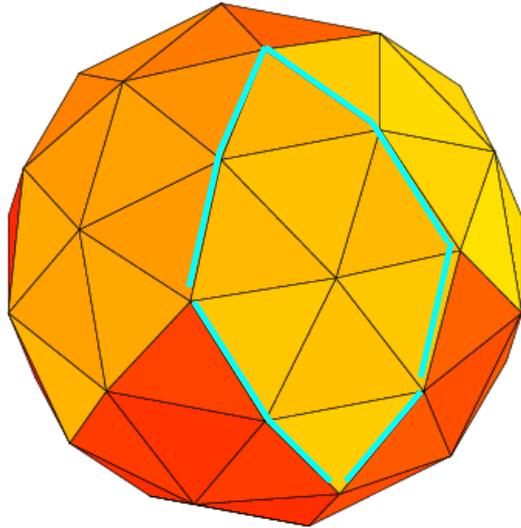


Glevel-5



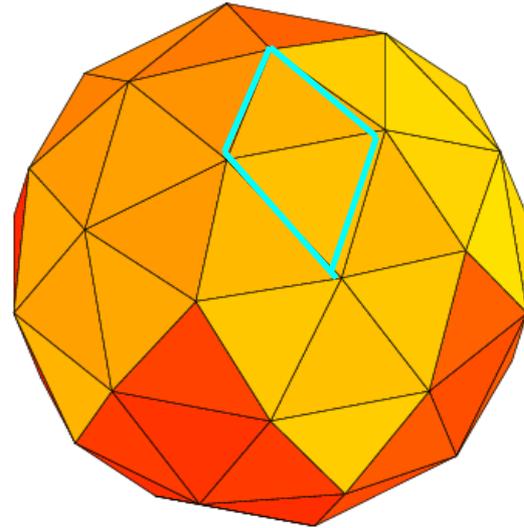
Non-hydrostatic AGCM: NICAM

Glevel-1



Rlevel-0

Glevel-1



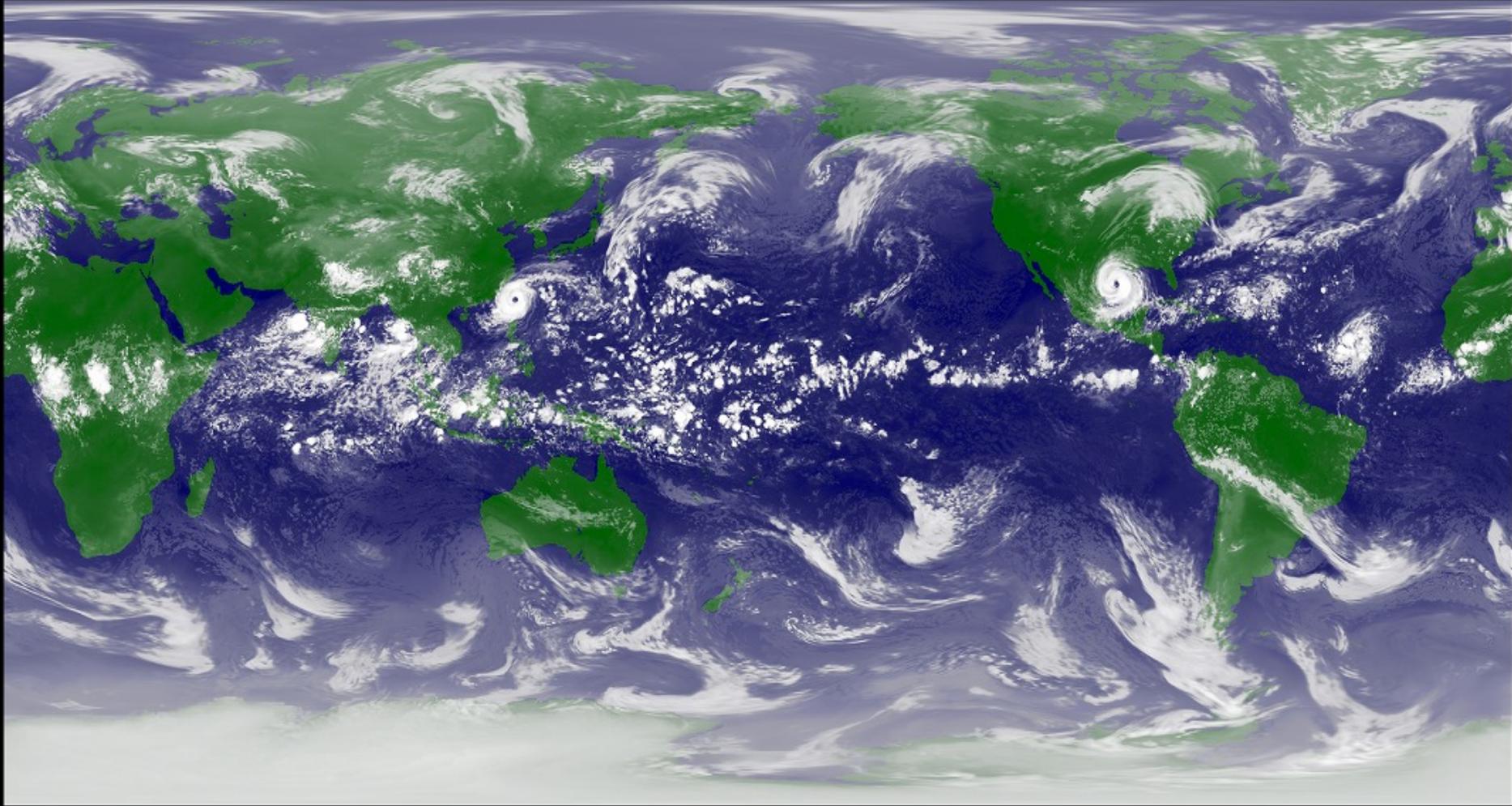
Rlevel-1

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

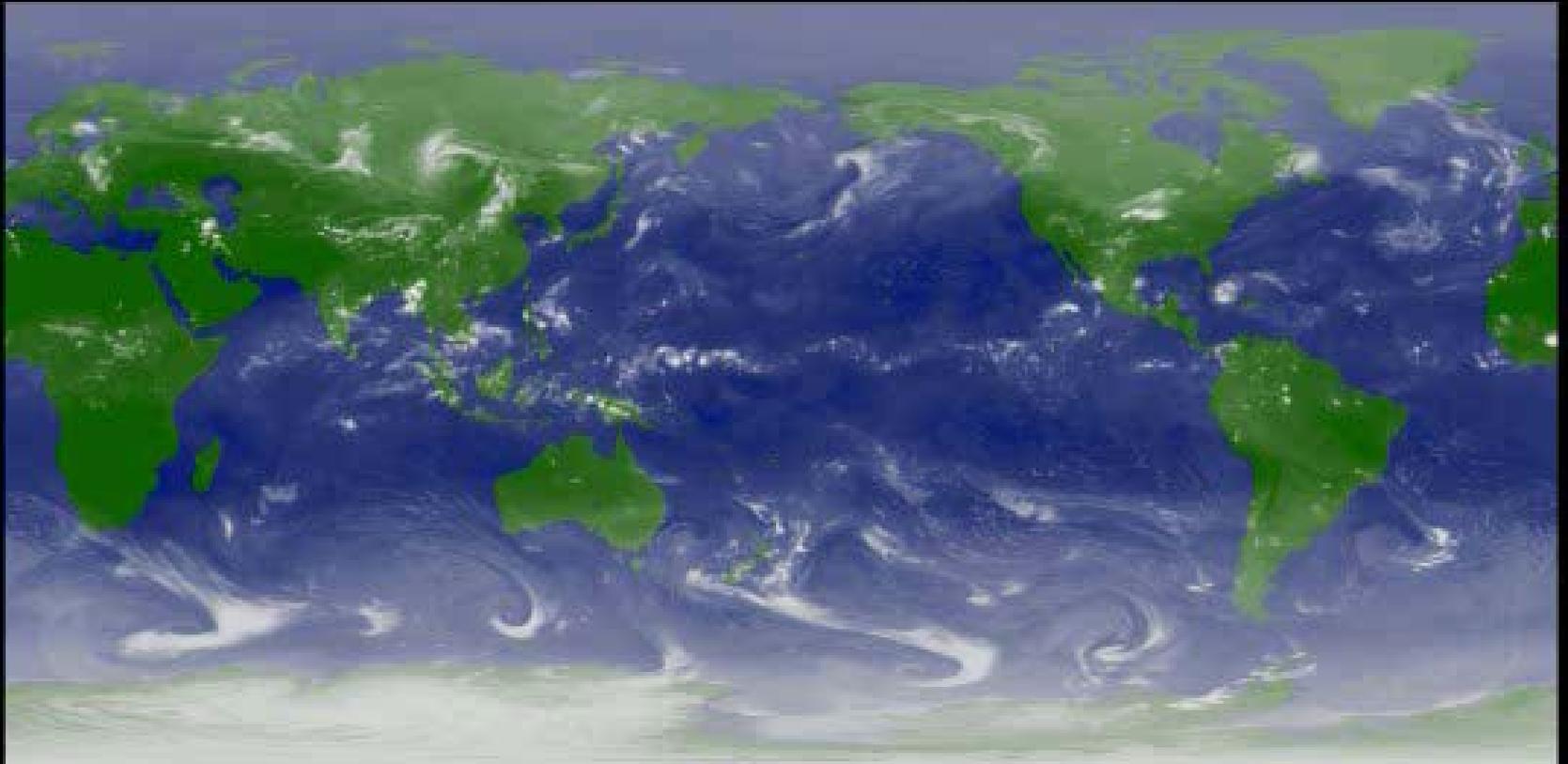
Numerical Simulation of Arctic and Tropical Cyclones Using NICAM Installed at CCS Tsukuba



Typhoon Sinlaku and Hurricane Ike in 2008

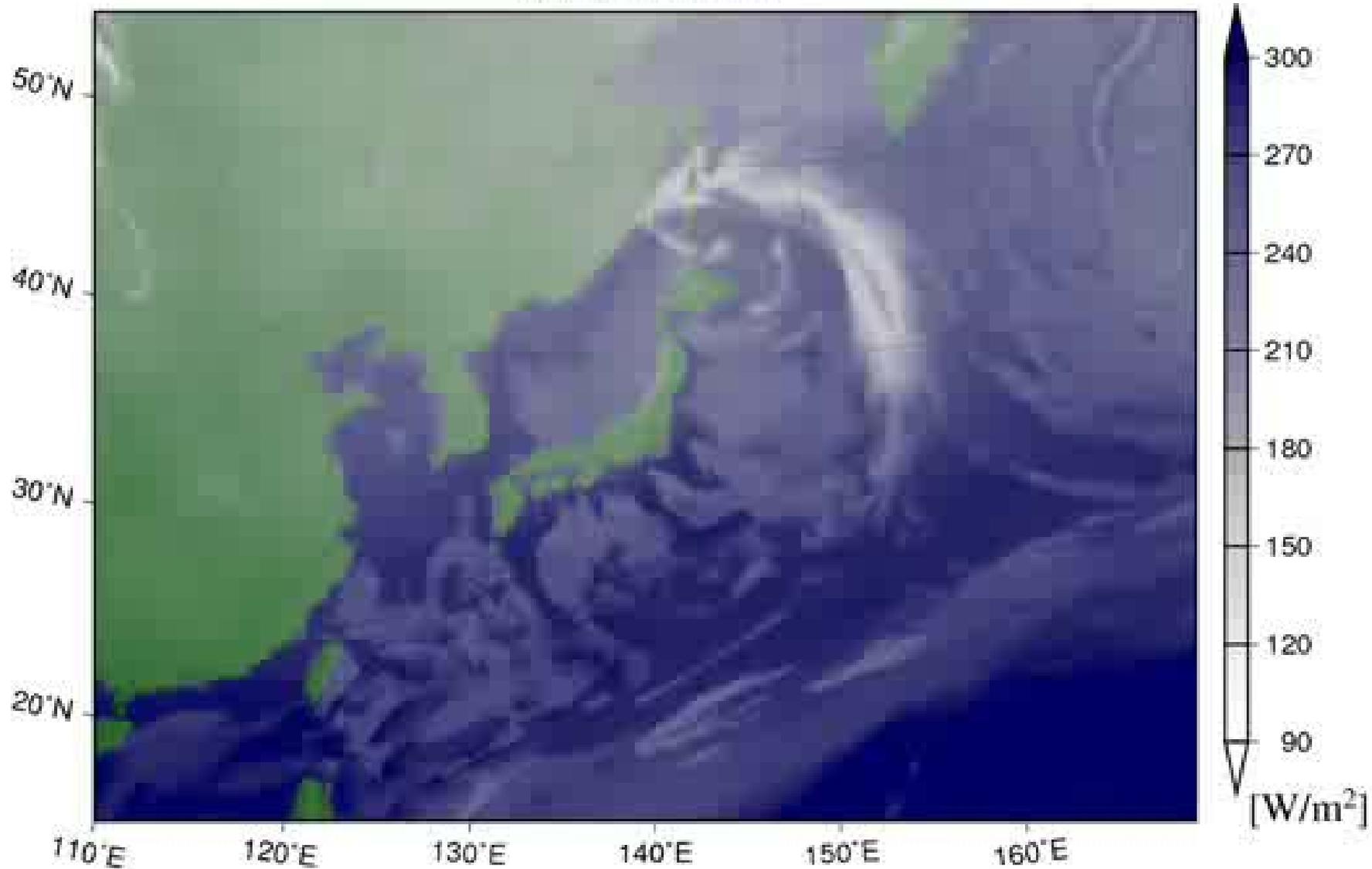
NICAM glevel-10

2008090812 Z



NICAM gl-10 IR (JAPAN)

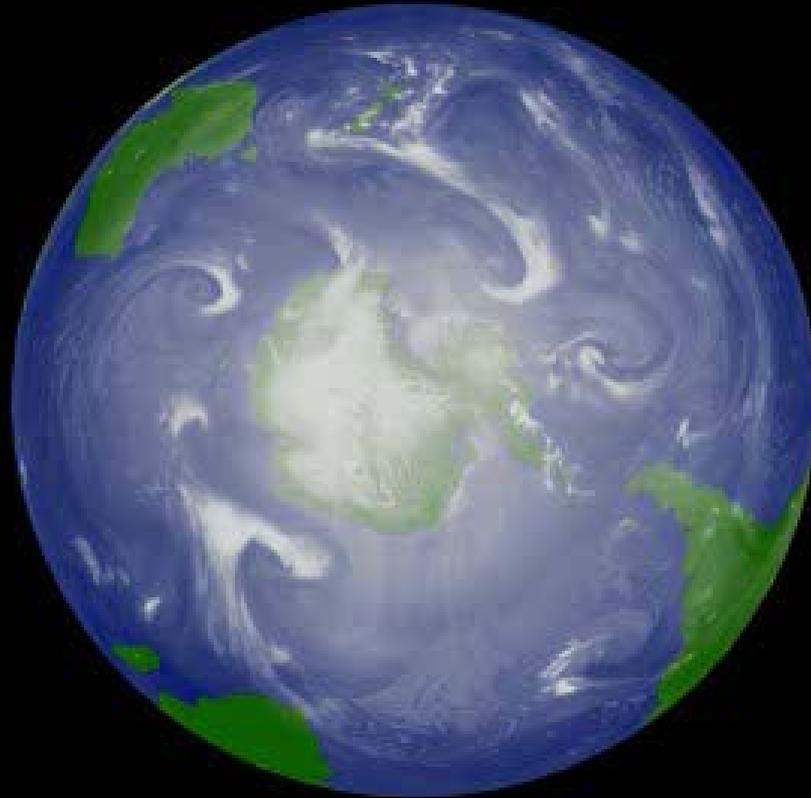
2009011512 Z



NICAM glevel-10
2009011512 Z

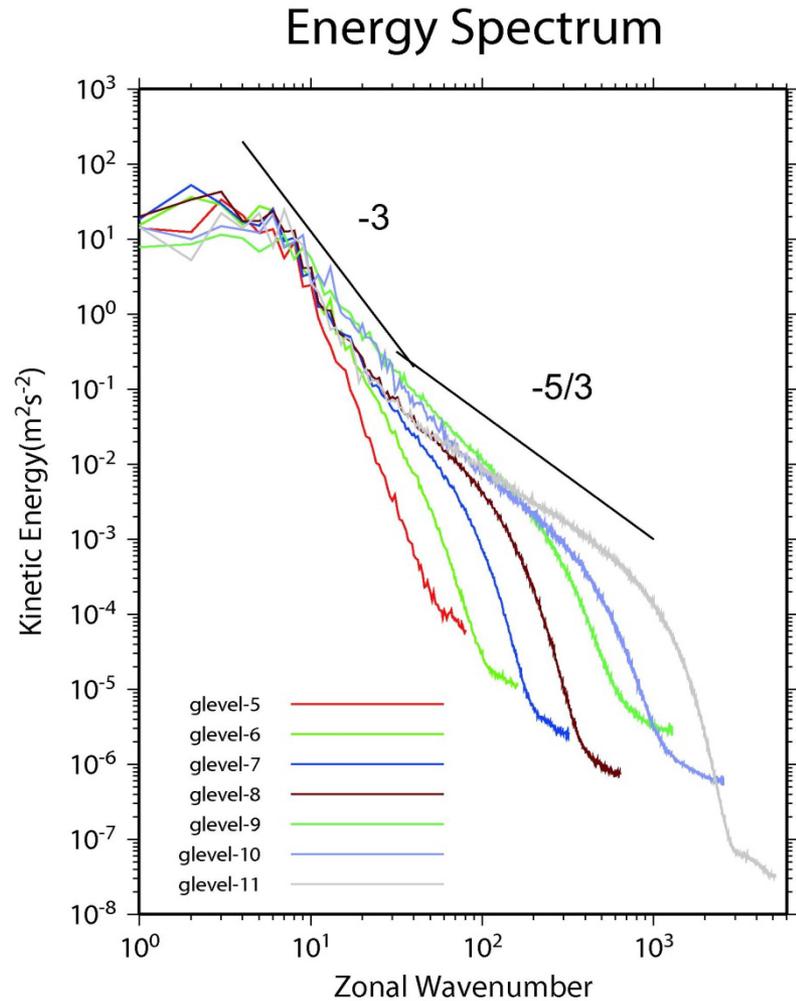
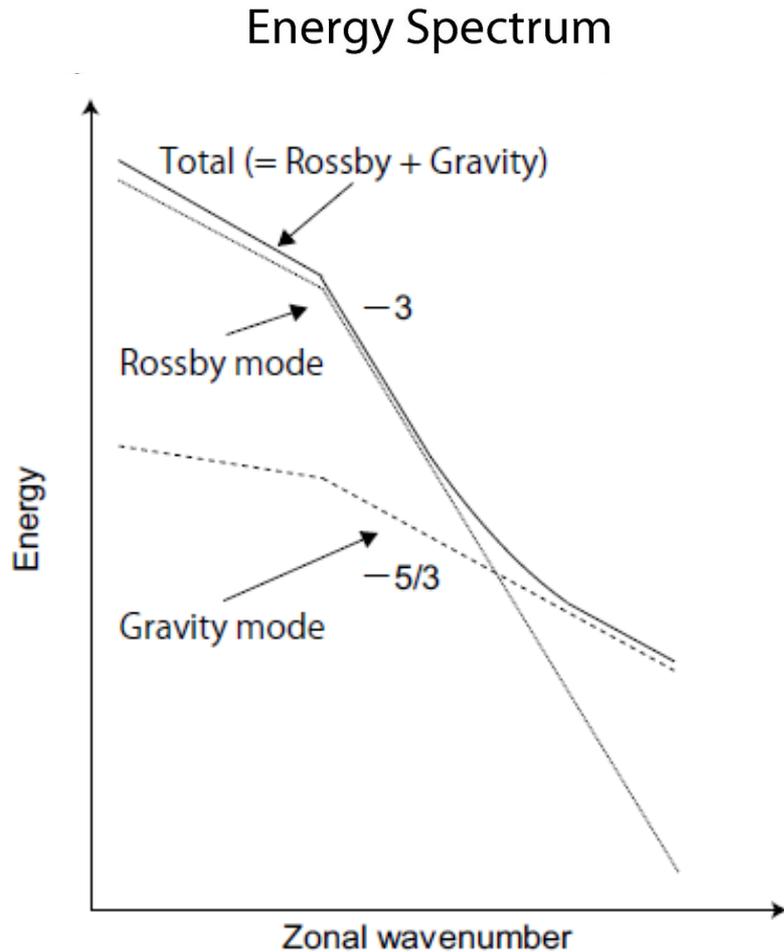


NICAM glevel-10
2008090812 Z



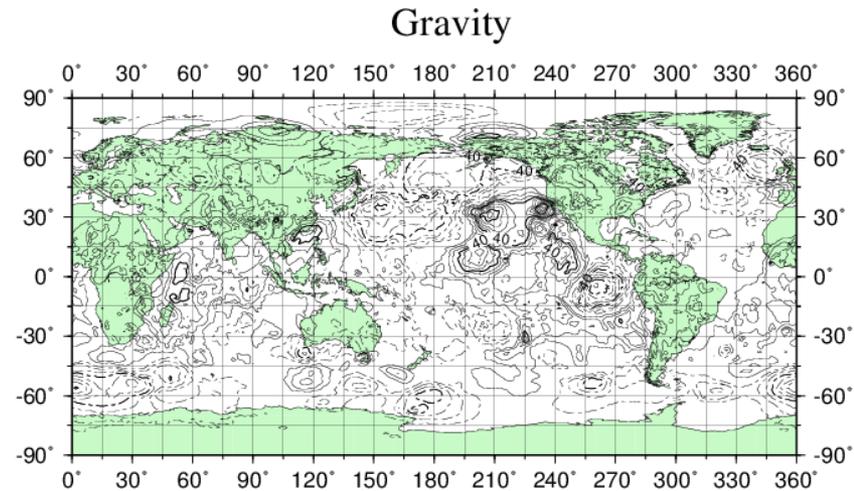
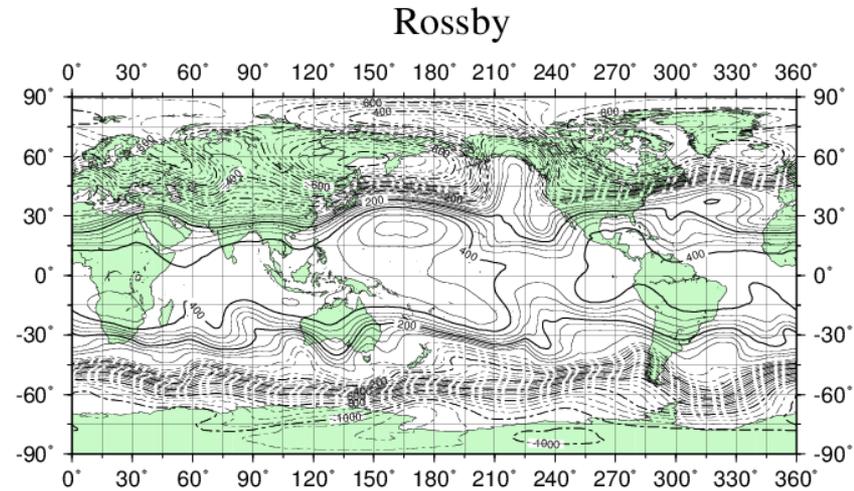
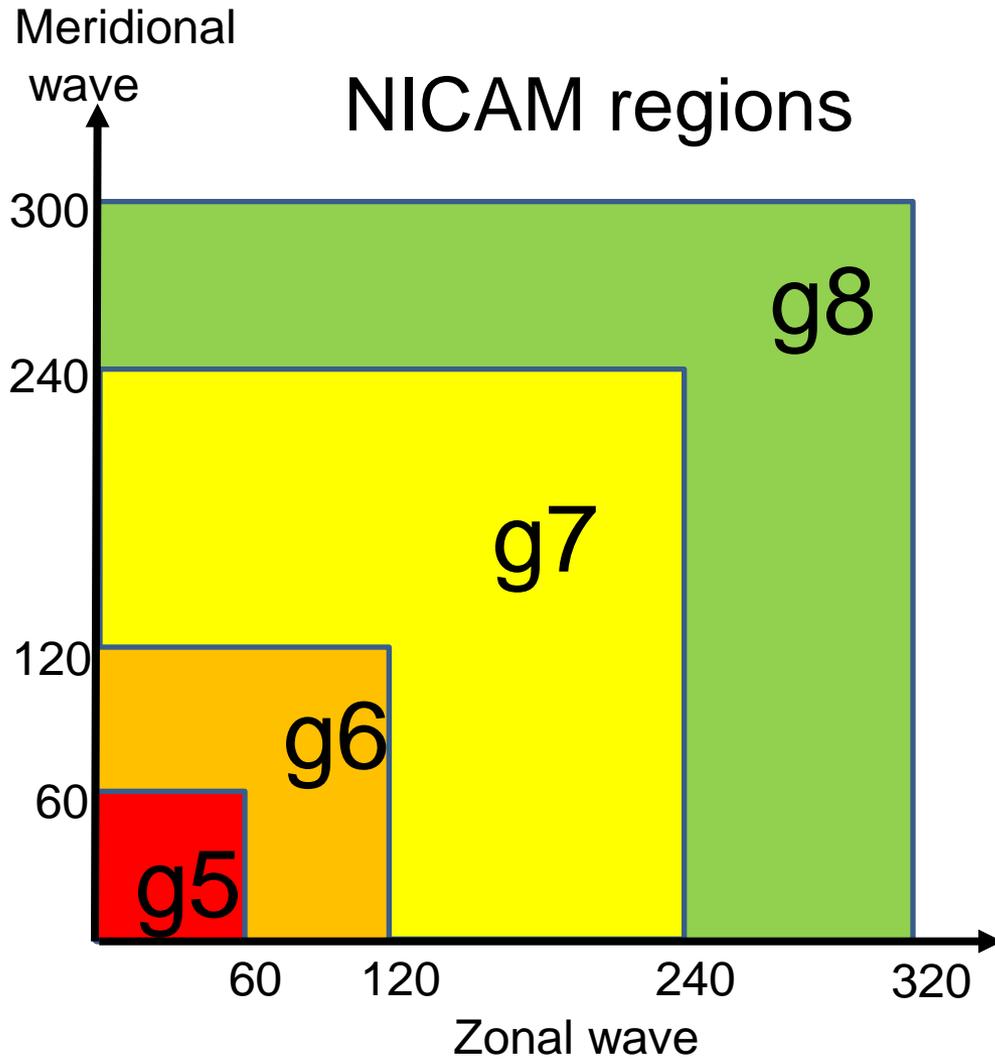
Global Energy Spectrum of NICAM

Normal mode energetics analysis



(Terasaki, Tanaka, and Satoh 2009, SOLA)

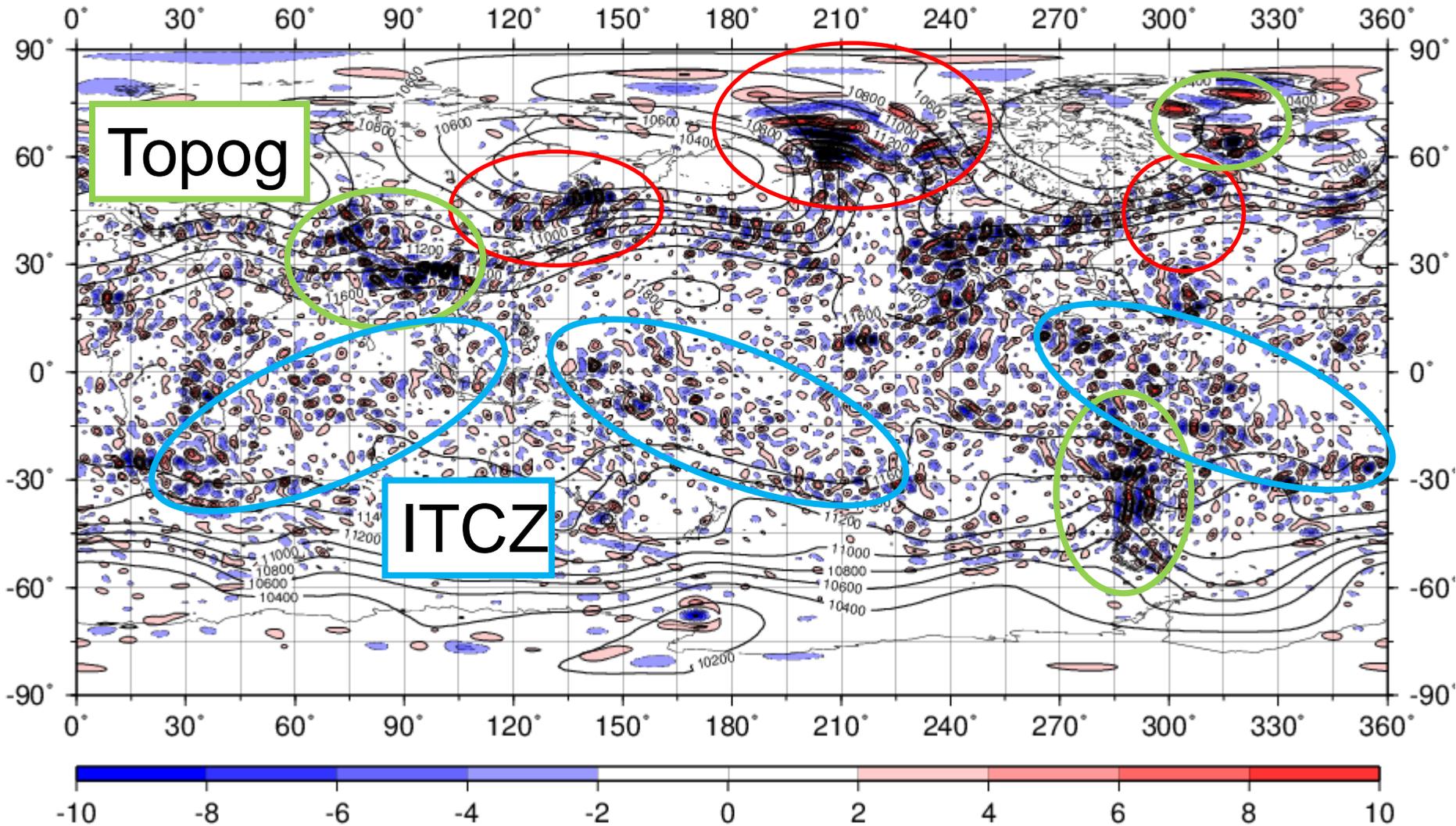
Rossby wave world and gravity wave world



Gravity waves in small scale

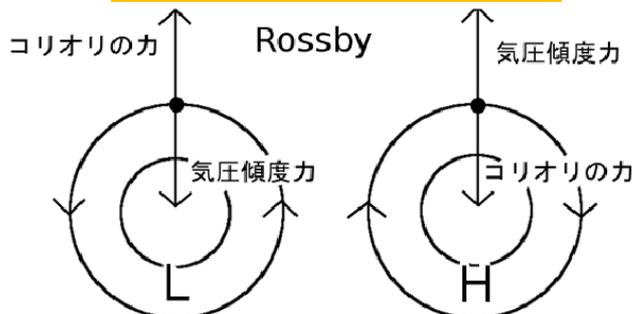
192 hPa Hight
NICAM glevel 8
2007/11/27/12Z + 72hour

Area B

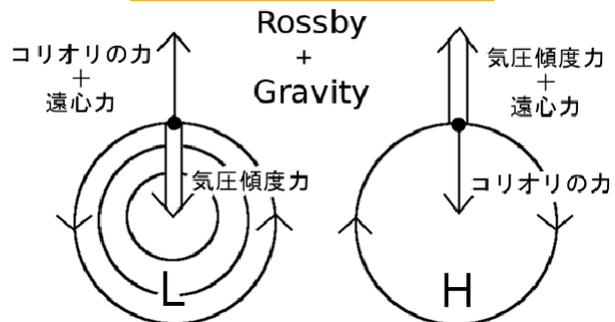


Gravity waves in large scale

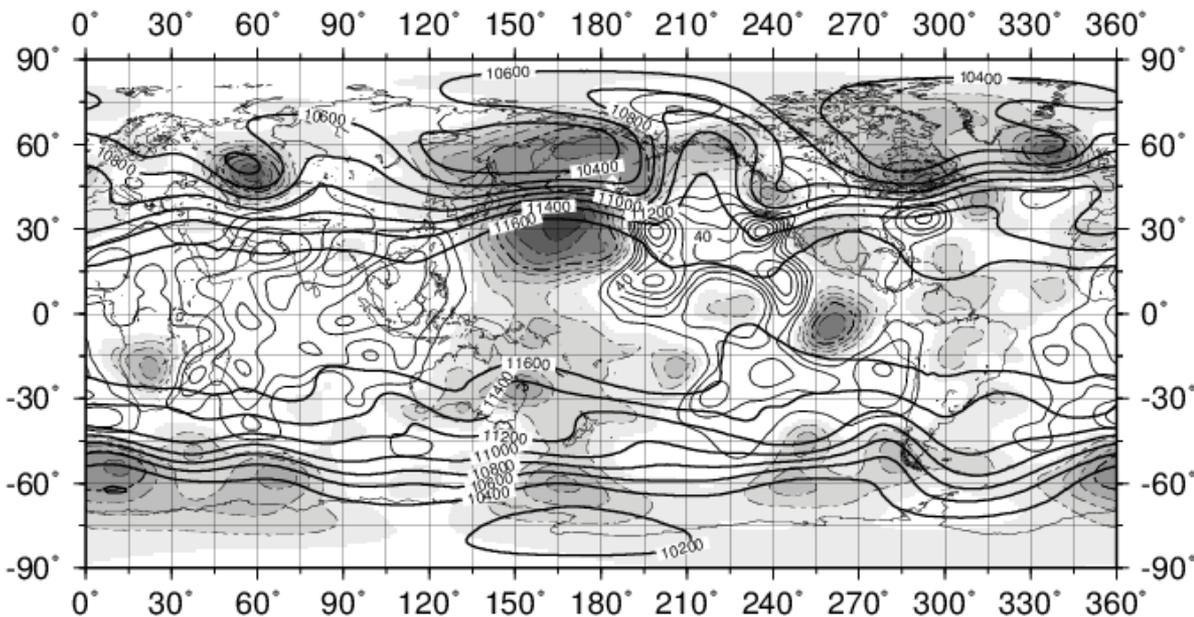
Geostrophic wind



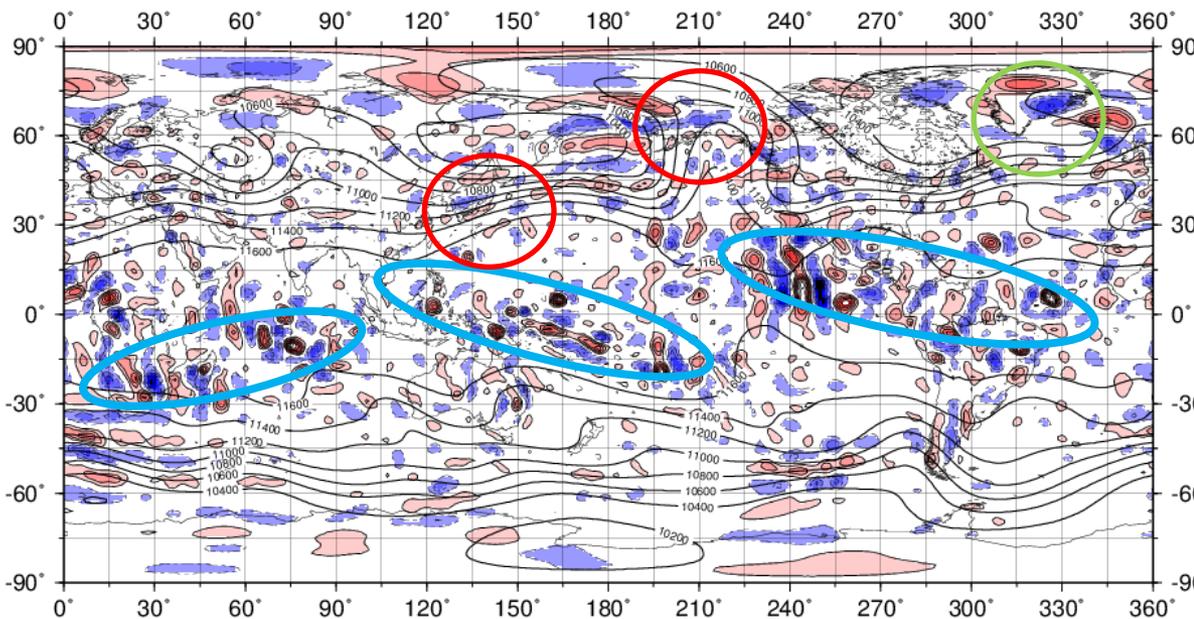
Gradient wind



Area A1

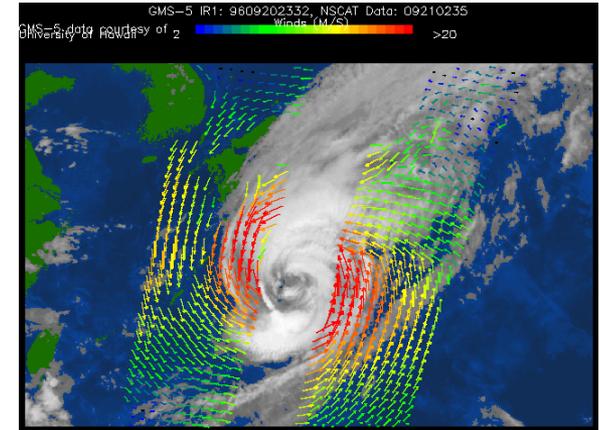


Area A2

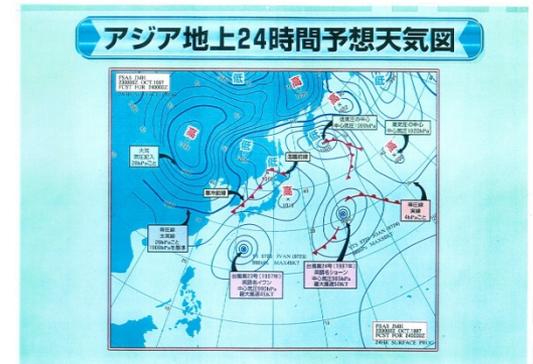
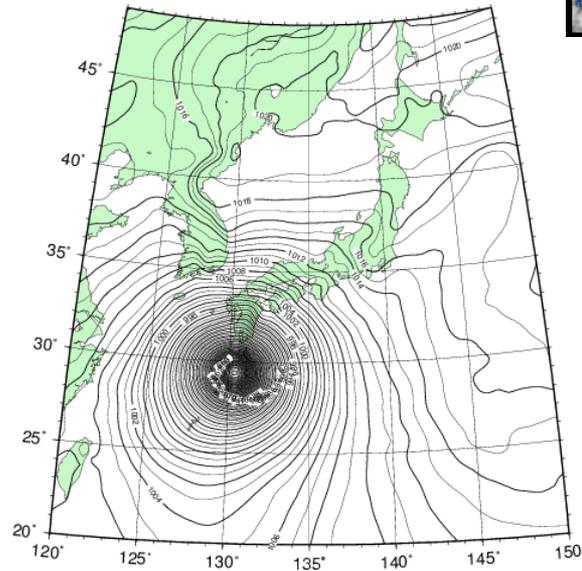
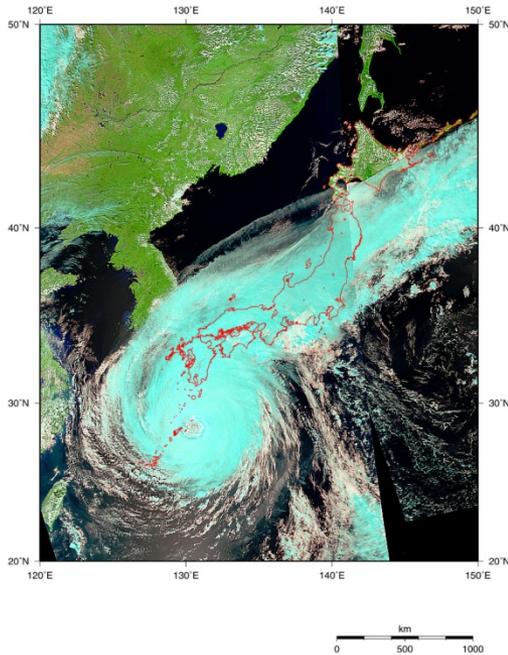


Tropical Cyclone

- Life cycle of Typhoon



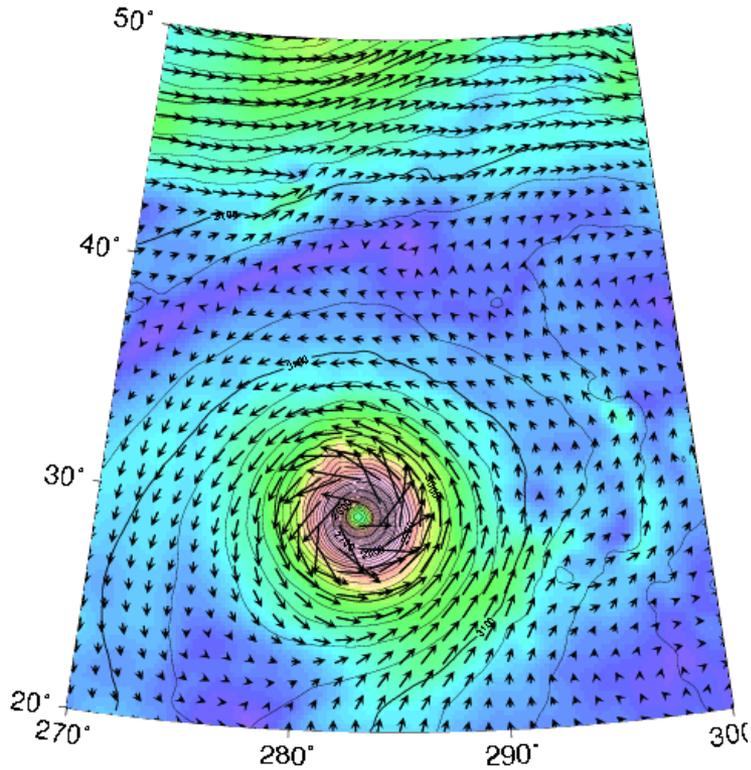
Sea-level Pressure (hPa)
2005090512 + 00 hr (JMA/GPV/RSM)



Tropical Cyclones

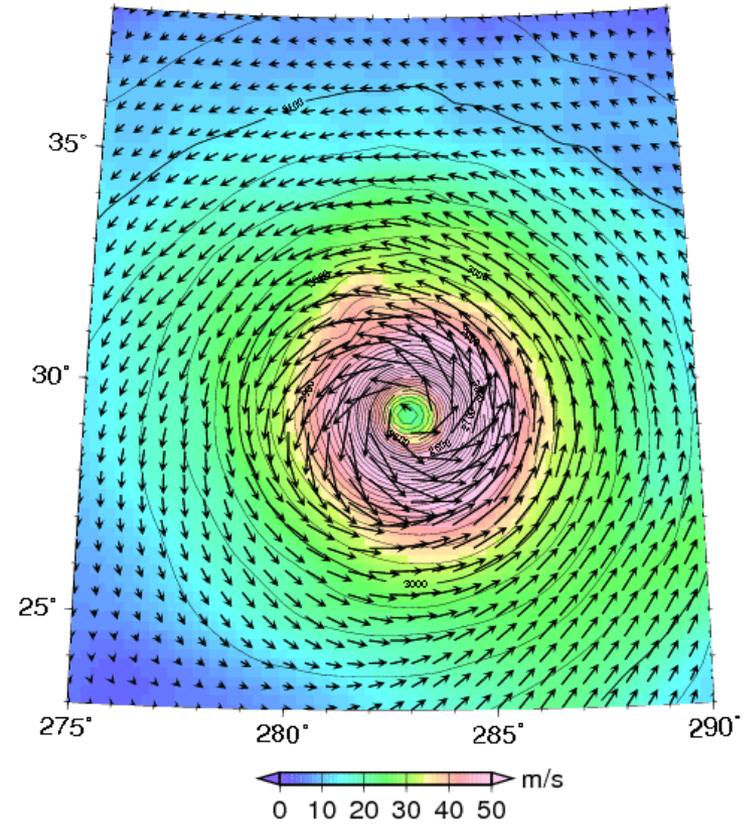
NICAM gl-8

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



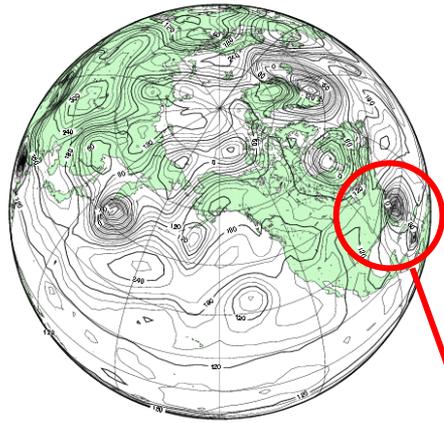
NICAM gl-8

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



1000 hPa Height

NICAM 2008070500Z+78HR



Global

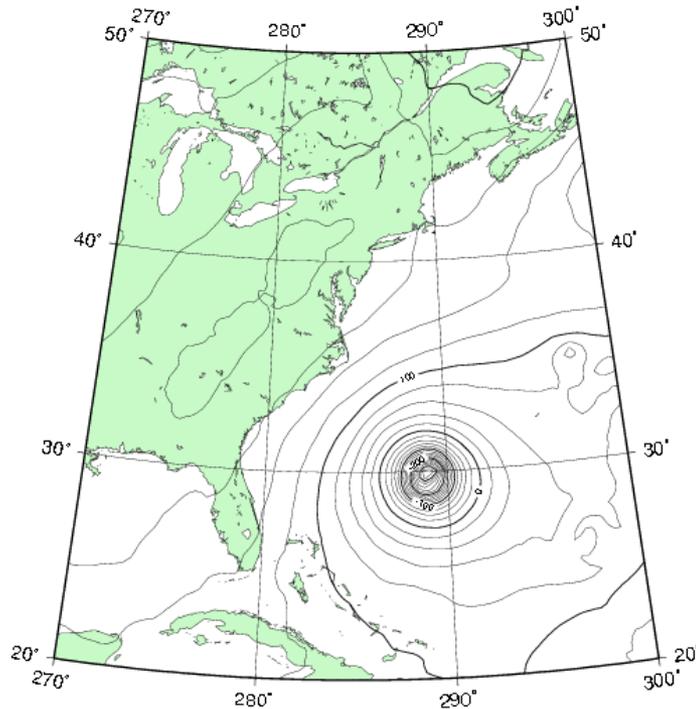
Tropical cyclone

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

1000 hPa Height

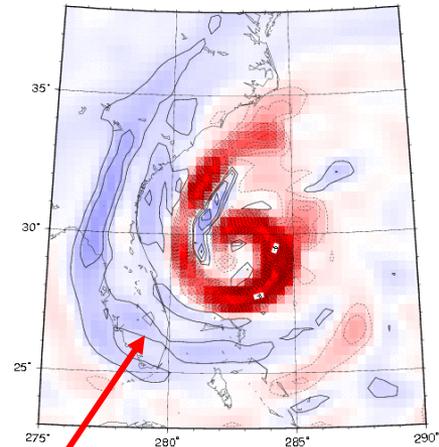
NICAM 2008070500Z+0HR

SLP



500 hPa Omega

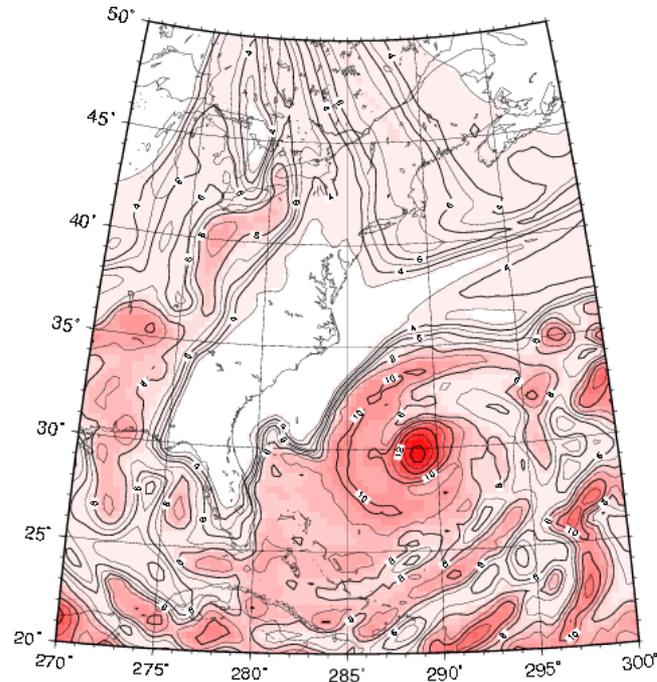
NICAM 2008070500Z+78HR



850 hPa S. Humidity

NICAM 2008070500Z+0HR

Humidity



Omega

Extra-tropical Cyclones

- Life cycle
- Warm and cold fronts

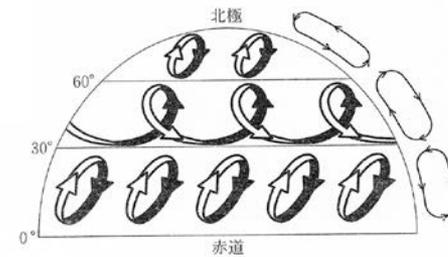
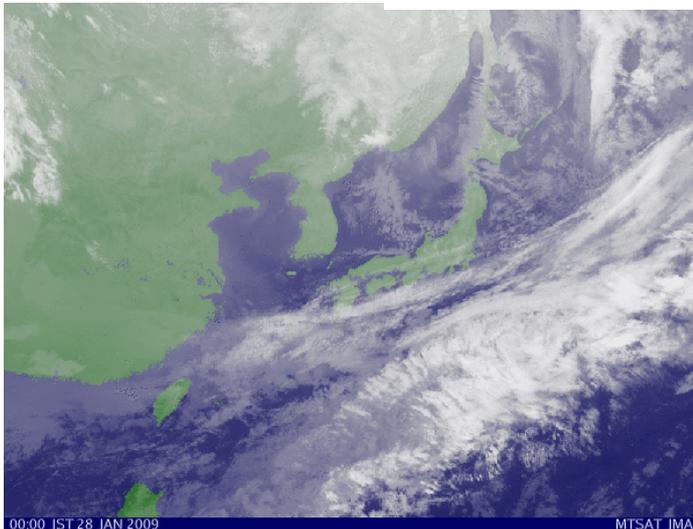
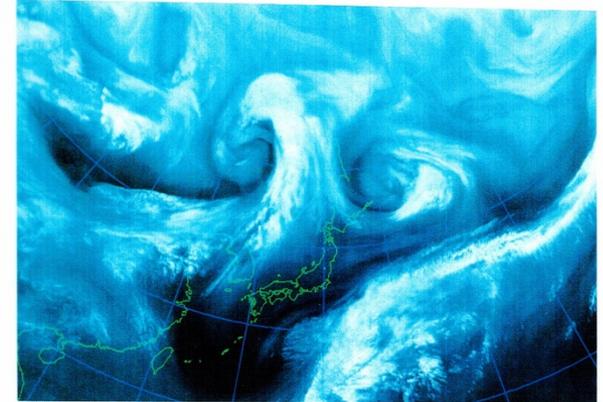
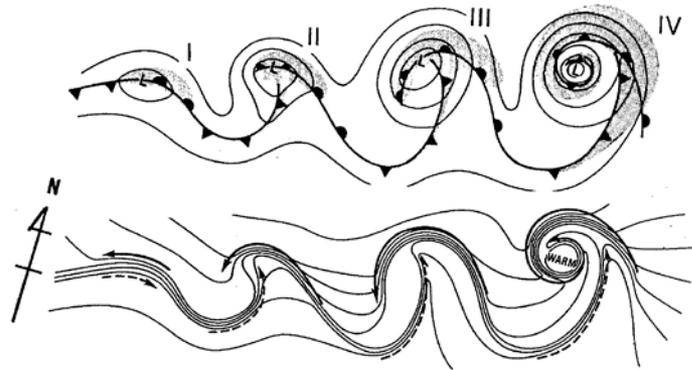
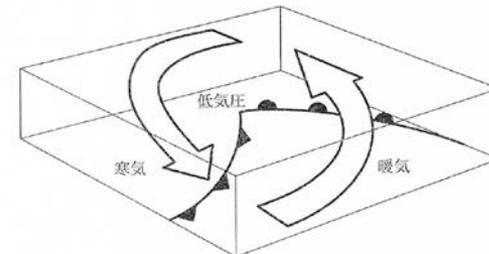


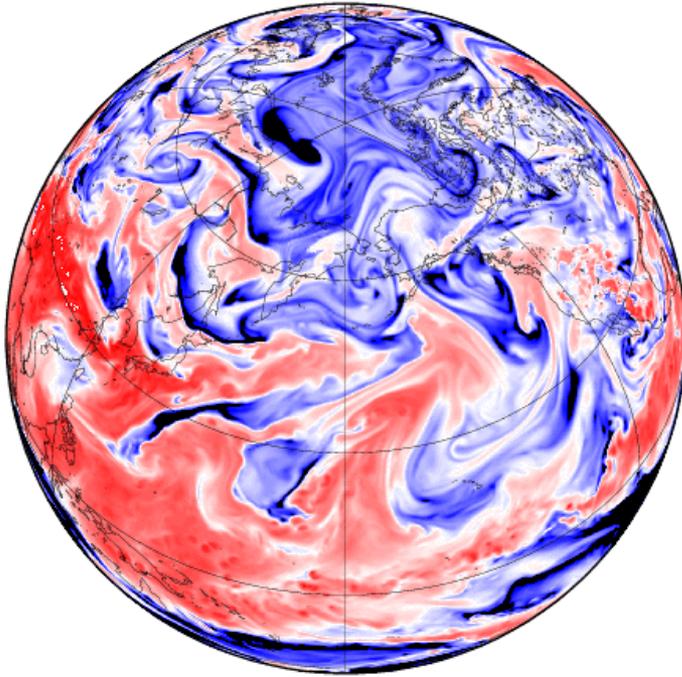
图 1



Water vapor in NICAM

500 hPa S. Humidity

NICAM 2008062100Z+0HR

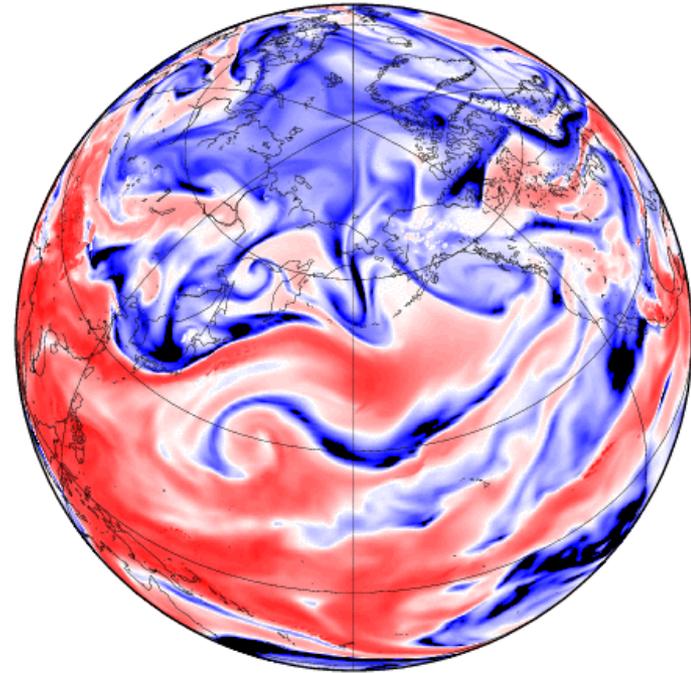


Glevel=9, (14km)

GMT 2009 Jan 30 22:26:44 CCS g10r4n256

500 hPa S. Humidity

NICAM 2004060100Z+0HR



Glevel=10, (7km)

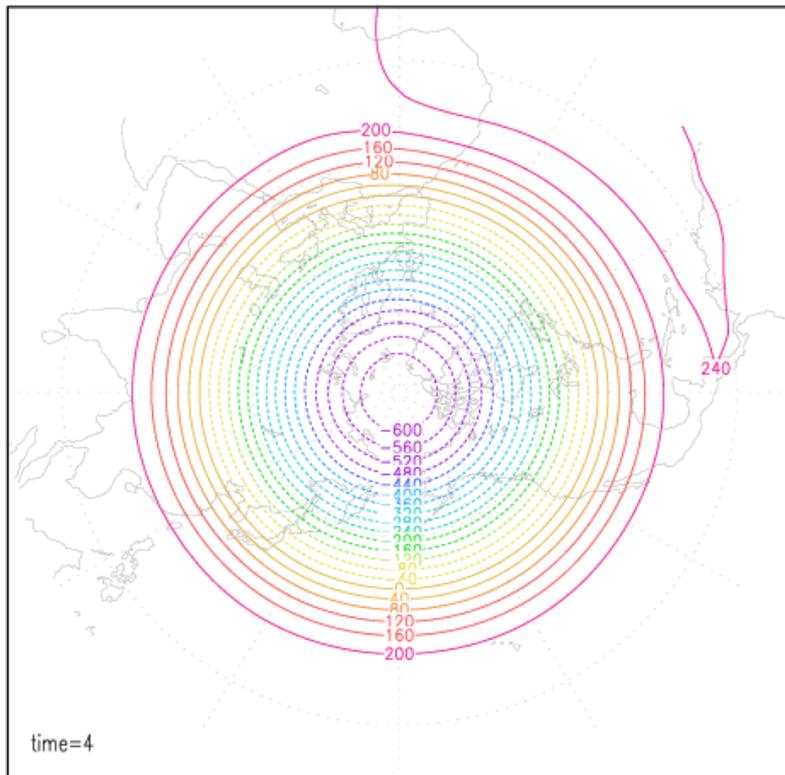
GMT 2009 Feb 4 11:21:23 CCS g10r4n256

Up-scale energy cascade

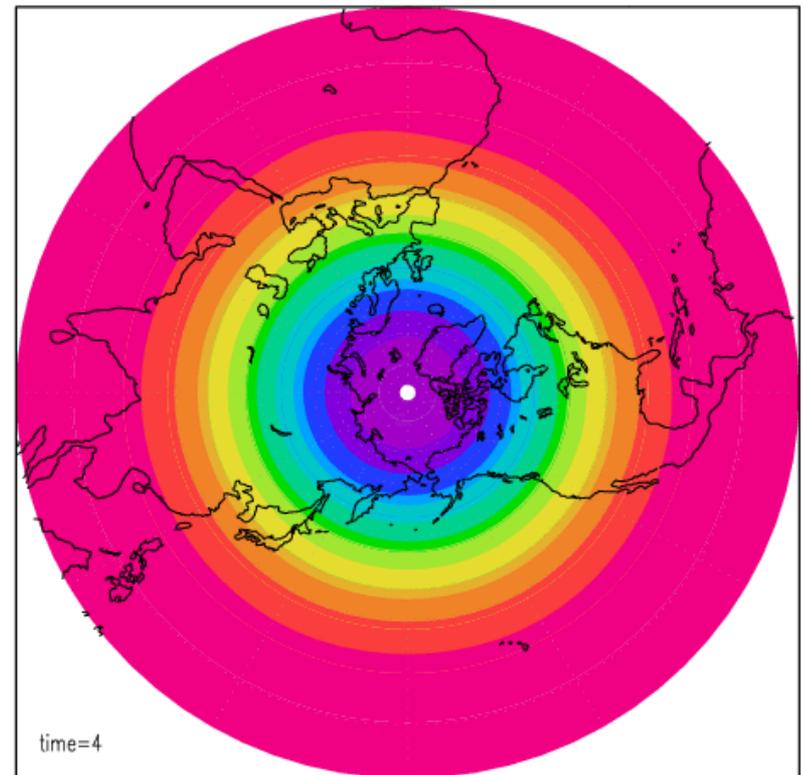
Rossby wave breaking for $n=6$

Growth rate $\times 1.7$

Barotropic Height
Wavenumber 6



Barotropic Height
Wavenumber 6

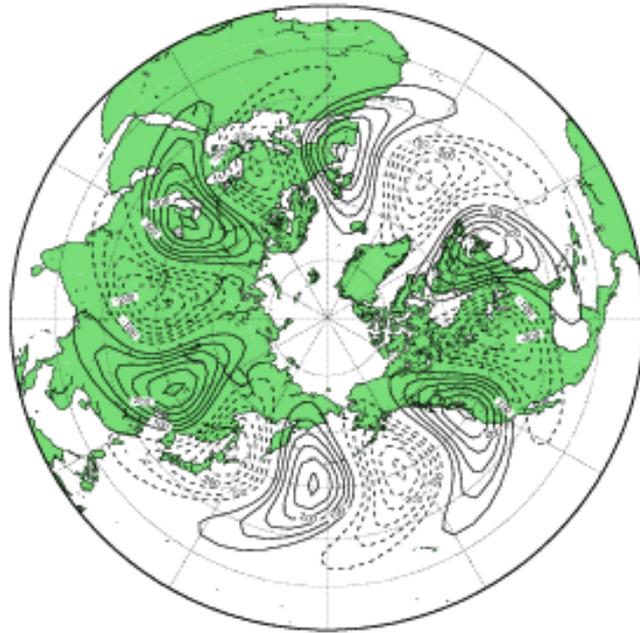


Baroclinic instability

Zonal basic state

Barotropic Height

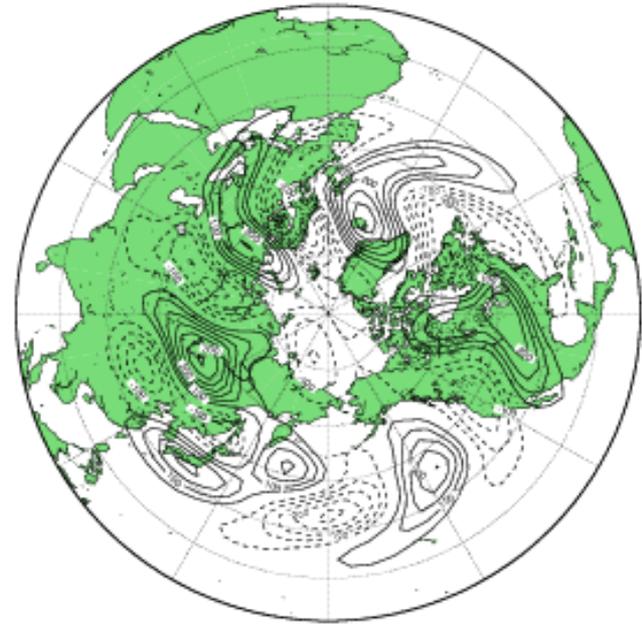
Linear Stability Analysis mode 1705, 0



3D basic state

Barotropic Height

LBM with no diffusion mode 1587, 0

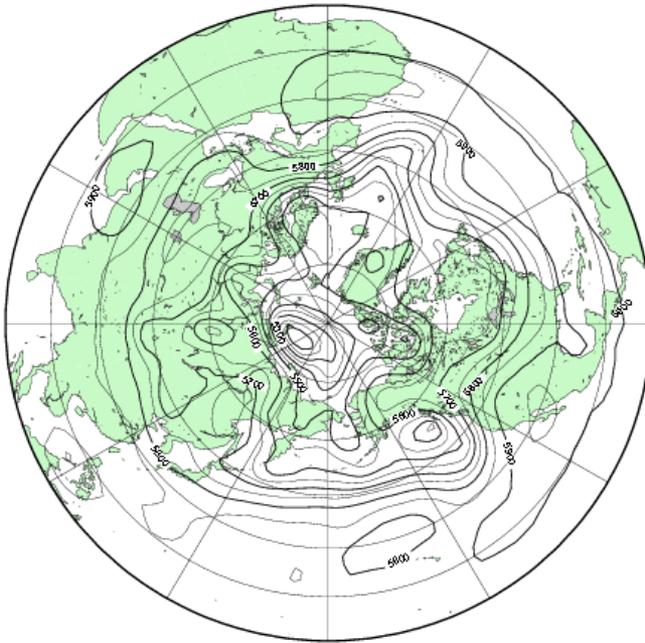


Arctic Cyclones SLP

10 day integration starting
From June 21, 2008
NICAM g18 and g19 r102-n512

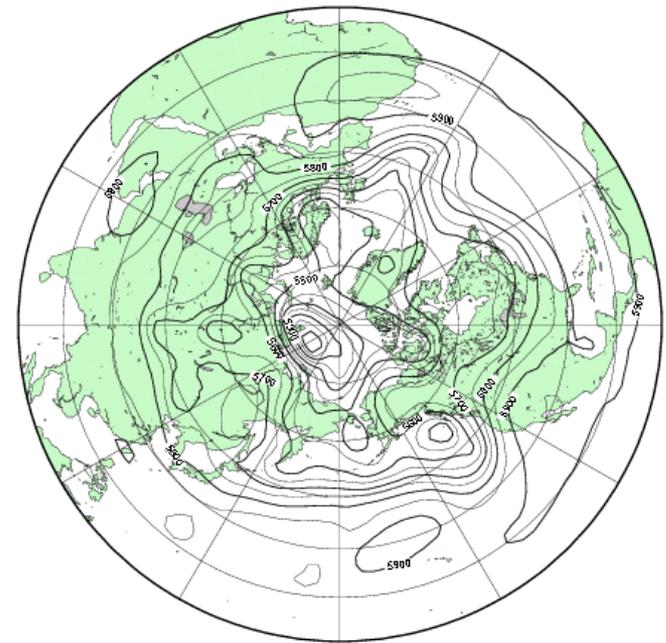
500 hPa Height

NICAM 2008062100Z+0HR



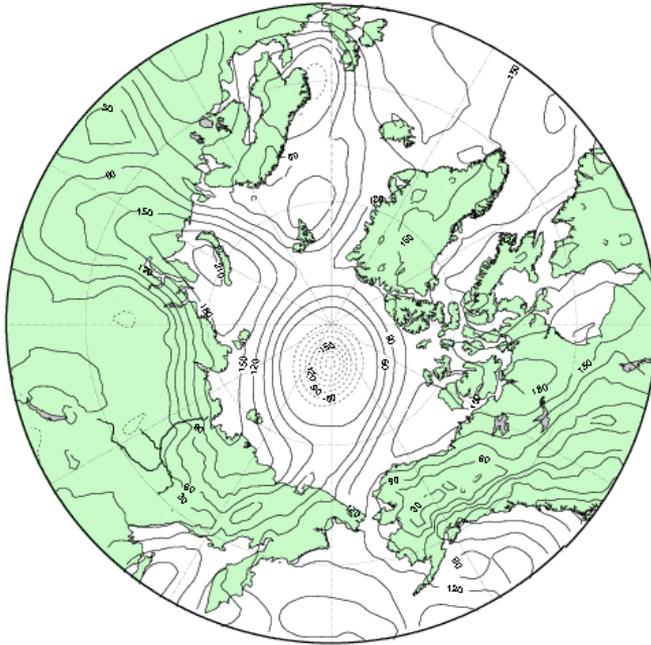
500 hPa Height

NICAM 2008062100Z+0HR

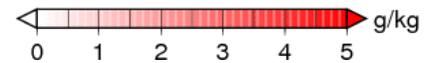
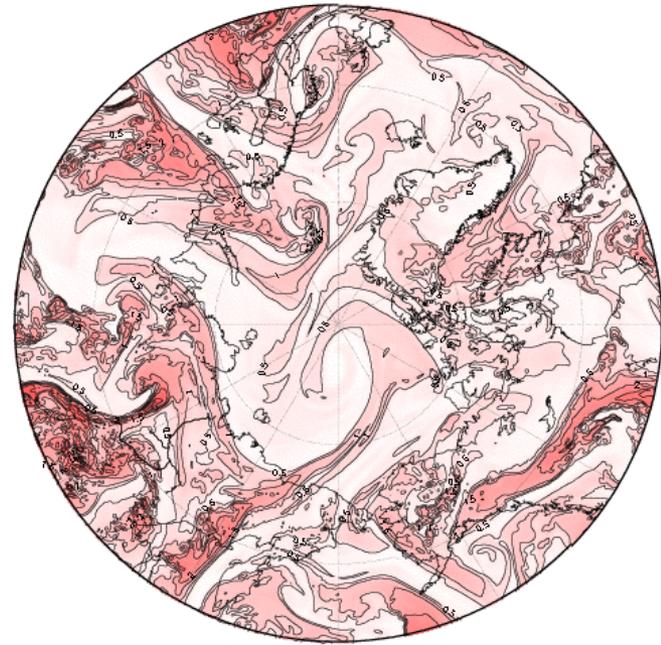


SLP and humidity

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



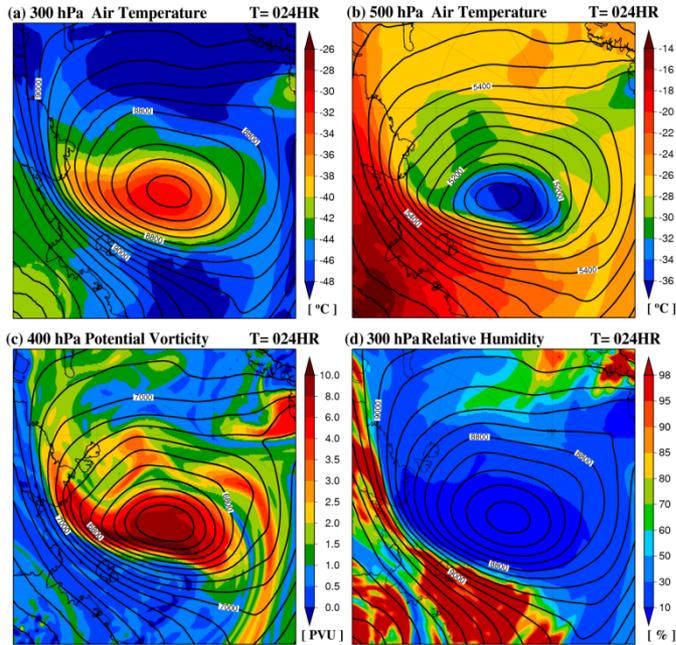
NICAM gl-9
500 hPa S. Humidity
2008062100Z+48HR



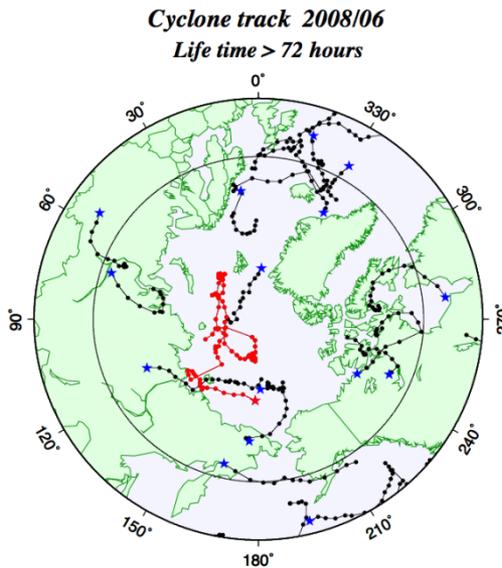
NICAM glevel-9
2008062100 Z



Arctic Cyclone in JRA-25 and NICAM

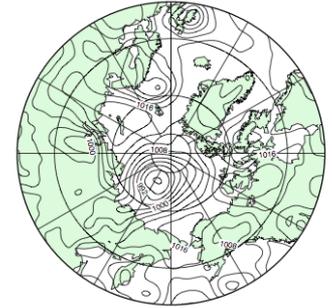


Tanaka and Yamagami 2012

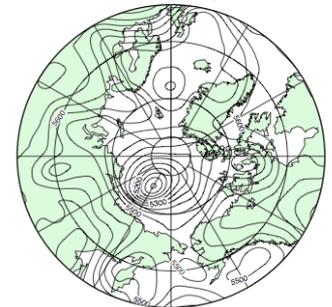


2008062206Z JRA25/JCDAS

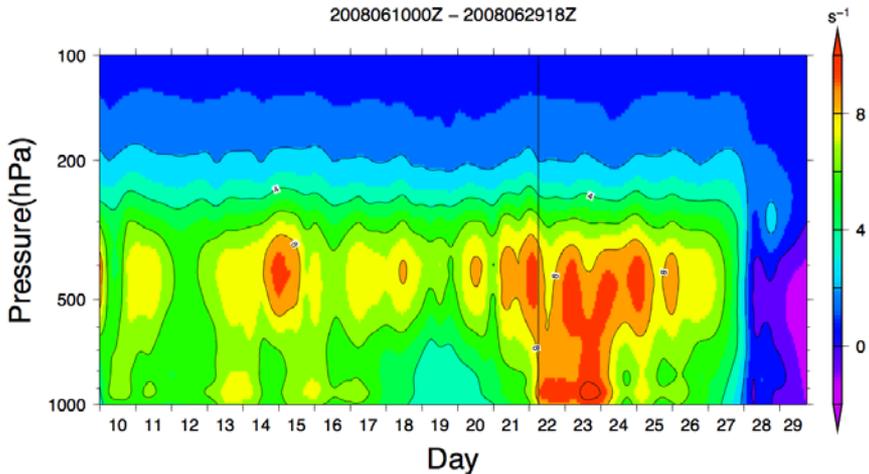
PRMSL



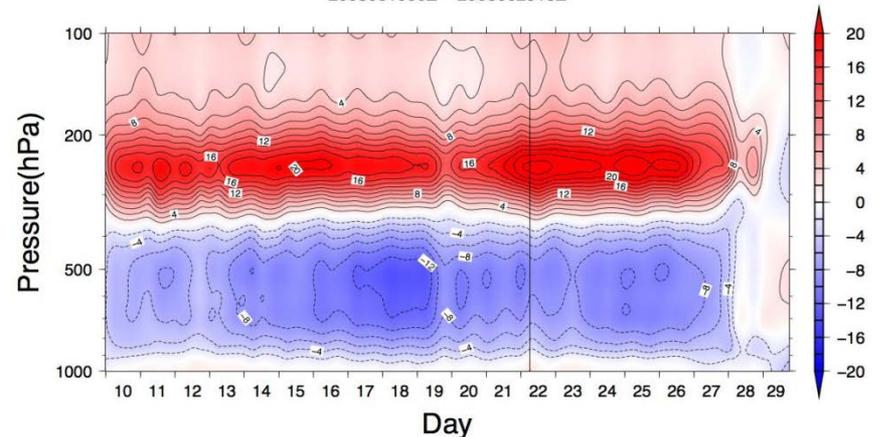
500hPa Height



Relative Vorticity
 Regional Average (Radius = 300 km)
 2008061000Z – 2008062918Z

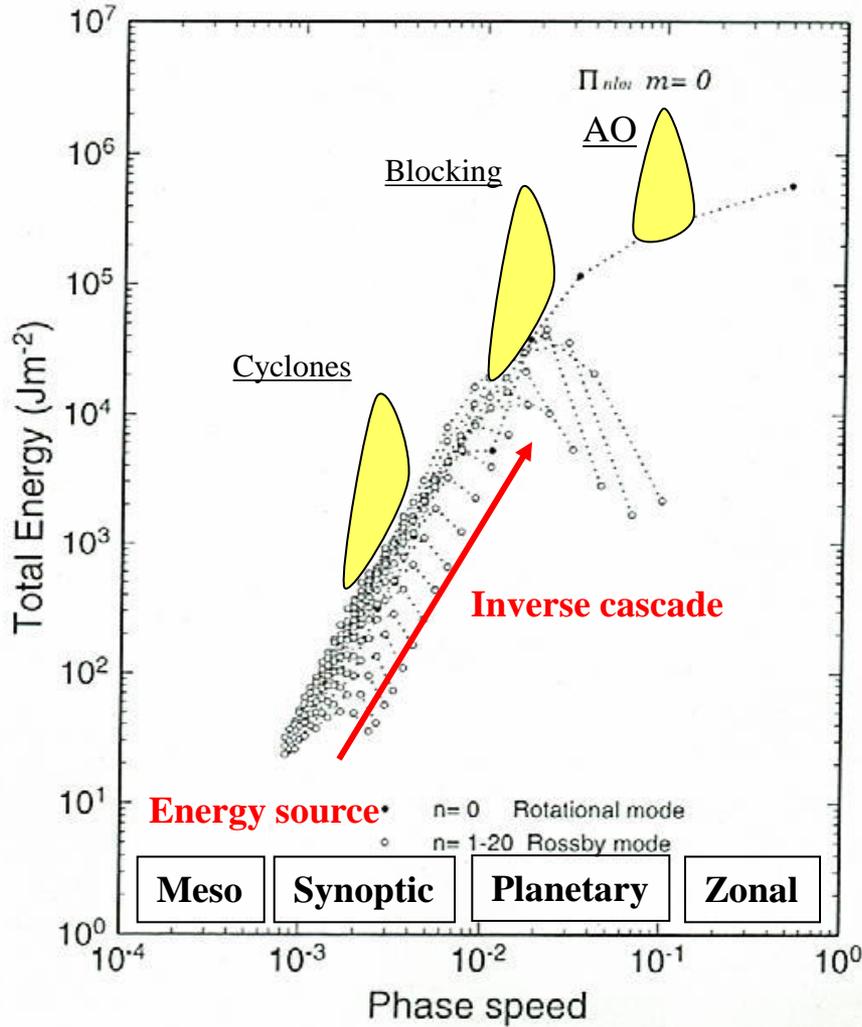


Potential Temperature Anomaly
 Regional average (Radius = 300 km)
 2008061000Z – 2008062918Z

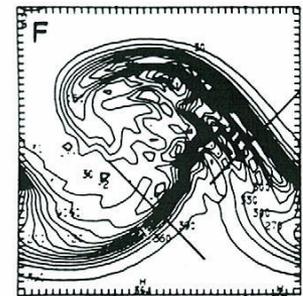
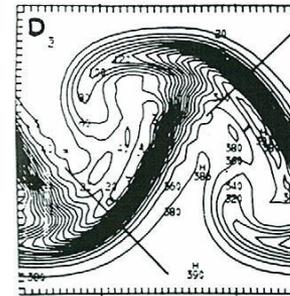
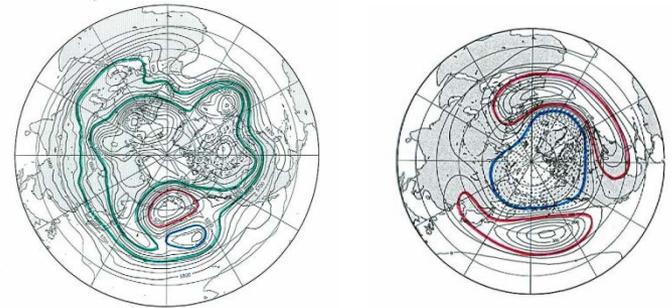


Total Energy Spectrum

NCEP/NCAR DJF 1950-1999



Low-frequency variability of the atmosphere



Arctic Oscillation

Singular eigenmode theory

AO (DJF)

Barotropic Height

Arctic Oscillation (DJF)

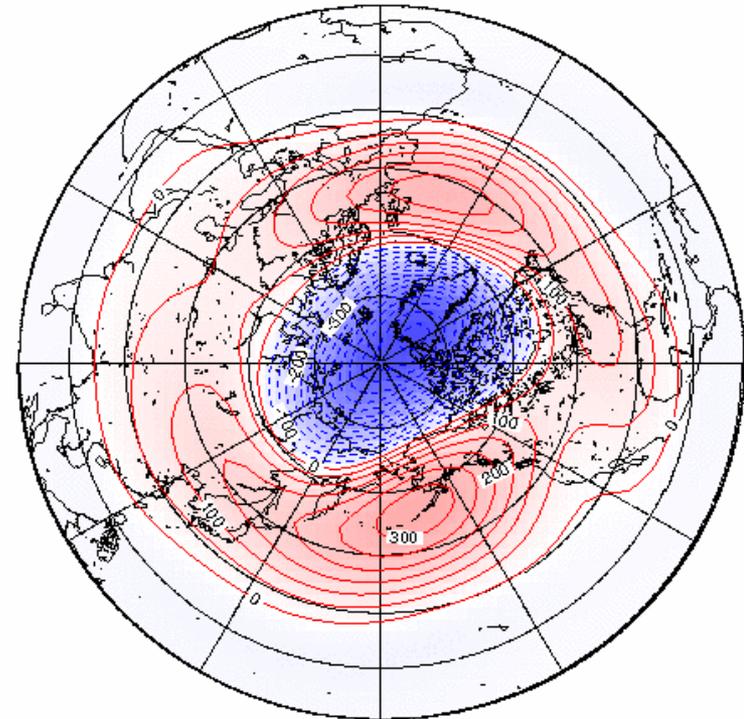
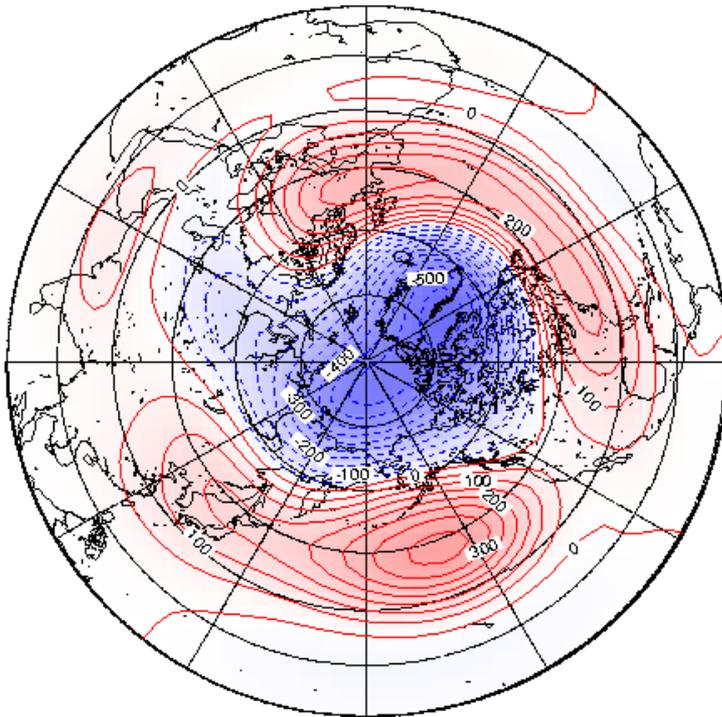
EOF-1

EVP-1

Eigenmode

Barotropic Height

Standing eigenmode EVP-1

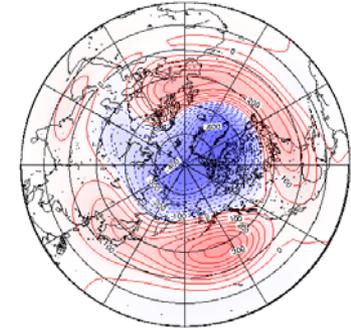


AOI Equation for AO Index

3D Spectral Primitive Equation

$$\underbrace{\frac{dw_i}{d\tau}}_{\text{Time change}} + \underbrace{i\sigma_i w_i}_{\text{L}} = \underbrace{-i \sum_{j=1}^K \sum_{k=1}^K r_{ijk} w_j w_k}_{\text{N}} + \underbrace{s_i}_{\text{F}}$$

AO eigen vector



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

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

AOI Equation

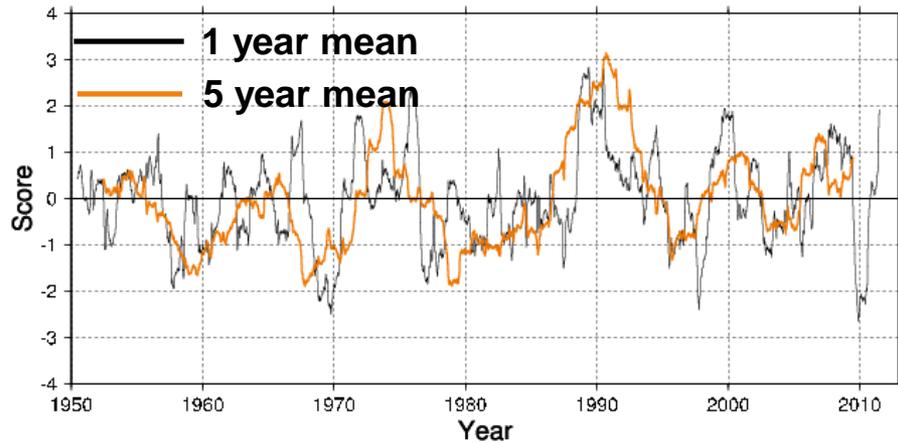
$$\underbrace{\frac{d \langle w_i', z_i \rangle}{dt}}_{\text{Time change of AOI}} = \underbrace{\langle -i\sigma_i w_i' - i \sum_{jk} r_{ijk} (\overline{w_k} w_j' + \overline{w_j} w_k'), z_i \rangle}_{\text{Linear term}} + \underbrace{\langle -i \sum_{jk} r_{ijk} w_j' w_k' - i \sum_{jk} r_{ijk} \overline{w_j} w_k', z_i \rangle}_{\text{Non-linear term}} + \underbrace{\langle f_i', z_i \rangle}_{\text{Forcing}}$$

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

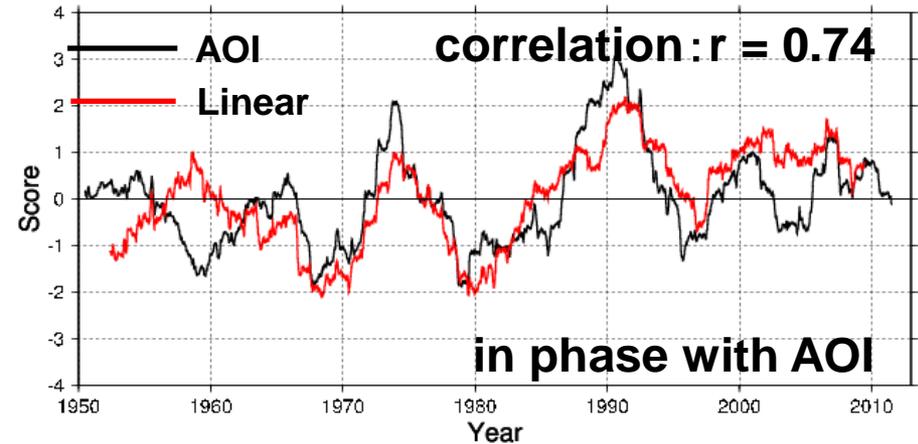
Results of time series for each term

AOI an AOI equation terms for 1950 to 2012 by NCEP

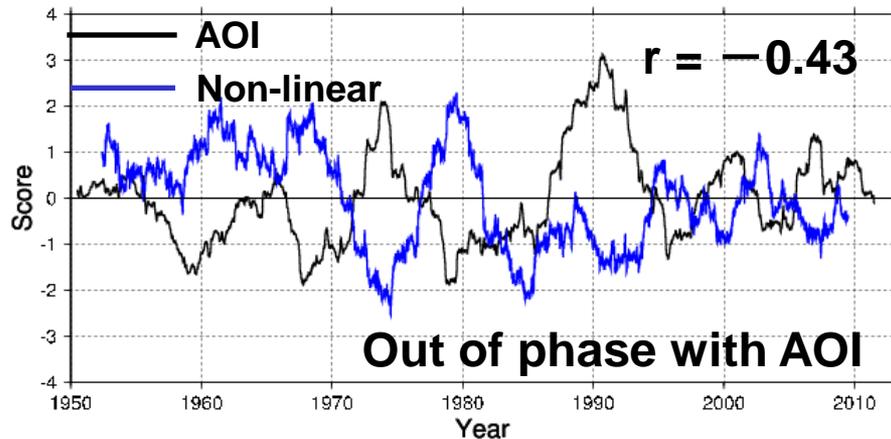
AOI



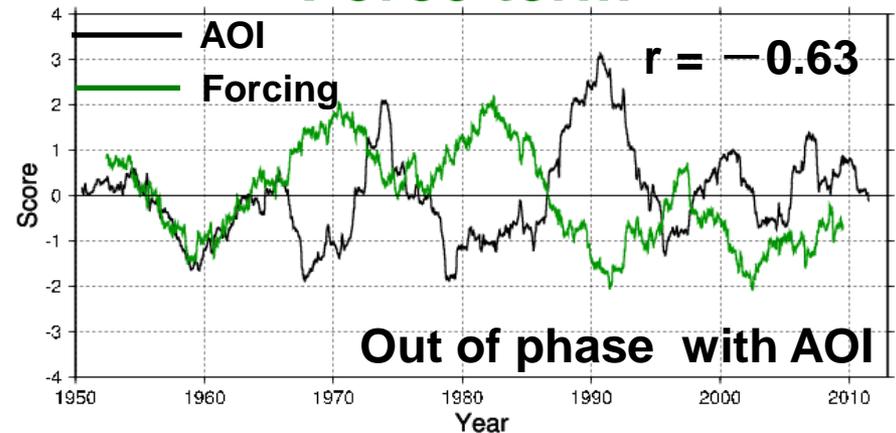
Linear term



Nonlinear term



Force term

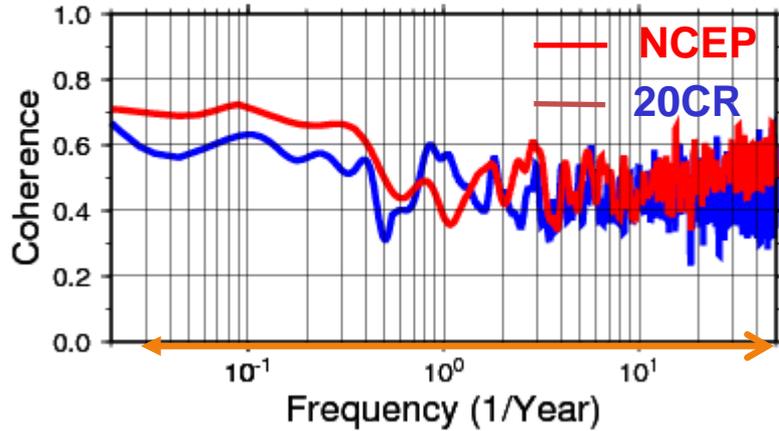


Cross-spectral analysis of time series

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

Coherence and Phase

AOI lags AOI Equation Linear term for Positive Phase



■ AOI and Linear Term

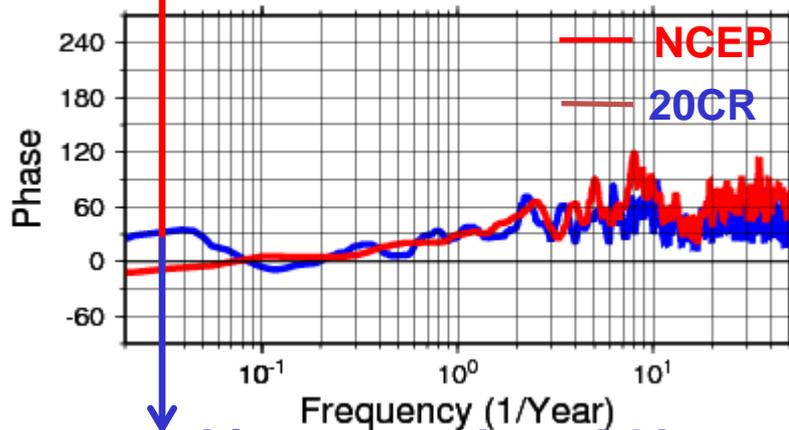
Coherence 0.4~0.6 is high

Low-frequency: L is in phase

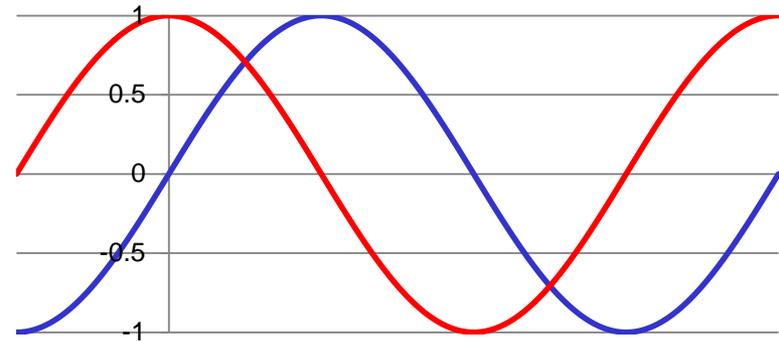
High-frequency: L leads AOI by 90°

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

Linear term leads AOI



Linear term lags AOI



Leads ←

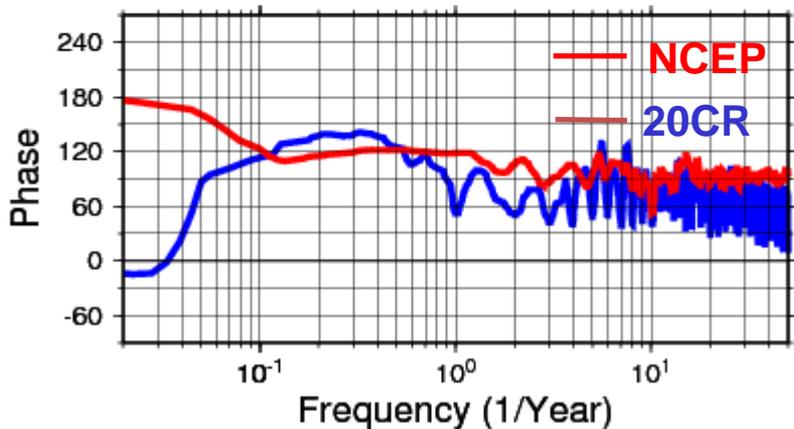
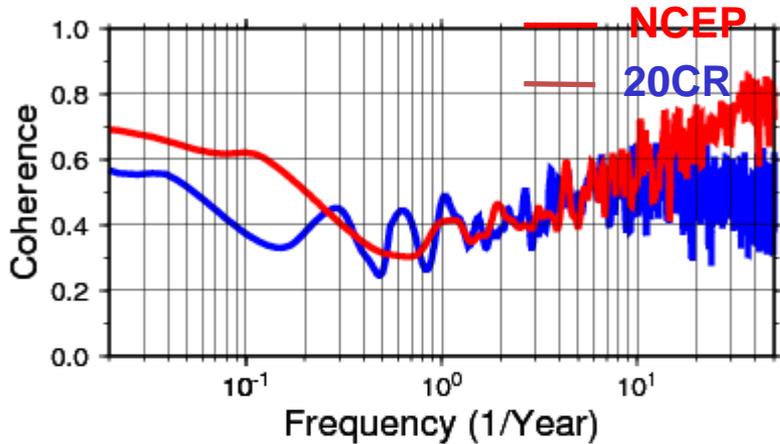
→ Lags

Cross-spectral analysis of time series

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

Coherence and Phase

AOI lags AOI Equation Nonlinear term for Positive Phase

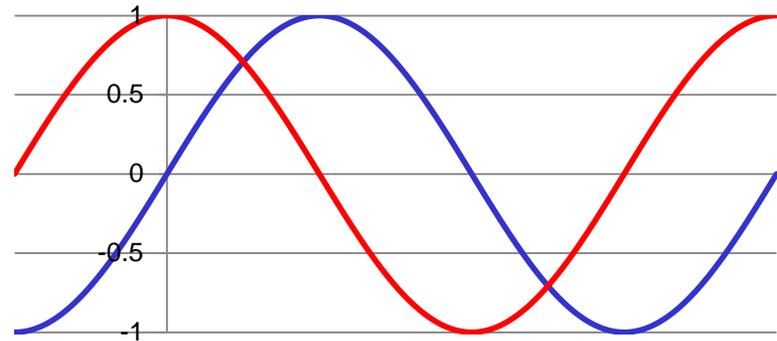


■ AOI and Non-linear Term

Coherence 0.4~0.8 is very high

Low-frequency: N is out of phase

High-frequency: N leads AOI by 90°



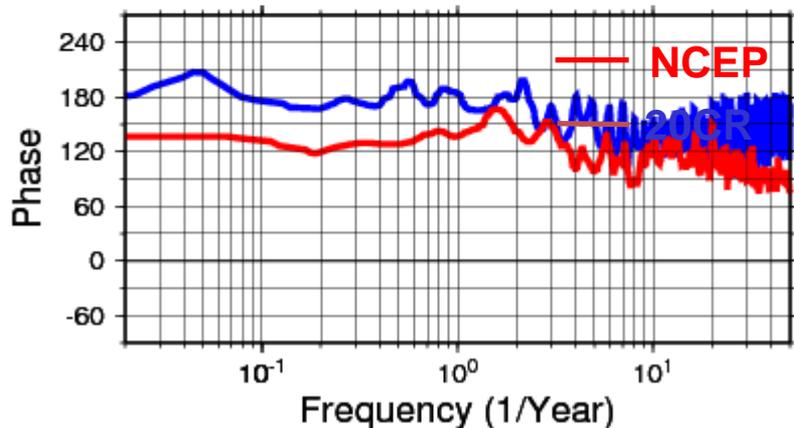
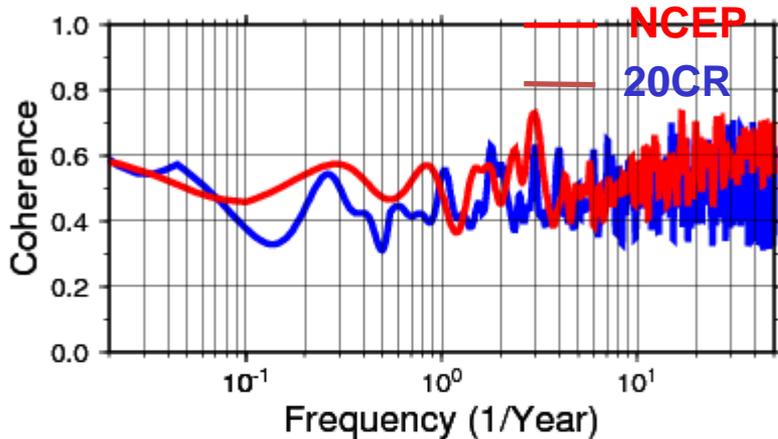
Leads ← (red arrow) (blue arrow) → Lags

Cross-spectral analysis of time series

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

Coherence and Phase

AOI lags AOI Equation Force term for Positive Phase

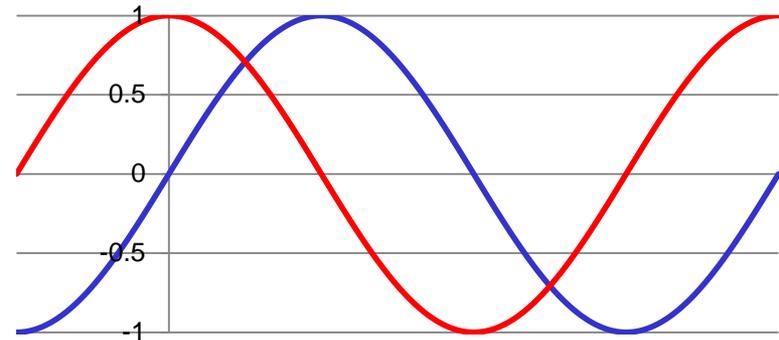


■ AOI and Forcing Term

Coherence 0.4~0.6 is high

Low-frequency: F is out of phase

High-frequency: F leads AOI by 90°



Leads ← (red arrow) (blue arrow) → 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