Composition and Transport in the Tropical Troposphere and Lower Stratosphere Meeting (under SPARC)
at NOAA in Boulder, Colorado, USA in July 20 - 23, 2015

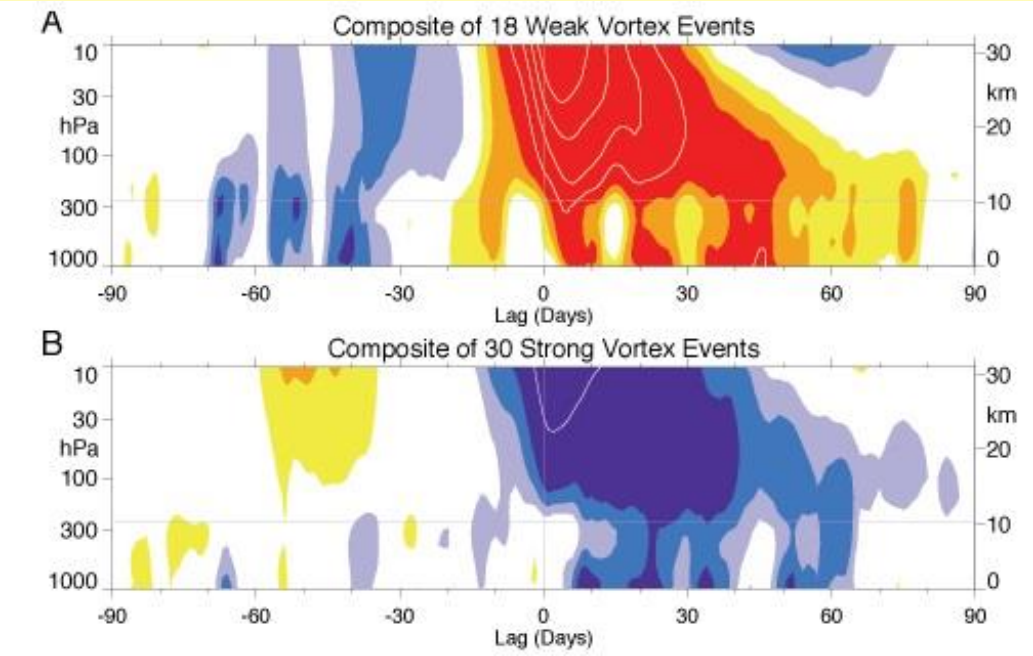
Research Collaborations on Stratosphere-Troposphere Dynamical Coupling in the Tropics in Association with the Project of Years of the Maritime Continent (YMC) for 2017-2019

Shigeo Yoden (Kyoto U., Japan)

1. Introduction

- WCRP SPARC
  - Stratosphere-troposphere Processes And their Role in Climate
  - SPARC themes
    - Climate-chemistry interactions
    - Detection, attribution and prediction of stratospheric change
    - Stratosphere-troposphere dynamical coupling

      Theme leads: Mark Baldwin (U. Exter), Shigeo Yoden (Kyoto U.)

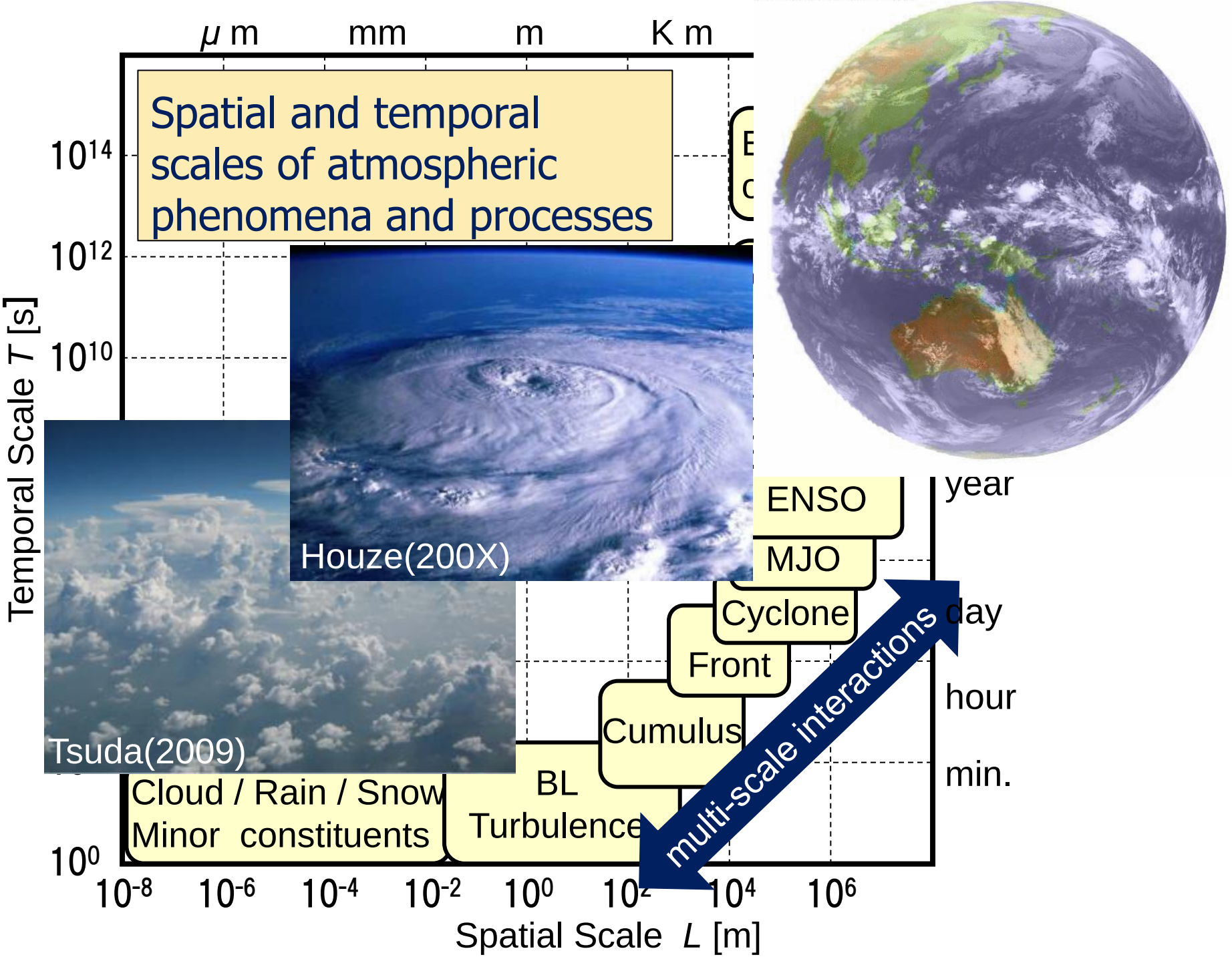


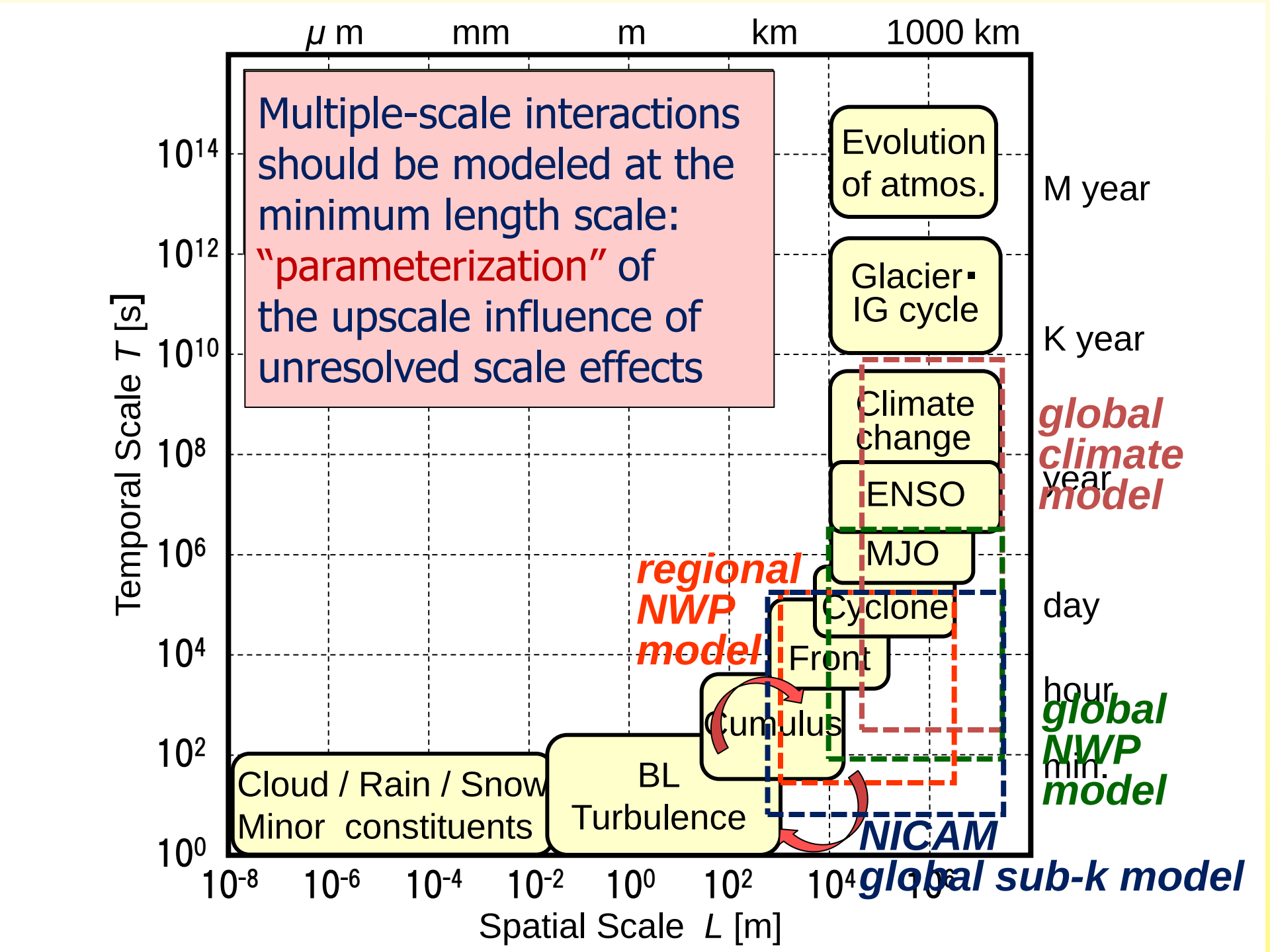
Baldwin and Dunkerton (2001)

SPARC Stratosphere-troposphere Processes And their Role in Climate

WCRP World Climate Research Programme

- A proposal of new activity on "stratosphere-troposphere dynamical coupling in the tropics"
  - workshops and a conference
  - a review, reports and a special issue/section
  - research collaborations in association with the project of Years of the Maritime Continent (YMC) for 2017-2019 under the endorsement/support of SPARC
    - next SPARC SSG meeting in November
- Tropical meteorology; dynamics in the tropics
  - multiscale interactions of moist convections
  - a totally different world from the extratropics where the quasi-geostrophic potential vorticity (QG-PV) dynamics prevails
    - small Coriolis parameter
    - small-scale moist convection is the predominant source of energy


μm
mm
m
Km
Spatial and temporal scales of atmospheric phenomena and processes
Houze(200X)
Tsuda(2009)
ENSO
MJO
Cyclone
Front
Cumulus
BL Turbulence
Cloud / Rain / Snow
Minor constituents
multi-scale interactions
year
day
hour
min.
Temporal Scale T [s]
Spatial Scale L [m]
10^14
10^12
10^10
10^0
10^-8
10^-6
10^-4
10^-2
10^0
10^2
10^4
10^6


μ m
mm
m
km
1000 km
Multiple-scale interactions should be modeled at the minimum length scale: "parameterization" of the upscale influence of unresolved scale effects
Evolution of atmos.
Glacier・IG cycle
Climate change
ENSO
MJO
Cyclone
Front
Cumulus
BL Turbulence
Cloud / Rain / Snow
Minor constituents
M year
K year
year
day
hour
min.
global climate model
regional NWP model
global NWP model
NICAM
global sub-k model
Temporal Scale T [s]
Spatial Scale L [m]
10^14
10^12
10^10
10^8
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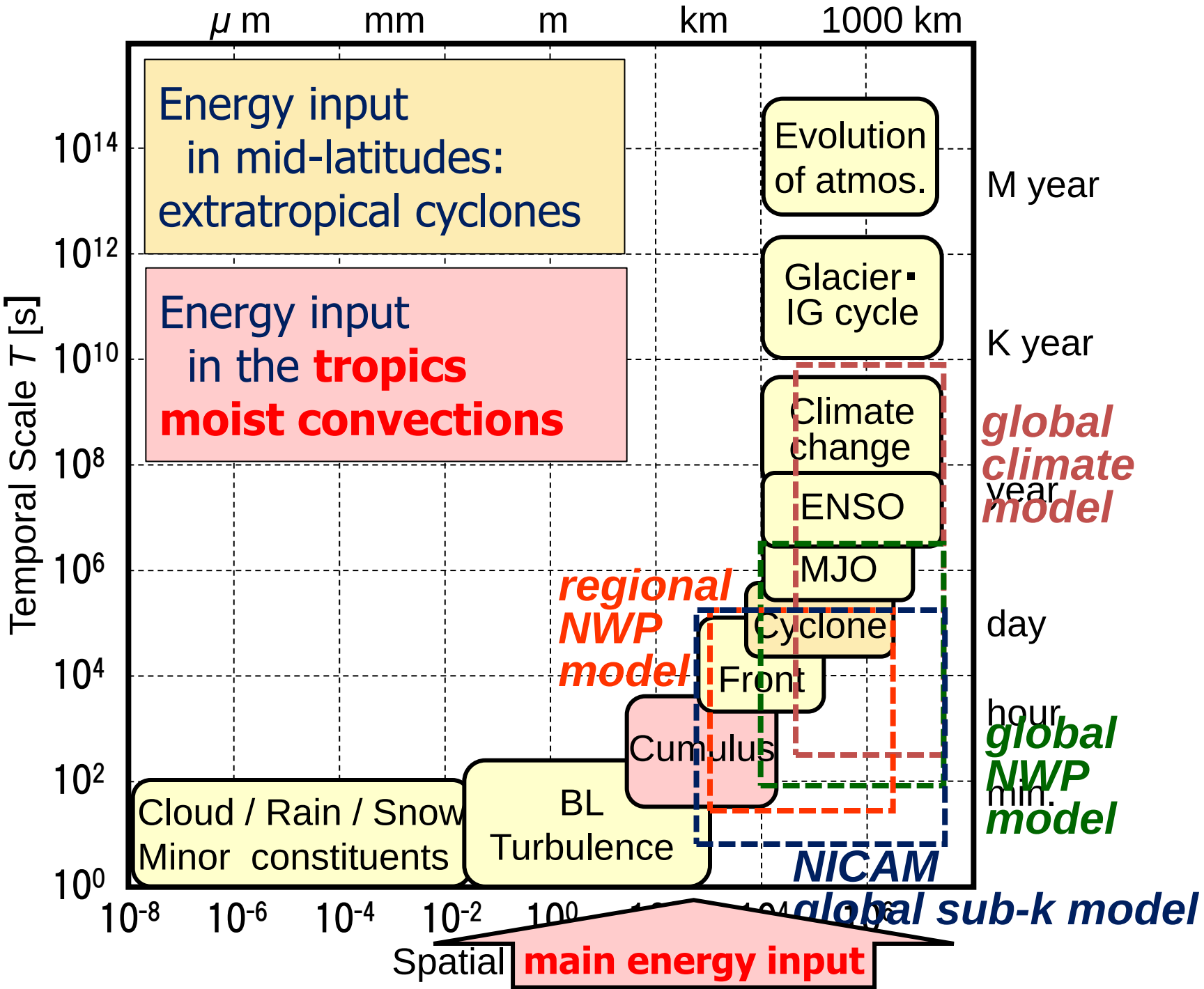
10^0
10^2
10^4
10^6


μ m
mm
m
km
1000 km
Energy input
in mid-latitudes:
extratropical cyclones
Energy input
in the tropics
moist convections
Temporal Scale T [s]
10^14
10^12
10^10
10^8
10^6
10^4
10^2
10^0
10^-8
10^-6
10^-4
10^-2
10^0
Spatial
Evolution
of atmos.
Glacier・
IG cycle
Climate
change
ENSO
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Cyclone
Front
Cumulus
BL
Turbulence
Cloud / Rain / Snow
Minor constituents
M year
K year
year
day
hour
min.
global
climate
model
regional
NWP
model
global
NWP
model
NICAM
global sub-k model
main energy input

2. S-T dynamical coupling in the tropics

- Multiscale interactions of moist convections produce a wide variety of coherent motions and structures of the tropical atmosphere
  - However, the scale separation is not very straightforward
  - it is hard to extract causality in the interactions

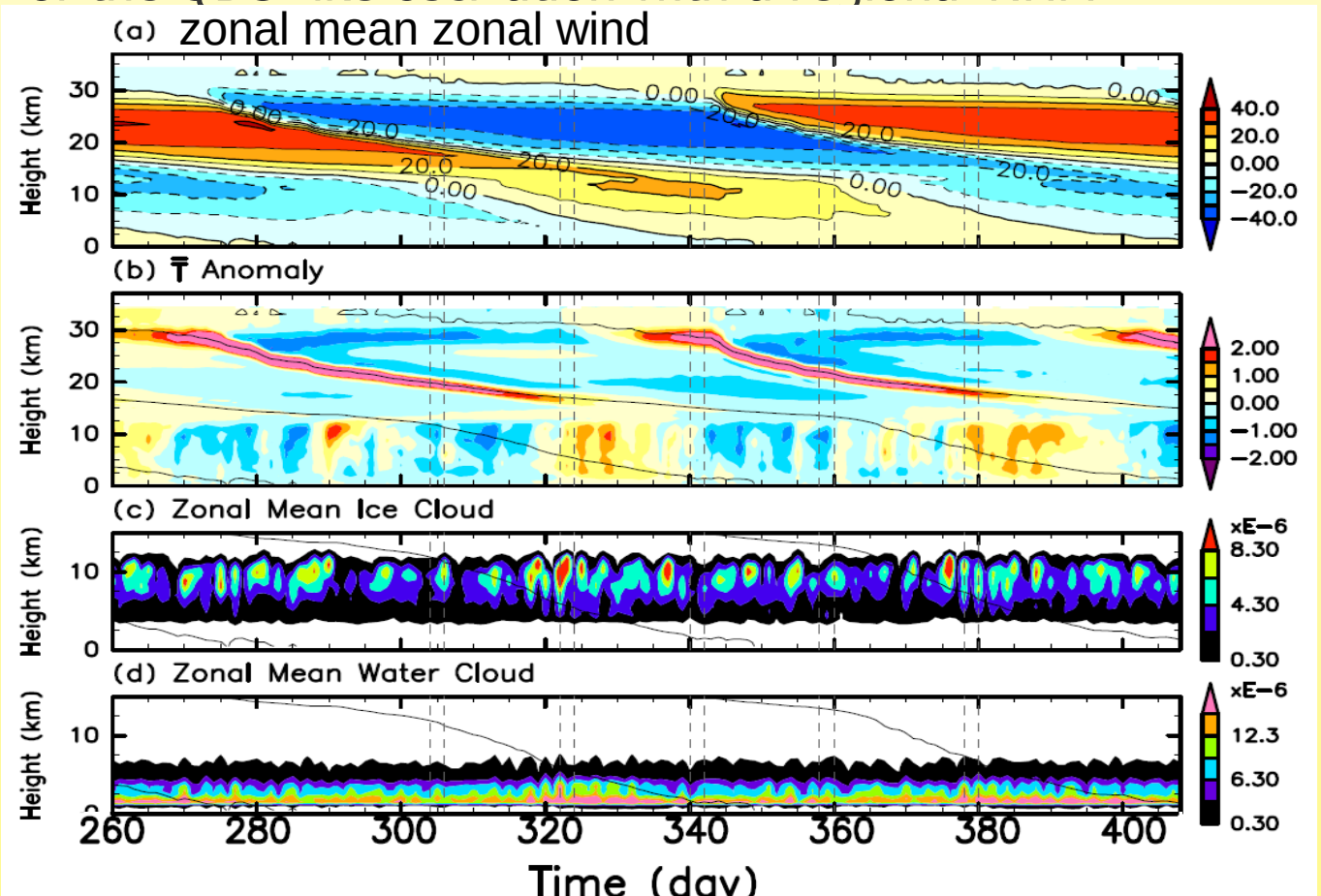
- On the other hand, the stratospheric influence on the tropospheric variations is weak, but it is clearly external
  - S-T coupling process in each time scale could be studied to know how large-scale stratospheric variations influence on moist convection
  - and thus to understand how stratospheric variations influence on the tropospheric variations in weather and climate continuum.

❖ Example of an idealized numerical experiment

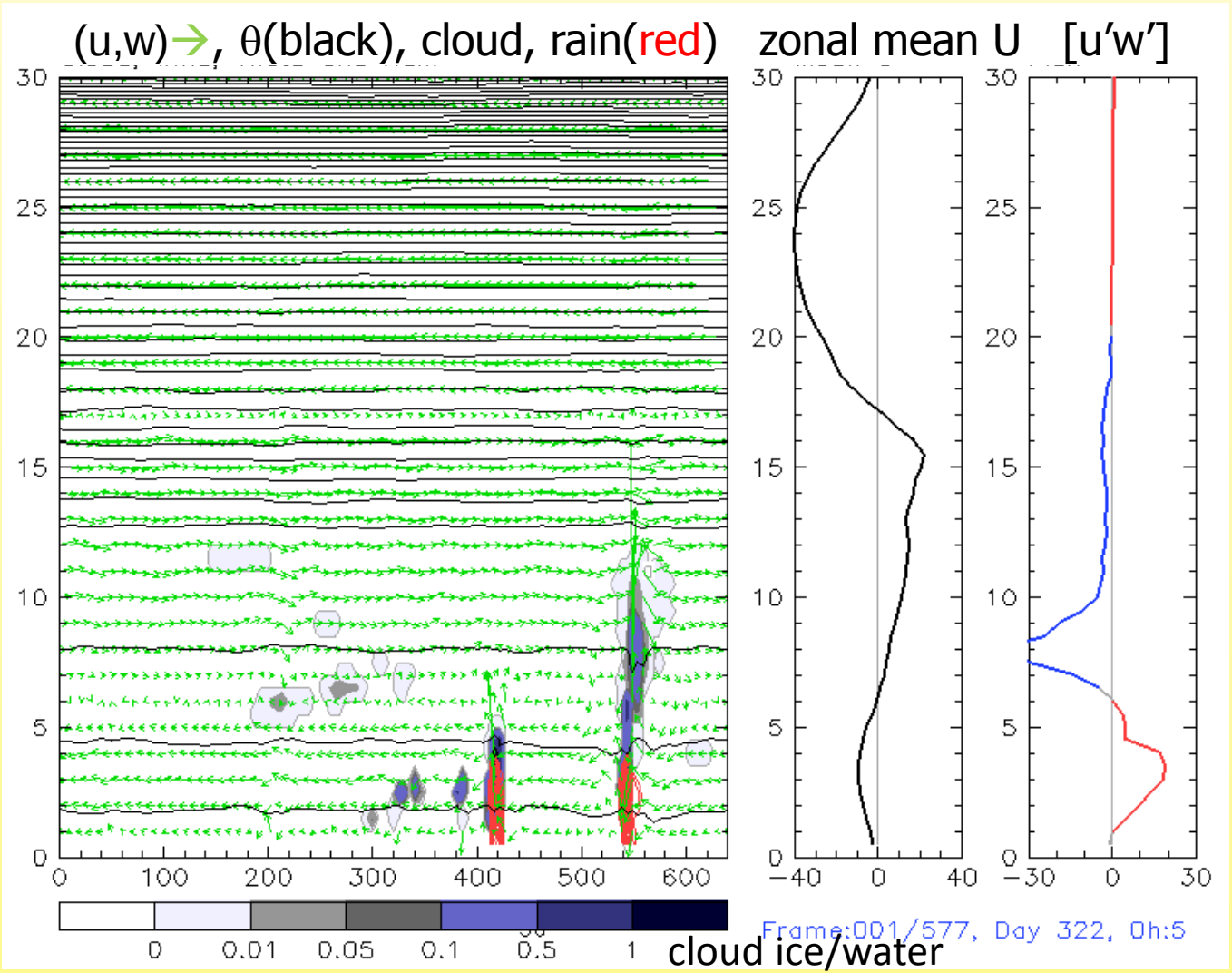
- Yoden, Bui, and Nishimoto, 2014:

  A minimal model of QBO-like oscillation in a stratosphere-troposphere coupled system under a radiative-moist convective quasi-equilibrium state. *SOLA*, Vol. 10, 112–116, doi:10.2151/sola.2014-023

  Held et al. (1993) experiment was reexamined to test the sensitivity of the QBO-like oscillation with a regional NHM



- in the minimal model, "QBO" influences on moist convective systems
  - Squall Line type ←→ Back Building type
- Animation for a two-day period of Squall Line type system

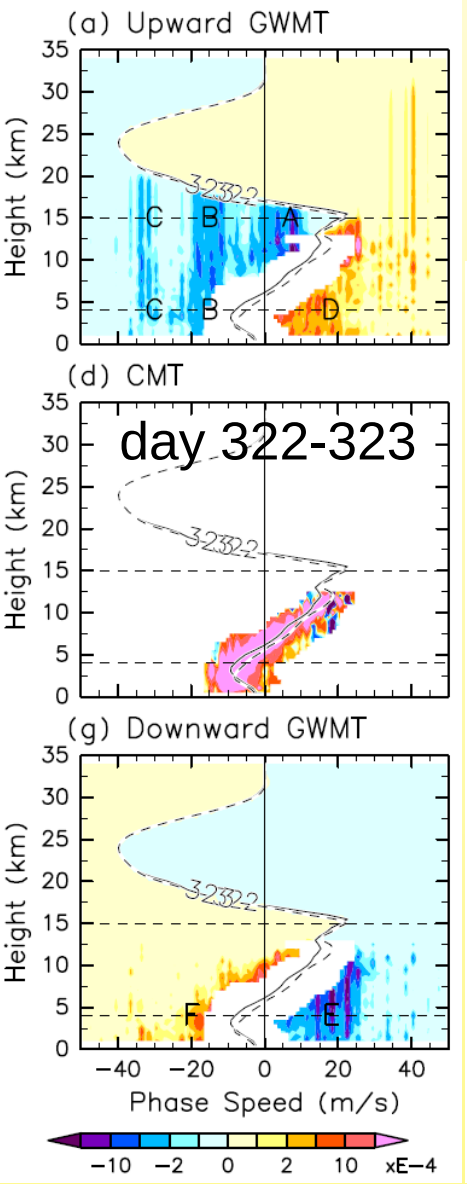


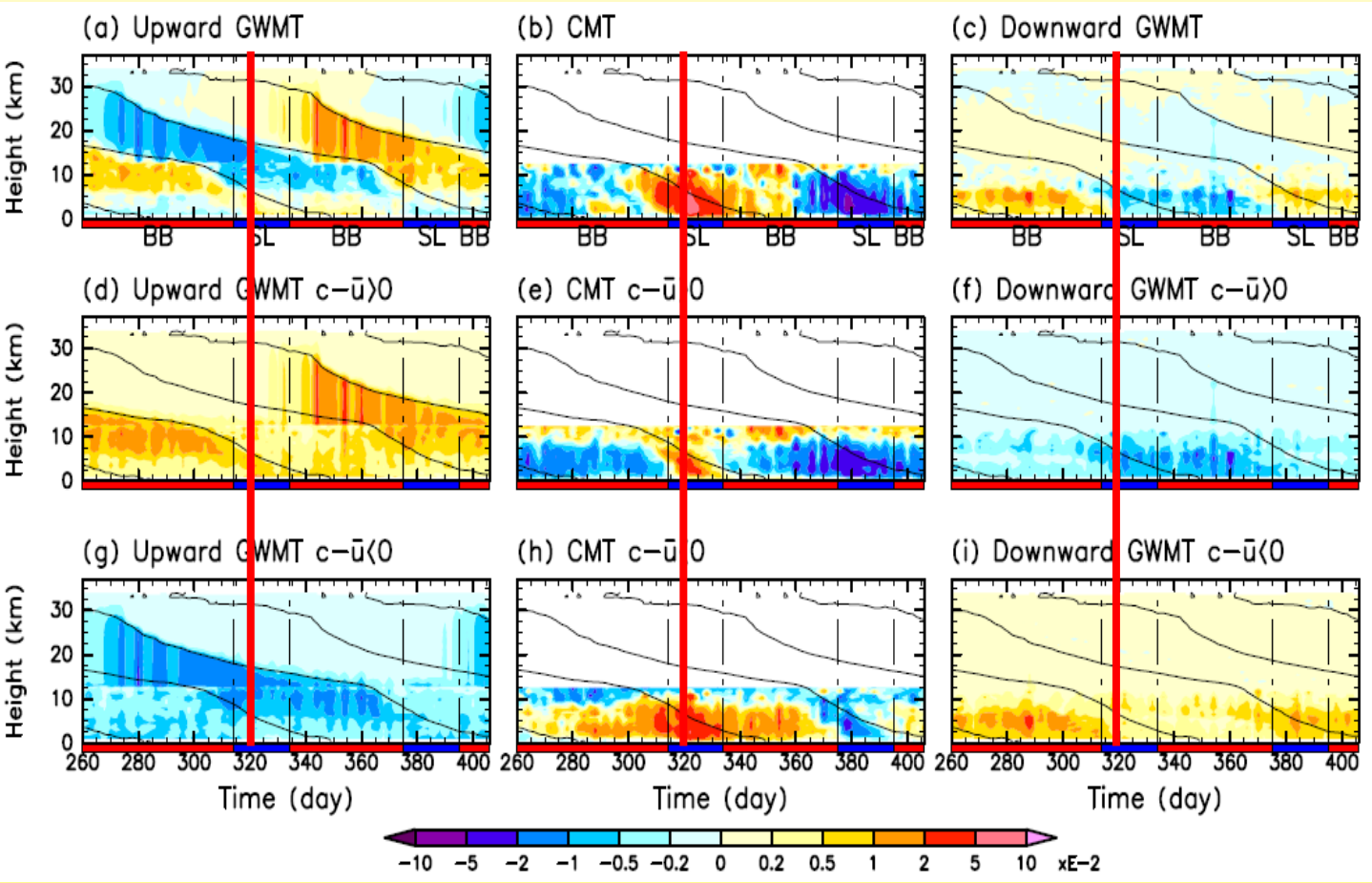
- Nishimoto, Yoden, and Bui, 2015:

  Vertical momentum transports associated with moist convection and gravity waves in a minimal model of QBO-like oscillation. *to be submitted*

Time-space co-spectral analysis based on the first Eliassen-Palm (EP) theorem:

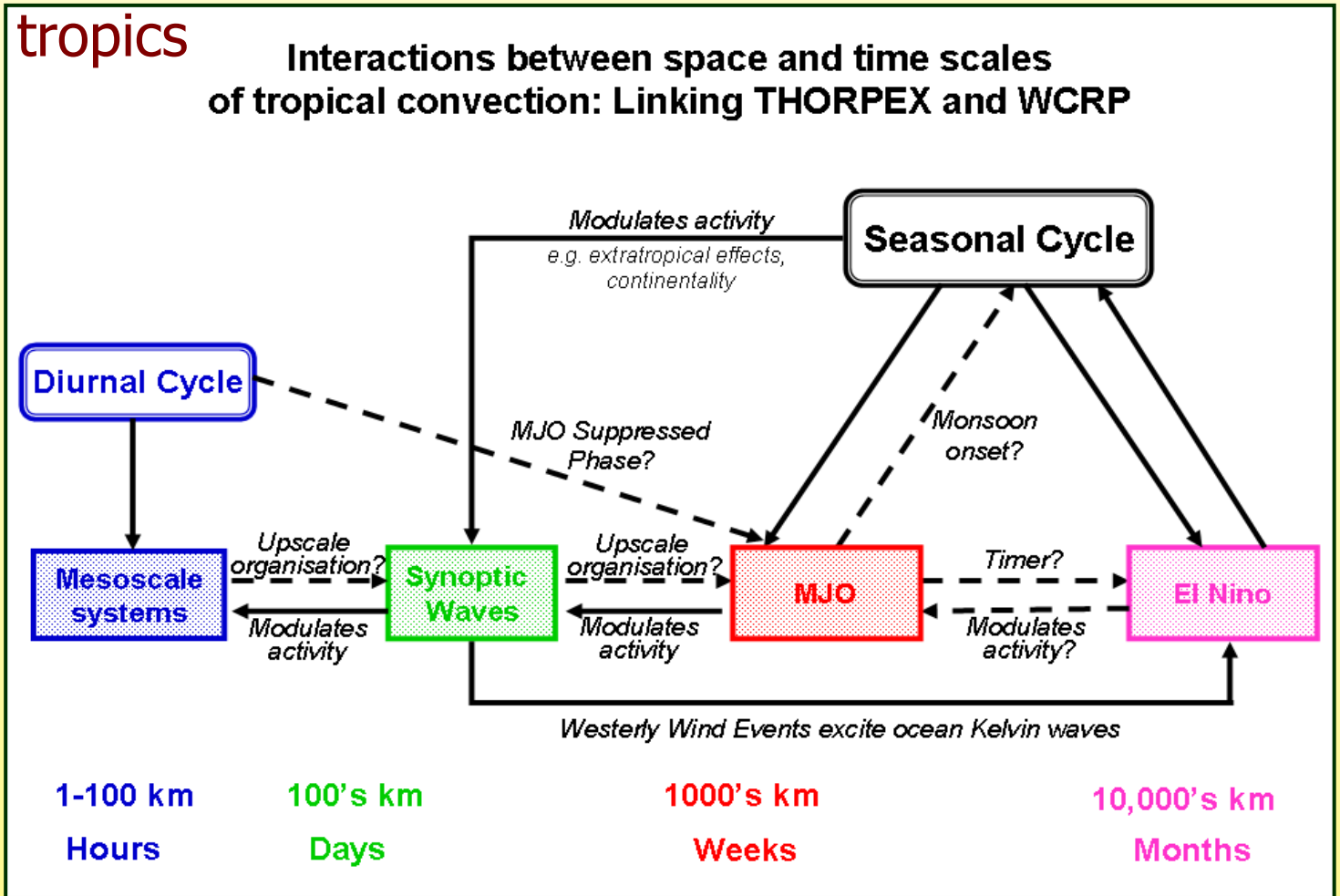
$$\overline{p'w'} = \rho_0 (c - \bar{u})\, \overline{u'w'} = c_{gz} \langle E \rangle$$



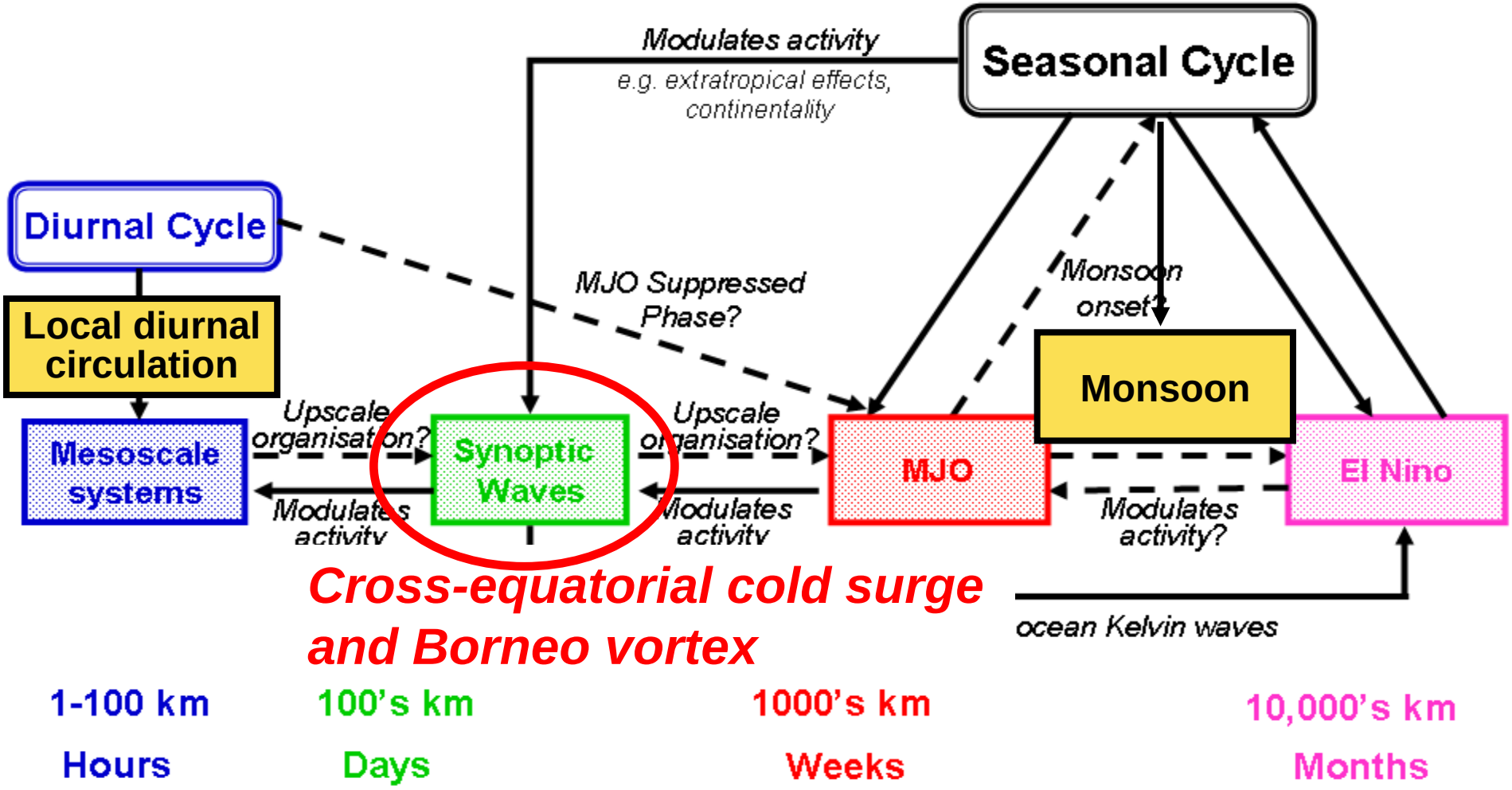


3. Preliminary review on the studies on S→T

- Possible stratospheric influence on multiscale interactions of moist convections in the tropics
  - Slingo (2006) : multiscale interactions of moist convections in the tropics

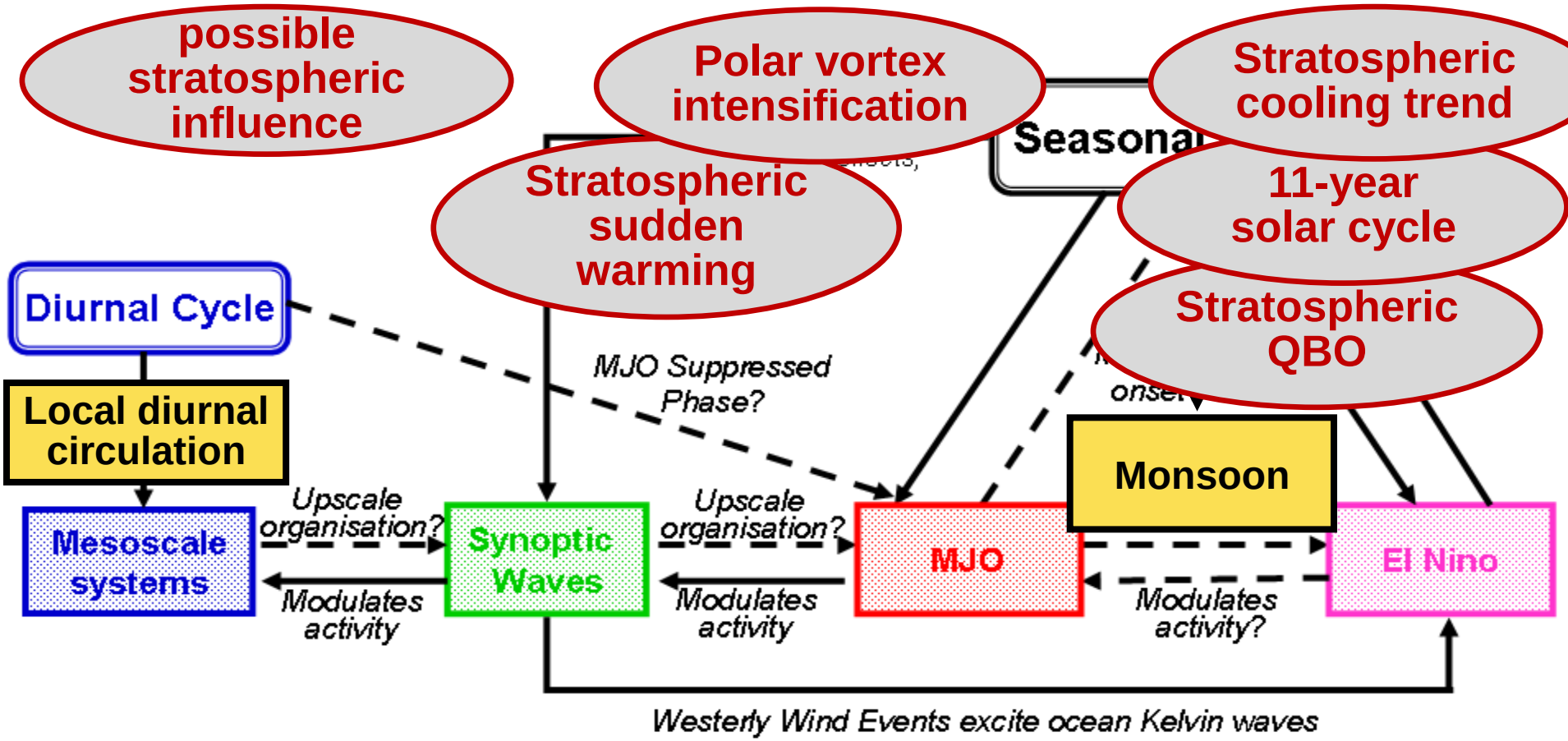


Interactions between space and time scales of tropical convection: Linking THORPEX and WCRP



Slingo (2006)

Interactions between space and time scales of tropical convection: Linking THORPEX and WCRP



Slingo (2006)

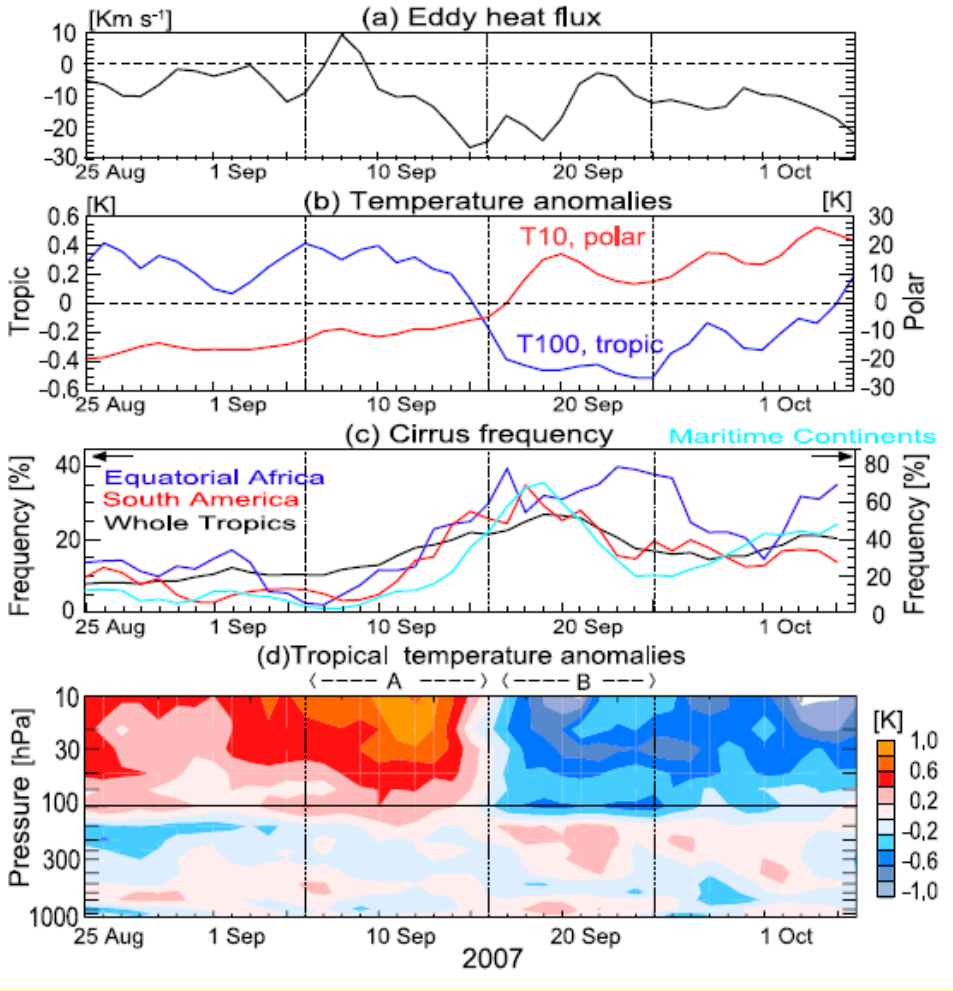
❖ Influence of a stratospheric sudden warming (SSW) event on the tropical troposphere

- response of extratropical diabatic circulation to a time-dependent wave driving may have an impact on low latitudes ←→ downward control principle for steady forcing
- Eguchi and Kodera (2010, *SOLA*)

  impacts of a 2007 SH SSW event on tropical clouds and moisture fields in the TTL
- Kodera et al. (2011, *JMSJ*)

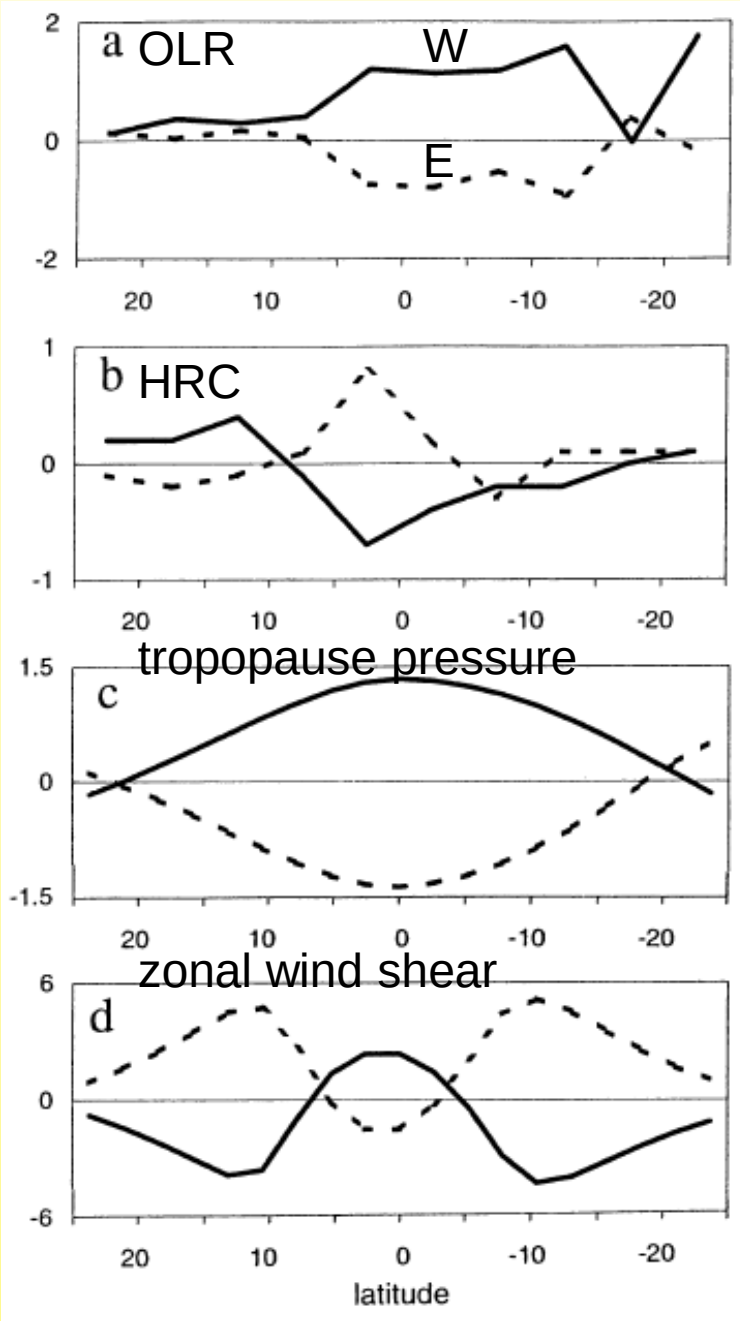
  sudden changes in the tropical troposphere associated with 2009 SSW event in the N.H.
- Dhaka et al. (2015, *Atm. Res.*)

  2009 SSW event in the N.H.



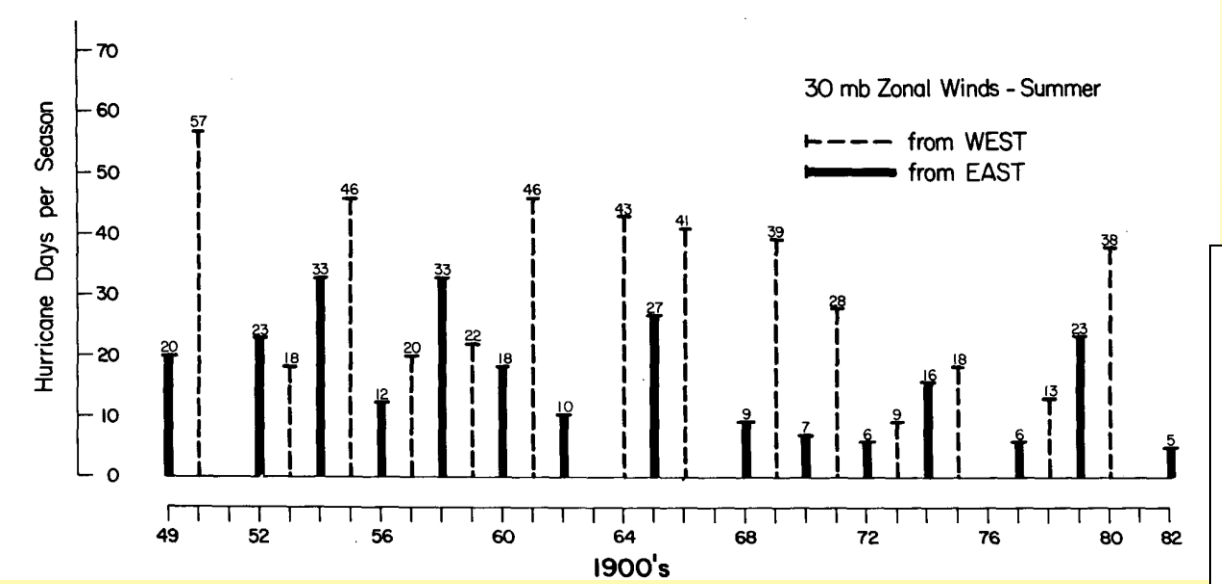
❖ Influence of the QBO on tropical deep convections as revealed by data analyses

- Collimore, et al. (1998, *GRL*)
- Collimore, et al. (2003, *J.Clim.*➔)
  - ➢ On the relationship between the QBO and tropical deep convection for 1958–2001
    - – OLR in the chronically convective regions (W m^{-2})
    - – highly reflective cloud (HRC) index
    - – tropopause pressure (hPa)
    - – 50–200hPa zonal wind shear(ms^{-1})
- Claud and Terray (2007, *J.Clim.*)
- Huang et al. (2012, *Clim.Dyn.*)
- Hu et al. (2012, *J.Clim.*)
- Liess and Geller (2012, *JGR*)
  - ➢ separating ENSO and other signals

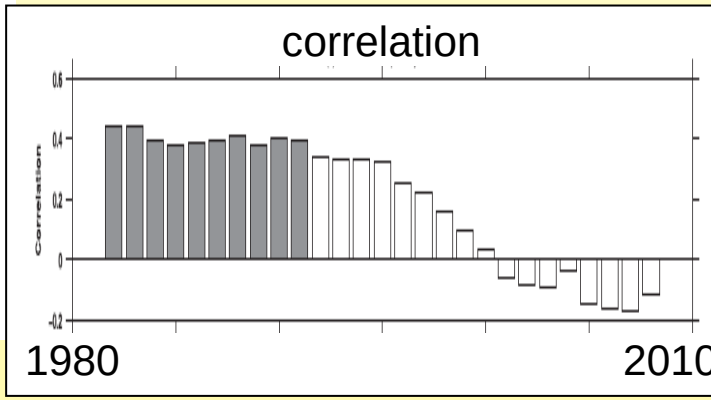


❖ Influence of the QBO on tropical cyclones (TCs)

- Gray (1984, *MWR*)
  - ➢ Atlantic seasonal hurricane frequency: El Niño and 30 mb QBO



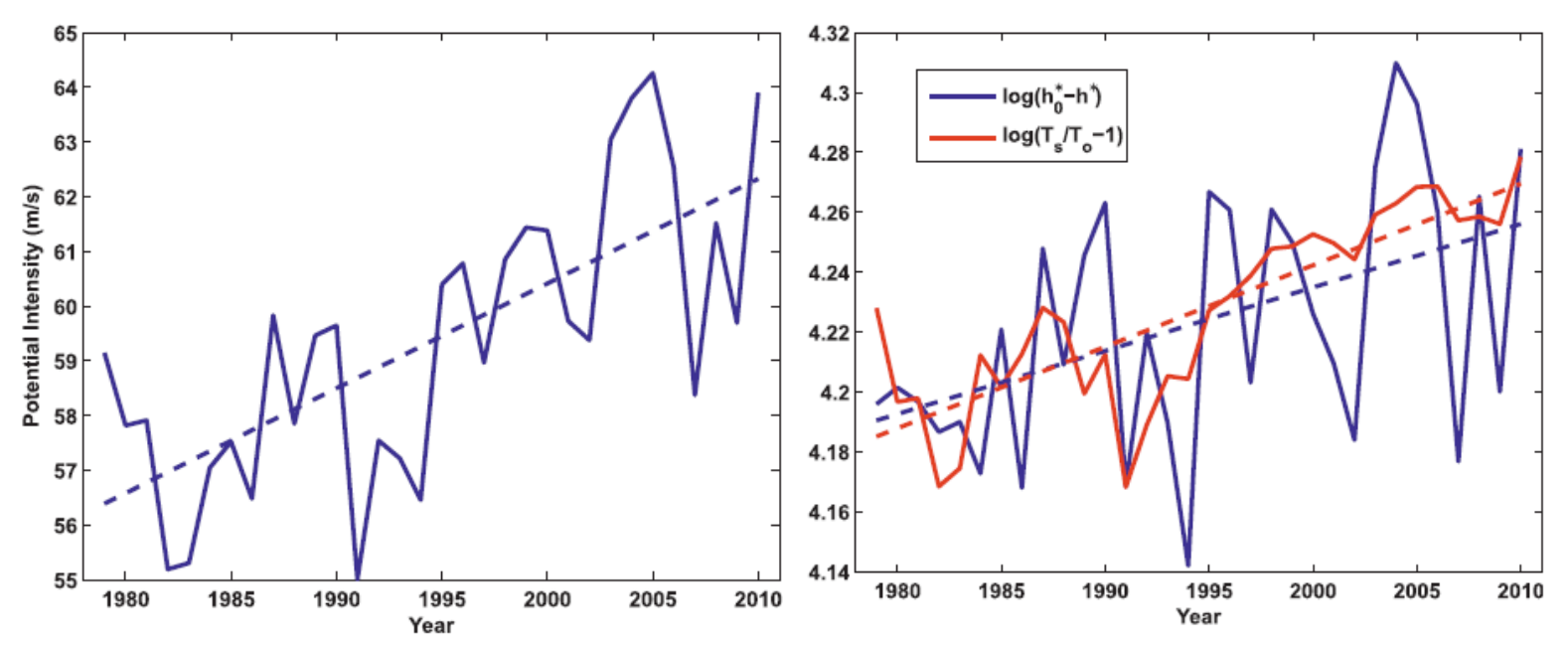
- also Elsner et al. (1999, *J.Clim.*)



- Camargo and Sobel (2010, *J.Clim.*➔)
  - ➢ 30-yr correlations of 30 hPa QBO with number of tropical cyclones
- Whitney and Hobgood (1997, *J.Clim.*)
  - ➢ maximum intensities of TCs in the eastern North Pacific Ocean
- Ho et al. (2009, *GRL*) and Fadnavis et al. (2013, *Int.J.Clim.*)
  - ➢ TC tracks in the western North Pacific and Bay of Bengal regions

❖ Influence of the stratospheric cooling trend on TCs

- Emanuel et al. (2013, *J.Clim.*)
  - ➢ influence of TTL cooling (outflow T ↓) on Atlantic hurricane activity

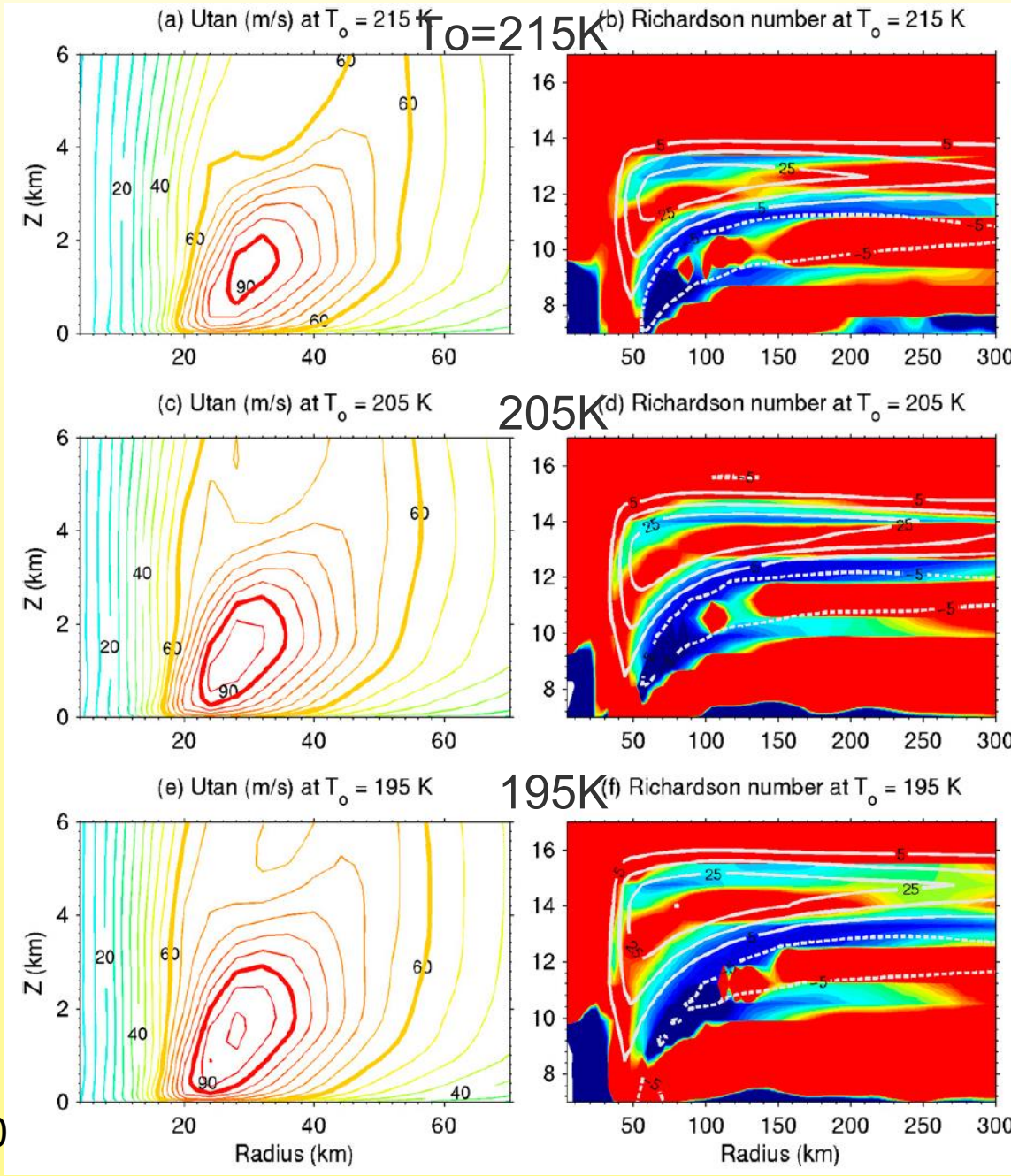


❖ Physical parameters related to the linkage around TTL

- dynamics: d**u**/dz, w
- thermodynamics: T, N^2
- tropopause height
- xxxxxxx ?

❖ Numerical model studies

- GCM studies
  - ➢ use of a hierarchy of numerical models for better understanding c.f., Garfinkel and Hartmann (2011a,b) for the QBO influence on T
- Regional CRM studies
  - ➢ Yoden et al. (2014) QBO-like oscillations
  - ➢ Wang et al. (2014➔) Impact of tropopause temperature on the intensity of TCs

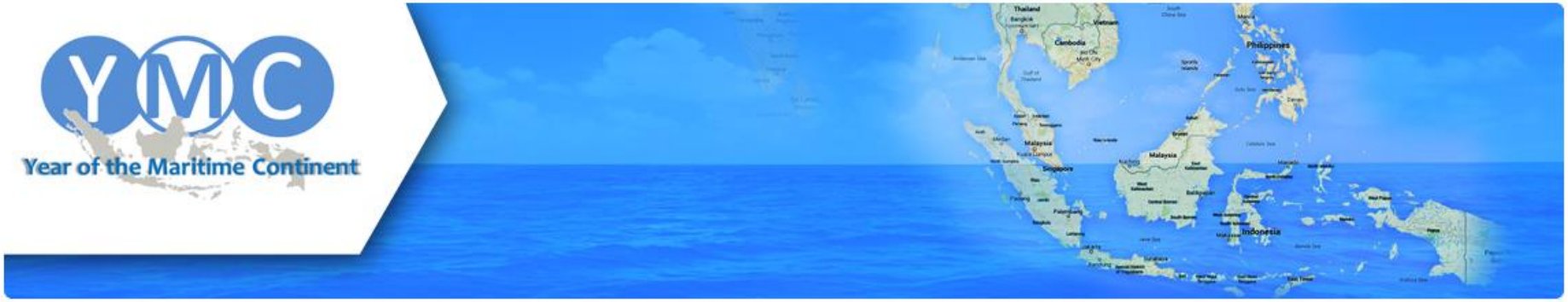


Wang et al. (2014) a radiative-convective equilibrium simulation with WRF Model v.3.0

4. Years of the Maritime Continents (2017-19)

http://www.bmkg.go.id/ymc/

http://www.jamstec.go.jp/ymc/

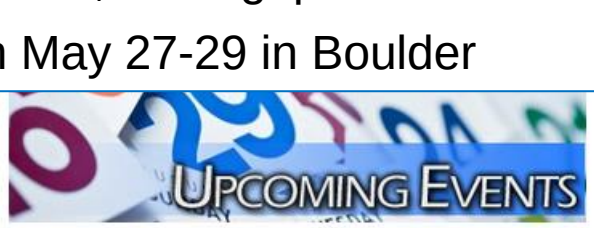


Year of the Maritime Continent (YMC)

is an international framework for international collaboration on field observations and modeling to better understand the role of the Maritime Continent on the global weather-climate continuum. More information on YMC in the about page.

1st International Science and Planning WS
In Jan. 28-30, 2015, in Singapore

US YMC WS in May 27-29 in Boulder



❖ Five Science Themes

1. Atmospheric Convection
2. Upper-Ocean Processes and Air-Sea Interaction
3. Stratosphere-Troposphere Interaction

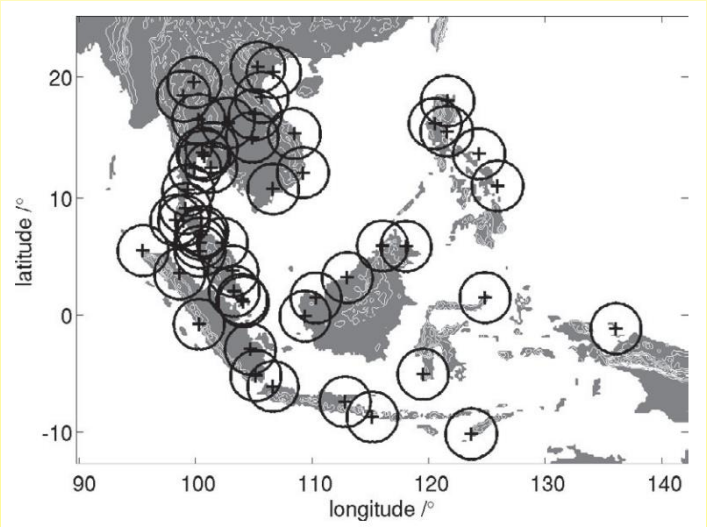
   Its objective is to improve understanding of processes governing the dynamical coupling of the stratosphere and troposphere and their mass exchanges over the MC.
4. Aerosol
5. Prediction Improvement

❖ Five Main Activities

1. Data Sharing
2. Field Campaign
3. Modeling
4. Prediction and Application
5. Outreaching and Capacity Building

❖ Research plan (tentative) for the dynamical part of the observations in Theme 3 S-T interaction

- wave analysis based on high vertical-resolution rawinsonde data archived for YMC (Tim Dunkerton's idea)
  - Hamilton and Vincent (1995) High-resolution radiosonde data offer new prospects for research, *Eos Trans. AGU*, **76**(49), 497–506
  - Love and Geller (2012) Research using high (and higher) resolution radiosonde data, *Eos Trans. AGU*, 2012, **93**, 35, 337
- networking of meteorological radars in SE Asia
  - Koh and Teo (2009 ➔) Toward a mesoscale observation network in Southeast Asia, *BAMS*, **90**(4), 481-488

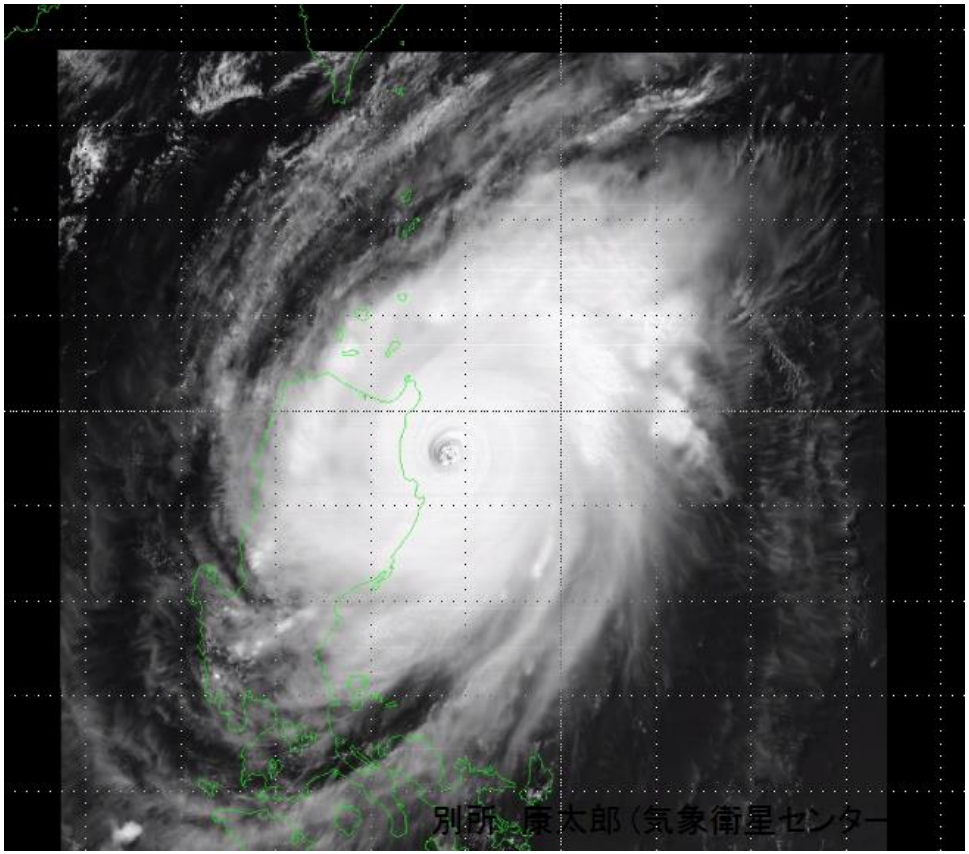


- super rapid scan of Geostationary Meteorological Satellite
  - Bessho (2015) Outline of new "Himawari" #8 ➔ next slide

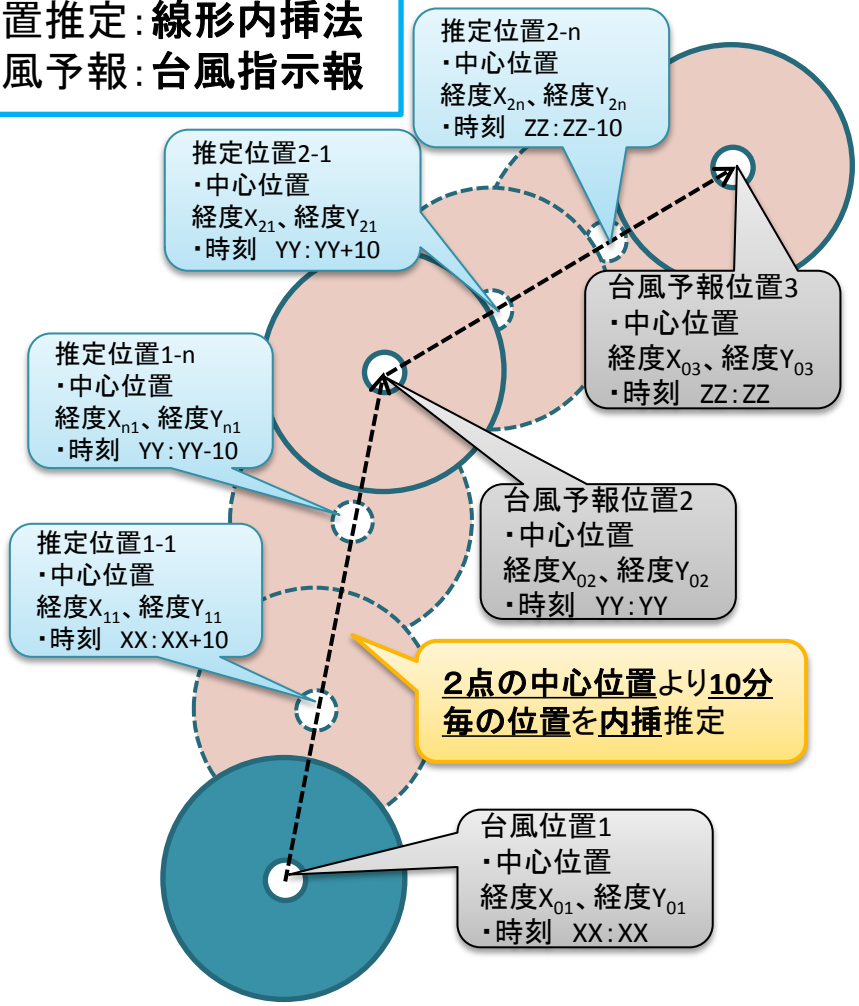
領域観測（機動観測域）

機動的観測（領域3）（2.5分間隔）
観測範囲: 1000km x 1000km
観測対象：台風等（任意）

位置推定：**線形内挿法**
台風予報：**台風指示報**



2015年5月10日06-19JST （台風1506）
可視画像



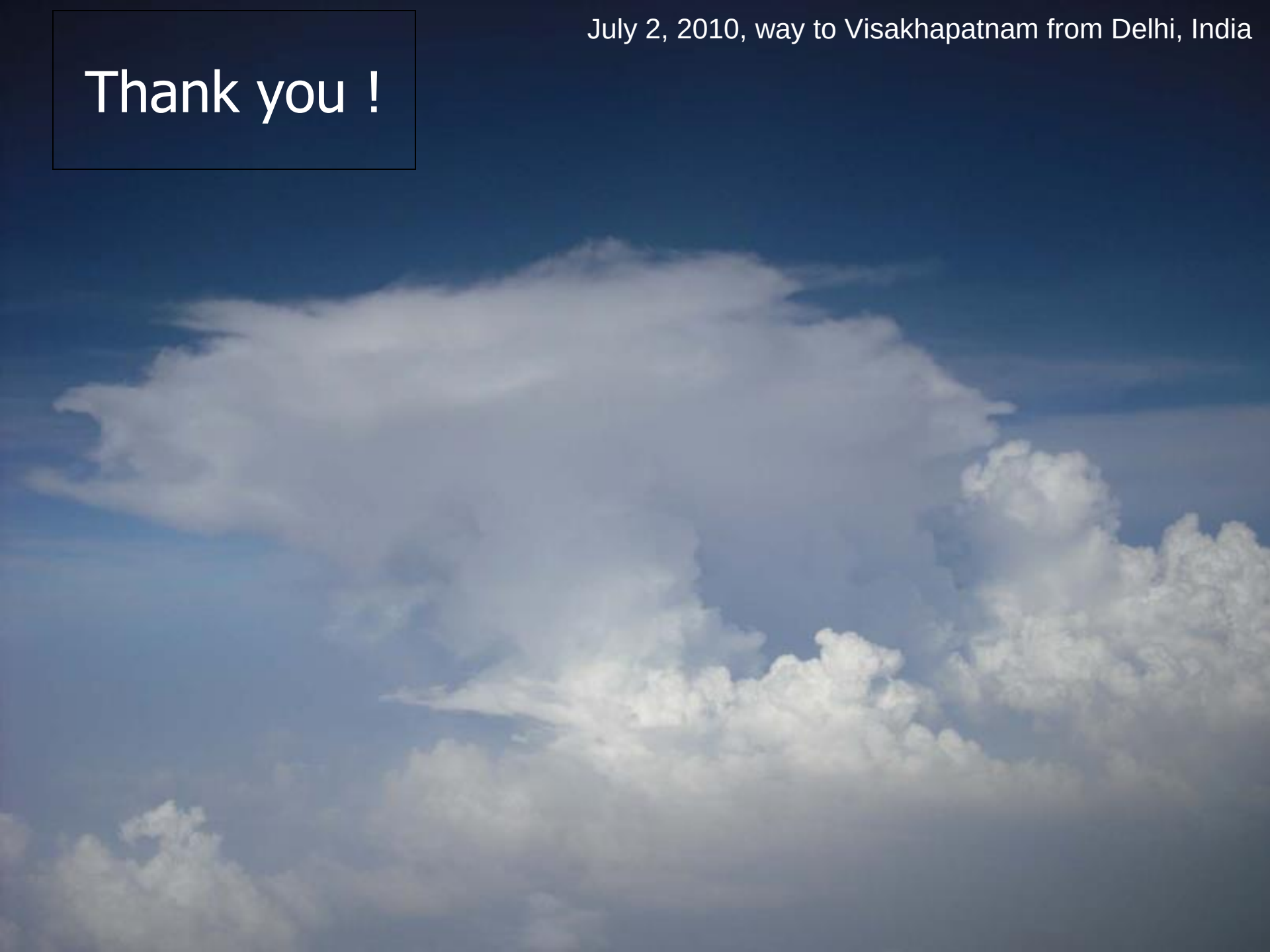
5. Near future activities and plan

- Workshop on the S-T dynamical coupling in the tropics
  - time: October 22(Thu) - 24(Sat), 2015
  - place: Kyoto U.
  - affirmed invitee:

    M. Geller, T. Hadi, P. Haynes, H. Hendon, K. Kodera, T.-Y. Koh, K. Sato, M. Shiotani, T. Tran, and a few more from overseas
  - main purpose of the closed brainstorming WS:
    to write a review paper on the subject (JMSJ or BAMS)

    It will be utilized for promoting the international collaborative research related to the subject under our JSPS core-to-core program and YMC
- Related planning meetings
  - 23rd SPARC Scientific Steering Group meeting
    in November 9-13 in Boulder, US
  - YMC 2nd International Science and Planning Workshop
    in November 24-27 in Jakarta, Indonesia

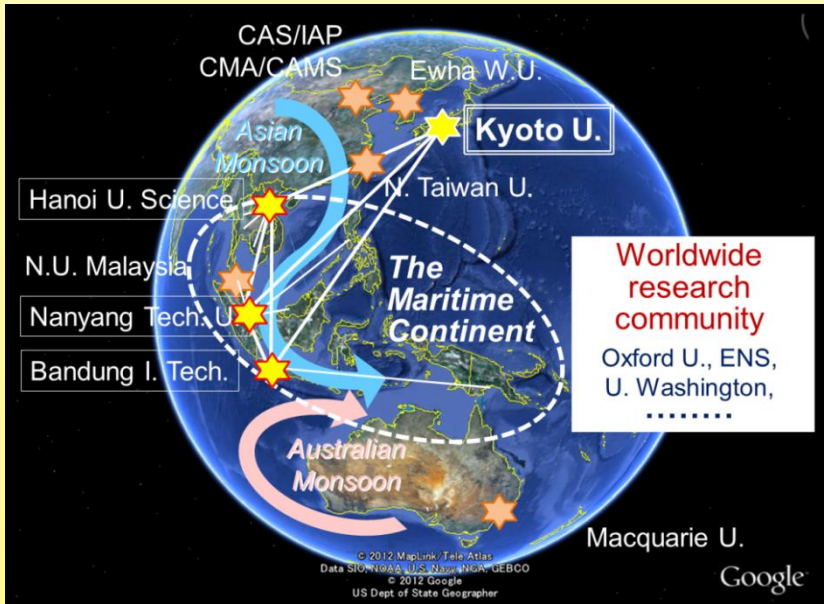
Thank you !



July 2, 2010, way to Visakhapatnam from Delhi, India

JSPS Core-to-Core Program Asia-Africa Science Platforms for FY2015-2017

- International research collaborations and networking on extreme weather in changing climate in the MC
  - Kyoto U., JMA/MRI, Riken/AICS
  - Indonesia, Singapore, Vietnam, and S/SE Asian countries
  - Numerical model studies with regional cloud-permitting nonhydrostatic models
    - JMA NHM, WRF, DWD HRM,…
  - Observations and data analyses
    - synoptic-scale disturbances
  - Applications of probabilistic NWP data
    - for societal, economic, and environmental decisions



❖ Research subjects related to the YMC

(1) Hindcast experiments on some typical events such as, cross-equatorial cold surge and Borneo vortex

<a> to check and tune the performance of numerical models

→ phenomenon oriented validation

<b> to make detailed dynamical analyses

including stratosphere-troposphere interaction

(2) Near real-time forecast experiments in collaboration with YMC observational campaigns through

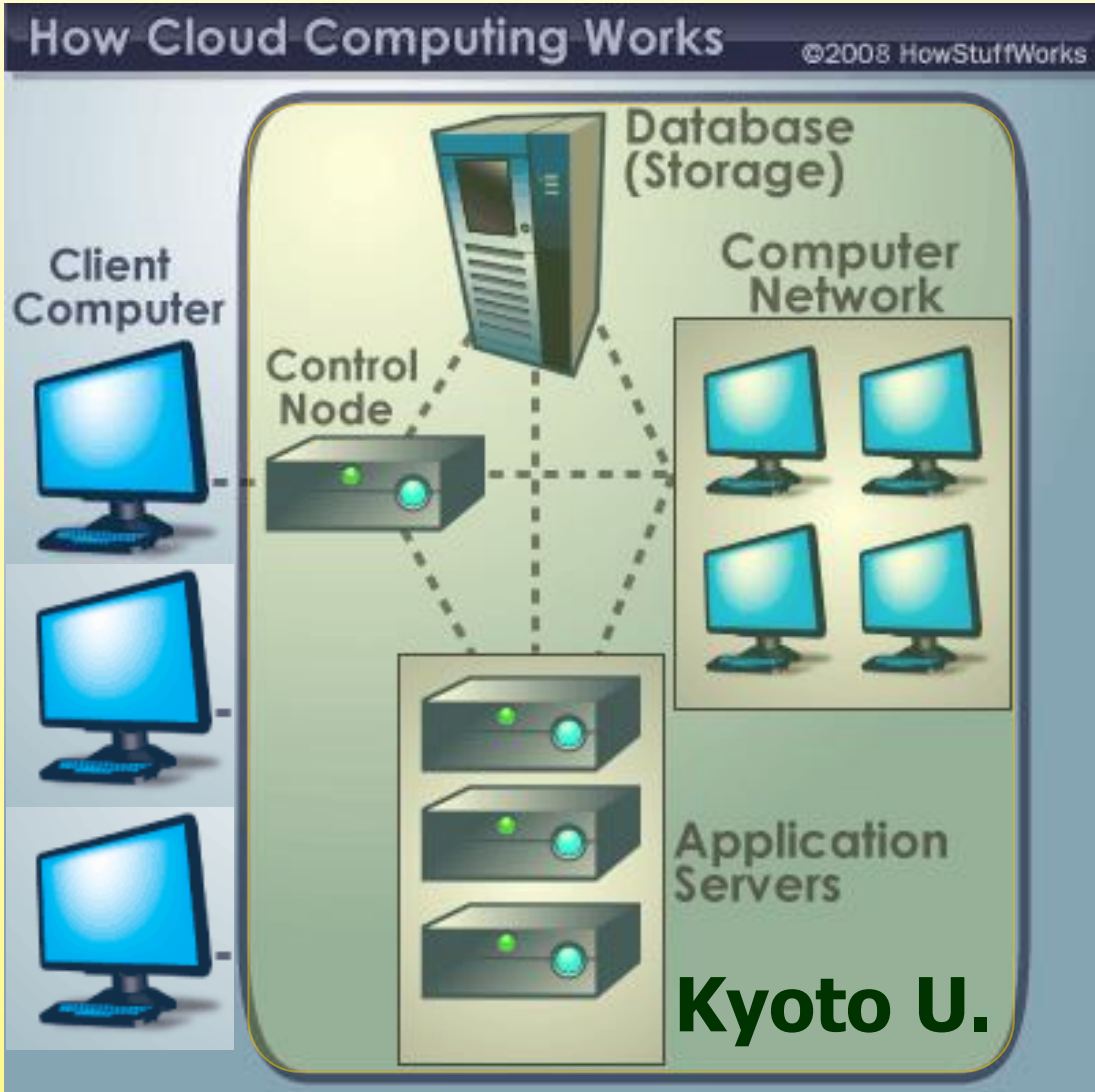
<a> design of adaptive observations

<b> assessment of their impact to improve the forecast

(3) Geophysical Fluid Dynamics-oriented numerical experiments for better understanding the fundamental dynamics related to "tropical meteorology"

- driven by moist convection
- multi-scale interactions with larger scales up to global scale
- little constraint of quasi-geostrophic balance
- stratosphere-troposphere interaction

- Multi-model and multi-analysis ensemble experiments by "cloud computing"
  - with our own application servers and database storages connected by Internet
    - NetCDF library
  - regional NHM
    - JMANHM, WRF, HRM…
  - analysis software
    - Dennou Ruby DCL
    - Gphys
    - Gfdnavi



http://computer.howstuffworks.com/cloud-computing/cloud-computing.htm

❖ Activities to foster the next generation of scientists and to make their network in S/SE Asian countries

(1) International Summer School

- one-week long to learn tropical meteorology, numerical modeling, …
- at Bandung (2015), Hanoi (2016), and Singapore (2017)

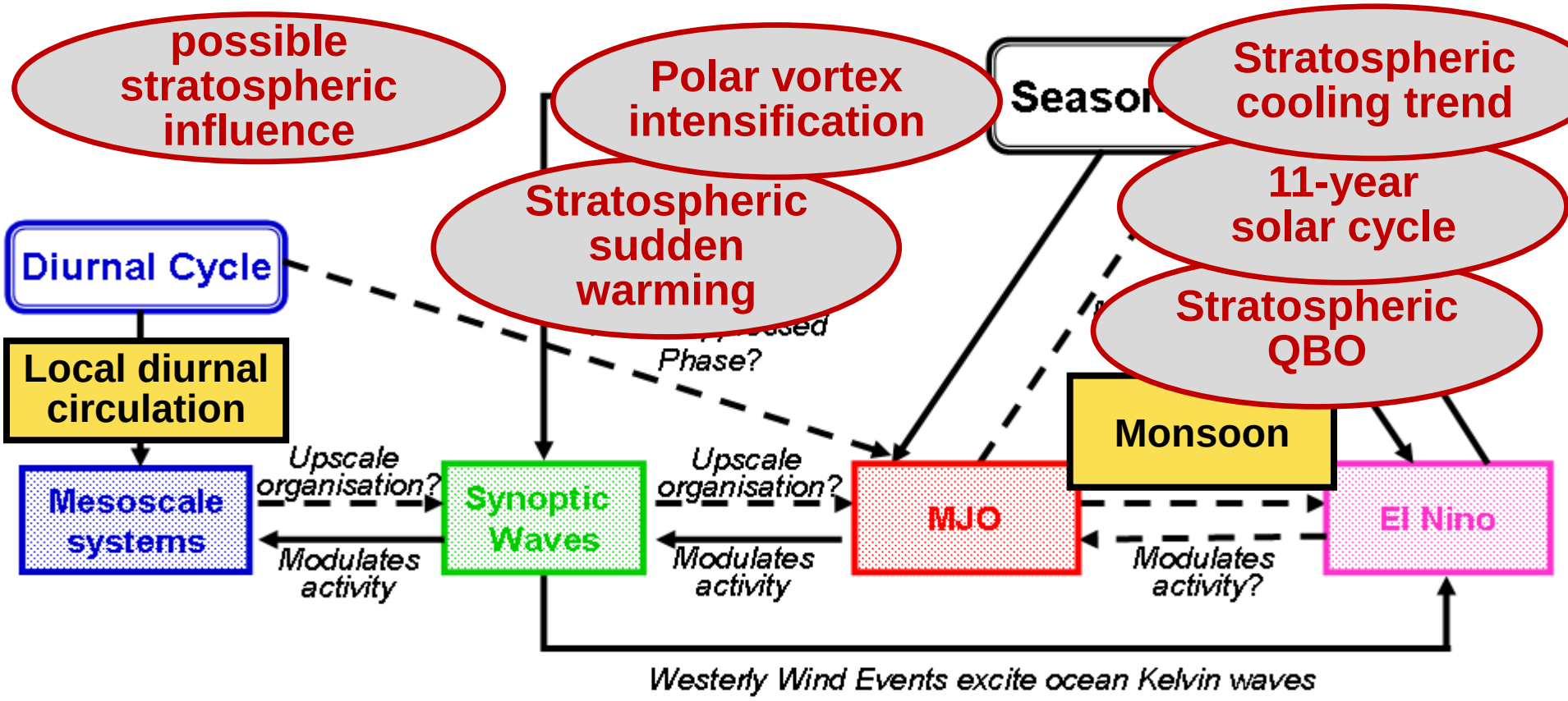
(2) International Workshop

(3) Textbooks on Tropical Meteorology

- Based on the lectures of International Summer School
- c.f., KAGI21 ISS (Kyoto U. Active Geosphere Investigation in 21st C.)

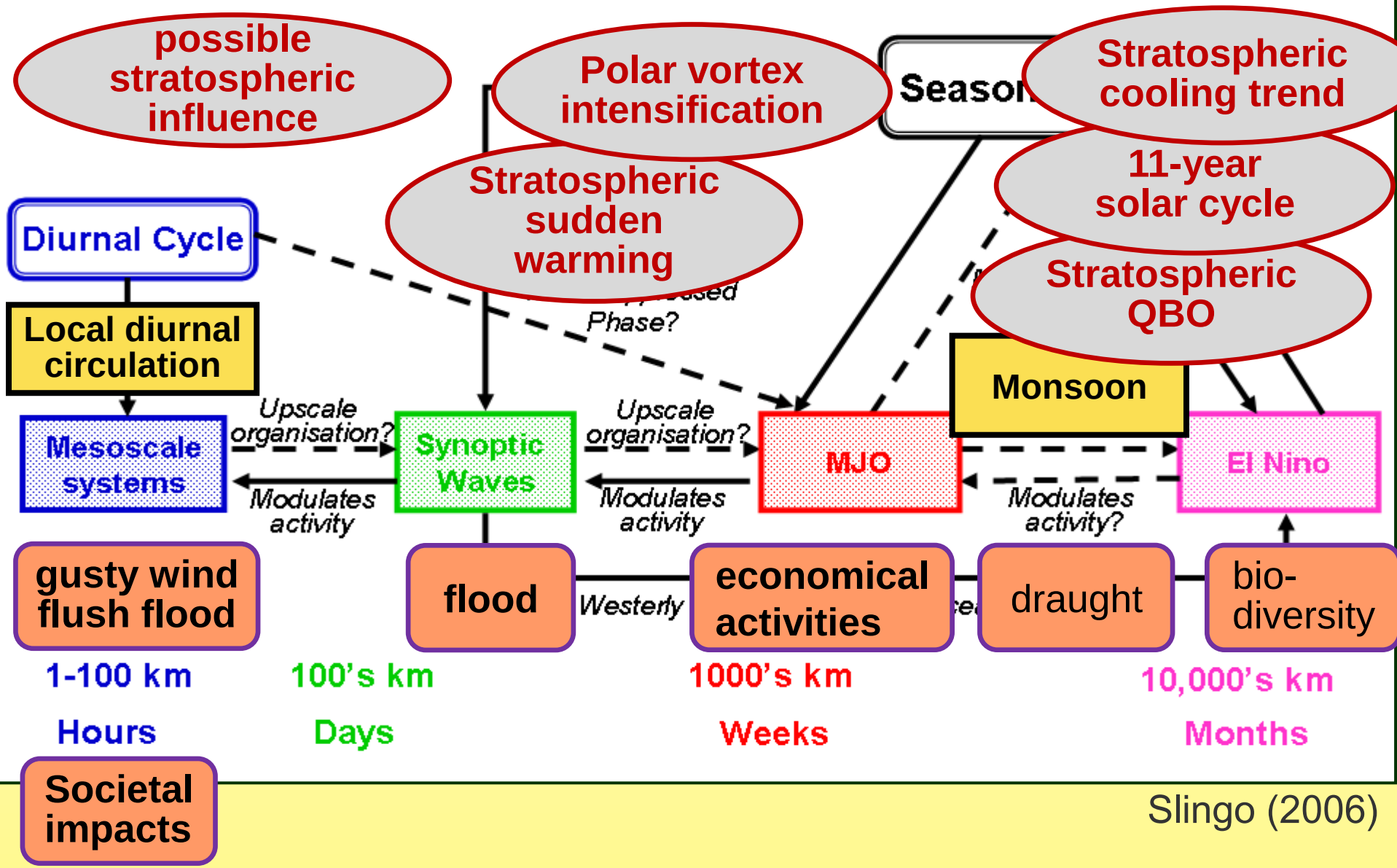
4 times in Bandung and
4 times in Kyoto
285 students from 21 countries
8th KAGI21 ISS in March 2015

Interactions between space and time scales of tropical convection: Linking THORPEX and WCRP



Slingo (2006)

Interactions between space and time scales of tropical convection: Linking THORPEX and WCRP



Slingo (2006)


August 8, 2014, Bandung, Indonesia Shigeo Yoden

Self-organization of convective clouds in the tropics

Interaction with complex topography and land-sea contrast, particularly in the Maritime Continent

Tsuda(2009)