Years of Maritime Continent Implementation Plan Workshop
24-26 November 2015
BMKG/Grand Mercure Hotel Kemayoran in Jakarta, Indonesia

International Research Collaborations on Stratosphere-Troposphere Dynamical Coupling in the Tropics under YMC

Shigeo Yoden (Kyoto U., Japan)

23rd SPRC SSG meeting
9-13 November 2015, Boulder, Colorado

Report on the International Workshop on Stratosphere-Troposphere Dynamical Coupling in the Tropics

held in
October 22-24, 2015,
Kyoto, Japan

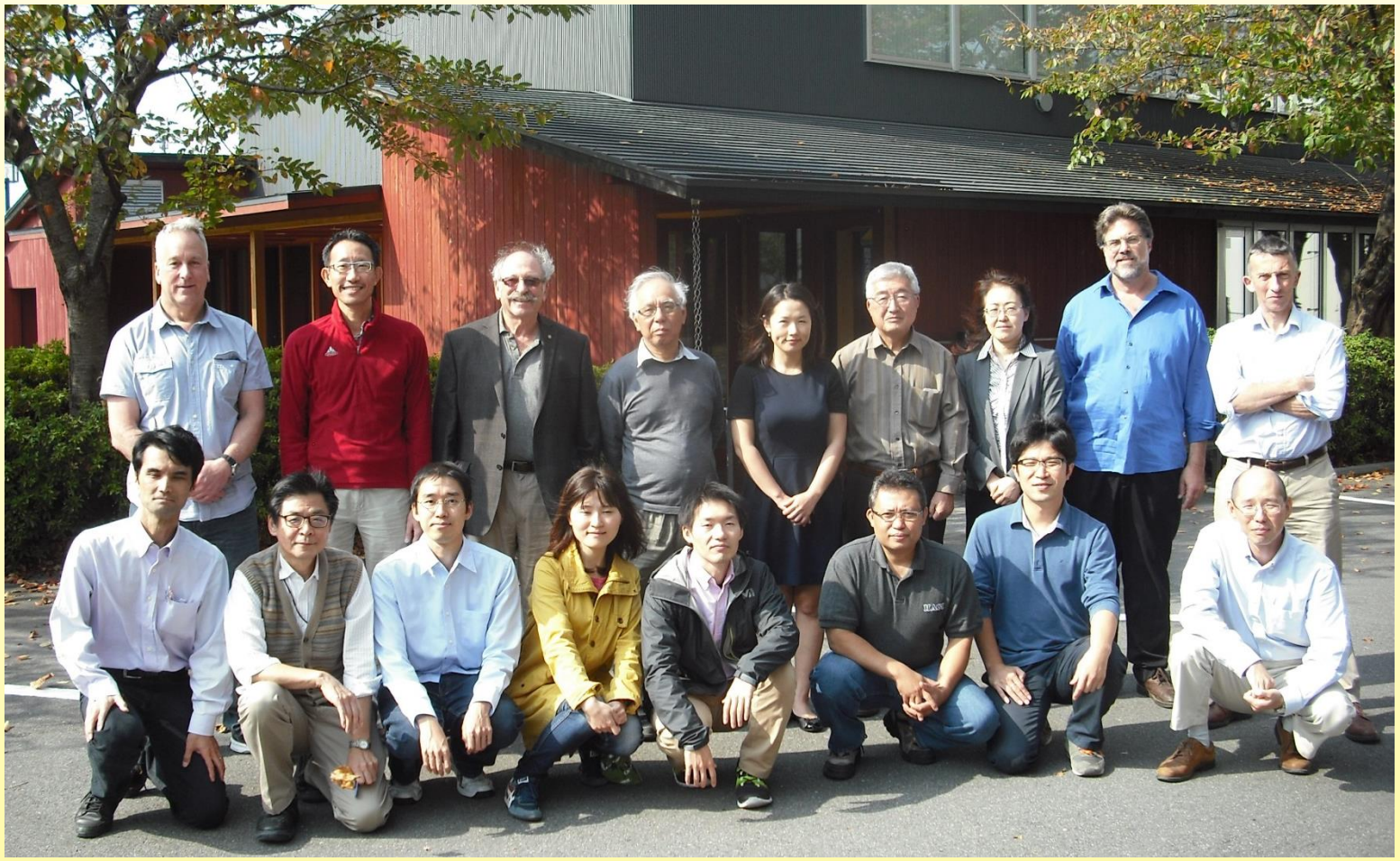
Shigeo Yoden (Kyoto U., Japan)

1. Summary

- What:
  18 researchers from 7 countries met
  to review the recent progress in the observational and numerical studies on stratosphere-troposphere dynamical coupling in the tropics, focusing on possible two-way interactions between the two “spheres”,
  and to discuss near future international collaborations on the subject.

- When:
  October 22(Thu) - 24(Sat), 2015

- Where:
  Grad.Sch.Sci. Seminar House, Kyoto U., Japan



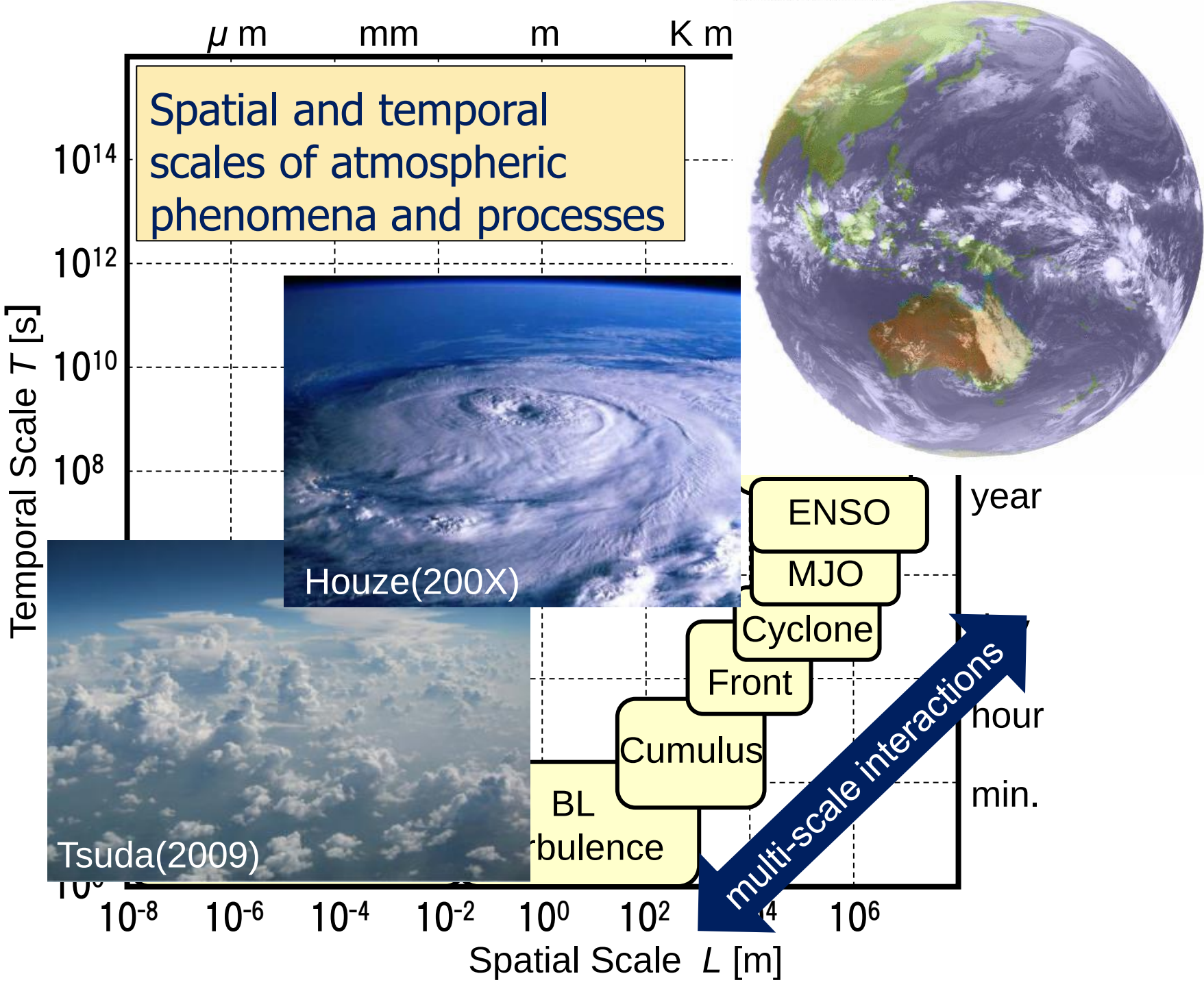
Marvin Geller (Stony Brook U.)	Tri Wahyu Hadi (I.T. Bandung)	Peter Haynes (U. Cambridge)
Harry Hendon (CAWCR-BoM)	Matt Hitchman (U.WisconsinM)	Keiichi Ishioka (Kyoto U.)
Ji-Eun Kim (NOAA/ESRL)	Kunihiko Kodera (Nagoya U.)	Tieh-Yong Koh (Nanyang T.U.)
Eriko Nishimoto (Kyoto U.)	Satoshi Noda (Kyoto U.)	Kaoru Sato (U. Tokyo)
Masato Shiotani (Kyoto U.)	Seok-Woo Son (Seoul N.U.)	Masakazu Taguchi (Aichi U.E.)
Toshitaka Tsuda (Kyoto U.)	Kohei Yoshida (JMA/MRI)	Shigeo Yoden (Kyoto U.)

2. Background

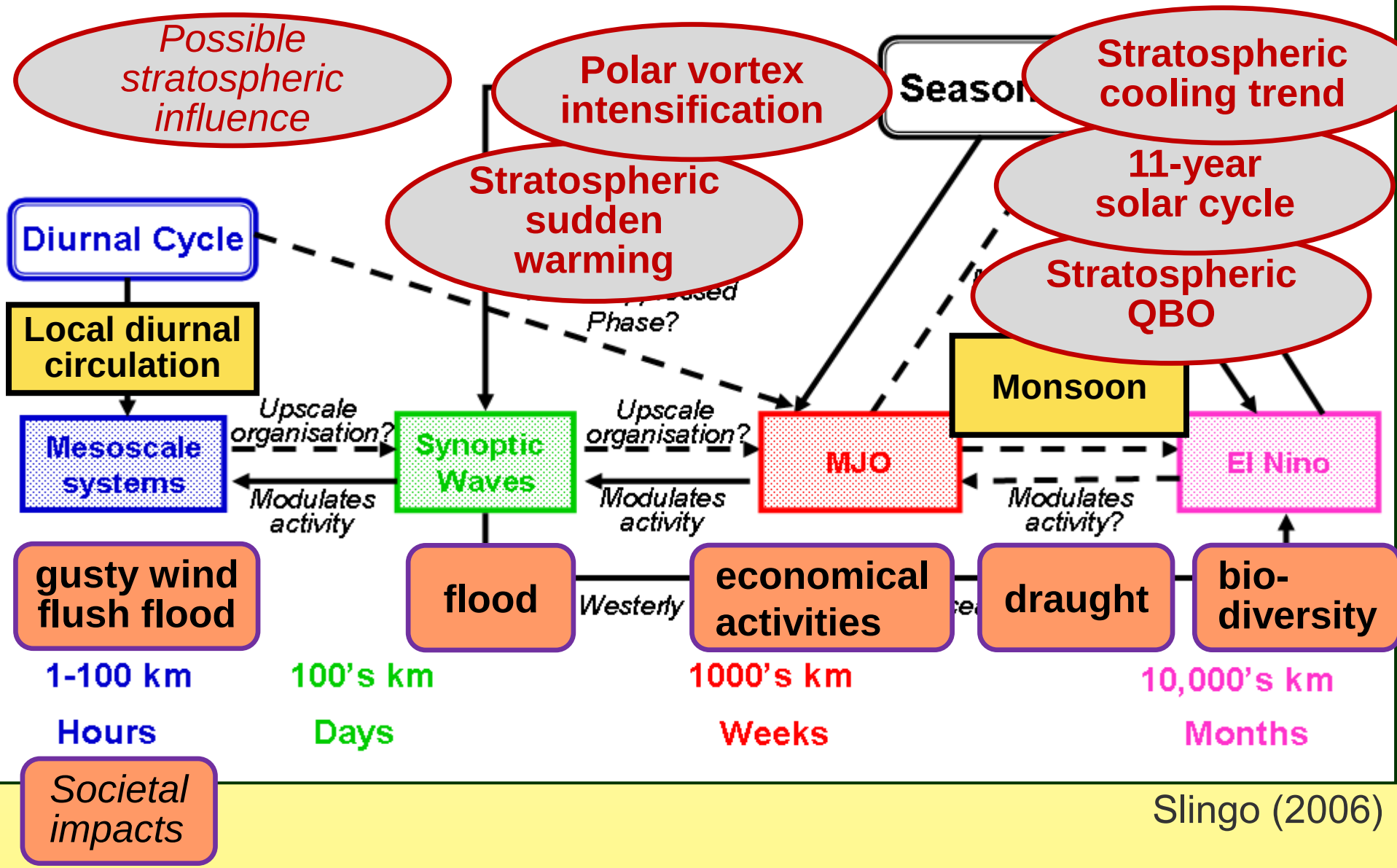
- WCRP/SPARC Theme 3
  - Stratosphere-troposphere dynamical coupling

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

    Mostly focusing on mid-latitudes and polar regions in these decades
- Tropical meteorology; dynamics in the tropics
  - multiscale interactions of moist convections
  - a totally different world from the extratropics where the quasi-geostrophic potential vorticity (PV) dynamics prevails
    - small Coriolis parameter
    - small-scale moist convection is the predominant source of energy
- Stratospheric influence on tropospheric variations ?
  - how can stratospheric variations influence on moist convection, and thus the tropospheric variations in weather and climate continuum ?


Spatial and temporal scales of atmospheric phenomena and processes
μ m
mm
m
K m
Temporal Scale T [s]
10^14
10^12
10^10
10^8
Houze(200X)
Tsuda(2009)
ENSO
MJO
Cyclone
Front
Cumulus
BL
rbulence
year
hour
min.
multi-scale interactions
10^-8
10^-6
10^-4
10^-2
10^0
10^2
10^6
Spatial Scale L [m]

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



Slingo (2006)

3. Some highlights discussed in the WS

- Observational facts

  revealed by statistical analyses and case studies

- New findings

  obtained by newly developed and advanced observations

- Numerical-model simulations and experiments

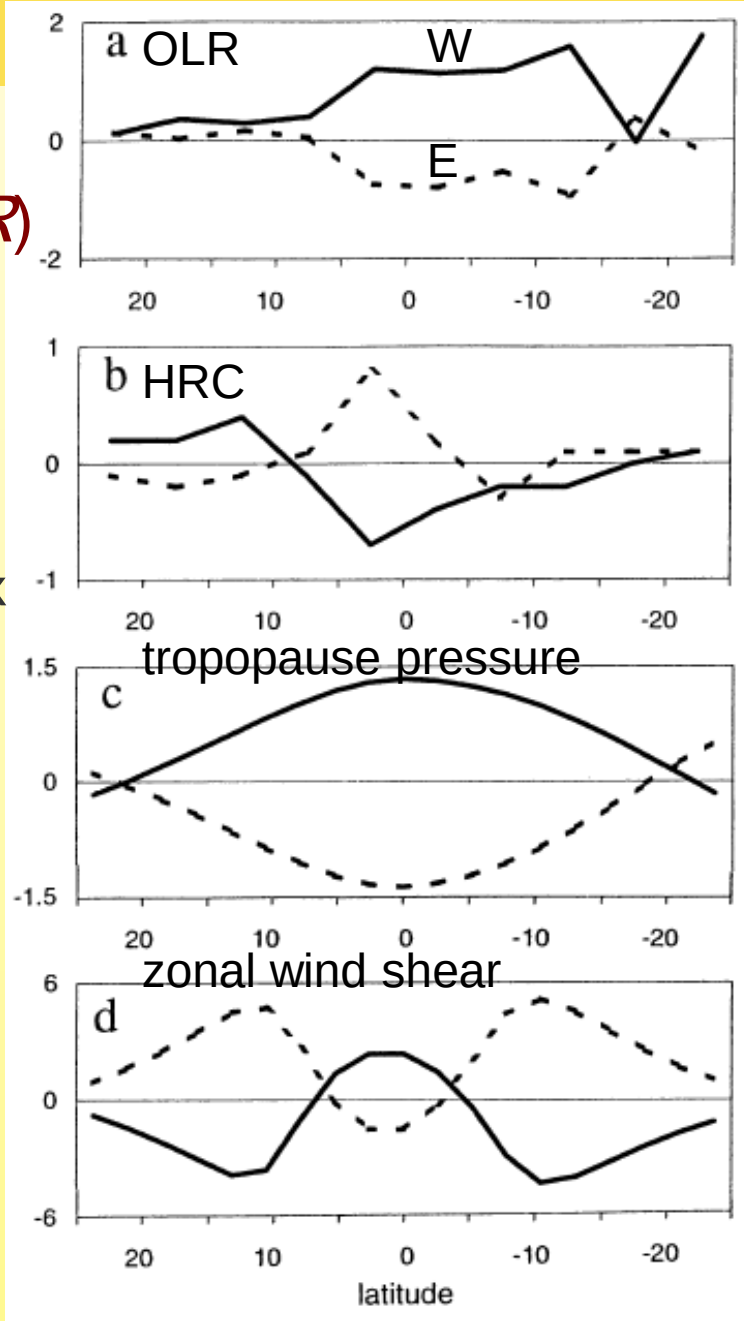
  with global and regional models for weather predictions and climate projections

- Theoretical backgrounds

  for better understanding the essence of dynamics and for providing powerful and effective analysis tools

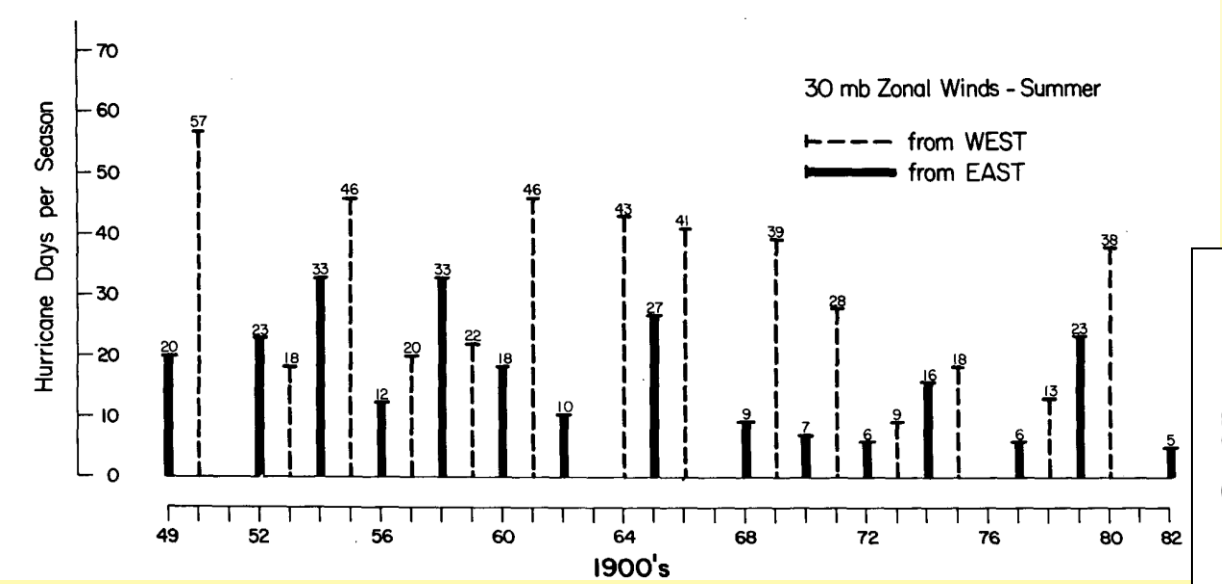
❖ Influence of the QBO on tropical deep convections as revealed by data analyses

- Collimore, et al. (1998, *GRL*)
- Huesmann & Hitchman (2001, *JGR*)
- Collimore, et al. (2003, *J.Clim.*➔)
  - ➢ On the relationship between the QBO and tropical deep convection for 1958–2001
    - – highly reflective cloud (HRC) index and other indices
- 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
- Yuan (2015, PhD Dissertation)

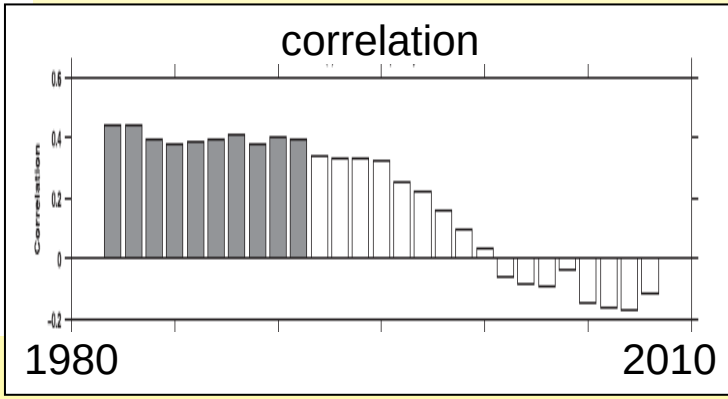


❖ Influence of the QBO on tropical cyclones (TCs)

- 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

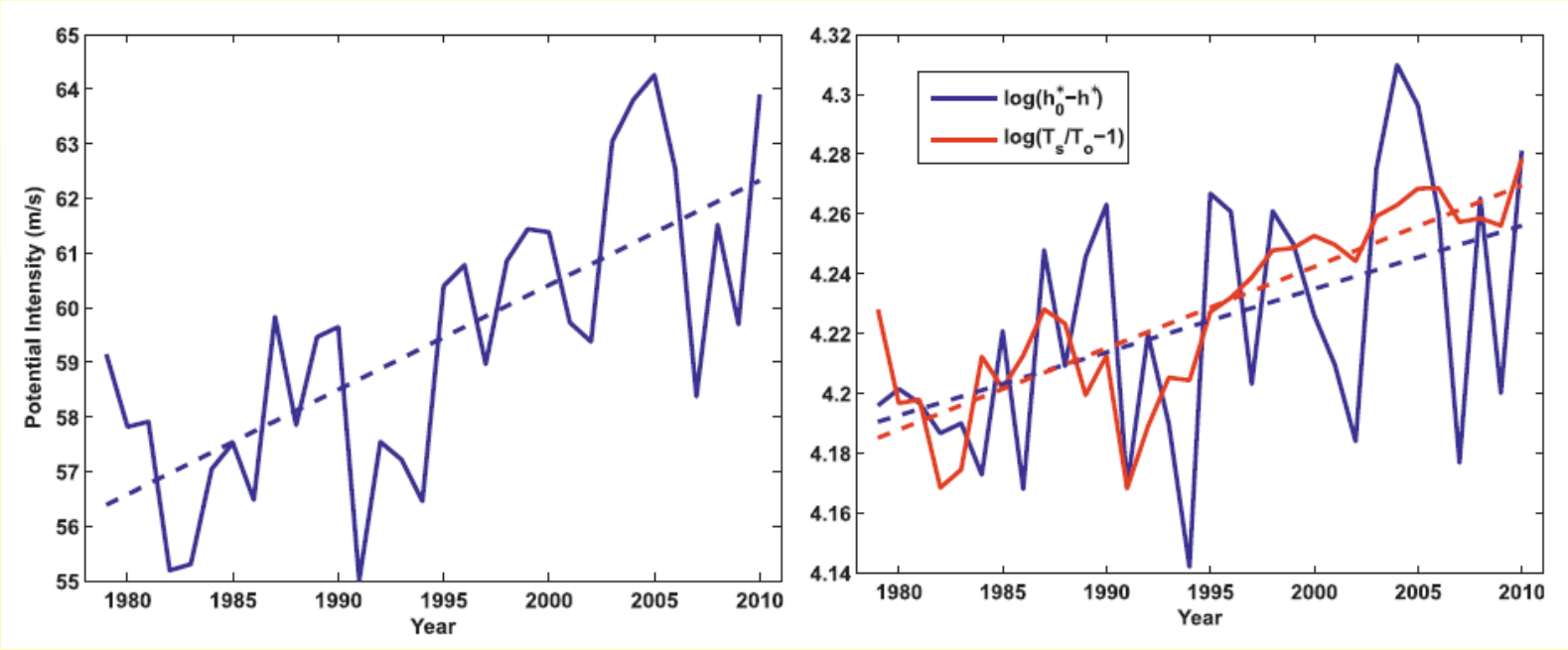
❖Influence of the QBO on Madden-Julian Oscillation

- Kuma (1990, *Int.J.Clim.*)
  - QBO and the intensity of the intra-seasonal oscillation (ISO) at 150 hPa is well correlated.
  - MJO-like ISO is stronger during E-QBO than W-QBO
- Liu et al. (2014, *JGR*)
  - Composite for E-QBO and W-QBO
  - Stronger convection in E-QBO with OLR anomaly for 1979-2012
- Yoo and Son (2015, *submitted to*)
  - MJO activities are generally stronger during E-QBO winters (DJF) than W-QBO winters
- Marshall, Hendon, and Son (2015, to be submitted to *GRL*)
  - QBO modulation of predictability of the MJO: increased forecast skill in E-QBO, because stronger MJO is easier to predict

Marshall et al.'s result has implication to sub-seasonal to seasonal (S2S) predictions

❖ 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: *du/dz*, *w*
- thermodynamics: *T*, N^2
- tropopause height
- xxxxxxx = amplification mechanism of small perturbation ?

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

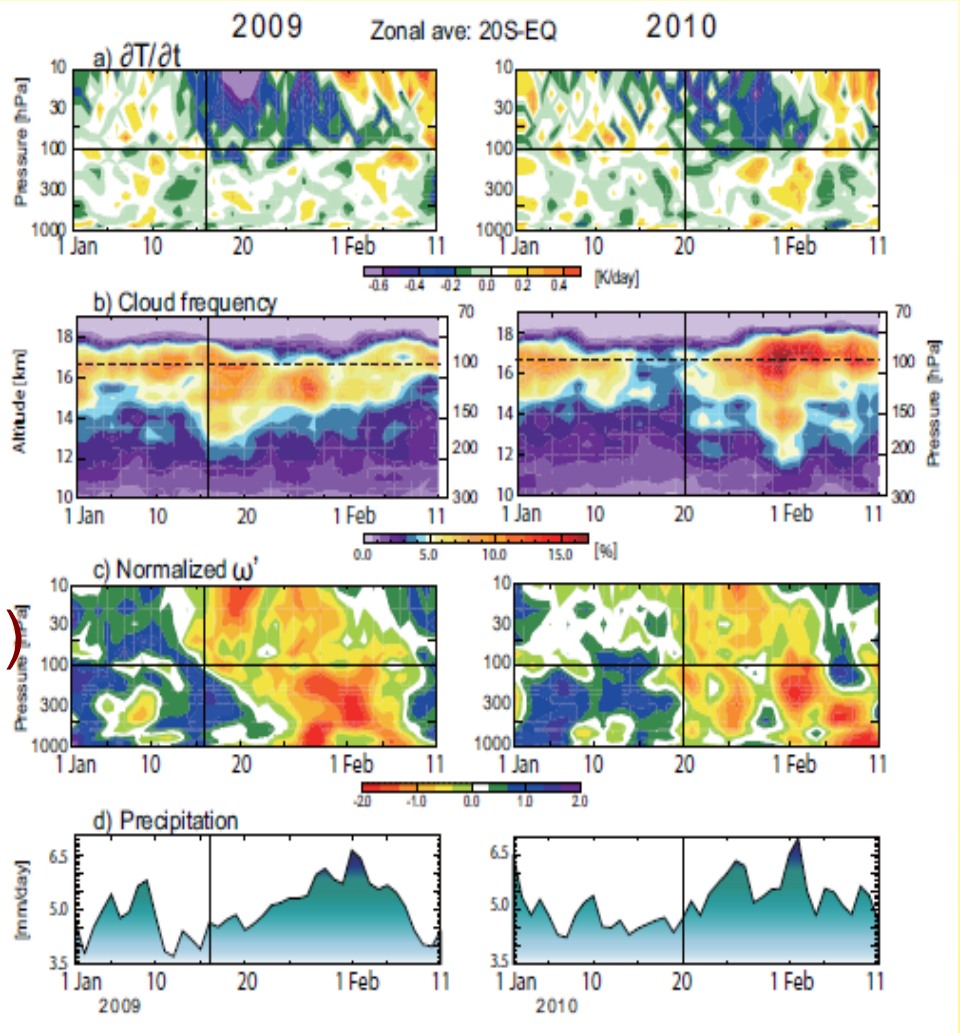
- response of extratropical diabatic circulation to a time-dependent wave driving may have an impact on low latitudes
- Eguchi and Kodera (2010, *SOLA*)

  impacts of 2007 SH SSW
- Kodera et al. (2011, *JMSJ*) Dhaka et al. (2015, *Atm. Res.*)

  2009 NH SSW
- Kodera et al. (2015, *ACP*➔)

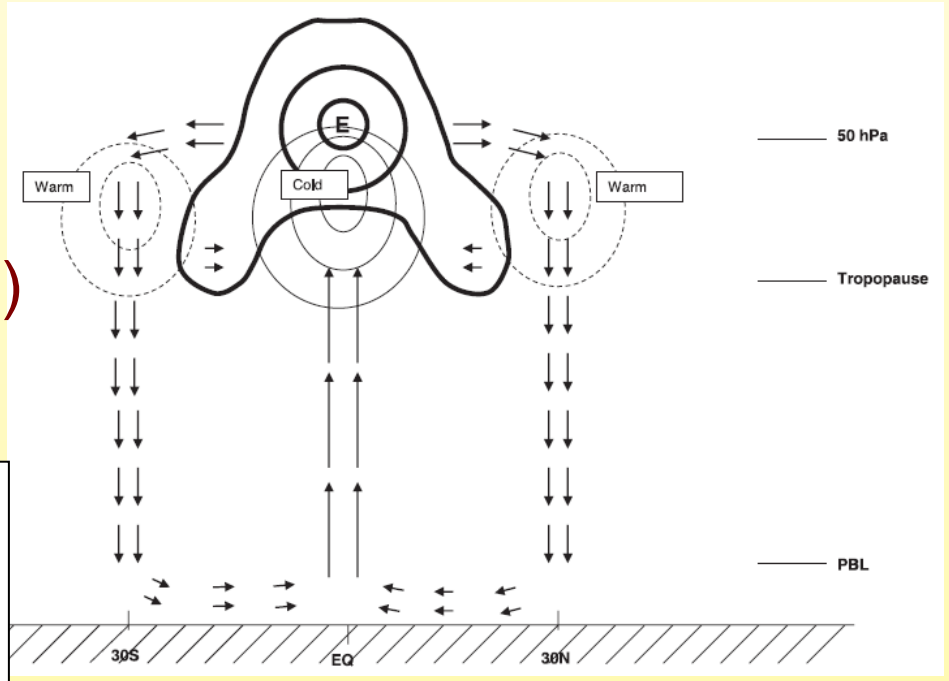
  the role of convective overshooting clouds
- Eguchi et al. (2015, *ACP*)

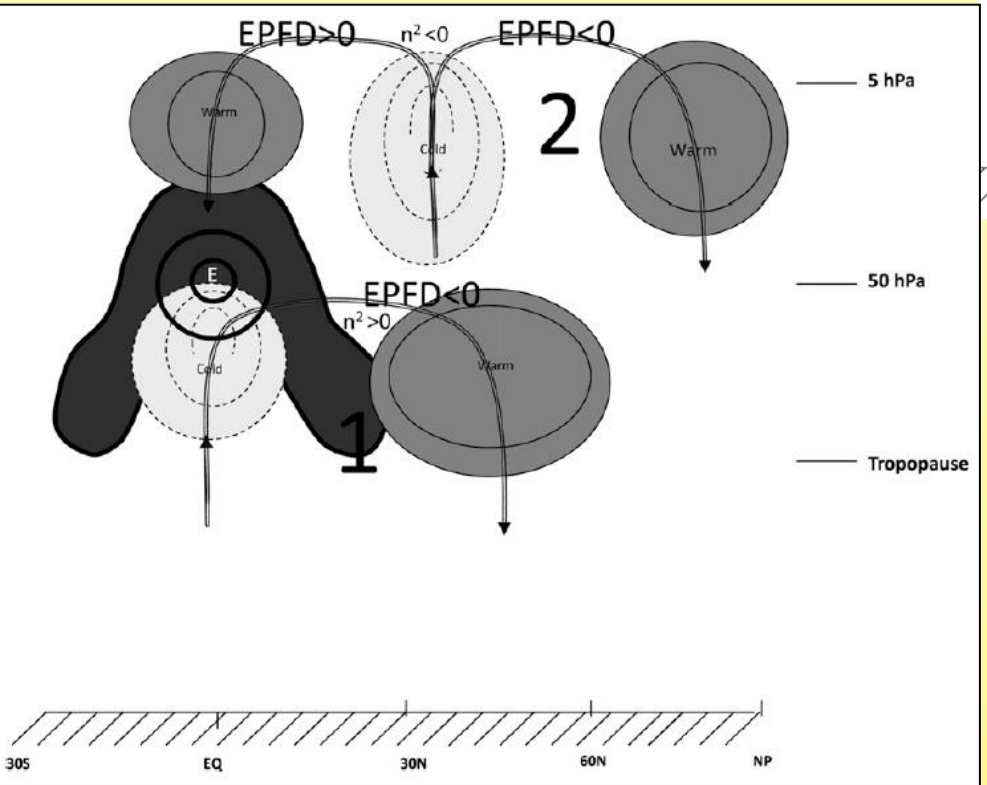
  NICAM study of a downward coupling through TTL



❖ Numerical model studies with GCMs

- Garfinkel and Hartmann (2011a,b, *JAS* ↓)
  - use of a hierarchy of numerical models for better understanding of the QBO influence on the troposphere
- Garfinkel et al. (2012, *JAS* ↓)
- ……





Whether is this effect on the subtropical jet felt in the subtropics/tropics (perhaps including some moist dynamics) ?

❖ Numerical model studies Regional CRMs

- Wang et al. (2014➔)

  Impact of tropopause temperature on the intensity of TCs

- Yoden et al. (2014)

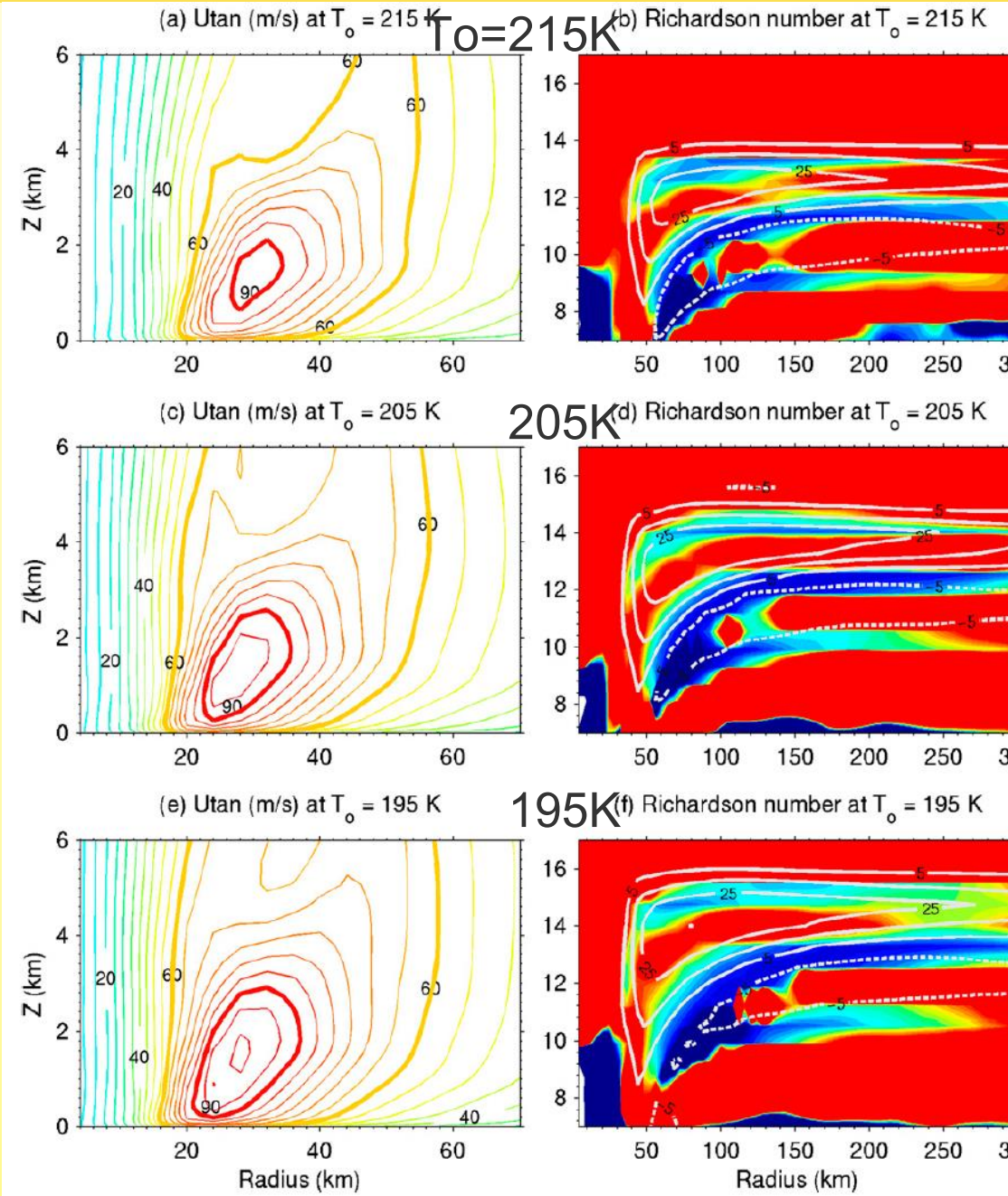
  QBO-like oscillations in a 2D S-T coupled system as a radiative-convective quasi-equilibrium

- Nie and Sobel (2015)

  Responses of tropical deep convection to the QBO

- Yuan (2015)

  QBO Influence on the organization of tropical convective systems



❖ New findings by newly developed and advanced observations

- migrating tides by SMILES (Sakazaki et al., 2013) and a zonally symmetric non-migrating tide (Sakazaki et al., 2015)
- ENSO and MJO modulation of gravity wave characteristics by AIRS (Sato et al., and Tsuchiya et al., submitted to *JGR*)
- high vertical resolution temperature profiles of COSMIC GPS-RO FSI (Full Spectrum Inversion; Jensen, 2005)
- vertical profiles of cirrus clouds and chemical composition around TTL by NASA ATTREX (Jensen et al., 2015, submitted to *BAMS*; Kim et al., to be submitted)
- new morphology of the QBO
  - weaker amplitude and faster phase propagation of the QBO for El Niño conditions (Taguchi, 2010, *JGR*)
  - zonally asymmetric components of zonal wind associated with the QBO, due to the longitudinal variation of GW source of Walker circulation filtering ??

❖ Theoretical backgrounds for better understanding the essence of dynamics and for providing powerful and effective analysis tools

- wave-induced mean meridional circulation in the winter stratosphere (Haynes et al. 1991, Holton et al., 1995)
  - ➢ deep branch of the BD circulation by planetary waves
  - ➢ shallow branch of the BD circulation by synoptic waves
  - ➢ downward control for steady forcing, whereas meridional extension for transient forcings (depending on the time scale)
- sustained upwelling in the tropical lower stratosphere requires low latitude forces ← GPS-RO (Randel & Wu, 2015)
- Extension of 3D diagnostics on wave-mean flow interactions and induced circulation for both GWs and PWs (Kinoshita and Sato, 2013; Sato et al., 2013) and also EQ waves (Kinoshita and Sato, 2014)
- Application of Fluctuation Dissipation Theorem (FDT) to climate response in the tropics as an ENSO-like pattern ?

4. Related projects and activities

- WCRP/SPARC/FISAPS(Fine Scale Atmospheric Processes and Structures) by Marvin Geller
  - utilise operational high vertical resolution radiosonde data to study various phenomena with vertical scale less than 1 km, such as GWs, TIL, PBL, turbulence, and so on

A Proposed WCRP/SPARC Project on Fine-Scale Atmospheric Structures and Processes (FISAPS)

Marv Geller

Stony Brook University (Emeritus)

Breaking Gravity wave into Turbulence

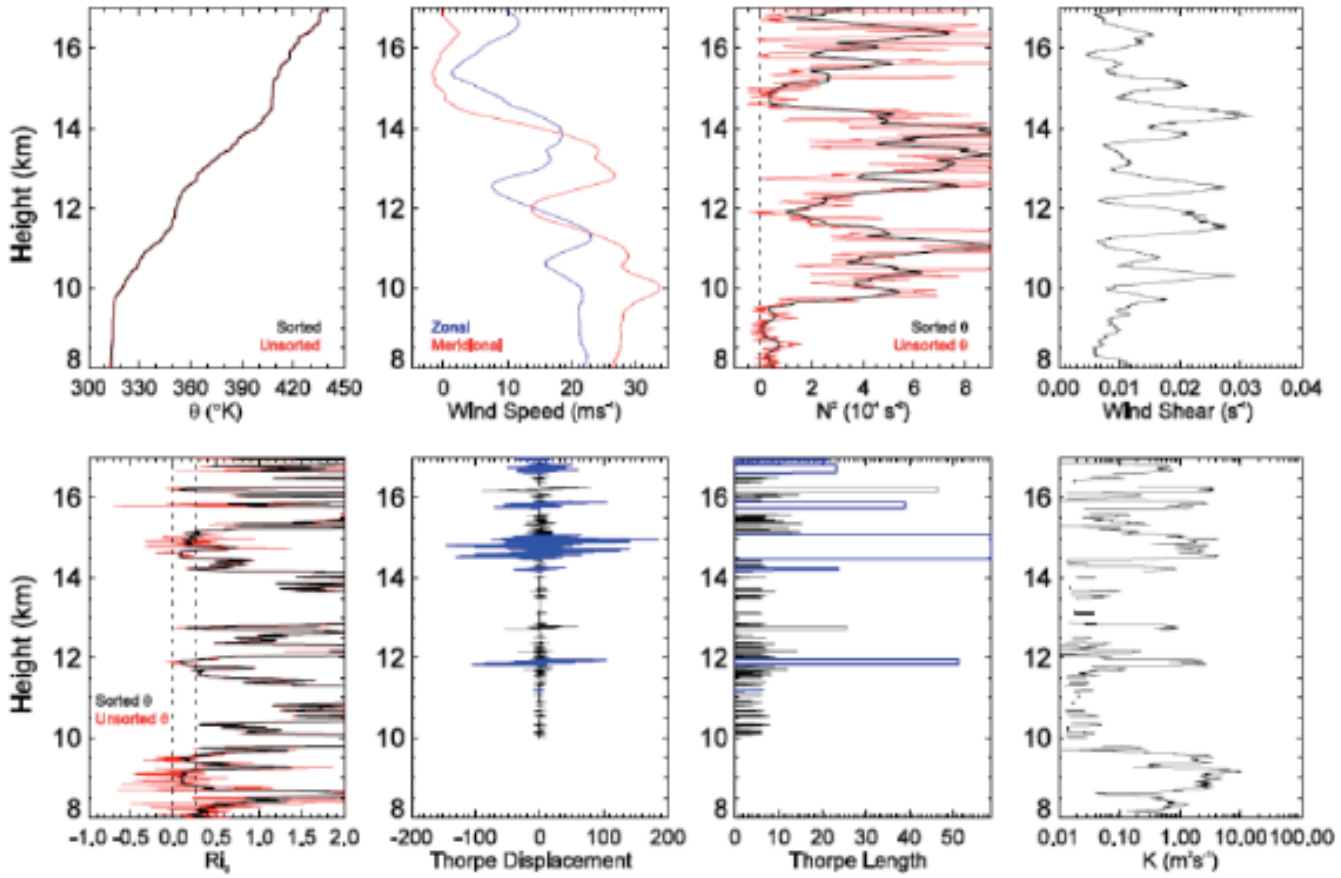


Figure 1. Profiles from high vertical-resolution radiosonde sounding made February 12, 2007 at Riverton, Wyoming. Variable plotted are (a) potential temperature (sorted monotonically increasing with height), (b) wind speed components, (c) Brunt-Väisälä frequency calculated using both sorted and unsorted potential temperature, θ, (d) wind shear, (e) Richardson Number calculated using both unsorted and sorted θ, (f) Thorpe Displacement in m, (f) Thorpe Length in m, and (g) turbulent eddy diffusivity. Thorpe displacements and lengths were calculated as in Wilson et al. (2010). From Love and Geller (2013).

Workshop on Research Applications of High Vertical Resolution Radiosonde Data; Stony Brook, New York, 27–29 May 2013

At that meeting, it was decided to propose FISAPS as a new SPARC/WCRP project.

FISAP Goals

- Improve understanding of atmospheric fine-scale structures and processes.
- Study phenomena with vertical dimensions smaller than 1 km: gravity waves, turbulence, atmospheric boundary layer, and the tropopause.
- Realize the full potential of both research and operational high resolution sounding data (e. g., radiosonde, radio occultation, ozone sondes, aircraft data).
- An important aspect of FISAPS is to encourage the wider availability of worldwide high resolution radiosonde data through encuraging nations to make these available, and steward its archiving and easy availability.

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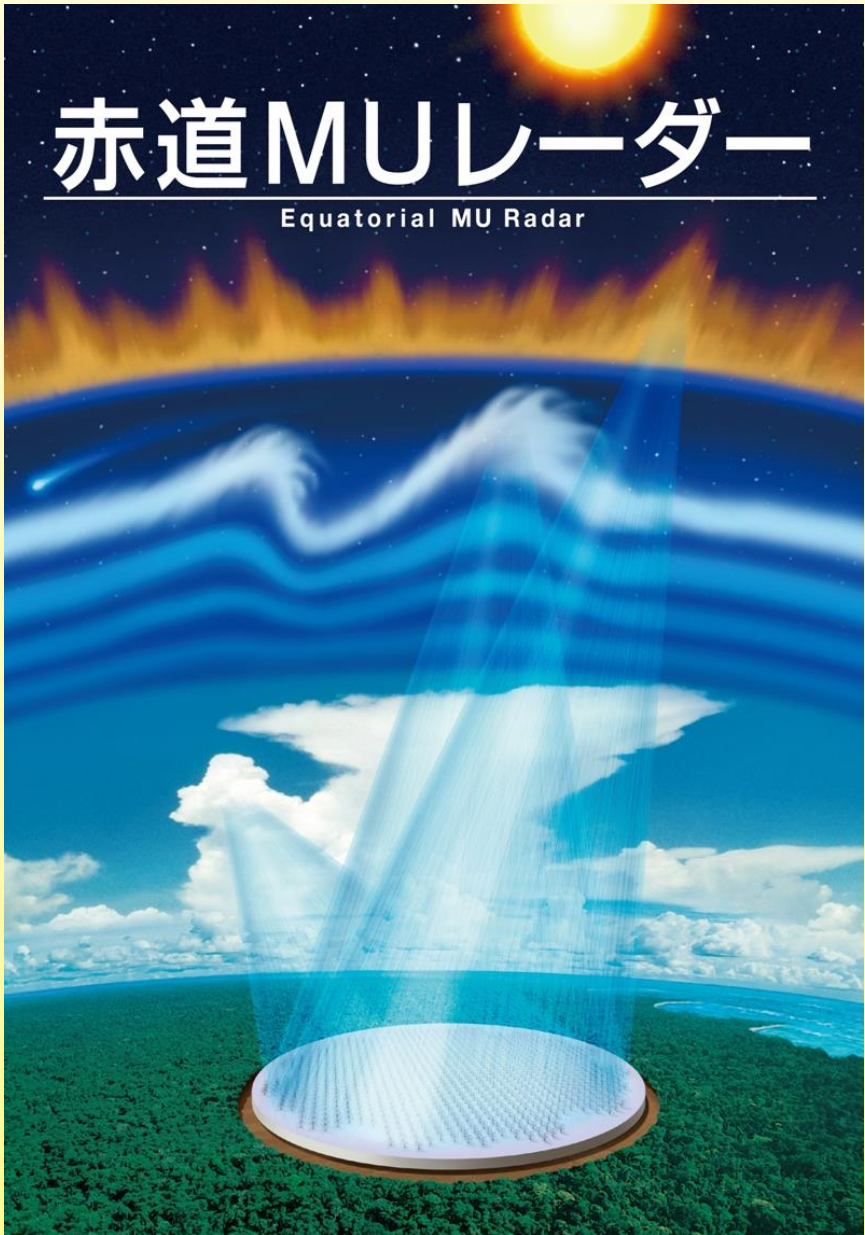
- Project of Equatorial MU Radar by Toshitaka Tsuda
  - “Equatorial fountains” of energy and material flows

❖ New scientific challenges of the Equatorial Middle and Upper Atmosphere Radar (EMU)

- proposed by RISH, Kyoto U.
- PI: Professor Toshitaka Tsuda
- http://www.rish.kyoto-u.ac.jp/emu/index-e.html



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  - “Equatorial fountains” of energy and material flows
- Research activities linked to YMC (Years of Maritime Continent) by Tri Wahyu Hadi and Tieh-Yong Koh
  - tropical meteorology and subseasonal to seasonal prediction
  - 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

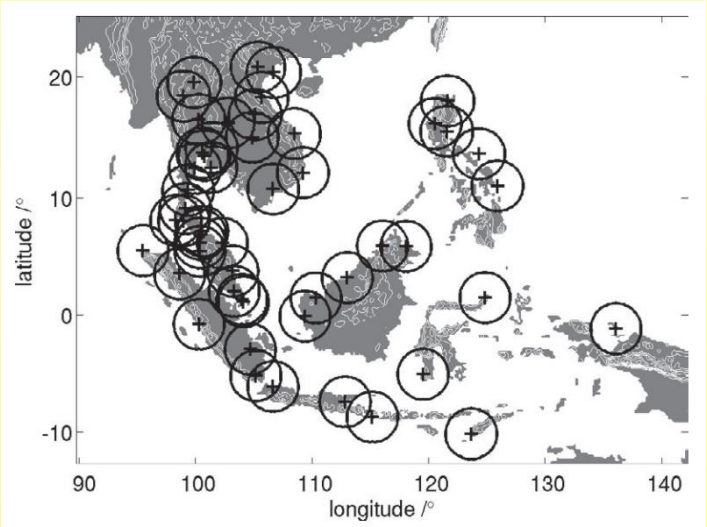
❖ Years of the Maritime Continents (2017-19)

- http://www.bmkg.go.id/ymc/ http://www.jamstec.go.jp/ymc/
- 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

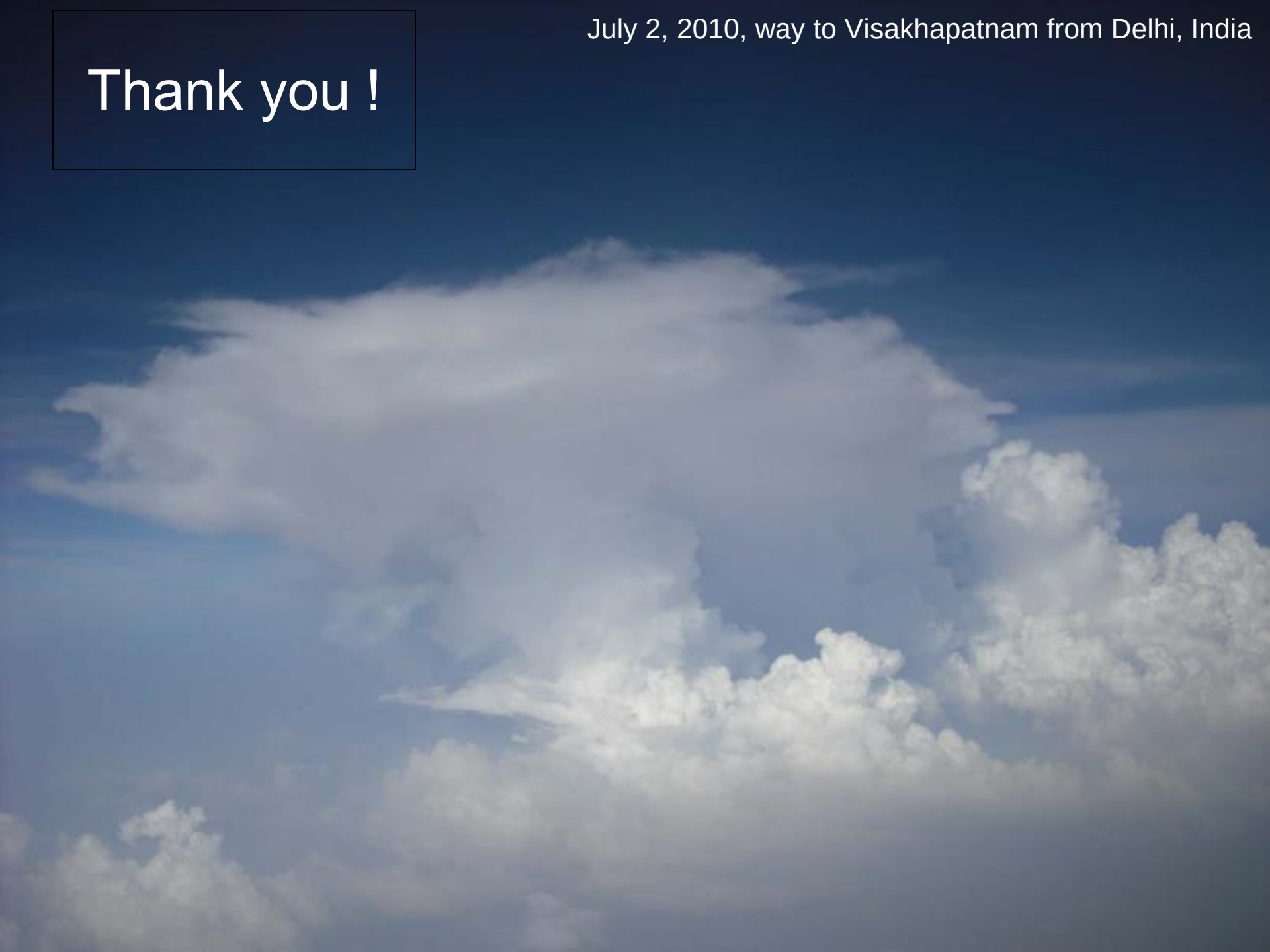
- wave analysis based on high vertical-resolution rawinsonde data archived for YMC (Tim Dunkerton's idea)
  - Hamilton and Vincent (1995) High-resolution radiosonde data offer new prospects for research, *Eos Trans. AGU*, **76**(49), 497–506
  - Love and Geller (2012) Research using high (and higher) resolution radiosonde data, *Eos Trans. AGU*, 2012, **93**, 35, 337 ➔ FISAPS
- 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

5. Deliverables

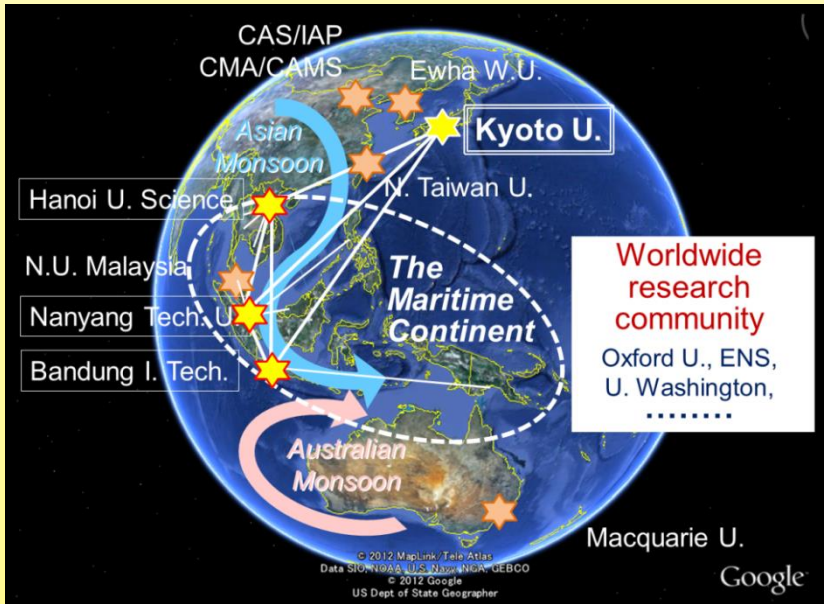
- Report on the IWS on S-T Dynamical Coupling in the Tropics to be submitted to *SPARC Newsletter* (within a month)
- Review paper on S-T Dynamical Coupling in the Tropics based on the IWS to be submitted to *JMSJ* or *BAMS* (within 1/2 year)
  - to be utilized for promoting the international collaborative research related to the subject under our JSPS core-to-core program and YMC
- Workshop or conference on S-T Dynamical Coupling in the Tropics to be held in Kyoto in 2017 and 2019 with a report article or a special issue/section
- Societal impacts of the collaborative research


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

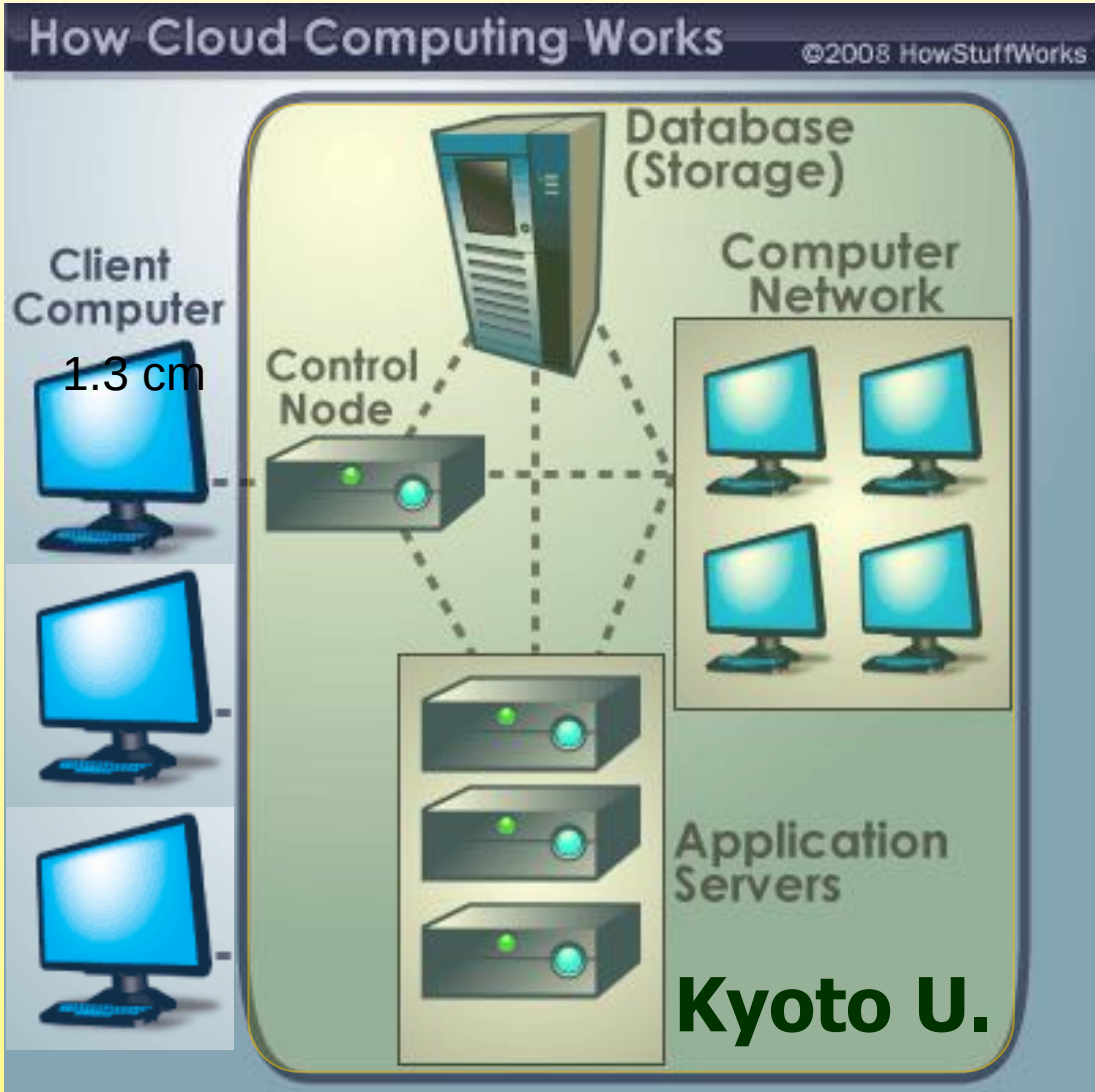
<b> assessment of their impact to improve the forecast

(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

❖ The First International Workshop on Extreme Weather in Changing Climate in the Maritime Continent and South-East Asian School on Tropical Atmospheric Science (SEASTAS)

- Time: SEASTAS: January 5(Tue) ~ 8(Fri), 2016
  IWS: January 6(Wed), 7(Thu), 2016
- Place: College of Earth Sciences and Technology, Bandung Institute of Technology, Indonesia
- Lectures:

  Tetsuo Nakazawa (NIMS/KMA)
  Van Tan Phan (Hanoi U. of Science)
  Seok-Woo Son (Seoul National U.) *
  Fredolin Tangang (National U. Malaysia)
  Manabu D. Yamanaka (JAMSTEC)
  Shigeo Yoden (Kyoto U.)
  and more * supported by SPARC

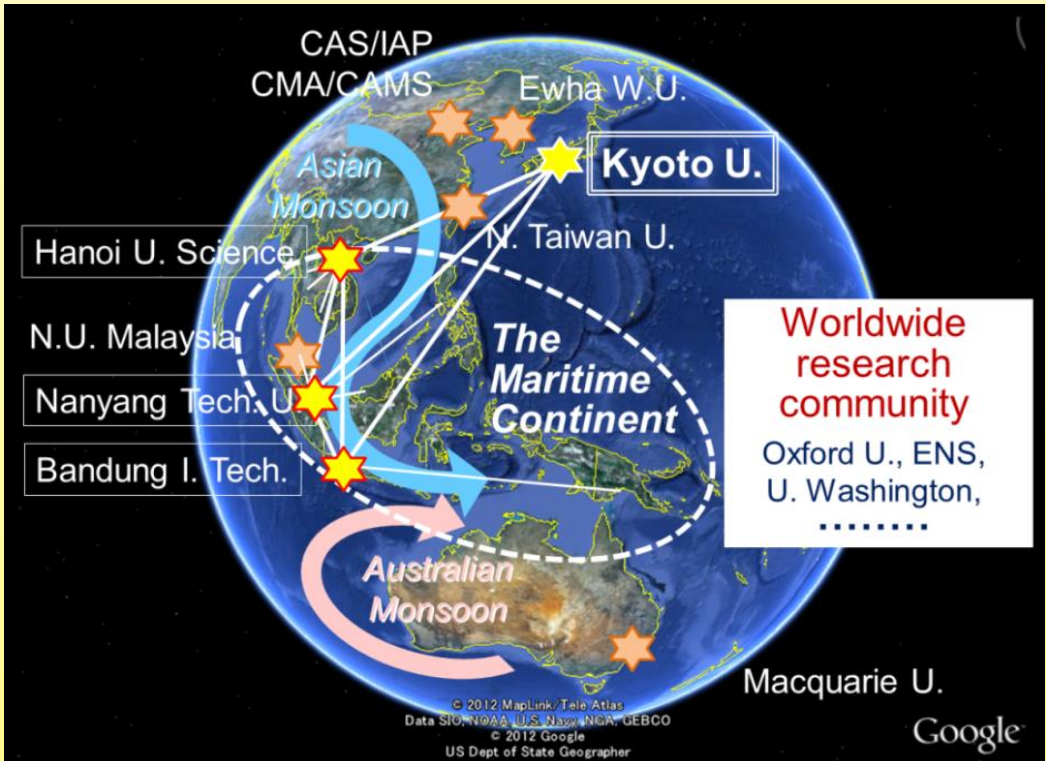
❖SEASTAS:

South-East Asian School on Tropical Atmospheric Science

- 1st year: Bandung Institute of Technology (Indonesia)
  main subject of "drought"
- 2nd year: Hanoi University of Science (Vietnam)
  main subject of "flood"
- 3rd year: Nanyang Technological University (Singapore)
  main subject of "haze"

❖Textbooks on Tropical Meteorology

- Based on the lectures of SEASTAS
- Springer or World Scientific Pub.



Self-organization of convective clouds in the tropics

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

Tsuda(2009)