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

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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)
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
Spatial and temporal scales of atmospheric phenomena and processes.

- Cloud / Rain / Snow
- Minor constituents
- BL Turbulence
- Cumulus
- Cyclone
- MJO
- ENSO
- Houze (200X)
- Tsuda (2009)

Temporal Scale $T \ [s]$

Spatial Scale $L \ [m]$

- $\mu m$
- mm
- m
- km

- $10^{-8}$
- $10^{-6}$
- $10^{-4}$
- $10^{-2}$
- $10^{0}$
- $10^{2}$
- $10^{4}$
- $10^{6}$

- year
- day
- hour
- min.

Multi-scale interactions
Multiple-scale interactions should be modeled at the minimum length scale: “parameterization” of the upscale influence of unresolved scale effects.
Energy input in mid-latitudes:
extratropical cyclones

Energy input in the **tropics**
moist convections

Energy input

Evolution of atmos.

Glacier-IG cycle

Climate change

ENSO

MJO

Cyclone

Front

Cumulus

BL

Turbulence

Cloud / Rain / Snow

Minor constituents

μm mm m km 1000 km

Spatial Scale L [m]

Temporal Scale T [s]

M year

K year

global climate model

day

hour

global NWP min. model

regional 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


- 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 $\leftrightarrow$ Back Building type

● Animation for a two-day period of Squall Line type system

![Graph showing atmospheric parameters over time](image)
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:

\[ p'w' = \rho_0(c - \bar{u})u'w' = c_{gz}\langle E \rangle \]
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

![Diagram showing interactions between space and time scales of tropical convection: Linking THORPEX and WCRP](image)
Interactions between space and time scales of tropical convection: Linking THORPEX and WCRP

- Local diurnal circulation
  - Diurnal Cycle
  - Mesoscale systems
  - Synoptic Waves
  - Cross-equatorial cold surge and Borneo vortex
  - 1-100 km (Hours)
  - 100’s km (Days)
  - 1000’s km (Weeks)
  - 10,000’s km (Months)

- Seasonal Cycle
  - Modulates activity (e.g., extratropical effects, continentality)
  - MJO Suppressed Phase?
  - Monsoon onset?

- Monsoon
  - Modulates activity?

- El Nino

Slingo (2006)
Interactions between space and time scales of tropical convection: Linking THORPEX and WCRP

- possible stratospheric influence
- Polar vortex intensification
- Stratospheric sudden warming
- Stratospheric cooling trend
- 11-year solar cycle
- Stratospheric QBO
- Monsoon
- El Nino

Diurnal Cycle

Local diurnal circulation

Mesoscale systems

Synoptic Waves

MJO

Westery Wind Events excite ocean Kelvin waves

1-100 km

Hours

100’s km

Days

1000’s km

Weeks

10,000’s km

Months

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 $\leftarrow \rightarrow$ 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.

  - 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*)
  
  - 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$^{-1}$)

- 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

  - 30-yr correlations of 30 hPa QBO with number of tropical cyclones

  - maximum intensities of TCs in the eastern North Pacific Ocean

  - TC tracks in the western North Pacific and Bay of Bengal regions

- also Elsner et al. (1999, *J.Clim.*)
Influence of the stratospheric cooling trend on TCs

- Emanuel et al. (2013, *J.Clim.*)
- Influence of TTL cooling (outflow $T \downarrow$) on Atlantic hurricane activity

Physical parameters related to the linkage around TTL

- Dynamics: $\frac{du}{dz}, w$
- Thermodynamics: $T, N^2$
- Tropopause height
- xxxxxxxx?
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)

- networking of meteorological radars in SE Asia

- 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）

機動の観測（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

推定位置1-1
・中心位置
経度X11、経度Y11
・時刻 XX:XX+10

推定位置1-n
・中心位置
経度Xn1、経度Yn1
・時刻 YY:YY-10

推定位置2-1
・中心位置
経度X21、経度Y21
・時刻 YY:YY+10

推定位置2-n
・中心位置
経度X2n、経度Y2n
・時刻 ZZ:ZZ-10

台風予報位置3
・中心位置
経度X03、経度Y03
・時刻 ZZ:ZZ

2点の中心位置より10分毎の位置を内挿推定

可視画像
2015/5/10 06-19JST （台風1506）
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
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

\(\rightarrow\) 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

- **Local diurnal circulation**
  - **Mesoscale systems**
    - Upscale organisation?
      - Modulates activity
  - **Synoptic waves**
    - Upscale organisation?
      - Modulates activity
  - **Polar vortex intensification**
  - **Stratospheric sudden warming**
  - **Stratospheric cooling trend**
  - **11-year solar cycle**
  - **Stratospheric QBO**
  - **Seasonal cycle**
  - **Monsoon**
  - **El Nino**

Westerly Wind Events excite ocean Kelvin waves

- 1-100 km
  - Hours
- 100’s km
  - Days
- 1000’s km
  - Weeks
- 10,000’s km
  - Months

*Slingo (2006)*
Interactions between space and time scales of tropical convection: Linking THORPEX and WCRP

- Possible stratospheric influence
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  - Mesoscale systems
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  - Synoptic waves
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- Polar vortex intensification
- Stratospheric sudden warming
  - Stratospheric cooling trend
    - 11-year solar cycle
    - Stratospheric QBO
- Monsoon
- El Nino
- MJO
- Gusty wind flush flood
  - 1-100 km
  - Hours
- Flood
  - 100’s km
  - Days
- Economical activities
  - 1000’s km
  - Weeks
- Draught
  - 10,000’s km
  - Months
- Biological diversity

Societal impacts

Slingo (2006)
Self-organization of convective clouds in the tropics
Interaction with complex topography and land-sea contrast, particularly in the Maritime Continent