Excitation of Atmospheric Oscillations by Planetary Rotation and Revolution:

Observational Evidence, Interpretation and Mysteries in the Earth's Equatorial Climate

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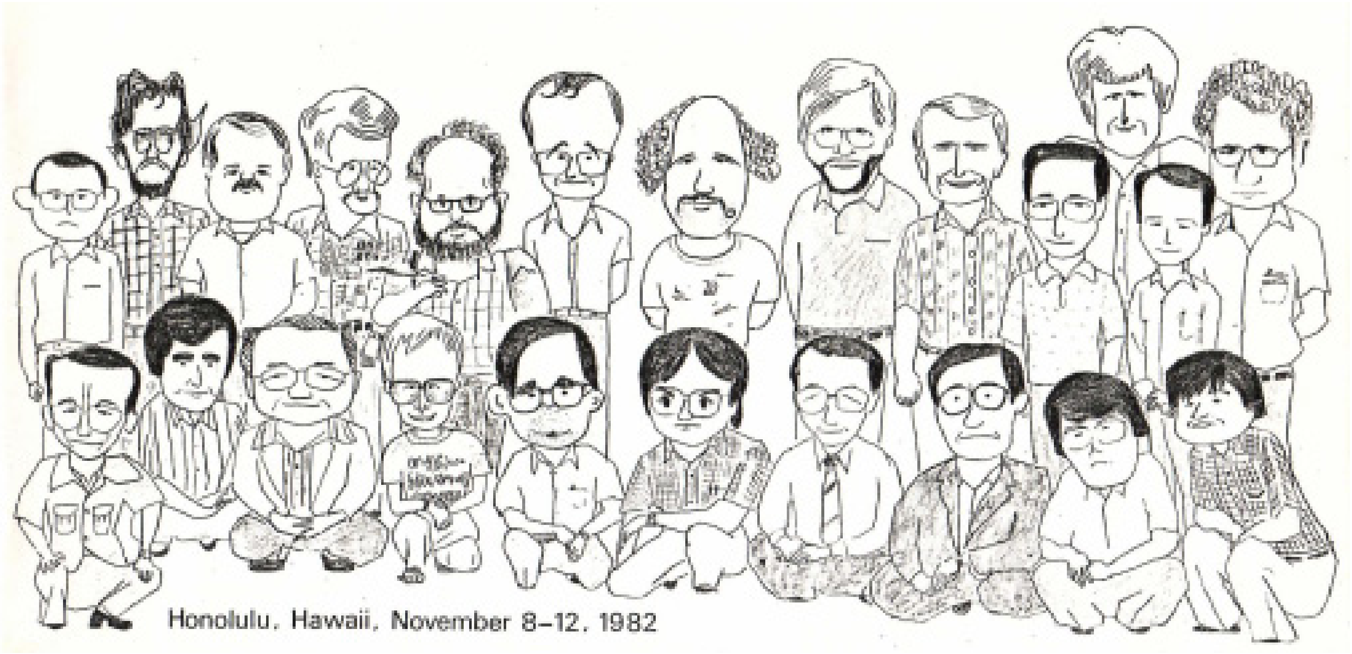
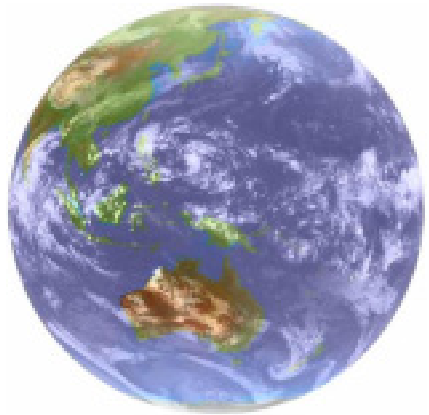
IORGC/JAMASTEC, DEPS-CPS/Kobe University



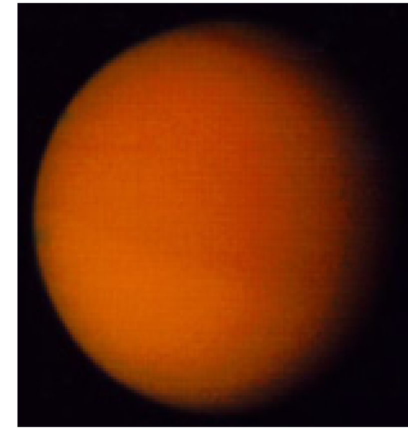
Planets in the solar system

Venus

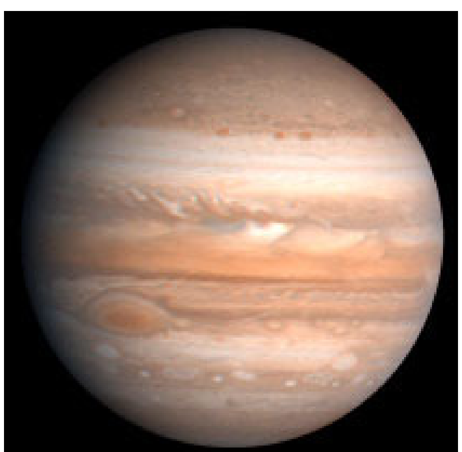


Earth

Mars

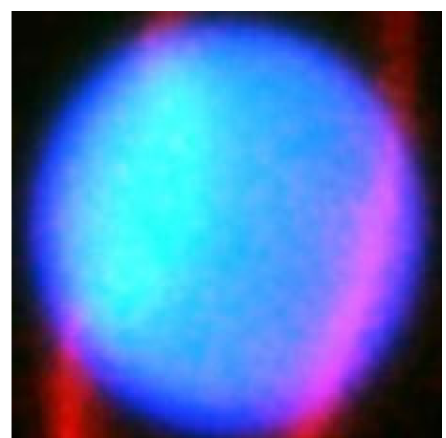


Titan



Jupiter

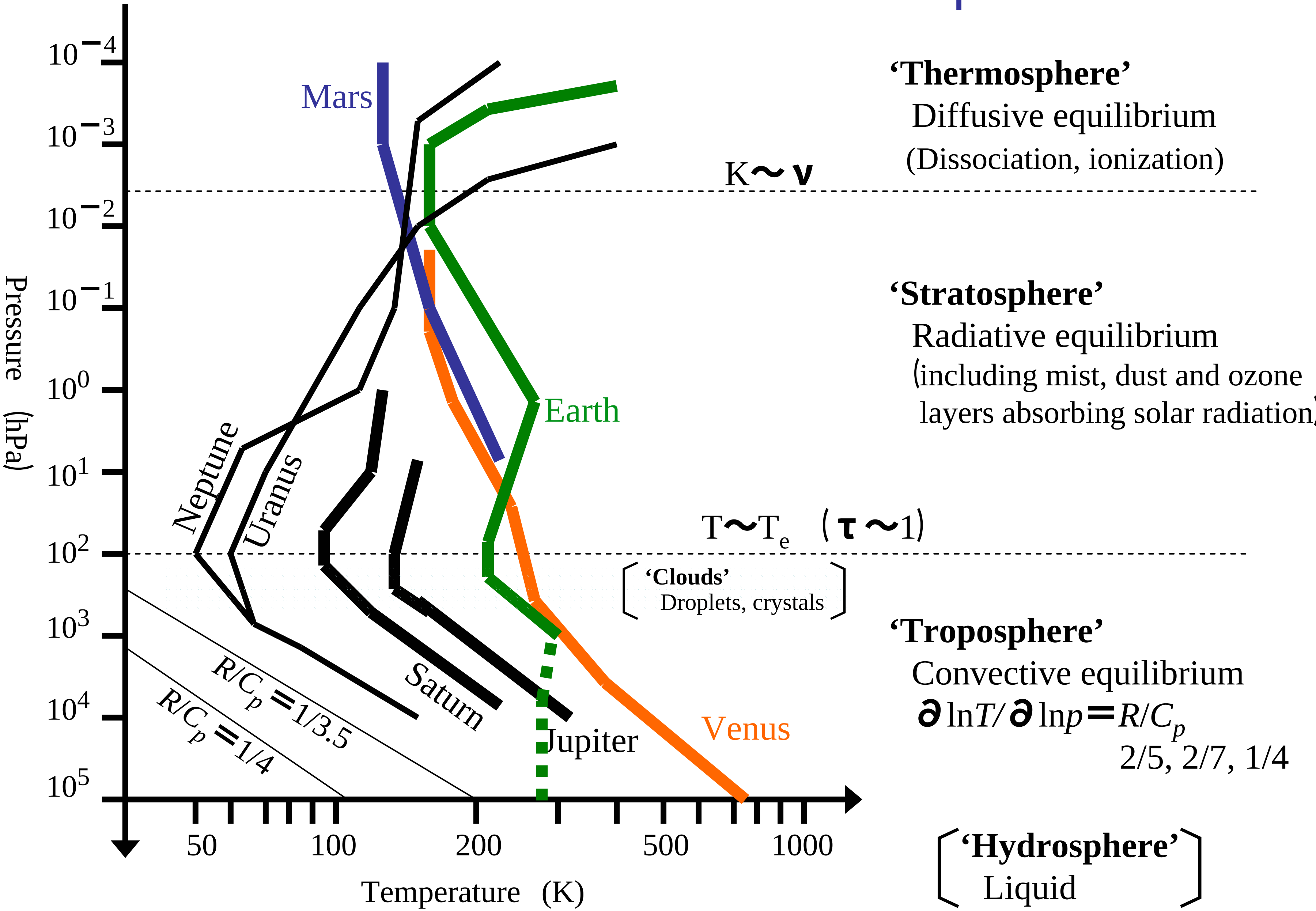
Saturn



Uranus

Neptune

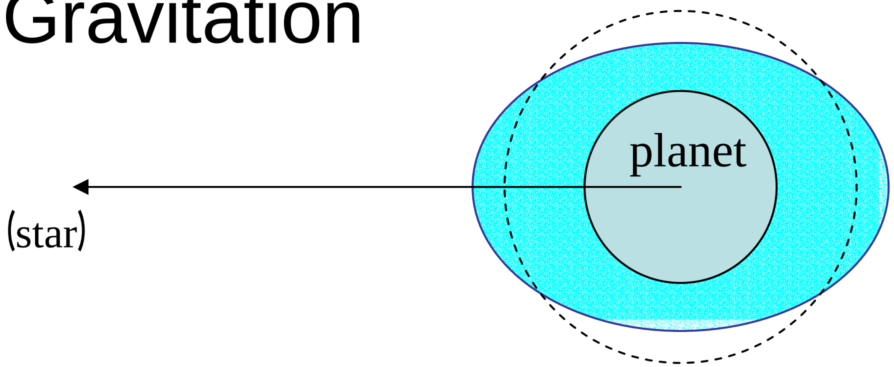
Vertical structure of atmosphere



Two major forcings of star on planet

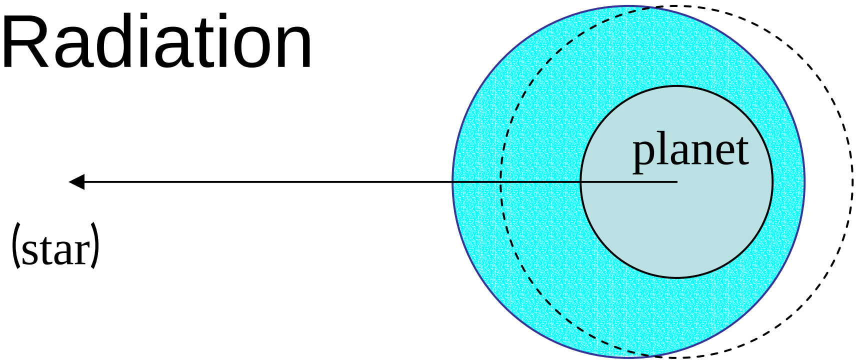
Both ∝ $(\text{distance})^{-2}$, but planetary response is different

- Gravitation



Balanced with
revolutional centrifugal force
Revolutional orbit (Kepler's laws)
⇒ Stellar distance
⇒ Stellar radiation, annual length
Oceanic tides, planetary tides

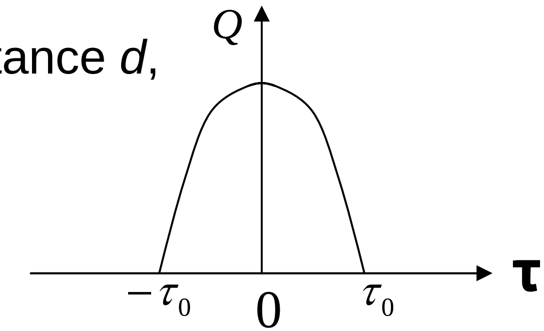
- Radiation



Balanced with planetary IR cooling
- Time scale ≫ rotation
  ⇒Meridional differential heating
- Time scale ∼ rotation
  ⇒Zonal diffrential heating
  Atmospheric tides

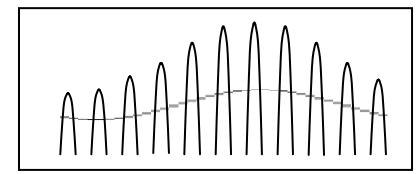
Solar heating (function of latitude and time (season and LT))

Solar constant S_0, Mean revolution radius (AU) d_0, Solar distance d,



$$Q = S_0 \left(\frac{d_0}{d}\right)^2 \cos\theta_s$$

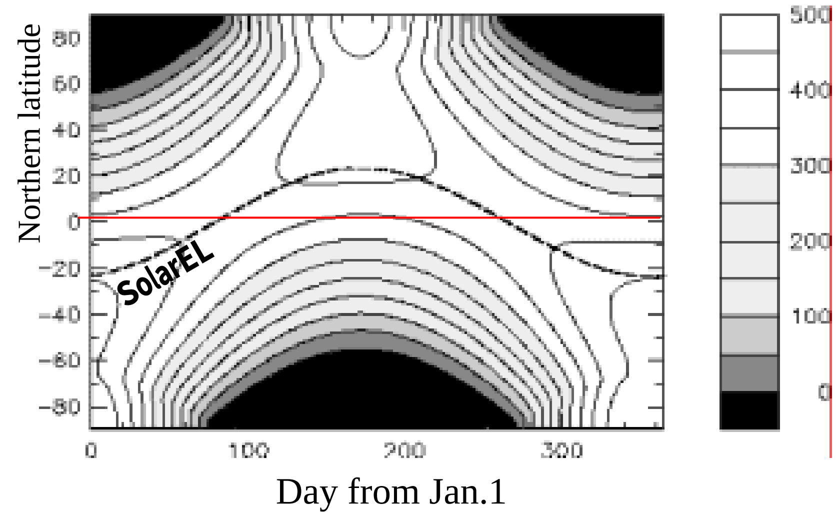
$$\left(\frac{d_0}{d}\right)^2 = 1.000110 + 0.034221\cos\frac{2\pi t}{1\text{year}} + 0.000719\cos 2\frac{2\pi t}{1\text{year}} + \cdots$$
$$+ 0.001280\sin\frac{2\pi t}{1\text{year}} + 0.000077\sin 2\frac{2\pi t}{1\text{year}} + \cdots$$



Solar zenith angle θ_s, Solar declination φ_s

$$\cos\theta_s = \sin\varphi_s \sin\varphi + \cos\varphi_s \cos\varphi \cos\tau \qquad (-\tau_0 \le \tau \le \tau_0)$$

$$\varphi_s = 0.006918 - 0.399912\cos\frac{2\pi t}{1\text{year}} - 0.006758\cos 2\frac{2\pi t}{1\text{year}} - \cdots$$
$$+ 0.070257\sin\frac{2\pi t}{1\text{year}} + 0.000907\sin 2\frac{2\pi t}{1\text{year}} + \cdots$$



Solar hour angle τ, sunrise/sunset τ_0

$$\cos\tau_0 = -\tan\varphi_s \tan\varphi$$

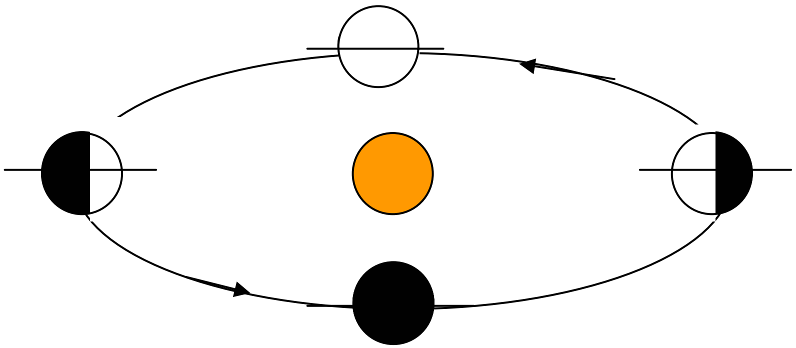
Daily-mean solar radiation:

$$\overline{Q}^{\text{daily}} \equiv \frac{\int_{-\tau_0}^{\tau_0} Q\,d\tau}{\int_{-\pi/2}^{\pi/2} d\tau} = \frac{S_0}{\pi}\left(\frac{d_0}{d}\right)^2 \left(\sin\varphi_s \cdot \tau_0 \sin\varphi + \cos\varphi_s \cdot \sin\tau_0 \cos\varphi\right)$$

Anti-symmetric   Symmetric

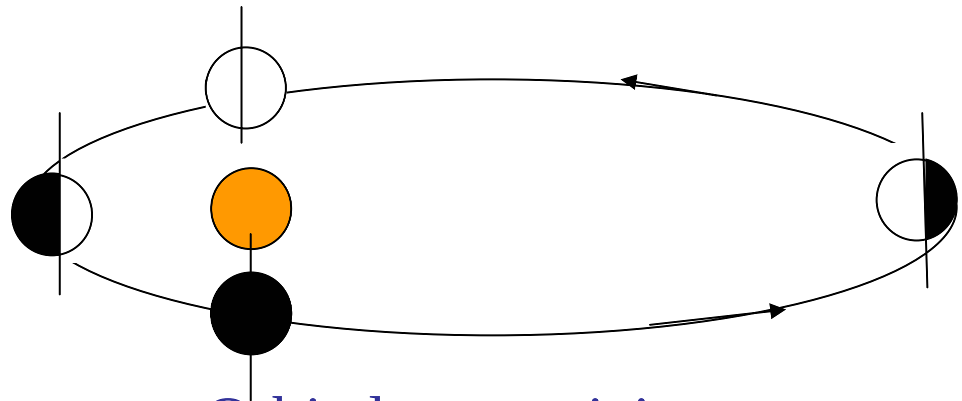
Two limited cases of seasonal cycle forcing

‘Uranus’

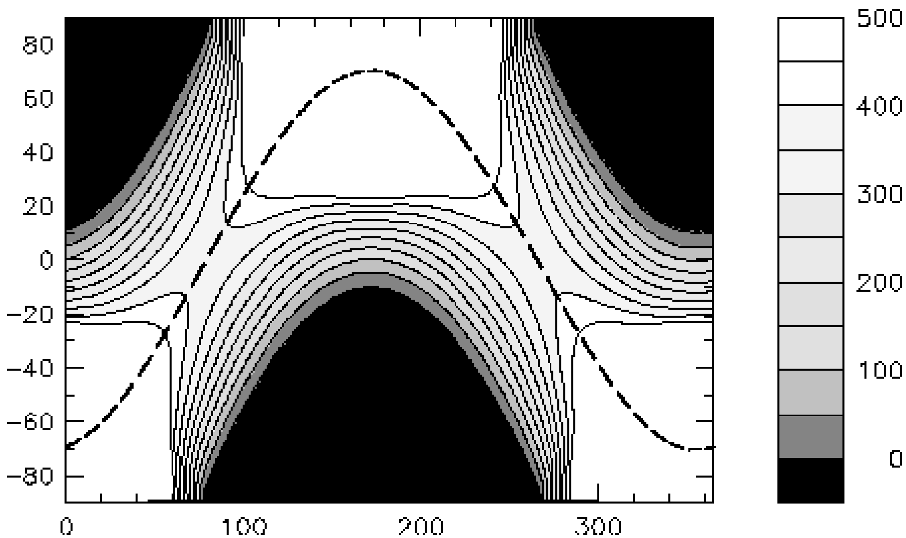


Rotation-axis inclination

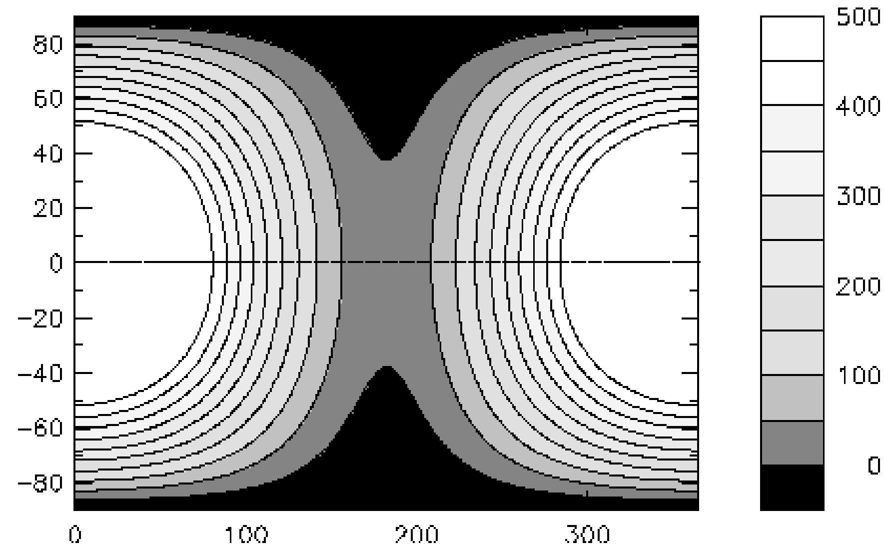
‘a type of extra-solar planet’



Orbital eccentricity

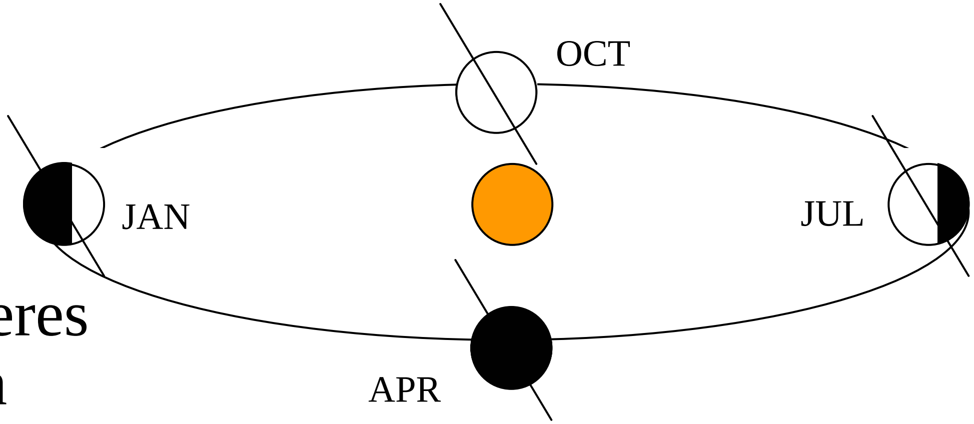


Hemispherically anti-phase

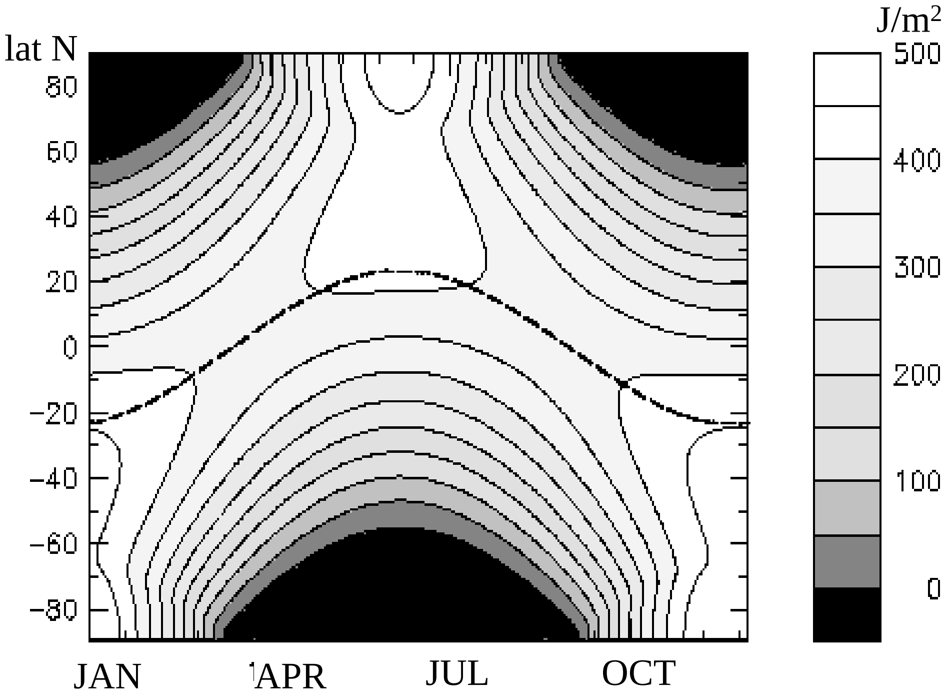


Hemispherically in-phase

Latitudinal/Seasonal variations of Solar radiation Induced by Earth's Rotation/Revolution

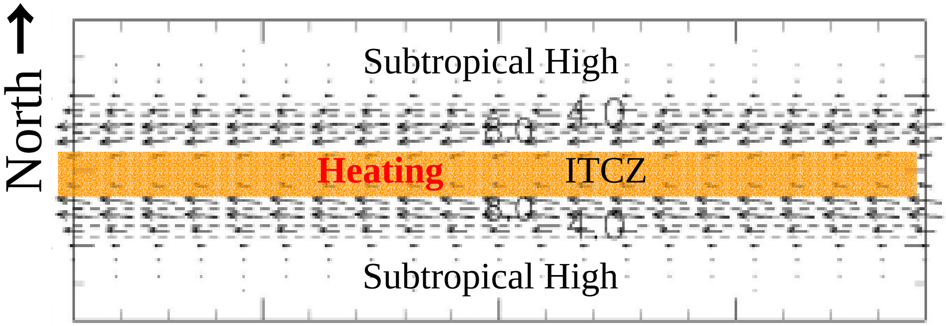


- Almost circular orbit
  + inclined rotation axis
  → Summer/winter hemispheres
  2 : 1 solar radiation
  at mid-latitude

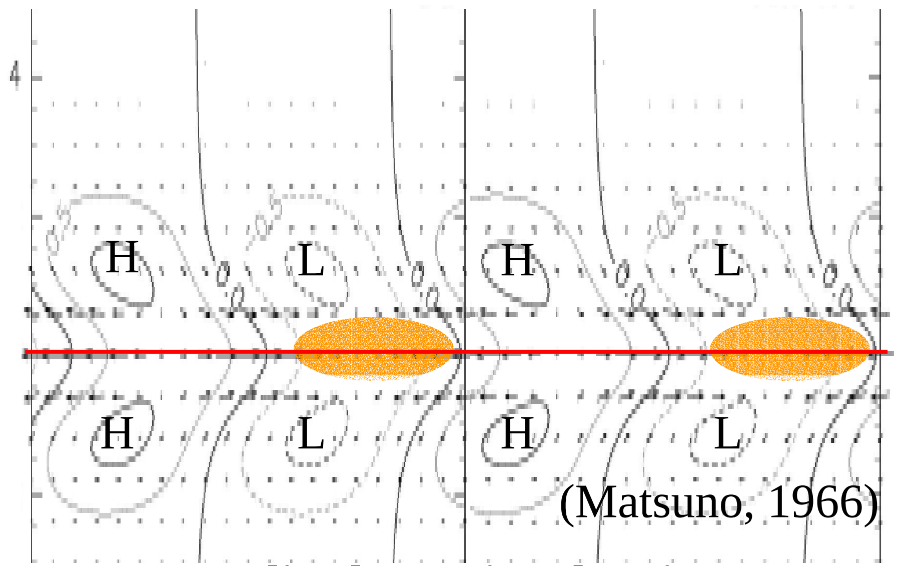


- Equatorial solar radiation
  → Max. at equinoxes
  ～5% larger than solstices
  (Differences smaller than
  clear/cloudy differences)
  → Semi-annual periodicity
  (Annual periodicity does not appear only by the solar radiation)

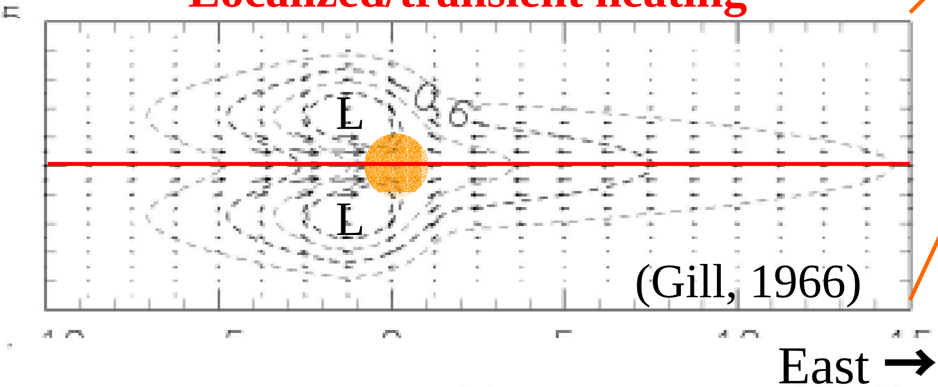
Equatorial forcing and atmospheric response

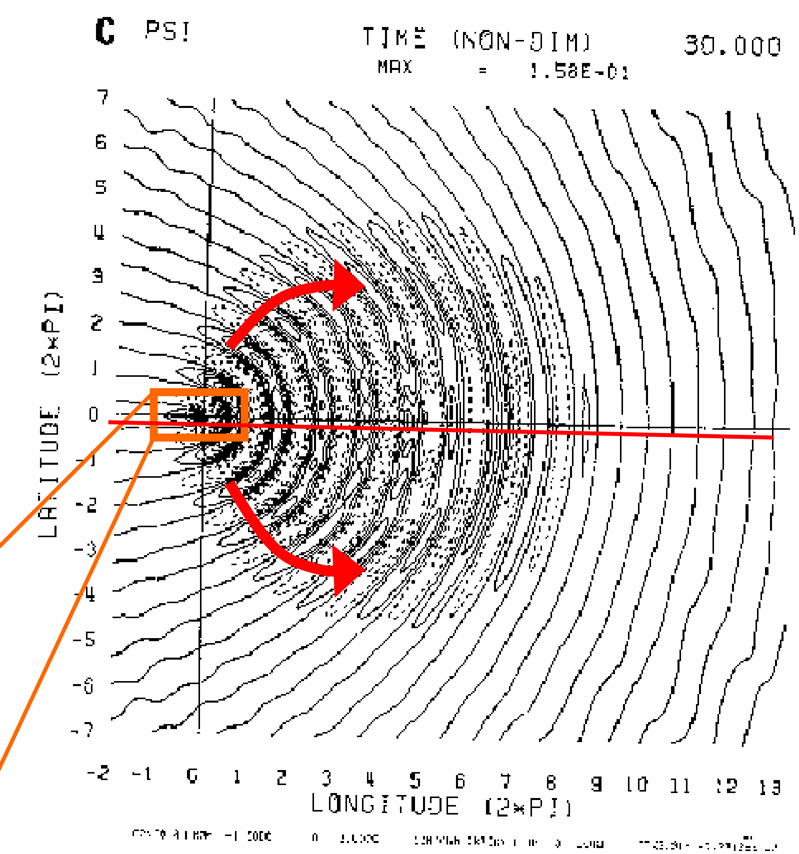


(Yamanaka & M. Hayashi, 2005; Matsuda & Kosaka, 2005)



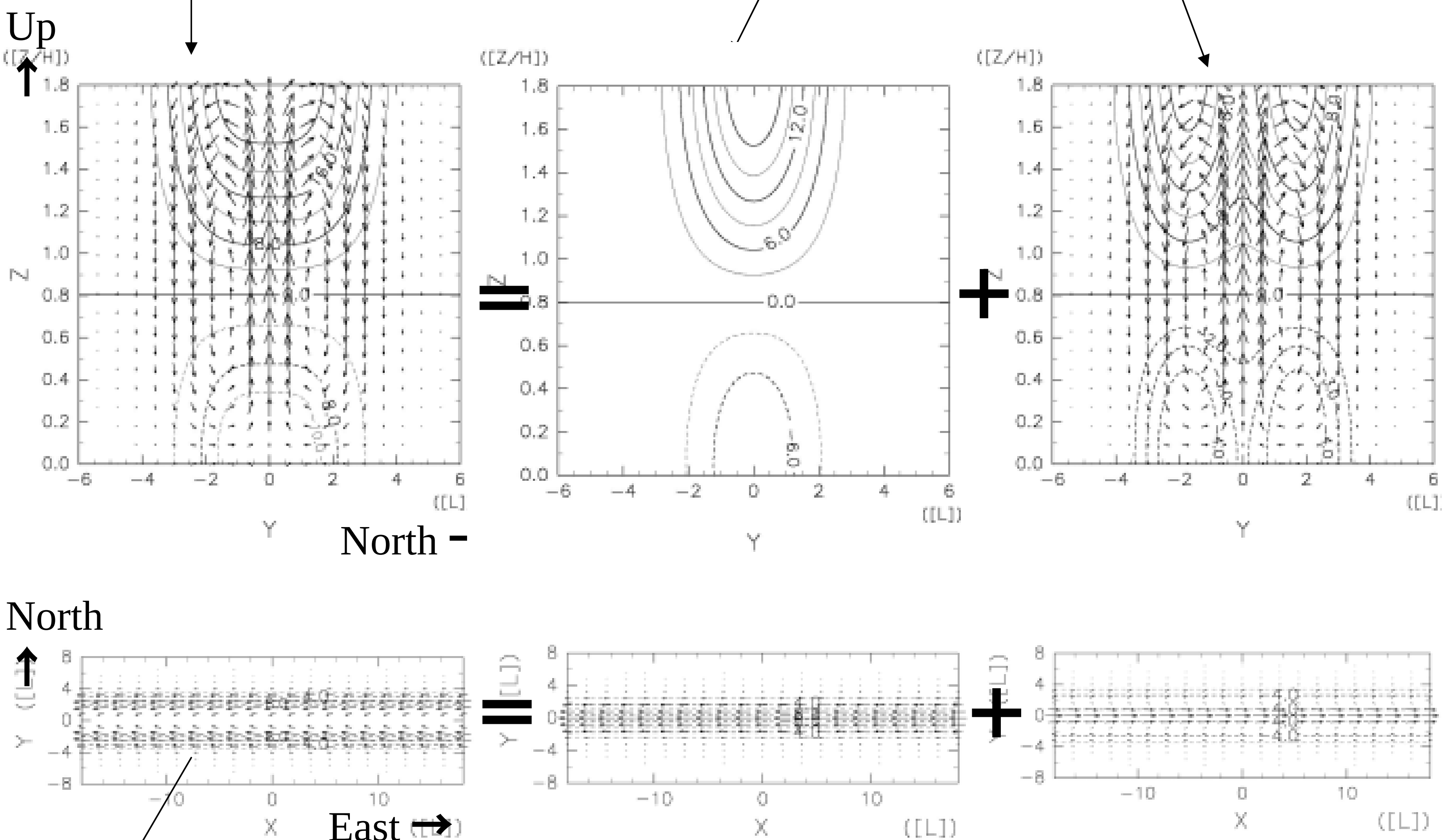
Localized/transient heating





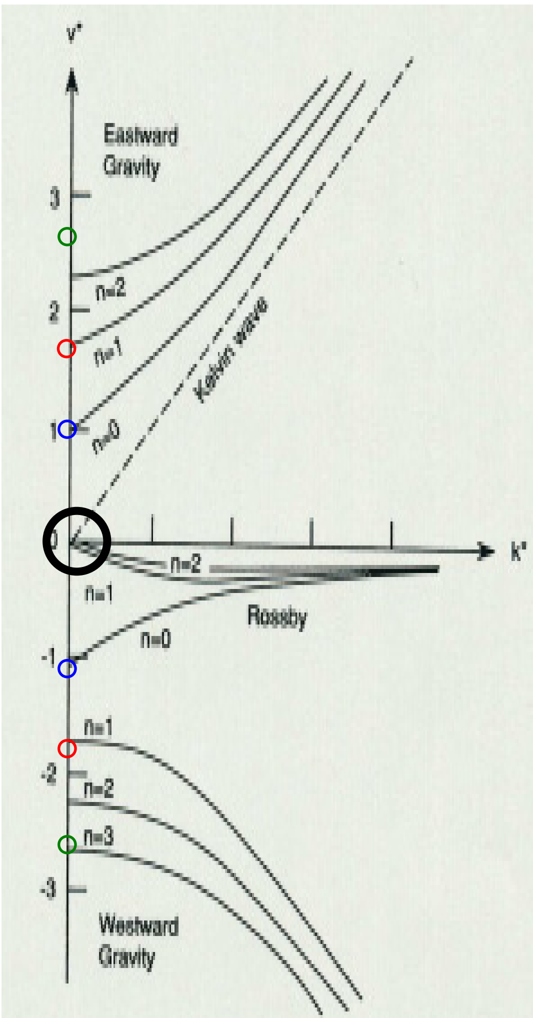
(Y.-Y. Hayashi, 1987)

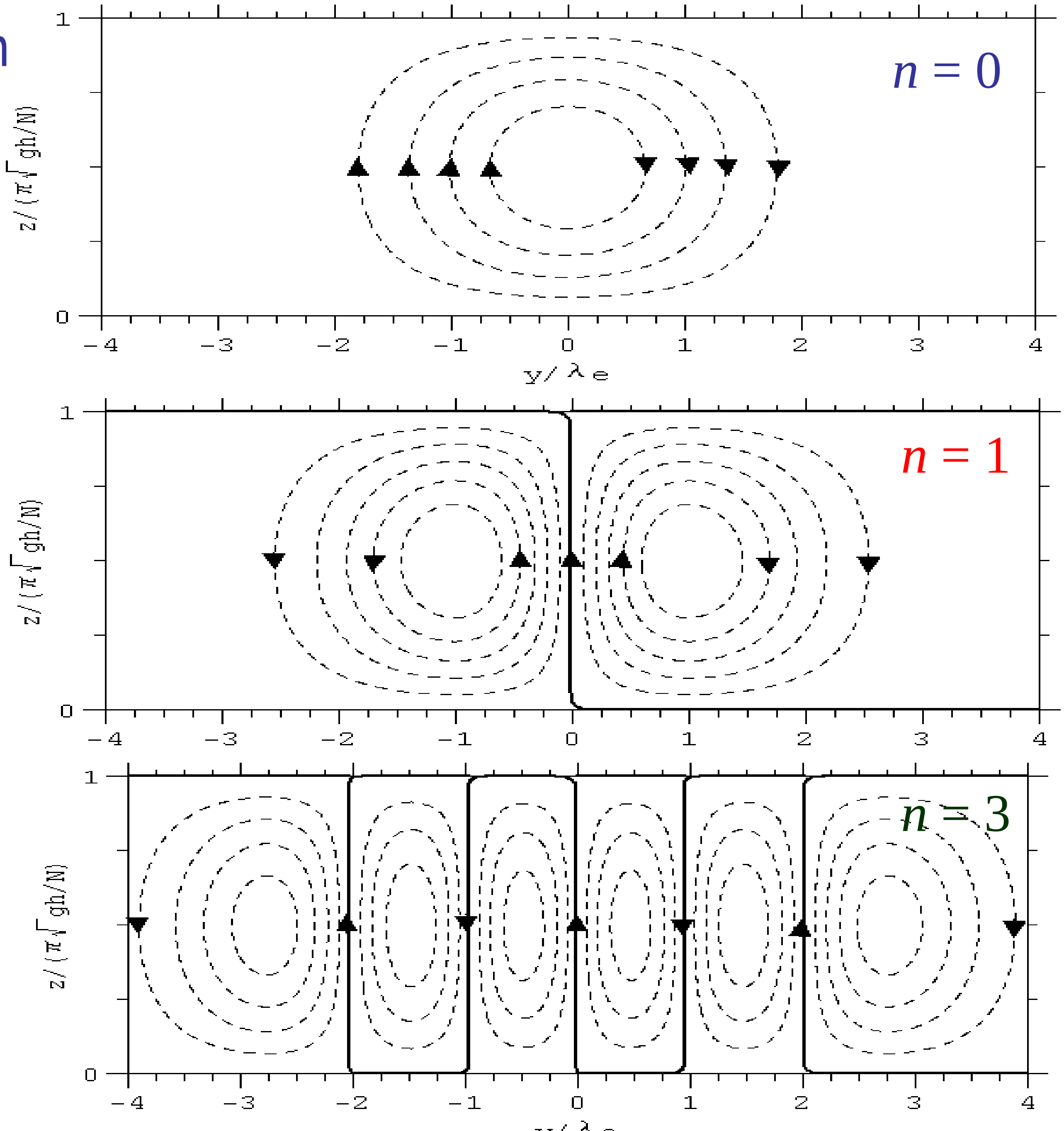
Hadley cell by zero-zwn Kelvin and Rossby waves



Trade wind zones are separated in the both sides of ITCZ.

Meridional circulation by zero zwn waves





‘Aqua Planet’ simulation

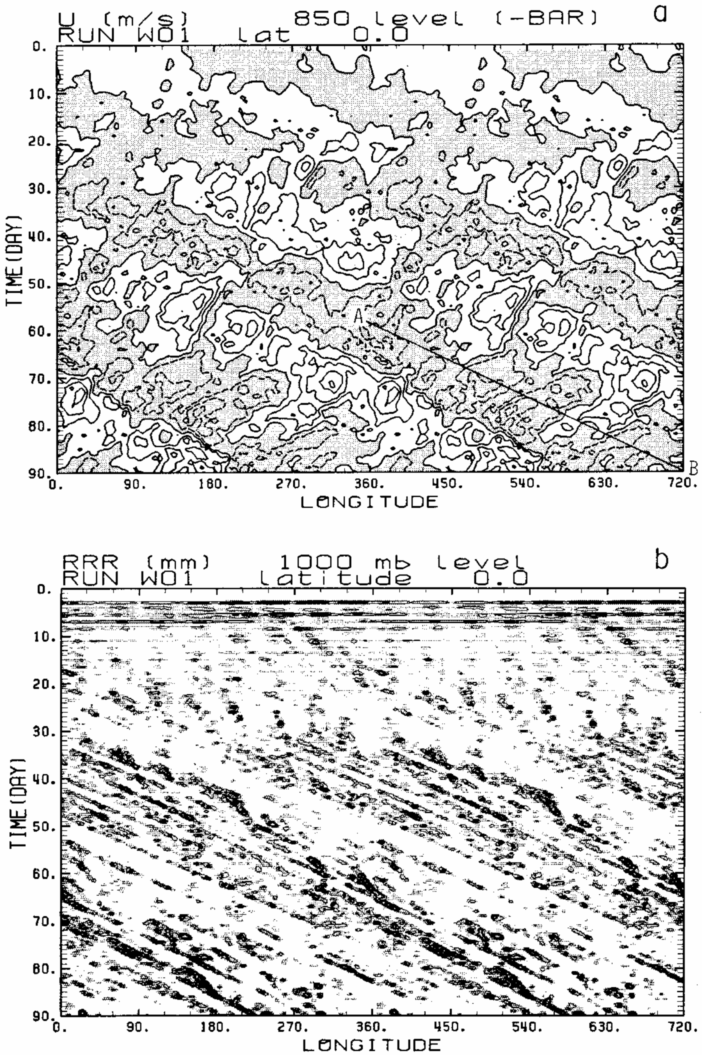


Fig. 3 Longitude-time sections of (a) 850 mb zonal wind deviation (u') and (b) precipitation per 12 hours. The figures are duplicated in the longitudinal direction to clarify the periodicity. The contour intervals are 2.5 m/s for u' and 2.5 mm/12 h for precipitation. The regions of (a) easterly ($u' < 0$) and (b) precipitation greater than 1 mm/12 h are shaded. The line segment AB denotes the phase line (c_0 = 15 m/s) along which the composite structures are constructed.

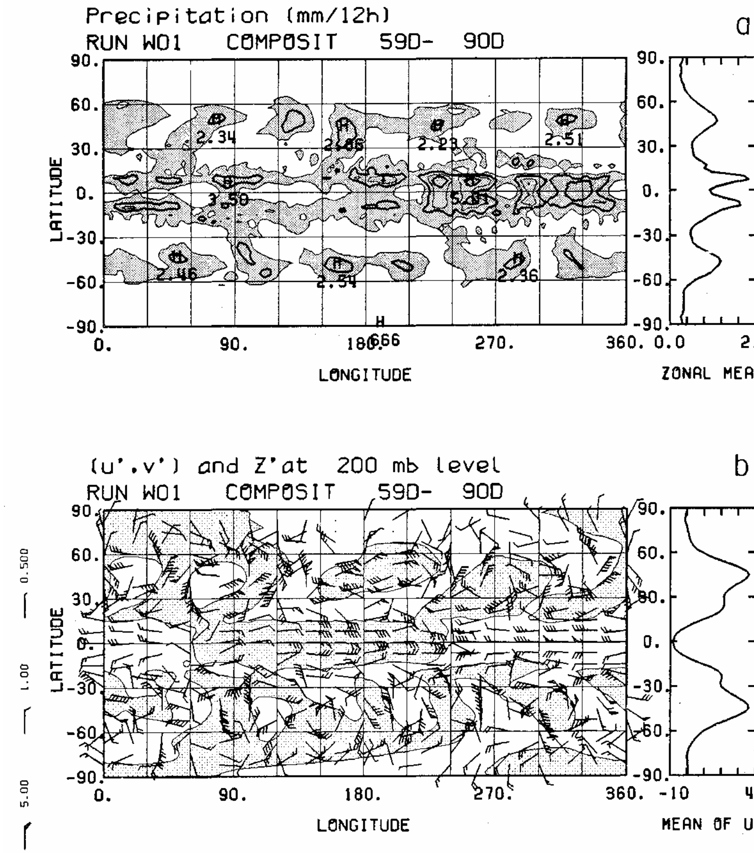


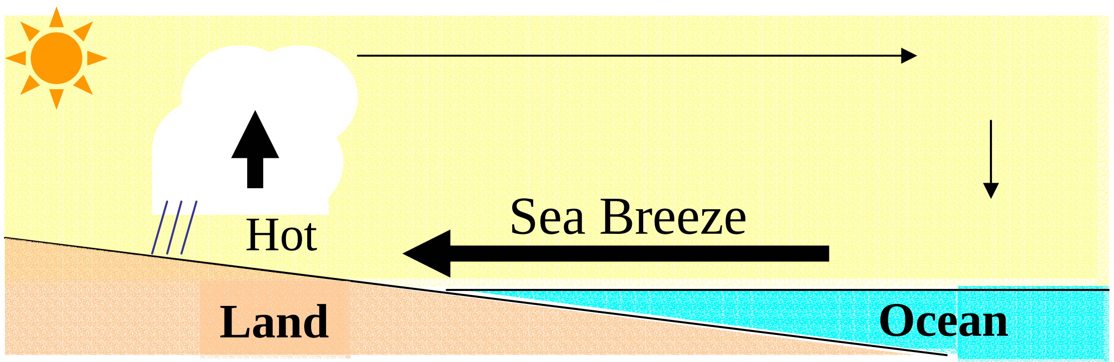
Fig. 5 Composite fields along the phase speed c_0 = 15 m/s for t = 59–90 days of (a) precipitation and (b) wind deviation (u', v') and geopotential height (Z') at 200 mb. The regions of (a) precipitation greater than 1 mm/12 h and (b) $Z' < 0$ are shaded. The contour interval for (a) is 1 mm/12 h. The unit of barbs plotted to the left is m/s. Zonal mean values of (a) precipitation (mm/h) and (b) zonal wind (m/s) are plotted to the right side of each figures.

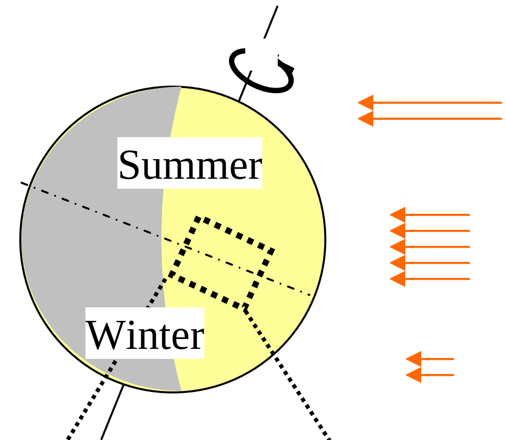
"Planetological" Monsoon

Axi-Symmetric Meridional Circulation due to Differential Solar Heating

"Terrestrial" Monsoon

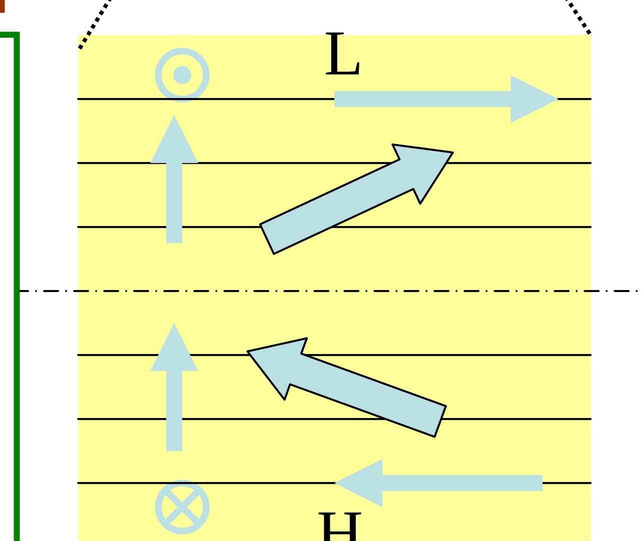
Sea-Land Breeze Analogue





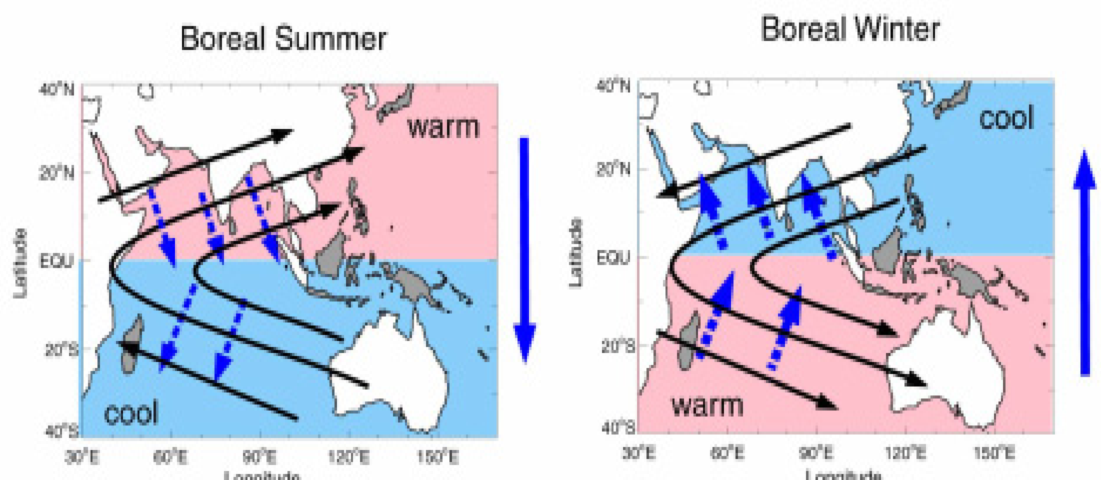
Annual Osci. (Eq. Anti-Symmetric)

⇒ Monsoon Circulation



(cf. Mesosphere, Mars)

Monsoon-driven Seasonal Ocean Current



(Webster, 1999)

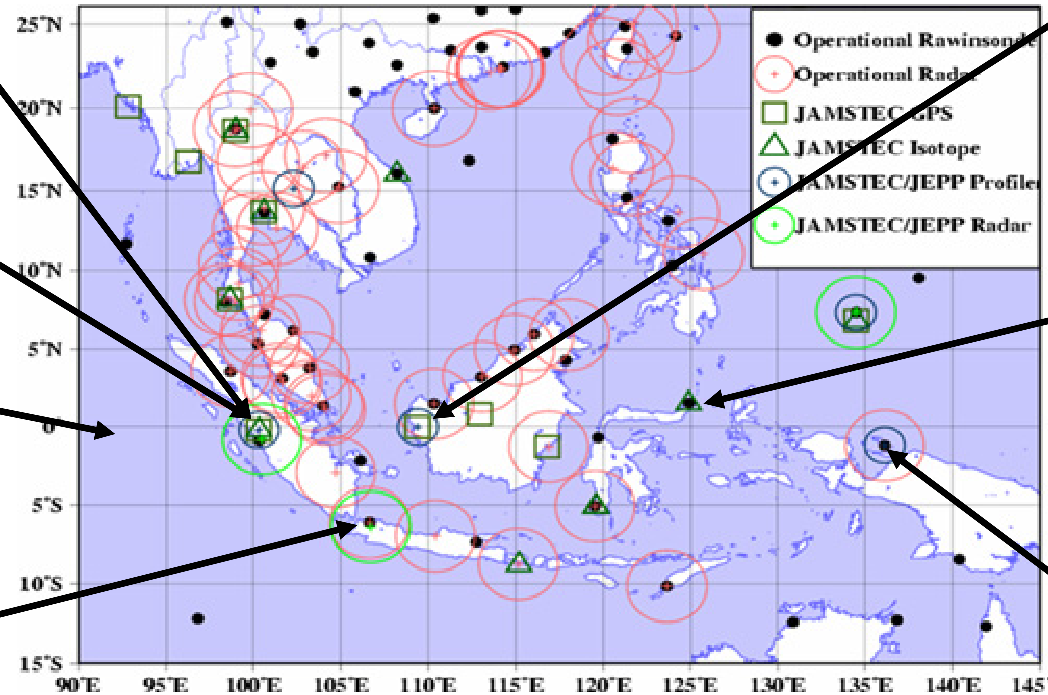
Seasonal Variation		Diurnal Variation
Revolution	Planetary motion	Rotation
Latitudinal/Season	Diffrential	(Longitudinal/LT)
Continent-Ocean	Solar heating	Land-Sea, Mt-Valley
(Meridional circ.)		(Thermal Tides)
Monsoon	Horiz. Conv.	Local circulation
(Planetary waves)	(Waves)	(Gravity waves)
↓↑	↓↑	↓↑
Rainy season	Cloud	Evening shower
Summer + IMC, etc.	Variety	Sea-wind only, etc.
Year-to-year	Variability	Day-to-day
Interannual		Intraseasonal

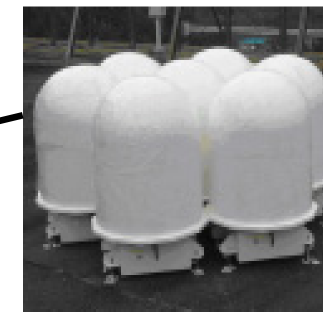
Harimau Japan EOS Promotion Program (JEPP) + Indonesian Research/Technology Grant BPPT

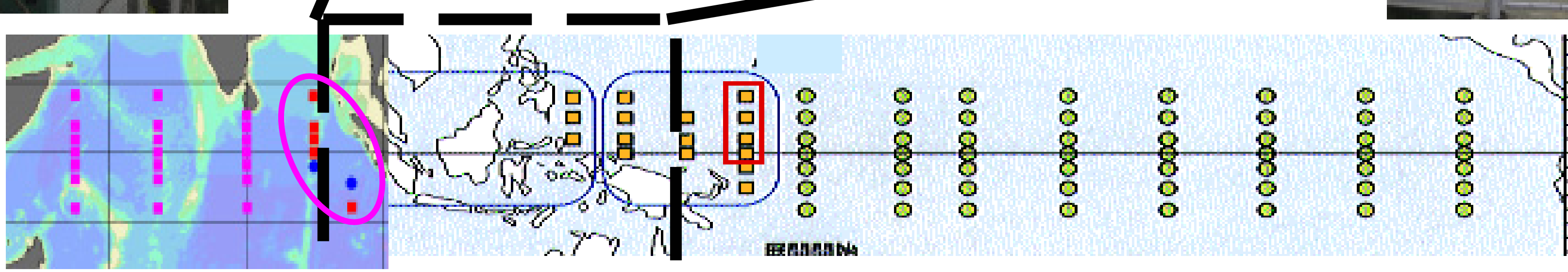
Hydrometeorological Array for ISV-Monsoon Automonitoring (HARIMAU)

http://www.jamstec.go.jp/iorgc/harimau/HARIMAU.html

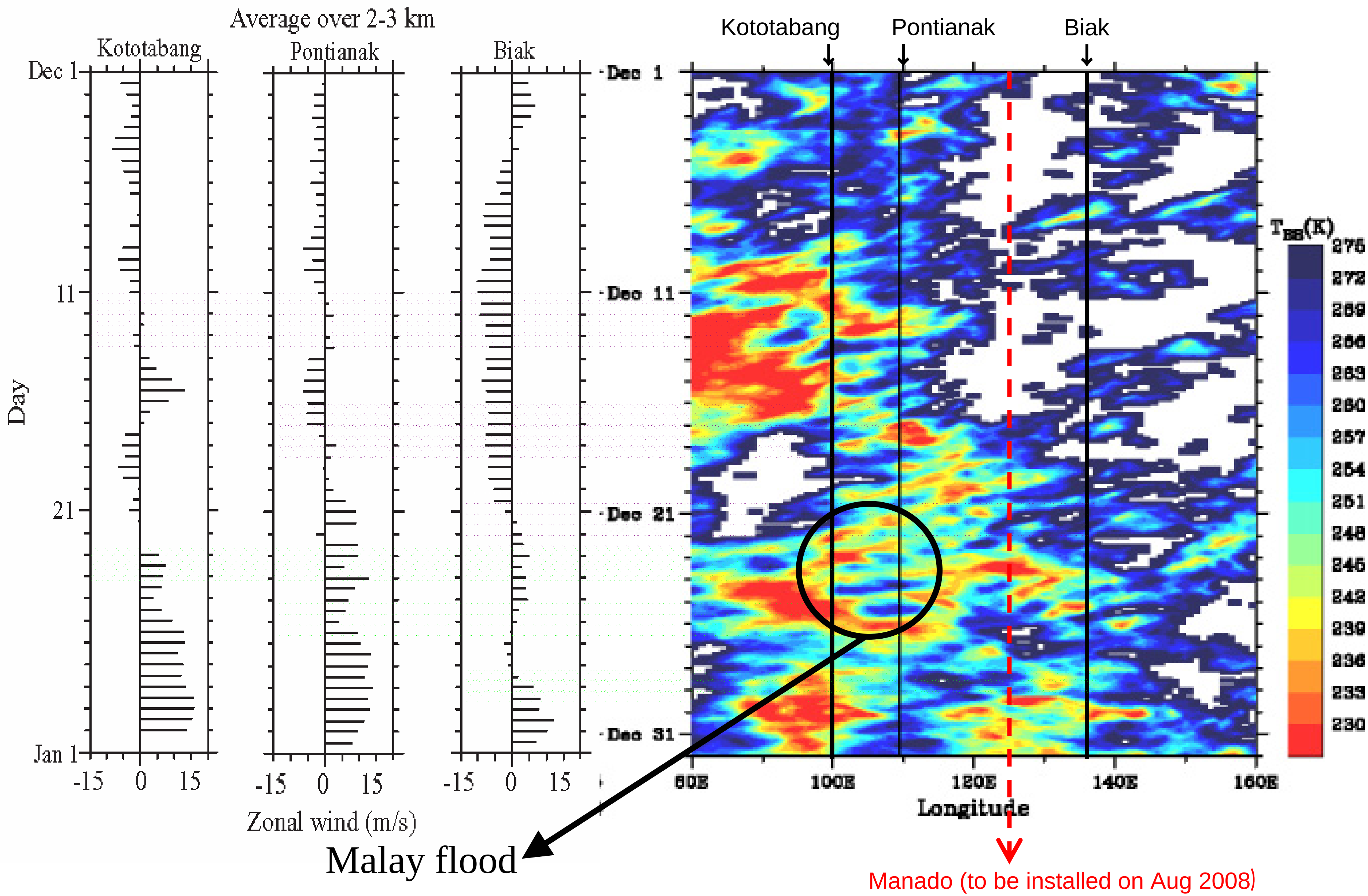
mdy@jamstec.go.jp







ISVs by WPR network



(Yamanaka et al., 2008, *J. Disaster Res.*, in press)

Self-Enhancement of Diurnal Cycle by Cloud-Precipitation Process

- Even <u>in the *rainy* season</u>, <u>over the *land*</u>,

Clear sky in the morning,
Maximum solar heating

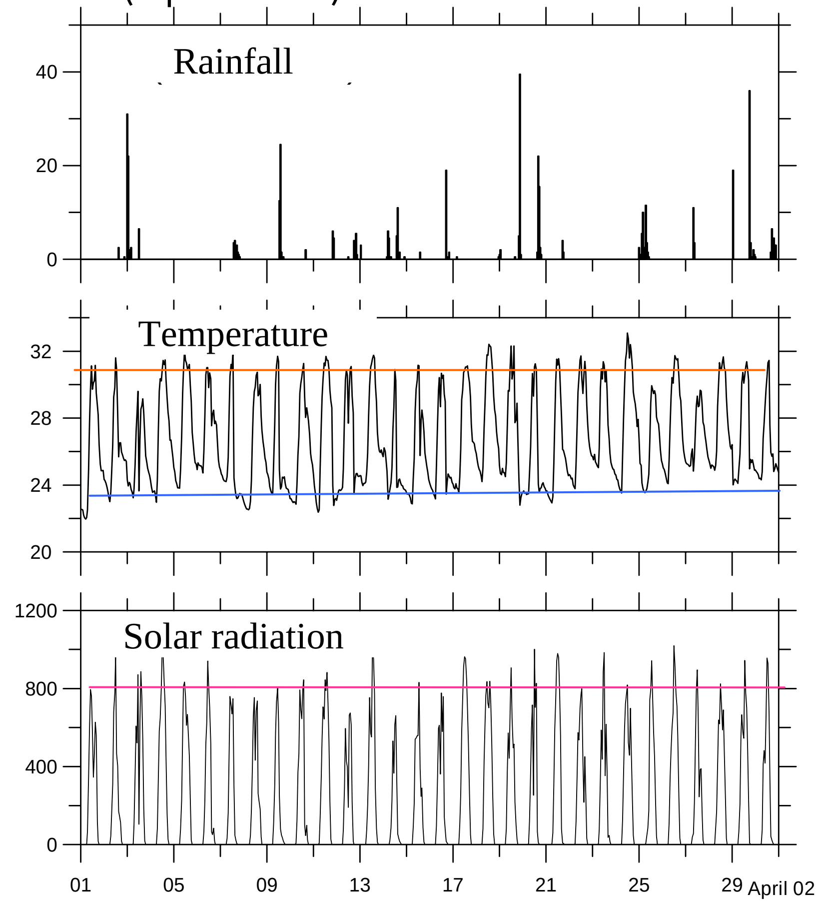
↓

Active convective clouds in the afternoon,
Sea-breeze-like circulation,
bringing water vapor from sea to land

↓

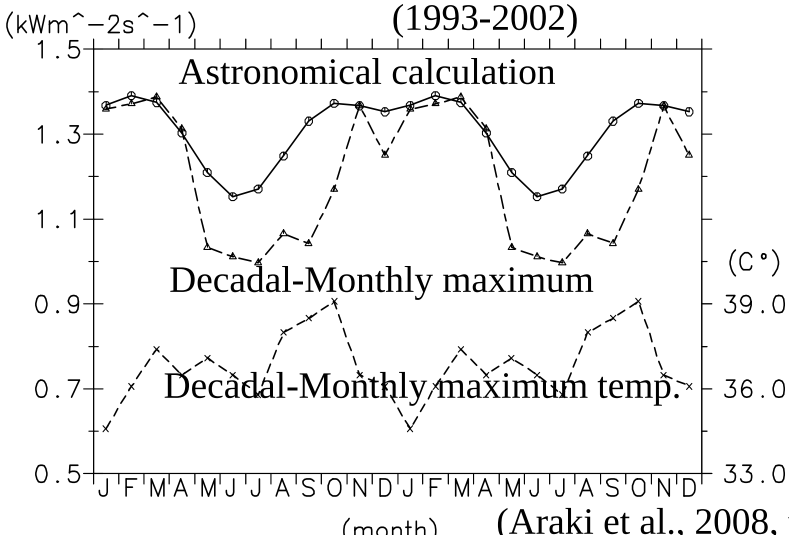
Strong rainfall in the evening,
Washing out aerosols,
resetting atmospheric transparency

Rainfall, Temperature & Solar radiation at Pontianak, West Kalimantan (April 2002)



(Wu et al., 2008, in preparation)

11-13LT Solar radiation at Serpong, West Jawa (1993-2002)

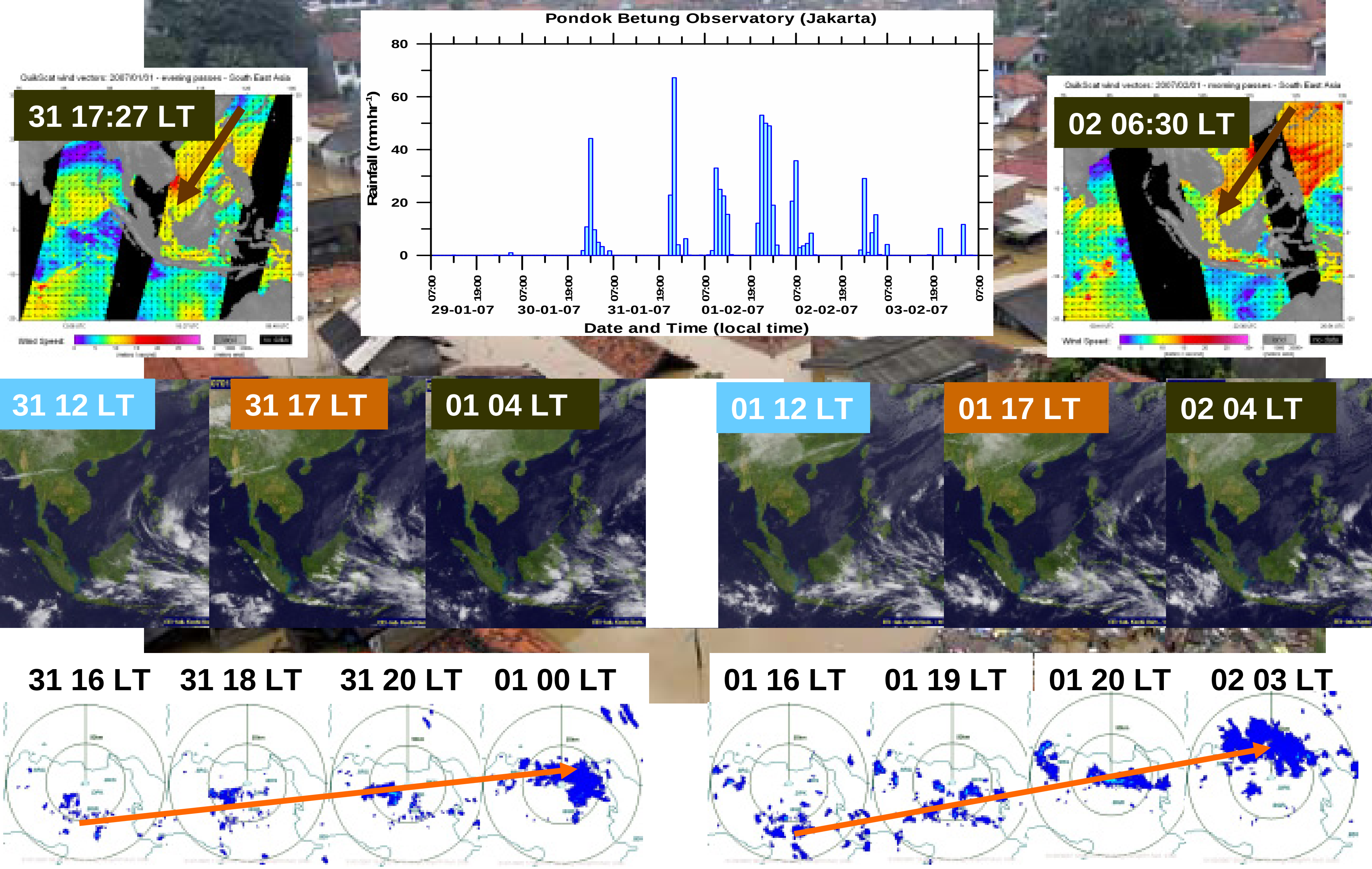


(Araki et al., 2008, to be submitted)

No "tropical night" in the tropics !

Diurnal cycle enhanced by monsoon beyond equato

(Jan-Feb 07 Jakarta flood) (Wu et al., 2007, *SOLA*)



Harimau

GEO Ministerial Summit

Earth Observation for Sustainable Growth and Development

Draft GEO Report on Progress - Annex

Cape Town, 30 November 2007

Table 1. Example Early Achievements by GEO Societal Benefit Area

Disasters: Reducing Loss of Life and Property from Natural and Human and Induced Disa

- Global Wildland Fire Early Warning System
- Sentinel-Asia
- Standards-based, All-Hazards, All-Media Public Warning
- Hydrometeorological ARray for ISV-Monsoon AUtomonitoring HARIMAU

16	Hydrometeorological ARray for ISV-Monsoon AUtomonitoring HARIMAU It is an observation system made of Rain Radars and wind-profilers installed in the Indonesian maritime continent (IMC), to observe IMC-excited global climate variations such as El Nino, with a large potential to prevent hydro meteorological / climatological disasters such as flood not only in IMC but also all over the world Data are openly available on the internet in real time. Collaborating countries are: Japan, Indonesia, Thailand, Vietnam, Myanmar	Three major stations installed and data available.
17	Dust and sand storm European and Saharan monitor	Products over Europe

Apr 2007: Abe & Bush agreed GEOSS promotion
May 2007: Abe's "Cool Earth 50" policy
Jun 2007: GEO Early Achievements nominated
G8 Summit (Heiligendamm, Germany)
・・・・
Nov 2007 GEO Summit IV（Cape Town, RSA）
Dec 2007 COP XIII (Bali, Indonesia)
Fukuda at AP Water Summit (Oita,Japan)
・・・・
July 2008 G8+12 Summit（Toyako, Japan）

“Post-JEPP” by a new Japanese governmental policy on Global Issues (FY2008-10)

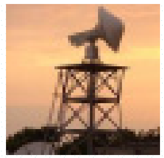
Japan EOS Promotion Program

Hydrometeorological ARray for Isv-Monsoon AUtomonitoring

(JEPP-HARIMAU)

Meteorological Doppler radars
(Horizontal obs of rain and wind)

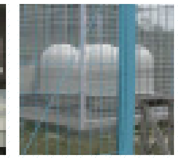
Wind Profilers
(Vertical profiles of 3D wind velocities)

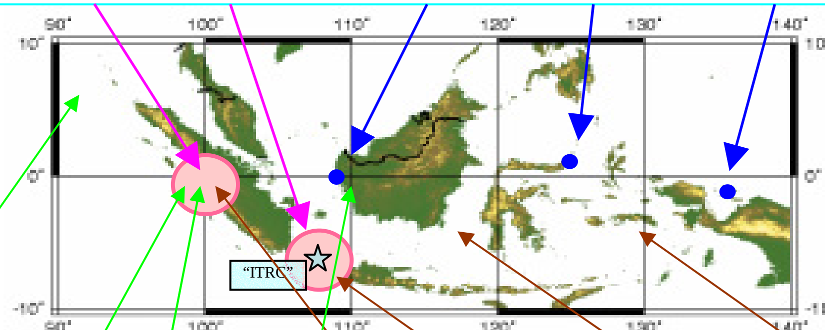

MIA/Padang
(Oct 2006)


Serpong/Jakarta
(Sep 2007)


Pontianak/Kalimantan
(Feb 2007)


Manado/Sulawesi
(FY 2008)


Biak/Papua
(Mar 2007)



<Science promotion>

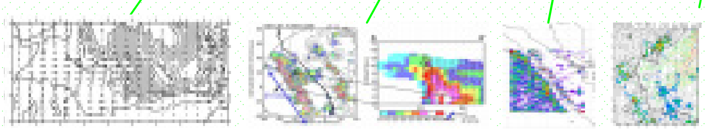
- **Diurnal variation** (DV) self-enhancement through cloud process
- **ISVs (superclusters) and Monsoons** interacting with DV
- **Interannual variations** (such as ENSO, IOD) originated near IMC

<Social benefits>

- **Capacity development** on hydrometeorology and climatology in IMC
- **Disaster prevention** and assessment for abnormal climate in IMC
- **Security for Japanese** (30,000 - 100,000) living/staying in IMC for business/sightseeing

JST/MEXT ⇒ basic research

- Development of next-generation radars/profilers
- Establishment of equatorial (moist & ageostrophic) GFD
- Promotion of interdisciplinary inside/outside of EPS



ODA/JICA/MOFA ⇒ Indonesian side

- Construction of “ITRC” as a COE for tropical sciences
- ”Radar-AMeDAS” like system for IMC
- Collaborative paper production with young scientists