Quick Summary of Aqua Planet Experiment (APE)

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Background

The Gap between Simulation and Understanding in Climate Modeling

BY ISAAC M. HELD

Should we strive to construct climate models of lasting value? Or should we accept as inevitable the obsolescence of our models as computer power increases?

THE NEED FOR MODEL HIERARCHIES. The complexity of the climate system presents a challenge to climate theory, and to the manner in which theory and observations interact, eliciting a range of responses. On the one hand, we try to *simulate* by capturing as much of the dynamics as

the stated goal of improving these comprehensive models.

Due to the great practical value of simulations, and the opportunities provided by the continuing increases in computational power, the importance of understanding is occasionally questioned. What does

Held (2005) Bulletin of the American Meteorological Soc.

[English | Japanese] [GFD Dennou Club / dcmodel]

GFD Dennou Club Dcmodel project

What is dcmodel?

The goal of dcmodel project is developing hierarchical numerical models for fluid dynamics in Earth and planetary sciences.

Products

Fluid models

agcm5
A general circulation model based on primitive equation system (Fortran 77, old project)

DCPAM
A general circulation model based on primitive equation system (Fortran 90, new project) for planetary atmospheres with spmodel as a dynamical core

deepconv
A two-dimensional non-hydrostatic fluid model

dynamo
A MHD dynamo model in a rotating sphere and spherical shells (written with spmodel library)

spmodel
Hierarchical spectral models for geophysical fluid dynamics (equation-like expression of ISPACK covered with Fortran 90 interface)

ISPACK
Spectral transformation library for numerical fluid dynamics and barotoropic / shallow water models with plane or spherical geometries

gms
A grid model development tool and sample programs

IGModel
An icosahedral grid atmospheric model

Energy model

oboro
An equiribrium cloud condensation model by using Gibbs free energy minimization method

dcrtm **(Sorry, this page is described in Japanese)**
A radiative transfer model for planetary atmospheres

I/O library

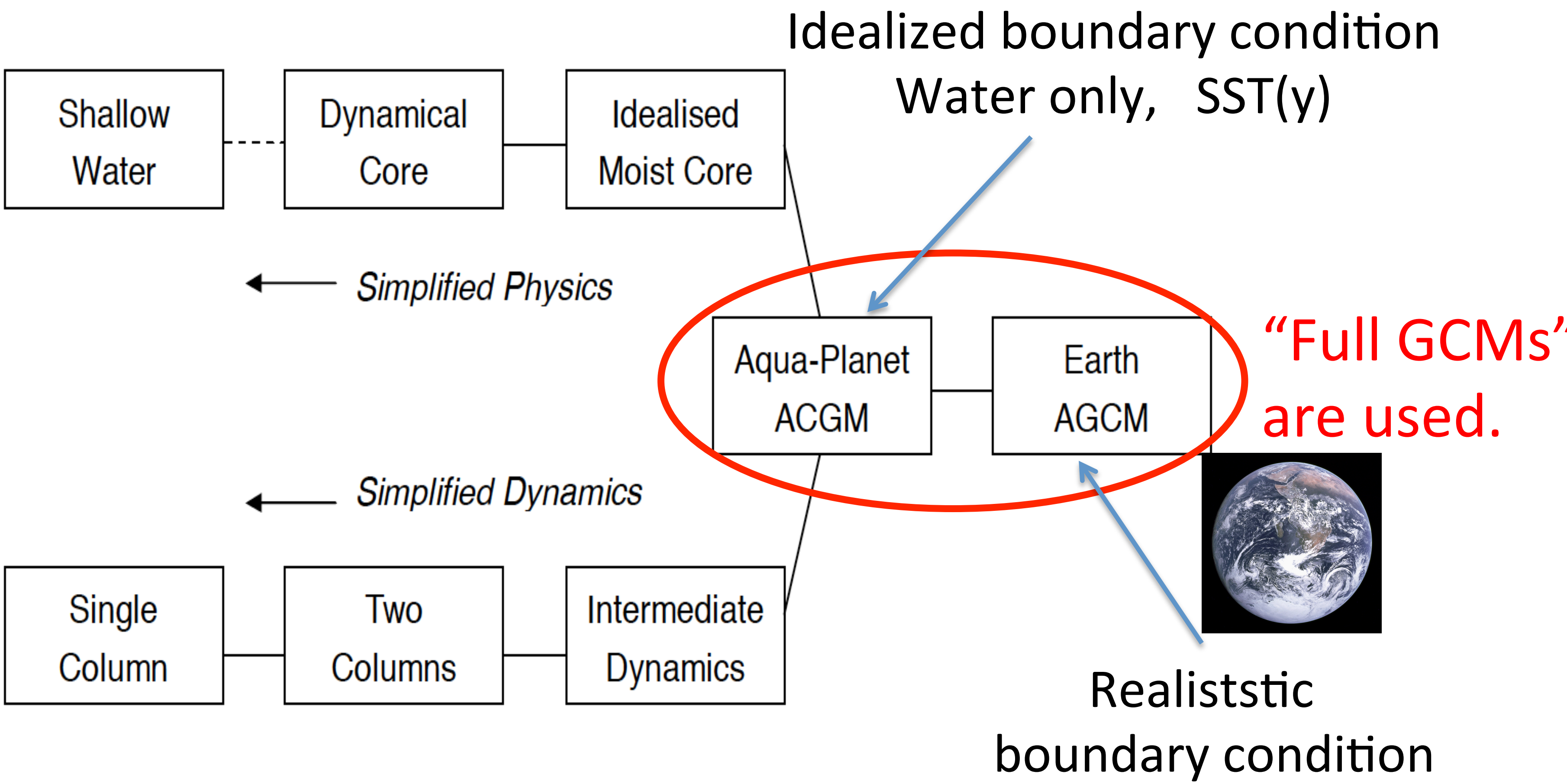
gtool5
Fortran 90/95 library for hierarchical numerical models

We have been developing
a hierarchy of numerical models.

地球流体電脳倶楽部
GFD　Electric brain Club

to be the contents of the talks tomorrow

Aqua Planet Experiment in the hierarchy of models

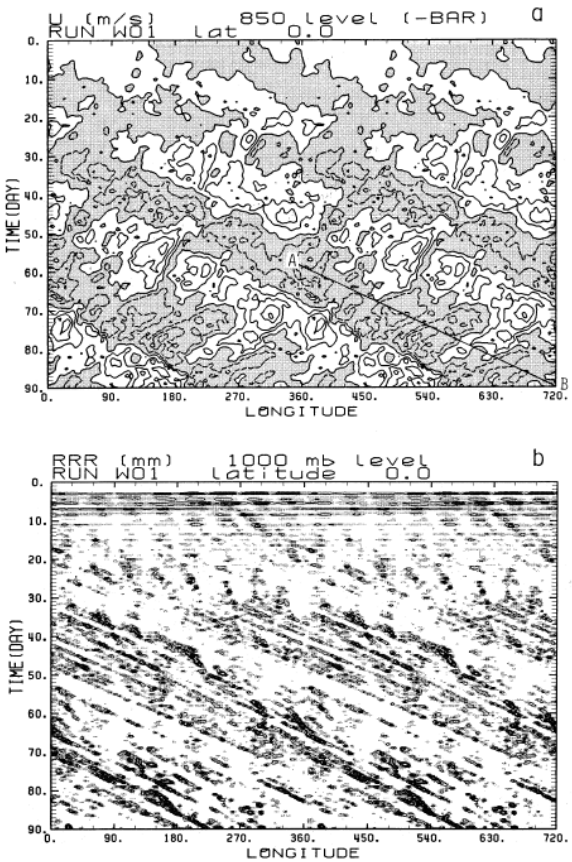


Blackburn and Hoskins (2013)

The Earliest Aqua Planet Experiment

Hayashi and Sumi (1986)

August 1986 Y.-Y. Hayashi and A. Sumi 455



U

Rain

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.

features in the numerical model

observed features

OLR (cloud activity)

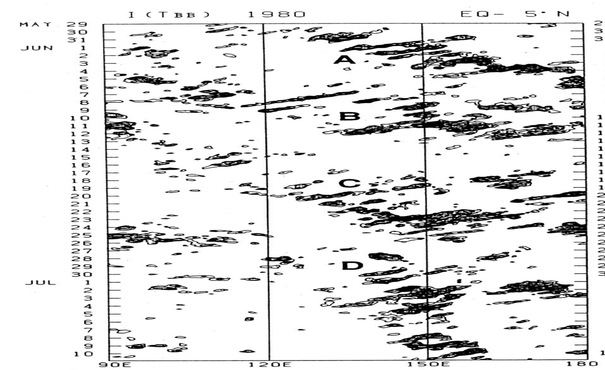
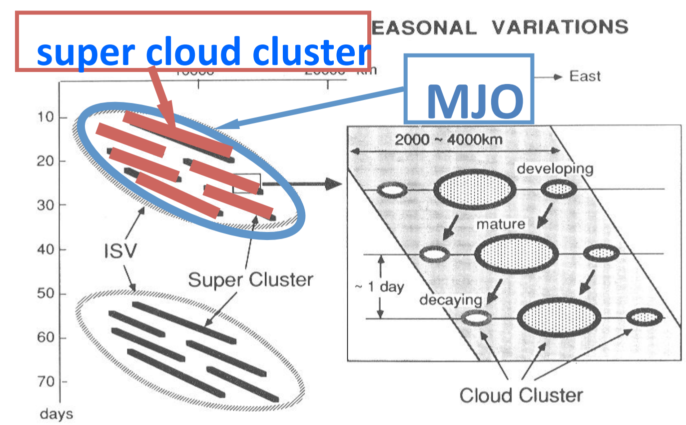


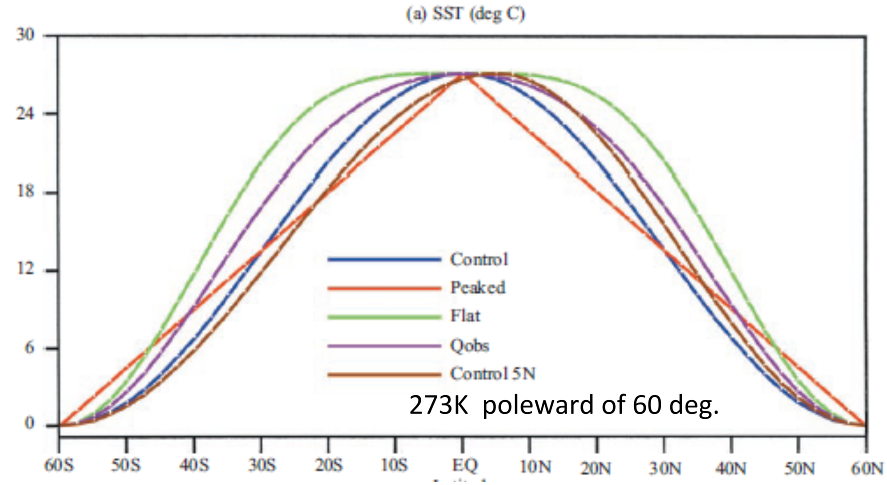
Fig. 2. Time-longitude section of T_{BB} index (I_{TBB}) integrated between the equator and 5°N obtained from the 3-hourly GMS IR data from 29 May 00Z to 10 July 21Z, 1980. Symbols A to D denote the same super cluster as in Fig. 1. Contour interval is 10, and shading denotes the region where values are greater than 20.



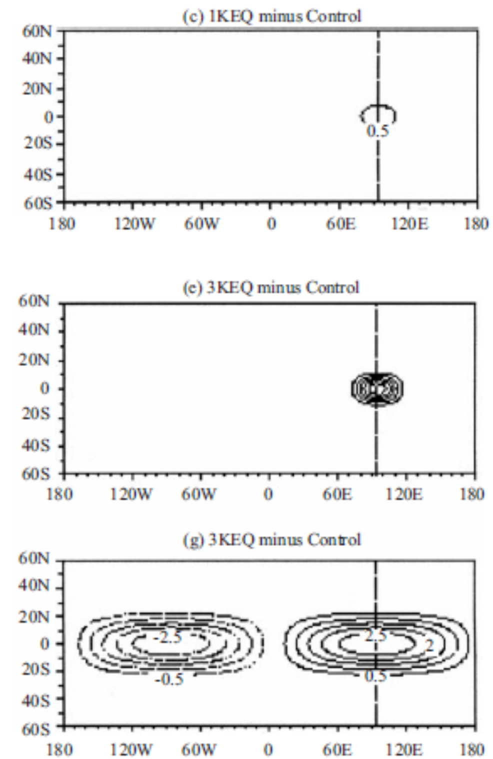
Schematic diagram for hierarchy of ISV. (Nakazawa, 1988)

The APE project

APE Aqua-Planet Experiment Project



Proposal : Neale and Hoskins (2000a,b)
Numerical Experiments Performed: 2003-2006
Workshops: 2005@Reading UK, 2007@Choshi JP
Results: APE ATLAS (2011), JMSJ Special Issue (2011)



Idealised climates simulated by AGCMs which are being used and developed for NWP and climate research.

Several idealised distributions of SST, focusing on
- the distribution and variability of convection in the tropics
- the storm-tracks in mid-latitudes.

A benchmark of current model behavior
Understand the causes of inter-model differences
subgrid-scale parameterization suites,
dynamical cores, resolution

Group-ID	Resolution,	Dynamics, horizontal	Deepconvection
AGUforAPE	T39L48 (3x3)	Spectral	Emanuel (1991)
CGAM	2.5 x 3.75 L30	Arakawa B grid	Gregory-Rowntree penetrative mass-flux convection
CSIRO (standard)	C48 L18 (2x2)	Conformal cubic grid	Mass flux type with downdraft
CSIRO (old)	C48 L18 (2x2)	Conformal cubic grid	Mass flux type with downdraft
DWD	ni=64 L31	icosahedral grid	Bulk mass flux (Tiedke, 1989)
ECMWF	T159L60 (2x2)	Spectral	Bulk mass flux (Tiedke, 1989)
ECMWF_07	T159L60 (2x2)	Spectral	Bulk mass flux (Tiedke, 1989)
FRCGC	7km mesh (0.063x)	Icosahedral grid	Cumulus (partial) resolving
GSFC	2 x 2.5 L34	4th order global grid	Relaxed AS (Moorthi &Suarez, 1992)
GFDL	?	?	Relaxed AS
K-1 Japan	T42L20 (2.8x2.8)	Spectral	Prognostic AS (Pan &Randall, 1998)
LASG	R42L9 (2.8x2.8)	Spectral	Slingo cloud parameterization scheme, Manable convective parameterization
MIT	?	?	Relaxed AS (Moorthi &Suarez, 1992)
MRI	T42L30 (2.8x2.8)	Spectral	Prognostic AS
NCAR	T42 L26 ? (2.8x2.8)	Spectral	Zhang and McFarlane (1995)
UKMO_n48	N48L38 (2.5x3.75)	Arakawa C grid	Gregory-Rowntree
UKMO_n96	N96L38 (1.25x1.625)	Arakawa C grid	Gregory-Rowntree

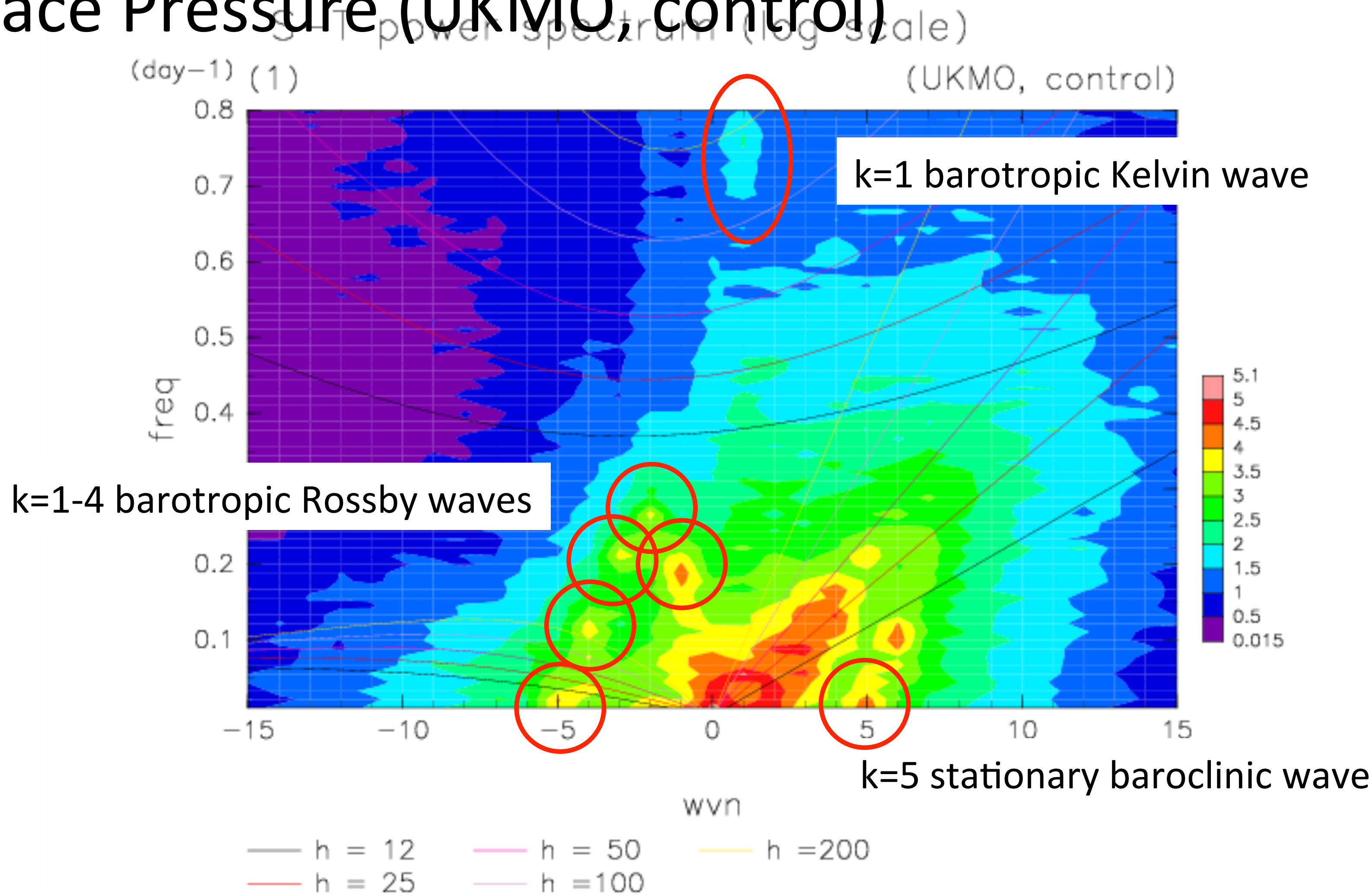
14 groups from 6 countries + ECMWF

See “APE ATLAS” Williamson et al (2012) for details.

NOTABLE FEATURES FOUND IN APE OWING TO IT'S IDEALIZED SET-UP

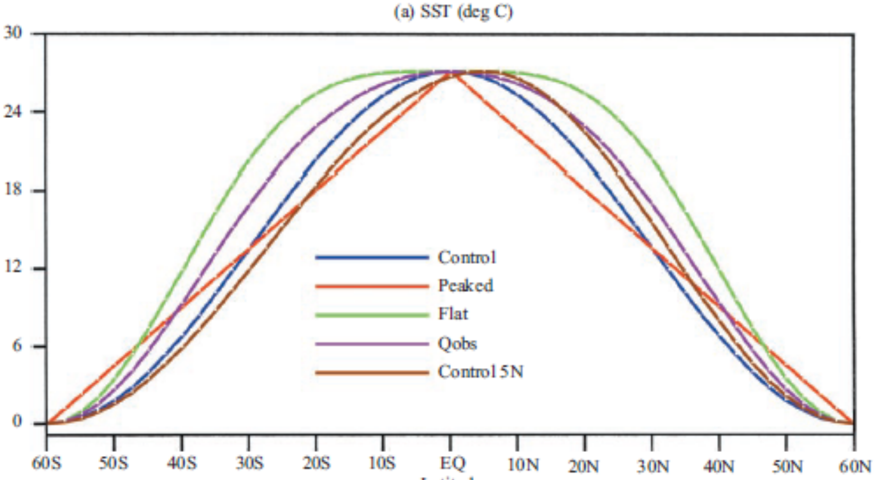
Normal Modes easy to identify

Example1: “raw” Wavenuber-Frequency Spectrum of Surface Pressure (UKMO, control)

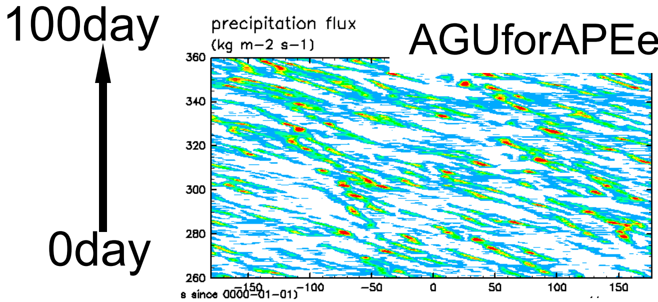


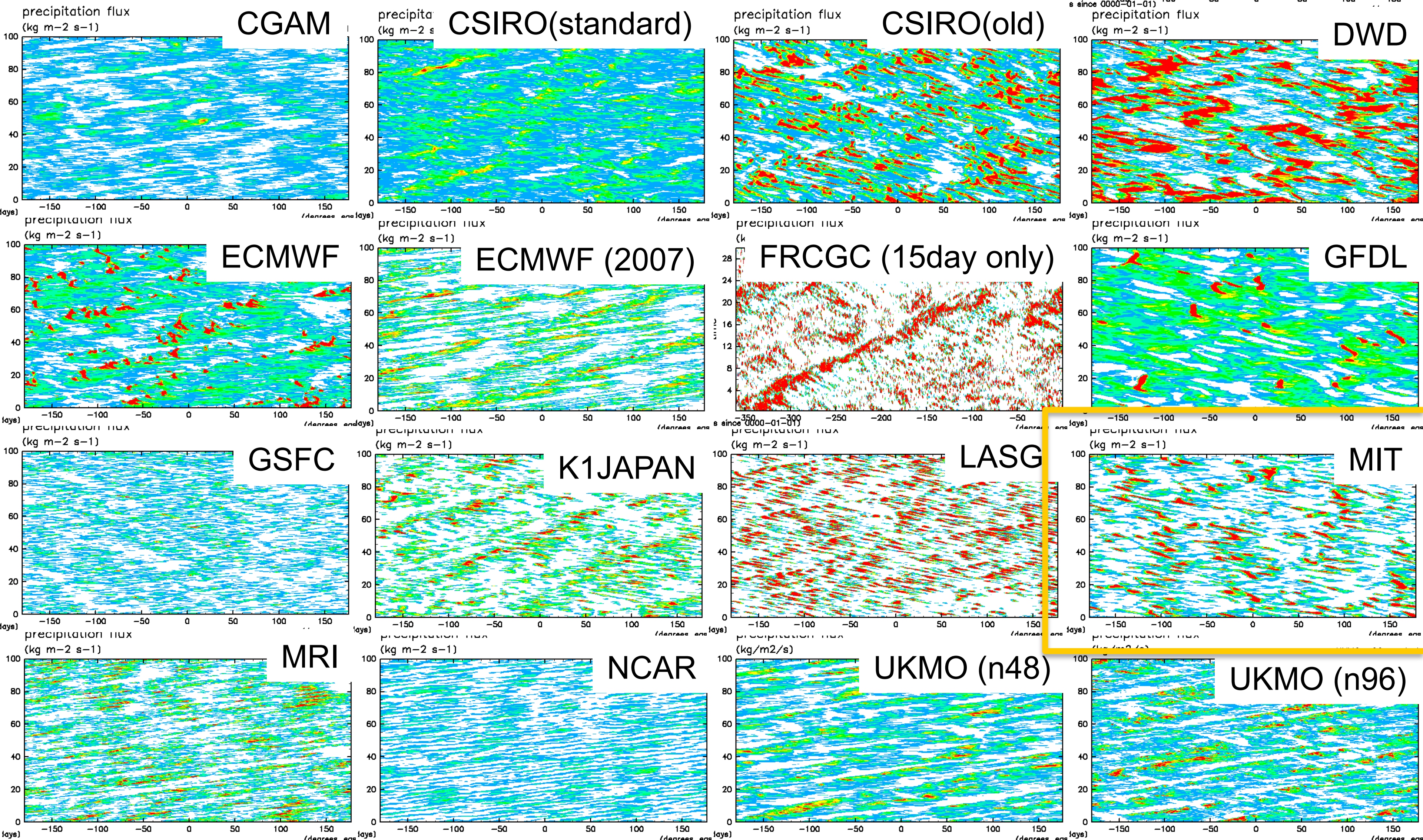
EXAMPLE OF COMPARISON
(ZONALLY UNIFORM SST)

DIVERSITY OF TROPICAL CONVECTIVE ACTIVITY

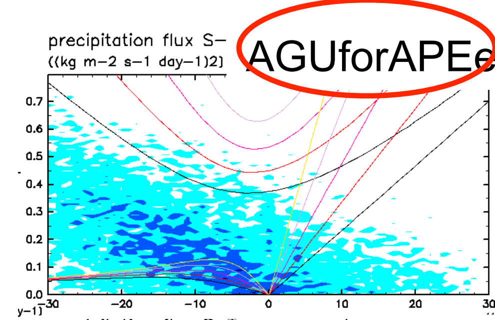


Precipitation at EQ (x,t)

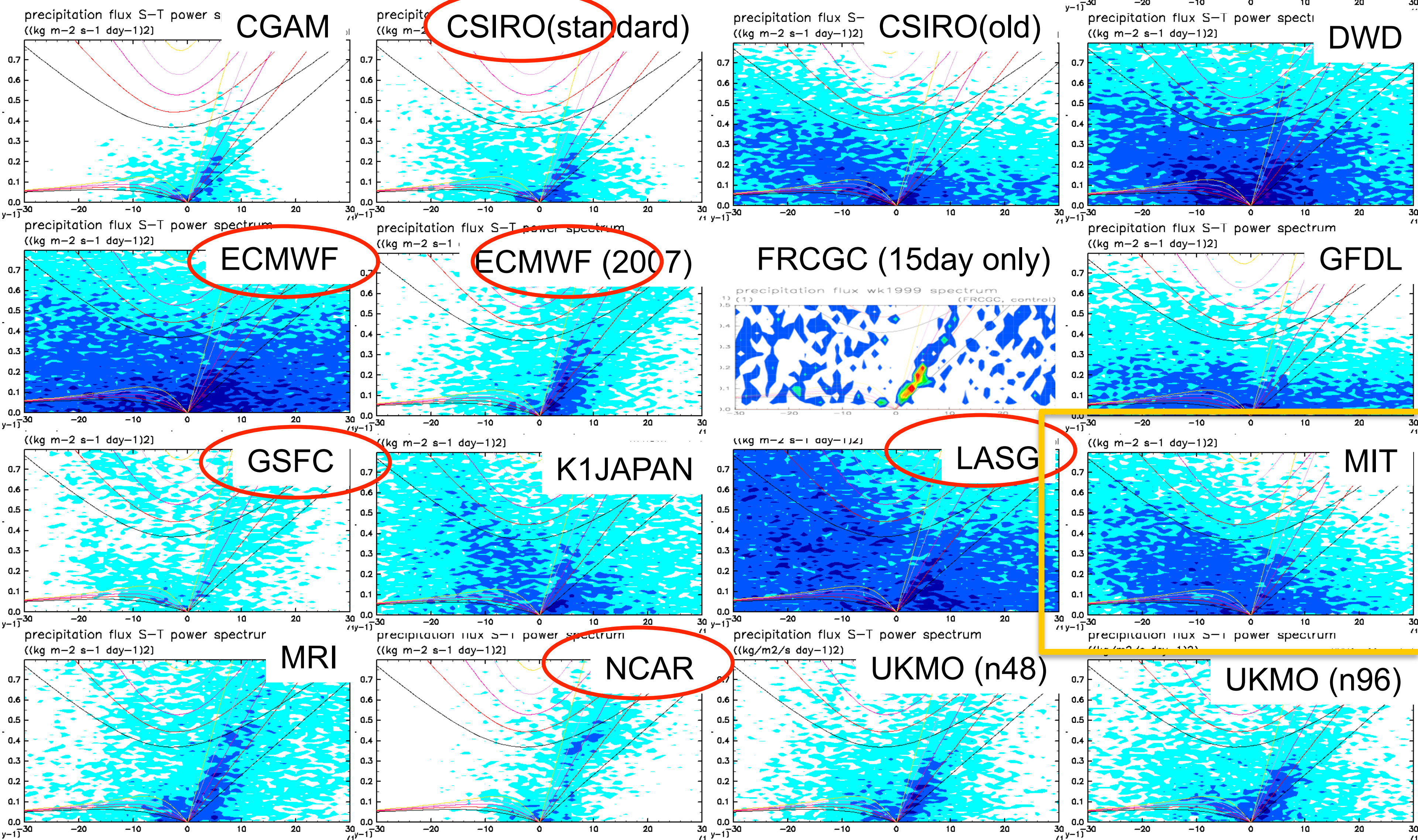




Precipitation Spectra

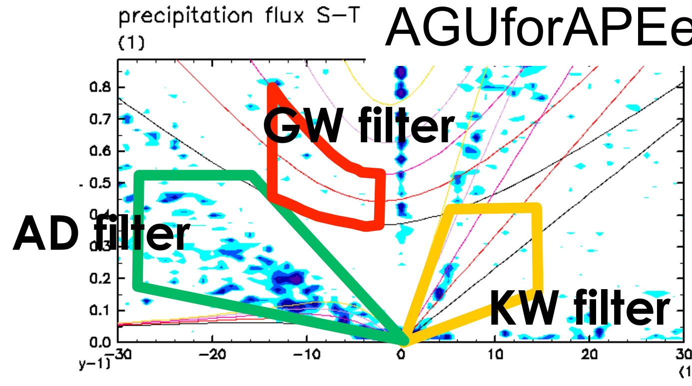


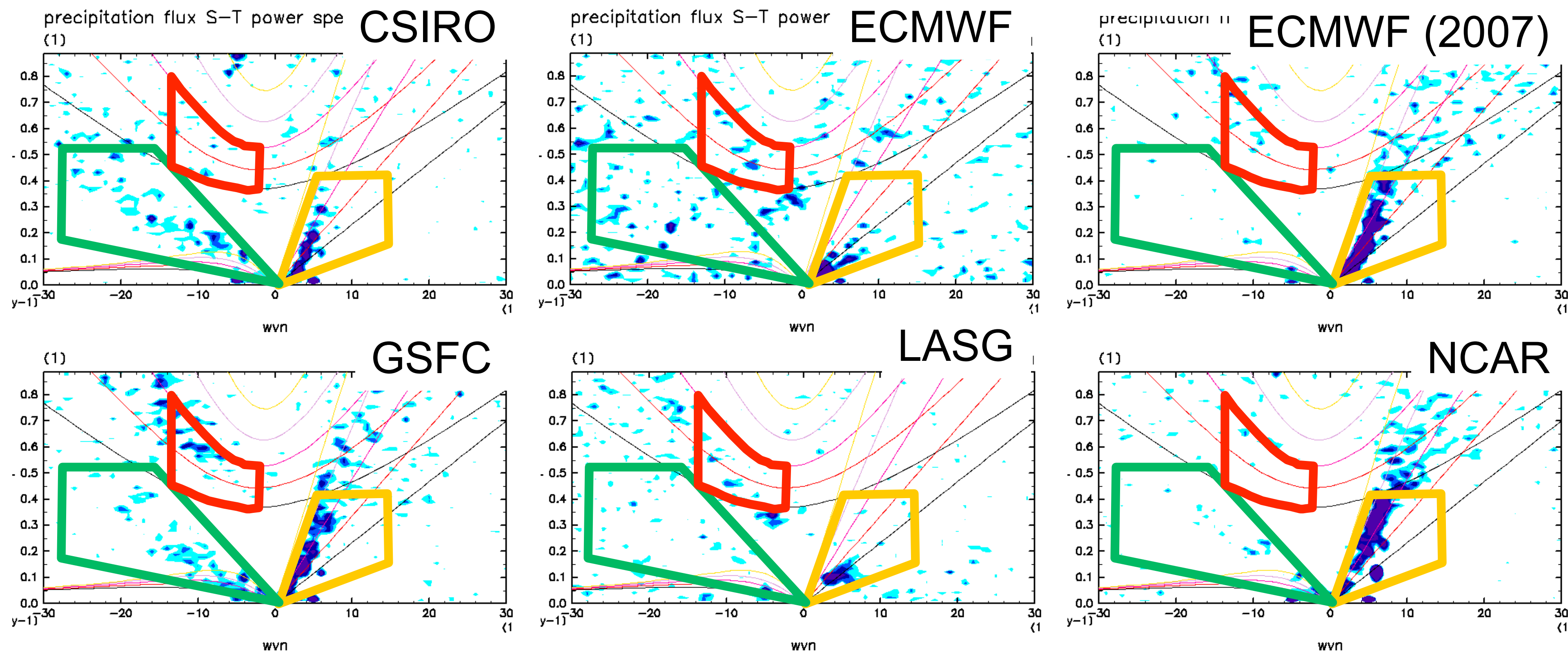
Kelvin wave like signal can be found in most models.



Spectral filters
defined from Wheeler & Kiladis plots

KW filter : Kelvin wave signals
GW filter : westward gravity wave signals
AD filter : “advective” signals

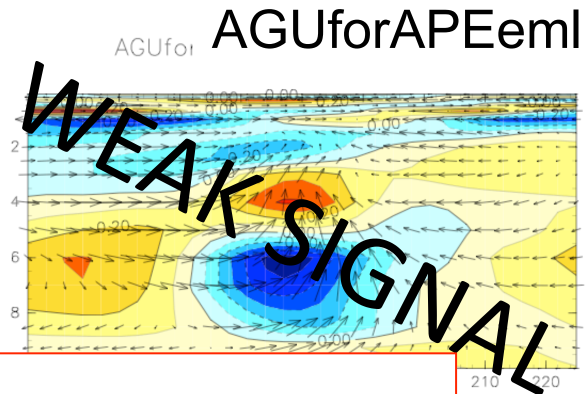


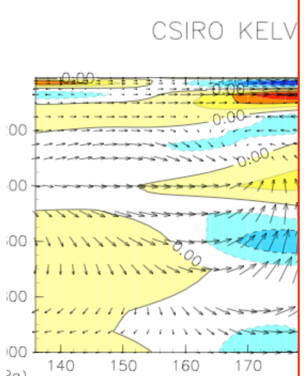


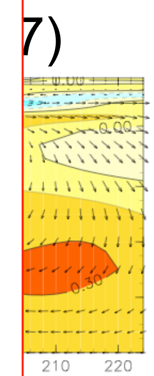
KW filter / composite [T, (u, omg)]

Westward phse tilt? … Probably.

ECMWF(05/07) and LASG.
 Westward phase tilt is evident (wave-CISK like).
GSFC : Eastward tilt
AGUforAPE: cold upward motion

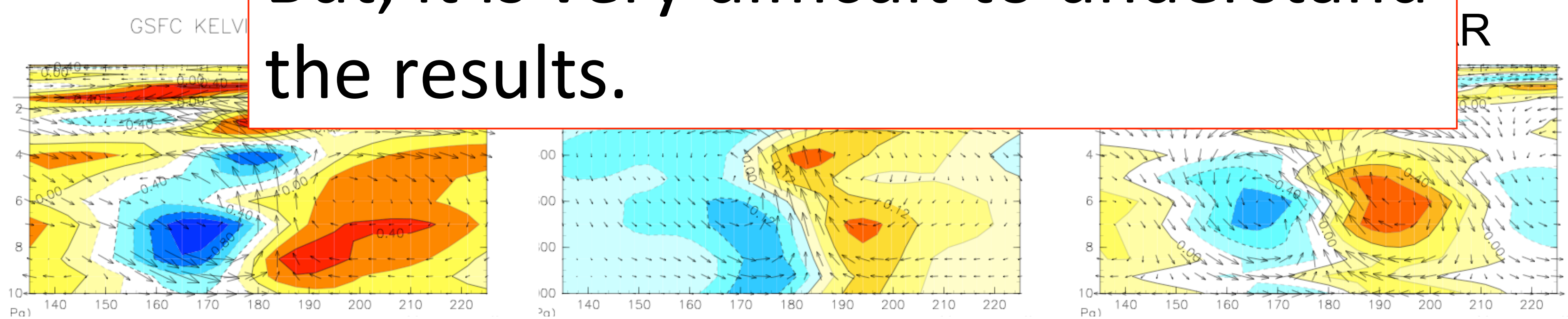




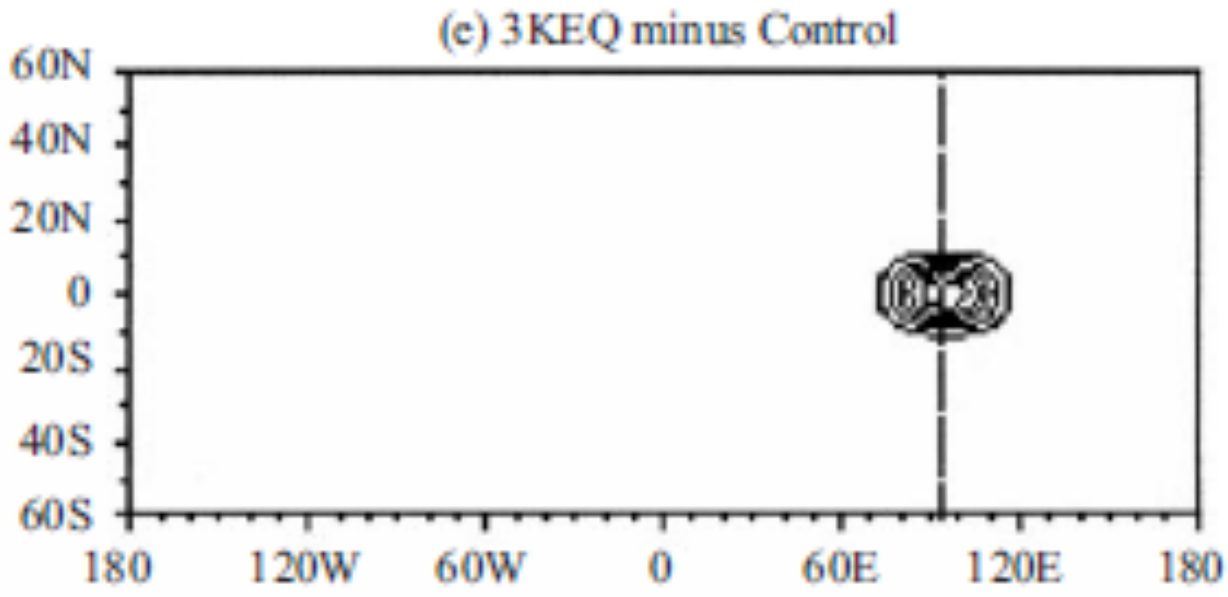


You may want to know
why these difference develop.

But, it is very difficult to understand
the results.



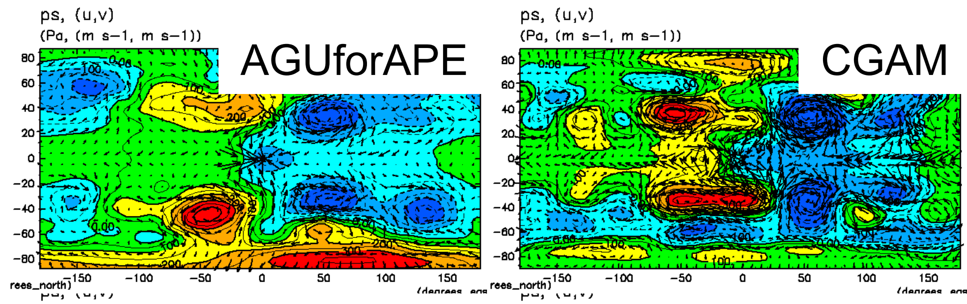
EXAMPLE OF COMPARISON (WITH SST ANOMALY)

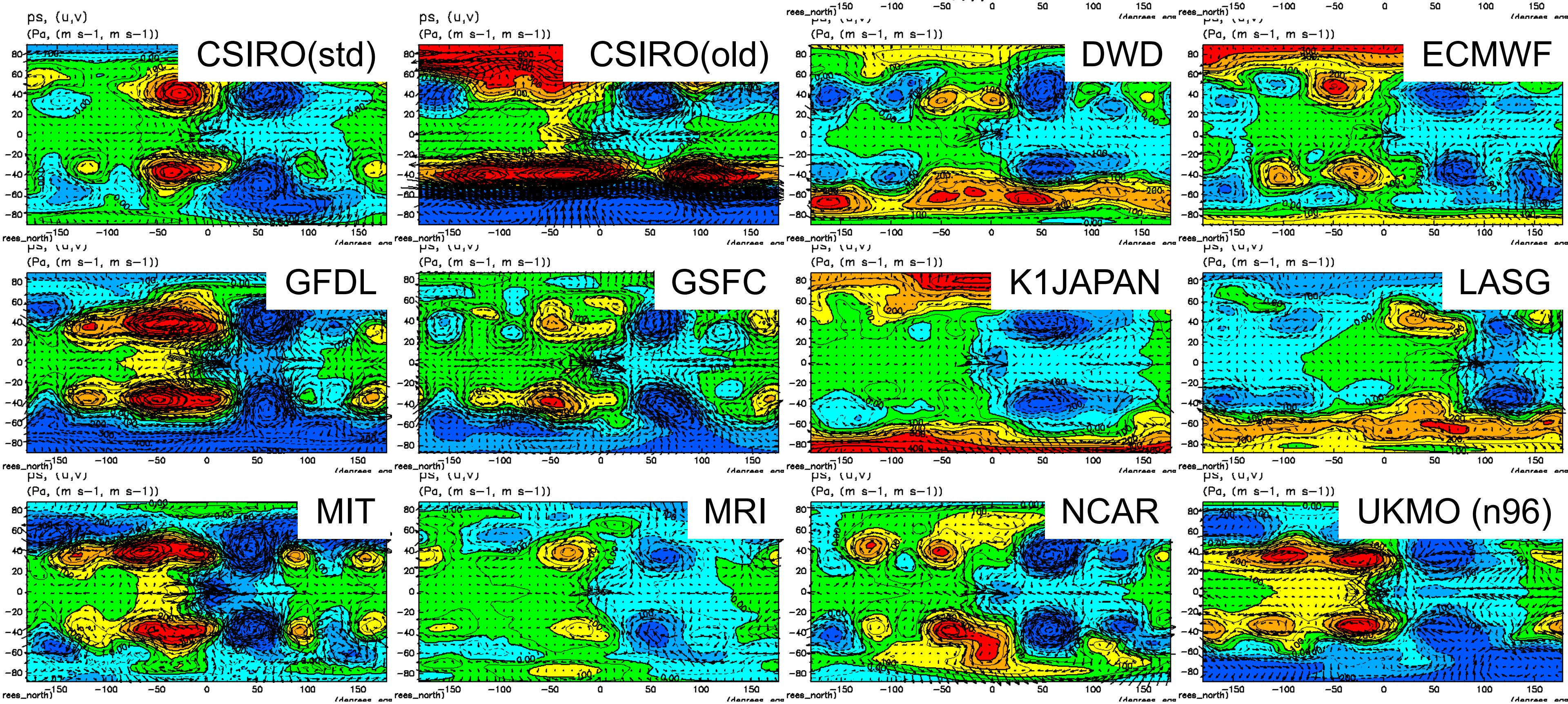


RESPONSE TO SST ANOMALY IS VERY "STRANGE".

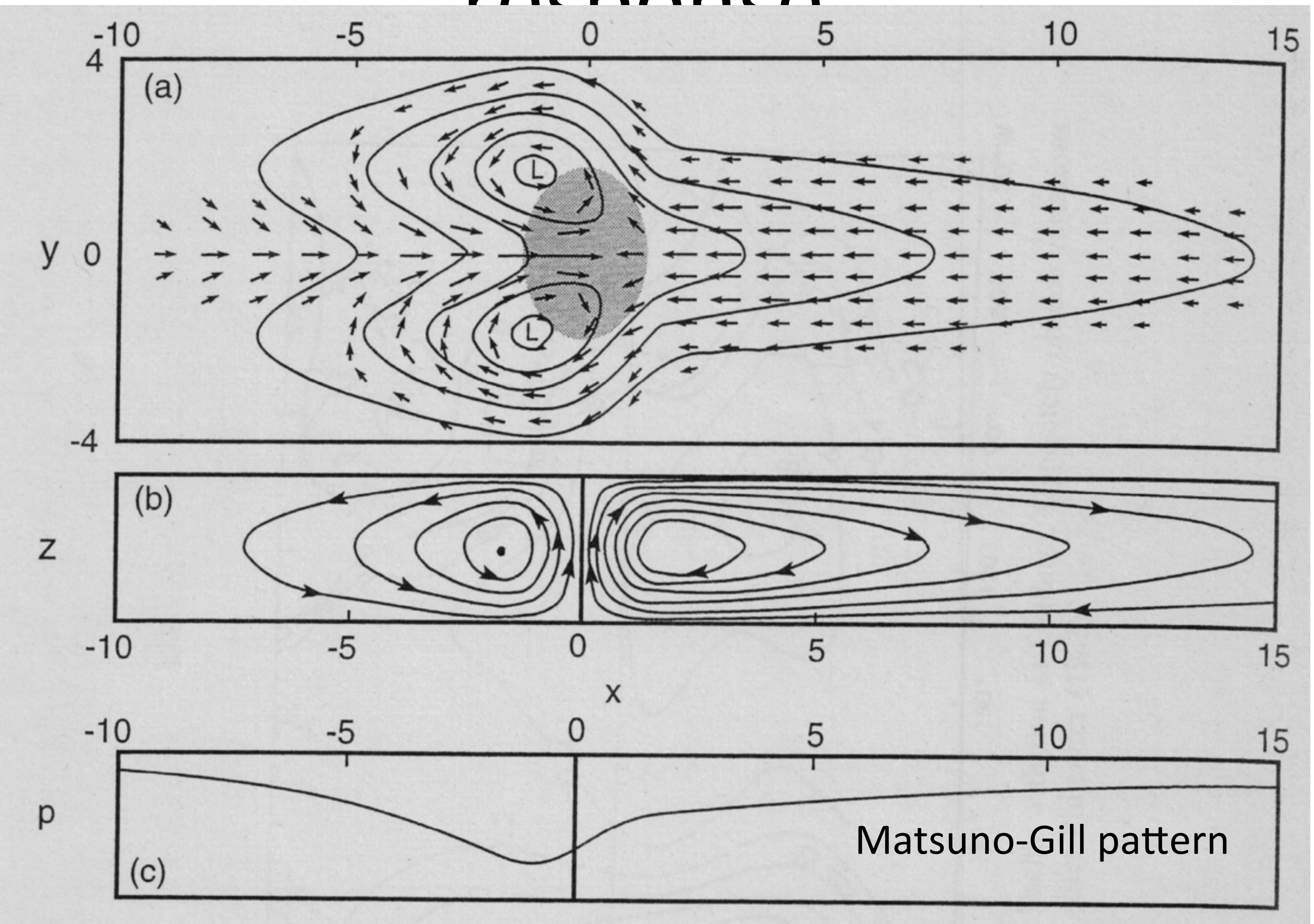
Surface pressure and wind (3keq)

The intensity of
mid latitude Rossby response
diverges considerably.





More "dynamically based" view N-S symmetric equatorial thermal response

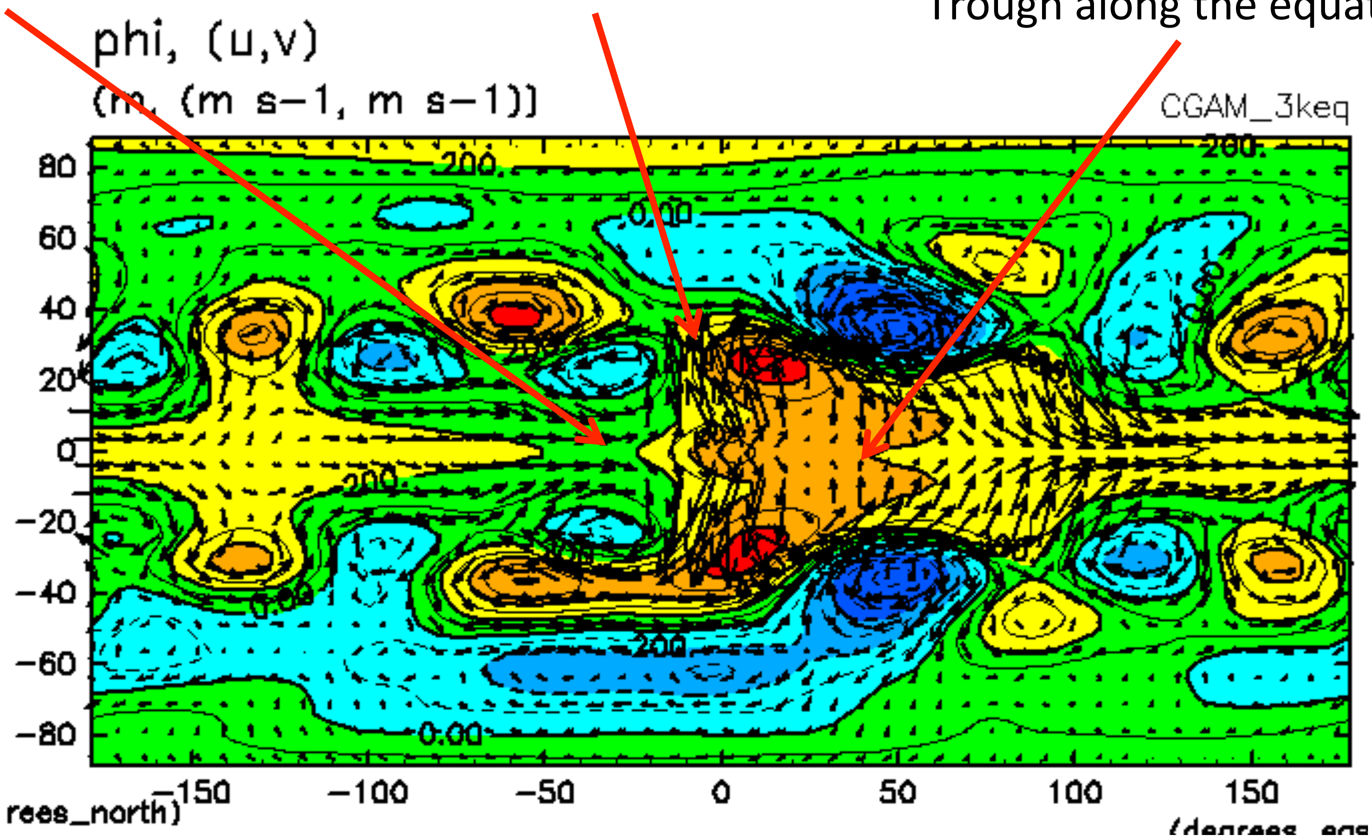


Significant difference from classical Matsuno-Gill pattren

No westward outflow.

Poleward outflow

No eastward outflow.
Trough along the equator.

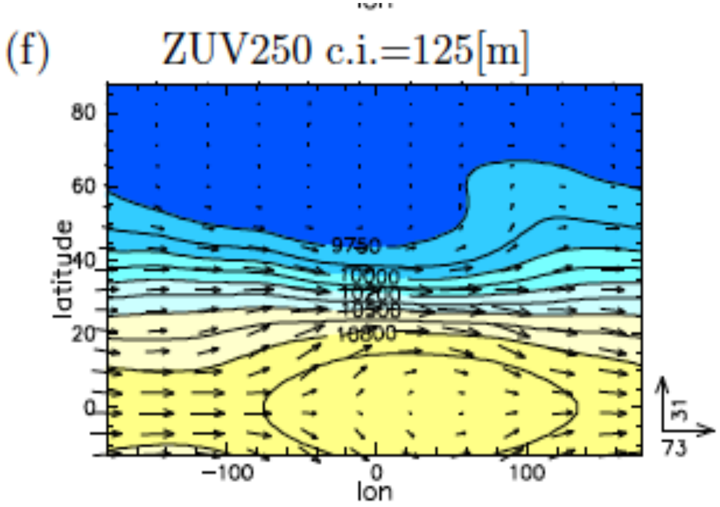


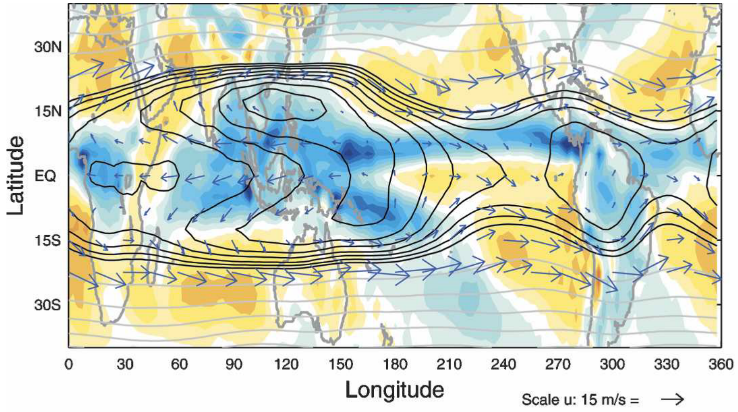
upper tropospheric response (CGAM)

3KW1 vs "Walker circulation"

In APE,
high pressure
develops
to the east of
warm SST area.

In the real atmosphere,
high pressure develops
to the west of
warm SST area.

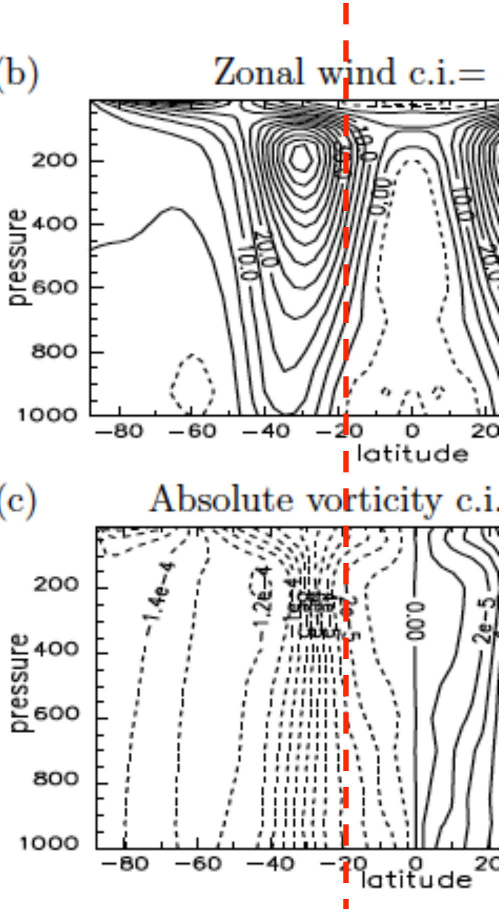


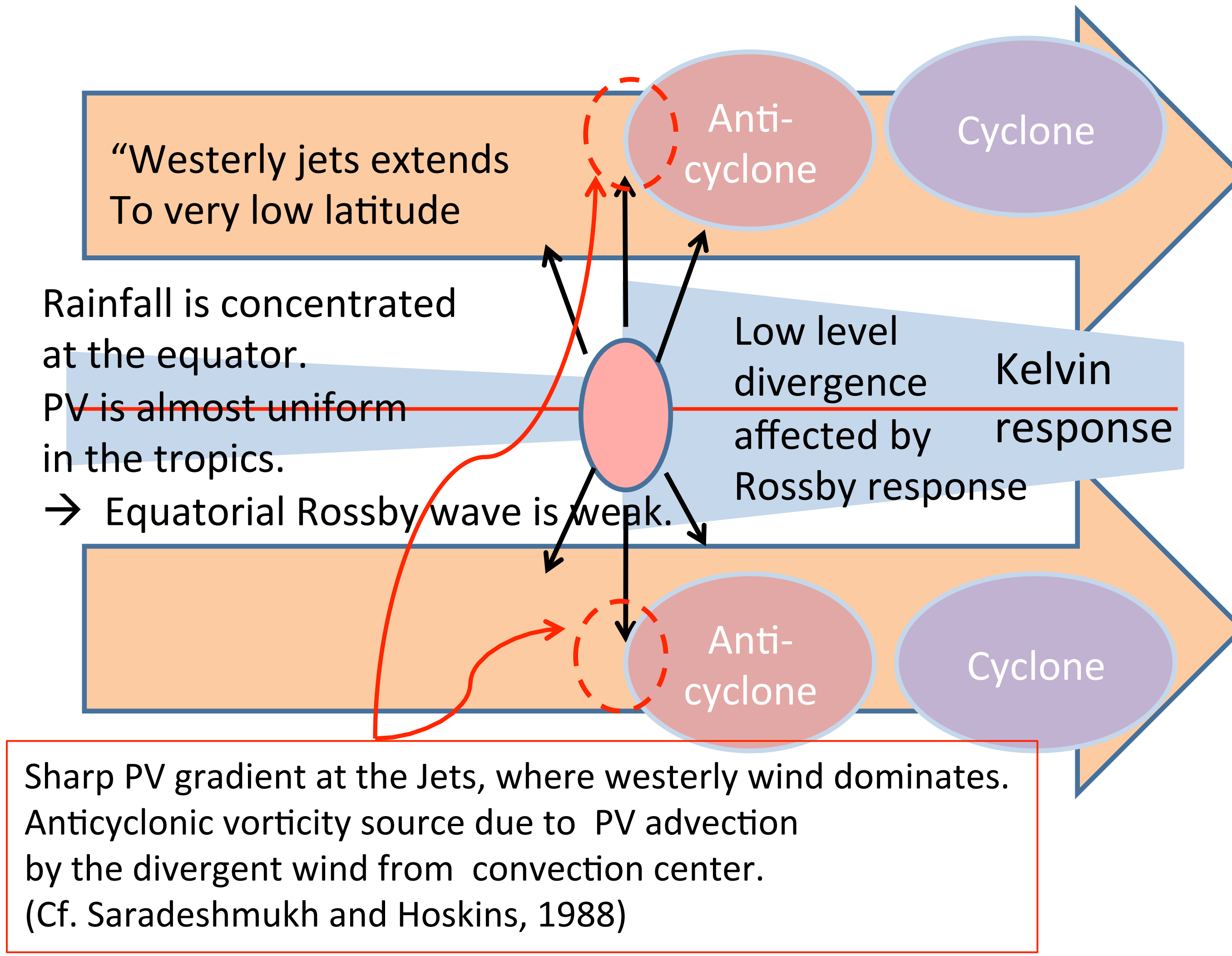


upper tropospheric pressure and wind fields

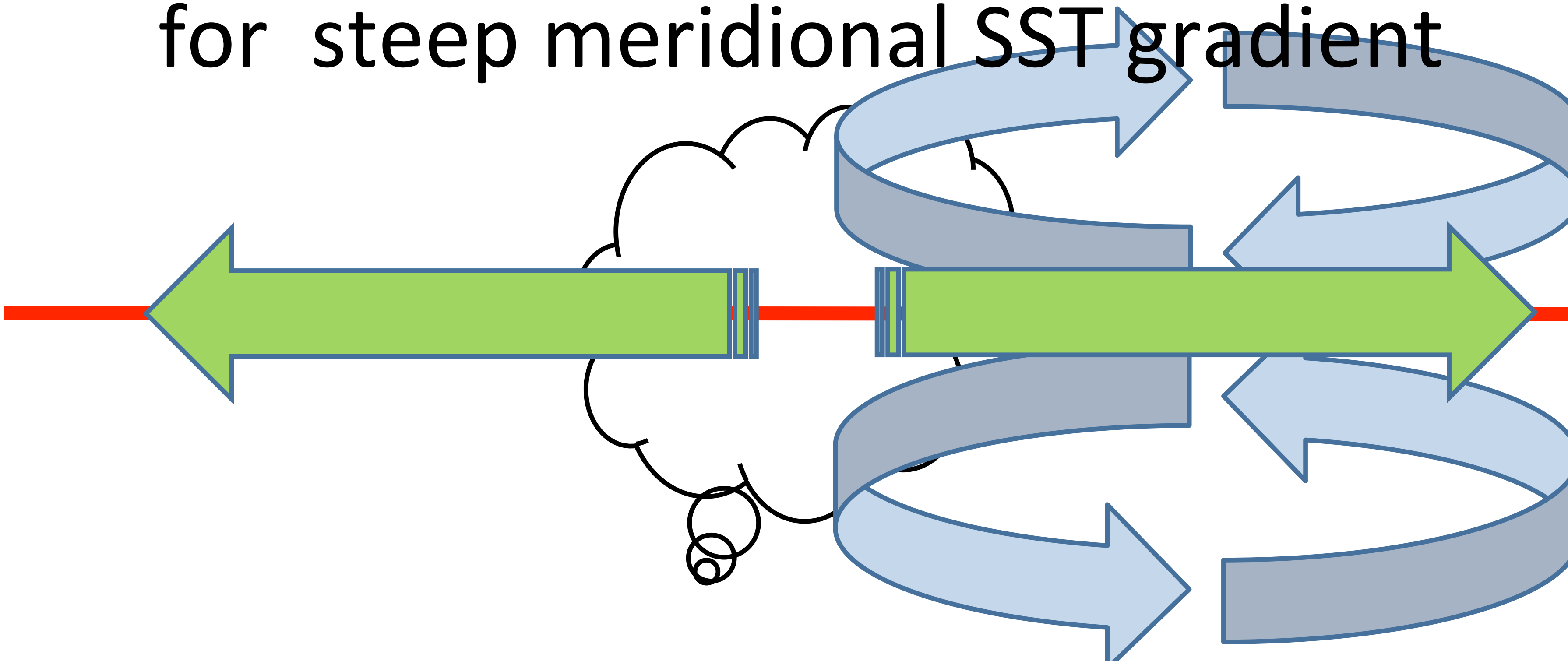
Why is the response in APE strange?

Zonal mean state
obtained in APE
is not so realistic.



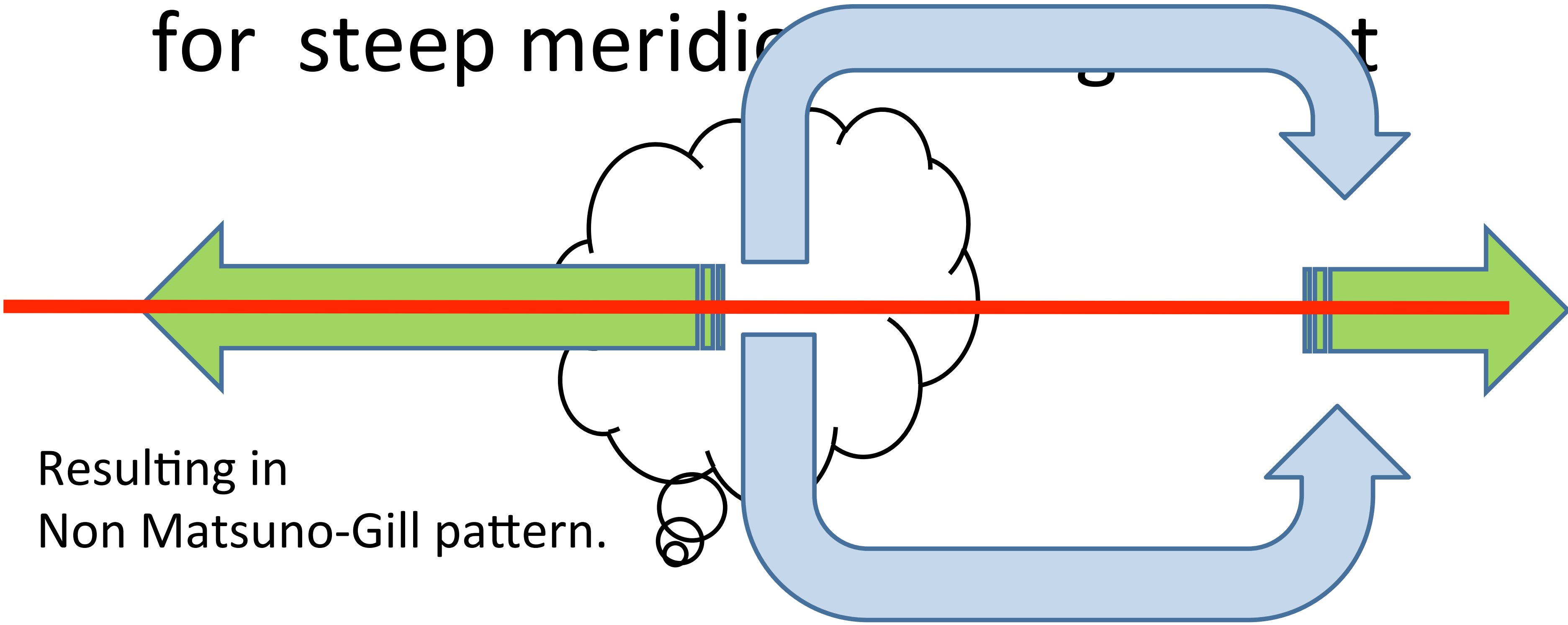


Upper tropospheric circulation associated with Kelvin & Rossby response for steep meridional SST gradient



Destructive superposition of Kelvin and Rossby responses of equtorial zonal wind

Upper tropospheric circulation associated with Kelvin & Rossby response for steep meridi… t

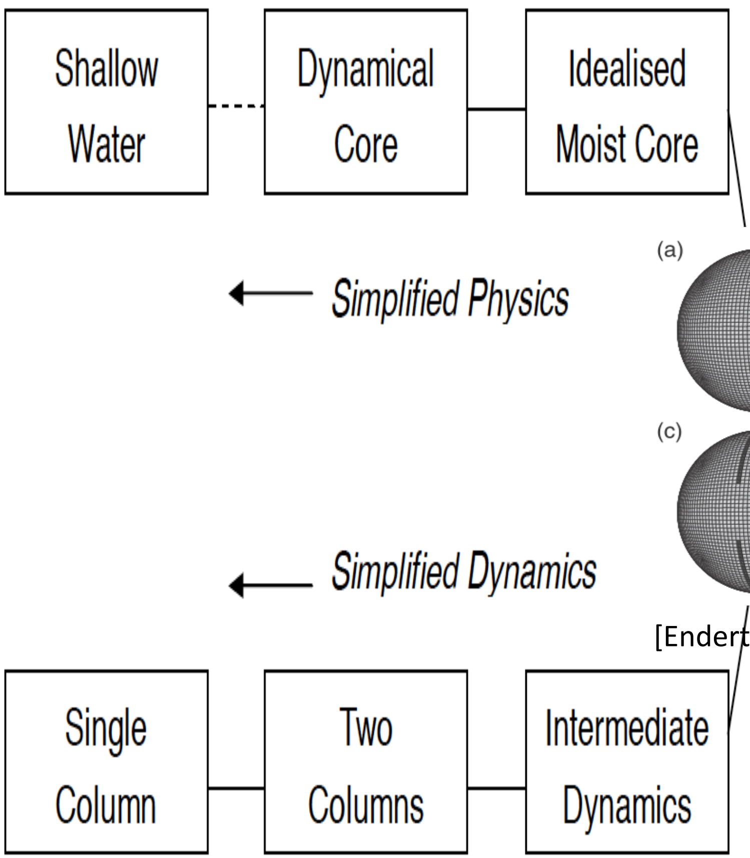


Resulting in
Non Matsuno-Gill pattern.

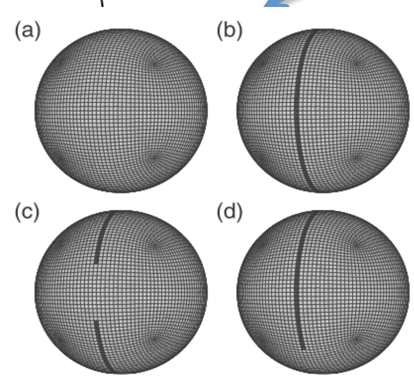
Retrospect on APE

- APE as Idealized experiments
  - Simple set-up allows clear display of "waves" and their mutual interaction.
    - Interpretation, however, is not necessarily easy.
  - It is not easy to choose or justify setup
    - Apparently subtle difference in set-up can result in large difference.
    - Compromise between "reality" and "idealization"
- APE as an intercomparison project
  - Variety among results from different models is VERY DIVERSE.
    - Interpretation, again, is not necessarily easy. To help it, we need
      - Enough data (variables, space-time coverage/resolution)
      - Enough description of participating models (source codes?)
      - Cooperation among modelers, theoreticians, and data-analysts

hierarchy considering ocean



A class of idealized boundary conditions



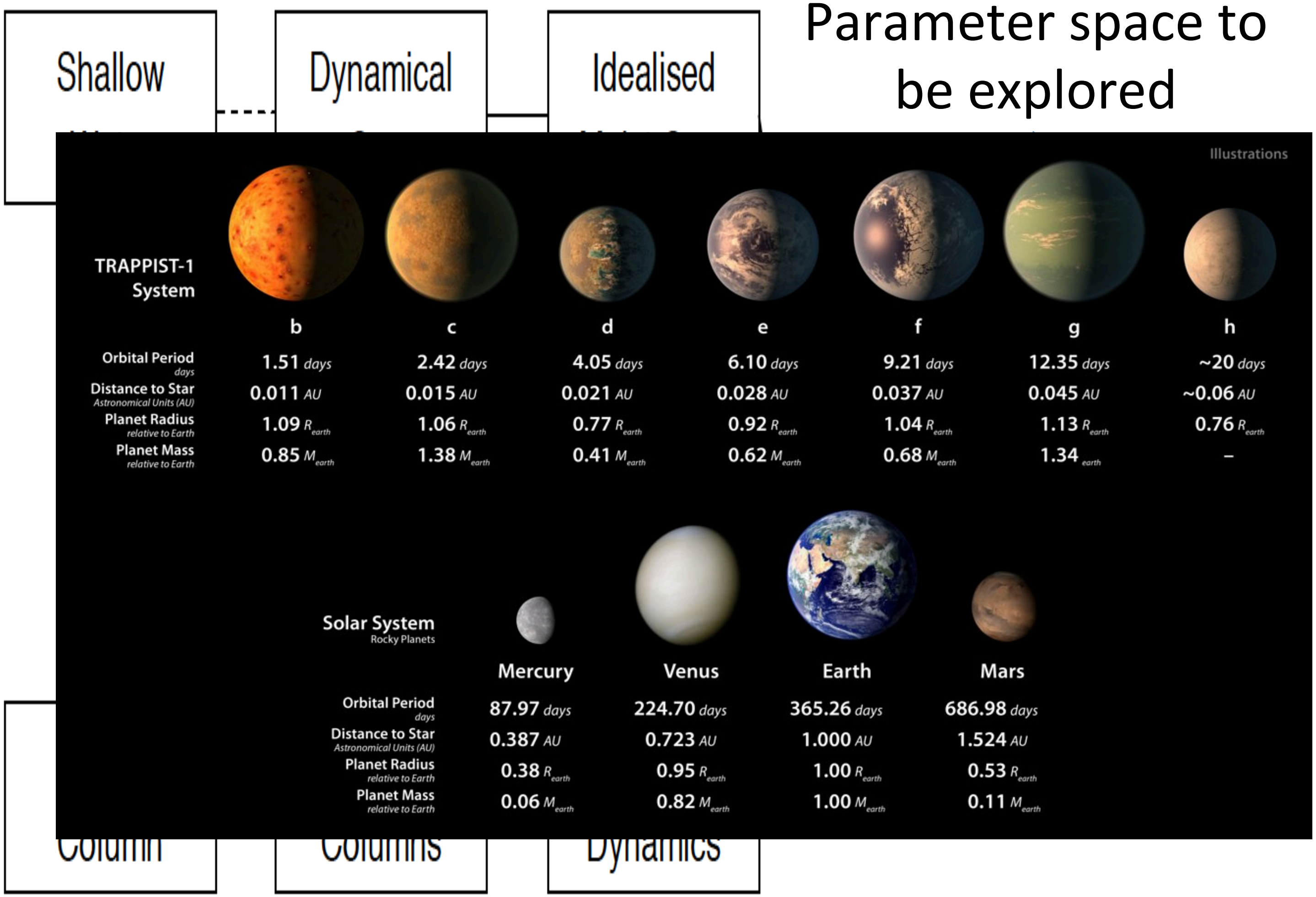
[Enderton and Marshall(2009) Fig. 2]

Realiststic boundary condition

hierarchy for exoplanets

Parameter space to be explored

The Earth is one of them



http://www.eso.org/public/images/eso1706m/