AOSC680
Water Planet and Weather Predictability

Chapters 6 & 7 in *Atmosphere, Clouds, and Climate* by David Randall

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Supervised by Ross Salawitch

Chapter 6 | “The Water Planet”

Figure 6.1: Vertical Profile of Globally Averaged Specific Humidity

Which latitude(s) have relatively high/low water vapor?

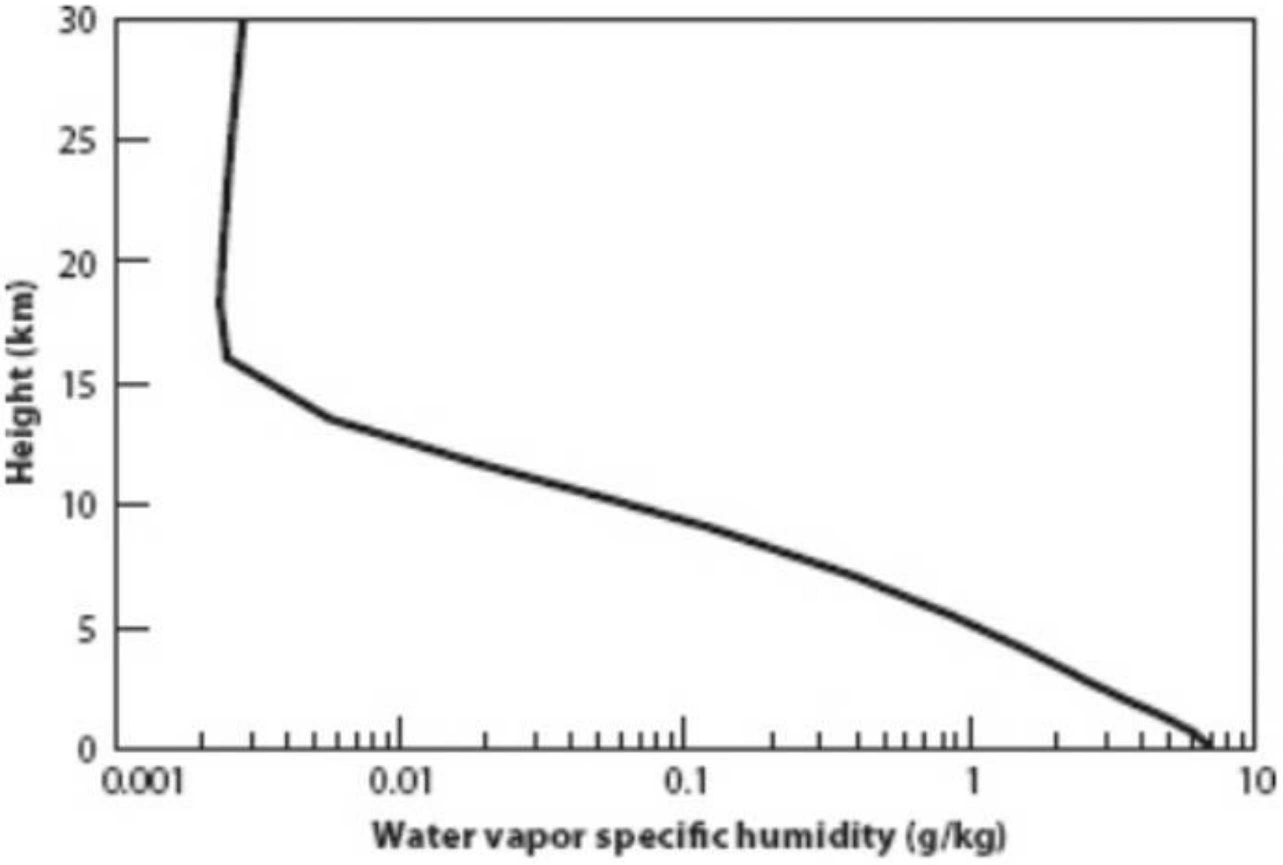


Figure 6.1. The vertical profile of the globally averaged specific humidity. Note that the horizontal scale is logarithmic. In the lower troposphere, tropical values are larger than plotted here, and high-latitude values are smaller.

Randall (2012)

Relative Humidity and the Hadley Circulation: January

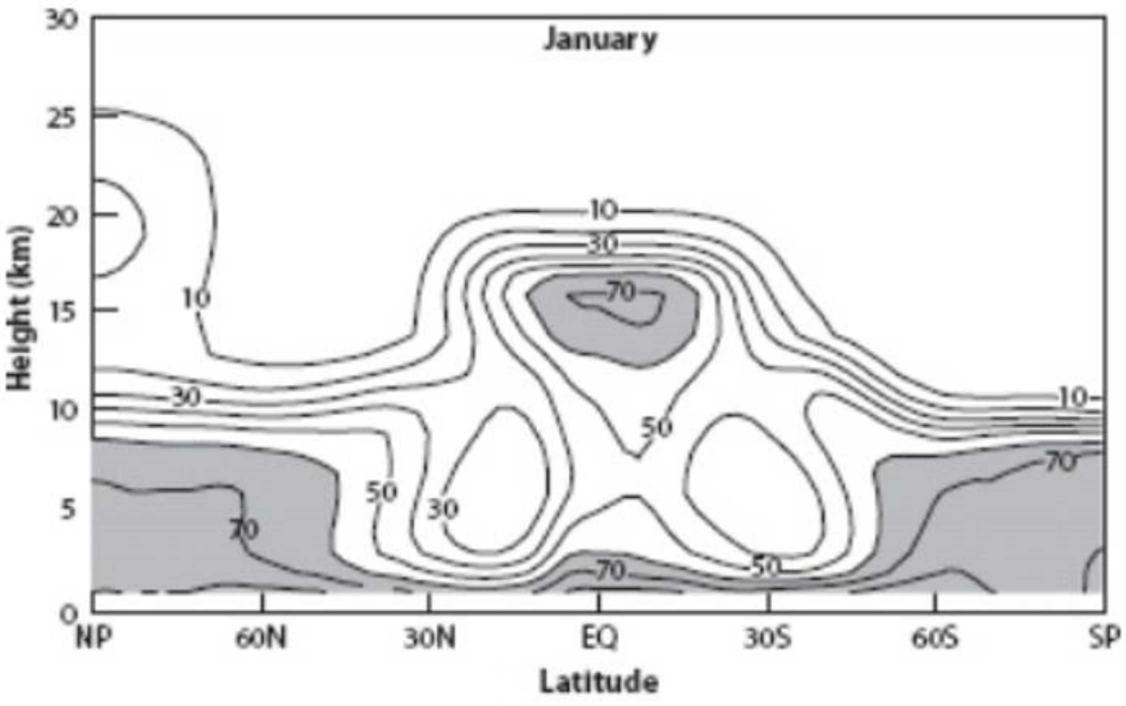


Fig. 6.2 | Latitude-Height Distribution of Zonally Averaged Relative Humidity (%)

Randall (2012)

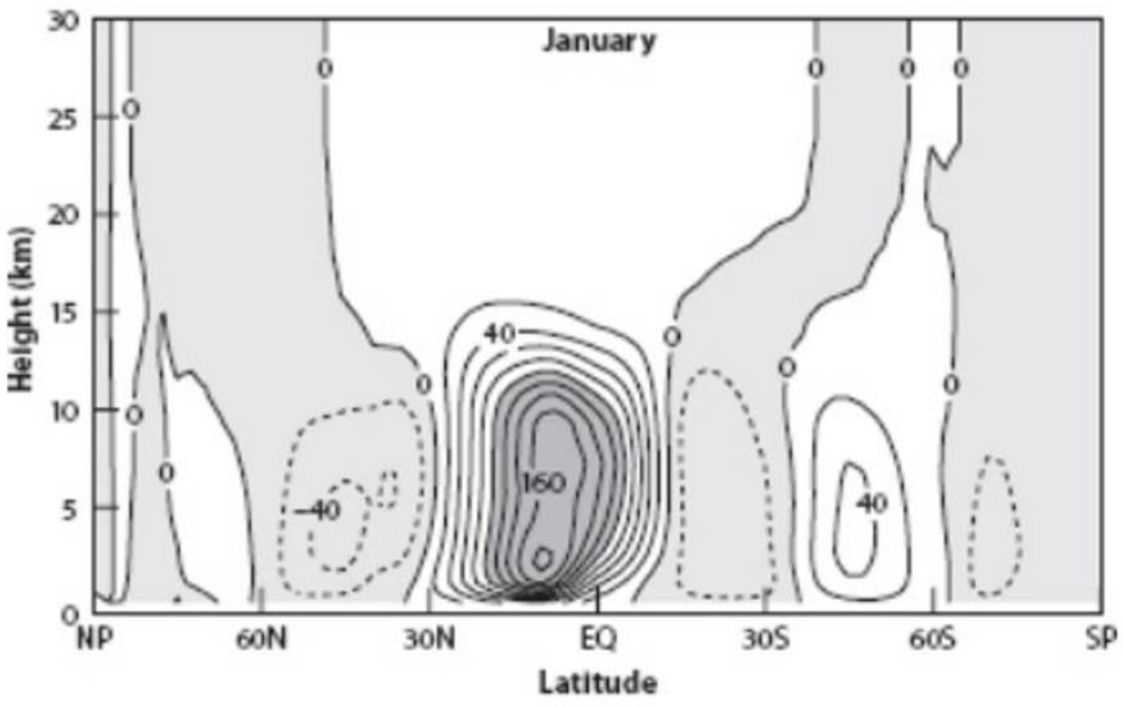


Fig. 4.1 | Latitude-Height Distribution of Zonally Averaged Streamfunction of Mean Meridional Circulation (10^{12} g/s)

Randall (2012)

Relative Humidity and the Hadley Circulation: July

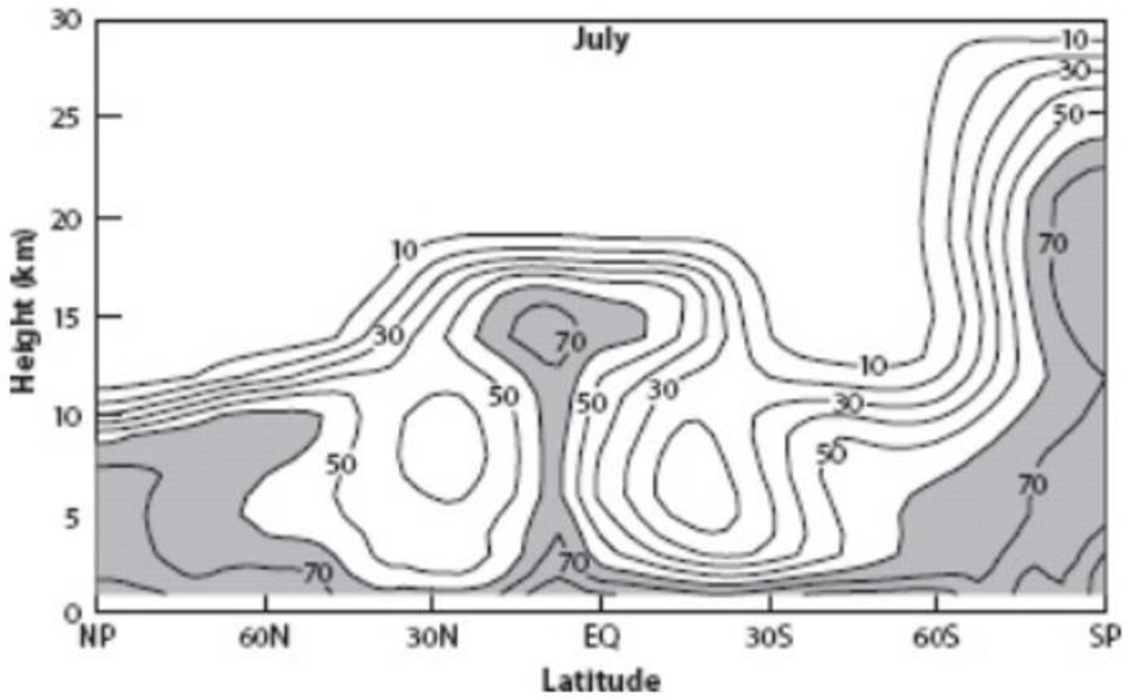


Fig. 6.2 | Latitude-Height Distribution of Zonally Averaged Relative Humidity (%)

Randall (2012)

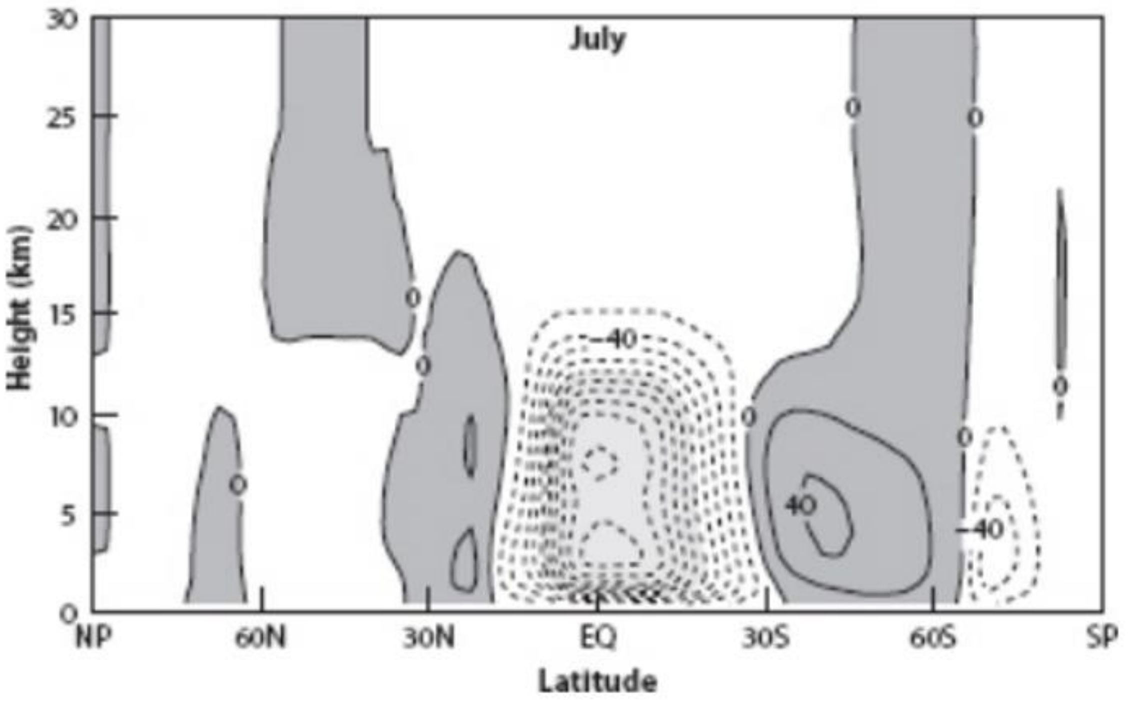
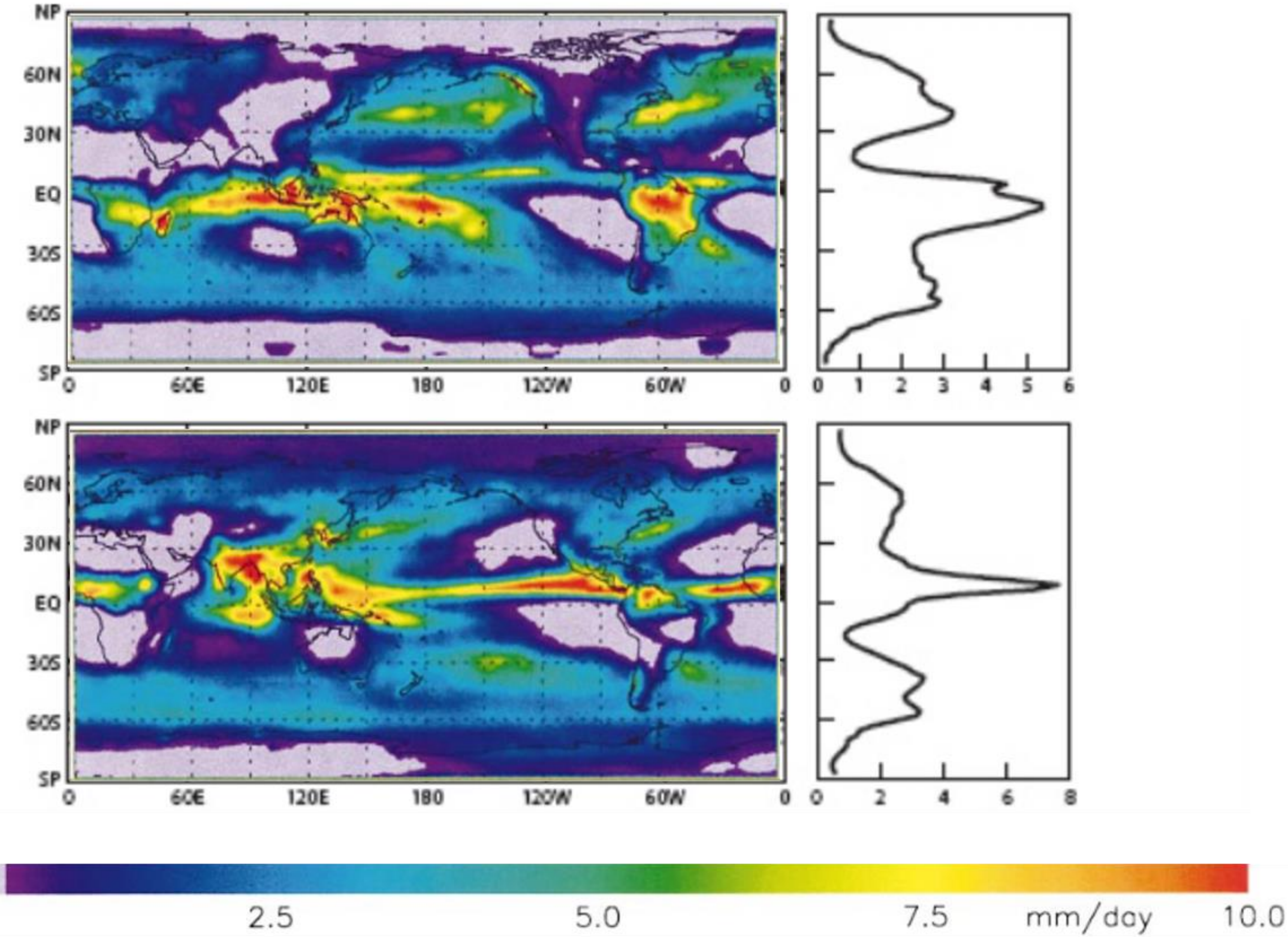


Fig. 4.1 | Latitude-Height Distribution of Zonally Averaged Streamfunction of Mean Meridional Circulation (10^{12} g/s)

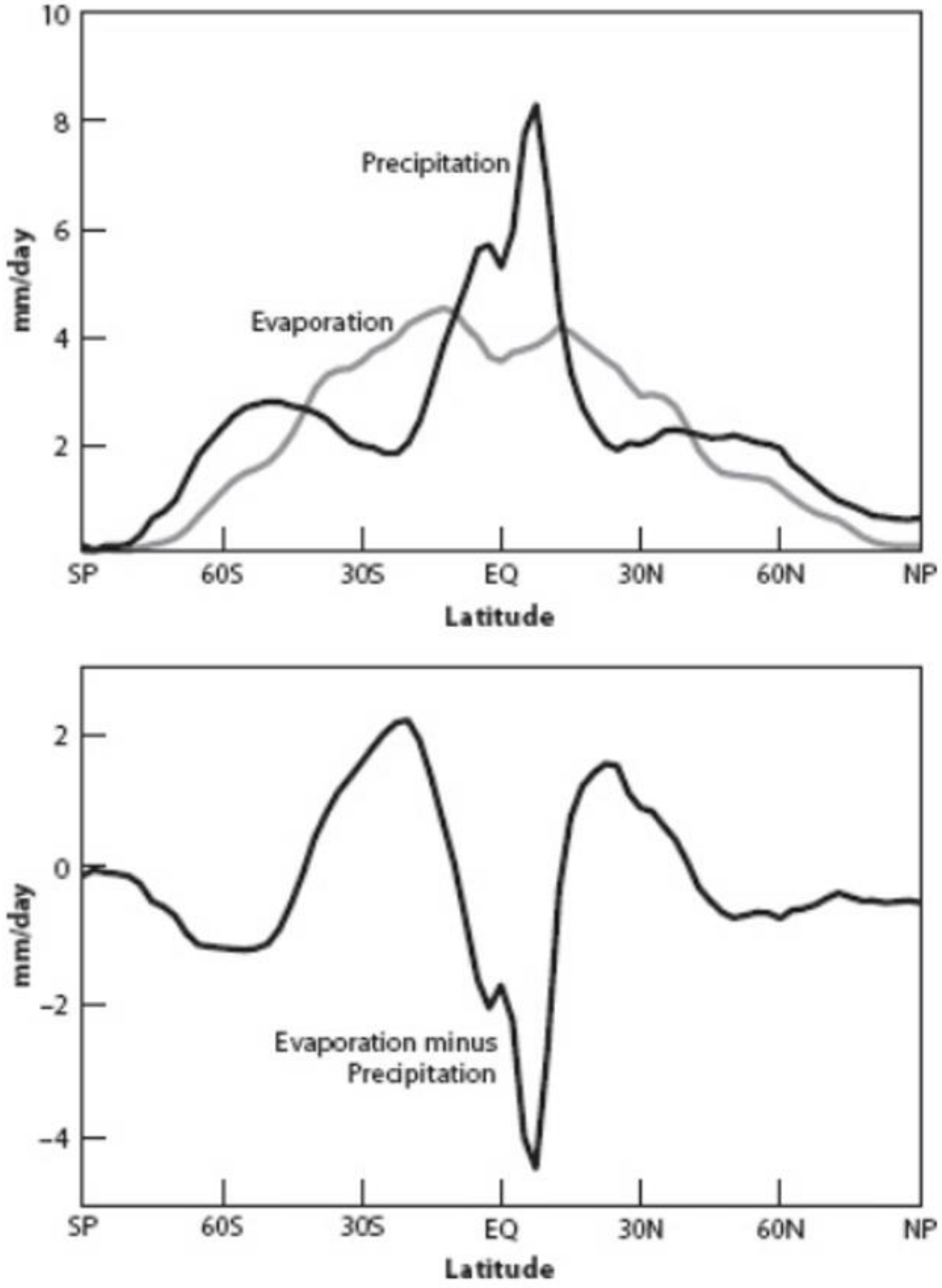
Randall (2012)

Fig. 6.3 Maps of the January and July Precipitation Rate (GPCC)



Randall (2012) Source: https://journals.ametsoc.org/view/journals/hydr/4/6/1525-7541_2003_004_1147_tvgpcp_2_0_co_2.xml

Fig. 6.4 | Zonally & Annually Averaged Evaporation and Precipitation Rates and their Differences



Randall (2012)

Admission Ticket Q1

- What is the Walker Circulation?
- How does it differ from the Hadley Cell Circulation?

Hadley—Walker Circulation

Where Is Outgoing LW Radiation stronger?

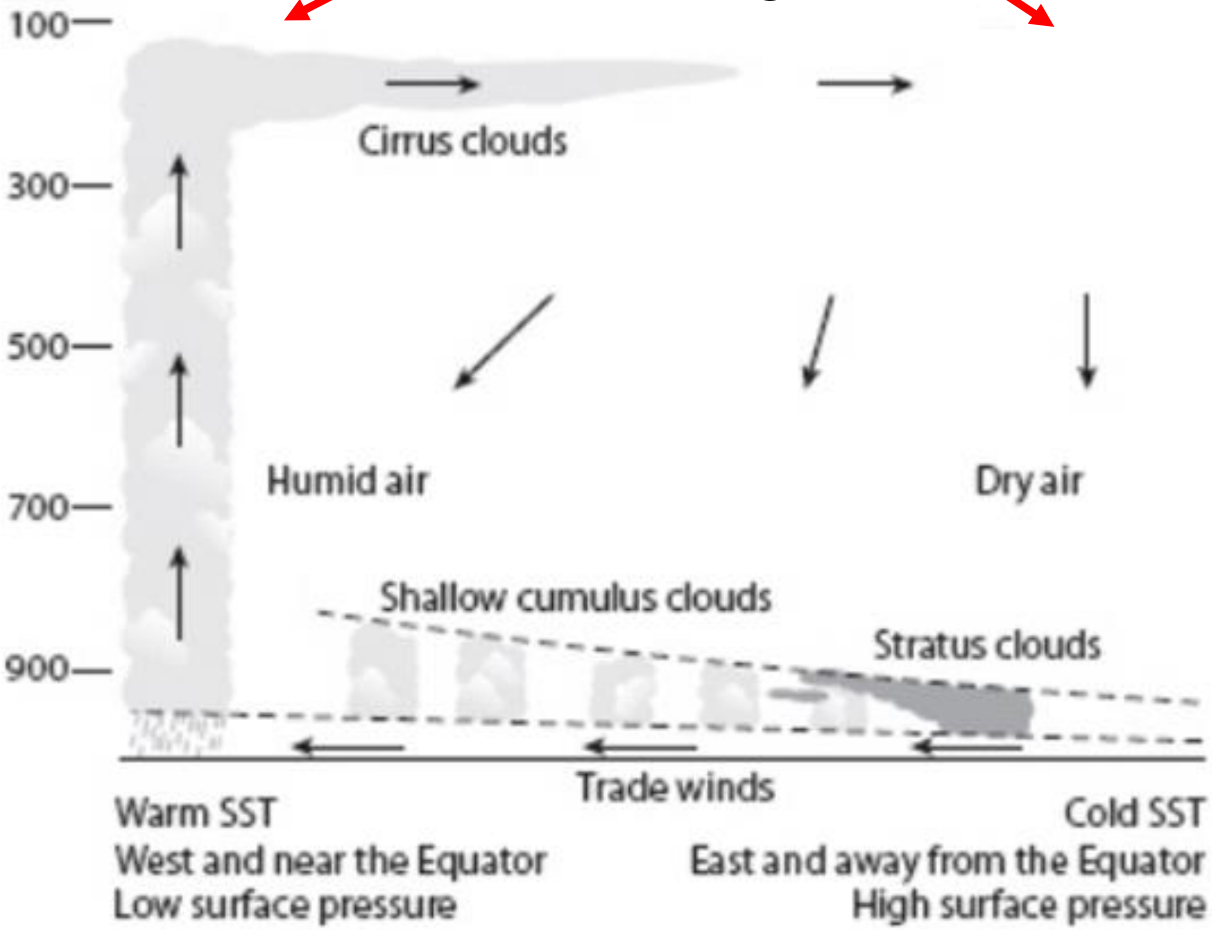


Figure 6.5. Schematic diagram showing the relationship of horizontal and vertical motions, cloud types, OLR, and SST, in the Hadley-Walker circulation of the Northern Hemisphere tropics and subtropics.

Source: Adapted from Schubert et al. (1995) and Pierrehumbert (1995). Randall (2012)

Heating and Vertical Motion in the Tropics

$$\frac{Ds}{Dt} \cong \frac{\partial s}{\partial z}\frac{Dz}{Dt} \qquad (6.1)$$

$$\left(\frac{\partial s}{\partial z}\right)\rho w = \mathrm{Q} \qquad (6.2)$$

Randall (2012)

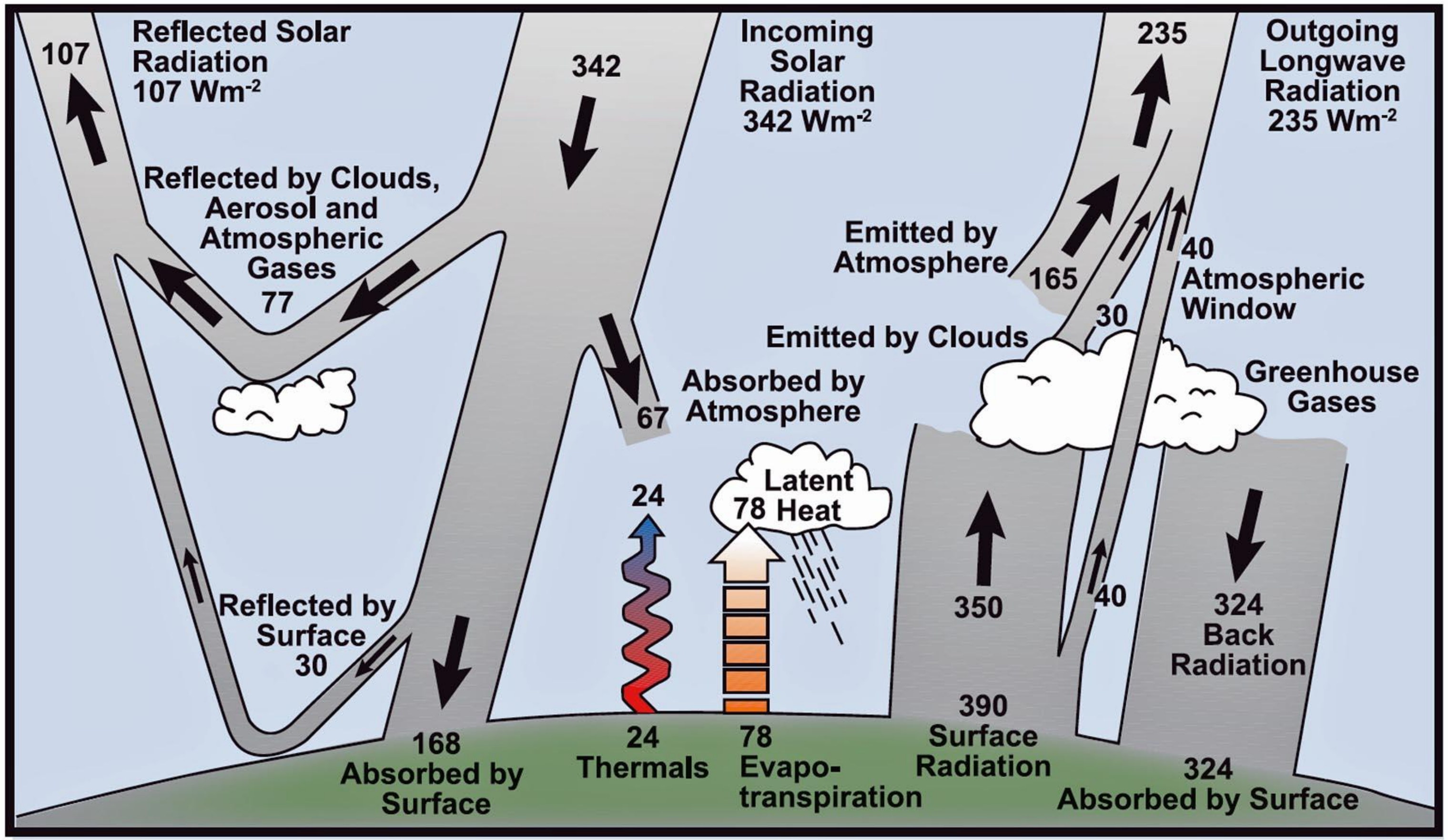
What does each term mean?

How does Eq. (6.2) explain the physics/dynamics in Warm Pools and Cold Pools?

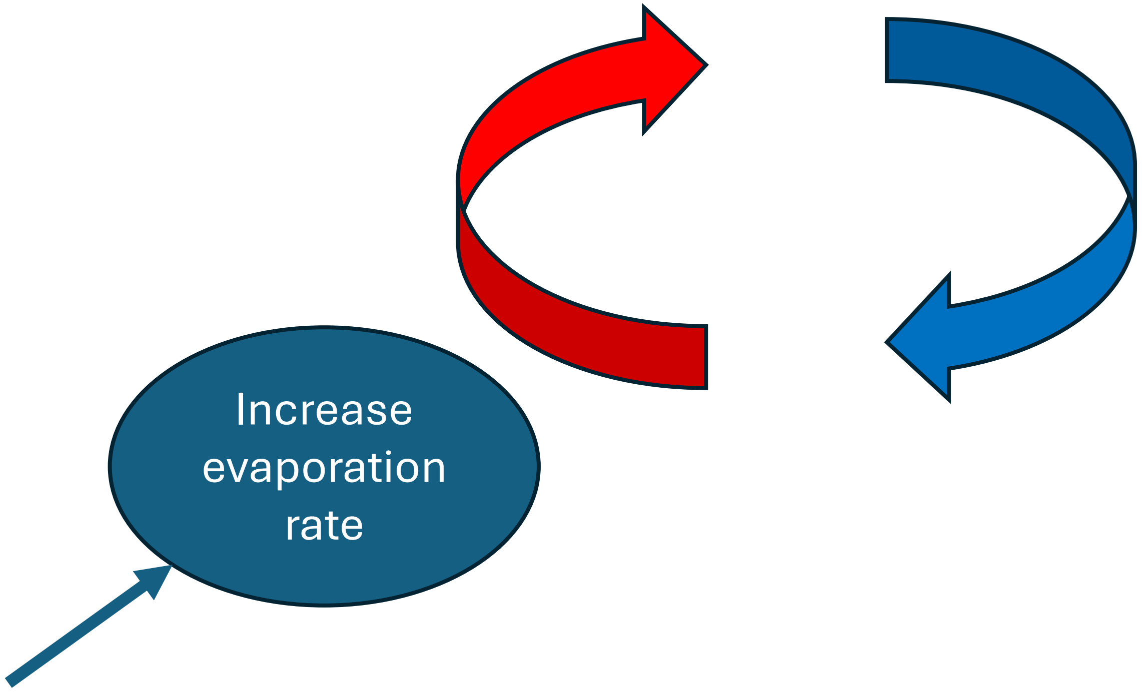
…

Admission Ticket Q2:

- What determines speed of atmospheric water cycle?
- How would this cycle change as Earth warms?



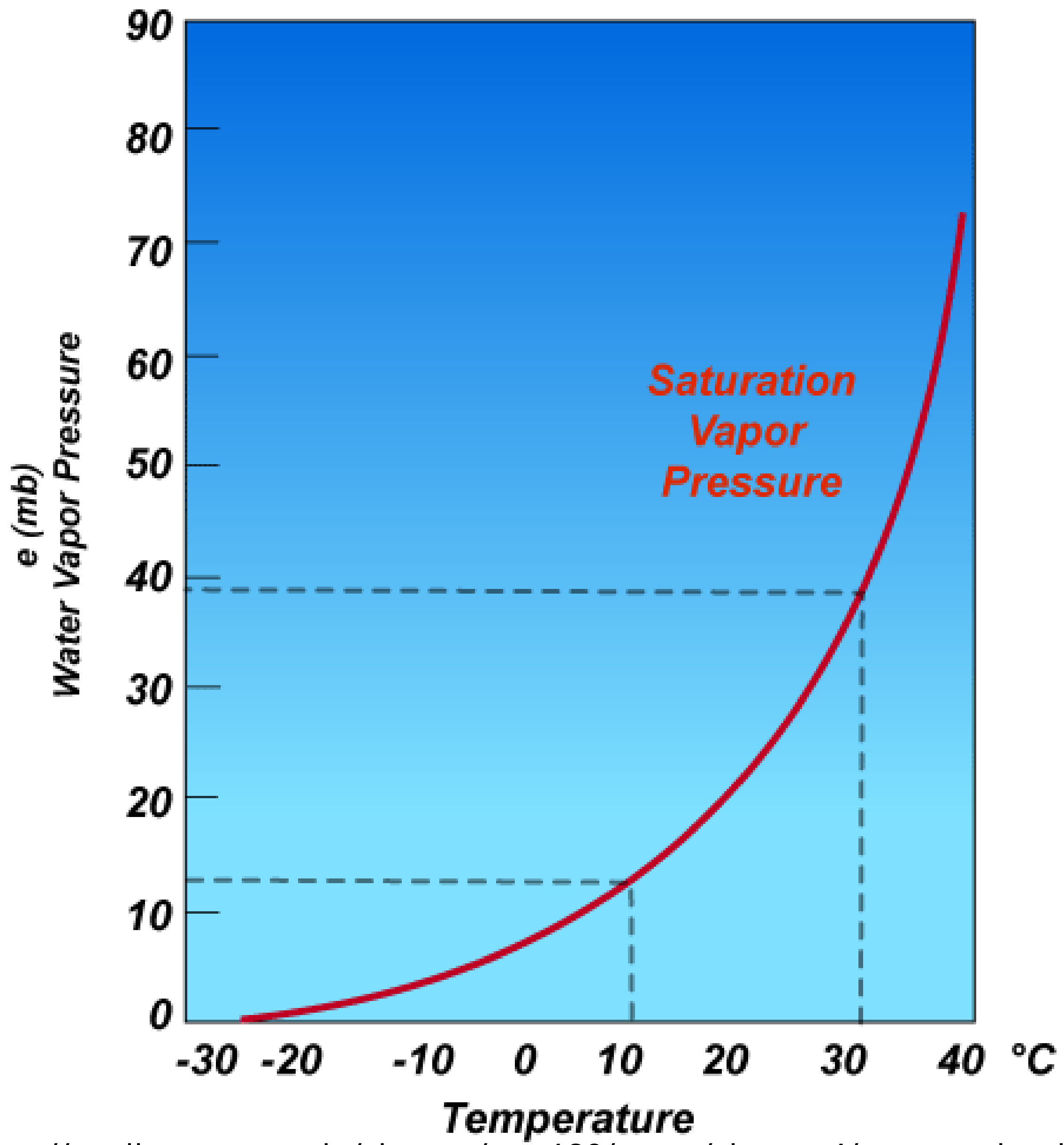
Water Cycle Strengthening: Negative Feedback



START

Admission Ticket Q2:

- What determines speed of atmospheric water cycle?
- How would this cycle change as Earth warms?



https://apollo.nvu.vsc.edu/classes/met130/notes/chapter4/es_temp.html

Water vapor feedback effects at

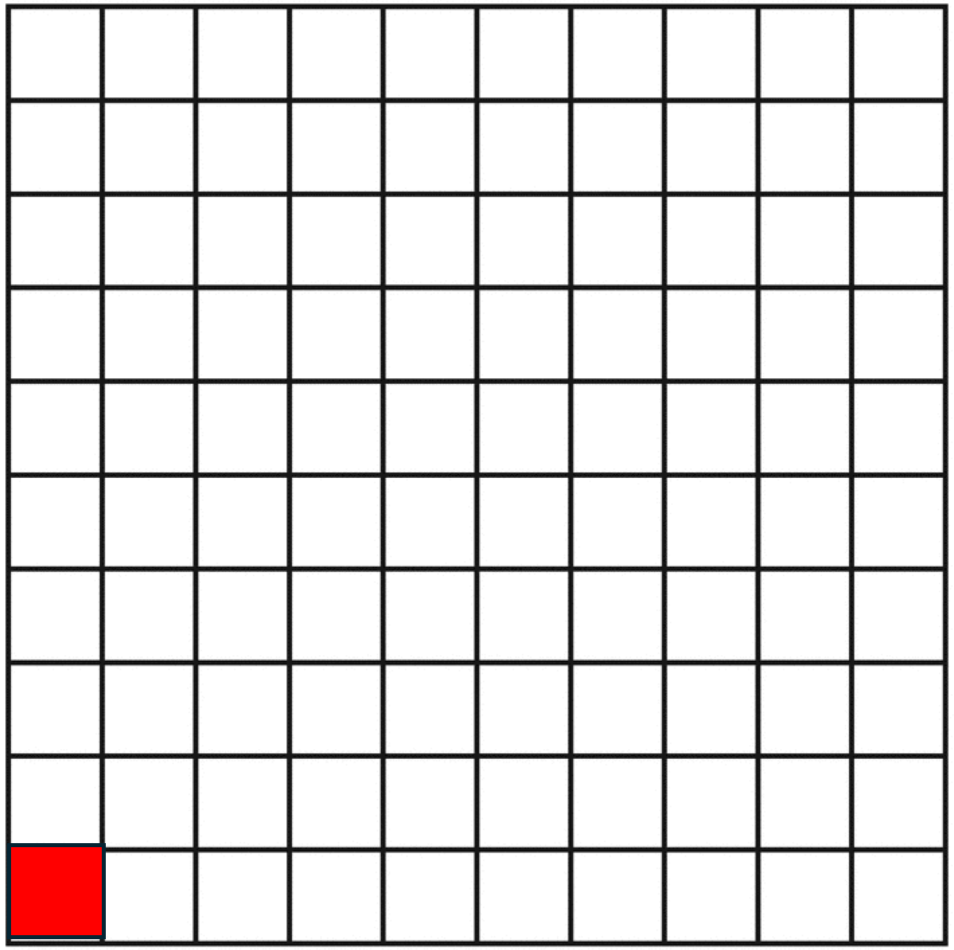
- Surface?
- Atmosphere?

Chapter 7 | “Predictability of Weather and Climate”

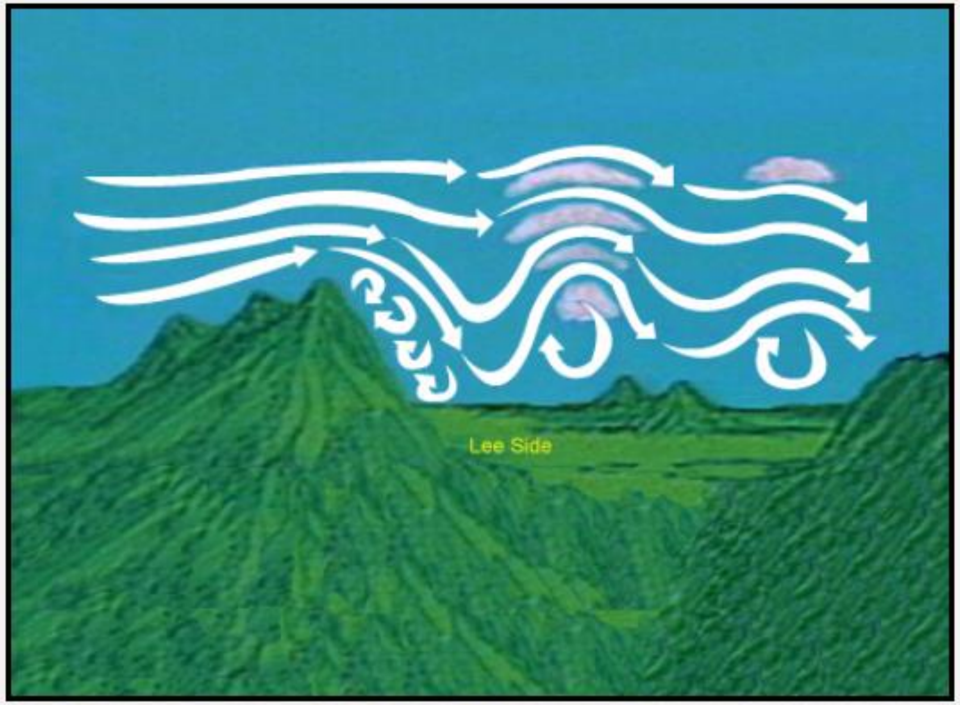
Admission Ticket Q3: Did you learn anything new about how forecasts are made?

What I Learned: Model Resolution Advancements

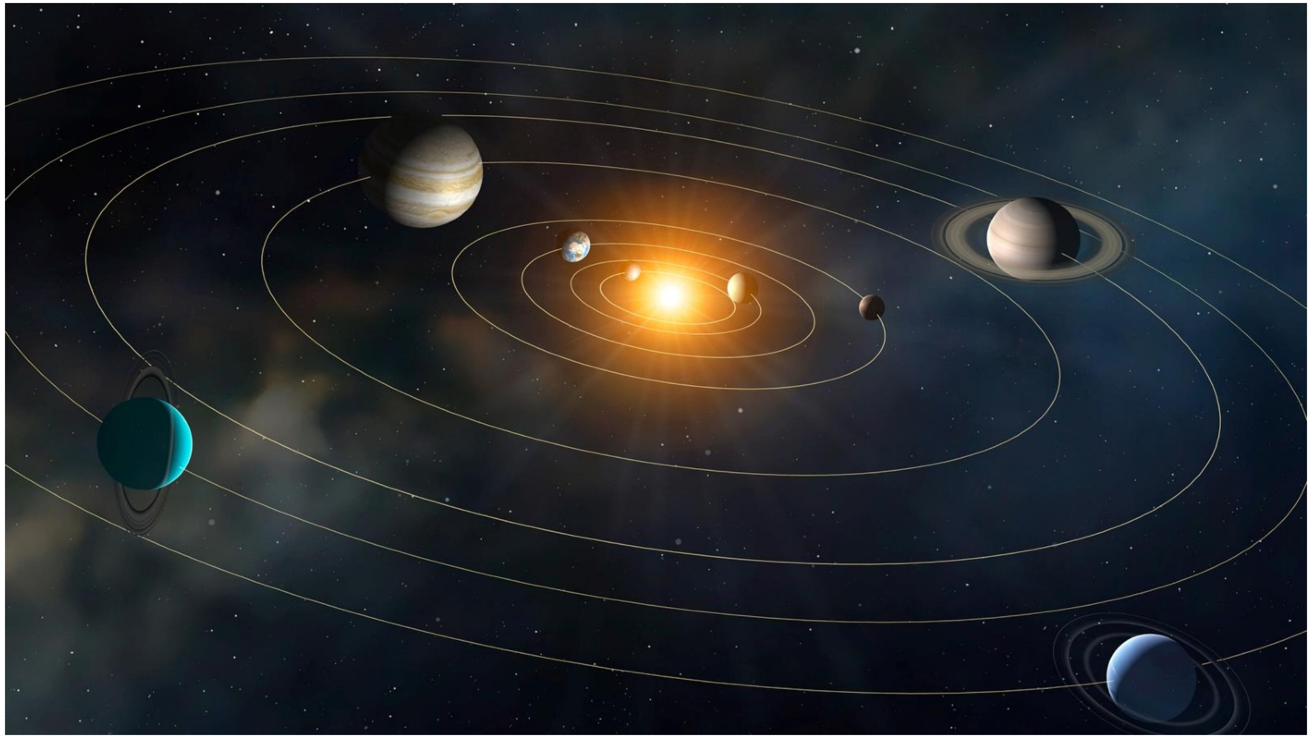
- 2011: ~30km horizontal res
- 2024: 3 km horizontal res (HRRR)
- 100x-fold increase



What I Learned: Turbulence is RELATIVE



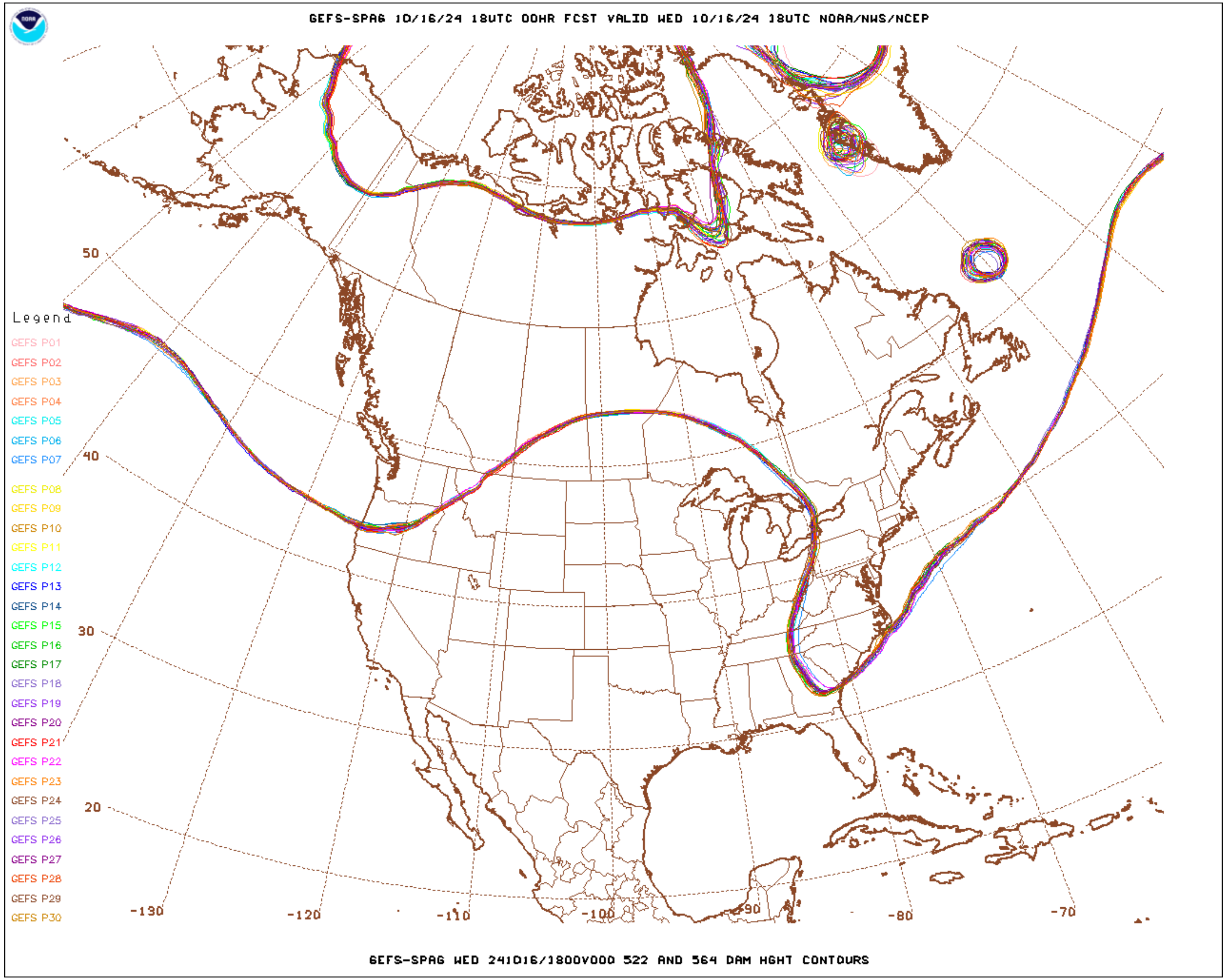
Lee waves cause updrafts and downdrafts



Both motions above can be considered “turbulent”, under what condition?

Fig. 7.1 Substitute: GEFS Spaghetti Plot (Day 0)

Initial Time:
16 Oct 2024
18 UTC



Lorenz's Toy Model

$$\dot{X} = -\sigma X + \sigma Y,$$
$$\dot{Y} = -XZ + rX - Y,$$
$$\dot{Z} = XY - bZ.$$

σ=10, b=8/3, r=24.74

Which expressions in the toy model best explain the shape of the solution?

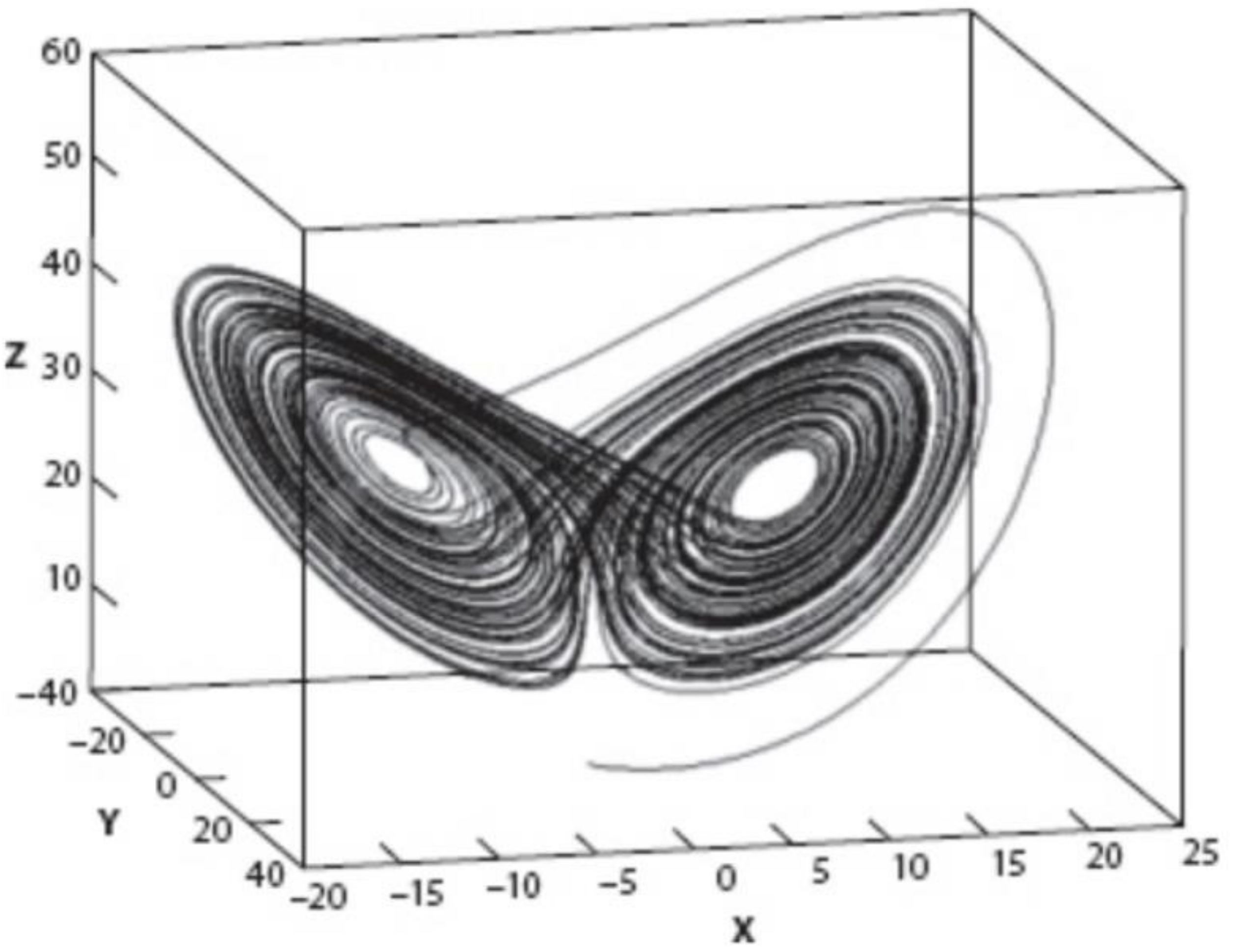


Figure 7.2. The Butterfly Attractor of Lorenz (1963), obtained as the solution of (1).

Randall (2012)

Fig. 7.3 | Error Growth Evolution

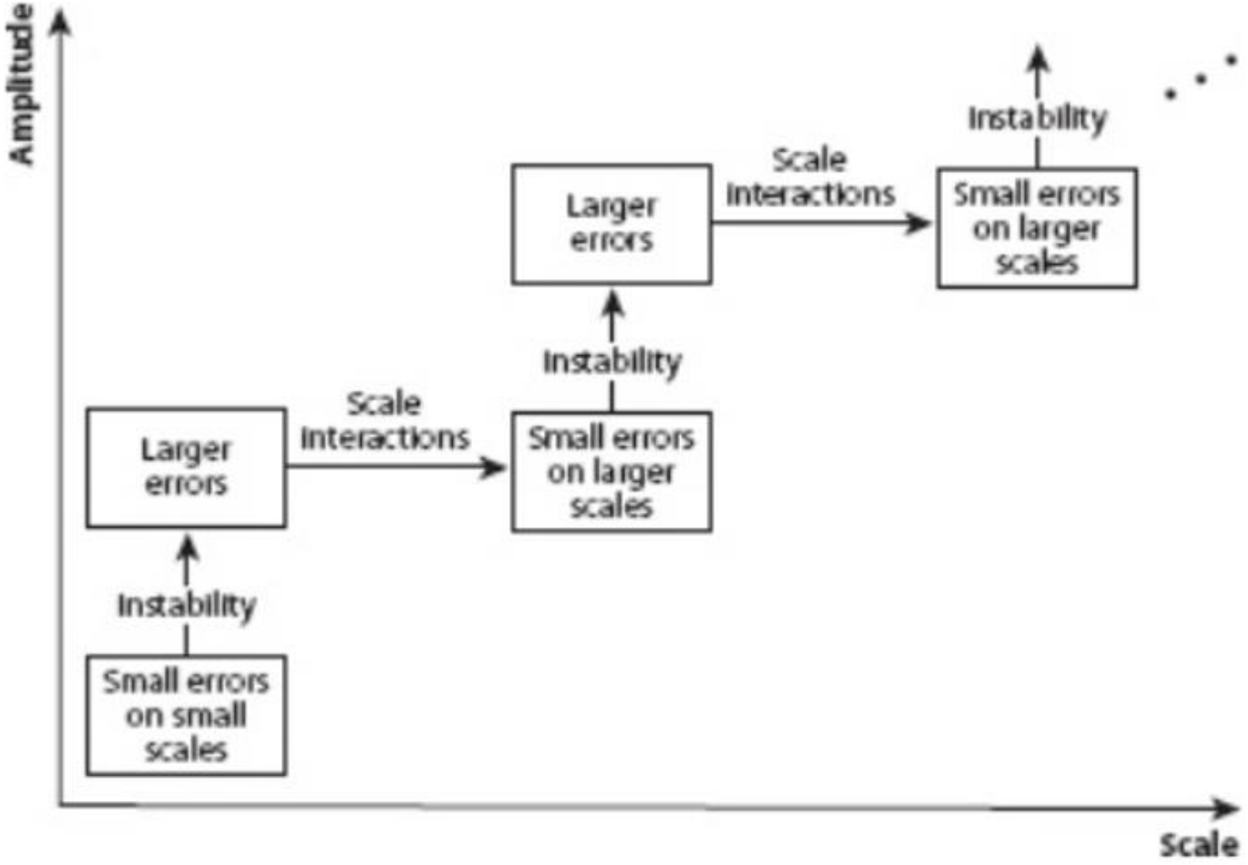


Figure 7.3. Sketch illustrating the roles of instability in leading to error growth, and of scale interactions in leading to the spreading of error from small scales to larger scales. The figure could be continued indefinitely toward the upper right.

Randall (2012)

Fig. 7.4 | Determining Limit of Predictability - Dynamical Approach

"Limit of Predictability" – Forecast is no better than a random guess

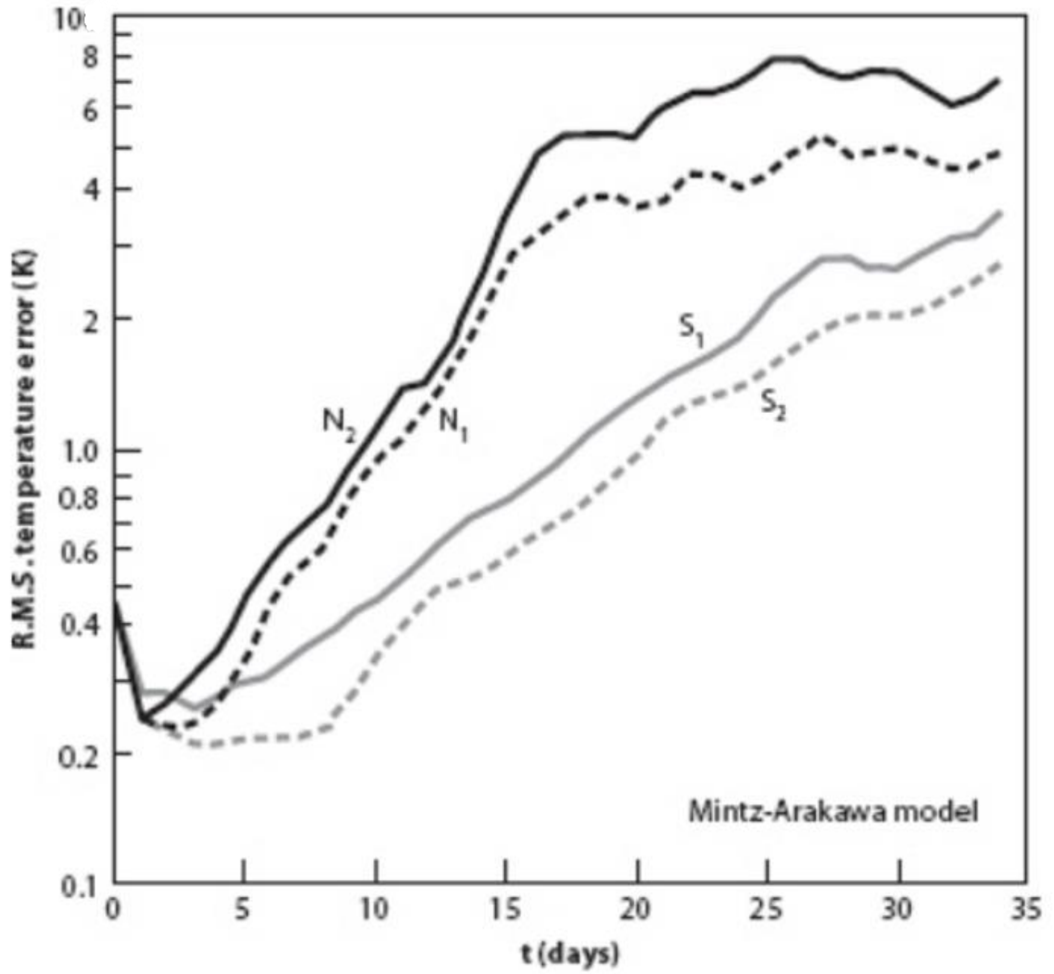


Figure 7.4. Root mean square temperature error in January simulations performed with a two-level global atmospheric model developed by A. Arakawa and Y. Mintz at the University of California, Los Angeles.

N and S denote the Northern and Southern Hemispheres, respectively. The subscripts 1 and 2 denote the two model levels.

Source: Charney et al. (1966).

Randall (2012)

Fig. 7.5 | Climate Forecasting Application

Analogies:

- Contours/Shaded regions: Preferred states of the atmosphere
  - Say $X \propto$ Temperature; $Y \propto$ Humidity
- Arrow direction: Climate forcing
  - Ex: Earth's orbital procession (seasons)

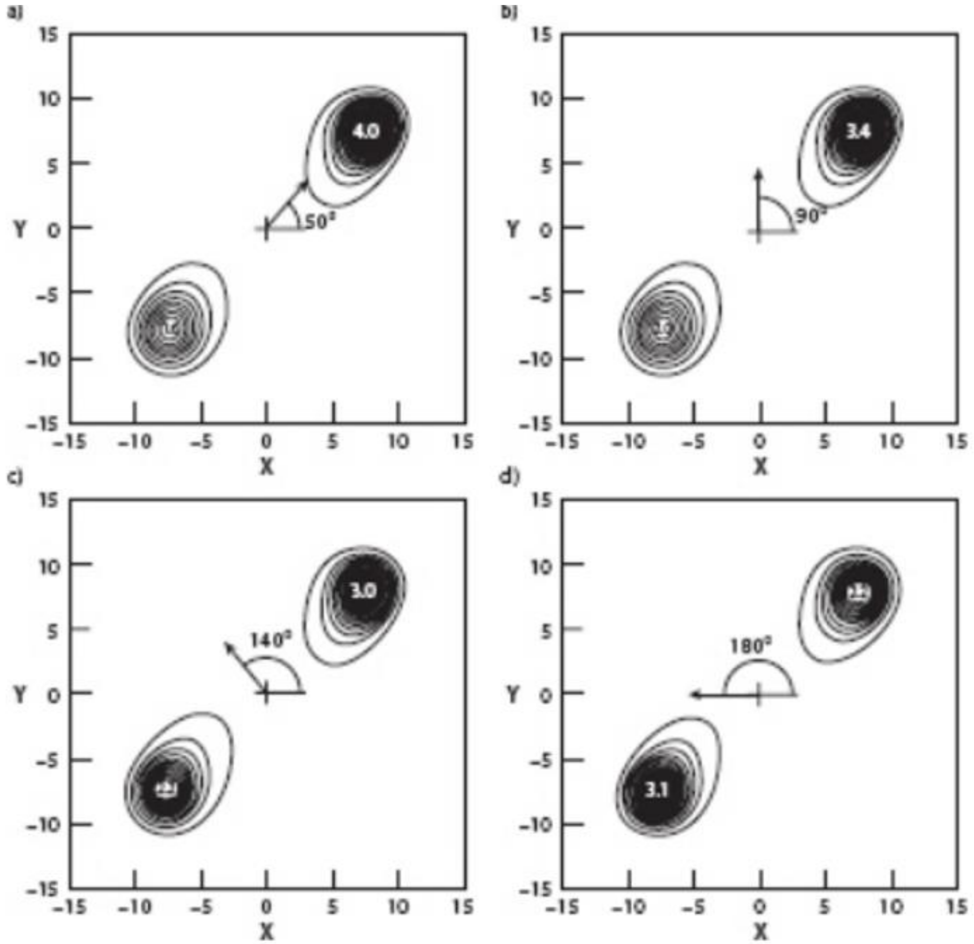


Figure 7.5. The impacts of various imposed forcings on the PDF of the butterfly model, as seen in the (X,Y) plane.

The plot shows the frequency with which the solution of the model visits each point in the plane. The arrows show the direction of the forcing, as represented by the angle θ in Equation (2). The oval-shaped contours denote regions that are visited frequently. These are the "attractors" of the model. Although the centroids of the attractors do not move as the angle of the forcing changes, the amount of time spent near each attractor does change. This can be seen from the "blackness" of the attractor maxima in the plot.

Source: Palmer (1999).

Randall (2012)