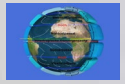
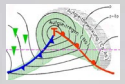
MARINE METEOROLOGY

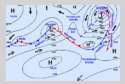
Deutscher Wetterdienst, Marine Met Office Hamburg
bernd.richter@web.de
www.vorticity.de

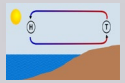


- 01 Global Circulation


- 02 Meteorological Parameters

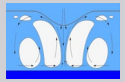

- 03 Ideal Cyclone 

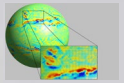
Clouds

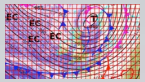

- 04 Other Pressure Patterns


- 05 Small-scale Processes

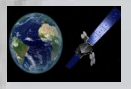

- 06 Synoptic Weather Regimes


- 07 Tropical Storms, Severe Weather


- 08 Weather Analysis and Forecast

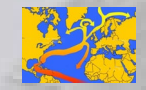

- 09 Weather Forecast Products, GRIB

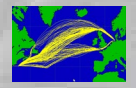

- 10 Remote Sensing Satellite and Radar





- 11 Sea and Swell


- 12 Currents ICE AMOC Tides

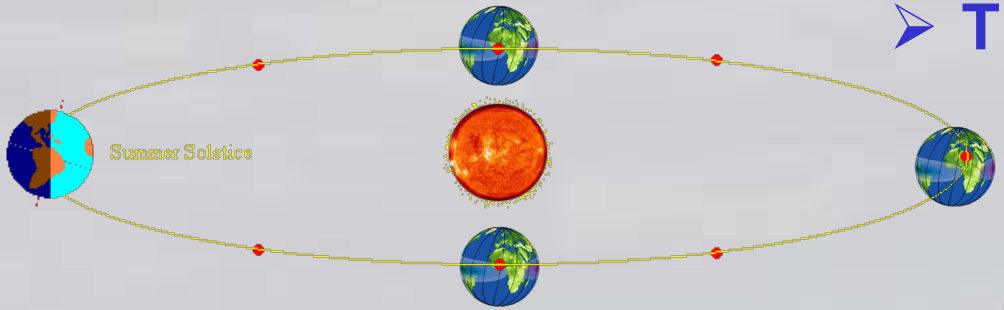

- 13 Marine Climatology and Global Change


- 14 Course Summary, Debriefing

Nothing is more practical than a good Theory Immanuel Kant

WHY DO WE HAVE THE GLOBAL CIRCULATION ?

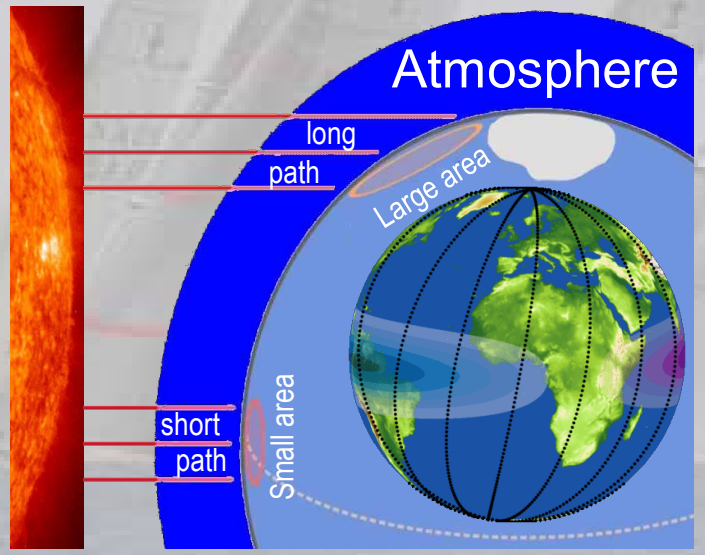
- **The Sun is shining …**

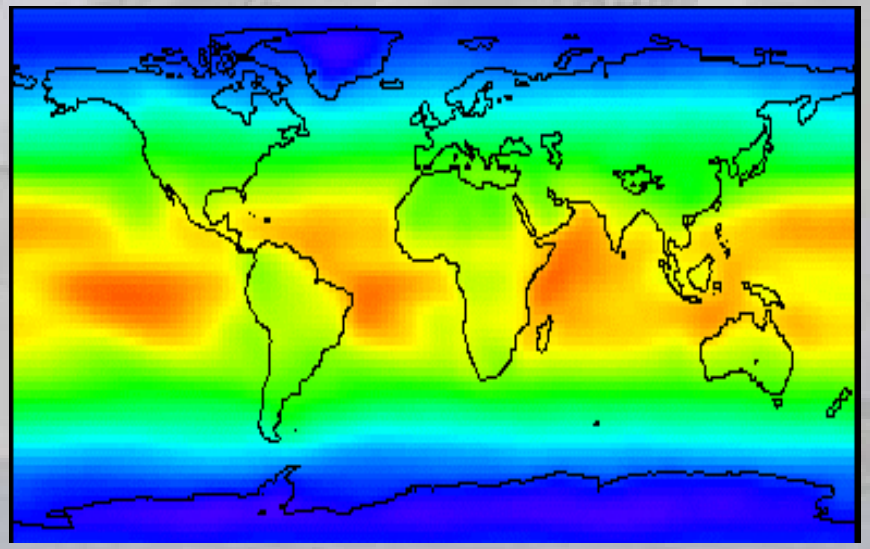


- **The Earth…**
  - …. is a sphere, circumference 40000 km / 21600 nm
  - … orbits the Sun 1 / year
  - … rotates around its axis 1 / day

- **This results in …**

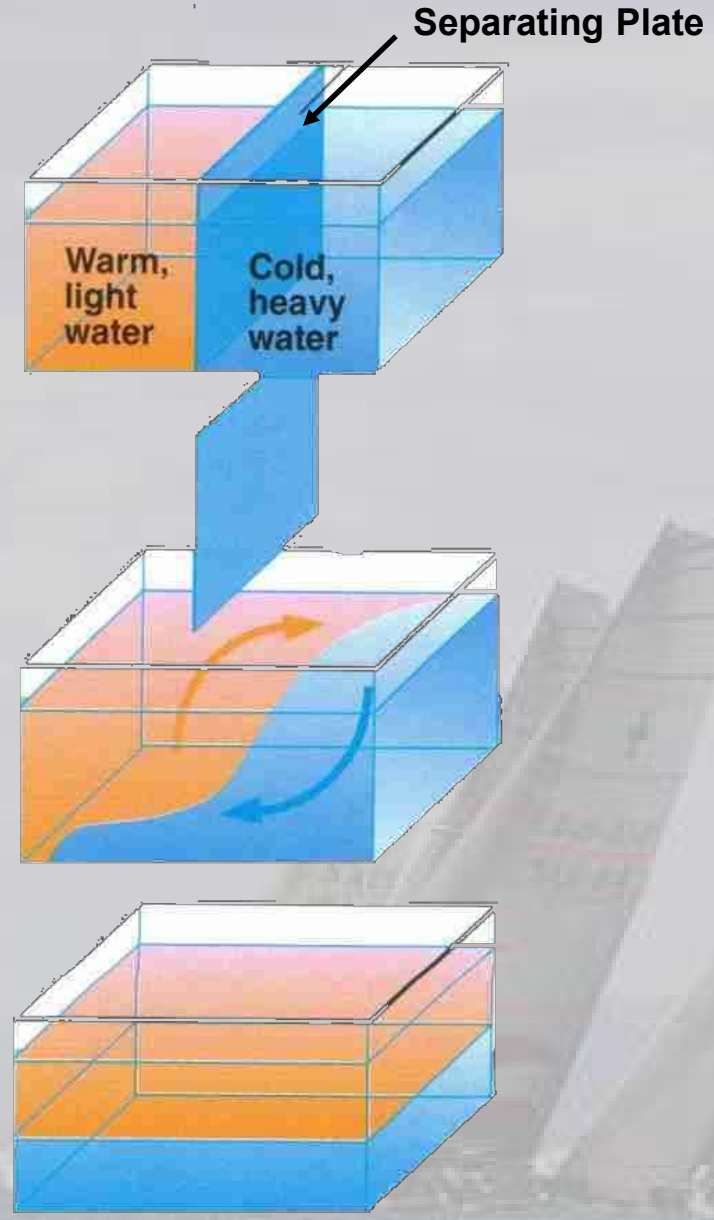
… Meridional (N/S) Temperature-Gradient, which directly (physically) drives the Global Circulation.



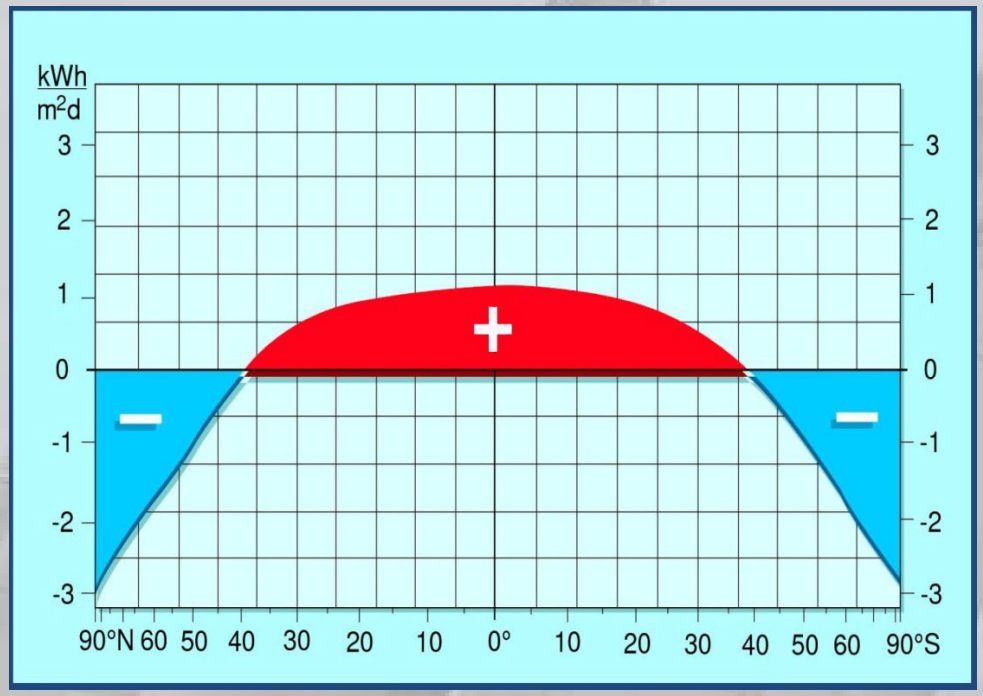


Energy Aspects

$E_{pot} + E_{kin} = const.$



$E_{pot} > min$



North Pole Equator South Pole

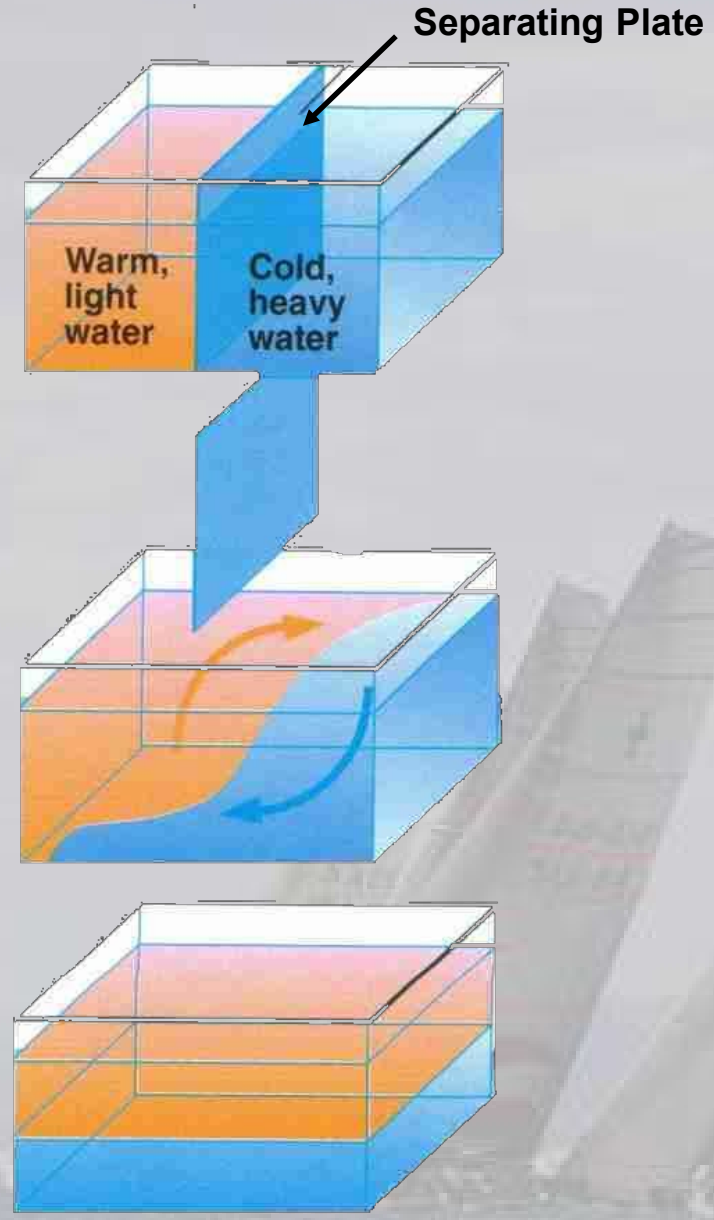
$E_{pot} = min$

E_{pot} Decrease <=> E_{kin} Increase

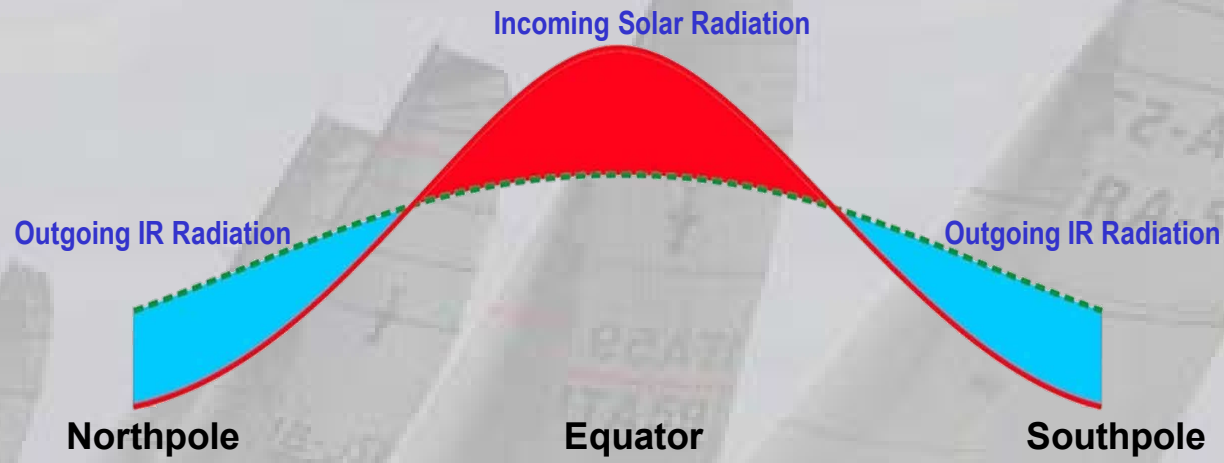
WIND !

Energy Aspects

$E_{pot} + E_{kin} = const.$



$E_{pot} > min$



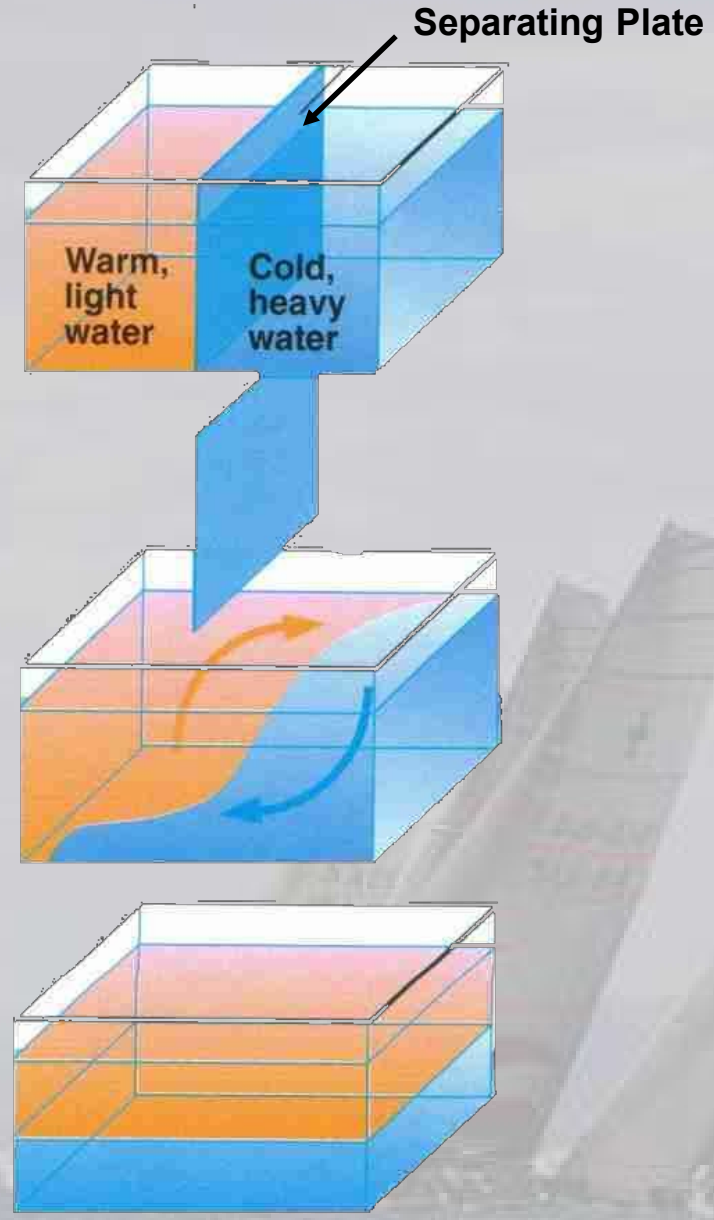
$E_{pot} = min$

E_{pot} Decrease <=> E_{kin} Increase

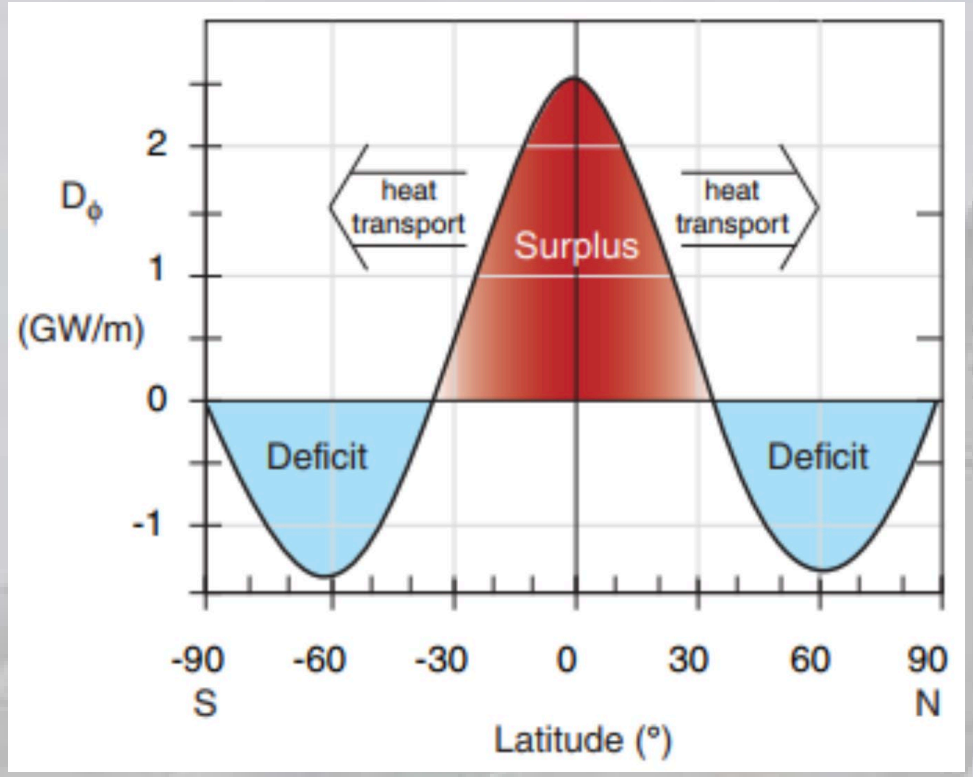
WIND !

Energy Aspects

$E_{pot} + E_{kin} = const.$



$E_{pot} > min$



South Pole Equator North Pole

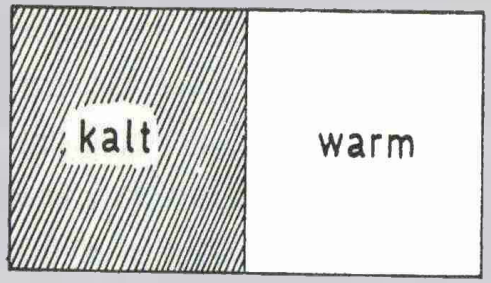
$E_{pot} = min$

E_{pot} Decrease <=> E_{kin} Increase

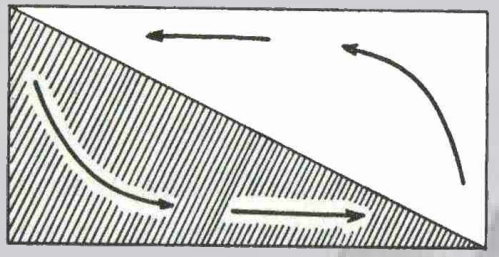
WIND !

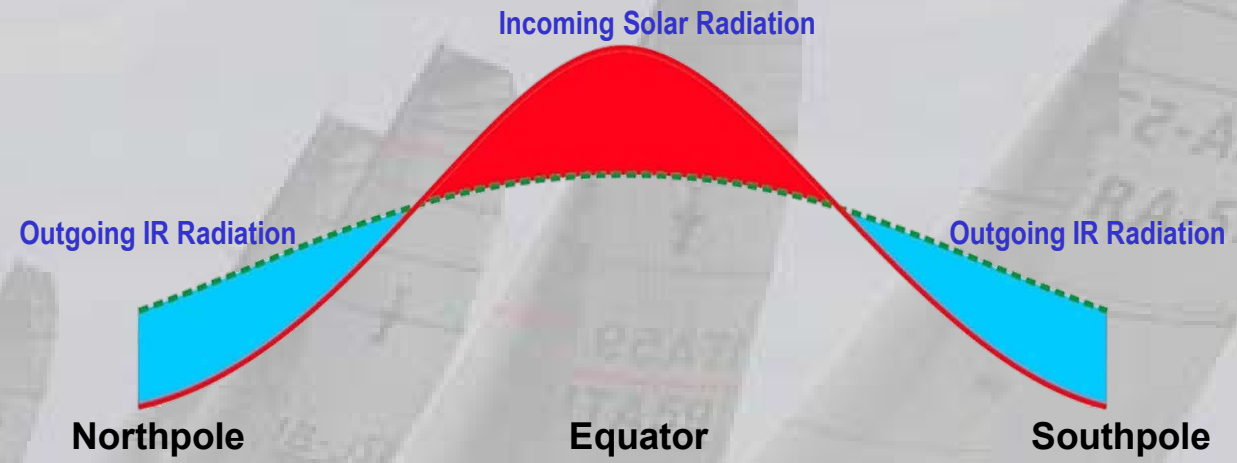
Energy Aspects

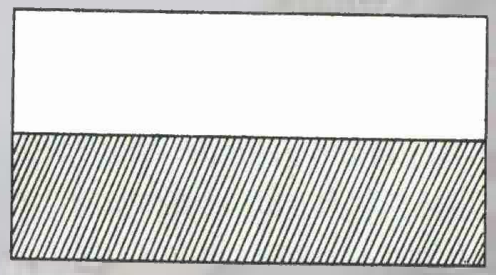
$E_{pot} + E_{kin} = const.$



$E_{pot} > min$





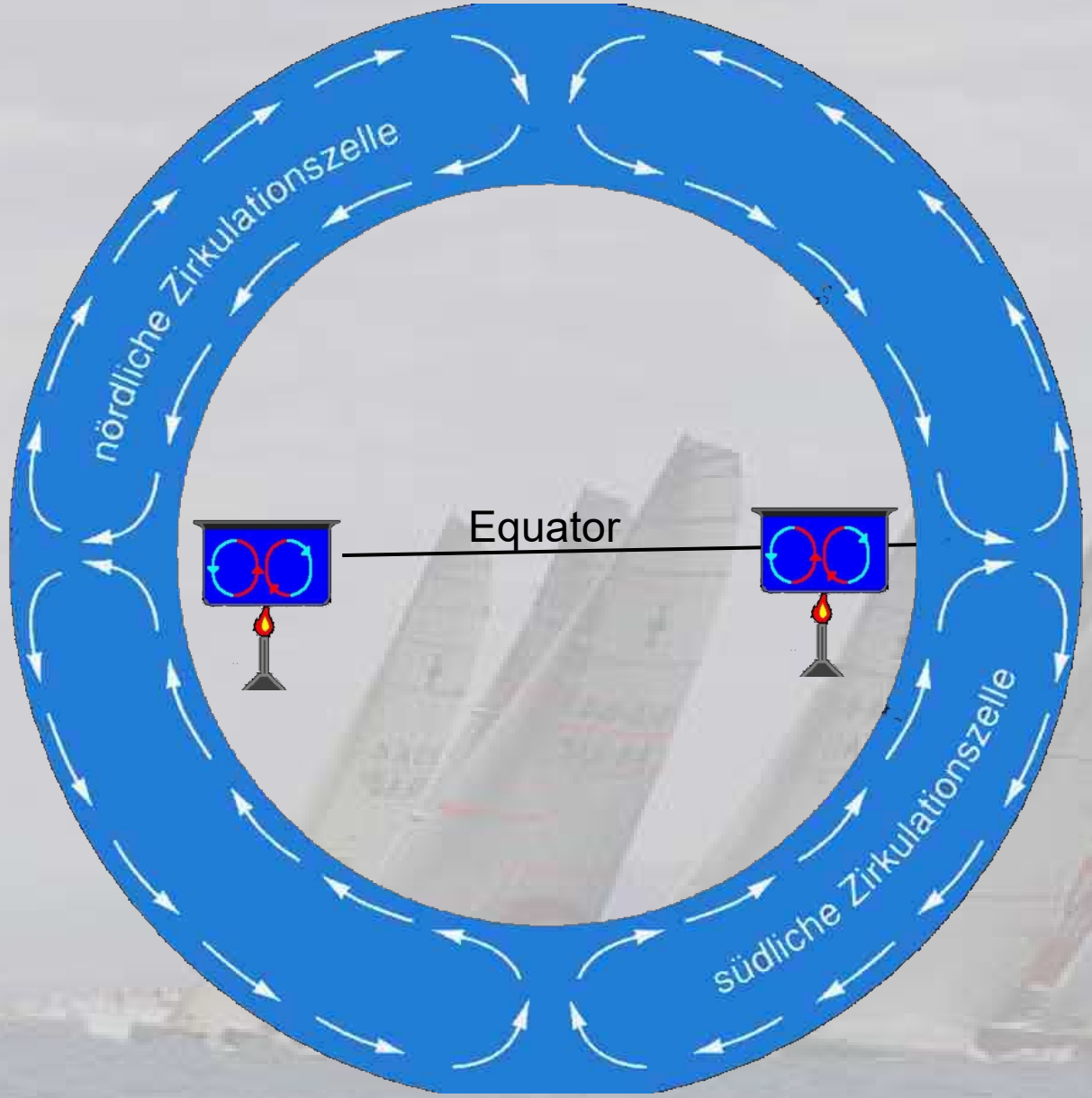


$E_{pot} = min$

E_{pot} Decrease <=> E_{kin} Increase

WIND !

Global Circulation without Coriolis Force



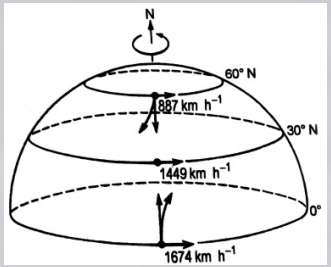
The heating of the atmosphere by solar radiation near the Equator is a direct heat engine, i.e. warm air is cooled down by lifting

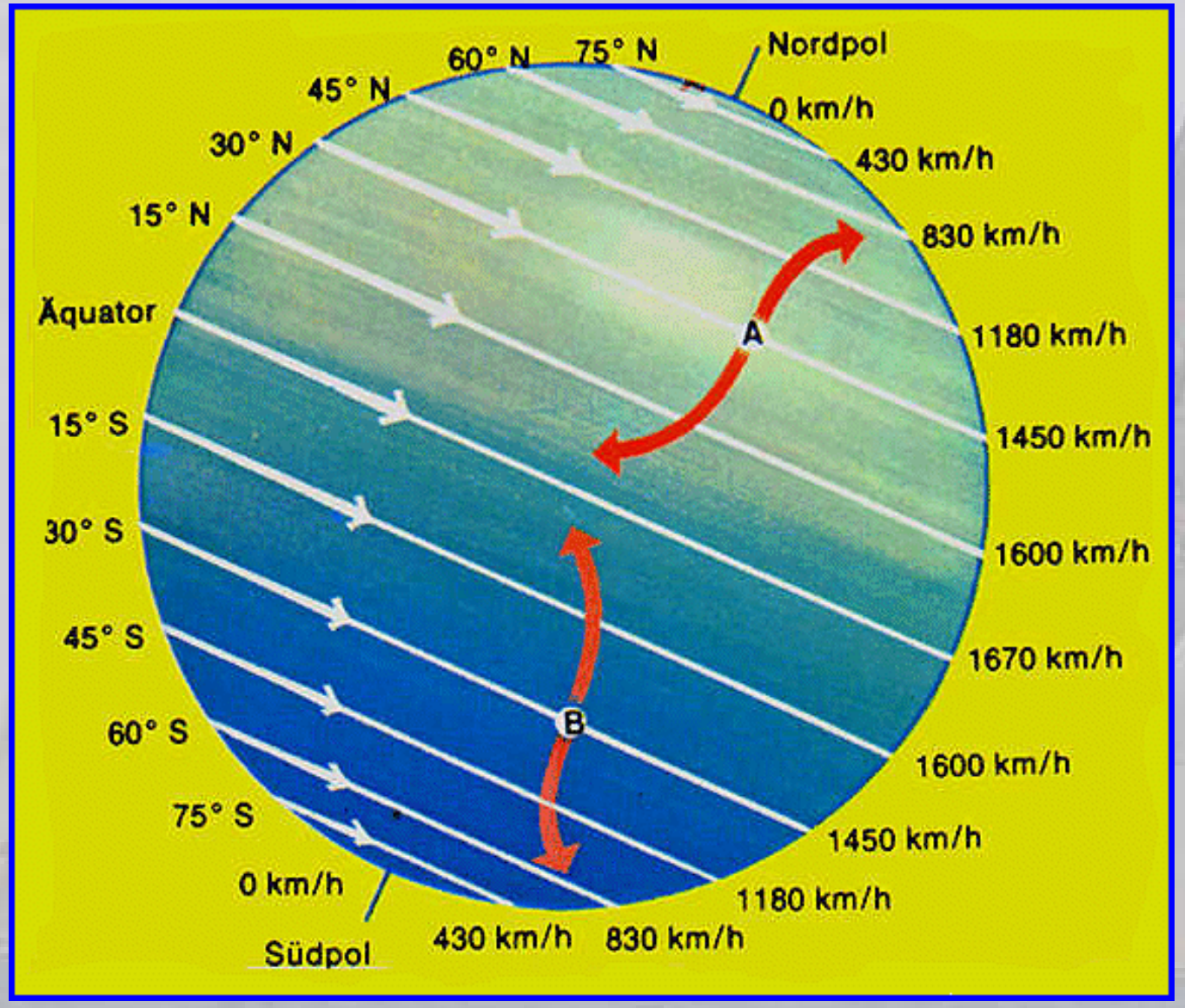
If cold air comes under subsidence (to higher pressure) and is thus heated, it would be an indirect heat engine

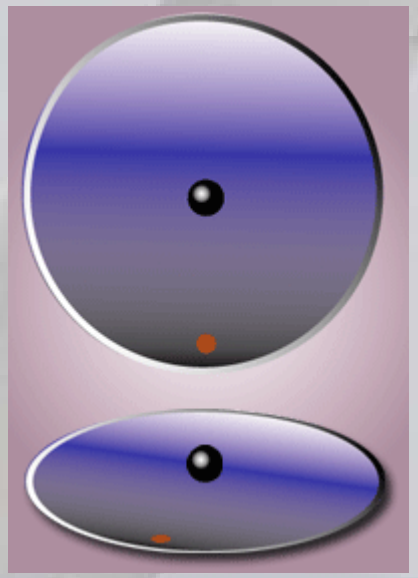
Global Circulation without Coriolis Force

Hadley 1735

Coriolis Force

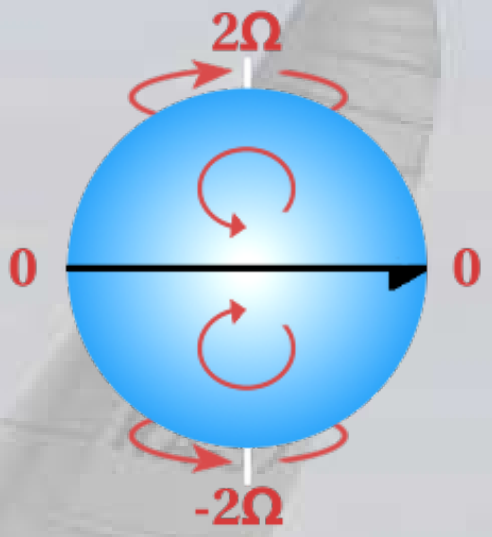






CORIOLIS FORCE ...

- … $\Omega = 2 * \pi / 86.164$ Earth's Angular velocity
  86.164 Siderial Day / 86.400 Solar Day

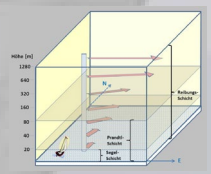


- … $2 * \Omega * \sin(\varphi = \text{latitude})$ Coriolis frequency

- … Coriolis Force = wind velocity * Coriolis frequency

- … Acts perpendicular to the direction of motion
  Is a Pseudo (fictitious) Force does not perform physical work
  Deflects air particles Northern Hemisphere to the right
  Southern Hemisphere to the left

Veering of the wind with increasing height (boundary layer only)
Decrease of friction ⇔ Increase of windspeed



- … Determines the direction of rotation of Lows and Highs
  Northern Hemisphere: Low: counterclockwise High: clockwise
  Southern Hemisphere: Low: clockwise High: counterclockwise

Der Coriolis Effect is important, because it …

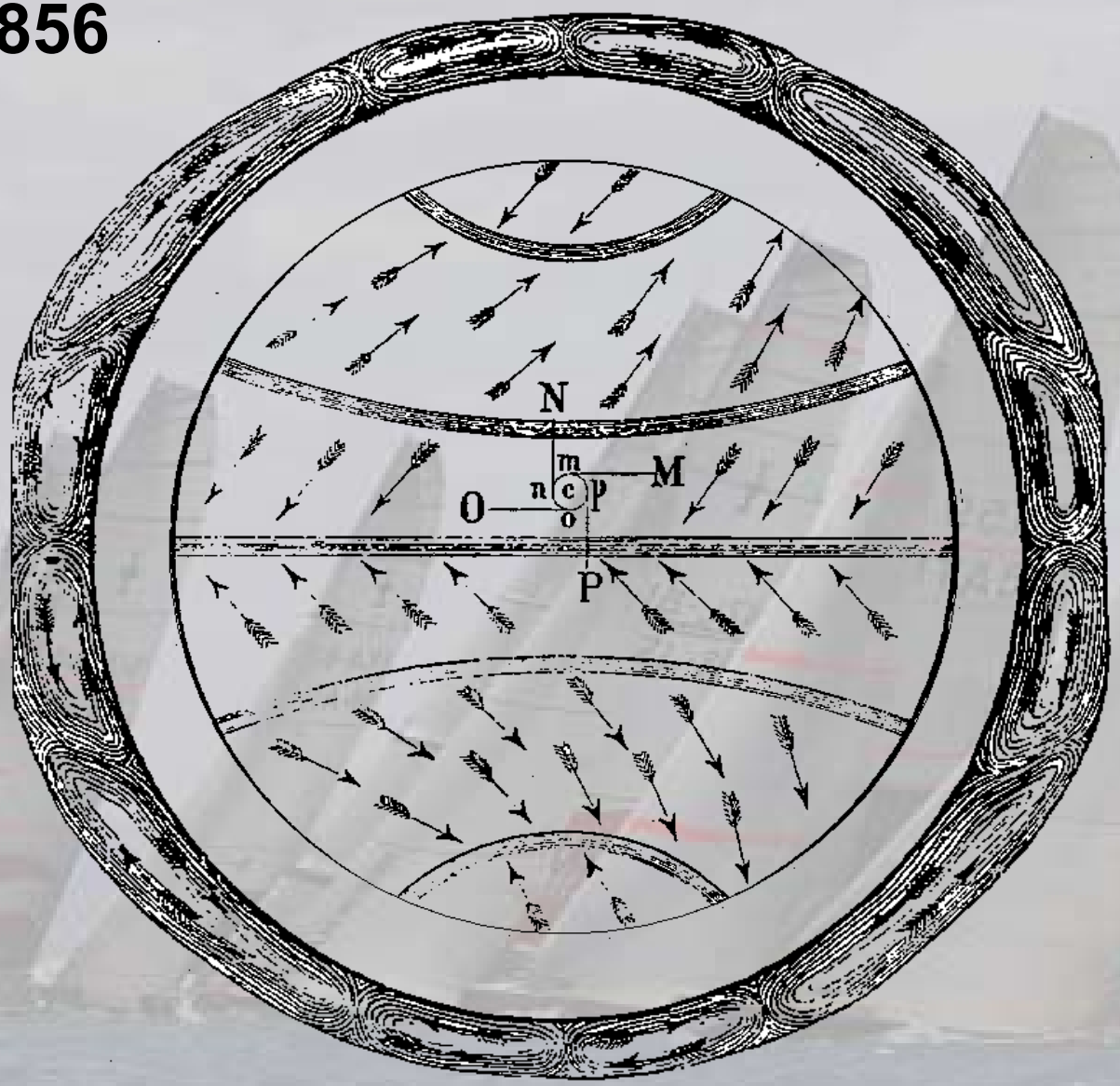
- ... Governs the Global Circulation of the Atmosphere
  - Climate Zones
  - Global Precipitation Patterns
  - Variation of Surface Wind Direction

- ... Governs the Global Oceanic Circulation
  - Coastal Currents
  - Westward Intensification (Intensification of Ocean currents on the western edge of oceanic basins (Atlantic: Gulfstream, Pacific: Kiushio)
  - Heat Transfer from Equator to the Poles

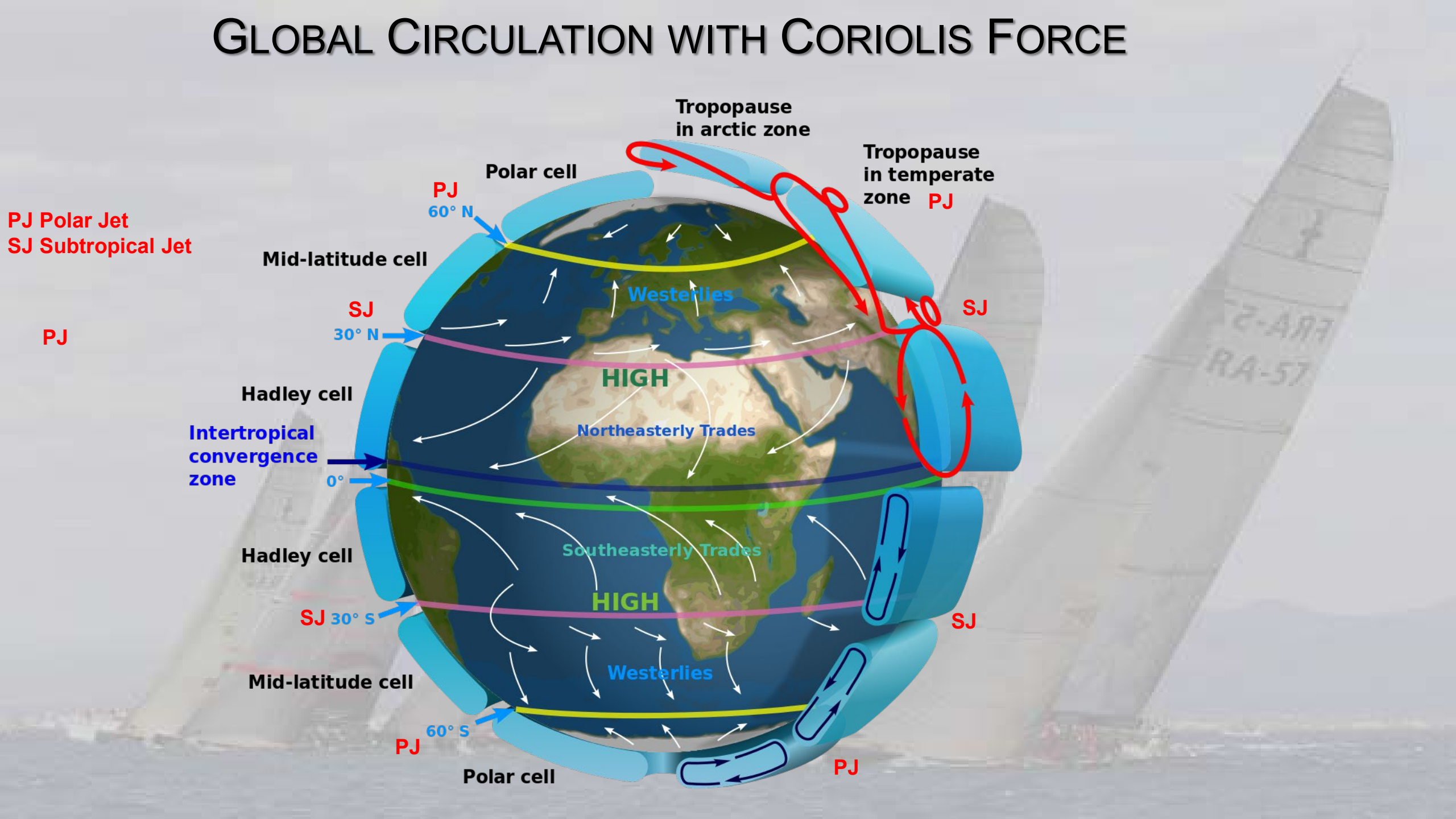
- … Governs the Oceanic Mixture (Ekman-Spiral)
  - Upwelling Areas La Niña (Absence: El Niño)
  - Mixing of Oceanic boundary layer

GLOBAL CIRCULATION WITH CORIOLIS FORCE

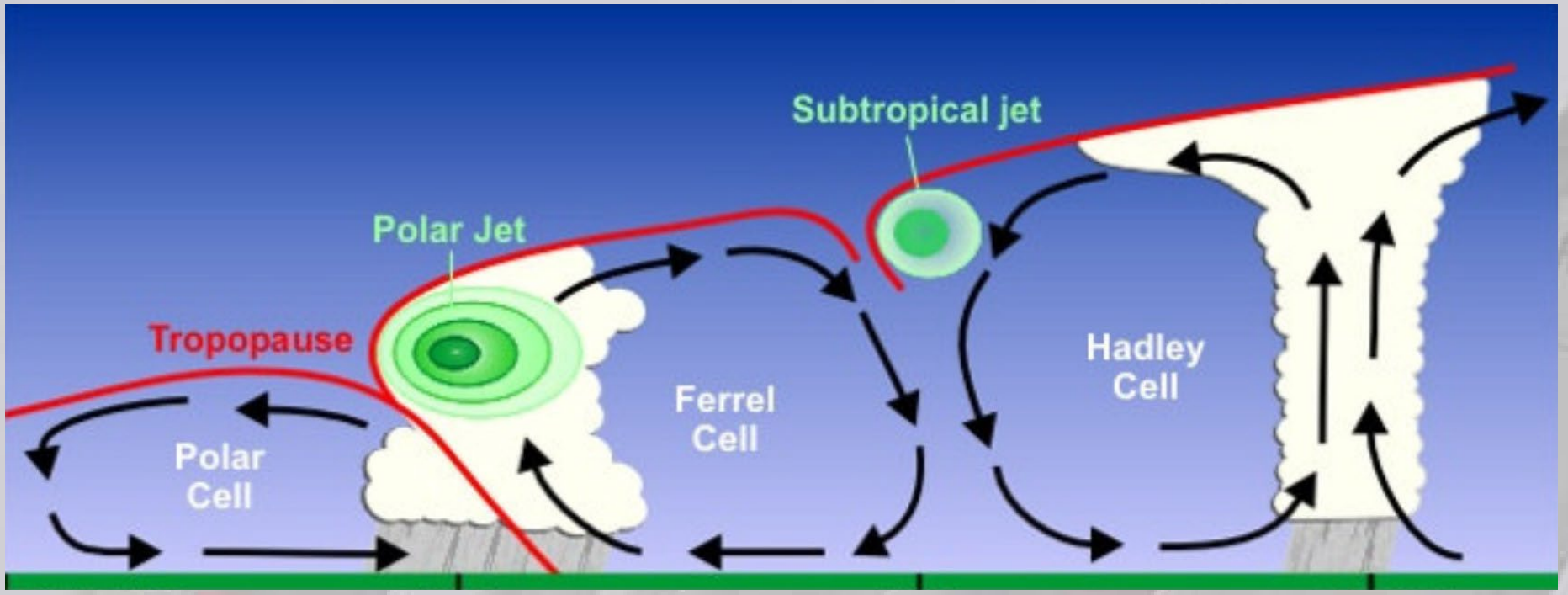
Dove 1856

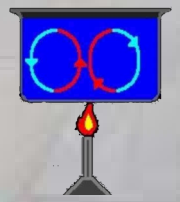


Global Circulation with Coriolis Force



Cross-section Hadley - / Ferrel - and Polar - Cell





reverse direct

thermal circulation

Simulation in a Rotating Tank

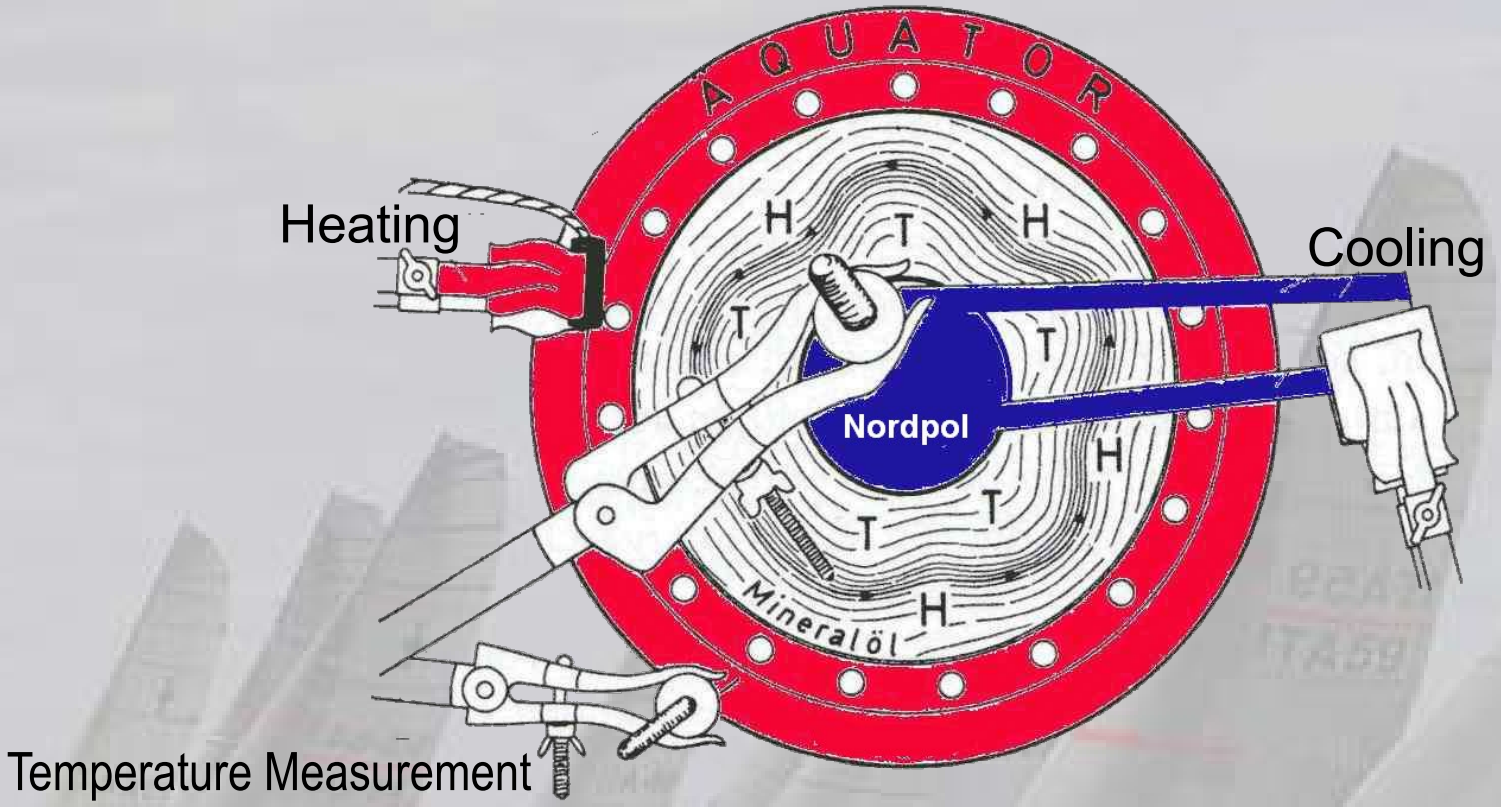


Abb. 10. Simulierung der Strömungsverhältnisse auf der rotierenden Erde durch ein Experiment im Lamont Geological Observatory. Eine mit Mineralöl gefüllte zylindrische Schale wird in Rotation versetzt. Die Heizung am Schalenrand und die Kühlung an der Drehachse erfolgt mit Wasser. Durch Aluminiumpulver werden die (hier schematisch angedeuteten) Zirkulationen in der Flüssigkeit sichtbar gemacht. Man erkennt die Ausbildung eines „Starkwindbandes" und „Wellen" (Hochkeile und Tiefströge), die große Ähnlichkeit zu den in der Atmosphäre auftretenden Stromfeldern zeigen

Northern Hemisphere Circulation 500 hPa

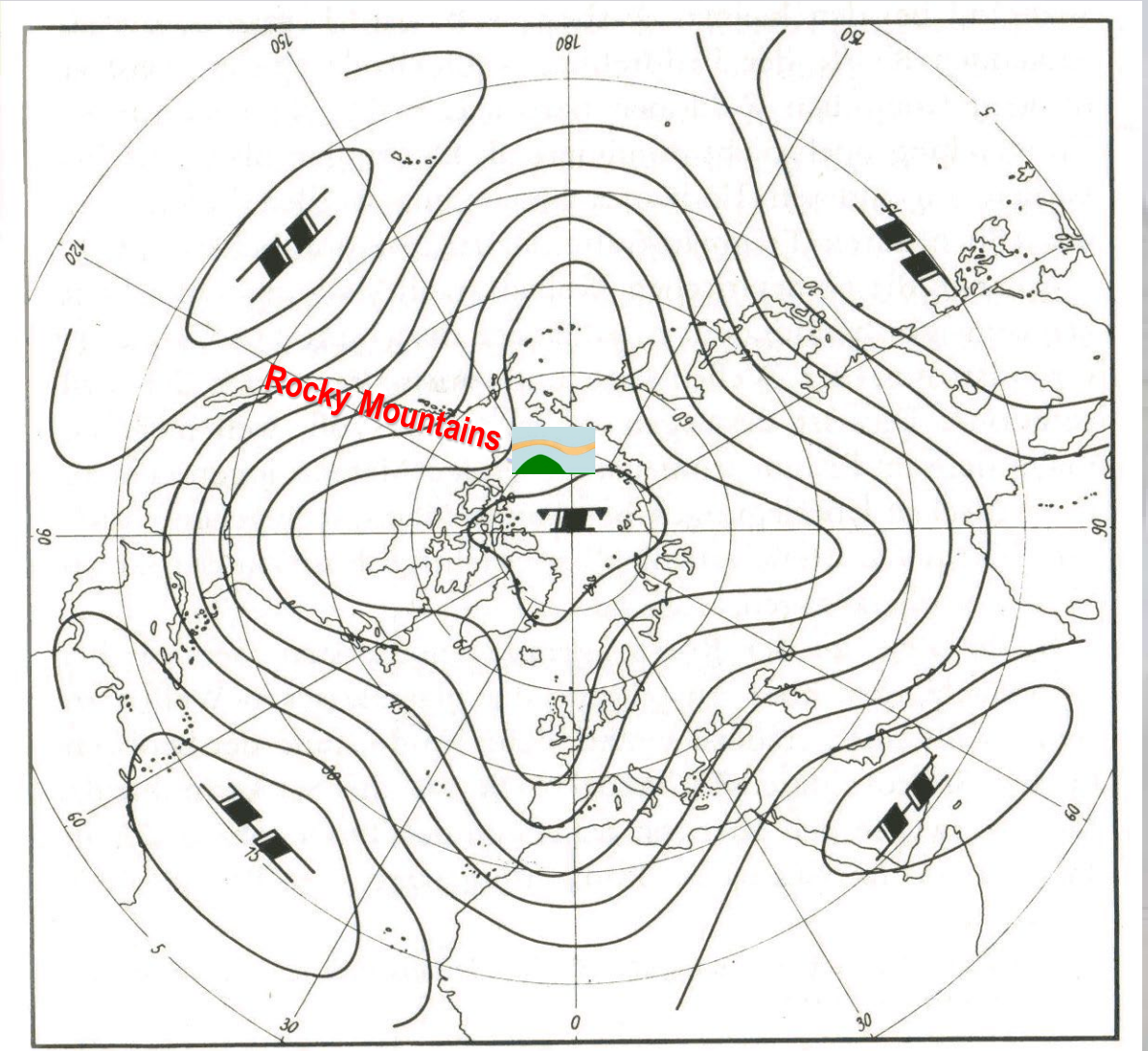
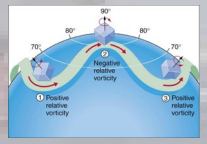
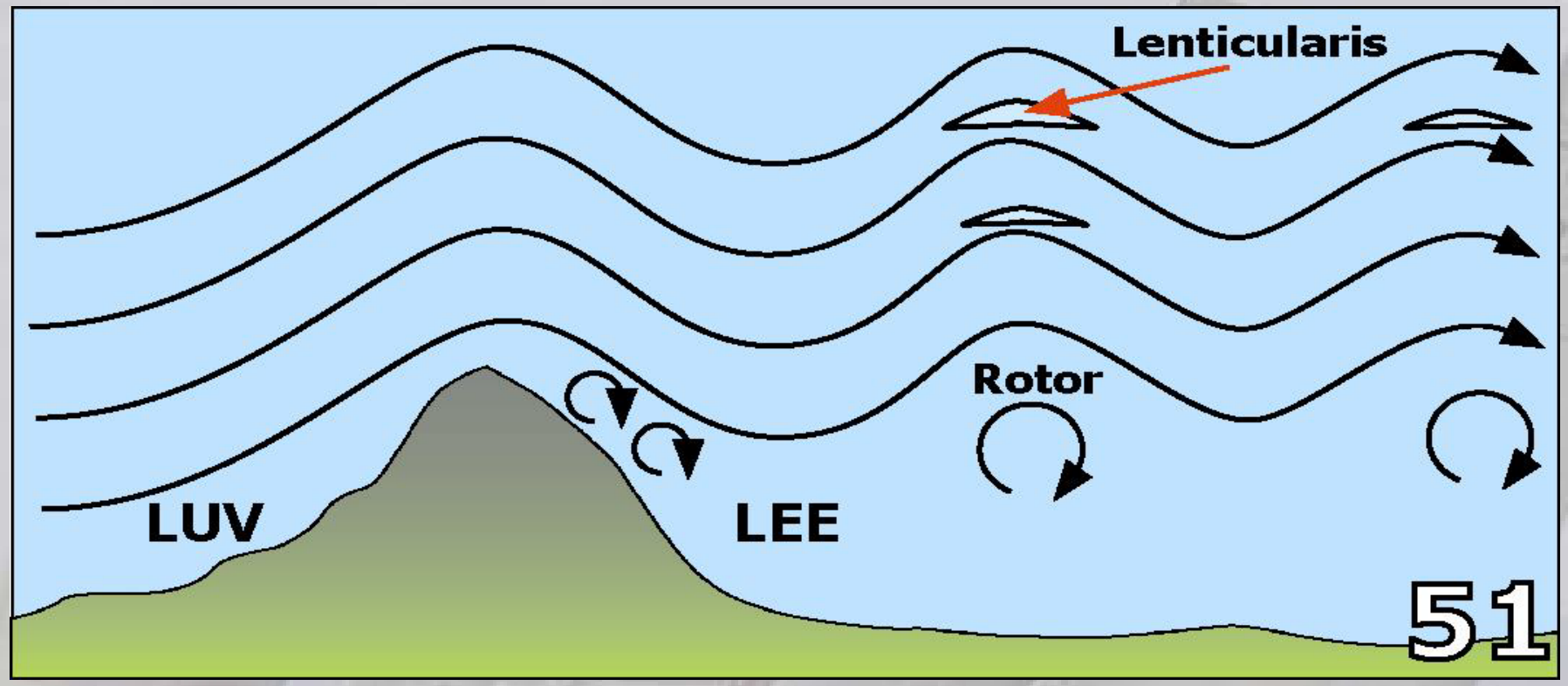


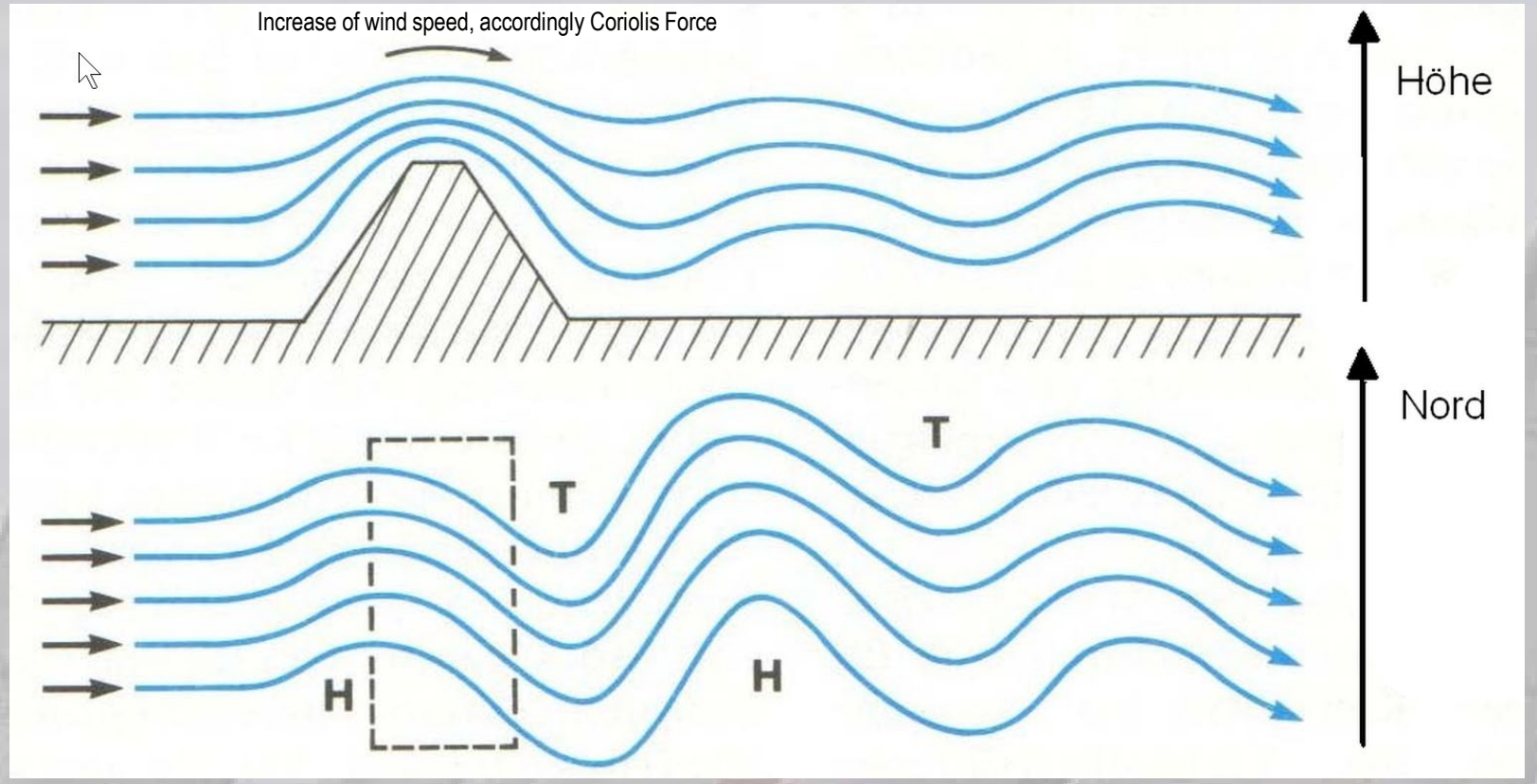
Abb. 28. Schematische Darstellung von planetarischen Wellen mit der Wellenzahl 4 in der freien Atmosphäre



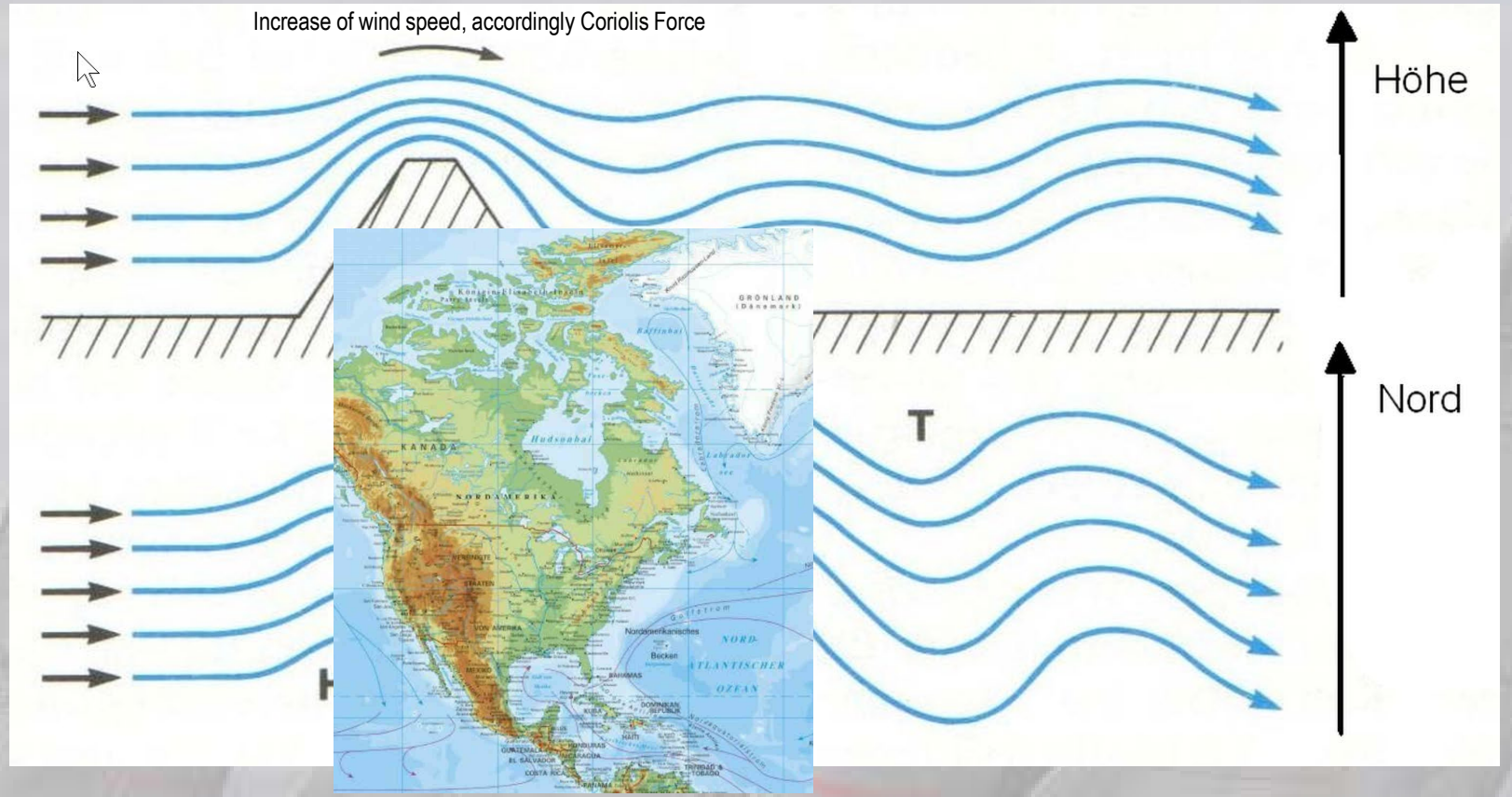
Air flow over mountains



Air flow over mountains



Air flow over mountains



Northern Hemisphere Circulation MSL Pressure

- SAT Zirkumpolar
- SAT Global Mercator
- SAT Global Hammer
- SAT Europa 5km

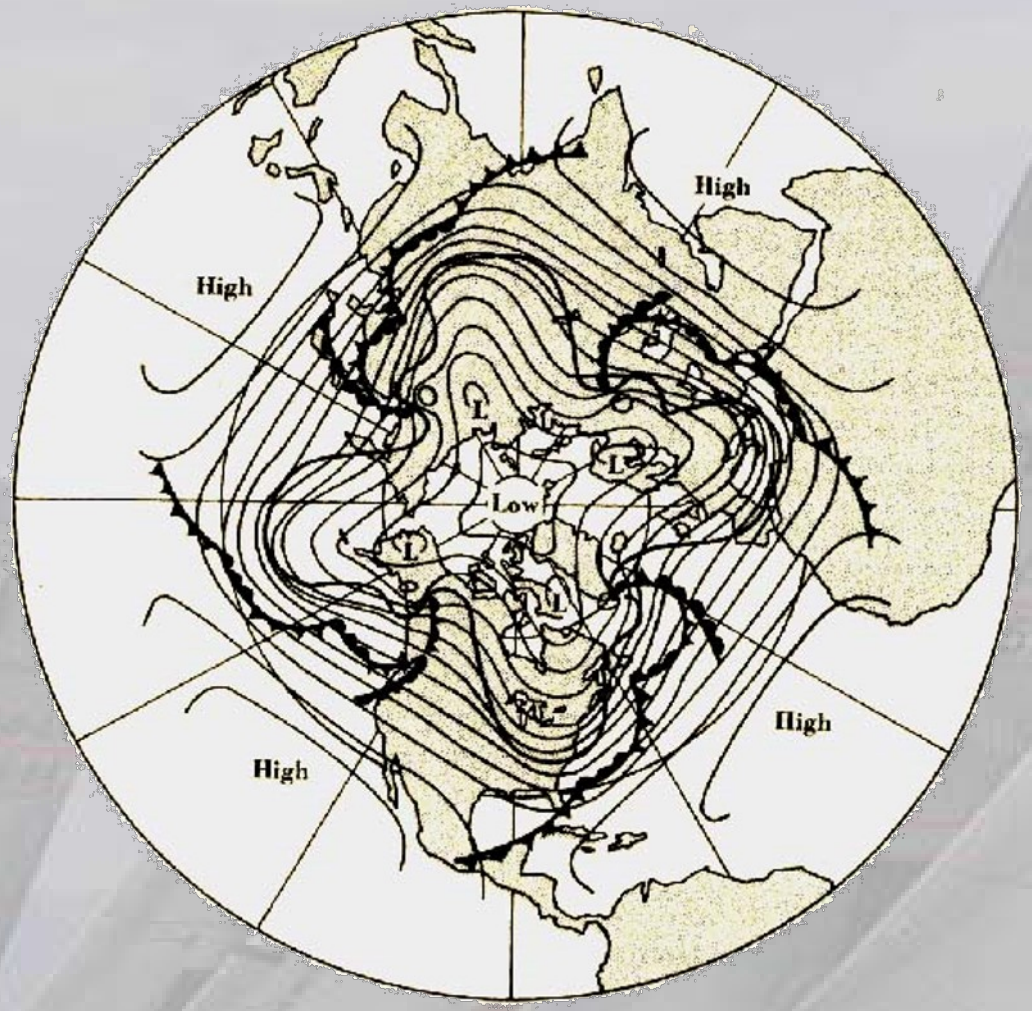
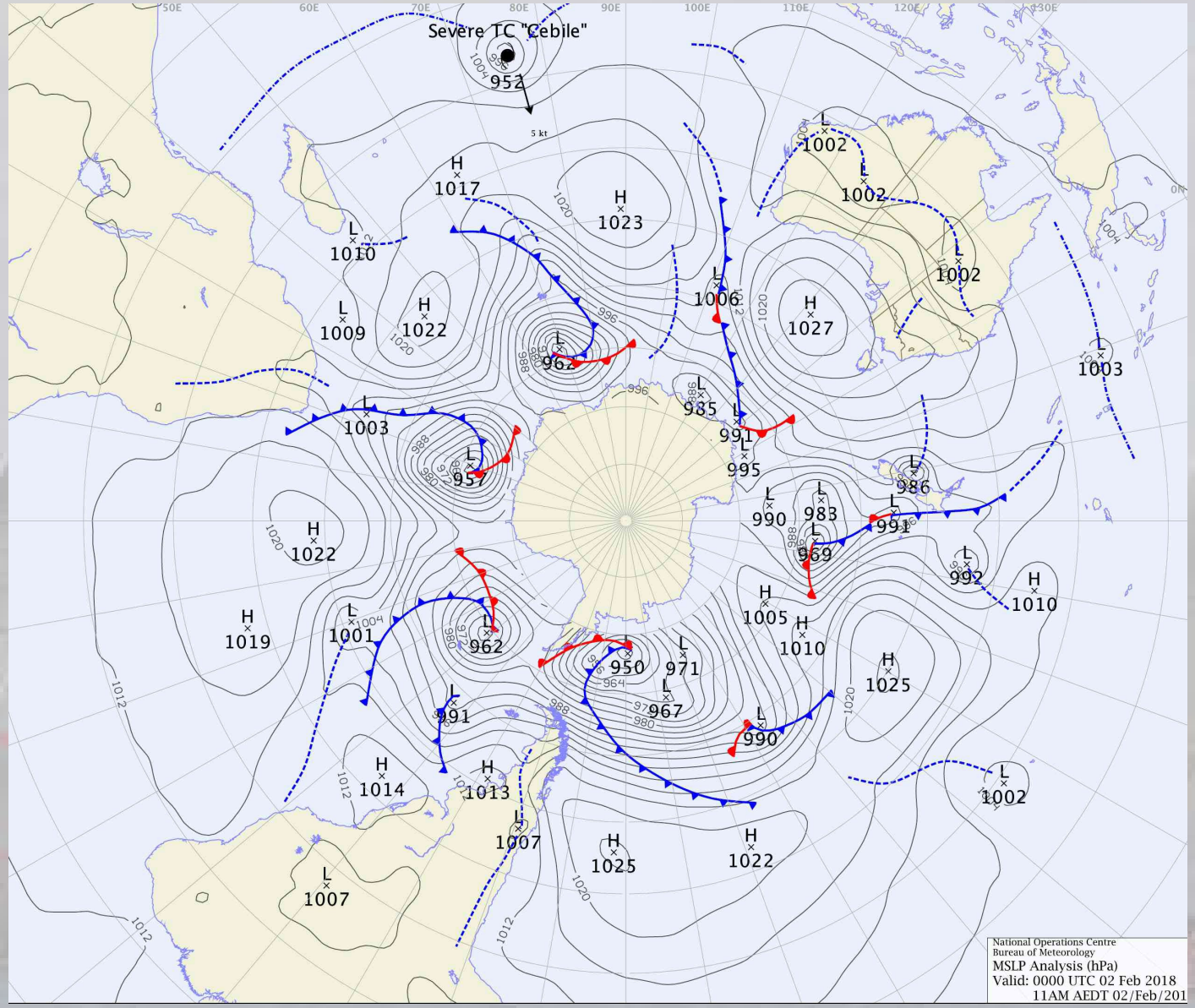
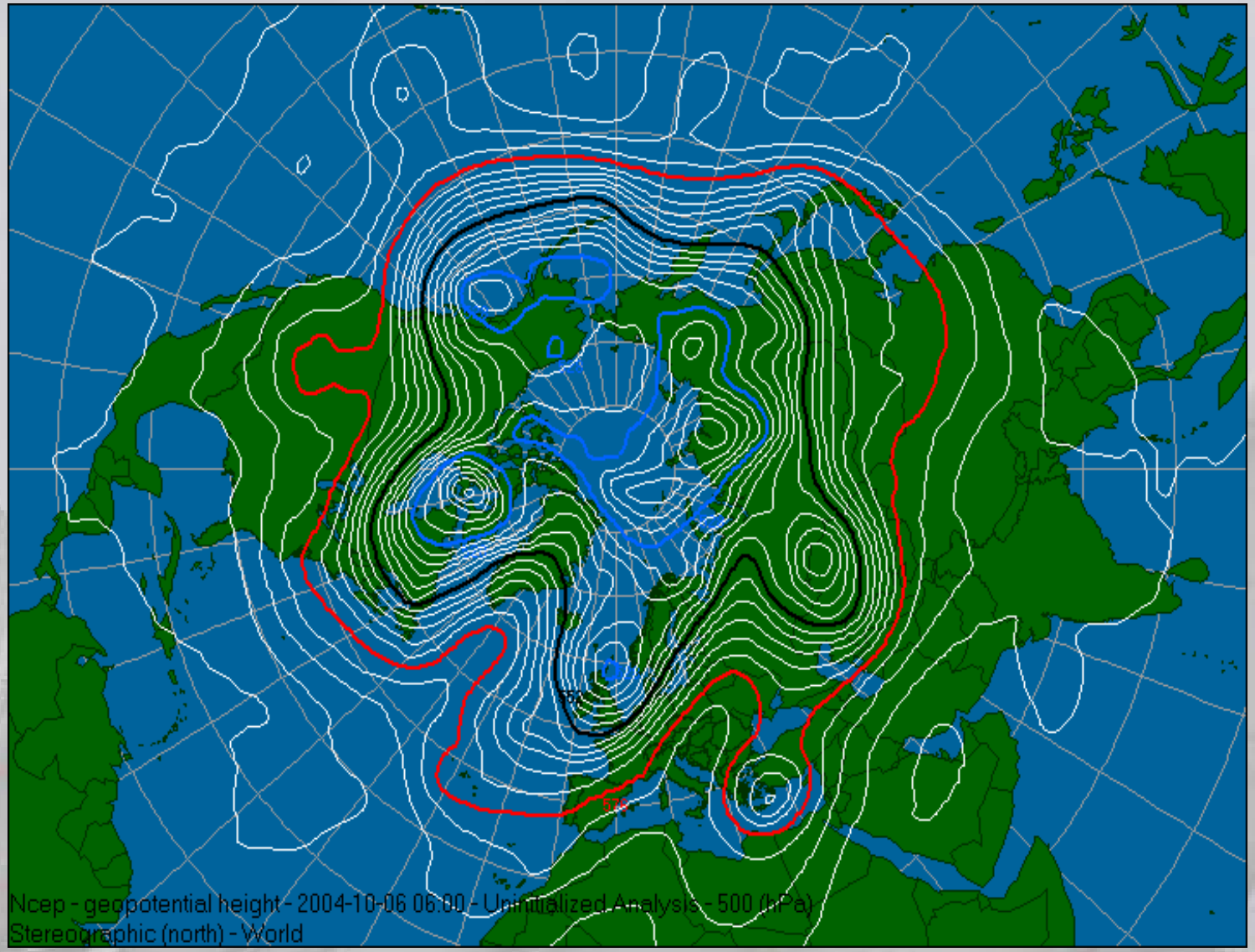
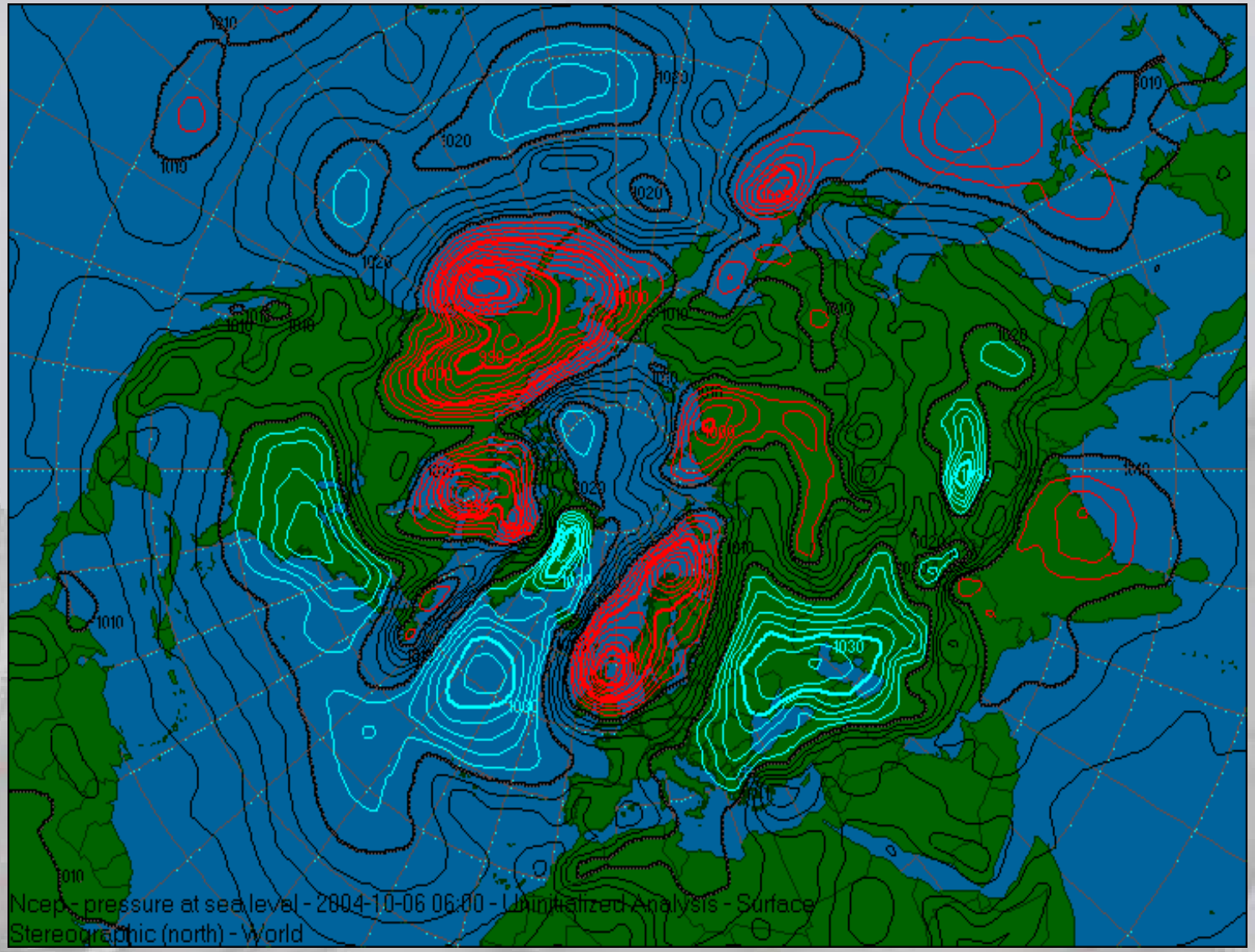


Fig. 13.15 Schematic chart showing four cyclone families at sea level and four long waves aloft. (*After Palmén.*)

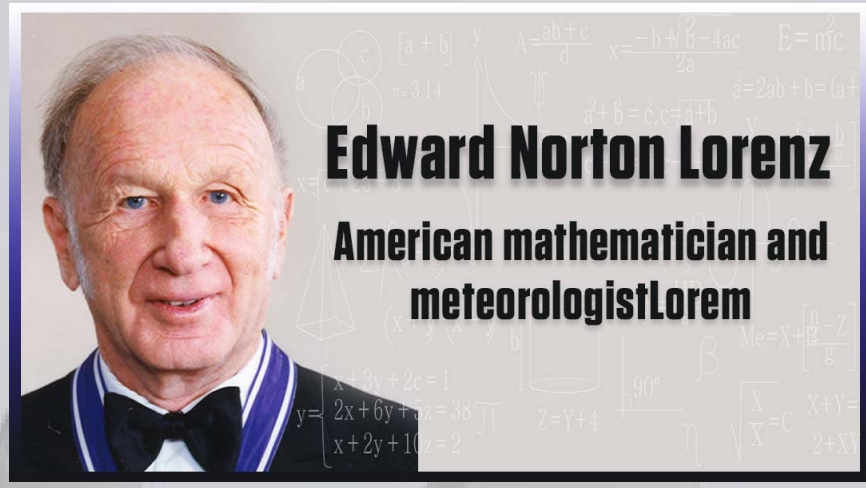
Southern Hemisphere Circulation MSL Pressure




Ncep - geopotential height - 2004-10-06 06:00 - Uninitialized Analysis - 500 (hPa)
Stereographic (north) - World


Ncep - pressure at sea level - 2004-10-06 06:00 - Uninitialized Analysis - Surface
Stereographic (north) - World

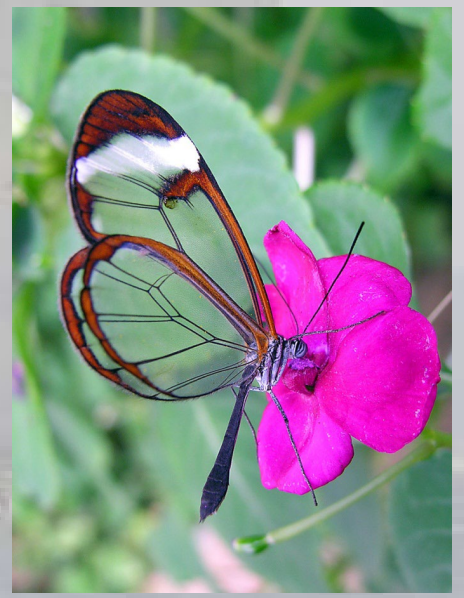
EDWARD N. LORENZ 1917 - 2008



- 1961 Chaos – Theory
- Experiments using different Computers
  - Same NWP model, same initial state – after 4 days diverging results
- Experiments using the same computer
  - Same NWP model, disturbed initial state – after 4 days diverging results

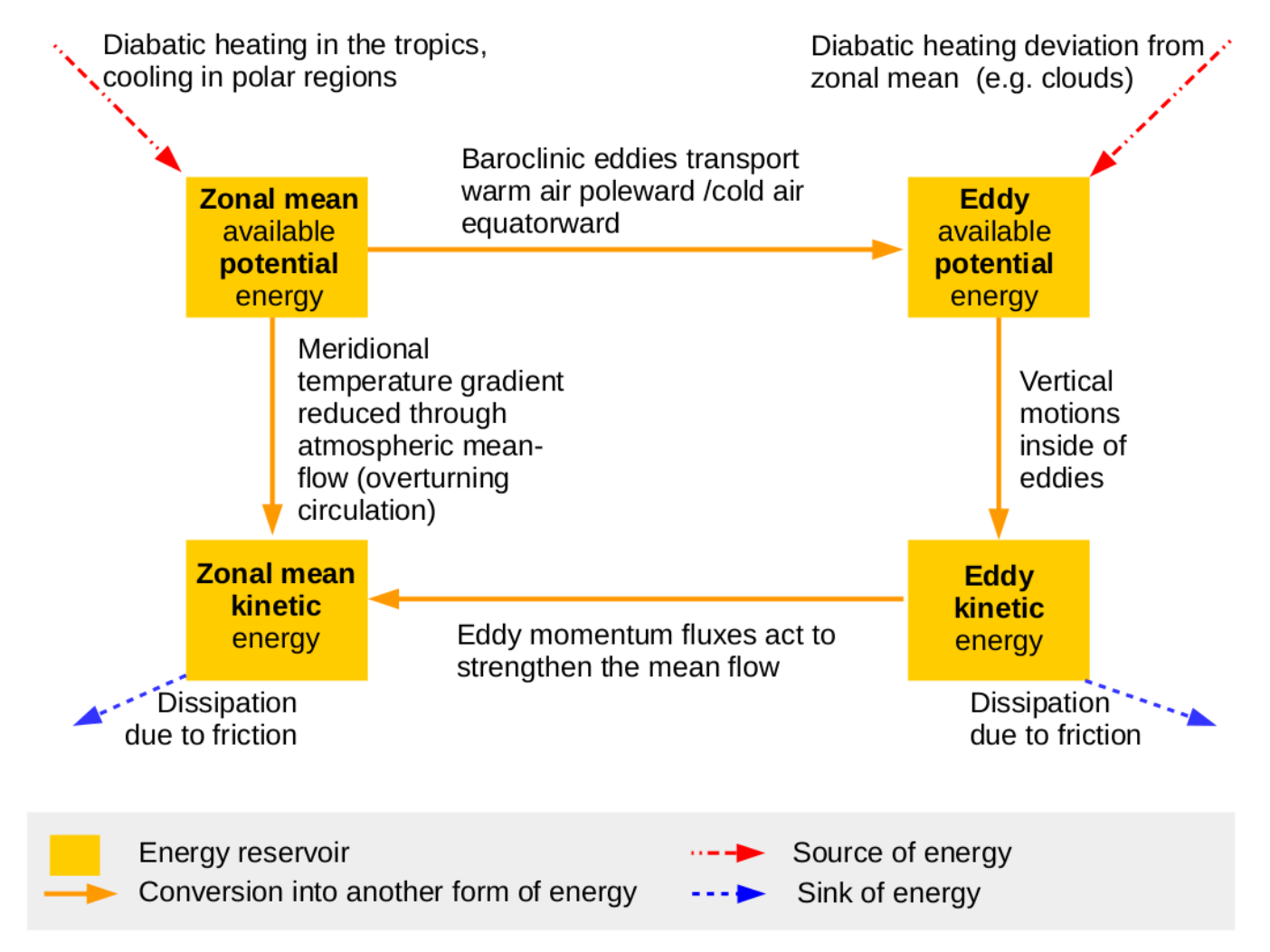
Predictability: Does the flap of a butterfly's wings in Brazil set off a tornado in Texas ?

This is the basis for the later development of Ensemble Forecast Technology



EDWARD N. LORENZ 1917 - 2008

1955 Available Potential Energy and the Maintenance of the General Circulation



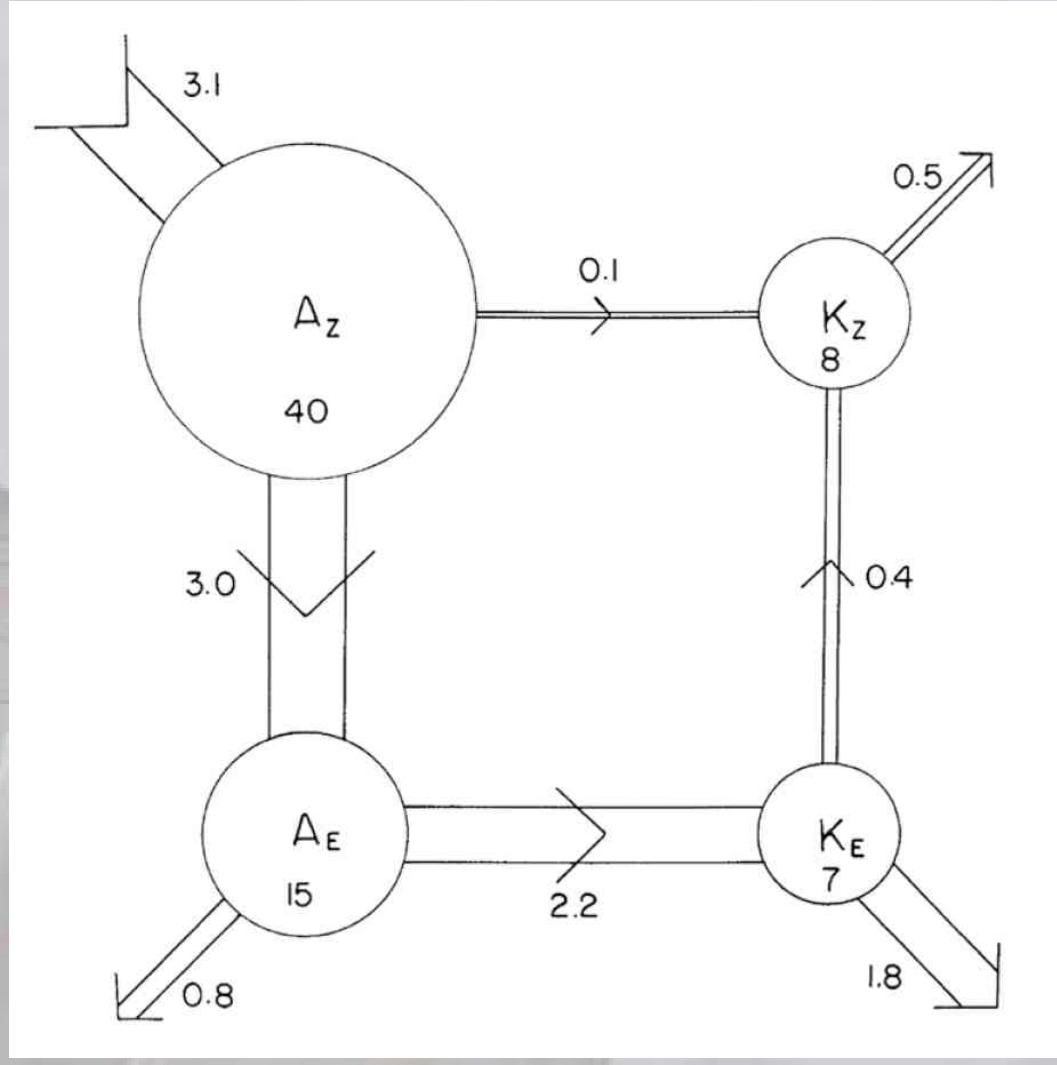


Figure 2. Estimates of the annual-mean, depth-integrated, area-averaged energy cycle among the zonal-mean and eddy available potential and kinetic energy components in the Northern Hemisphere. *A* denotes available potential energy, *K* denotes kinetic energy, and the subscripts *Z* and *E* denote the zonally averaged and eddy components. Units are 10^5 J/m^2 for energies and W/m^2 for generation and dissipation (exterior arrows) and conversion (connecting arrows) rates. From Lorenz (1967), adapted from Oort (1964).

CHECKLIST GLOBAL CIRCULATION

Global Circulation

- ✓ Global Circulation is driven by solar radiation and geometrical (Earth as sphere) and astronomical parameters (slant Earth axis)

- ✓ Coriolis Force

  - ✓ $\Omega = 2 * \pi / 86.164$
  - ✓ $2 * \Omega * \sin(\varphi = \text{latitude})$ Coriolis frequency
  - ✓ Coriolis Force = wind velocity * Coriolis frequency
  - ✓ Increases with latitude, Zero at Equator
  - ✓ Proportional to windspeed
  - ✓ Acts perpendicular to direction of motion
  - ✓ Acts to the right (Northern Hemisphere) and left (Southern Hemisphere), respectively

- ✓ Circulation Cells: Hadley~ (suptropical), Ferrel~ (mid-latitude), Polar~ (Polar regions)

Checklist Global Circulation

Global Windsystems

- ✓ Global Windsystems (MSLP, Upper Air), Wavenumber, Upper Air Trough/Ridge (Tank experiment)
- ✓ Innertropical Convergence Zone (ITCZ), Trade winds, Subtropical High, Westerly Winds
- ✓ Impact of Rocky Mountains on Global Circulation, Leeward trough, Downstream advection of warm-moist air NE-ward to Newfoundland by SW wind near East Coast of USA
- ✓ Advection of polar cold air from Labrador Sea by NW winds
- ✓ Intensification of meridional (N-S) temperature gradient by four center pressure pattern
- ✓ Formation of frontal zone, Cyclogenetic orographic effects by Greenland mountains

QUESTIONS YOU SHOULD BE ABLE TO ANSWER

Global Circulation

- ✓ What drives the General Circulation ?
  - ✓ Solar radiation
    - ✓ Earth as a sphere
    - ✓ Slant Earth axis
    - ✓ Resulting meridional Temperature Gradient

- ✓ Which are the main characteristics of the Coriolis Force?
  - ✓ Increases with latitude, Zero at Equator
  - ✓ Proportional to windspeed,
  - ✓ Perpendicular to windspeed: NH to right, SH to left

- ✓ How many Circulation Cells form the Global Circulation?
  - ✓ 3: Hadley Cell Ferrell Cell Polar Cell

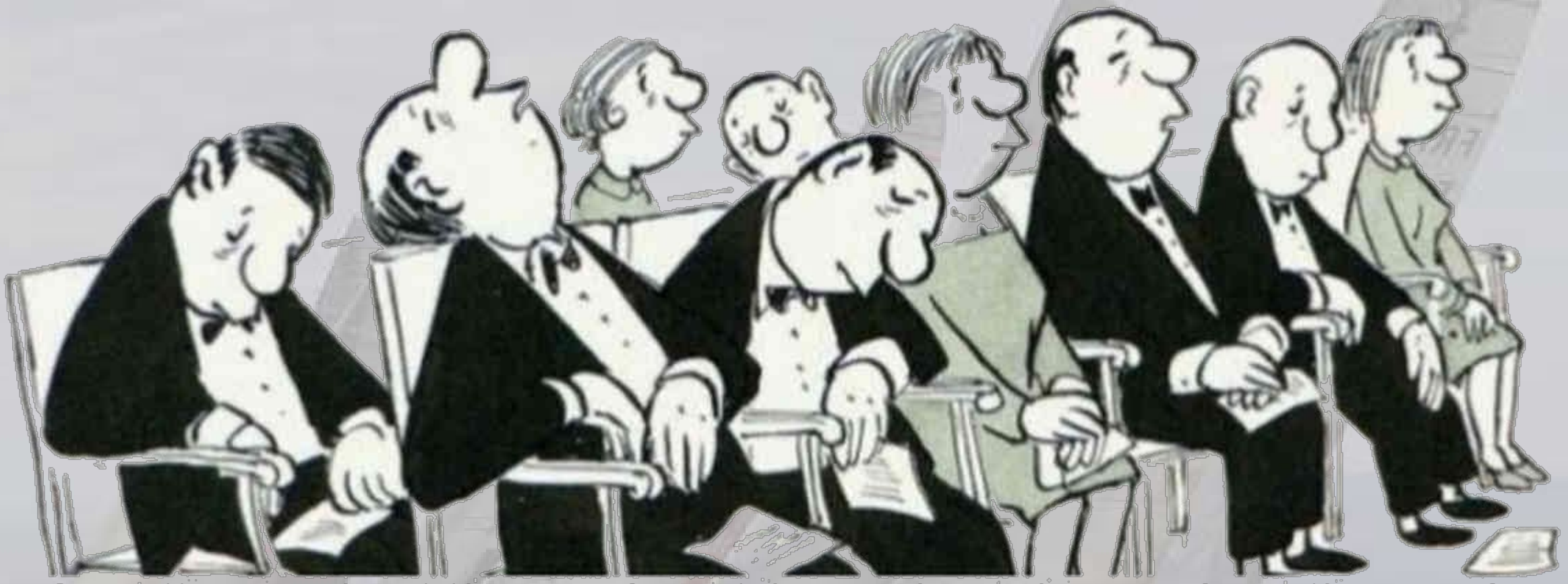
QUESTIONS YOU SHOULD BE ABLE TO ANSWER

Global Circulation

- ✓ What is the wavenumber of the Global Circulation? Which are its characteristics?
  - ✓ The wavenumber is the number of waves of the windflow over the Earth‘s surface (360°)
  - ✓ The higher the wavenumber, the faster it propagates to the East
  - ✓ Wavenumber n = 4 (Rossby wavelenght) is stationary
  - ✓ Wavenumbers n < 4 become retrograde (propagate to the West)

- ✓ What is the wavenumber of the Global Circulation? Which are its characteristics?

Thank you for your attention !

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