



What Makes the Oceans Move in Circles?

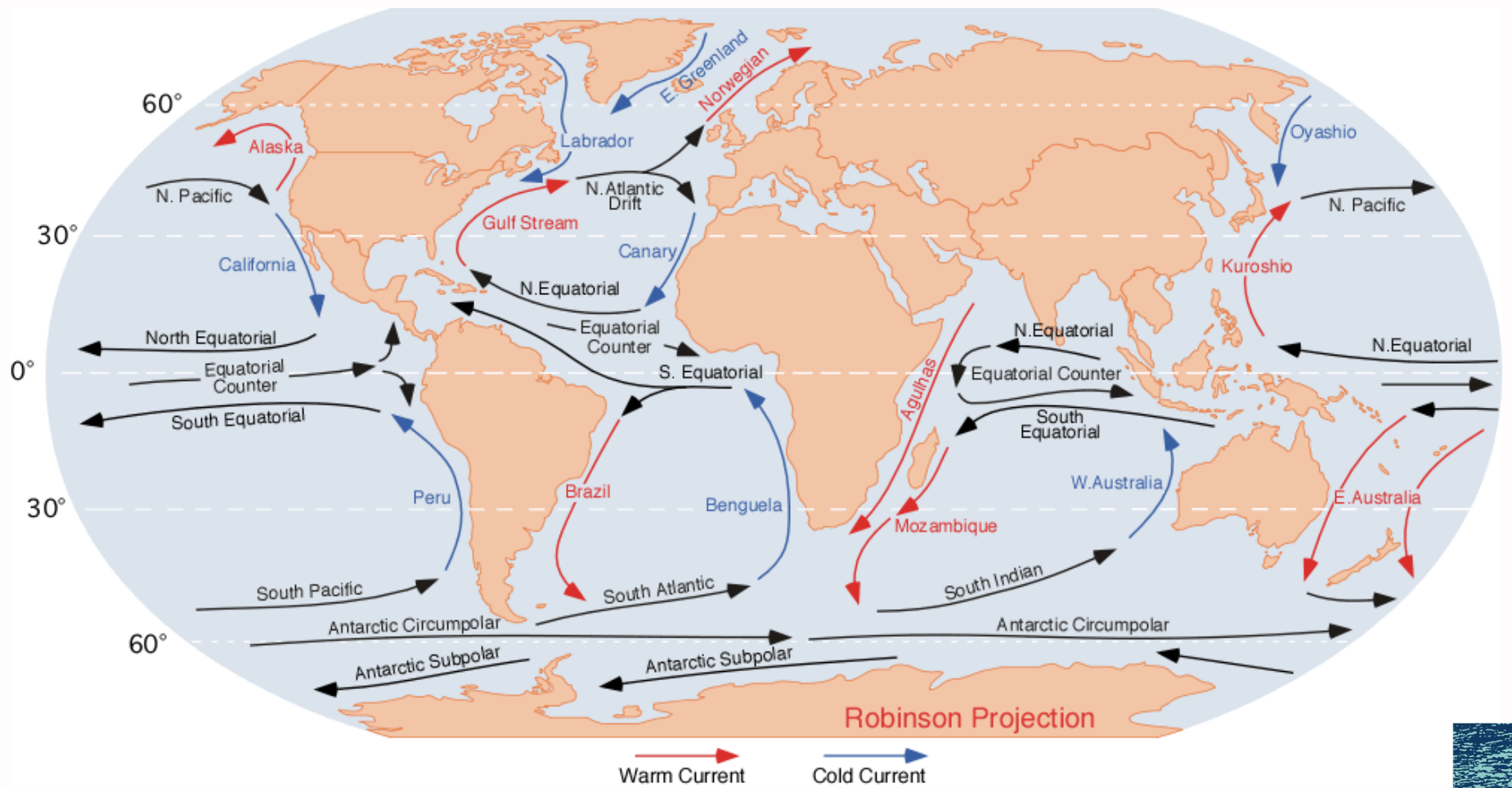
Kevin R. Bodge, Ph.D., P.E.

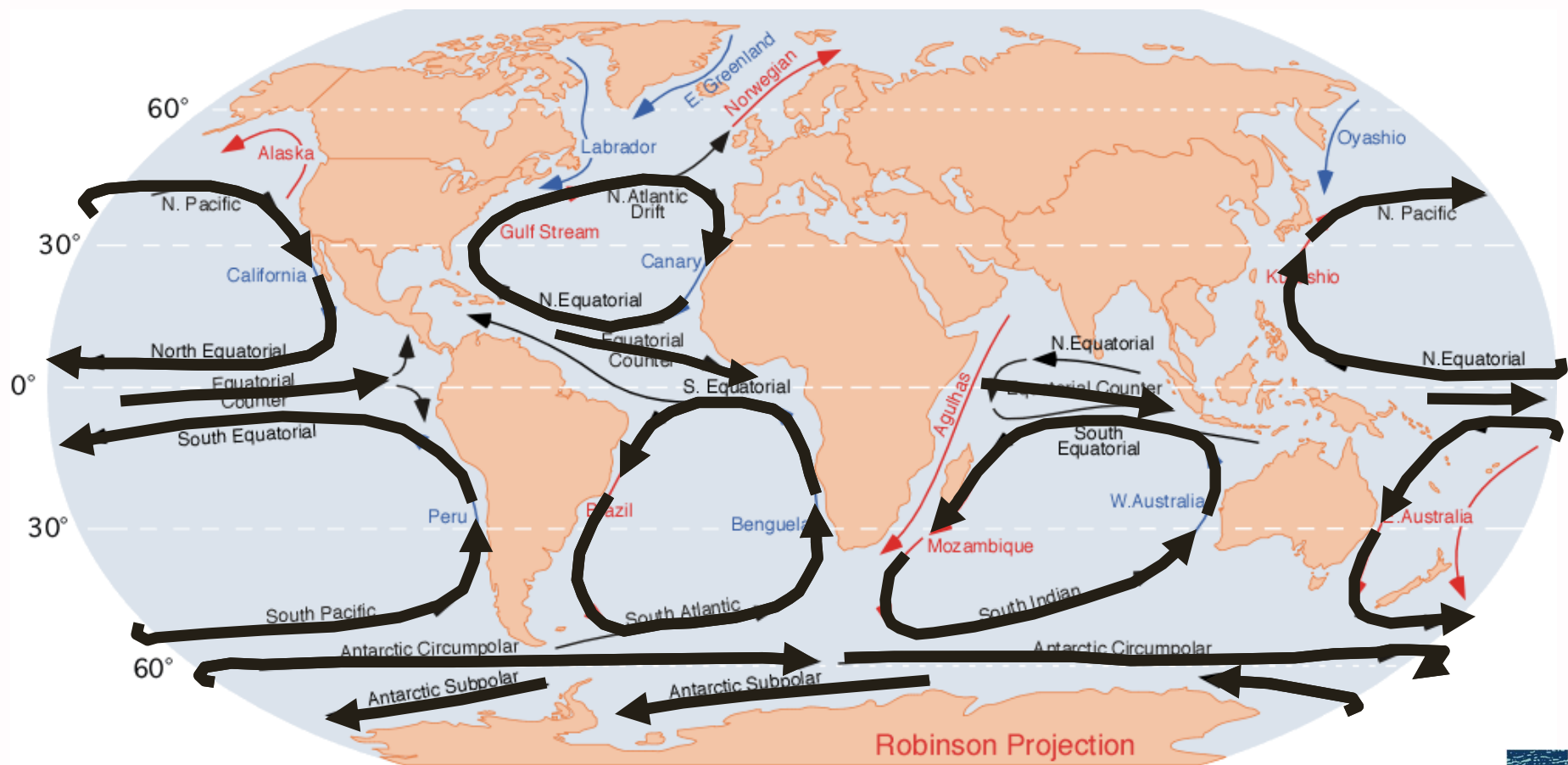
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Surface Ocean Currents – uppermost 10% of world ocean

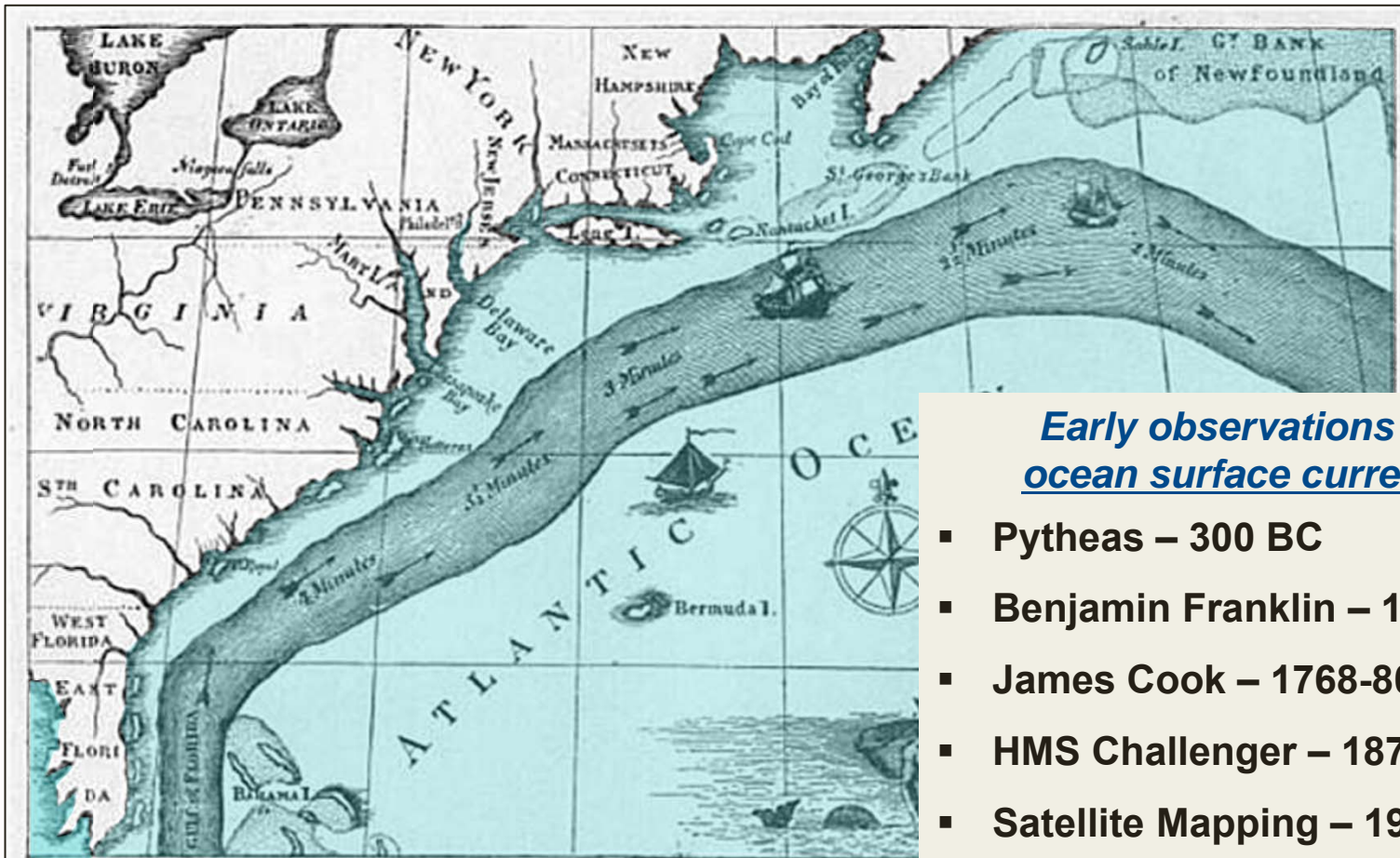
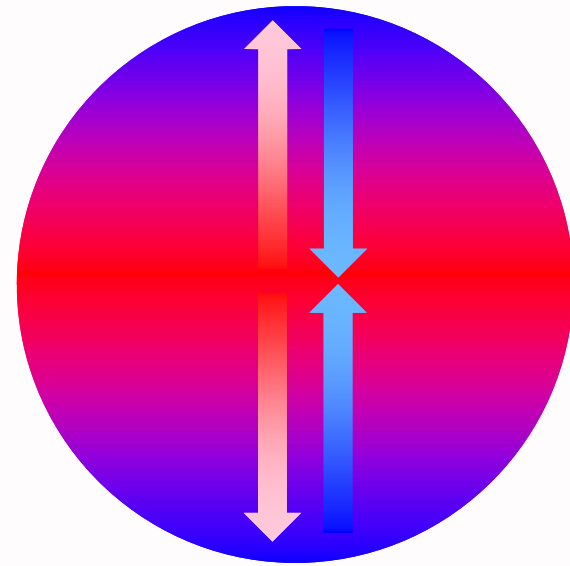


FIG. 173. — FRANKLIN'S CHART OF THE GULF STREAM.

Early observations of ocean surface currents

- Pytheas – 300 BC
- Benjamin Franklin – 1770
- James Cook – 1768-80
- HMS Challenger – 1872-76
- Satellite Mapping – 1980's

- **Circulation redistributes differential HEAT across the globe.**
- **Circulation patterns are modified by Earth's rotation & continents.**
- **The upper 1 meter of ocean surface:**
 - has as much HEAT as the entire atmosphere, and
 - evaporates every year.



Differential HEATING across the globe drives atmospheric & ocean circulation



Heating causes air to rise

Surface air flows in...



...to fill the void



**HEAT
= WIND**



Heating causes surface water to expand

Surface flow

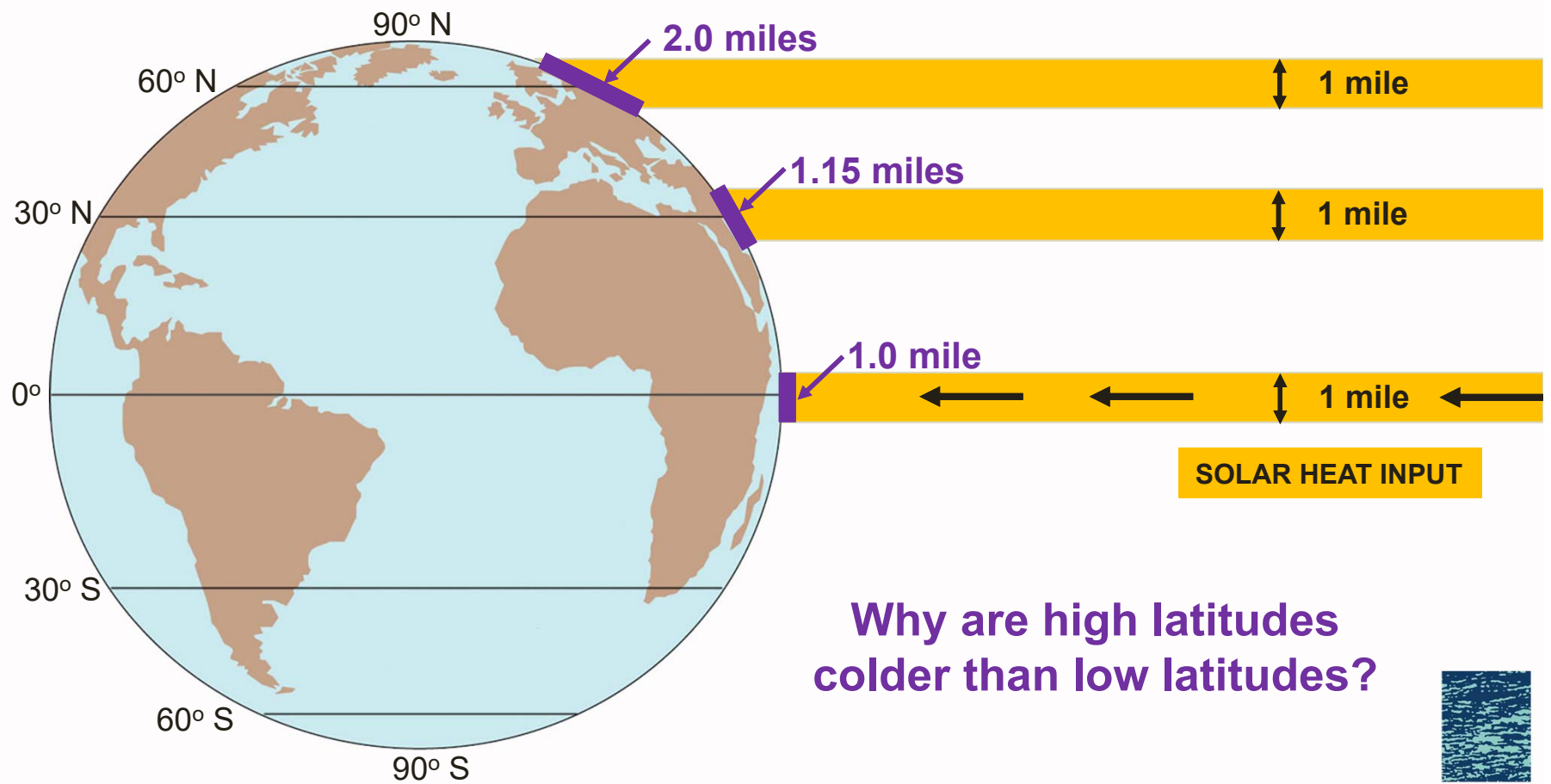


Surface flow

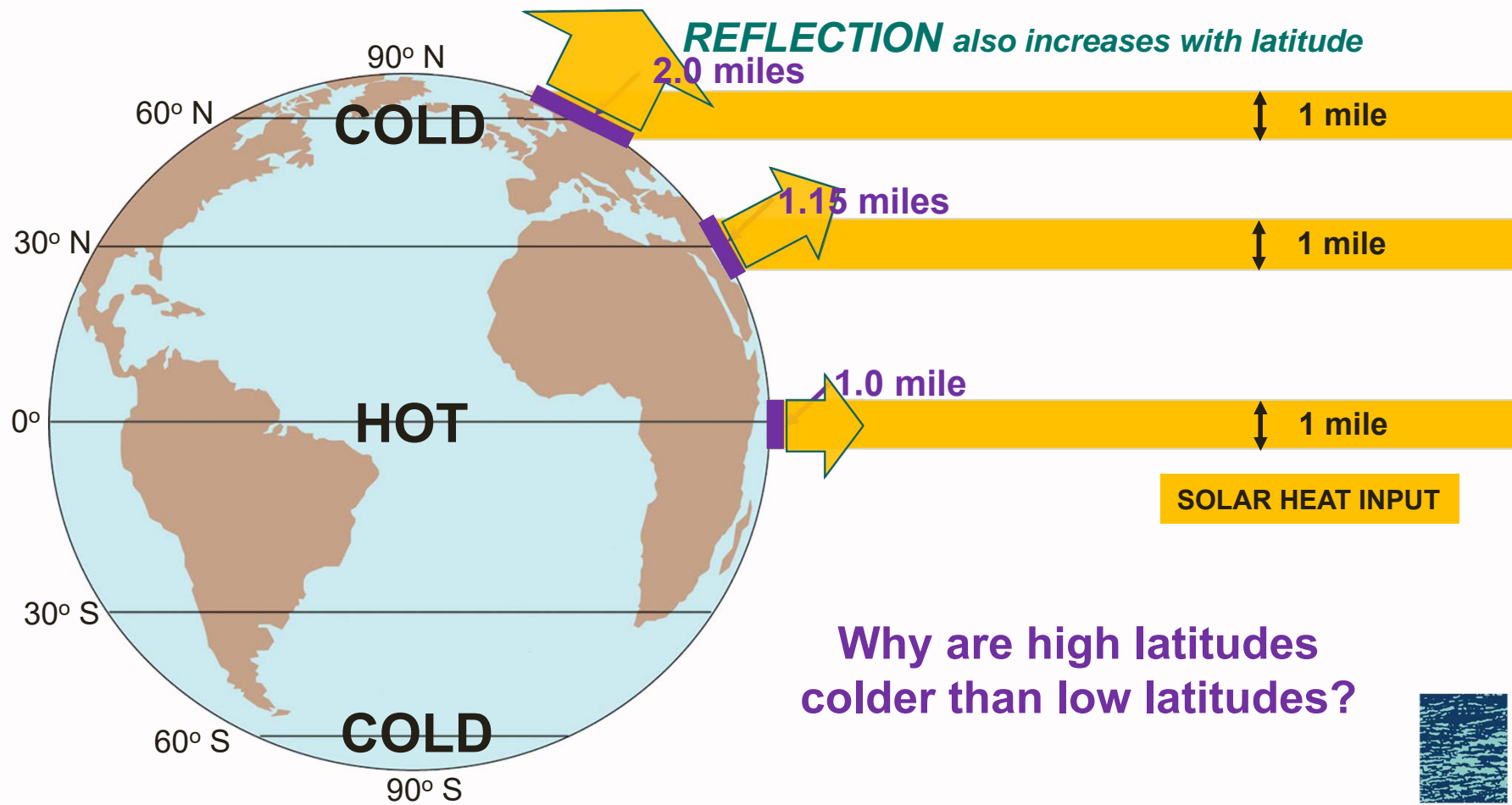


HEAT

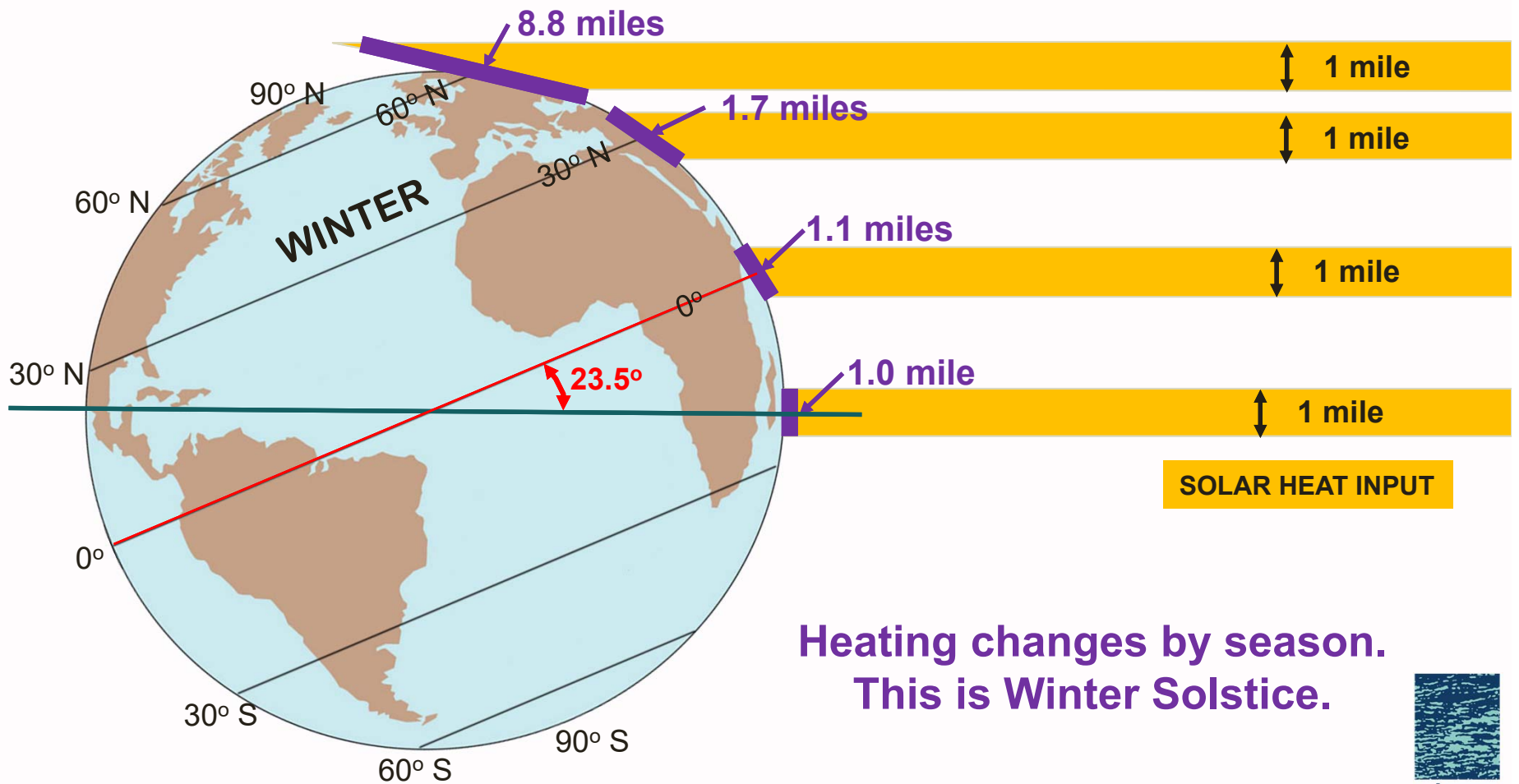




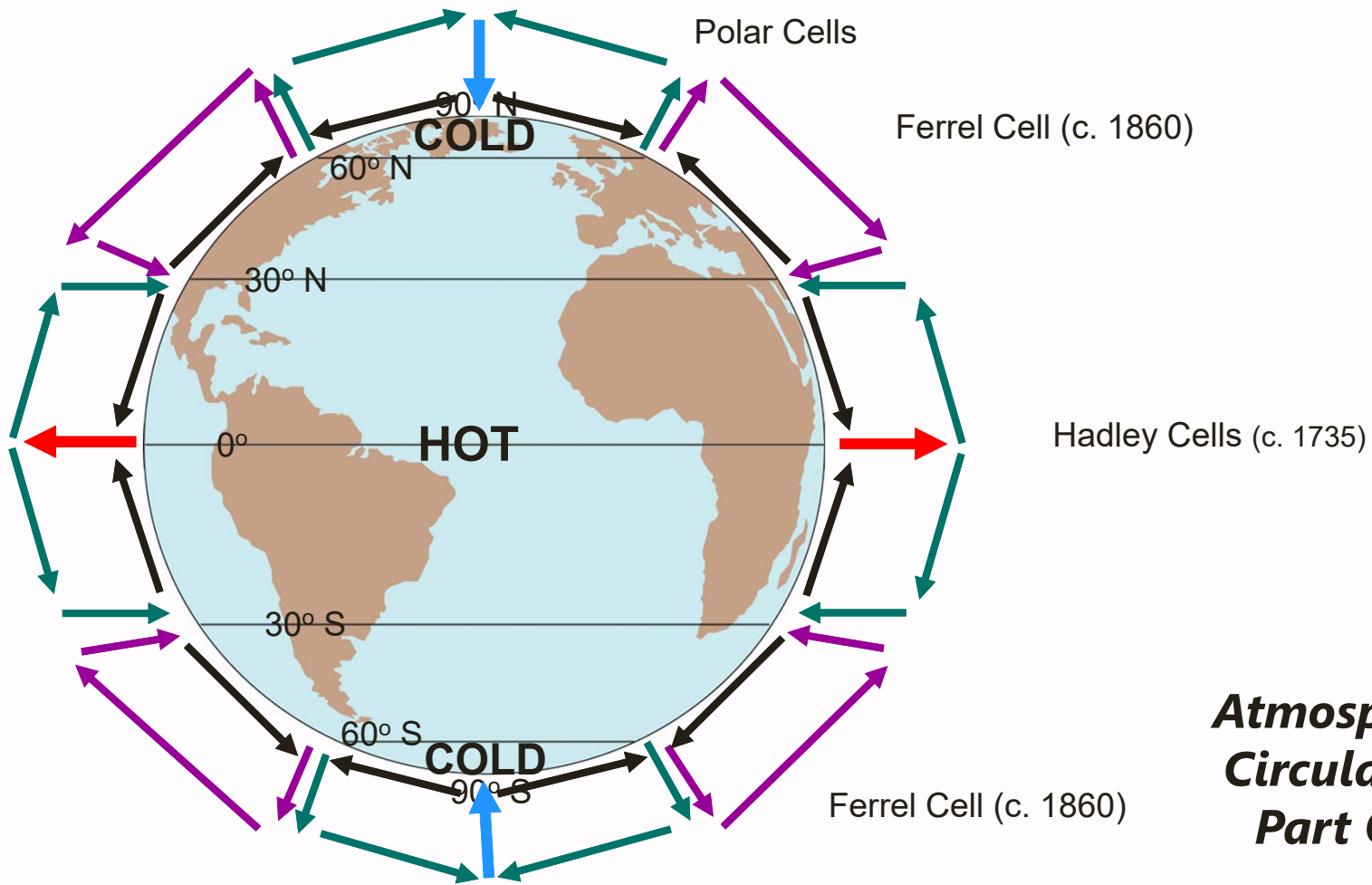
Why are high latitudes colder than low latitudes?



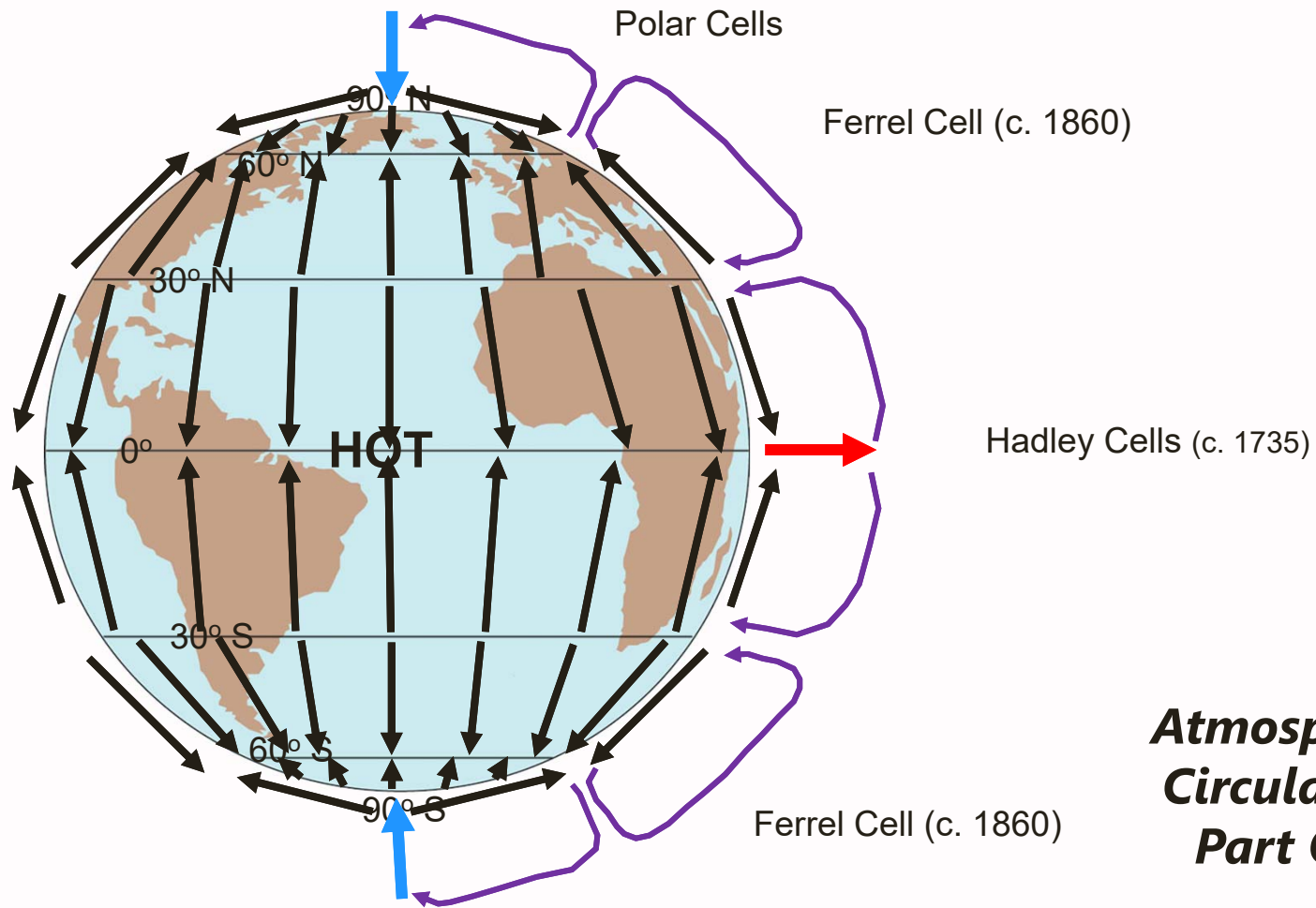
Why are high latitudes colder than low latitudes?



Heating changes by season.
This is Winter Solstice.

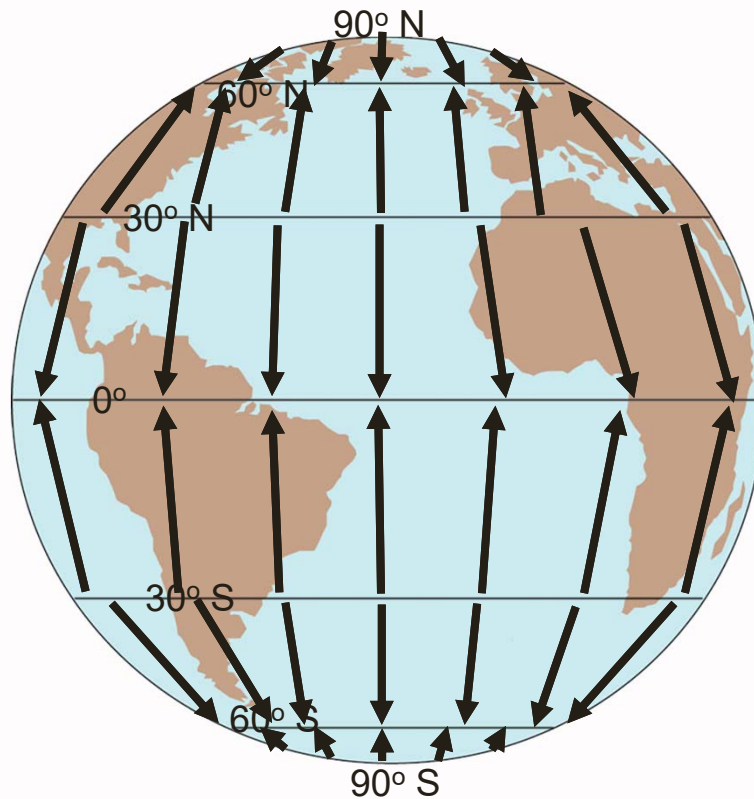


**Atmospheric
Circulation:
Part One**



**Atmospheric
Circulation:
Part One**

Polar Cells



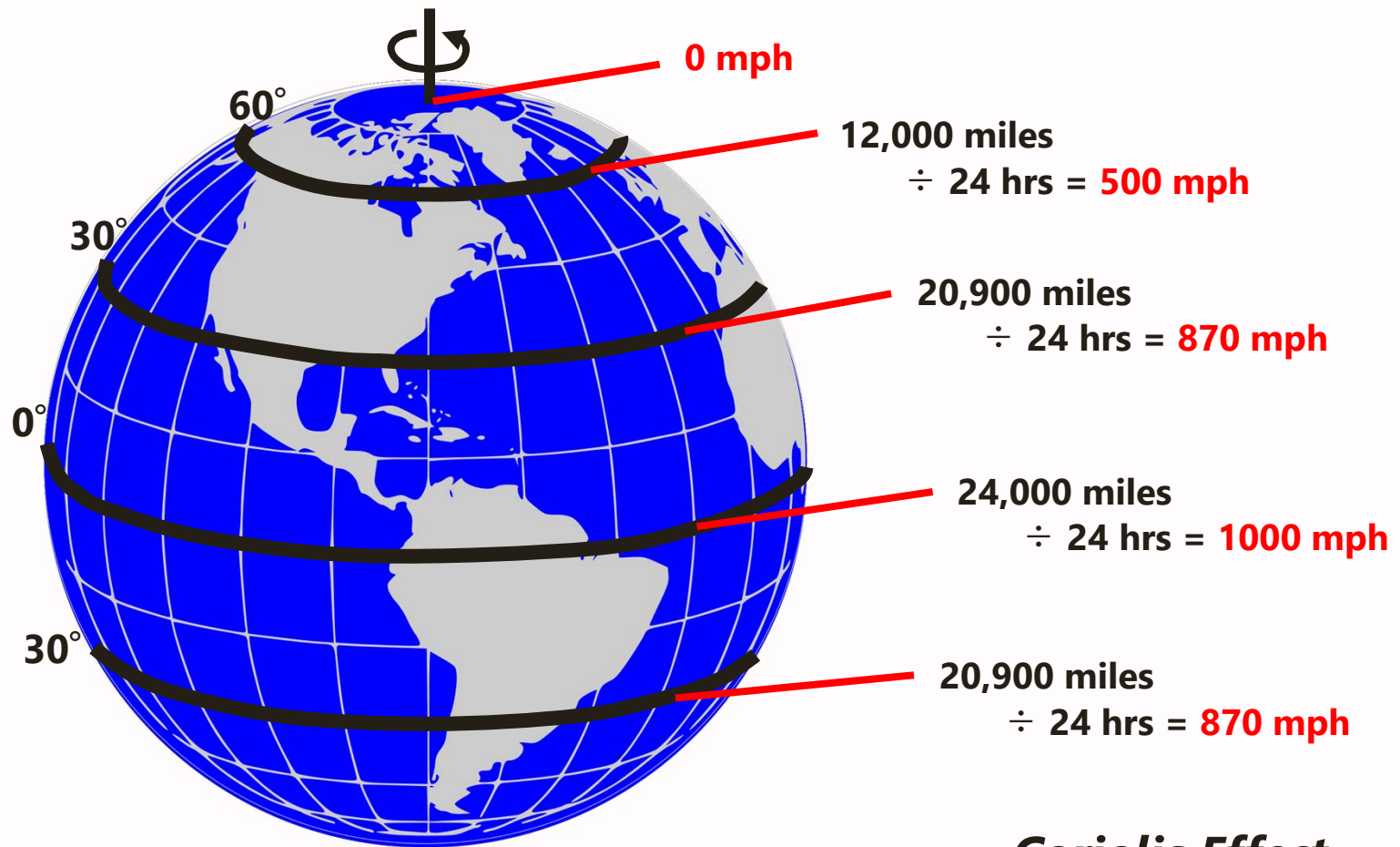
Ferrel Cell

*Principal surface wind
flow directions implied
by heat circulation cells*

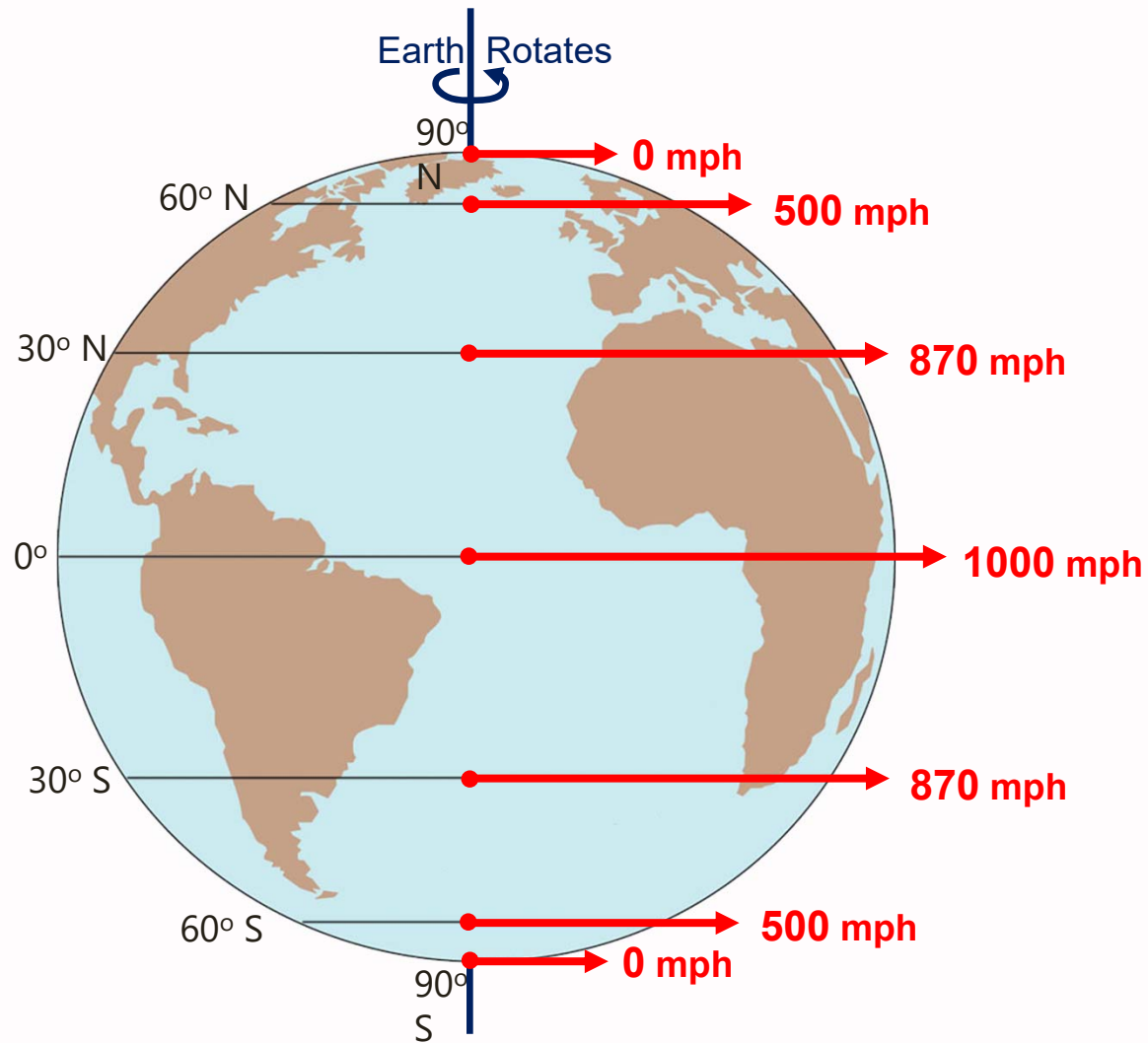
Hadley Cells

Ferrel Cell

Atmospheric Circulation: Part One

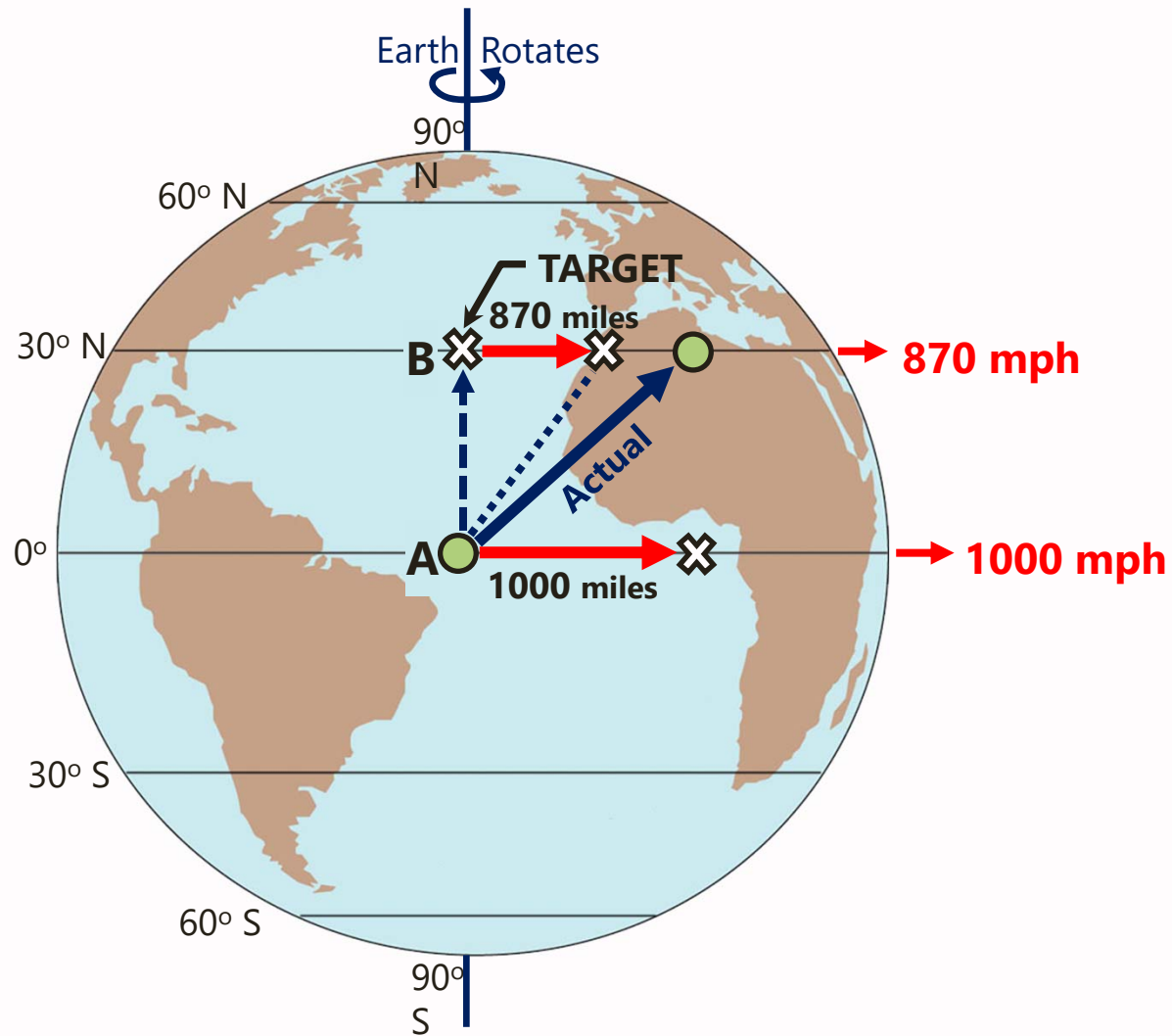


Coriolis Effect



**Speed of Earth's
Surface Rotation**

Coriolis Effect

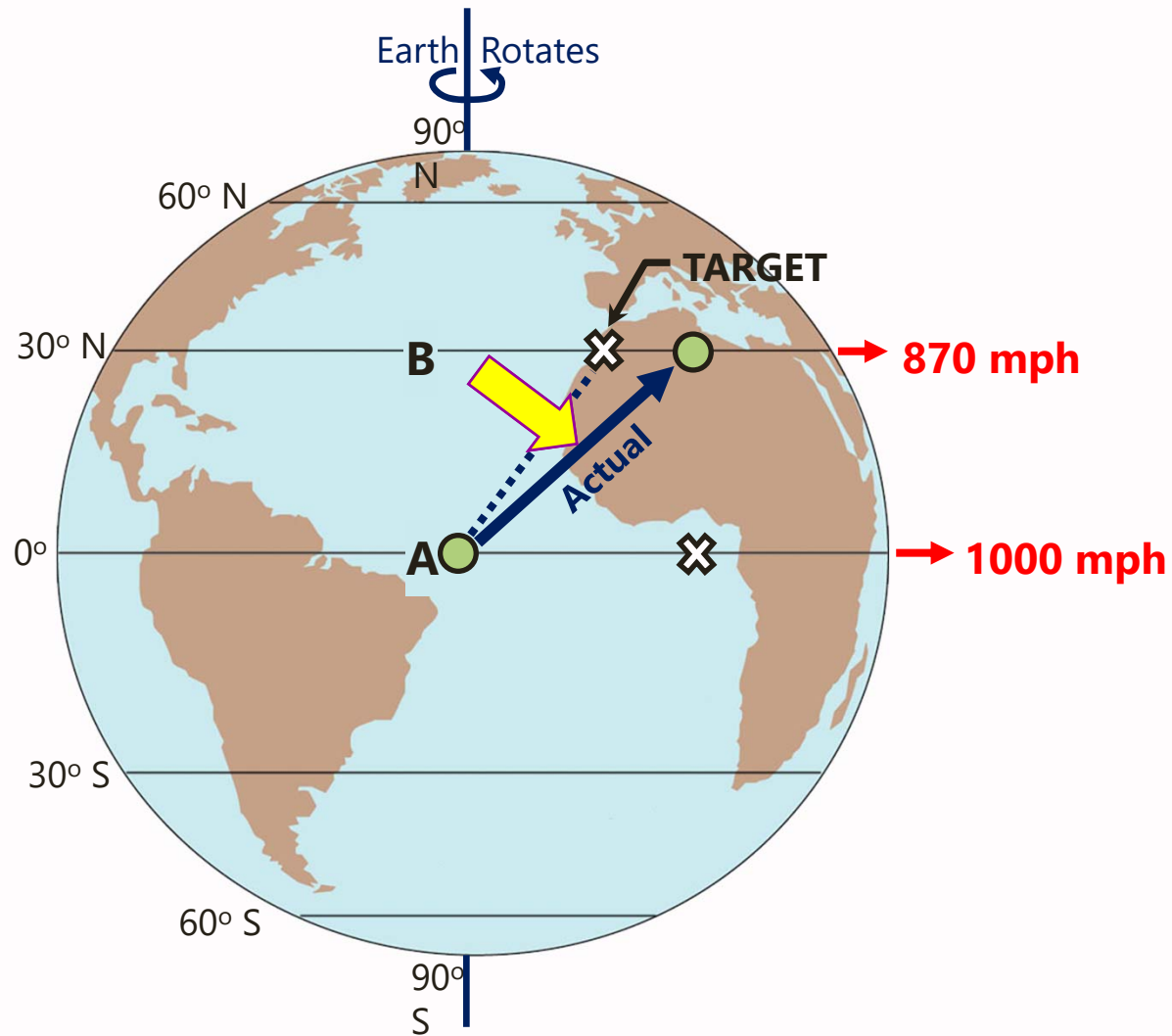


Throw a ball from
A to B

North Hemisphere

Coriolis Effect



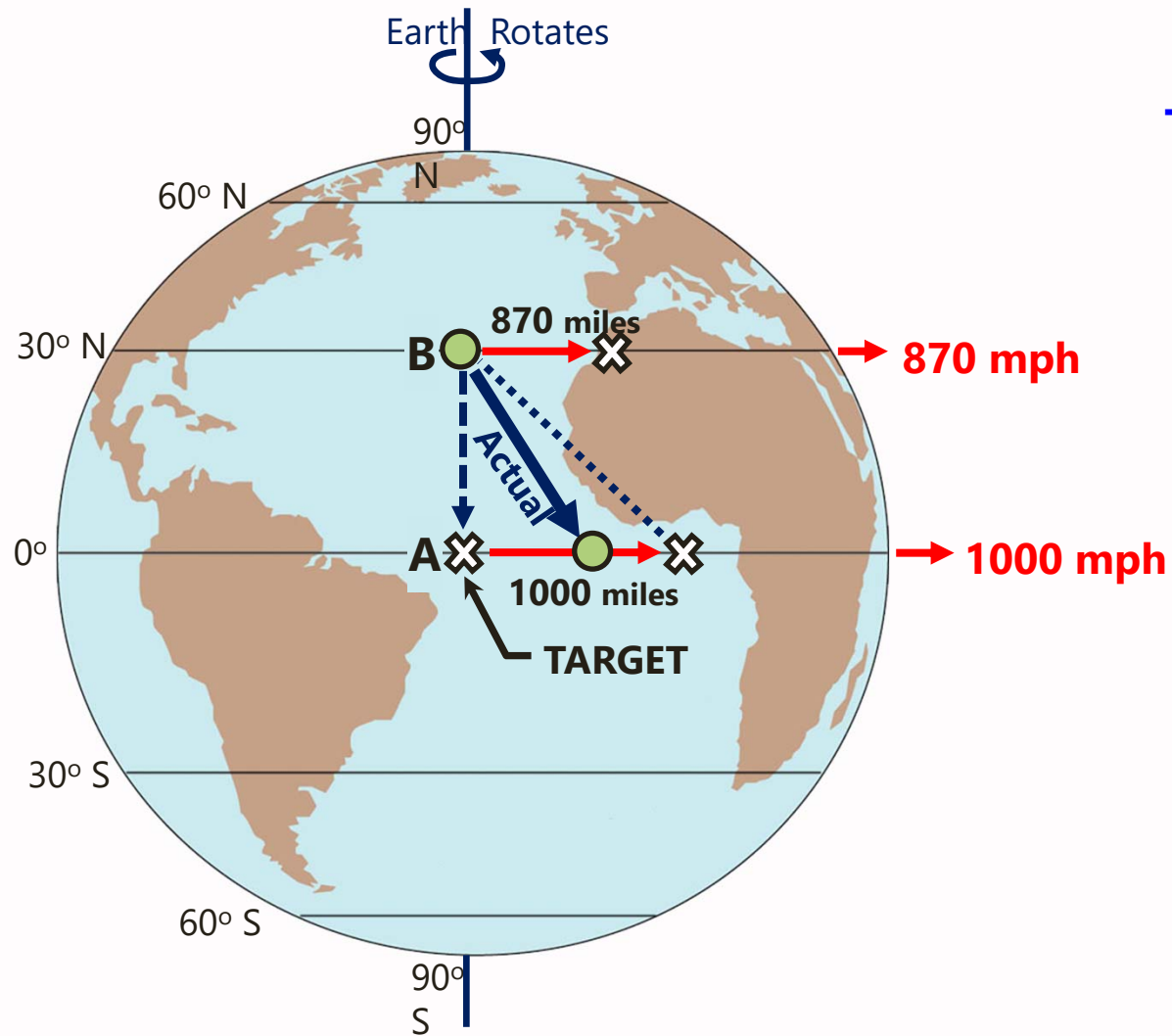


Throw a ball from
A to B

North Hemisphere

*Motion deflects to
the RIGHT of the
expected path*

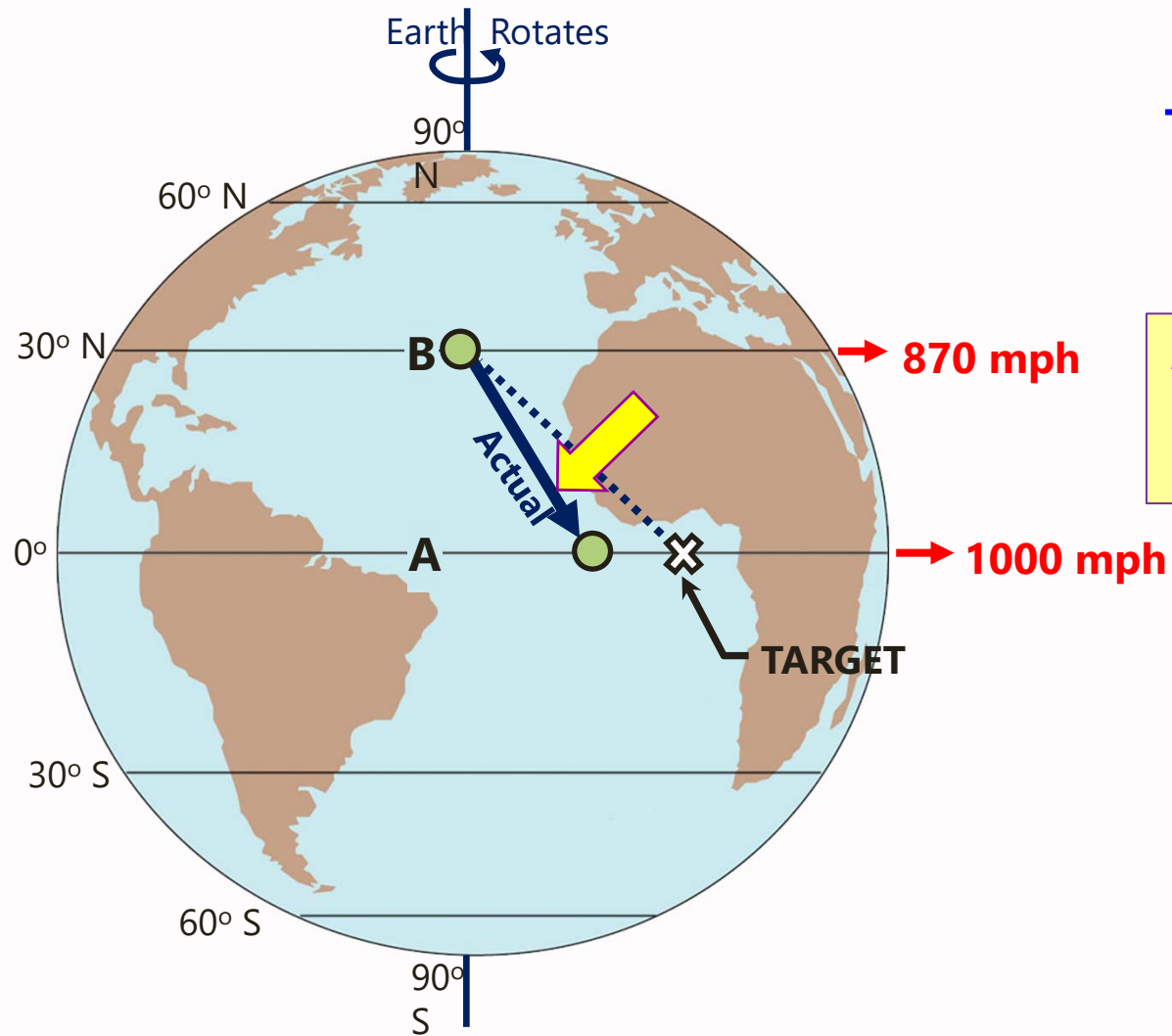
Coriolis Effect



Throw a ball from
B to A

North Hemisphere

Coriolis Effect

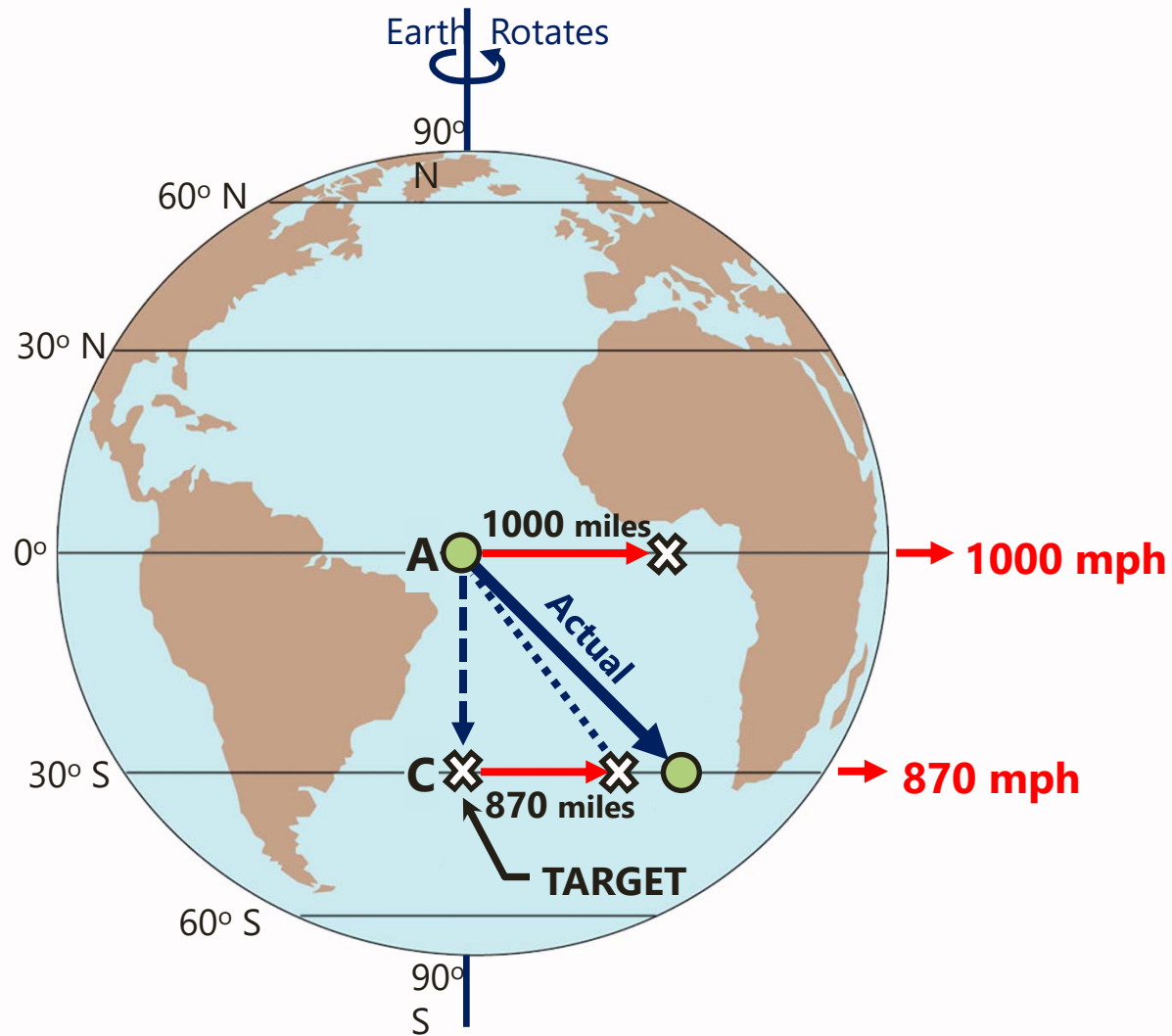


Throw a ball from
B to A

North Hemisphere

*Motion deflects to
the RIGHT of the
expected path*

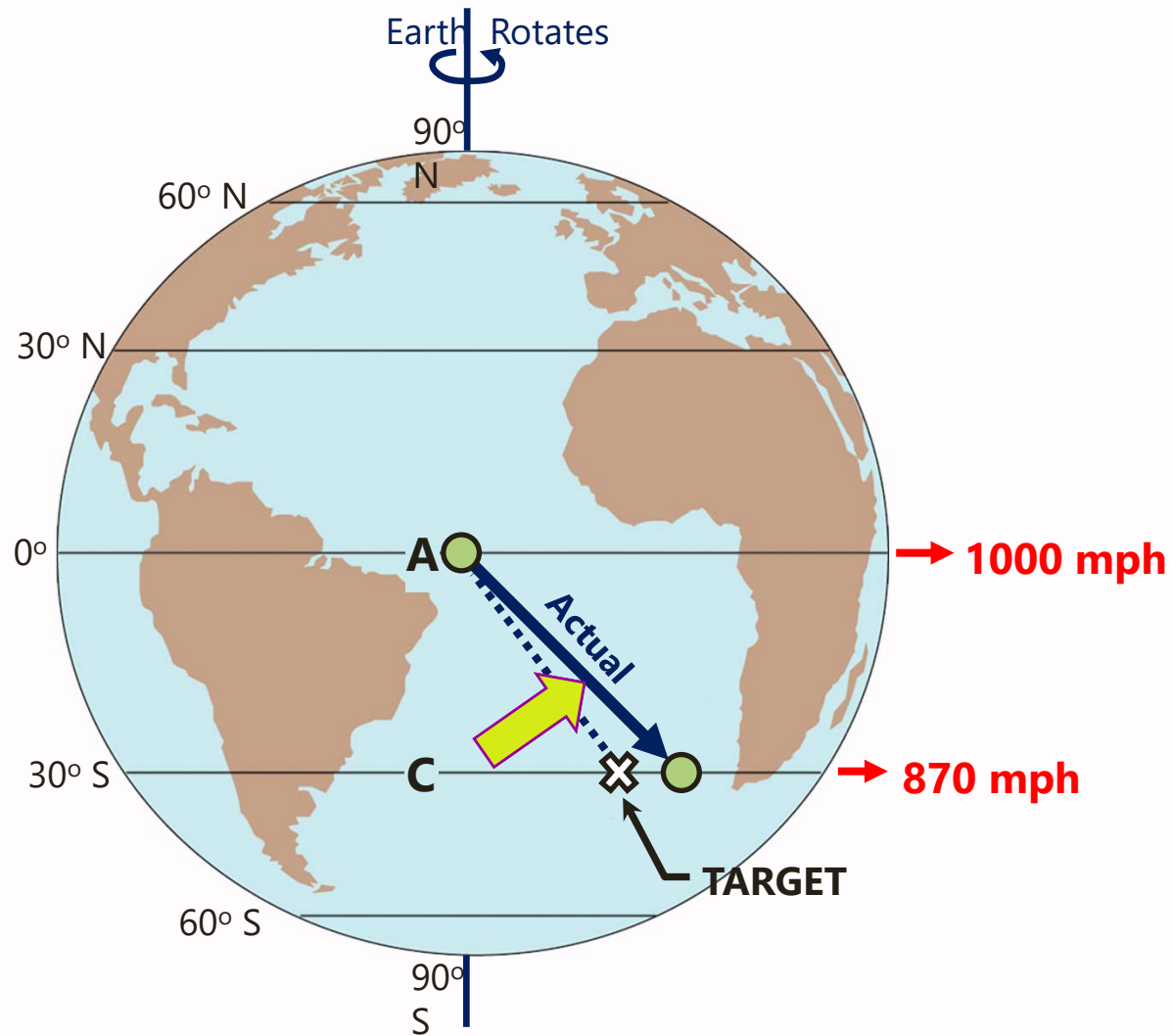
Coriolis Effect



Throw a ball from
A to C

South Hemisphere

Coriolis Effect

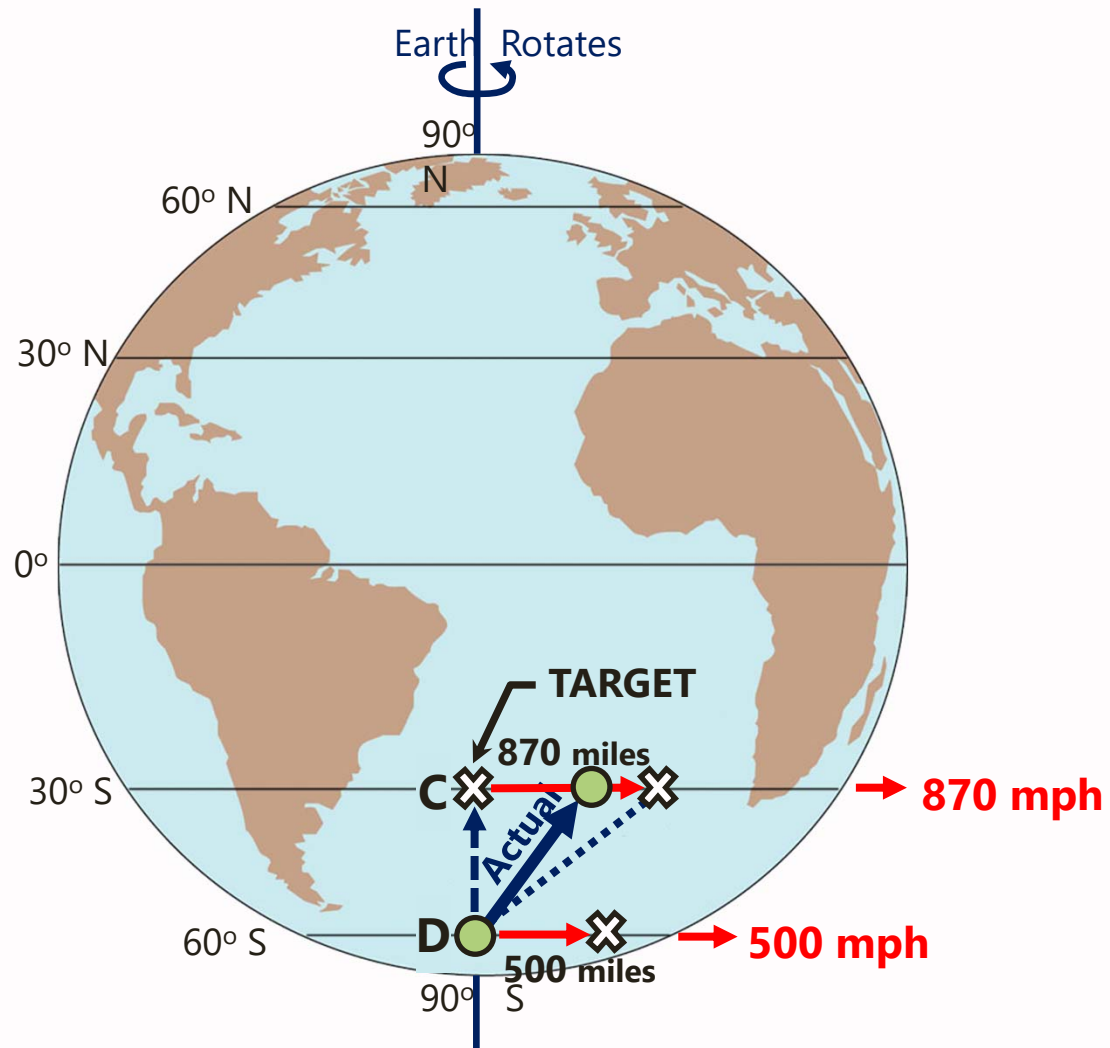


Throw a ball from
A to C

South Hemisphere

*Motion deflects to
the LEFT of the
expected path*

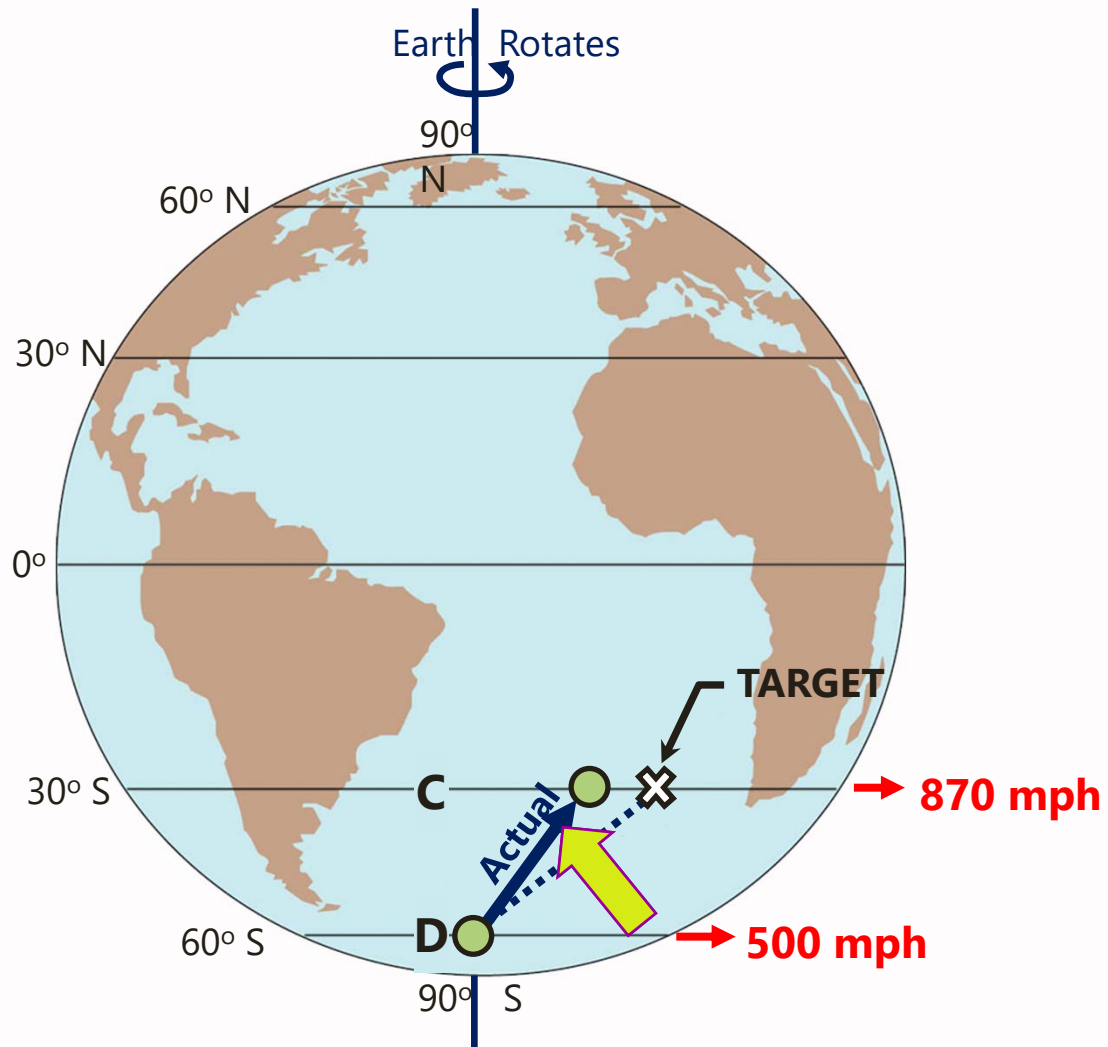
Coriolis Effect



Throw a ball from
D to C

South Hemisphere

Coriolis Effect



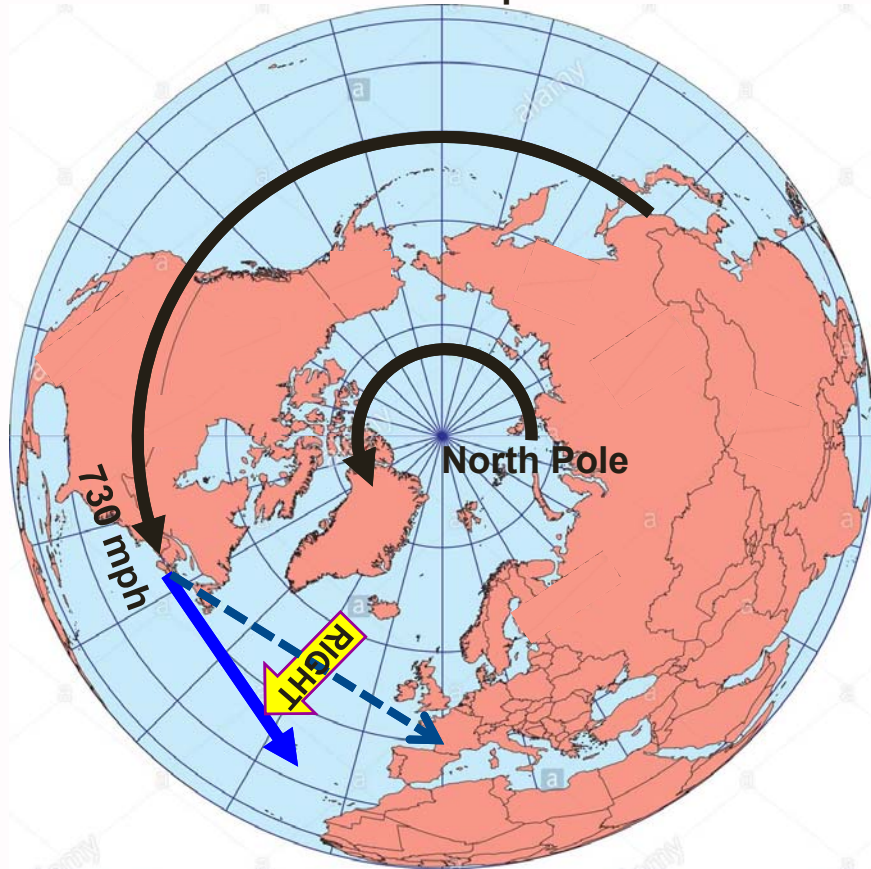
Throw a ball from
D to C

South Hemisphere

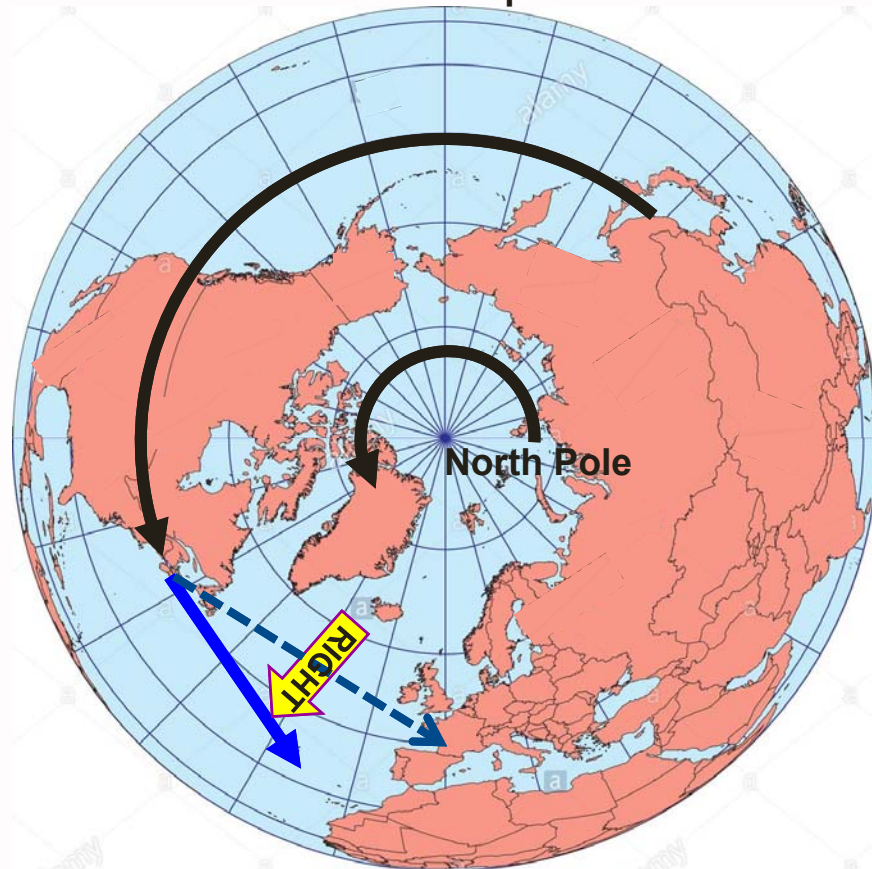
*Motion deflects to
the LEFT of the
expected path*

Coriolis Effect

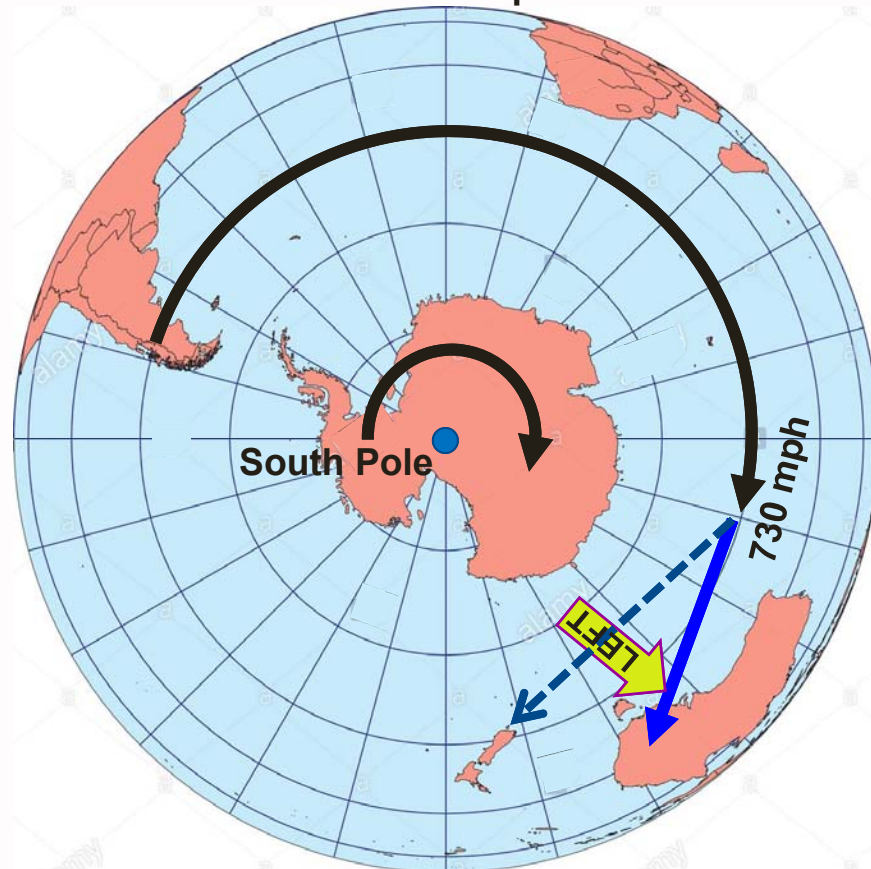
View from Above North Hemisphere

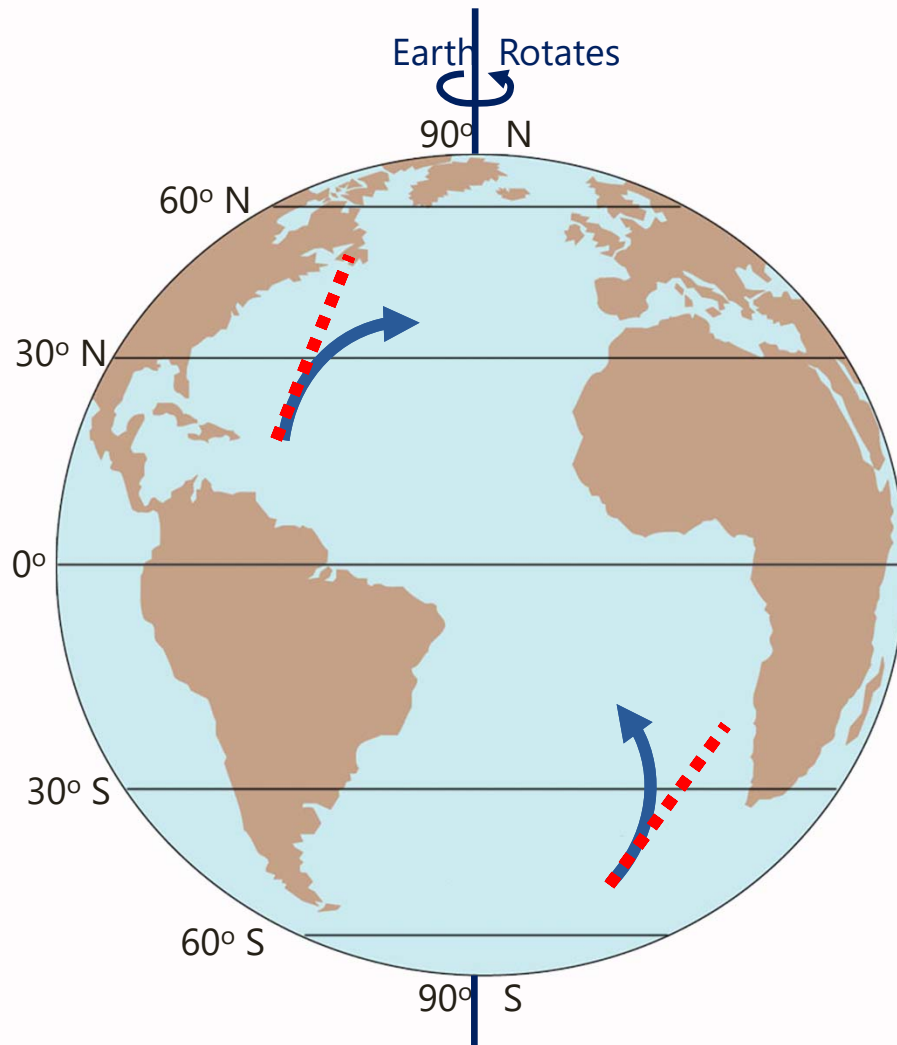


View from Above
North Hemisphere



View from Below
South Hemisphere

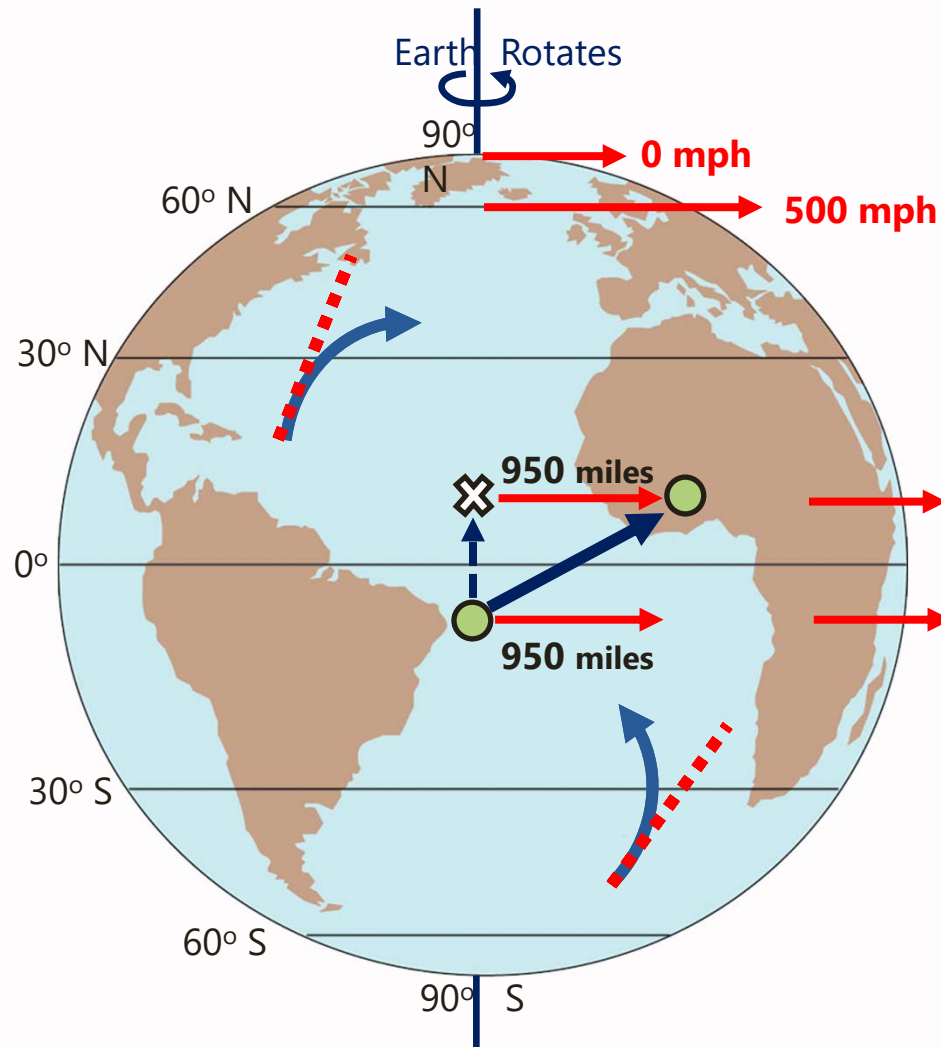




***NORTH Hemisphere:
Motion deflects to the
RIGHT of the expected path***

***SOUTH Hemisphere:
Motion deflects to the
LEFT of the expected path***

Coriolis Effect



At the Poles, there is *maximum* Coriolis Effect

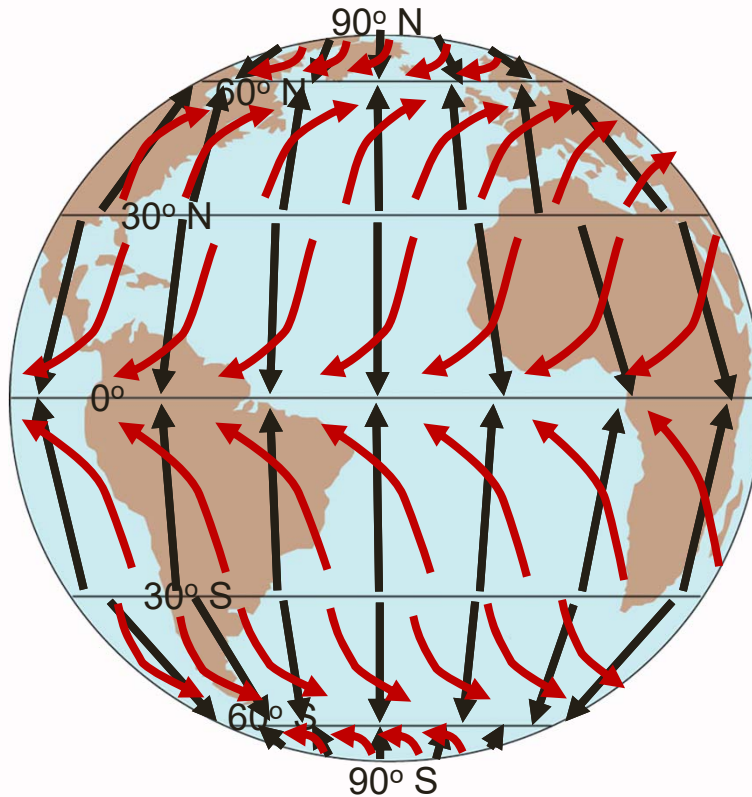
NORTH Hemisphere:
Motion deflects to the RIGHT of the expected path

Across and near the Equator, there is *little* Coriolis Effect

SOUTH Hemisphere:
Motion deflects to the LEFT of the expected path

Coriolis Effect

Polar Cells



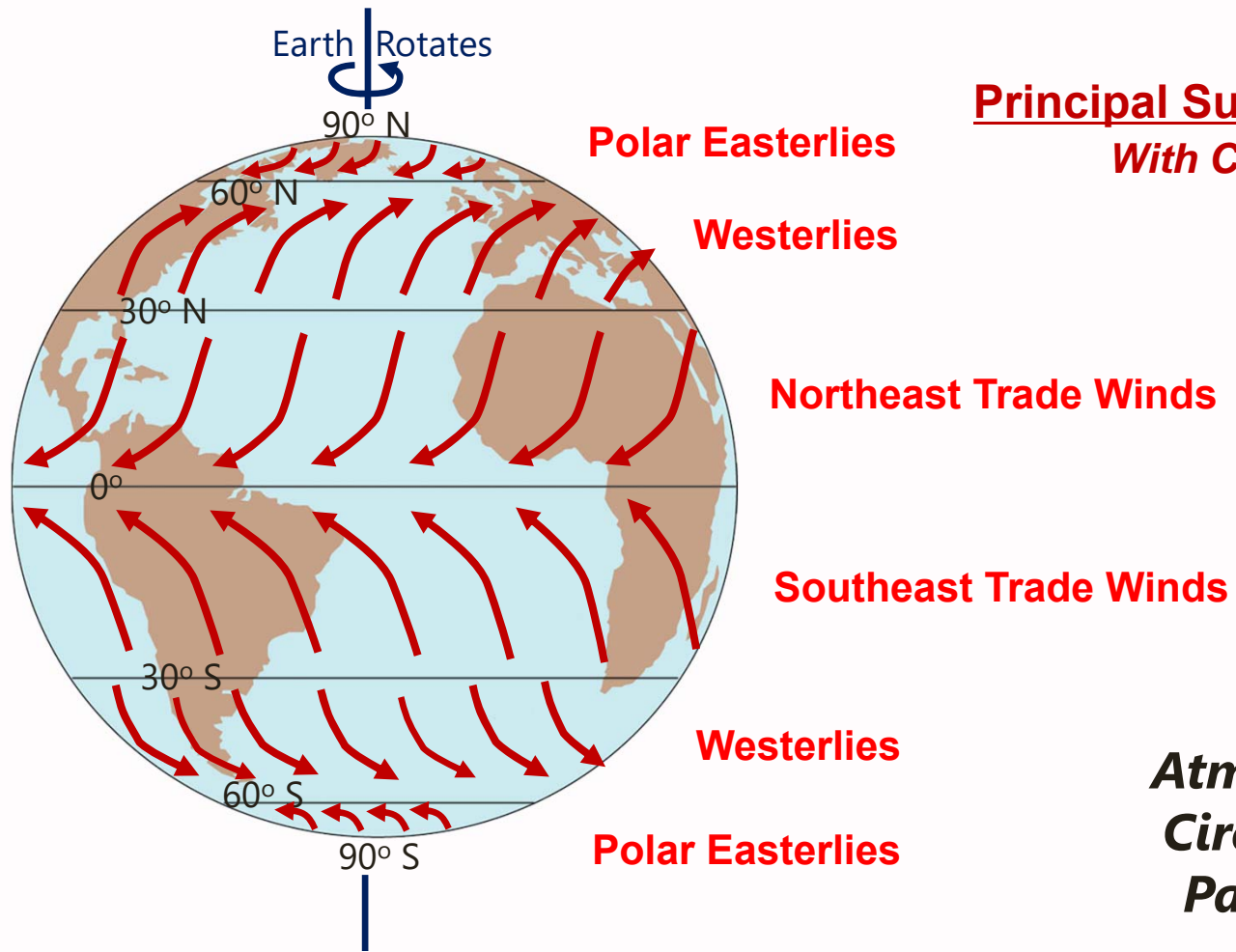
Principal Surface Winds
Ferrel Cell ***With Coriolis Effect***

*Principal surface wind
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Hadley Cells

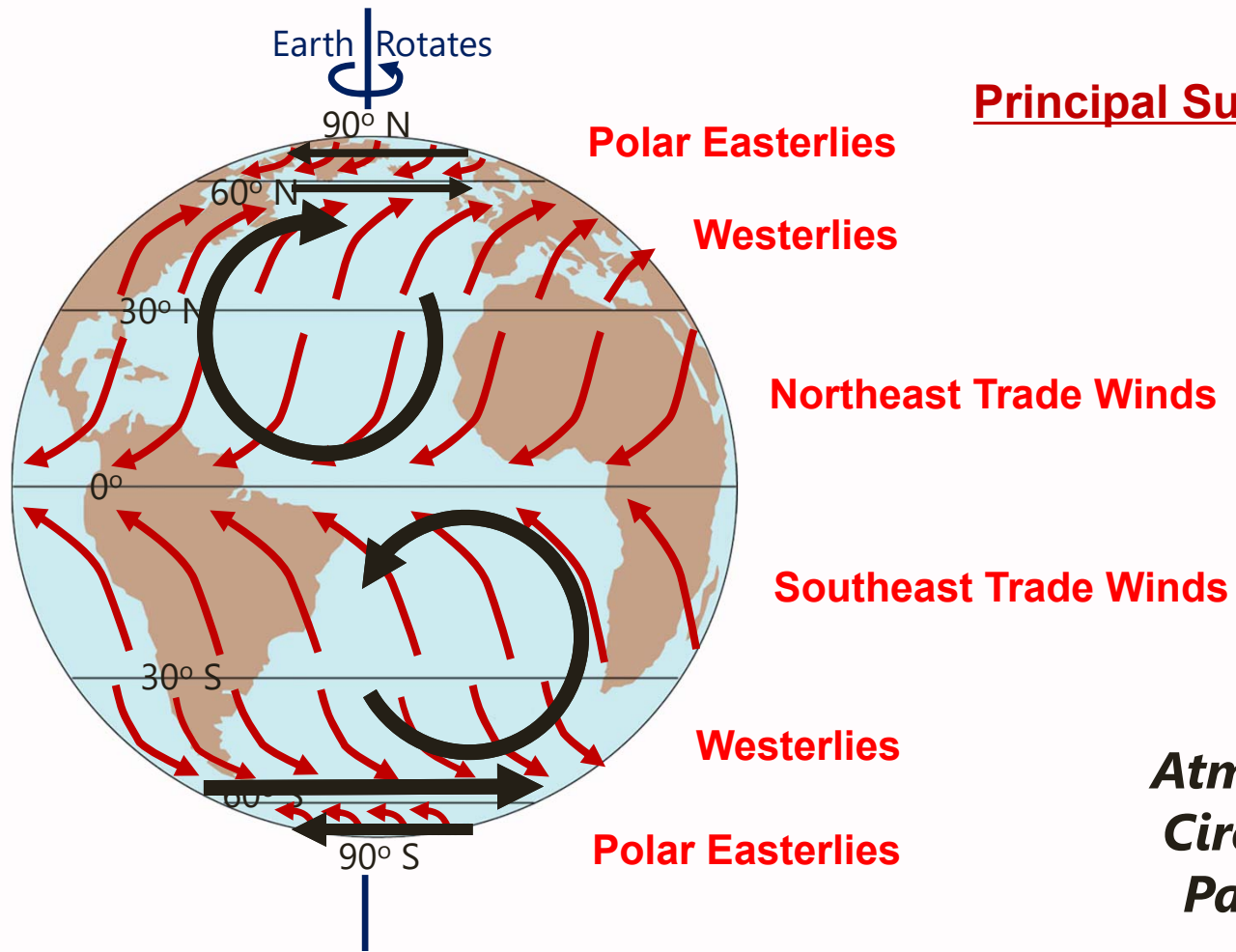
Ferrel Cell

**Atmospheric
Circulation:
Part TWO**



Principal Surface Winds
With Coriolis Effect

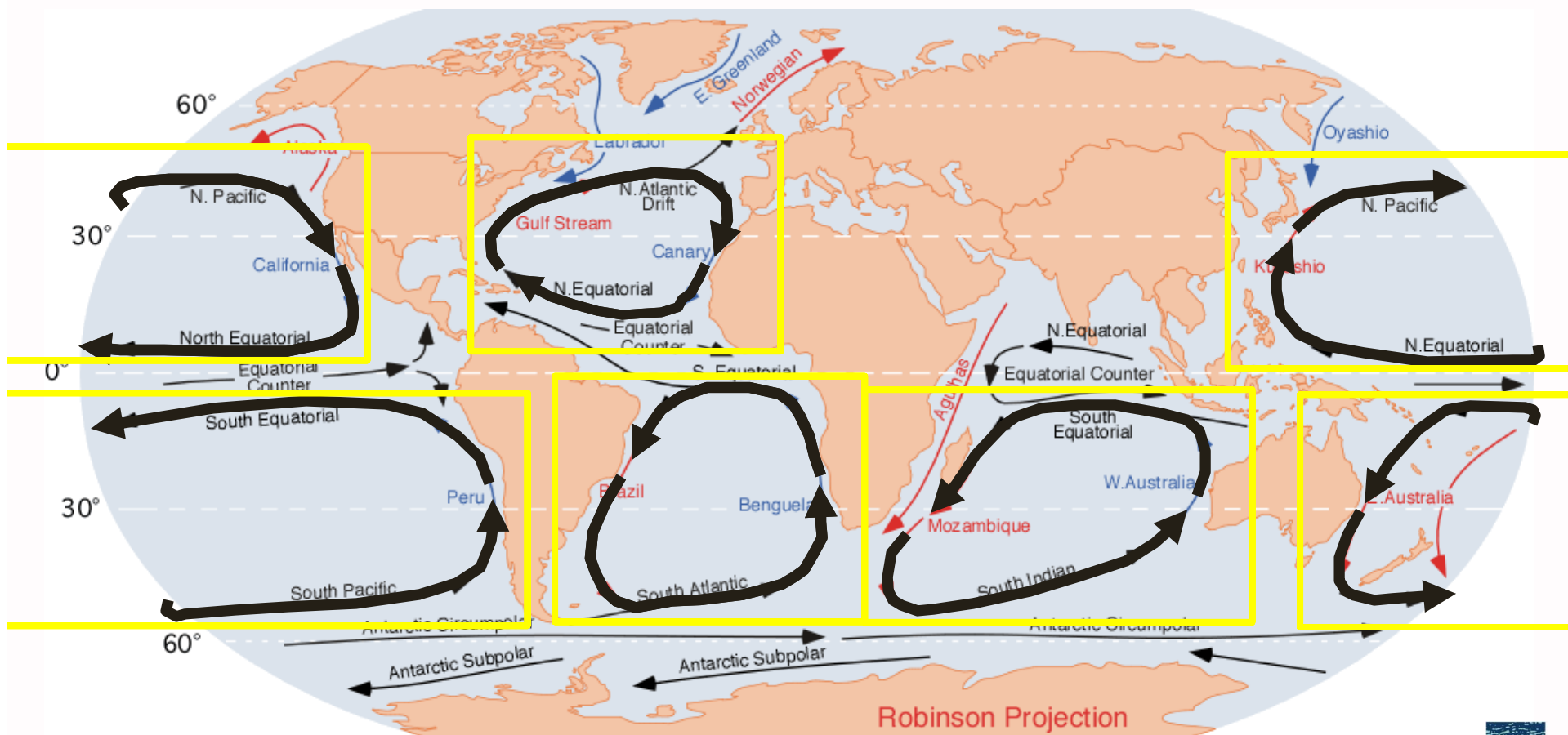
***Atmospheric
 Circulation:
 Part TWO***



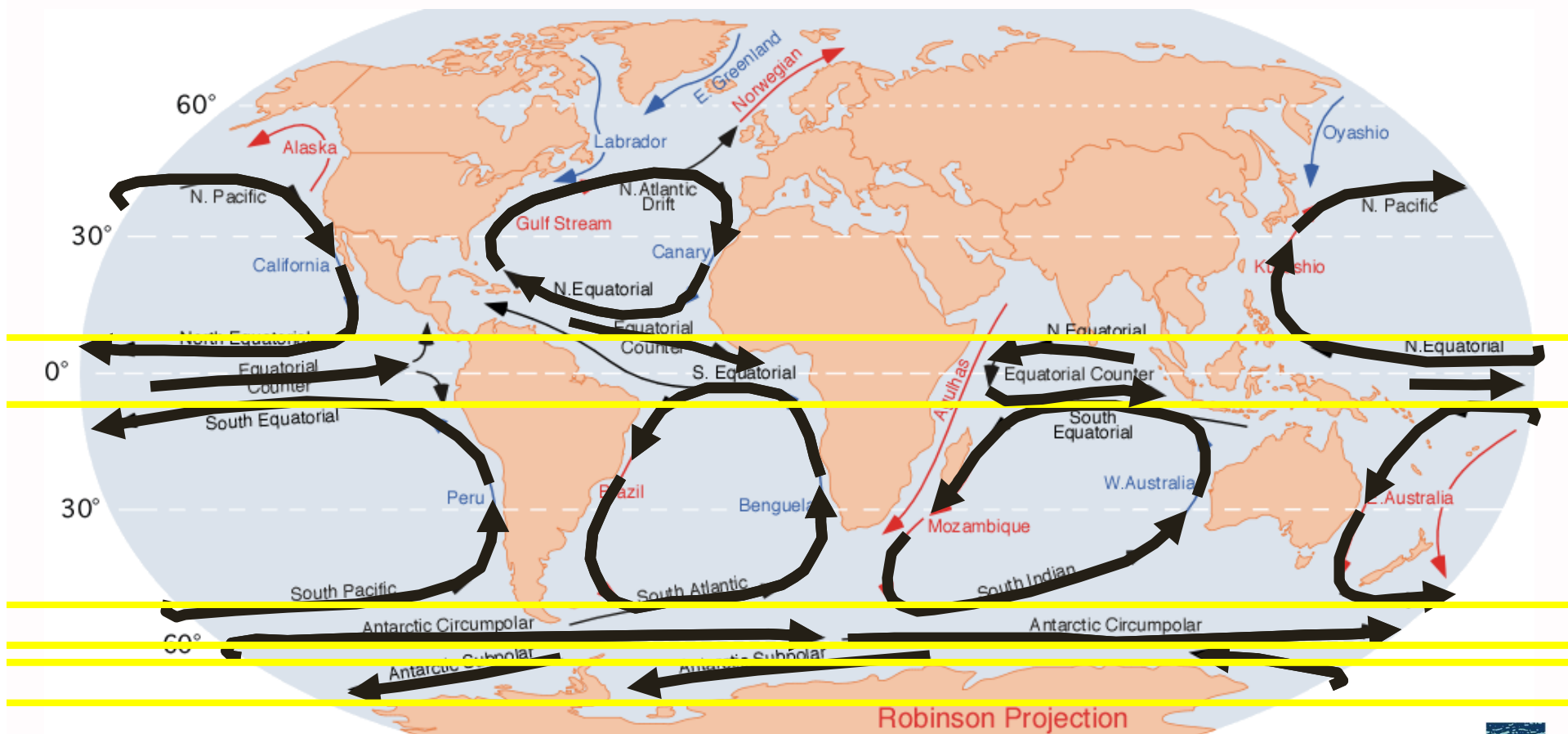
Principal Surface Winds

Atmospheric Circulation: Part TWO

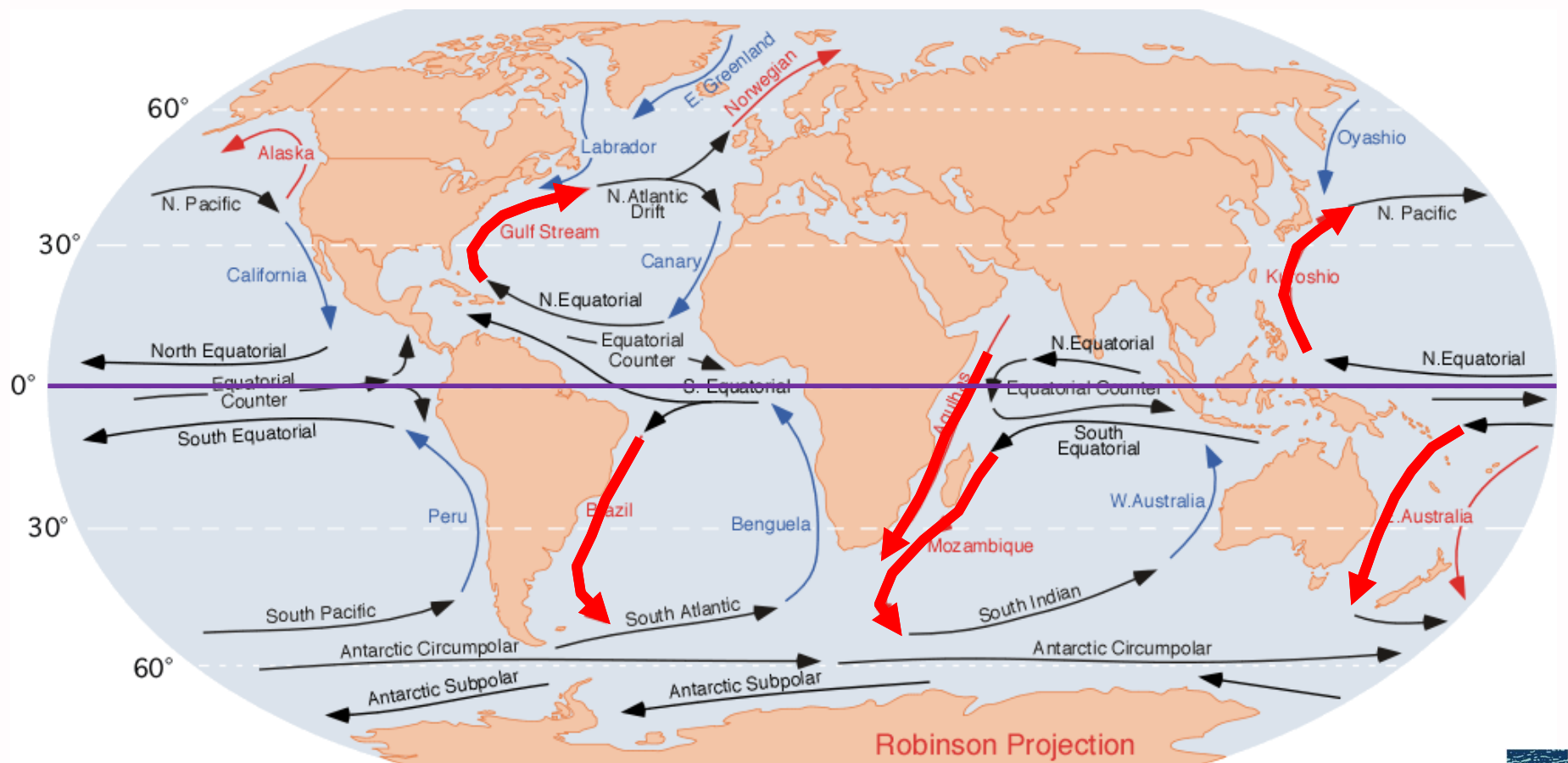




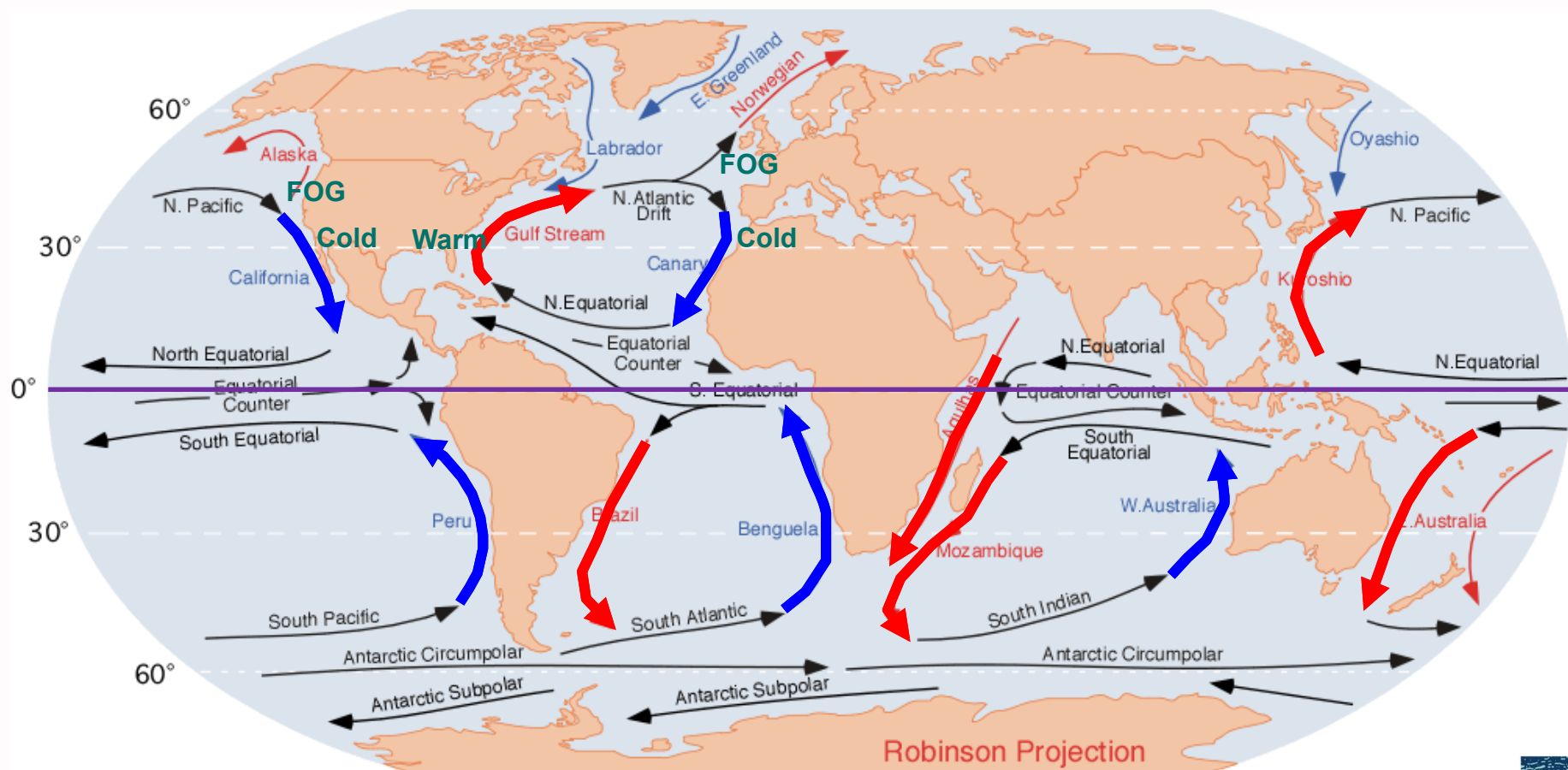
Surface Ocean Currents – uppermost 10% of world ocean



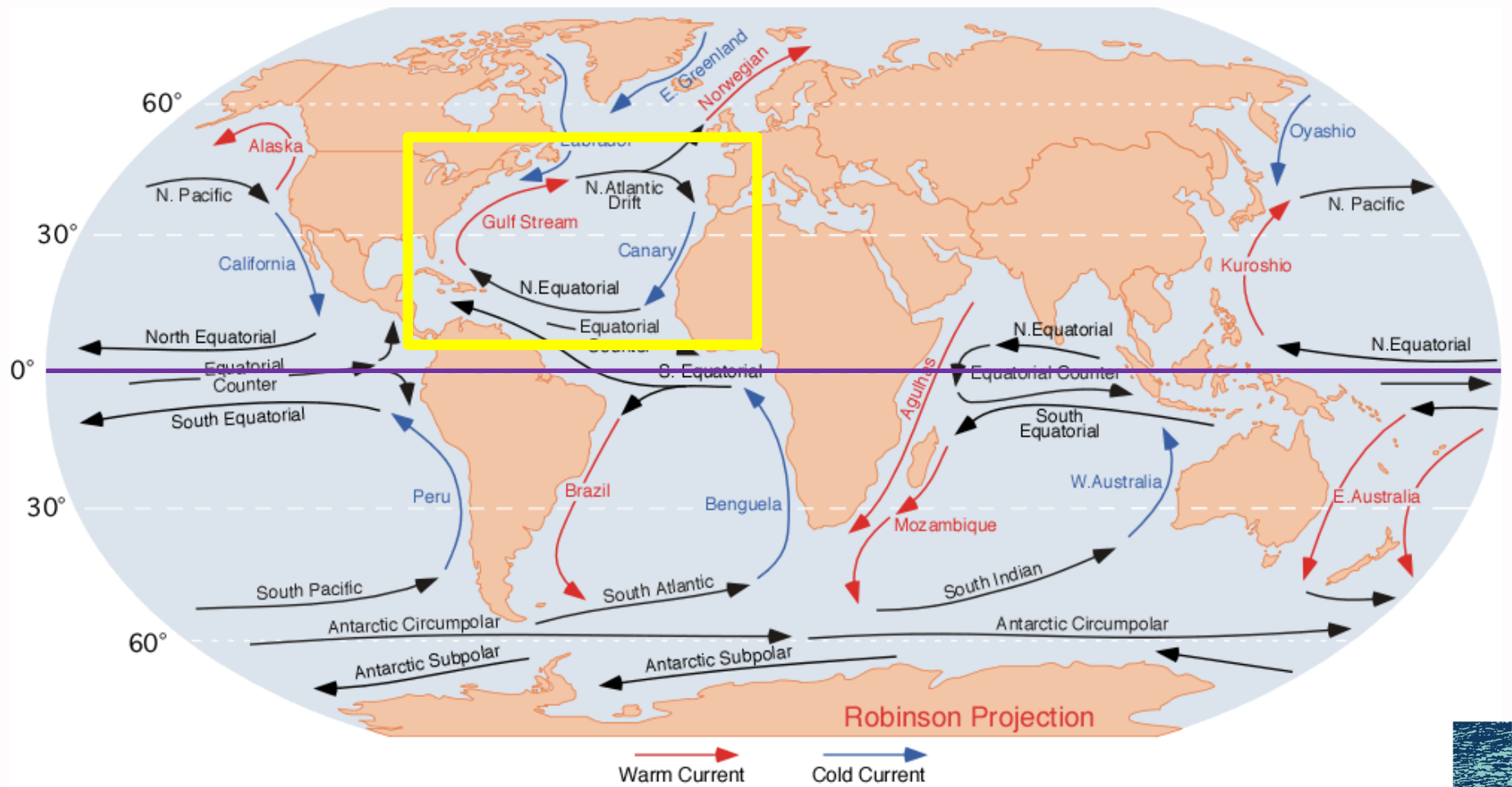
Surface Ocean Currents – uppermost 10% of world ocean

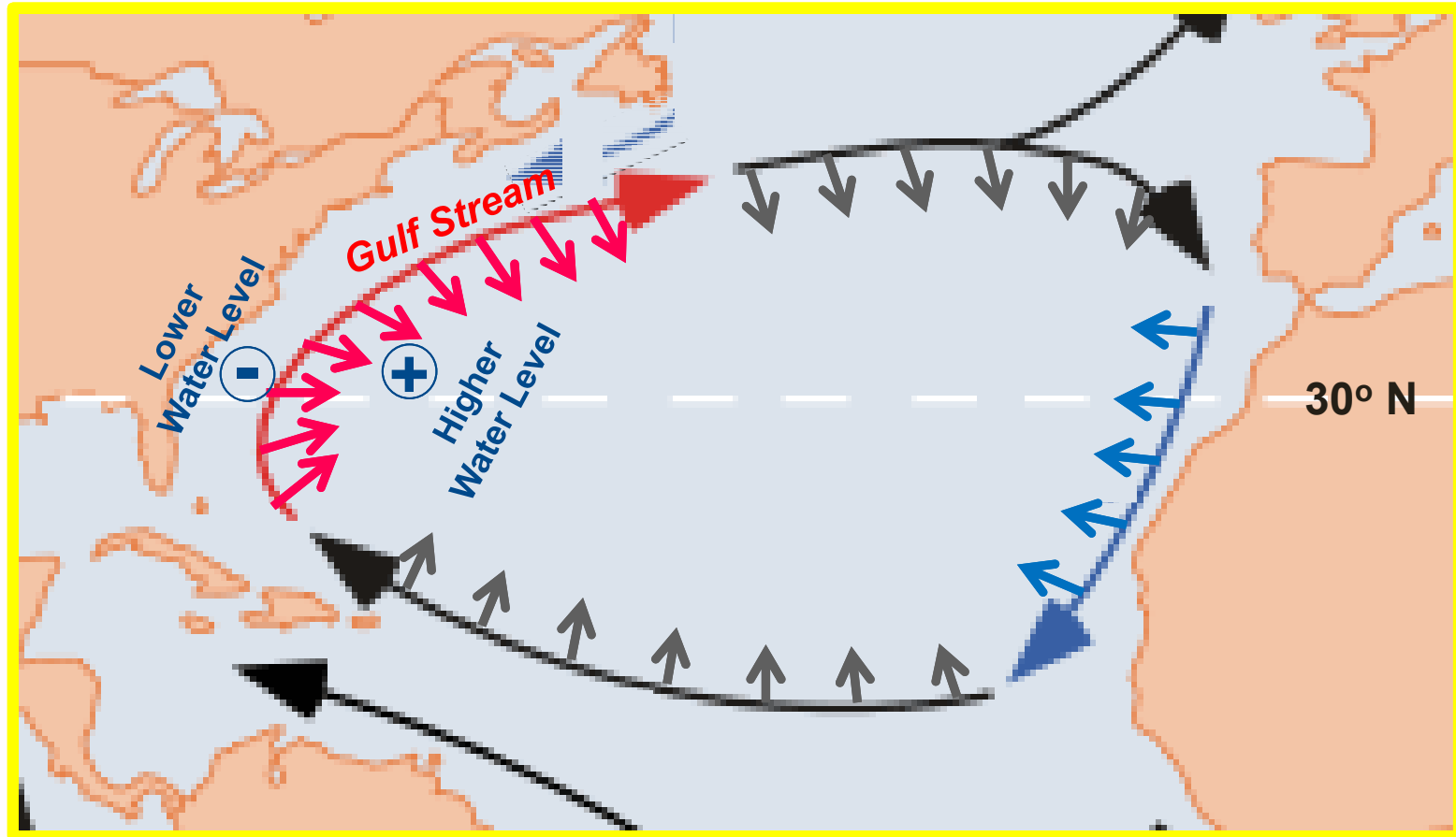


Western boundary currents are strongest (and warm)

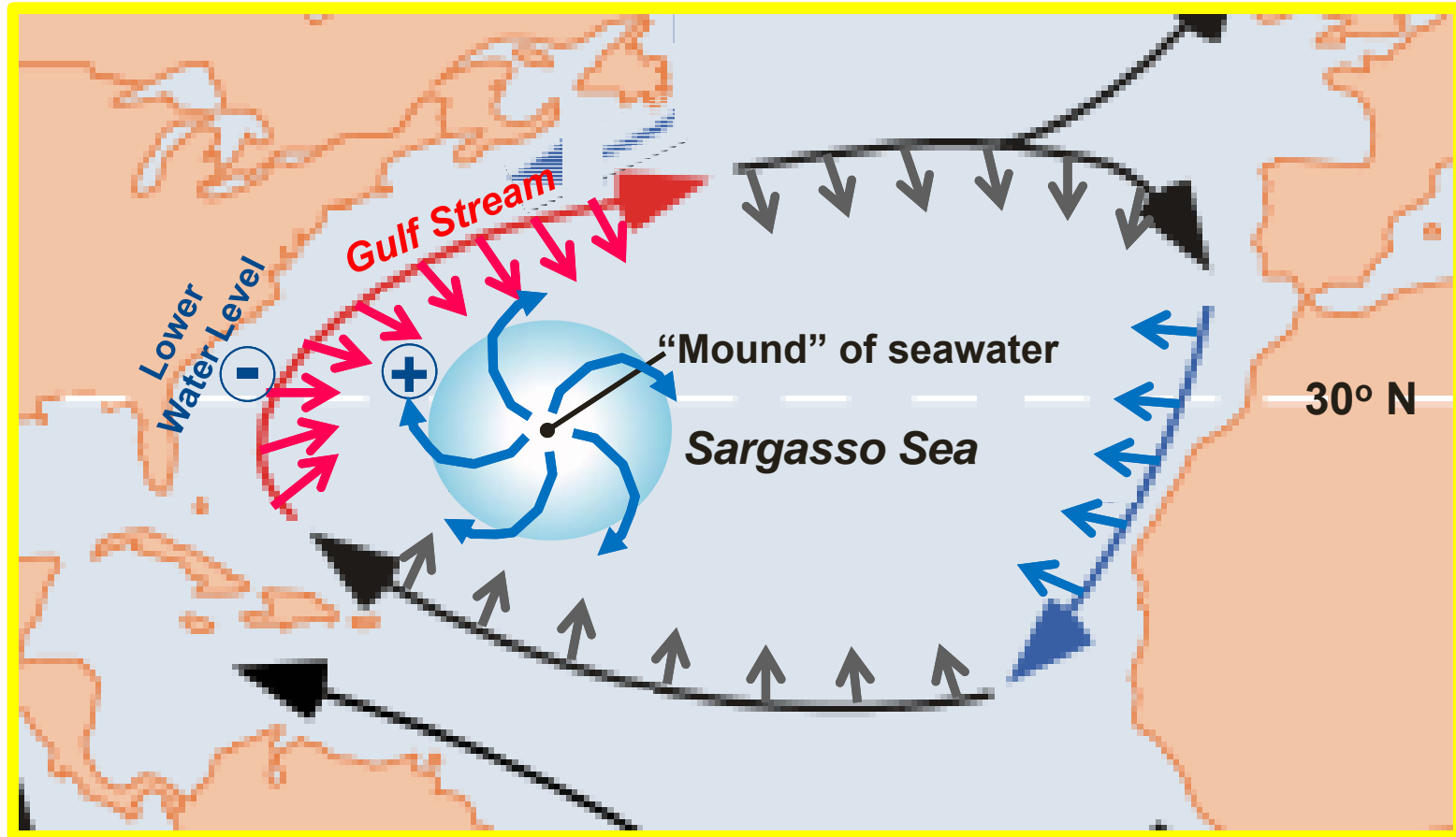


Eastern boundary currents are weakest (and cold)

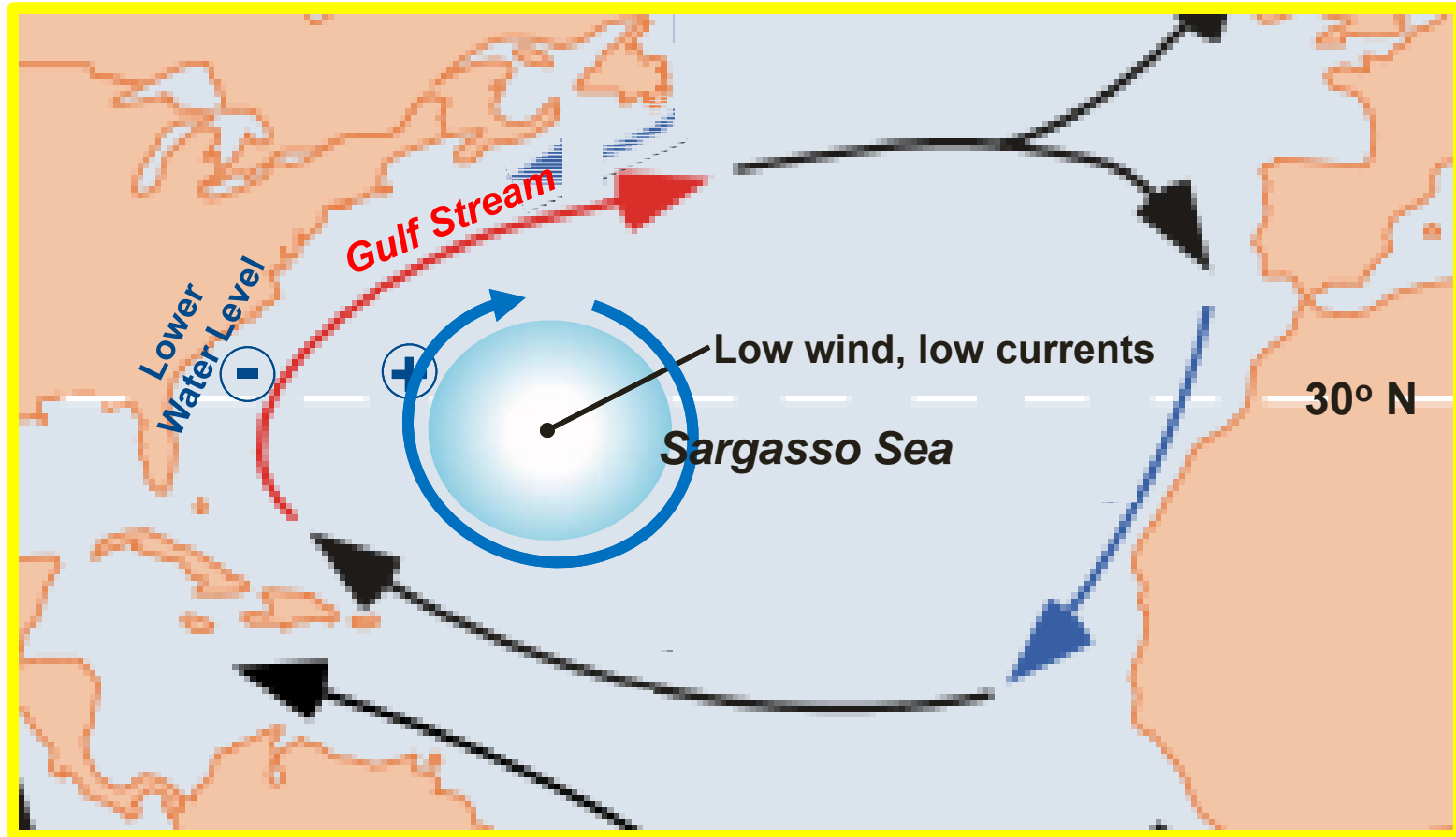




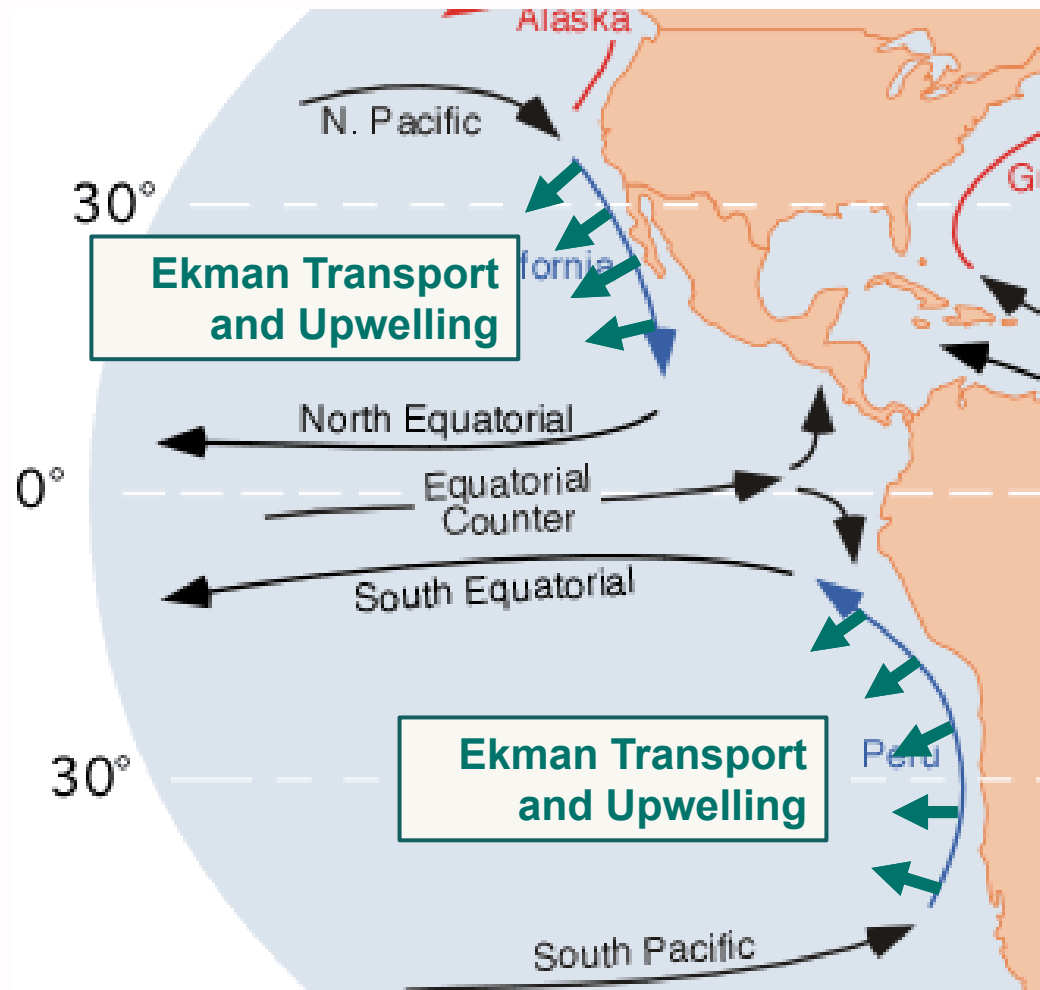
Ekman Transport

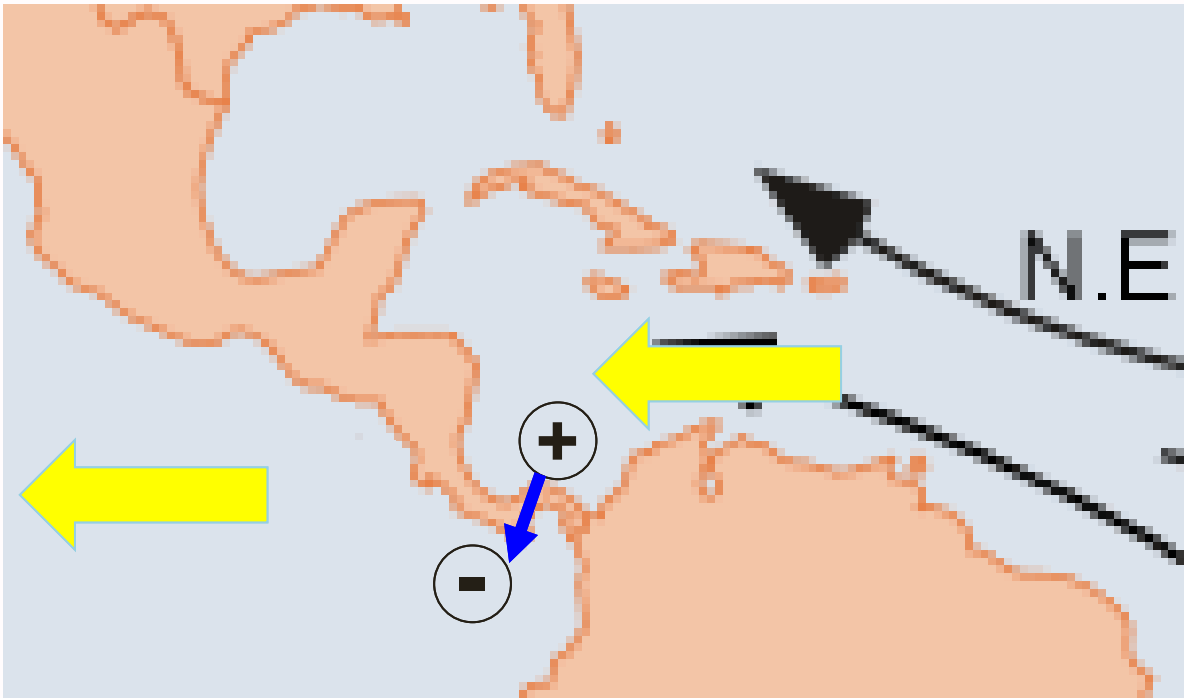


Sargasso Sea



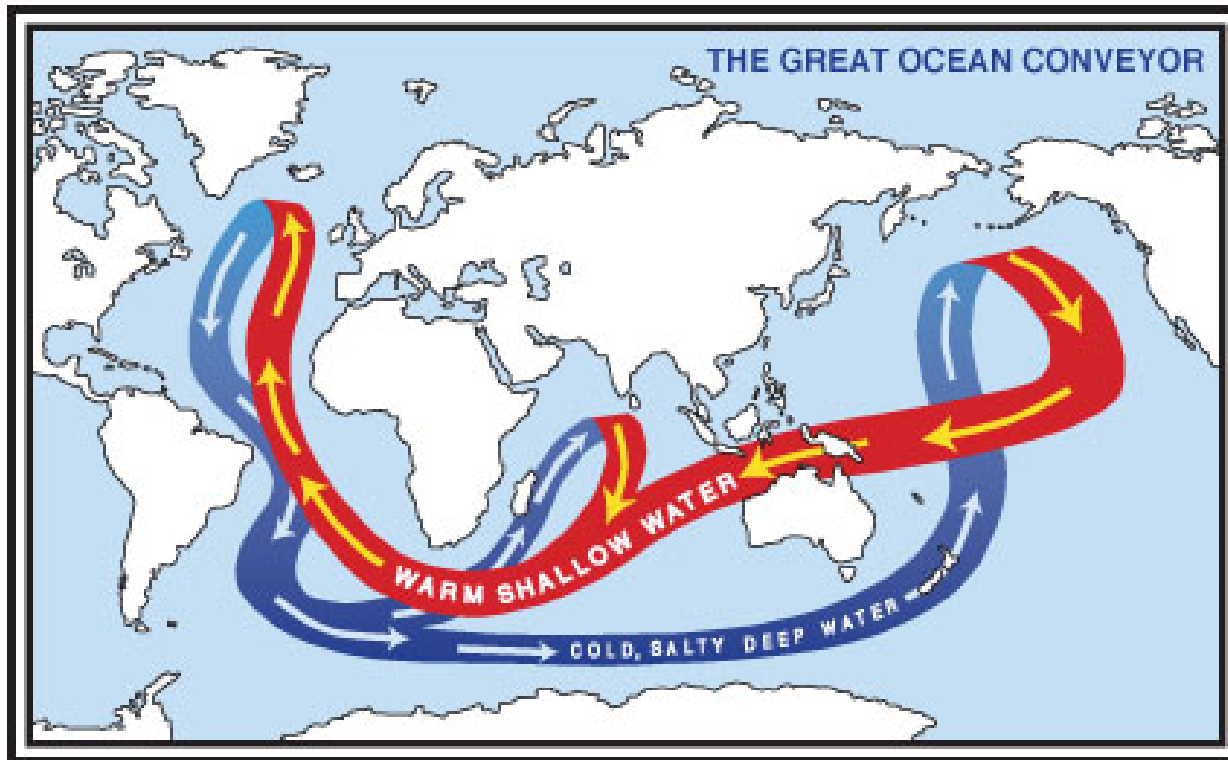
Sargasso Sea





Panama Canal Zone





90% of ocean circulation is below the surface flow:

THERMOHALINE CIRCULATION

That's a topic for another day....



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