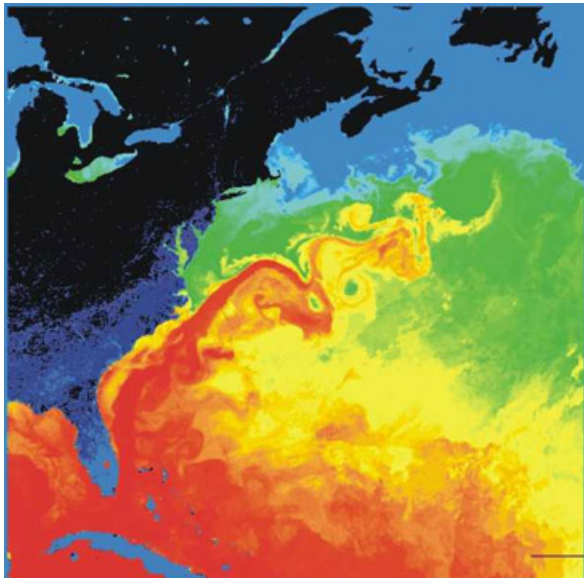
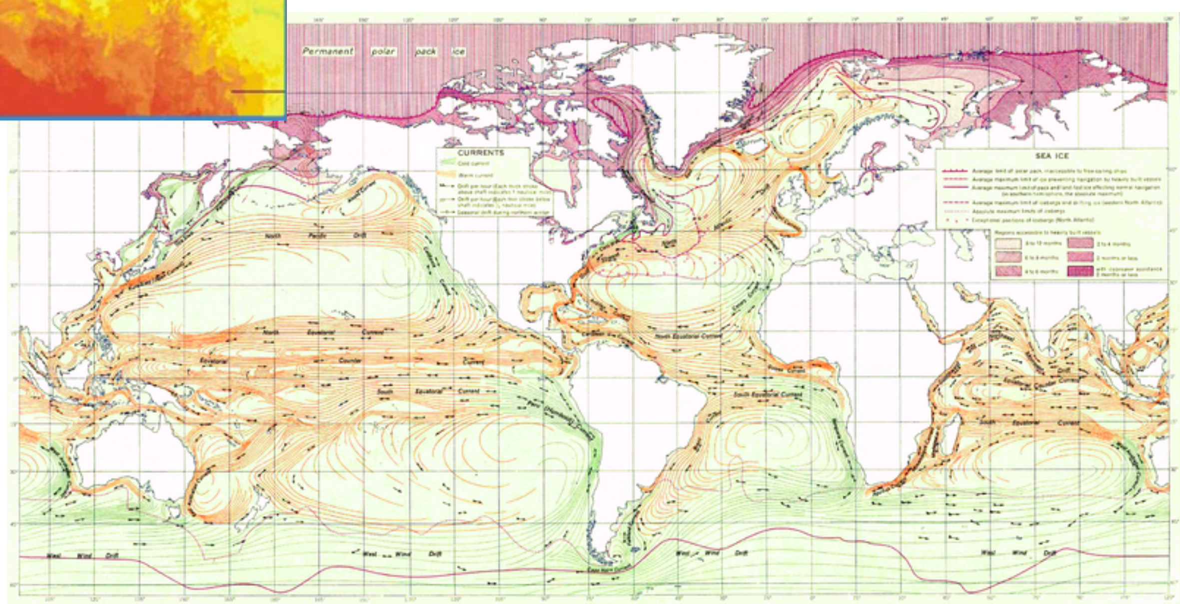
Η κυκλοφορία στον παγκόσμιο ωκεανό

3. The restless world ocean (observing the oceanic circulation)

Sarantis Sofianos
Dept. of Physics, University of Athens



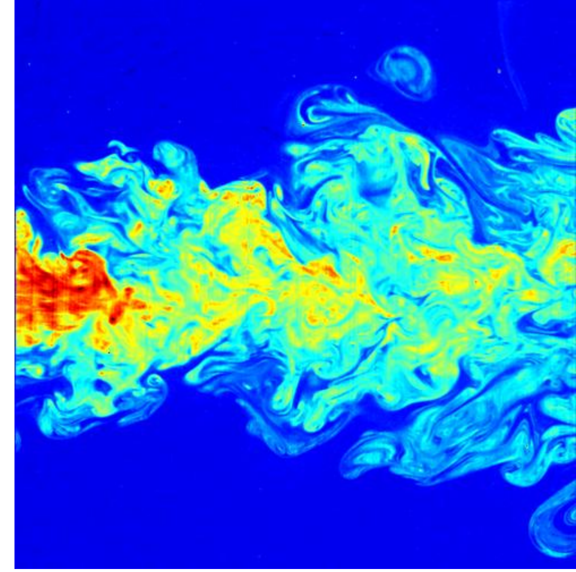


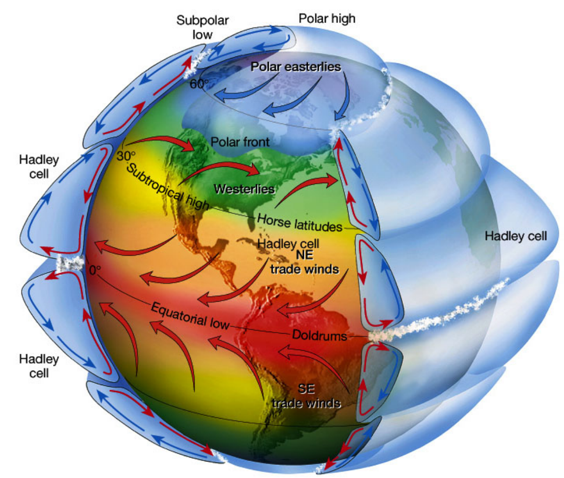
Forcing Mechanisms

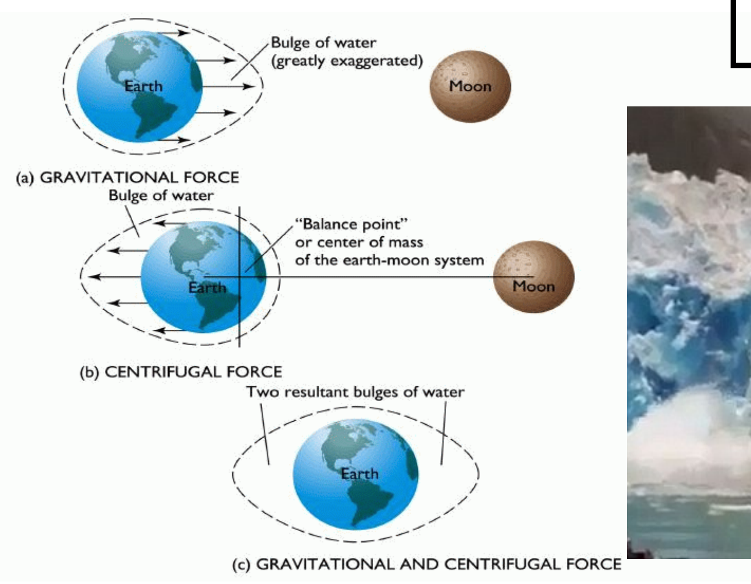
- Winds and Friction
- Heat Transfer
- Evaporation
- Precipitation
- River runoff
- Glacier formation/melting
- Astronomical forcing
- Ocean bottom changes

Ocean Response

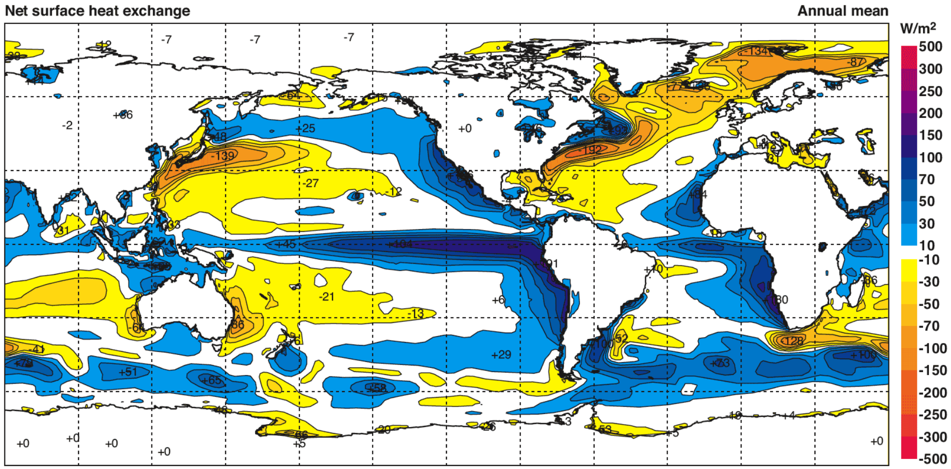
✓Ocean Currents
✓Wind waves
✓Large scale waves
✓Tides
✓Internal waves
✓Upwelling/downwelling
✓Tsunamis
✓Turbulence and mixing
✓ …..



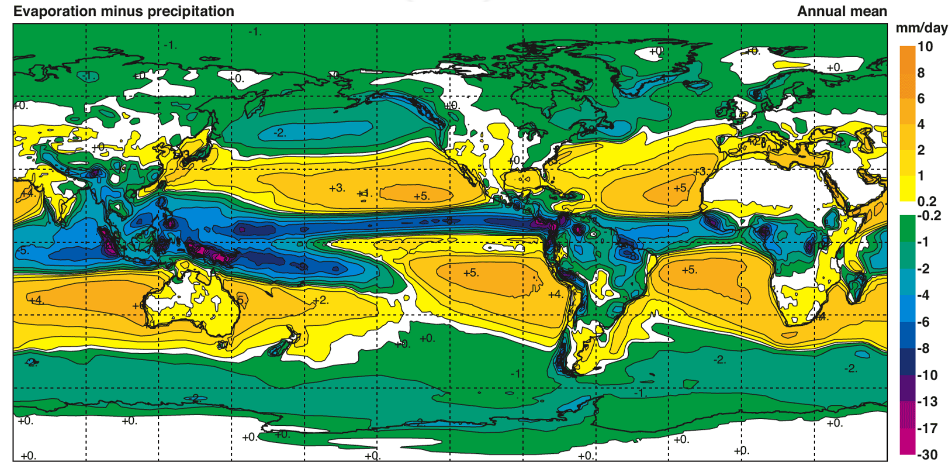




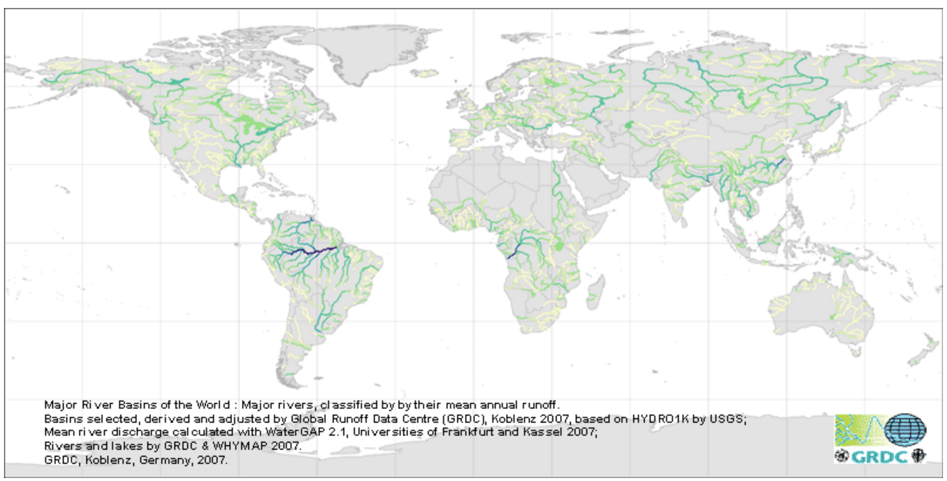
Global sea surface heat flux (Q_{NET})



Global sea surface evaporation-precipitation (E-P)



Global River Runoff (R)



BUOYANCY FORCING

Buoyancy

$$b' = -g\frac{\rho'}{\bar{\rho}}$$

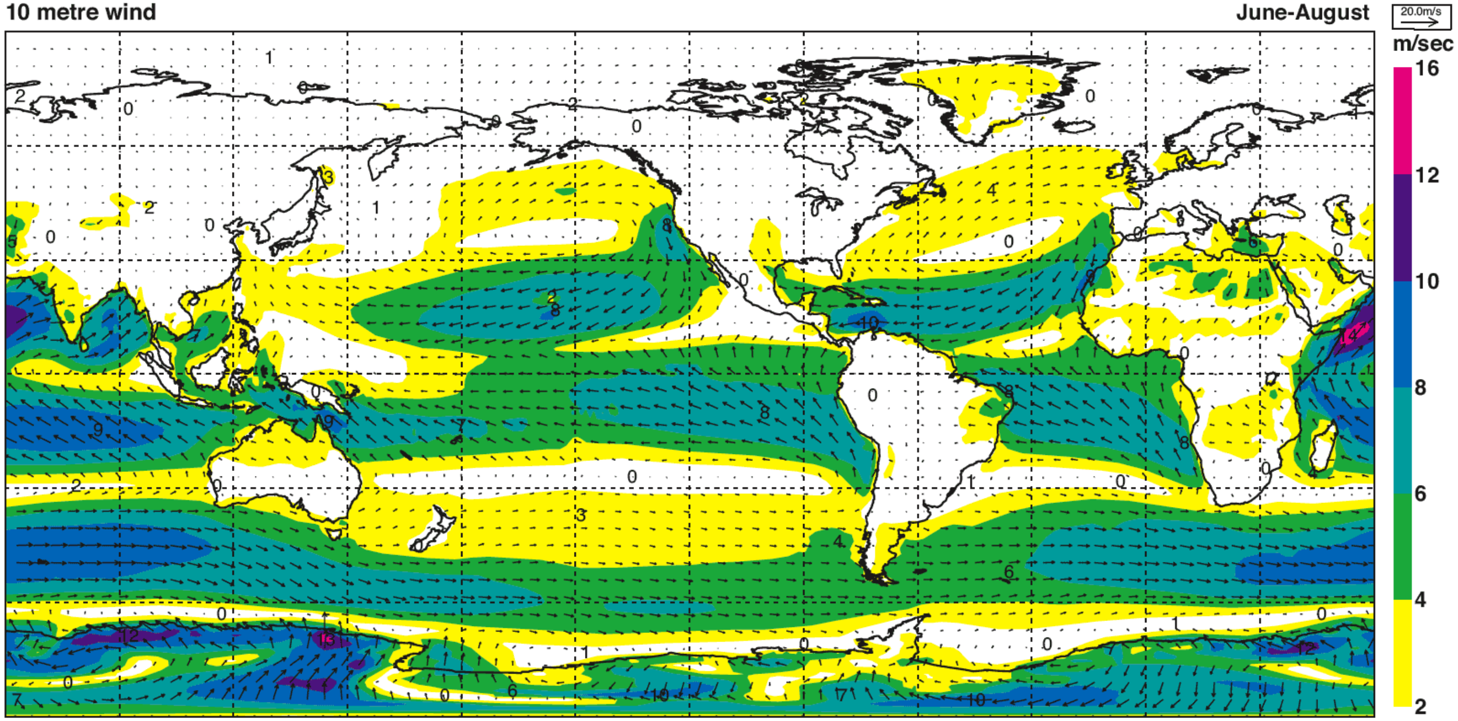
and Buoyancy Flux due to heat and freshwater flux

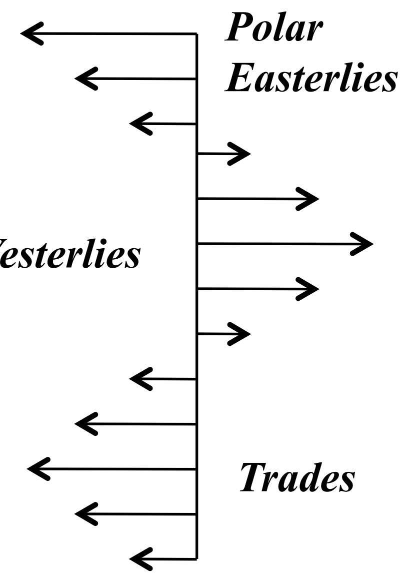
$$B = -g\alpha Q_{TOT}/\rho_w c_p + g\beta S\left(\frac{Q_L}{L_V} - \Pr\right)$$

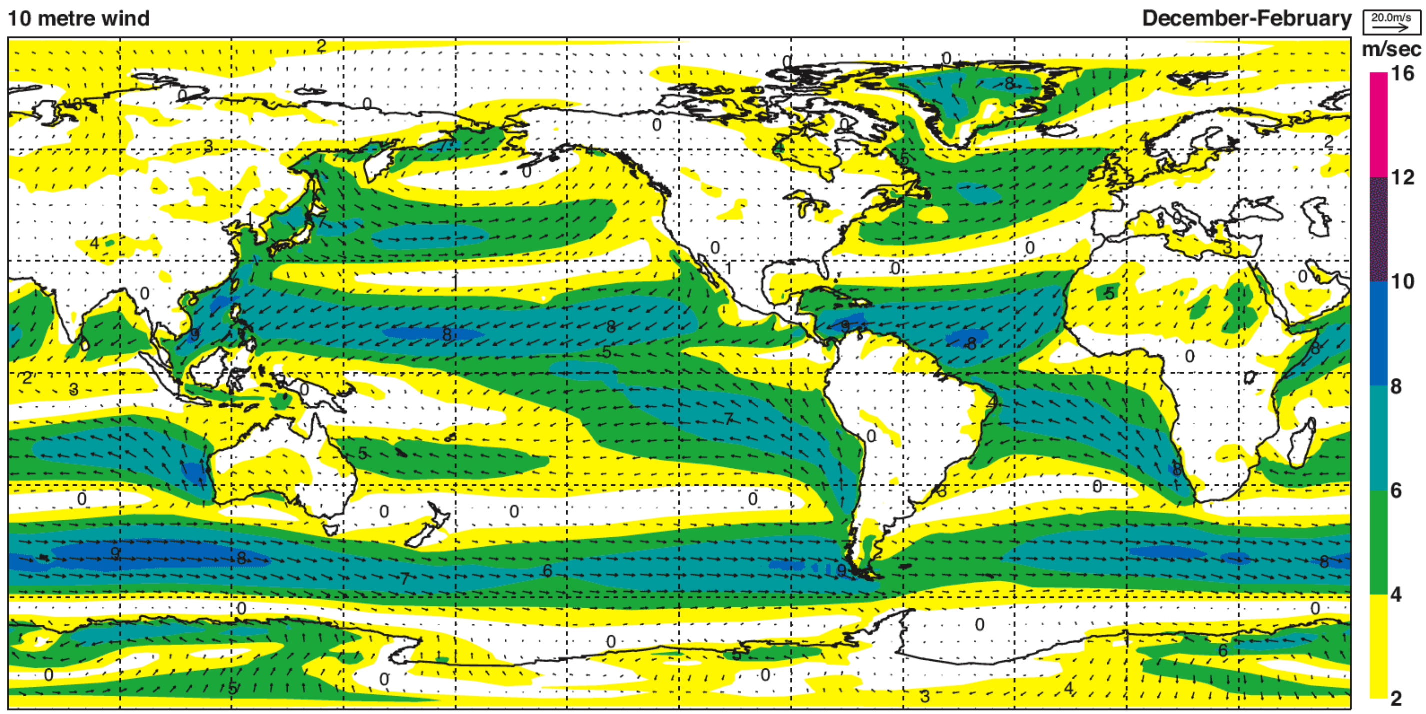
$$\alpha = -\frac{1}{\rho}\left(\frac{\partial\rho}{\partial T}\right)_{P,S}$$

$$\beta = \frac{1}{\rho}\left(\frac{\partial\rho}{\partial S}\right)_{P,T}$$

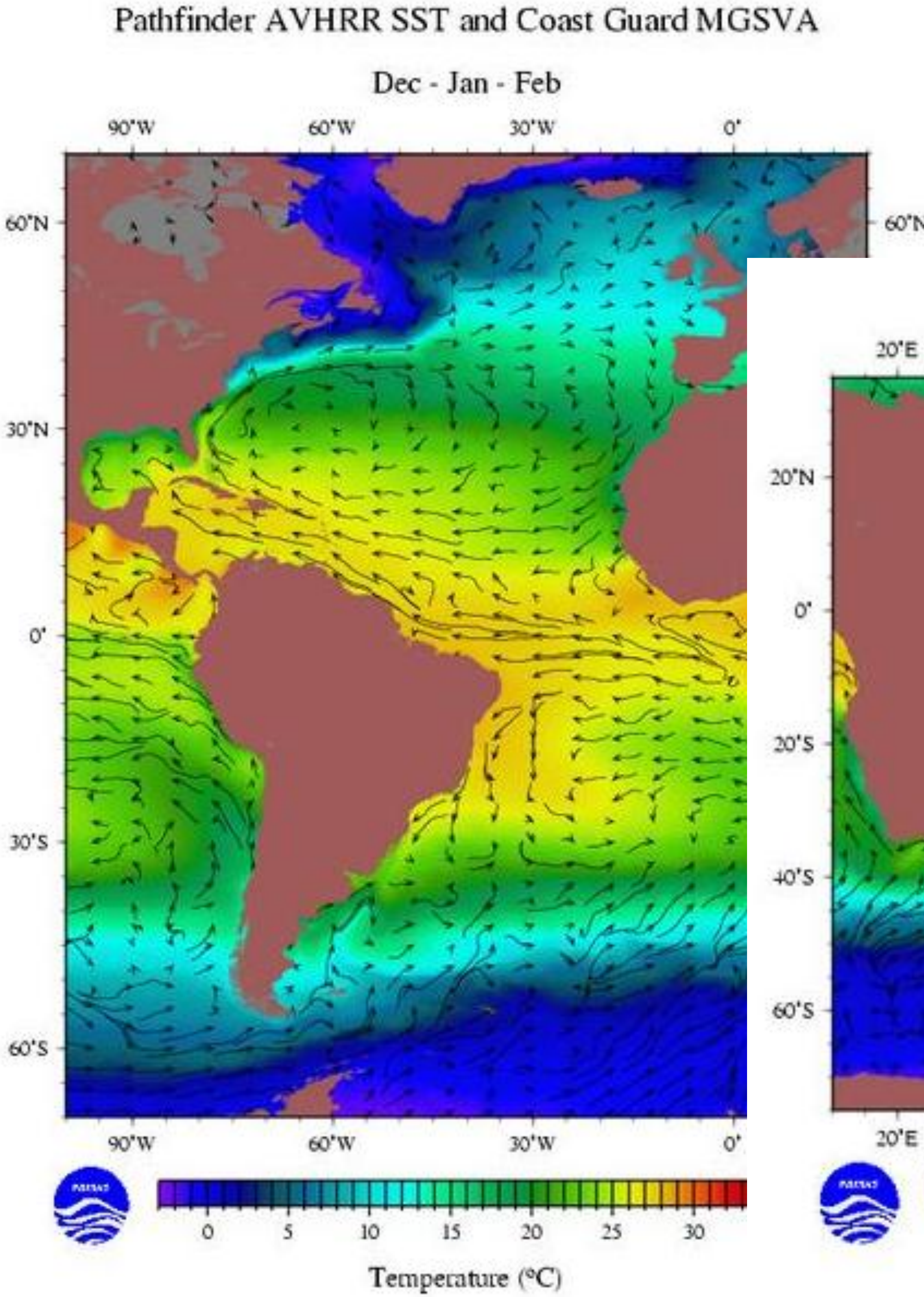
WIND FORCING

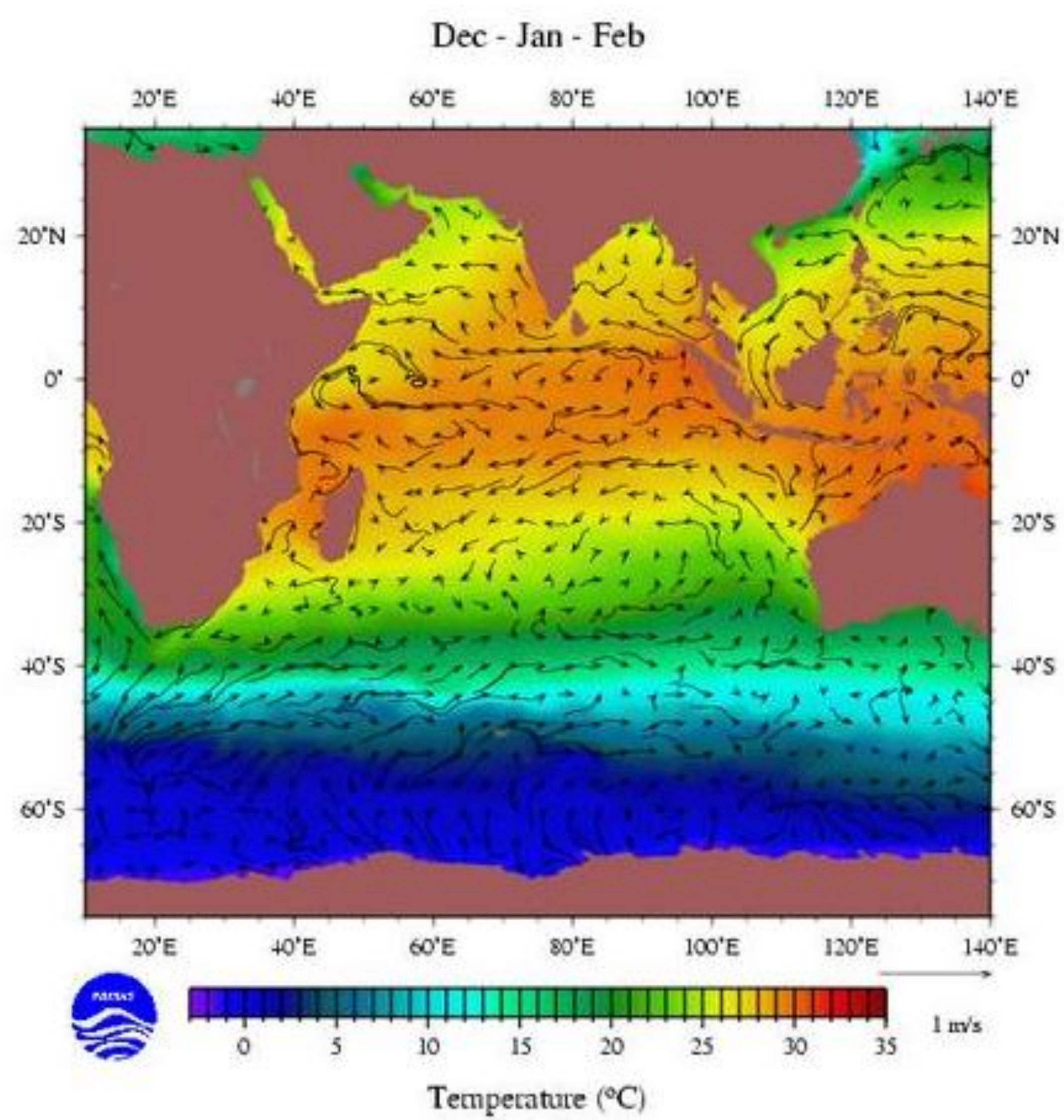




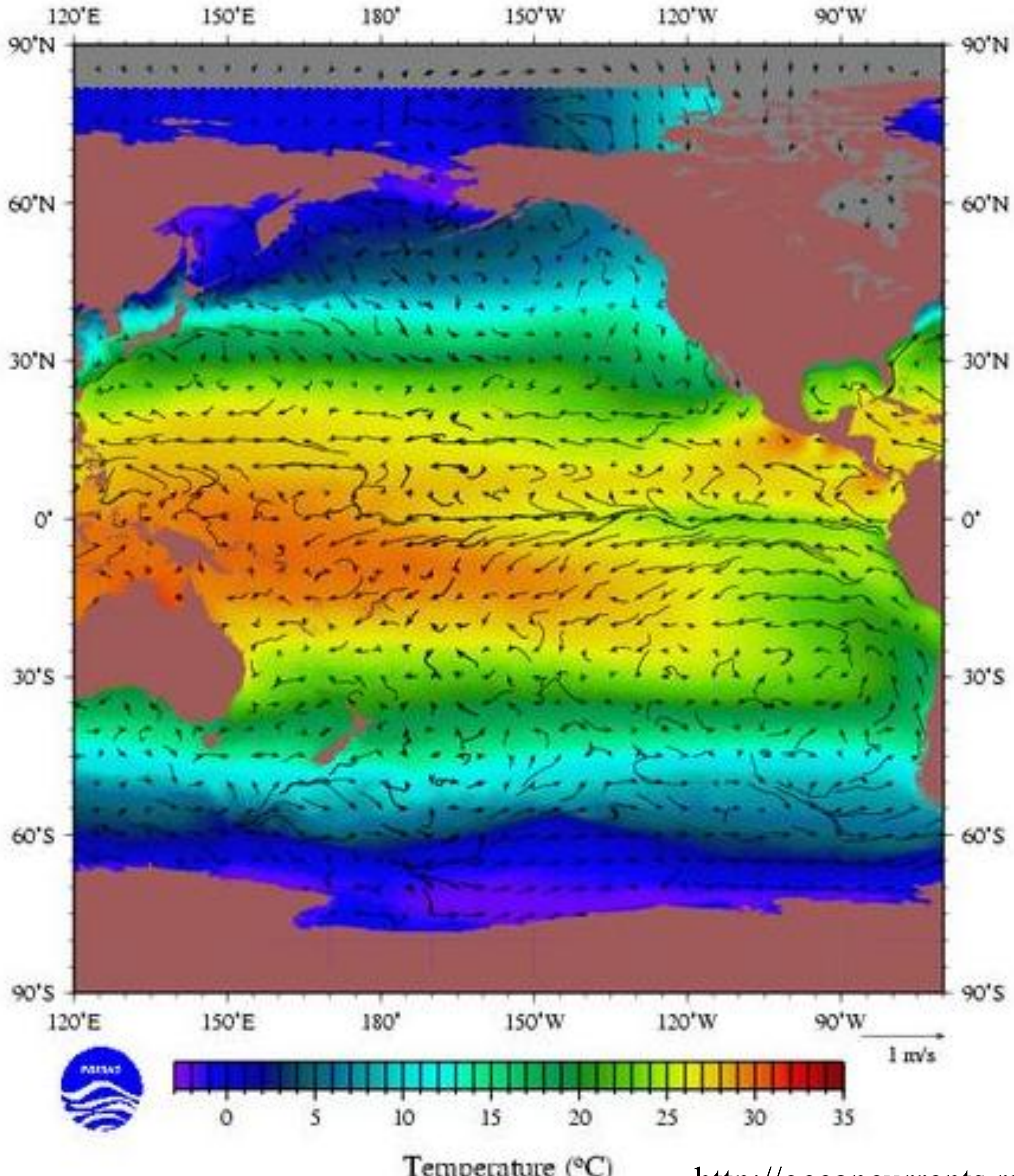


Surface drift (1)



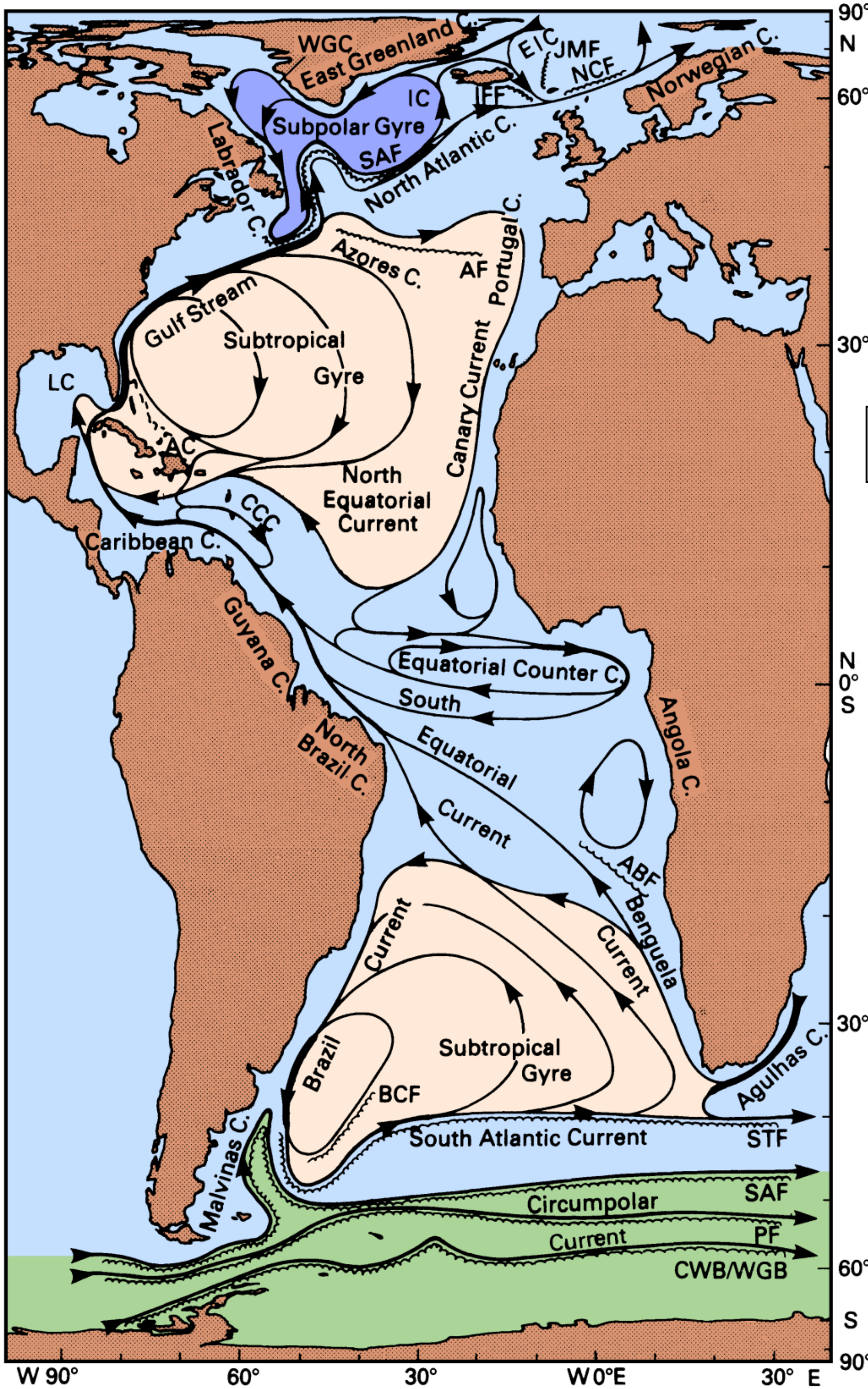


Surface drift (2)



http://oceancurrents.rsmas.miami.edu

Atlantic Circulation



Subpolar gyre

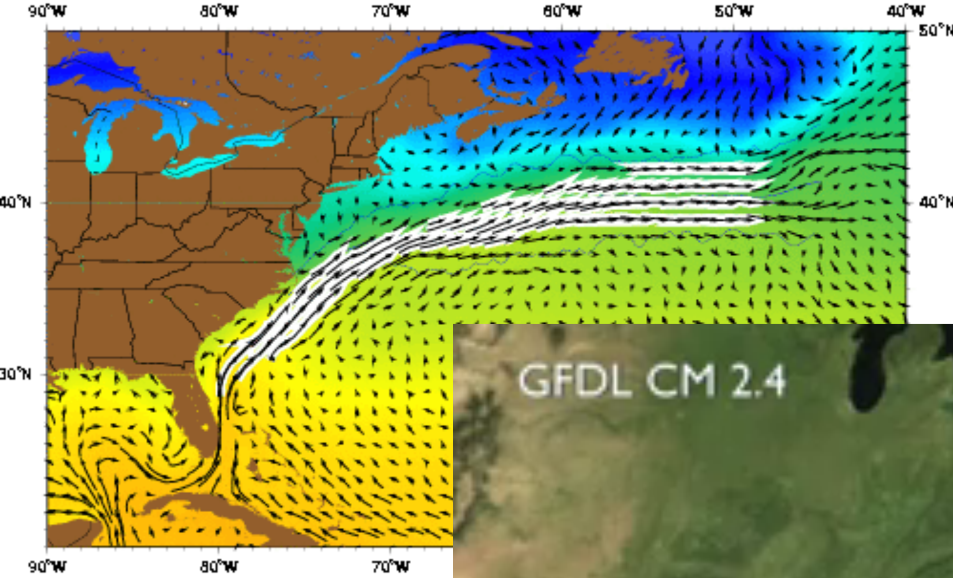
Subtropical gyre

Equatorial Current System

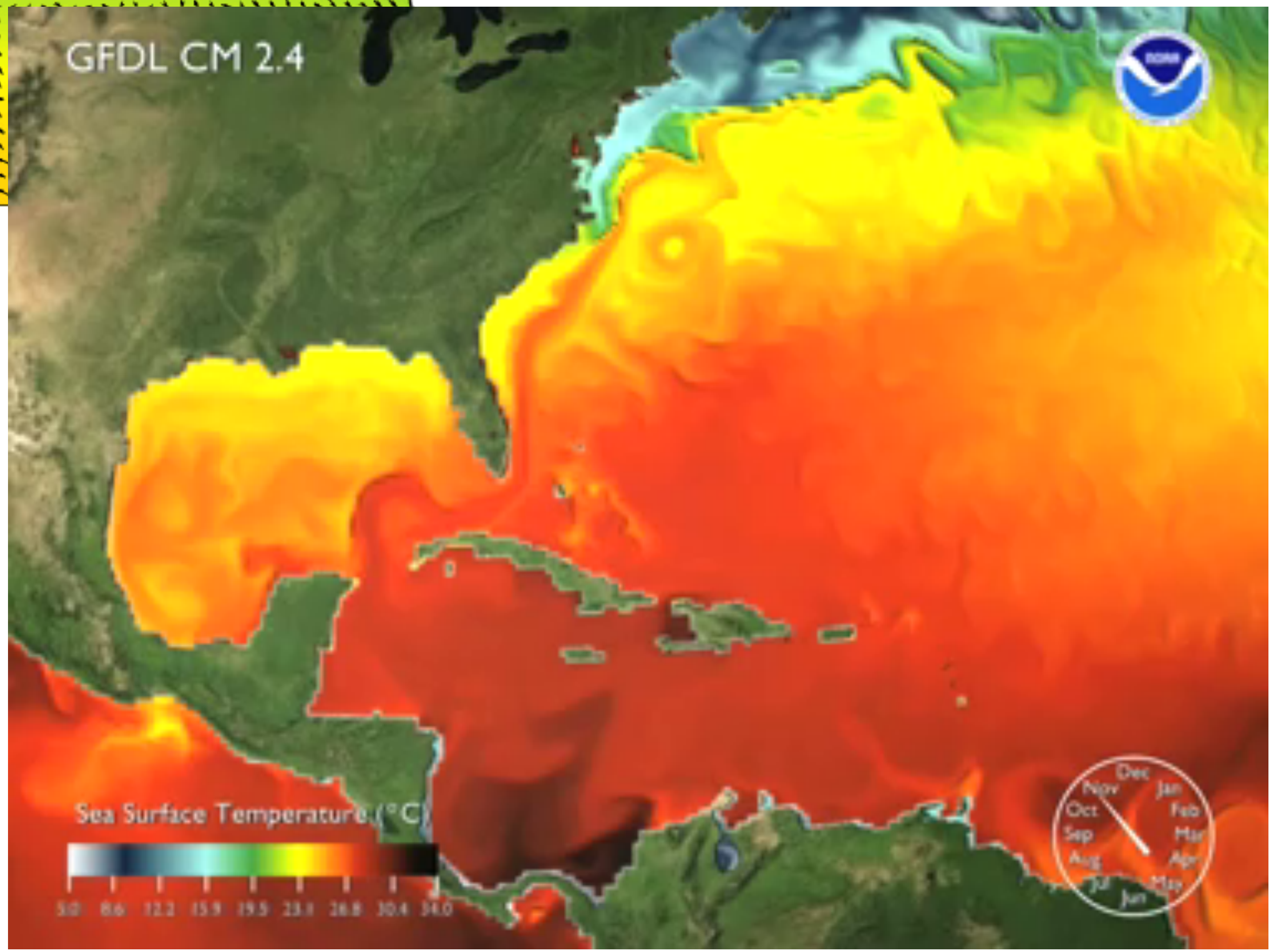
Subtropical gyre

(Antarctic Circumpolar Current)

Subpolar gyre



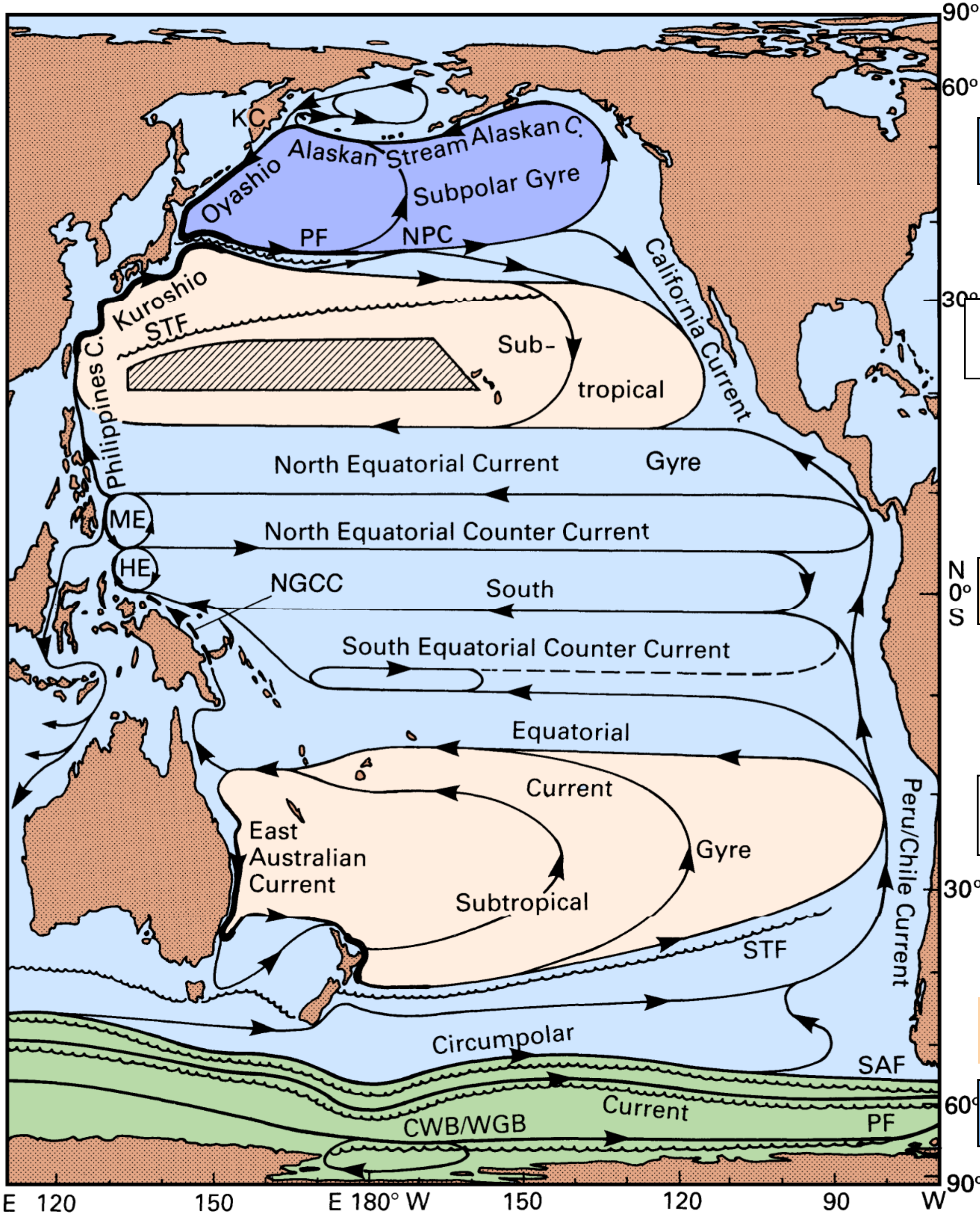
The Gulf Stream System



Looking behind the "mean" circulation patterns:

Circulation is dominated by spatial and temporal **variability** at various scales

Pacific Circulation



Subpolar gyre

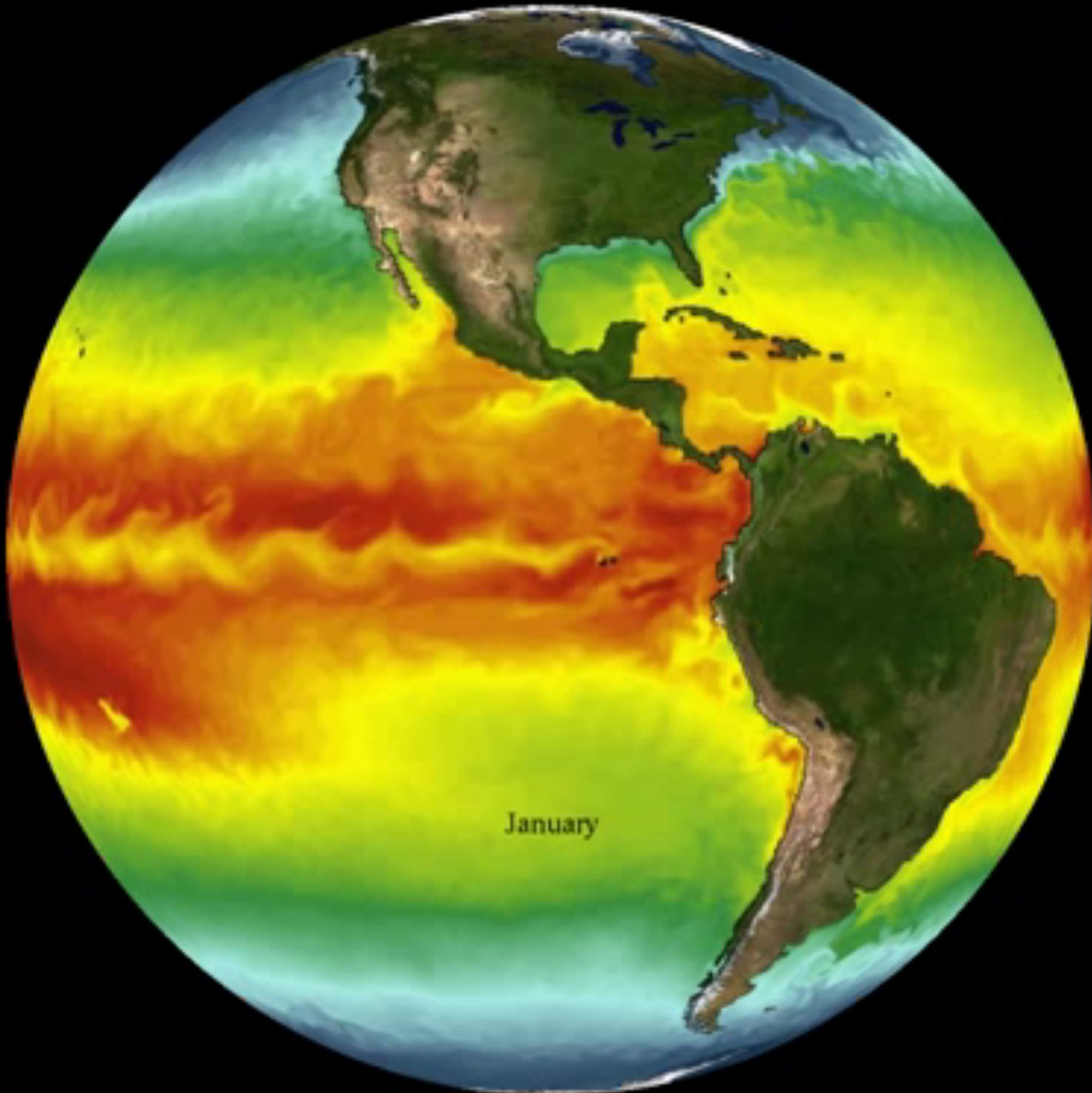
Subtropical gyre

Equatorial Current System

Subtropical gyre

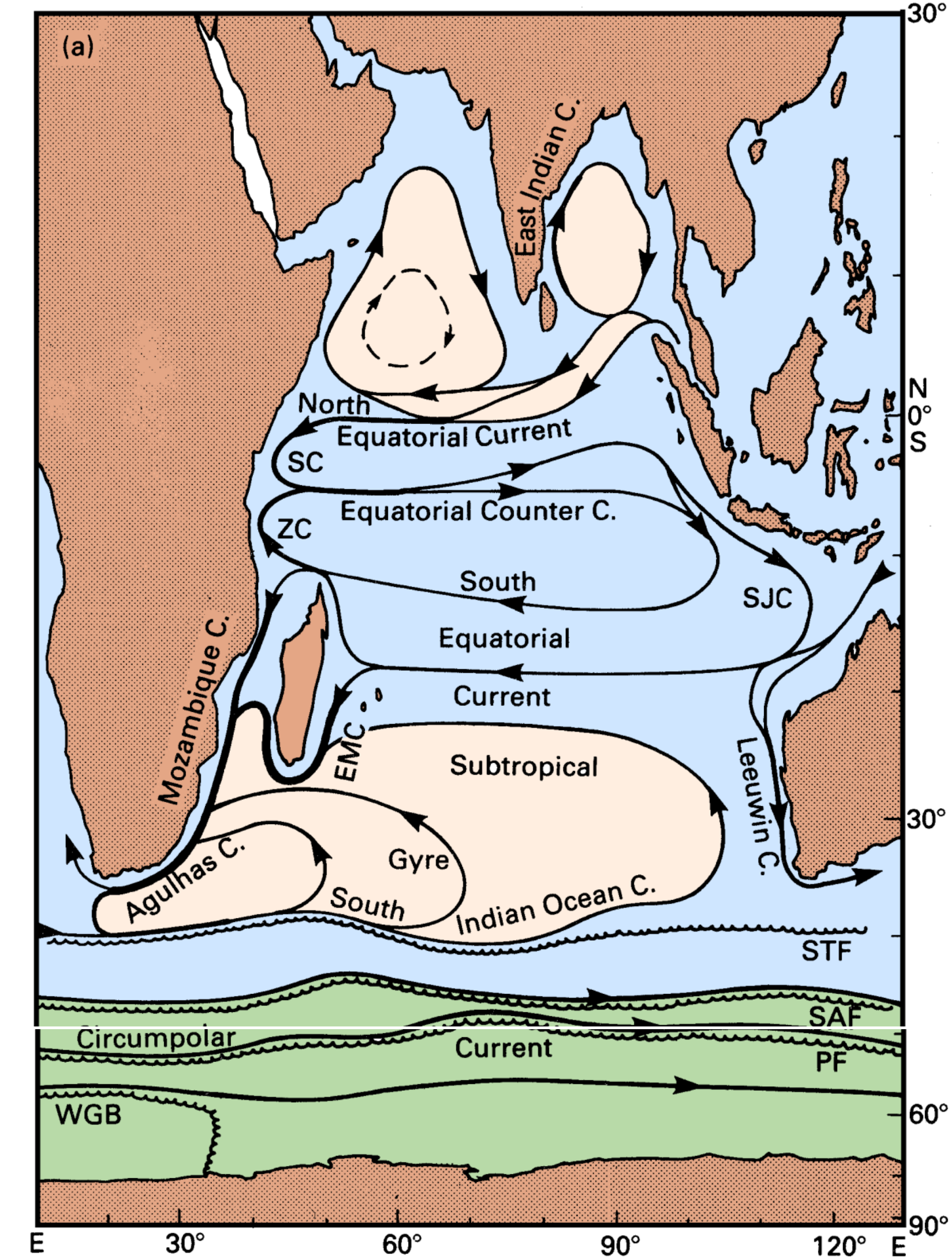
(Antarctic Circumpolar Current)

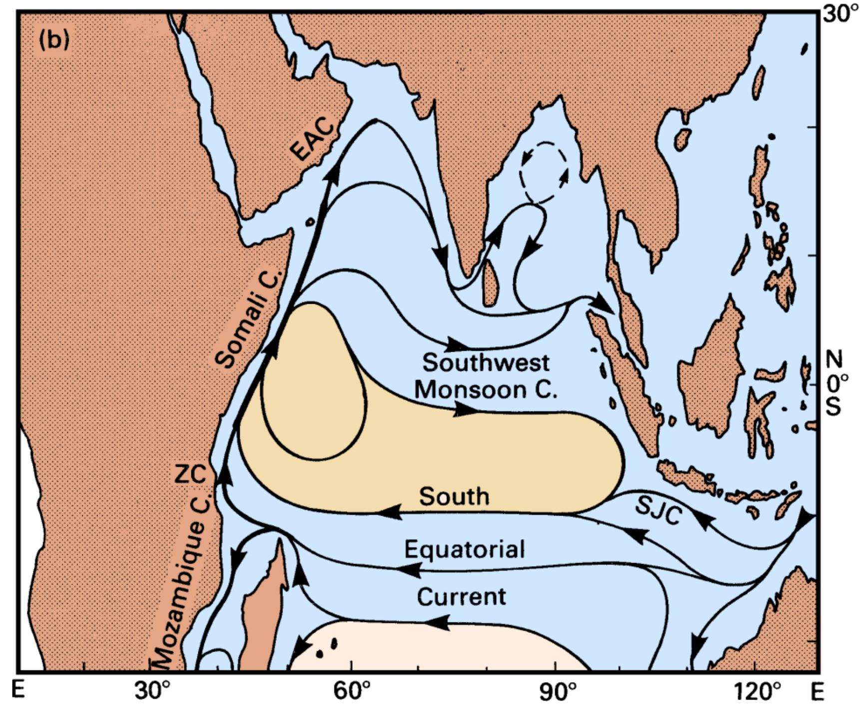
Subpolar gyre



The Pacific Equatorial System

Indian Circulation





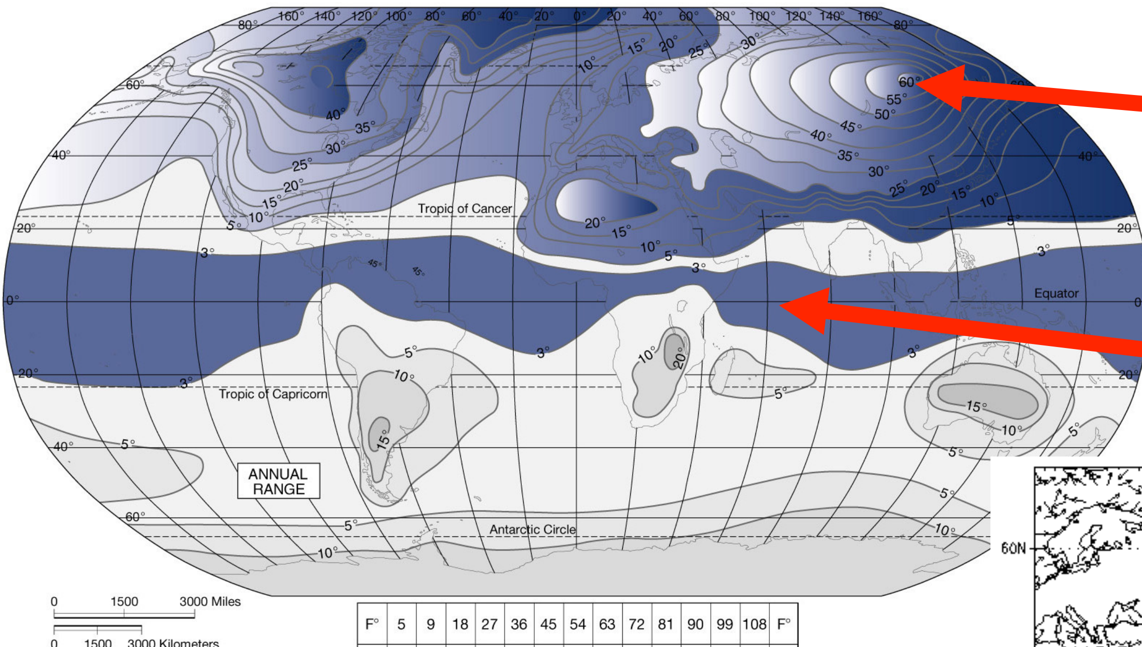
Surface temperature range that results in the monsoon

Sea surface temperature variations are much smaller than land surface temperature variations. (Mainly the seasonal cycle)

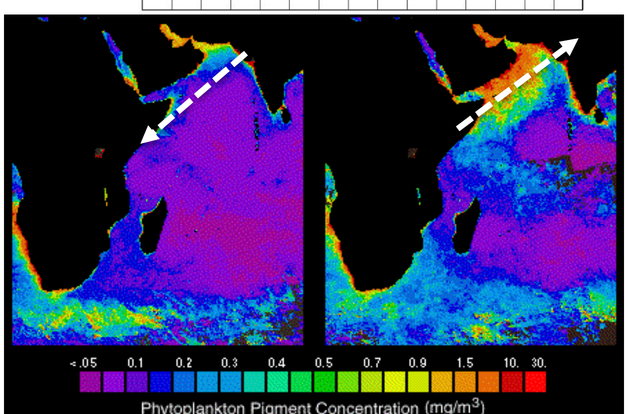
Kump et al. (2004)

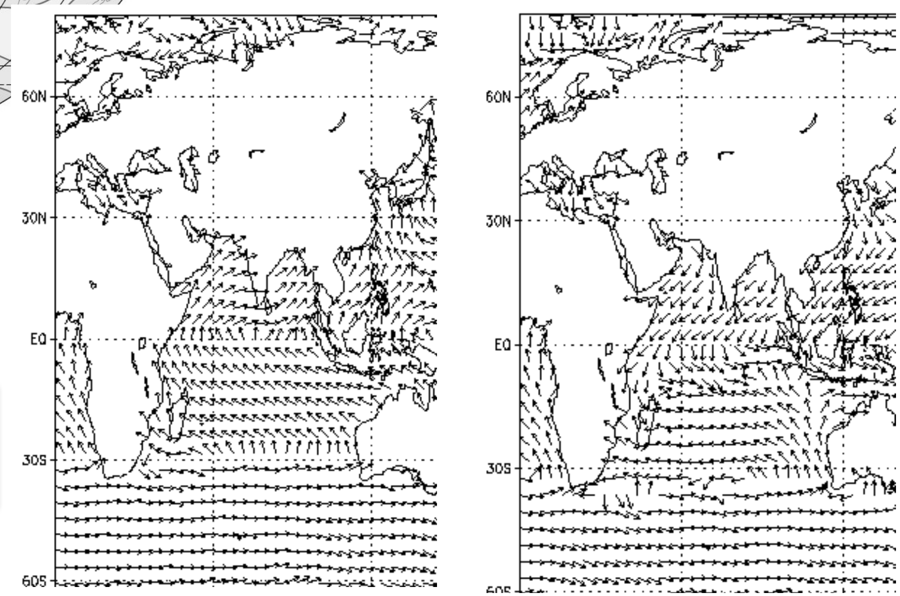
Tibetan plateau: range of 60°C

Ocean: range of 3 to 5°C

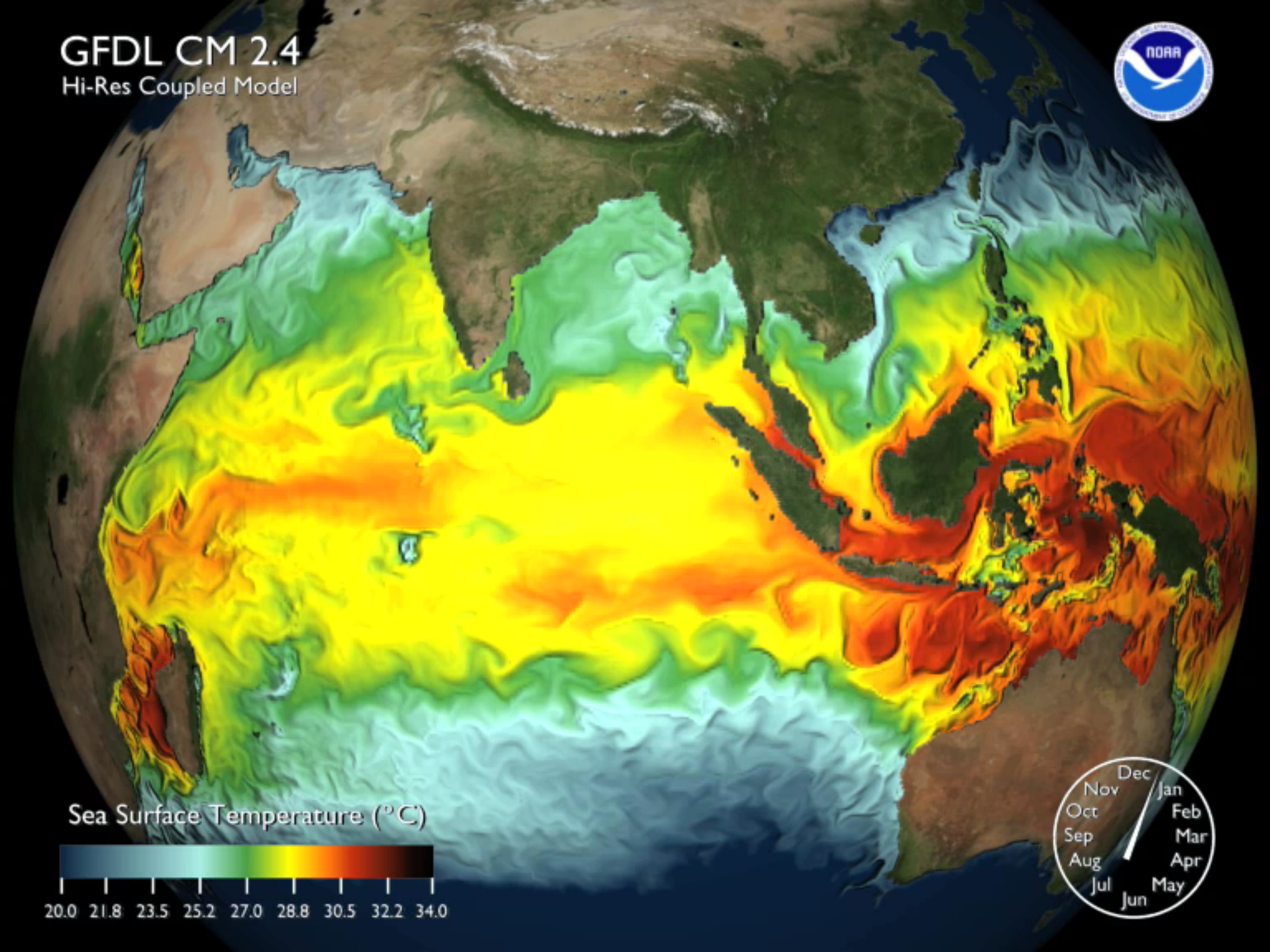


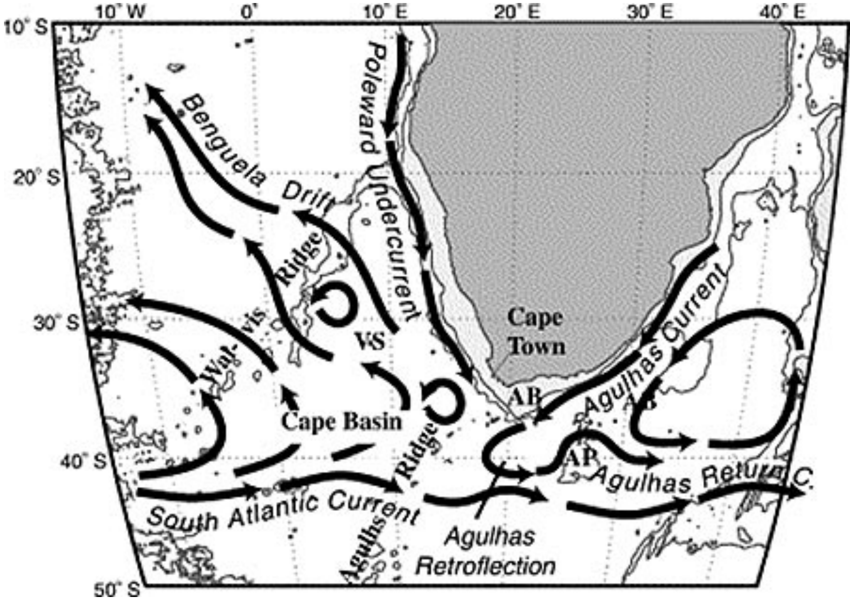
F°	5	9	18	27	36	45	54	63	72	81	90	99	108	F°
C°	3	5	10	15	20	25	30	35	40	45	50	55	60	C°



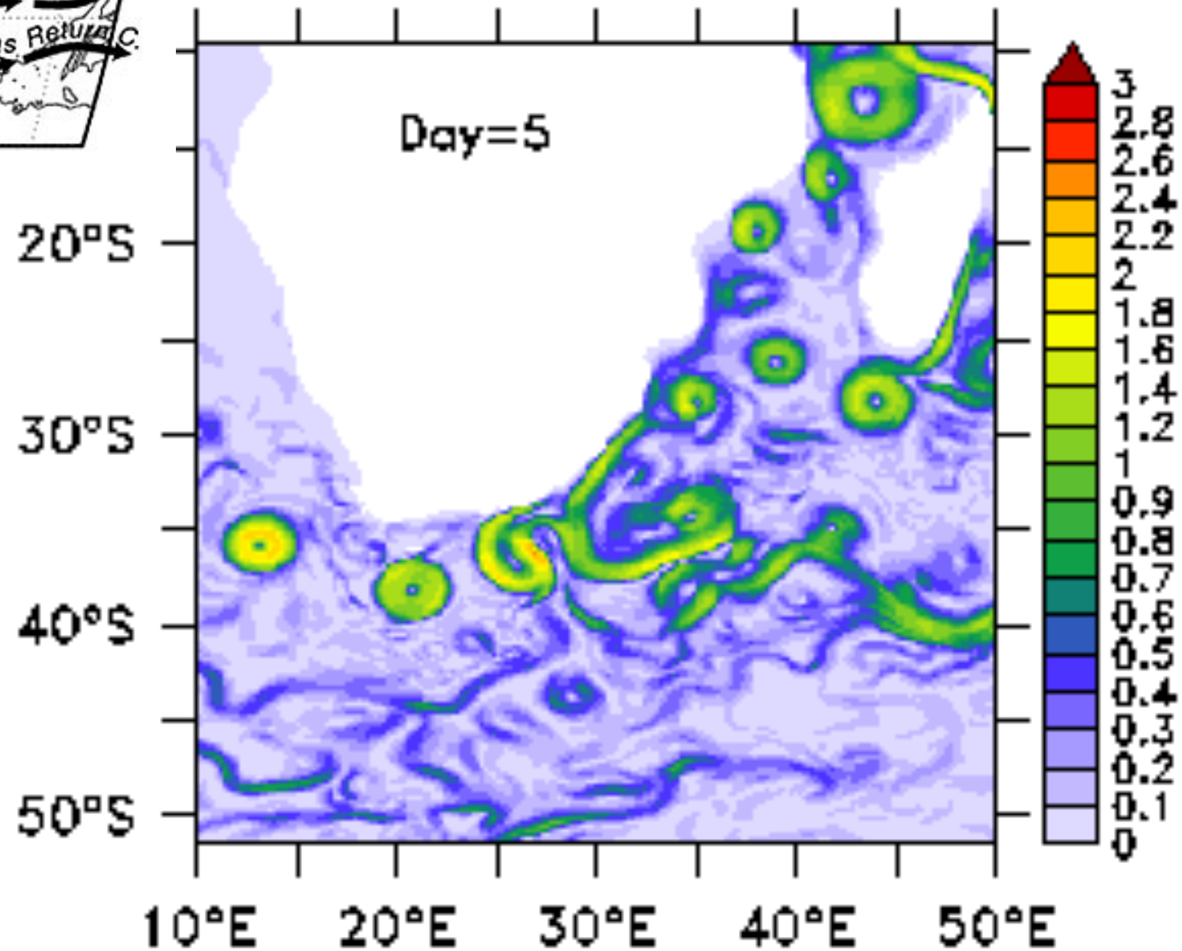


Jun-Aug (SW monsoon) **Dec-Feb (NE monsoon)**


GFDL CM 2.4
Hi-Res Coupled Model
NOAA
Sea Surface Temperature (°C)
20.0 21.8 23.5 25.2 27.0 28.8 30.5 32.2 34.0
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov



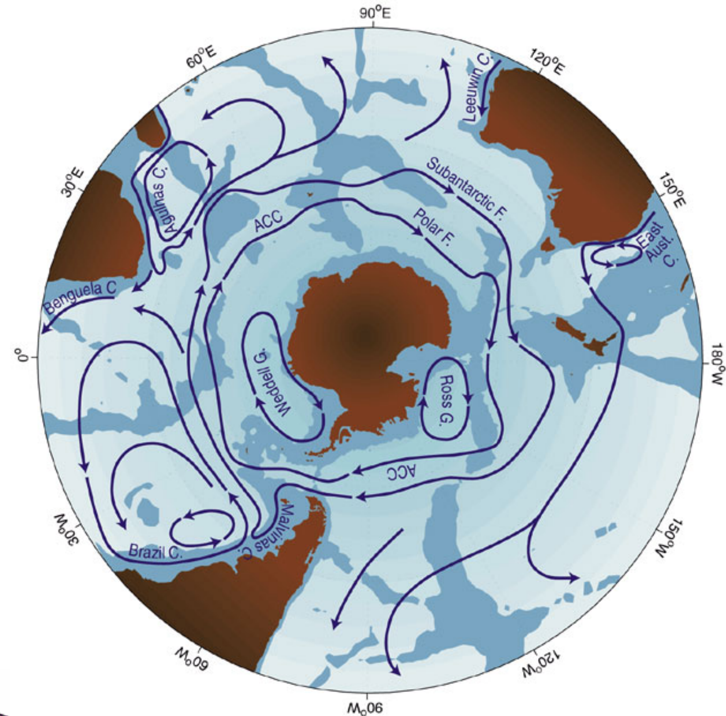
The Aghulas Current System

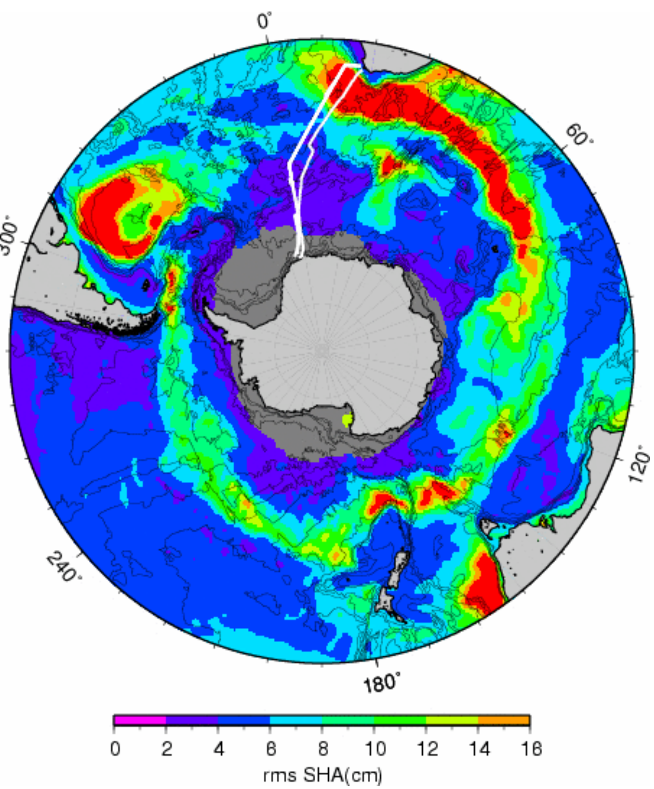


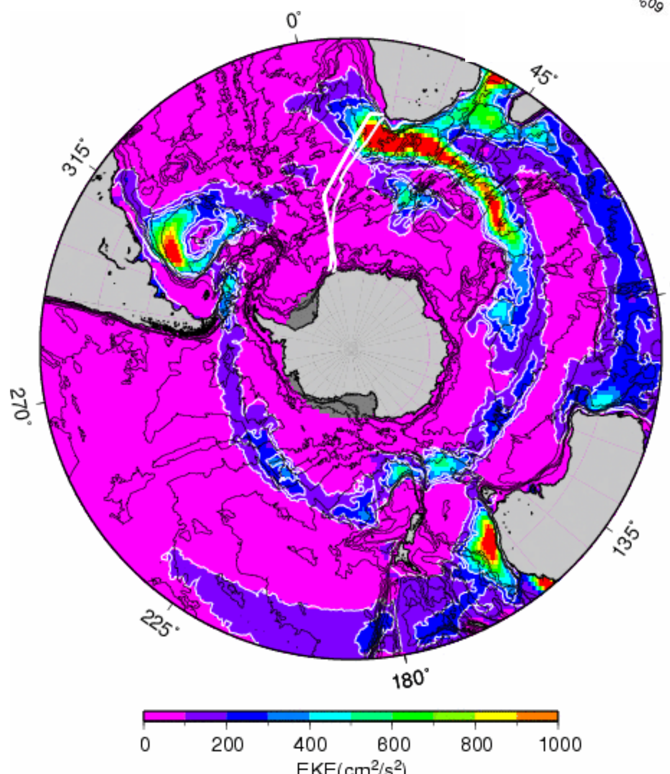
- Aghulas Current
- Aghulas retroflection and return current
- Aghulas Eddies

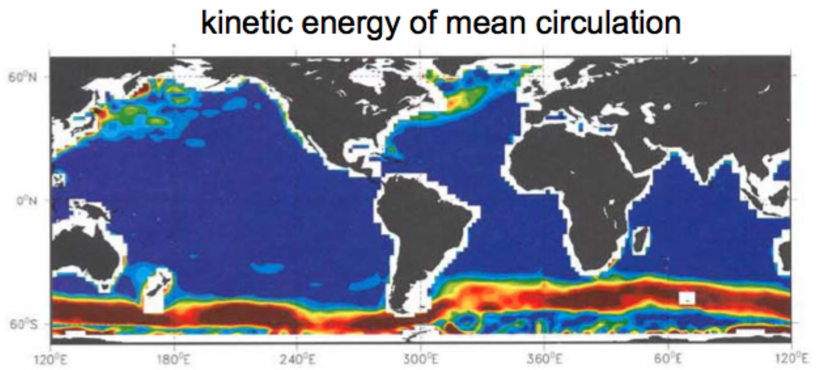
Antarctic Circumpolar Current

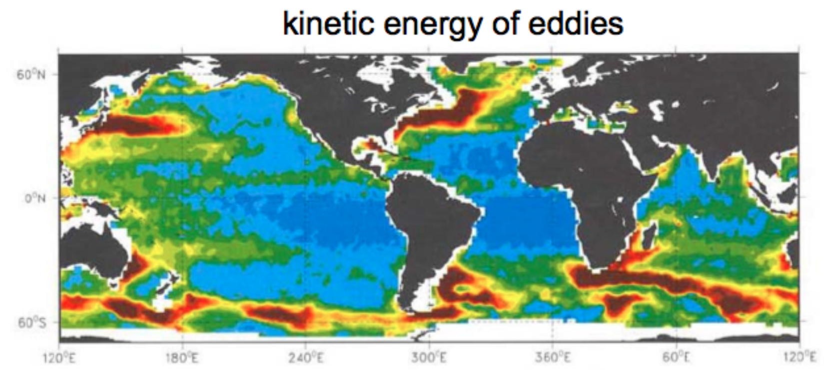
Transports ~140 Sv
(140 x 10^6 m^3/s)



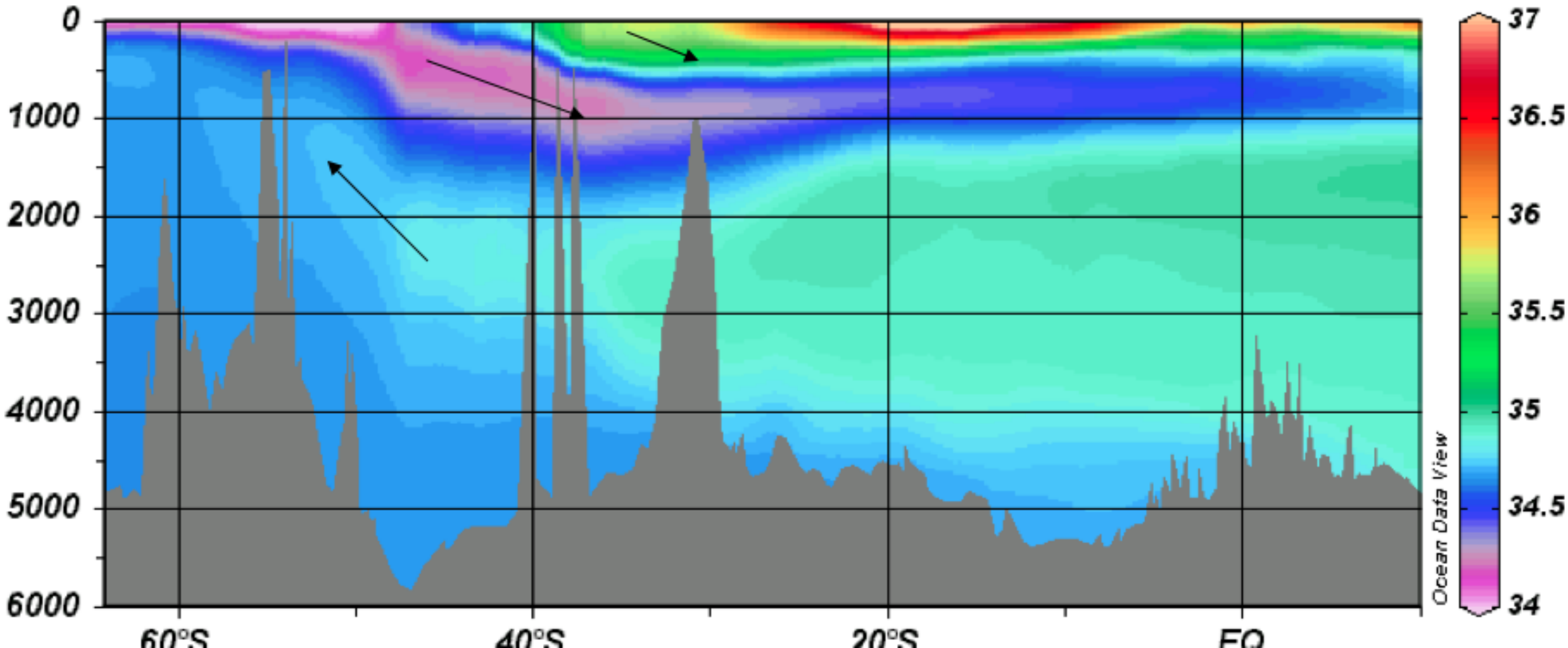




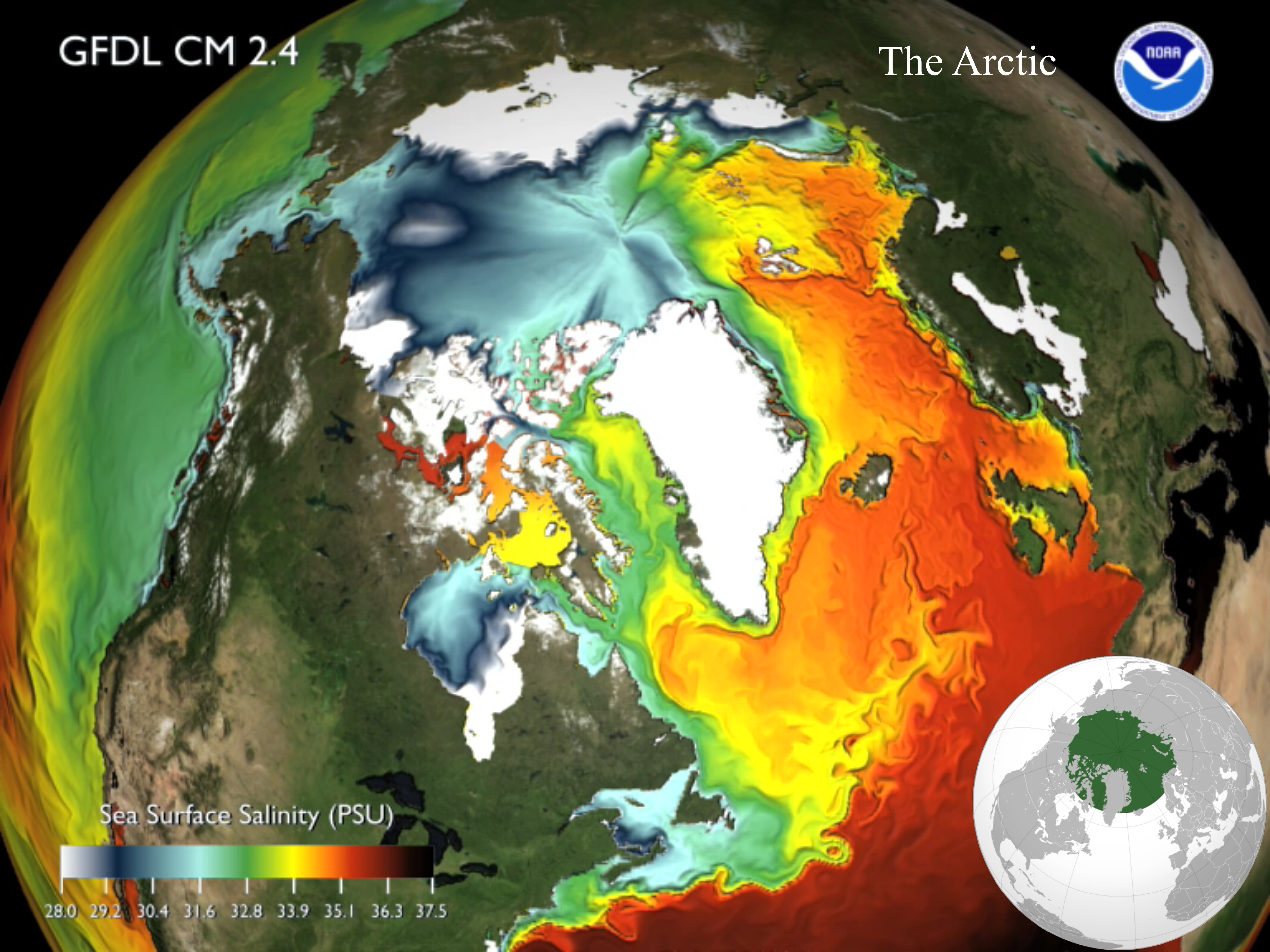




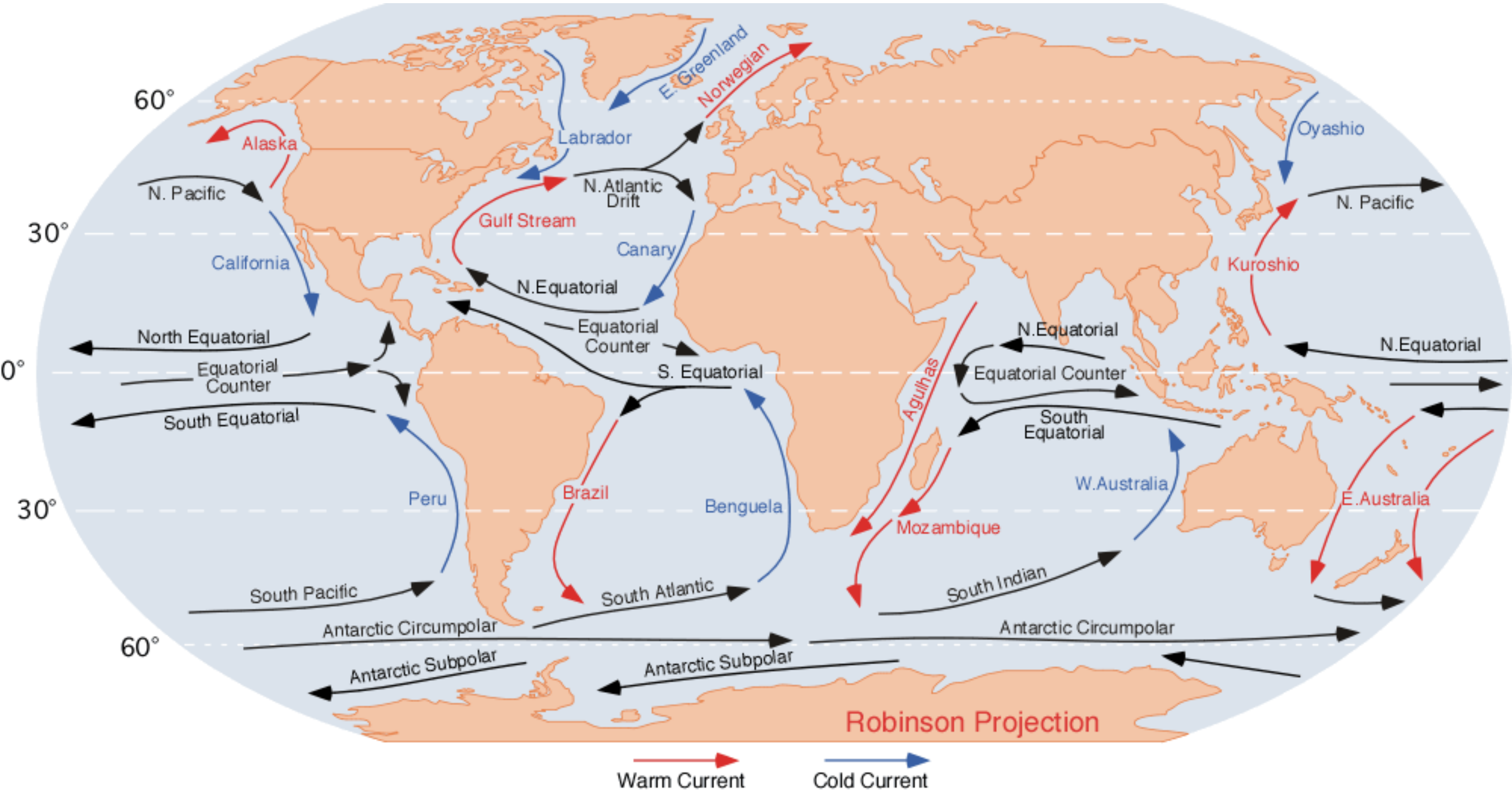
The energetics and vertical structure at AACC

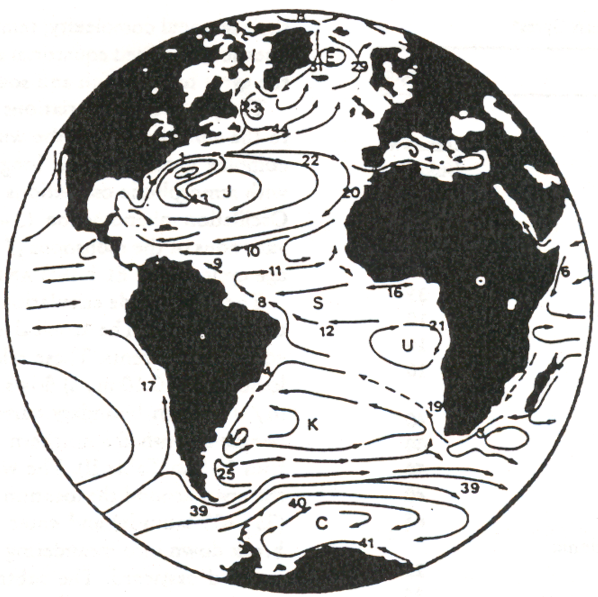


The Arctic


GFDL CM 2.4
Sea Surface Salinity (PSU)
28.0 29.2 30.4 31.6 32.8 33.9 35.1 36.3 37.5

SYNTHESIS (The "mean" flow)





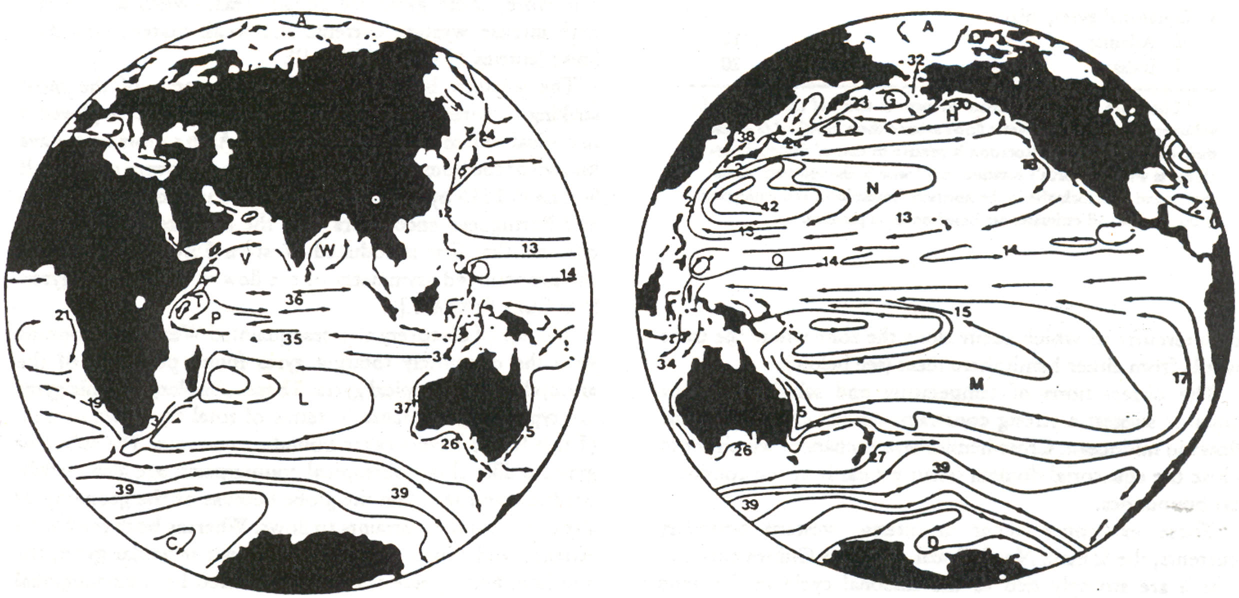
a

Table II Major Ocean Currents of the World[a]

Name	Transport	Name	Transport
1. Gulf Stream	30–150	23. Labrador	4–8
2. Kuroshio	60–90	24. Oyashio	2–3
3. Agulhas	20–90	25. Malvinas/Falkland	10
4. Brazil	12–70	26. Flinders	?
5. East Australian	12–57	27. Southland	?
6. Somali (northern winter)	20	28. Irminger	2–4
7. Somali (northern summer)	65	29. Norwegian	2–4
8. North Brazil	10–30	30. Alaskan Stream	9
9. Guiana	10	31. East Greenland	7–35
10. North Equatorial (Atlantic)	15	32. Bering Strait	0.5–1
11. North Equatorial Counter (Atlantic)	18	33. Kamchatka	8–20
12. South Equatorial (Atlantic)	15	34. Indonesian Throughflow	5–15
13. North Equatorial (Pacific)	30	35. South Equatorial (Indian)	30
14. North Equatorial Counter (Pacific)	5–10	36. Indian Monsoon	?
15. South Equatorial (Pacific)	12–60	37. Leeuwin	3–5
16. Guinea	3	38. Tsushima	1–2
17. Peru	12–19	39. Antarctic Circumpolar Current	130
18. California	4–13	40. Weddell–Scotia Confluence[b]	40–90
19. Bengulea	7–15	41. Antarctic Coastal Current	10
20. Canary	8	42. Subtropical Counter Current (Pacific)	8–18
21. Angola	5	43. Subtropical Counter Current (Atlantic)	4–10
22. Azores	8	44. North Atlantic Drift	30

[a] Currents are split into various categories. Numbers correspond to Fig. 2. Transport estimates suggest uncertainties and/or annual range in 10^6 m^3/s. The variations in transport tied to the annual signal and to observational problems (eddies) make any attempt to discern long-term climate signals in these currents difficult.

[b] The Weddell–Scotia Confluence is actually the meeting of two currents at the edge of the Weddell Gyre.



b

c

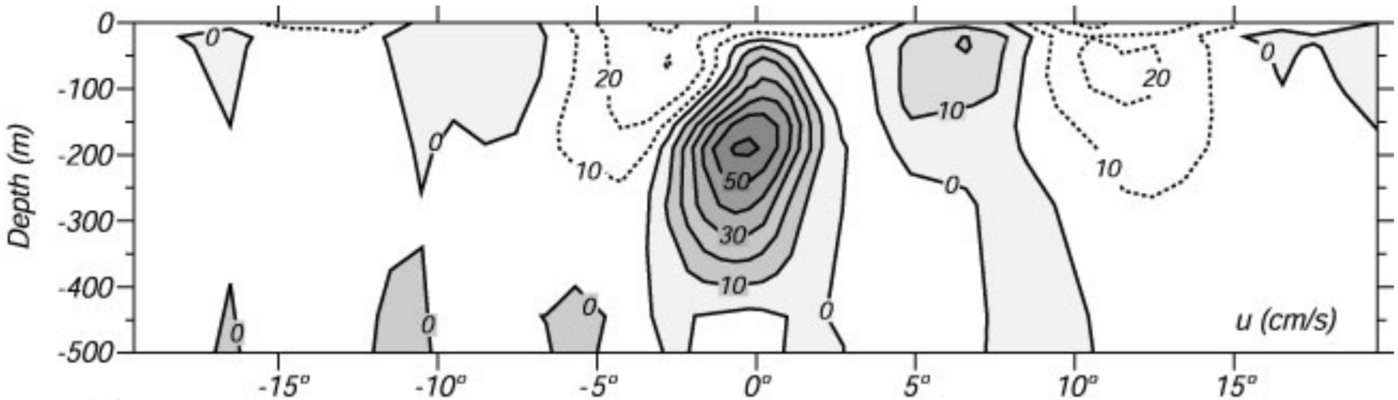
Fig. 2 Distribution of gyres and surface currents in (a) the Atlantic, (b) the Indian Ocean, and (c) the Pacific. Gyre names and transports are given in Table I. Similar information about the currents is given in Table II.

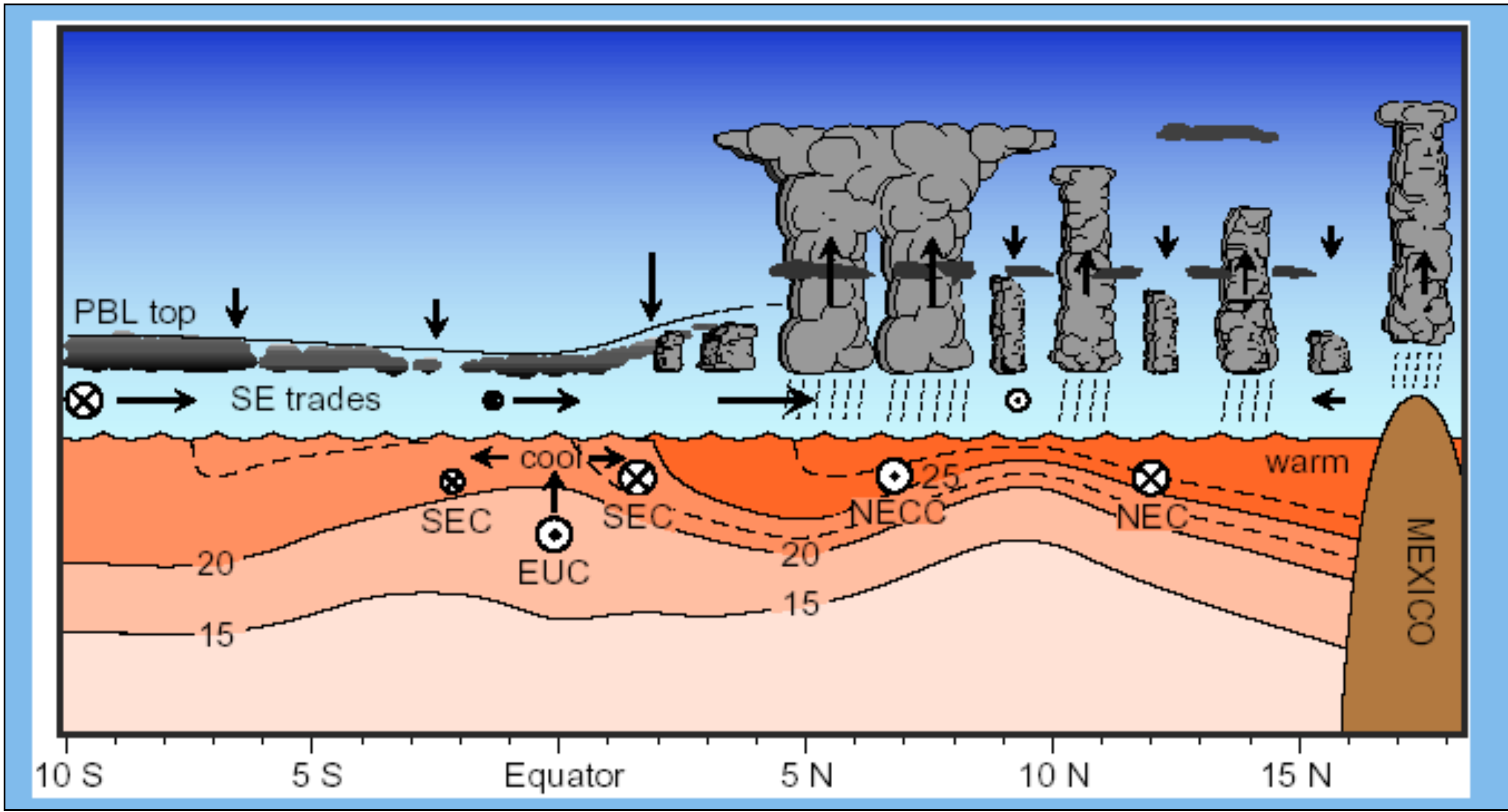
Table I Major Ocean Gyres[a]

Gyres, rotation	Strength
1. Polar gyres, cyclonic	
A. Beaufort Gyre	Unknown
B. Cross Arctic Drift	Unknown
C. Weddell Sea	40–90
D. Ross Sea	Weak
2. Subpolar gyres, cyclonic	
E. Norwegian–Greenland Sea	35
F. North Atlantic	35
G. Bering Sea	10
H. Alaskan Gyre	10
I. Western Subarctic	10
3. Subtropical gyres, anticyclonic	
J. North Atlantic	40
K. South Atlantic	30
L. South Indian	50
M. South Pacific	40
N. North Pacific	65
4. Equatorial Counter Current, cyclonic	
O. North Atlantic	25
P. South Indian	35
Q. North Pacific	40
R. South Pacific	20
5. Equatorial gyres, mixed	
S. Atlantic	12
T. Indian	20

[a] Listed are their approximate strength in terms of transport—the volumetric rate at which water flows around them in 10^6 m^3/s—and their sense of rotation. Rotation is relative to that of the earth; cyclonic is with the earth's rotation (clockwise in the southern hemisphere and anticlockwise in the northern hemisphere) and anticyclonic is the reverse. All estimates are based on wind patterns.

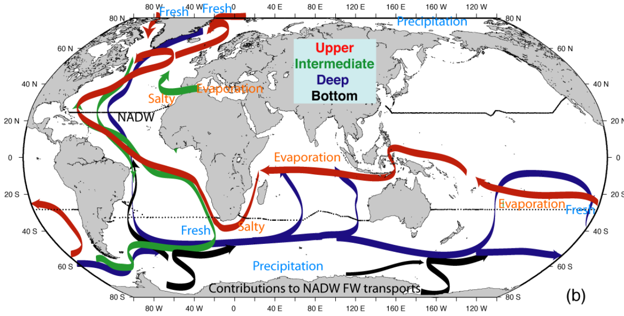
EQUATORIAL CURRENT SYSTEM

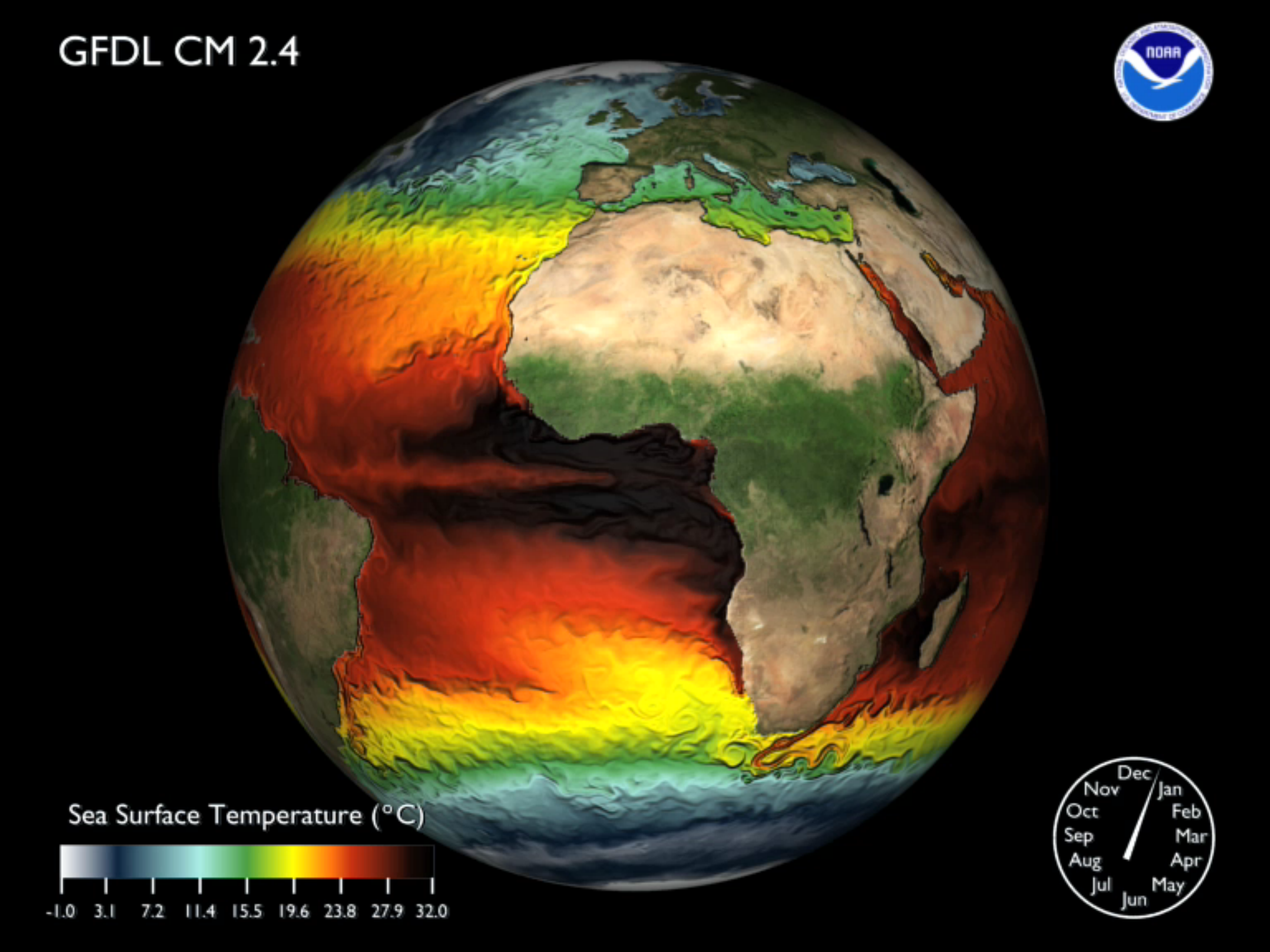




Global Thermohaline Circulation

The "conveyor belt"




GFDL CM 2.4
Sea Surface Temperature (°C)
-1.0 3.1 7.2 11.4 15.5 19.6 23.8 27.9 32.0
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov
NOAA