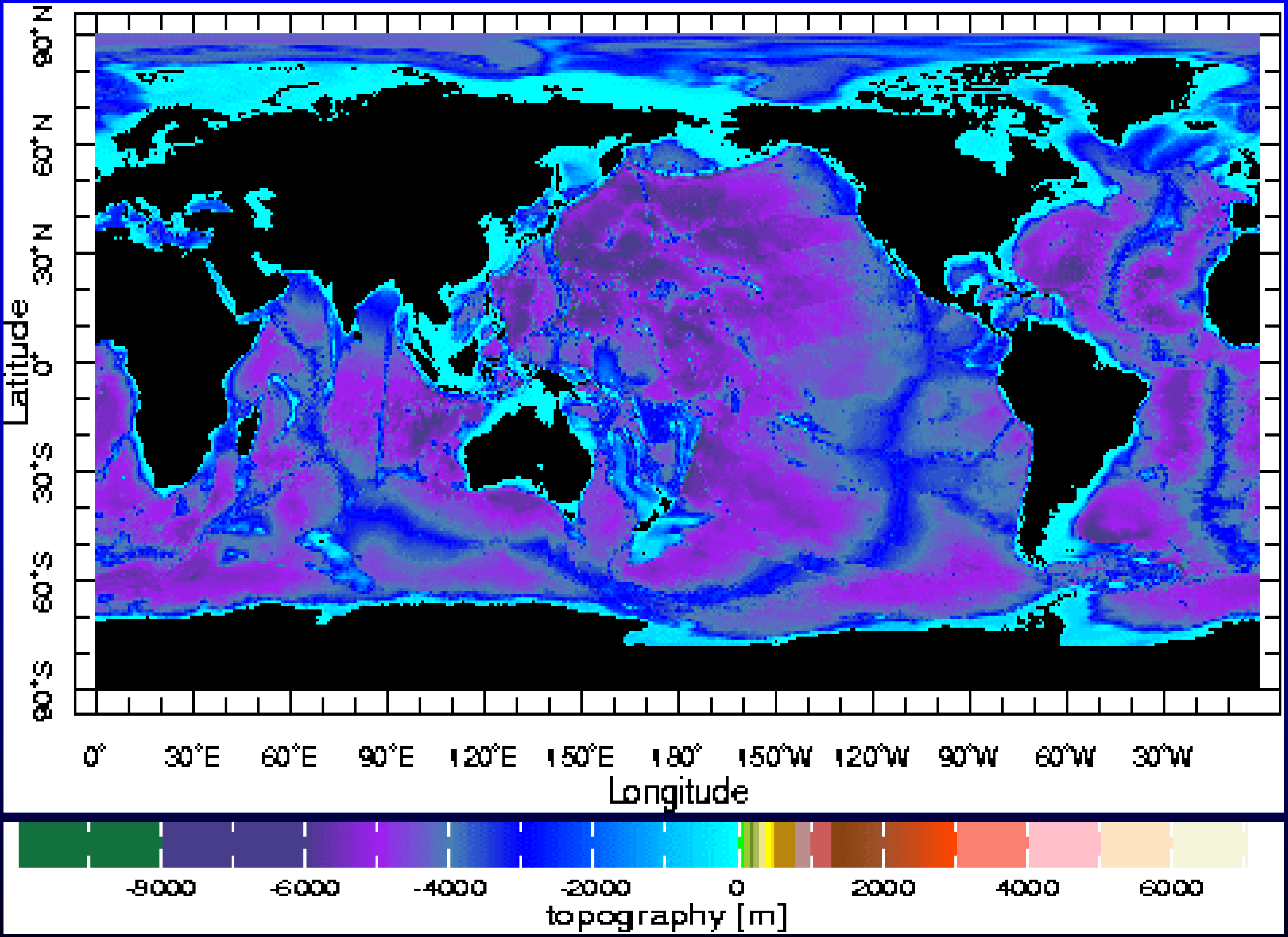
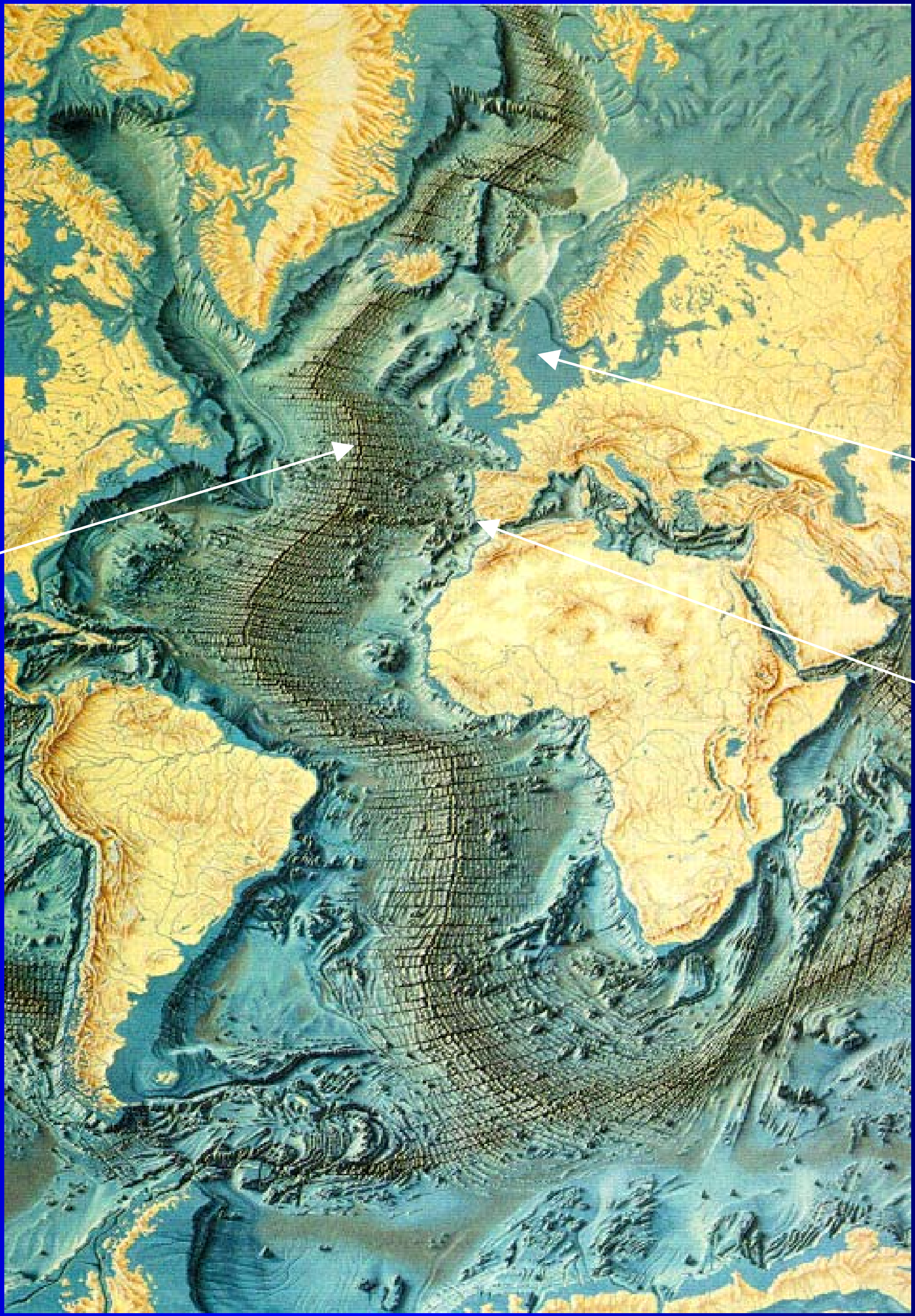
Constituintes maioritários da água do mar (S=35)

Constituinte	$g\ kg^{-1}$
Catiões	
Sódio	10.77
Magnésio	1.30
Cálcio	0.412
Potássio	0.399
Estrôncio	0.008
Aniões	
Cloreto	19.34
Sulfato	2.71
Brometo	0.067
Carbono	
Carbono inôrganico	0.023 (pH 8.4) - 0.027 (pH 7.8)

World ocean bathymetry - NOAA



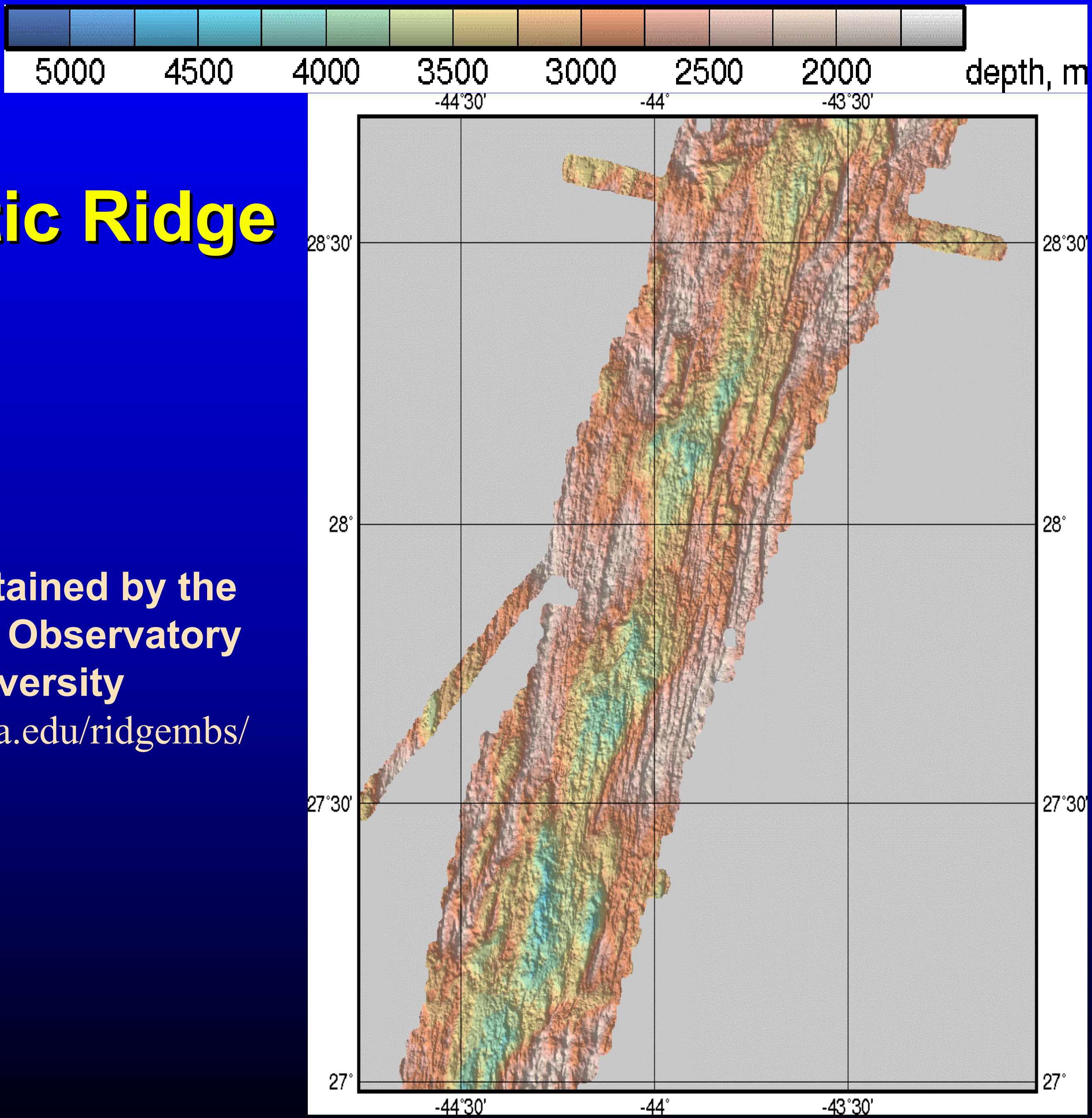
Batimetria do Oceano Atlântico



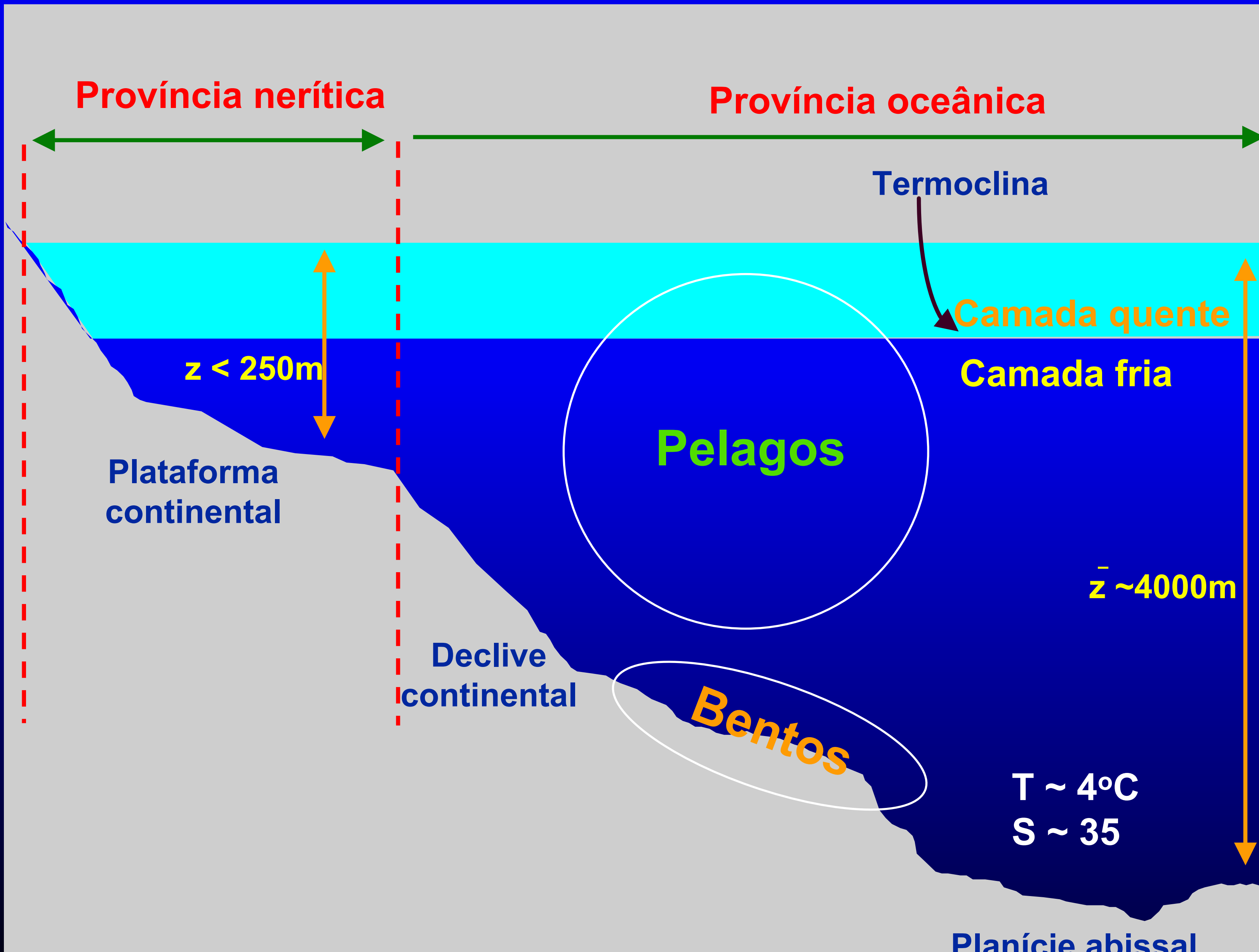
North Atlantic Ridge

Bathymetry profile obtained by the Lamont-Doherty Earth Observatory at Columbia University

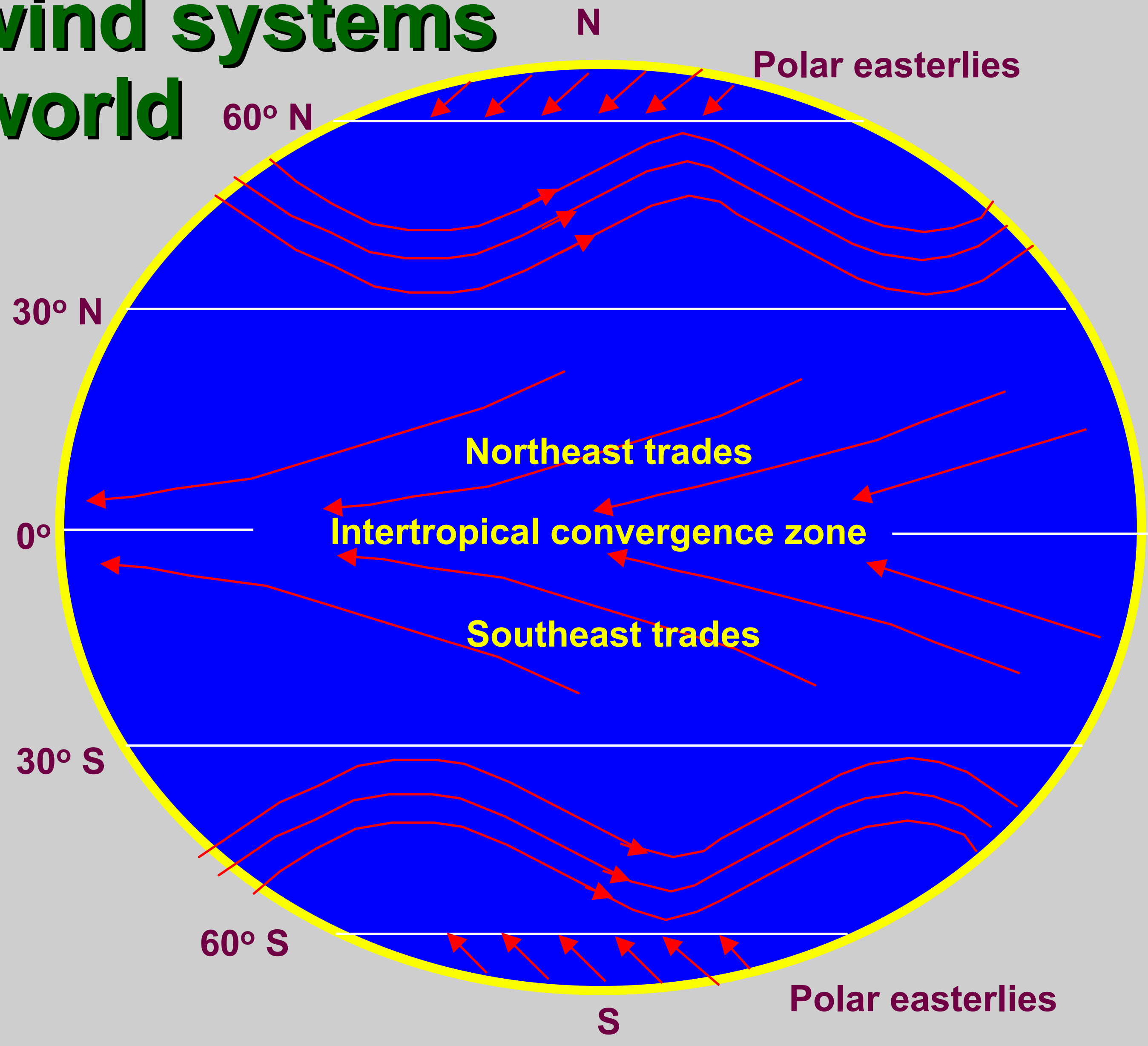
http://imager.ldeo.columbia.edu/ridgembs/



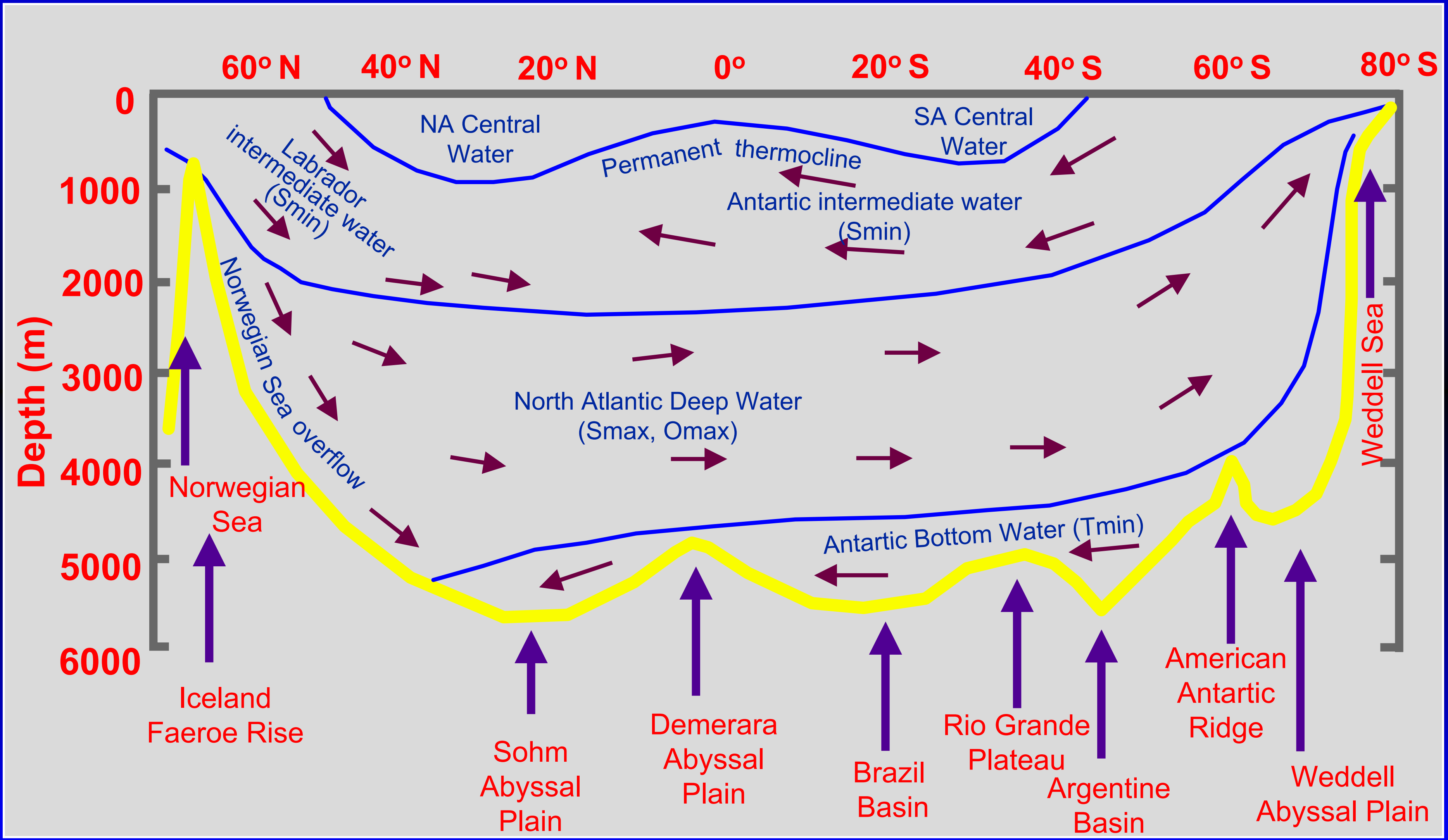
Características gerais do oceano



Major wind systems of the world



General sub-surface circulation of the World Ocean



Adapted from Dietrich et al., 1980 - General Oceanography: An Introduction

Coriolis effect

- Coriolis parameter = $2\Omega \sin \phi$

Where:

Ω = rate of angular rotation of the earth
ϕ = latitude

- Coriolis acceleration = $2\Omega v \sin \phi$

Where:

v = velocity

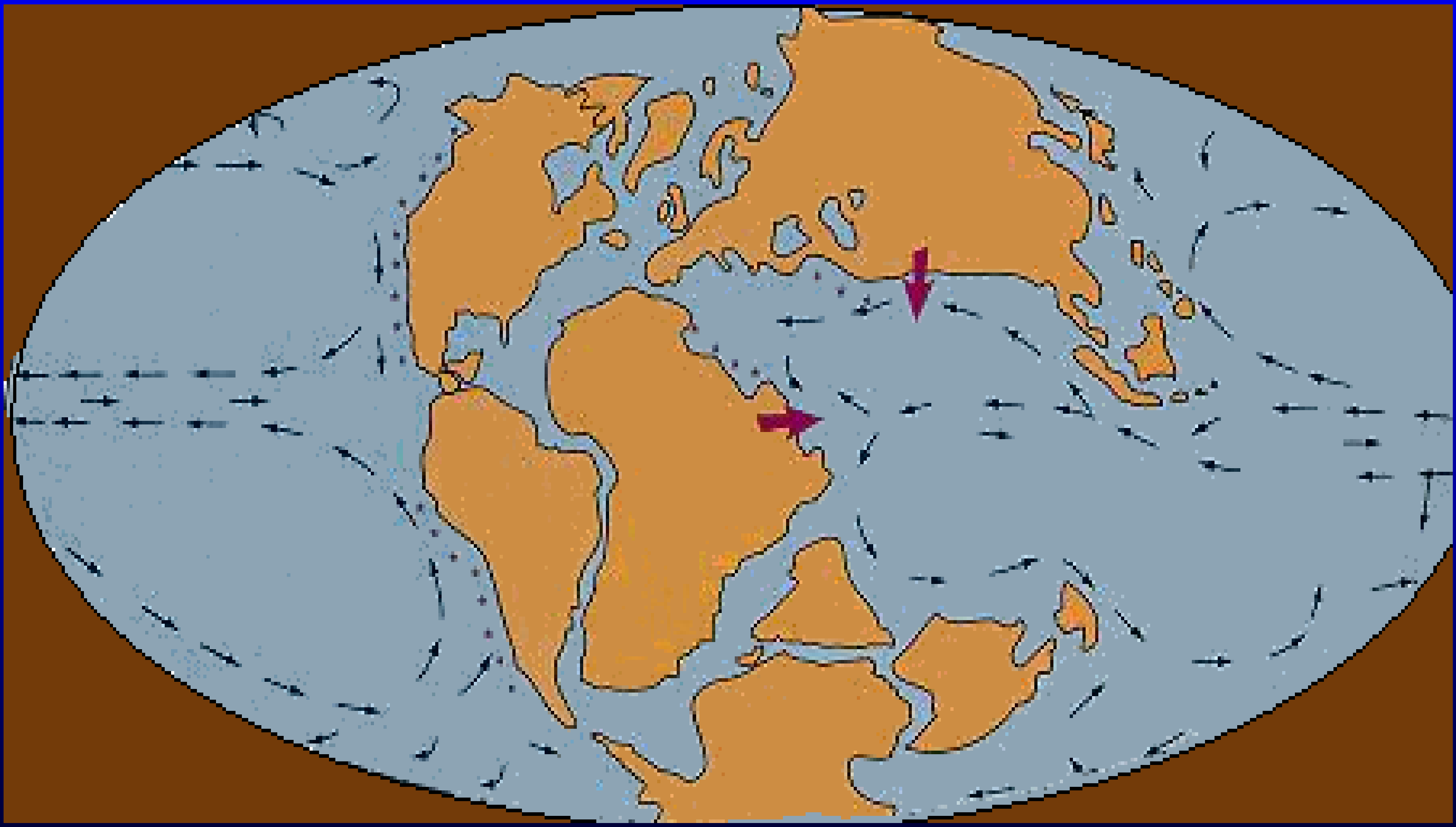
F=ma therefore:

- Coriolis force = $2\Omega m v \sin \phi$

Where:

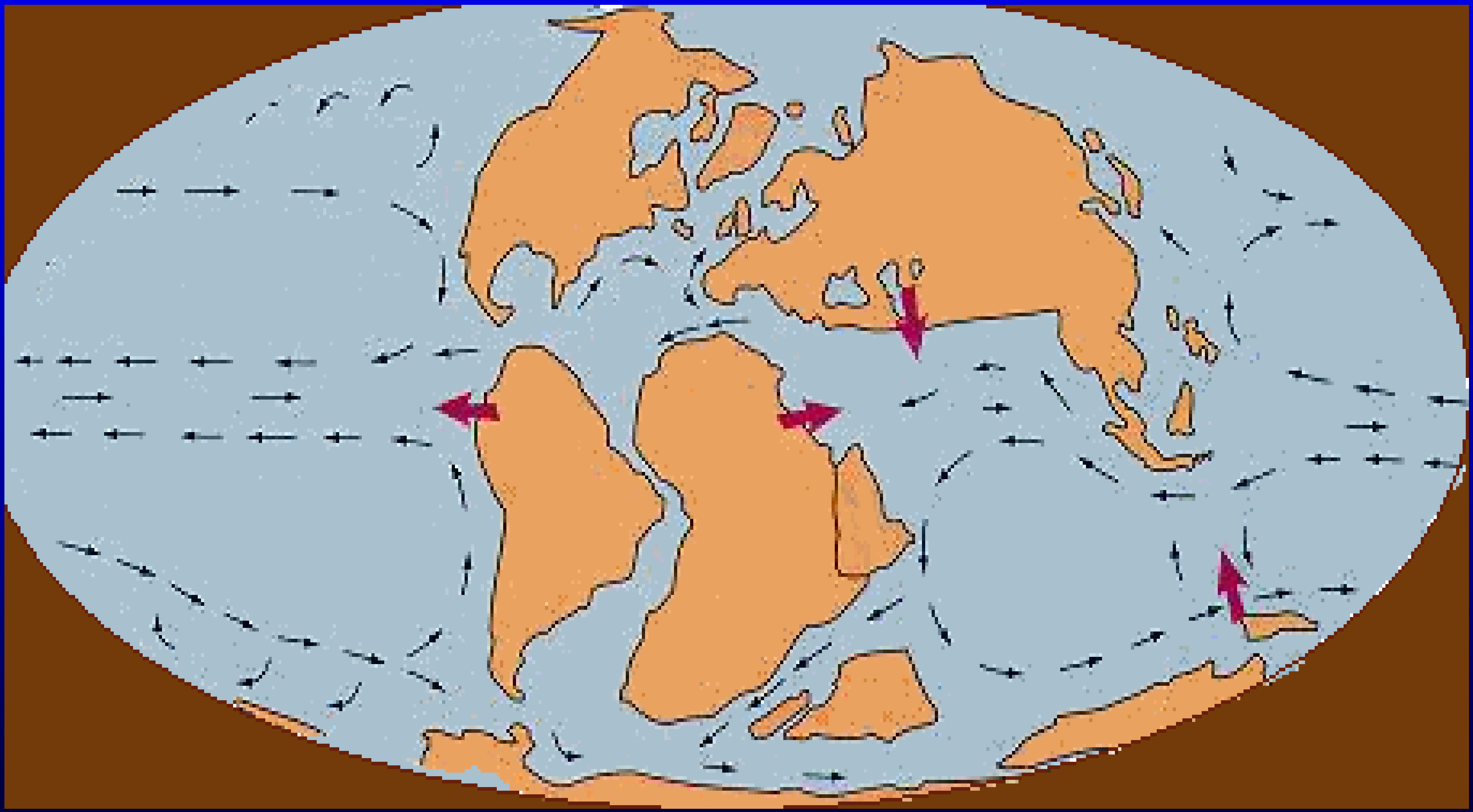
m = mass

Ocean circulation - 160 million years ago



http://earth.usc.edu/~stott/Catalina/Oceans.html

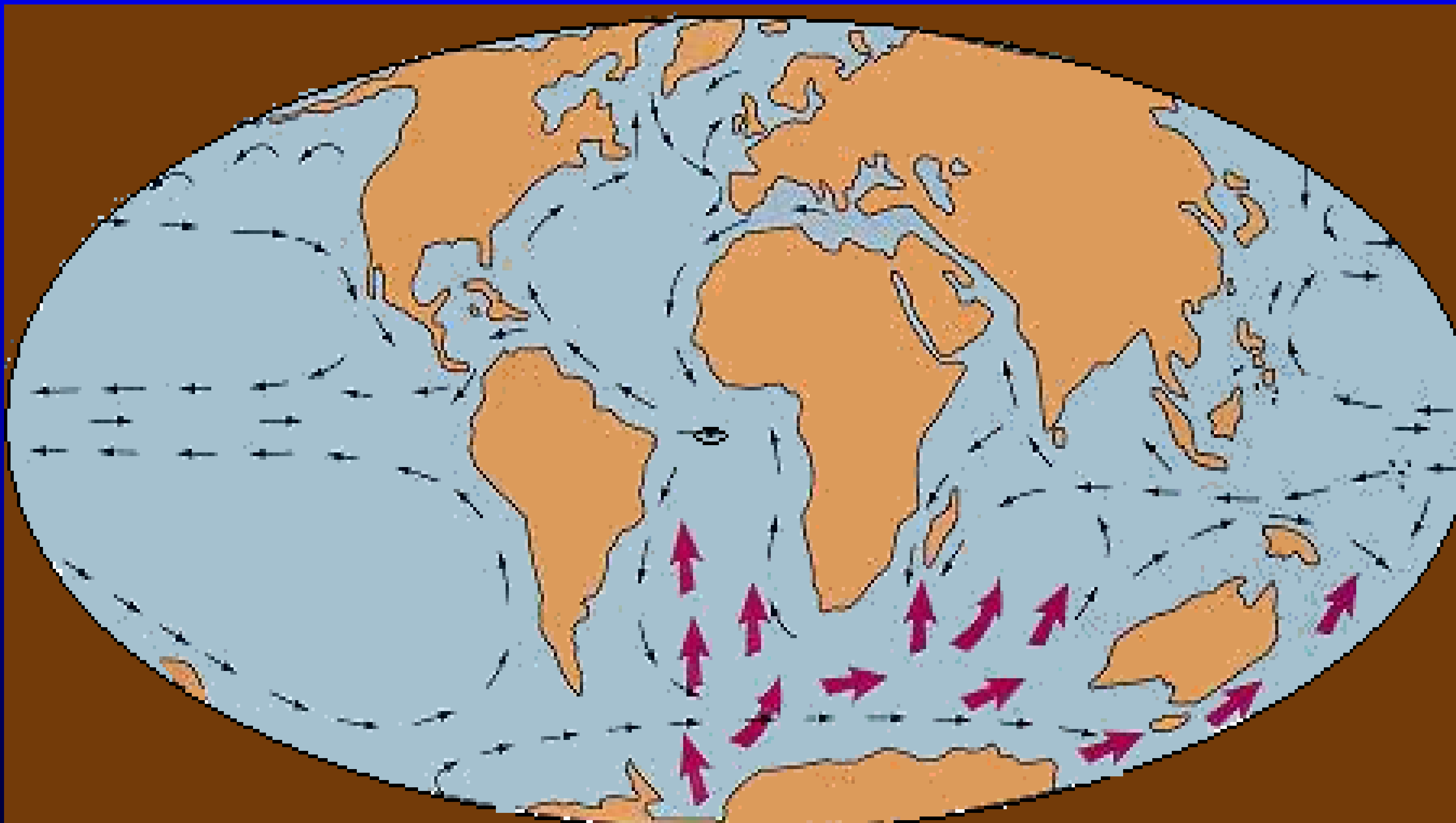
Ocean circulation - 100 million years ago



→ Currents
→ Continental drift

http://earth.usc.edu/~stott/Catalina/Oceans.html

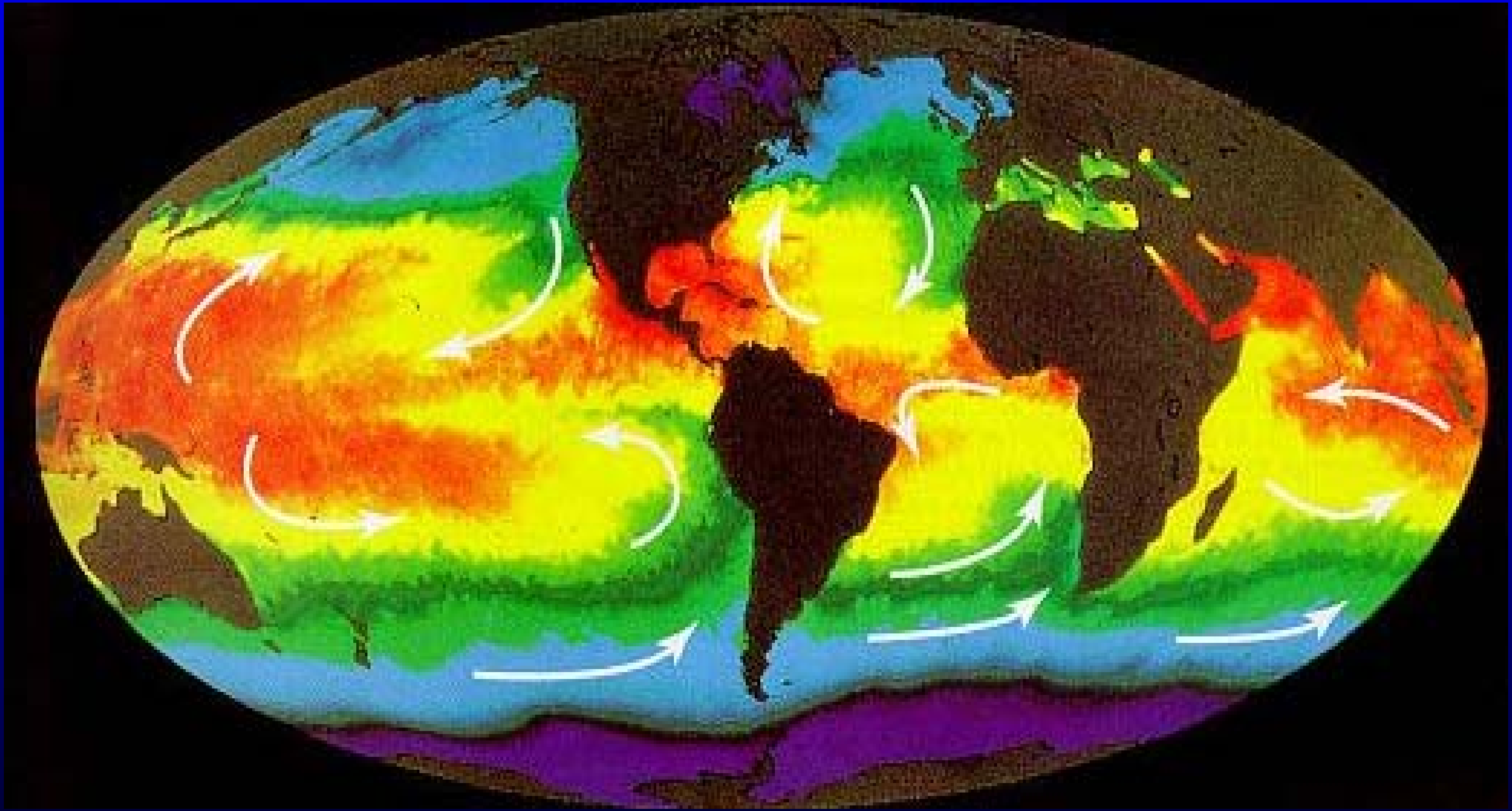
Ocean circulation - 30 million years ago



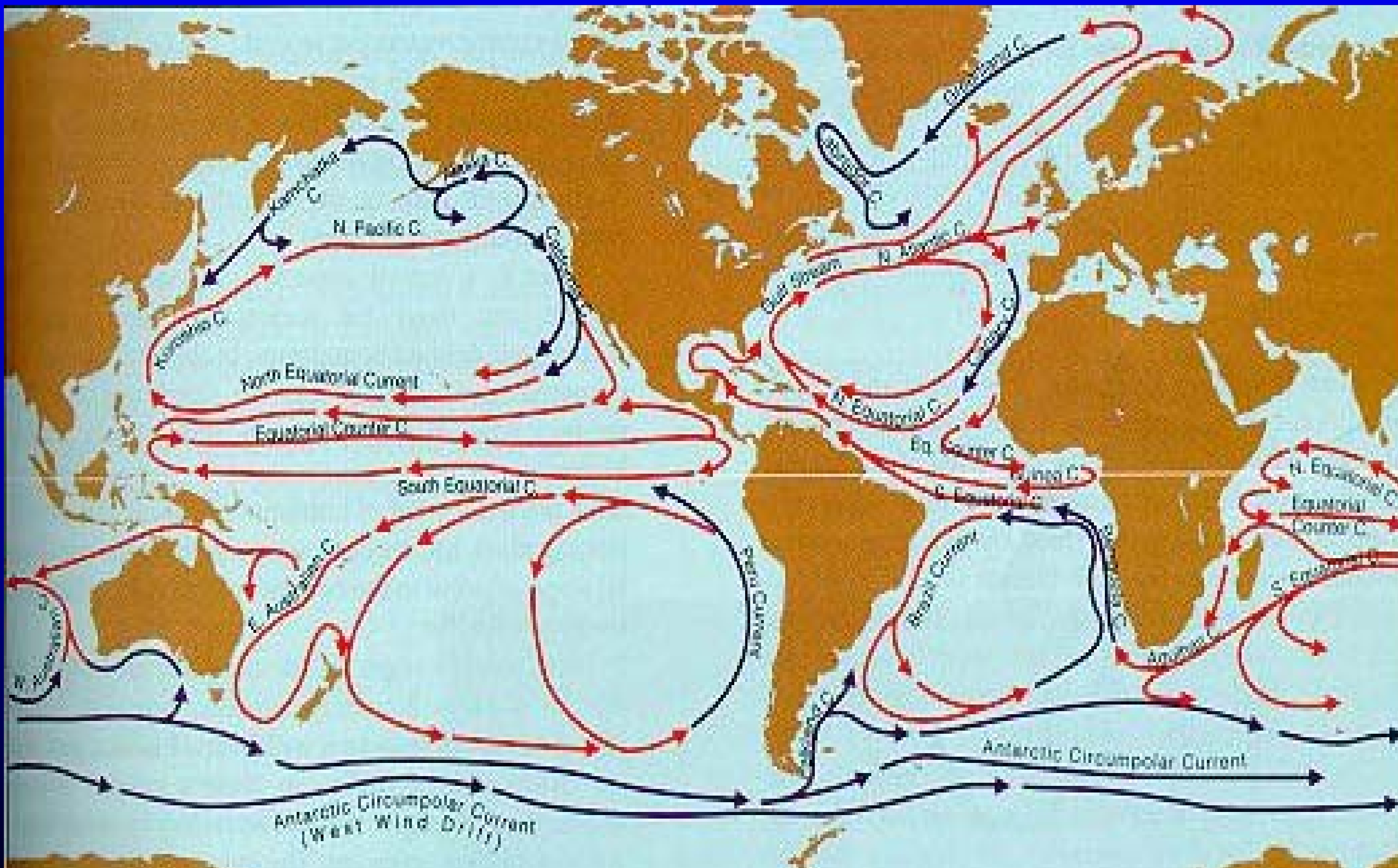
→ Currents
→ Continental drift

http://earth.usc.edu/~stott/Catalina/Oceans.html

Global ocean - surface gyres and temperatures



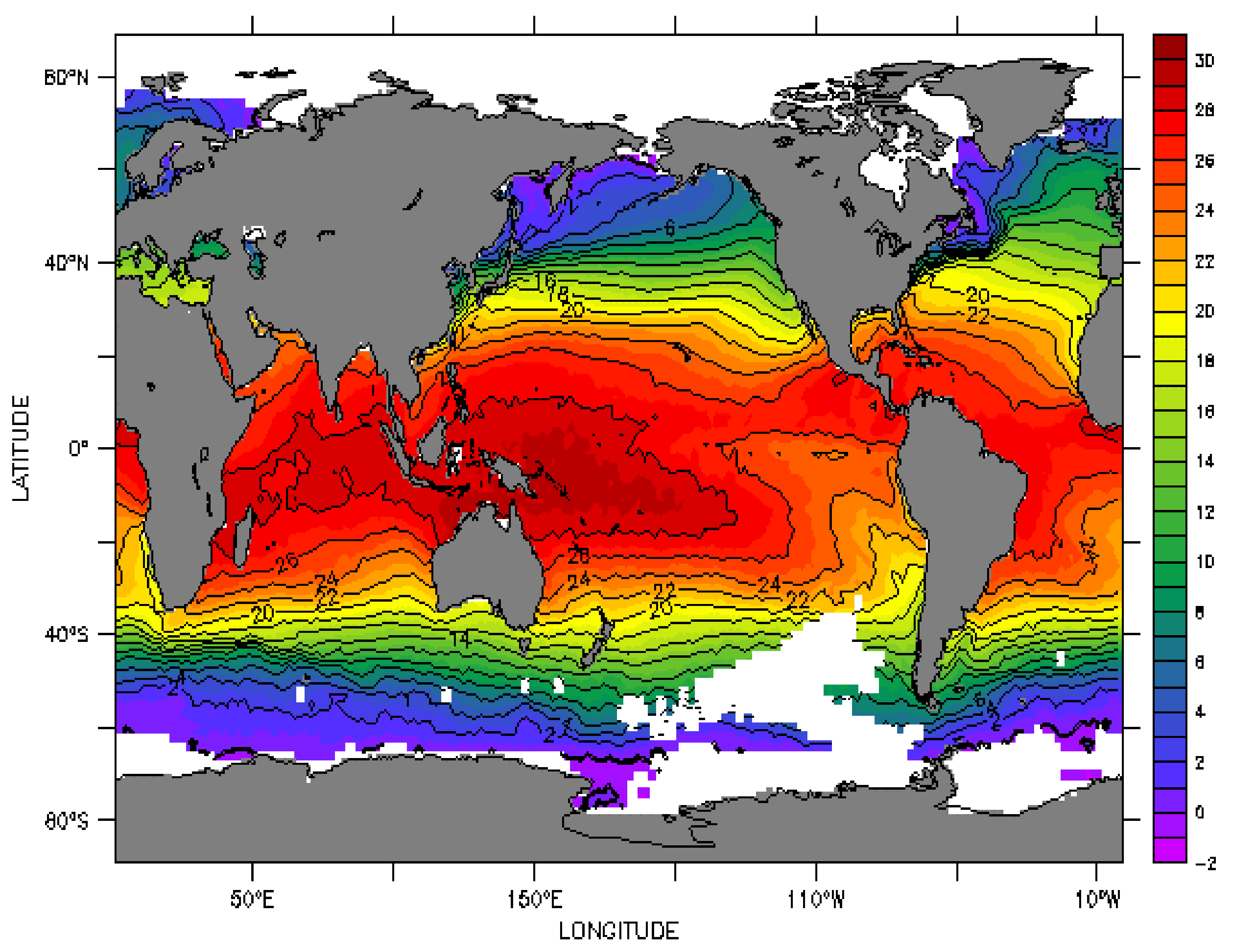
Surface currents in the global ocean



Cold current

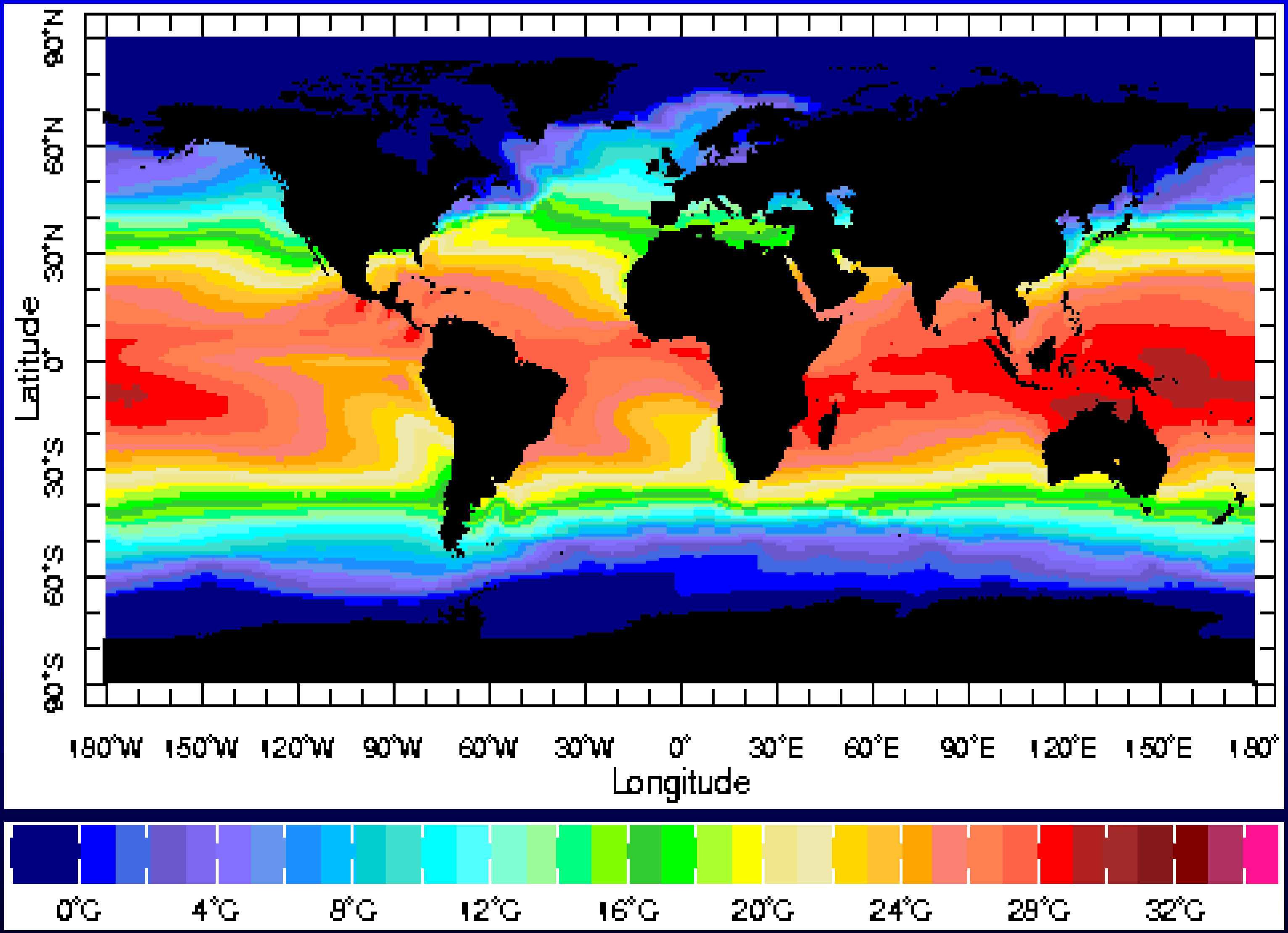
Warm current

Sea surface temperature - NOAA



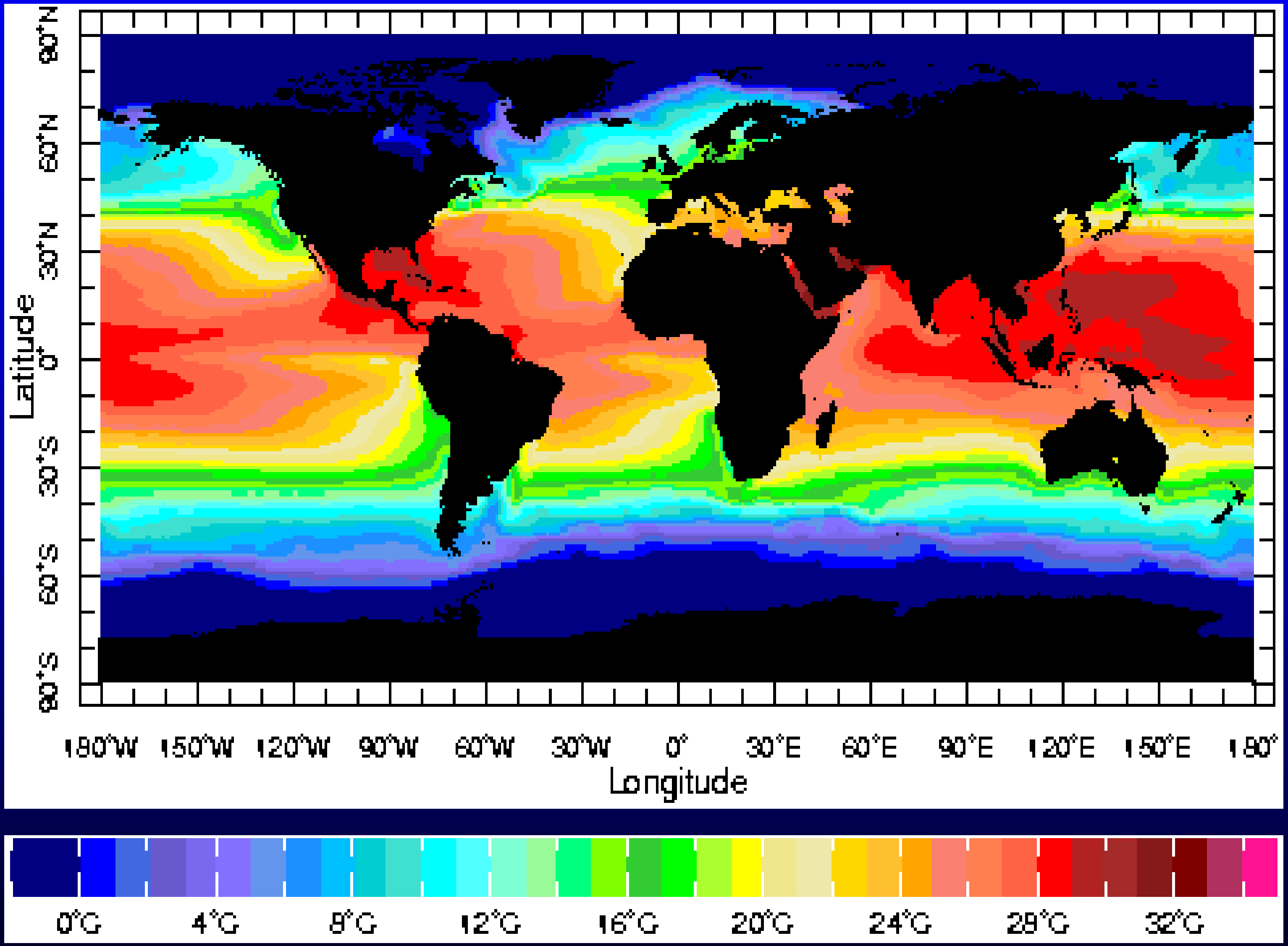
Data in oC - COADS monthly climatology dataset (1946-1989)

Global ocean surface temperature



December temperature (oC) - Data from NOAA

Global ocean surface temperature



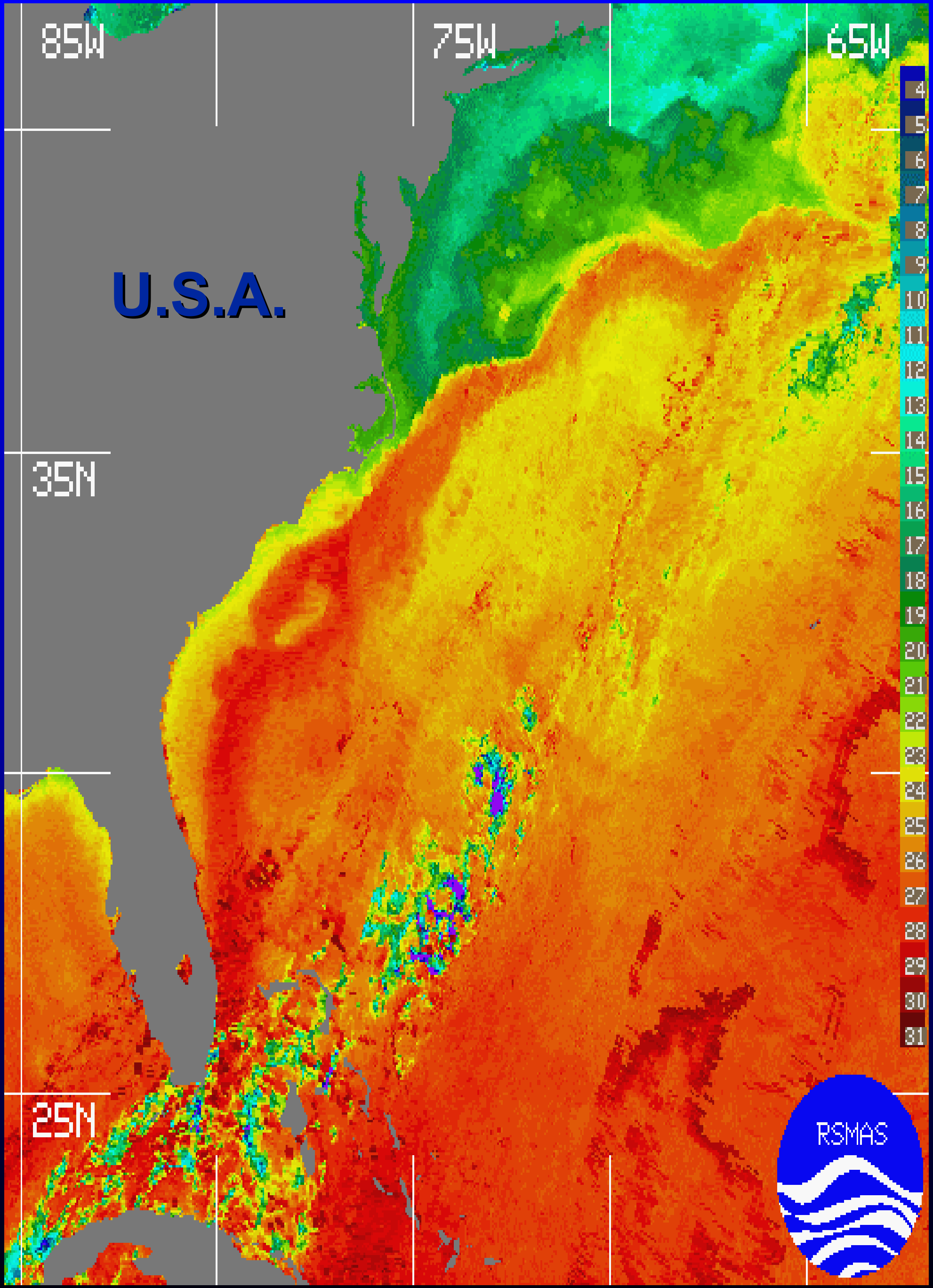
July temperature (oC) - Data from NOAA

North Atlantic gyre

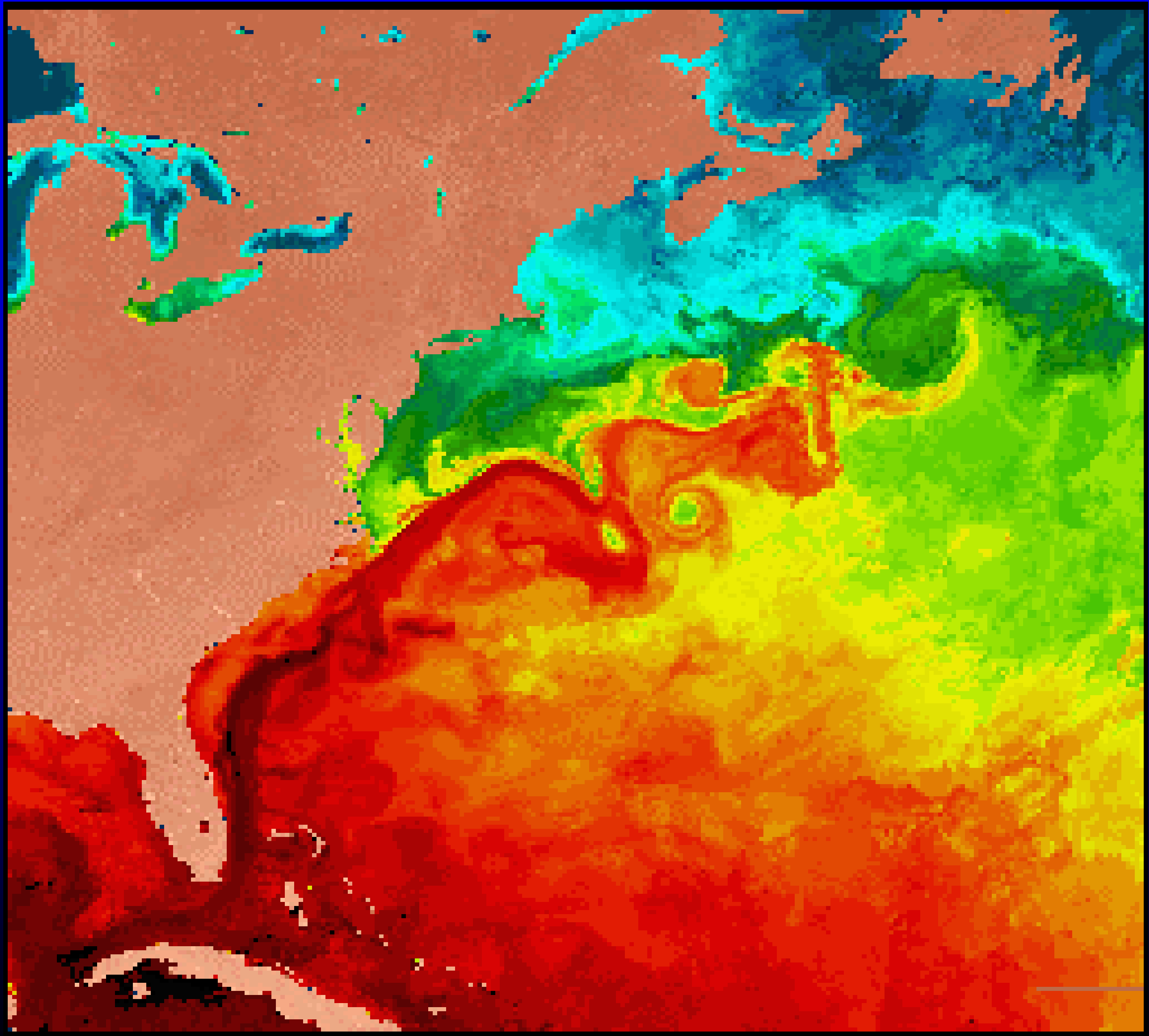
Flows in Sverdrup (1 Sv = 10^6 m^3 s^{-1})

Gulf stream current

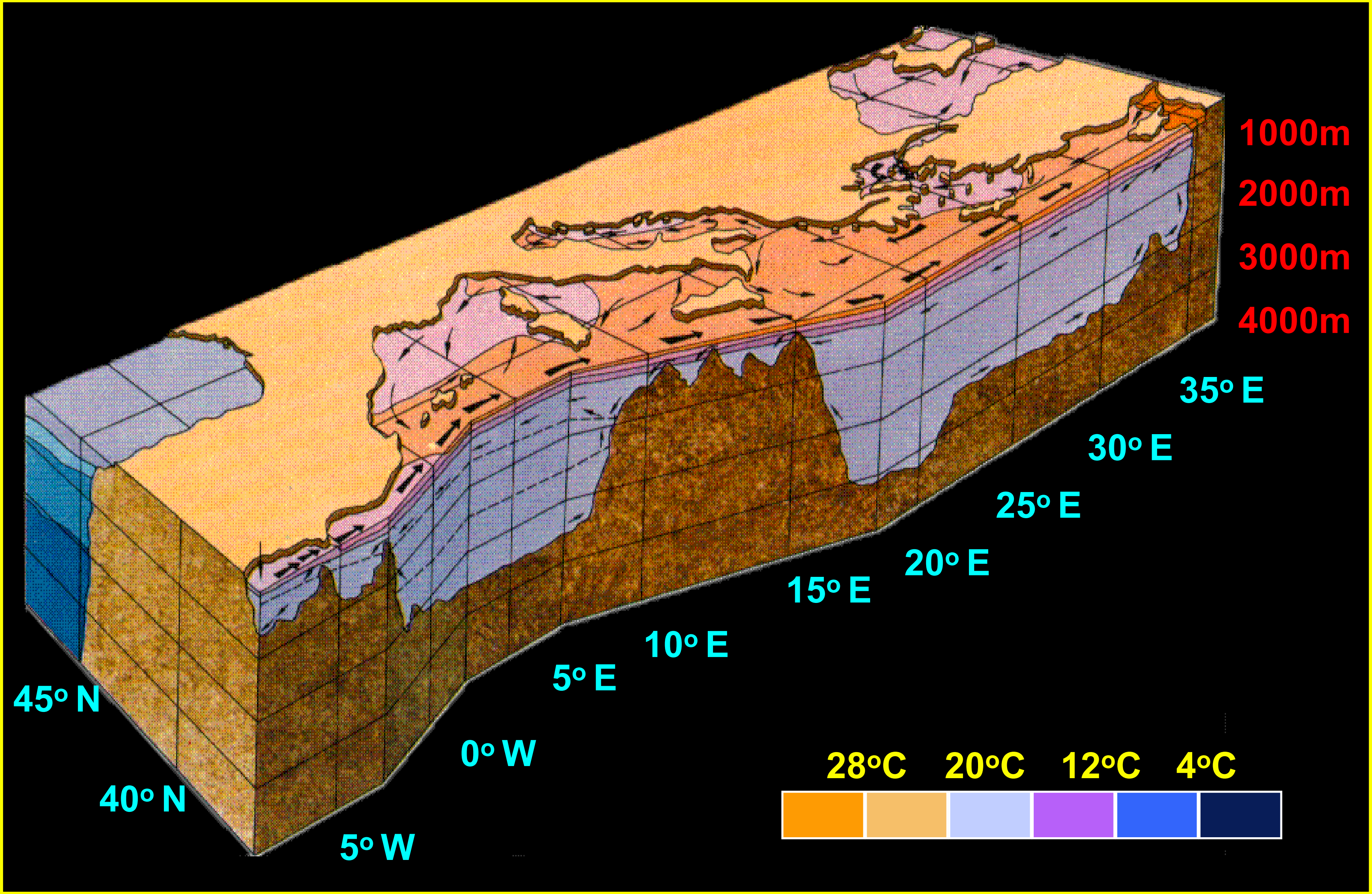
Temperature profile (oC)



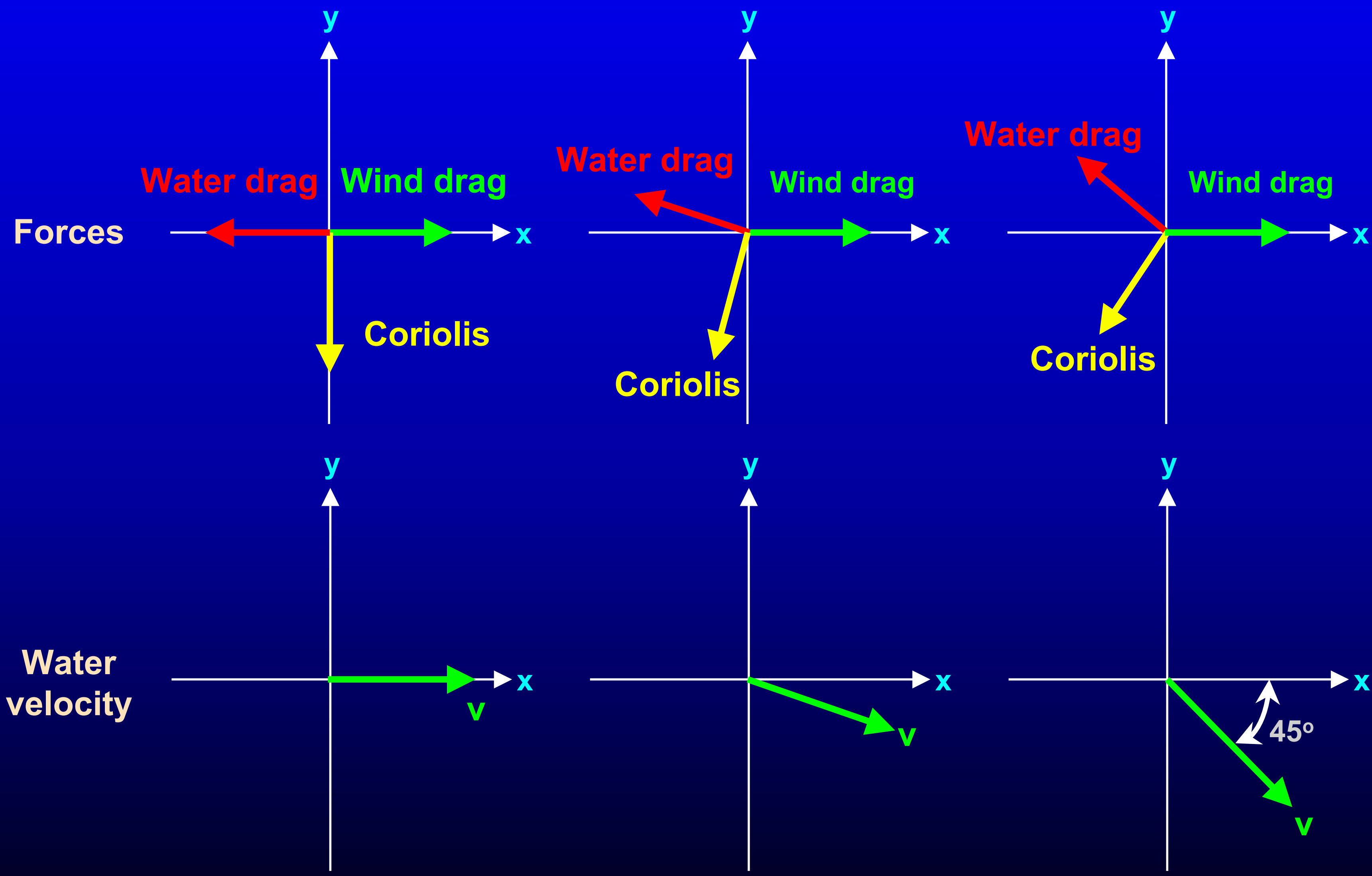
Gulf stream current, showing ring formation



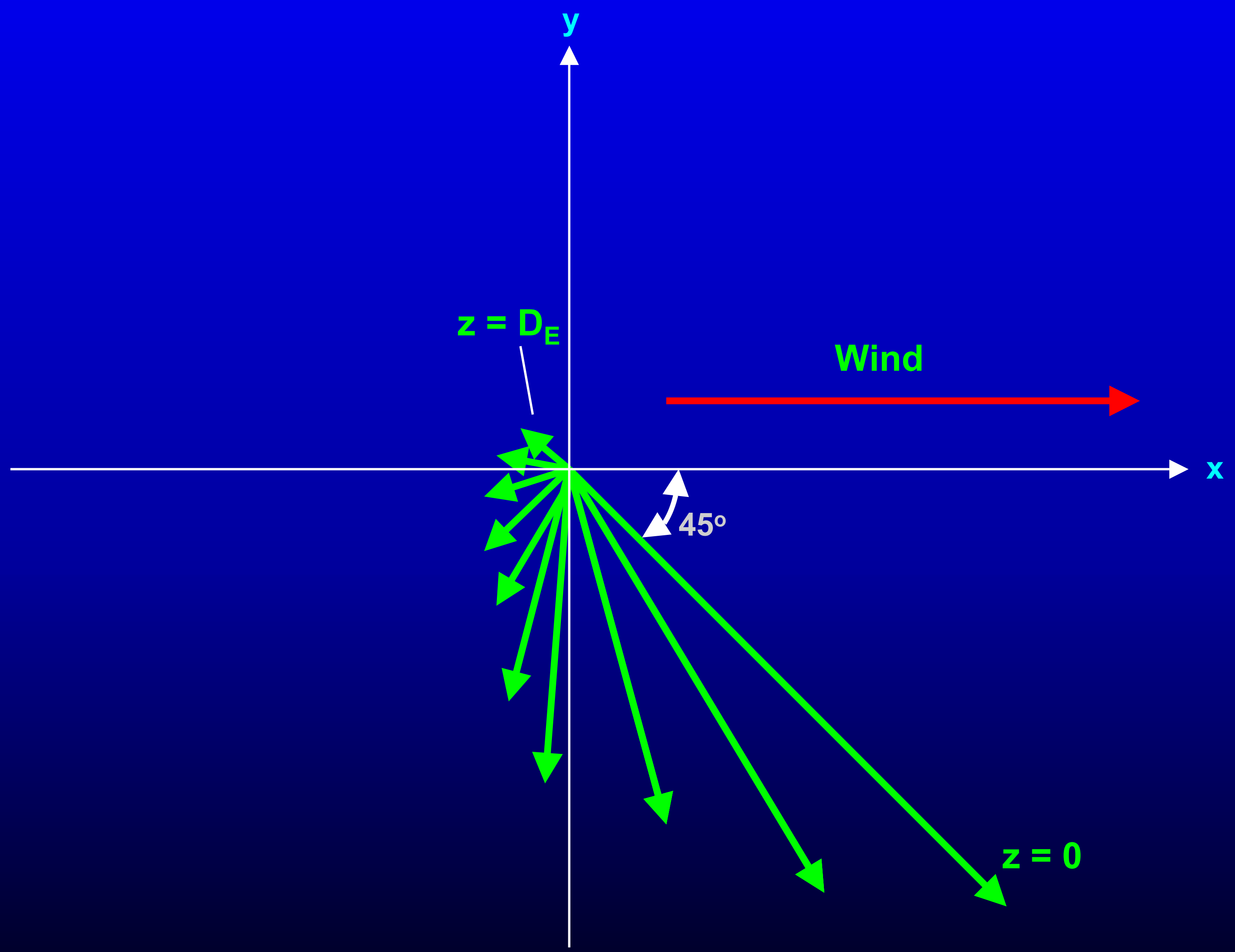
Circulação geral do Mar Mediterrâneo



Wind-driven surface currents

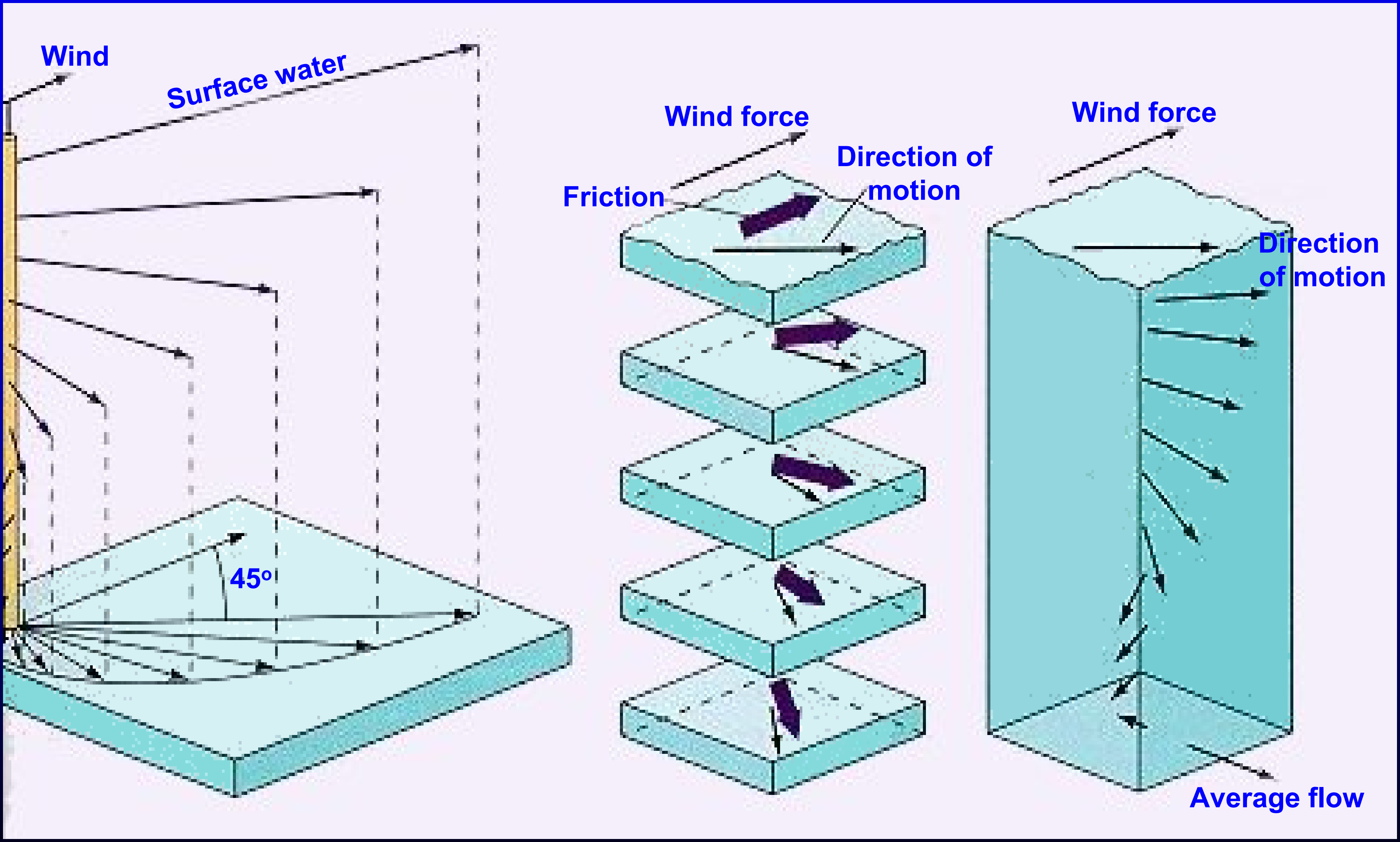


Eckman spiral - schematic representation

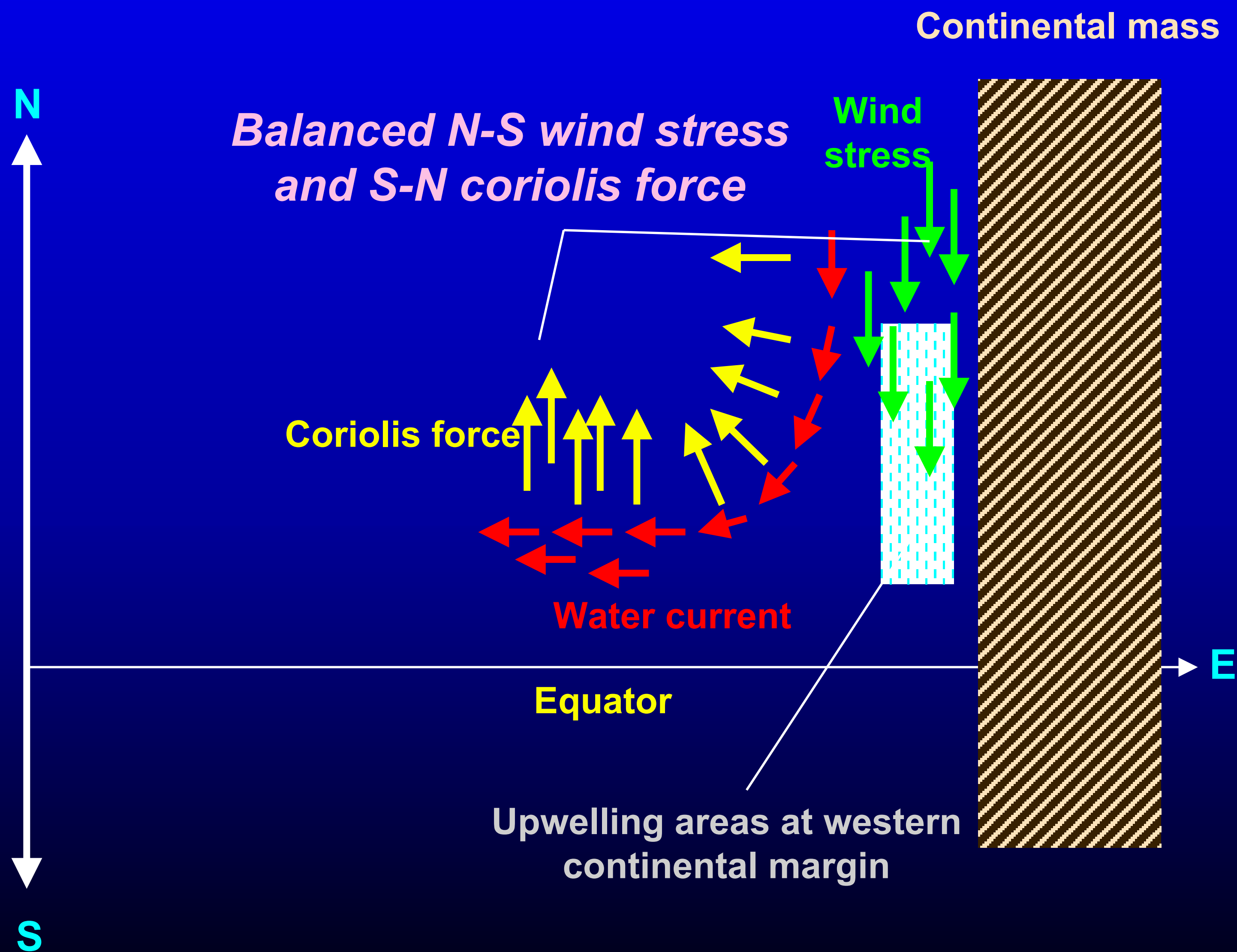


Horizontal projection of currents at 11 equally-spaced levels from the surface to bottom of the Eckman layer (D_E)

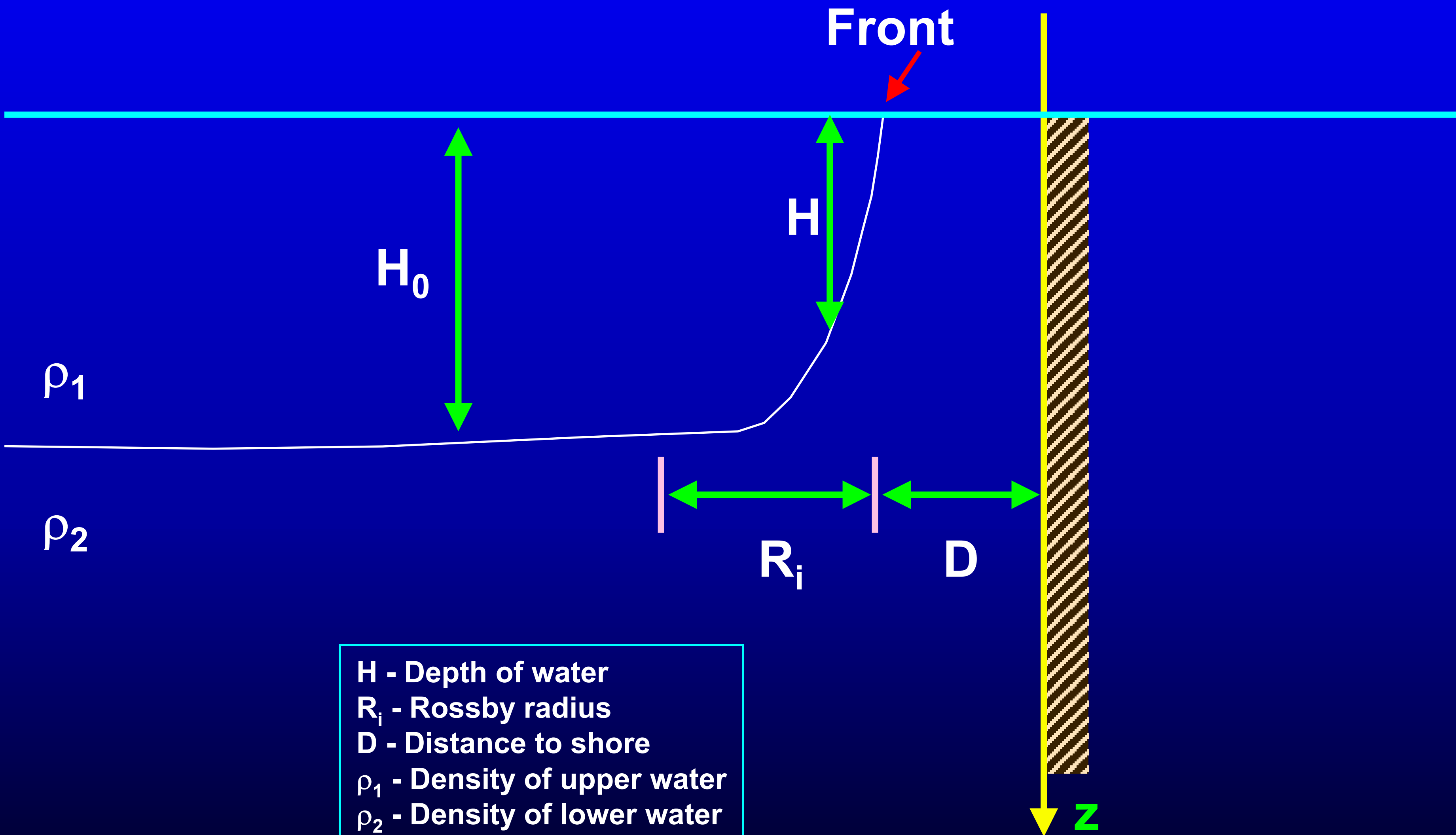
Eckman spiral - schematic representation



Geostrophic balance



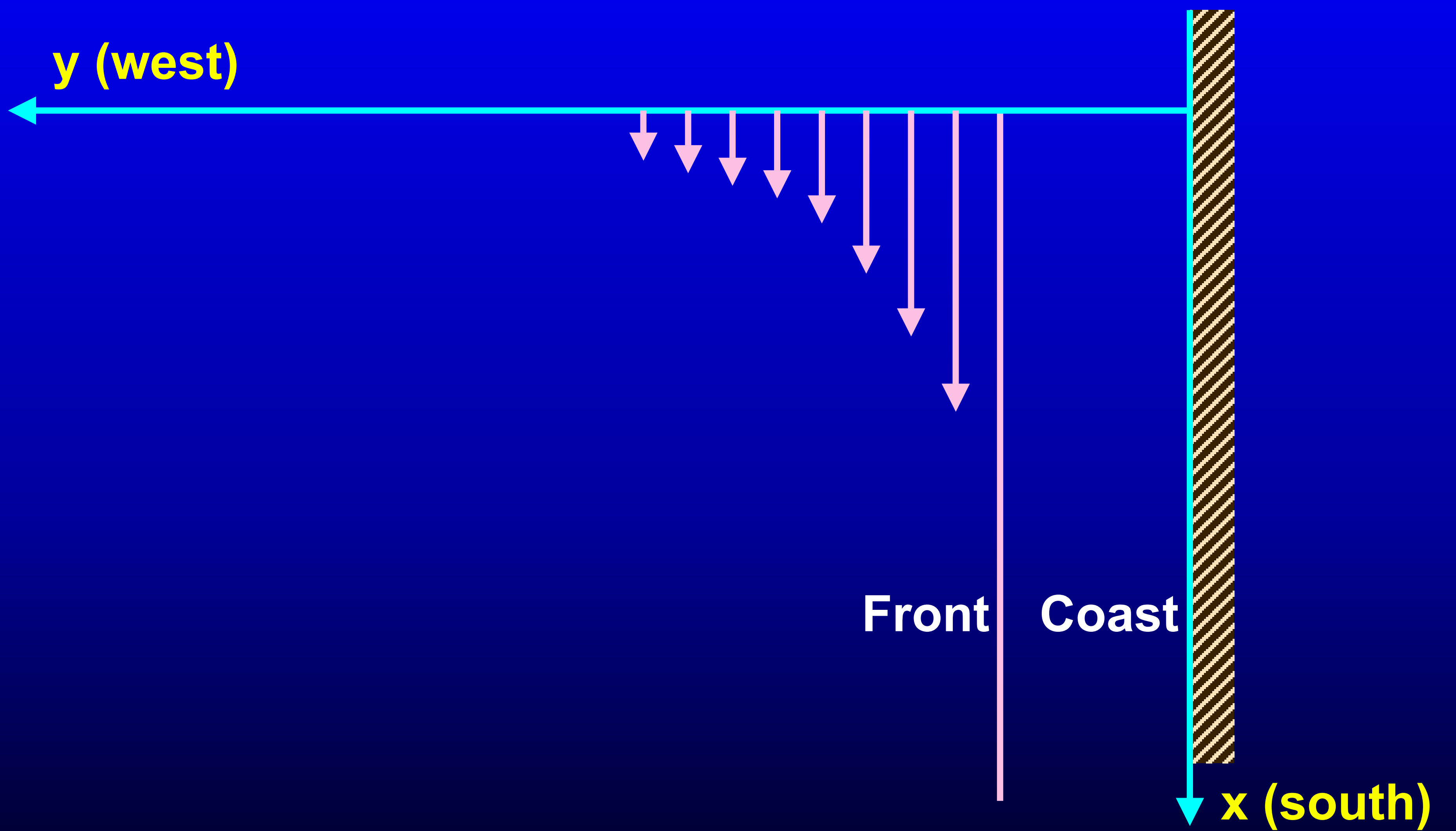
Coastal upwelling - vertical section



H - Depth of water
R_i - Rossby radius
D - Distance to shore
ρ_1 - Density of upper water
ρ_2 - Density of lower water
z - Depth

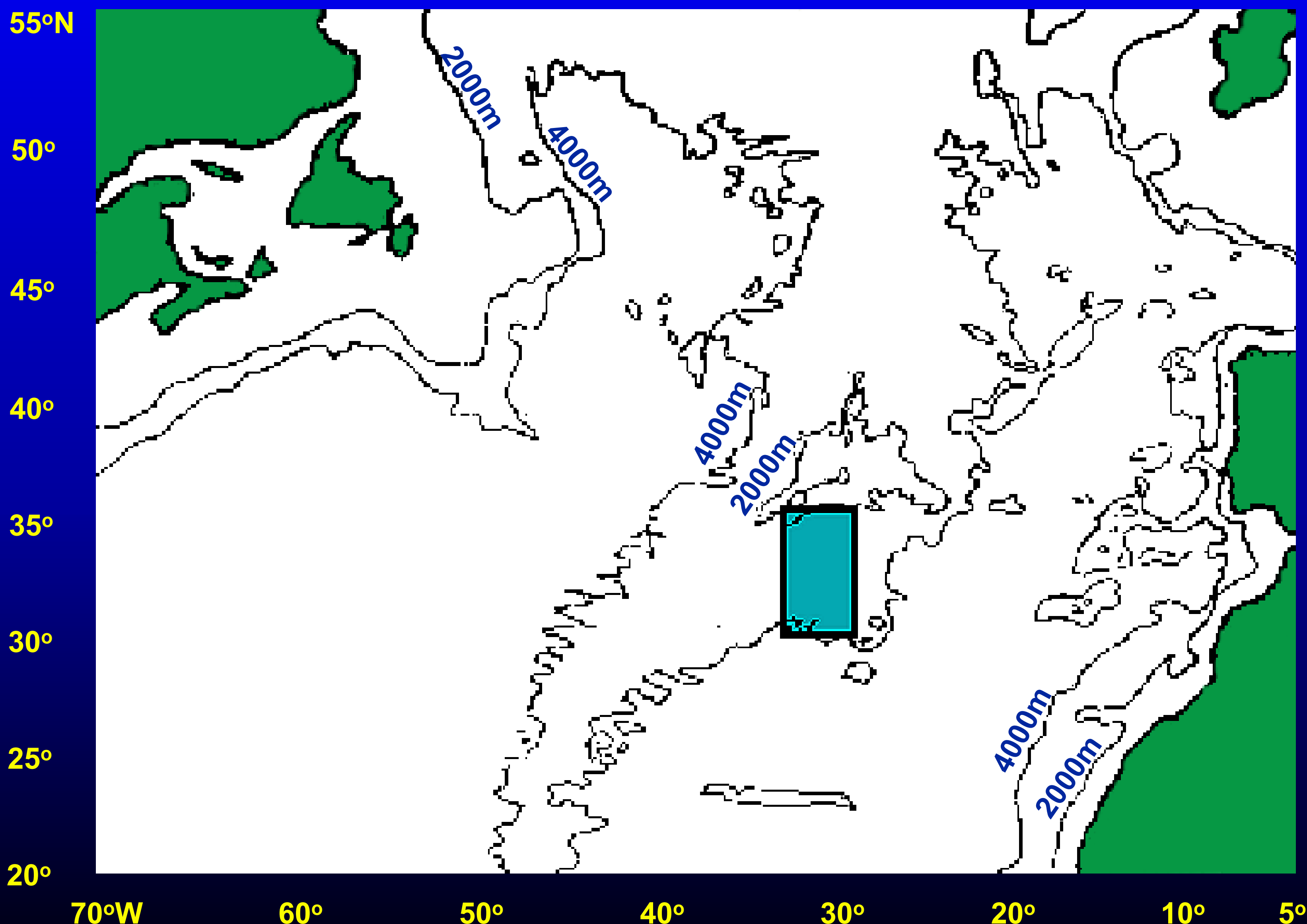
Mann & Lazier - Dynamics of Marine Ecosystems, Blackwell, 1991

Coastal upwelling - plan view



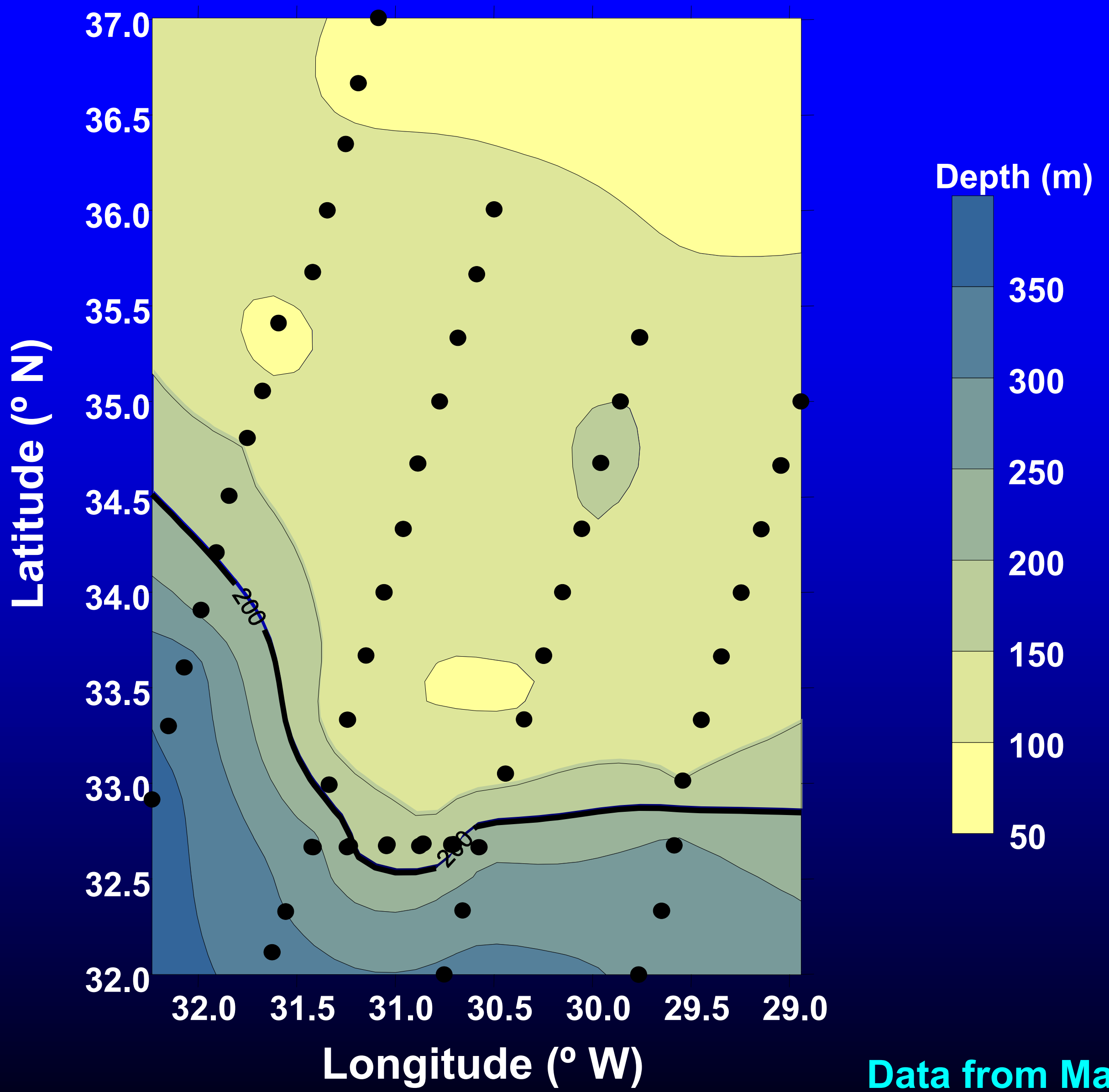
Mann & Lazier - Dynamics of Marine Ecosystems, Blackwell, 1991

Azores Front



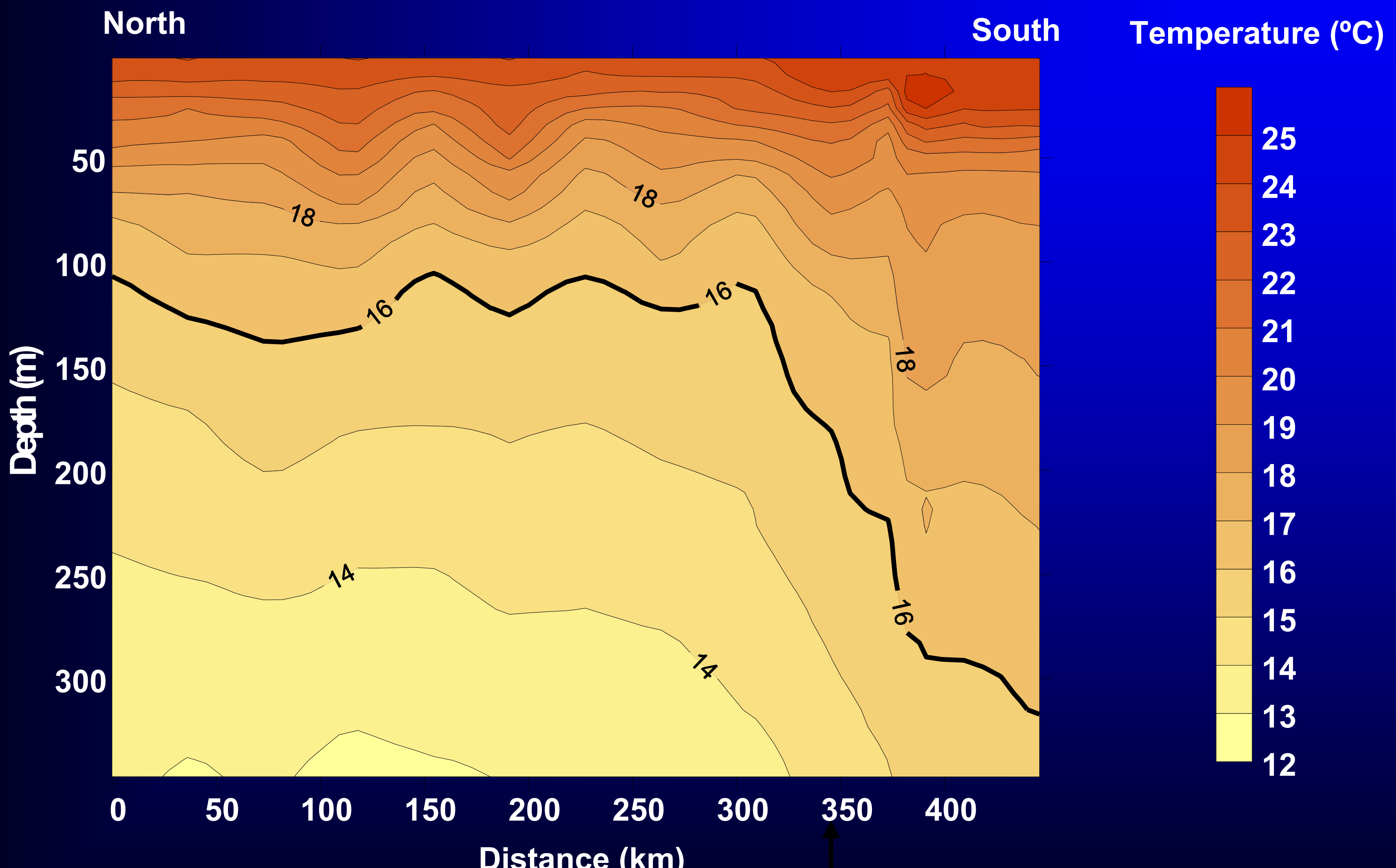
Data from Macedo et al, 1999

Azores Front depth contours



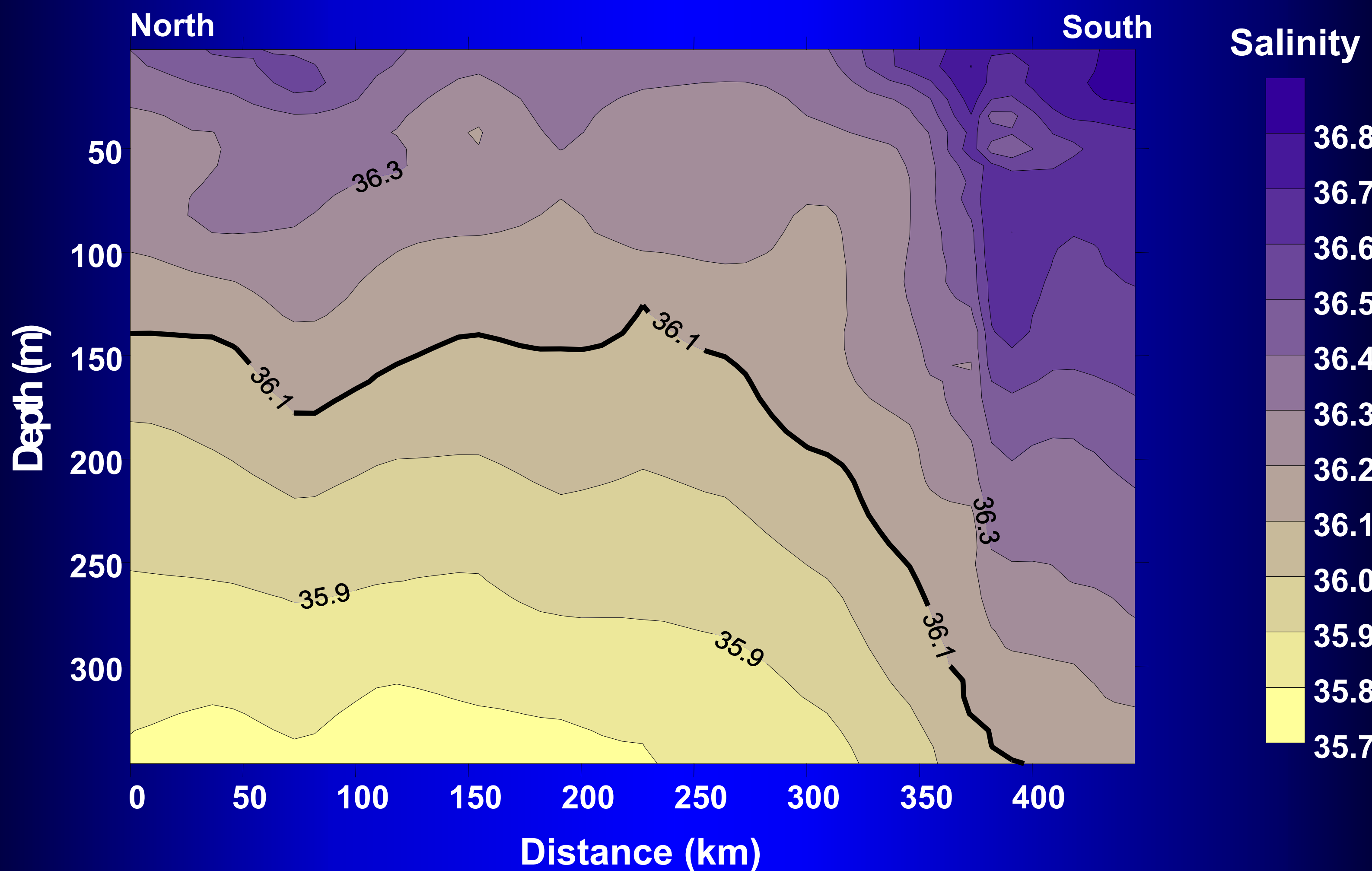
Data from Macedo et al, 1999

Temperature profile - Azores Front



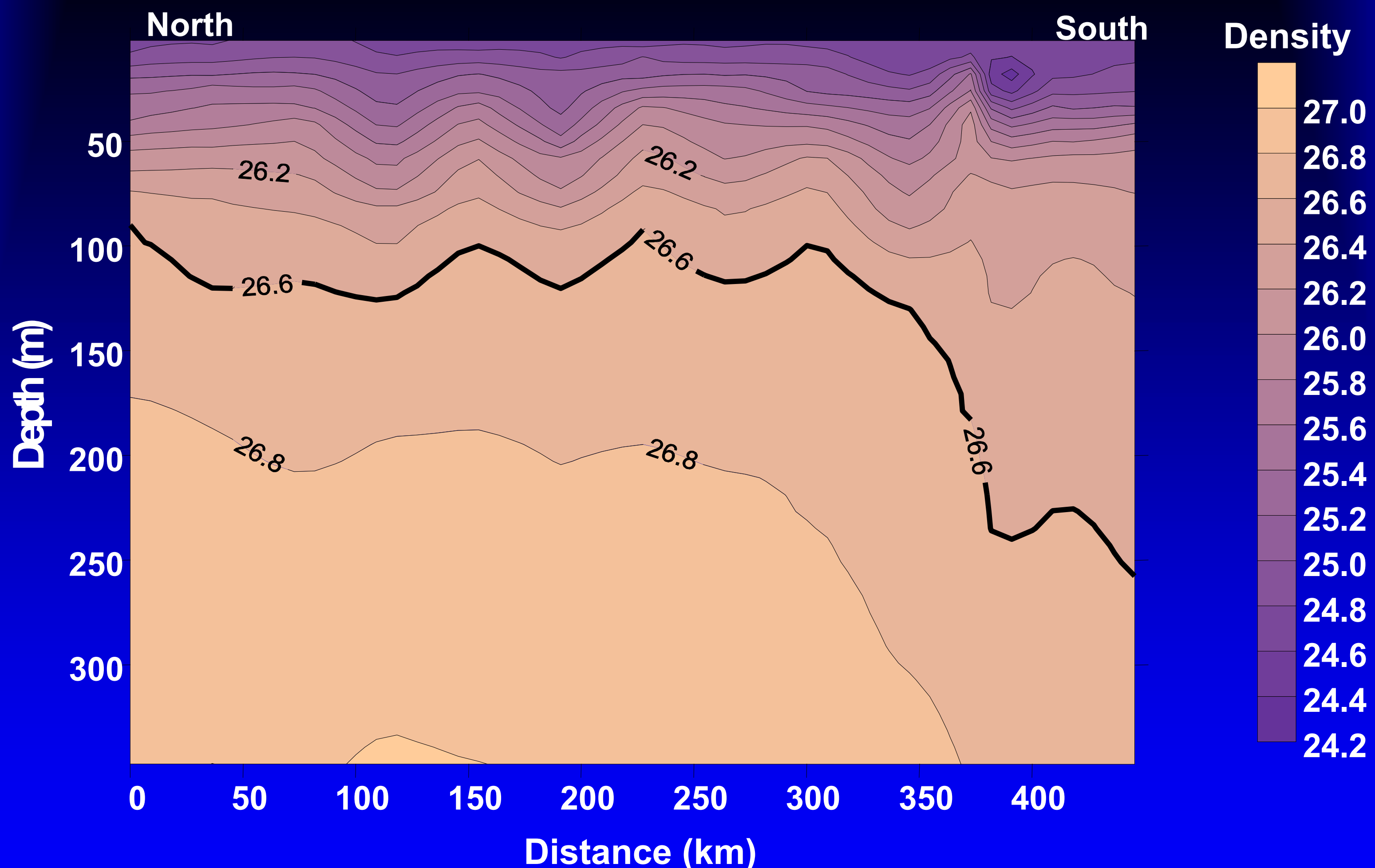
Data from Macedo et al, 1999

Salinity profile - Azores Front



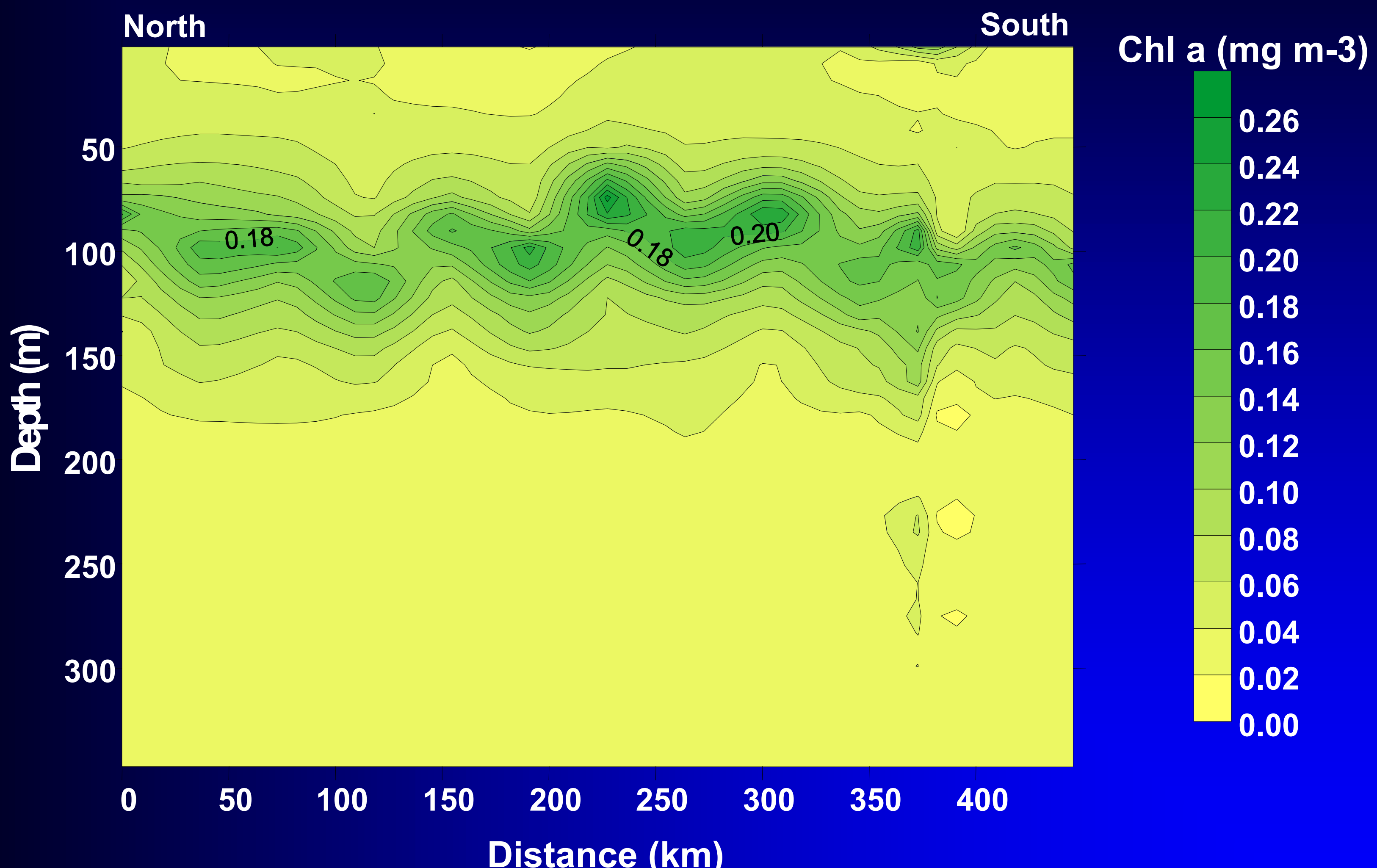
Data from Macedo et al, 1999

Density profile - Azores Front



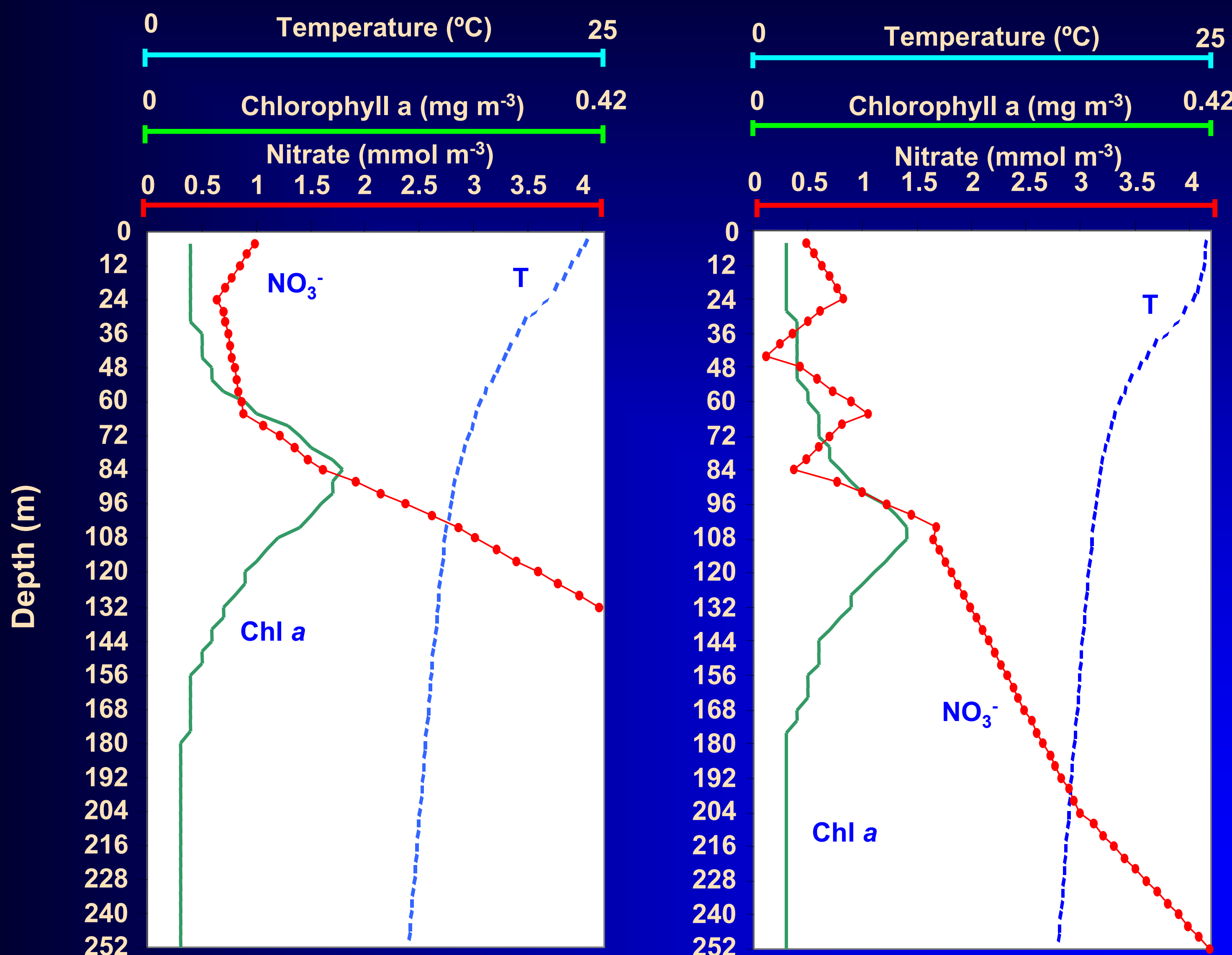
Data from Macedo et al, 1999

Chlorophyll *a* profile - Azores Front



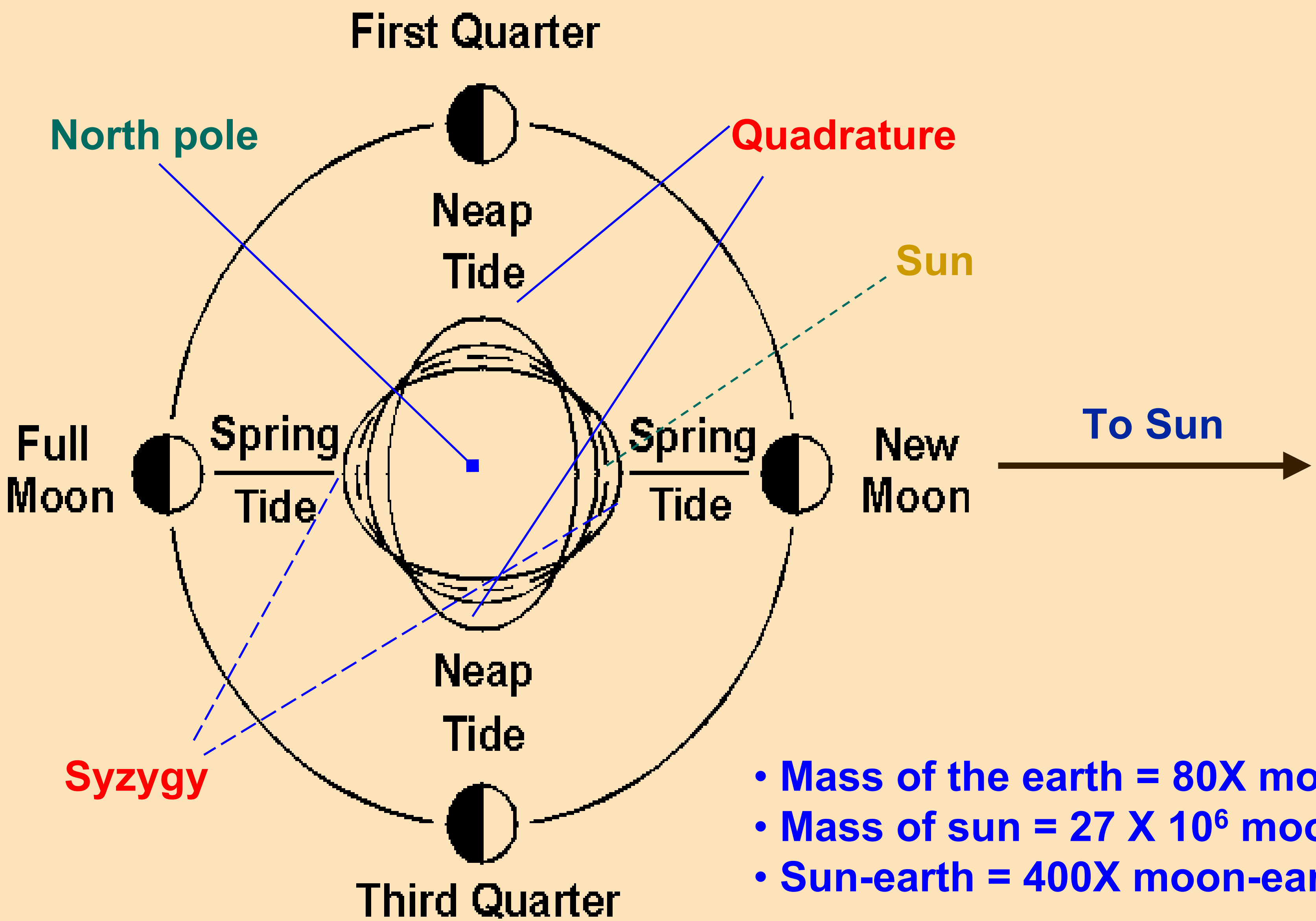
Data from Macedo et al, 1999

Vertical profiles for temperature, chlorophyll a and nitrate - Azores Front



North Data from Macedo et al, 1999 South

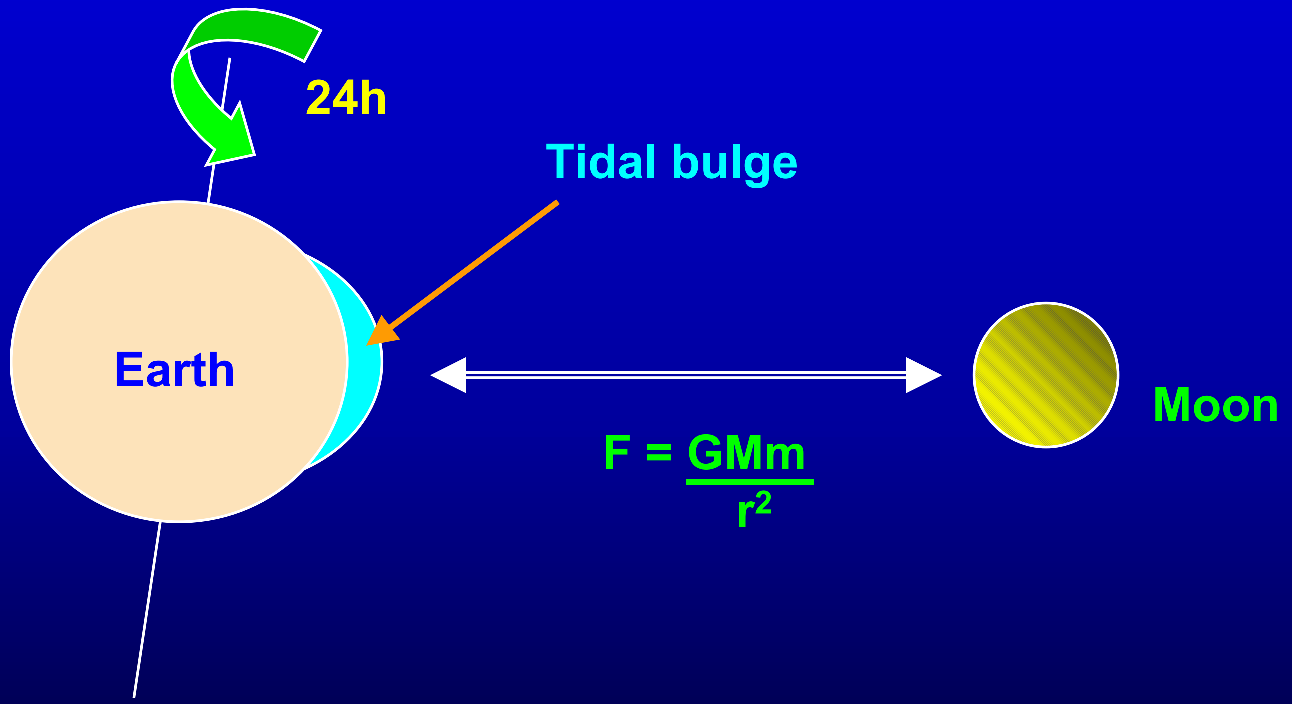
Tides and tide generating forces



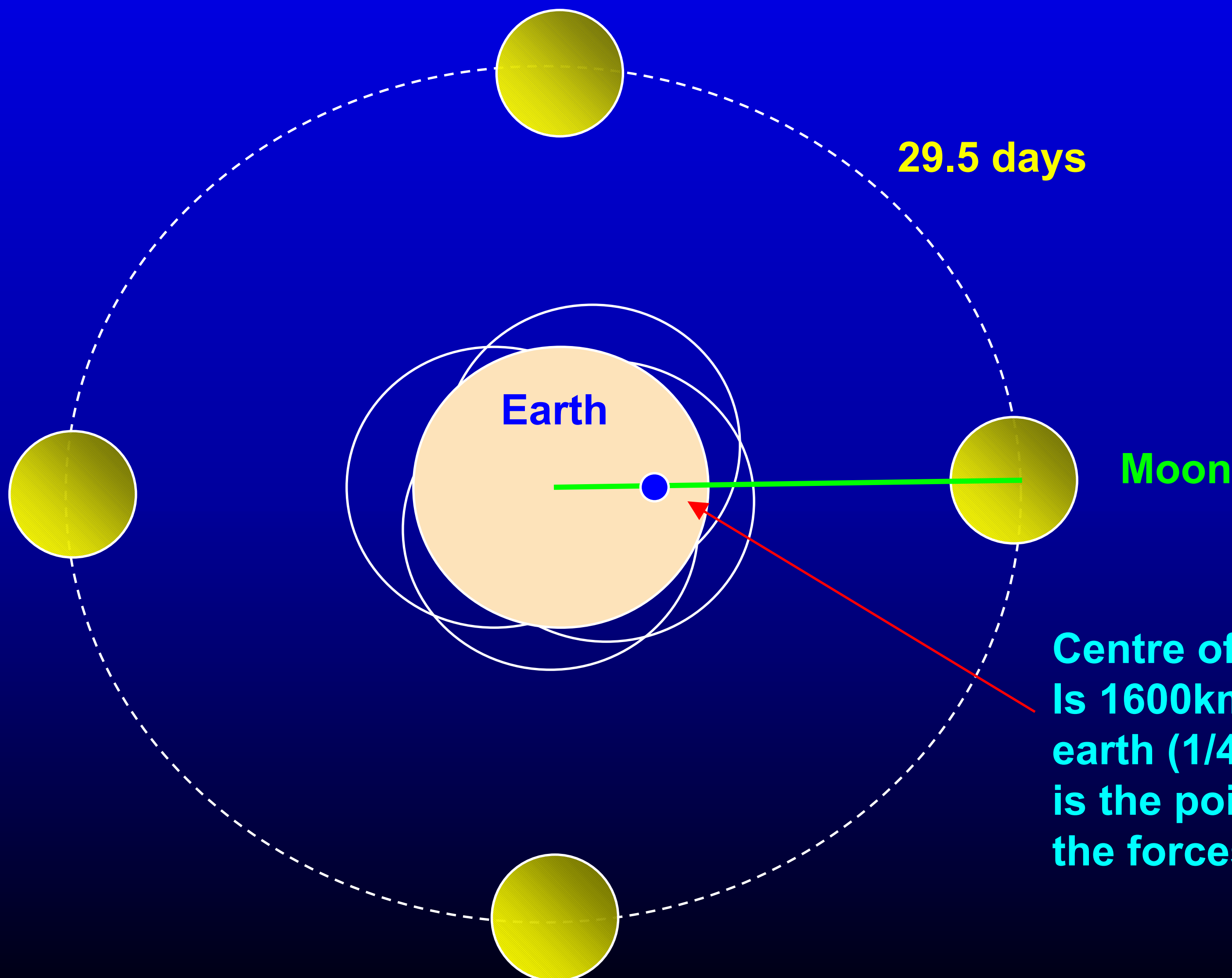
- Mass of the earth = 80X moon
- Mass of sun = 27 X 10^6 moon
- Sun-earth = 400X moon-earth

Tides and tide generating forces

Model for a daily tide

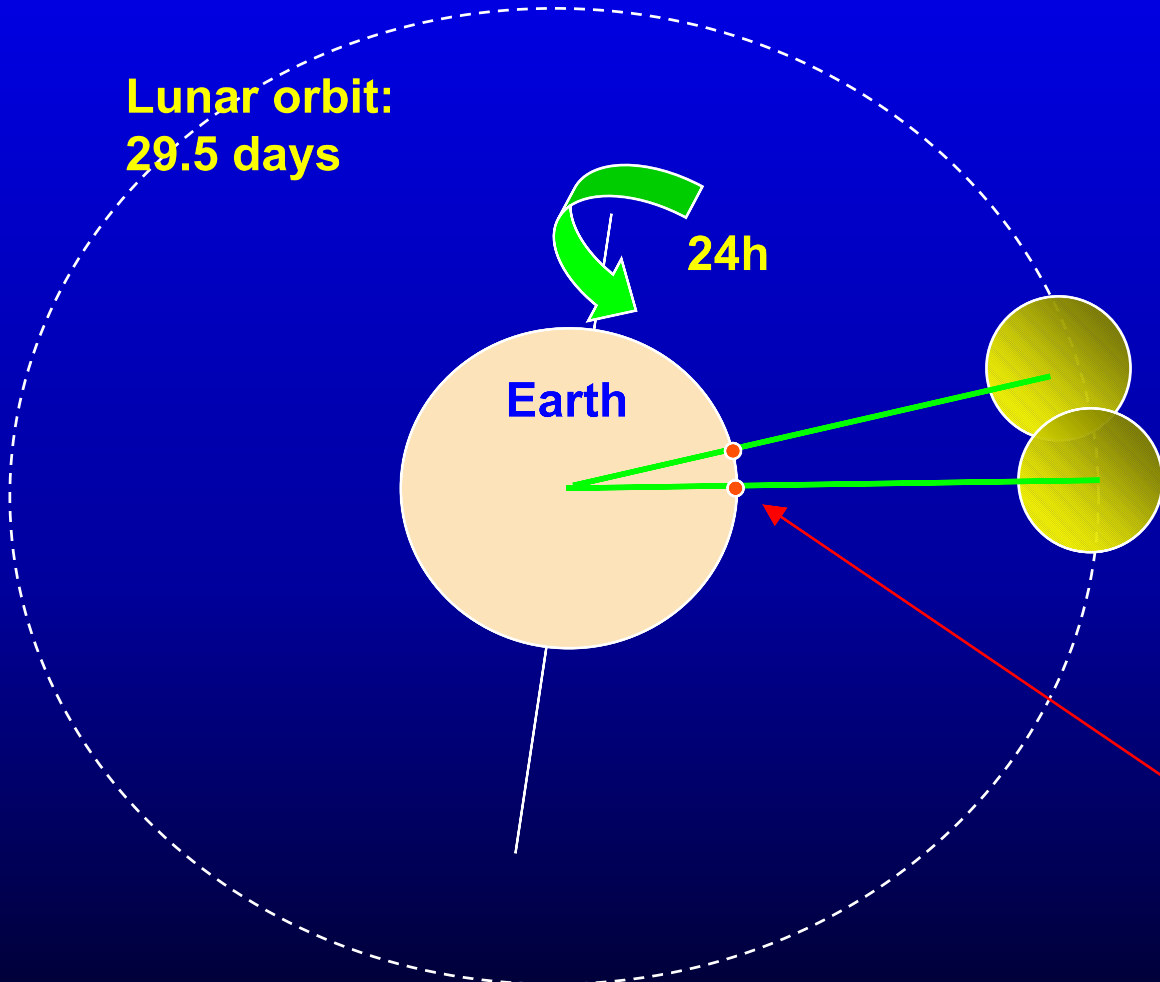


Tides and tide generating forces
Model for a semi-diurnal tide



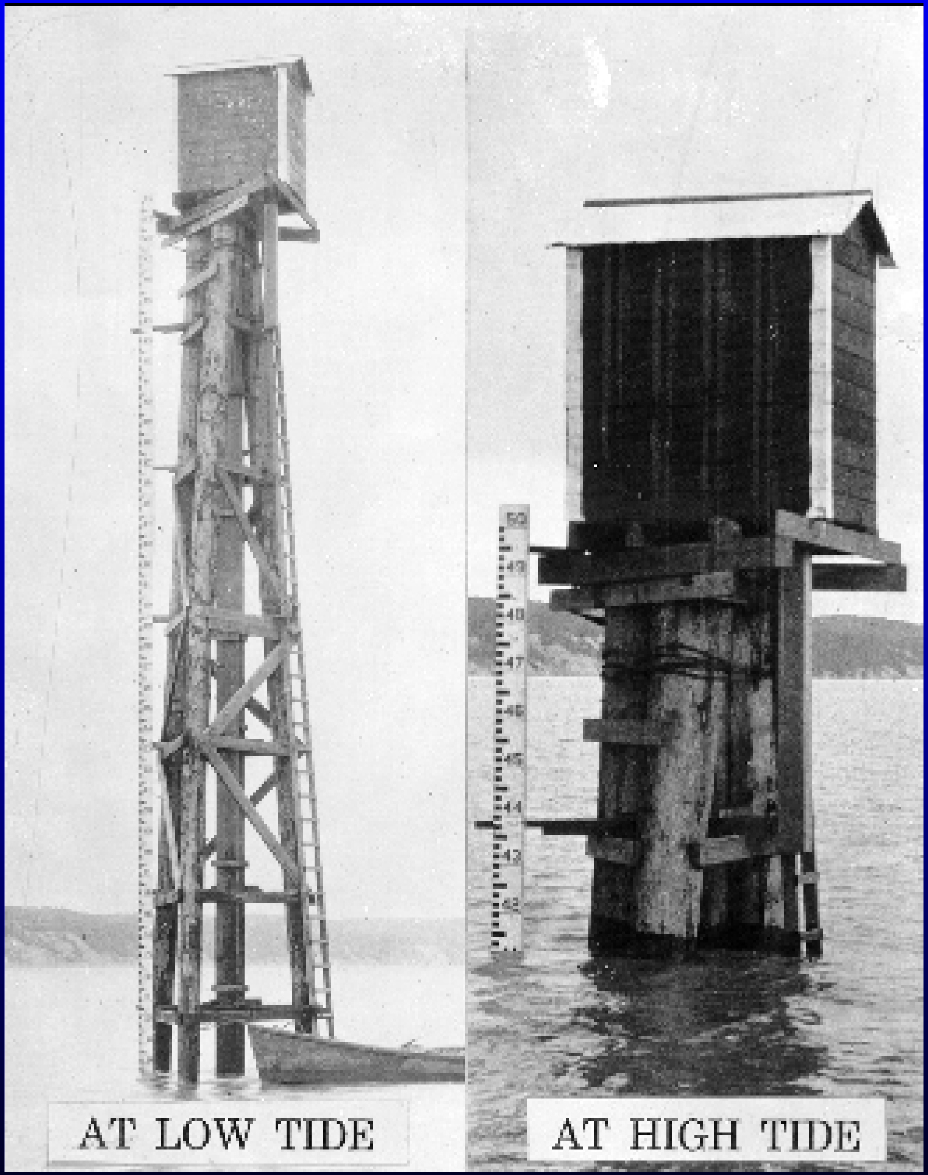
Centre of rotation
Is 1600km inside the
earth (1/4 radius), and
is the point about which
the forces are balanced

Tides and tide generating forces
Model for tidal delay

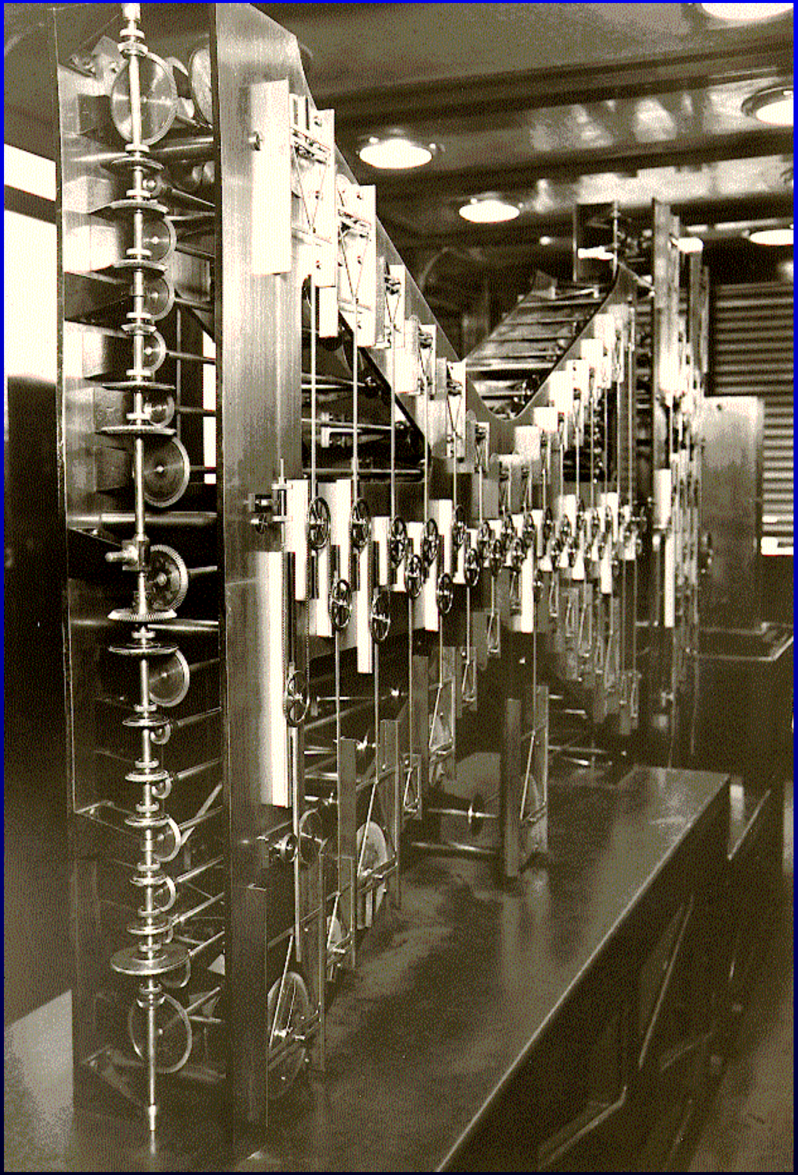


Every day the moon moves approximately 360/30 degrees, i.e. 12°. The time on earth equivalent to 1 degree is 24 * 60 / 360 = 4 minutes, therefore the time lag is 12 * 4 = 48 minutes

Early tide gauges and prediction equipment



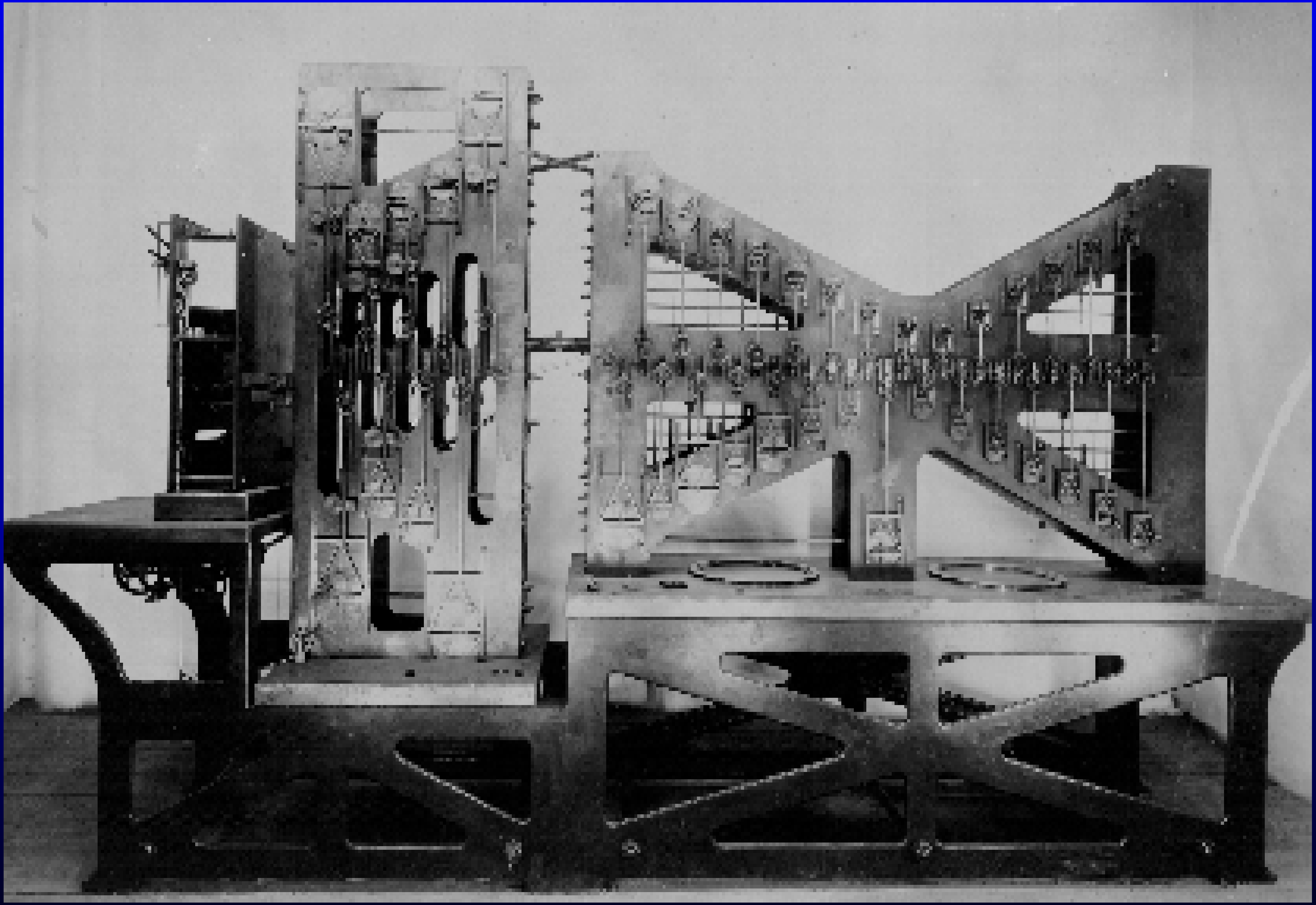
Tide gauge at Anchorage, Alaska



Mechanical tide prediction machine

NOAA website

Mechanical tide prediction equipment



NOAA website

Tides in the real ocean

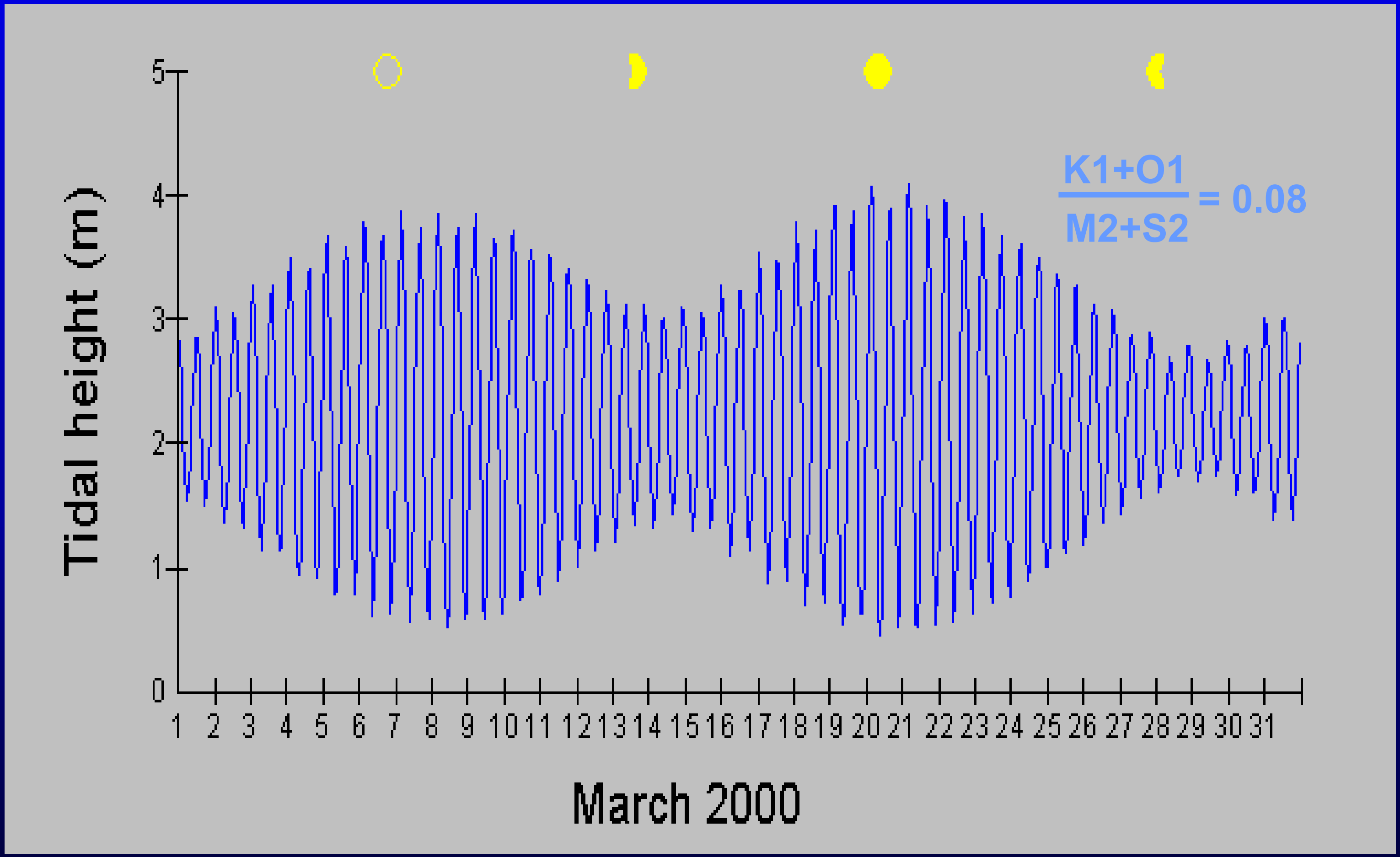
Types of constituents

- Semi-diurnal
- Diurnal
- Long-period
- Over 20 constituents may be required for accurate prediction

4 most important constituents

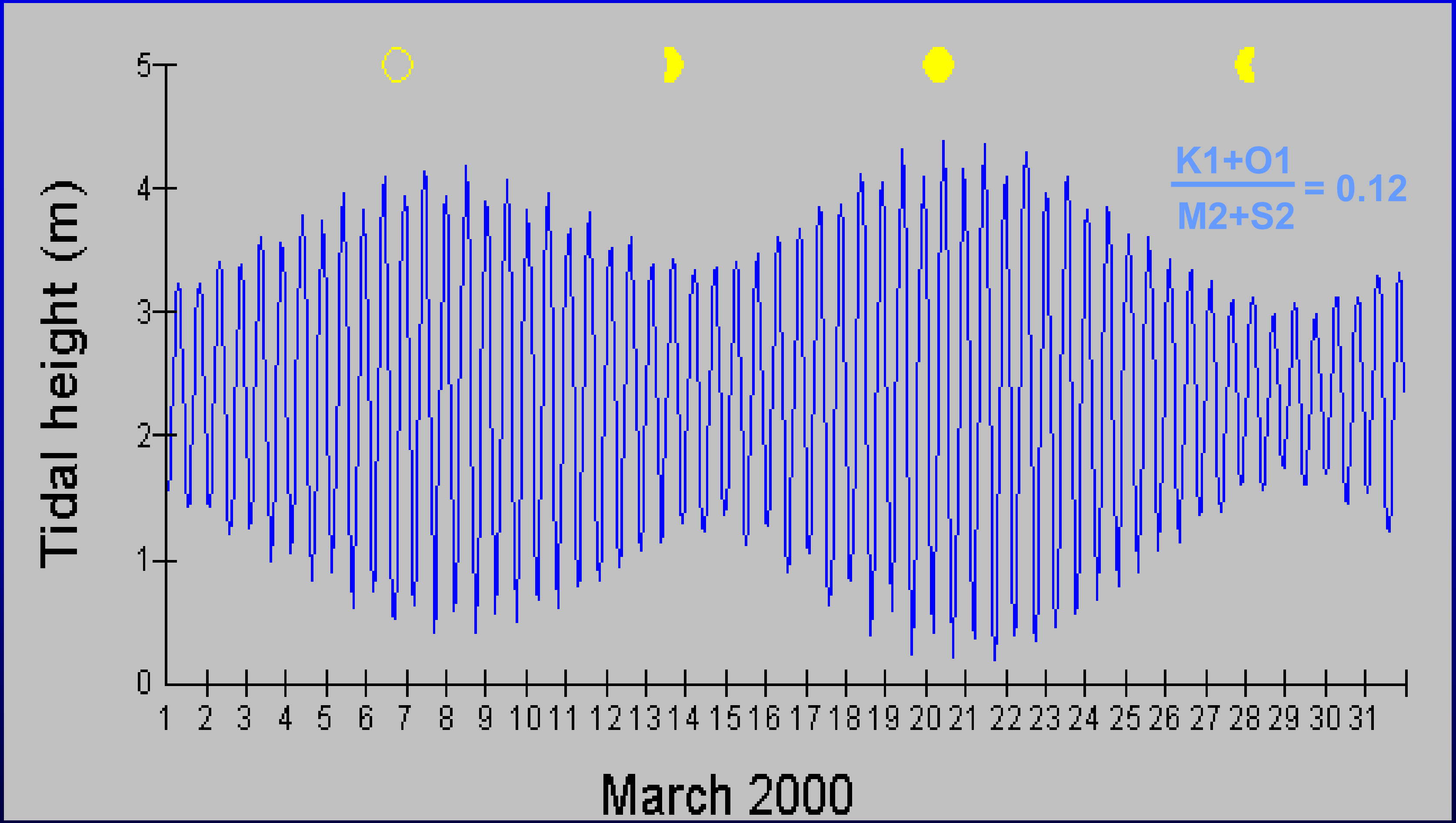
Constituent	Symbol	Period
Lunar semi-diurnal	M_2	12.42h
Solar semi-diurnal	S_2	12.00h
Luni-solar diurnal	K_1	23.93h
Principal lunar diurnal	O_1	25.82h

Tides for March 2000 - Tejo Estuary



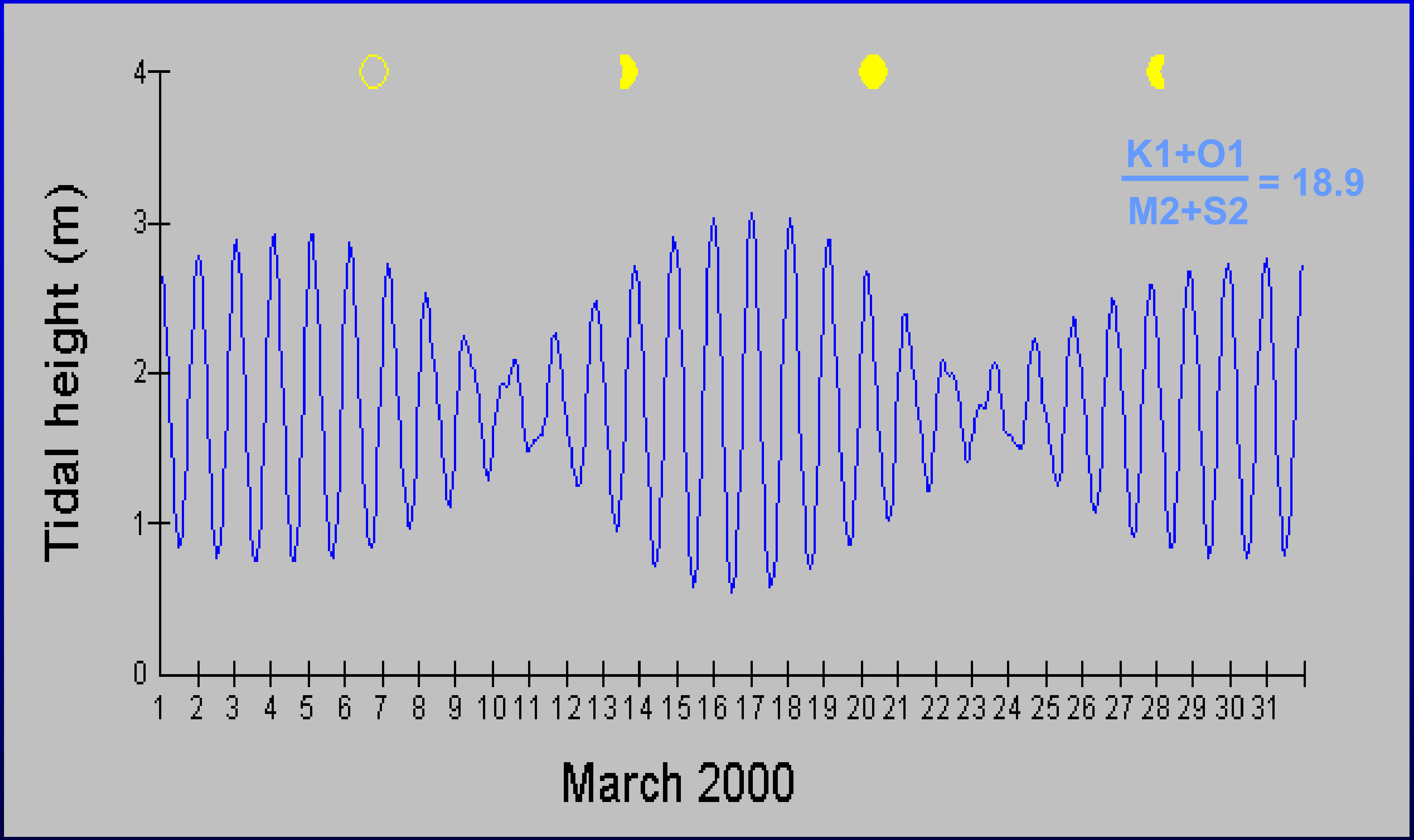
Data from Oceanus™ - http://tejo.dcea.fct.unl.pt

Tides for March 2000 - Dublin Bay



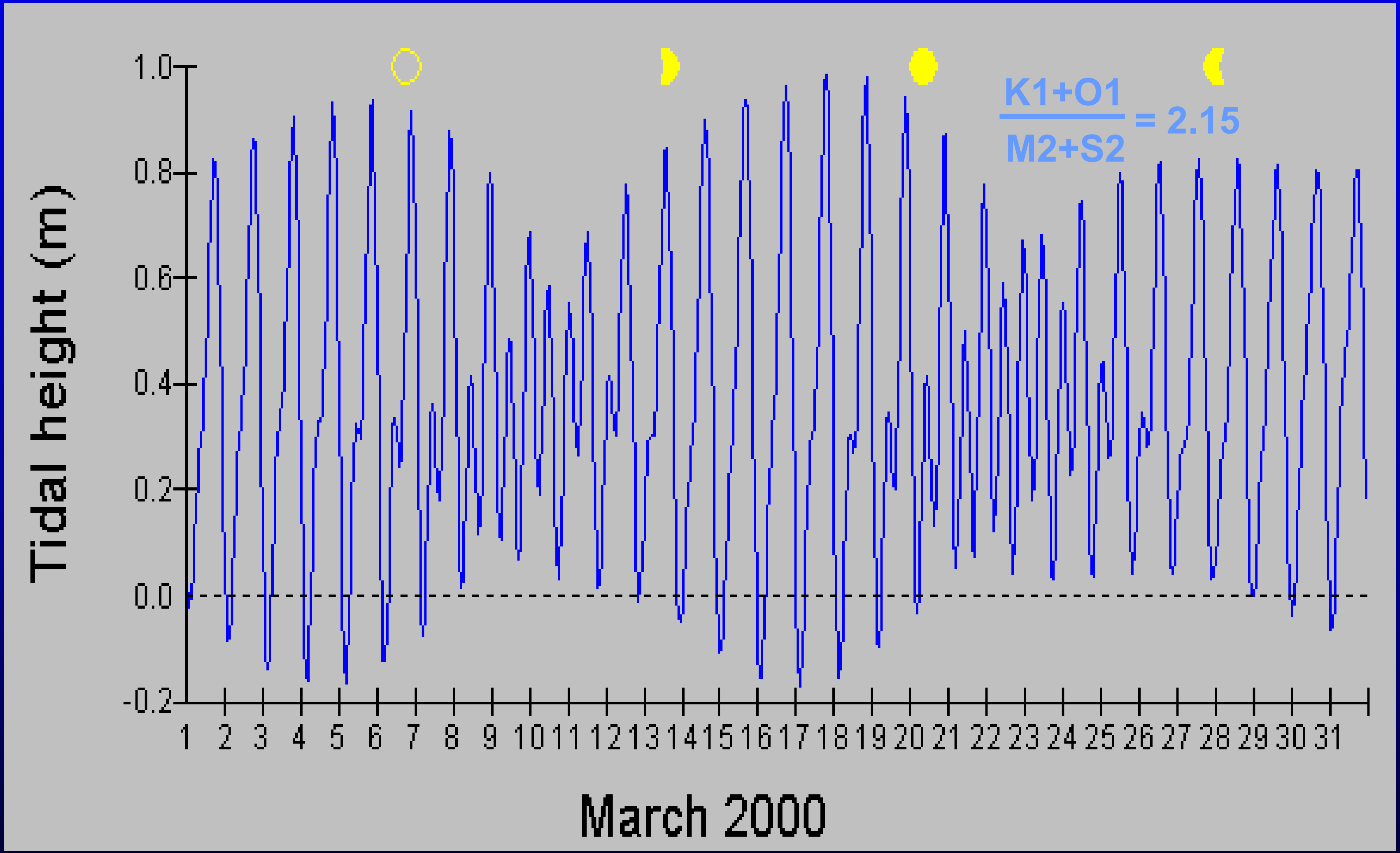
Data from Oceanus™ - http://tejo.dcea.fct.unl.pt

Tides for March 2000 - Do-Son (Vietnam)



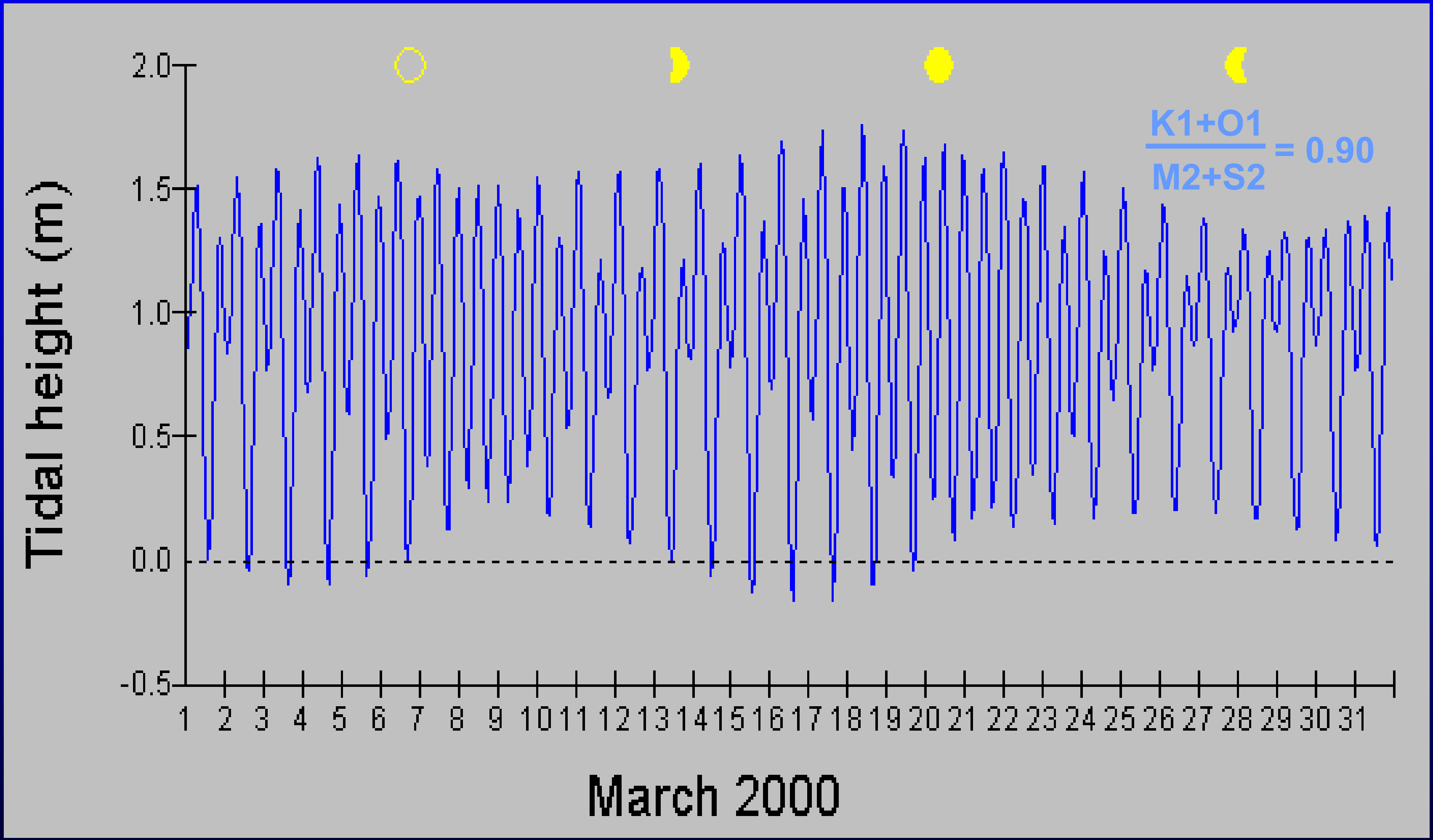
Data from Oceanus™ - http://tejo.dcea.fct.unl.pt

Tides for March 2000 - Manila



Data from Oceanus™ - http://tejo.dcea.fct.unl.pt

Tides for March 2000 - S. Francisco Bay



Data from Oceanus[TM] - http://tejo.dcea.fct.unl.pt

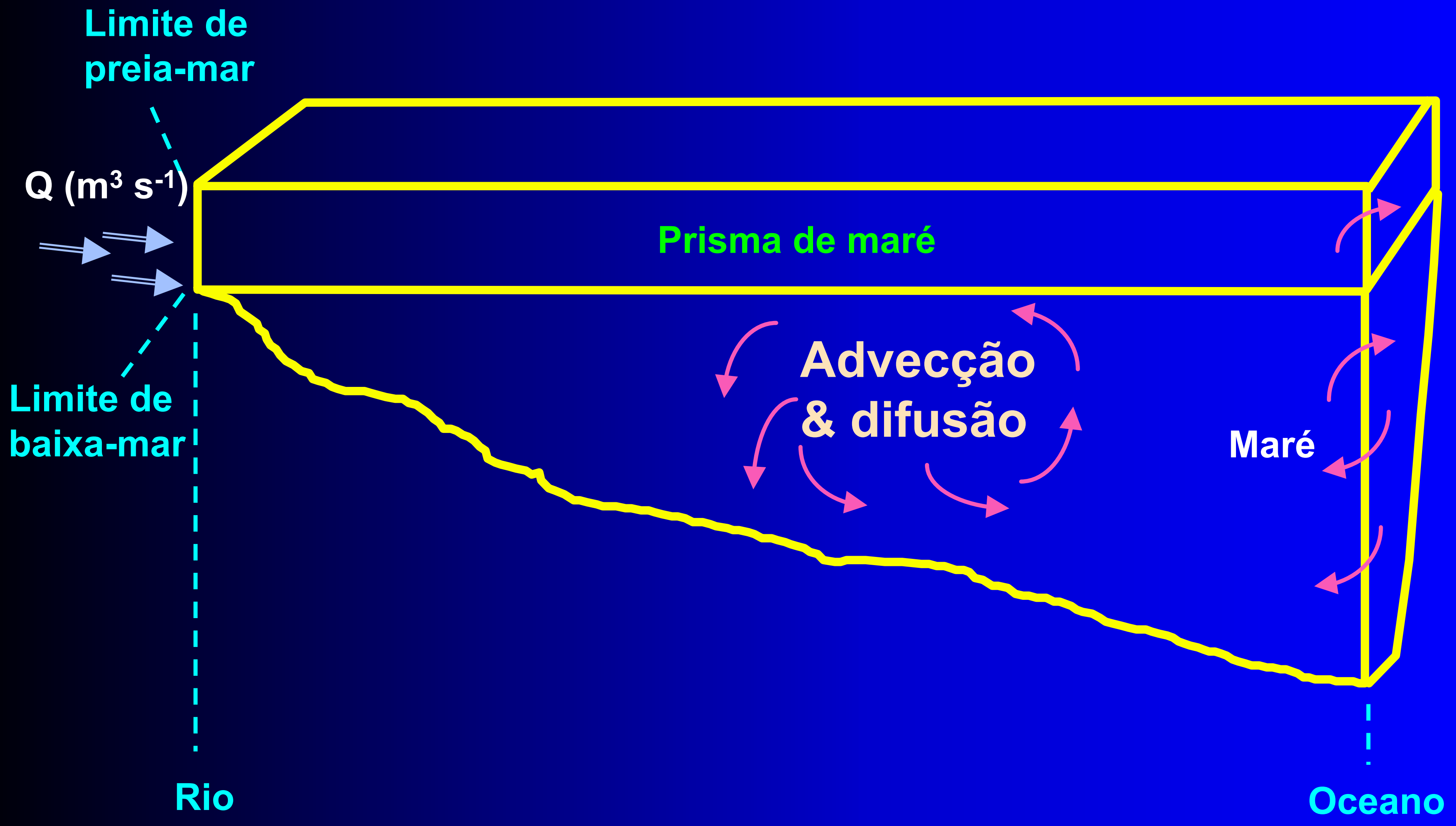
Bay of Fundy
Extreme tidal range (>16m max)

Low tide

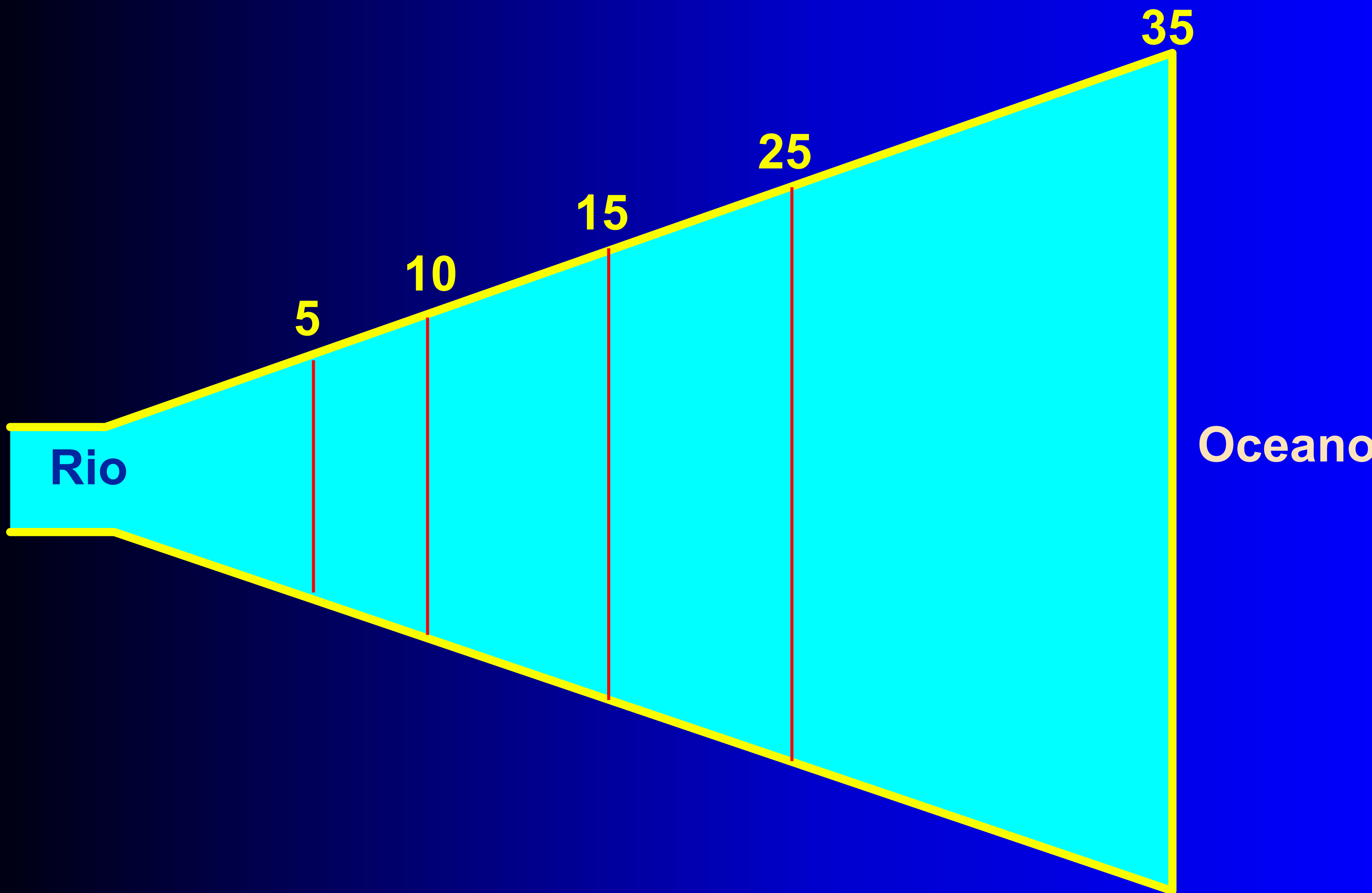
High tide

Tagus estuary - Space shuttle image

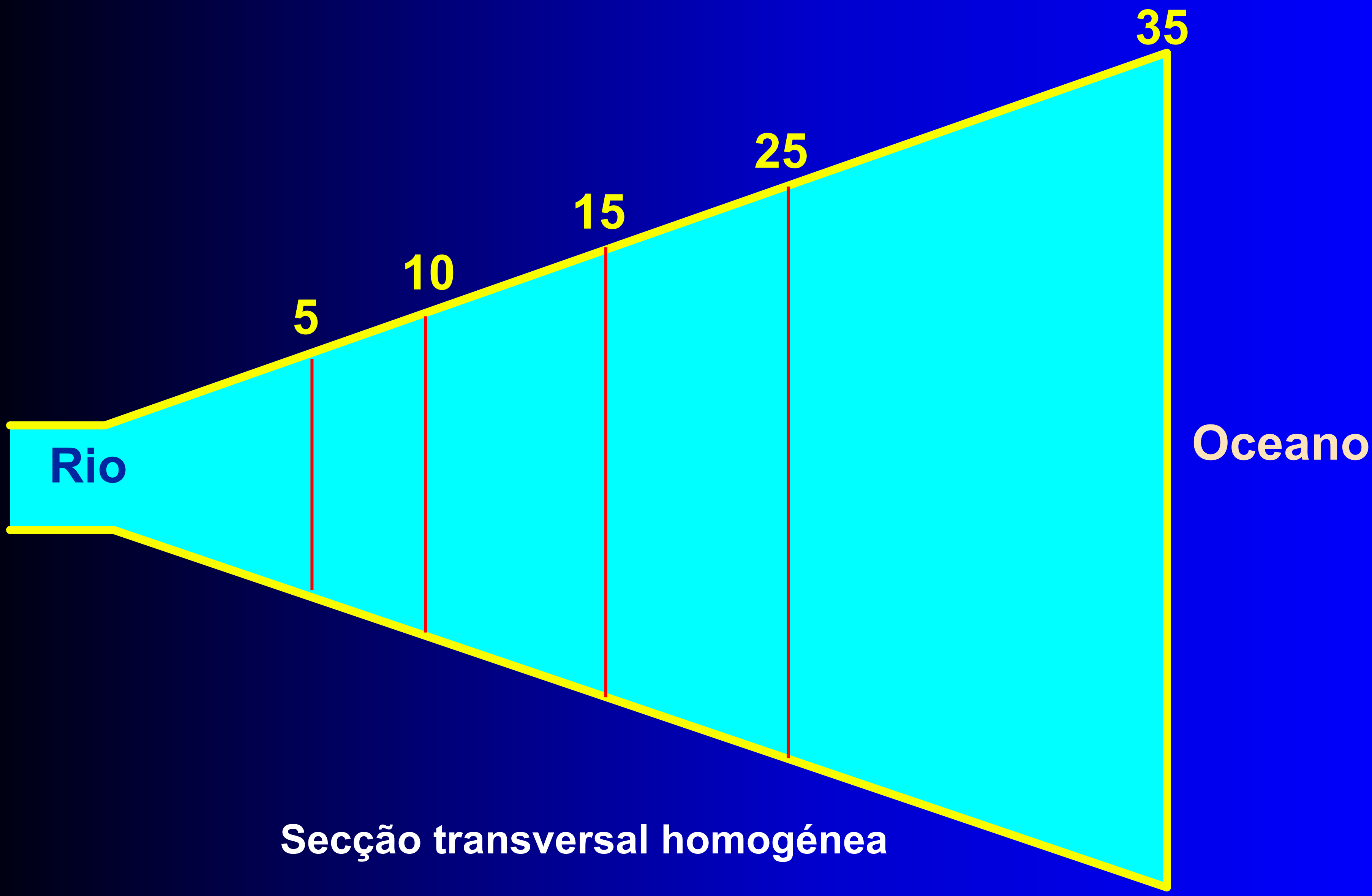
Caracterização geral de um estuário



Distribuição longitudinal de salinidade

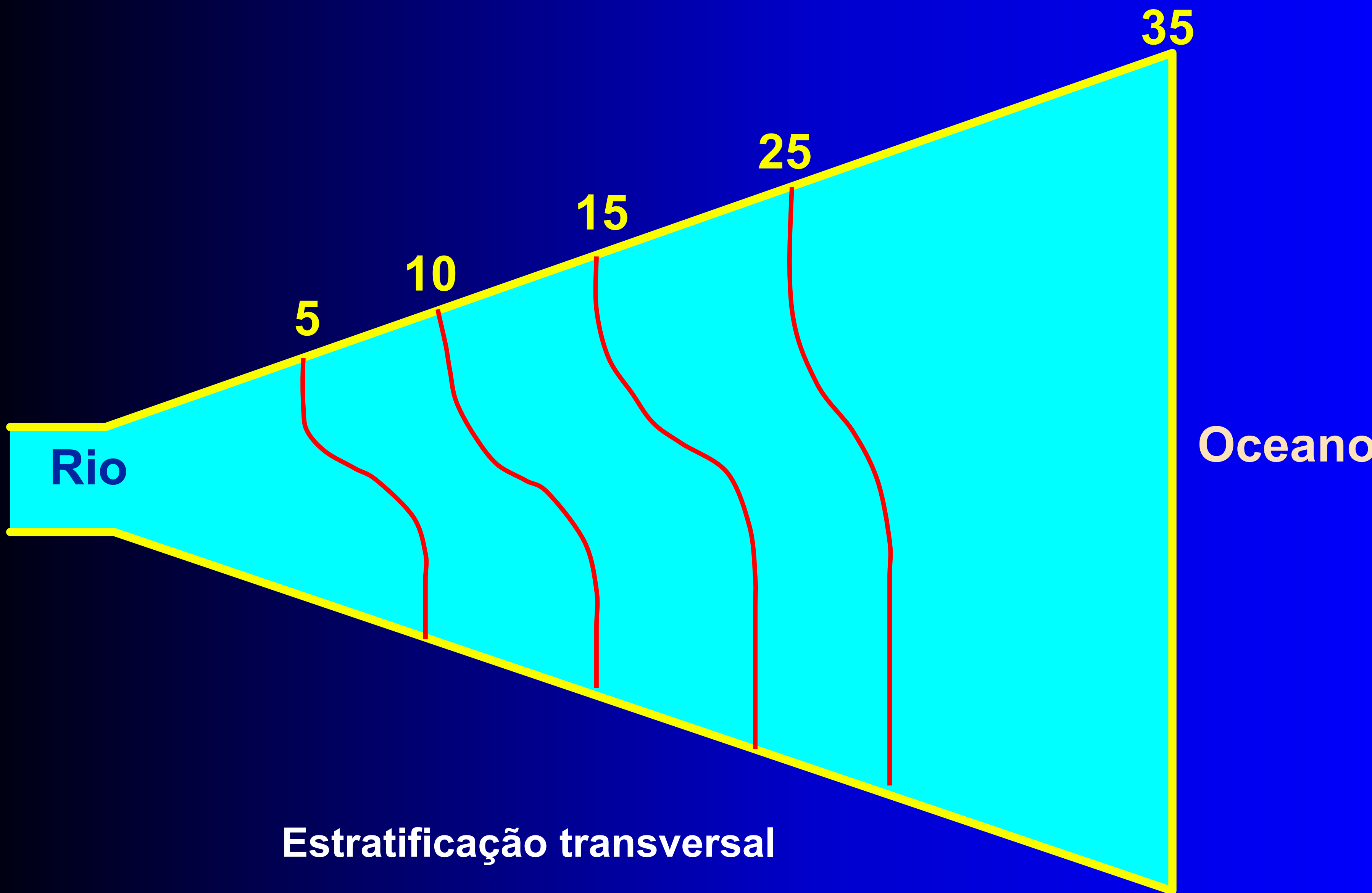


Distribuição transversal de salinidade

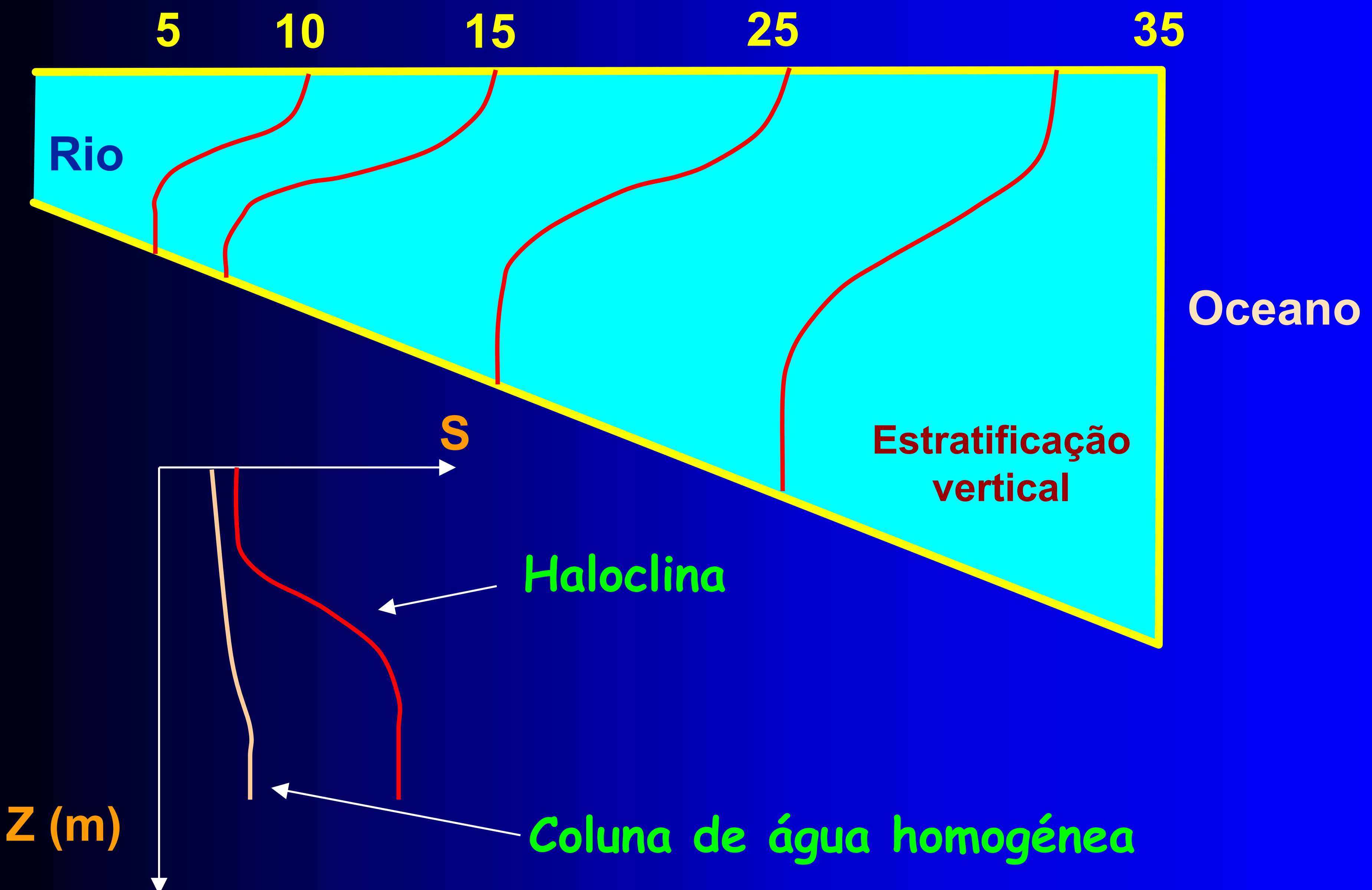


Secção transversal homogénea

Distribuição transversal de salinidade

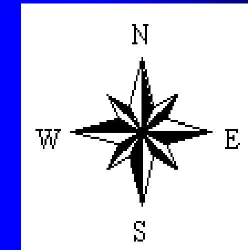


Distribuição vertical de salinidade

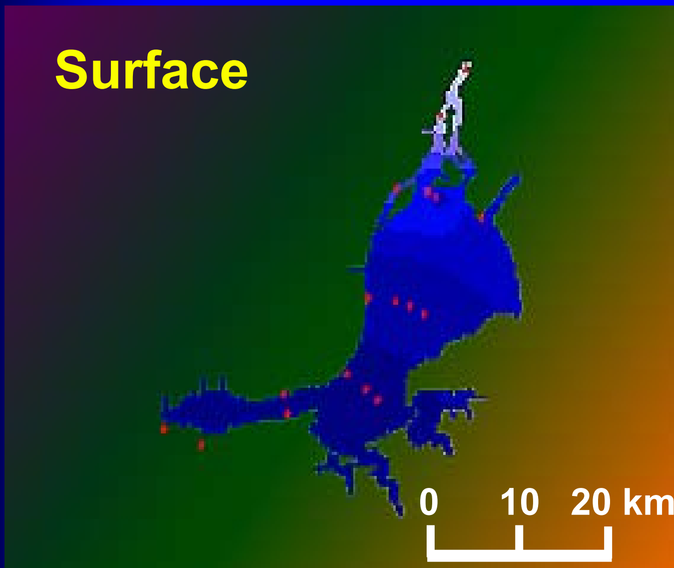


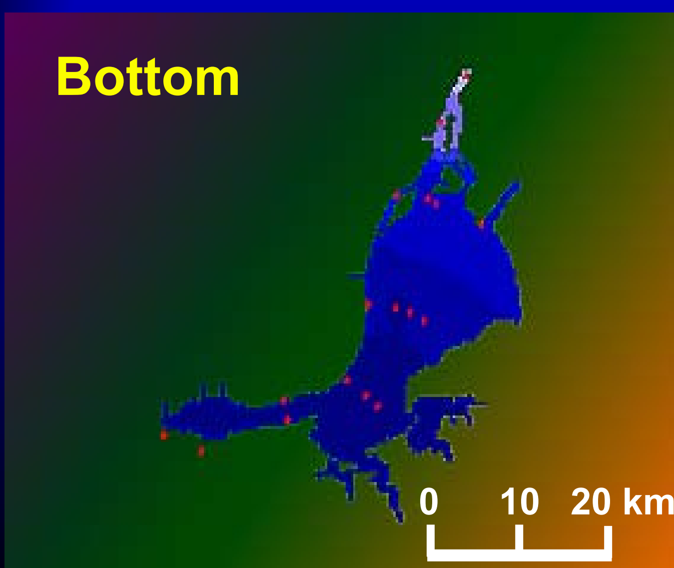
GIS - Salinity

Tagus estuary



Summer





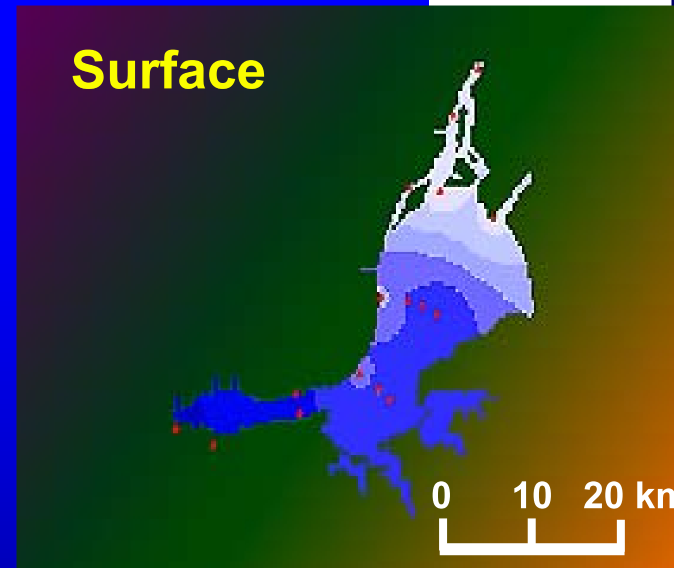
Summer Salinity (psu)

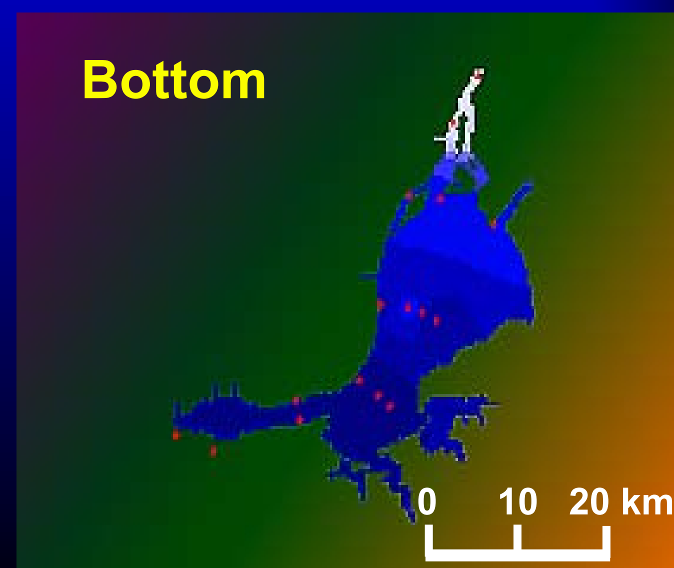
- 0 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 27.5
- 27.5 - 30
- 30 - 32
- 32 - 34
- 34 - 36
- No Data

Winter Salinity (psu)

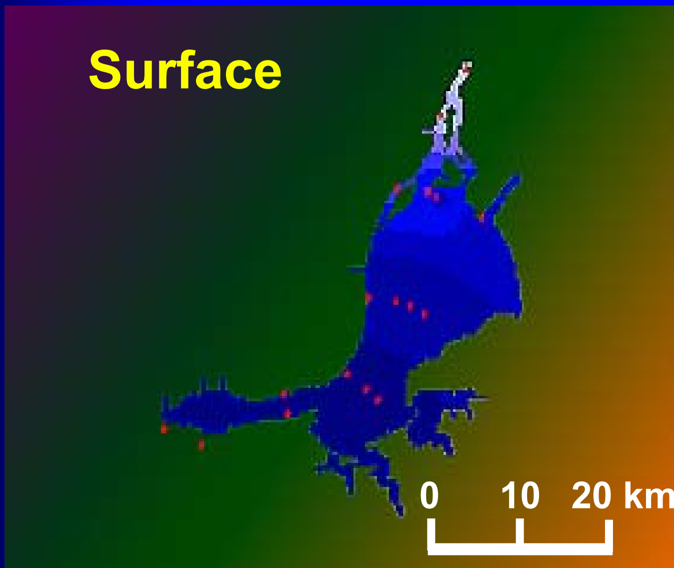
- 0 - 2.5
- 2.5 - 5
- 5 - 7.5
- 7.5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 36
- No Data

Winter



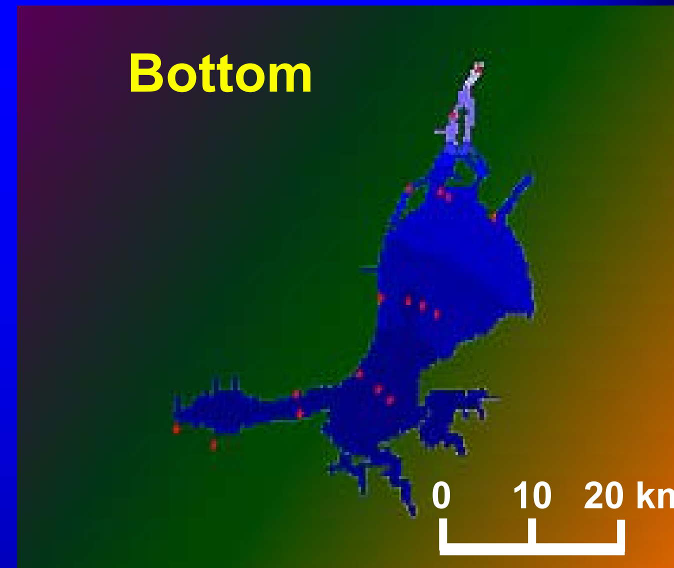


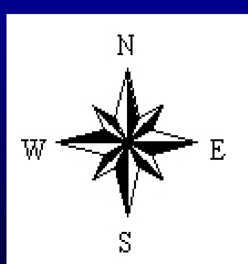
GIS - Salinity
Tagus estuary - Summer

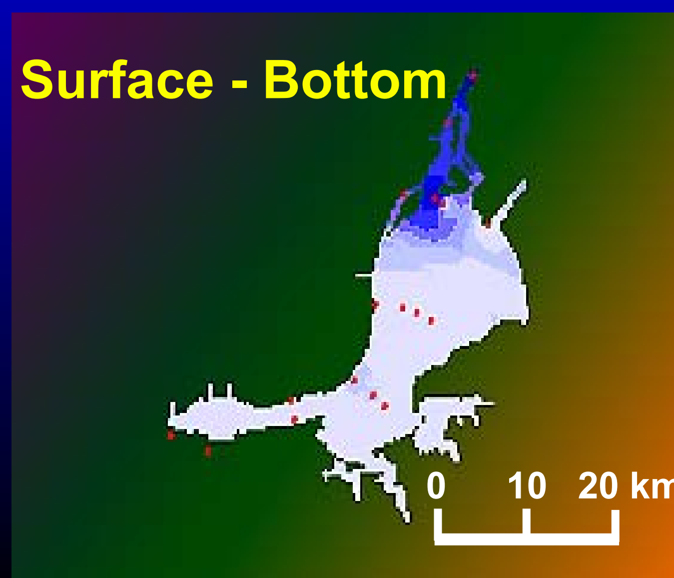


Salinity (psu)

	0 - 10
	10 - 15
	15 - 20
	20 - 25
	25 - 27.5
	27.5 - 30
	30 - 32
	32 - 34
	34 - 36
	No Data





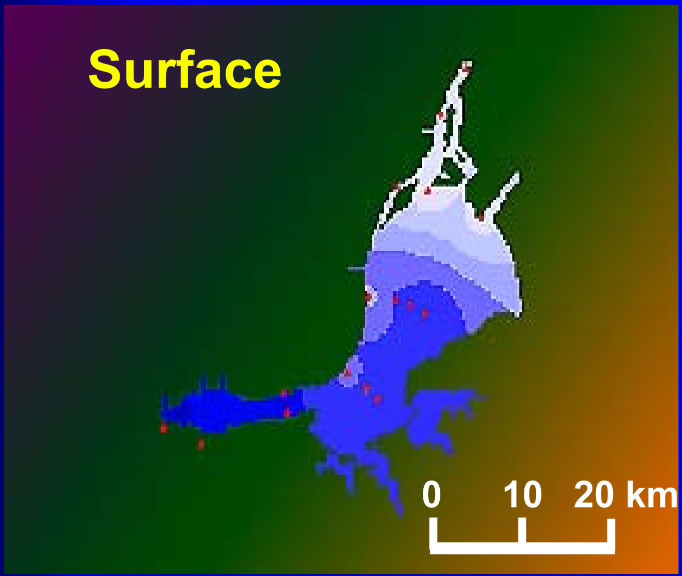


Surface - Bottom Salinity (psu)

	-36 - -10
	-10 - -5
	-5 - -4
	-4 - -3
	-3 - -2
	-2 - -1.5
	-1.5 - -1
	-1 - -0.5
	-0.5 - 0
	No Data

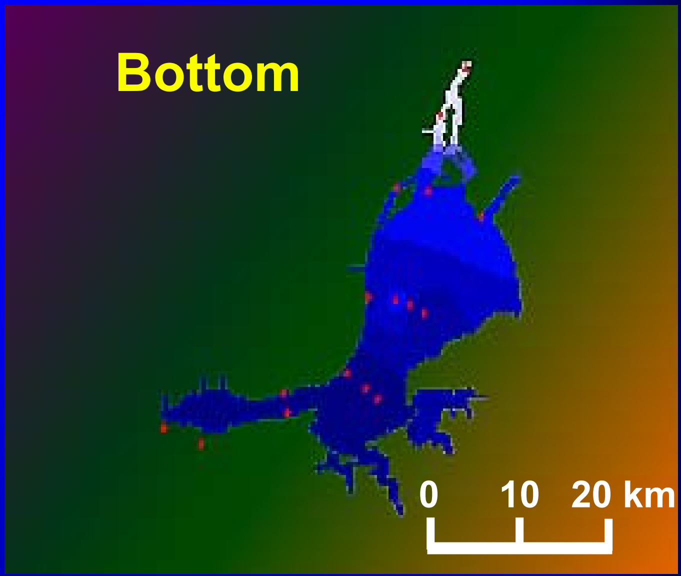
GIS - Salinity

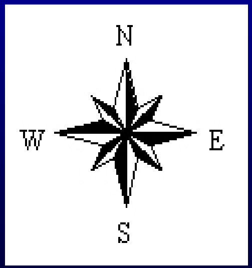
Tagus estuary - Winter

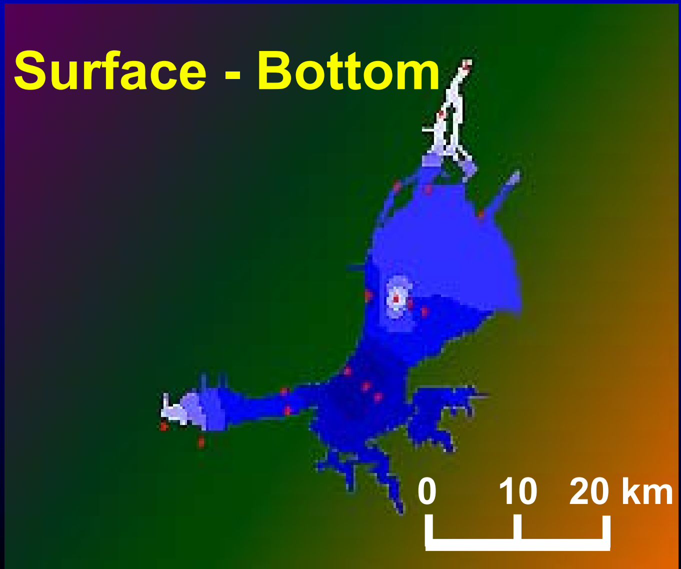


Salinity (psu)

- 0 - 2.5
- 2.5 - 5
- 5 - 7.5
- 7.5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 36
- No Data



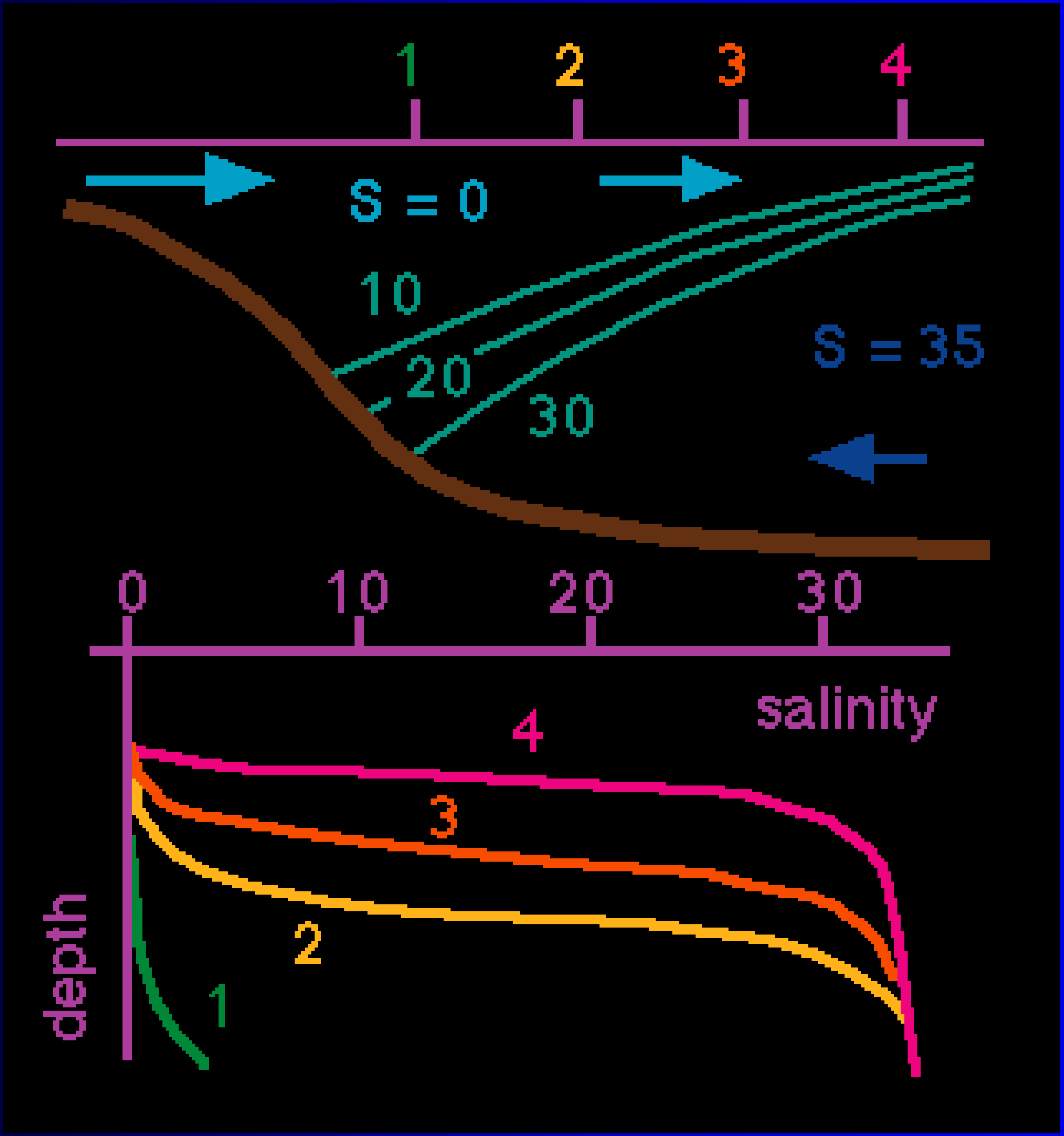




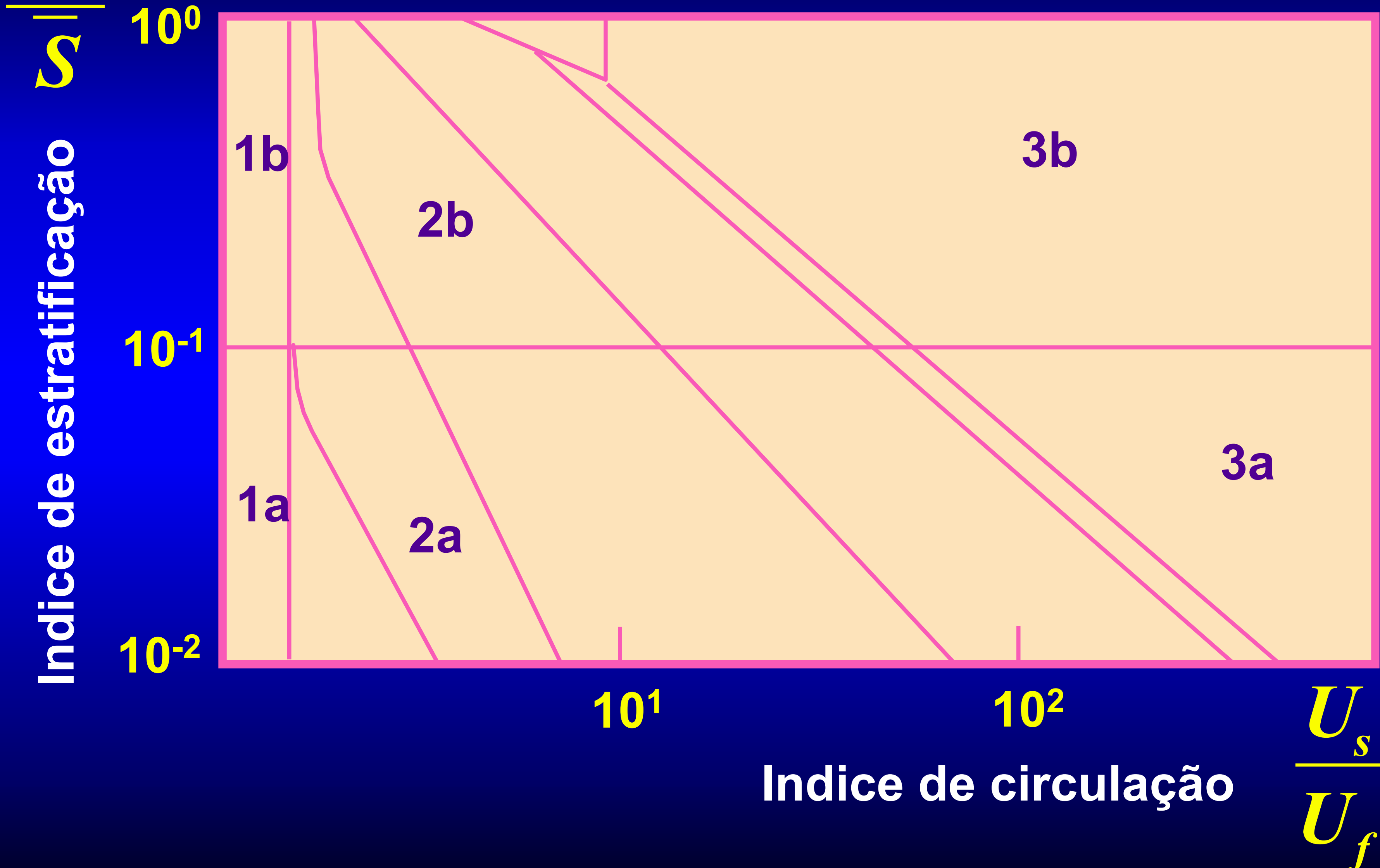
Surface - Bottom Salinity (psu)

- -36 - -25
- -25 - -20
- -20 - -17.5
- -17.5 - -15
- -15 - -12.5
- -12.5 - -10
- -10 - -7.5
- -7.5 - -5
- -5 - 0
- No Data

Salt wedge estuary



Classificação de estuários de Hansen & Rattray



Hansen & Rattray, 1966 - Limnology & Oceanography *11*, 319-326

Diagrama de diluição esquemático
- Sódio -

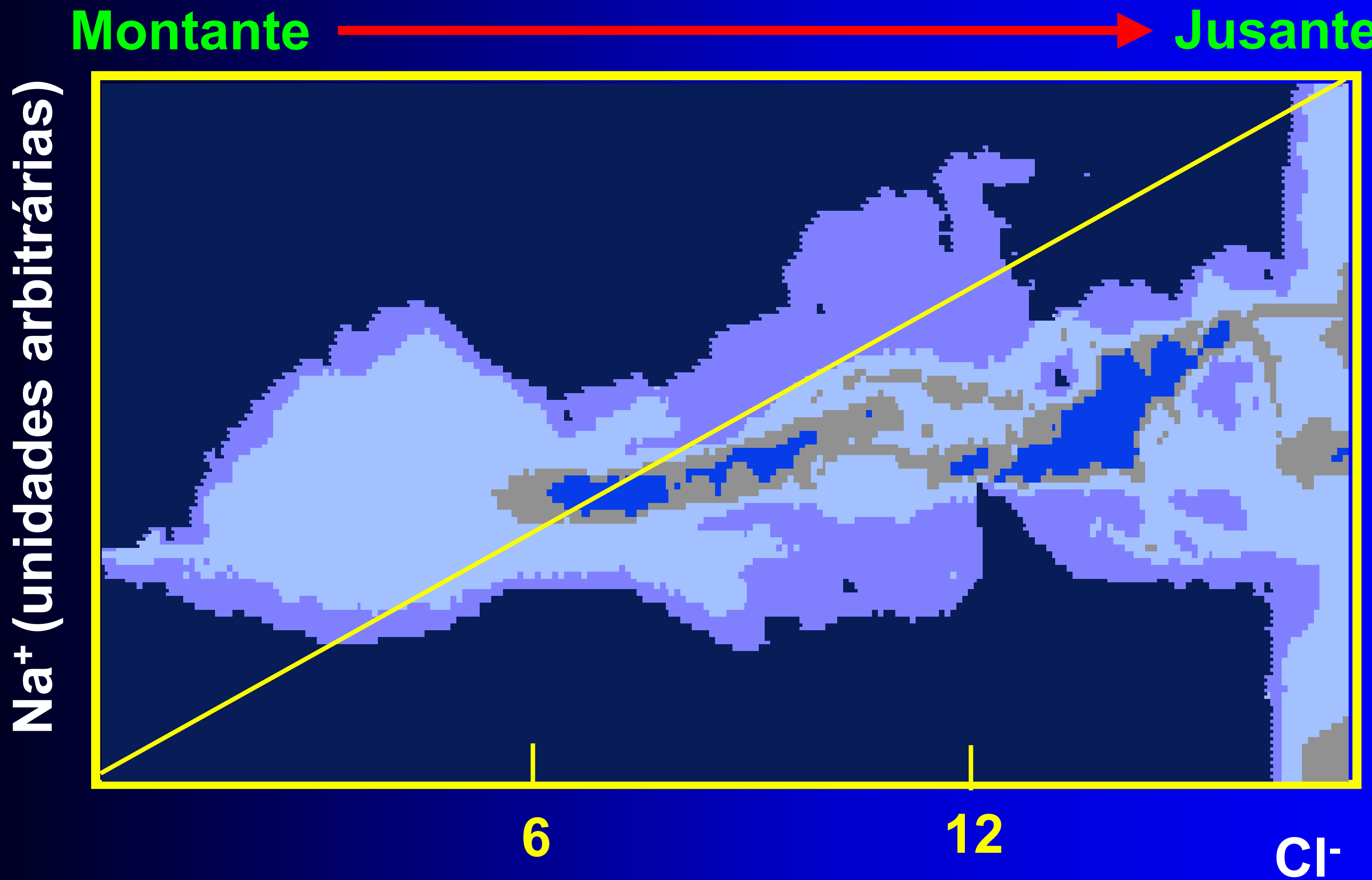


Diagrama de diluição esquemático
- Cálcio -

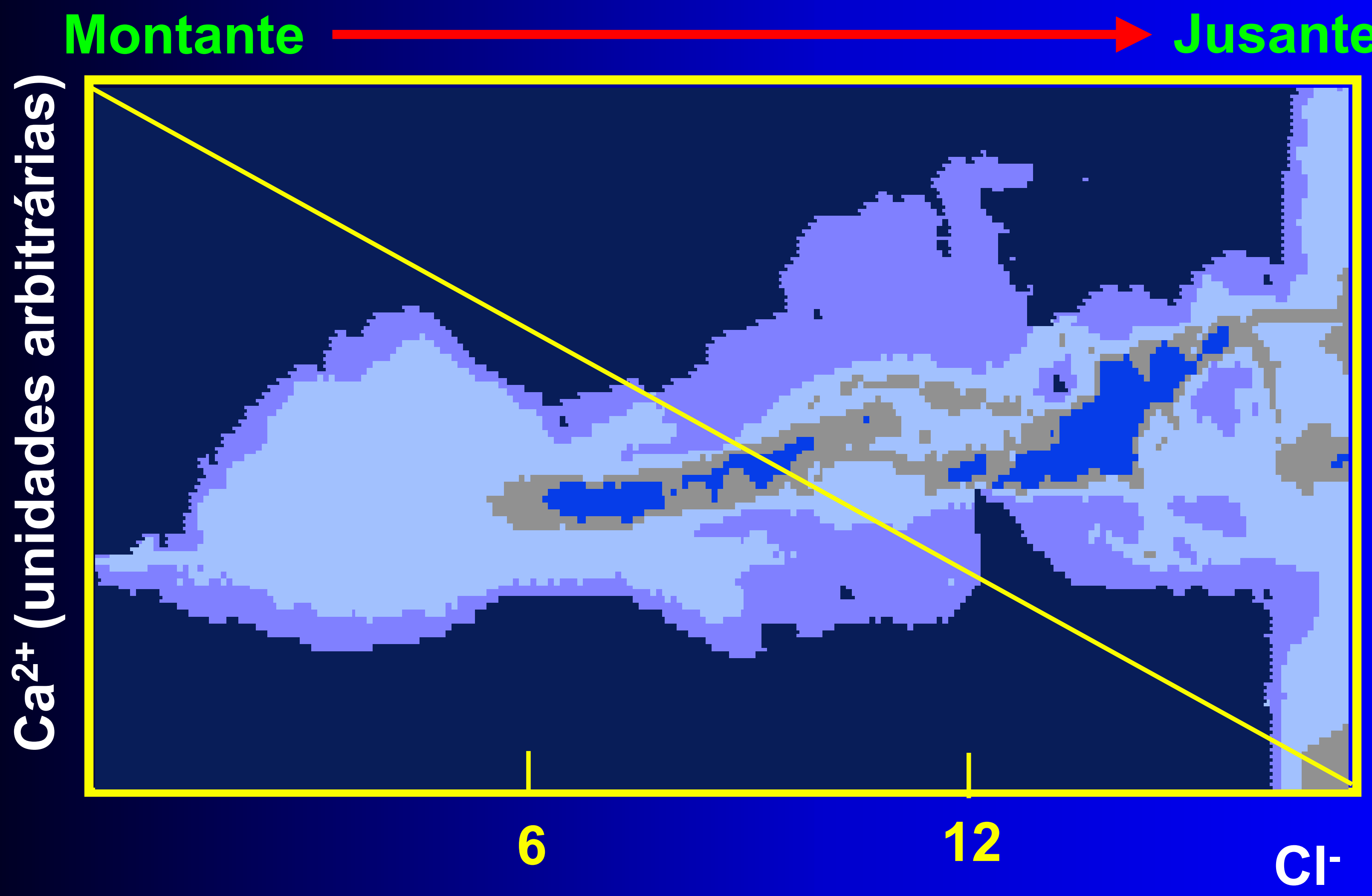


Diagrama de diluição esquemático
- Sílica (inverno) -

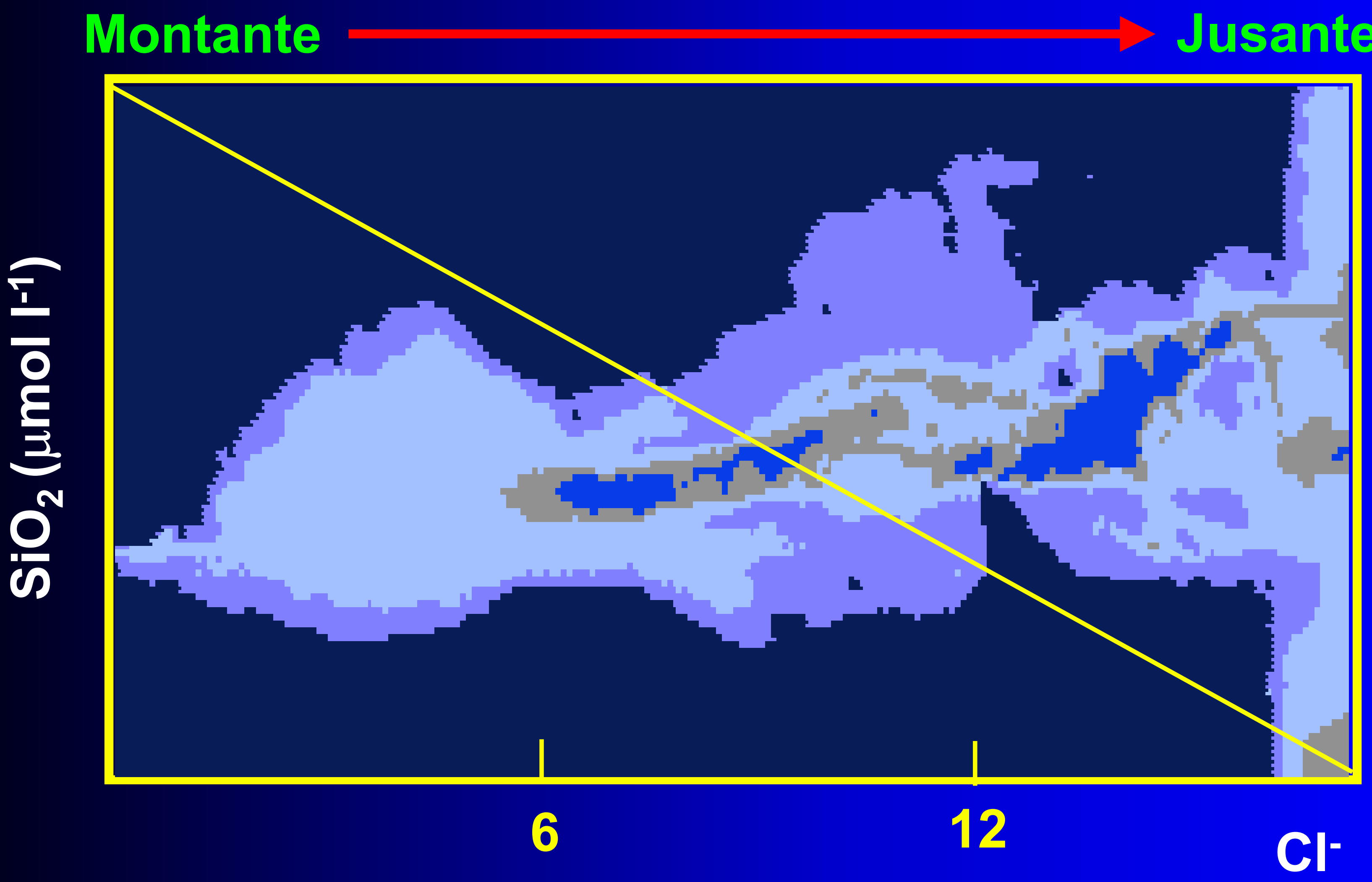


Diagrama de diluição esquemático
- Sílica (primavera/verão) -

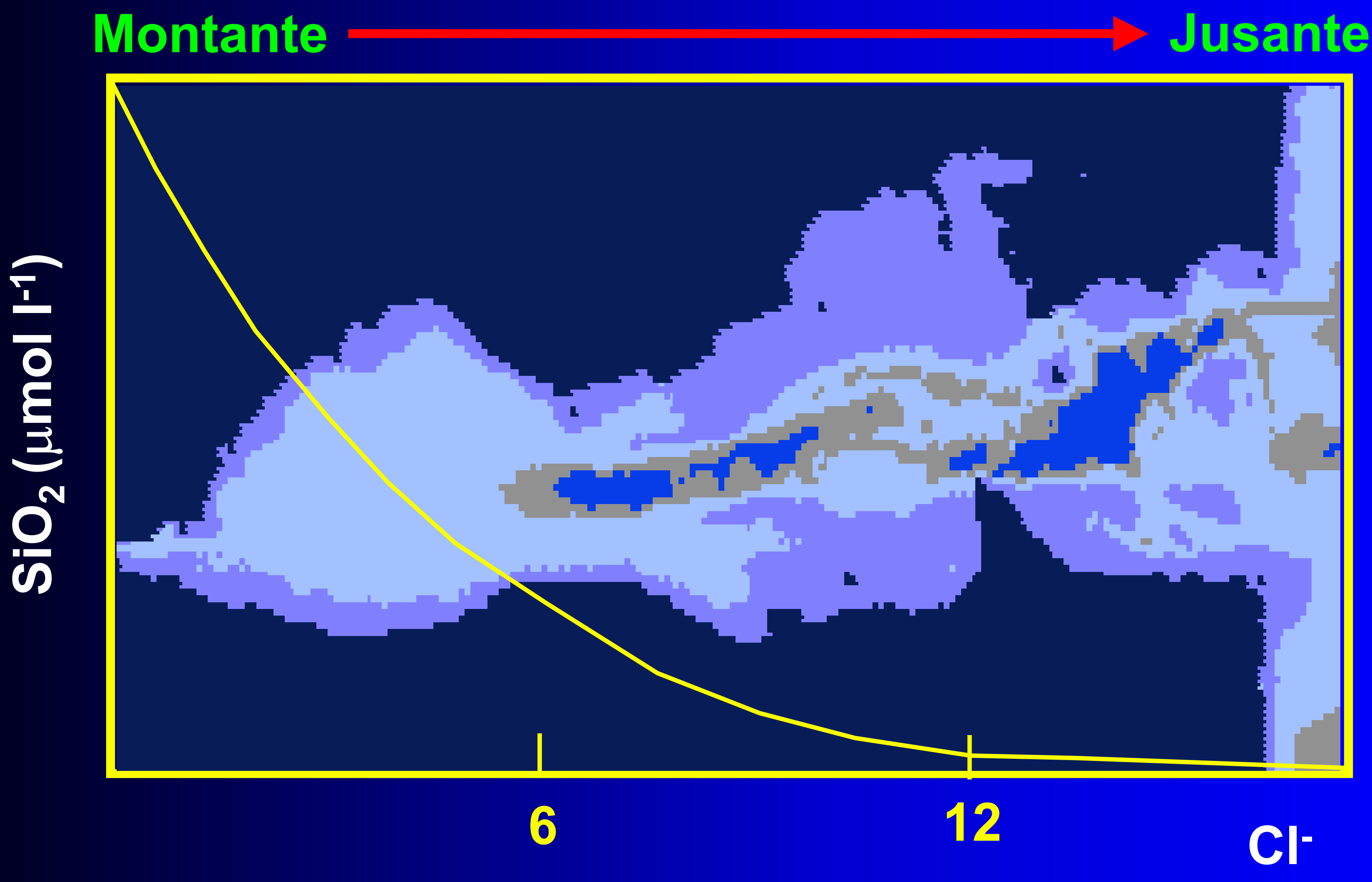


Diagrama de diluição esquemático
- Nitrato (primavera/verão) -

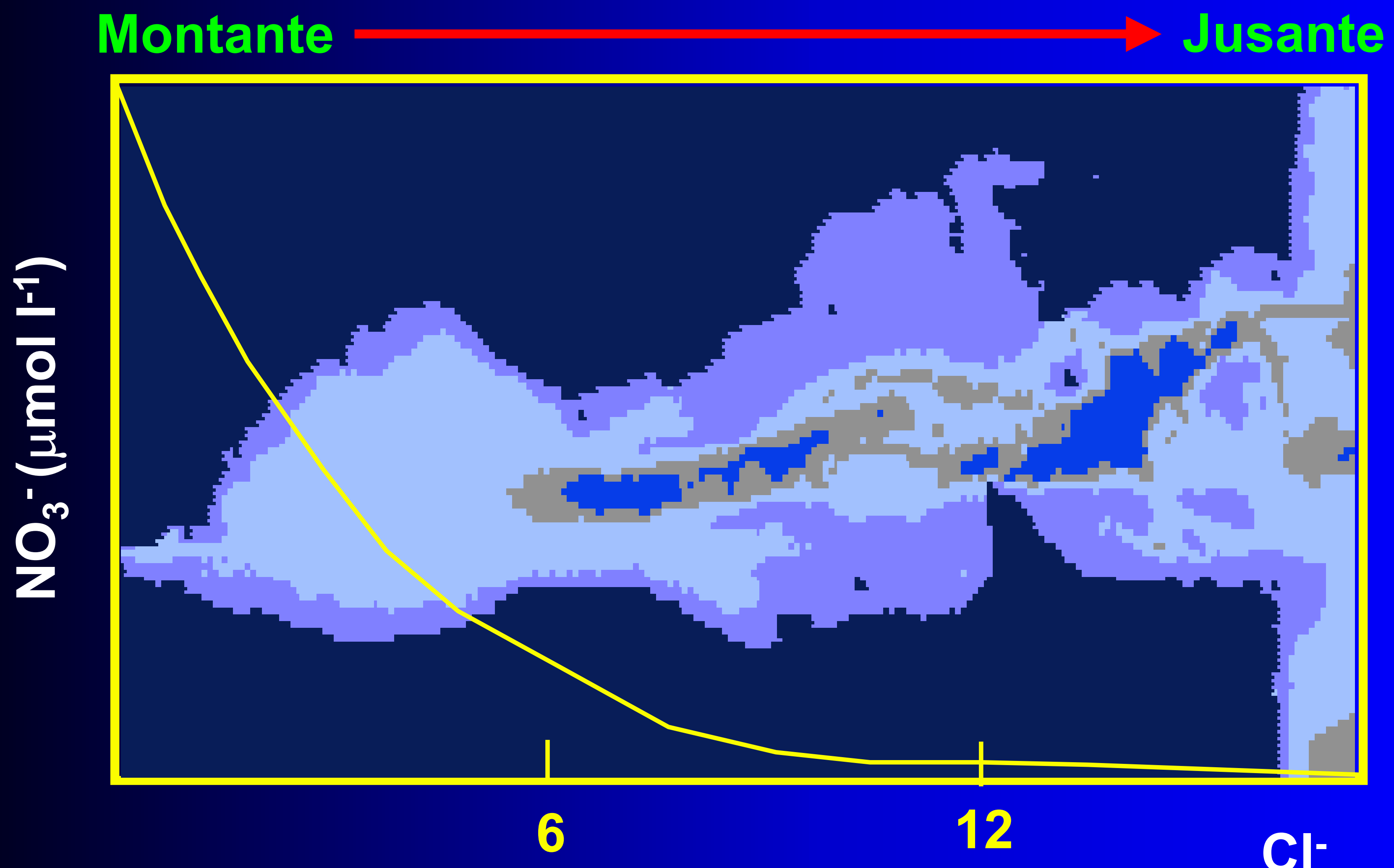


Diagrama de diluição
Estuário do Tejo - Nitrato

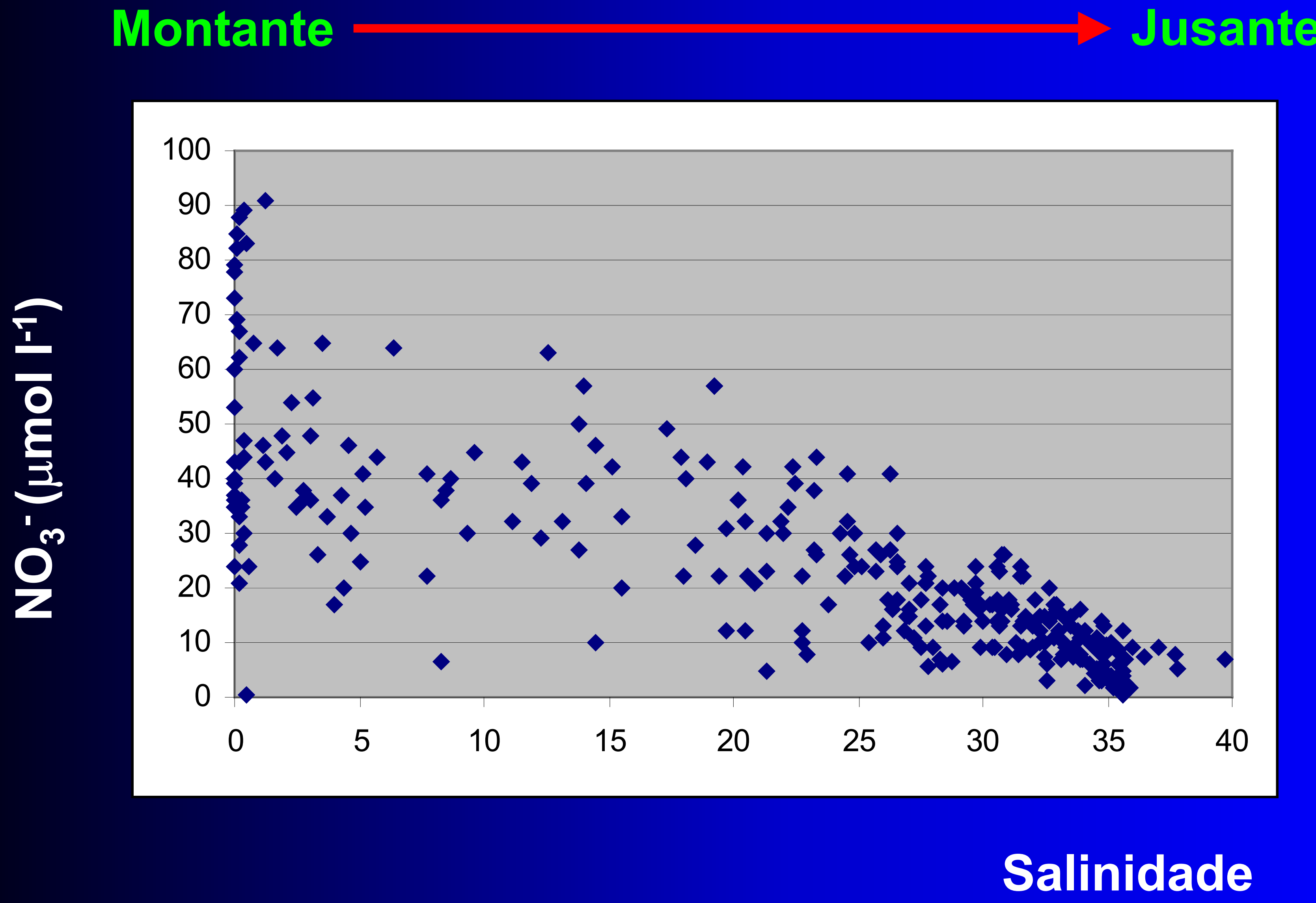


Diagrama de diluição
Estuário do Guadiana - Nitrato

Montante → Jusante

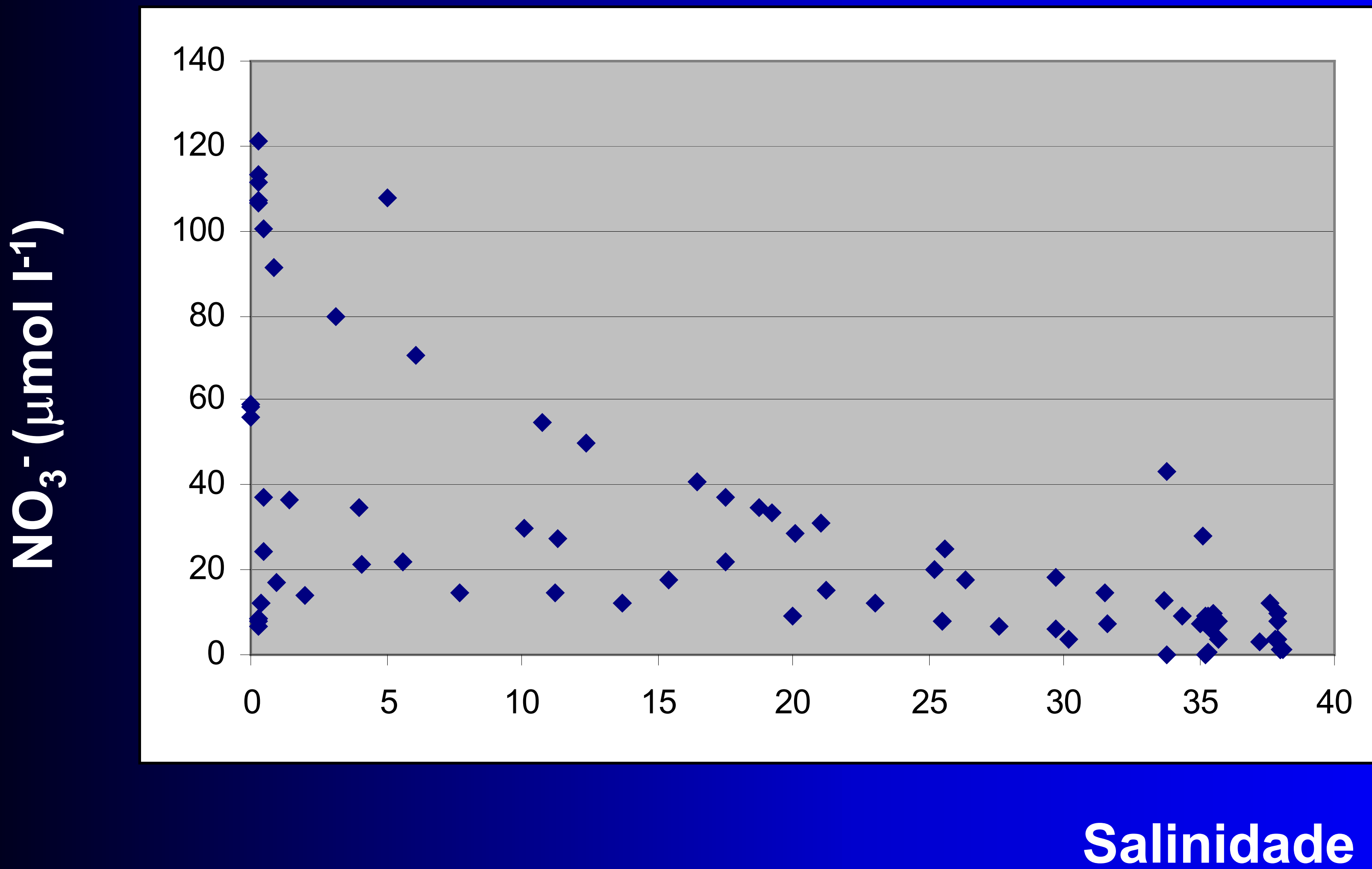


Diagrama de diluição esquemático
- Ferro dissolvido -

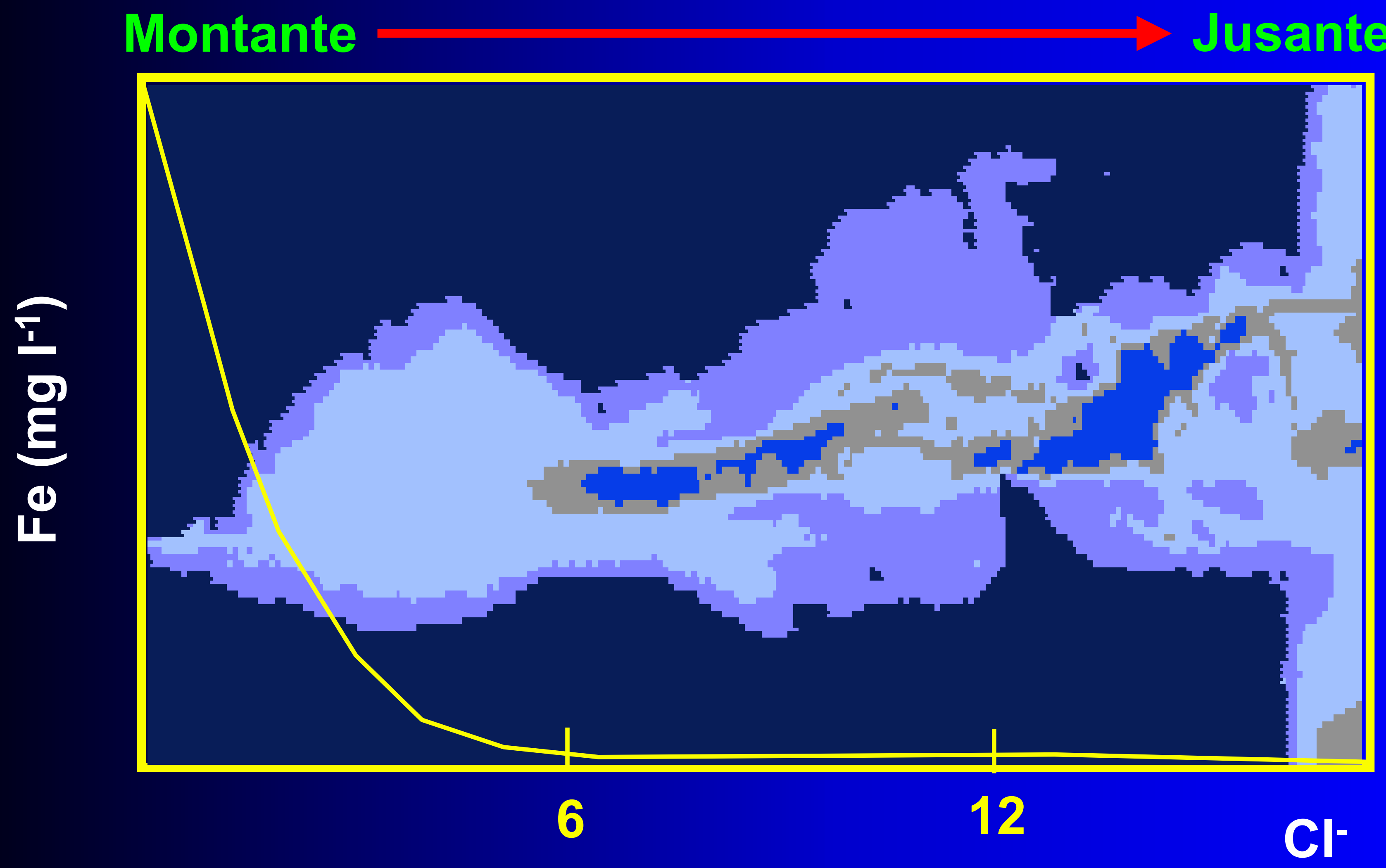


Diagrama de diluição esquemático - Azoto amoniacal -

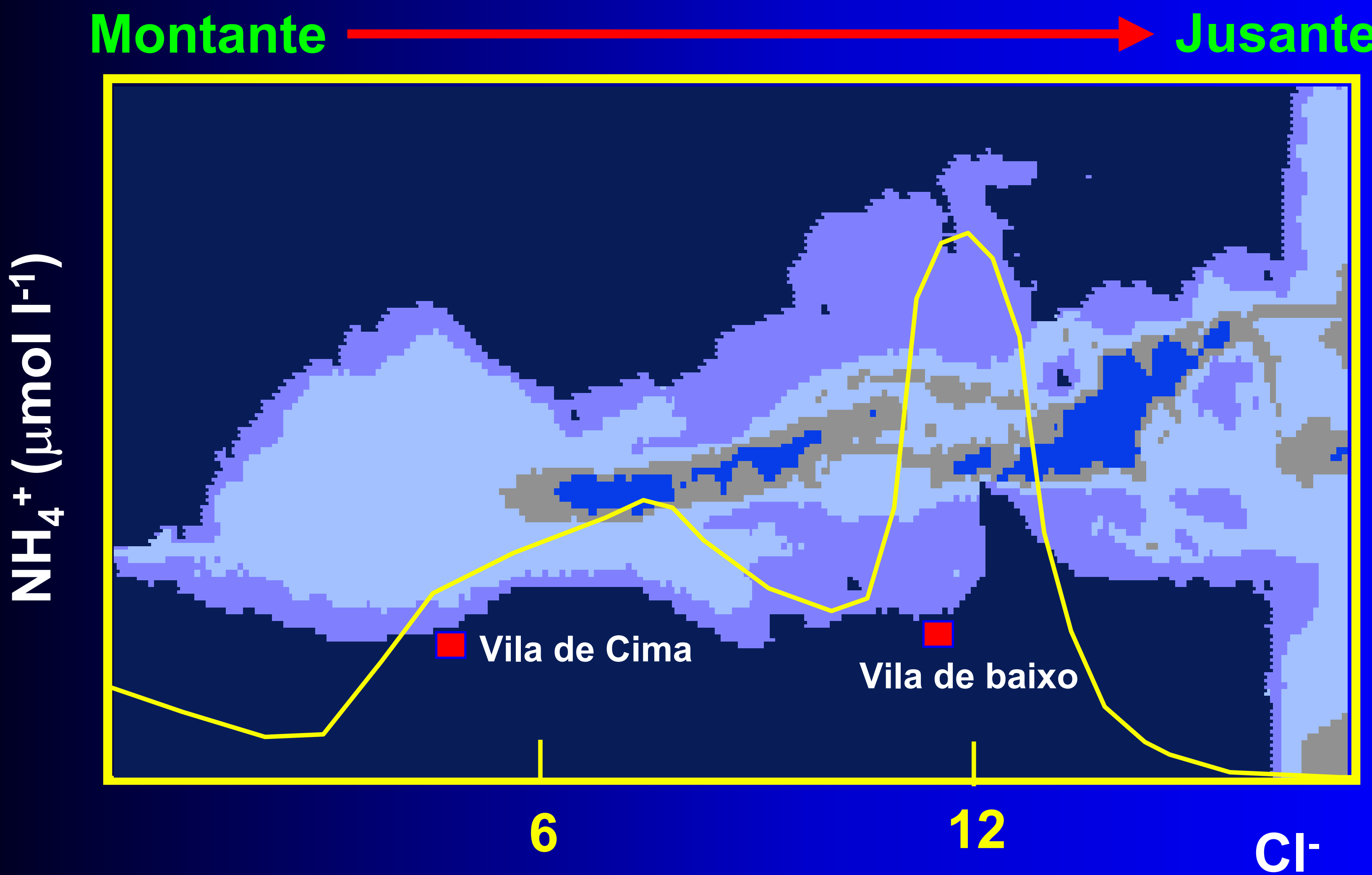
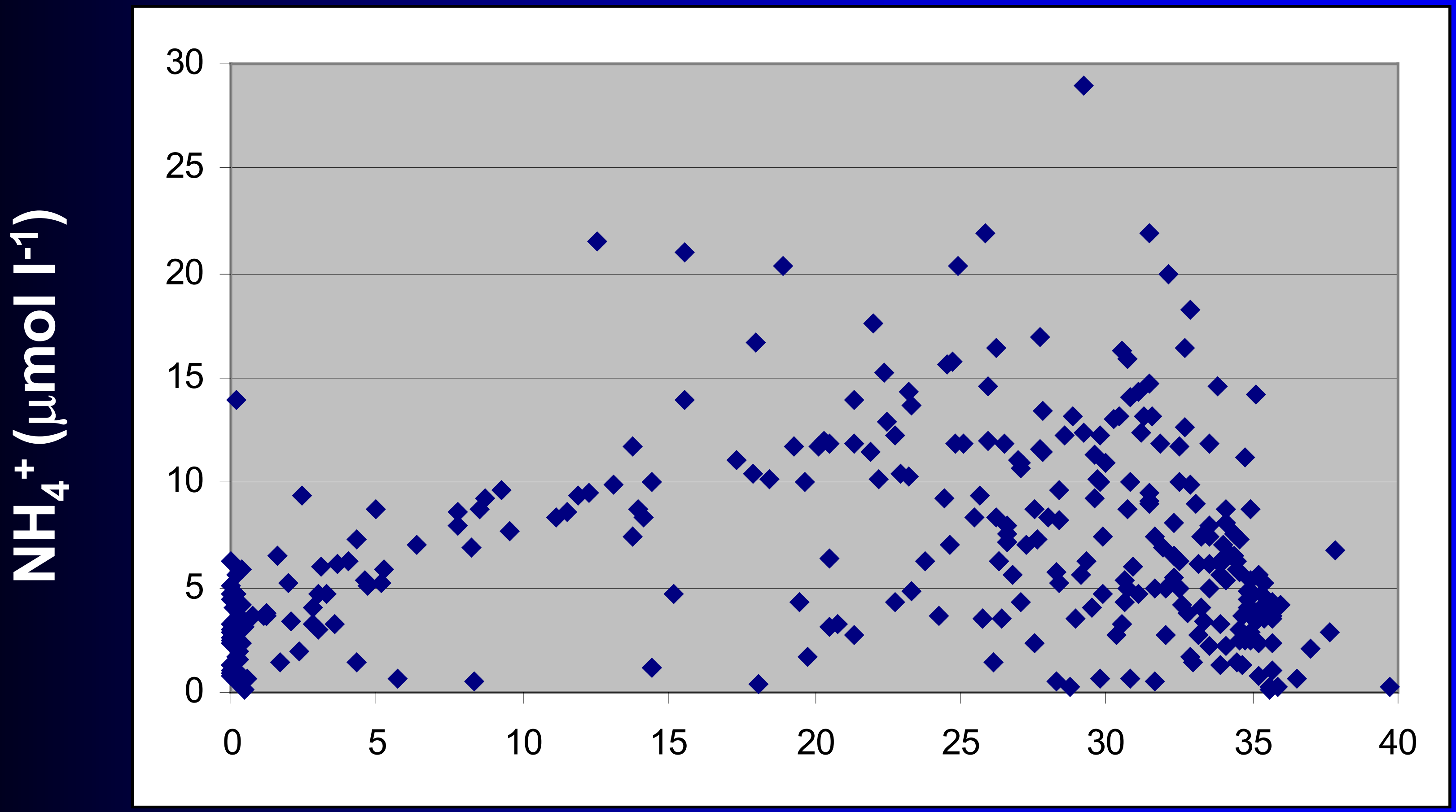


Diagrama de diluição
Estuário do Tejo - Azoto amoniacal

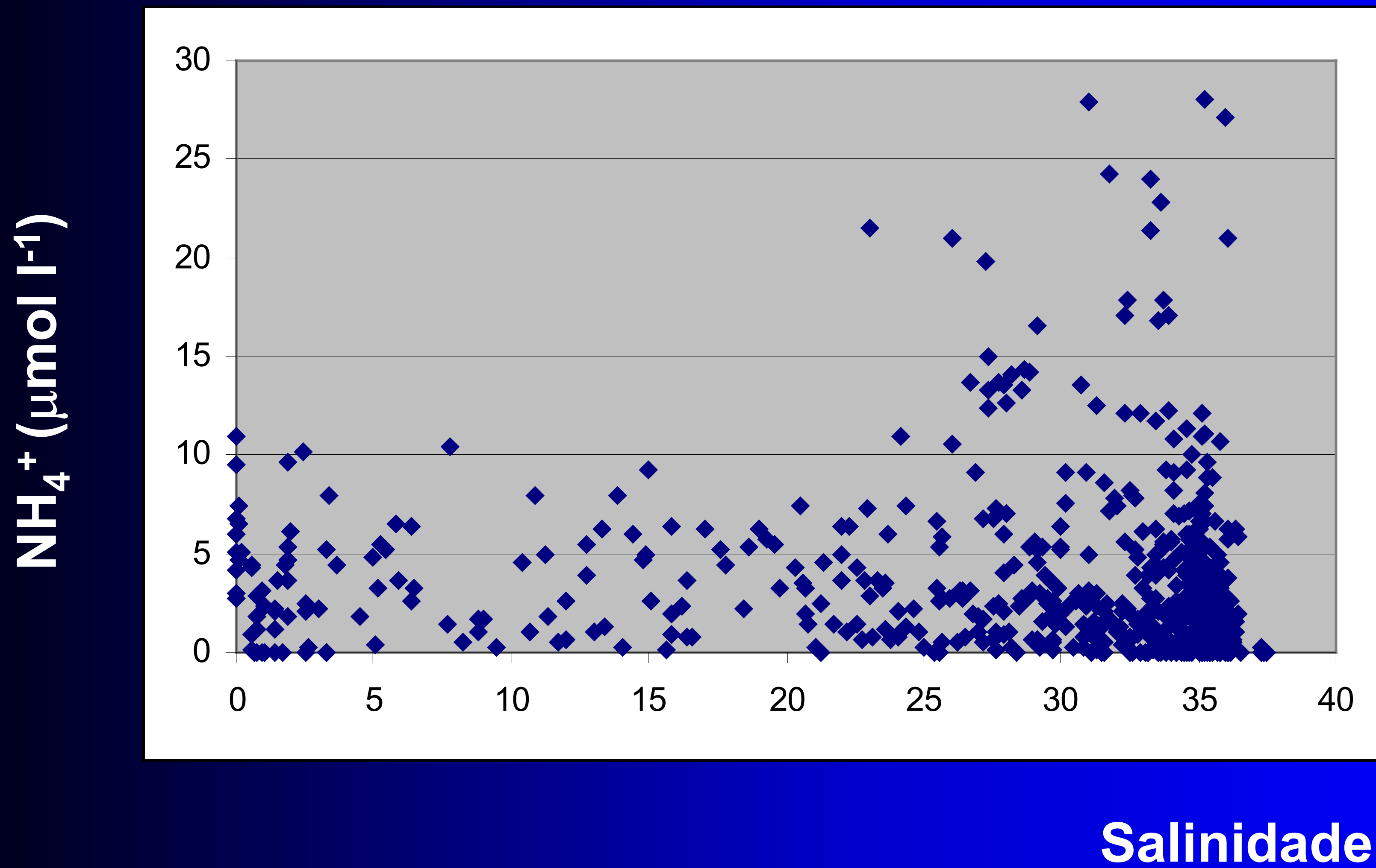
Montante → **Jusante**



Salinidade

Diagrama de diluição
Estuário do Sado - Azoto amoniacal

Montante → **Jusante**



Surface area to volume ratio (sinking rates)

Sea surface

Fall velocity

$$W = \frac{2}{9}\,\frac{g(D-d)r^2}{u}$$

1mm cube
surface area = $6mm^2$
volume = $1mm^3$
$\frac{\text{surface area}}{\text{volume}} = 6$

10mm cube
surface area = $600mm^2$
volume = $1000mm^3$
$\frac{\text{surface area}}{\text{volume}} = 0.6$

Relationship between forces

$$Re = \frac{ud}{v}$$

z (depth)

Reynolds number for different organisms

Organism	Re
Large whale (10 ms^{-1})	300 000 000
Tuna (10 m s^{-1})	30 000 000
Duck flying (20 ms^{-1})	300 000
Dragonfly (7 m s^{-1})	30 000
Copepod in a pulse of 20 cm s^{-1}	300
Smallest flying insects	30
Invertebrate larva 0.3mm long at 1 mm s^{-1}	0.3
Sea urchin sperm advancing the species at 0.3 mm s^{-1}	0.03

Vogel, S, 1981 - Life in moving fluids. The physical biology of flow. Willard Grant Press, Boston, 352 pp.

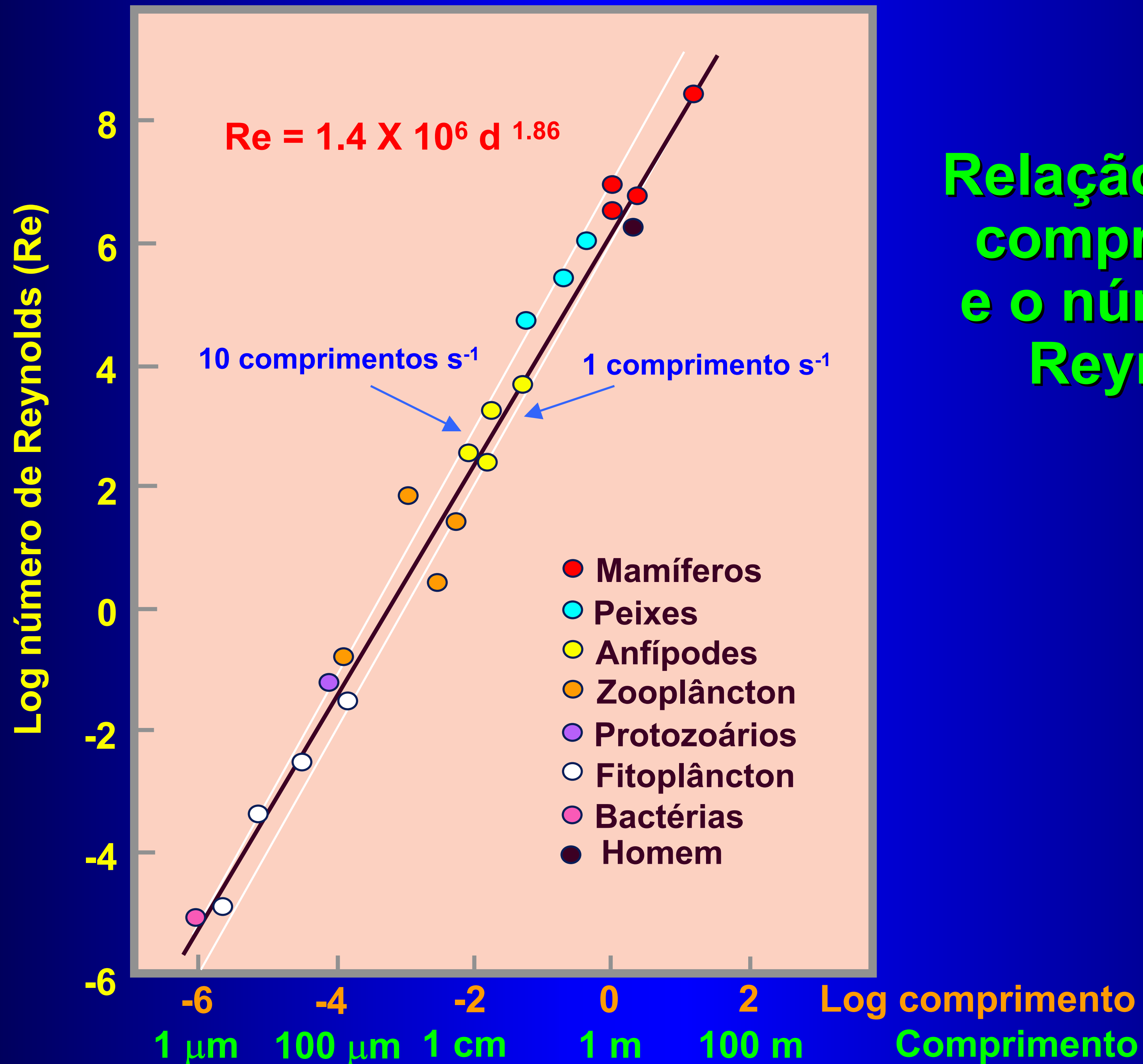
Re = ud/v (2500 ~ threshold between laminar and turbulent flow)

$Re = 1.4 \times 10^6 \; d^{1.86}$

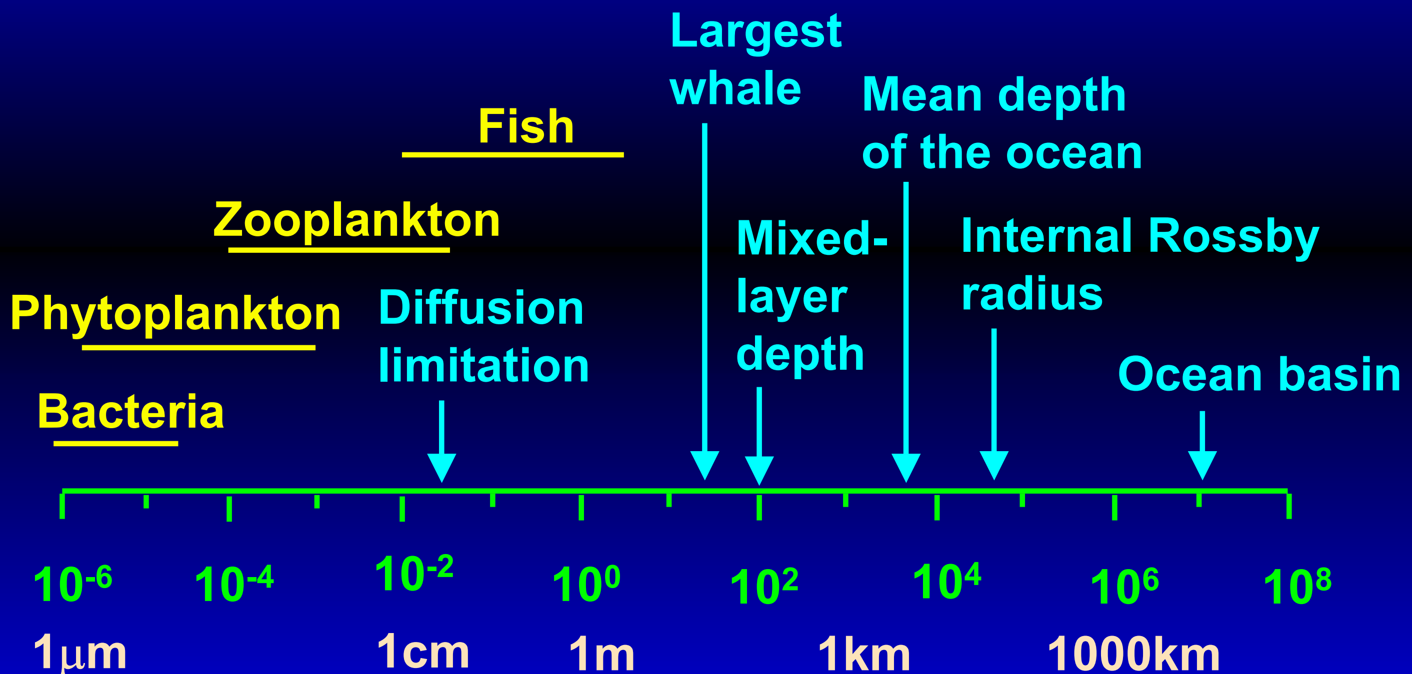
Relationship between length and swimming speed

u (m s-1) = $1.4 \times d^{0.86}$ (kinematic viscosity = 10^{-6} m^2 s^{-1})

Relação entre o comprimento e o número de Reynolds

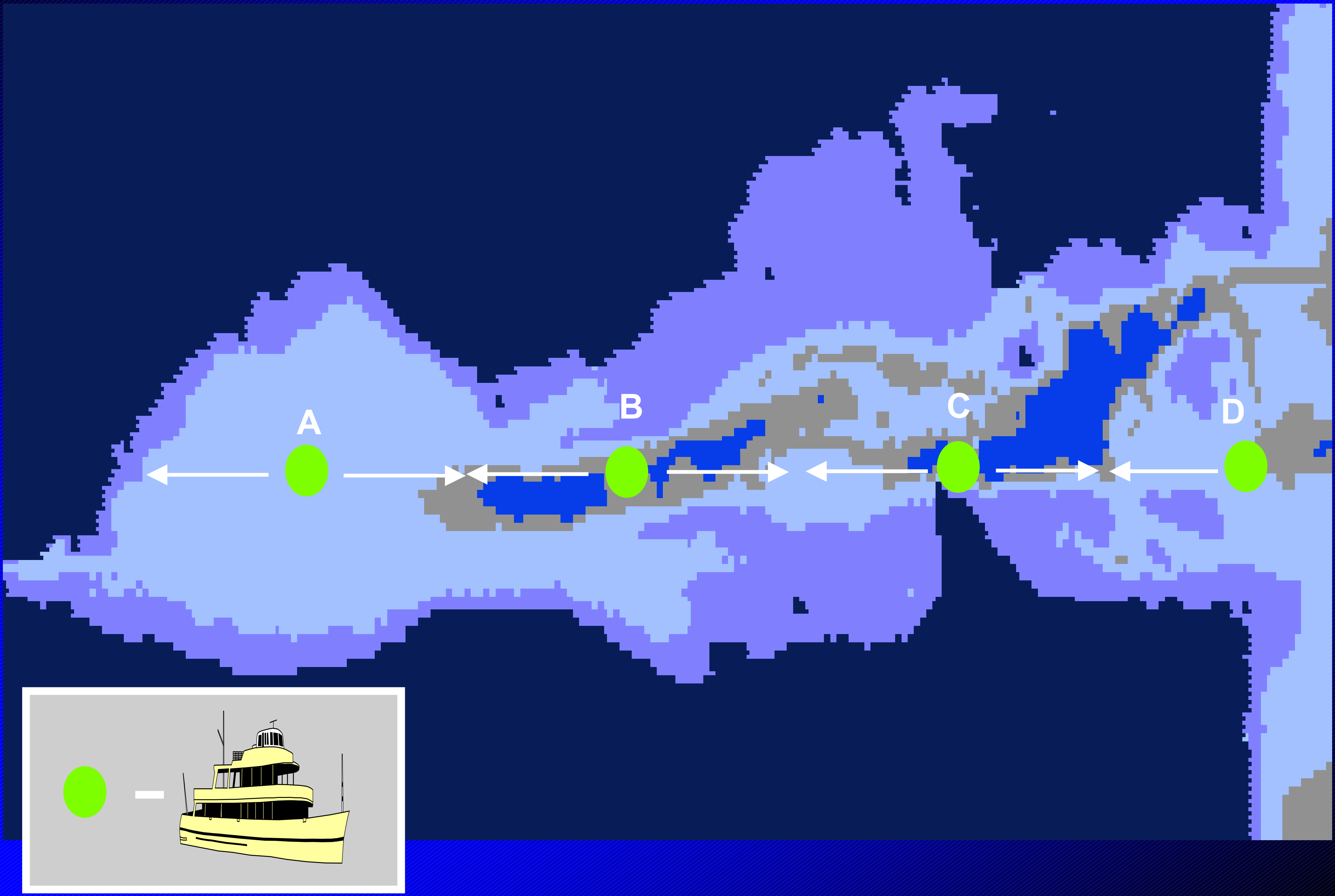


The length scale
1μm-100000km



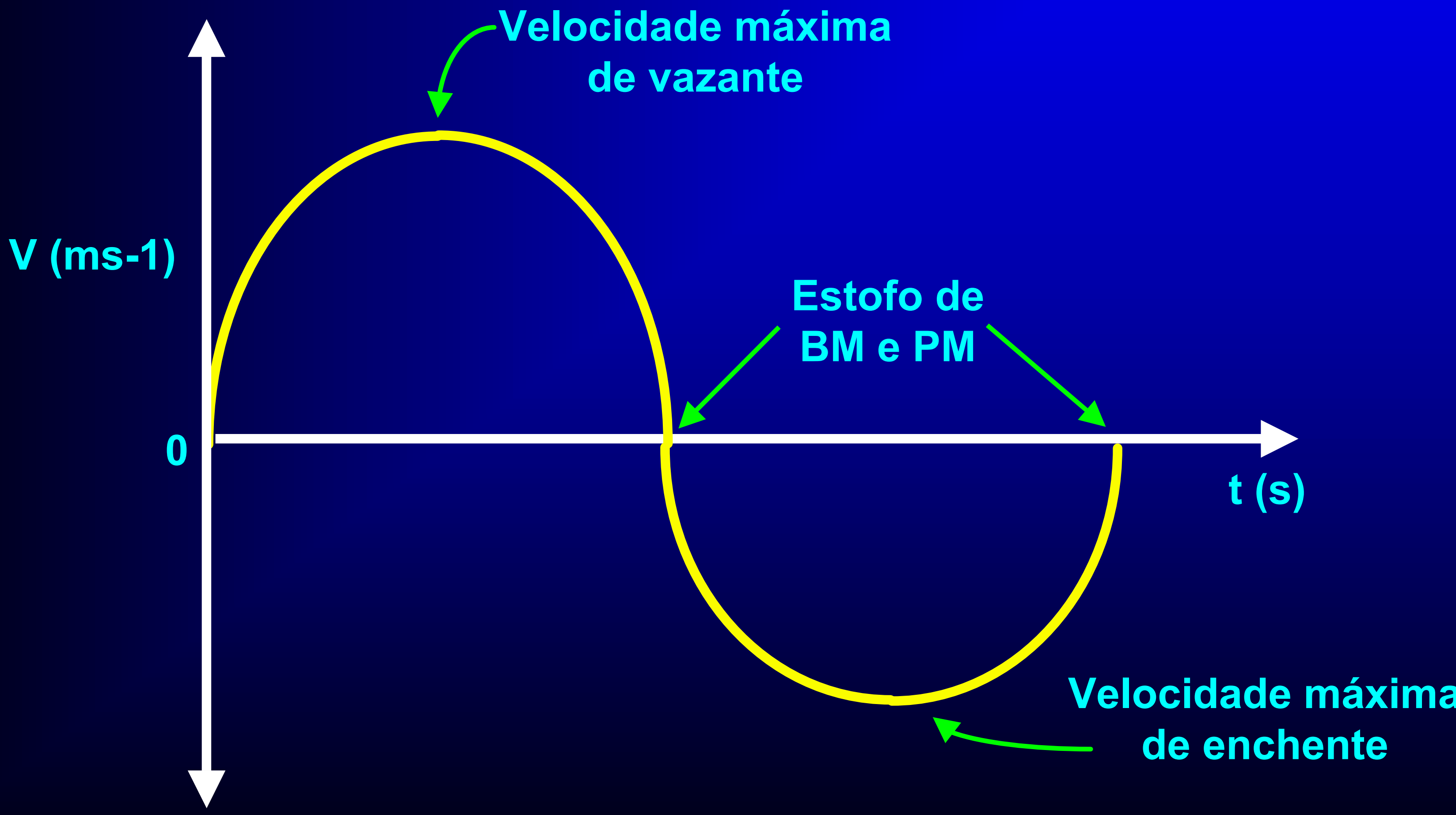
Mann & Lazier, Dynamics of Marine Ecosystems, Blackwell 1991

Amostragem Euleriana

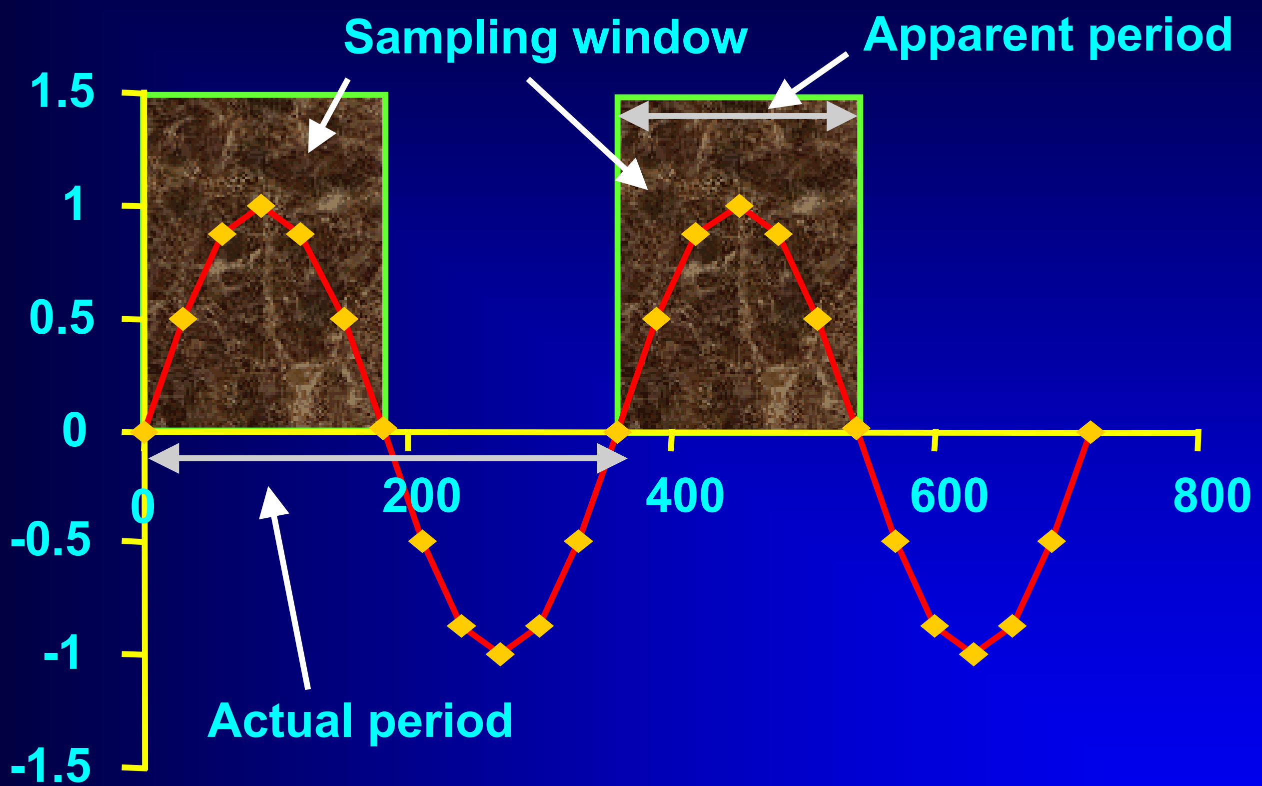


Amostragem Euleriana

$$\int V\,dt = h/3\,(y0+4y1+2y2+...+4y_{n-1}+y_n)$$

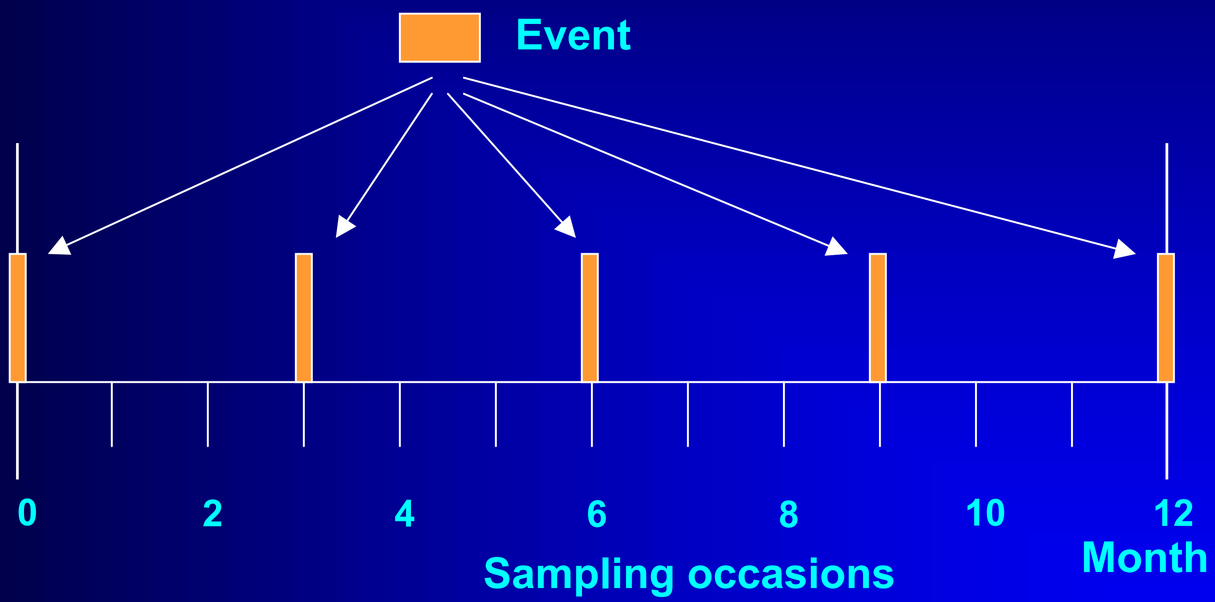


Sampling period and actual period



Actual period is double the apparent period

Sampling frequency and event occurrence



Event occurs every 3 months (seasonally), but <u>appears</u> to occur every <u>six</u> months