浙江大学
Zhejiang University

浙江大学海洋学院
OCEAN COLLEGE, ZHEJIANG UNIVERSITY

2017年青年教师教学竞赛参赛课程

《物理海洋学》

—— 海洋学院·李爽

宽厚 · 跨越

海洋学院·海之声队

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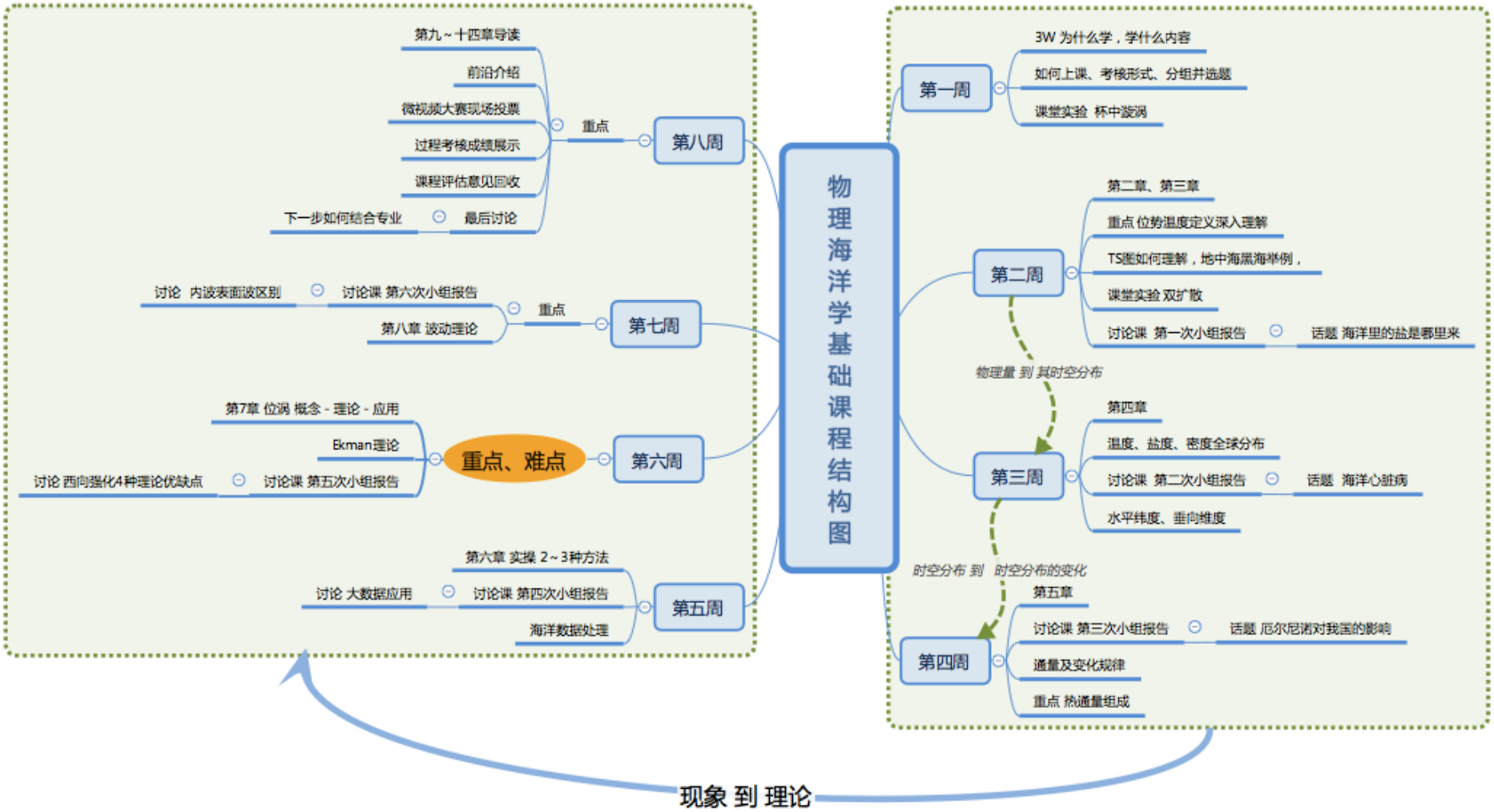
- 合理的梯队——正高、副高、中级
- 科学的课程——工程&科学、公选&院选、必修&选修
- 优秀的教师——年富力强、男女搭配、专兼结合
- 得力的组织——名师领衔、海洋特色、严谨求是

课程目录


物理海洋学基础课程结构图
第一周
3W 为什么学，学什么内容
如何上课、考核形式、分组并选题
课堂实验 杯中漩涡
第二周
第二章、第三章
重点 位势温度定义深入理解
TS图如何理解，地中海黑海举例，
课堂实验 双扩散
讨论课 第一次小组报告
话题 海洋里的盐是哪里来
物理量 到 其时空分布
第三周
第四章
温度、盐度、密度全球分布
讨论课 第二次小组报告
话题 海洋心脏病
水平纬度、垂向维度
时空分布 到 时空分布的变化
第四周
第五章
讨论课 第三次小组报告
话题 厄尔尼诺对我国的影响
通量及变化规律
重点 热通量组成
现象 到 理论
第五周
第六章 实操 2～3种方法
讨论 大数据应用
讨论课 第四次小组报告
海洋数据处理
第六周
重点、难点
第7章 位涡 概念 - 理论 - 应用
Ekman理论
讨论 西向强化4种理论优缺点
讨论课 第五次小组报告
第七周
重点
讨论 内波表面波区别
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第八周
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前沿介绍
微视频大赛现场投票
过程考核成绩展示
课程评估意见回收
下一步如何结合专业
最后讨论

动力部分知识体系

Dynamical Oceanography ---To describe and understand oce
processes via simple laws such as Newton's laws of mot

Difficulties: (1) Ocean is rotating, (2) Ocean is a continuum i
discrete particles.

Long Range Goal ---> Prediction ---> Environmental Manage

Concepts to be introduced:
(1) Geostrophy
(2) Geostrophy & Friction ----> Ekman layer & upwelling dynamics
(3) Geostrophy & Stratification ---> Gulf Stream structure & River
plumes
(4) Vorticity
(5) Potential Vorticity
(6) Conservation of Potential Vorticity + Coastally Trapped Waves
(Rossby, Continental Shelf & Kelvin Waves)
(7) Sverdrup Relationship + Davidson Current off Californ
(8) Western Boundary Currents ---> Gulf St
(9) El Niño and Southern Oscillation

层化	旋转
✔	

目标、重点、难点

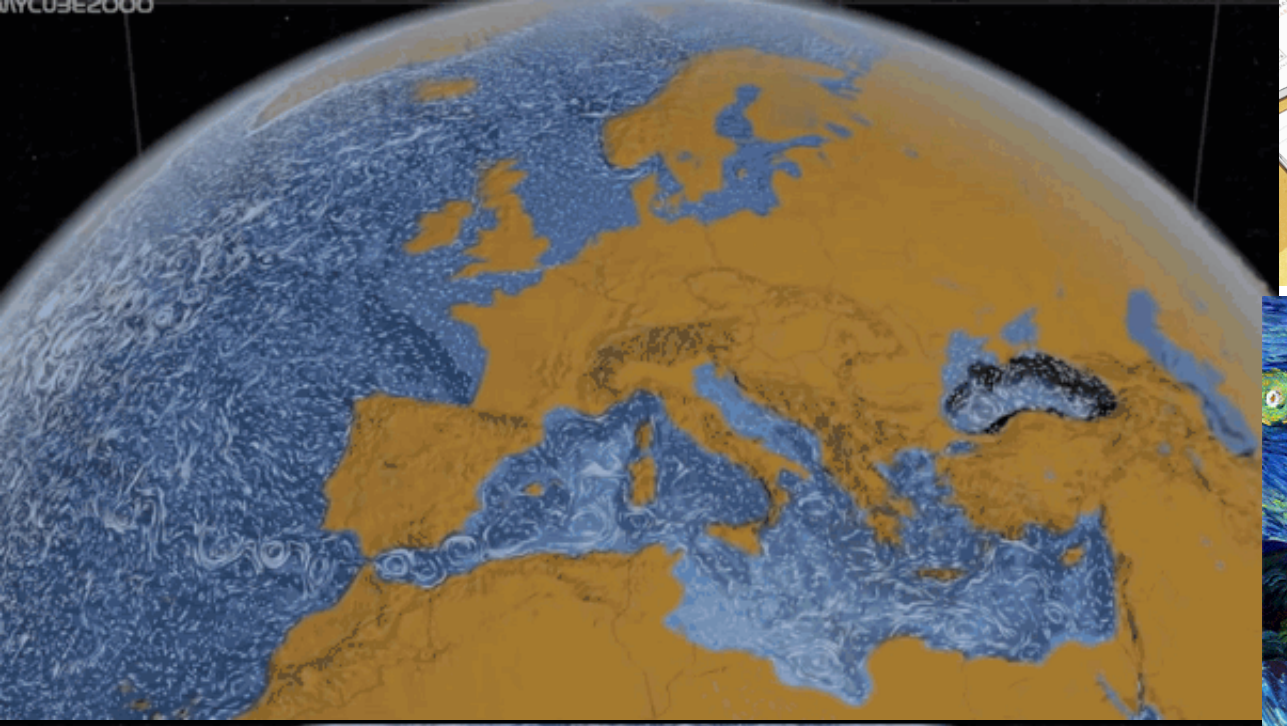
he north pole, 30N, equator,

lis force in relation to the
relation to the velocity?

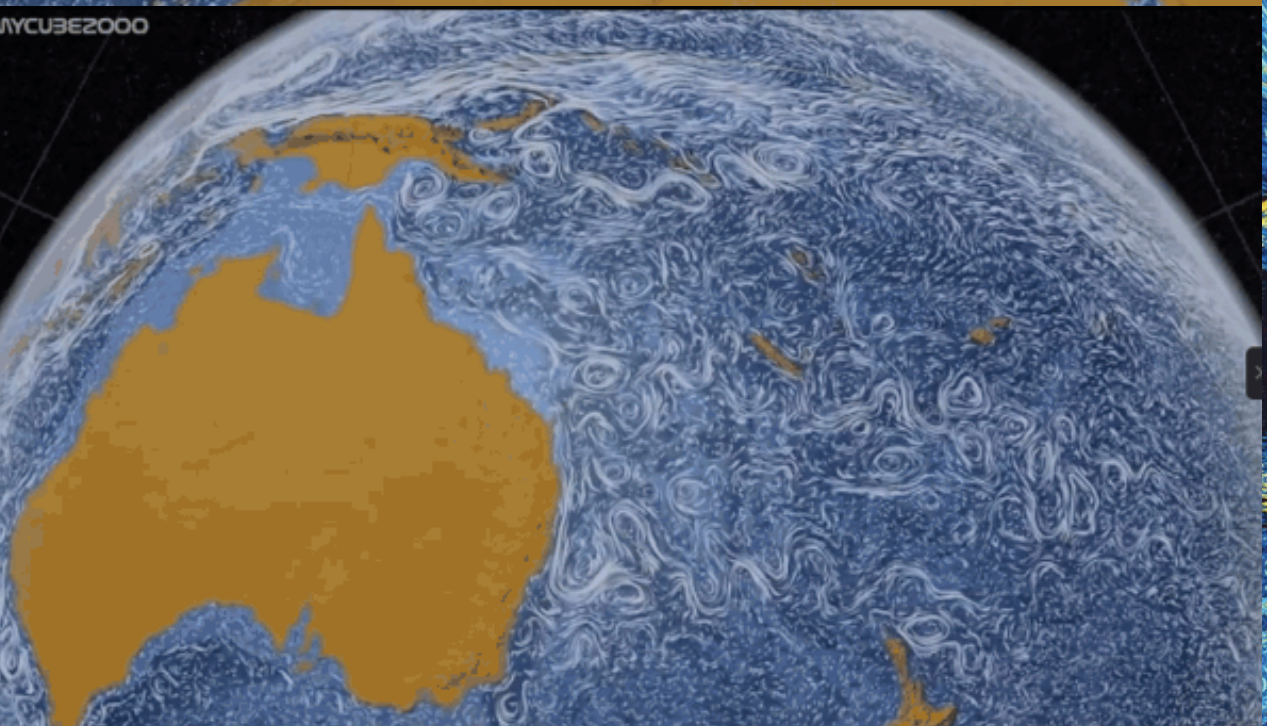
evel of known motion" be a
(What can we actually
an

assumption of geostrophy?)

4. Name the three contributing factors to potential vorticity.
5. How does Ekman pumping connect to the Sverdrup interior flow? Explain using potential vorticity arguments


MYCUBE2000


RECALL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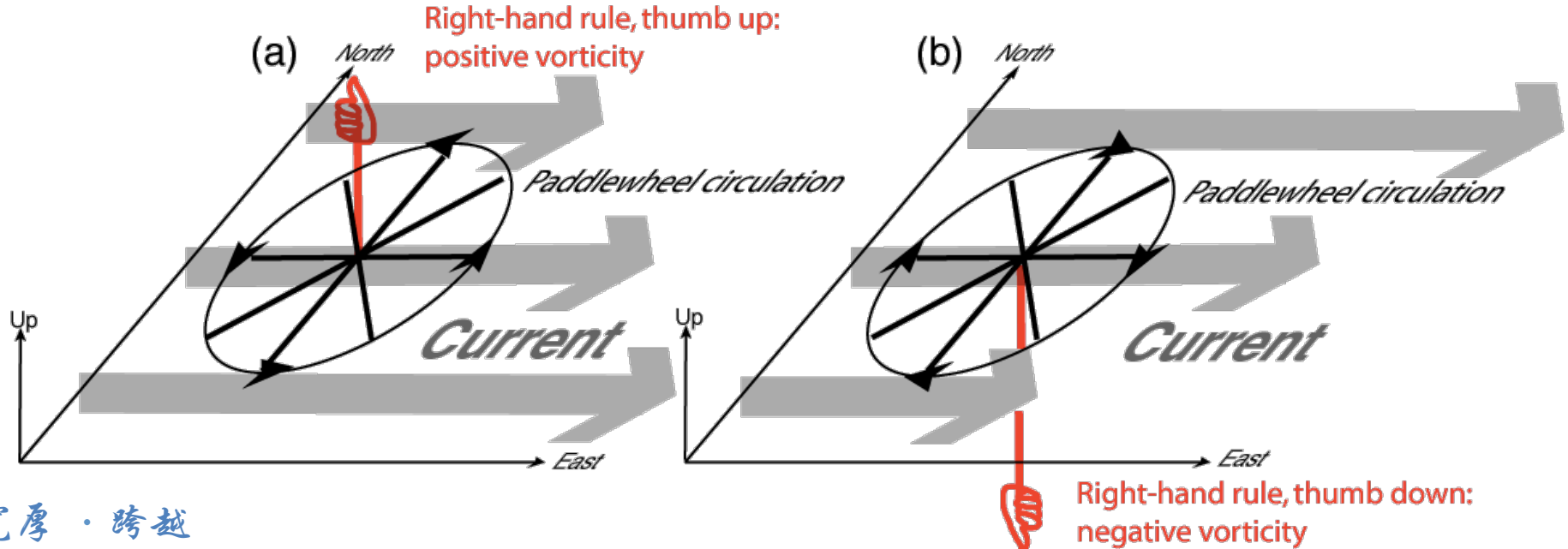
概念

- Vorticity is the angular velocity at a point in a fluid.

$\omega_{planetary} = 2\Omega$

where $\Omega = 2\pi/\text{day} = 2\pi/86400 \text{ sec} = 7.27 \times 10^{-5} \text{ sec}^{-1}$, so $\omega_{planetary} = 1.454 \times 10^{-4} \text{ sec}^{-1}$.

- Vorticity is a vector, and points out of the plane in which the fluid turns.



概念： PV

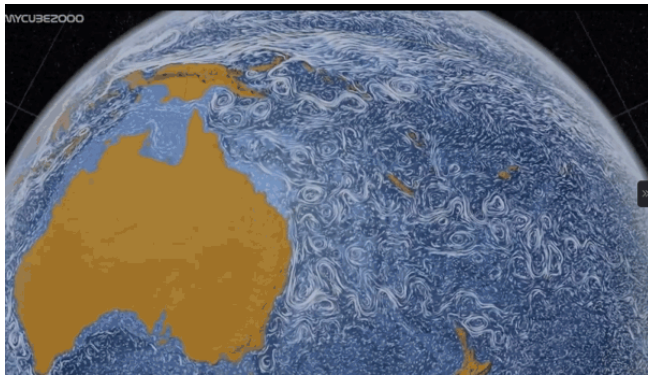
Vorticity is exactly related to the concept of curl in calculus. The vorticity vector $\boldsymbol{\omega}$ is the curl of the velocity vector **v**,

$$\boldsymbol{\omega} = \nabla \times \mathbf{v} = \mathbf{i}\,(\partial v/\partial z - \partial w/\partial y) + \mathbf{j}\,(\partial w/\partial x - \partial u/\partial z) + \mathbf{k}\,(\partial v/\partial x - \partial u/\partial y)$$

where (i, j, k) is the unit vector in Cartesian coordinates (x, y, z) with corresponding velocity components (u, v, w). Vorticity has units of inverse time, for instance, $(\text{sec})^{-1}$.

The vorticity of the fluid motion itself is called the ***relative vorticity*** when it is calculated from the water velocities relative to the Earth's surface (which itself is rotating).

Total vorticity = relative vorticity + planetary vorticity.

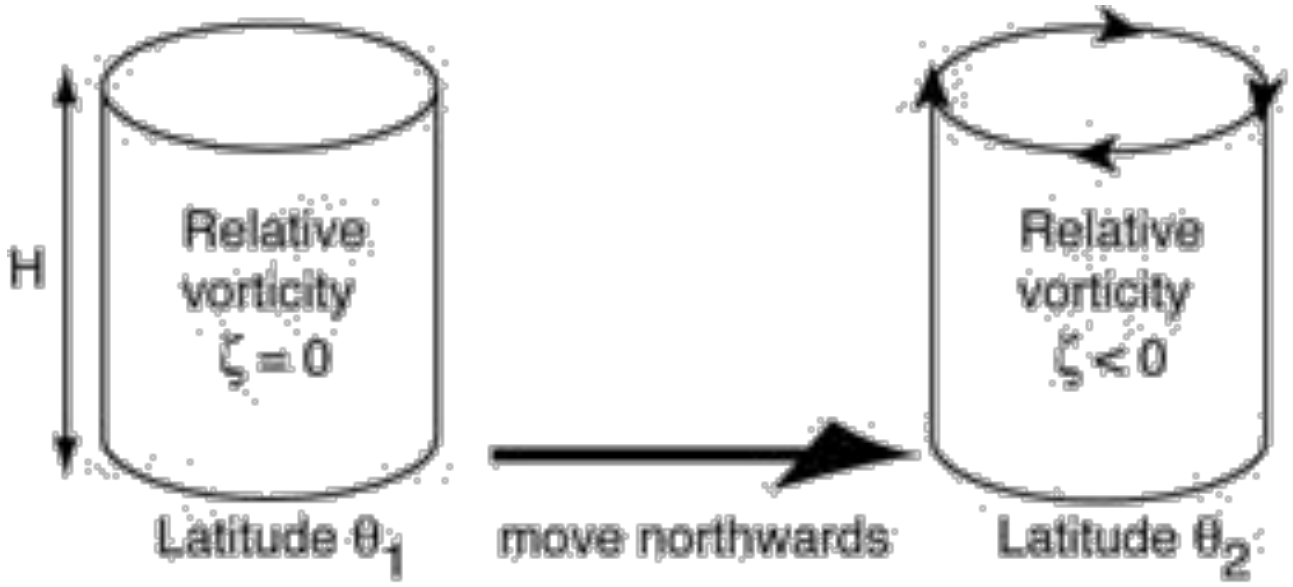


PV守恒理论

Conservation of PV is one of the most important concepts in fluid dynamics

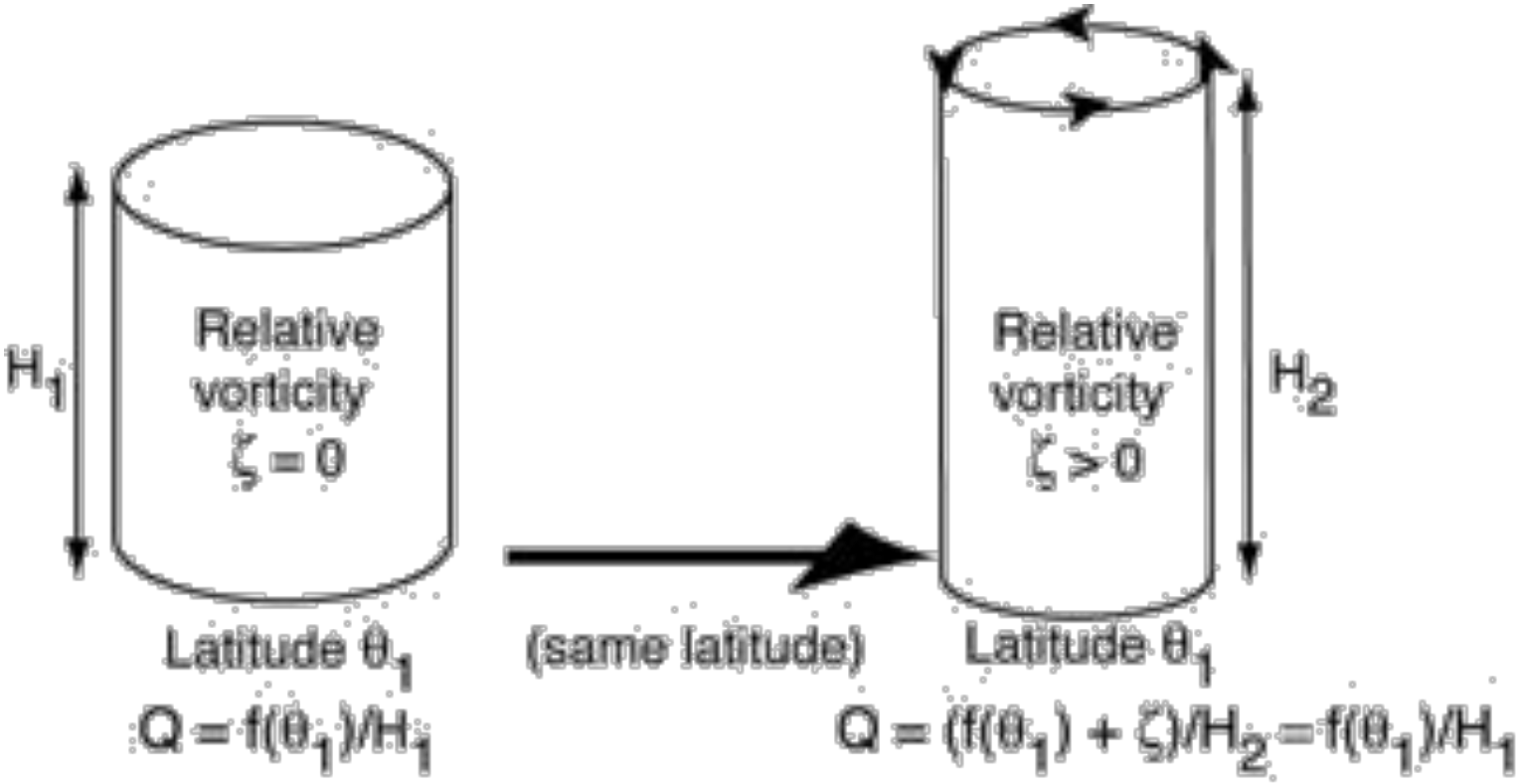
When there are no forces on the fluid, PV Q is **conserved**.

例1 应用



Conservation of potential vorticity Q in the absence of stretching (northern hemisphere):
balance of planetary vorticity and relative vorticity

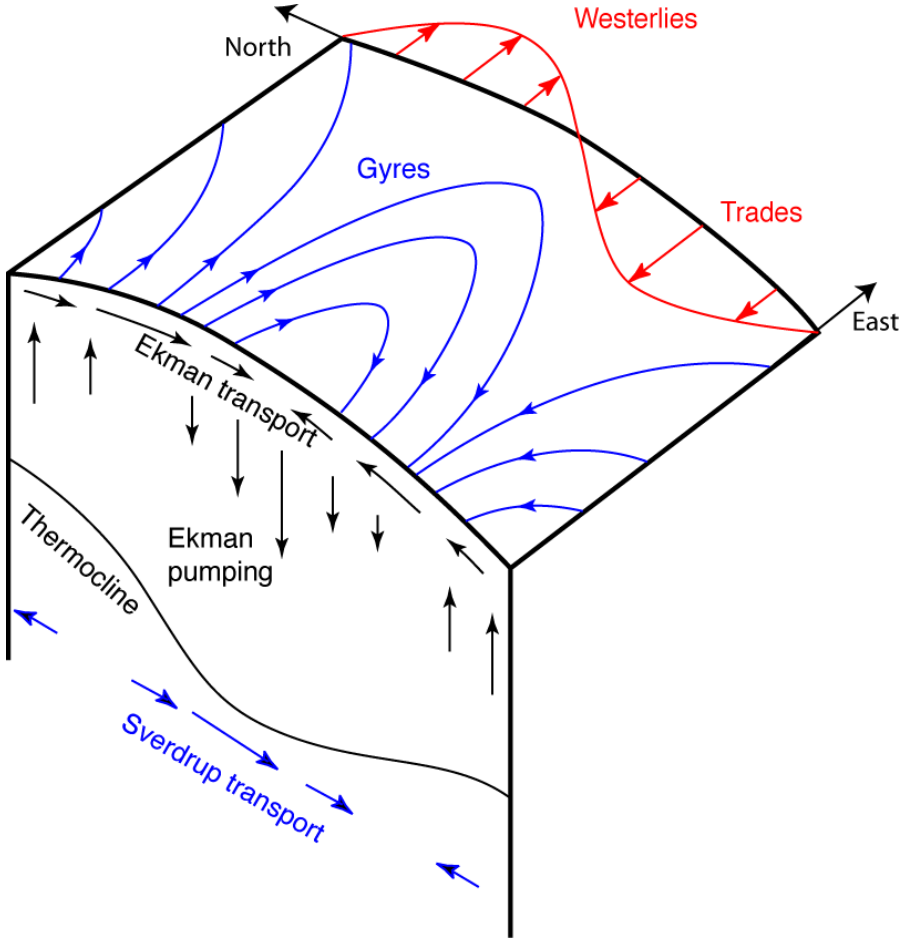
例2 应用



Conservation of potential vorticity Q in the absence of planetary vorticity change (northern hemisphere): balance of relative vorticity and stretching

例3 联合应用

Sverdrup Balance



- Wind causes Ekman transport and convergence
- Ekman pumping provides the squashing or stretching.
- The water columns must respond, either through change in relative vorticity or change in planetary vorticity (latitude). They do not spin up in place, but rather change latitude.

Squashing -> equatorward movement Stretching -> poleward

再重复

How to measure vorticity on a rotating globe?

$$\zeta ----vorticity \quad or \quad relative \quad vorticity$$

$$f+\zeta ----absolute \quad vorticity \quad (fluid+earth's \quad vorticity)$$

$$(f+\zeta)/h ----potential \quad vorticity,$$

$$where \quad h = water \quad depth$$

Conservation of potential vorticity in a homogeneous and inviscid ocean

In the absence of external forcing,

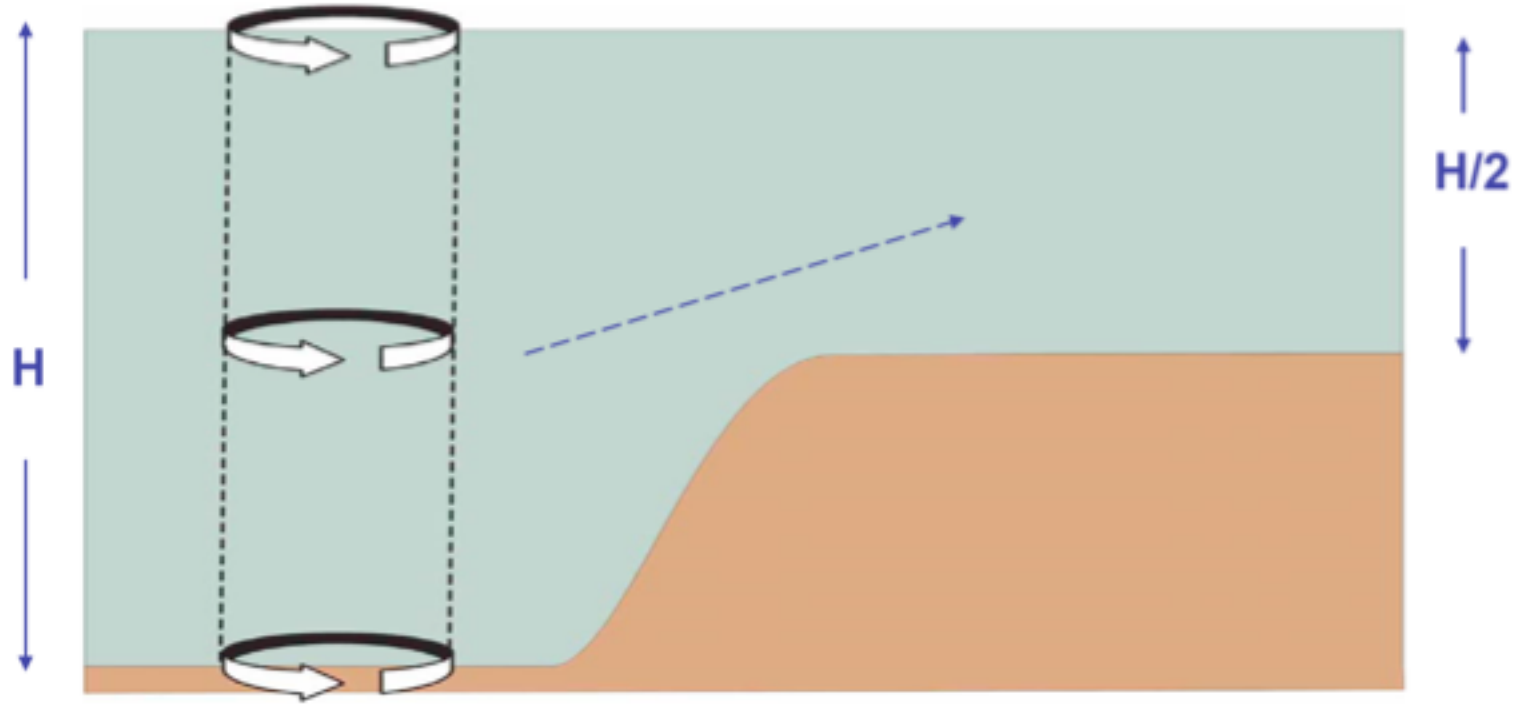
$$PV = \frac{f+\zeta}{h} = const$$

This conservation law can be rigorously derived from Newton's laws of motion.

例1 应用 OMS

Northern Hemisphere Scenario : $\dfrac{\zeta + f}{H} = const$

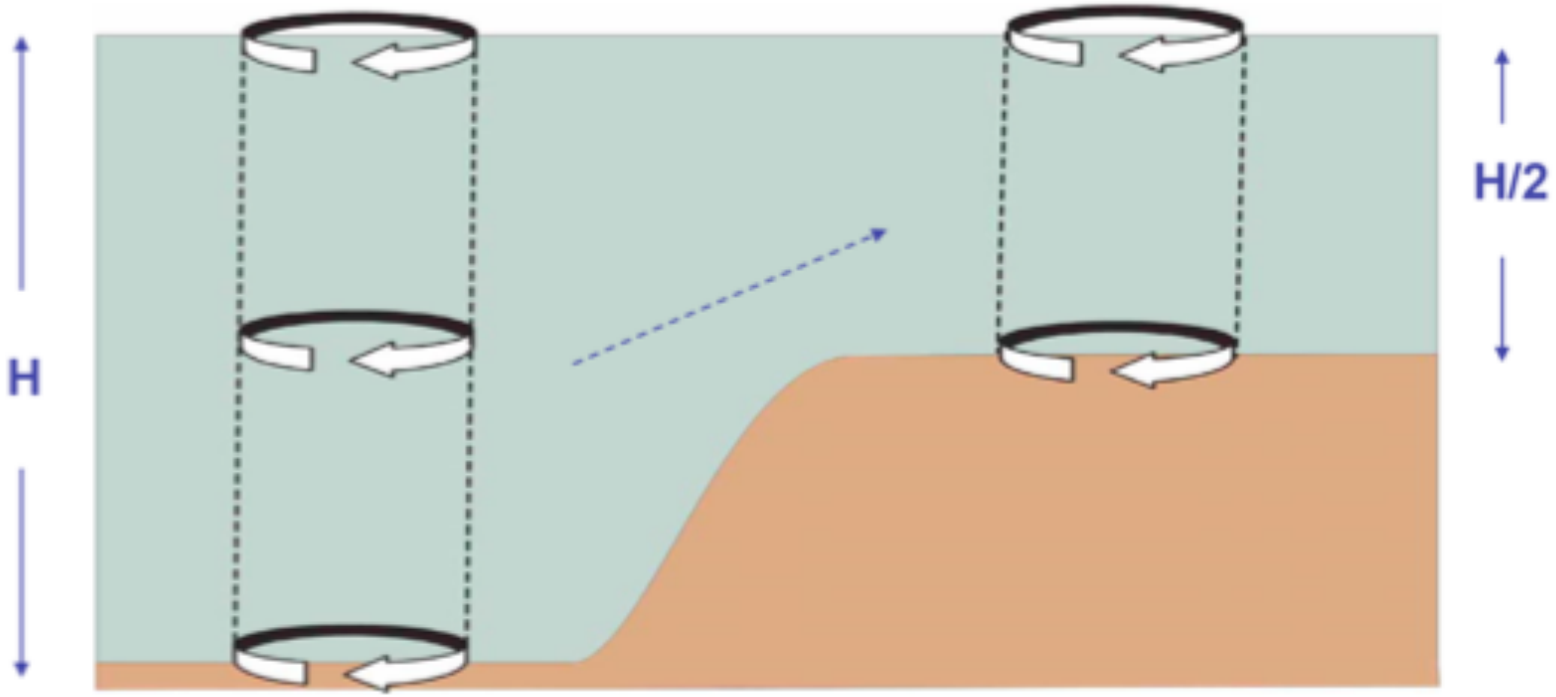
$\zeta = f$



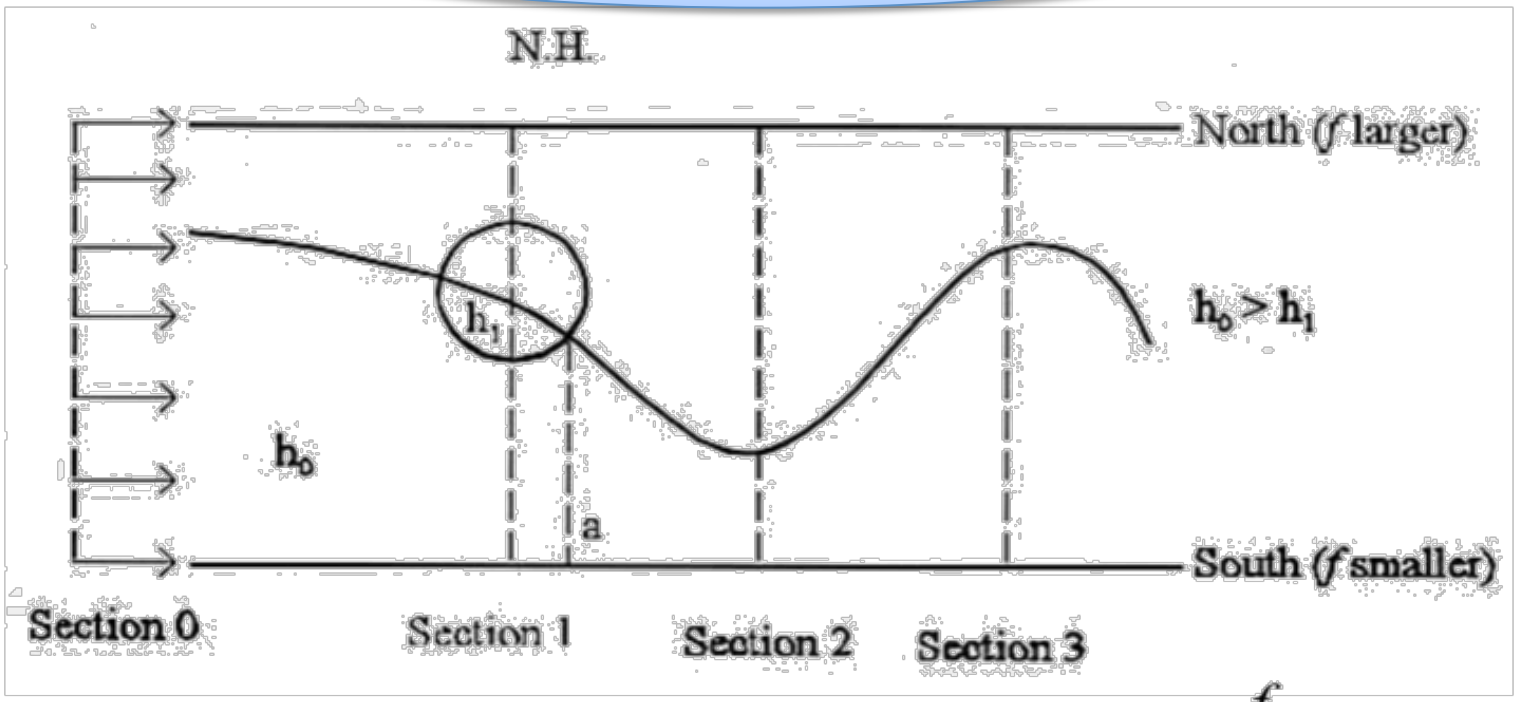
例2 应用OMS

Northern Hemisphere Scenario : $\dfrac{\zeta + f}{H} = const$

$\zeta = -f$



例3 应用 OMS



$$At \quad 0: \quad \zeta = 0, \quad h = h_0, \quad f = f_0, \quad PV = \frac{f_0}{h_0}$$

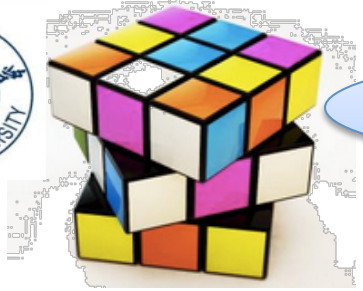
$$0 \rightarrow 1: \frac{f_0}{h_0} = \frac{f_0 + \zeta_1}{h_1}, \quad h_1 < h_0, \quad \zeta_1 < 0$$

$$a \rightarrow 2: \quad \frac{f_0 + \zeta_a}{h_0} = \frac{f_2 + \zeta_2}{h_0} \quad \Rightarrow \quad f_a + \zeta_a = f_2 + \zeta_2$$

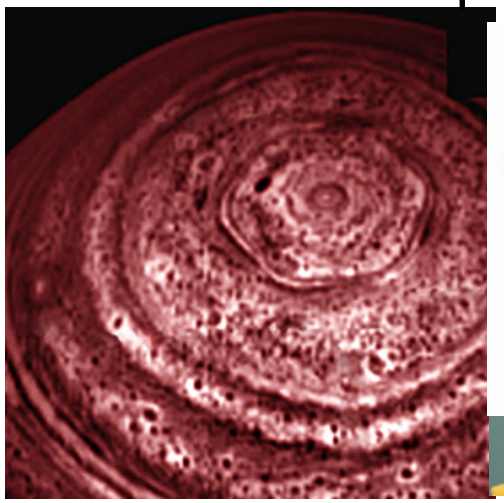
$$f_2 < f_a \quad \Rightarrow \quad \zeta_2 > \zeta_a \quad until \quad \zeta_2 > 0$$

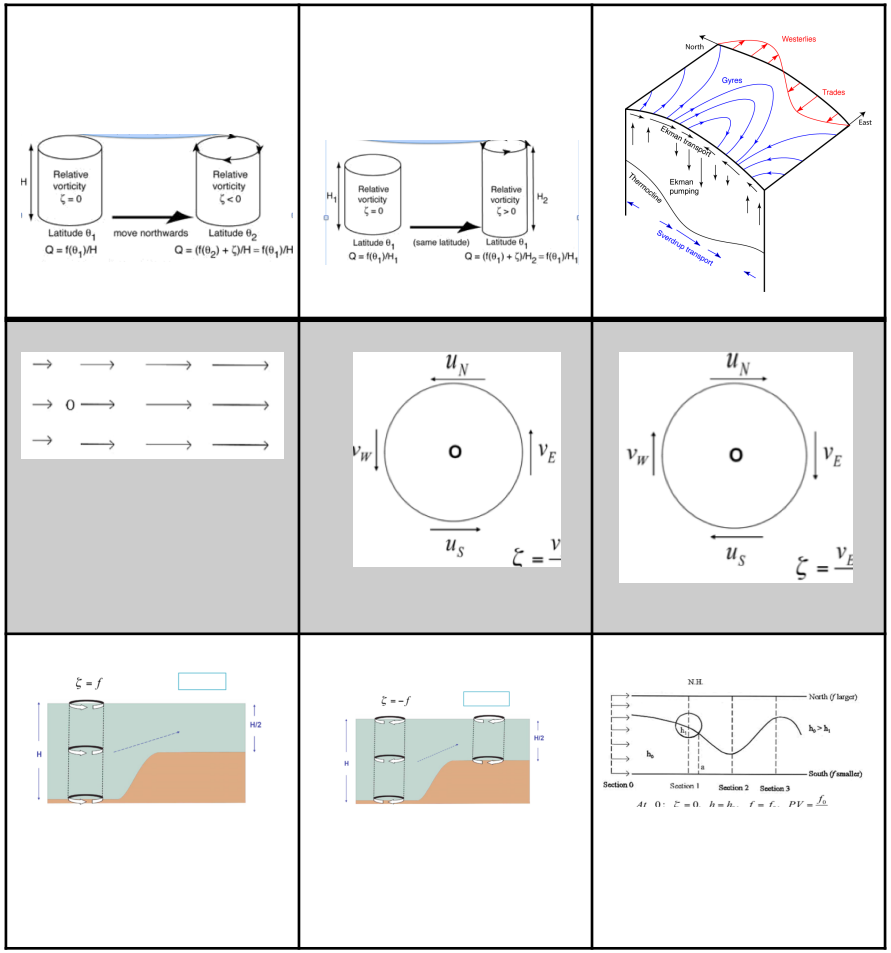
and so on... The wave train is called Lee Rossby Waves

迁移

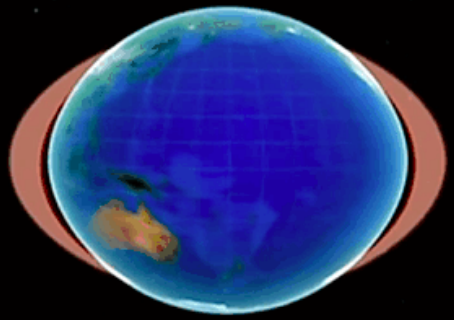


Saturn’s north polar hexagon



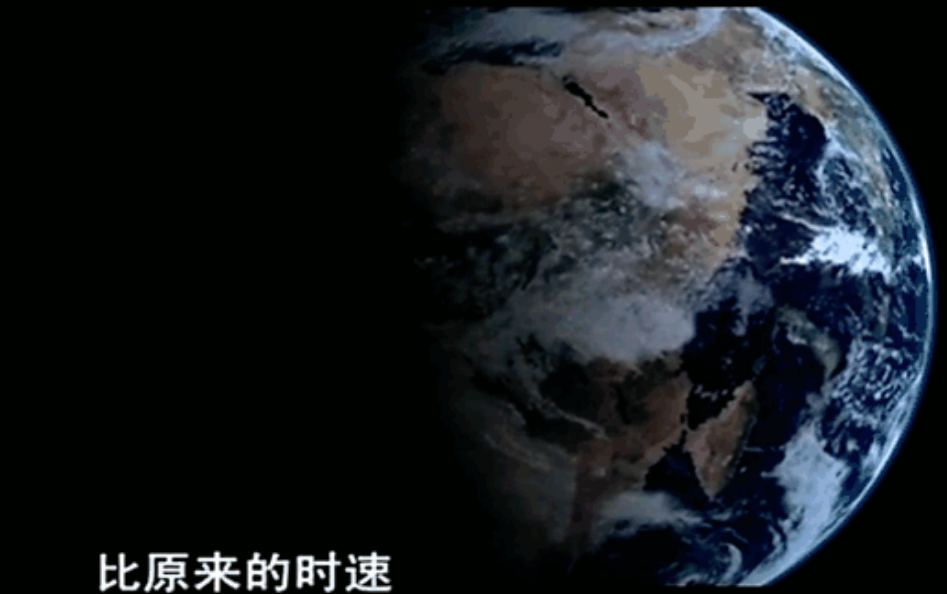


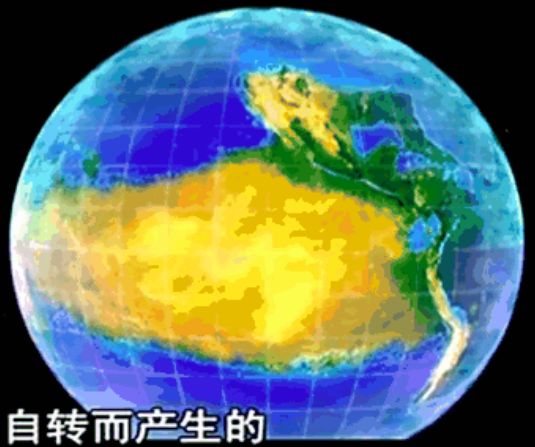
STOP ?



地球中部赤道地区的

AFTERMATH WHEN THE EARTH STOP SPINNING





比原来的时速

原来因自转而产生的