دانشگاه رازی

Geophysical Fluid Dynamics

Lecture 2

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IMPORTANCE OF GEOPHYSICAL FLUID DYNAMICS

Without its atmosphere and oceans, it is certain that our planet would not sustain life.

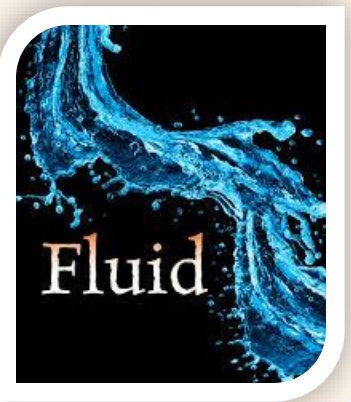
The natural fluid motions occurring in these systems are therefore of vital importance to us, and their understanding extends beyond intellectual curiosity it is a necessity.

Historically, weather vagaries have baffled scientists and laypersons alike since times immemorial.

Likewise, conditions at sea have long influenced a wide range of human activities, from exploration to commerce, tourism, fisheries, and even wars.

Such pressing questions cannot find answers without, first, an in-depth understanding of atmospheric and oceanic dynamics and, second, the development of predictive models.

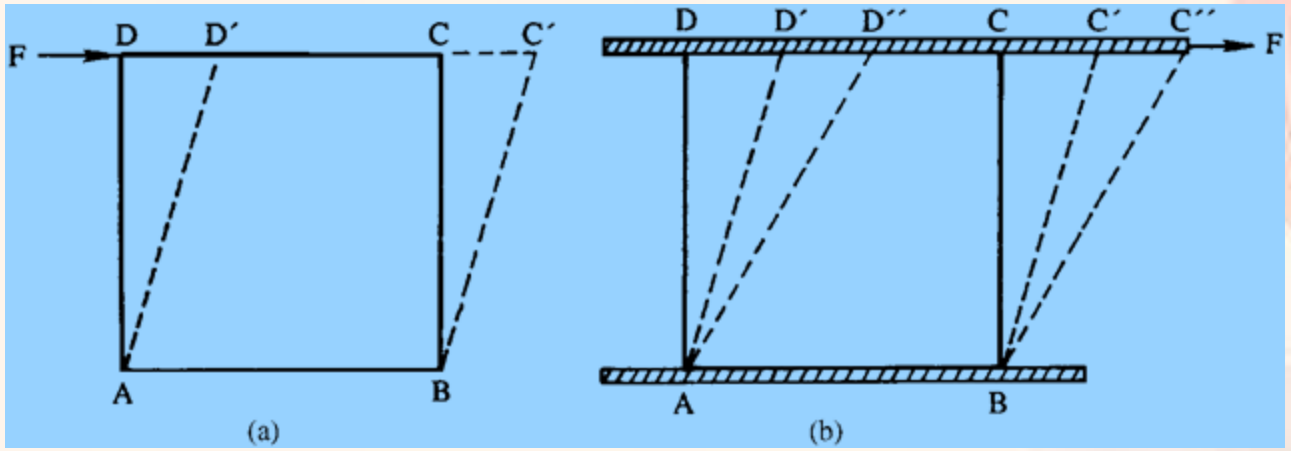
In this twin endeavor, geophysical fluid dynamics assumes an essential role, and the numerical aspects should not be underestimated in view of the required predictive tools.



Definition of a Fluid

In general, a fluid is defined by the relative ease with which it may be deformed, and by the fact that it does not have a preferred shape

A simple fluid is defined as a substance which cannot withstand any tendency by applied forces to deform it in any way which leaves the volume unchanged.
Since most fluids such as water and air luckily behave in this manner, simple fluids will be considered in the present context.



Deformation of solid and fluid elements: (a) solid; and (b) fluid.

Continuum Hypothesis

Since a fluid is made up of molecules, a full description would depend on the dynamics of each molecule.
However a description at this level is quite difficult since this would mean a wildly non-uniform distribution of properties

Properties of Fluids

A full description of fluid properties requires utilization of the theory of thermodynamics.

Since we need to consider incompressible, homogeneous fluids in this introduction, we do not need to review thermodynamics at present.

A review of thermodynamics will eventually become necessary in the subsequent stratified fluids volume.

Mechanical properties such as stress and rate of deformation will be studied within the present context.

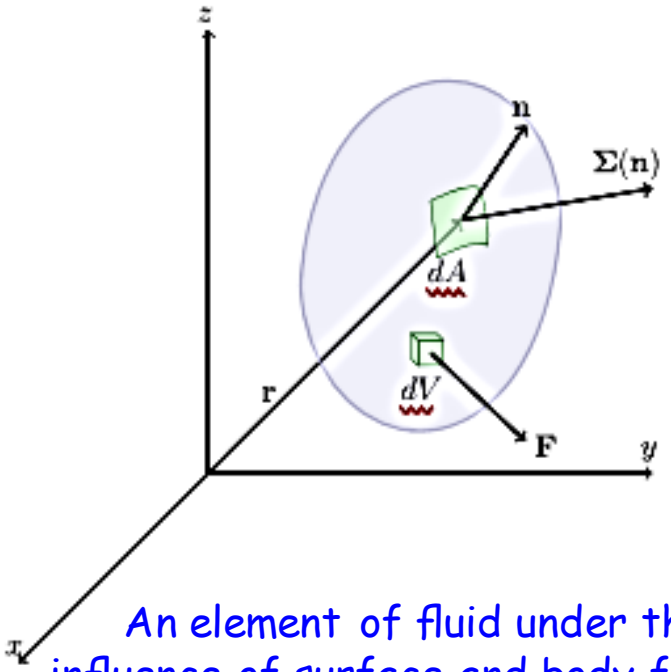
Volume and Surface Forces

Volume forces (or body forces) penetrate into the interior and act on distributed elements of fluid

$$\vec{F}(\vec{r},t)\rho\delta V$$

Where F is a body force per unit mass and ρ the density.
In the case of gravity F = g is the gravity force per unit mass.

Surface forces are forces of direct molecular origin and therefore decrease extremely rapidly with distance between interacting elements.



An element of fluid under the influence of surface and body forces

The total force exerted across the element is proportional to its area δA and is given by

$$\sum(\vec{n},\vec{r},t)\delta A$$

where Σ is the local stress (surface force per unit area) and n the unit normal to the surface.

The surface force on the other side of the area element is $\sum(-\vec{n},\vec{r},t) = -\sum(\vec{n},\vec{r},t)$

Dynamic Meteorology هواشناسی دینامیکی

The theoretical study of atmospheric motion with (at least) two important goals.

to provide understanding of the many facts involved in the phenomenon of atmospheric motion.

to provide a rational basis for the prediction of future atmospheric events.

متغیر های فیزیکی *Physical Variables*

وابسته

مستقل

وابسته: (یا نرده ای است مانند فشار هوا $\mathcal{P}$– دما -$\mathcal{T}$ چگالیρ و یا برداری مانند سرعت $\mathcal{V}$ – شتاب a – نیرو F)

مستقل: (یا زمانی t و یا مکانی x,y,z)

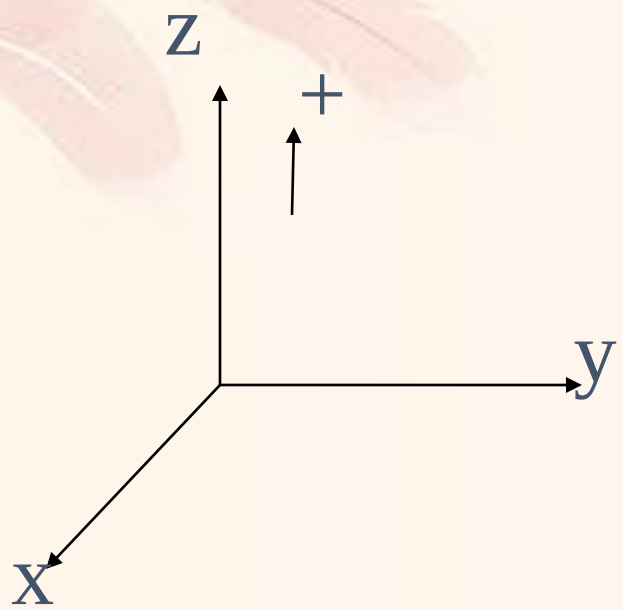
در نتیجه هر متغیر مانند $\mathcal{P}$ را می توان متغیری از مکان و زمان در نظرگرفت:

$$\mathcal{P}=\mathcal{P}(x,y,z)$$

هر بسته هوا ممکن است با مکان و زمان تغییر کند که این تغییر مختصات را میتوان سرعت نامید.

$$V = V(x, y, z, t)$$

$$V(u, v, w)$$



مولفه سرعت در دستگاه کارتزین (قائم):

$$u = \frac{dx}{dt}, v = \frac{dy}{dt}, w = \frac{dz}{dt}$$

w= +3m/s حرکت صعودی

w= -3 m/s حرکت نزولی

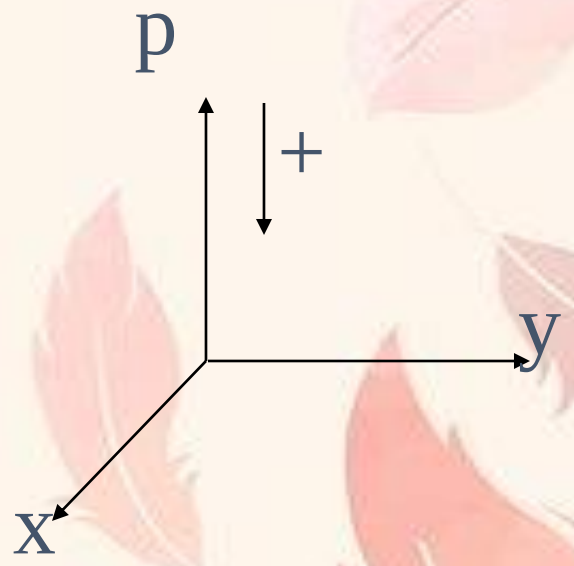
دستگاه مختصات فیزیکی

مولفه سرعت در دستگاه p:

$$u = \frac{dx}{dt}$$

$$v = \frac{dy}{dt}$$

$$\omega = \frac{dp}{dt}$$



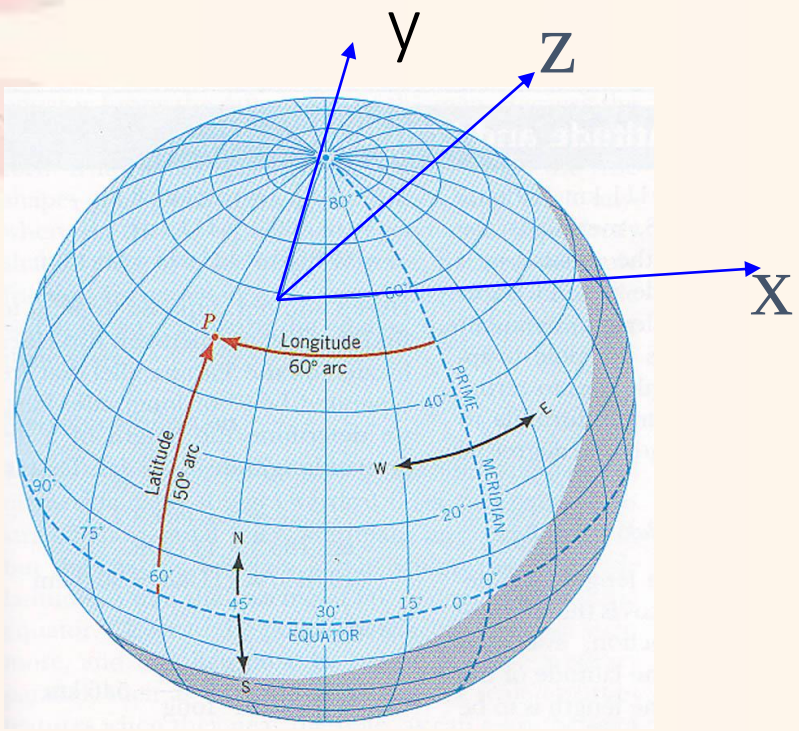
حرکت نزولی ω= +2 mbar/s

حرکت صعودی ω= -2 mbar/s

1mb=100Pa=1hPa

1bar=10^5 Pa

انتخاب محورها



محور xها : در راستای محورهای عرض جغرافیایی (مدارات) از غرب به شرق.

محور yها : در راستای محورهای طول جغرافیایی (نصف النهارات) از جنوب به شمال.

محور zها : قائم بر سطح و از سطح زمین به طرف بالا در نظر گرفته می شود.

Operators Importance

اهمیت عملگر ها

1) The Gradient of a Scalar Function

The **gradient** operator is a *vector* operator, written and called ``del.'' It is defined as

$$\vec{\nabla} \equiv \hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$$

and can be applied directly to any *scalar* function of (x,y,z). Say T(x,y,z) to turn it into a *vector* function,

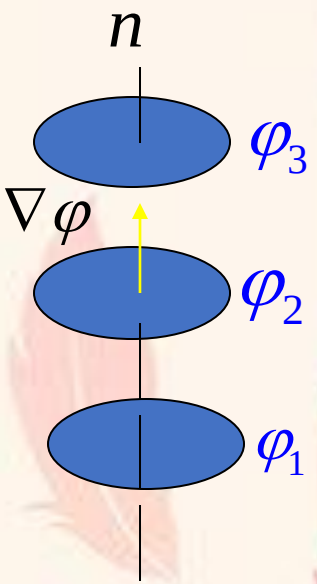
$$\vec{\nabla} \equiv \hat{i}\frac{\partial T}{\partial x} + \hat{j}\frac{\partial T}{\partial y} + \hat{k}\frac{\partial T}{\partial z}$$

the gradient is the rate of change of a function, or the derivative of a multi-variable function,

یک تابع عددی در نظر بگیرید که بصورت $\varphi = f(x, y, z)$ تعریف شده باشد.

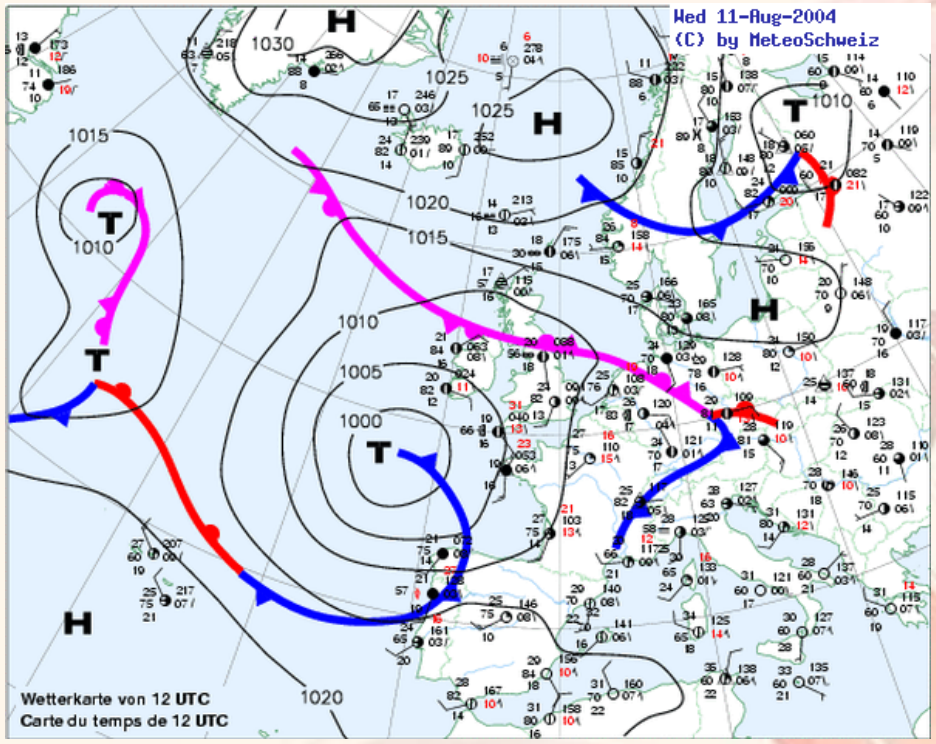
$$\vec{\nabla}\varphi = \hat{i}\frac{\partial\varphi}{\partial x} + \hat{j}\frac{\partial\varphi}{\partial y} + \hat{k}\frac{\partial\varphi}{\partial z}$$

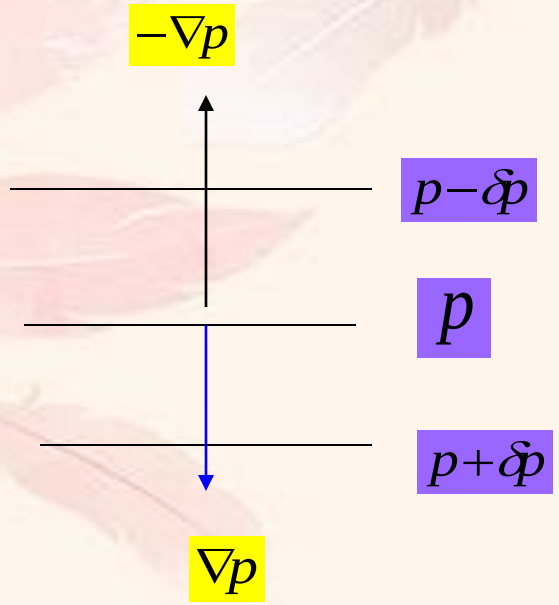
برداریست در جهت n و نشان دهنده حداکثر میزان فضایی تغییر φ است

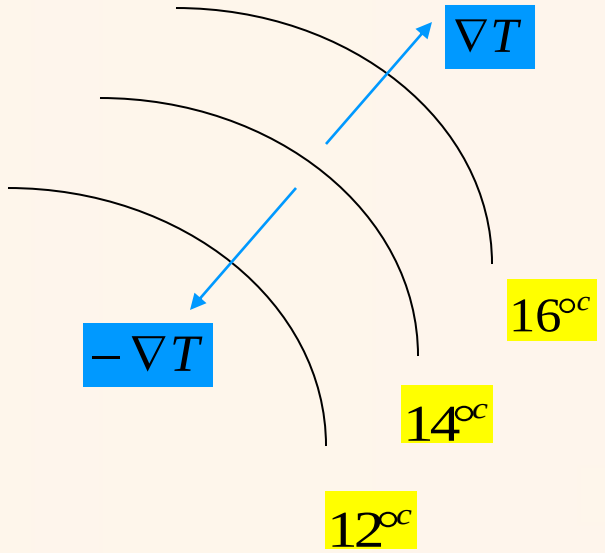


مفهوم گرادیان در هواشناسی

بر روی نقشه های هواشناسی خطوط همدما یا هم فشار را رسم می کنند یعنی نقاطی را که دارای یک دما یا یک فشار هستند به هم وصل می کنند آنگاه گرادیان دما در هر نقطه از فضا بر خط همدما و گرادیان فشار در هر نقطه از فضا بر خط هم فشار عمود است.





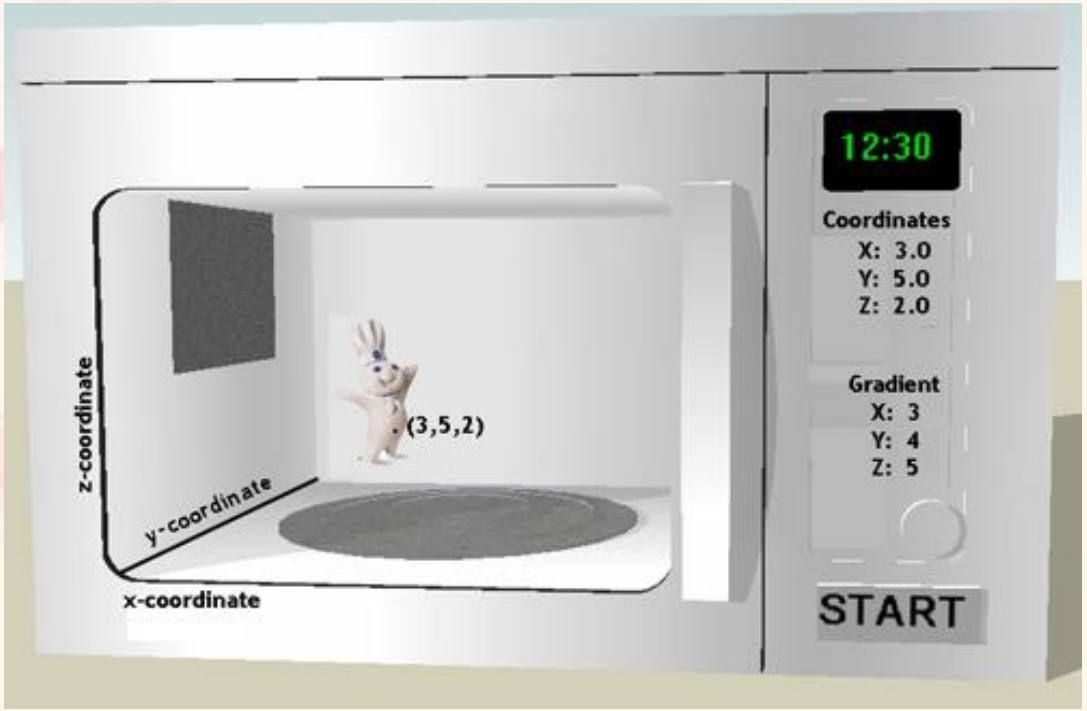


در هواشناسی $-\nabla p$ را گرادیان گویند و حالت مثبت را فرازه نامند.

Gradient: The space rate of decrease of a function.

$$-\nabla\varphi = \hat{i}\frac{\partial\varphi}{\partial x} + \hat{j}\frac{\partial\varphi}{\partial y} + \hat{k}\frac{\partial\varphi}{\partial z}$$

Ascendent: The negative of the gradient



Be careful not to confuse the coordinates and the gradient. The coordinates are the current location, measured on the x-y-z axis.

The gradient is a direction to move from our current location, such as move up, down, left or right.