Introduction to Dynamics (Ocean And Atmosphere)

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We got an overview of the Dynamics -I subject and the necessity of the subject in Atmospheric and Ocean studies. Due to change of conditions at every point in Ocean and Atmosphere, we have to study differential equations. We would be using mathematical language like for position of
Particle (x, y, z),
Velocity (u, v, w),
Pressure P etc and
Operators like
d/dt,
Nabla,
Laplacian etc.
Scales and dimensions like L, T, M, K, E (length, time, mass, temperature and energy resp.)are very important parts of dynamics study as they give you different scales for the quantities.
As the earth is surrounded by different layers of atmospheres .we will use the dynamics tools to find out the interaction between layers of atmospheres and oceans too. As earth is rotating we will also study the rotational system components and dynamics of thin layers as shown in fig.1.

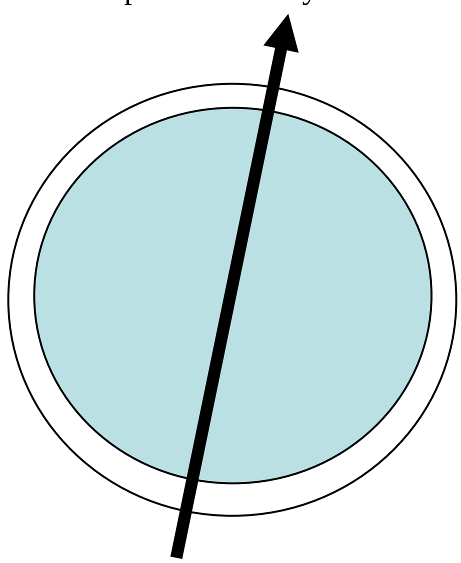


Fig 1: Schematic diagram of thin rotating layers

The variables like salnity, pressure in oceans and humidity and concerned factors in atmosphere. With all these things Units are also important part when we study any mathematical and Physical system.e.g.

T	temperature	in K
θ	potential temperature	in K
p	pressure	in N m^{-2}
ρ	density	in kg m^{-3}
$\mathbf{u}$	velocity	in m s^{-1}
E	internal energy per mass	in J $kg^{-1} = m^2 s^{-2}$
H	enthalpy per mass	in J $kg^{-1} = m^2 s^{-2}$
G	Gibbs potential	in J $kg^{-1} = m^2 s^{-2}$
s	entropy per mass	in J kg^{-1} K^{-1}

The present ocean system is like a conveyor belt. The ocean mass is transferred from one part to another by this belt as shown is fig.2

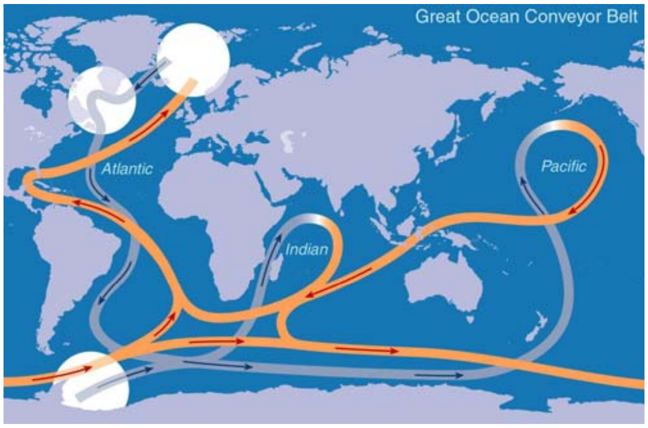


Fig.2: Schematic view of the large scale ocean circulation

While studying dynamics the study of Wind systems is an important part.e.g.it is seen as the high pressure belts around 30 deg. North and low pressure belts on the equator(fig.3).The goal of this study is to find out the equations of these processes.

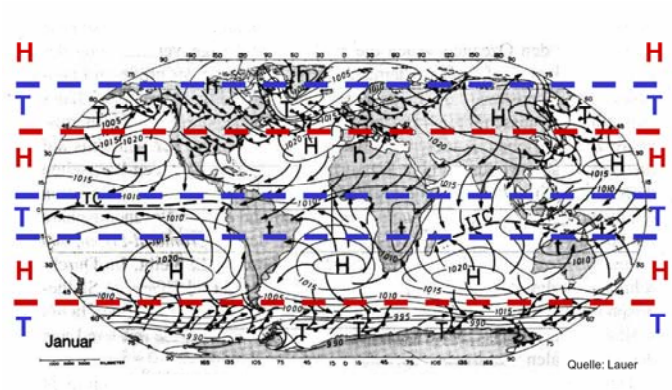
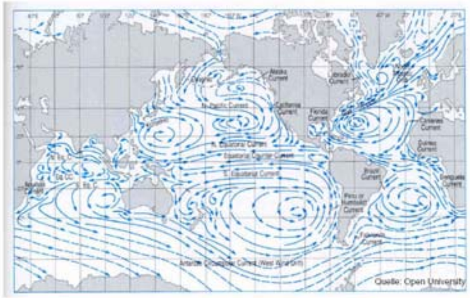


Fig 3:Boreal winter high and low pressure centres and associated atmospheric surface wind

This study will also include phenomenon like asymmetry in currents, vertical gradients in Atmosphere and oceans, mathematical study of different kinds of water masses.(fig 4)



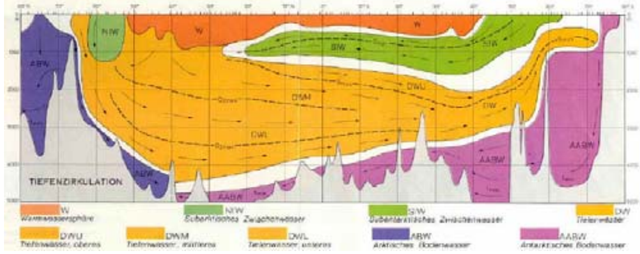


Fig.4: water mass circulation and wind pattern

The basic equations in fluid and atmospheric dynamics are written by Euler and De'alembert. The basic idea of Euler theory was movement in Oceans and atmosphere are considered motions in vector field. Therefore whole dynamics is like a continuum.(Refer fig 5)

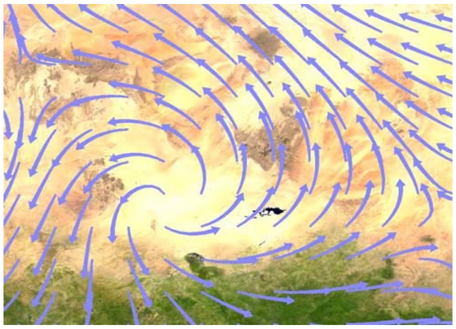


Fig.5:In most cases the fluid is considered to be a continuum, whereas for rarefied gases one needs to take into account the behaviour of molecules statistical way (-> Boltzmann equation)

To start with the Dynamics course after this brief introduction by two basic equations

Euler $$(\vec{v} \cdot \vec{\nabla})\vec{v} + \frac{d\vec{v}}{dt} = \frac{-1}{\rho}\vec{\nabla}P + \vec{g}$$

Continuity $$\frac{d\rho}{dt} = -\vec{\nabla} \cdot \rho\vec{v}$$

The comparison of movement in solid mechanics ,static fluid and fluid dynamics can be illustrated by fig.7.The In mechanical flow shape of the body is conserved, while in static flow body changes its shape.

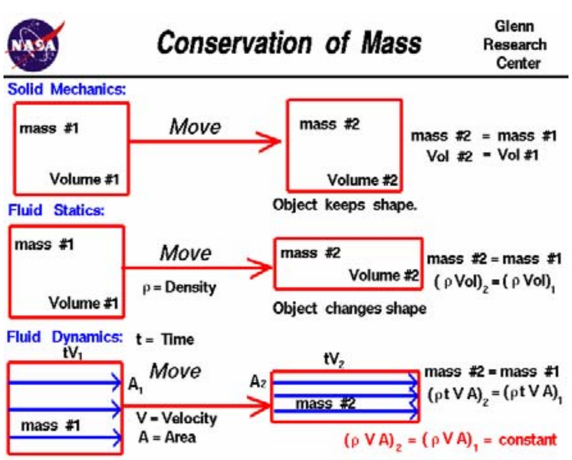


Fig.6: Consevation of mass

The Continuity equation can be derived easily from law of Conservation of Mass, by considering Bernoulli's set up (fig. 7)

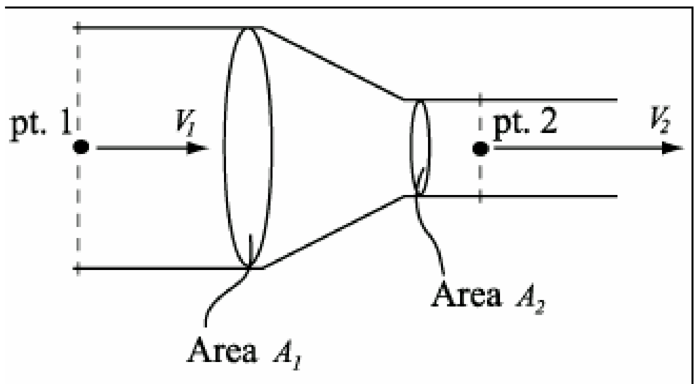


Fig.7: Bernoulli's setup

When a fluid of density ρ_1, from area A_1 to area A_2 of density ρ_2, then the mass of the system is conserved, as shown by equation below

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

Now we will se the Euler's Equation and considering the R.H.S. of the equation and considering the g in the 3rd direction. As for large scale systems in oceans and atmosphere velocity in the 3rd direction is very small so L.H.S. equals to 0.
Therefore we end up in **Hydrostatic approximation**.

$$\mathbf{Dp/dz = -\rho.g}$$

Where, ρ =density

It is equivalent of Newton's second law for fluids, including the effect of neighbouring fluids and the force of gravity. In it, the vector v is the velocity field a point in space. V is not the velocity of a particular parcel of fluid, except when it is at that point in space.
The right side includes the force on a unit volume due to the pressure gradient, grad P, and the force on a unit volume due to the gravitational field, g. The force of neighbouring fluid points towards lower pressure; this is the origin of the minus sign on the pressure gradient term.

R.H.S. of the Euler's equations is not complete, so in the next task is to study more about the other forces involved like Coriolis force, Friction, centrifugal force.