IMD-WMO Joint group fellowship training program on NWP

Theme: Parameterization of physical processes

Lecture-1 & 2

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Parameterization of physical processes

- Why parameterization?
    - Sub grid scale physical processes
    - Importance of such processes
- Parameterization-Definition
- Different sub-grid scale processes & their parameterization:
    - PBL parameterization
    - Convective parameterization
    - Orographic drag parameterization
    - Radiation parameterization

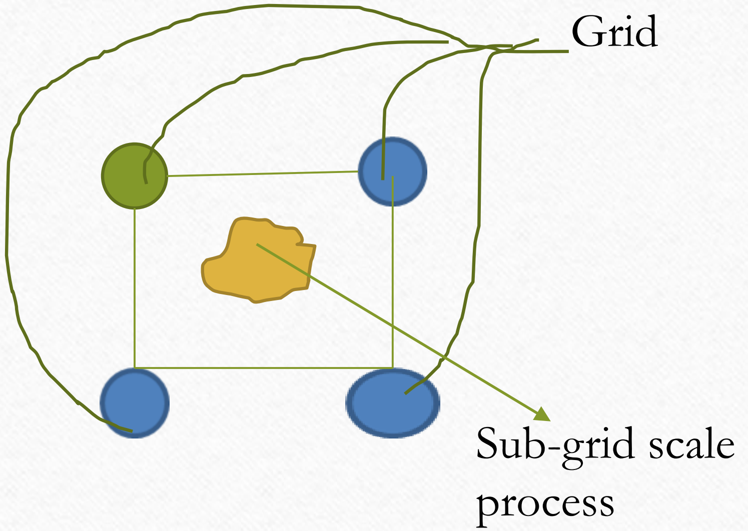
- Sub grid scale Physical processes: Any physical process whose spatial dimension is less than a grid, then it is called a sub grid scale physical process.
- Examples: Eddy turbulent transfer, convection, etc.

Importance of sub-grid scale physical processes

- Sub-grid scale physical processes many times may be skipped to be measured or observed using conventional grid, as shown in the adjoining figure.

- But such event may have significant influence on the values of the variables at the grids.

- If the effects of such events are not incorporated in the NWP model, then it may severely affect the accuracy of prediction.



- Thus it is imperative to incorporate the statistical effect of sub-grid scale physical processes on the values of the variables at the grids.

- The process by which the statistical effects of sub-grid scale physical processes on the grid scale variables are being incorporated in a NWP model is known as parameterization of physical process.
- As such, all physical processes, responsible for the changes in the 7 basic Meteorological variables, viz., u, v, w, p, T, ρ & q at any point must be correctly translated mathematically, followed by correct representations in the governing equations.

PBL parameterization

- PBL is the lower most part of the atmosphere, extending up to a few cms to a few kms from MSL, is characterized by turbulent/eddy motion.
- These eddies are capable of transporting different physical properties from one point to other in space, thereby influencing the grid scale budgets of the physical properties. It is known as eddy or turbulent flux.
- Although eddy fluxes are taking place horizontally and vertically both, but vertical eddy fluxes are very much stronger as compared to horizontal.
- In PBL these vertical eddy fluxes are parameterized, using many schemes, viz., flux gradient, bulk-aerodynamic, etc., as and where applicable.

Convection parameterization

- convection is a key component of the hydrological cycle. It's a key process in regulating the water vapor in the atmosphere, which provides the largest feedback for climate change.
- Precipitation from deep convection is also associated with strong & damaging wind, hails, tornadoes, lightning and flash floods.
- Thus without a reasonable representation of all types of moist convection in NWP models it is impossible to predict either the small or large scale atmospheric circulations correctly.
- In convection parametrization effects of latent heat release, transport of heat, moisture, momentum and the precipitation; produced by deep moist convection, are parameterized using Kuo, Arakawa-Schubert, Betts-Miller-Janjig, Klen-Fitch, etc. schemes.

Radiation parameterization

- Solar energy enters the atmosphere in the form of short wavelength (or *shortwave*) radiation.
- SWR during its travel interacts with land, water bodies, clouds and other atmospheric sources of water molecules, other air molecules and aerosol.
- These interactions can result in absorption and subsequent terrestrial reemission as *longwave radiation*.
- The relevant radiative transfer processes, viz., absorption, emission, transmission, and scattering are molecular-level processes much smaller than grid scale.
- Accordingly, above radiative transfer processes, resulting radiative flux and their impact upon the simulated atmosphere are parameterized in numerical models

Orographic drag parameterization

- When air flows across a mountain then pressure on the windward side is more than that on the leeward side. This pressure difference known as pressure drag or momentum flux.
- When a stably stratified airflow interacts with a small sized mountain then vertically propagating internal gravity waves are generated. These waves transports momentum vertical direction, causing a drag in the mean zonal flow.
- Similarly, based on the strength of mean flow, its stability and the height of the mountain; the air flows over or around an obstacle, which may lead to low level blocking of air on the windward side. It also causes drag.
- In orographic drag parameterization, above-mentioned drags are parameterized.

- When a mean flow interacts with an orographic barrier, then several phenomenon take place based on following factors:
  - Geometry of the barrier (a, b, H)
  - Brunt Vaisalla frequency of the mean flow $\left(N^2 = \frac{g}{\theta}\frac{\partial\theta}{\partial z}\right)$
  - Scorer parameter $\left(l^2 = \frac{N^2}{U^2} - \frac{1}{U}\frac{d^2U}{dz^2}\right)$
  - Inverse Froude Number$\left({F_r}^{-1} = \frac{NH}{U}\right)$ $F_r = \frac{U}{NH} \approx \frac{K}{P}$
  - Richardson number $\left(R_i = \frac{N^2}{\left(\frac{\partial U}{\partial z}\right)^2}\right)$

- Air easily flows over any obstacles to the flow for unstable $(N^2 < 0)$ or neutral $(N^2 = 0)$ stratification. However, for a moderately stable stratification this is not the case and in such case IGW can be produced.
- Inverse Froude number helps to determine whether or not the air flows over or around an obstacle.
  - $F_r \gg 1$, then air flows around the obstacle
  - $F_r \ll 1$, then air flows over the obstacle
  - $F_r \sim 1$, then both are possible

- When air flows across a mountain then pressure on the windward side is more than that on the leeward side.
- This pressure difference gives rise to an additional force in the horizontal momentum equation. This is known as pressure drag and also known as momentum flux and is denoted by $\rho_0 u' w'$.
- It's area averaged value $\overline{\overline{\rho_0 u' w'}}$ needs to be parameterized.

- When a stably stratified airflow interacts with a meso scale mountain then vertically propagating internal gravity waves are generated. These waves transports momentum vertical direction.
- Vertically transported momentum causes a drag in the mean zonal flow.
- Hence, if this is missed, then forecast of mean zonal wly is most likely to be overestimated.
- Thus it is essential to calculate such drag, produced by sub grid scale orography, at the surface and it's vertical distribution.
- It has two parts, viz., momentum flux associated with IGW and associated with low level blocking.

Thanks for kind patience hearing!