Numerical Weather Prediction (NWP)

Parameterization and physical processes:

Basic concepts of Planetary boundary layer, Land surface processes, Convection (Deep cumulus and shallow convection), Large scale condensation, Radiation (short wave and long wave parameterization), Cloud Radiation interaction, Dry and moist convective adjustment processes, Cloud microphysical parameterization

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Questions from the last class..

What is the criteria for RH for defining an air parcel as moist air?

Air can be considered a mixture of dry air and water vapor. If it contains water vapor it's called moist air, but the air's humidity can vary within broad limits. Extremes are completely dry air and air saturated with moisture.

KUO Type convection (1965, JAS, Vol. 22, 40-63)

- The effect on large scale motions of latent heat release by deep cumulus convection in a conditionally unstable atmosphere.
- It relates convective activity to total column moisture convergence, and come under deep-layer control scheme. It is a static scheme as it is not concerned with the details of convective processes and a moisture control scheme since it is closely tied to the available moisture.
- They have shown that deep cumulus convective motions bring the moist surface air directly to higher levels, the time changes of temperature and mixing ratio can be determined from the horizontal advection of humidity and the vertical temperature and humidity distributions.
- The derivation of the KUO scheme begins from the large scale equations in pressure co-ordinates (x,y,p) for the potential temperature and the water vapour mixing ratio

Deep layer control schemes relates the creation of CAPE by large scale processes to the development of convection. These schemes could be termed “supply side” approaches as it is assumed that convection consumes the CAPE that is created.

- In Kuo scheme, part of the moisture condenses, releasing latent heat and increasing rainfall. The rest is used to increase the relative humidity of the environment.

- Cloud dynamics and microphysics are not computed in Kuo Scheme, cloud types are not classified and the altitudes of cloud bases and tops can't be found.

Assumptions concerning deep cumulus clouds

Cumulus convection always occurs in region of deep layer of conditionally unstable atmosphere and mean low level convergence

Such convective motions bring surface air to all levels up to a great height so that inside the cloud the vertical distribution of temperature and mixing ratio are those of the moist adiabat through the appropriate condensation level.

The base of the cloud is at the condensation level of the surface air and the top extends to the level where the moist adiabat through the condensation level meets the environmental temperature profile, or somewhat higher.

The cumulus clouds exist only momentarily. They dissolve by mixing with the environmental-air at the same level, so that the heat and moisture carried up by the cloud air are imparted to the environmental air.

Kuo Scheme: Description, Models, & Trigger

Description: This is a simple scheme that produces precipitation and increases static stability by emulating the moist-adiabatic ascent of a parcel. It adjusts the temperature and moisture profiles toward moist adiabatic.

Convective Process:

Trigger: Convection is triggered by any amount of CAPE and column-integrated moisture convergence exceeding a threshold value.

Kuo Scheme: Convective Changes

Convective changes:

- Moves the temperature profile through the depth of cloud towards low-level moist adiabat. Some of the moisture moistens the environment while some falls instantly as rain.

- The amount of rain produced varies by model, even for the same conditions. That's because the parameter that divides the moisture supply into the part that moistens the environment and the part that falls as rain can vary from model to model.

Kuo Scheme: Link to Large-scale Forcing & Final State

- **Link to large-scale forcing**: The intensity and continuation of convective precipitation depend upon low-level moisture convergence because the scheme assumes that convection consumes moisture at the rate supplied by the large-scale wind and moisture fields.

- **Final state**: Approaches moist adiabatic temperature and sub-saturated moisture profiles, but does not reach them. That's because the scheme assumes that convection does not occupy the entire grid column, although it continues to moisten and approach moist adiabatic as convection persists.

Kuo Scheme: Strengths & Limitations

Strengths

- Essence and behaviour is easy to understand
- Runs quickly; does not require much computing resources

Limitations

- Simplistic scheme; cannot represent the variety of things that happen in nature
- Does not account for the strength of cap inhibiting convective development
- Positive feedback (including precipitation bull's-eyes) sometimes occurs because the model response to parameterized convective heating may generate moisture convergence, which triggers the scheme again. This behaviour stems from assuming that moisture convergence causes convection

Role of CP in Models

In nature, convection serves not only to produce precipitation, but also to transport heat upward, redistribute moisture, and thereby stabilize the atmosphere. If enough convection occurs over a large enough area, it can also create outflow jets and mid-level vortices and drive larger atmospheric circulations that affect weather in distant locations, etc. Additionally, through the formation of clouds, it influences the radiation budget (cloud-radiation interaction) on the Earth.

Sample question:

1. _____________ Scheme is a moisture adjustment scheme
2. Kuo assumed total rate of moisture accession as the sum of _________________ and ______________________________________. (Vertically intergrated moisture flux convergence and vertical flux of water vapor from surface)
3. Kuo assumed that (i) atmosphere should be conditionally unstable and (ii) presence of large scale moisture convergence.
4. Arakawa Schubert scheme is an instability control scheme.
5. Arakawa Schubert’s scheme can be categorized as mass flux scheme.
6. In Arakawa Schubert Scheme more the entrainment shallower will be the cloud depth.
7. In Arakawa Schubert Scheme, larger value of entrainment rate leads to shallower cloud.
8. Subgrid scale processes are parameterized.
9. Explain Kuo’s convective parameterization scheme
10. What is sub grid scale parameterization? Mention different important such processes.
11. How convection triggered in Kuo Scheme?

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