THE BASIC PRINCIPLES OF CONSERVATION IN ECOLOGY.

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Abstract: This article is devoted to the field of atmospheric physics and thermodynamics, with a focus on the hydrodynamic modeling of moist air and clouds. Specifically, it addresses:

Thermodynamics of phase transitions: Examining how evaporation and condensation impact the dynamics of moist air.

Hydrodynamics in the atmosphere: Deriving and analyzing conservation laws (mass, momentum, energy) for the vertical motion of air, including one-dimensional simplifications for thermal convection.

Applications to meteorology and climate science: Understanding the behavior of clouds and their role in atmospheric processes, which is critical for weather prediction and studying climate dynamics.

Integration of artificial intelligence: Mentioned as a tool for developing or enhancing the mathematical models.

This problem is central to ecological modeling because it bridges atmospheric physics with the understanding of natural systems. Improved models of cloud dynamics and phase transitions are critical for predicting ecological changes, managing natural resources, and addressing environmental challenges posed by climate change.

The cessation or significant reduction of rainfall in Central Asia over the last 20 years is a pressing ecological and environmental issue. Investigating the causes and ecological factors influencing this phenomenon is crucial for understanding its impacts and developing mitigation strategies

Increasing temperatures might disturb atmospheric circulation patterns, limiting the flow of moist air to Central Asia, while changes in the hydrological cycle could lead to reduced evaporation and precipitation rates.

In atmospheric processes, particularly for moist air, thermal convection primarily occurs in the vertical direction, which allows for the simplification of the equations by considering them in a one-dimensional framework along the vertical axis **z**. The following are the simplified one-dimensional forms of the conservation equations, accounting for phase transitions and the second law of thermodynamics.

In one-dimensional form, the continuity equation is written as:

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho v_z)}{\partial z} = 0,$$

here ρ — The moist air density, v_z) — The vertical component of velocity.

For the vertical component of velocity, the equation of motion is as follows:

$$\frac{\partial v_z}{\partial t} + v_z \frac{\partial v_z}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial z} + g + F_{\text{external}},$$

here p — the pressure of moist air, g — the acceleration due to gravity, $F_{external}$\(F_{\text — external forces, for example, a

Korriolis forces.
In one-dimensional form, the energy equation for moist air, taking into account phase transitions, is written as follows:

$$\frac{\partial(\rho e)}{\partial t}+\frac{\partial(\rho e v_z)}{\partial z}=-p\frac{\partial v_z}{\partial z}+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+L_v\frac{\partial m_v}{\partial t},$$

here e — internal energy per unit mass, k — latent heat per unit mass, T — temperature, L_v — latent heat of phase transition., m_v — mass of water vapor.
The state equation for moist air in one-dimensional form remains unchanged:

$$p=\rho R_d T+\rho_v R_v T,$$

here R_d — The gas constant per unit mass for dry air, R_v — The gas constant per unit mass for water vapor, ρ_v — density of water vapor.
The equation for the mass of water vapor , taking into account phase transitions, in one-dimensional form is written as:

$$\frac{\partial m_v}{\partial t}+\frac{\partial(m_v v_z)}{\partial z}=E-C,$$

here E — evaporation rate, C — condensation rate. An expression for E and C:

$$E=\alpha(e_s-e_a),\quad C=\beta(e_a-e_s),$$

here e_s — Saturation vapor pressure, e_a — partial pressure of water vapor.
The entropy conservation equation , taking into account phase transitions and irreversible processes, in one-dimensional form is as follows:

$$\frac{\partial(\rho s)}{\partial t}+\frac{\partial(\rho s v_z)}{\partial z}=\frac{1}{T}\left(\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+L_v\frac{\partial m_v}{\partial t}+\dot{q}_{\text{ирр}}\right),$$

These equations fully describe the behavior of moist air, taking into account phase transitions, thermal effects, and changes in the mass of water vapor.
For the one-dimensional case, let's write the system of differential equations describing the evaporation and condensation of moist air. In this case, we will consider only the vertical direction .
The rates of evaporation E and condensation C depend on thermodynamic parameters such as temperature, pressure, humidity, and the properties of the medium where phase transitions occur. Let us examine how these rates are related to other thermodynamic quantities
The evaporation rate E characterizes the amount of water vapor formed per unit time as a result of the evaporation of water or the liquid phase. It depends on factors such as the surface temperature of the water, the partial pressure of water vapor in the surrounding air, wind speed, and other variables.
Temperature T: Evaporation increases with temperature, as raising the temperature increases the kinetic energy of the liquid molecules, leading to a higher number of molecules leaving the liquid phase.
Partial pressure of water vapor e_a The lower the partial pressure of water vapor in the surrounding air e_a The evaporation rate E characterizes the amount of water vapor formed per unit time as a result of the evaporation of water or the liquid phase. It depends on factors such as

the surface temperature of the water, the partial pressure of water vapor in the surrounding air, wind speed, and other variables.

Saturation vapor pressure e_s(T) is the vapor pressure at which water vapor is in equilibrium with liquid water at a given temperature T. The evaporation rate depends on the difference between the saturation vapor pressure and the partial pressure of water vapor.

$$E = \alpha(e_s(T) - e_a),$$

here α — the evaporation coefficient, which depends on environmental conditions (e.g., wind, turbulence, etc.)The condensation rate \(C \) is the amount of water vapor condensing into the liquid phase per unit time. Condensation occurs when the partial pressure of water vapor in the air exceeds the saturation vapor pressure at a given temperature, i.e., when the air is supersaturated.

Temperature T: As the temperature decreases, the saturation vapor pressure e_s(T) decreases. If the partial pressure of water vapor ,e_a remains constant or decreases more slowly, this can lead to condensation.

$$C = \beta(e_a - e_s(T)),$$

Here β — the condensation coefficient, which also depends on environmental conditions.

Relationship with other thermodynamic parameters.The rates of evaporation and condensation also depend on the following parameters:

Air humidity (r): Air humidity affects the partial pressure of water vapor \(e_a\). More humid air (higher \(e_a \) slows down evaporation and accelerates condensation.

Temperature gradient: The temperature gradient (the difference between the water surface temperature and the surrounding air temperature) plays a critical role in heat exchange processes, which in turn influences the rates of evaporation and condensation.

Wind speed: Wind facilitates the transport of water vapor, reducing the vapor concentration above the water surface, thereby increasing evaporation. At the same time, strong wind can accelerate condensation by carrying vapor to colder regions.

Thermal conductivity of the medium (k): Evaporation and condensation also depend on the transfer of heat between the liquid and the air. The thermal conductivity of the medium affects the rate of heat exchange, influencing the intensity of phase transitions.

These processes can be summarized as follows: Evaporation occurs when the partial pressure of water vapor in the air is less than the saturation vapor pressure at the given water surface temperature.Condensation occurs when the partial pressure of water vapor exceeds the saturation vapor pressure, leading to the supersaturation of air with water vapor.

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