

Introduction

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Introduction

- Average vertical temperature profile $T(t, z)$ of atmosphere.

- Average vertical temperature profile $T(t, z)$ of atmosphere.

1. The analysed quantity is the atmospheric temperature profile averaged over all latitudes and longitudes.

Introduction

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Introduction

- Average vertical temperature profile $T(t, z)$ of atmosphere.
- Radiative Transfer Equation (RTE).

- Average vertical temperature profile $T(t, z)$ of atmosphere.
- Radiative Transfer Equation (RTE).

1. The analysed quantity is the atmospheric temperature profile averaged over all latitudes and longitudes.
2. RTE describes radiative processes.

Introduction

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Introduction

- Average vertical temperature profile $T(t, z)$ of atmosphere.
- Radiative Transfer Equation (RTE).
- Fluid dynamics equations.

- Average vertical temperature profile $T(t, z)$ of atmosphere.
- Radiative Transfer Equation (RTE).
- Fluid dynamics equations.

1. The analysed quantity is the atmospheric temperature profile averaged over all latitudes and longitudes.
2. RTE describes radiative processes.
3. Fluid dynamics equations describe convective processes.

Hypotheses

- Thermodynamic energy equation in Local Thermodynamic Equilibrium (LTE):

$$\frac{\partial T}{\partial t} = -\frac{1}{\rho c_P} \frac{\partial q}{\partial z} \quad . \quad (1)$$

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Hypotheses

- Thermodynamic energy equation in Local Thermodynamic Equilibrium (LTE):

$$\frac{\partial T}{\partial t} = -\frac{1}{\rho c_P} \frac{\partial q}{\partial z} \quad . \quad (1)$$

Hypotheses

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Hypotheses

- Thermodynamic energy equation in Local Thermodynamic Equilibrium (LTE):

$$\frac{\partial T}{\partial t} = -\frac{1}{\rho c_P} \frac{\partial q}{\partial z} \quad . \quad (1)$$

- Radiative-convective equilibrium.

- Thermodynamic energy equation in Local Thermodynamic Equilibrium (LTE):

$$\frac{\partial T}{\partial t} = -\frac{1}{\rho c_P} \frac{\partial q}{\partial z} \quad . \quad (1)$$

- Radiative-convective equilibrium.

Hypotheses

- Thermodynamic energy equation in Local Thermodynamic Equilibrium (LTE):

$$\frac{\partial T}{\partial t} = -\frac{1}{\rho c_P} \frac{\partial q}{\partial z} \quad . \quad (1)$$

- Radiative-convective equilibrium.
- Grey atmosphere.

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Hypotheses

1. Quantities do not depend on the frequency of electromagnetic radiation.

- Thermodynamic energy equation in Local Thermodynamic Equilibrium (LTE):

$$\frac{\partial T}{\partial t} = -\frac{1}{\rho c_P} \frac{\partial q}{\partial z} \quad . \quad (1)$$

- Radiative-convective equilibrium.
- Grey atmosphere.

Additional hypotheses

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Additional hypotheses

- Hypotheses on the planet.

- Hypotheses on the planet.

1. Diurnal cycle, constant irradiance, constant Bond albedo, blackbody surface, constant gravitational acceleration.

Additional hypotheses

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Additional hypotheses

- Hypotheses on the planet.
- Hypotheses on the atmosphere composition.

- Hypotheses on the planet.
- Hypotheses on the atmosphere composition.

1. Diurnal cycle, constant irradiance, constant Bond albedo, blackbody surface, constant gravitational acceleration.
2. Hydrostatic equilibrium, constant specific heat at constant pressure, scattering is neglected, absorption coefficient depends only on altitude, constant mass attenuation coefficient, ideal gas.

Additional hypotheses

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Additional hypotheses

- Hypotheses on the planet.
- Hypotheses on the atmosphere composition.
- Hypotheses on total heat flux.

- Hypotheses on the planet.
- Hypotheses on the atmosphere composition.
- Hypotheses on total heat flux.

1. Diurnal cycle, constant irradiance, constant Bond albedo, blackbody surface, constant gravitational acceleration.
2. Hydrostatic equilibrium, constant specific heat at constant pressure, scattering is neglected, absorption coefficient depends only on altitude, constant mass attenuation coefficient, ideal gas.
3. Heat flux determined only by radiative and convective processes, two-stream approximation, numerical correction for convection.

$$P(z) = P_k \exp\left(-\frac{z - z_k}{z_0}\right) \quad (2)$$

- Relation between pressure and altitude:

$$P(z) = P_g \exp\left(-\frac{z - z_g}{z_0}\right) \quad . \quad (2)$$

$$\delta(P) = \frac{P_{\text{ref}}}{g}(P - P_{\text{TDA}}) \quad (3)$$

Vertical coordinates

- Relation between pressure and altitude:

$$P(z) = P_g \exp\left(-\frac{z - z_g}{z_0}\right) . \quad (2)$$

- Relation between optical depth and pressure:

$$\delta(P) = \frac{\mu_m}{g}(P - P_{\text{TOA}}) . \quad (3)$$

- Relation between optical depth and altitude:

$$\delta(z) = \frac{\mu_m}{g}\left(P_g \exp\left(-\frac{z - z_g}{z_0}\right) - P_{\text{TOA}}\right) . \quad (4)$$

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Introduction

└ Vertical coordinates

- Relation between pressure and altitude:

$$P(z) = P_g \exp\left(-\frac{z - z_g}{z_0}\right) . \quad (2)$$

- Relation between optical depth and pressure:

$$\delta(P) = \frac{\mu_m}{g}(P - P_{\text{TOA}}) . \quad (3)$$

- Relation between optical depth and altitude:

$$\delta(z) = \frac{\mu_m}{g}\left(P_g \exp\left(-\frac{z - z_g}{z_0}\right) - P_{\text{TOA}}\right) . \quad (4)$$

Analytical solution

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Radiative equilibrium

└ Analytical solution

Radiative-convective equilibrium in a grey atmosphere

Marco Casari

Introduction

Radiative equilibrium

Radiative-convective equilibrium

Conclusion

Numerical solution

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Radiative equilibrium

└ Numerical solution

Radiative-convective equilibrium in a grey atmosphere

Marco Casari

Introduction

Radiative equilibrium

Radiative-convective equilibrium

Conclusion

Radiative-convective equilibrium

Radiative-convective equilibrium in a grey atmosphere

Marco Casari

Introduction

Radiative equilibrium

Radiative-convective equilibrium

Conclusion

2023-10-02

Radiative-convective equilibrium in a grey atmosphere

└ Radiative-convective equilibrium

└ Radiative-convective equilibrium

