

Introduction to Environmental Physics

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Key concepts, fundamental principles, and typical applications

1. What Is Environmental Physics?

Aspect	Description
Definition	The branch of physics that studies physical processes governing the natural environment and their interaction with human activities.
Scope	Atmosphere, hydrosphere, lithosphere, biosphere, and the interfaces among them.
Goal	Quantify, model, and predict environmental behavior to support sustainable management, risk assessment, and policy-making.
Interdisciplinary Links	Meteorology, climatology, oceanography, geophysics, ecology, engineering, and environmental chemistry.

2. Fundamental Physical Quantities

Quantity	Symbol	SI Unit	Typical Environmental Example
Temperature	(T)	Kelvin (K)	Sea-surface temperature, air temperature profiles
Pressure	(p)	Pascal (Pa)	Atmospheric pressure, hydrostatic pressure in lakes
Density	(ρ)	$\text{kg}\cdot\text{m}^{-3}$	Air density, water density, soil bulk density
Energy	(E)	Joule (J)	Solar irradiance, heat content of oceans
Flux (heat, mass, momentum)	(F)	$\text{W}\cdot\text{m}^{-2}$, $\text{kg}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$	Sensible heat flux, evapotranspiration rate
Radiative intensity	(I)	$\text{W}\cdot\text{m}^{-2}\cdot\text{sr}^{-1}$	Solar spectral irradiance

3. Core Physical Processes

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3.1 Energy Balance

$$[\underbrace{S_{\downarrow}}_{\text{incoming solar}} + \underbrace{L_{\downarrow}}_{\text{downward longwave}} = \underbrace{L_{\uparrow}}_{\text{upward longwave}} + \underbrace{H}_{\text{sensible heat}} + \underbrace{E}_{\text{latent heat}} + \underbrace{G}_{\text{ground heat flux}}]$$

- **Solar radiation (($S_{\downarrow}$))** – primary energy source, varies with latitude, season, and atmospheric composition.
- **Longwave radiation ((L))** – emitted by Earth's surface and atmosphere; controlled by temperature and greenhouse gases.
- **Sensible heat ((H))** – heat transferred by conduction and convection.
- **Latent heat ((E))** – energy absorbed/released during phase changes of water (evaporation, condensation).
- **Ground heat flux ((G))** – conduction into/out of the soil or ocean mixed layer.

3.2 Fluid Dynamics (Atmosphere & Ocean)

- **Continuity equation** (mass conservation): $[\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0]$
- **Navier–Stokes equations** (momentum): $[\rho \left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right) = -\nabla p + \rho \mathbf{g} + \mu \nabla^2 \mathbf{v}]$
- **Thermodynamic energy equation** (first law): $[\rho c_p \left(\frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T \right) = \dots]$