Analysis of temperature distribution in a naturally ventilated single-span greenhouse using computational fluid dynamics

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SUPPLEMENTARY MATERIAL

The airflow pattern in the greenhouse is governed by three equations according to modern fluid dynamics: conservation of mass equation, conservation of momentum equation, and conservation of energy equation.

The continuity equation describes mass conservation within a control volume due to variations in density over time.

$$\frac{\partial \rho}{\partial t} + \nabla \, . \, (\rho v) = 0 \tag{1}$$

where ρ is the density (kg/m^3) of the fluid, t is the time (s), v is the velocity vector (m/s), and $\nabla .$ denotes the divergence operator.

The energy conservation equation corresponds to the spatial distribution of thermal energy within the computational unit, resulting in changes in its enthalpy due to convection, conduction, and heat sources.

$$\rho\left(\frac{\partial v}{\partial t} + v \, . \nabla v\right) = -\nabla p + \nabla \, . \, \tau + \rho g \tag{2}$$

where p is the pressure (N/m^2), τ is the stress tensor (Pa), and g is the gravitational acceleration vector (m/s^2), and ρg therefore represents the body force per unit volume (N/m^3). All other symbols have units given above.

The energy conservation equation corresponds to the spatial distribution of the resultant forces on the computational unit, which leads to changes in its energy.

$$\rho\left(\frac{\partial h}{\partial t} + v \, . \nabla h\right) = \nabla \, . (\kappa \nabla \mathrm{T}) + \sigma + \Phi + S_h \tag{3}$$

where h is the specific enthalpy (J/kg), , T is the temperature (K), κ is the thermal conductivity (W/m/K), σ is the radiative (or volumetric) heat source term (W/m^3), Φ is the viscous dissipation term (W/m^3), and S_h represents any volumetric heat generation (W/m^3).