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Simulation and Validation of Pan Evaporation Using COMSOL Multiphysics®

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Class A Evaporation Pan

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Interested Communities

- Water Resource Managers – Hydrologists
- Soil Scientists
- Agronomists
- Meteorologists

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Common Equations

- Penman $\mathrm{E[mm/d]} = 0.35(1 + 0.24u)(es - ea)$
- Thornwaite $\mathrm{E[cm/mo]} = 1.6\left(\frac{10T}{I}\right)a$
- Romaneko $\mathrm{E[mm/mo]} = 0.0018(25 + T)^2(10 - hn)$
- Turc $\mathrm{E[mm/d]} = 0.013\big(\mathrm{T}/(15 + T)\big)(R + 50)$
- Others

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Table 1. Selected Equations Developed for Calculation of Potential Evapotranspiration (PET) or Evaporation

Method	Reference	Equation	Developed for
Brutsaert-Stricker,* cal cm^{-2} d^{-1}	*Brutsaert and Stricker* [1979]	$PET = (2\alpha - 1)(s/(s+\gamma))(Q_n - Q_x) - (\gamma/(s+\gamma))[0.26(1+0.86U_2) \cdot (e_0 - e_a)]$	PET, daily
DeBruin,* cal cm^{-2} d^{-1}	*DeBruin* [1978]	$PET = (\alpha/(\alpha - 1))1.141(\gamma/(s+\gamma)) \cdot [(3.6 + 2.5(U_3))(e_0 - e_a)]$	PET, for periods of 10 days or greater
DeBruin-Keijman,* cal cm^{-2} d^{-1}	*DeBruin and Keijman* [1979]	$PET = [SVP/(0.95SVP + 0.63\gamma)] \cdot (Q_n - Q_x)$	PET, daily
Hamon, cm d^{-1}	*Hamon* [1961]	$PET = [0.55(D/12)^2(SVD/100)]2.54$	PET, daily
Jensen-Haise, cm d^{-1}	*McGuinness and Bordne* [1972]	$PET = \{[((0.014T_a) - 0.50)(Q_s)]0.000673\}2.54$	PET for periods greater than 5 days (Nebraska)
Makkink, cm d^{-1}	*McGuinness and Bordne* [1972]	$PET = [0.61(s/(s+\gamma))(Q_s/L)] - 0.012$	PET, monthly (Holland)
Mass transfer, cm d^{-1}	*Harbeck et al.* [1958]	$E = NU_2(e_0 - e_a)$	Evaporation, depending on calibration of N
Papadakis, cm $month^{-1}$	*McGuinness and Bordne* [1972]	$PET = 0.5625[e_0\max - (e_0\min - 2)]$	PET, monthly
Penman,* cal cm^{-2} d^{-1}	*Jensen et al.* [1974]	$PET = (s/(s+\gamma))(Q_n - Q_x) + (\gamma/(s+\gamma))[(15.36(0.5 + 0.01U_2)) \cdot (e_0 - e_a)]$	PET, for periods greater than 10 days
Priestley-Taylor, cm d^{-1}	*Stewart and Rouse* [1976]	$PET = \alpha(s/(s+\gamma))[(Q_n - Q_x)/L]$	PET for periods of 10 days or greater
Stephens-Stewart, cm d^{-1}	*McGuinness and Bordne* [1972]	$PET = \{[(0.0082T_a) - 0.19] \cdot (Q_s/1500)\}2.54$	PET, monthly (Florida)

COMSOL Multiphysics Approach

$$\rho\frac{\partial \mathbf{u}}{\partial t} + \rho(\mathbf{u}\cdot\nabla)\mathbf{u} = \nabla\cdot[-p\mathbf{I} + \mu(\nabla\mathbf{u} + (\nabla\mathbf{u})^T)] + \mathbf{F}$$

$$\frac{\partial c_i}{\partial t} + \nabla\cdot(-D\nabla c_i) + \mathbf{u}\cdot\nabla c_i = R_i$$

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Parameters and Variables

- Air Temperature
- Diffusion Coefficient – Water Vapor in Air
- Saturated Air (moles/m^3)
- Absolute Humidity (moles/m^3)
- Wind Speed

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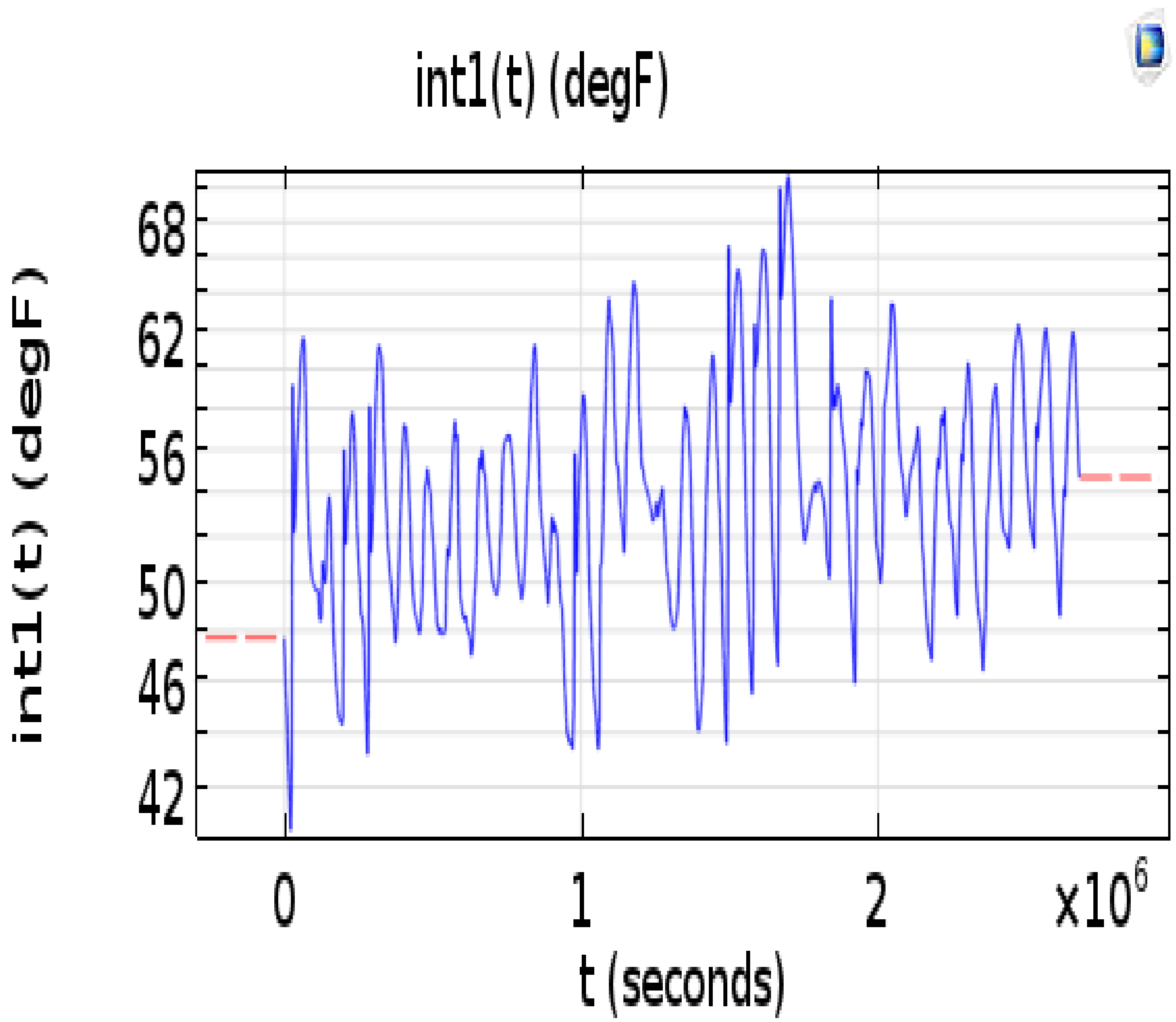
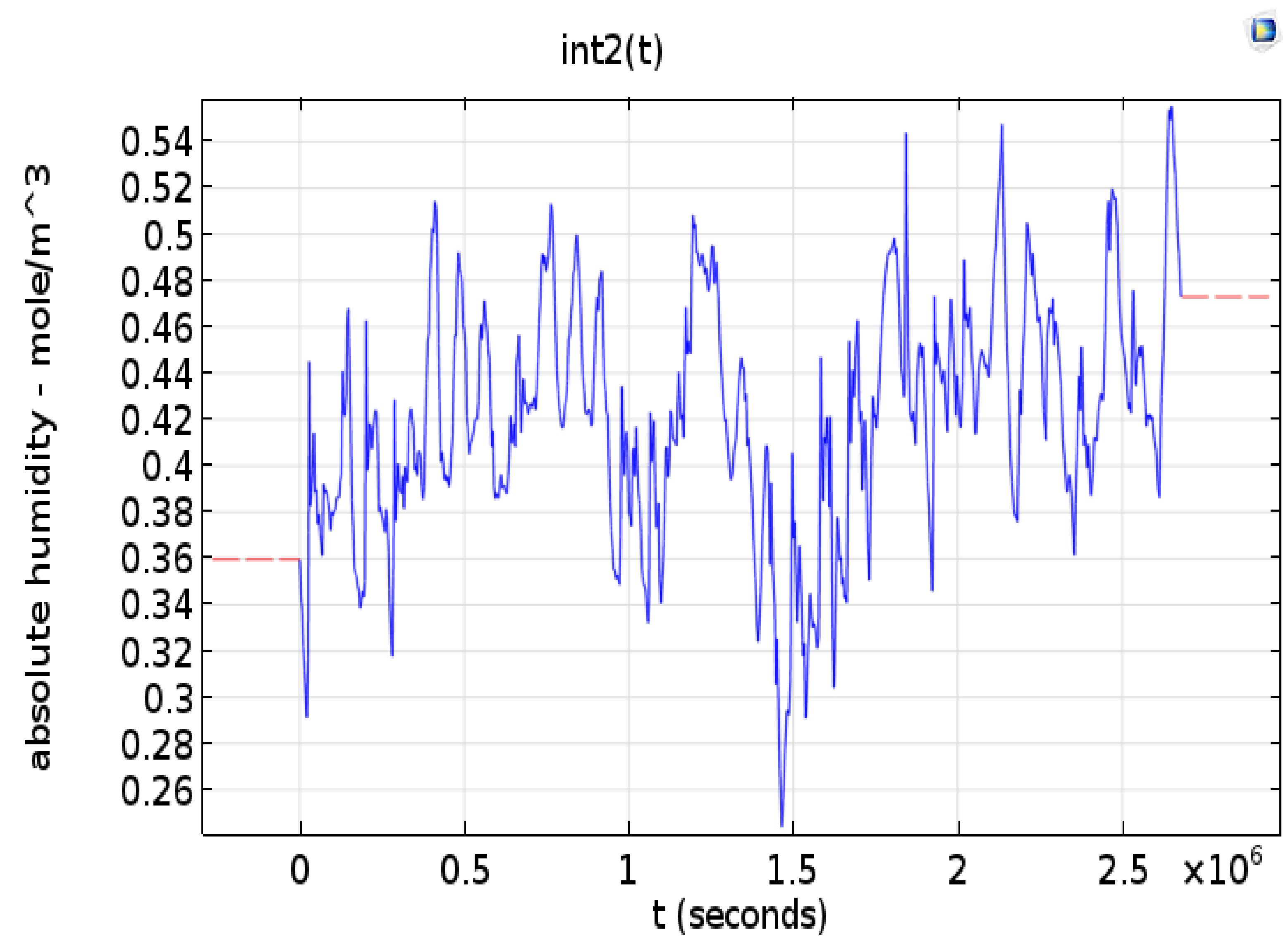
Ambient Air Temperature and Absolute Humidity Variations





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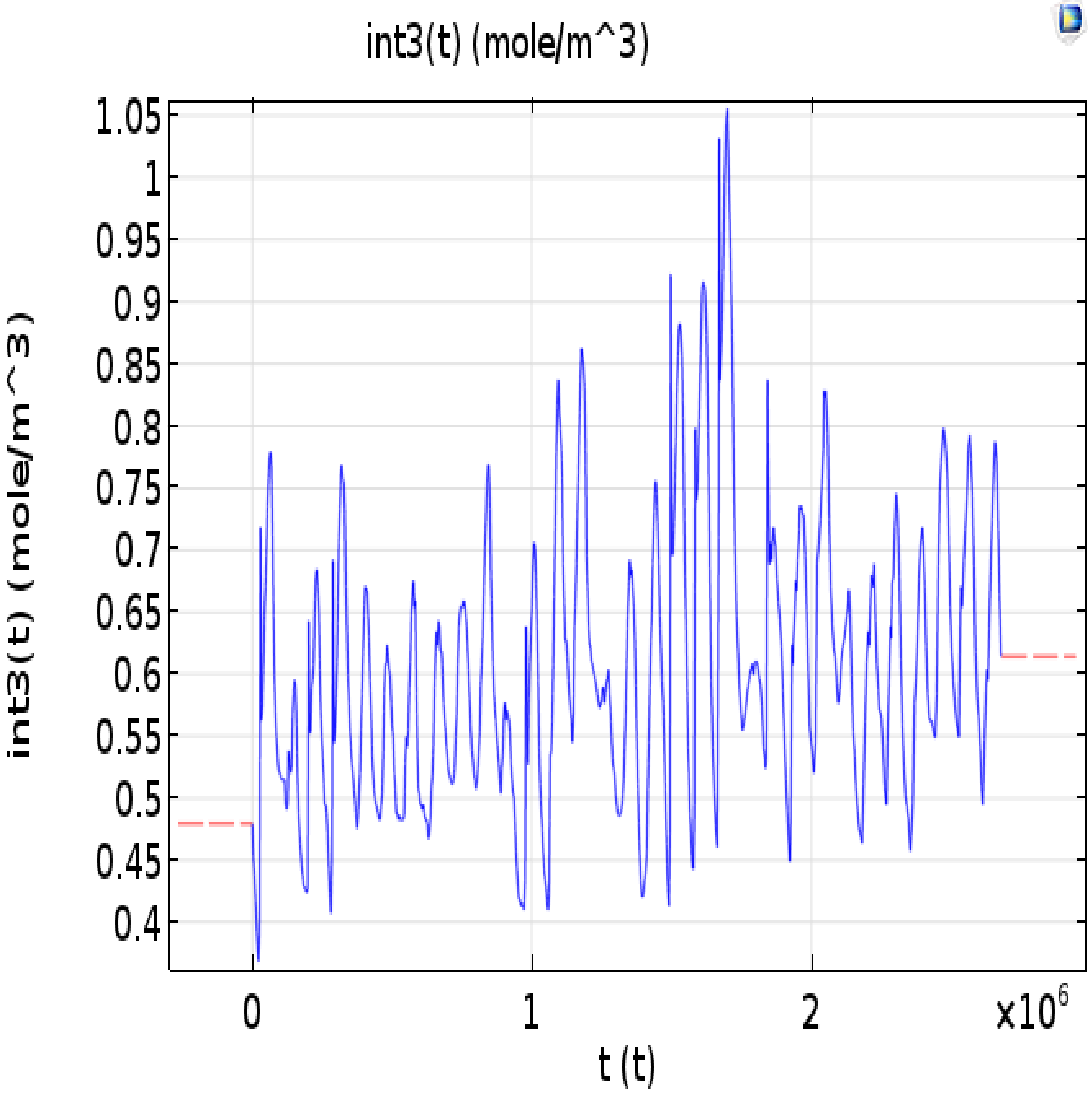
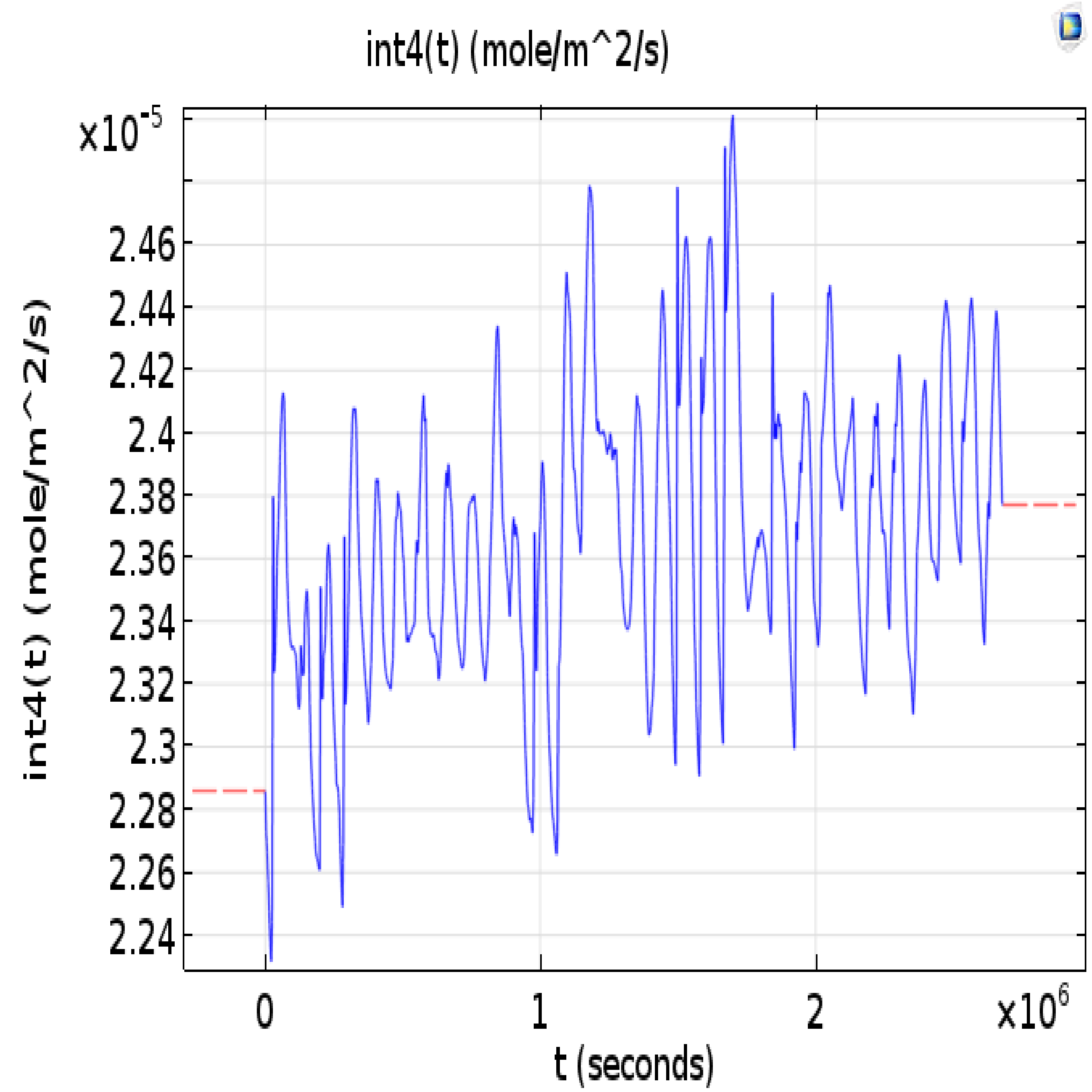
Saturated Air Absolute Humidity and Diffusion Coefficient





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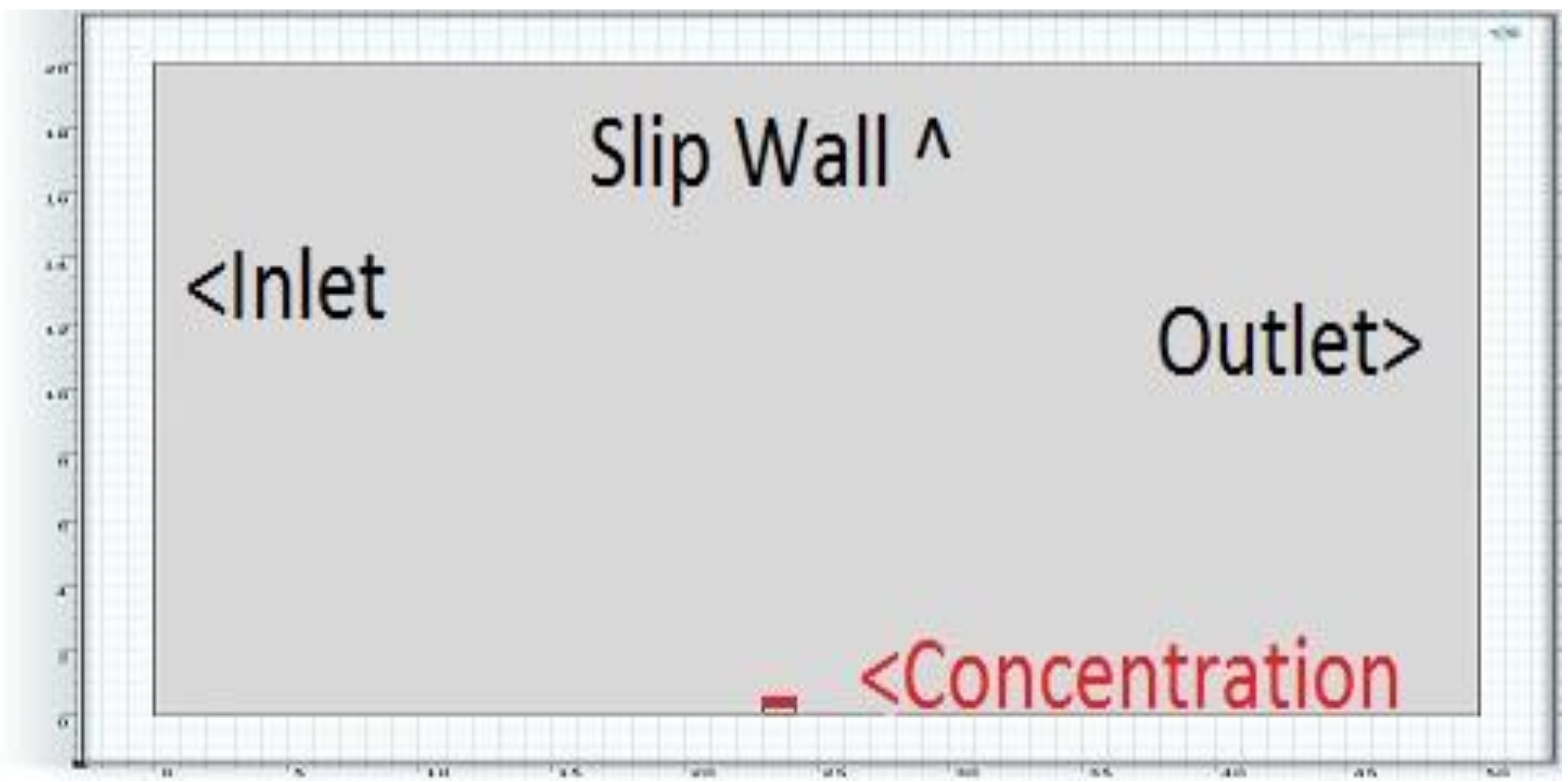
Model Geometry



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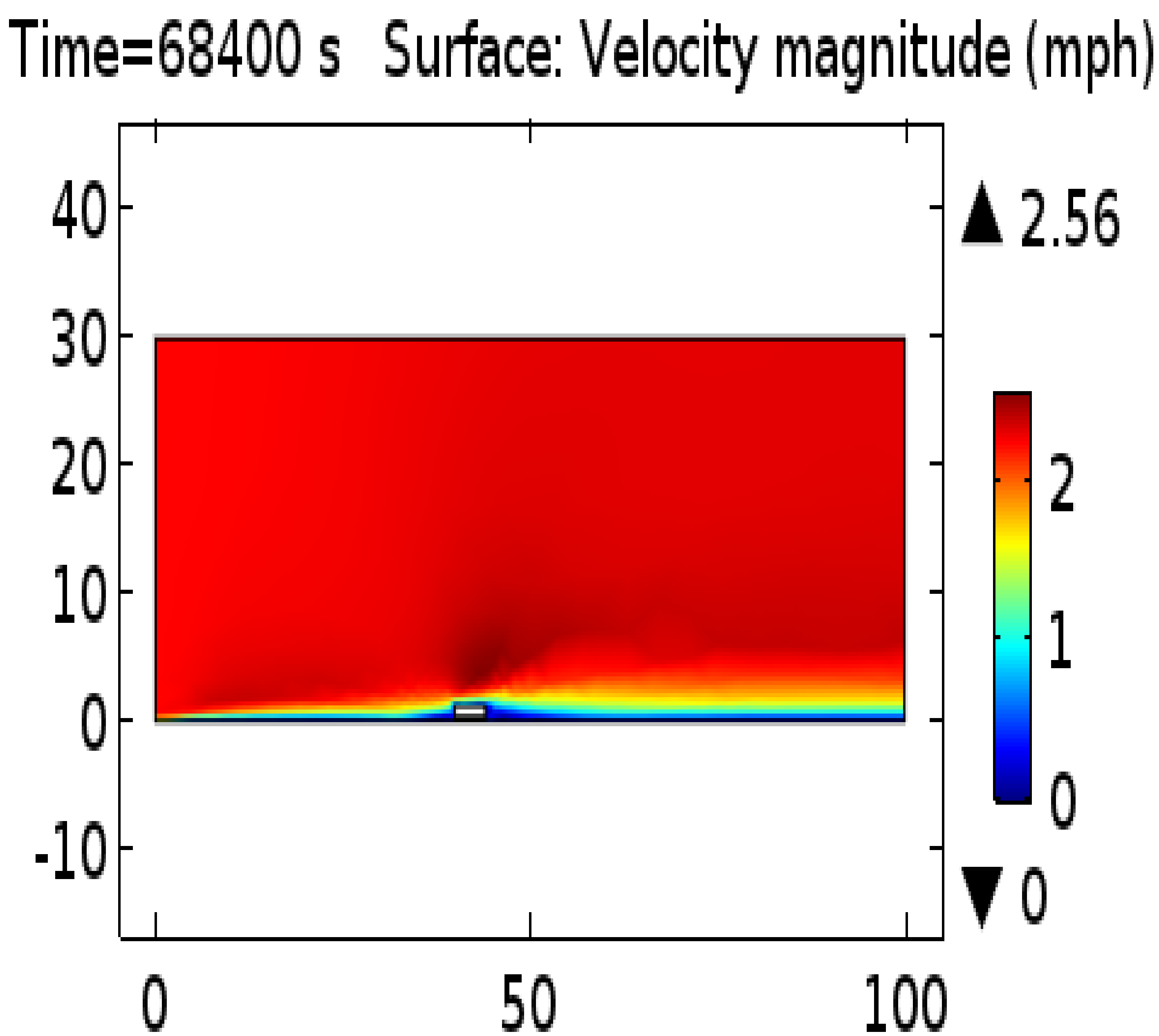
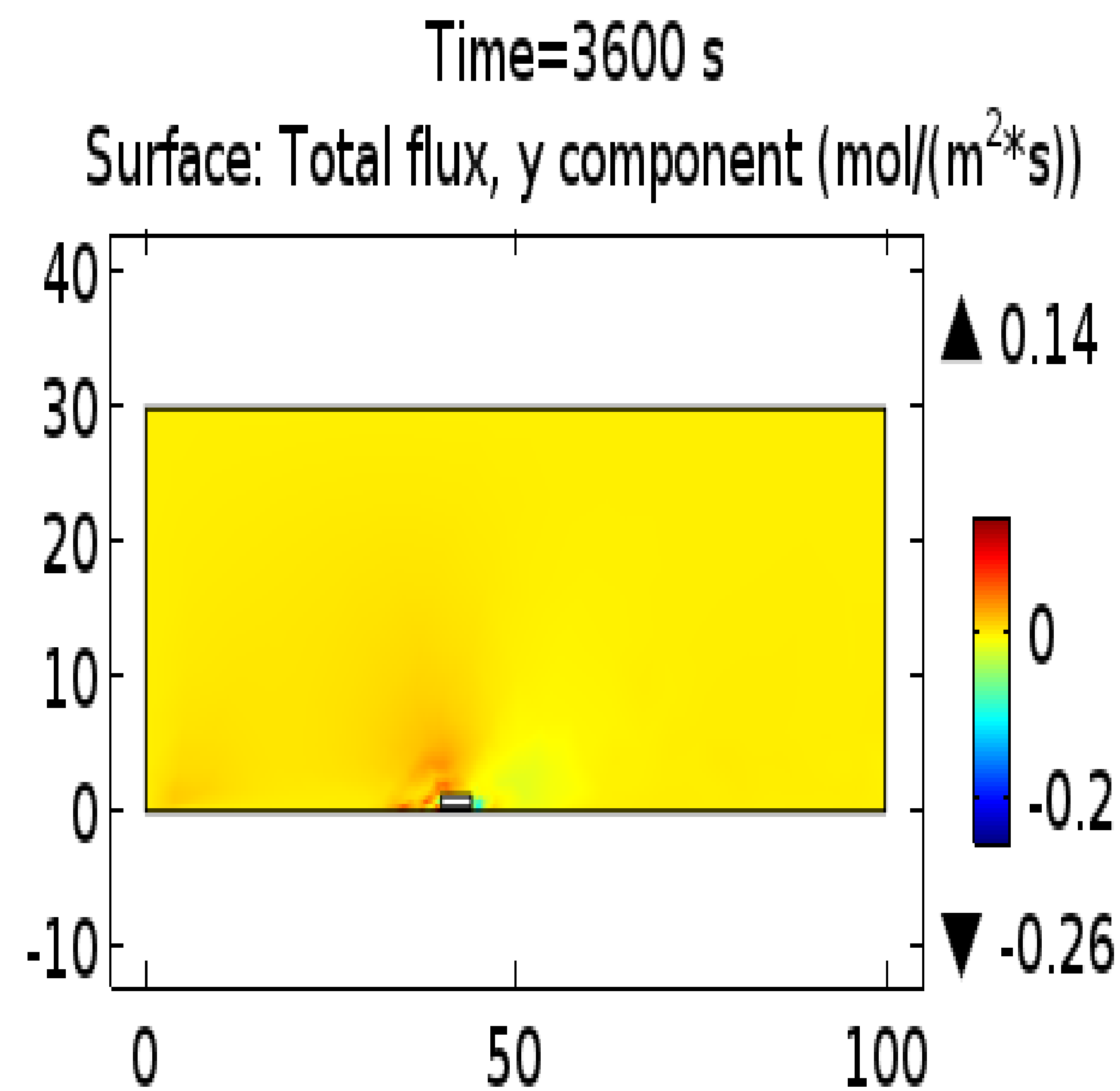
Simulation Results





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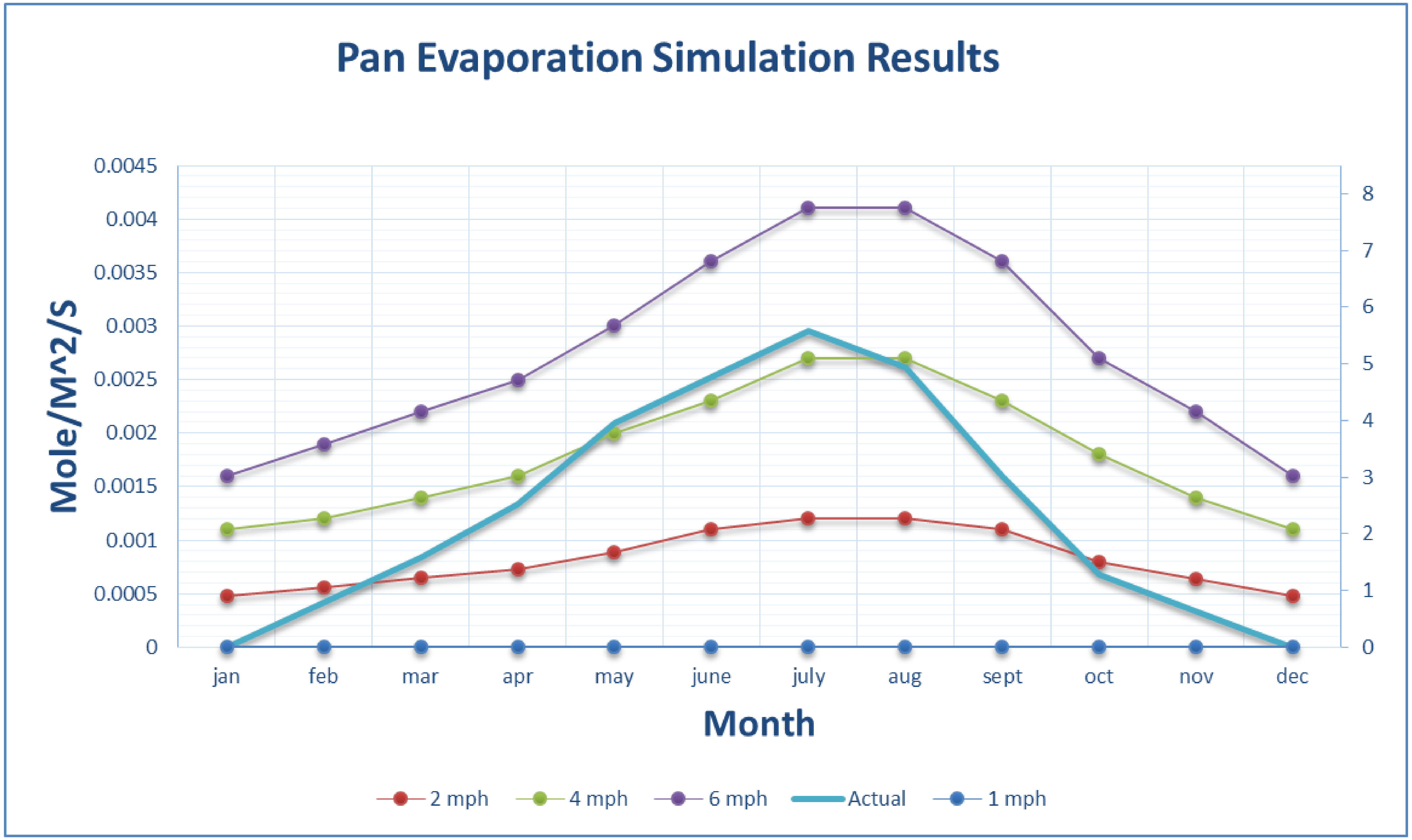
Validation Results



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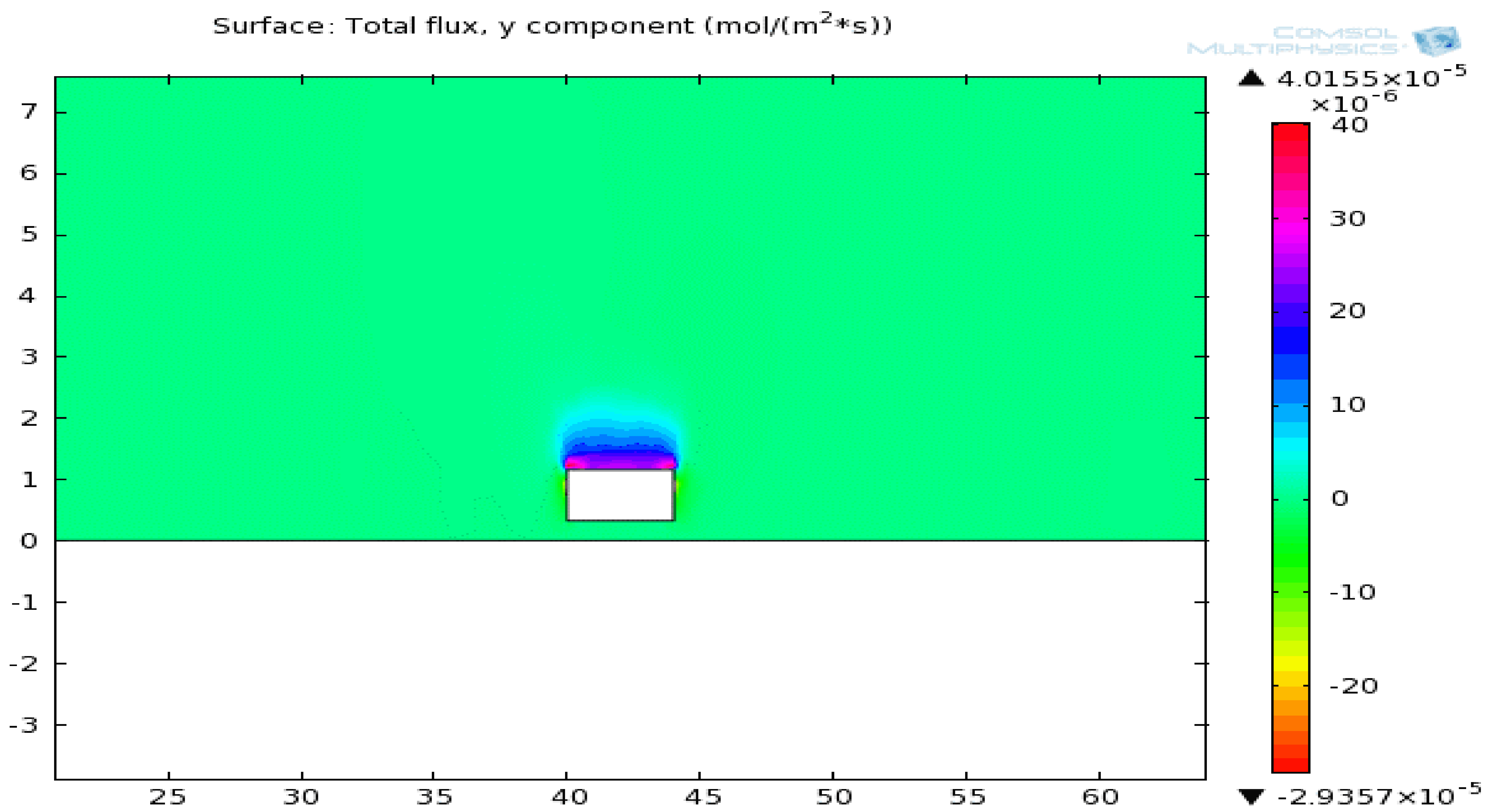
Summary



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Acknowledgements

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