Temperature Multi-stability

From non-linear radiation terms

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Key Points

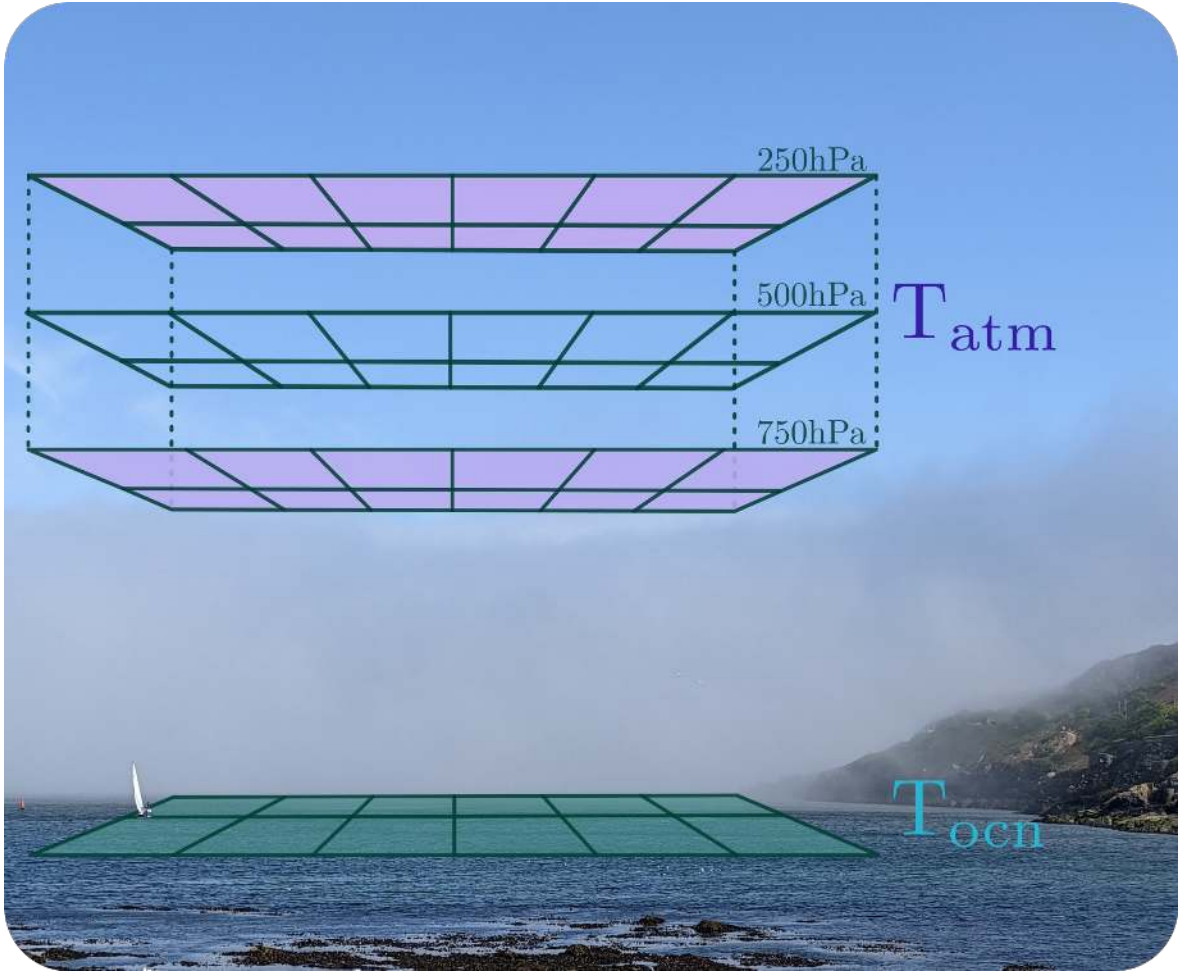
The Model

Modifications

Results

Key Points

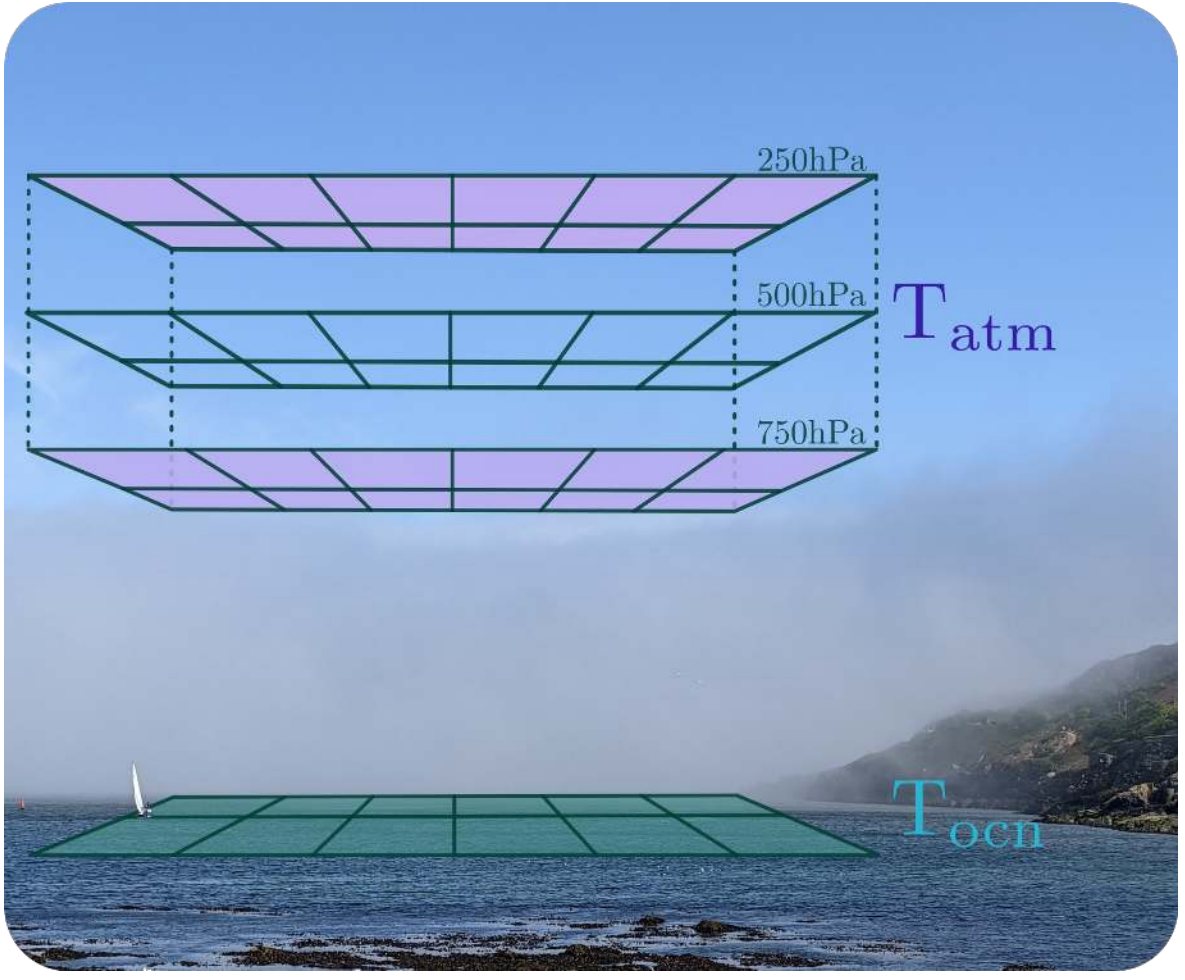
QGS Model



QGS Model

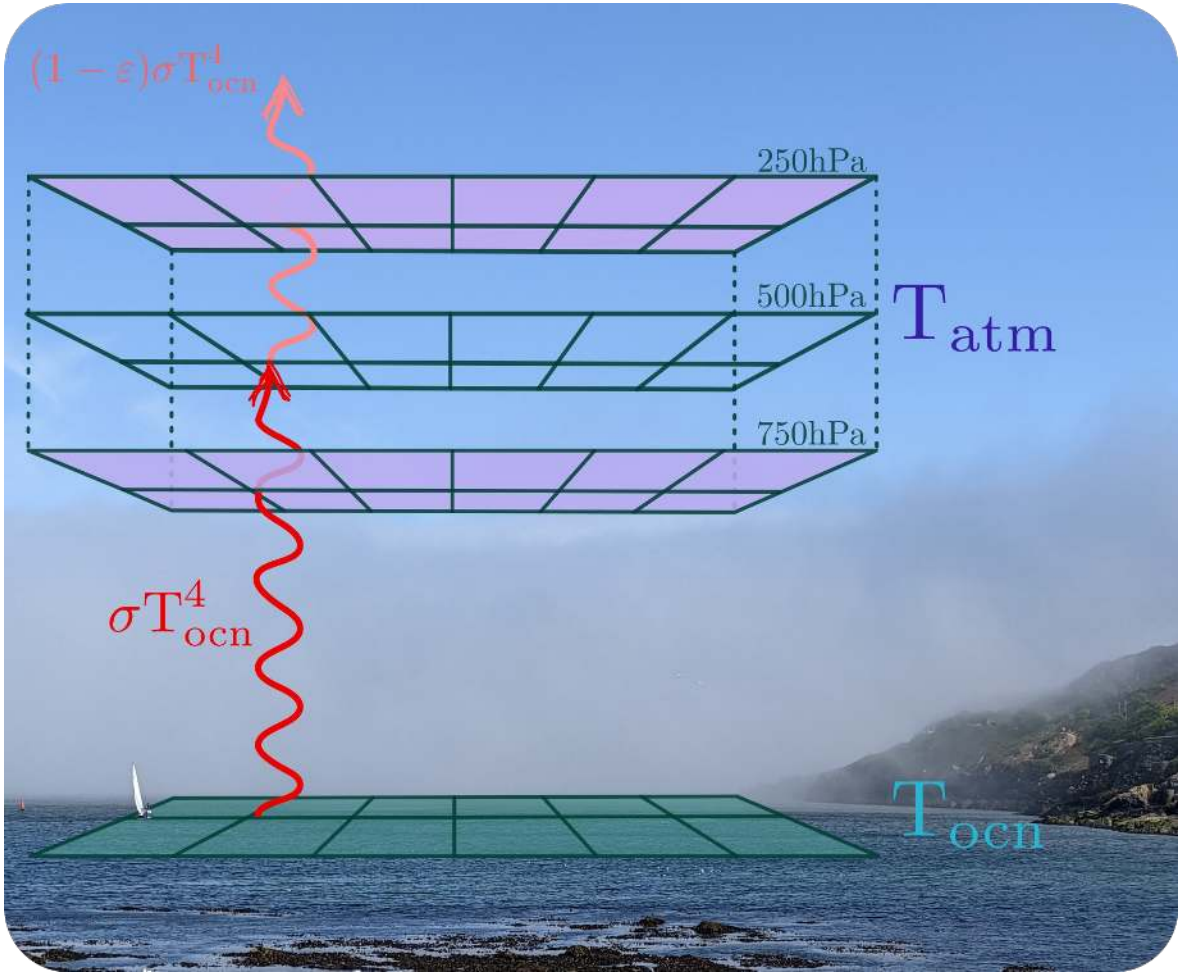
Stefan Boltzmann Law

QGS Model



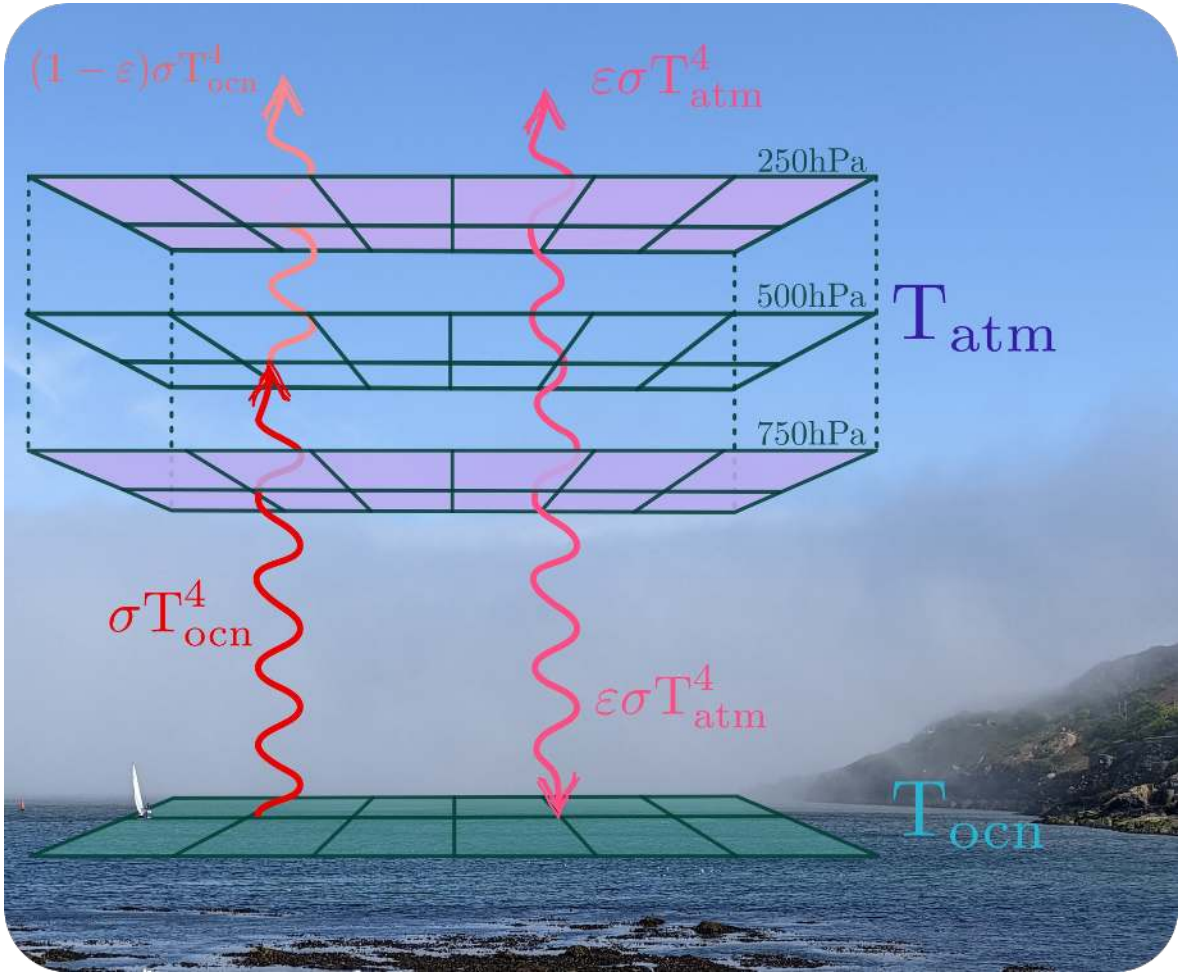
QGS Model

Radiation



QGS Model

Radiation



QGS Model

Temperature Equation

$$\gamma_o\left(\frac{\partial \mathrm{T}_o}{\partial t} + J(\psi_o, \mathrm{T}_o)\right) = -\lambda(\mathrm{T}_o - \mathrm{T}_\mathrm{a}) - \sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_\mathrm{a}^4 + R_o$$

QGS Model

Temperature Equation

$$\gamma_o\left(\frac{\partial \mathrm{T}_o}{\partial t} + J(\psi_o, \mathrm{T}_o)\right) = -\lambda(\mathrm{T}_o - \mathrm{T}_\mathrm{a}) - \sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_\mathrm{a}^4 + R_o$$

QGS Model

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QGS Model

Linearisation

$$-\sigma_B \mathrm{T}_o^4 + \varepsilon \sigma_B \mathrm{T}_\mathrm{a}^4$$

QGS Model

Linearisation

$$\mathrm{T}_o = \mathrm{T}_{o,0} + \delta\mathrm{T}_o(t,x,y)$$

$$-\sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_{\mathrm{a}}^4$$

QGS Model

Linearisation

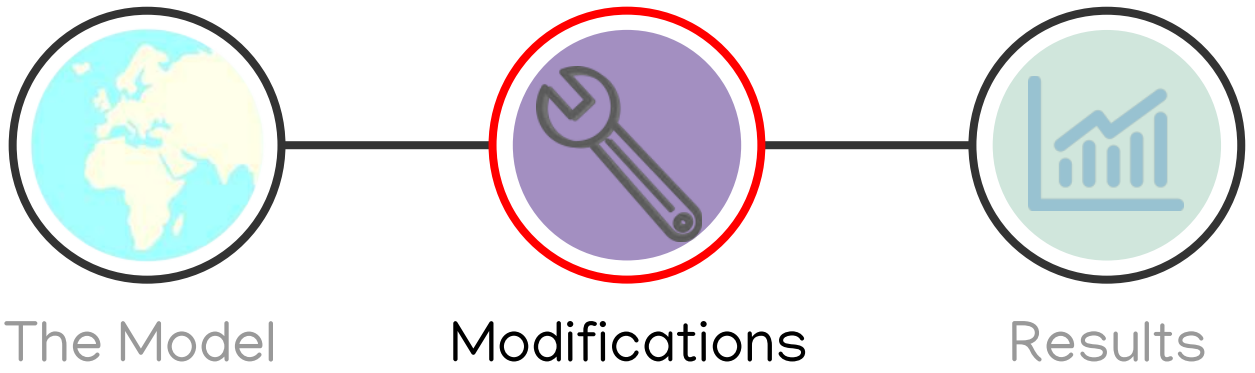
$$\mathrm{T}_o = \mathrm{T}_{o,0} + \delta\mathrm{T}_o(t,x,y)$$

$$-\sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_\mathrm{a}^4$$

$O(\delta\mathrm{T}_o)$

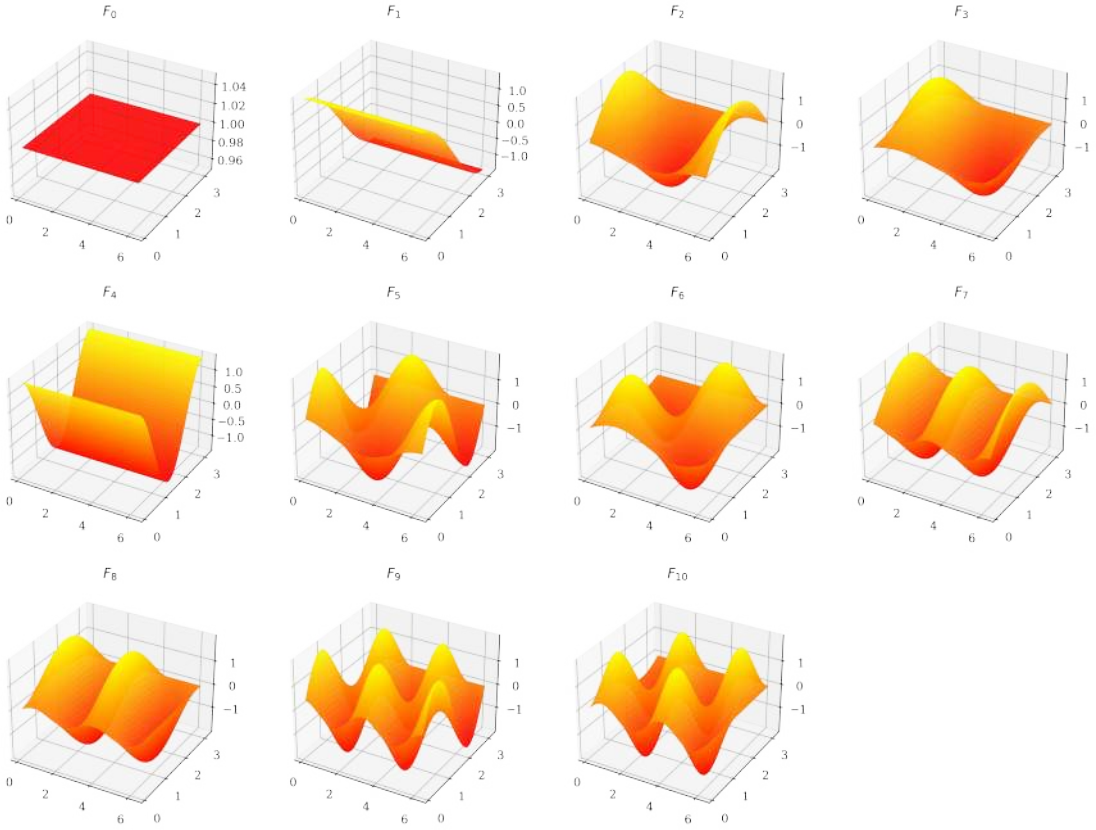
$$-4\sigma_B \mathrm{T}_{o,0}^3 \delta\mathrm{T}_o + 4\varepsilon\sigma_B \mathrm{T}_{\mathrm{a},0}^3 \delta\mathrm{T}_\mathrm{a}$$

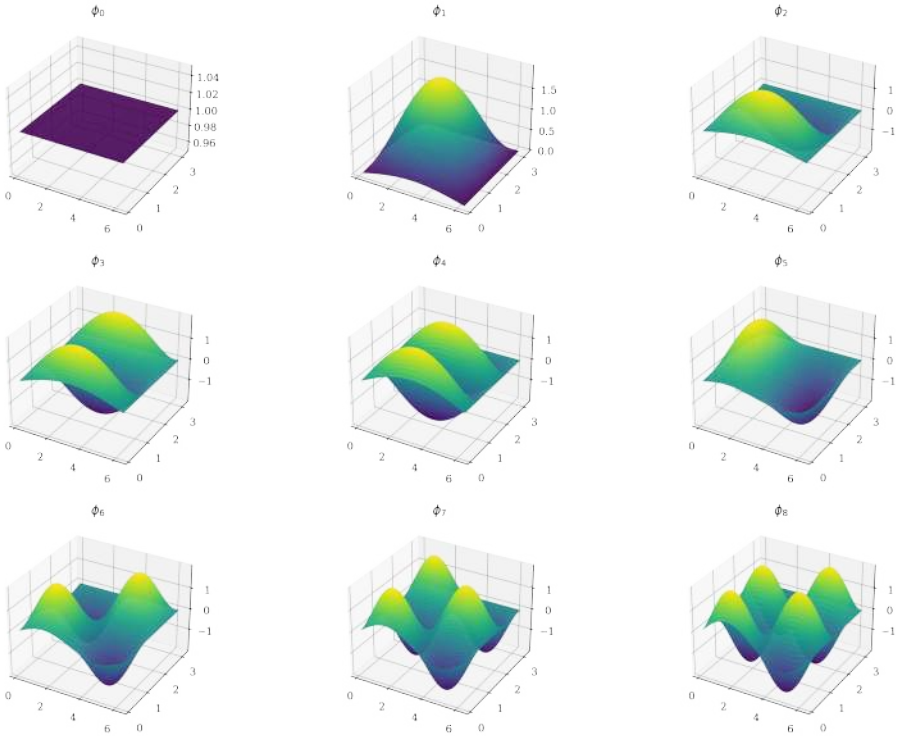
Key Points



Modifications

New Modes





Modifications

Dynamic Equilibrium

$$\mathrm{T}_o = \mathrm{T}_{o,0}(t) + \delta\mathrm{T}_o(t,x,y)$$

$$-\sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_{\mathrm{a}}^4$$

Modifications

Dynamic Equilibrium

$$\mathrm{T}_o = \mathrm{T}_{o,0}(t) + \delta\mathrm{T}_o(t,x,y)$$

$$-\sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_{\mathrm{a}}^4$$

$$O(\delta\mathrm{T}_o)$$

Modifications

Dynamic Equilibrium

$$\mathrm{T}_o = \boxed{\mathrm{T}_{o,0}(t)} + \delta\mathrm{T}_o(t,x,y)$$

$$-\sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_{\mathrm{a}}^4$$

$$O(\delta\mathrm{T}_o)$$

$$-\sigma_B \mathrm{T}_{o,0}^4 + \varepsilon\sigma_B \mathrm{T}_{\mathrm{a},0}^4 + f(\delta\mathrm{T}_o) + g(\delta\mathrm{T}_{\mathrm{a}})$$

Modifications

Non-Linear Equation

$$\mathrm{T}_o(t,x,y)$$

$$-\sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_{\mathrm{a}}^4$$

Modifications

Non-Linear Equation

$$\mathrm{T}_o(t,x,y)$$

$$-\sigma_B \mathrm{T}_o^4 + \varepsilon\sigma_B \mathrm{T}_{\mathrm{a}}^4$$

Problem:

5–6x run time

Modifications

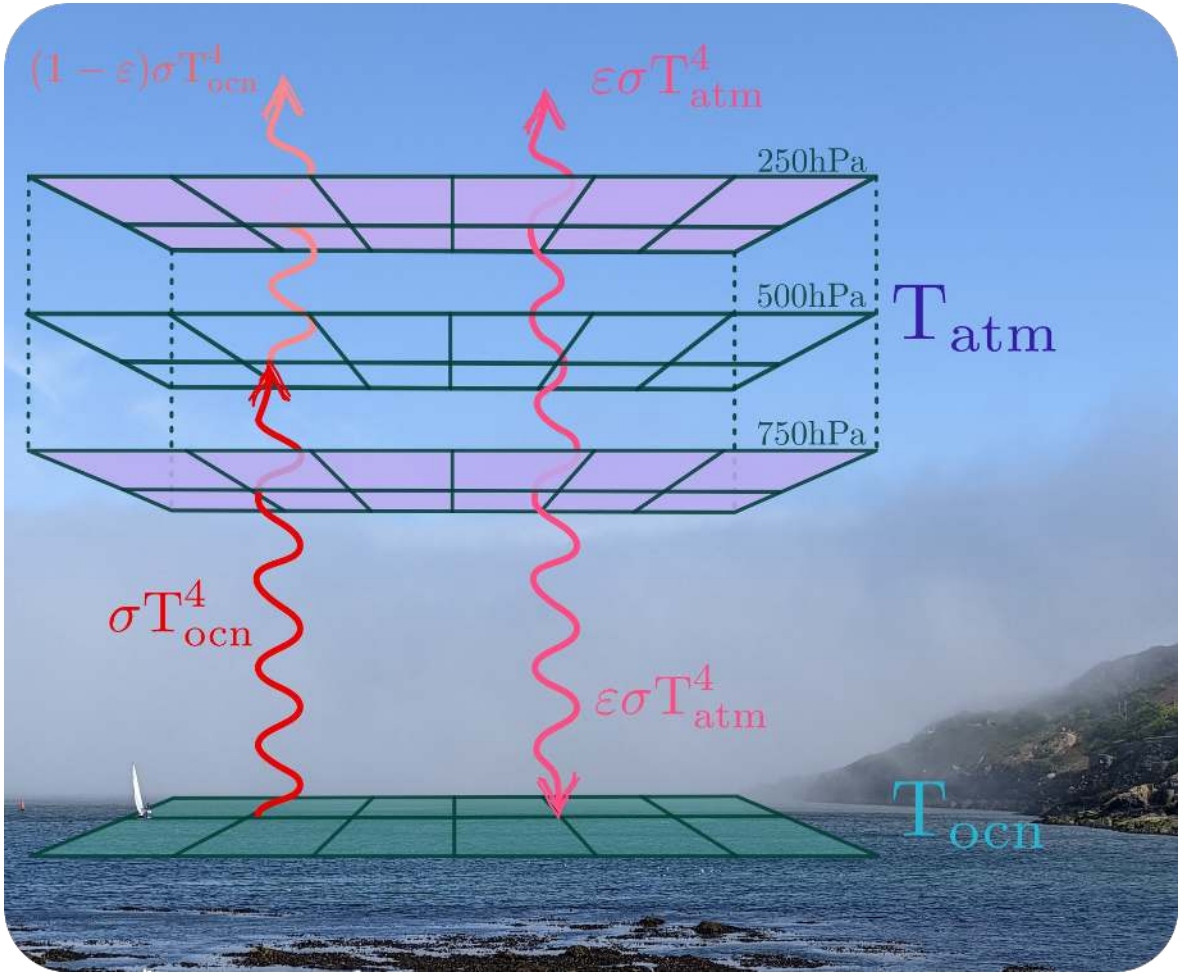
Model Summary

	Model	T^4 Radiation Terms	T_0 Equilibrium Temperature
	Linearised	Linearised	Constant
	Dynamic Temperature	Linearised	Dynamic
	Non-Linear	Non-Linearised	Dynamic

Key Points

Model Parameters

Emissivity ε



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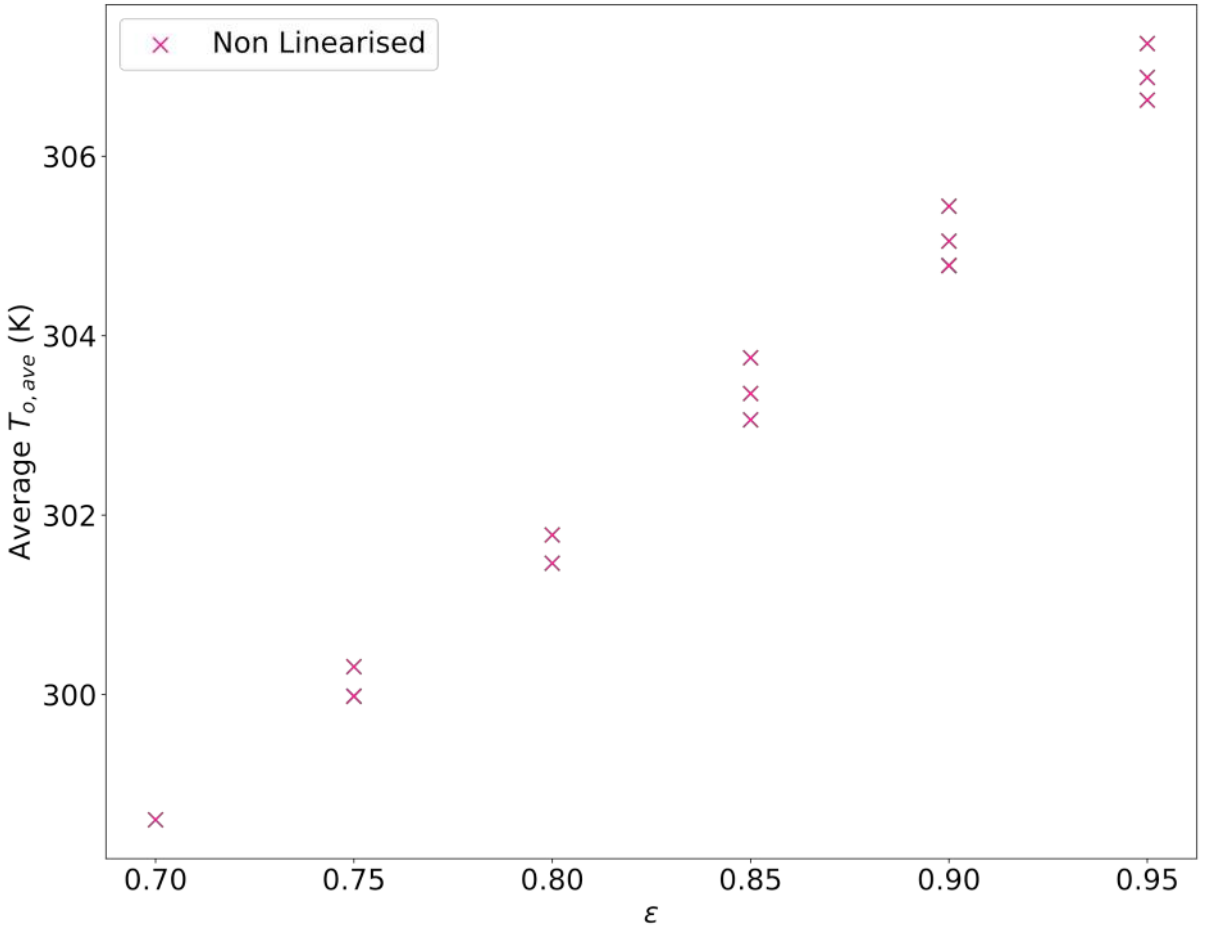

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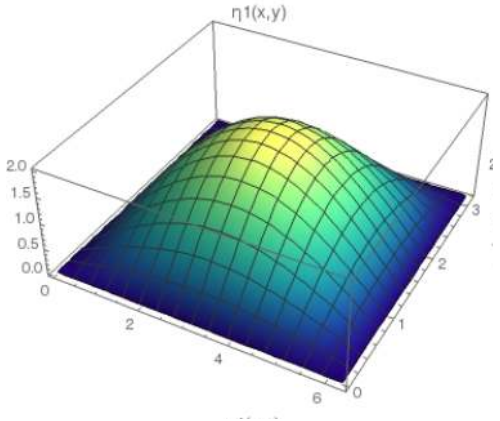

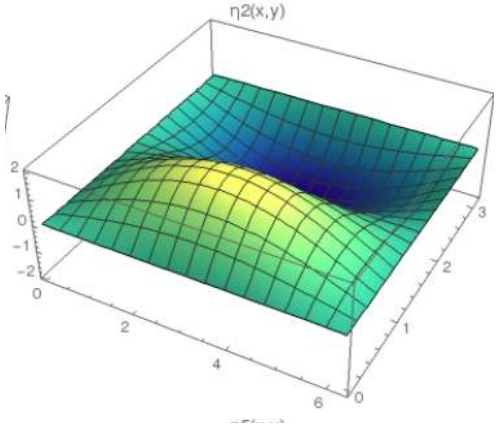

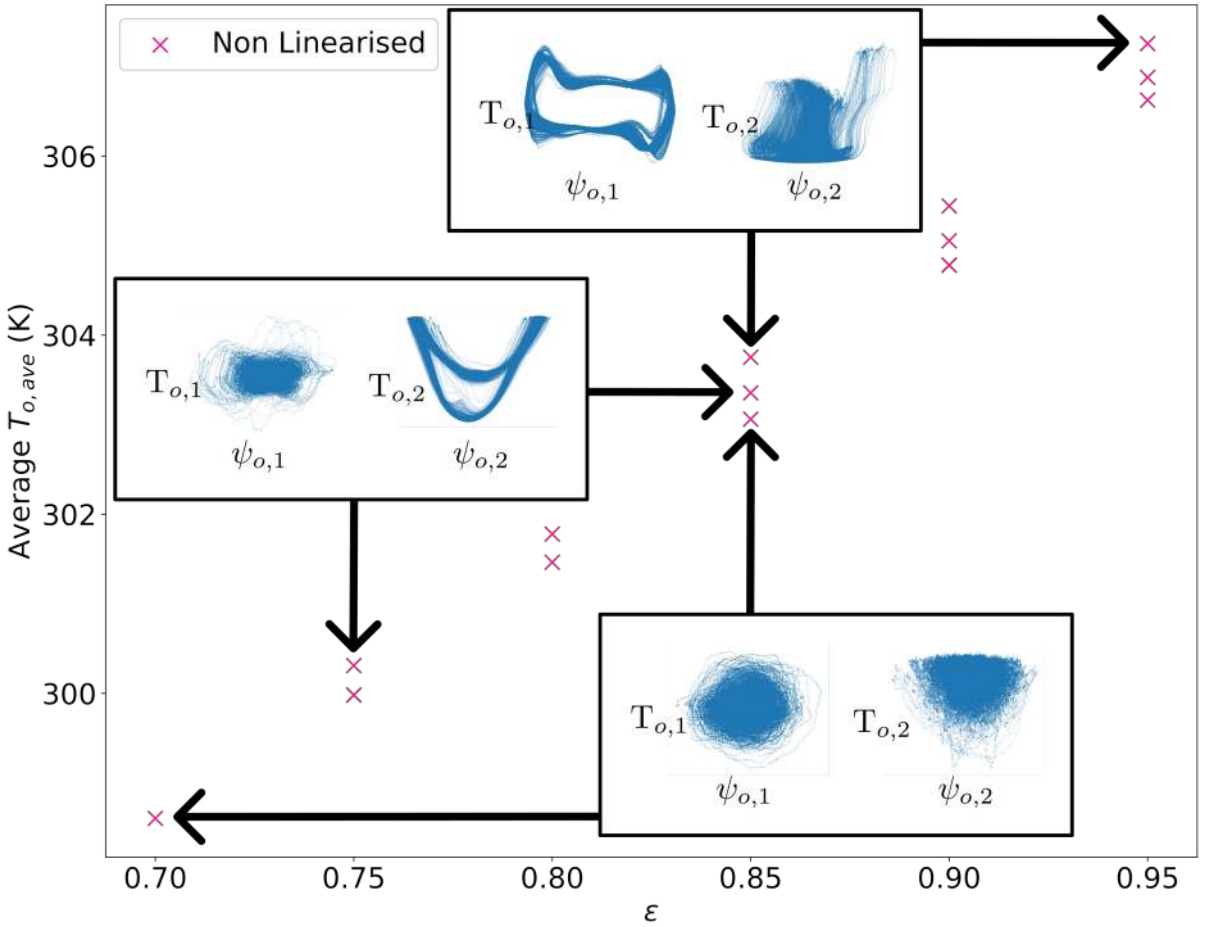

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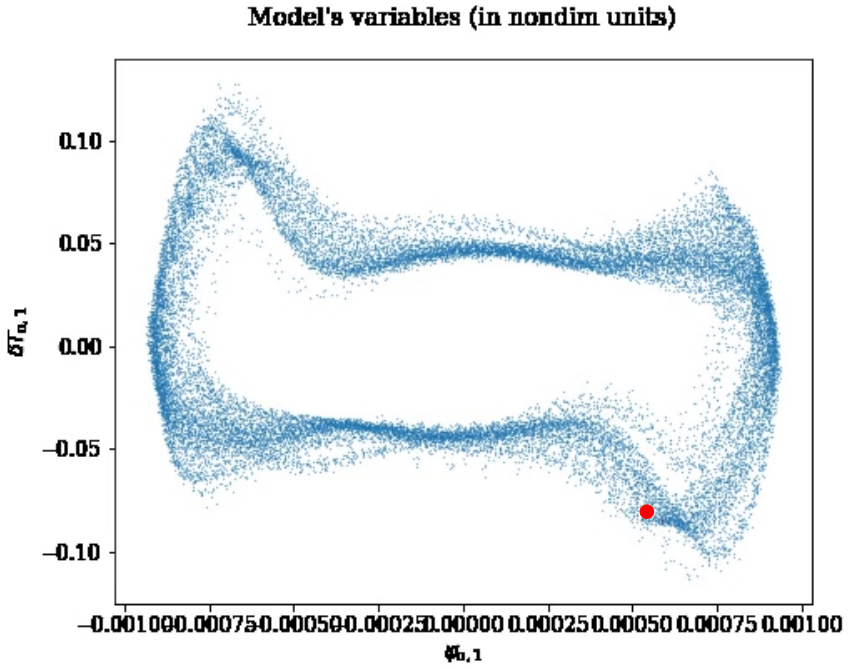

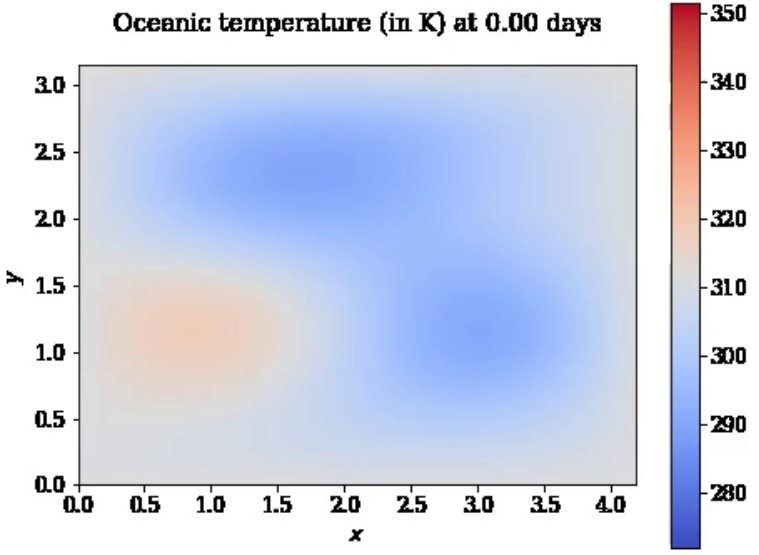

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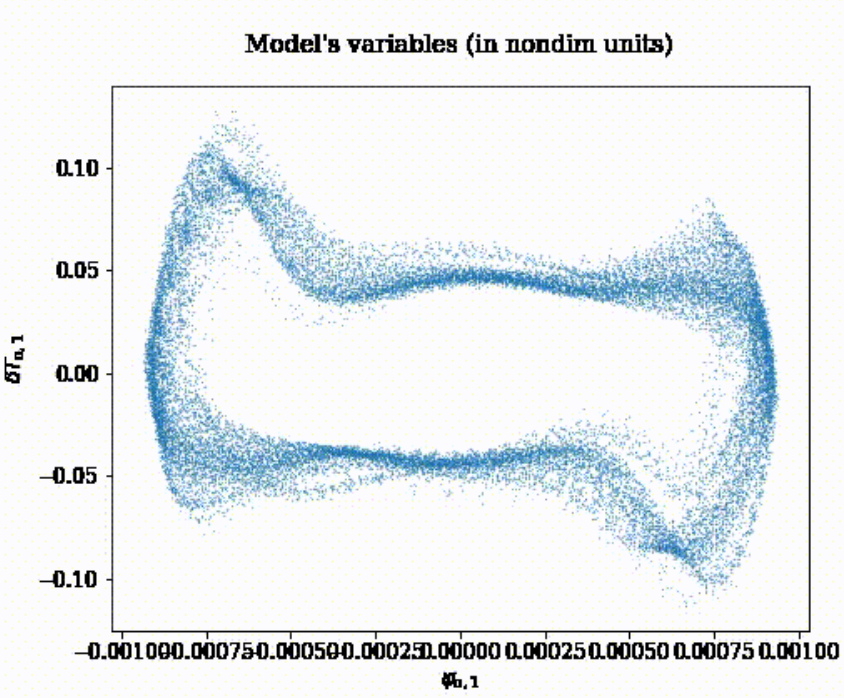

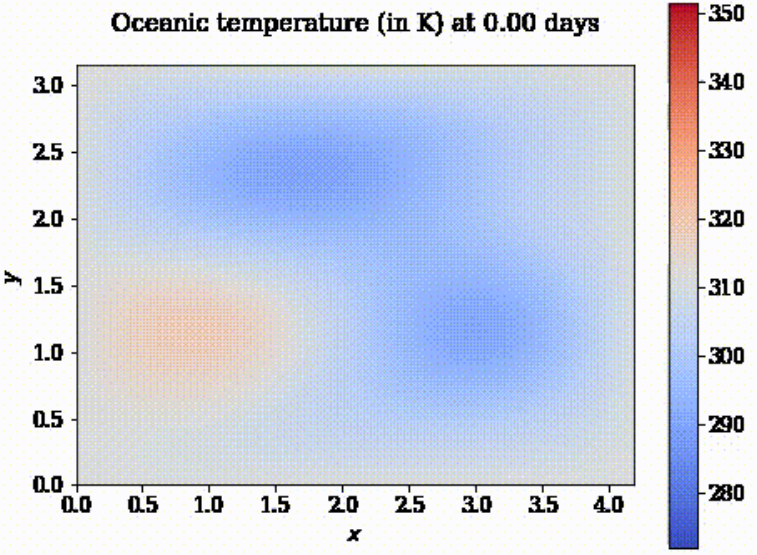

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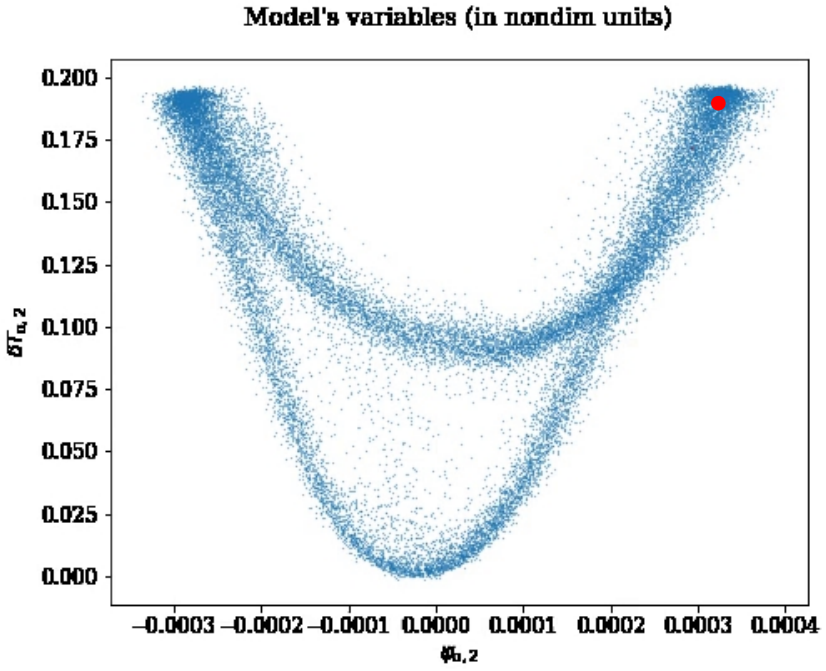

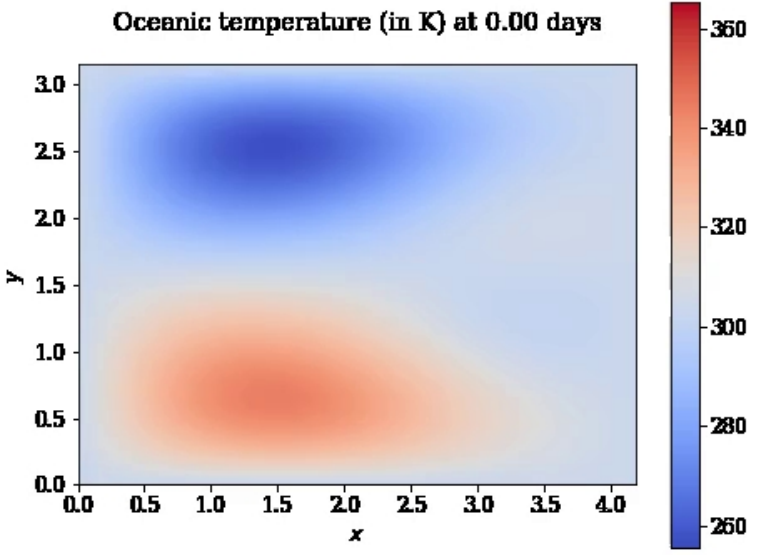

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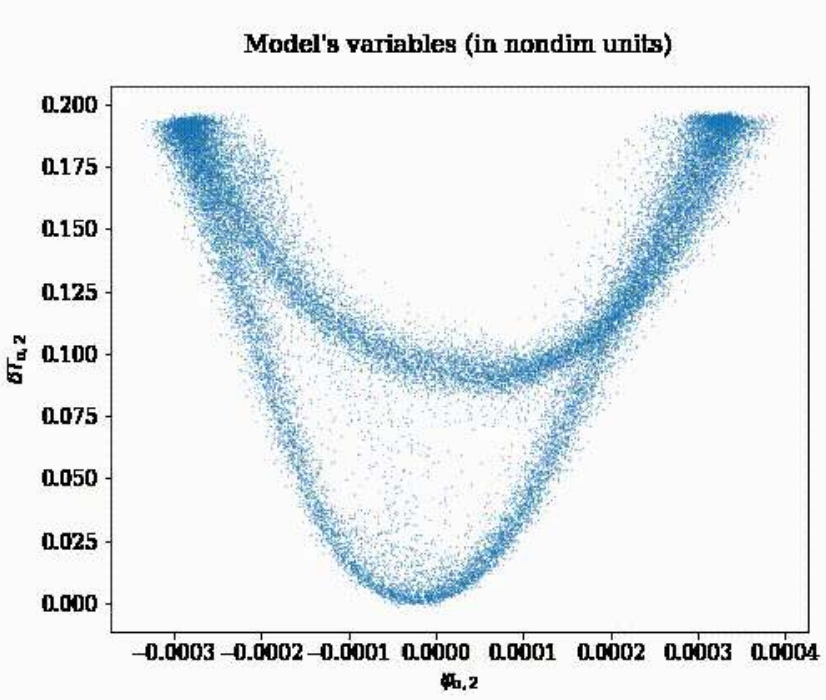
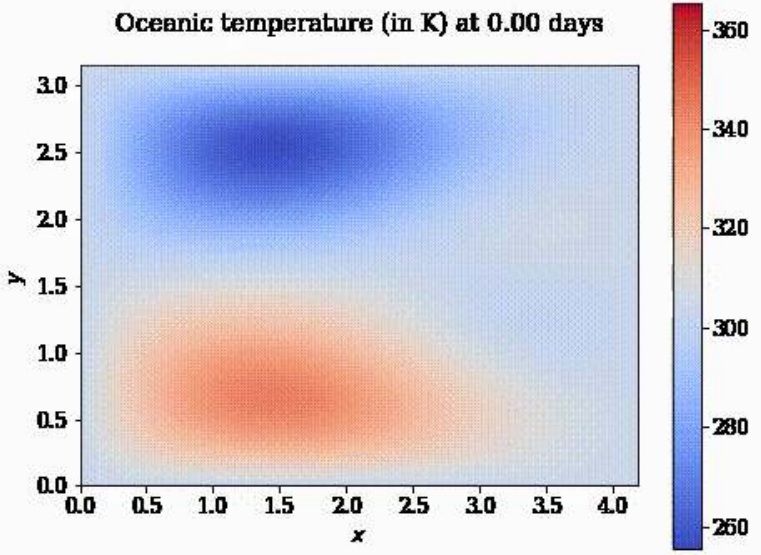
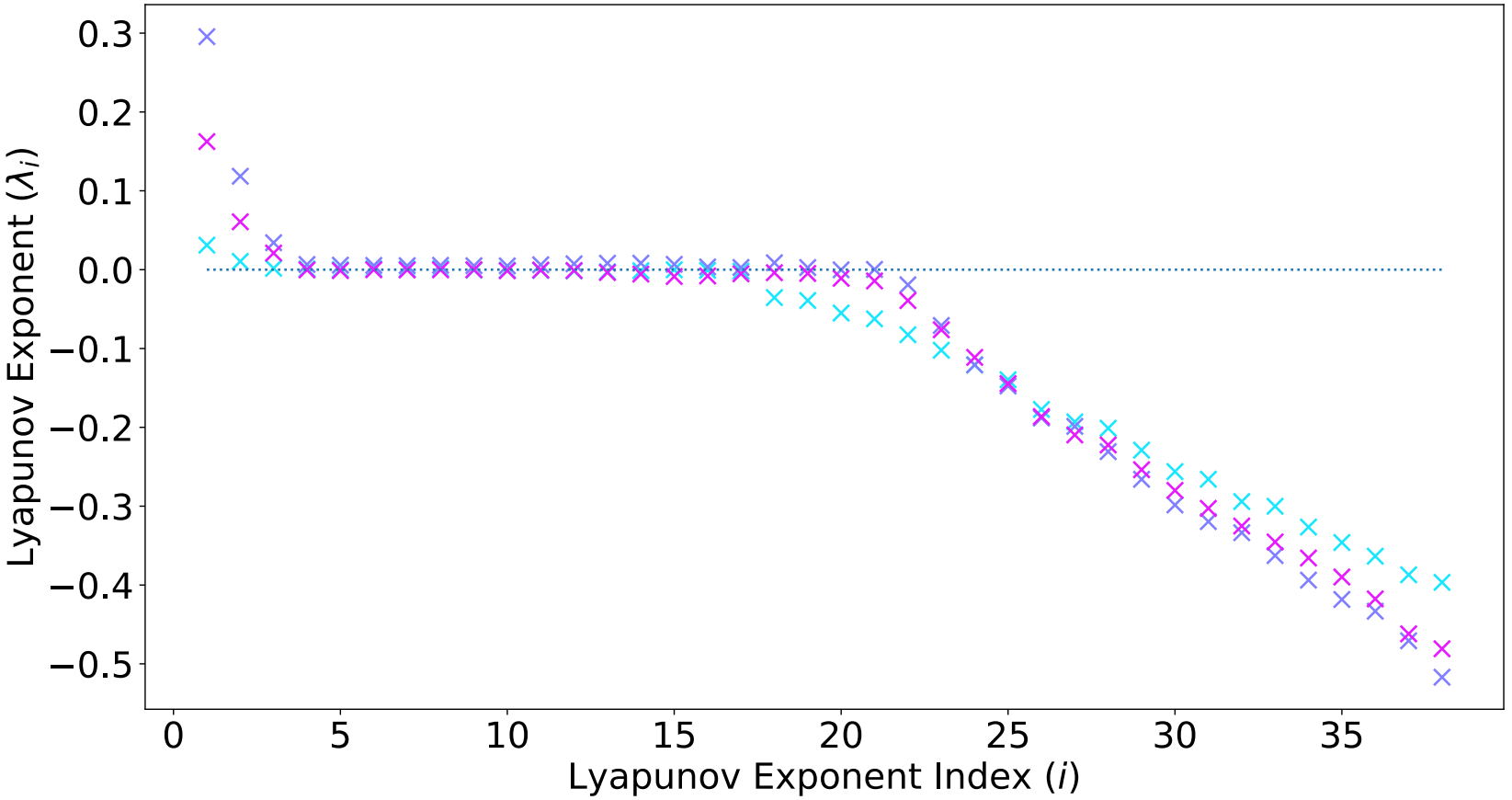




Model Outputs

Lyapunov Exponents



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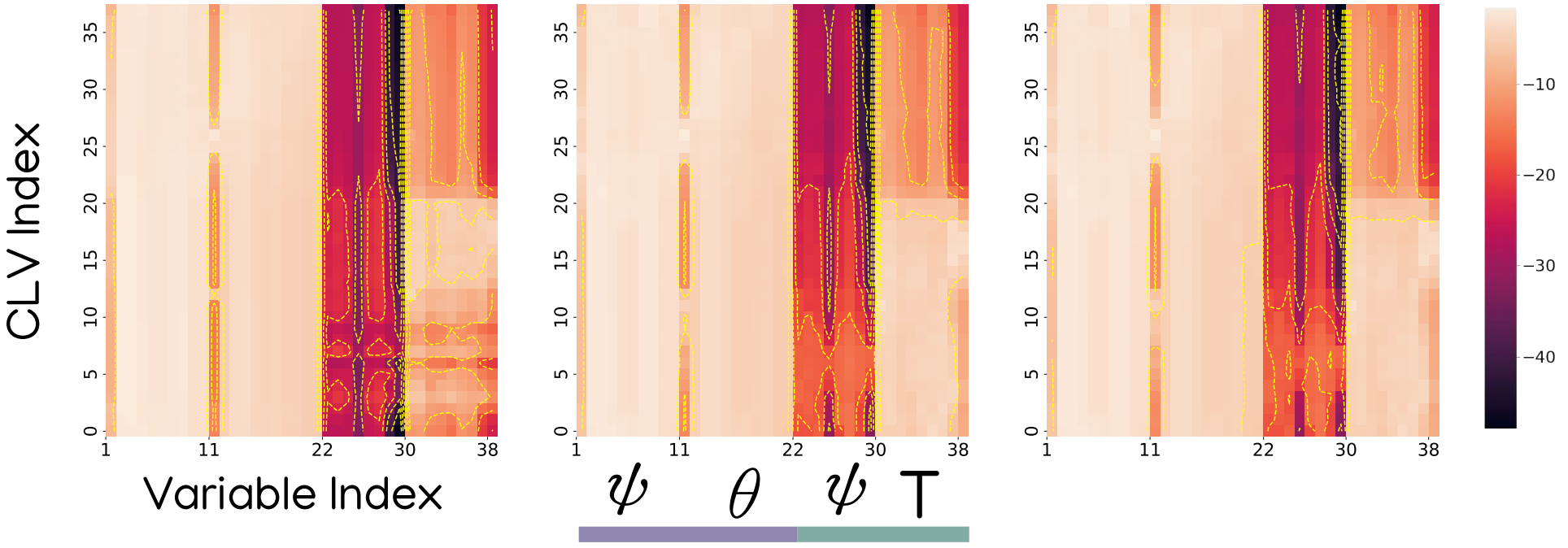

Conclusion

Non linear radiation terms produce temperature multi-stabilities

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Non linear radiation terms produce temperature multi-stabilities

Multi-stabilities produce distinct behaviour

Conclusion

Non linear radiation terms produce temperature multi-stabilities

Multi-stabilities produce distinct behaviour

Multi-stabilities in majority of cases produced by dynamic equilibria

Thank you

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De Cruz et al. (2016)
The Modular Arbitrary-Order Ocean-Atmosphere Model: MAOOAM v1.0