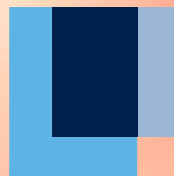# Multistability in a Coupled Ocean-Atmosphere Low Order Model

Oisín Hamilton

Jonathan Demaeyer
Stéphane Vannitsem
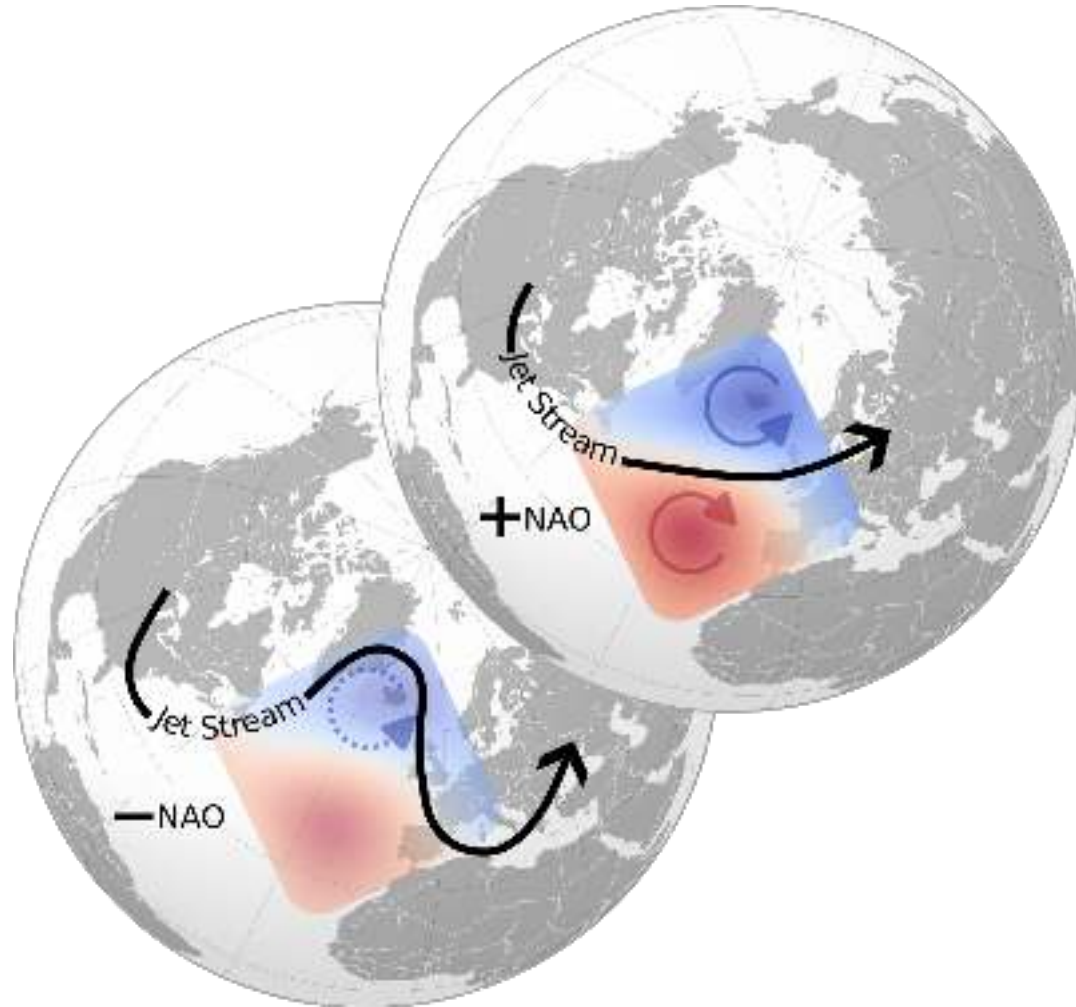Michel Cruicifix

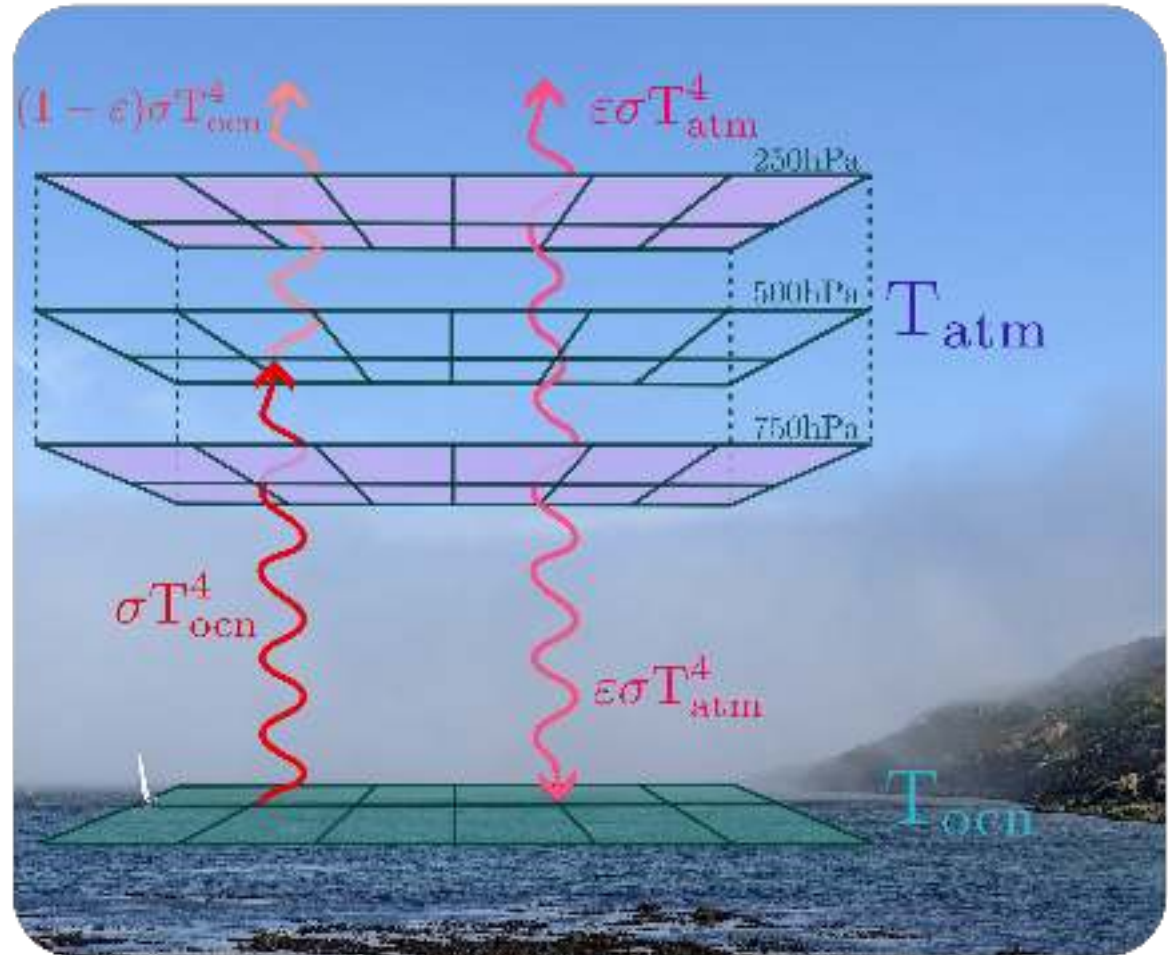# Motivation

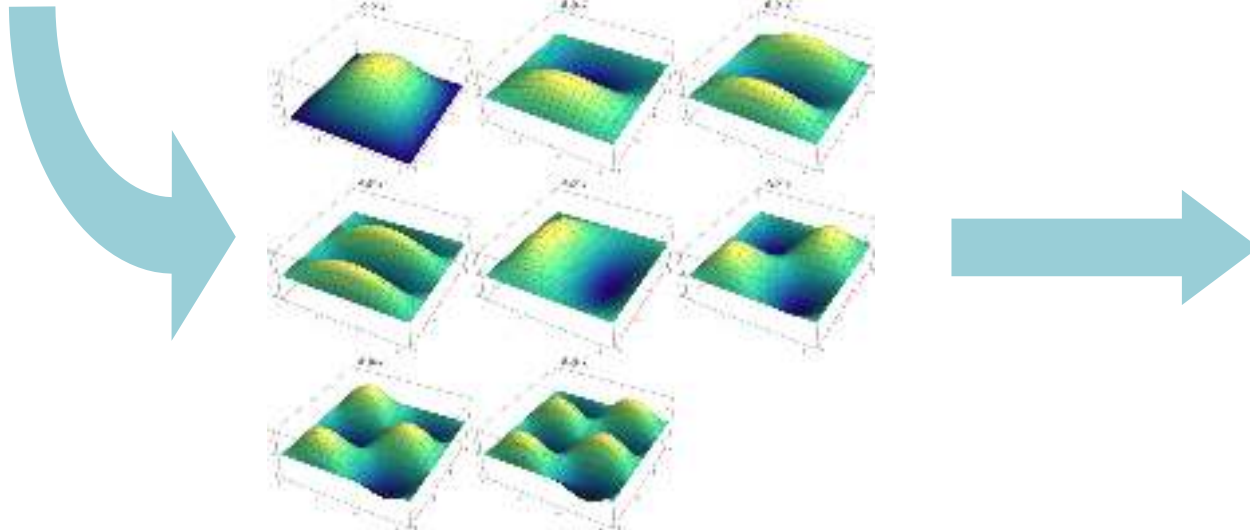# qgs Model

Quasi–Geostrophic
Spectral model

qgs Model

$$\frac{\partial}{\partial t}\left(\nabla^2\psi_{\mathrm{a}}\right) + J\left(\psi_{\mathrm{a}}, \nabla^2\psi_{\mathrm{a}}\right) + \beta\frac{\partial\psi_{\mathrm{a}}}{\partial x} = +k_d'\nabla^2\left(\psi_{\mathrm{a}}^1 - \psi_{\mathrm{a}}\right) - \frac{f_0}{\Delta p}\omega - k_d\nabla^2\left(\psi_{\mathrm{a}} - \psi_{\mathrm{o}}\right)$$

$$\frac{\partial}{\partial t}\left(\nabla^2\psi_{\mathrm{o}} - \frac{\psi_{\mathrm{o}}}{L_{\mathrm{R}}^2}\right) + J\left(\psi_{\mathrm{o}}, \nabla^2\psi_{\mathrm{o}}\right) + \beta\frac{\partial\psi_{\mathrm{o}}}{\partial x} = -r\nabla^2\psi_{\mathrm{o}} + \frac{C}{\rho_{\mathrm{o}}h}\nabla^2\left(\psi_{\mathrm{a}}^3 - \psi_{\mathrm{o}}\right).$$

$$\gamma_{\mathrm{a}}\left(\frac{\partial T_{\mathrm{a}}}{\partial t} + J\left(\psi_{\mathrm{a}}, T_{\mathrm{a}}\right) - \sigma\omega\frac{p}{R}\right) = -\lambda\left(T_{\mathrm{a}} - T_{\mathrm{o}}\right) + \epsilon_{\mathrm{a}}\sigma_{\mathrm{B}}T_{\mathrm{o}}^4 - 2\epsilon_{\mathrm{a}}\sigma_{\mathrm{B}}T_{\mathrm{a}}^4 + R_{\mathrm{a}}$$

$$\gamma_{\mathrm{o}}\left(\frac{\partial T_{\mathrm{o}}}{\partial t} + J\left(\psi_{\mathrm{o}}, T_{\mathrm{o}}\right)\right) = -\lambda\left(T_{\mathrm{o}} - T_{\mathrm{a}}\right) - \sigma_{\mathrm{B}}T_{\mathrm{o}}^4 + \epsilon_{\mathrm{a}}\sigma_{\mathrm{B}}T_{\mathrm{a}}^4 + R_{\mathrm{o}}$$

$$\dot{\psi}_{\mathrm{a},i} = \ldots$$

$$\dot{\theta}_{\mathrm{a},i} = \ldots$$

$$\dot{\psi}_{\mathrm{o},i} = \ldots$$

$$\dot{\delta T}_{\mathrm{o},i} = \ldots$$

Model Results

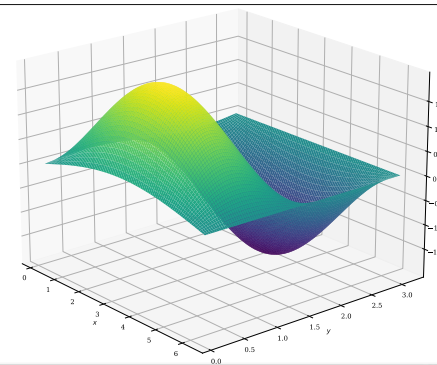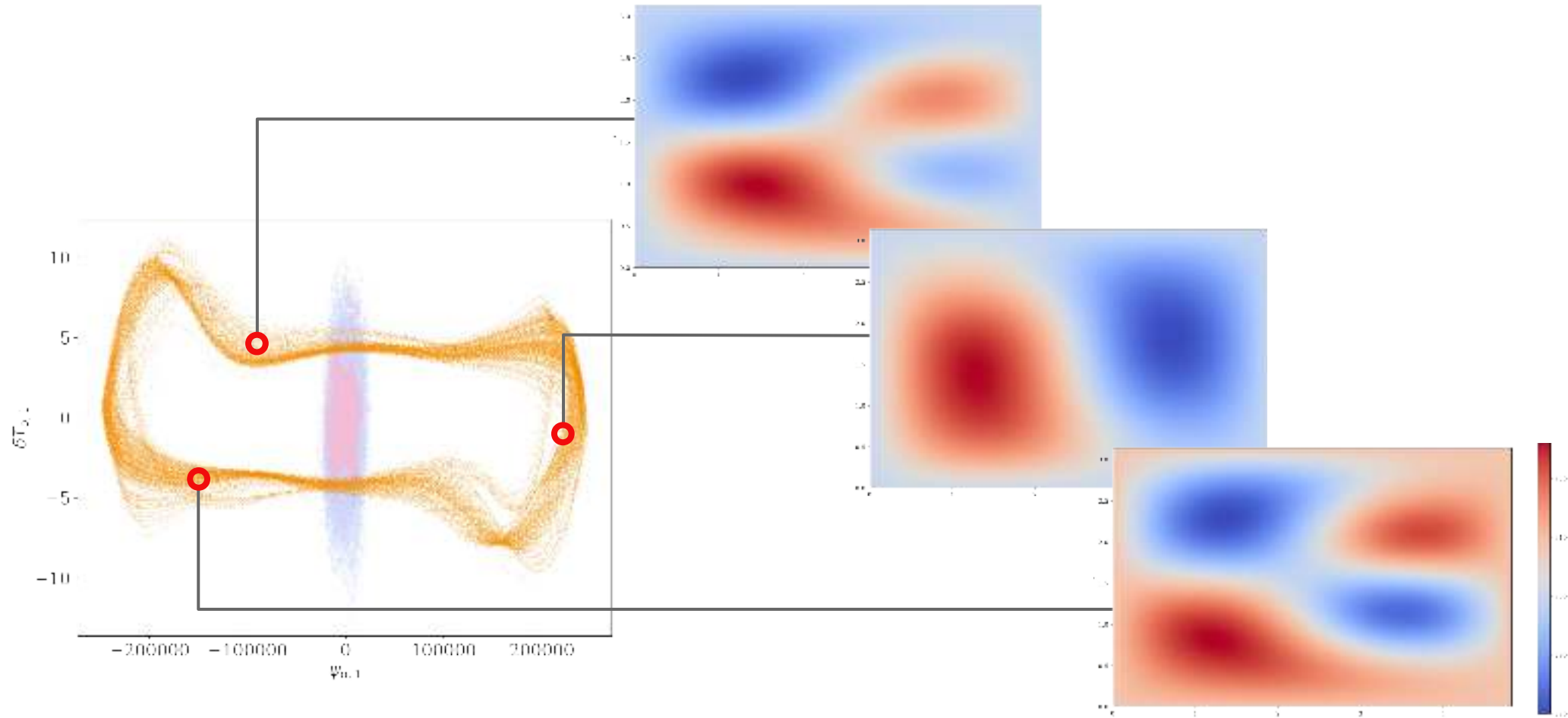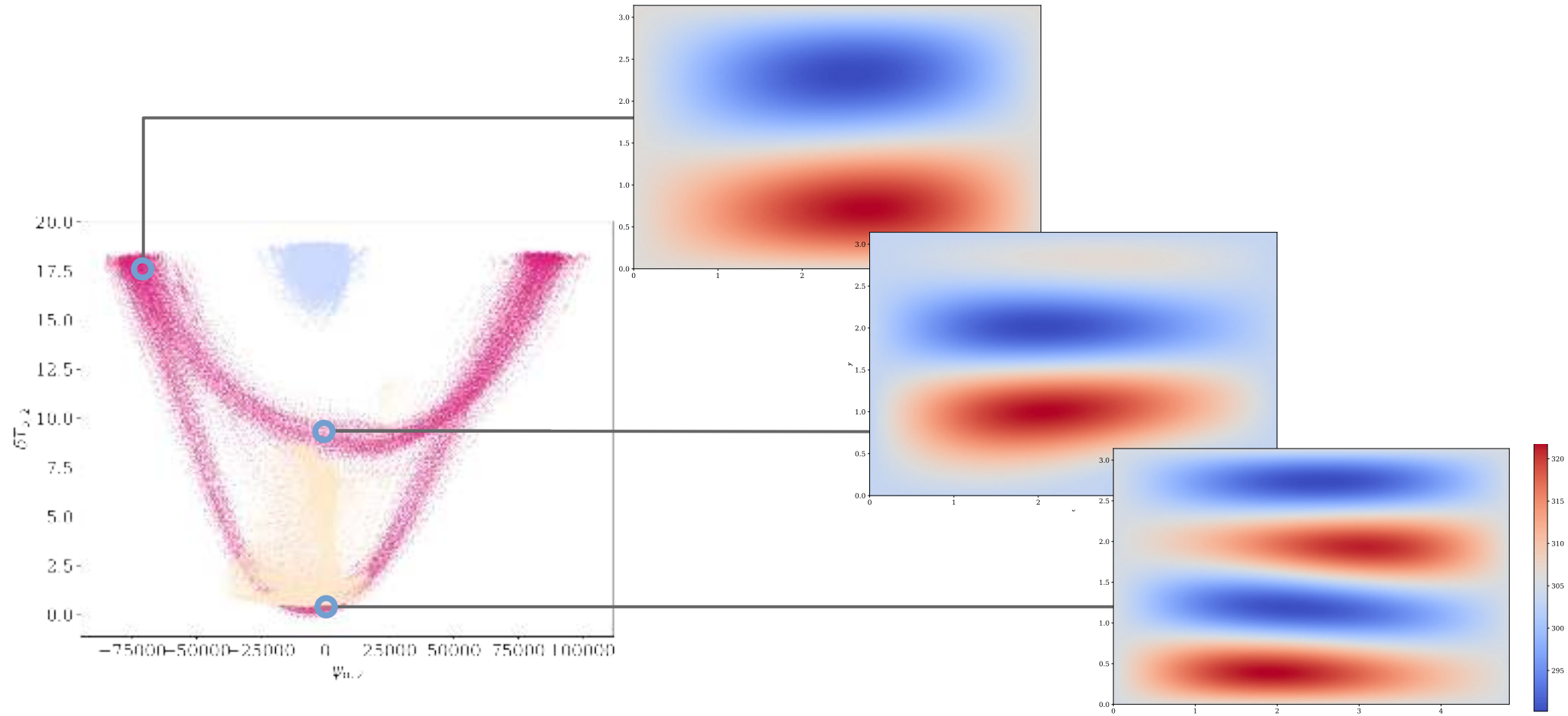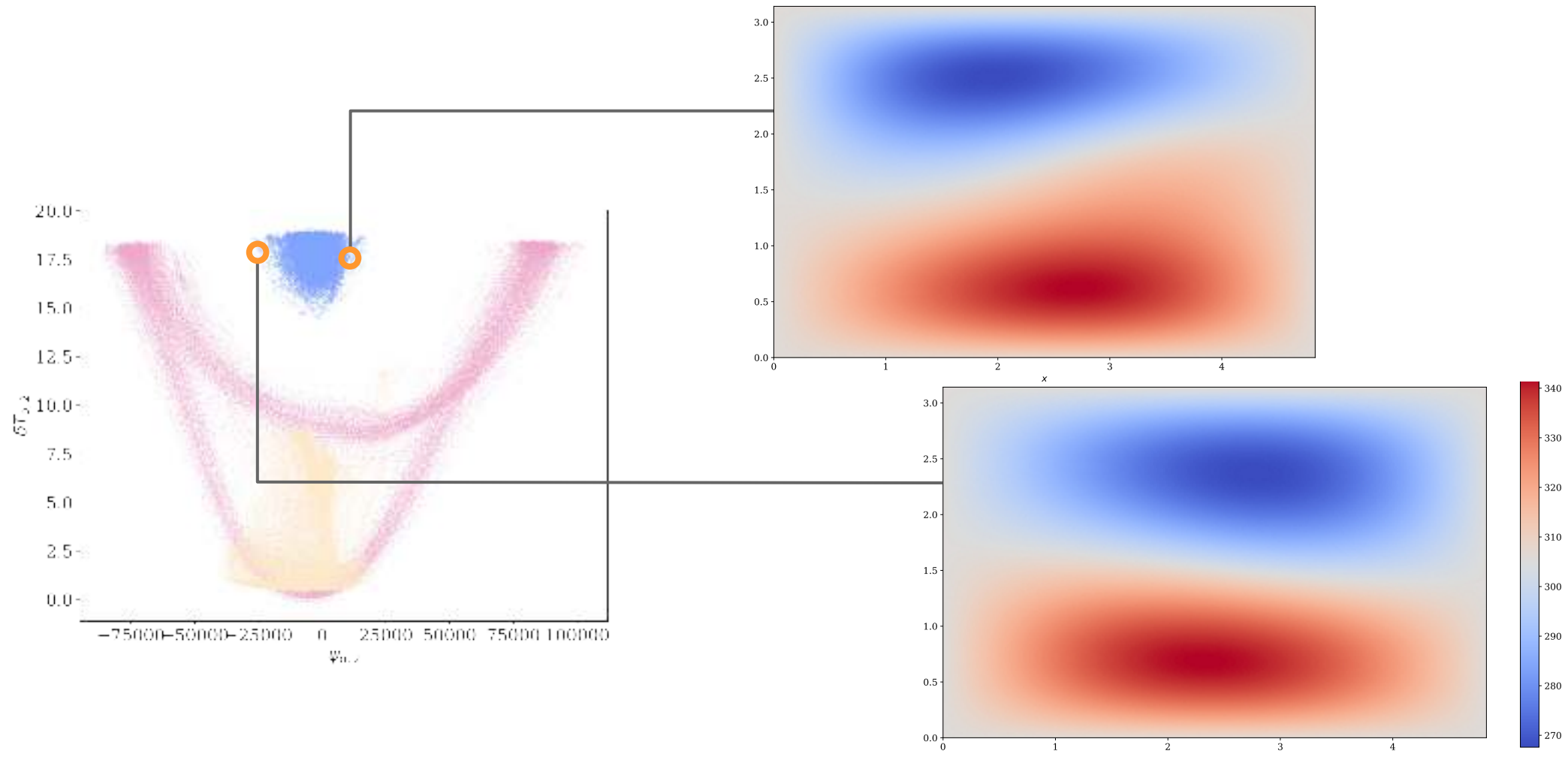ϕ_1

ϕ_2

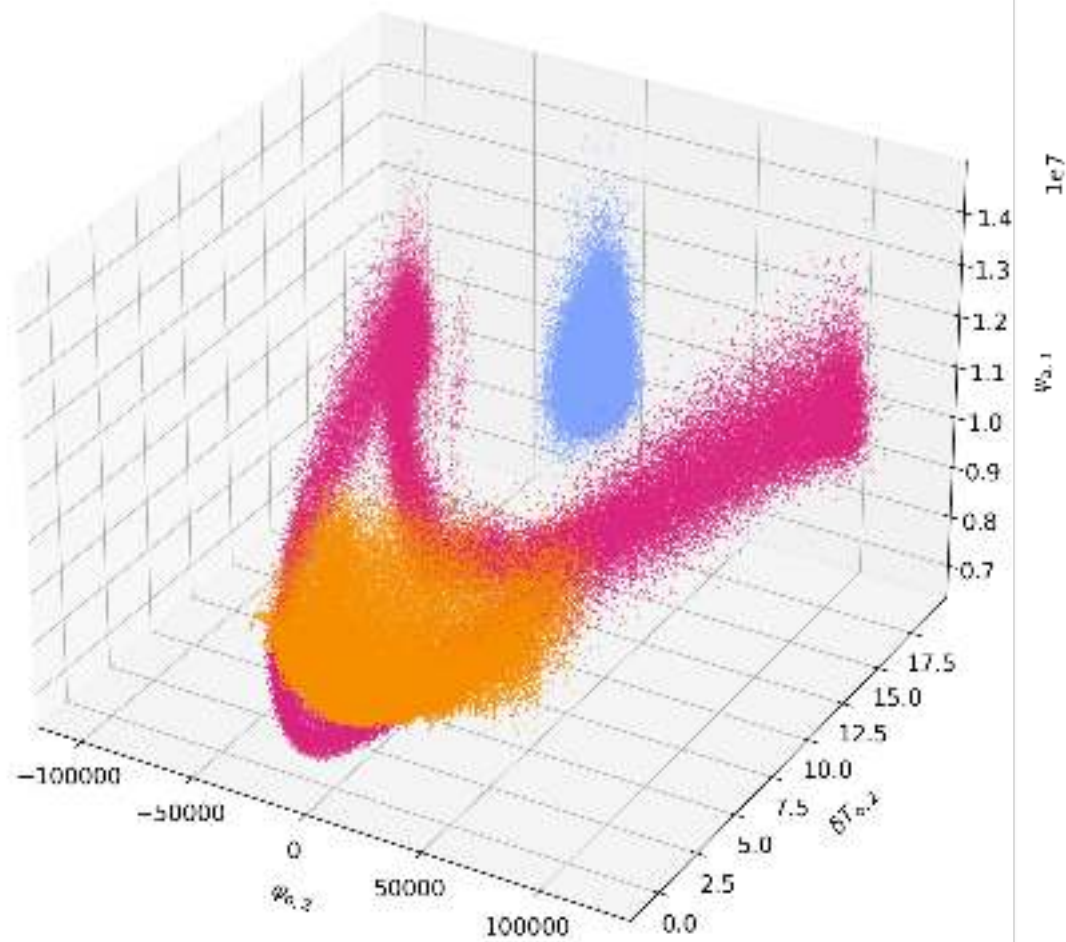# Model Results

ϕ_1
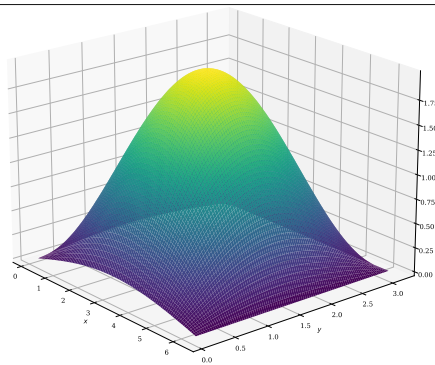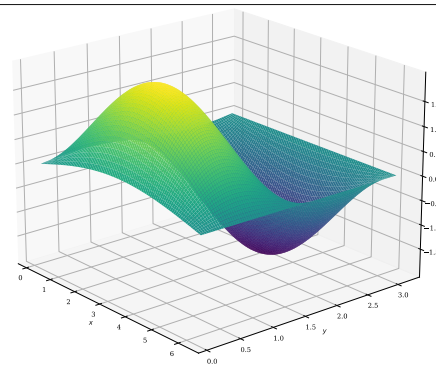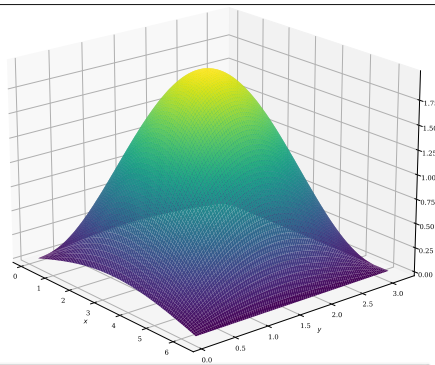
ϕ_2
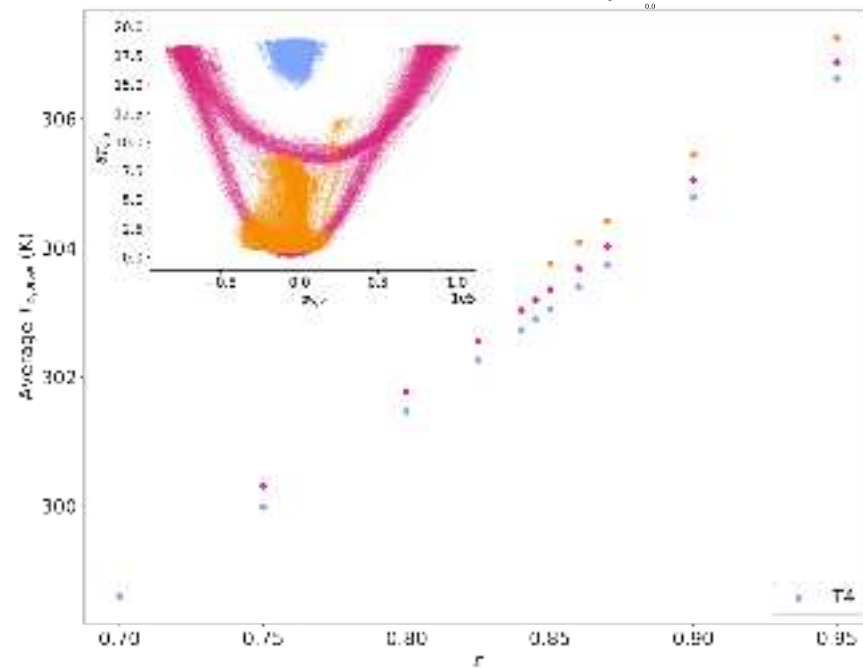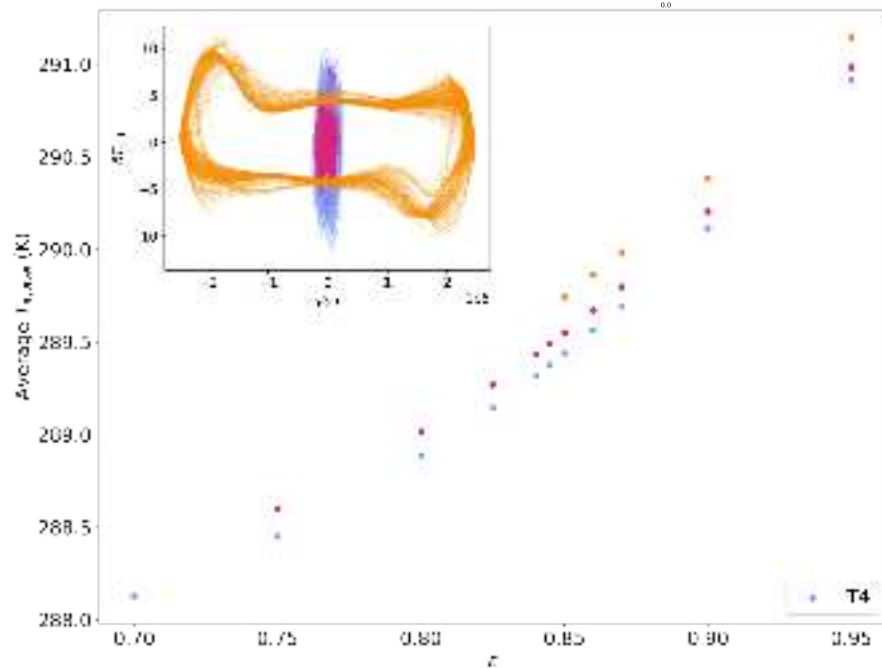
Model Results

Model Results

Model Results

Coupling

Coupling
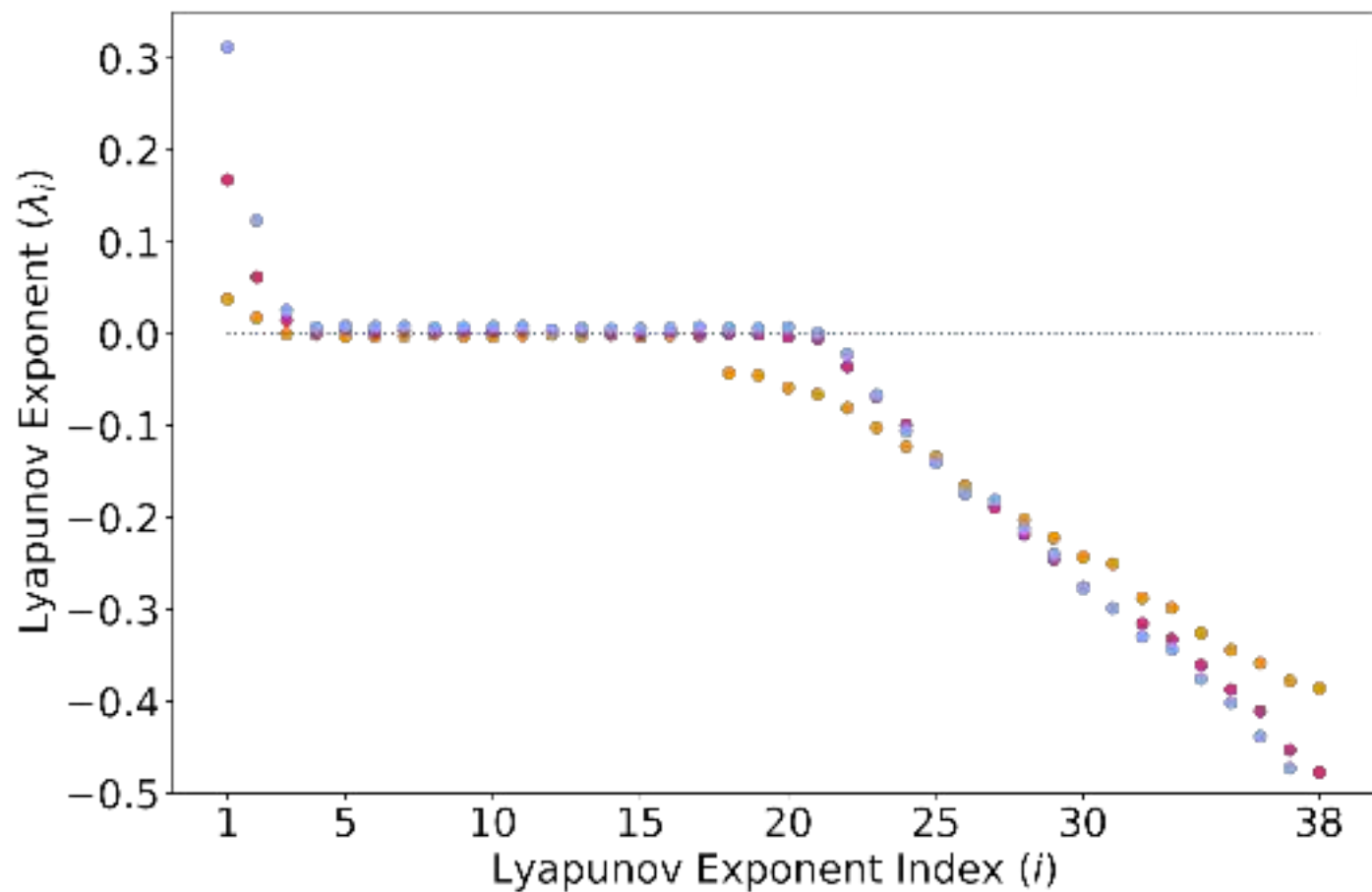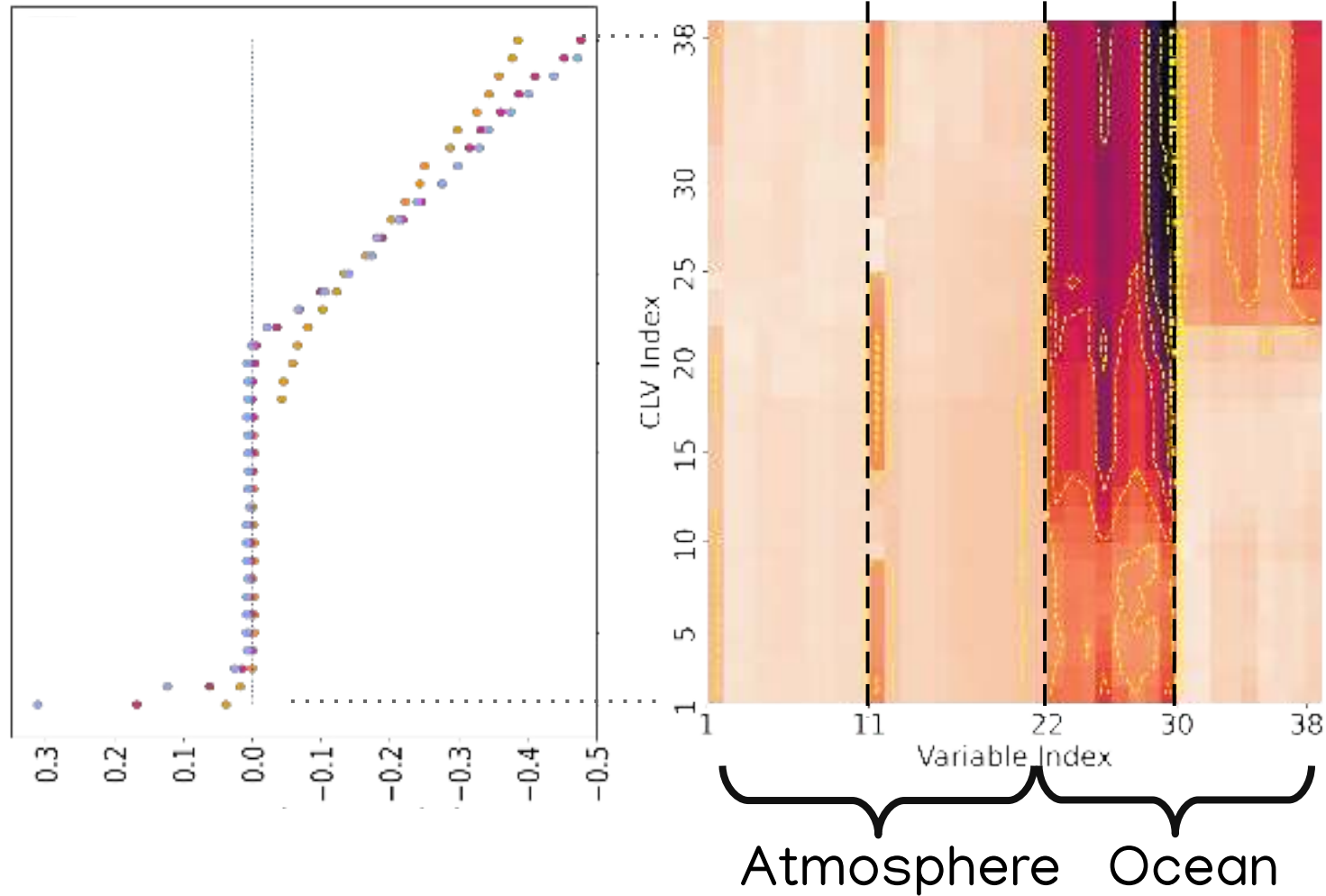
Coupling

Coupling

Additional Information

Multistability in a Coupled Ocean-Atmosphere Reduced Order Model: Non-linear Temperature Equations

Oisín Hamilton[1,2] | Jonathan Demaeyer[1] | Stéphane Vannitsem[1] | Michel Crucifix[2]

Additional Information
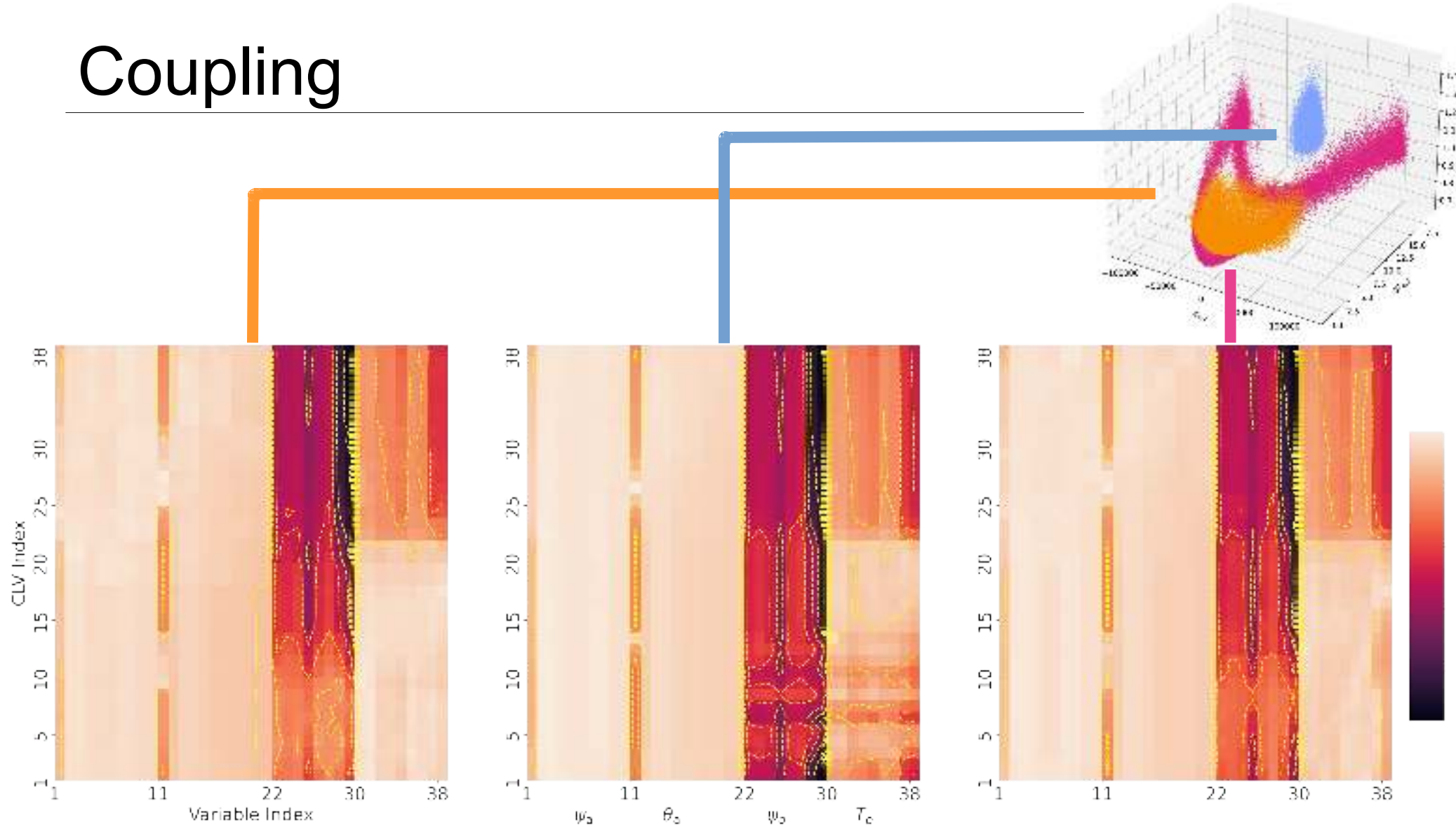

QG Equations

Projected Symbolic ODEs

RESEARCH ARTICLE
Quarterly Journal of the Royal Meterological Society

Multistability in a Coupled Ocean-Atmosphere Reduced Order Model: Non-linear Temperature Equations

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Conclusions

Not linearising the σT^4 terms produces multiple attractors

These attractors present distinct coupled flows

The coupled flows have different predictability

github.com/Climdyn/qgs

Thank you
oisin.hamilton@meteo.be