A multi-wave model for the Quasi-Biennial Oscillation: Plumb's model extended

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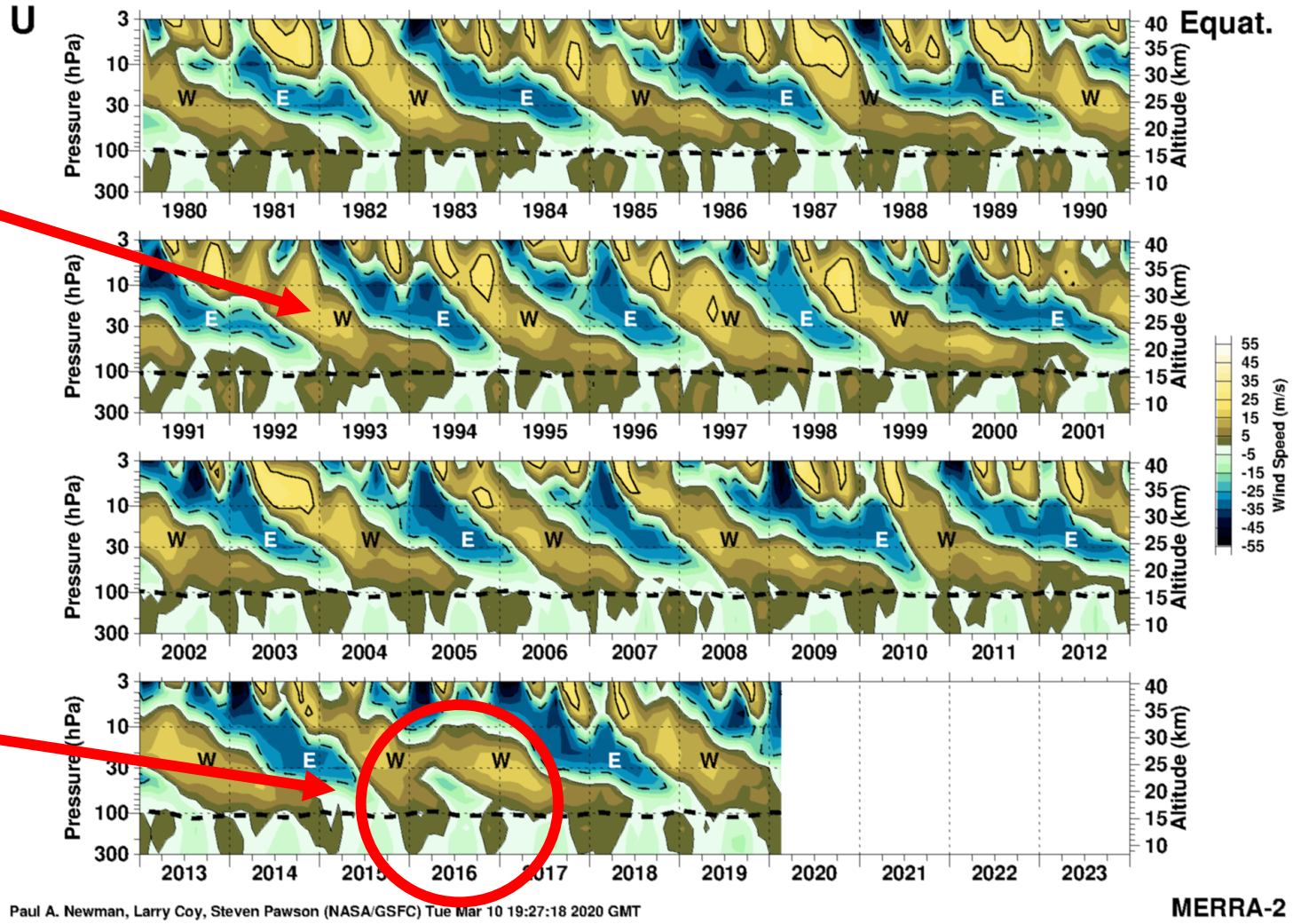
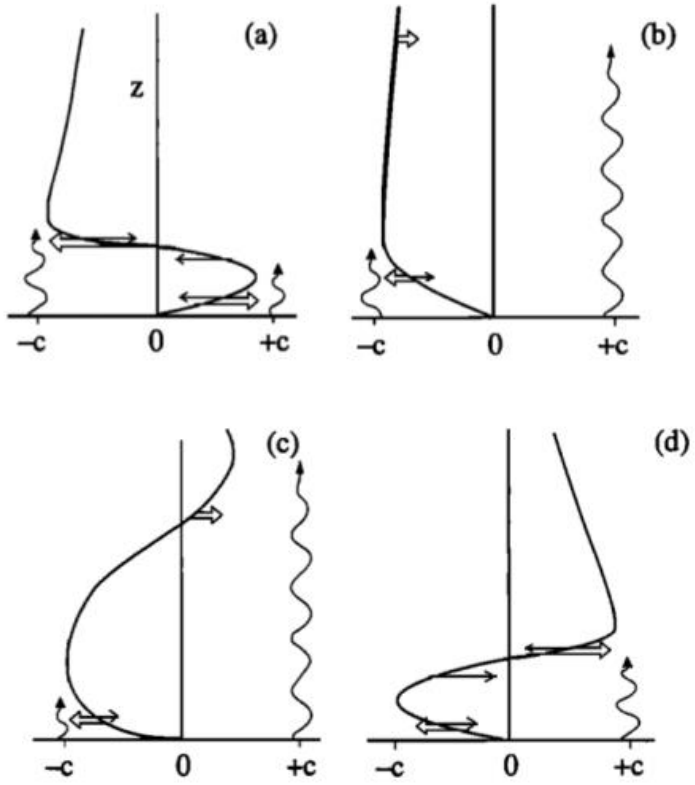
Periodic reversals of the zonal flow at equatorial latitude in the Earth's stratosphere. The period is 28 months.

A disruption appears in 2016

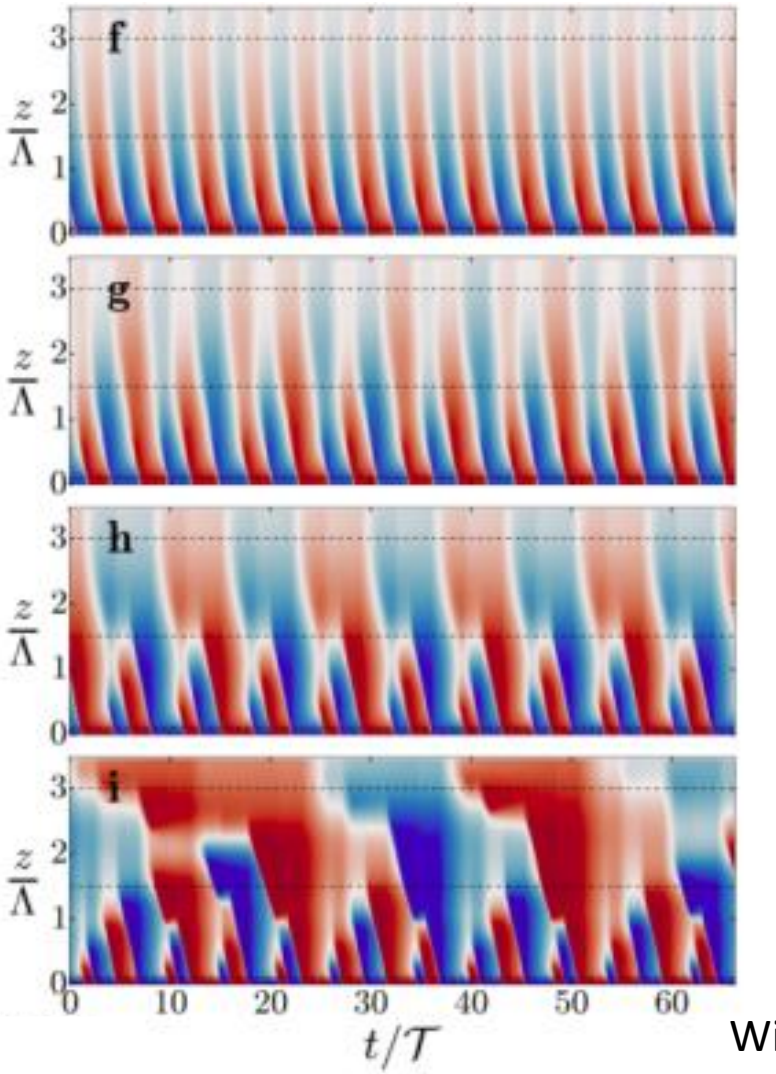


Mean-flow equation : $\partial_t \overline{u} - Re^{-1}\partial_{zz}^2 \overline{u} = -\partial_z \overline{u'w'}$

Plumb, 1984



At the bottom, two IGWs with same frequencies and opposite phase speeds are generated.
They propagate in a stratified fluid and due to their « anti-difffusive » effect, they generate an oscillating horizontal large-scale flow



Renaud et al., PRL, 2019

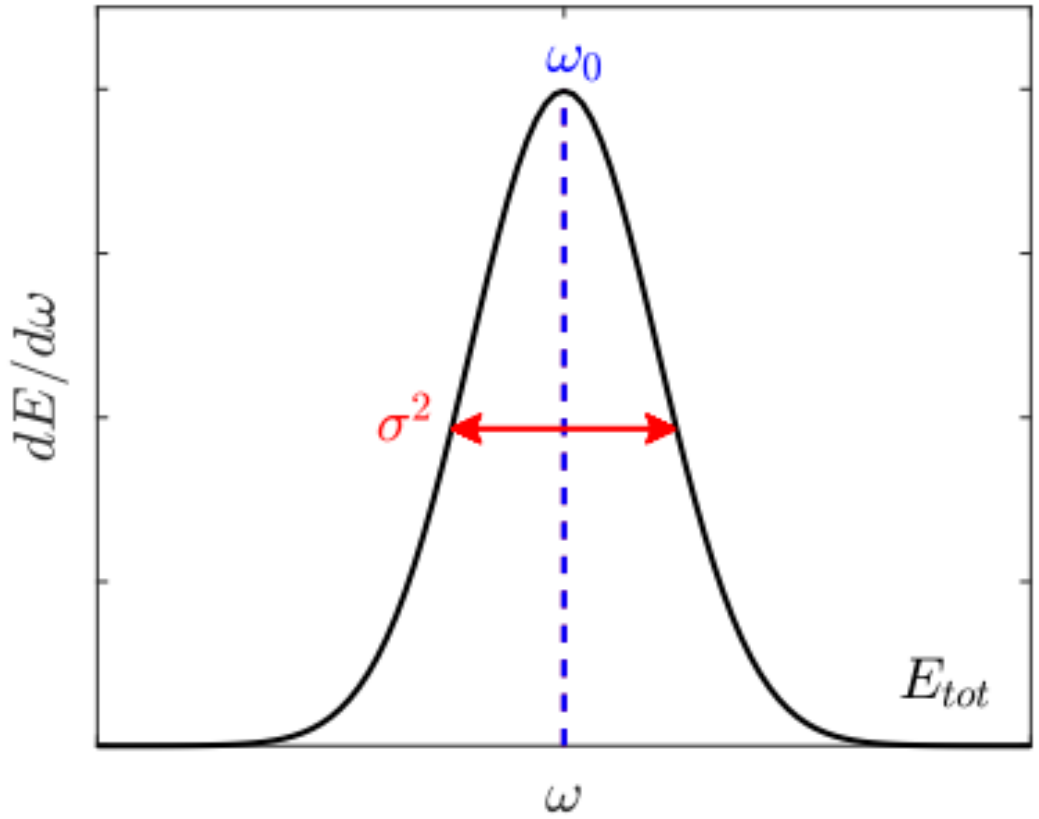
$Re \nearrow$

With increasing Re, non-periodic behaviours emerge in the model

What happens if the forcing is stochastic ?

We consider a Gaussian distribution of energy among frequencies.

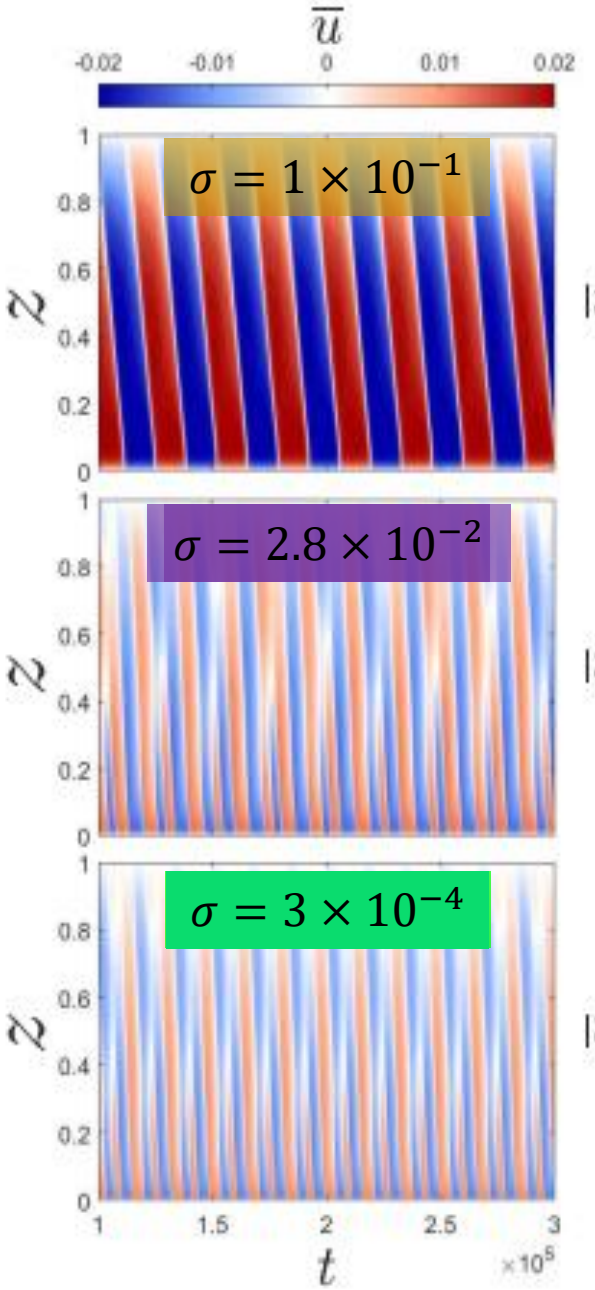
- If $\sigma \to 0$, the forcing is monochromatic and we obtain the results from the monochromatic studies
- If $\sigma \to \infty$, the forcing corresponds to a white noise spectrum

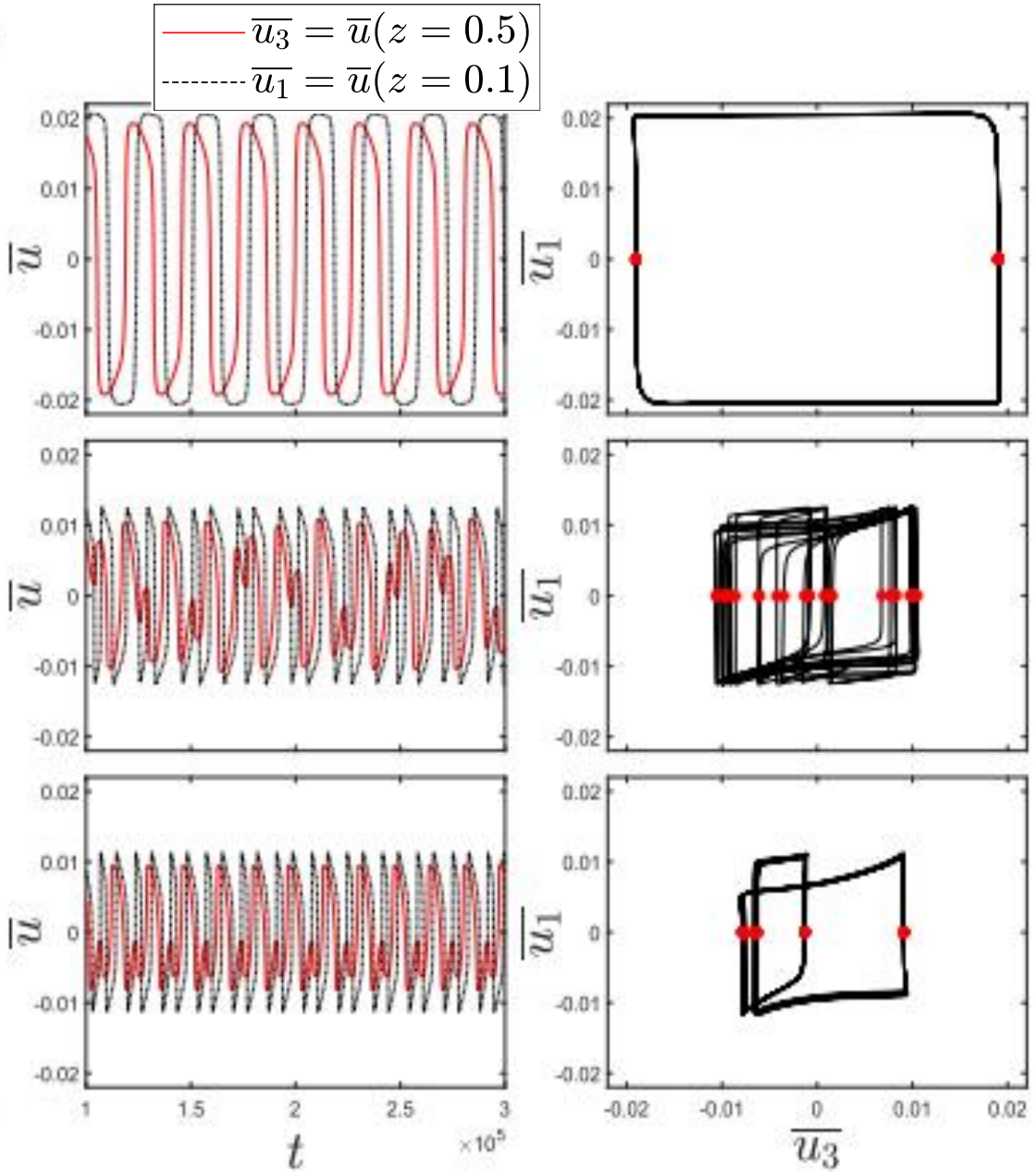


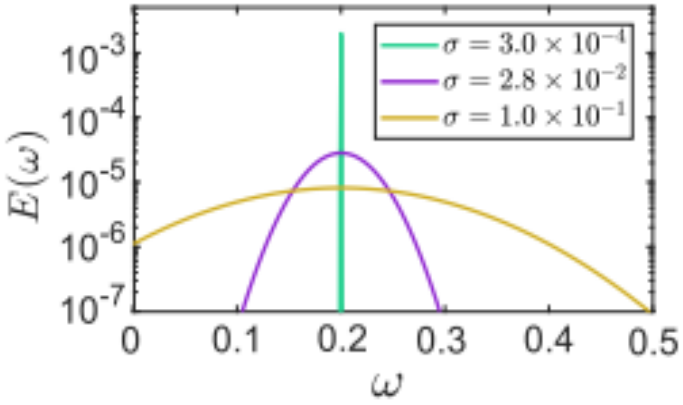
$\boldsymbol{\sigma}$ is varied in a systematic study, keeping $\boldsymbol{\omega_0}$ and $\boldsymbol{E_{tot}}$ constant

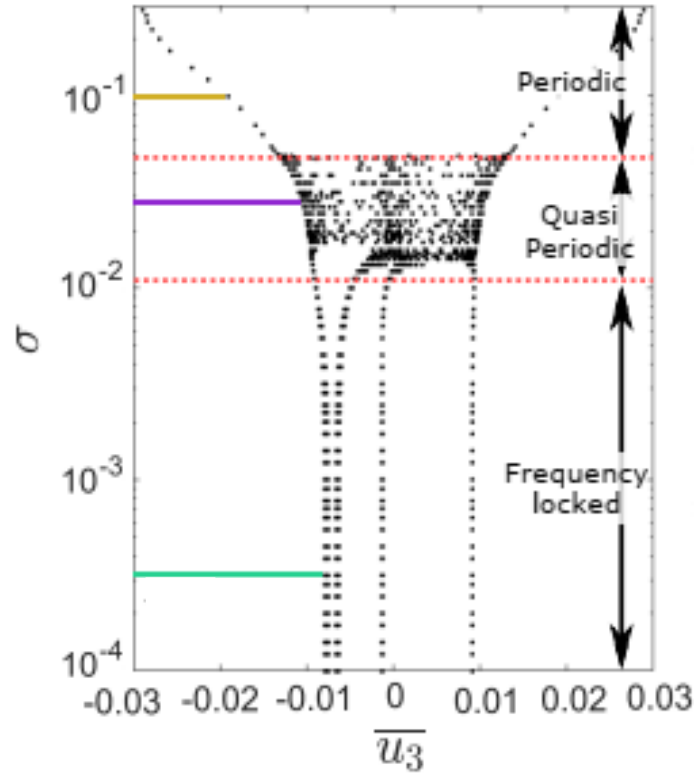
The forcing is considered as a sum of independant waves.

Results







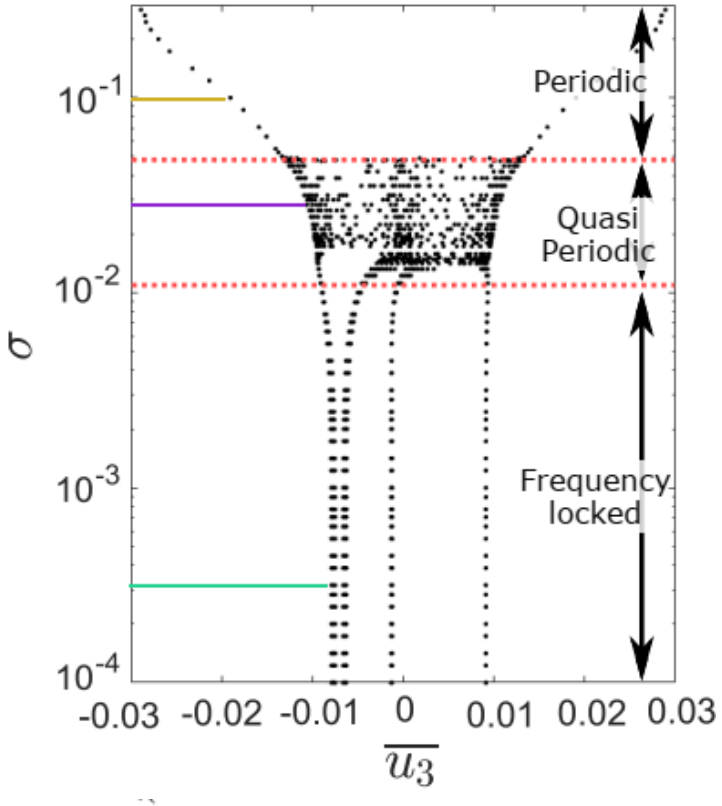


Time series for 3 different σ

The red dots correspond to the values of $\overline{u}(z = 0.5)$ when $\overline{u}(z = 0.1) = 0$. For each σ, the red dots are reproduced in the Poincaré map, showing the bifurcations with varying σ.

Multi-modal excitation to model the Quasi-Biennial Oscillation, 2020, PRL (in review)

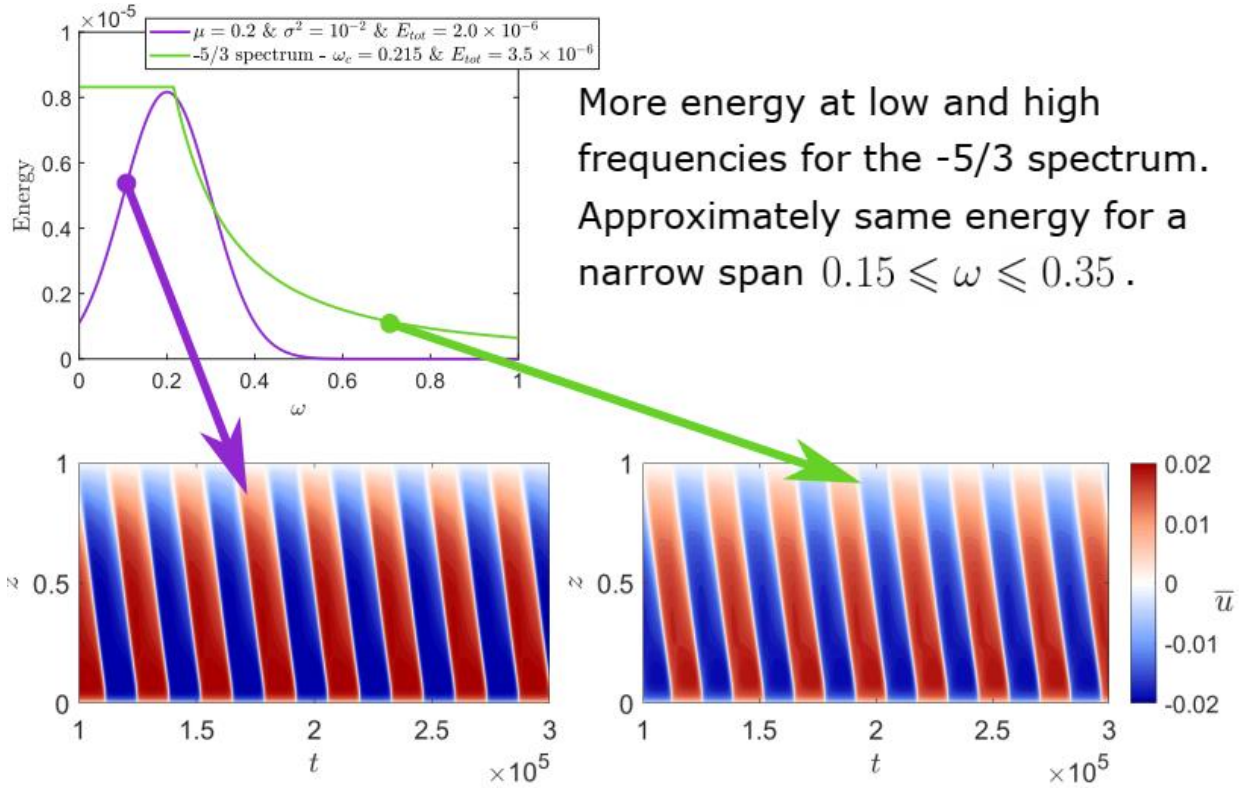
Conclusion



Monochromatic forcing generates frequency-locked oscillations. A multi-wave forcing, with the same amount of energy, drive periodic oscillations.

High frequency waves have a higher impact on the oscillations properties.

Non-unicity of the QBO answer for various stochastic excitations.



More energy at low and high frequencies for the -5/3 spectrum. Approximately same energy for a narrow span $0.15 \leqslant \omega \leqslant 0.35$.

The oscillations in both cases are very similar in terms of period and amplitude, suggesting that different excitation spectra can lead to equivalent large-scale flow properties.

Driving the right oscillations in a model does not imply that the forcing parameters are the right ones.