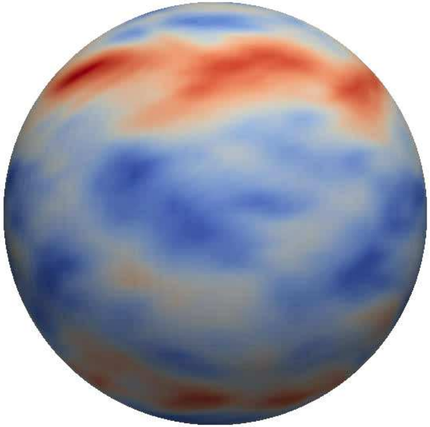

Data driven stochastic parameterisation of the subgrid interactions between eddies, climate and topography in a baroclinic quasi-geostrophic atmospheric model.

Vassili Kitsios & Jorgen S. Frederiksen

ACCESS Science Day, 24th of March 2019

OCEANS AND ATMOSPHERE
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CLIMATE ANALYSIS FORECAST ENSEMBLE system

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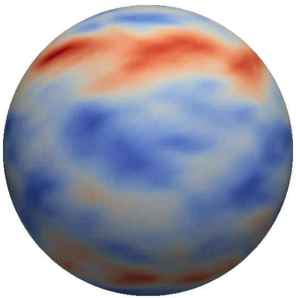
Motivation - Reduce GCM Resolution Dependence

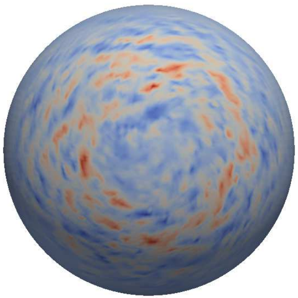
- Present work focussed on improving accuracy of GCMs, by reducing their resolution dependence.
- It is not possible to simulate all of the scales of motion, hence:
  - the large eddies are resolved by a computational grid
  - unresolved sub-grid scale (SGS) interactions are parameterised
- Typical approach: **Physical Hypothesis** $\rightarrow$ **Subgrid Model**
- Present approach: **Subgrid Model from DNS** $\rightarrow$ **Physical interpretation**
- Present stochastic subgrid modelling approach successfully applied to:



2-level QG Atmos.

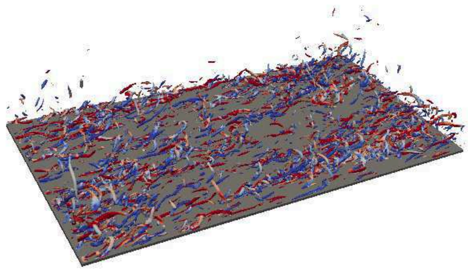
Kitsios et. al. (2012, JAS)

Kitsios et. al. (2019, JAS)



2-level QG Ocean

Kitsios et. al. (2013, OM)

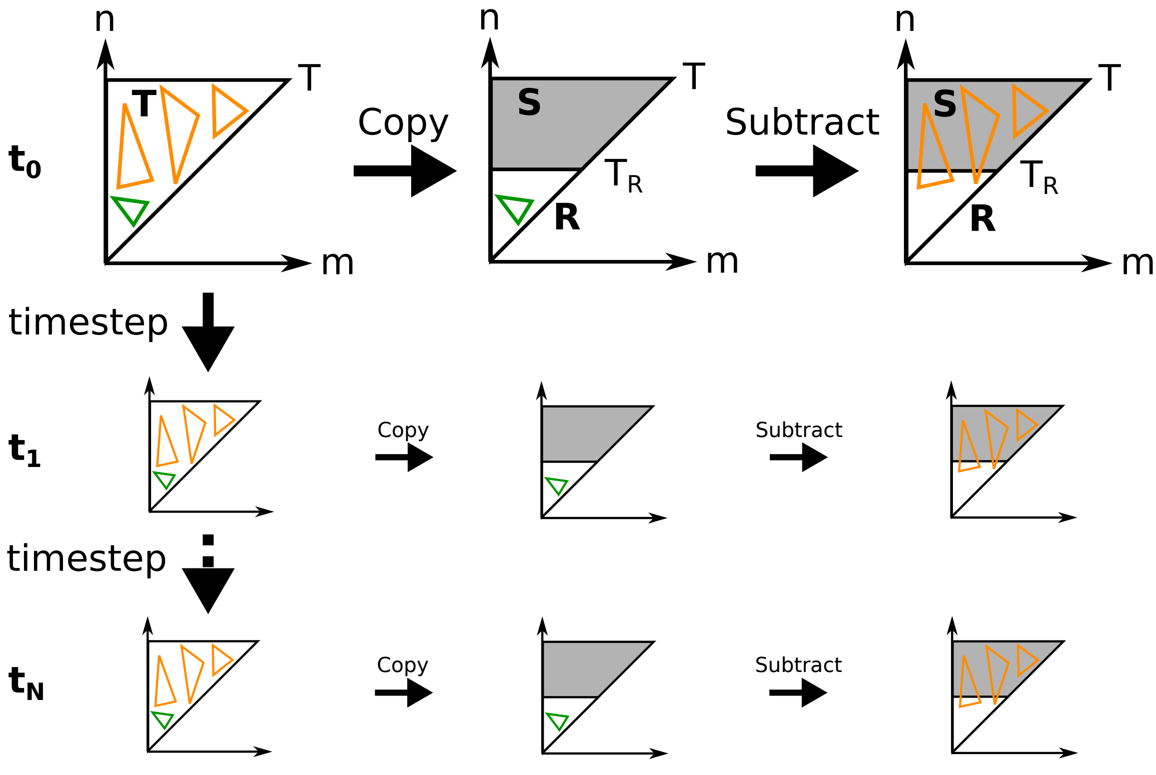


386-level Channel Flow

Kitsios et. al. (2017, C&F)

Decomposition of Scales: Triangular Truncation

DNS	Truncated DNS	Subgrid Tendency
$\frac{\partial \mathbf{q}}{\partial t} \equiv \mathbf{q}_t = \mathcal{N}(\mathbf{q}; \mathbf{T})$	$\mathbf{q}_t^{\mathbf{R}} = \mathcal{N}(\mathbf{q}; \mathbf{R})$	$\mathbf{q}_t^{\mathbf{S}} = \mathbf{q}_t - \mathbf{q}_t^{\mathbf{R}} \equiv \mathcal{N}(\mathbf{q}; \mathbf{S})$



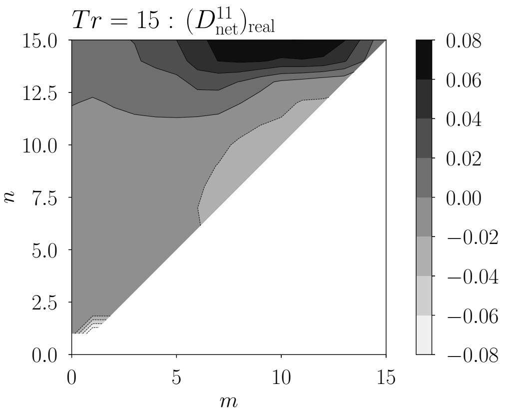
- In most primitive form, subgrid modelling relates $\mathbf{q}_t^{\mathbf{S}}$ to $\mathbf{q}$.

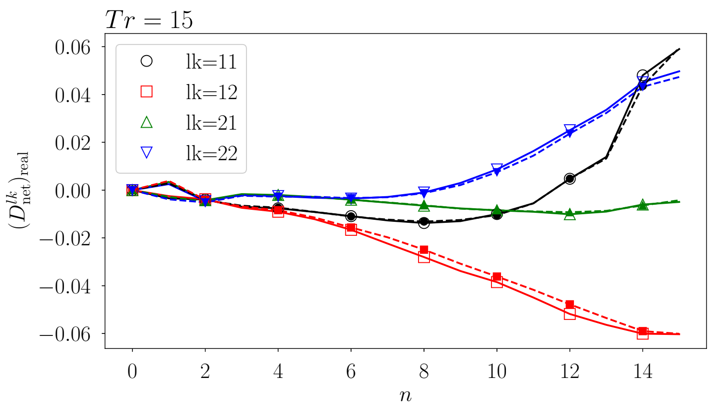
Fluctuating Subgrid Tendency : Eddy-Eddy Interactions

- Subgrid interactions are *local* in wavenumbers space, not grid space.
- Unique Matrix captures level interactions per scale (Frederiksen & Kepert, 2006)

Deterministic	Stochastic
$\widehat{\mathbf{q}}_t^{\mathbf{S}}(t) = -\mathbf{D}_{\mathbf{net}}\widehat{\mathbf{q}}(t)$	$\widehat{\mathbf{q}}_t^{\mathbf{S}}(t) = -\mathbf{D}_{\mathbf{d}}\widehat{\mathbf{q}}(t) + \widehat{\mathbf{f}}(t)$
$\left\langle \widehat{\mathbf{q}}_t^{\mathbf{S}}(t)\widehat{\mathbf{q}}^{\dagger}(t)\right\rangle = -\mathbf{D}_{\mathbf{net}}\left\langle \widehat{\mathbf{q}}(t)\widehat{\mathbf{q}}^{\dagger}(t)\right\rangle$	$\mathbf{D}_{\mathbf{d}}$ incorporates history
$\mathbf{D}_{\mathbf{net}} = -\left\langle \widehat{\mathbf{q}}_t^{\mathbf{S}}(t)\widehat{\mathbf{q}}^{\dagger}(t)\right\rangle \left\langle \widehat{\mathbf{q}}(t)\widehat{\mathbf{q}}^{\dagger}(t)\right\rangle^{-1}$	$\mathbf{D}_{\mathbf{b}} \propto$ variance of $\widehat{\mathbf{f}}(t)$

- At $T_R = 15$ baroclinic instability is not completely resolved
- Dissipation anisotropic, negative for many scales, off diagonals significant





Solid - Jan.

Dash - July

All Subgrid Interactions

$$\widehat{\mathbf{q}}^{\mathrm{S}}_t = -\mathbf{D}_{\mathrm{d}}\widehat{\mathbf{q}}(t) + \widehat{\mathbf{f}}(t)$$

$$\mathbf{q}^{\mathrm{S}}_t = \widehat{\mathbf{q}}^{\mathrm{S}}_t$$

eddy-eddy:
subgrid eddies with *resolved eddies*

$$+\mathbf{J}$$

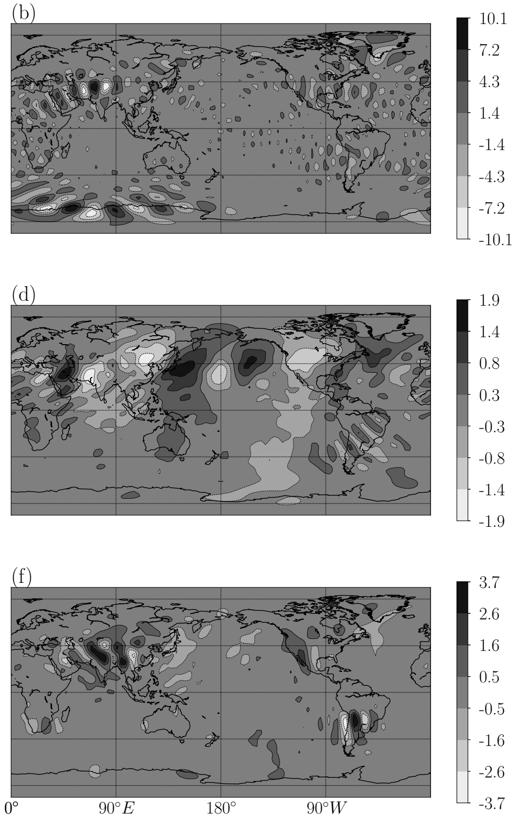
meanfield Jacobian:
subgrid meanfield & topography with *resolved meanfield & topography*

$$-\bar{\mathbf{D}}\bar{\mathbf{q}}$$

eddy-meanfield:
subgrid eddies with *resolved meanfield*

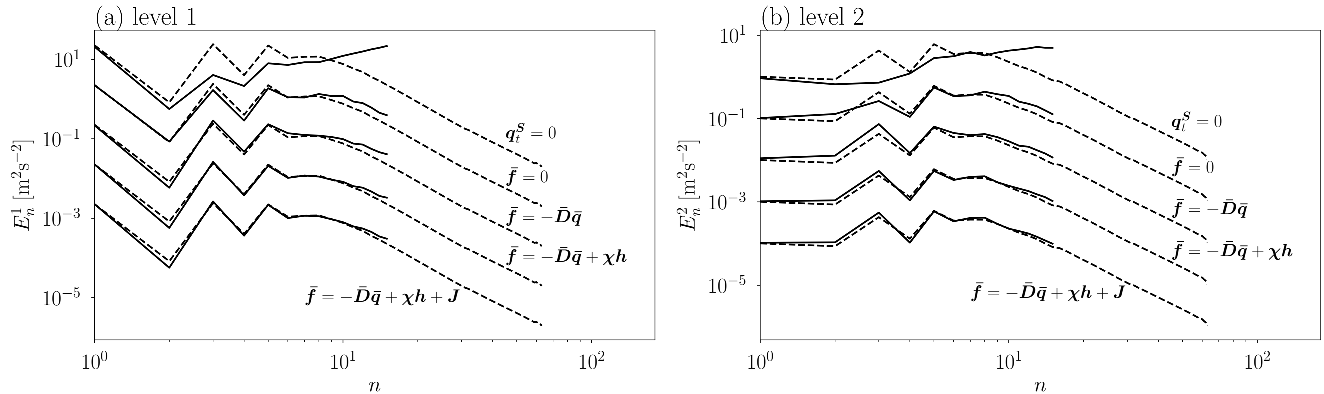
$$+\boldsymbol{\chi}h$$

eddy-topographic:
subgrid eddies with *resolved topography*



Validation: comparison of $T_R = 15$ LES to $T_R = 63$ DNS

- Eddy-eddy parameterisation has the dominant impact.
- Best agreement in terms of the kinetic energy spectra, mean nonzonal streamfunction (not shown), and mean zonal velocity (not shown) requires parameterisation of all subgrid interactions.



Related ongoing subgrid parameterisation research:

1. Working with Peter Dobrohotoff, Martin Dix and Jorgen Frederiksen to modify the eddy-eddy parameterisation in the ACCESS atmospheric model.
2. Assessing spectral properties of the MOM ocean model at various resolutions and dissipation operators.
3. Applying approach to a quasi-geostrophic Antarctic circumpolar current.

Thank You

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