Diagnostic of energy cascades in the IFS

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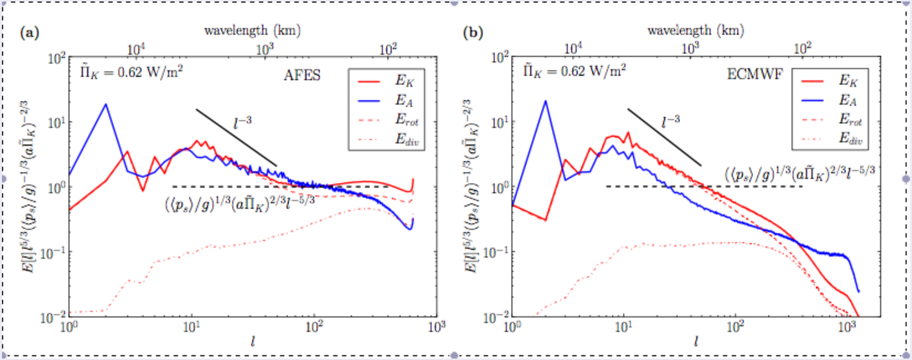
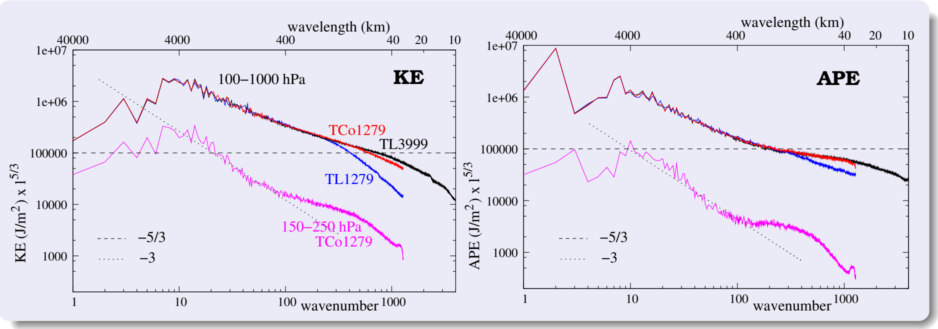
- Investigate the role of numerics and parametrisations in the energy cascades
- Investigate the role of stochastic physics and backscatter scheme

IFS versus AFES (Augier and Lindborg, 2013)



KE/APE spectra in the current IFS



Power spectra

Spectral representation of KE power spectrum on the sphere

$$E_{K\,n}(p) = \sum_{m=-n}^{m=n} (2-\delta_m^0) \frac{a^2(|\zeta|_{m,n}^2 + |d|_{m,n}^2)}{2n(n+1)}$$

where m is the zonal wavenumber and n the total wavenumber.

Global mean

$$< E_K(p) >= \sum_{n=0}^{n=N} E_{K\,n}(p)$$

Equation for KE and APE spectral variances (AL13)

$$
\begin{aligned}
\partial_t E_{K\,n} &= C_n + T_{K\,n} + L_n + F^{p_b}_{K\;n} - F^{p_t}_{K\;n} - D_{K\,n} \\
\partial_t E_{A\,n} &= -C_n + T_{A\,n} + F^{p_b}_{A\;n} - F^{p_t}_{A\;n} + G_n - D_{A\,n}
\end{aligned}
$$

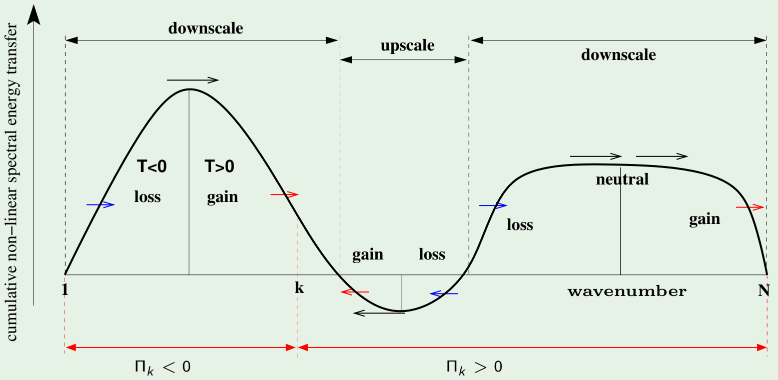
- C_n is the conversion term from APE into KE,
- T_n is the tendency of KE/APE due to the non-linear spectral transfer between wavenumber n and the other wavenumbers,
- L_n is the Coriolis contribution to the spectral transfer,
- F_n are the "resolved" vertical fluxes of KE or APE at the top and bottom boundaries,
- G_n is the "diabatic" term
- D_n are the dissipation terms

Cascades

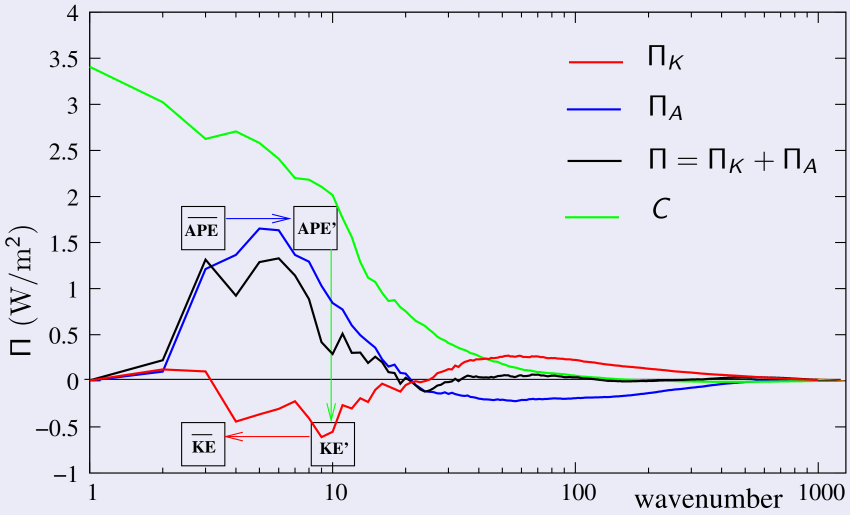
Cumulative spectral energy transfers (AL13)

$\Pi_n = \sum_{i=N}^{i=n} T_i$ with $\Pi_{n=0} = \sum_{i=N}^{i=0} T_i = \int_{sphere} \left[\vec{\nabla}_h . (e.\vec{u_h}) \right] = 0$

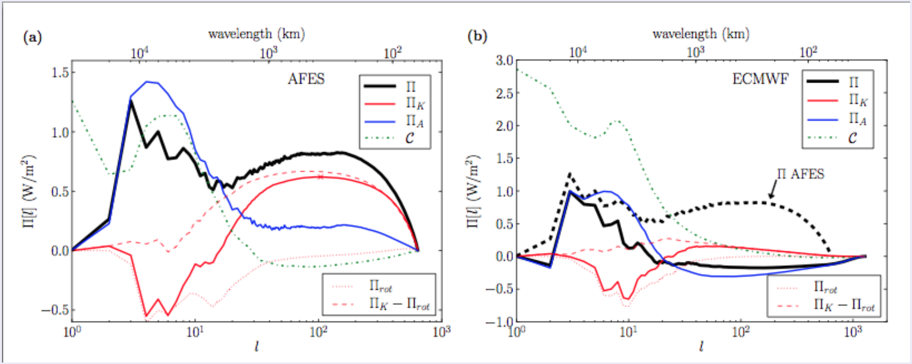
$\Longrightarrow \quad T_i = \partial \Pi_i / \partial n$



NL spectral transfer in the IFS (TL1279)



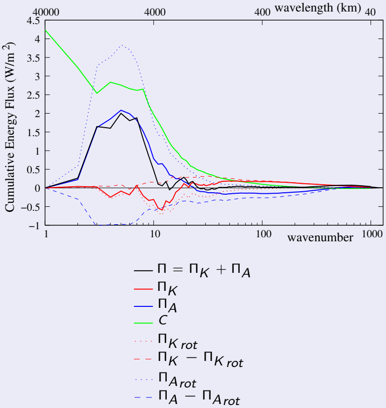
IFS versus AFES (AL13)



In the oper IFS, there is almost no energy cascade for total energy at the mesoscales.

NL spectral transfer in the IFS (TCo1279)

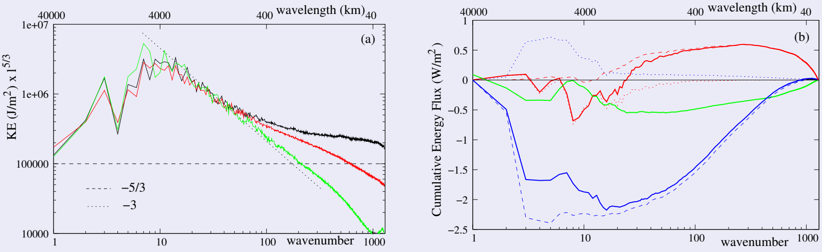
TCo1279



$$\Delta\mathcal{D}_K \simeq \Delta\mathcal{C} + \Delta\Pi_K$$
$$\Delta(\mathcal{G} - \mathcal{D}_A) \simeq \Delta\mathcal{C} - \Delta\Pi_A$$

	n=0-20	n=20-1279
$\Delta\mathcal{C}$	3.53	0.70
$\Delta\Pi_A$	-0.14	0.14
$\Delta\Pi_K$	-0.07	0.07
$\Delta\mathcal{D}_K$	3.46	0.77
$\Delta\mathcal{G} - \Delta\mathcal{D}_A$	3.67	0.56
$\Delta\mathcal{G} - \Delta\mathcal{D}$	0.21	-0.21

Sensitivity: DynCore only (same I.C. as full model)

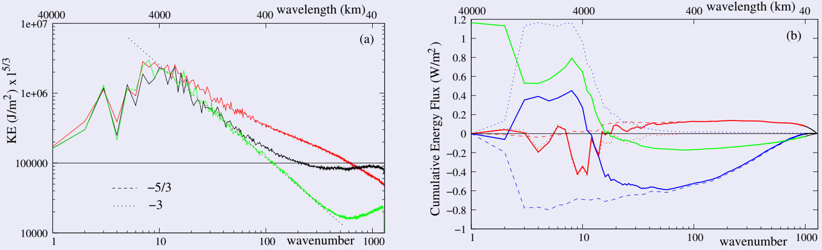


KE spectra

- black: adiabatic run with orography
- green: adiabatic run, flat orography
- red: full model

NL transfers for the adiabatic run with orography

Sensitivity: Held and Suarez

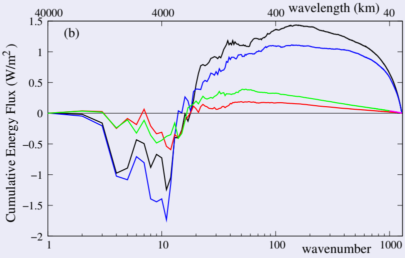


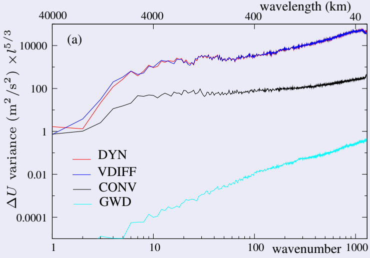
KE spectra

- black: Held&Suarez run with orography
- green: Held&Suarez run, flat orography
- red: full model

NL transfers for the Held&Suarez run with orography

Sensitivity: Vertical Diffusion Parametrisation



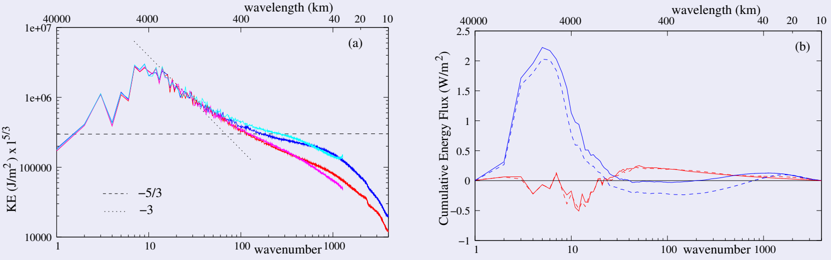


Π_K

- black: no-VDIFF in the whole atmosphere
- blue: no-VDIFF in the boundary layer and at the surface
- green: no-VDIFF only in the free atmosphere
- red: full model

Variance of zonal wind tendencies

Sensitivity: Convection Scheme



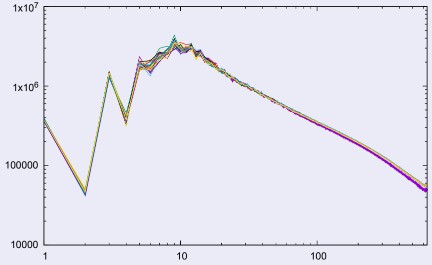
KE spectra

- magenta: TCo1279, with convection scheme
- red: TL3999, with convection scheme
- cyan: TCo1279, without convection scheme
- blue: TL3999, without convection scheme

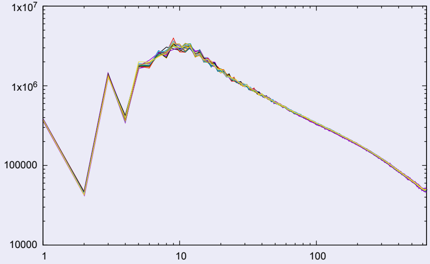
NL transfers with (solid lines) and without (dashed lines) convection scheme.

KE spectra of EPS members (TCo639, no I.C. pert.)

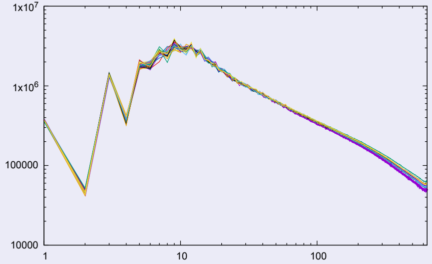
SPPT + SPBS



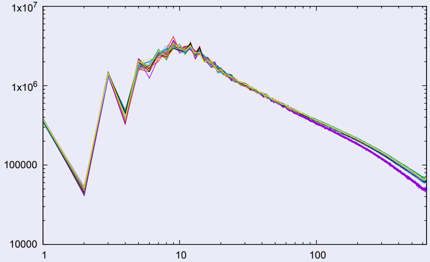
SPBS only



SPP

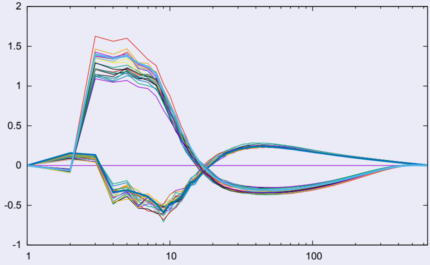


SPP+SPPT

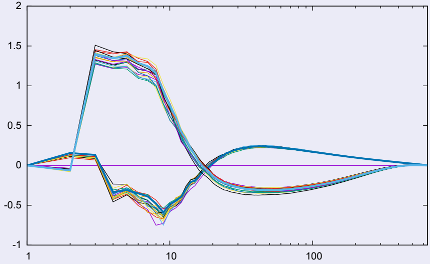


Cumulative N.L. transfers (troposphere)

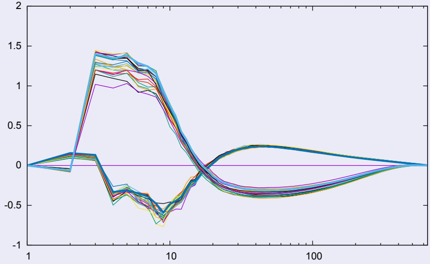
SPPT + SPBS



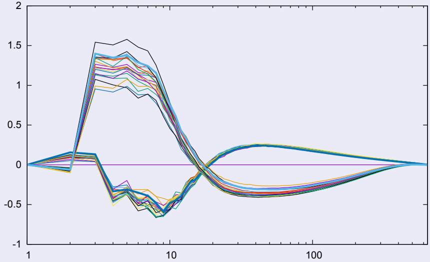
SPBS only



SPP

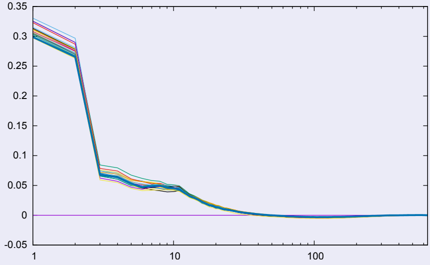


SPP+SPPT

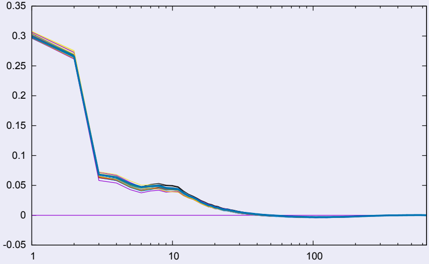


Cumulative APE→KE conversion (surface)

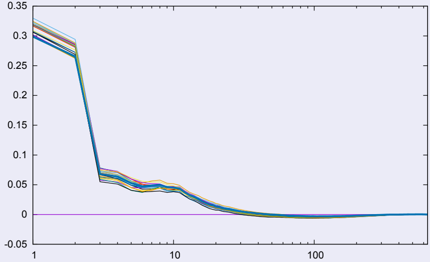
SPPT + SPBS



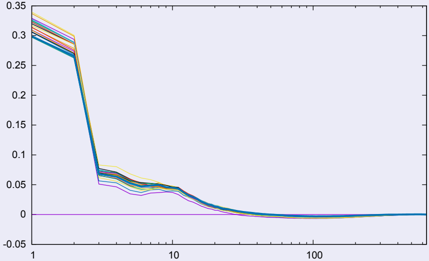
SPBS only



SPP



SPP+SPPT



Conclusion/Future Work

- Spectra and explicit non-linear transfers as defined by AL2013 are constrained by the parametrisations, in particular the vertical diffusion.
- Parametrisations inject "directly" variance at all scales (energy transfer not shown by the explicit NL transfers). Do parametrisation control model error growth?
- Compute closed budgets with detailed terms, including parametrisations.
- New diagnostic to analyse stochastic perturbations in the EPS.