Exploring the impacts of stochastic representations of model uncertainties

…in the physics and dynamics components…

Sarah-Jane Lock, Martin Leutbecher, Peter Bechtold, Richard Forbes, Michail Diamantakis

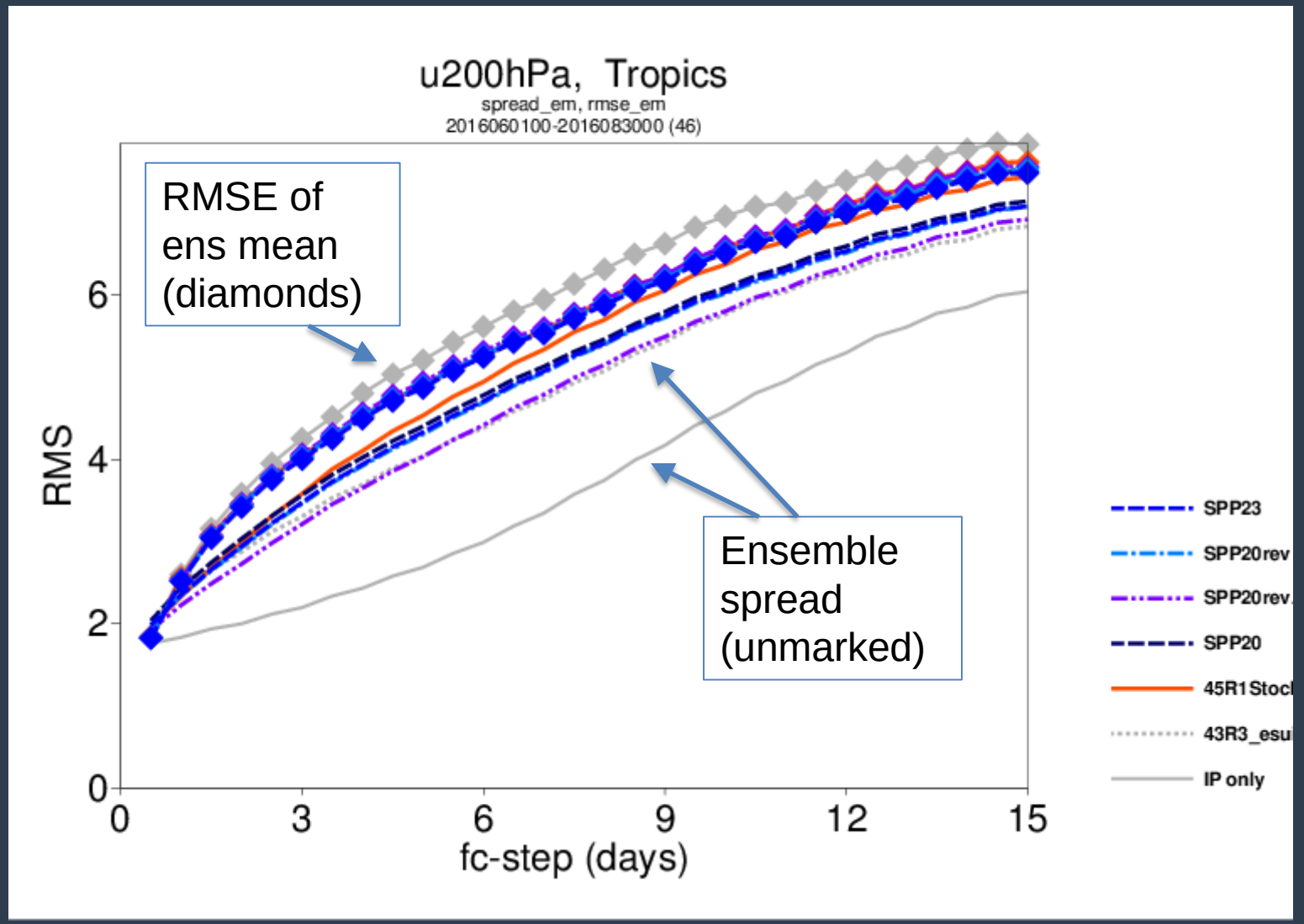
Research Department, ECMWF

sarah-jane.lock@ecmwf.int

ECMWF

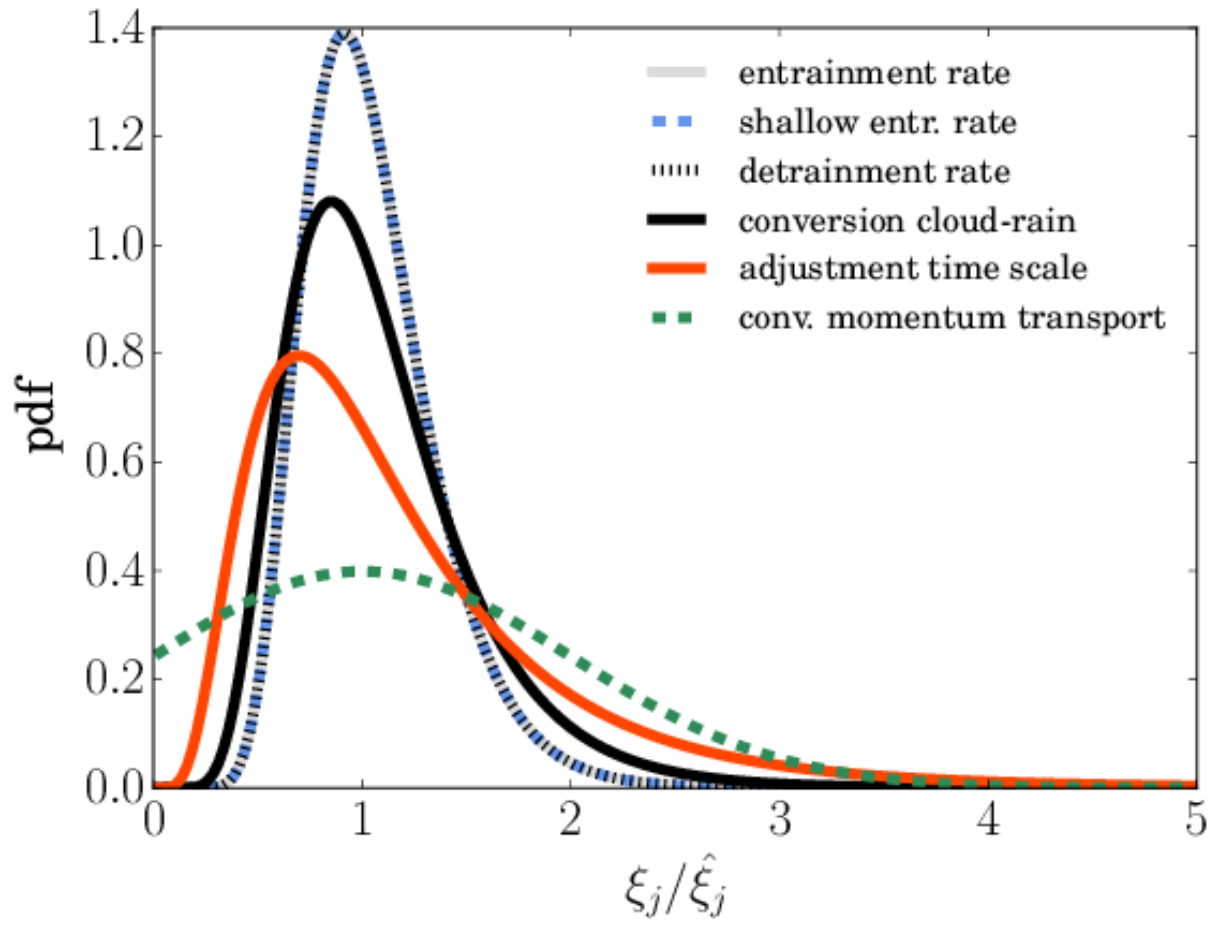
© ECMWF July 11, 2018

Background: Stochastic representations of model uncertainties



sarah-jane.lock@ecmwf.int

Stochastic model uncertainty representation: physics via **SPP**



Stochastically Perturbed Parametrisations (SPP)

(Ollinaho et al., 2017, QJRMS)

Quantities within parametrisation schemes are multiplied with noise from a 2D random pattern:

$$\xi = r\hat{\xi}$$

correlated in space (2000 km) and time (72 h).

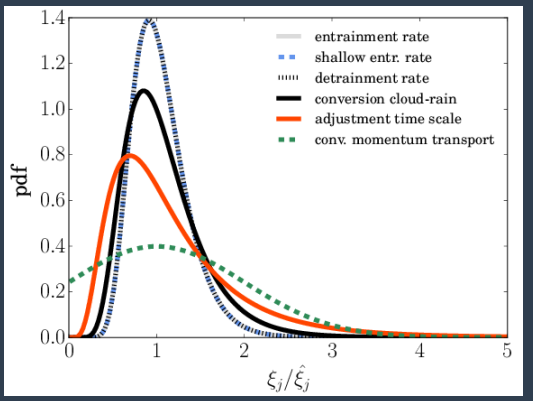
e.g. convection scheme parameters are perturbed with numbers drawn from distributions shown

Currently: **20 independent perturbations** of quantities in:

- boundary layer
- radiation
- large-scale precipitation and cloud
- convection

sarah-jane.lock@ecmwf.int

Stochastic model uncertainty representation: **“SPP20”**



Turbulent diffusion & sub-grid orography (4)
- transfer coefficient for momentum
- coeff. in turb. orographic form drag scheme
- stdev of subgrid orography
- vertical mixing length scale (stable BL)

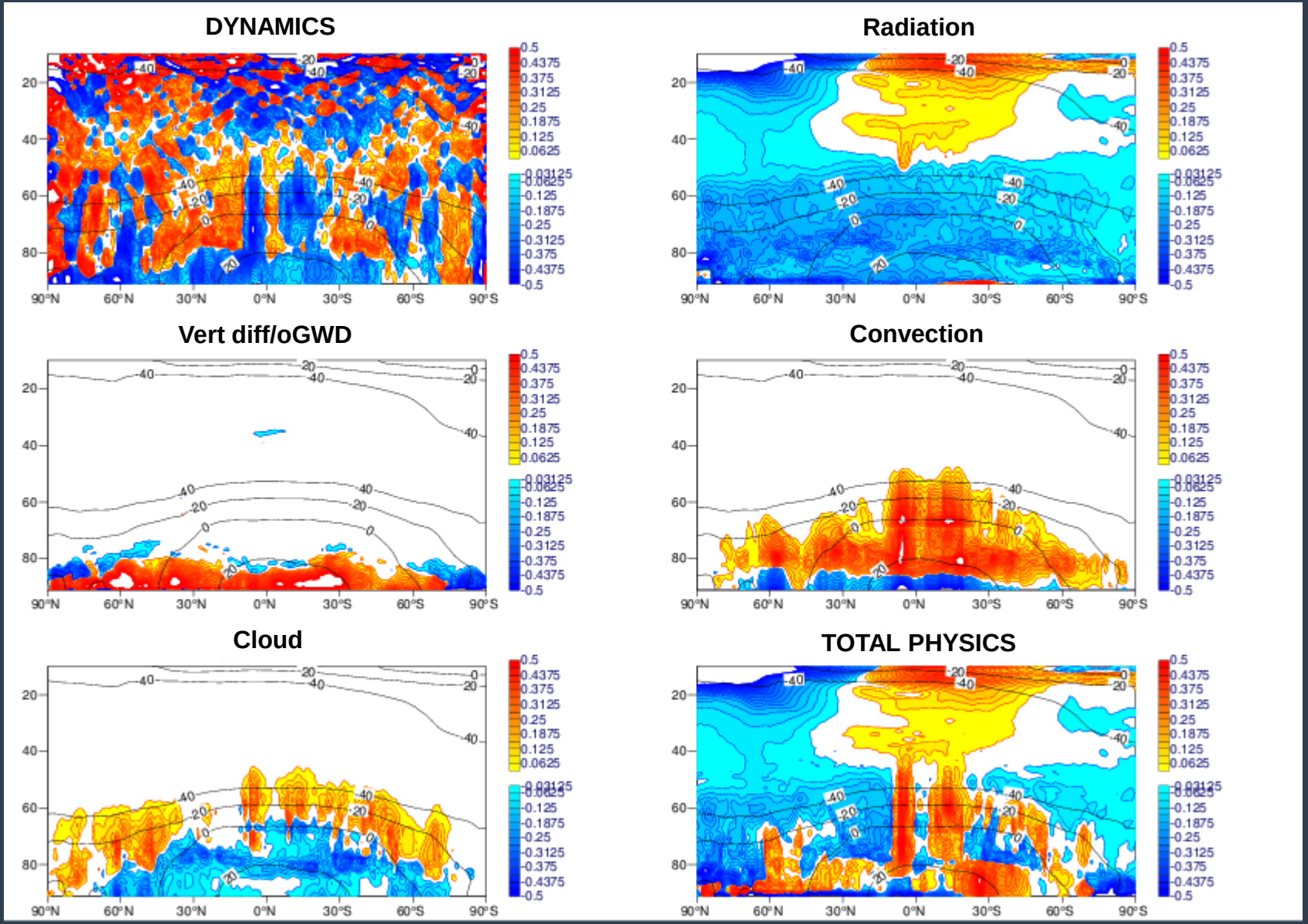
Convection (7)
- entrainment rate
- shallow entrainment rate
- detrainment rate for penetrative convection
- conversion coefficient cloud to rain
- conv. momentum transport (meridional/zonal)
- adjustment time scale in CAPE closure

Radiation (5)
- cloud vert. decorrelation height in McICA
- fractional stdev of horizontal distrib. of water content
- effective radius of cloud water and ice
- scale height of aerosol norm. vert. distrib.
- optical thickness of aerosol

Large-scale precipitation & cloud (4)
- RH threshold for onset of stratiform cond.
- diffusion coeff. for evap. of turb. mixing
- critical cloud water content
- threshold for snow autoconversion

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

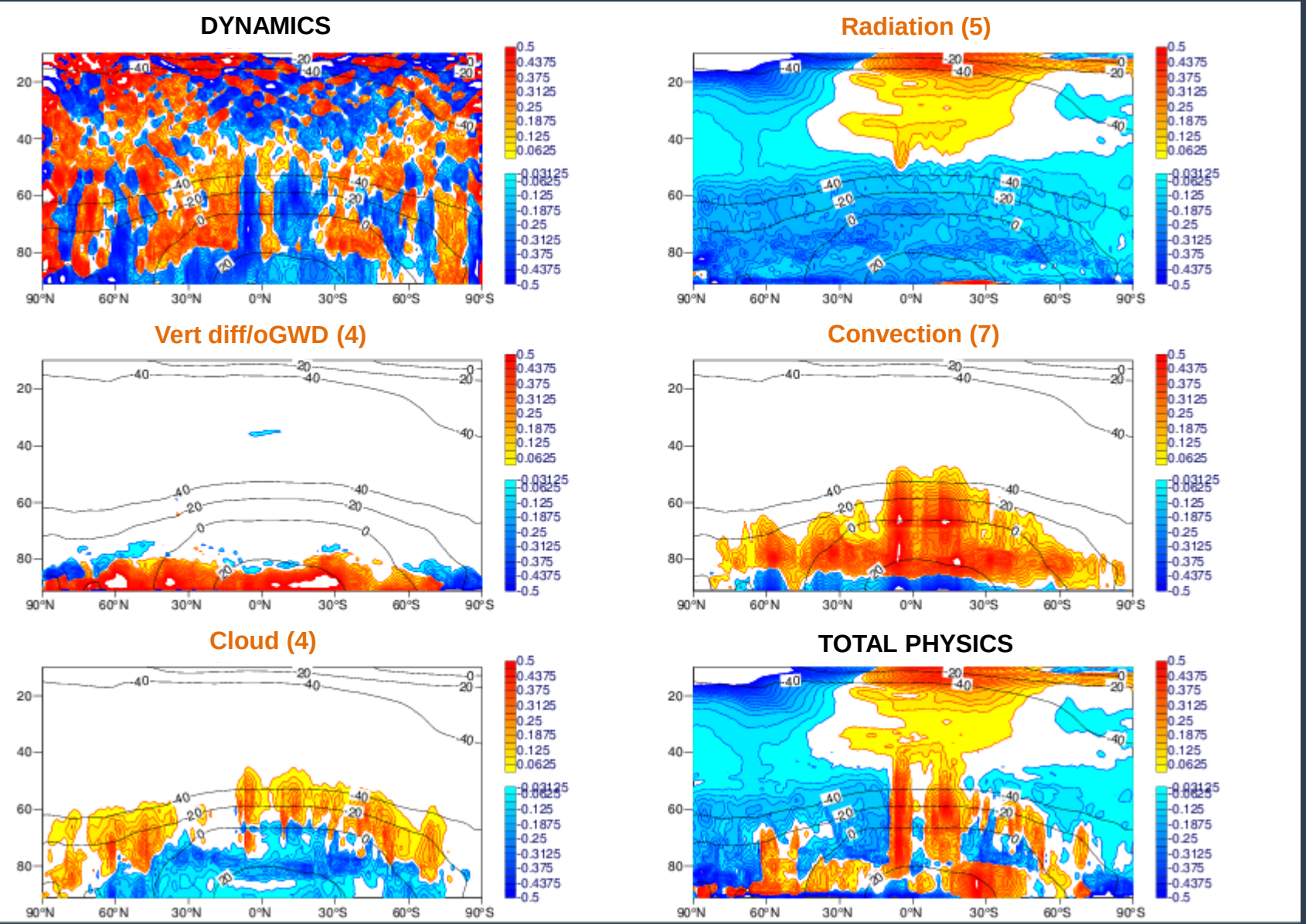
Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

Contours: $\pm[0.03-0.5]$ K/3h

Control forecast
(unperturbed model)

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

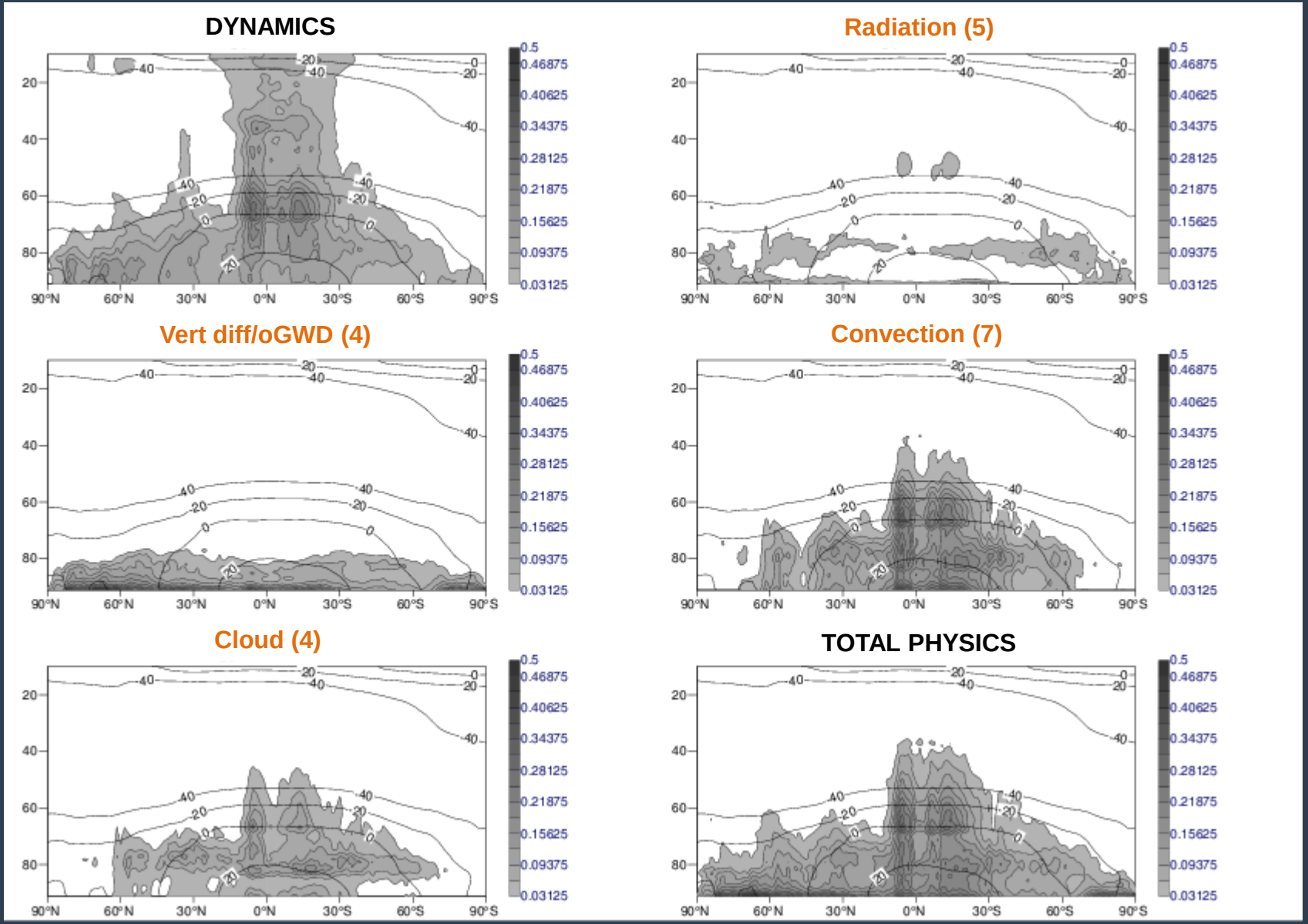
Contours: $\pm[0.03-0.5]$ K/3h

SPP20: default

Ensemble mean
(20 members)

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

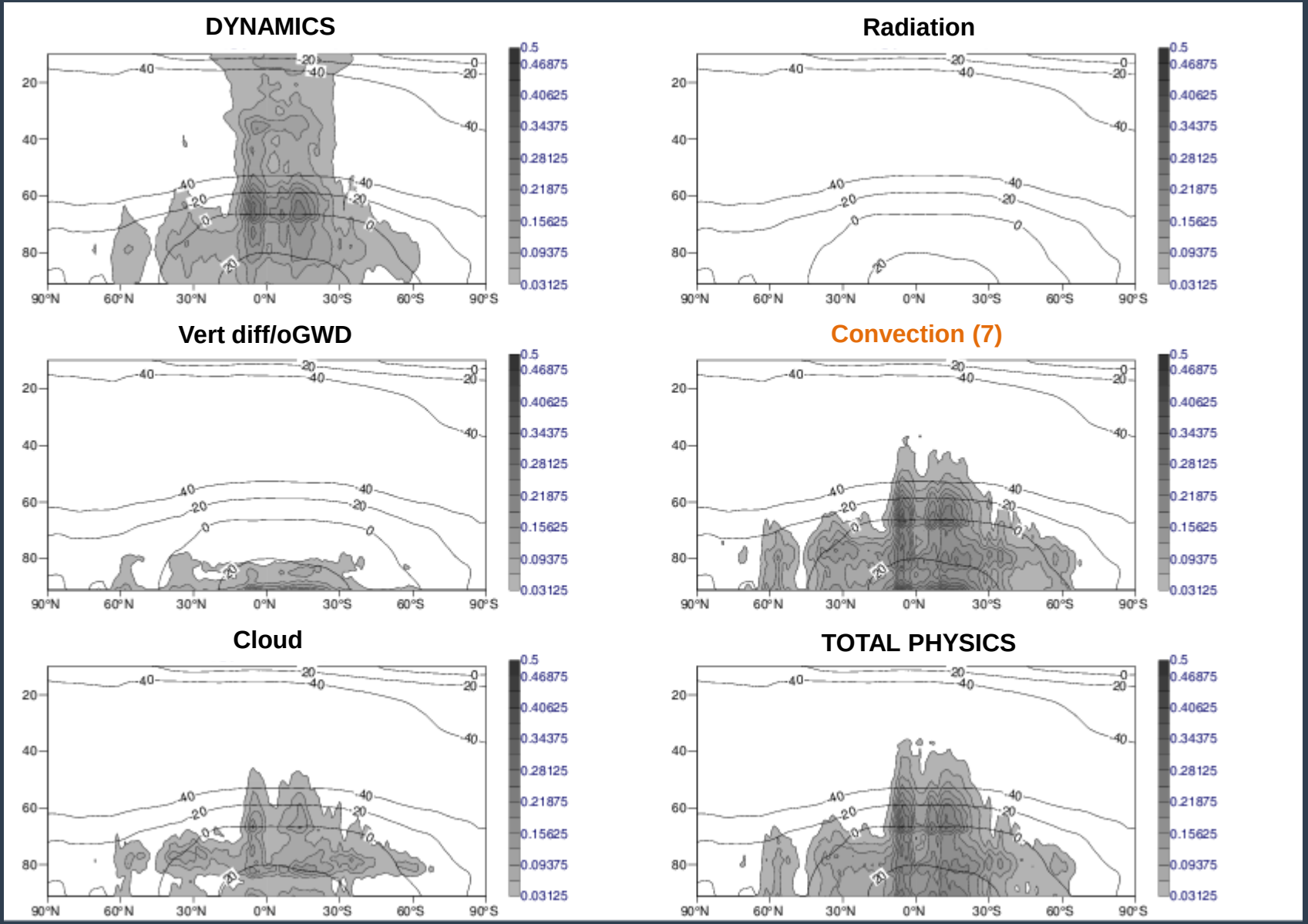
Contours: $[0.03 - 0.5]$ K/3h

SPP20: default

Ensemble standard deviation
(20 members)

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

Contours: $[0.03 - 0.5]$ K/3h

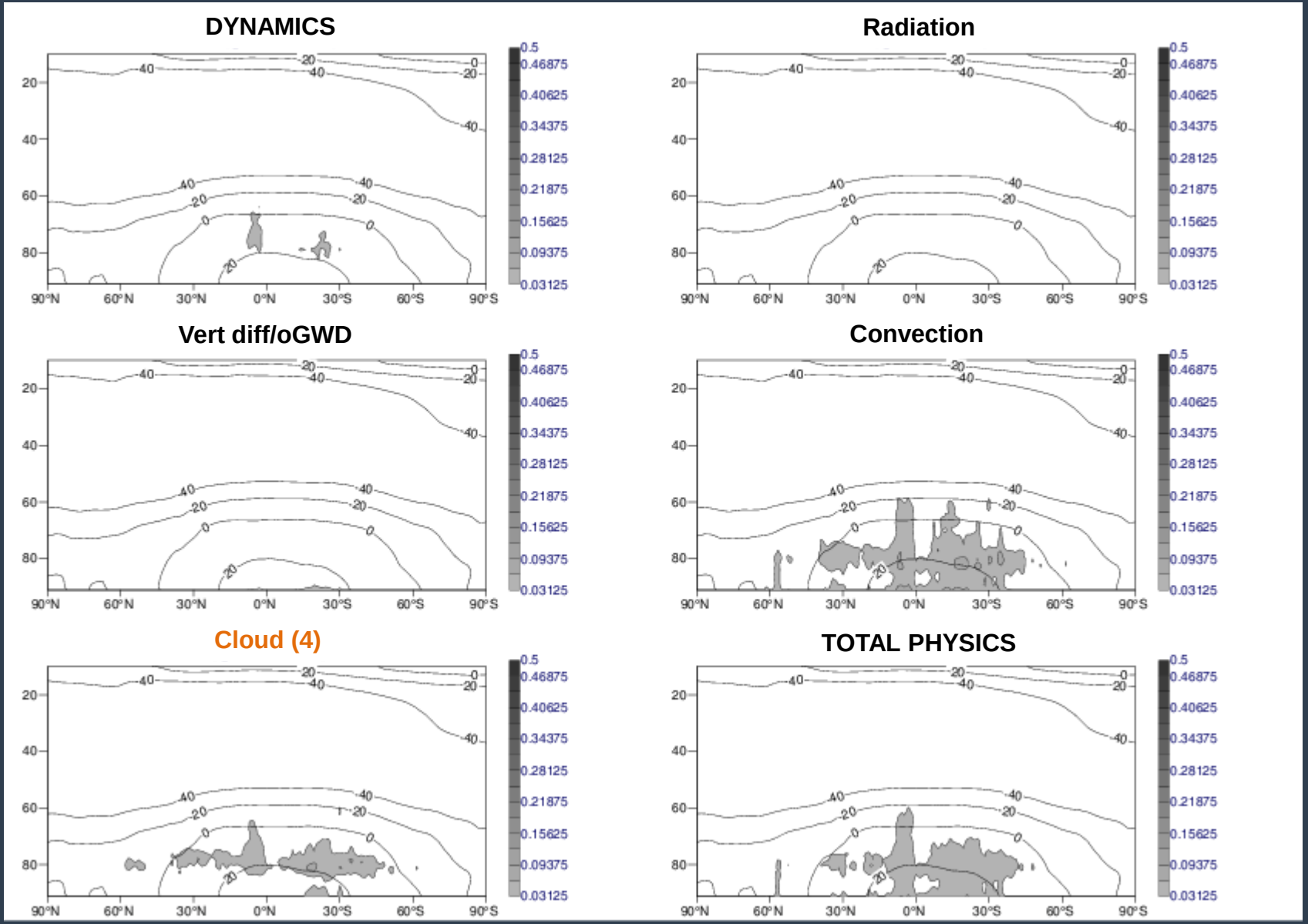
SPP (7): Convection

- deep entrainment rate
- shallow entrainment rate
- detrainment rate for penetrative convection
- conversion coefficient cloud to rain
- conv. momentum transport (meridional/zonal)
- adjustment time scale in CAPE closure

Ensemble standard deviation
(20 members)

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

Contours: $[0.03 - 0.5]$ K/3h

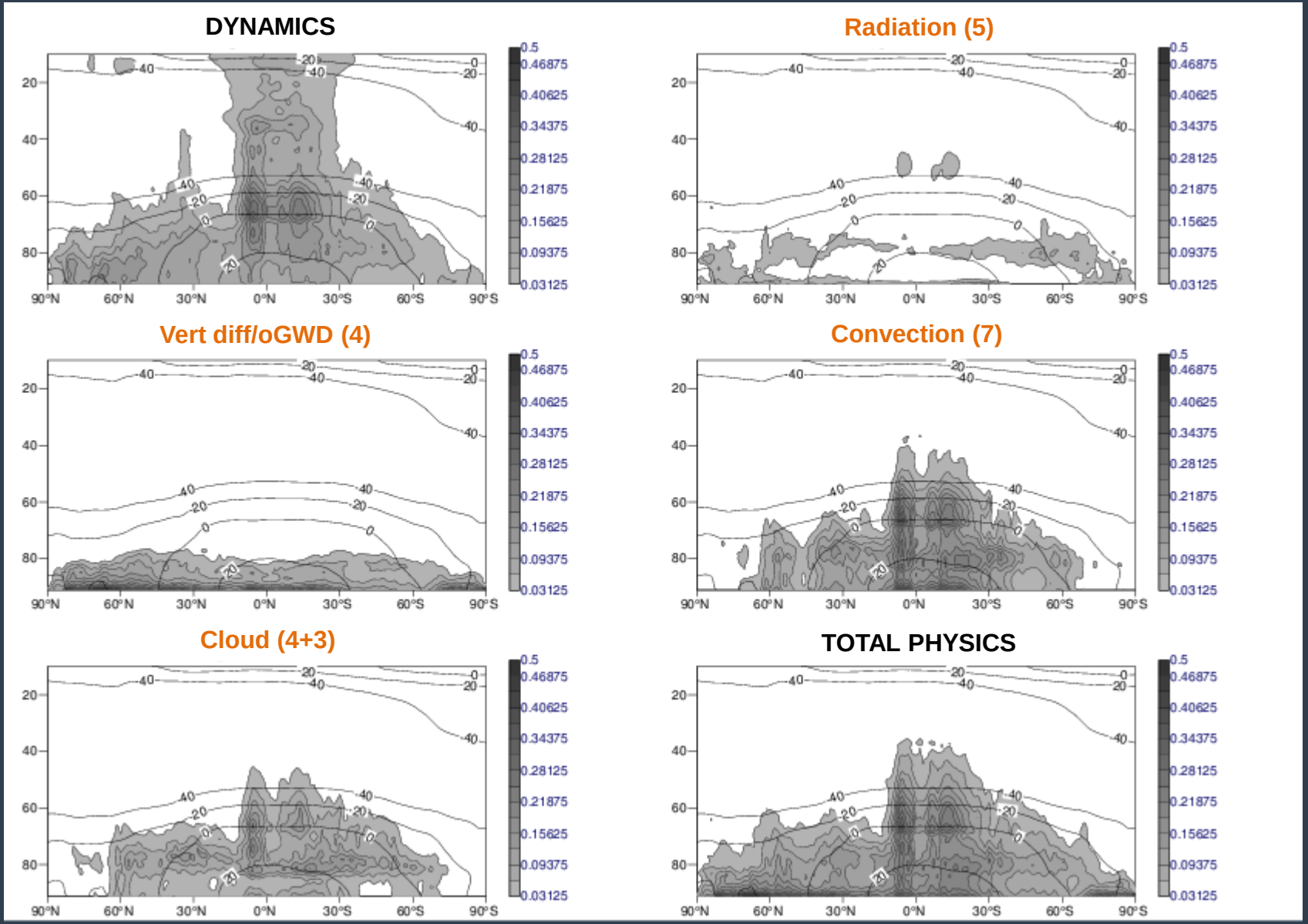
SPP (4): LSP/Cloud

- RH threshold for onset of stratiform condensation
- diffusion coeff. for evap. of turbulent mixing
- critical cloud water content
- threshold for snow autoconversion

Ensemble standard deviation
(20 members)

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

Contours: $[0.03 - 0.5]$ K/3h

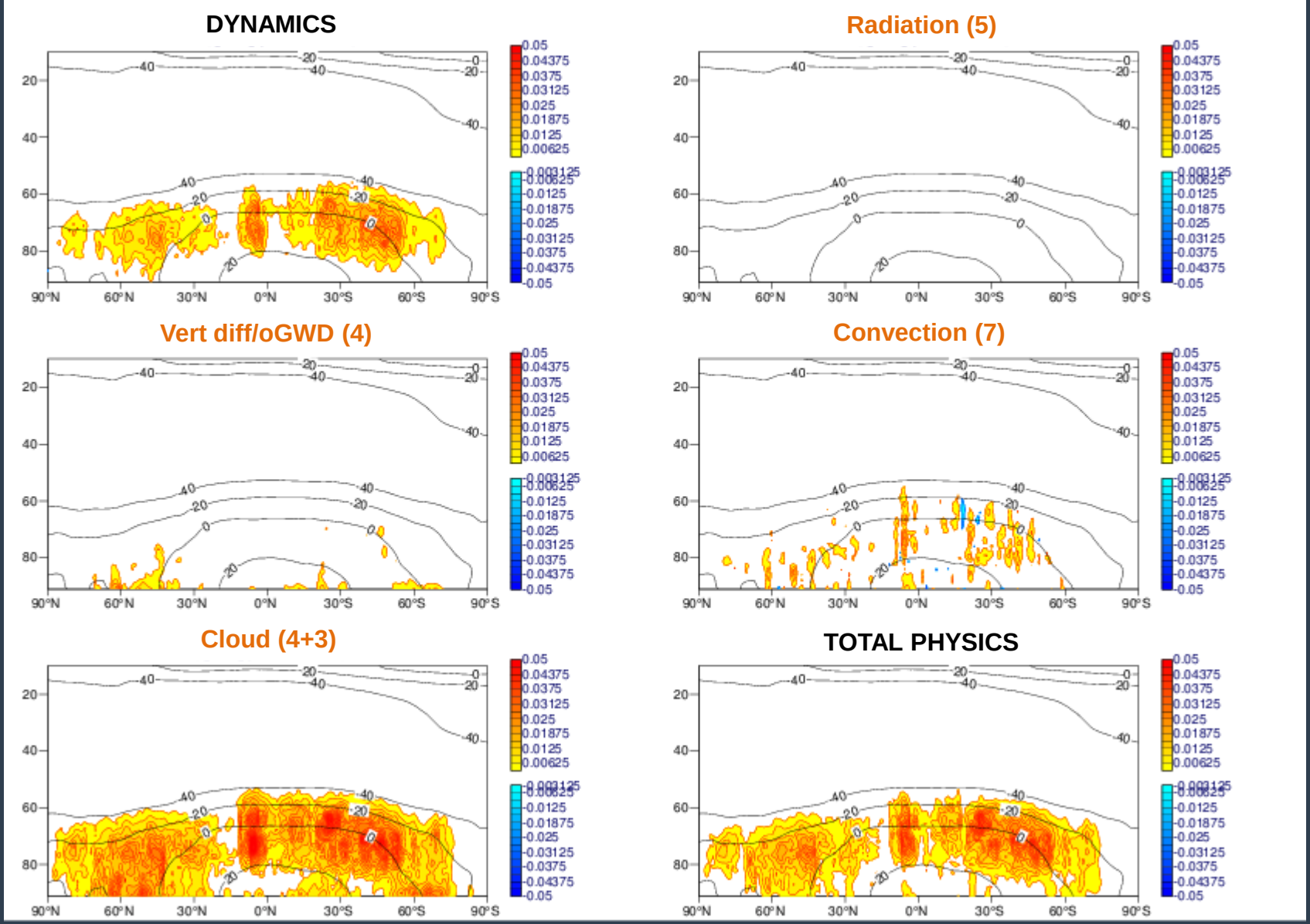
SPP23: new microphysics perturbations

- rain evaporation rate
- snow sublimation rate
- saturation adjustment due to adiabatic vertical velocity

Ensemble standard deviation (20 members)

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

Contours: $[0.003 - 0.05]$ K/3h

SPP23 – SPP20

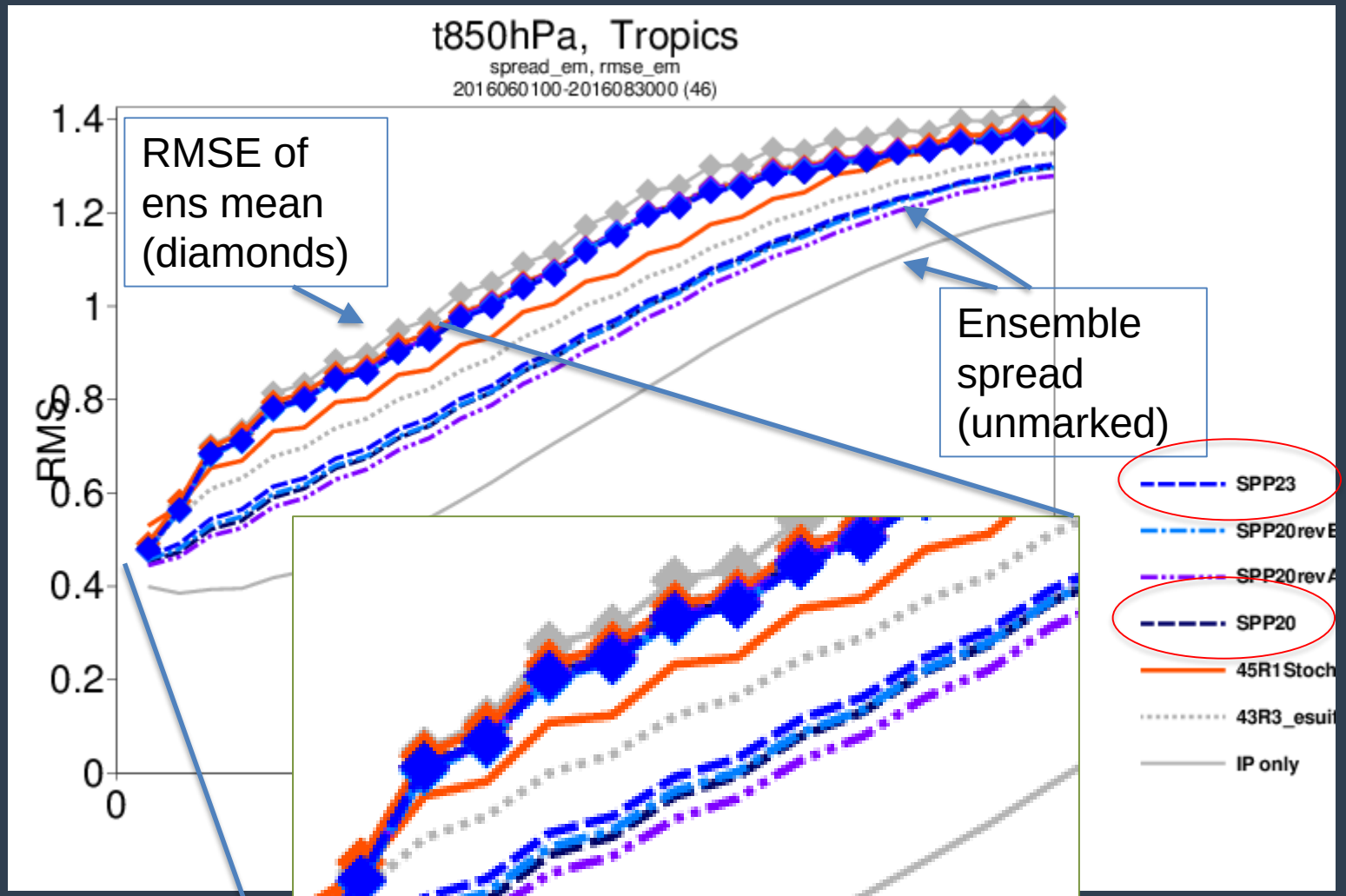
Impact from:

- rain evaporation rate
- snow sublimation rate
- saturation adjustment due to adiabatic vertical velocity

Ensemble standard deviation (20 members)

sarah-jane.lock@ecmwf.int

Recall: Improving the spread/error relationship



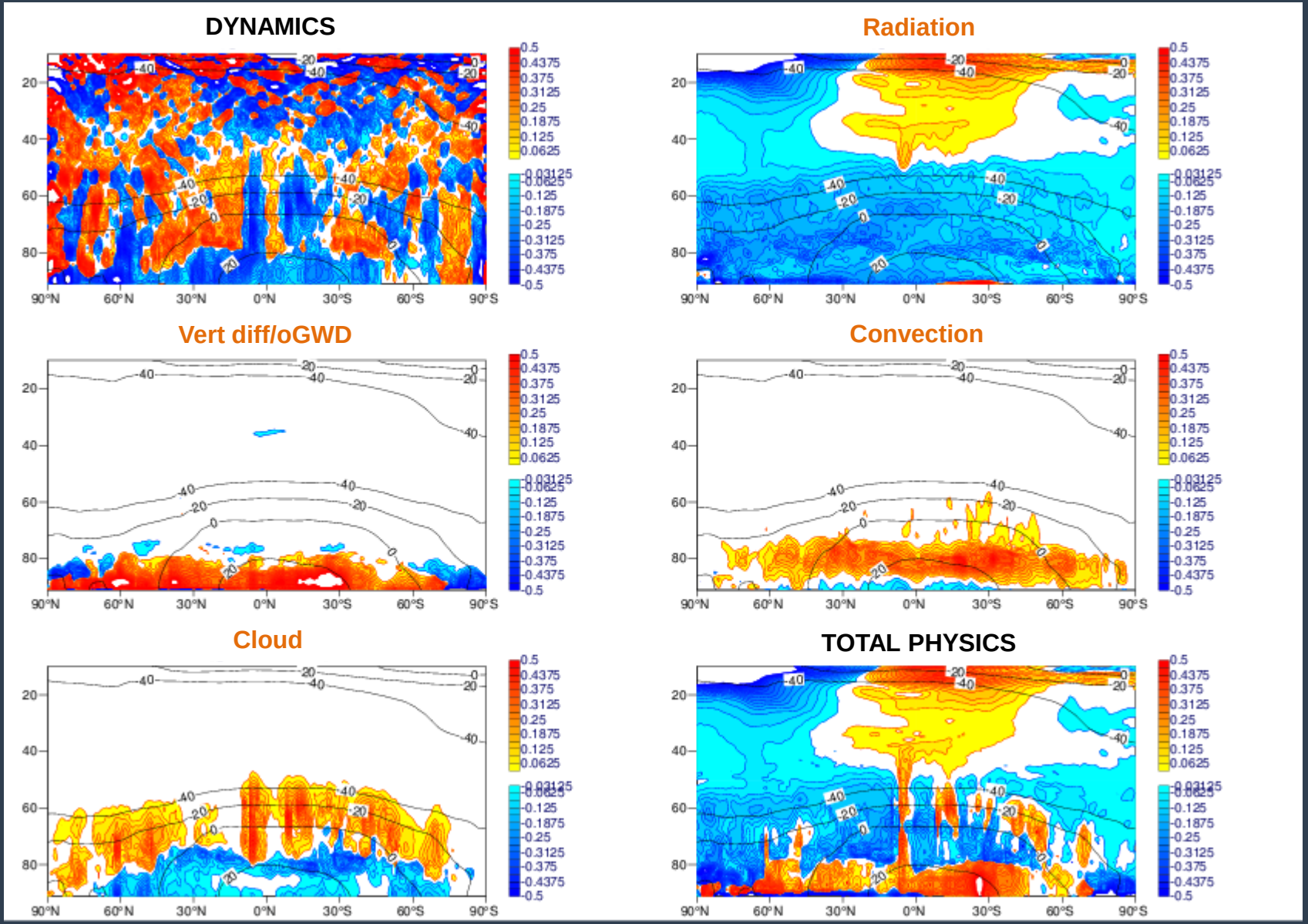
SPP20 –> SPP23

Impact from:

- rain evaporation rate
- snow sublimation rate
- saturation adjustment due to adiabatic vertical velocity

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

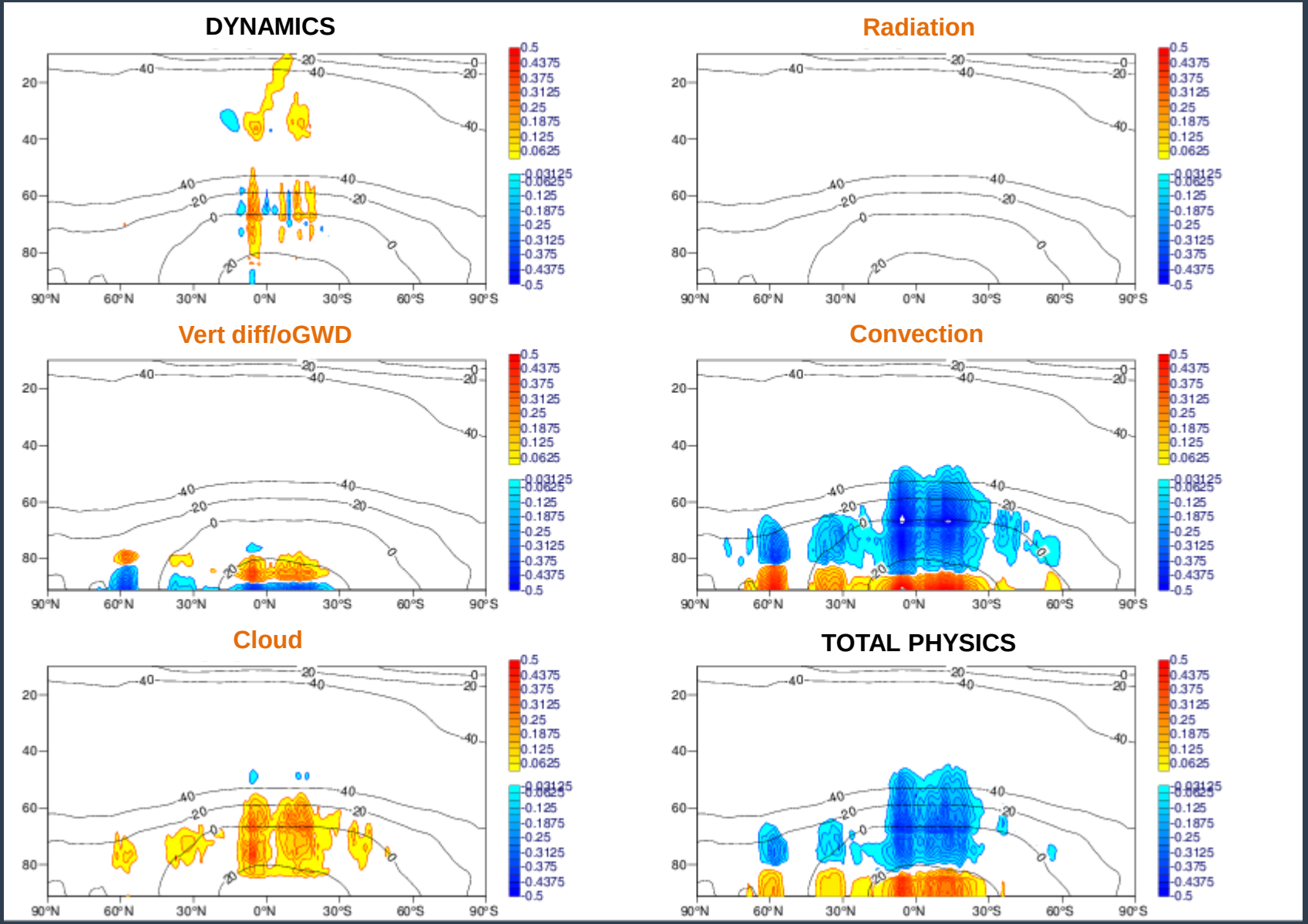
Contours: $[0.03 - 0.5]$ K/3h

SPP, deep convection param OFF

Ensemble mean
(20 members)

sarah-jane.lock@ecmwf.int

Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

Contours: $[0.03 - 0.5]$ K/3h

SPP, deep convection param OFF

minus

SPP

Ensemble mean
(20 members)

sarah-jane.lock@ecmwf.int

Stochastic model uncertainty representation: dynamics via **STOCHDP**

Stochastically perturbed semi-Lagrangian departure points (STOCHDP)

(outlined in Leutbecher et al., 2017, QJRMS)

Diamantakis & Magnusson (2016): convergence rate of semi-Lagrangian departure point (DP) estimates is slowest where the flow is most complex.

=> Flow-dependent model uncertainty representation for the DP estimate:

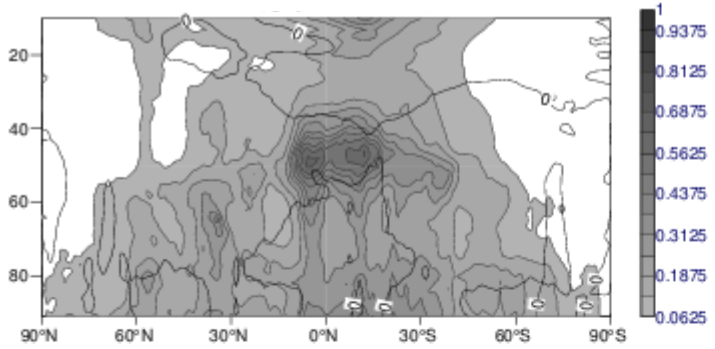
$$x^{(l)\prime} = x^{(l)} + e\left(x^{(l)} - x^{(l-m)}\right)$$

where $x^{(l)}$ is the lat/lon/vertical DP component at the l-th iteration, perturbed with a random number, e, modulated by the level of convergence between 2 iterations.

sarah-jane.lock@ecmwf.int

Diagnosing **STOCHDP** impacts: model tendencies, U

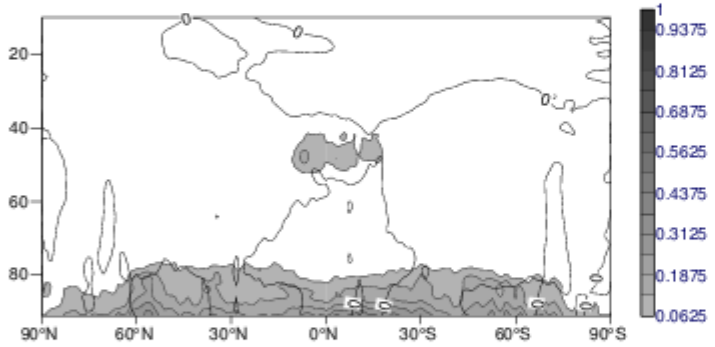
DYNAMICS



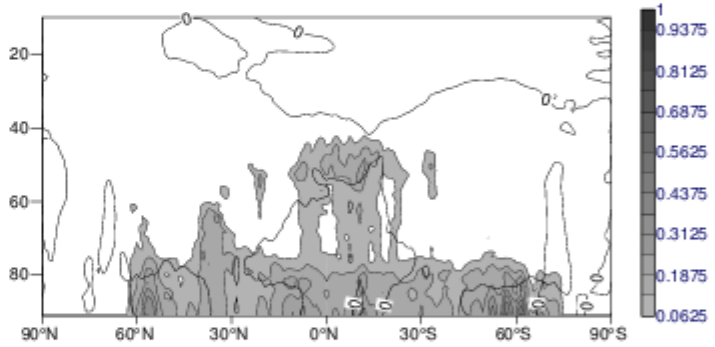
WARNING!

First results – lots more testing / development to do!

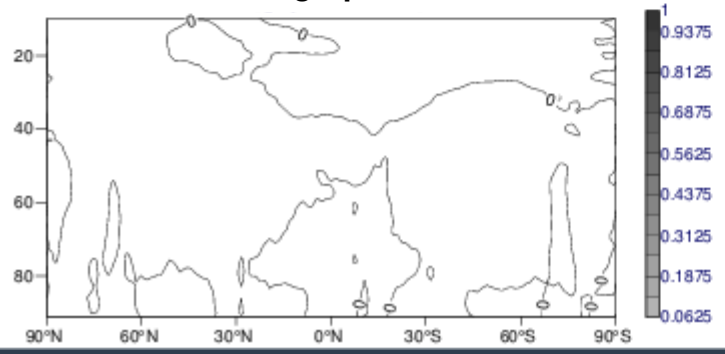
Vert diff/oGWD



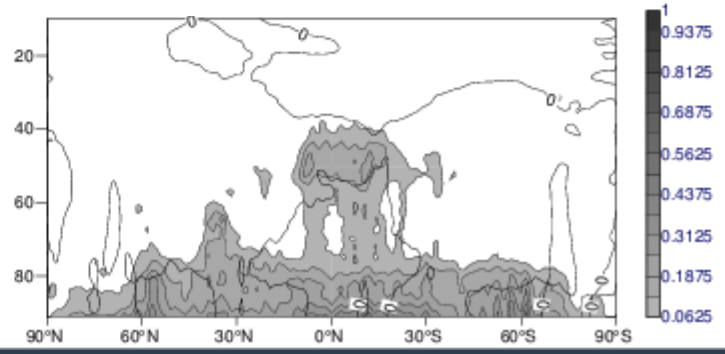
Convection



Non-orographic GWD



TOTAL PHYSICS



U tendencies, accumulated 21-24h

Zonally-averaged cross-sections
Model levels: 10-91 (>1 hPa)

Contours: $[0.06 - 1.0]$ $(ms^{-1})3h$

STOCHDP

- vertical
- latitudinal
- longitudinal

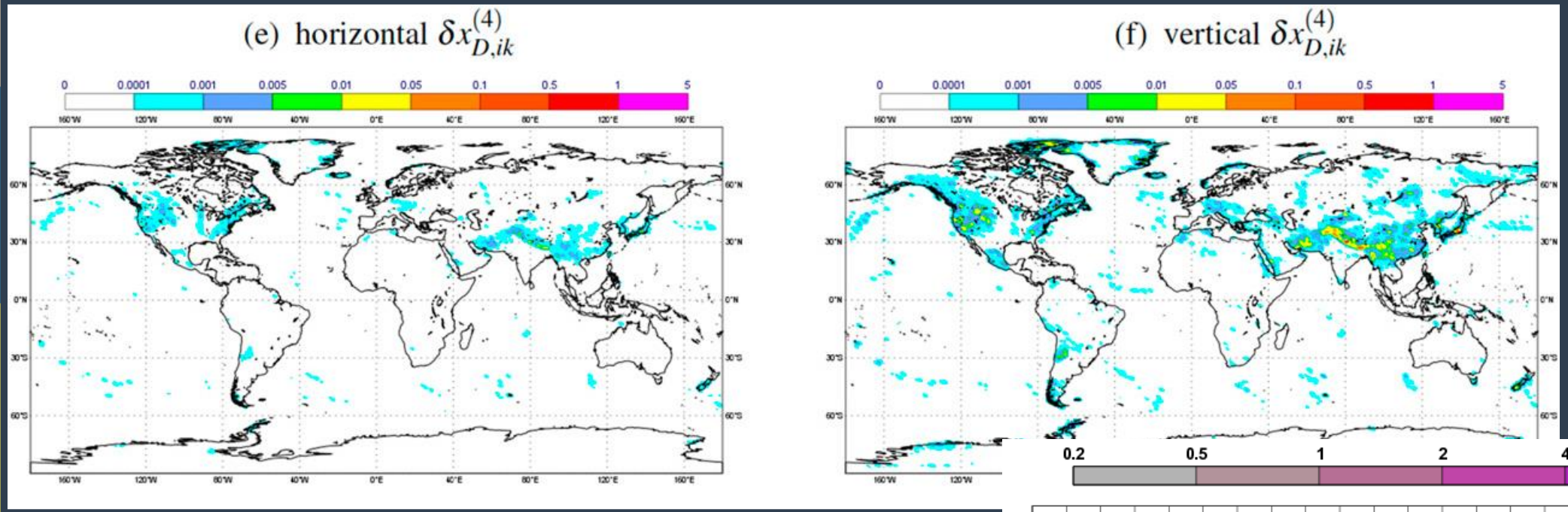
} components all perturbed

- correlation scales: 8 x (Δx,Δt)
- modulated by difference between the 5th (final) and 3rd iterations

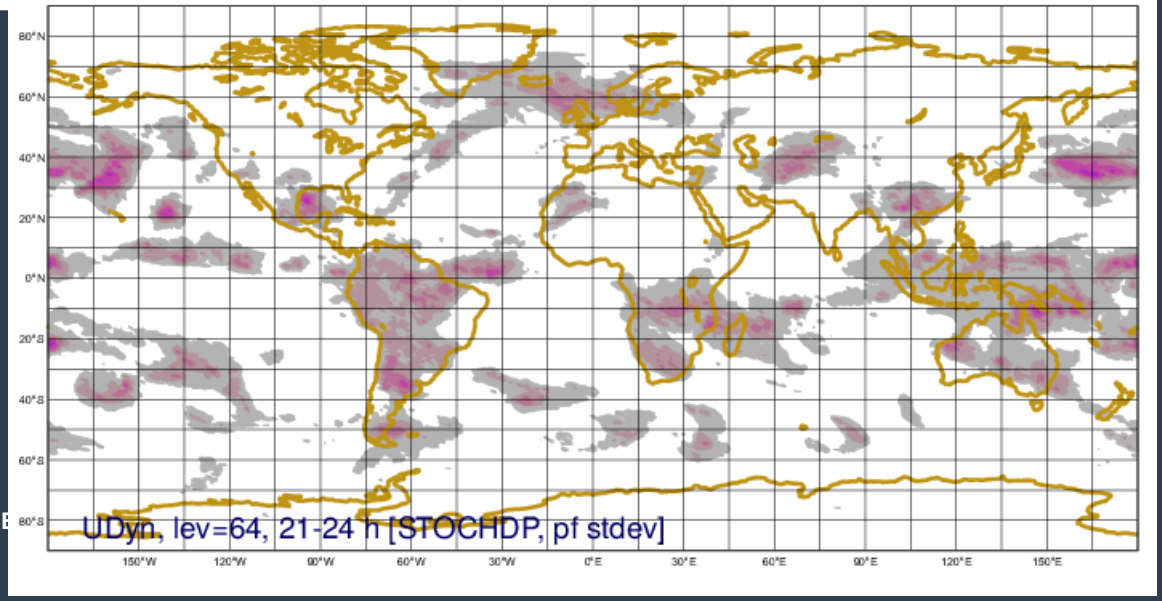
Ensemble standard deviation (20 members)

sarah-jane.lock@ecmwf.int

Diagnosing **STOCHDP** impacts: model tendencies, U



Diamantakis & Magnusson (2016), Fig. 2:
Scaled difference in DP estimate (4th – 3rd iteration)
HRES model level 96 (~500hPa)



U tendencies from dynamics,
accumulated 21-24h, stdev

Model level 64 (~500 hPa)

Model uncertainty representations in physics and dynamics

- **SPP**: attributes model uncertainty close to its assumed sources
  - Potential to focus on processes aside from deep convection
  - Assessing impacts on tendency budgets is useful diagnostic/development tool
  - ➢ Looking ahead (greyzone): indicate increasing importance of cloud/BL parametrisations and dynamics tendencies
- **STOCHDP** experiments:
  - First sight of impact of perturbations to the dynamics – semi-Lagrangian DP estimate
  - Very early days – lots still to test, explore, refine!
    - ➢ Correlation scales?
    - ➢ Random number distributions?
    - ➢ Approximate the convergence rate?

- **Future:** can we build a reliable ensemble with **SPP + STOCHDP ?**

sarah-jane.lock@ecmwf.int

Exploring the impacts of stochastic representations of model uncertainties

…in the physics and dynamics components…

Sarah-Jane Lock, Martin Leutbecher, Peter Bechtold, Richard Forbes, Michail Diamantakis

Thank you for your attention!

ECMWF

© ECMWF July 11, 2018