Exploring stochastic model uncertainty representations

… with relevance to the greyzone …

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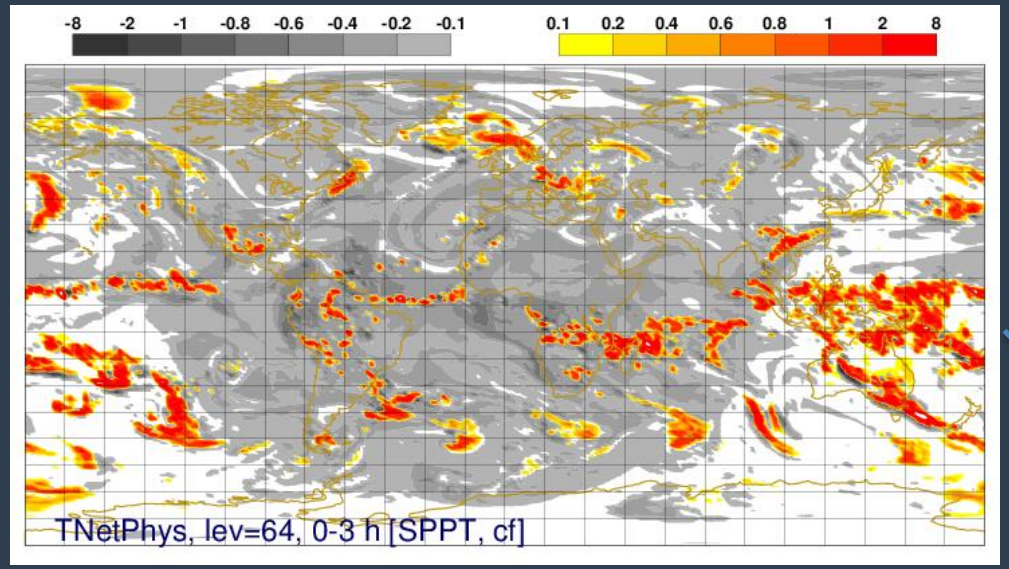
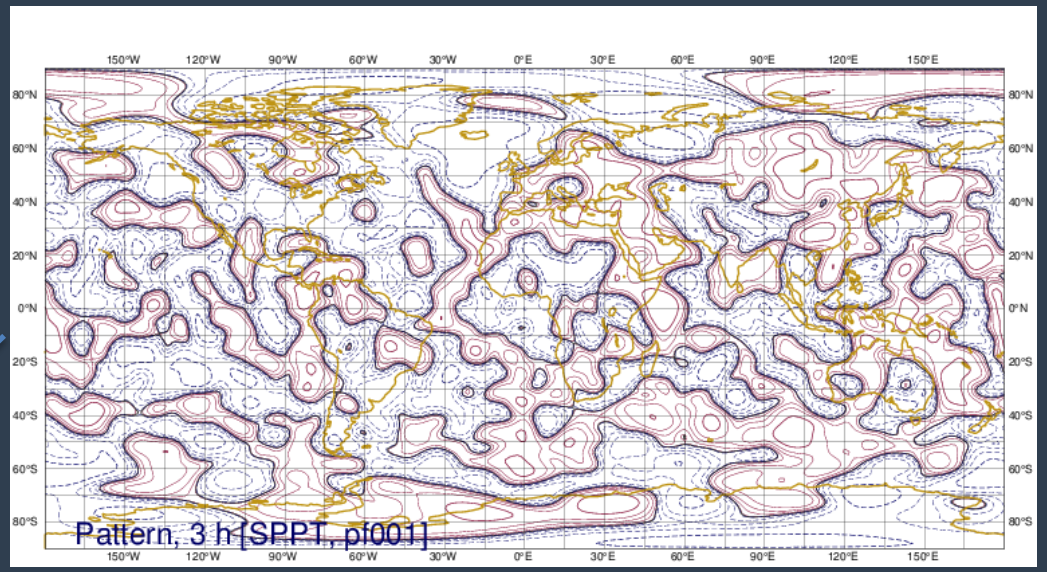
Stochastic model uncertainty representations I: **SPPT**

Net physics:
T tendencies (K/3h), 0-3h, model level 64



Unperturbed model

Random pattern:
$r \sim N[0, 0.55]$, time/spatial correlations (6 h/500 km)



e.g. member #1

$$X' = (1 + r)X$$

Perturbed forecast

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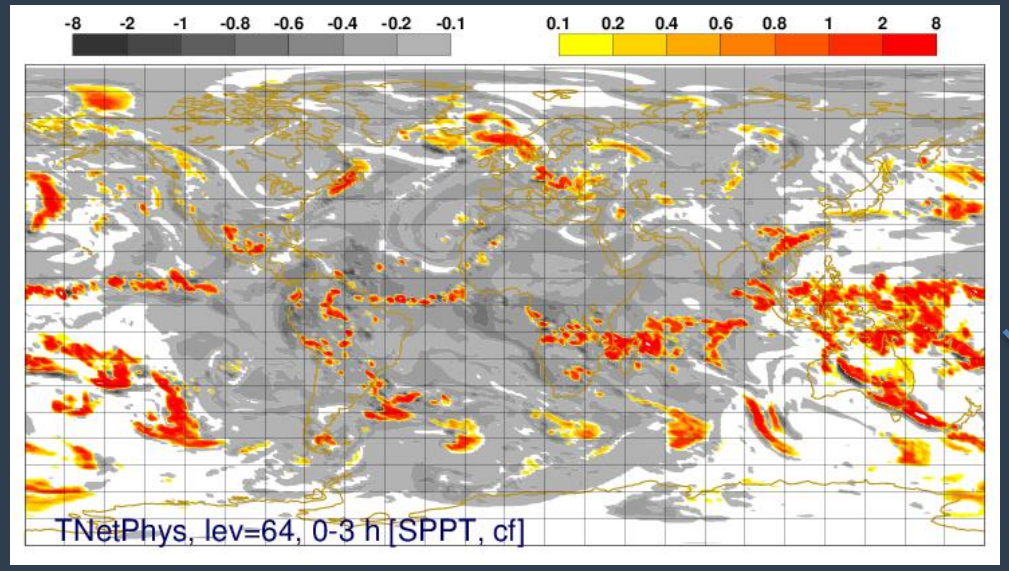

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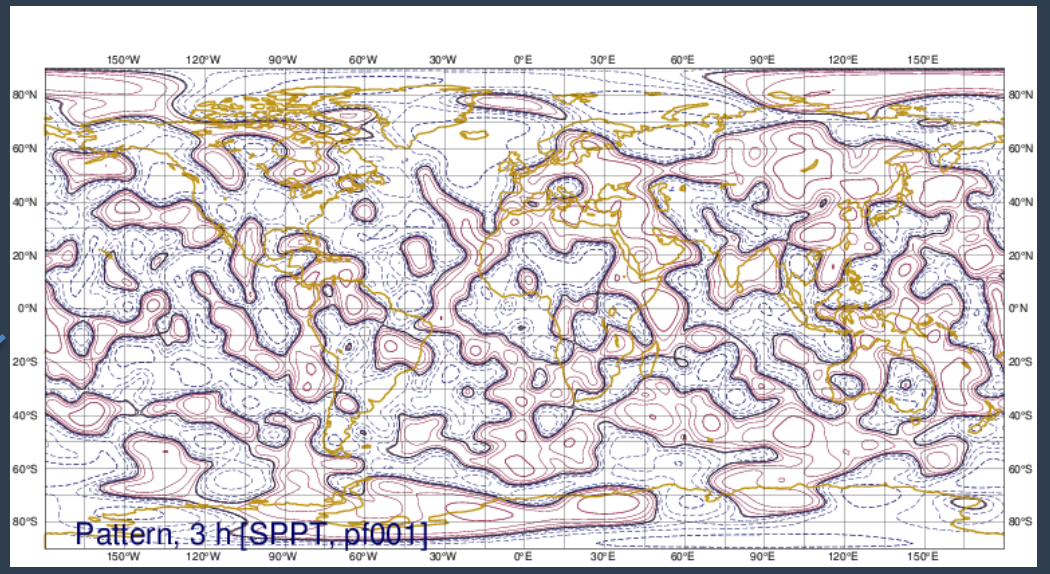
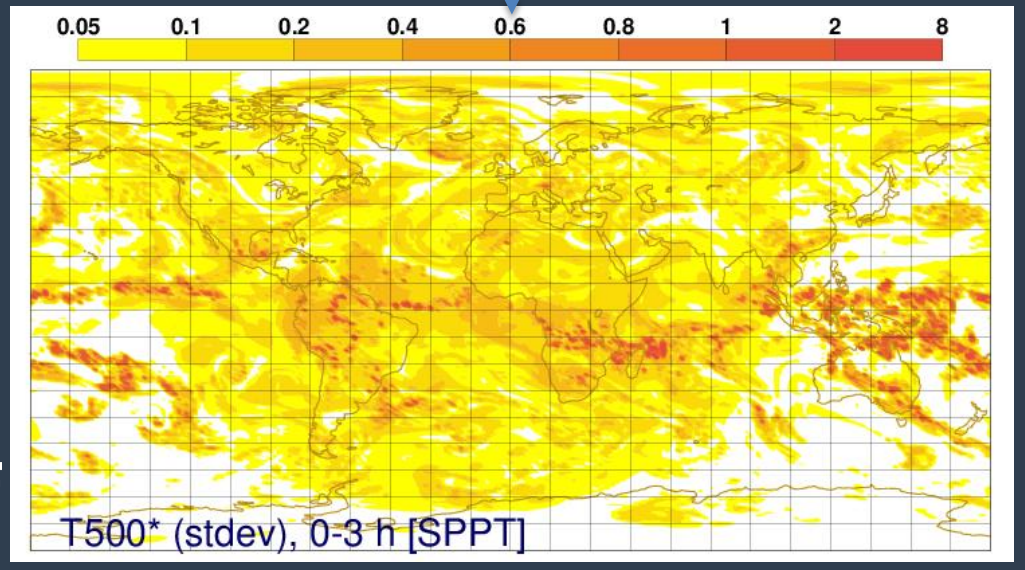


e.g. member #1
red, solid: $0<r<+1$
blue, dash: $-1<r<0$



Ensemble standard deviation
(20 perturbed members)

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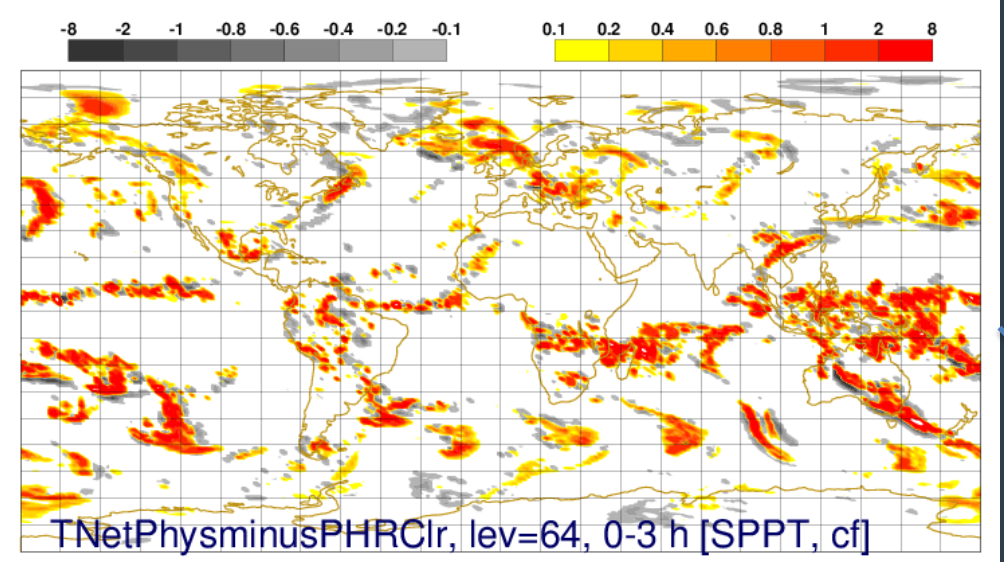
Stochastic model uncertainty representation II: **SPPT** (revised)

Net physics *minus clear-sky heating rates (radiation)*:
T tendencies (K/3h), 0-3h, model level 64



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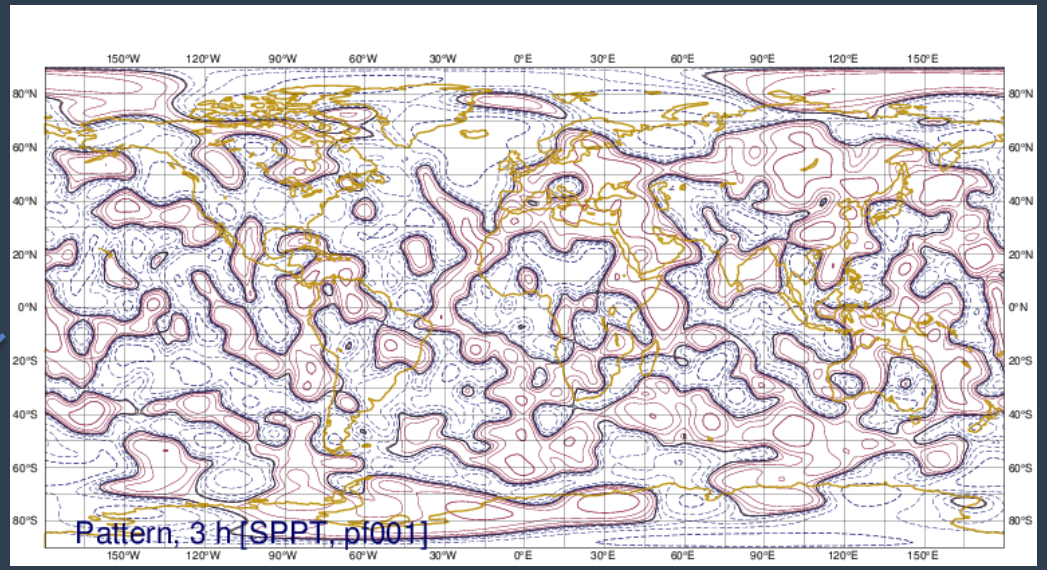

e.g. member #1
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$$X' = (X_1' + X_2) = (1 + r)X_1 + X_2$$

Perturbed forecast

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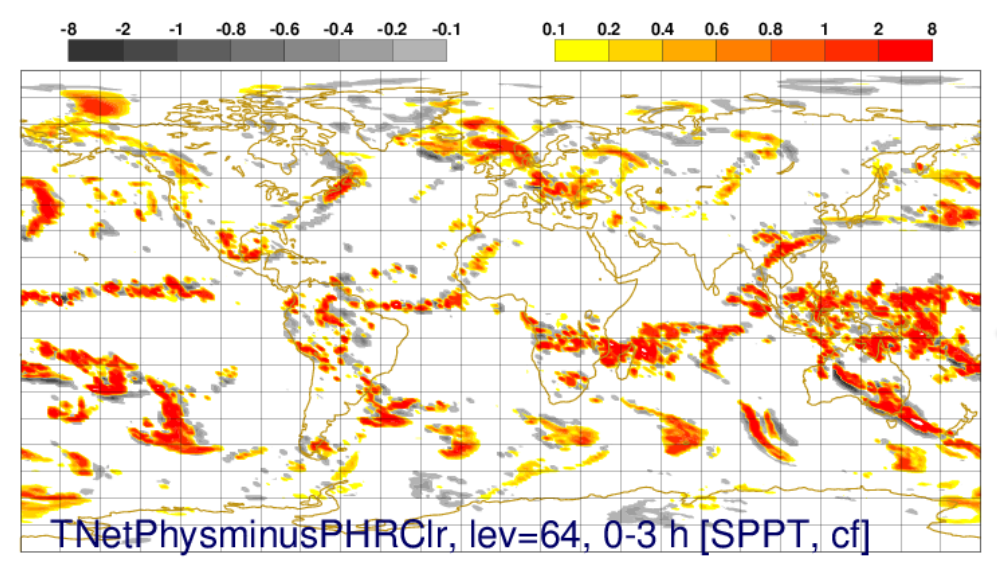
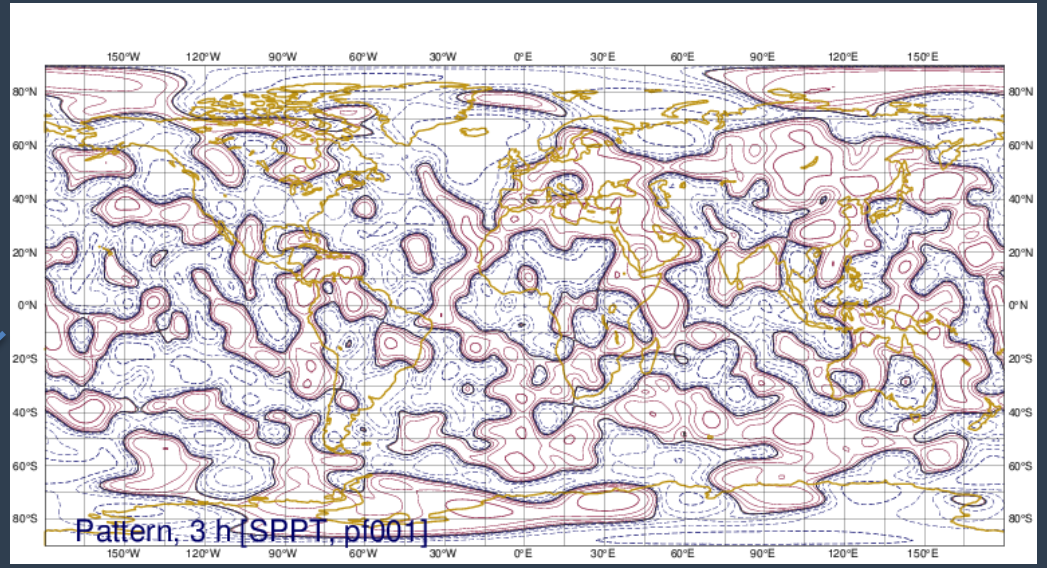
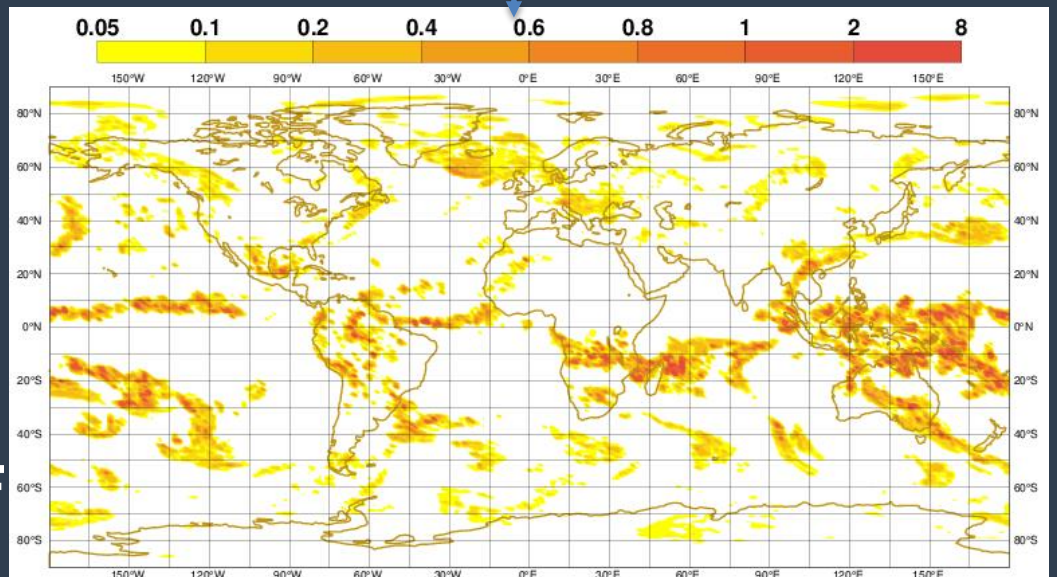


Unperturbed model

Random pattern:
r~*N*[0,0.55], time/spatial correlations (6 h/500 km)





e.g. member #1
red, solid: 0<*r*<+1
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Ensemble standard deviation
(20 perturbed members)

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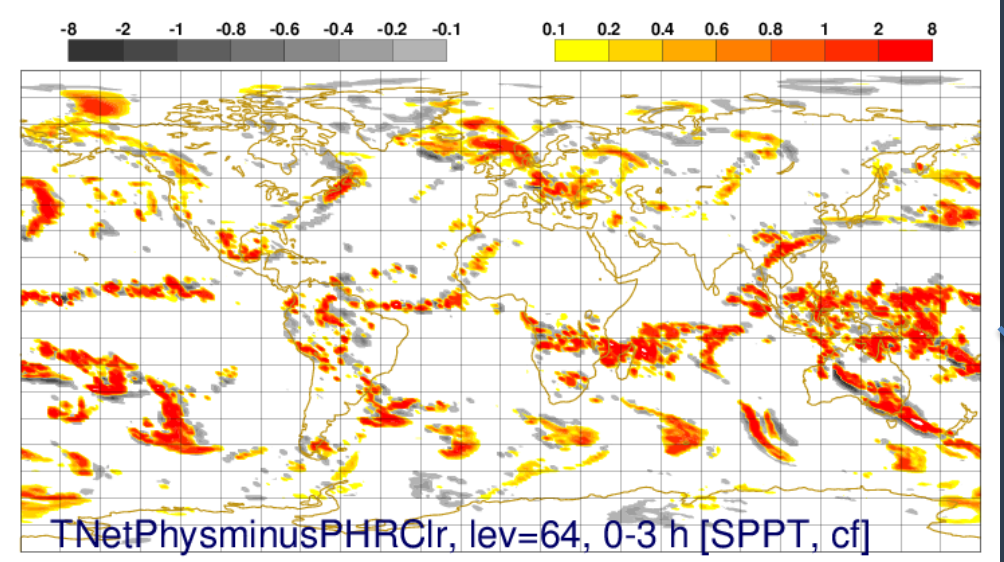

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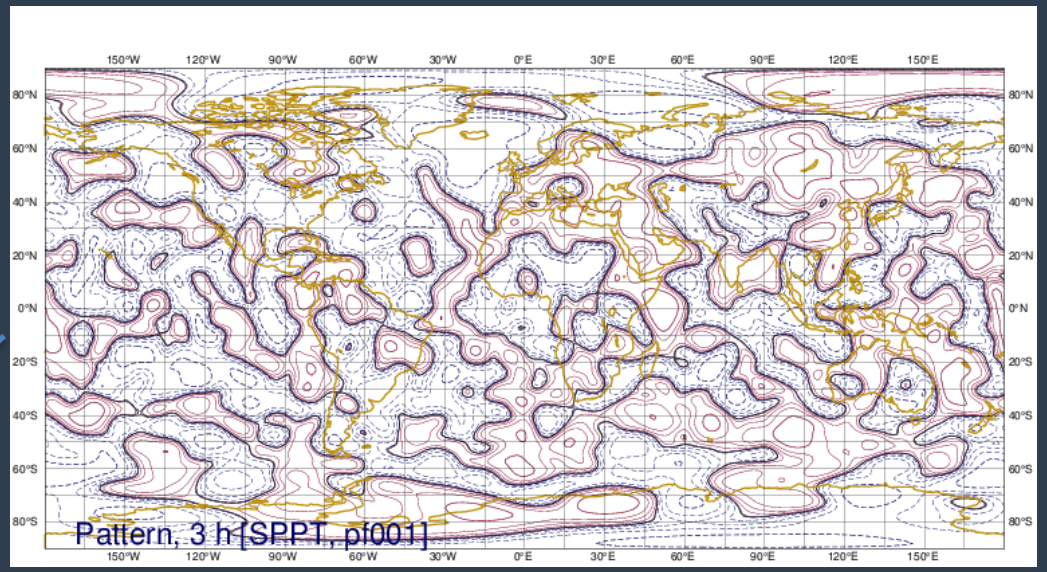

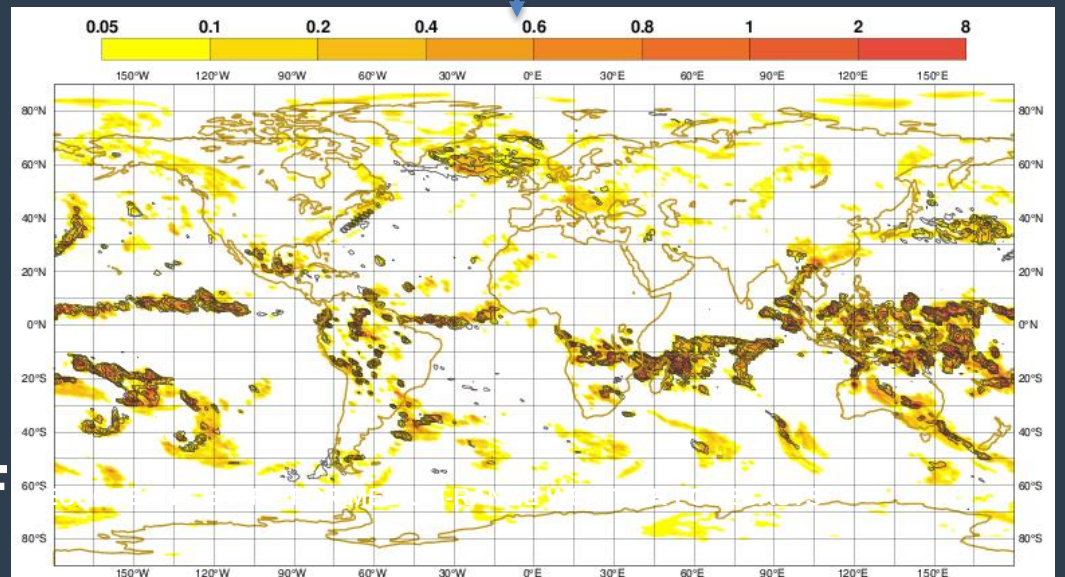

e.g. member #1
red, solid: 0<*r*<+1
blue, dash: -1<*r*<0

SPPT: *physics tendencies associated with deep convection generate much of the ensemble spread*

Ensemble standard deviation
(20 perturbed members)
+ convective precip (ens mean)

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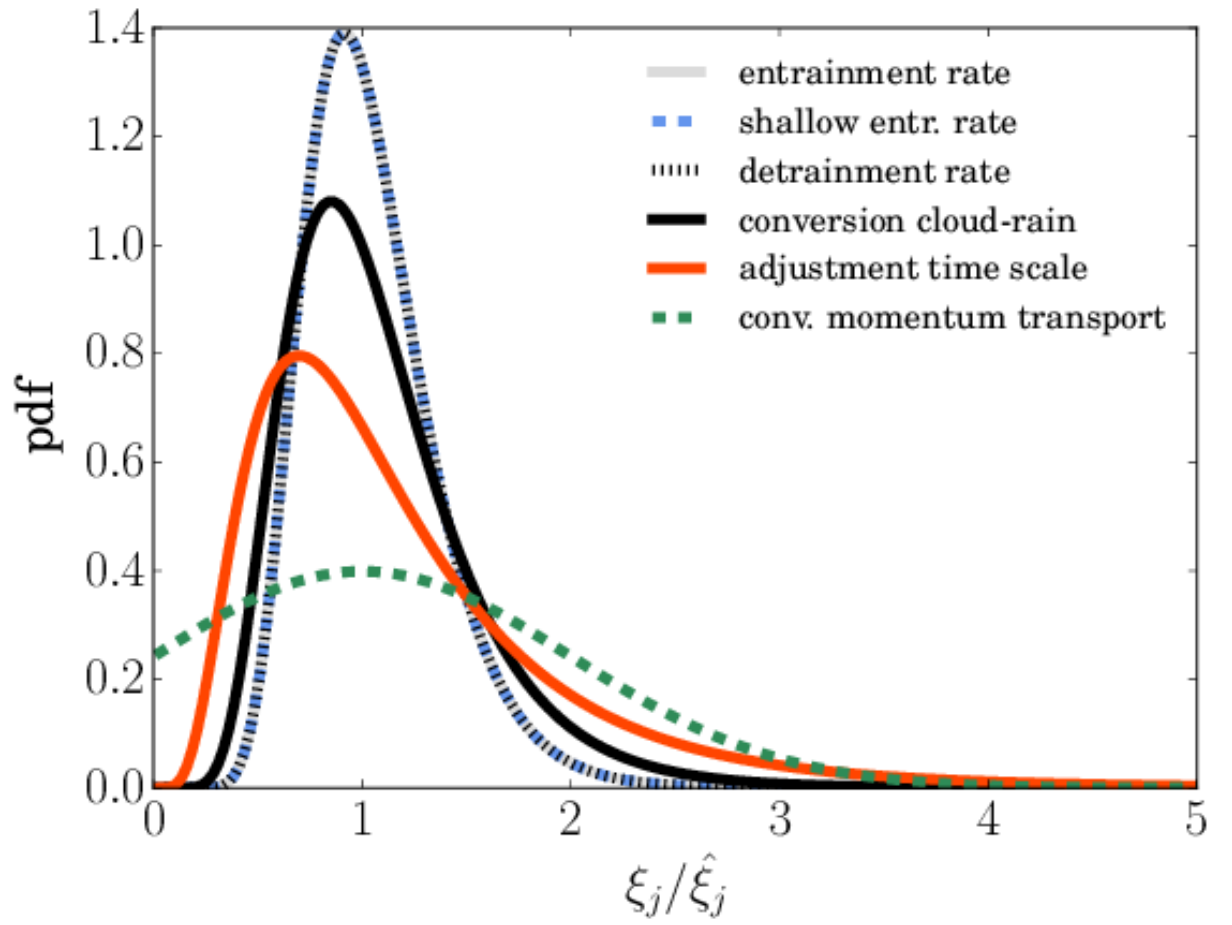
Stochastic model uncertainty representation III: SPP



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

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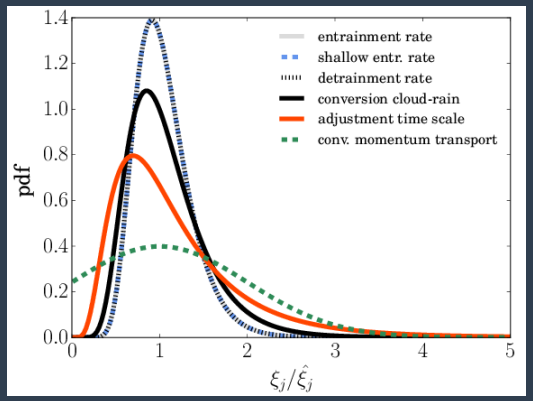
Stochastic model uncertainty representation III: SPP



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

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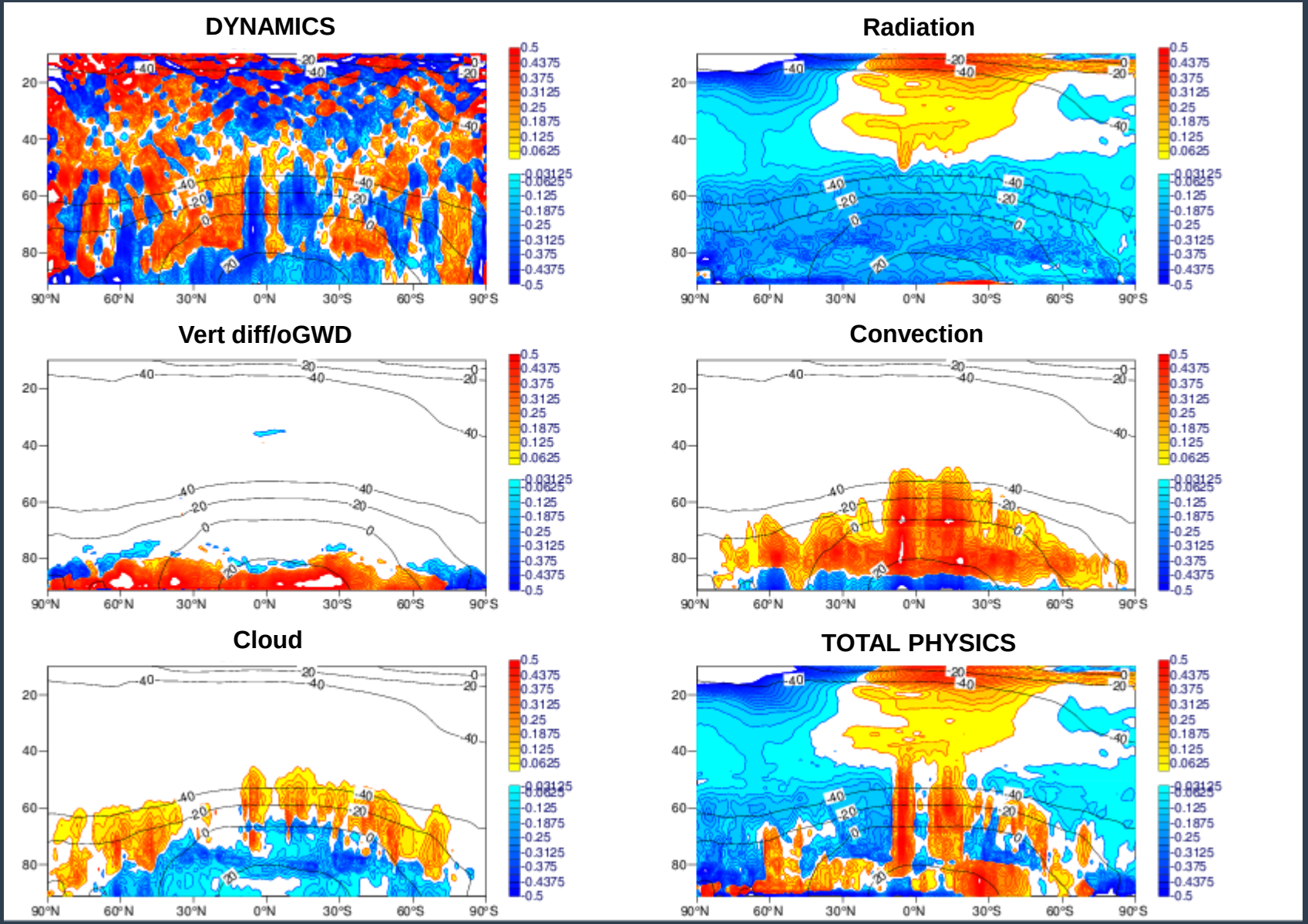
Diagnosing **SPP** impacts: model tendencies, T



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)

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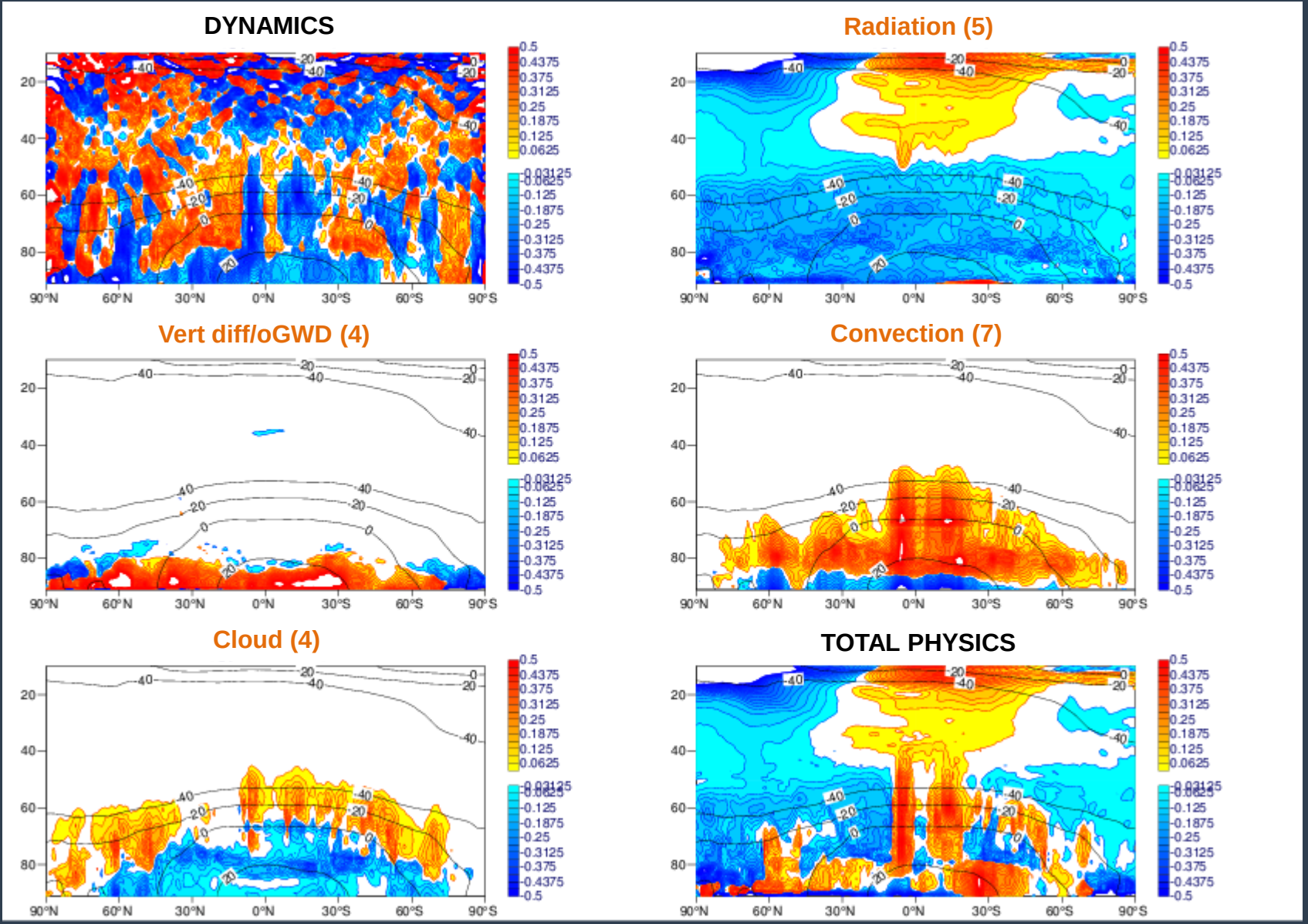

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SPP (20): default

Ensemble mean
(20 members)

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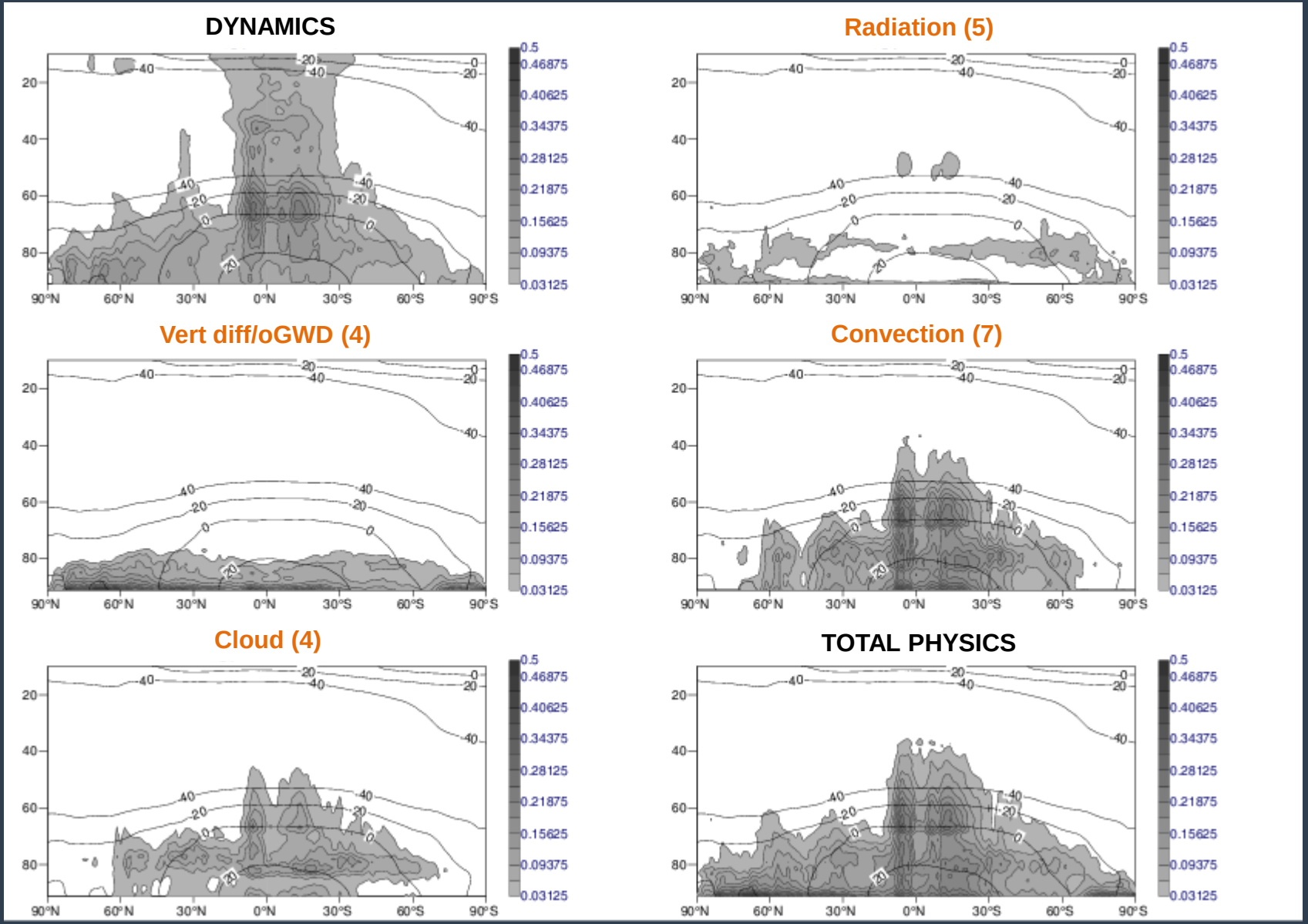

T tendencies, accumulated 0-3h

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

SPP (20): default

Ensemble standard deviation
(20 members)

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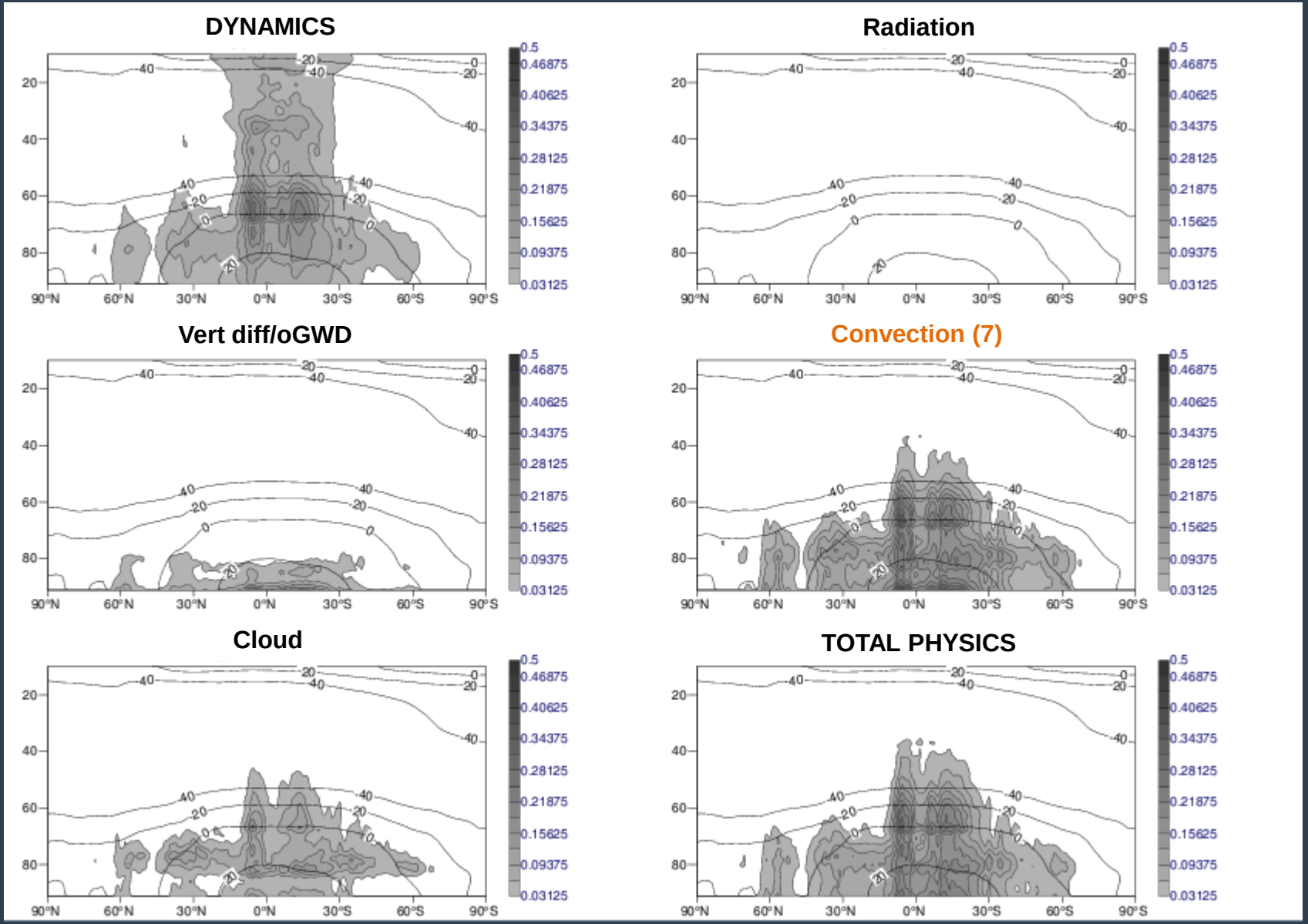

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- detrainment rate for penetrative convection
- conversion coefficient cloud to rain
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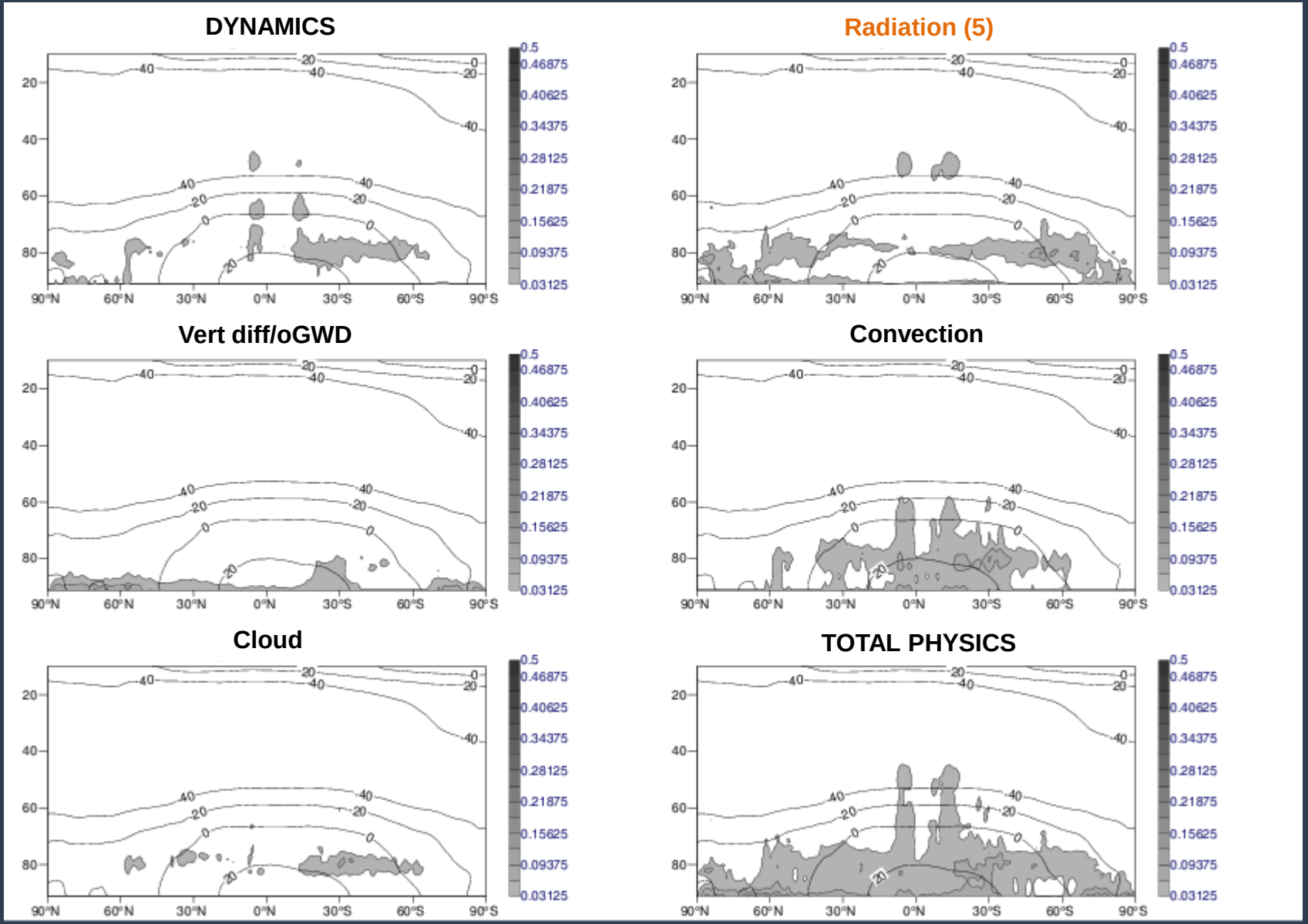

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Zonally-averaged cross-sections
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Contours: $[0.03 - 0.5]$ K/3h

SPP (5): radiation

- cloud vert. decorrelation height, McICA
- fractional stdev of horizontal distrib. of water content
- effective radius of cloud water and ice
- scale height of aerosol norm. vert. distrib.
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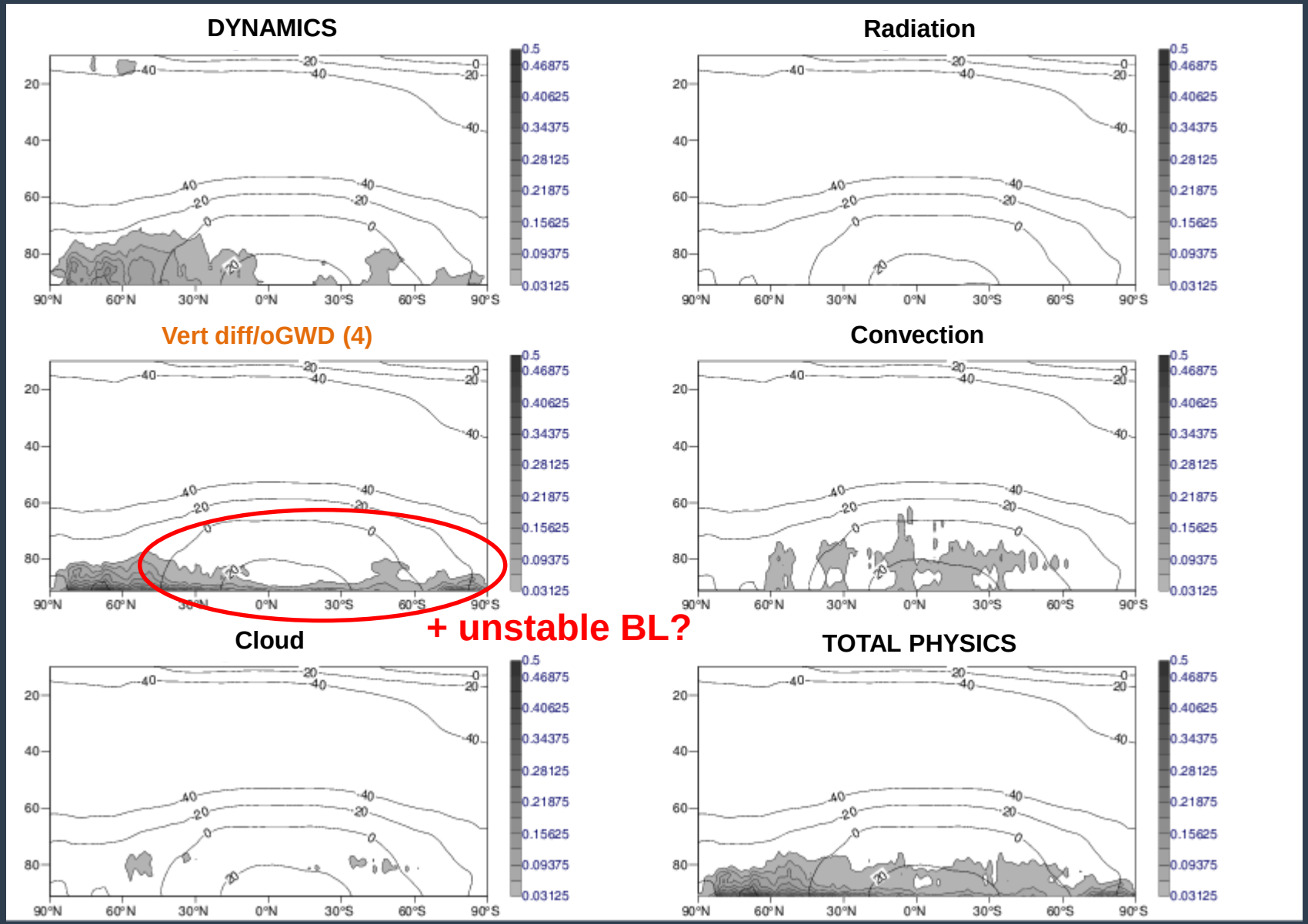
Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

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

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

SPP (4): BL schemes

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

Ensemble standard deviation (20 members)

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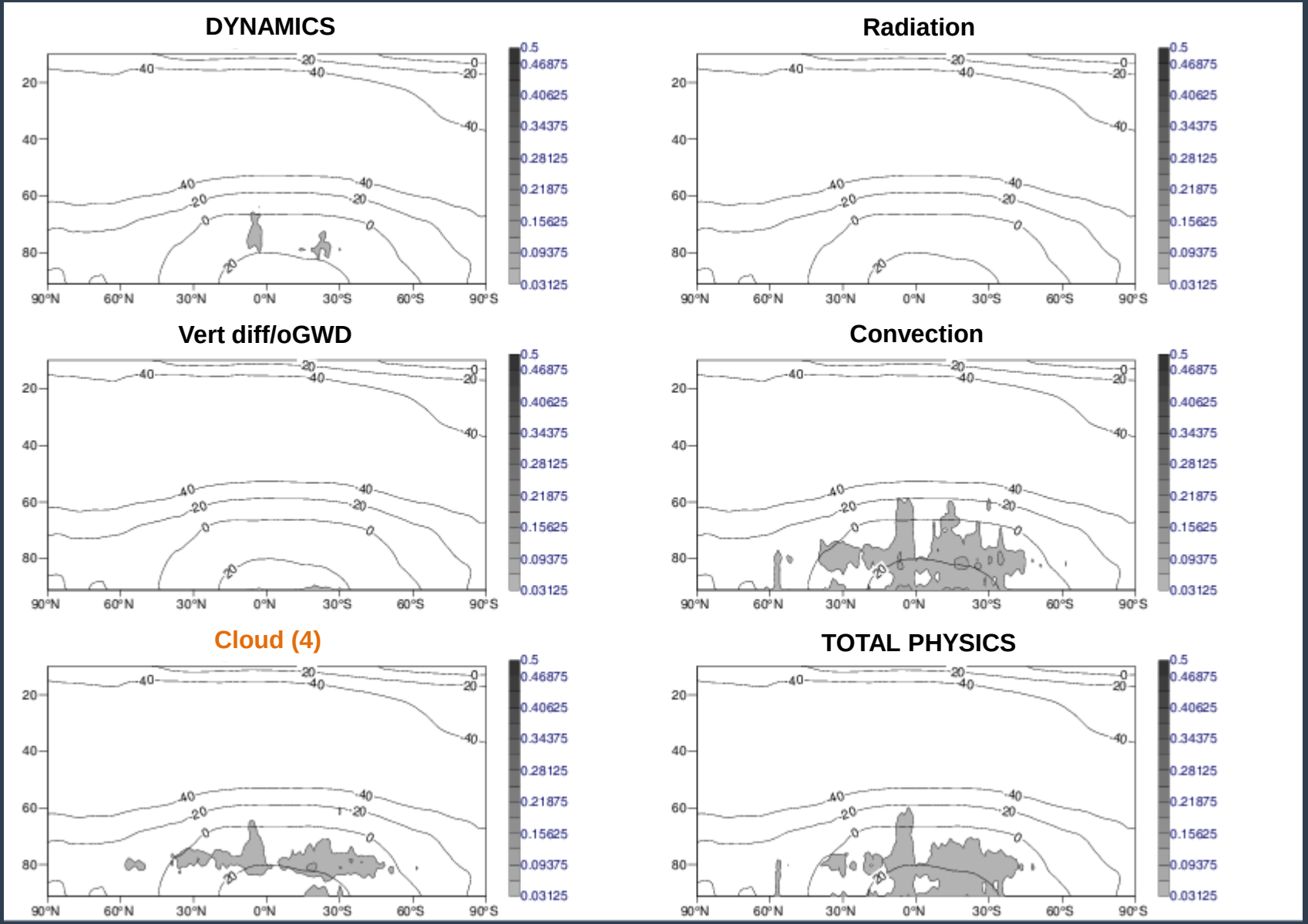

T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
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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)

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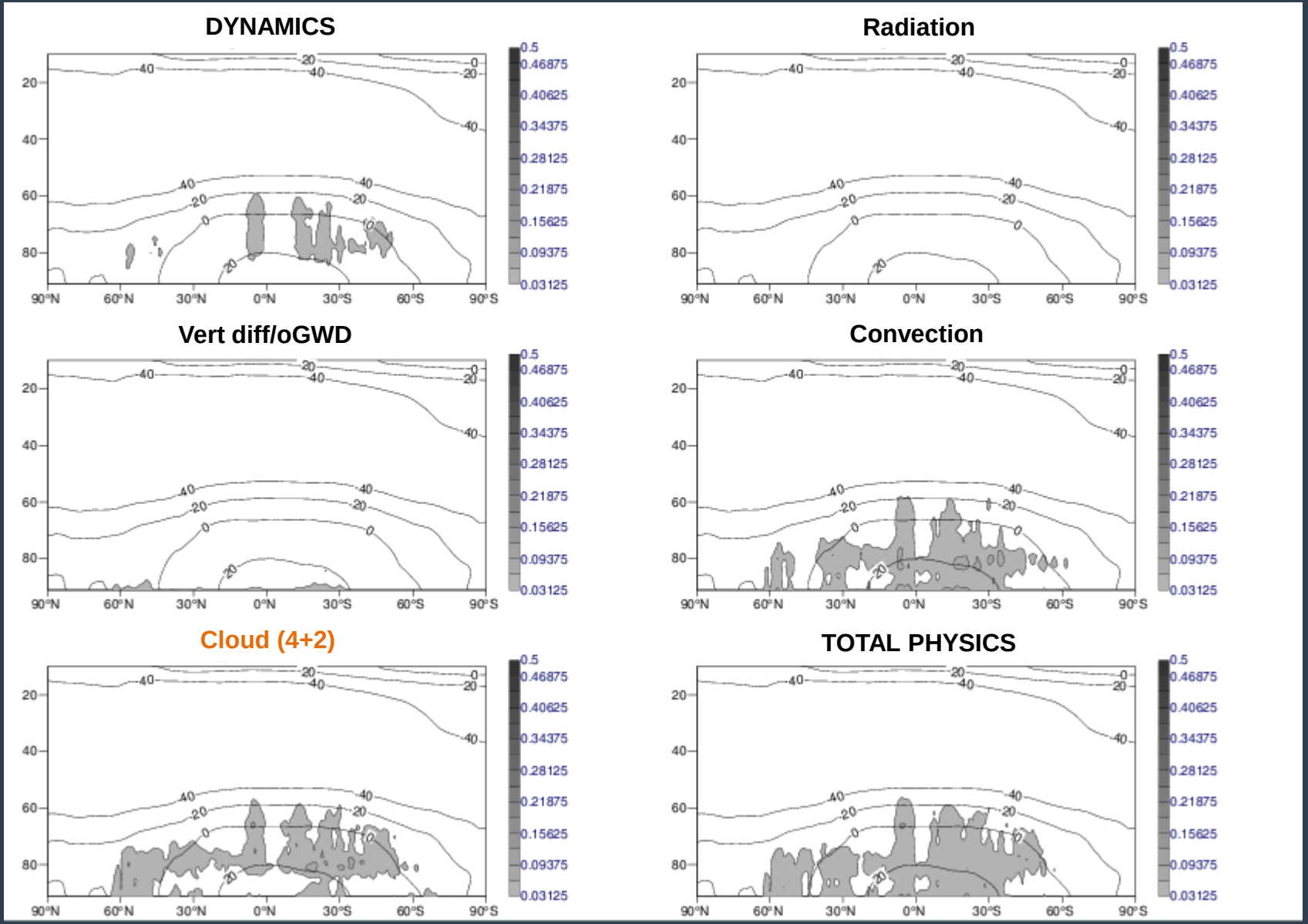
Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

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

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

SPP (4+2): LSP/Cloud
+ rain evaporation rate
+ snow sublimation rate

Ensemble standard deviation (20 members)

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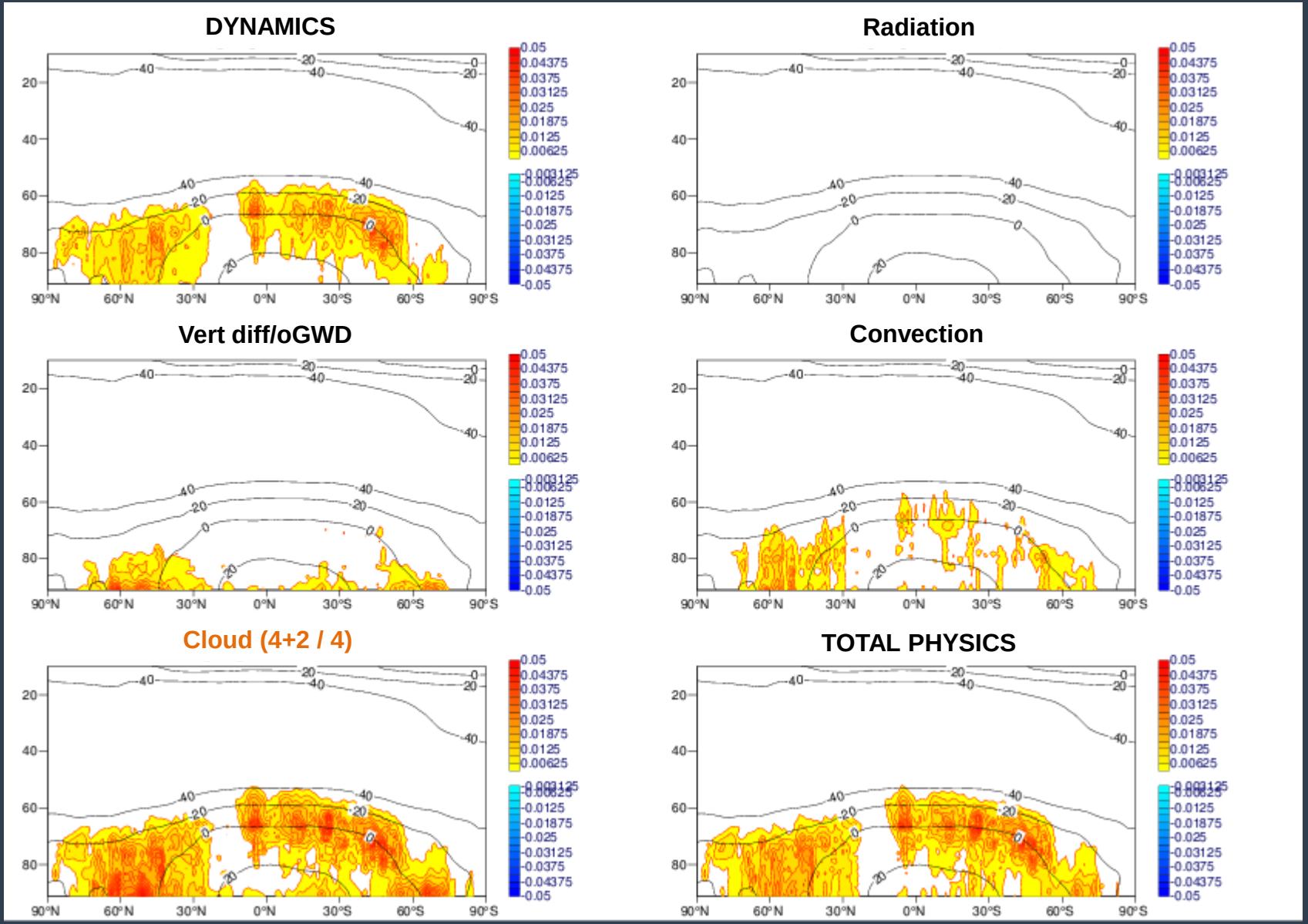
Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

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

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

SPP (4+2): LSP/Cloud
+ rain evaporation rate
+ snow sublimation rate

minus

SPP (4): LSP/Cloud

Ensemble standard deviation
(20 members)

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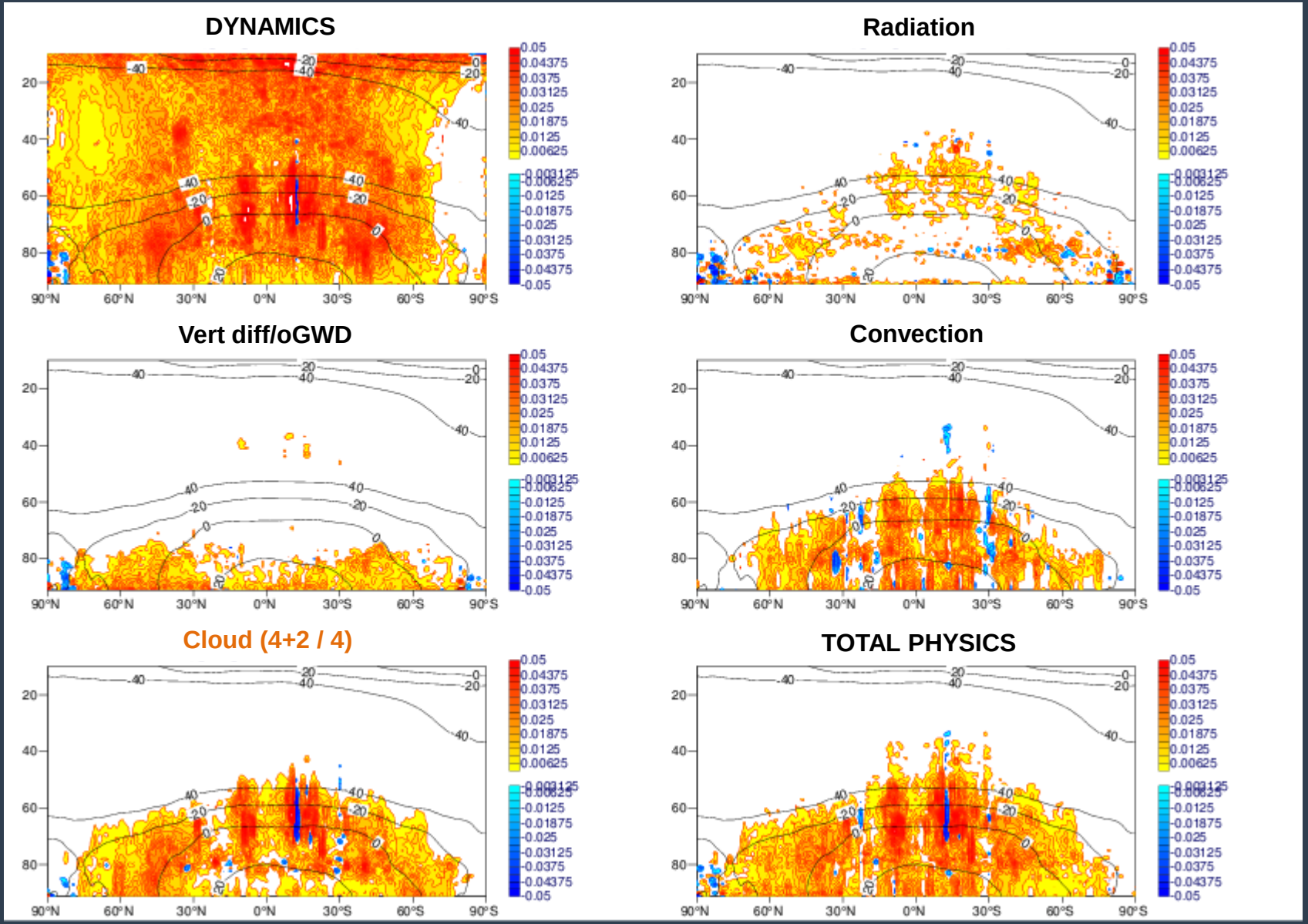
Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 45-48h

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

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

SPP (4+2): LSP/Cloud
+ rain evaporation rate
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minus

SPP (4): LSP/Cloud

Ensemble standard deviation
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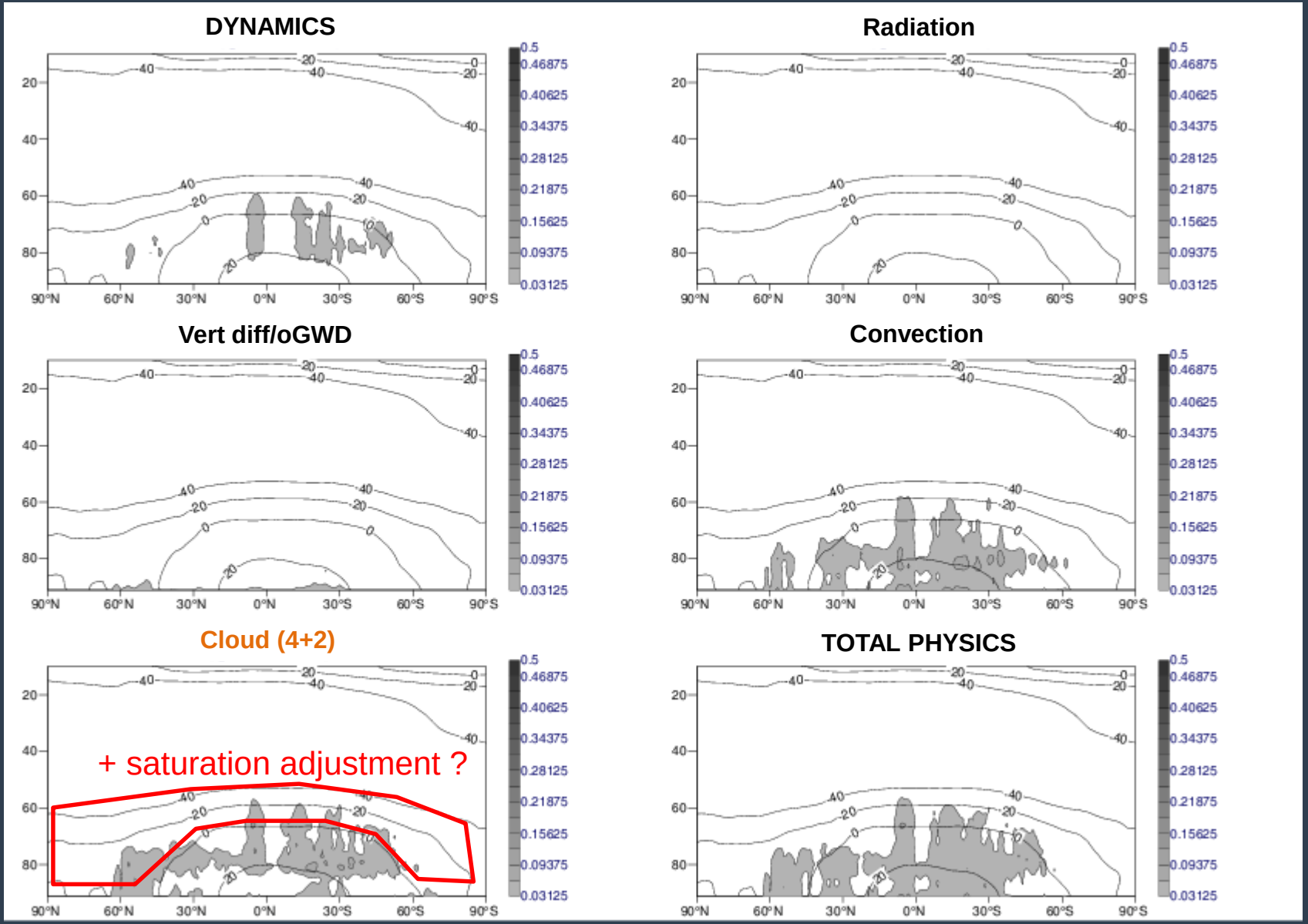
Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

Zonally-averaged cross-sections
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SPP (4+2): LSP/Cloud
+ rain evaporation rate
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… scope for further improvement

Ensemble standard deviation
(20 members)

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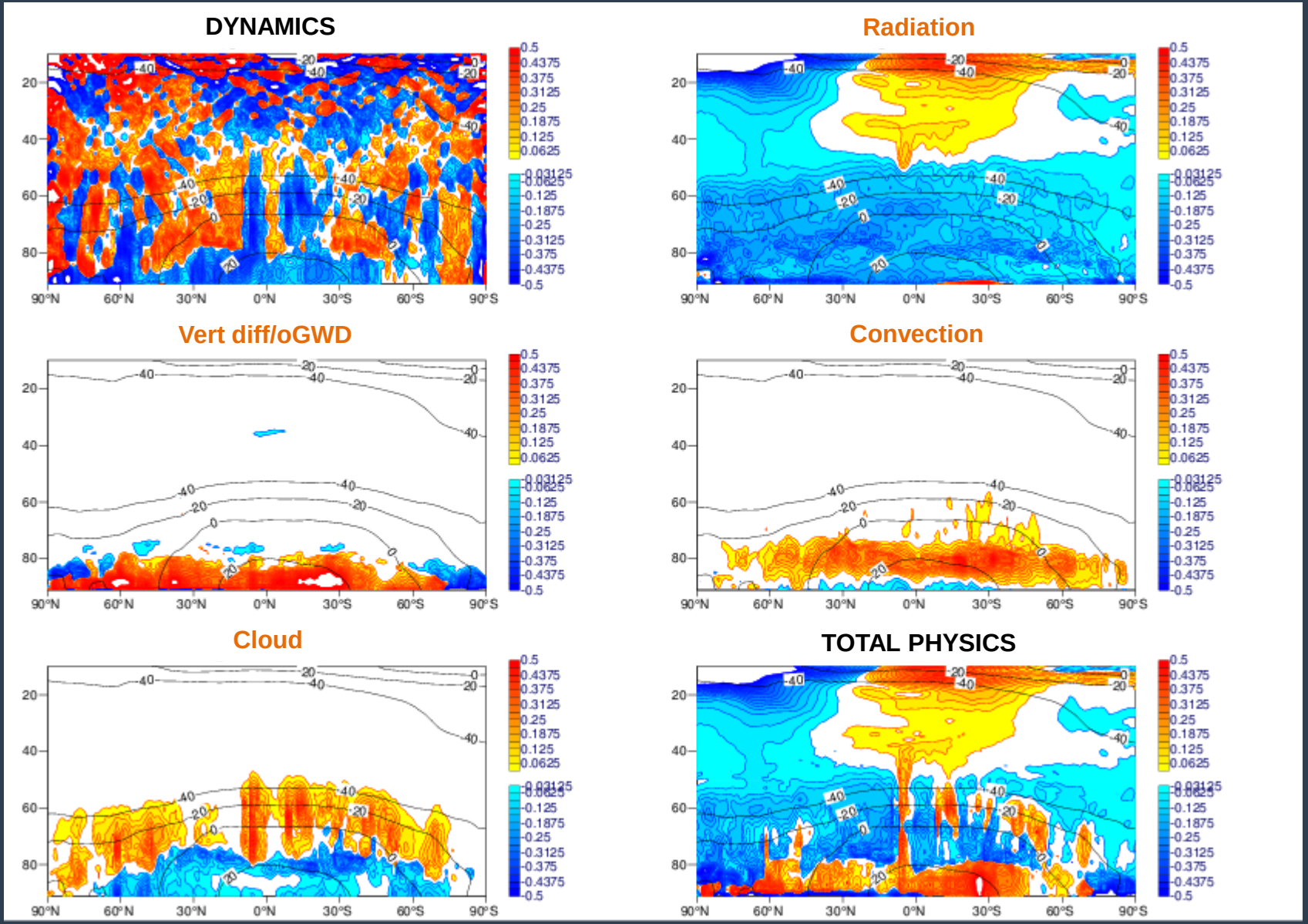
Diagnosing **SPP** impacts: model tendencies, T



T tendencies, accumulated 0-3h

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SPP, deep convection param OFF

Ensemble mean
(20 members)

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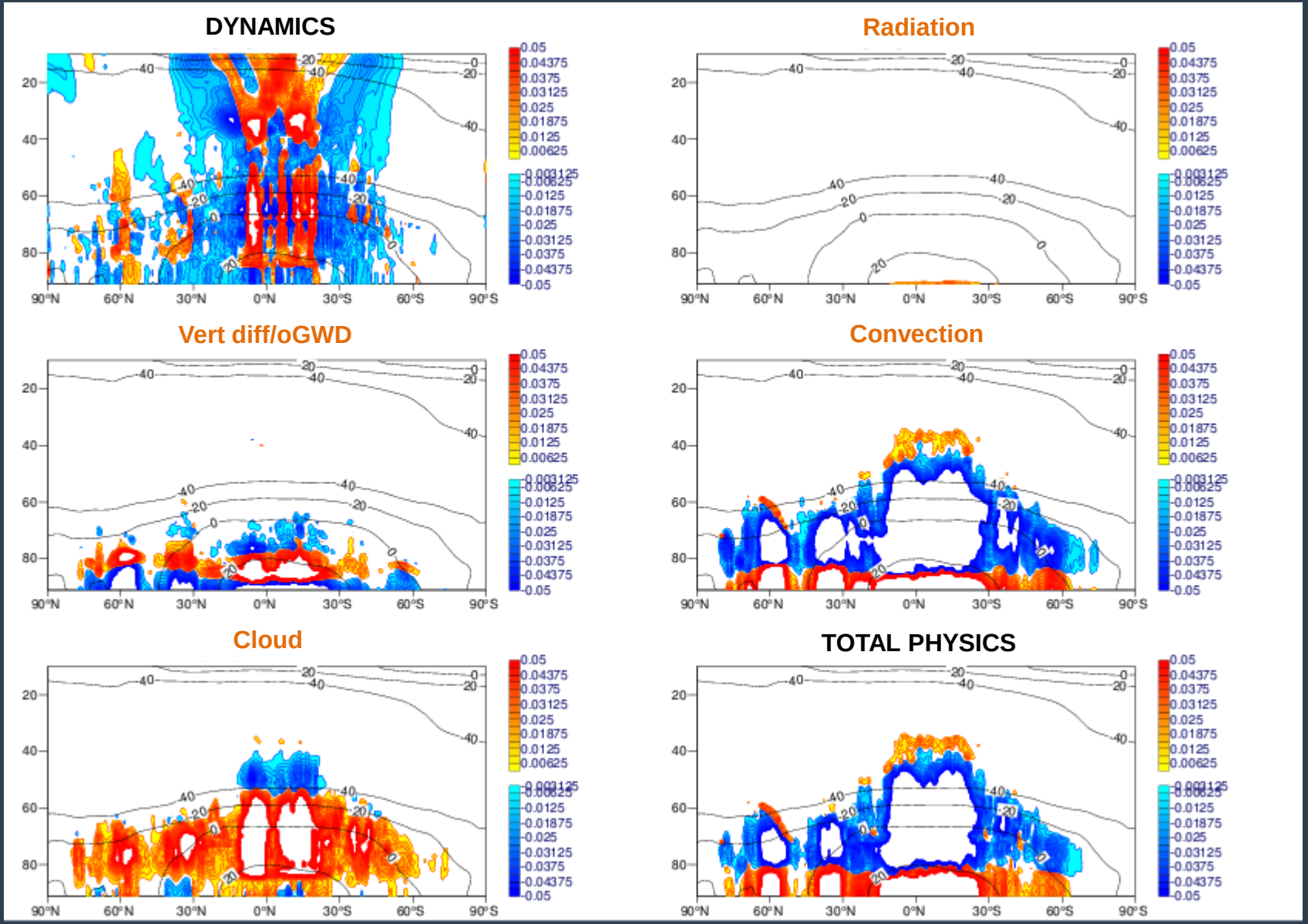

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SPP, deep convection param OFF

minus

SPP

Ensemble mean
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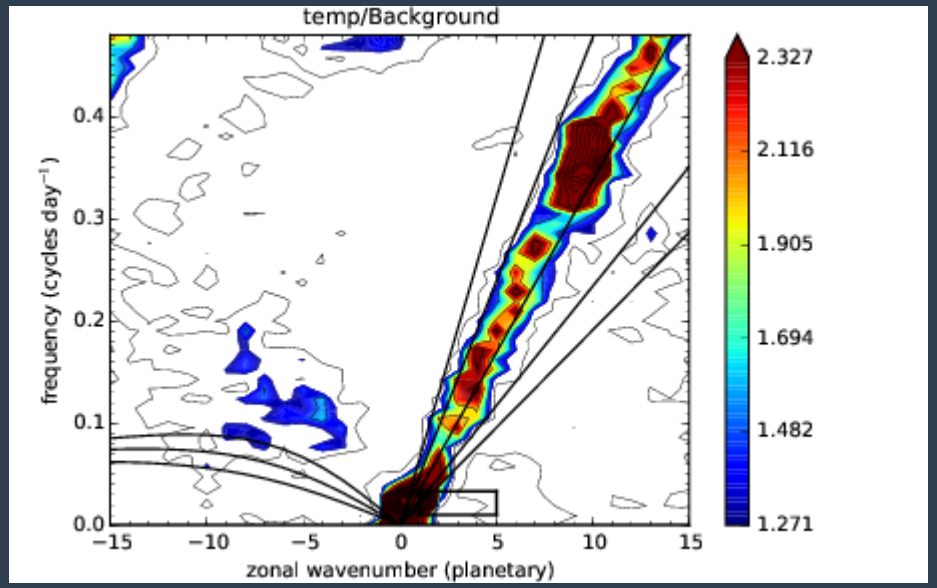
Diagnosing **SPP** impacts: Aquaplanet – temperature

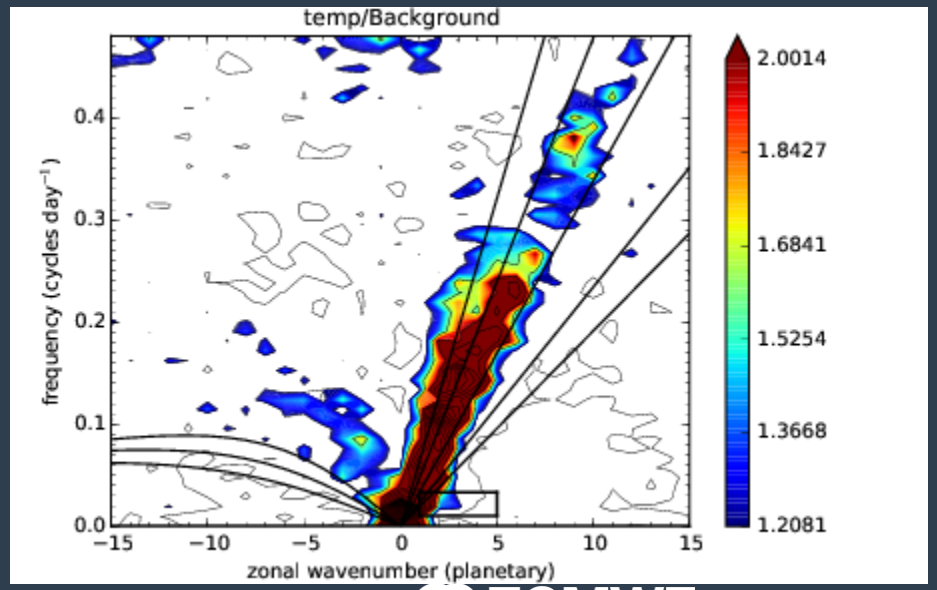


Wheeler-Kiladis diagrams:

k-f spectrum of convectively coupled equatorial waves (CCEW) (symmetric component)

15N-15S

Unperturbed model



SPP

Experiments:

- no land
- constant SSTs
- full IFS physics
- 13-month integrations
- 4 start dates

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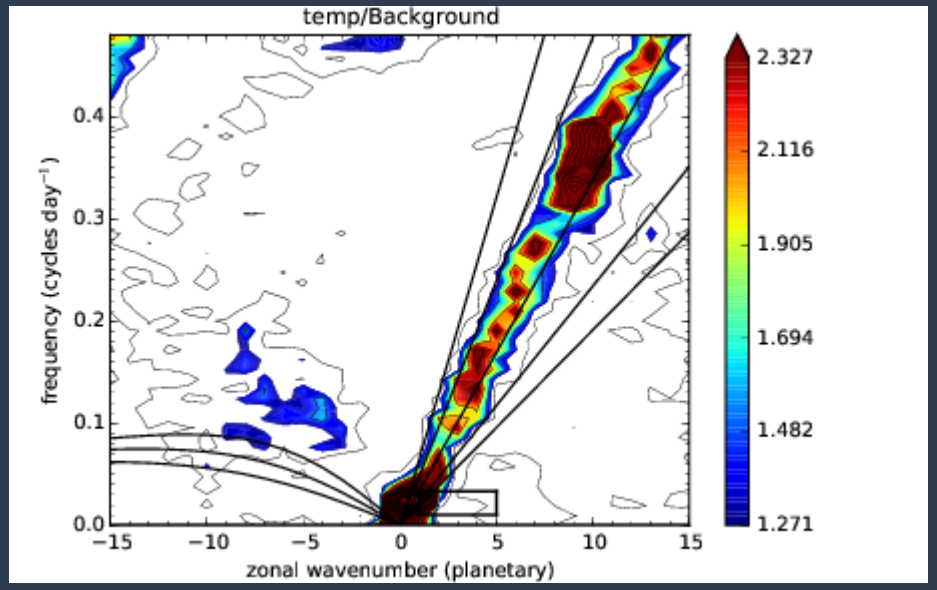
Diagnosing **SPP** impacts: Aquaplanet – temperature



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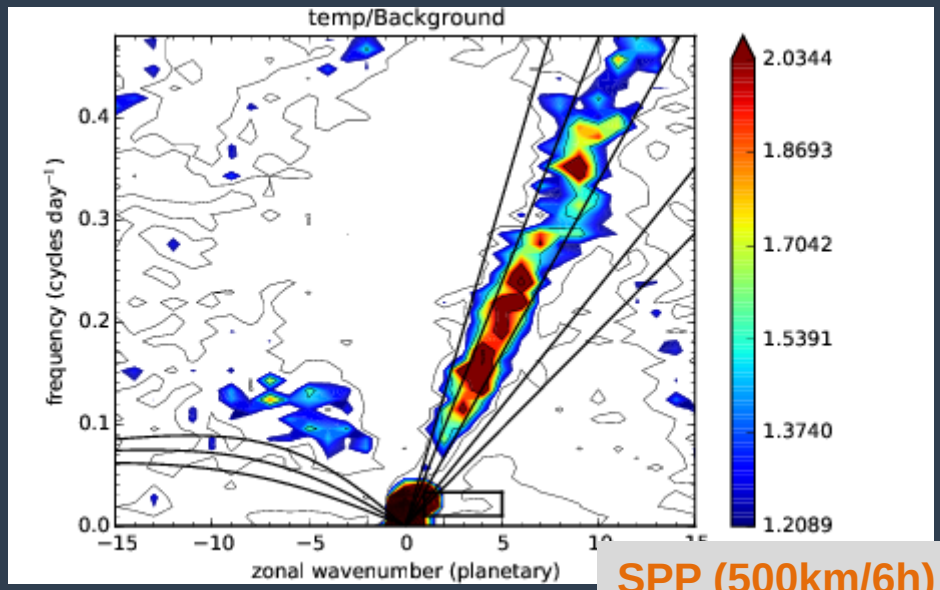
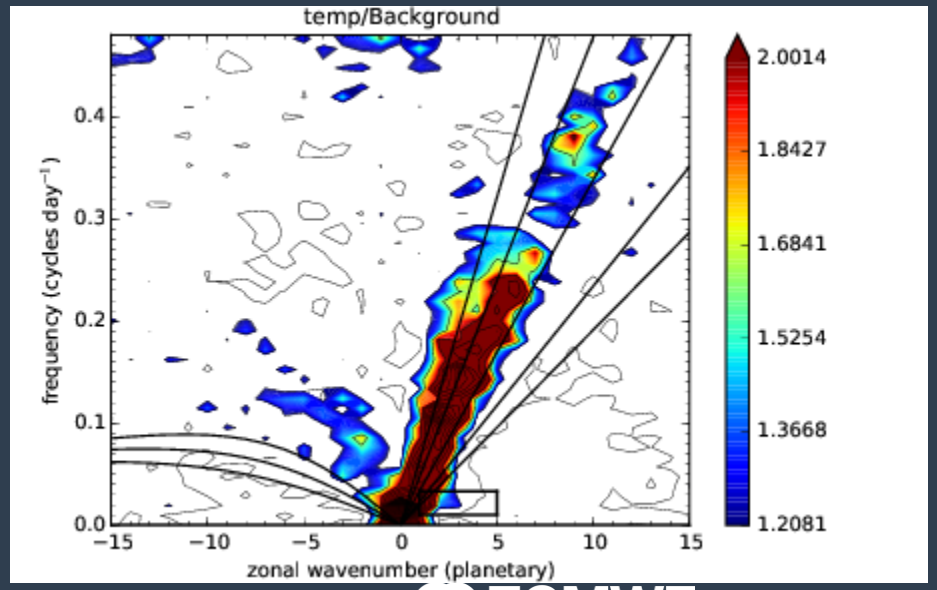
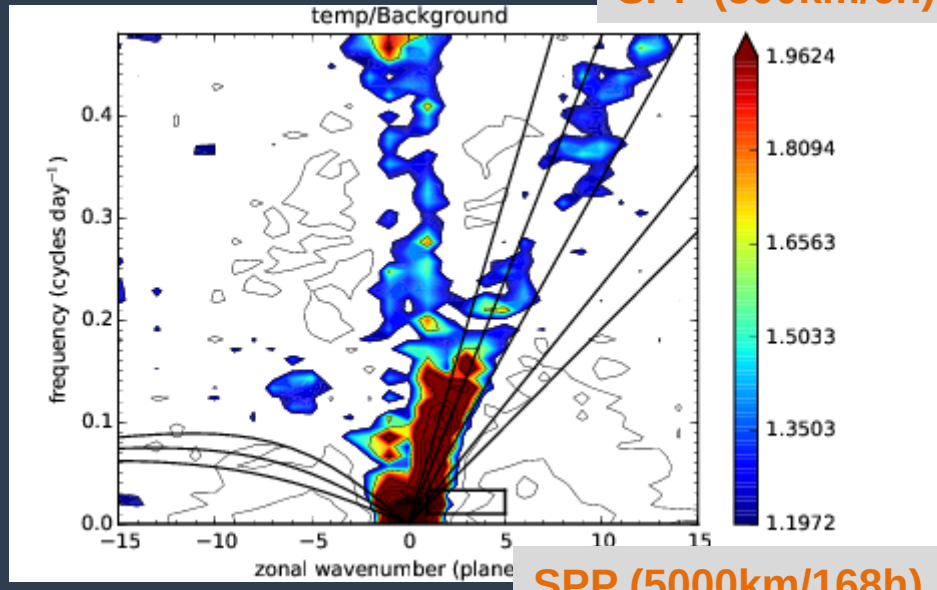


SPP (500km/6h)



SPP (500km/72h)



SPP (5000km/168h)

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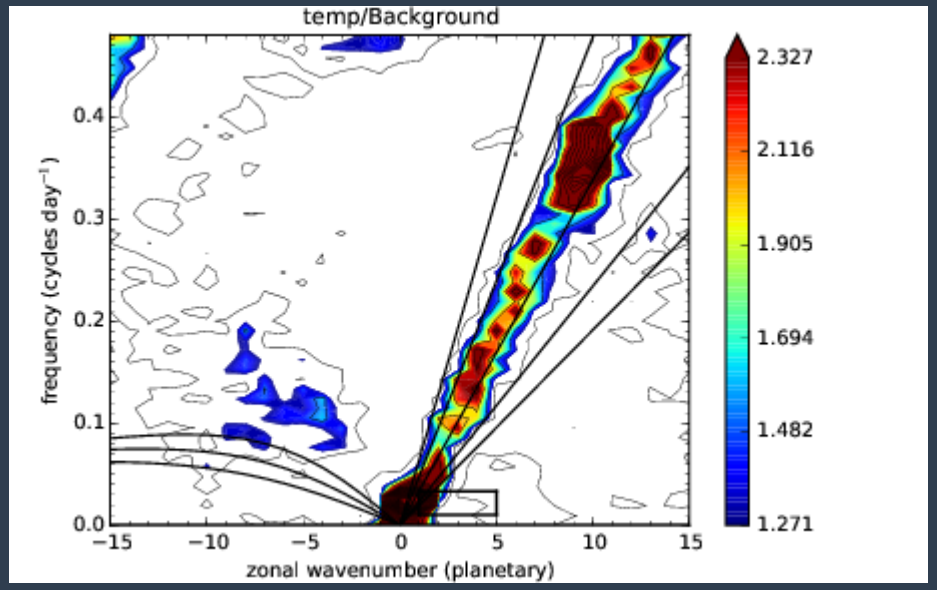
Diagnosing **SPP** impacts: Aquaplanet – temperature

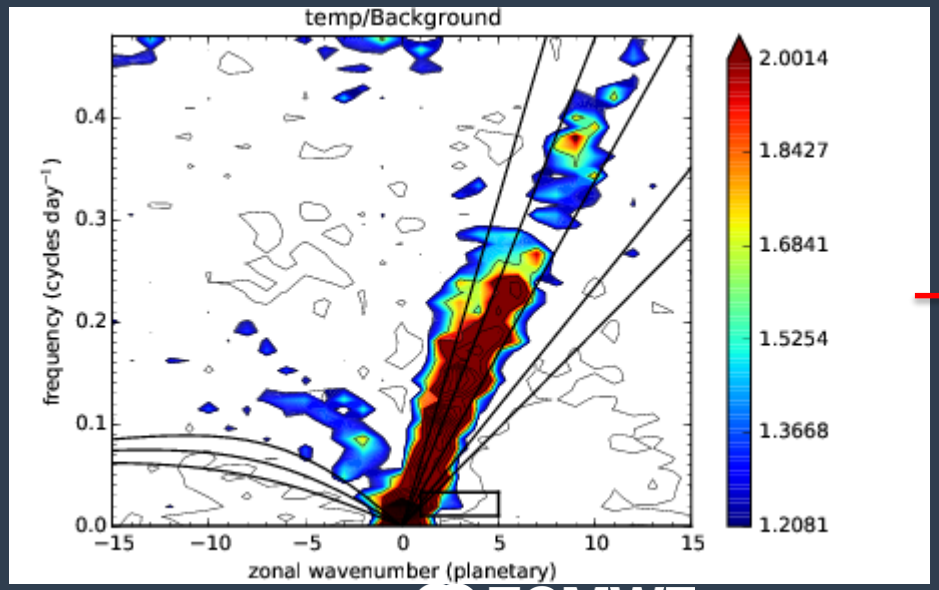


Wheeler-Kiladis diagrams:

k-f spectrum of convectively coupled equatorial waves (CCEW) (symmetric component)

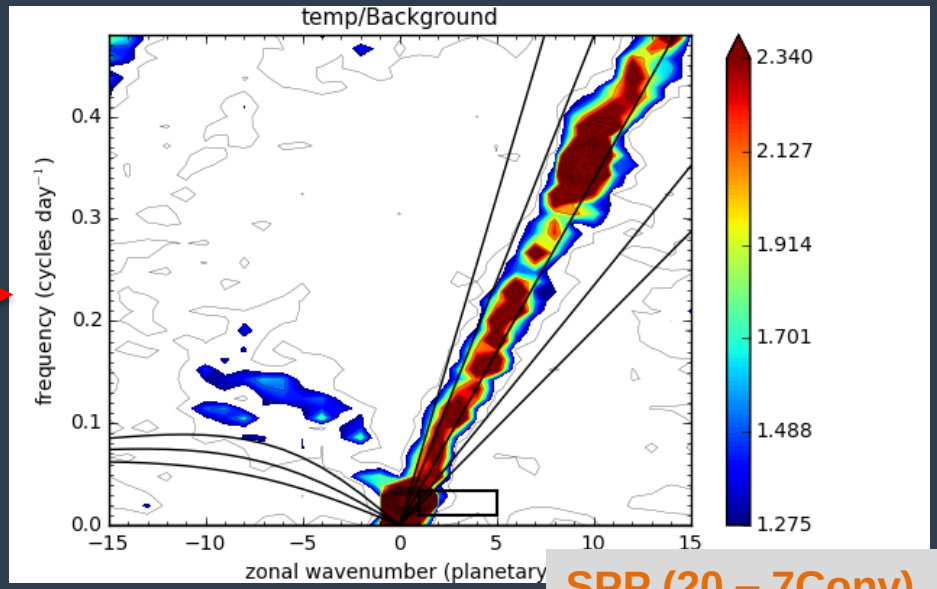
15N-15S

Unperturbed model



exclude Convection(7) perturbations

SPP (500km/72h)



SPP (20 – 7Conv)

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…relevance for the greyzone…?

- **SPPT**: current stochastic model uncertainty representations very dependent on tendencies from the deep convection scheme
- **SPP**: greater control over attribution/representation of model uncertainty
  - Potential to focus on processes aside from deep convection
  - Assessing impacts on tendency budgets is useful diagnostic/development tool
  - ➢ Indicate increasing importance of cloud/BL parametrisations and dynamics tendencies
- **Aquaplanet** experiments:
  - Simplified environment for testing physics perturbations
  - Highlight impact of correlation scales in the random patterns
  - *Possible route to cost-effective explicit convection experiments – via small-planet?*

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Exploring stochastic model uncertainty representations

… with relevance to the greyzone …

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Thank you for your attention!

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