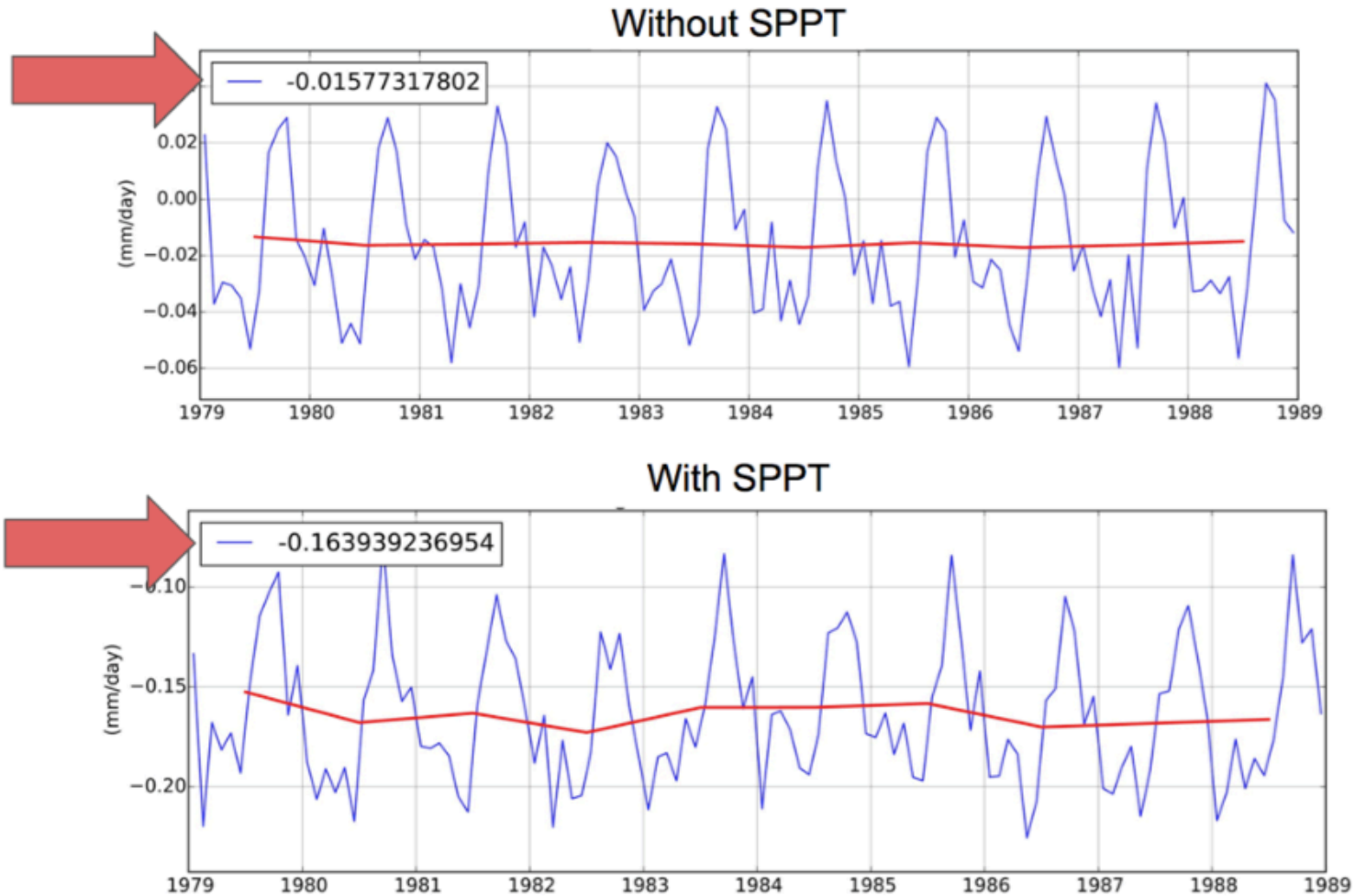
SPPT and water conservation in IFS

work in progress

June 25, 2017

Precipitation - Evaporation



- SPPT leads to water budget residual of $\approx$ -0.15 mm/day, hence drying of the atmosphere

Total column water vapour

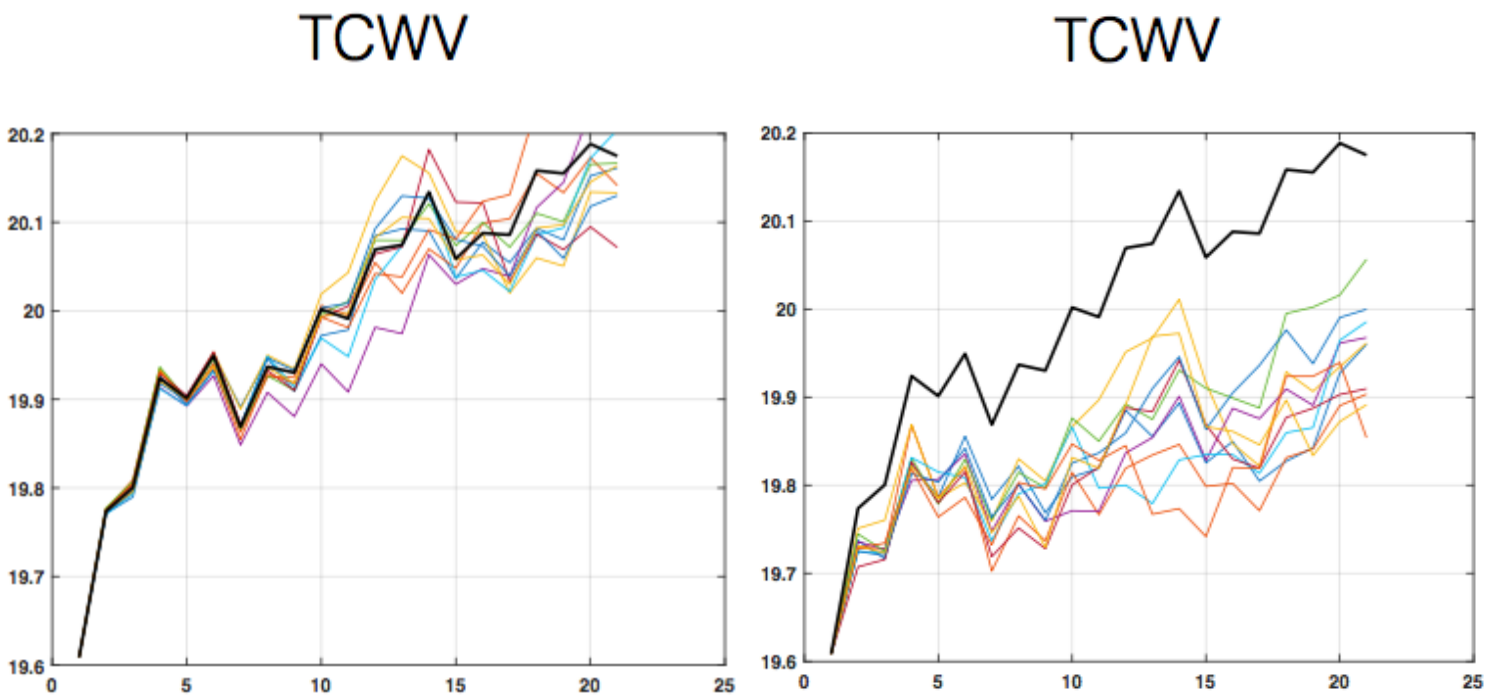


Figure: Without SPPT vs. with SPPT in the first 20 days of forecast

- control (black)
- ensemble member (colors)

Water budget

Let q be the water content in a grid cell, $\mathbf{F}$ be its flux, then

$$\partial_t q = -\nabla \cdot \mathbf{F}$$

Vertical integration yields

$$\int_{p_s(t)}^{p_{top}} \partial_t q \; dp = -\underbrace{\int_{p_s(t)}^{p_{top}} \nabla_H \cdot \mathbf{F}_H \; dp}_{\equiv VIMD} - P - E$$

Interchanging integral and temporal derivative

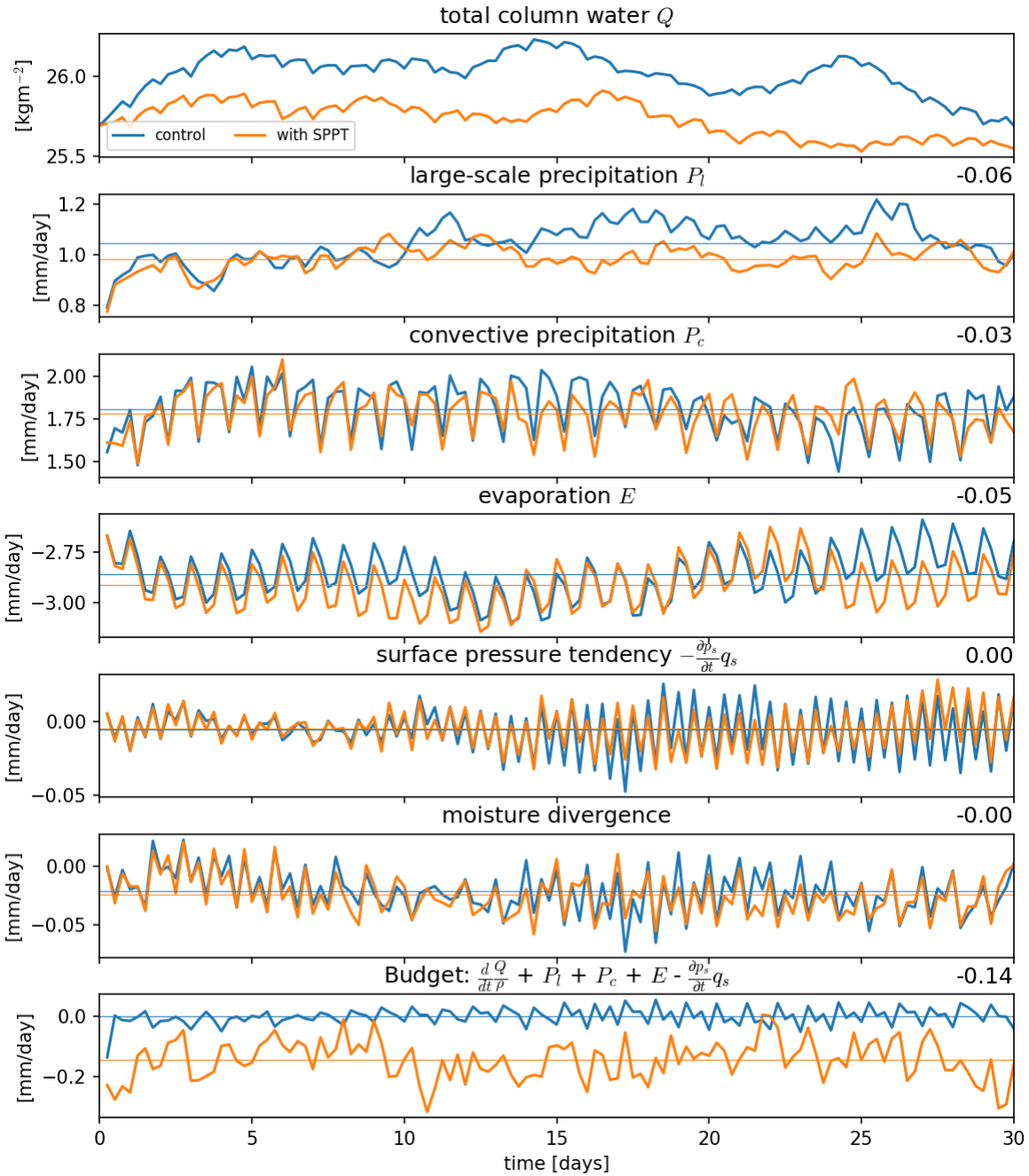
$$\partial_t TCW + q|_{p=p_s} \partial_t p_s + VIMD + P + E = 0$$

Note, that with the global integral $\langle\rangle$

$$\langle VIMD \rangle = 0$$

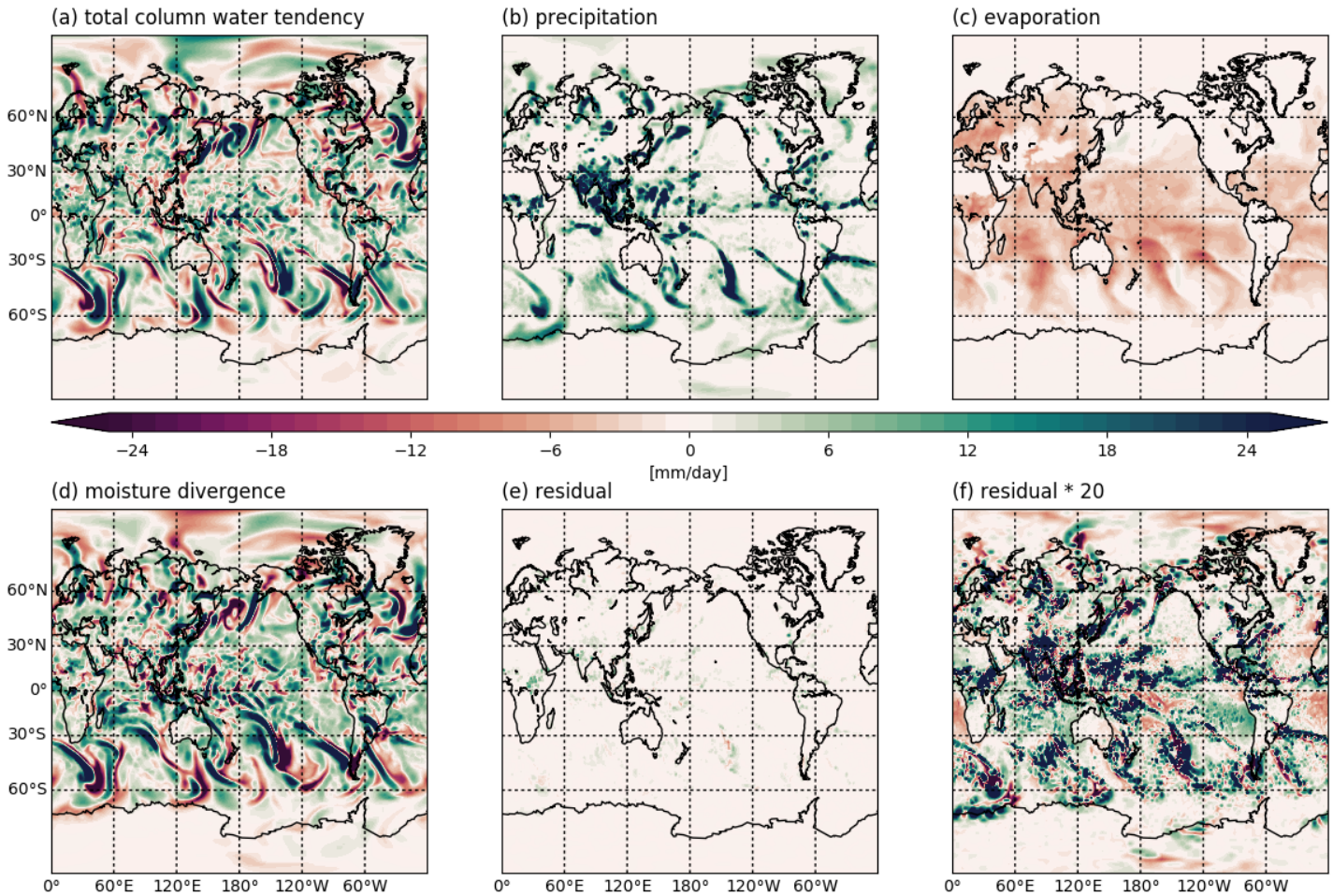
should vanish.

Water budget in IFS



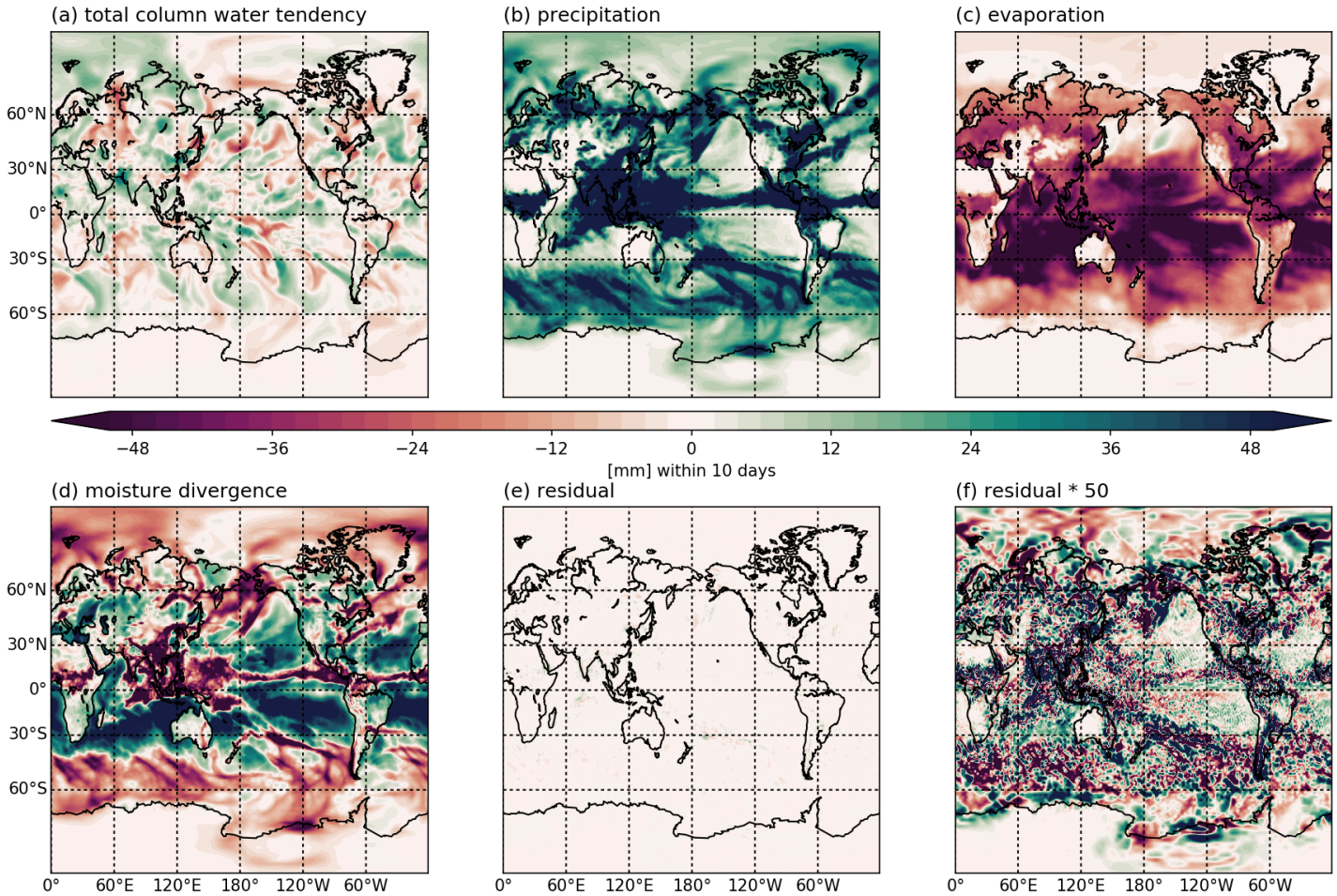
Water budget in IFS

10 days after forecast initilization, without SPPT



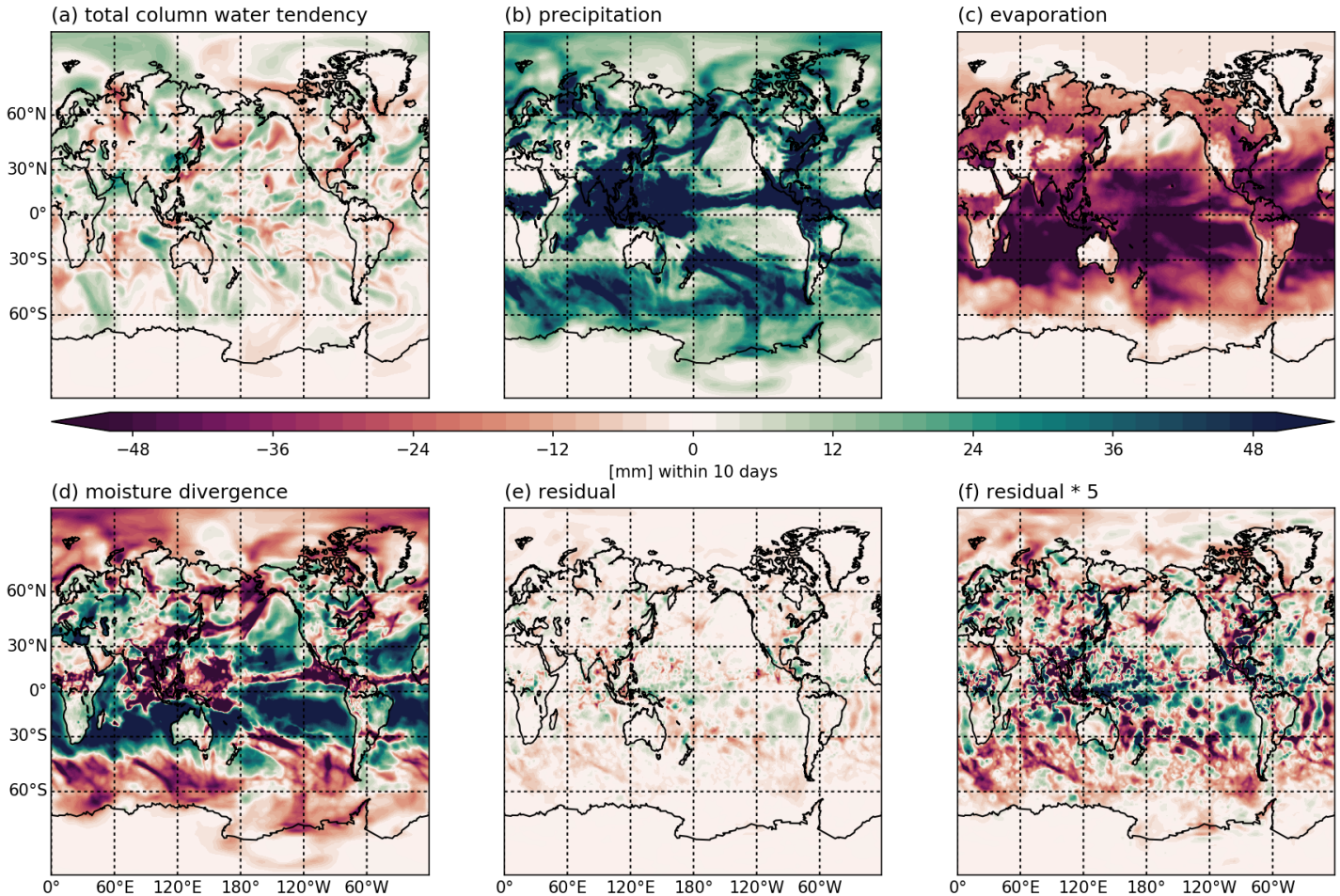
Water budget in IFS

integrated over 10 days after forecast initilization, without SPPT

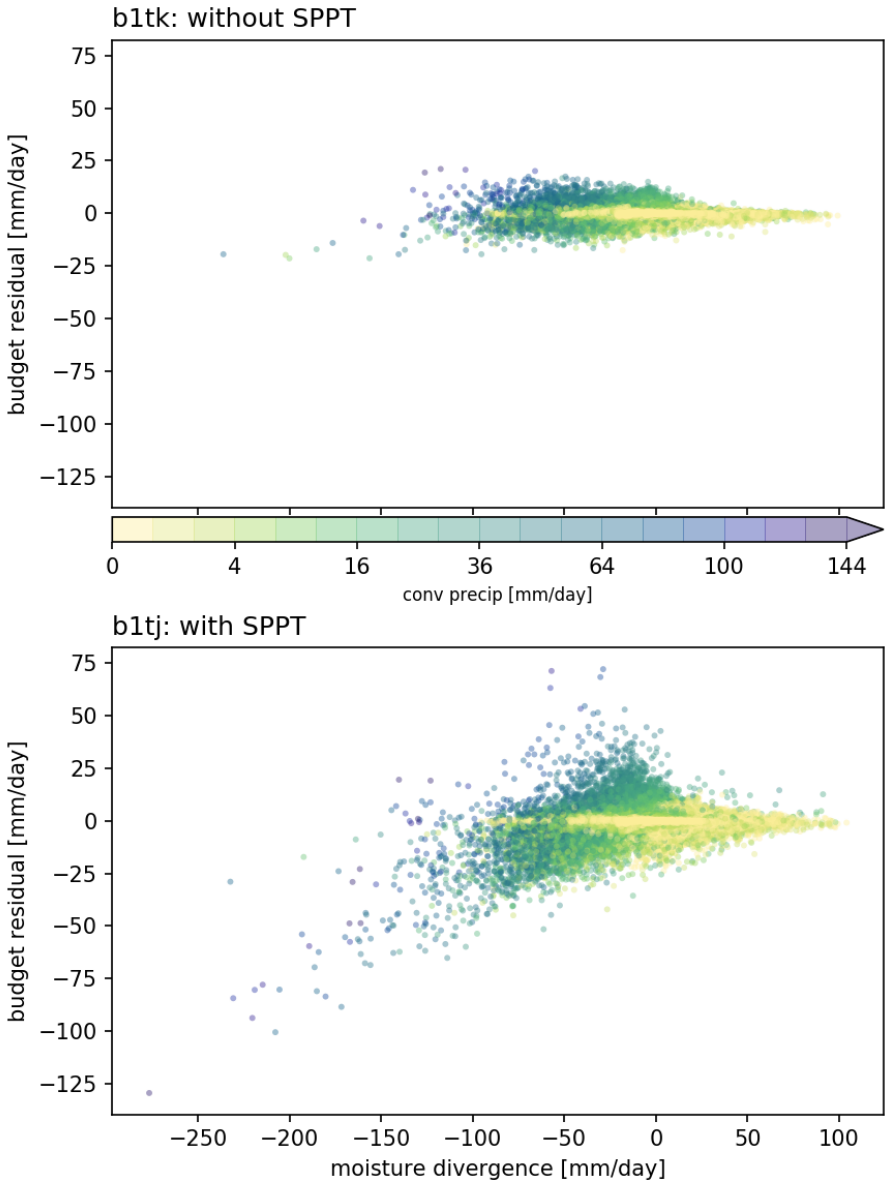


Water budget in IFS

integrated over 10 days after forecast initilization, with SPPT

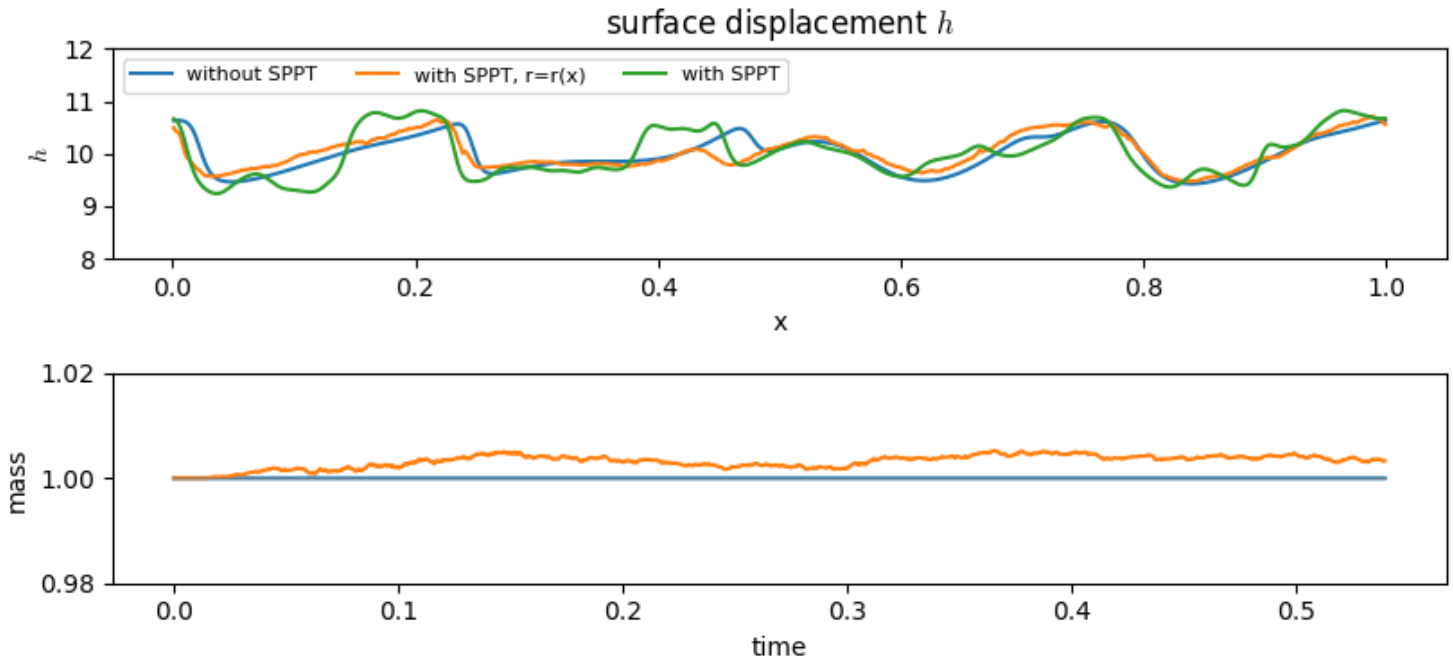


Water budget in IFS - when does water vanish?



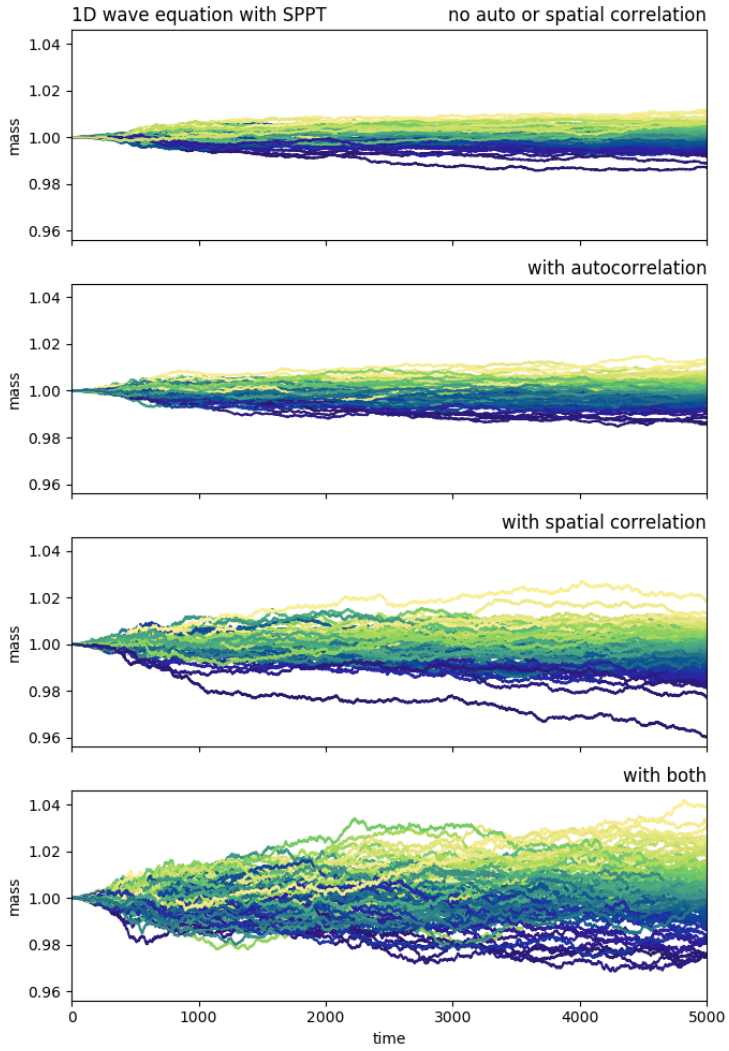
Back to the roots: 1D wave equation and SPPT

$$\partial_t u = -u\partial_x u - g\partial_x h + \mathcal{D} + \mathcal{F}$$
$$\partial_t h = -(1+r)\partial_x(uh)$$



- r = r(t) yields conservation of mass
- r = r(x,t) non-conservation of mass, random walk

Back to the roots: 1D wave equation and SPPT



- r = r(x,t), more autocorrelation yields a faster deviation

Water budget in IFS with SPPT

with Q the total column water

deterministic model

$$dQ = \partial_t Q - Q_{ten}^{dyn} - Q_{ten}^{phys} + P - E = 0$$

with SPPT

$$\begin{aligned} dQ_{SPPT} &= \partial_t Q - Q_{ten}^{dyn} - (1+r)Q_{ten}^{phys} + P - E \\ &= -rQ_{ten}^{phys} \end{aligned}$$

- Any correlation between r and Q_{ten}^{phys} ?

Water budget in IFS with SPPT

with Q the total column water

deterministic model

$$dQ = \partial_t Q - Q_{ten}^{dyn} - Q_{ten}^{phys} + P - E = 0$$

with SPPT and surface perturbation

$$\begin{aligned} dQ_{surf.pert.} &= \partial_t TCW - Q_{ten}^{dyn} - (1+r)\left(Q_{ten}^{phys} + P - E\right) \\ &= -r(Q_{ten}^{phys} - P + E) \end{aligned}$$

- Are P, E completely balanced by Q_{ten}^{phys}?

Water budget in IFS

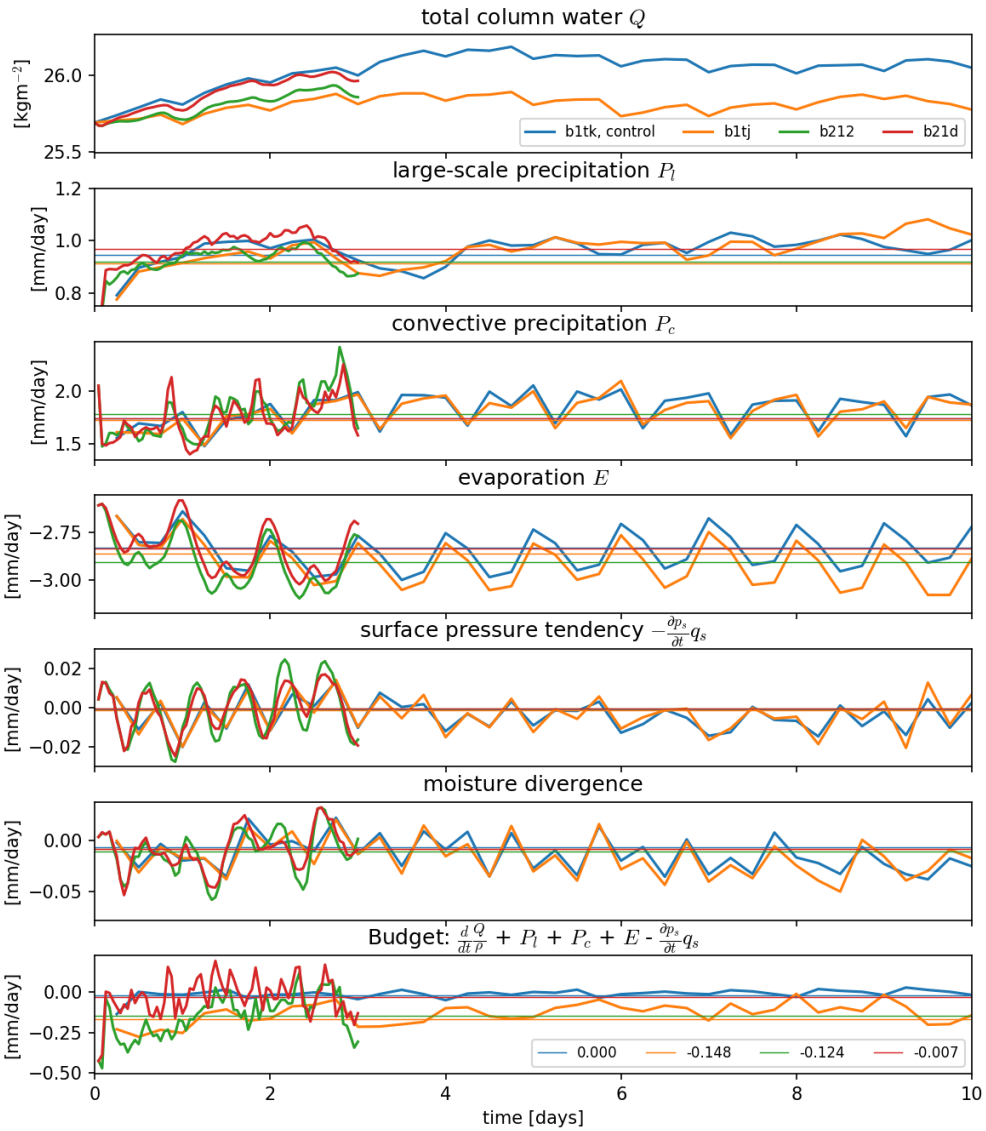


Figure: deterministic (blue), standard SPPT (orange), no BL-tapering (green), no autocorrelation (red)