Progress towards a novel convection parameterisation with stochastic elements

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Motivation

Convection in GCMs

"The **broad-scale features** of precipitation as simulated by the CMIP5 models are in modest agreement with observations, but there are **systematic errors in the Tropics**" (Flato et al., 2013)

Despite concerted efforts over the past 5 decades, **atmospheric convection is still unsatisfactorily represented** in global atmospheric models

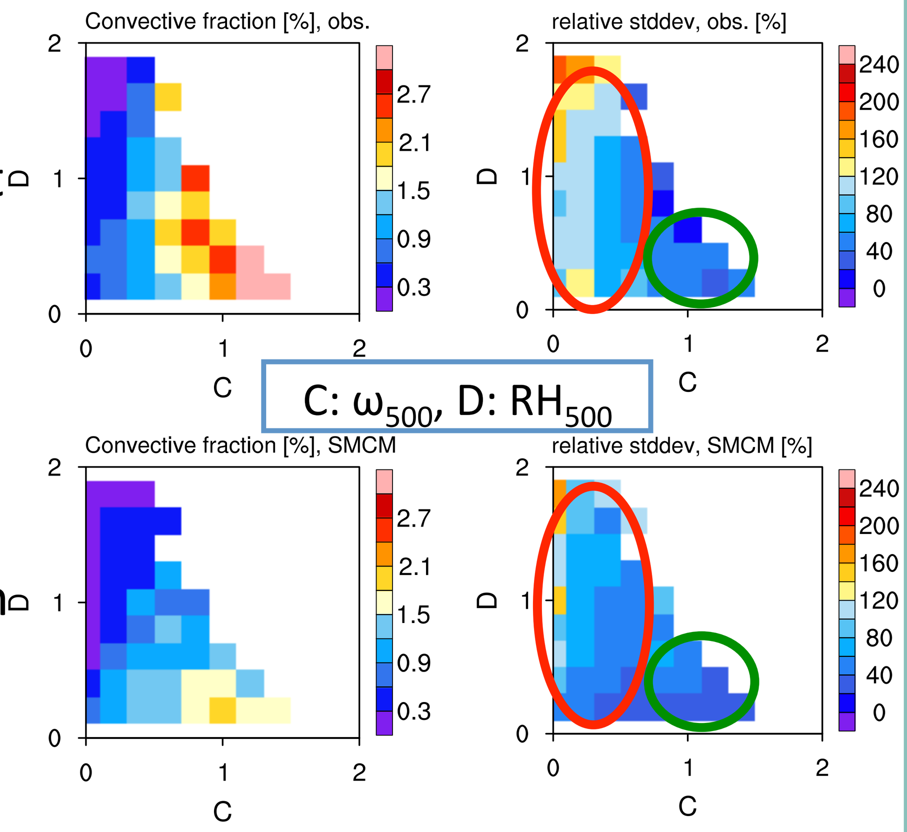
Essentials for future convection schemes

1) scale adaptive
   - with increasing resolution, the assumption of **"convective area << grid box area"** breaks down (e.g. Arakawa et al. (2011))
   - address the issue by defining cumulus mass fluxes as **"area of convective clouds x velocity"** and then parameterise the area
2) stochastic
   - **variability of subgrid-scale processes** has implications on the resolved large-scale processes (e.g. Horinouchi et al. (2003)), **deeming stochastic methods necessary** (e.g. Palmer (2012))

"Killing two birds with one stone"

The **Stochastic Multi Cloud Model** (SMCM, Khouider et al. (2010)) calculates **convective cloud area fractions** by means of a coarse-grained **stochastic Markov process.**

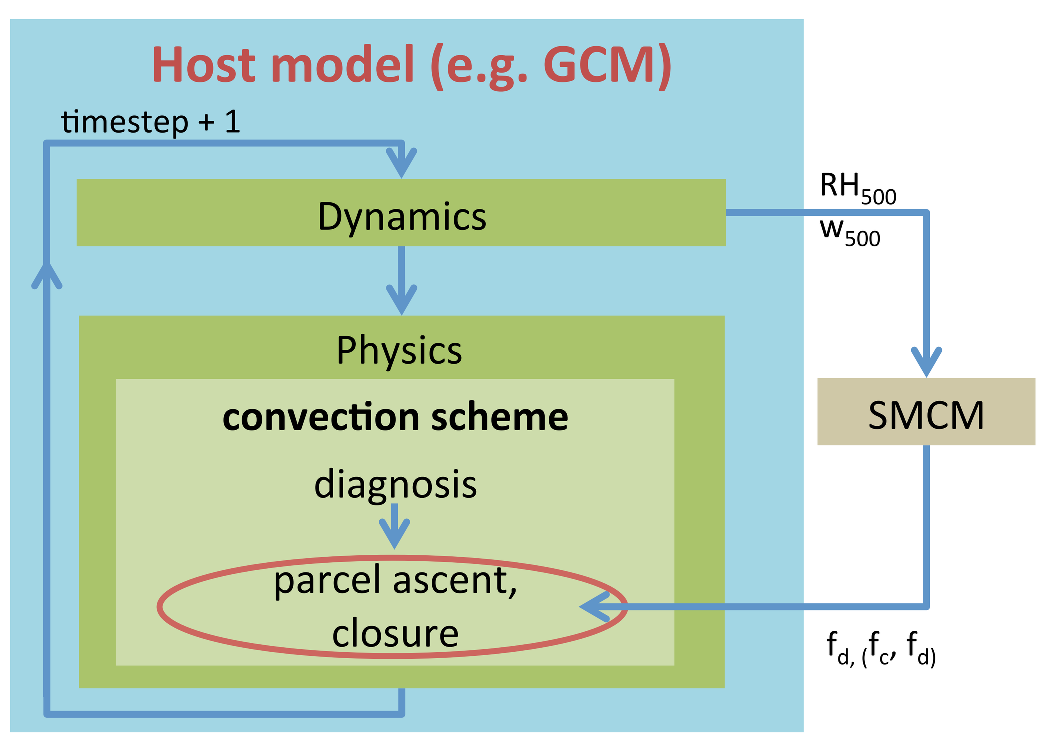
The SMCM has been shown to adequately simulate essential modes of tropical variability and **reproduce observed convective behaviour** (Peters et al. (2013)).



"**Stochastic** to **quasi-deterministic** transition" found in observations and also captured by the SMCM

Implementation

The SMCM as part of an existing scheme



For each host model timestep, do:

Provide grid-box mean values of **vertical velocity w** and **relative humidity RH** at 500hPa to the SMCM before start of model physics.

Pass **SMCM-calculated** deep convective area fraction $\mathbf{f_d}$ to the convection scheme.

Calculate convective cloud base mass flux as **"f_d x 1 ms^{-1}"**, let the existing cloud model do the up- and downdrafts and **don't close the scheme on CAPE!**

Future work may also include use of SMCM-calculated congestus and stratiform cloud area fractions (f_c, f_s)

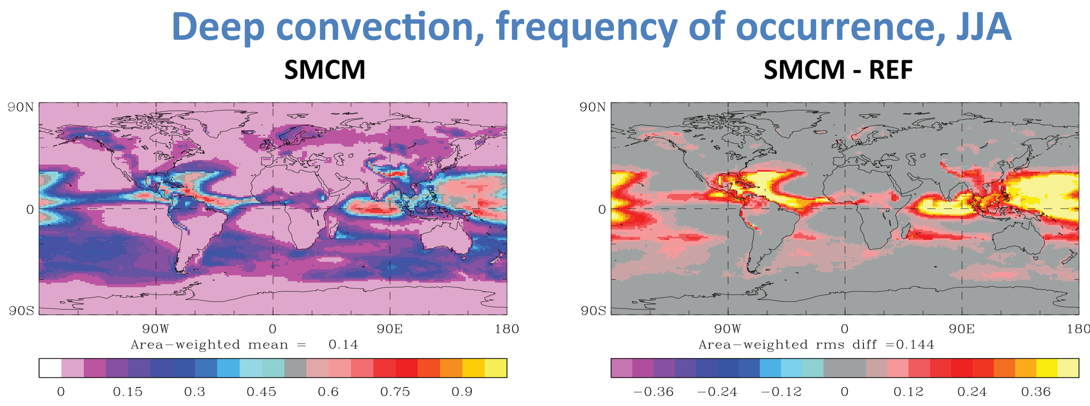
Models used and first test runs

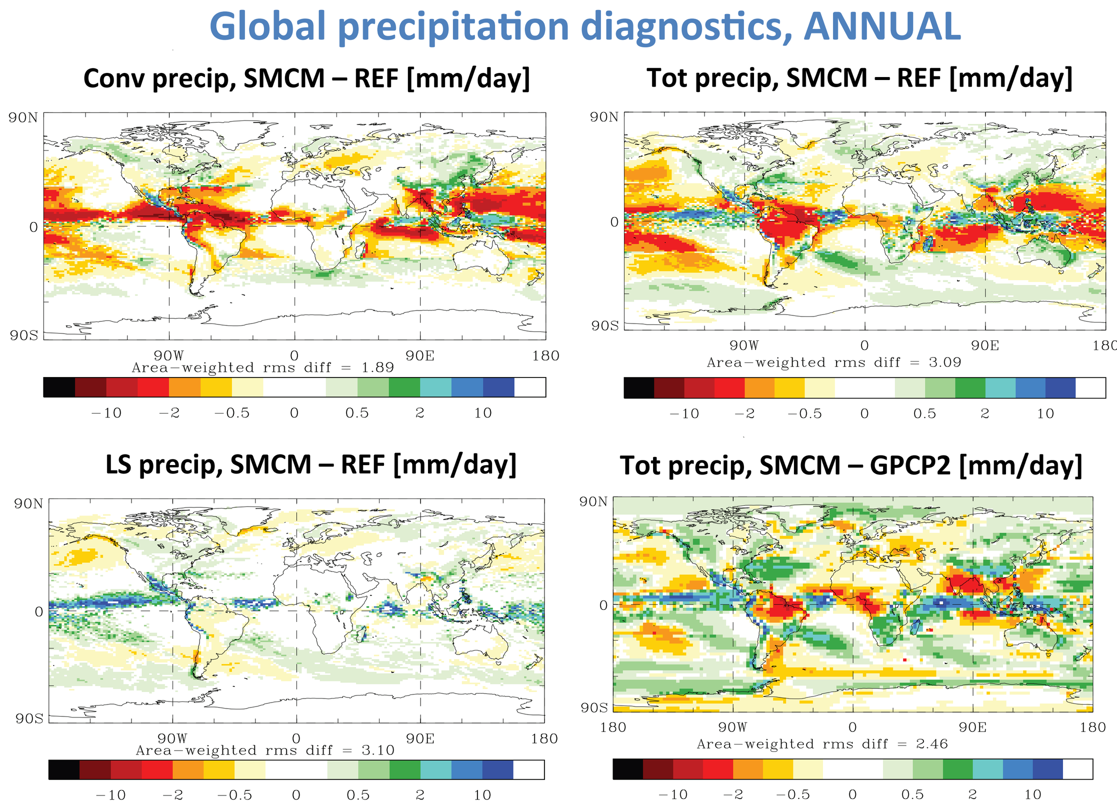
① **Met Office UM vn8.5**, GA5.0 physics, Gregory & Rowntree (1990) convection, convective diagnosis based on boundary layer type classification after Lock et al. (2000), SMCM applied to tropics only; N96L85 resolution (1.875°x1.25° at the equator), 20yr AMIP style runs (1989 – 2008)

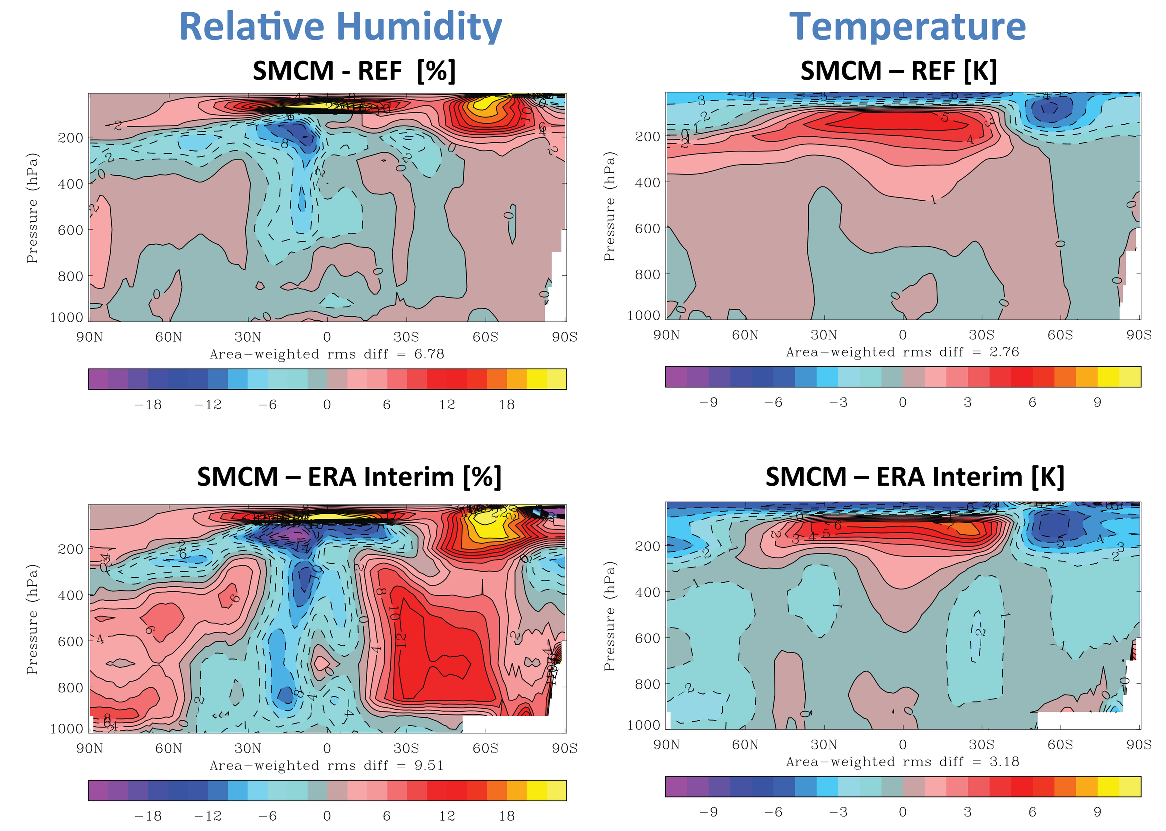
② **ECHAM6.2 (research version)**, Tiedtke (1989) with modifications by Nordeng (1994) convection, convective diagnosis based on boundary layer moisture convergence (among others, cf. Möbis and Stevens (2012)) SMCM applied globally; T63L47 (1.8°x1.8°) resolution, 5yr AMIP style runs (2003 – 2007)

Preliminary Results

UMvn8.5 GA5.0

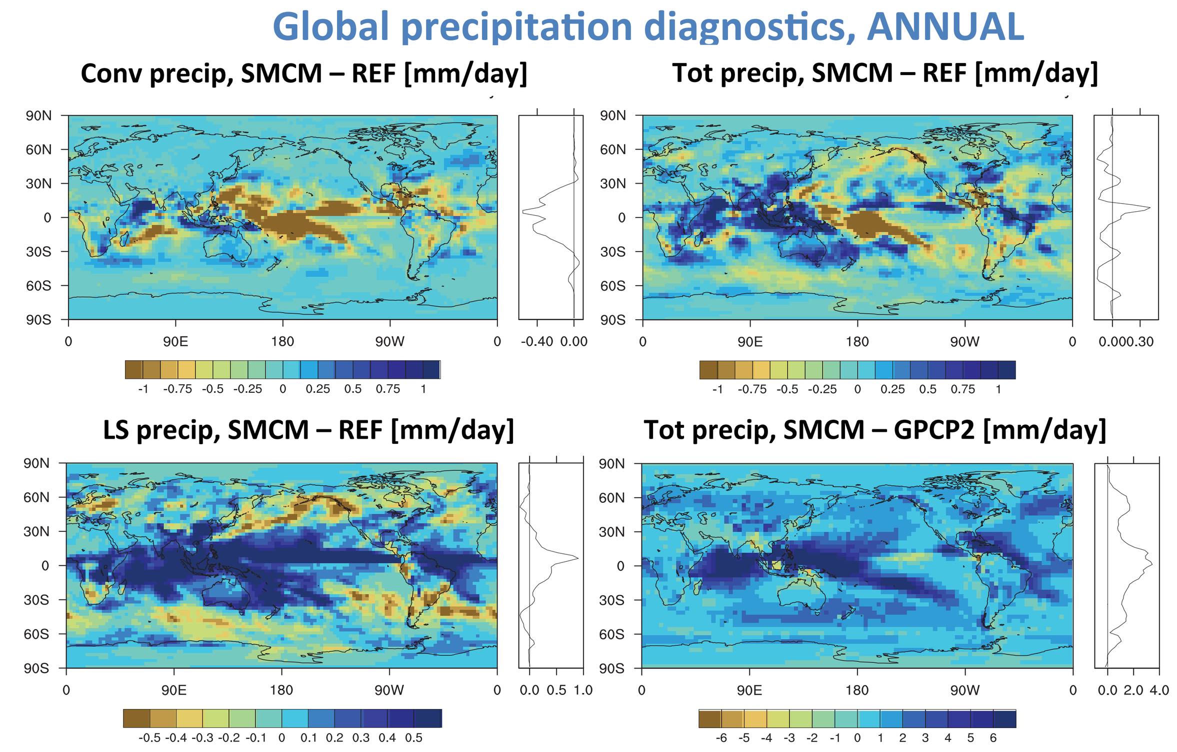


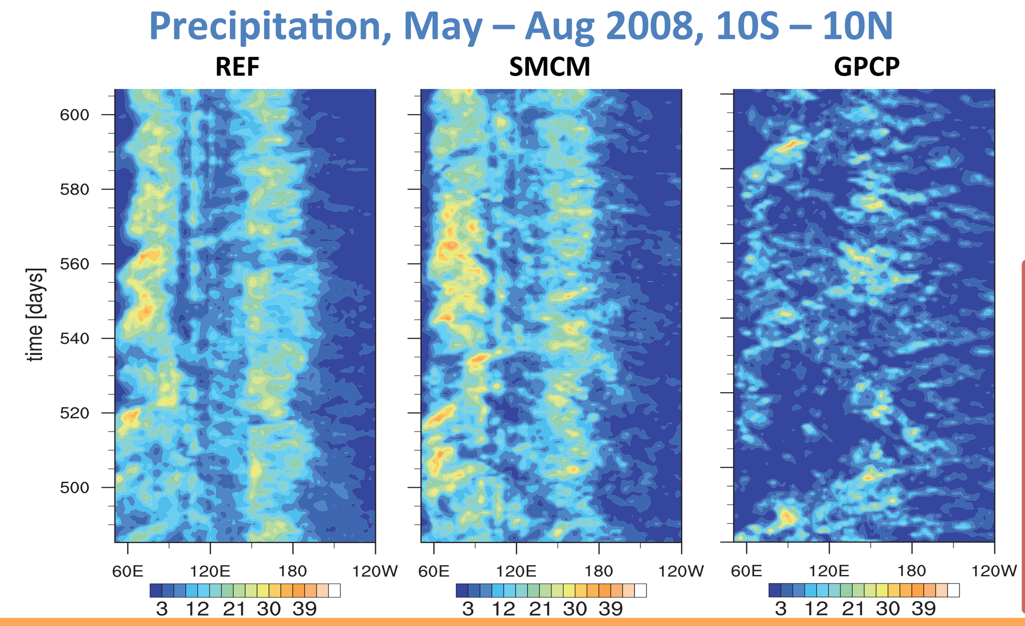


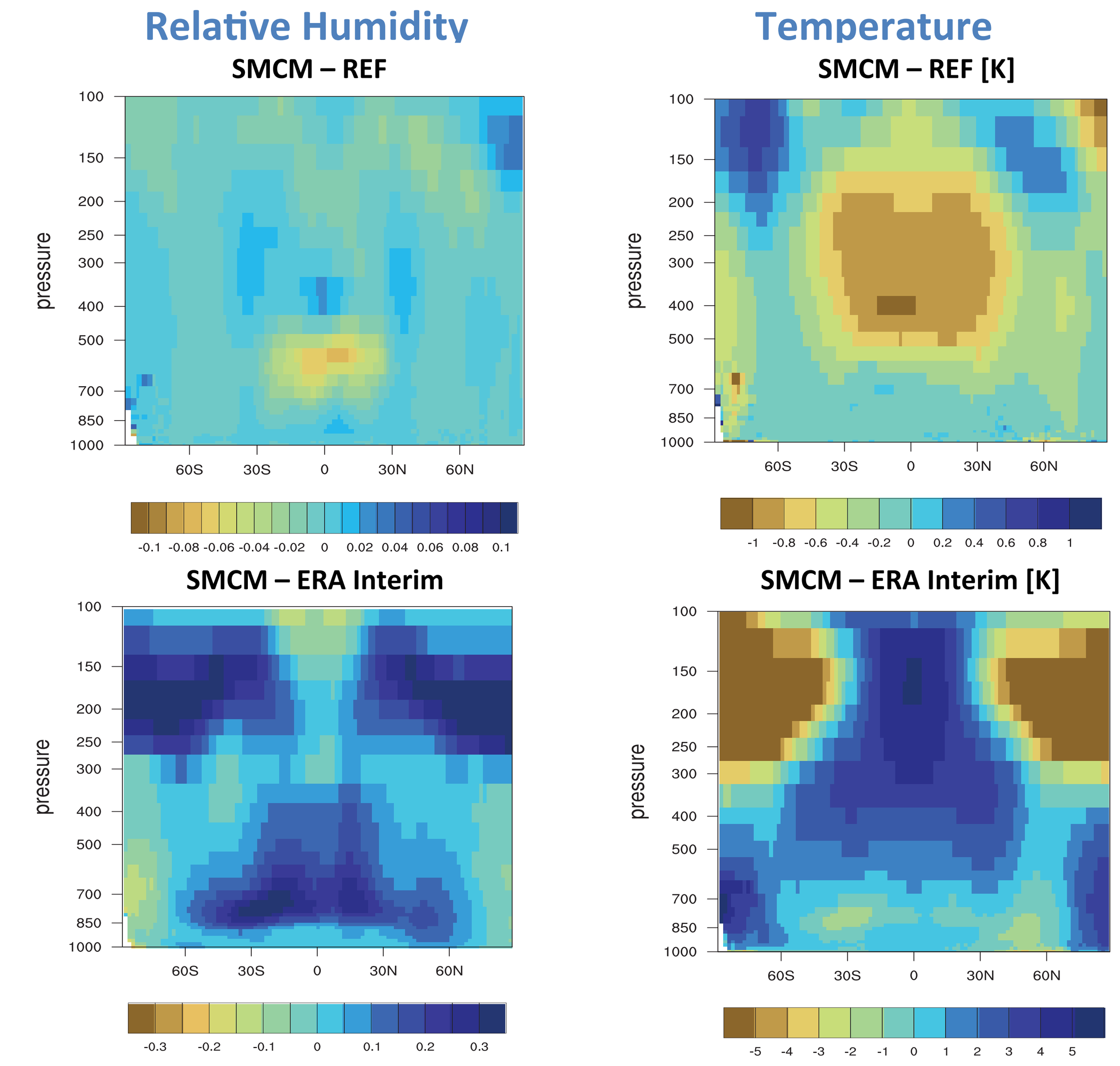


- **intensity of deep convection** per model timestep **substantially reduced**, making it more continuous ("convective memory")
- **RMS differences** w.r.t. observations **slightly worse** for all diagnostics compared to REF
- **substantial underestimation of precipitation over the Amazon**, possibly due to inconsistencies between the diagnosis and the SMCM submodel
- **overall promising results, considering there has been no tuning applied**

ECHAM







- **similar impact as in the UM**, i.e. weaker convection, especially evident in a cooler mid- to upper tropospere w.r.t. REF
- **increased organization of precip** compared to REF
- **RMS differences** to observations **smaller for SMCM than REF** (not shown) *(note that REF is untuned)*
- **like for the UM, these are promising results, further development/testing underway**

References

Arakawa et al. (2011), Atmos. Chem. Phys., 11, 3731 – 3742, 2011; **Flato et al. (2013)**, IPCC AR5, Evaluation of Climate Models, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013; **Gregory & Rowntree (1990)**, Mon. Wea. Rev., 118, 1483 – 1506, 1990; **Horinouchi et al. (2003)**, J. Atmos. Sci., 60, 2765 – 2782, 2003; **Palmer (2012)**, Q. J. Roy. Meteor. Soc., 138, 841 – 861, 2012; **Khouider et al. (2010)**, Commun. Math. Sci., 8, 187 – 216, 2010; **Lock et al. (2000)**, Mon. Wea. Rev., 128, 3187 – 3199, 2000; **Möbis and Stevens (2012)**, J. Adv. Model. Earth Sys., 4, M00A04, 2012; **Nordeng (1994)**, Tech. Memo. 206, ECMWF, 1994; **Peters et al. (2013)**, J. Atmos. Sci., 70, 3556 – 3575, 2013; **Tiedtke (1989)**, Mon. Wea. Rev., 117, 1779 – 1800, 1989;

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