KNMI Parameterization Testbed

Continuous single-column model evaluation at a permanent meteorological supersite

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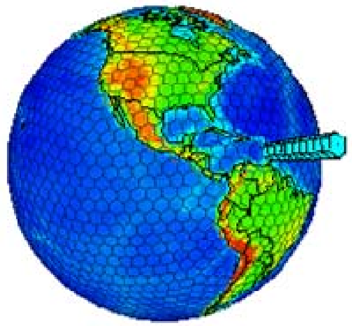
* Motivation and strategy:
  Towards statistically significant process-level evaluation

* First major results: A brief summary

* The role of KPT in EUCLIPSE

Process-level evaluation

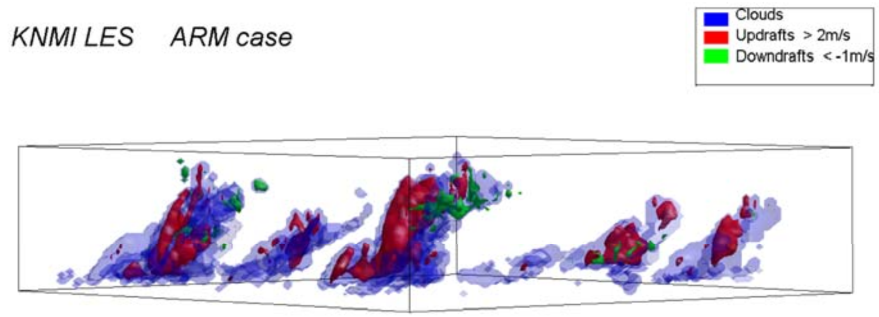
Single column model (SCM) simulation



Time-integration of a single column of sub-grid parameterizations in isolated mode, using prescribed large-scale forcings

Large-Eddy Simulation (LES)

3D simulation of turbulent flow at high resolution (~10m) in a small domain (~10km), using prescribed large-scale forcings



Classical GCSS approach:

Build <u>idealized cases</u> based on observations, considered typical for a specific weather regime of interest

LES models are inter-compared, SCMs are evaluated against LES

Potential issues

i) How representative are idealized cases of actual climate?

ii) Parameterizations might get calibrated to rare situations

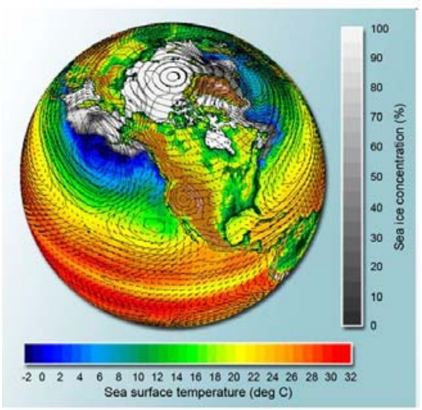
iii) Do the available cases represent those situations in which GCMs have most trouble?

iv) There is a wealth of potentially useful observational data out there that is not structurally used for evaluation (e.g. Jakob, BAMS 2010)

Q: How can we improve the statistical significance of SCM simulations?
How can we let GCM statistics guide the SCM effort?

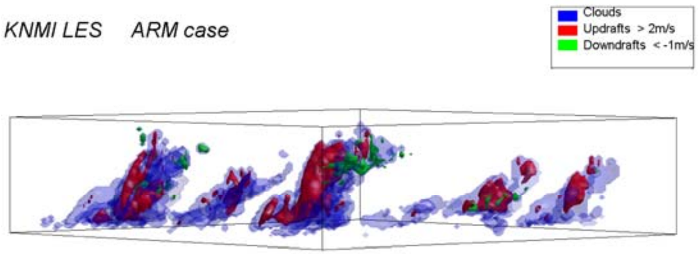
The evaluation dilemma:

Studies of global climate



Representative but complex

Process-level evaluation



Transparent but not necessarily representative

Transpose AMIP

Can we find the middle ground?

Testbeds

The KNMI Parameterization Testbed (KPT)

Goal: *To improve the statistical significance of process-level evaluation, while still maintaining the benefits of single-case studies*

Method:

* *To automatically generate continuous series of daily SCM and LES simulations, for long periods of time (years)*

* *To evaluate the complete parameterized system against observational datasets from meteorological supersites* ***at multiple timescales****

I. Generating long series of daily SCM and LES simulations

Allows generating monthly/yearly composite means:

* Improved statistical significance
* GCM and SCM can be compared at the same (long-term) statistical level
* Many different weather regimes are automatically captured

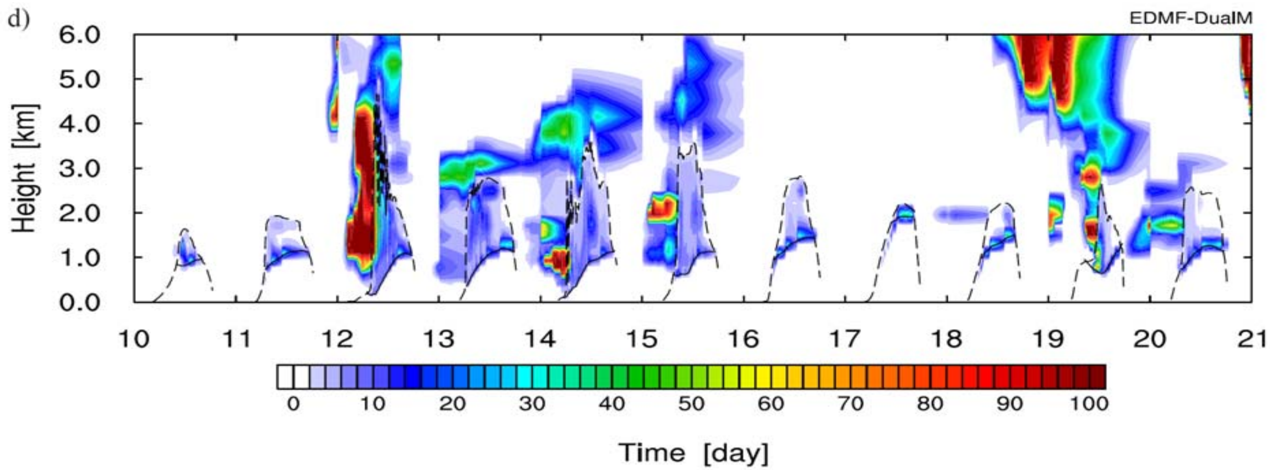
The capacity to still zoom in on individual days and study the original simulation data (at integration time-step) preserves the benefits of single-case studies:

* Model transparency & computational efficiency
* Exposes behavior at process-level, both numerical and conceptual

Relevance is assured:

Study cases that contribute most to a long-term bias

SCM results at Cabauw for June 2008



KPT model hierarchy

GCMs and/or RCMs provide large-scale forcings (RACMO, ERA Interim, HIRLAM)

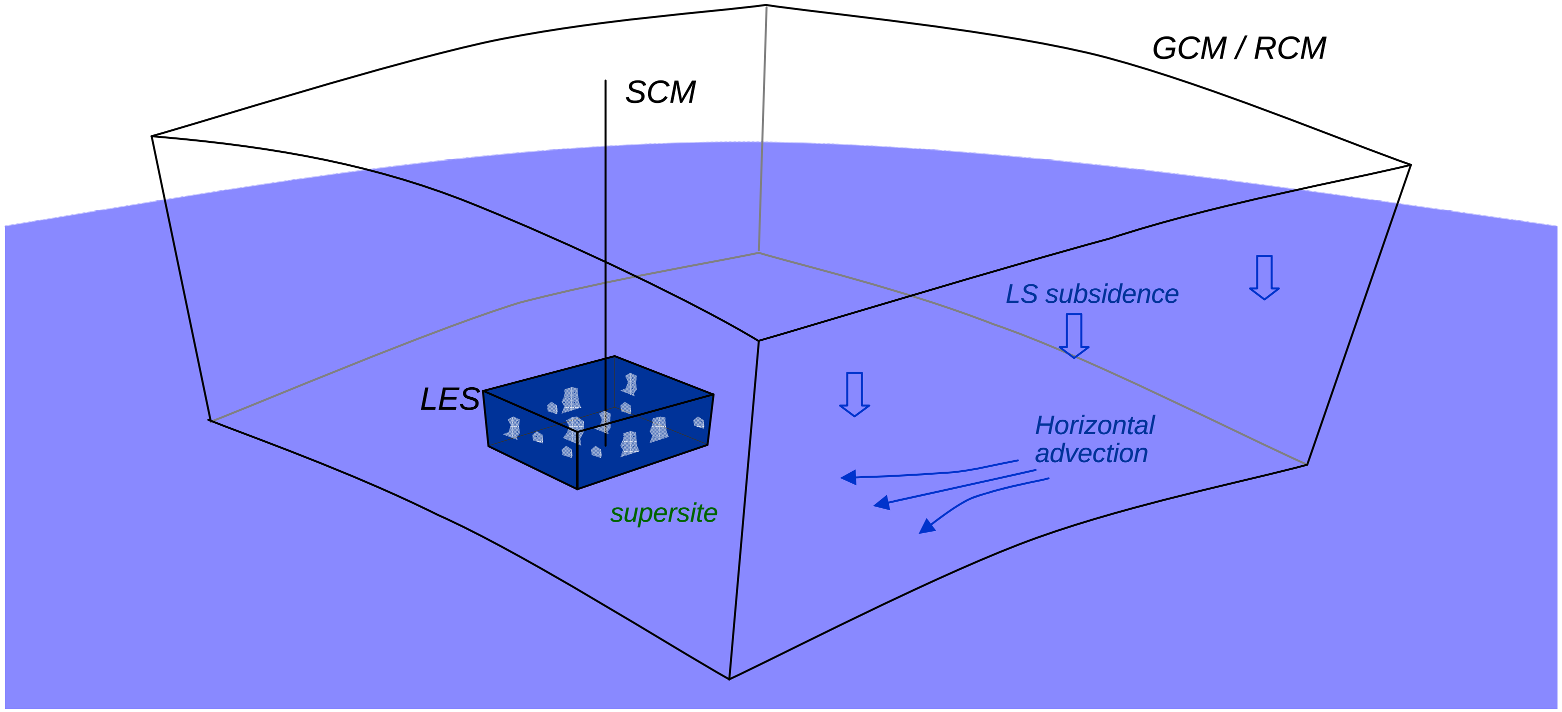
Automated short-range LES and SCM simulations, both daily forecasts and re-simulation of past periods

LES runs represent a high-resolution "downscaling" of the GCM state:

- Can provide info on small-scale spatial variability that instruments can not (yet) measure
- SCM and LES are ***exactly*** comparable, as their forcing is equivalent

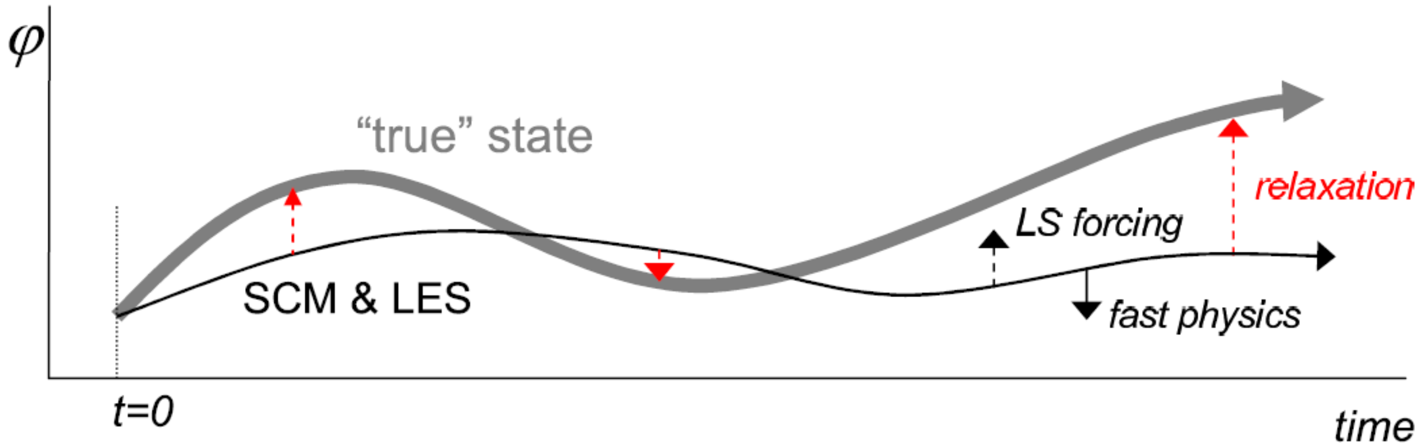
SCM and LES simulations can be constrained as appropriate

- Relaxation / assimilation, prescribed boundaries, etc.



Nudging towards a background state

Purpose: to get the mean model state as close to the observed state as possible, while still giving the fast physics enough freedom to create their own unique state



The "true" or background state can be either:

i) observed

ii) modeled (short-range forecasts)

iii) a blending of both (re-analysis)

Nudging techniques:

i) Newtonian relaxation (choose a typical timescale, depending on problem of interest)

ii) Data assimilation (ensemble Kalman filters), using local observations at Cabauw

Participating SCM and LES codes

Operational:

RACMO	*(regional climate & NWP)*
ECMWF	*(medium-range NWP, climate as EC-Earth)*
ECHAM	*(climate)*
HARMONIE	*(non-hydrostatic high-res NWP)*
WRF	*(research)*
DALES	*(LES)*
COBEL	*(local fog-forecasting)*

Have shown interest:

ICON (DWD)

LMD

UK Met Office

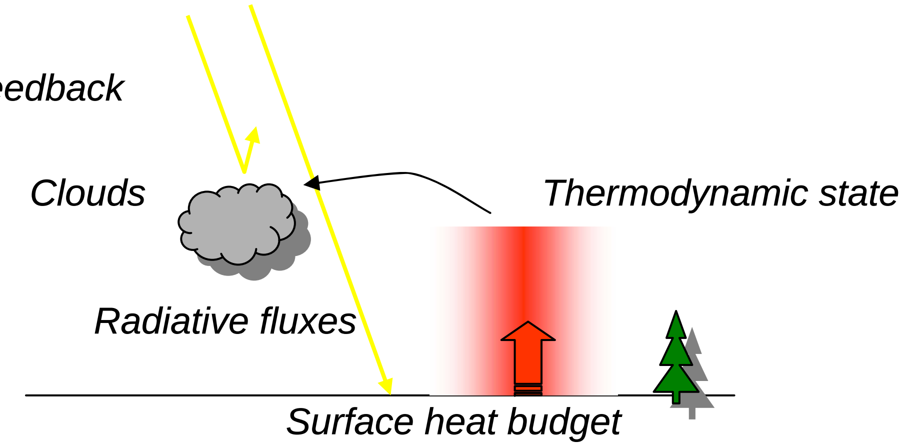
COSMO (DWD)

II. Comprehensive evaluation against observations

Simultaneously covering as many components of the parameterized system as possible with measurements

Purpose: the identification of compensating errors

Example:
the PBL cloud – radiation – surface feedback



Requires a multitude of independent measurements, with continuous long-term time-coverage, and available at high frequencies

Currently only available at a few meteorological supersites (Cabauw, CloudNet sites, ARM sites)

Cabauw observational datastreams currently available in KPT

In situ

- Surface thermodynamics
- Surface momentum
- Surface turbulence
- Tower thermodynamics
- Tower momentum
- Tower turbulence
- Standard surface radiative fluxes
- BSRN surface radiative fluxes
- Soil properties
- Radiosondes (De Bilt)
- Aerosols

Remote sensing

- Radar
- Ceilometers (CT75, LD40)
- Lidar (Leosphere)
- Microwave radiometer (HATPRO)
- CloudNet products (profiles)
- Various satellite datasets (MISR, GERB)

Expected soon: Spatial networks (covering "gridbox Holland")

- LD40 ceilometers
- Weather stations
- Radiosondes (variational analysis)

The graphical user interface

Beta version: http://www.knmi.nl/~neggers/KPT

Interactive visualization and inter-comparison of all types of datastreams at various time-scales

From integration-timestep to monthly / quarterly / yearly means

On-demand averaging

Digests datastreams (NetCDF) at any temporal /spatial resolution

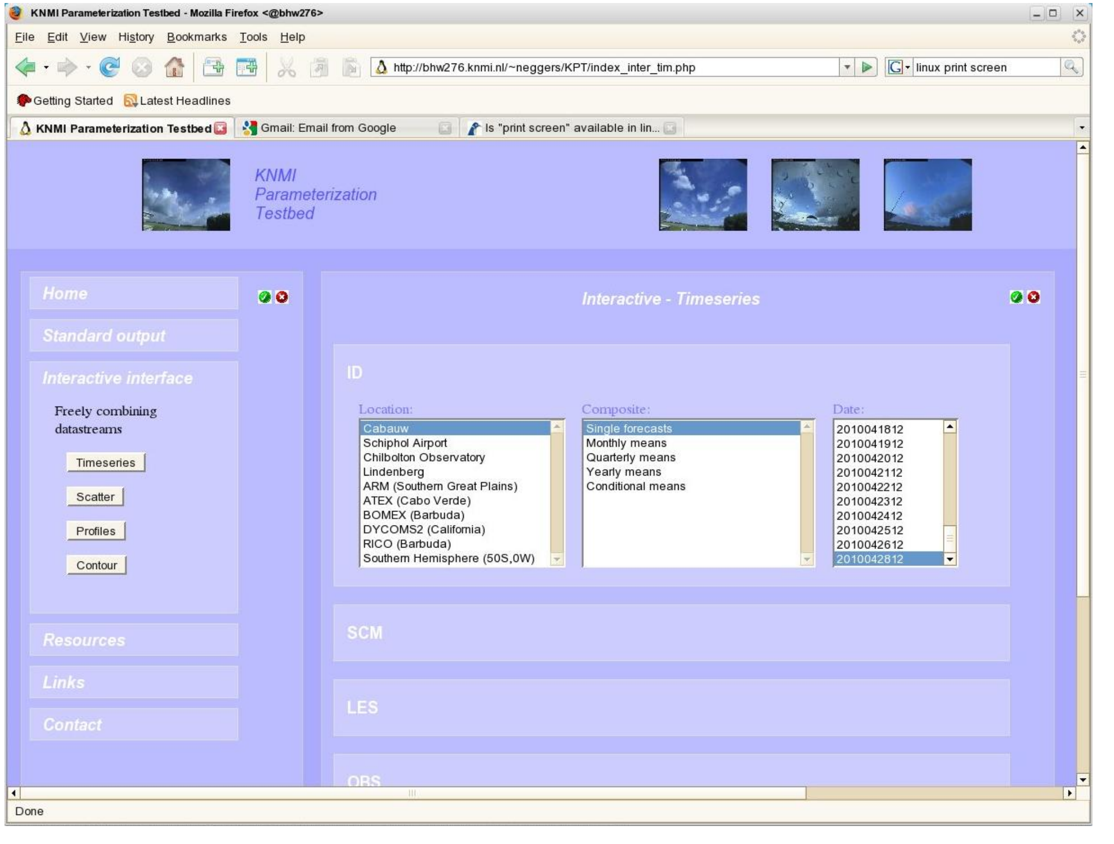
Uses NCL

Plot types:

* Timeseries
* Profiles
* Scatterplots
* Contour plots

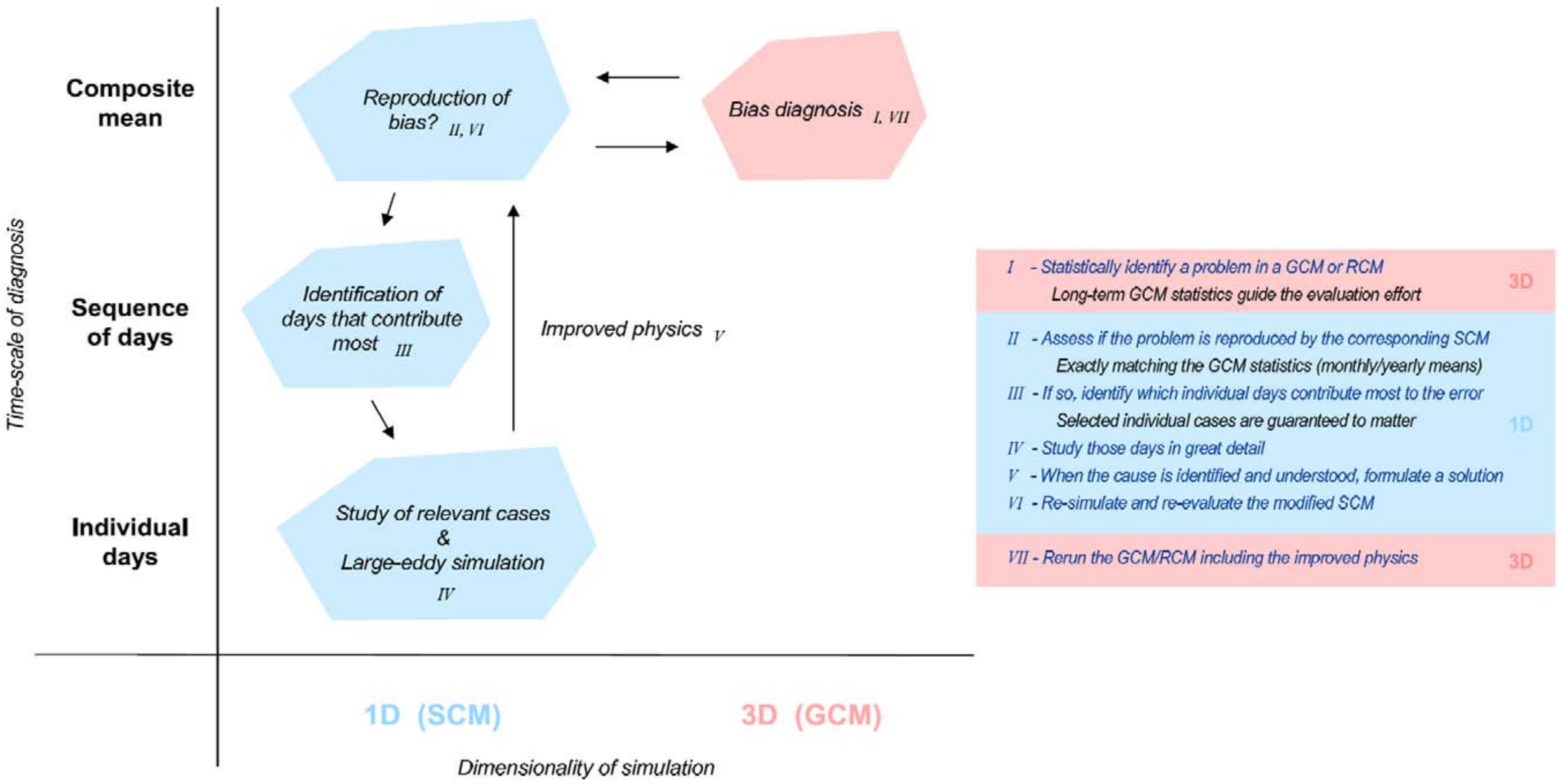
Other tools:

* Data quality plots
* Simulation chart
* Prefabricated plots
* Thumbnail viewer



KPT evaluation strategy

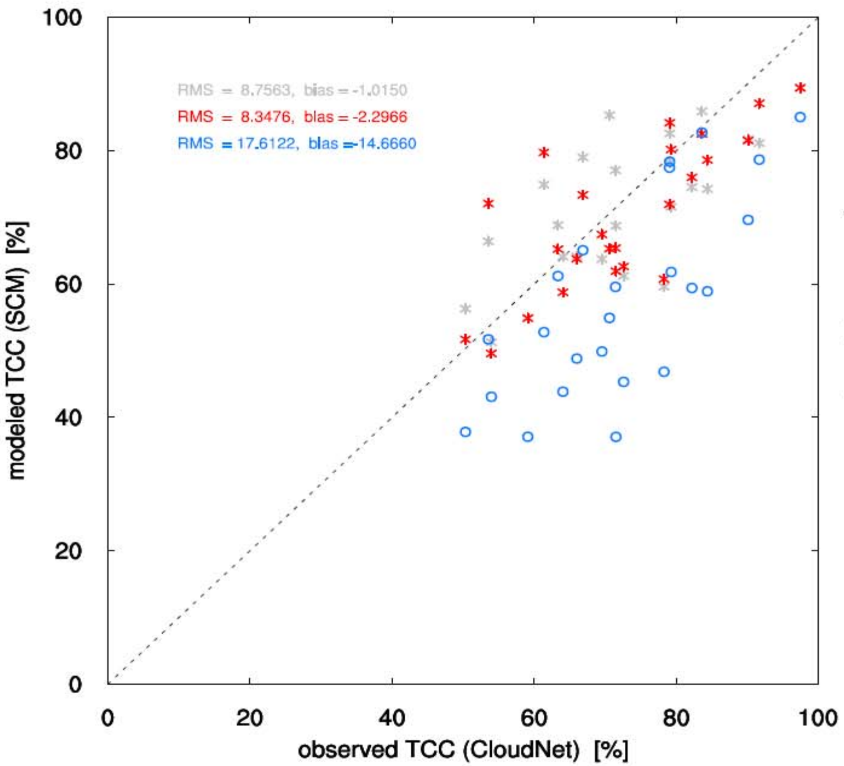
SCM process-level evaluation at various time-scales, guided by GCM statistics

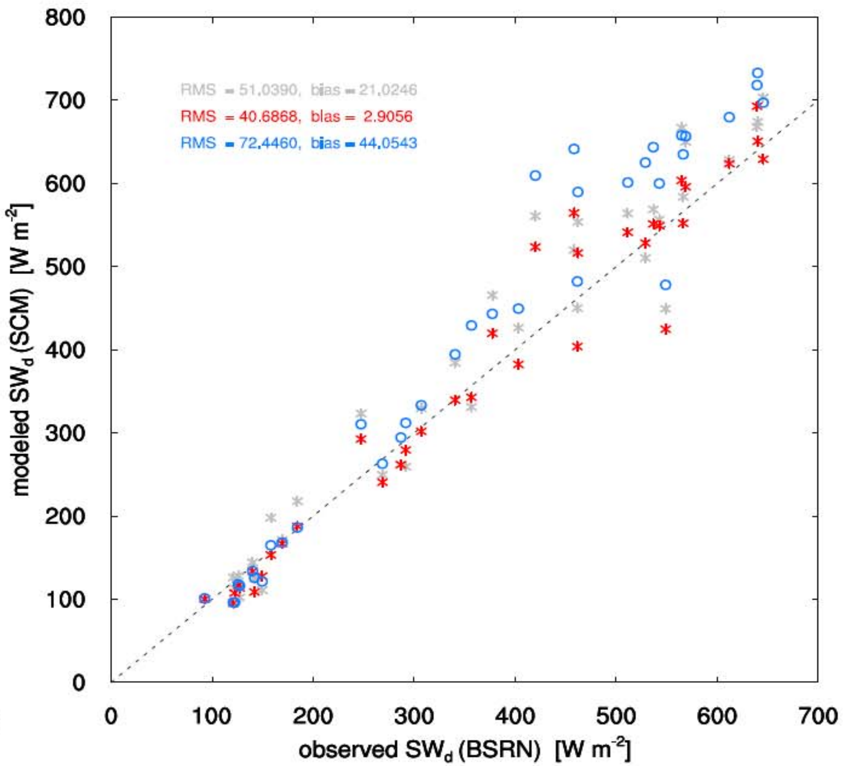


To be submitted to BAMS, September 2010

Example I: Long-term continuous SCM evaluation

Observed (x) versus modeled (y) monthly means at 12 UTC for 2007-2009

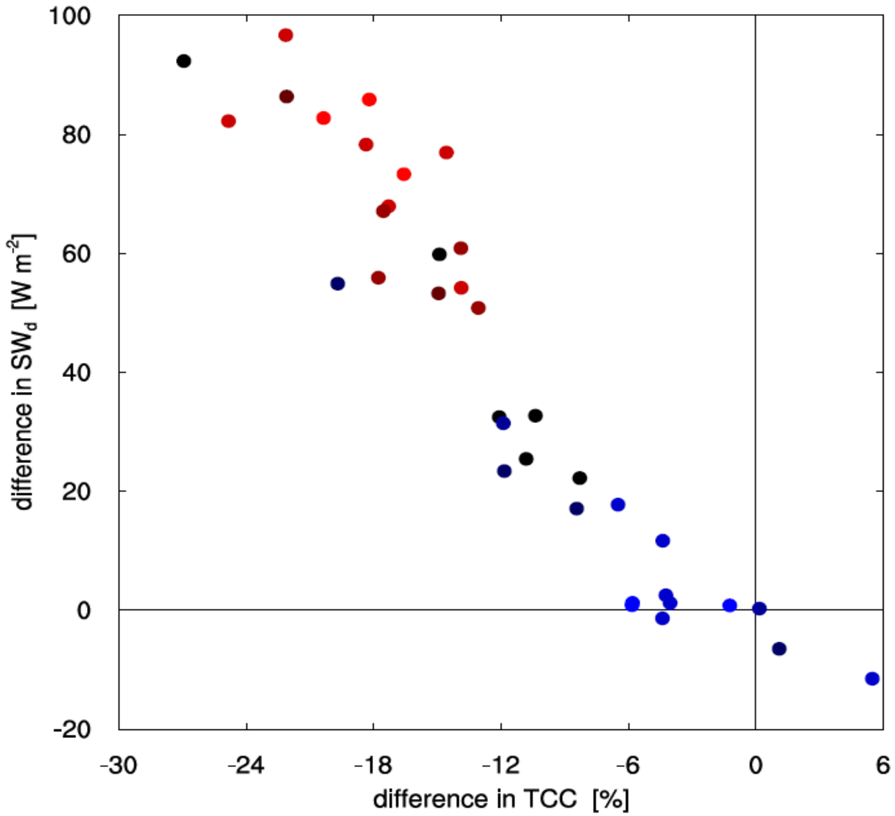


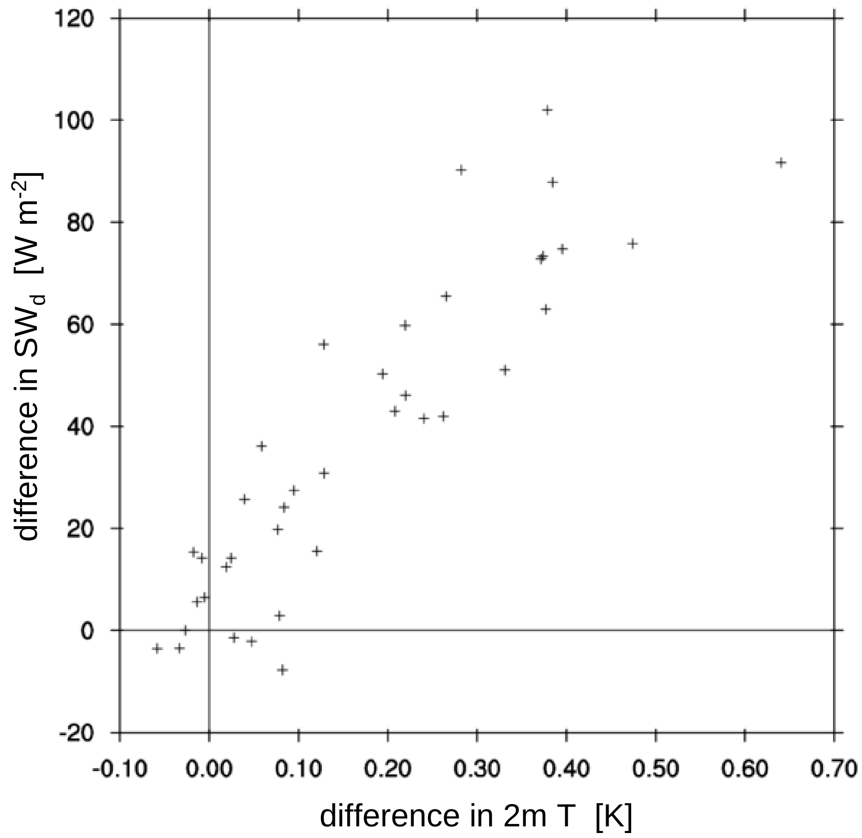


* *The SCM reproduces the behavior of its native GCM*
* *PBL physics can have big impact on summertime cloud-radiative climate*
* *Consistent bias against different observed parameters*

Grey: RACMO 3D (IFS physics)
Red: SCM CY31R1 (forced by RACMO)
Blue: SCM CY31R1 + EDMF-DualM (forced by RACMO)

Correlated model differences (new – old):





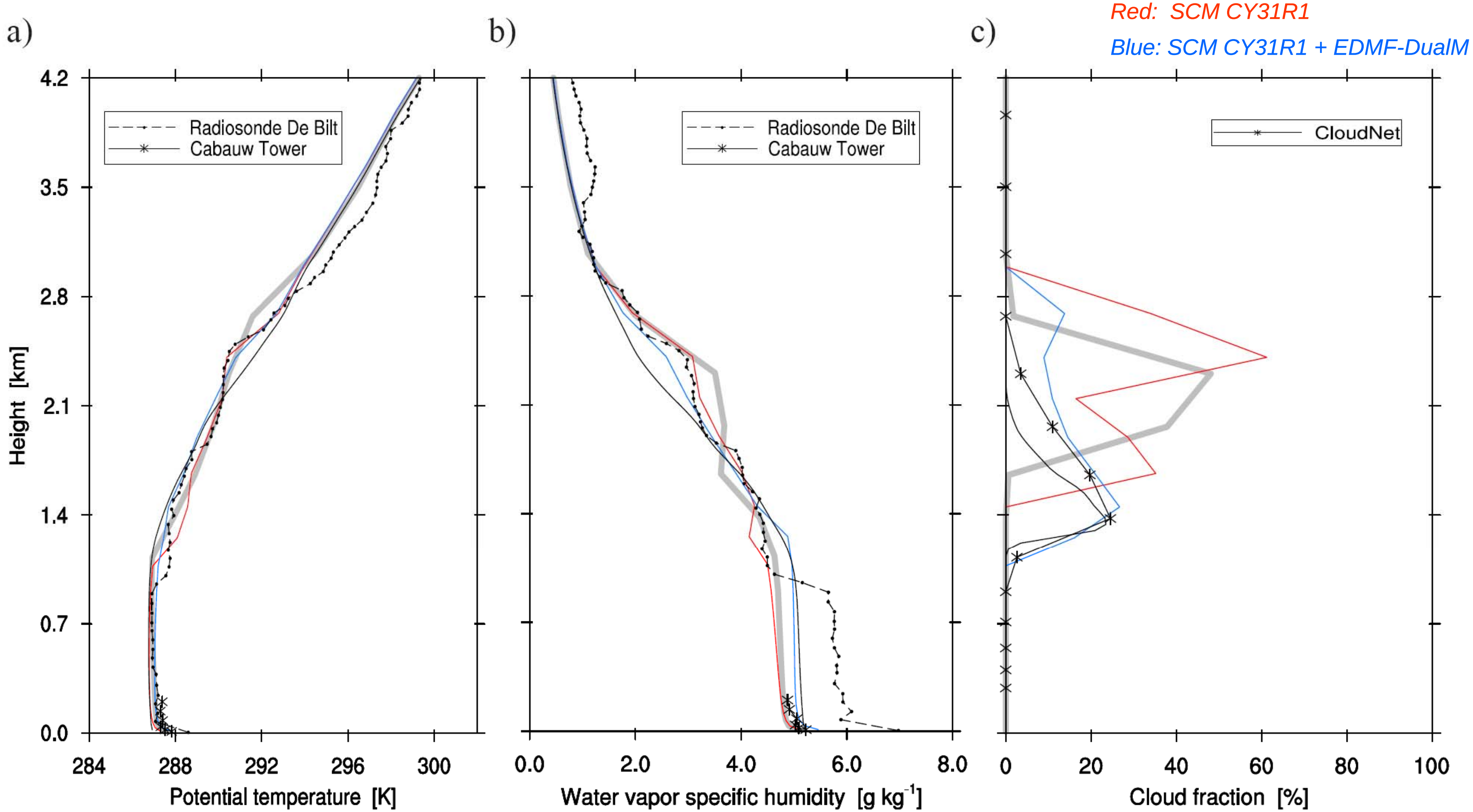
Coloring (in this plot only): seasonality, from red (summer) through black (equinox) to blue (winter)

Example II: Process-level case studies

Zooming in on days that contribute most to a bias in a long-term composite mean

16 June 2008 at Cabauw: shallow cumulus

Black: DALES
Red: SCM CY31R1
Blue: SCM CY31R1 + EDMF-DualM



Example III: Evaluation of SCM cloud properties against LES

EDMF-DualM: Good vertical cloud structure, not so good projected cloud cover

→ *Could it be the cloud overlap?*

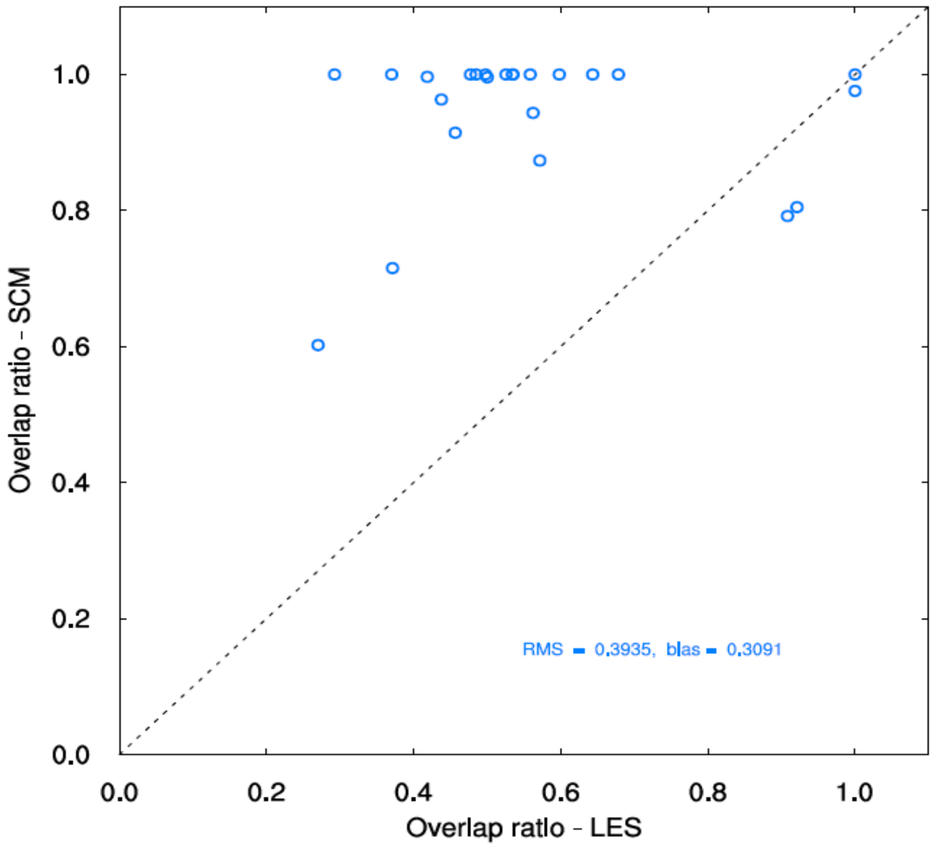
$$r = \frac{a_{\max}}{a_p}$$

maximum cloud fraction

TCC

By default the IFS uses the maximum-random overlap function

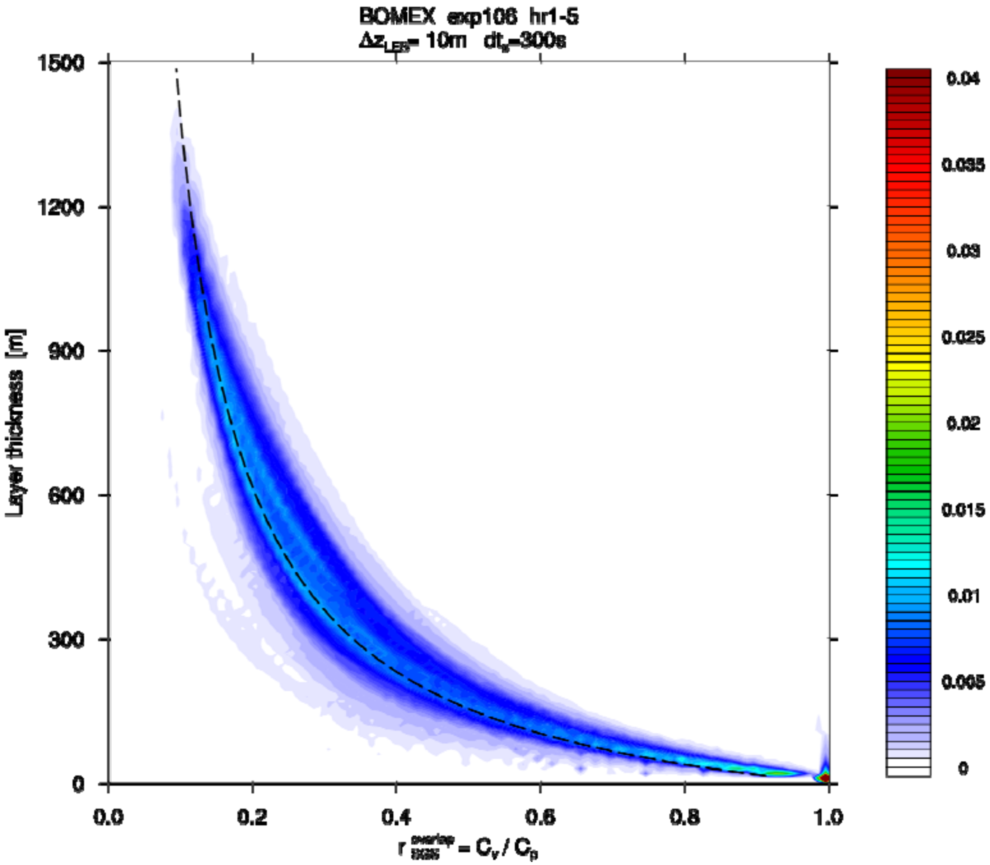
Daily SCM results at 12 UTC for June 2008 at Cabauw



Example IV: Insight and improved physics

Diagnosing the effective overlap over multiple adjacent cloudy model levels in a 3D LES snapshot

Ratio = C_v / C_p : volume-averaged / area-averaged cloud fraction *(Brooks, JAS, 2004)*



Average over 60 independent 3D snapshots from the BOMEX shallow cumulus case

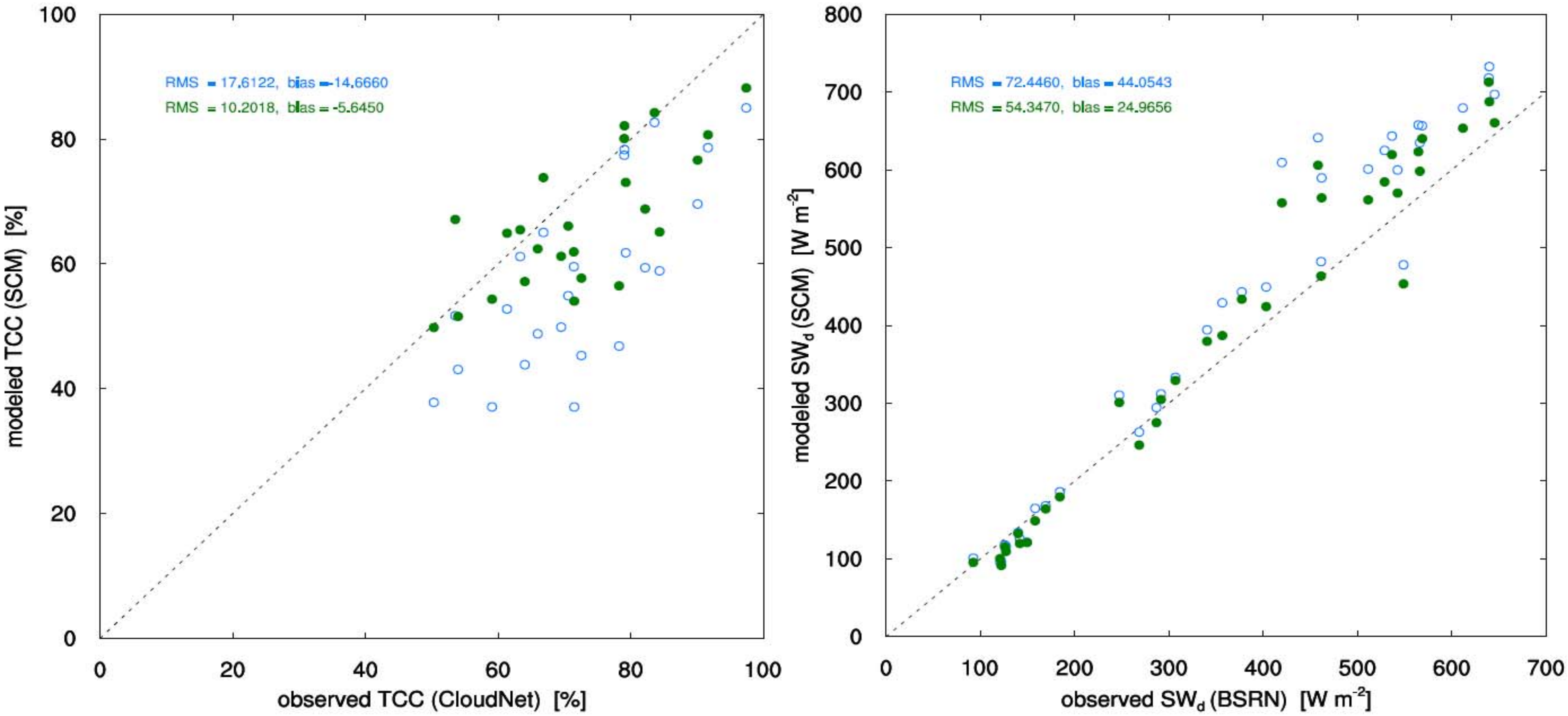
Vertical overlap in cumuliform boundary layer cloud fields is very inefficient at depth-scales that are sub-grid scale (SGS) at typical vertical resolutions in GCMs (~100-300m in the PBL cloud layer)

No operational GCM currently incorporates this behavior

To be submitted to GRL, September 2010

Example V: Rerunning the SCM with improved physics

Monthly mean results at 12 UTC for the period 2007-2009



Blue: SCM CY31R1 + EDMF-DualM

Green: SCM CY31R1 + EDMF-DualM including SGS overlap

Impact on monthly mean daytime SW_d: up to 50 W/m^2 !!

KPT - Current status & developments

BAMS paper on KPT

Acquisition and installation of KPT webserver for external access

Participation of KPT in the EUCLIPSE and U.S. DOE FASTER projects

Introducing more observational datastreams

First major result: Identification of a compensating error in the IFS physics.
GRL paper on cloud overlap to be submitted, J.Clim paper in preparation

Implementation of Ensemble-Kalman filter in SCM: application in local fog forecasting

SCM studies of cloud – aerosol interactions using Cabauw CCN measurements

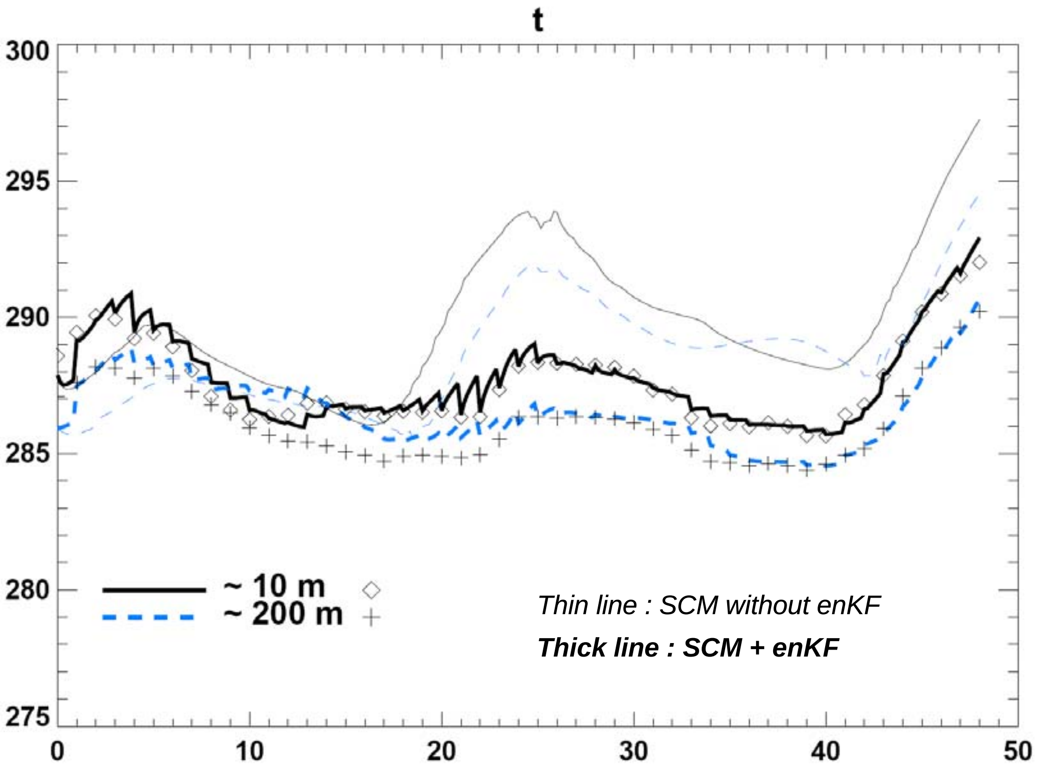
Ensemble Kalman Filters (enKF) in SCMs (Peter Baas)

*To get the mean model state *even closer* to the observed state*

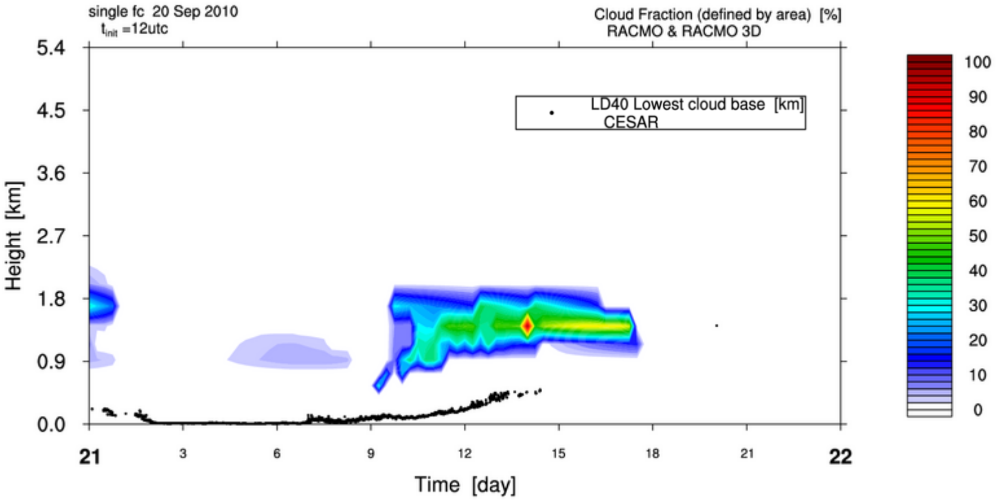
Purpose: to minimize the uncertainty in the imposed background state & forcings

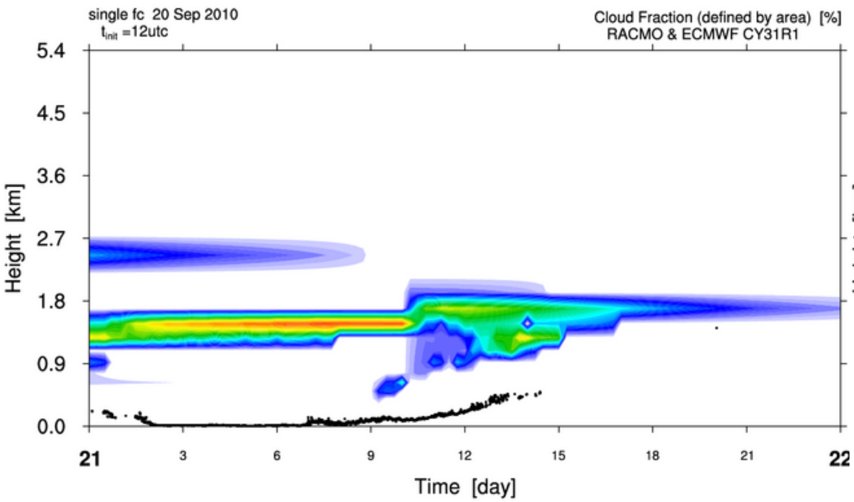
↑

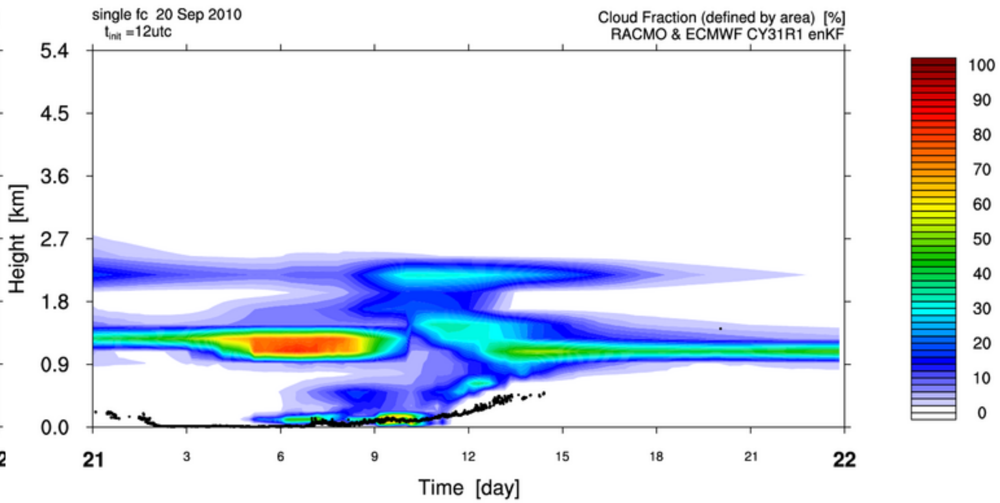
Improves the evaluation of the fast physics



Ensemble Kalman & SCM - opportunities in local fog forecasting





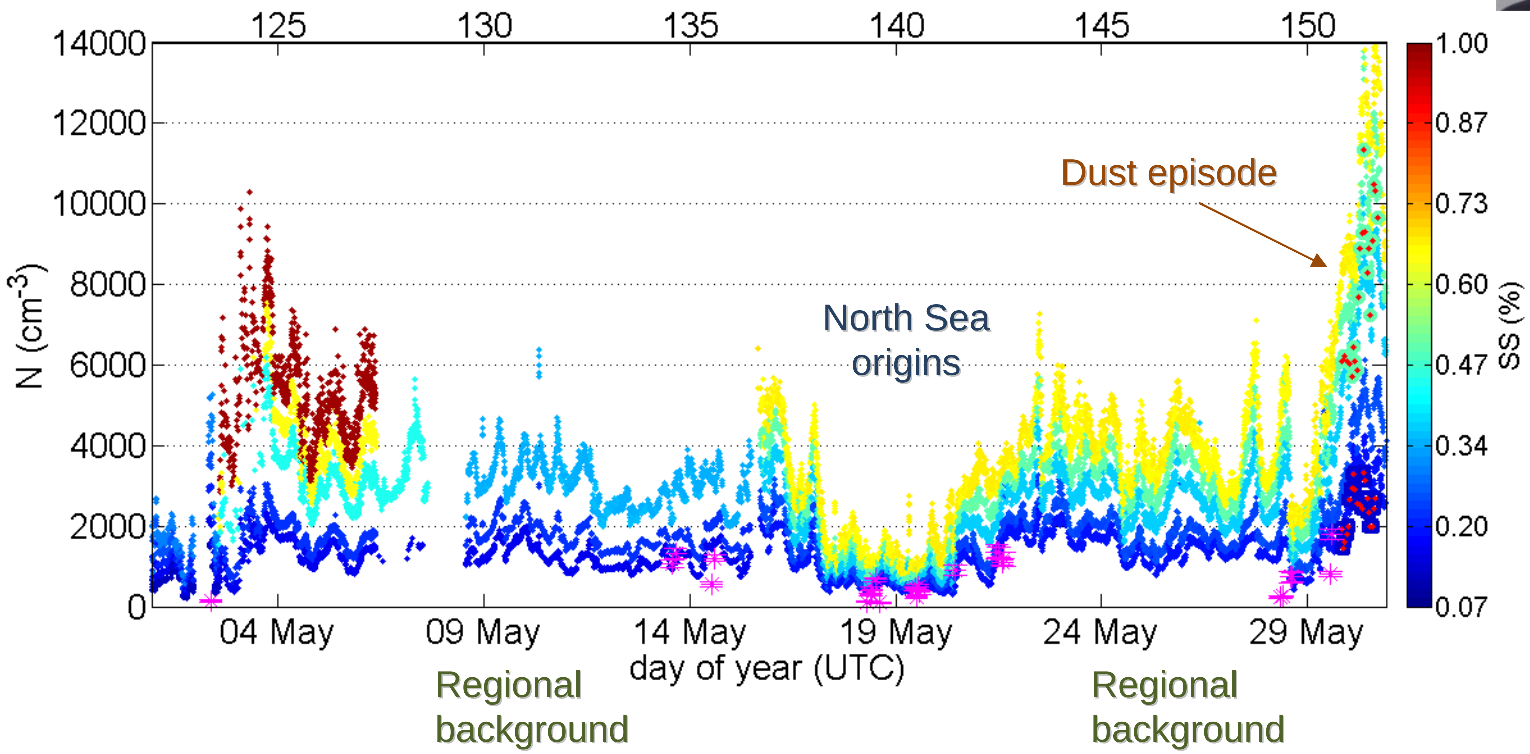


Exploring cloud-aerosol interactions

What are the impacts, are they significant, and why / how?

* *Implement a smarter microphysics package into the SCM (Olivier Geoffroy)*
* *Feed long SCM runs with observed CCNs at Cabauw (Reinout Boers)*
* *Study impacts & feedbacks at process-level*

CCN concentration at Cabauw during IMPACT (May 2008)



What can KPT mean within EUCLIPSE?

Main role: building bridges between GCMs and SCMs

** Investigation at process-level of typical model behavior that comes to light in the other WGs of EUCLIPSE*

** Multi-parameter confrontation of models against relevant observations as available at supersites, making use of simple metrics (e.g. multi-variable scores) to establish performance*

A pilot SCM evaluation study at selected gridpoints (CloudNet sites)?

** Long-term evaluation of the cloud-radiative climate of the various SCM codes participating in EUCLIPSE*