Basic Concepts for Convection Parameterization in Weather Forecast and Climate Models:

COST Action ES0905

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Meteo France

COST Action

(European Cooperation in Science and Technology):

European Network for Scientific Collaborations

(an Action is a Unit of Network)

Action ES0905: Feb 2010- Mar 2014

Purpose of the Talk: Scientific Report of the Major Achievements (personalized)

Background (MoU):

Convection Parameterization:

A Major Weakness of NWP Models

Objective (MoU):

To Provide Clear Theoretical Guidance on Convection Parameterization

Immediate Context(MoU):

Increasing Resolution with Half-Resolved Convection:

High-Resolution Limit?

Grey Zone Problem

Structure:

chair : co-chairs (2) :

MC (from each country: 20) :

WGs (4):

- **Mass-Flux**
- **Non Mass-Flux**
- **High-Resolution Limit**
- **Physics and Observations**

Activity Overview (Milestones):

- 5 Workshops : Report to Eos, BAMS(3+1?)
- 21WG Meetings
- 1 Summer (Training) School : Report Accepted to Eos
- 18+1 STSMs (Short-Term Scientific Missions)

- **5 Reviews:**
  - Quasi-Equilibrium (Yano and Plant 2012, Rev Geophys)
  - Entrainment-Detrainment (de Rooy et al., 2013, QJ)
  - Closure (Yano et al., 2013, ACP)
  - Bin and Bulk Microphysics (Khain et al., 2014, to be submitted to Rev. Geophys)
  - Precipitation Verification (Rezacova et al., 2014, a book chpater)
- **Monograph:**
  - "Parameterization of Atmospheric Convection", Vol I and II (Plant and Yano, Eds., Imperial College Press)
- **Final Scientific Report**: to be submitted to *Atmosphere*

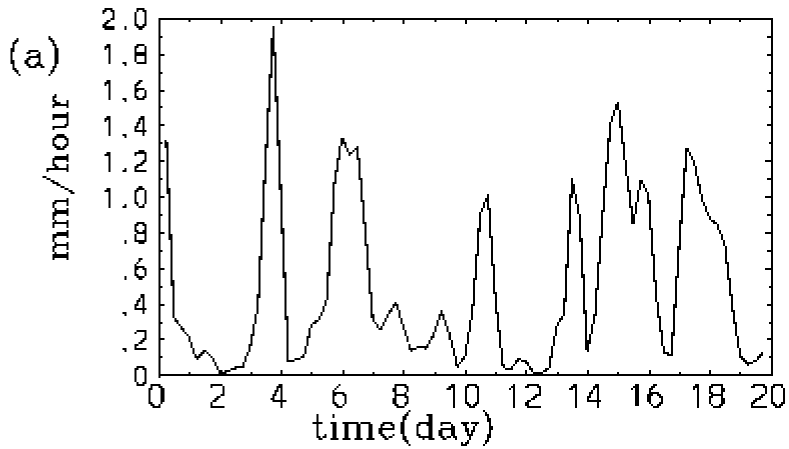
What is a Real Immediate Issue? :

Traditional Convective
Quasi-Equilibrium Parameterization:
Not Running as Designed/Intended

Performance of Quasi-Equilibrium based Parameterizations:

Observed Convective Precipitatoin:

GATE:



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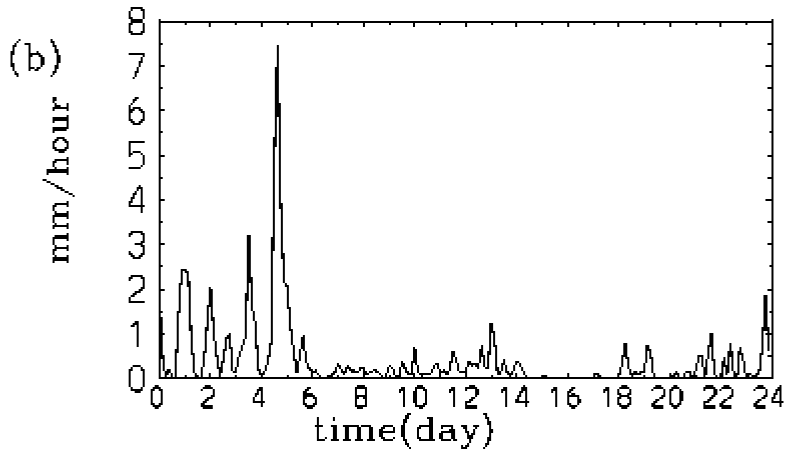

ACCESS (Australian UM):

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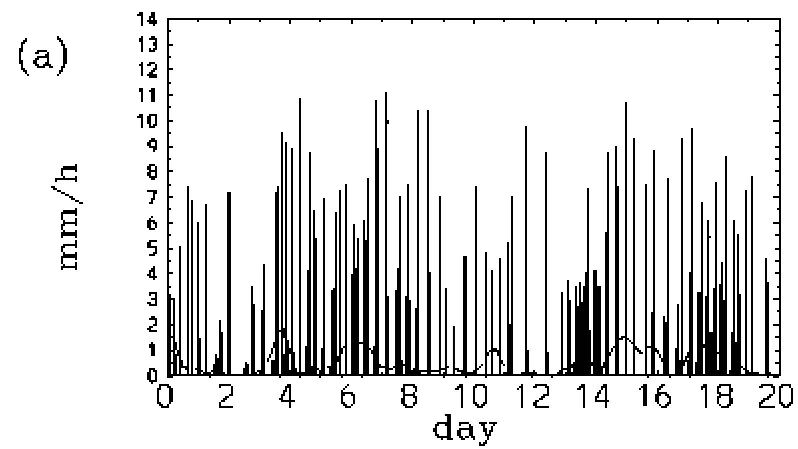

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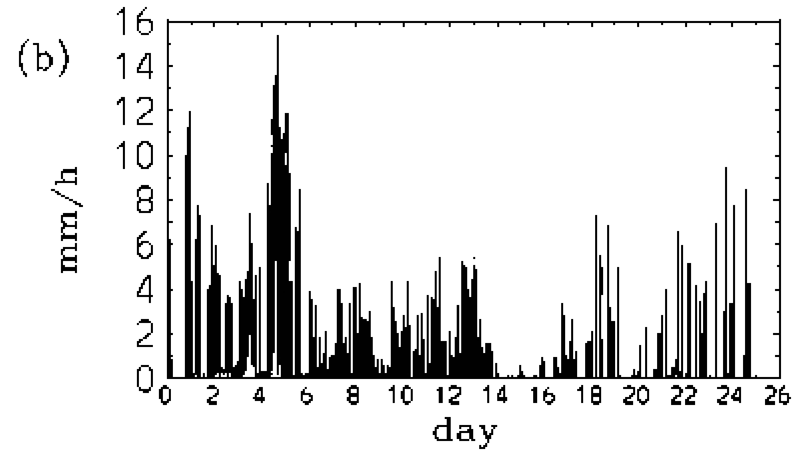

Performance of Quasi-Equilibrium based Parameterizations:

ACCESS (Australian UM):

ECHAM:

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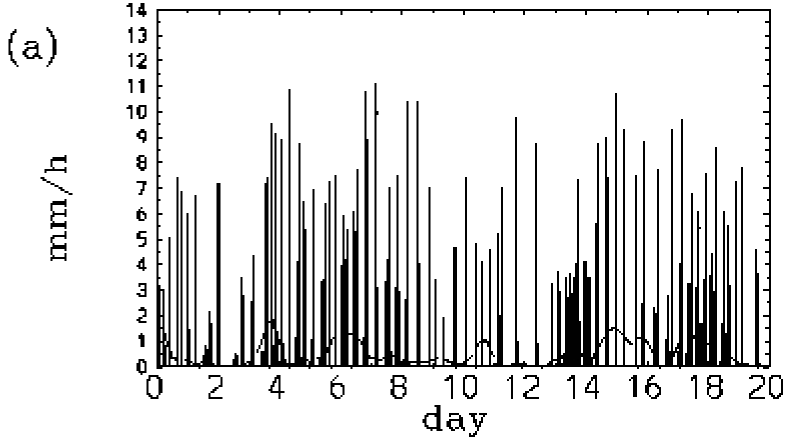

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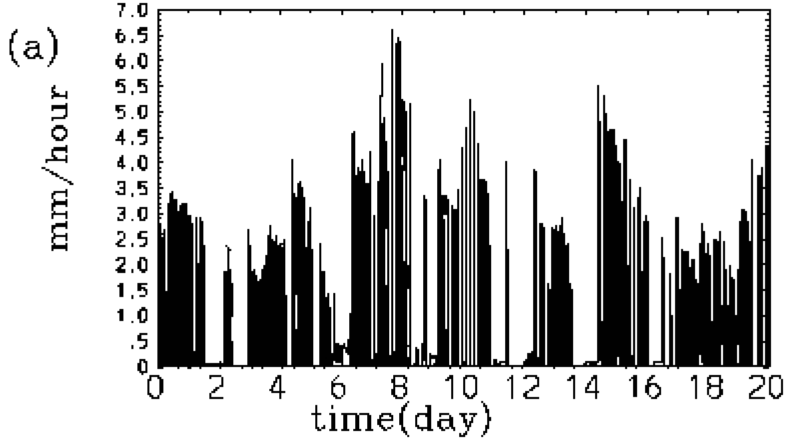

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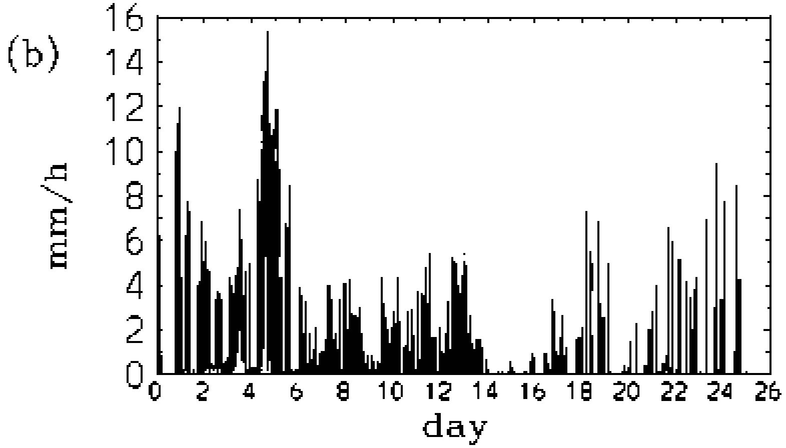

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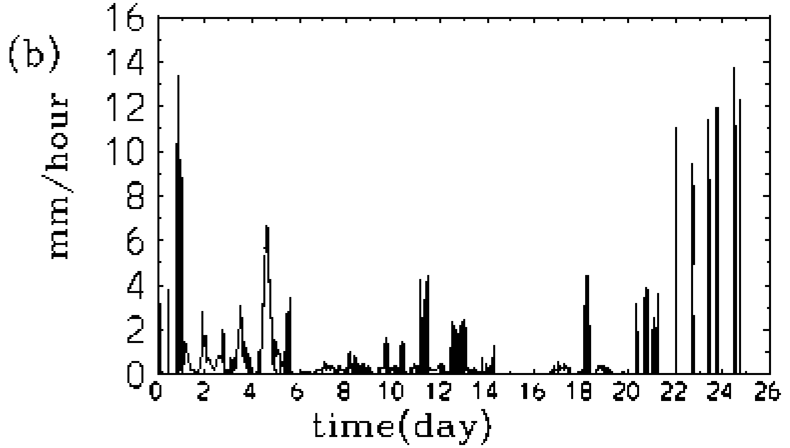

Traditional Convective Quasi-Equilibrium Parameterization: Not Running as Designed/Intended:

Basic Formulation for the Mass-Flux Parameterizatoin?:

- Entrainment-Detrainment
- Closure

Basic Mass-Flux Formulation:

$$M = \eta(z) M_B(t)$$

$\eta(z)$: Entrainment-Detrainment

$M_B(t)$: Closure

(we may set: $M_B=0$)

NB: Trigger :

NOT A Part of the Problem

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<u>NOT</u> A Part of the Problem:

Phenomenological Process Studies (LES/CRM/Satellite)

<u>DO NOT</u> directly Improve Parameterizations:

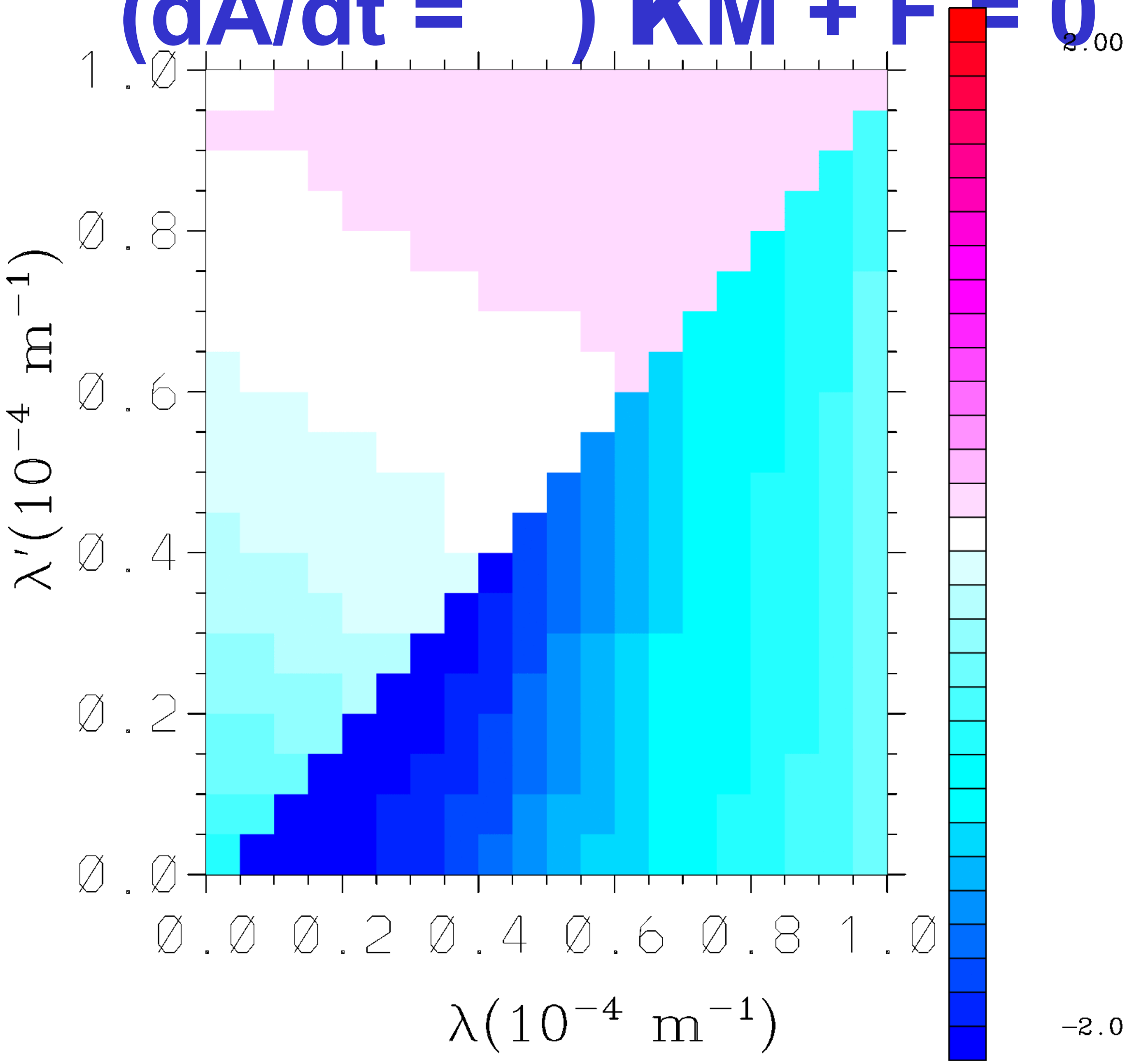
KNOW the Parameterization!:

•Convective Quasi-Equilibrium:

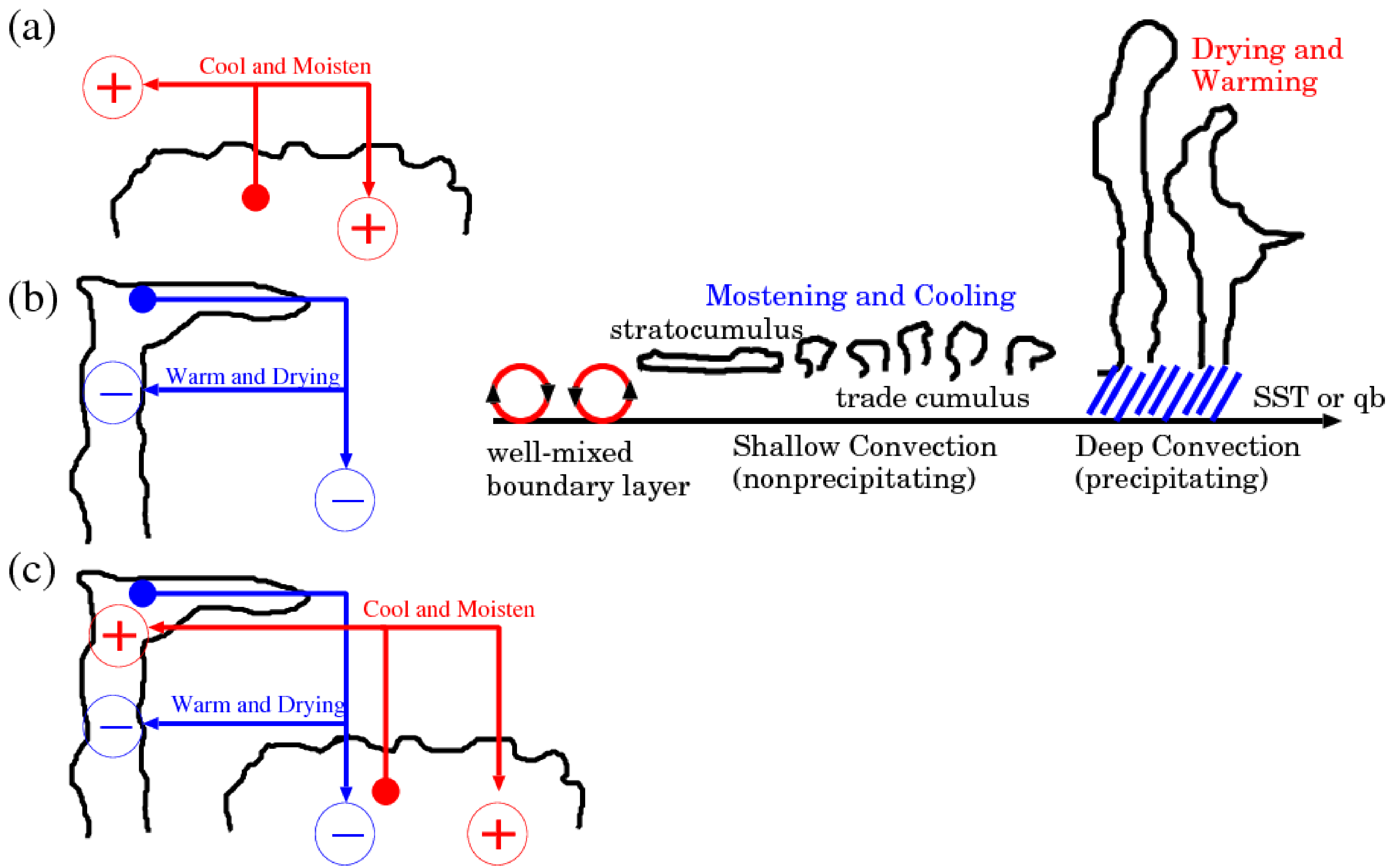
•Review (Yano and Plant 2012):

(dA/dt =) KM + F = 0

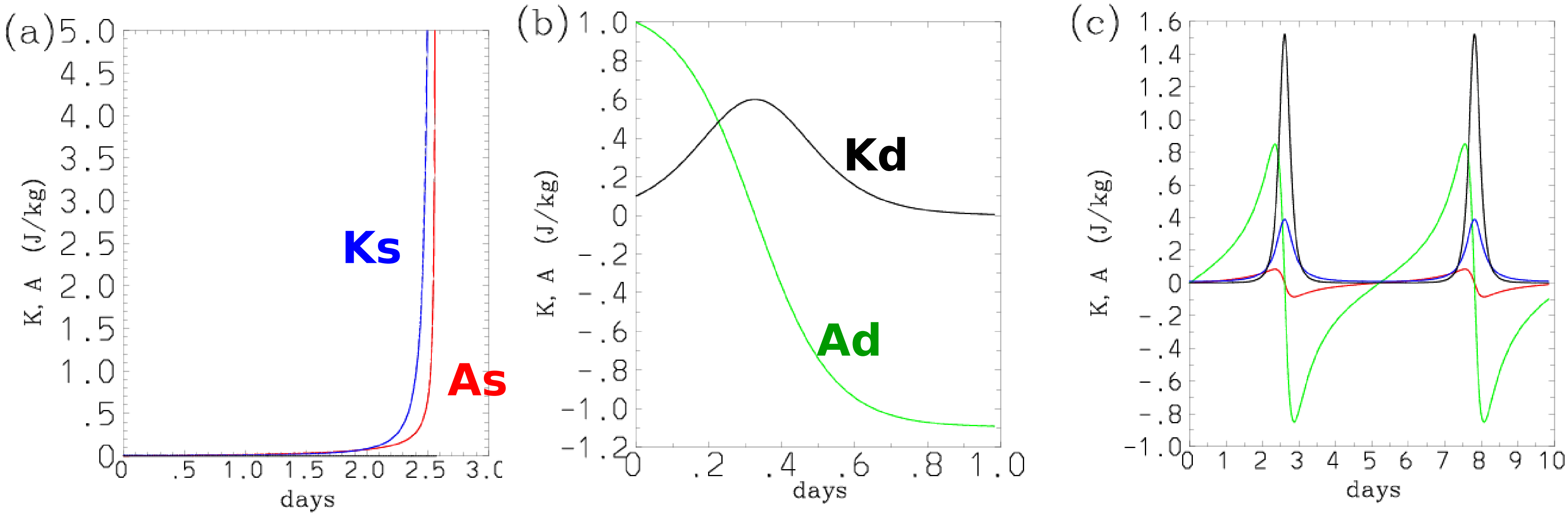
K = ?:



allow-to-Deep Transformation:



-Mode Interactions: Shallow and Deep

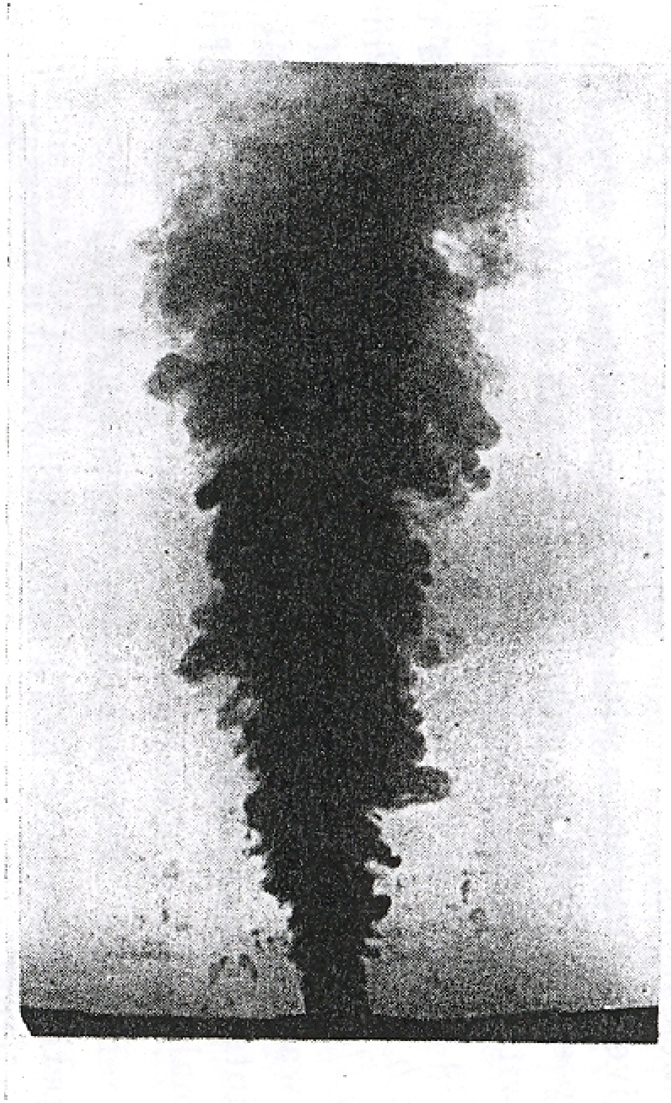


hallow-convection nly (Moist and Cool)

Deep-convection Only (Dry and Warm)

Coupling of Shallow and Deep convectio

•Entrainment-Detrainment



Morton et al., 1956

Anna Gorska, S. Malinovski, 2013

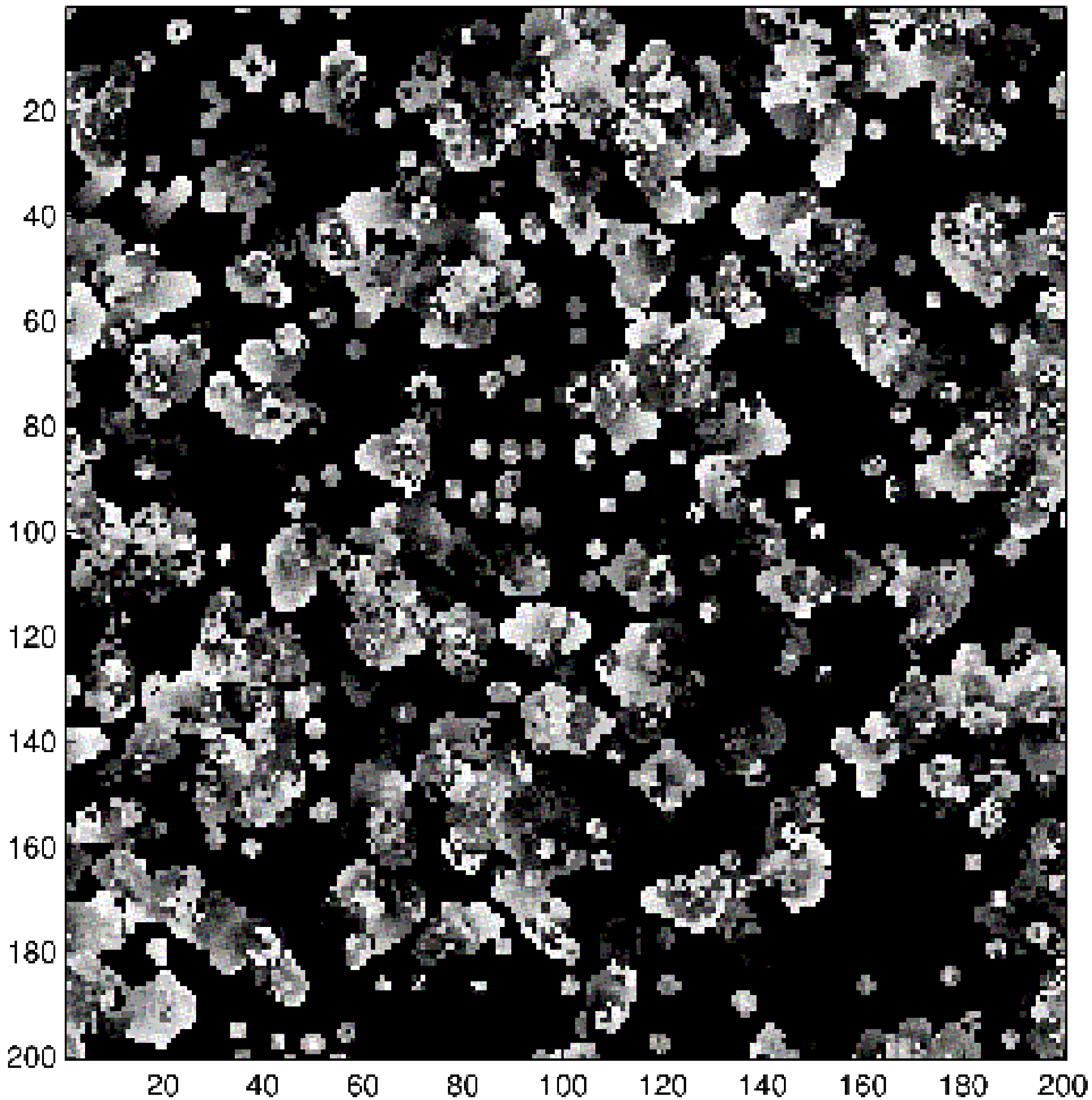
Alternative Possibilities:

- PDF
- Similarity Theory
- Cellular Automaton
- Statistical Mechanics
- Renormalization Group
- Lie Algebra

Observations and Verifications:

- Polarimetric Radar
- Lightening Data (EUCLID)
- Quantitative Precipitation Verification

Cellar Automaton (L. Bengtsson et al):



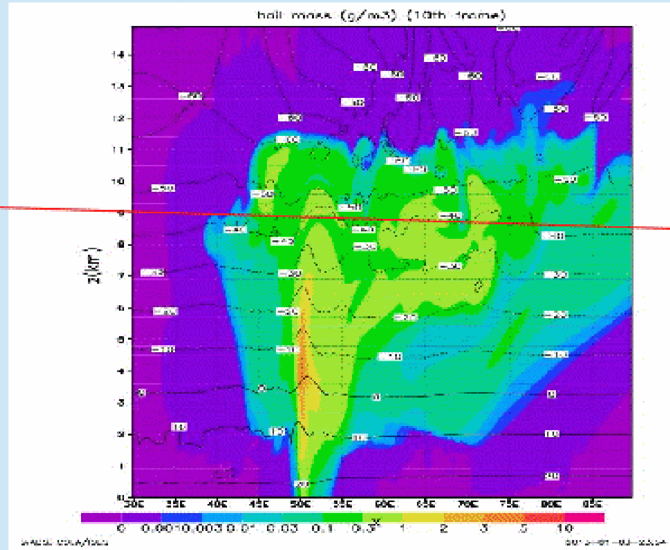
Hail Dynamics (V. Phillips et al):

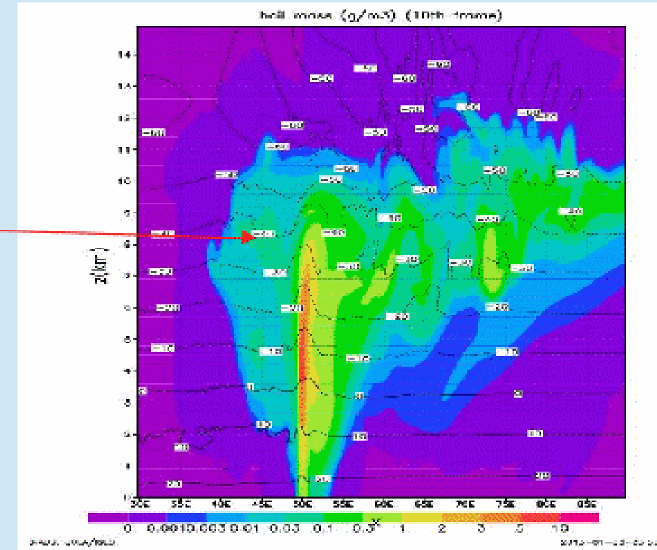
MARITIME AEROSOL

CONTINENTAL AEROSOL

Hail Mass

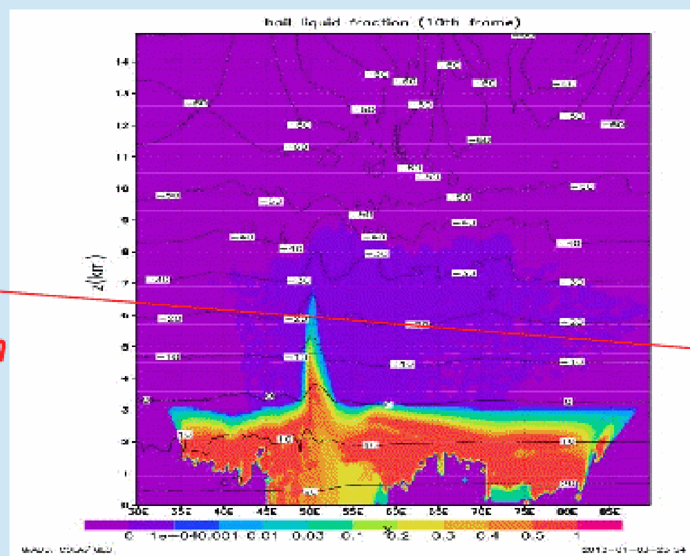
More hail from riming

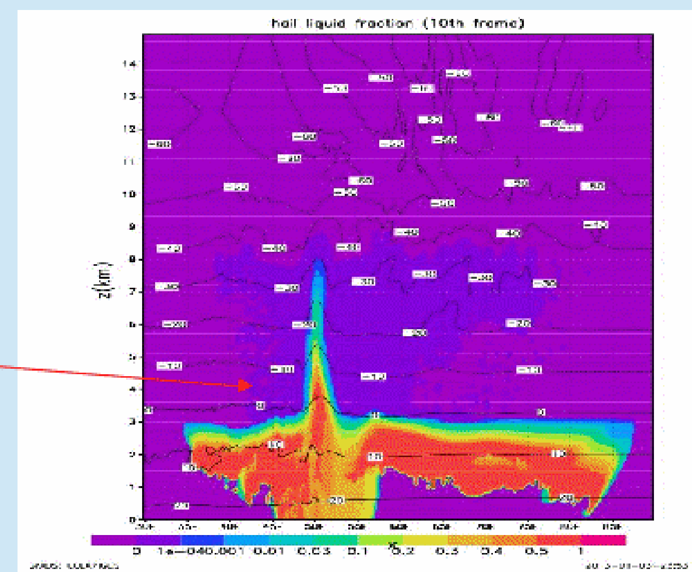




Liquid Fraction of Hail

More cloud-liquid boosts wet growth (and graupel)





3MT: High Resolution Limit (Geleyn et al)

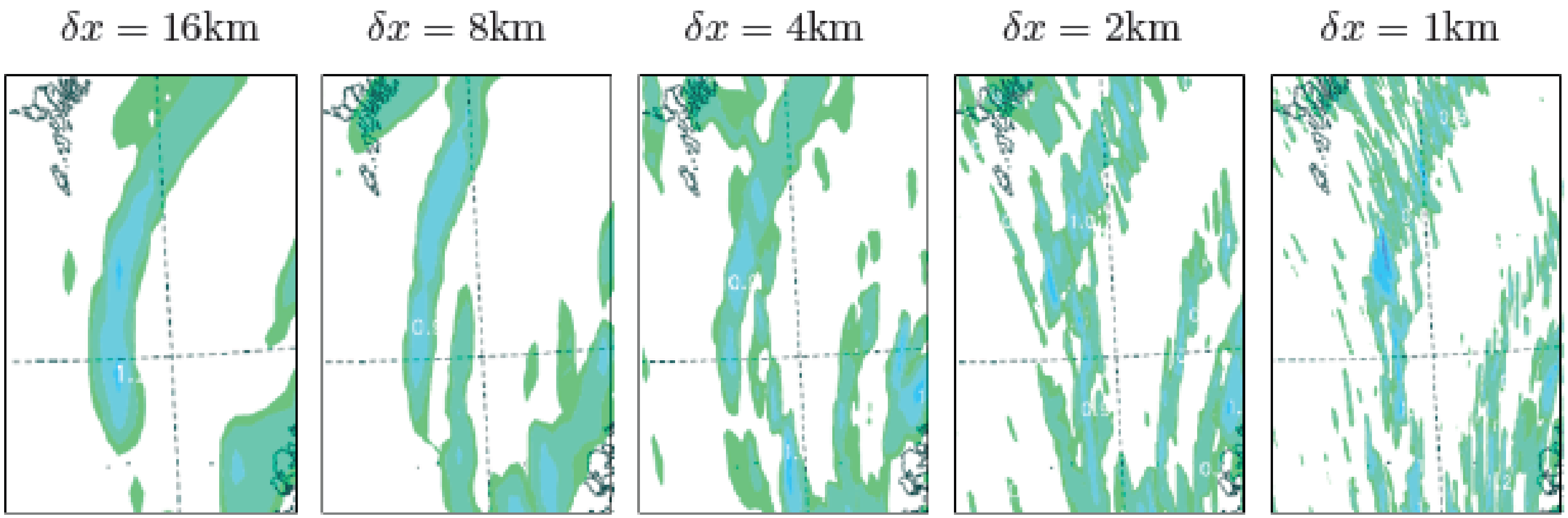


Figure C2: 1h precipitation amount forecast by the ALARO-0 baseline configuration including the 3MT scheme, for horizontal mesh-size 16km, 8km, 4km, 2km and 1km (from left to right). North Sea cold air outbreak case of the WGNE grey-zone intercomparison experiment, designed to explore the models' capacity to cope with partly resolved precipitating convection. This is a situation for which the 3MT scheme is targetted and it indeed delivers an unchanged basic solution with more and more details as resolution increases across the grey-zone. Forecast base 30 January 2010 at 12 UTC, forecast range +31h, sub-area results shown between the Feroes and Orkneys.

Concluding Perspective: Ontology

Needs for a Stronger Link between the Operations and Theoretical Research (Physics and Mathematics):

New Action Proposal:

NWP-Uncertainties:

Facing Uncertainties in convection-permitting Numerical Weather Prediction

Establishing *generality, consistency, and unification* of physical parameterizations in operational forecast models is becoming increasingly *urgent* with an accelerated increase in model resolutions. A *solid commitment* of the operational research centres is definitely required, but that is not enough. The pathway is *not unique*, and a choice is even not obvious for the very *ontological* reason. The problem must be seen *as a whole* before a right choice can be made. All the facets of the problem is put together into a single whole only under a *true interdisciplinarity* (Report, Workshop, Palma, March 2013, BAMS)

Web Page: convection.zmaw.de

Scientific Outcomes (cf., report to *Atmosphere*):

- **Identified Priorities (Mass Flux):**
  - **Clousre**
  - **Entrainment-Detrainment**

- **Pathways for Investigations (Palma Workshop Report, 2014, BAMS):**
  1) **Turbulence Studies**
  2) **Parameterization Formulation**
  3) **Process Studies (?)**

- **Major Achievement: Diurnal Convective Cycle by Closure (Yano et al., 2013, Bechtold et al., 2014)**

- **How to Maintain Fundamental Research Under the Current Funding Environment?**

- **Closure:**

- **Review (Yano et al., 2013):**

- **Two Decotopics Choices:**

- **Boundary-Layer Controlled Closure:**

More Popular, however less reliable due to too noisy Boundary-laye variability (Donner and Phillips 2003)

- **Parcel-Environment based Closure (Zhang 2002):**

Succesful Simulation Diurnal Convective Cycle (Bechtold et al., 2014)

Diurnal Cycle of Convection: Closure Modification

Bechtold, P., N. Semane, P. Lopez, J.-P. Chaboureau, A. Beljaars, and N. Bormann, 2014: Representing equilibrium and nonequilibrium convection in large-scale models. *J. Atmos. Sci.*, **71**, 734–753. doi: http://dx.doi.org/10.1175/JAS-D-13-0163.1

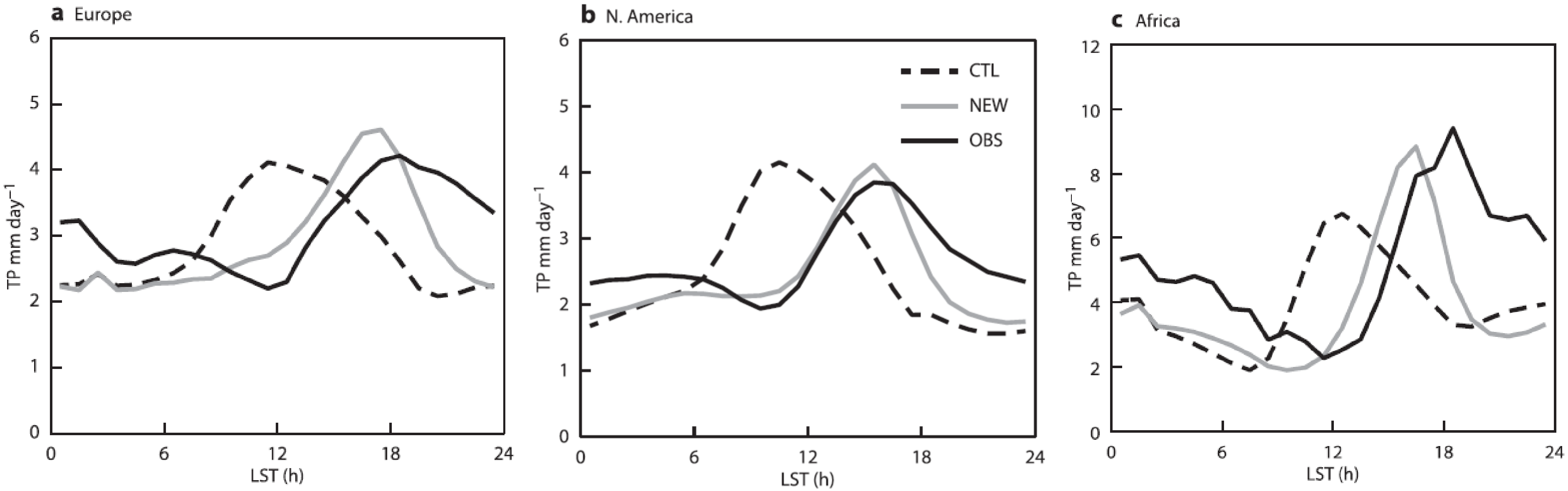


FIG. 5. Diurnal composites of area-averaged total precipitation (mm day^{-1}) from CTL (black solid lines) and NEW (dashed lines) against observations for JJA 2011 (Europe) and JJA 2011 and 2012 for the other areas: (a) Germany (48°–52°N, 7°–14°E) using DWD radar, (b) the eastern United States (30°–45°N, 100°–80°W) using NEXRAD, and (c) the central Sahel region (5°–20°N, 10°–30°E) using TRMM climatological radiometer data.

- **Entrainment-Detrainment:**

- Review (de Rooy et al., 2013):

- Robust Methodologies for Estimation from CRM and LES

- Identified Key Elements:

  Critical Fractional Mixing Ratio

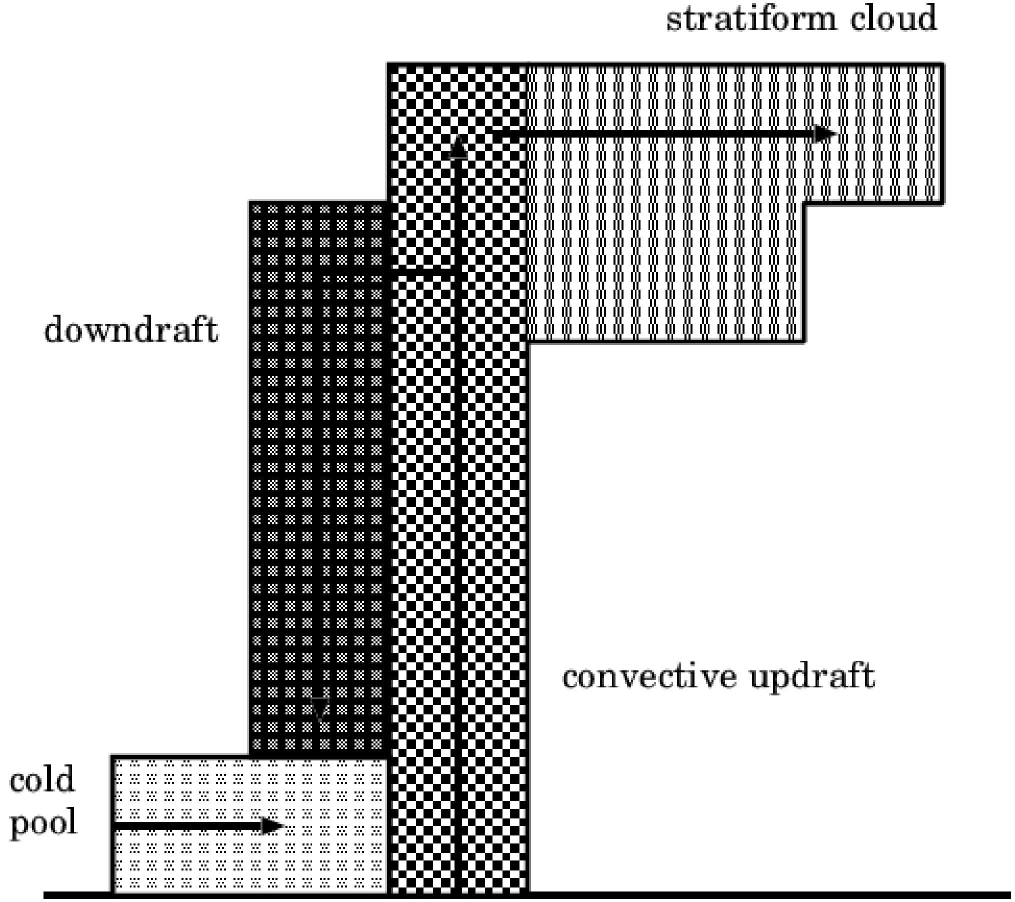
  Relative Humidity Dependence

  Importance of Detrainment

- Lack of Physical Principle

•General Unified Formulation (under Mass Flux):

SCA:



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