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Testing & Tuning of Revised Cloud Radiation Coupling T²(RC)² PP: an Overview

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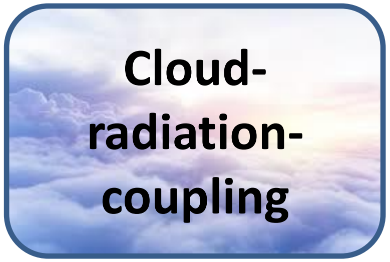
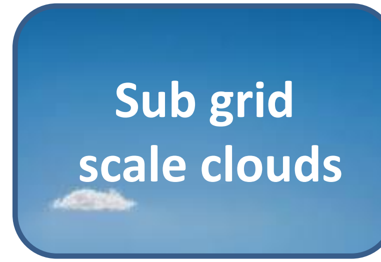
COSMO User Seminar - March 2016

Outline

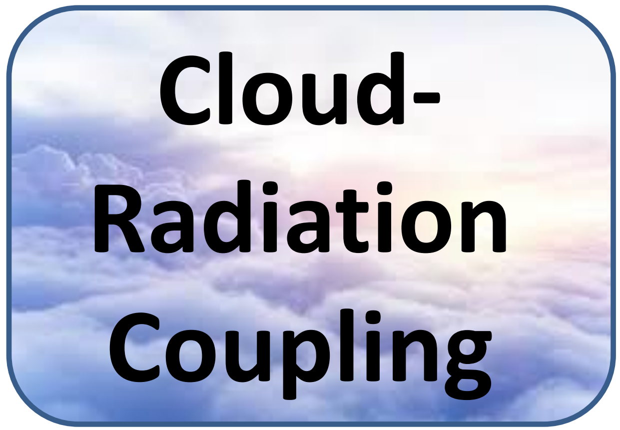
Revised
Cloud/aerosols
Radiation
Coupling





Testing &
Tuning

Run time
optimization


Cloud-
Radiation
Coupling

$(RC)^2$ - Summery

- Implemented new parameterizations of optical properties of cloud droplets and cloud ice from literature based on effective radius R_e

  optical properties = fct (qx, R_e)

- Extrapolation for larger R_e of snow, graupel and rain - large size approximation

- N_{c0} of cloud droplets was in the past constant but now is a new tuning parameter. Also implemented: climatological estimation based on Tegen (1997) aerosol climatology. Activation of CN parameterization after Segal and Khain (2006).

- Subgrid variability factor k for grid scale clouds investigated. Now treated as a new tuning parameter.

- Uncertain properties of SGS clouds are now treated as tuning parameters


Aerosols

New Kinne Aerosols Climatology

- MAC-v1 : Monthly aerosol radiative properties, with global coverage at a spatial resolution of 1° (2012)

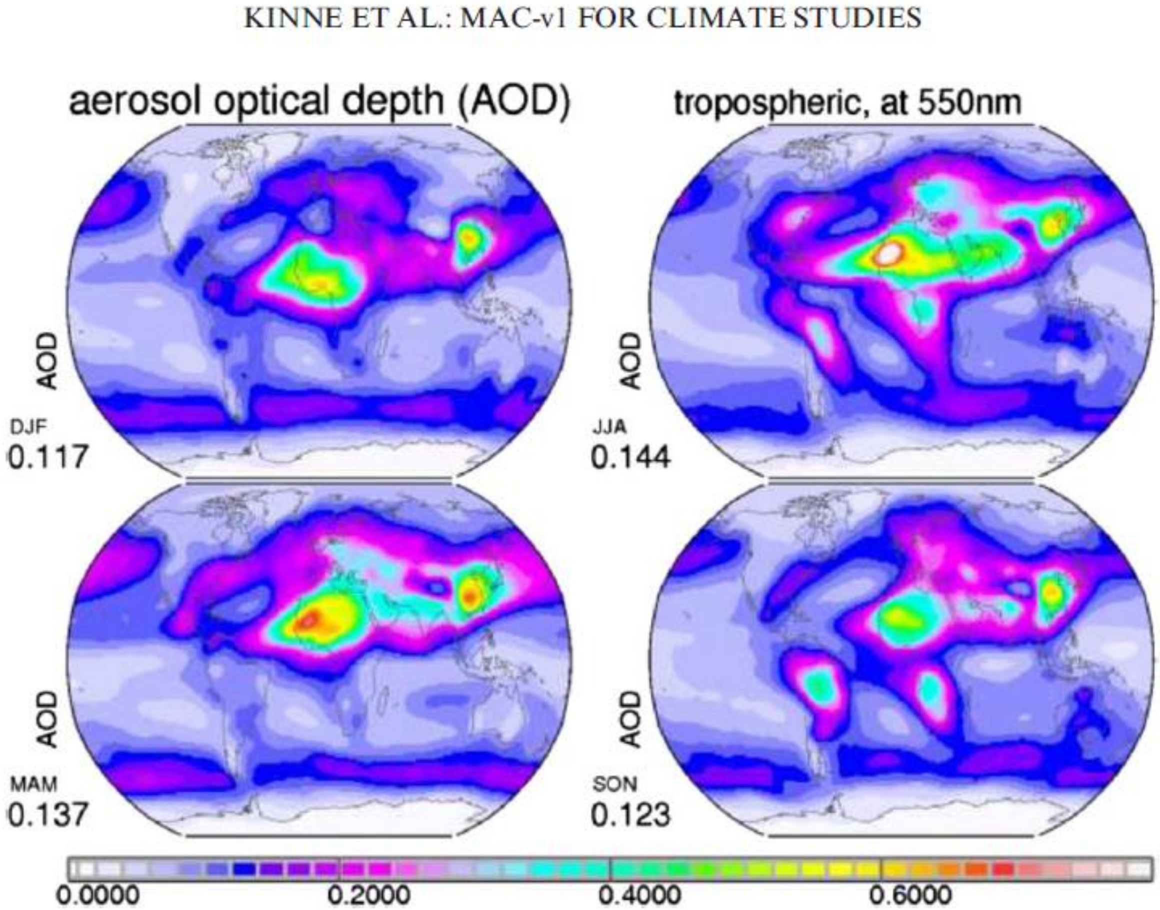
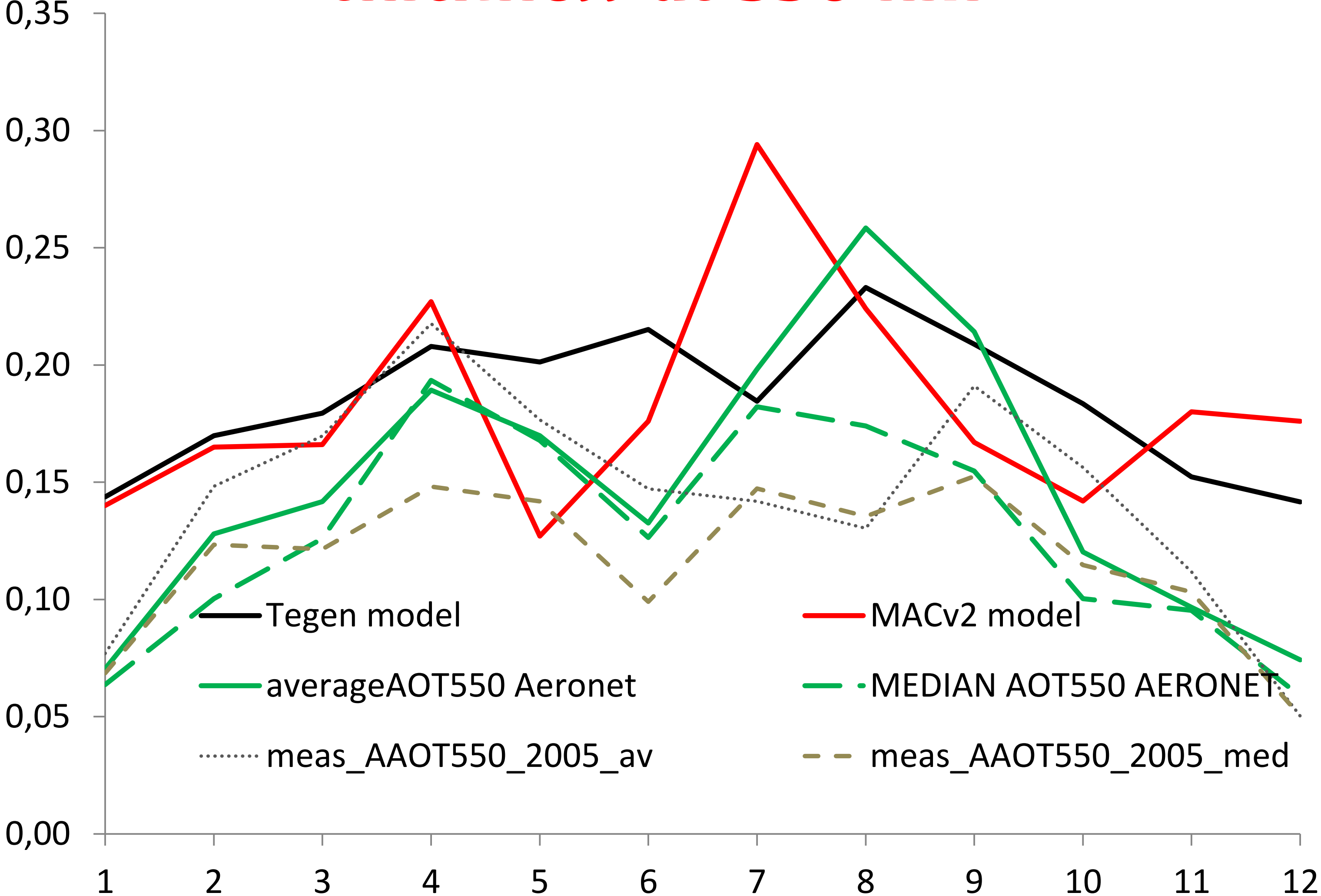


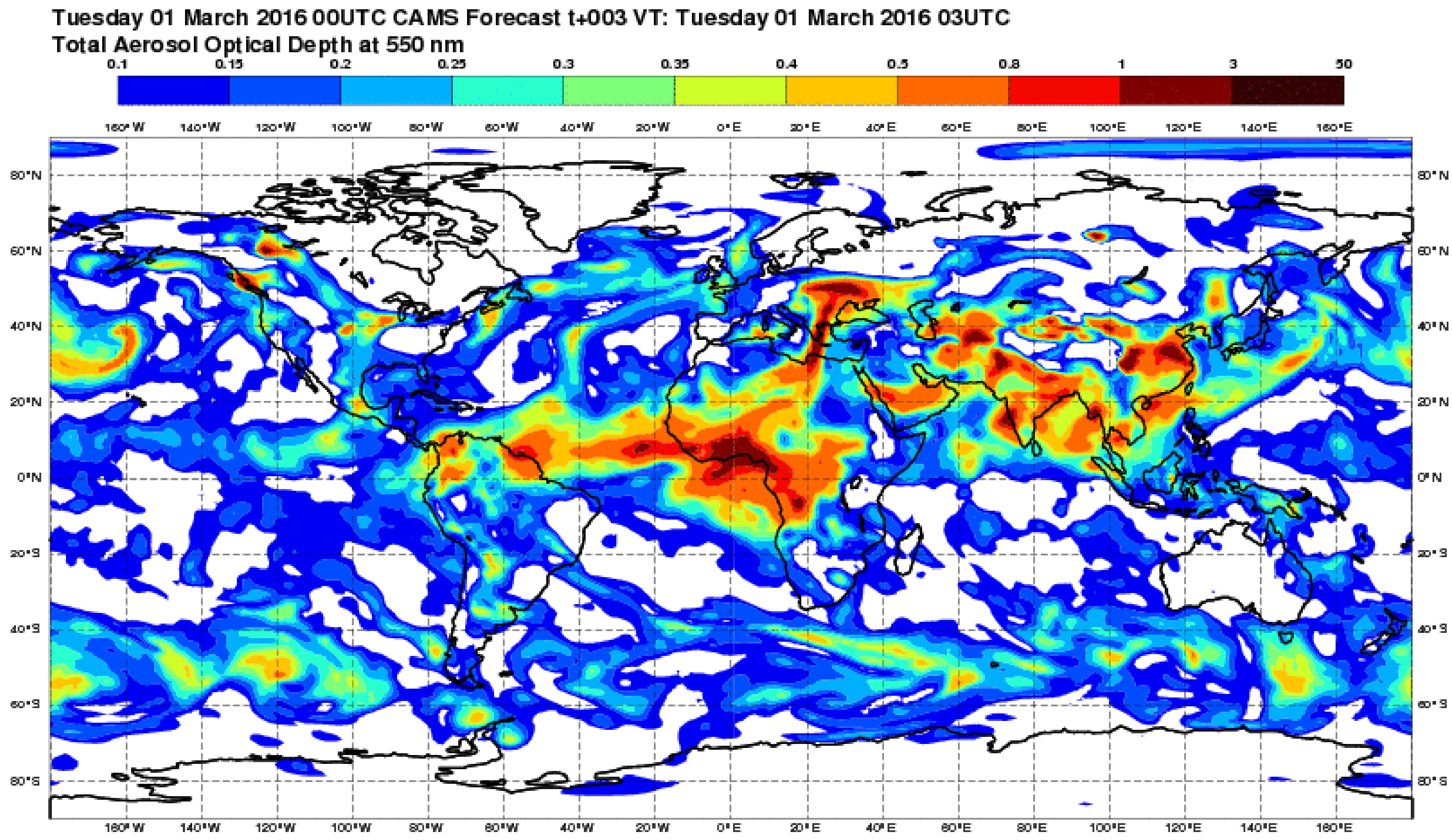
Figure 1. Seasonal average maps for the tropospheric midvisible AOD of the new MAC-v1 climatology for year 2000 conditions. Values below the labels indicate global averages.

Seasonal changes in aerosol optical thickness at 550 nm



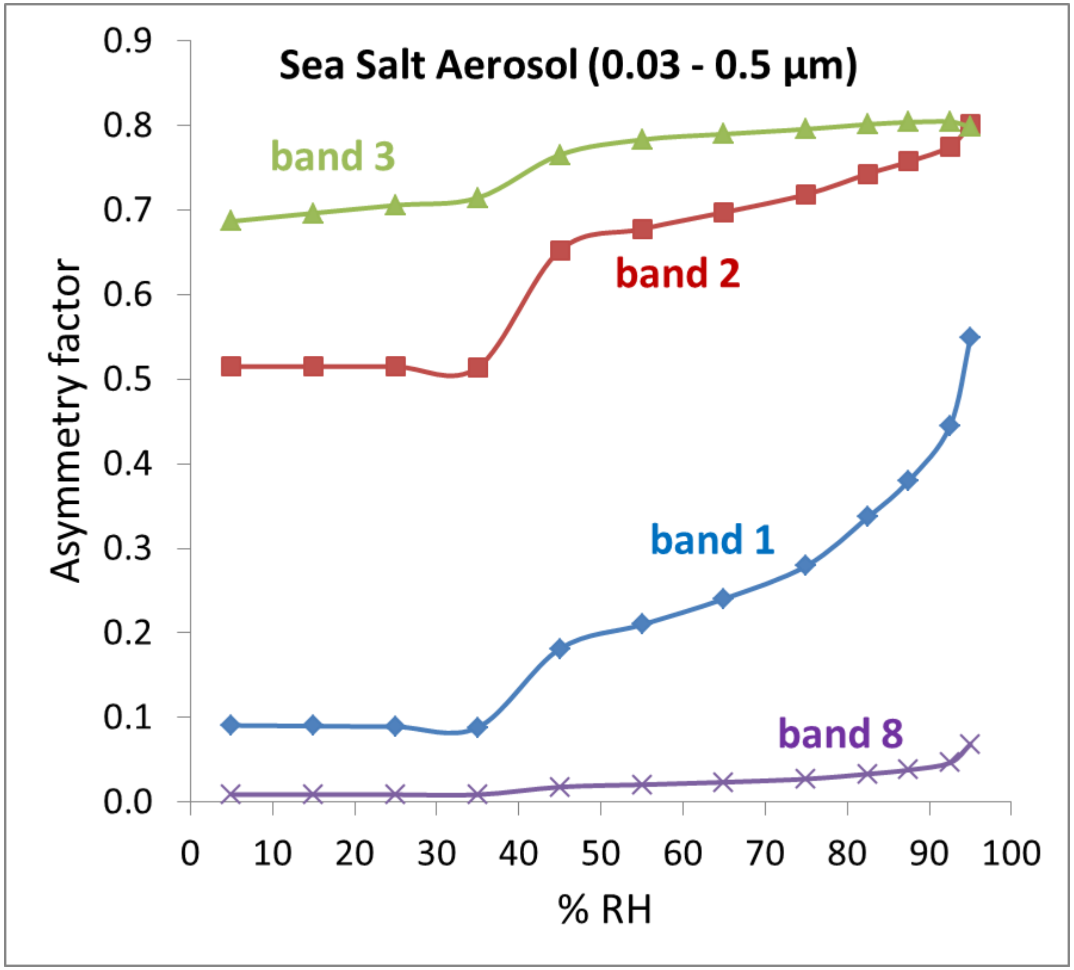
Chubarova 2016

From Climatology to Forecast - MACC (ECMWF) Prognostic Aerosols



+ 3D mixing ratios **Pre-operational**

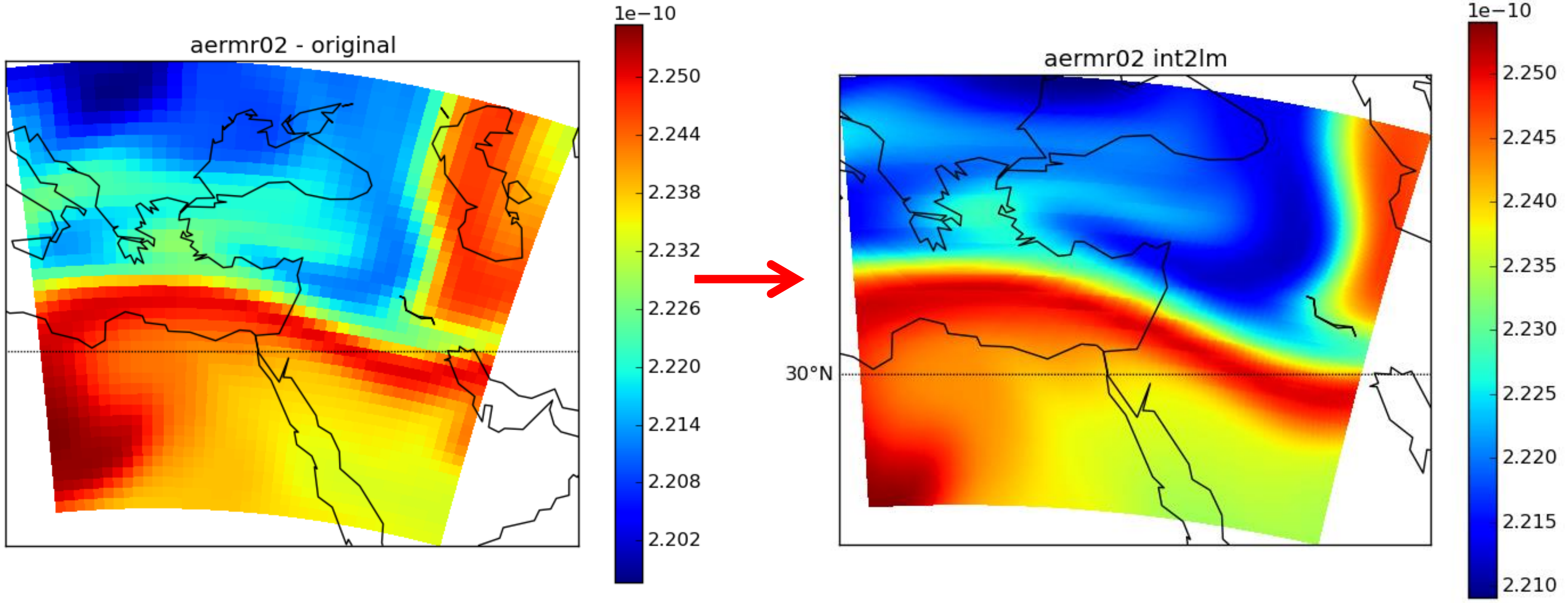
Adaptation of MACC aerosols optical properties ω, β_{ext}, g to COSMO

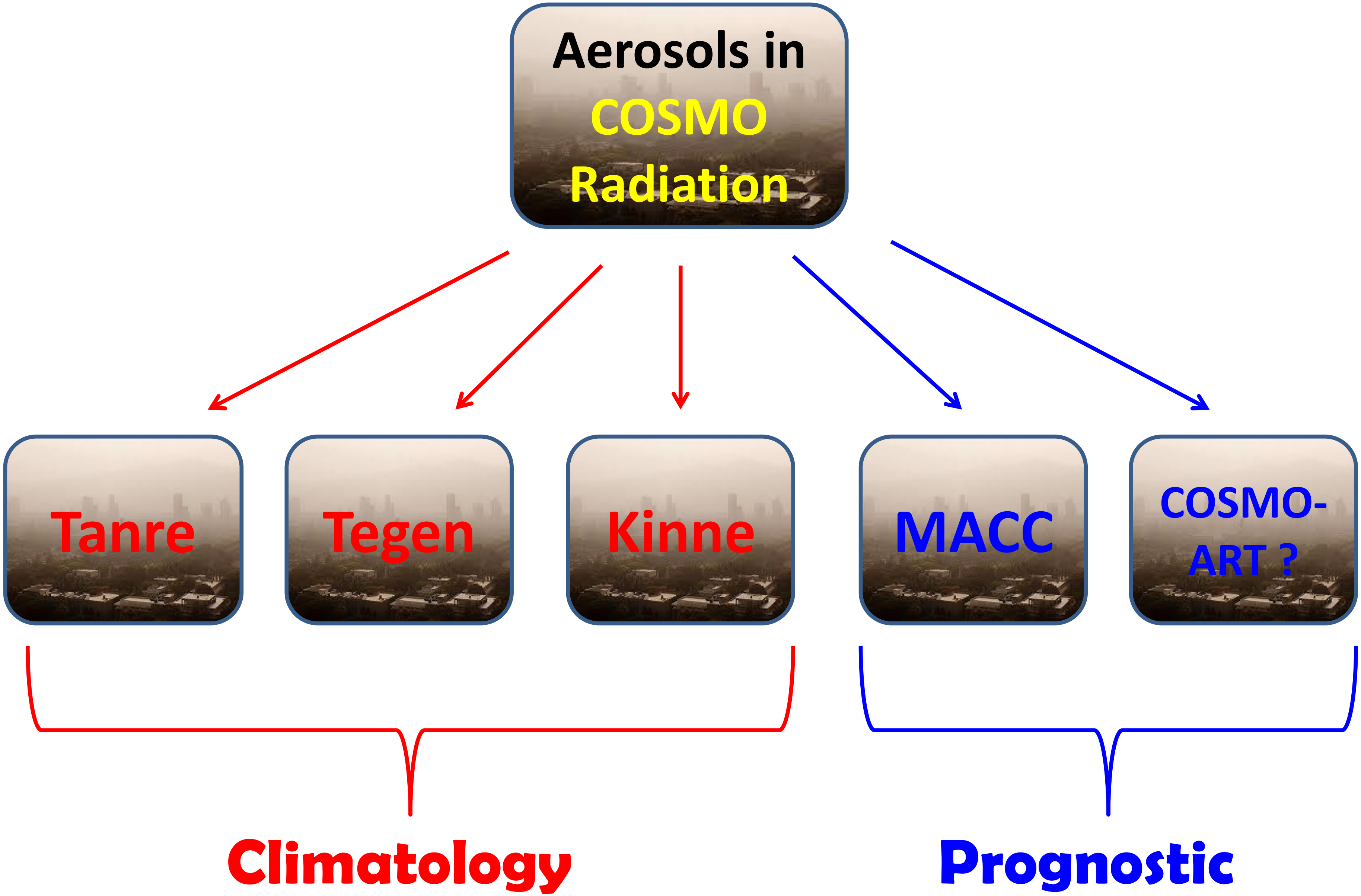


- Sea Salt Aerosol (0.03 - 0.5 µm)
- Sea Salt Aerosol (0.5 - 5 µm)
- Sea Salt Aerosol (5 - 20 µm)
- Dust Aerosol (0.03 - 0.55 µm)
- Dust Aerosol (0.55 - 0.9 µm)
- Dust Aerosol (0.9 - 20 µm)
- Hydrophobic Organic Matter Aerosol
- Hydrophilic Organic Matter Aerosol
- Hydrophobic Black Carbon Aerosol
- Hydrophilic Black Carbon Aerosol
- Sulphate Aerosol Mixing Ratio

Original data set by Alessio Bozo (ECMWF) 2015

Int2lm of 11 MACC aerosols fields

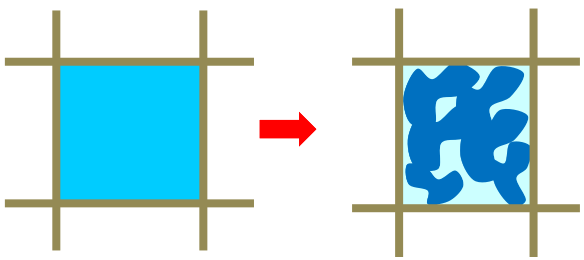



Aerosols in
COSMO
Radiation
Tanre
Tegen
Kinne
MACC
COSMO-
ART ?
Climatology
Prognostic

Sub grid scale clouds

Sub-Grid Scale (SGS) Clouds

- Revision of overall estimation of cloudiness – combination by information from turbulence and convection schemes
- Currently constant assumption for effective radius R_{eff} = 5 μm for water and 10 μm for ice → derive a parameterization for R_{eff} of SGSC
- SGS variability factor k "radqcfact"



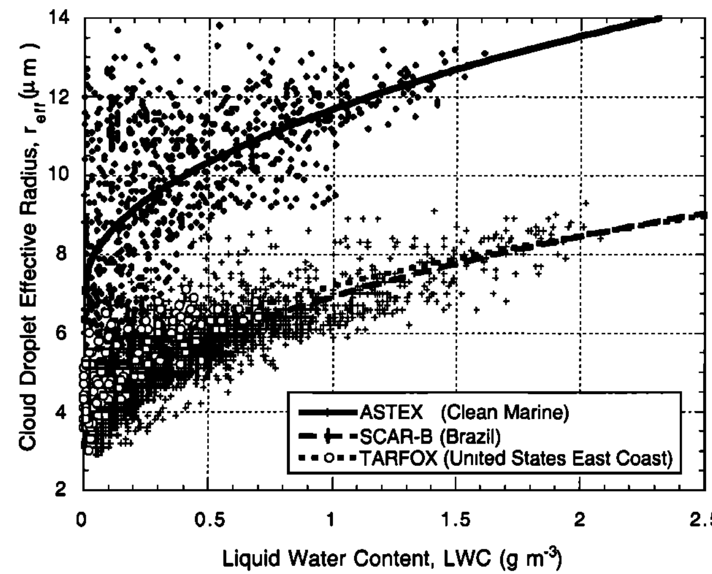


Figure 6. Cloud droplet effective radius (r_{eff}) versus liquid water content (LWC) for cumulus clouds in clean marine air over the northeastern Atlantic Ocean (diamonds, Atlantic Stratocumulus Transition Experiment (ASTEX)), in urban-industrial air off on the U.S. east coast (circles, Tropospheric Radiative Forcing Experiment (TARFOX)), and in air masses dominated by smoke from biomass burning (pluses, Brazil).

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 104, NO. D6, PAGES 6145–6153, MARCH 27, 1999

COSMO Sub-Grid Scale Clouds cloud cover

1. Default radiation scheme

CLC = fct(QC, QI, generalized RH_g, convective CLC_CON)

RH_g: blending in mixed-phase region between water and ice saturation, using prescribed ice fraction f_{ice} = linear ramp function of T between 0 (-5˚C) and 1 (-25˚C)

$RH_g := (QV+QC+QI) / QV_{sat,g} = (QV+QC+QI) / (QV_{sat,water} *(1-f_{ice}) + QV_{sat,ice}*f_{ice})$

CLC = CLC_SGS + CLC_CON * (1 – CLC_SGS)

QX_RAD = QX_CON * CLC_CON + max[QX_SGS, 0.5*QX] * CLC_SGS * (1 – CLC_CON)

2. Alternative radiation scheme

CLC = fct(QC, QI, QV, generalized RH_g, convective CLC_CON)

$RH_g := (QV+QC) / QV_{sat,water}$ where: CLC_SGS = 1.0 if QI > 0.0

QC_RAD = QCI_CON * CLC_CON + QC_SGS * CLC_SGS * (1 – CLC_CON)

3. Alternative statistical radiation scheme

CLC = fct(QC, QI, QV, DQ, σ_{DQ}, convective CLC_CON)

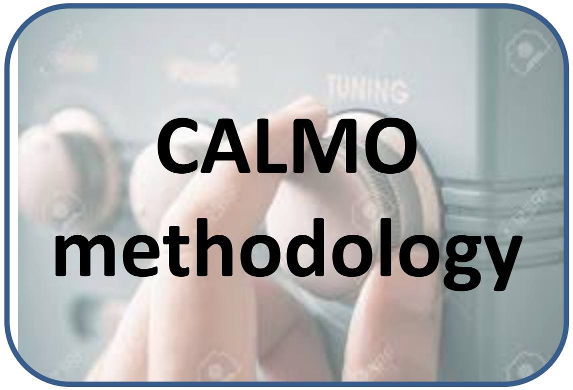
$DQ = QV + QC - QV_{sat,water}$ (saturation deficit) σ_{DQ} = MIN [stdev. of DQ from turb. , 0.001]

No mixed phase yet (RH_g)

QC_RAD = QCI_CON * CLC_CON + QC_SGS * CLC_SGS * (1 – CLC_CON)

Blahak , **Raschendorfer** 2015


Expert
tuning


TUNING
CALMO
methodology

Expert tuning

New radiation scheme ~ 30 new parameters: Which are most important?

↓

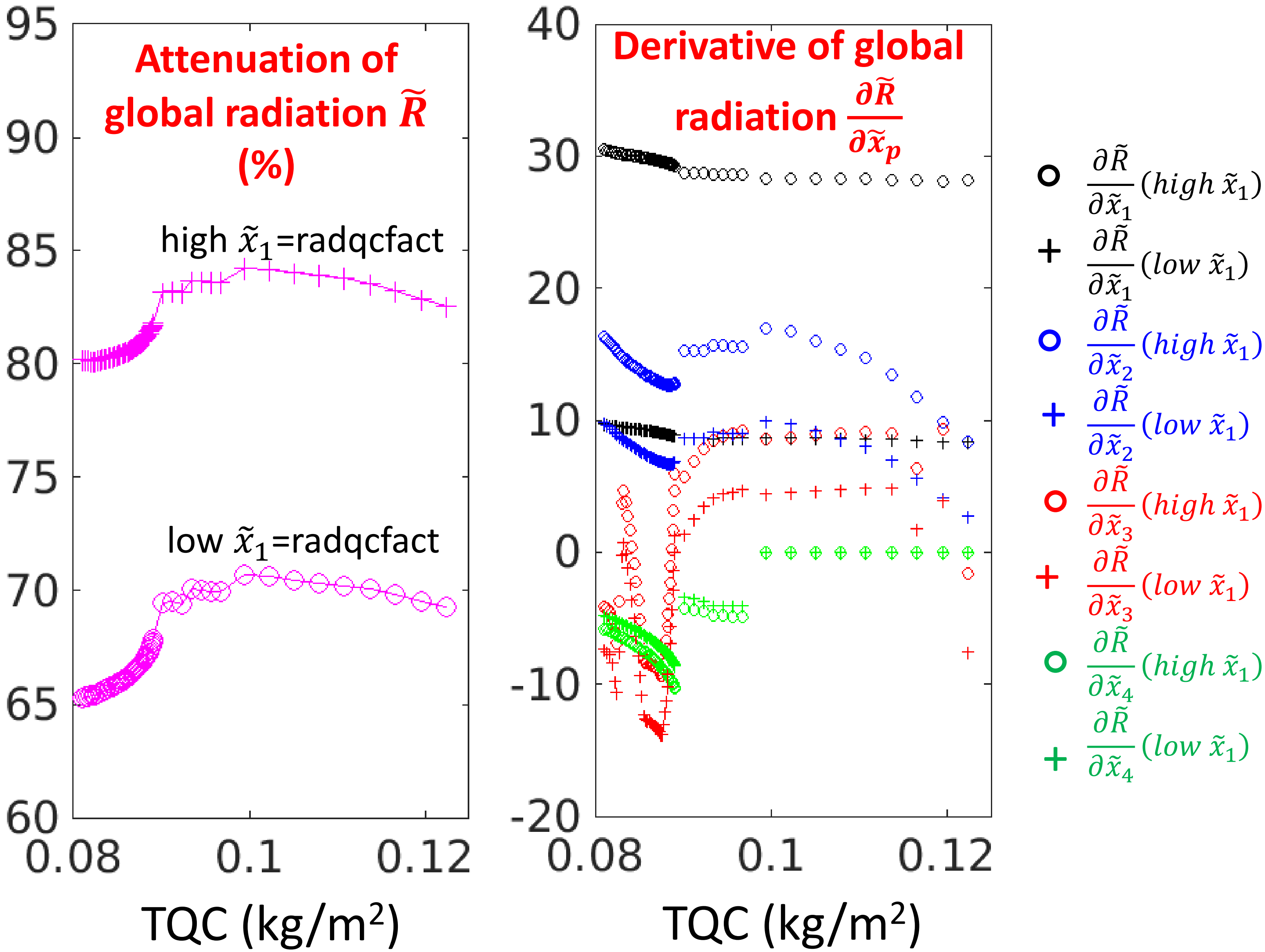
Use ***idealized*** COSMO framework to create different cloud types

↓

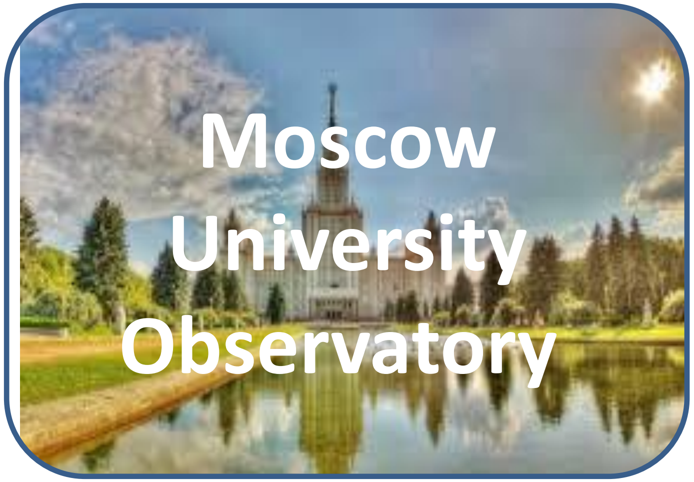
Cirrus	Stratus	Mixed phase	SGS Strato-cumulus	Shallow convective cumulus	Anvil of Cumulonimbus
p1,p2,p3,p4, p5,p7,p8,p9, p12,p14,p21, p22,p23,p27, p28,p29,p30	p1,p2,p4, p6,p13,p15, p16,p17,p24, p25, p26,p30	p1,p2,p3,p4,p5, p6,p7,p8,p9,p12, p13,p14,p15,p16, p17,p21,p22,p23, p24,p25,p26,p27, p28,p29,p30	p2,p4,p5,p6,p13,p15, p16,p17,p30	p2,p4,p5,p6,p13,p15, p16,p17, p30	p1,p2,p3,p4,p5,p7,p8,p9,p12, p14,p21,p22,p23,p27,p28, p29,p30

Khain 2015

CALMO methodology



Khain 2015

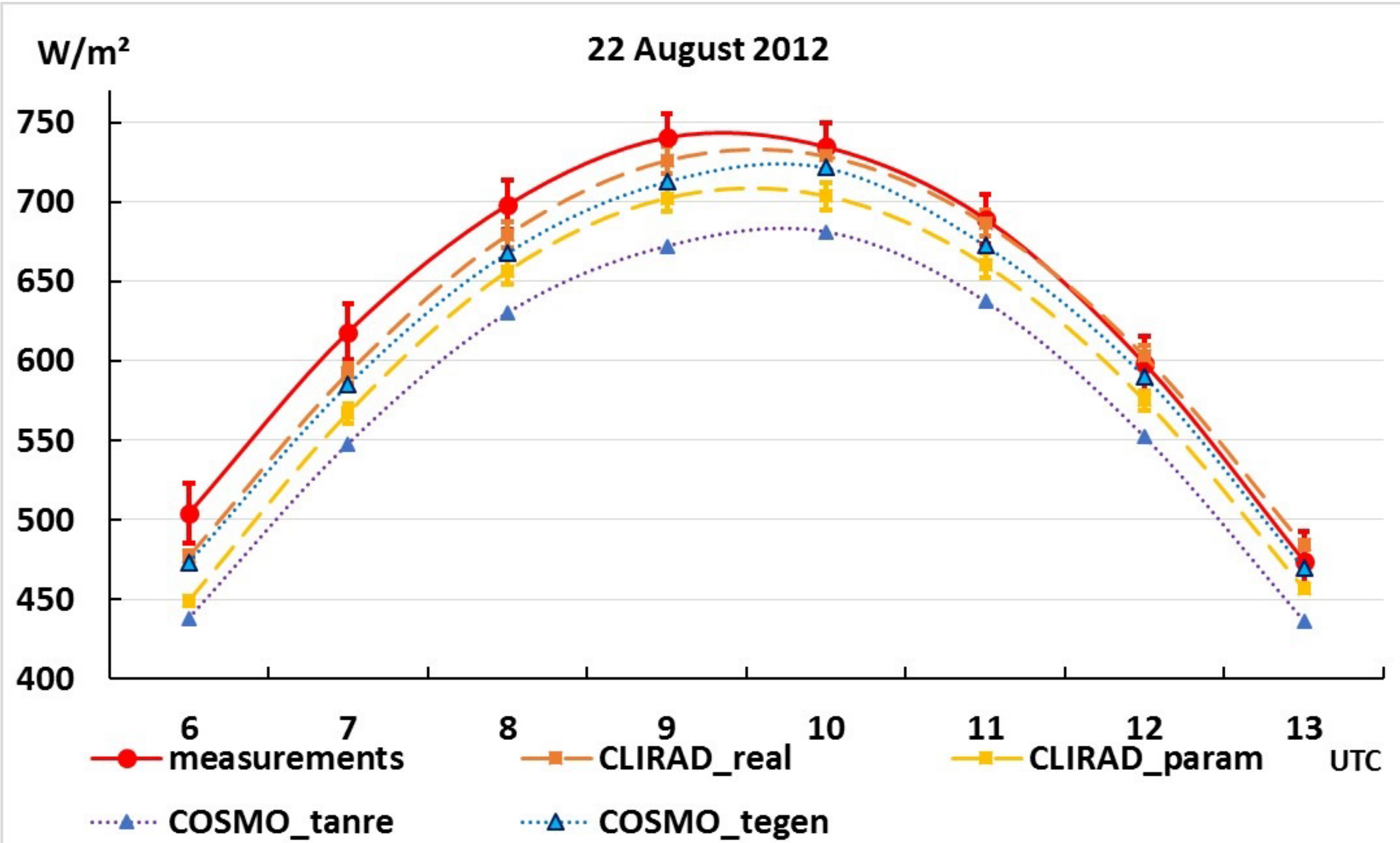

Moscow
University
Observatory

Testing the radiation code against experimental datasets

- Moscow State University Meteorological Observatory
- clear sky conditions: 15 - 20 cases
- cloudy conditions: 30 - 50 cases
- evaluate the forecast sensitivity to aerosol/cloud schemes applied in the radiative scheme: CLIRAD-SW model [Tarasova T.A., Fomin B.A., 2007], Benchmark Monte-Carlo RT model (Rublev et al., 2001), Complex of measurements at the MSU MO (Chubarova et al., 2014)

Chubarova 2016

Comparison with measured data



More to come: MACC, Kinne, cloud-ratiotion schemes

Chubarova 2016


Temporal
resolution

Optimizing Radiation scheme call time

- Radiation scheme current operational call time:

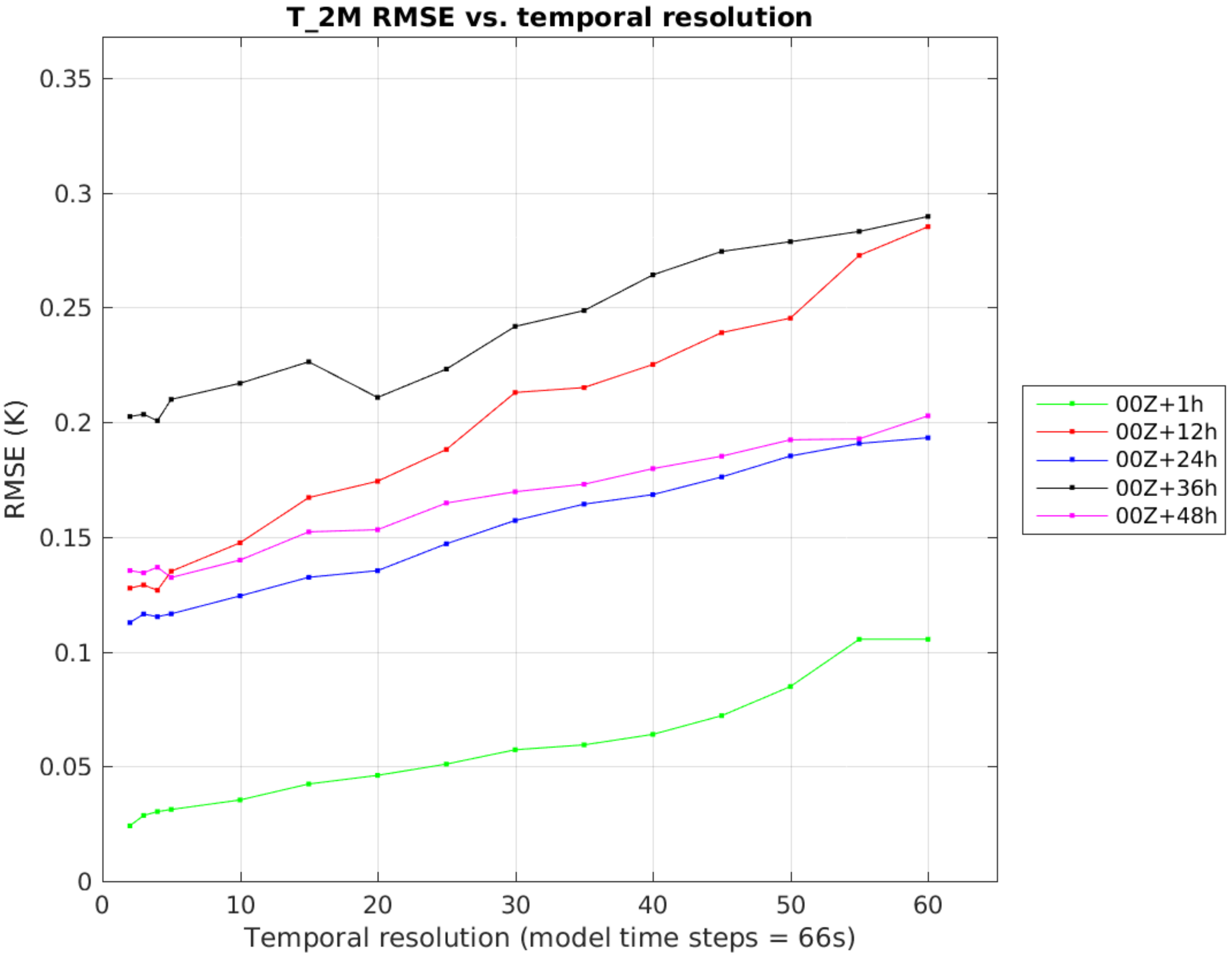
COSMO 7 km	COSMO 2.8 km
1 hour	15 minutes

- What is the optimal call to calculate the radiation fluxes?
- What happens in fast changing weather?

Optimizing Radiation scheme call time

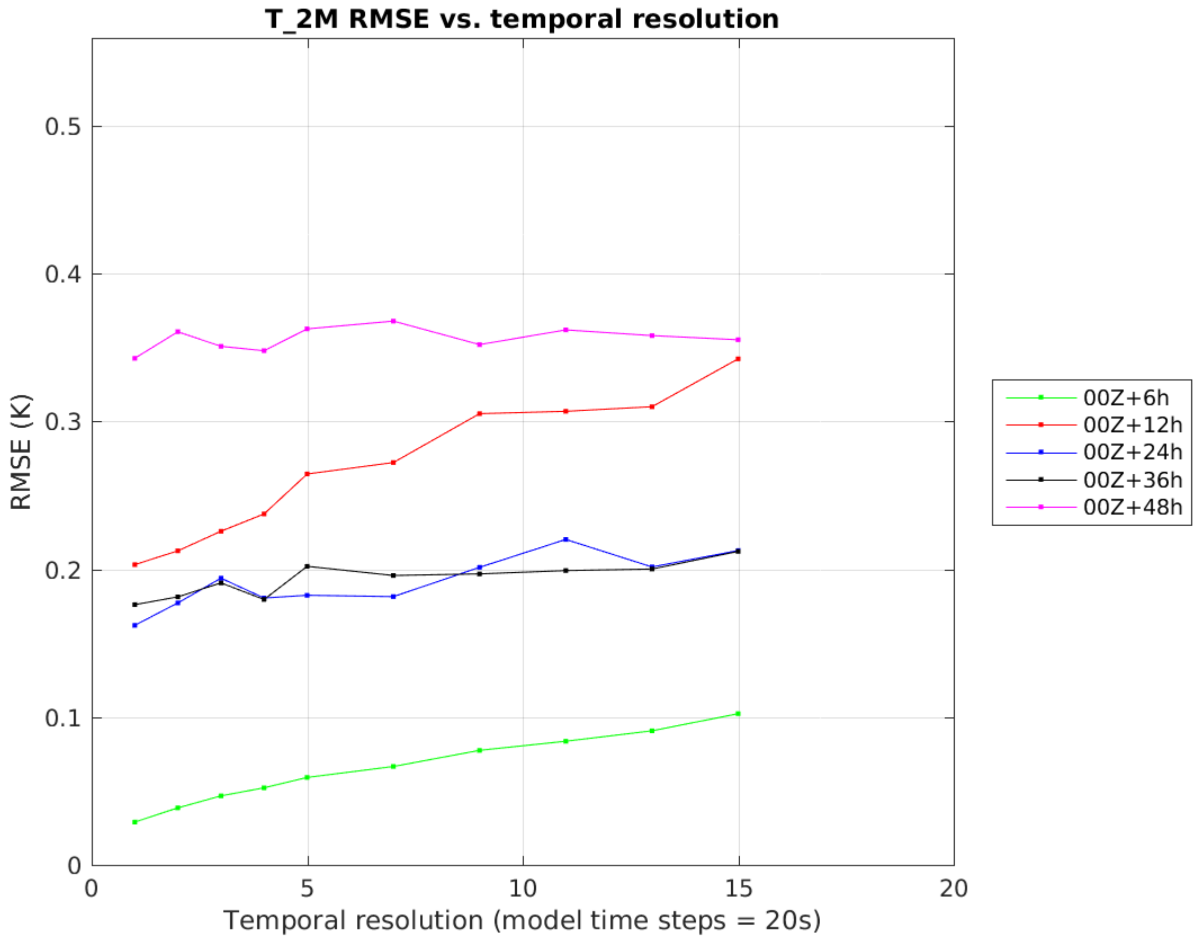
COSMO 7km

case study 23.04.2015 strong wind speed/partial cloudiness



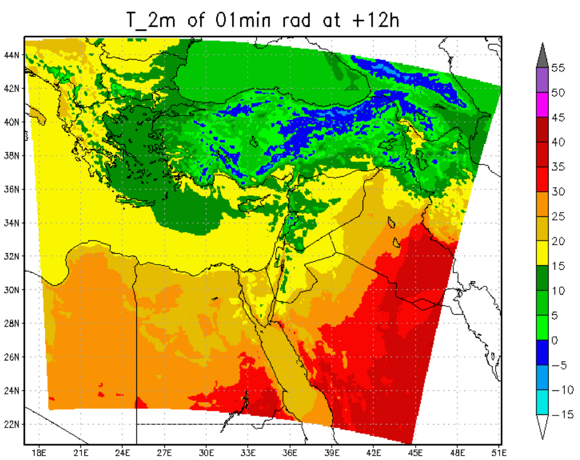
Optimizing Radiation scheme call time

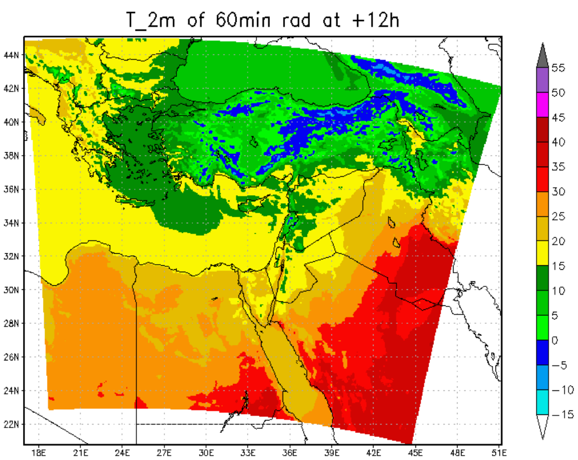
COSMO 2.8km

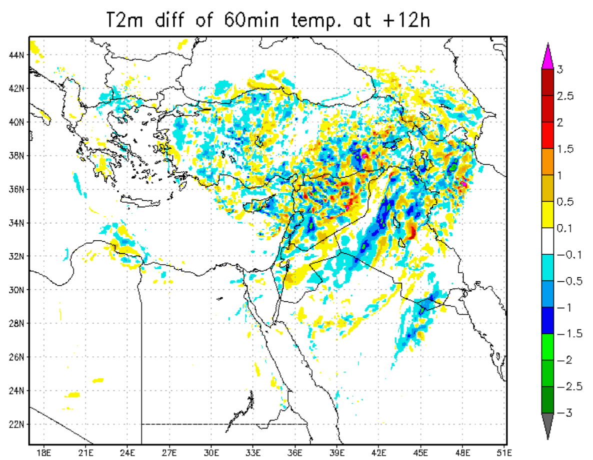


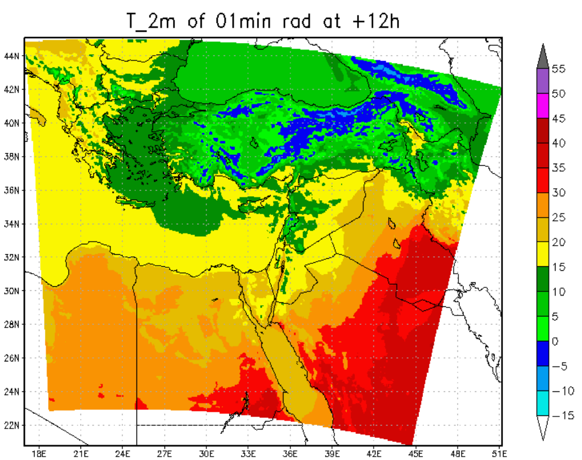
Optimizing Radiation scheme call time

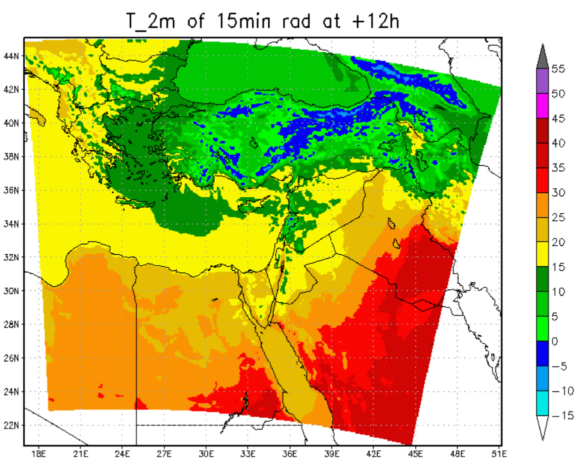
COSMO 7km

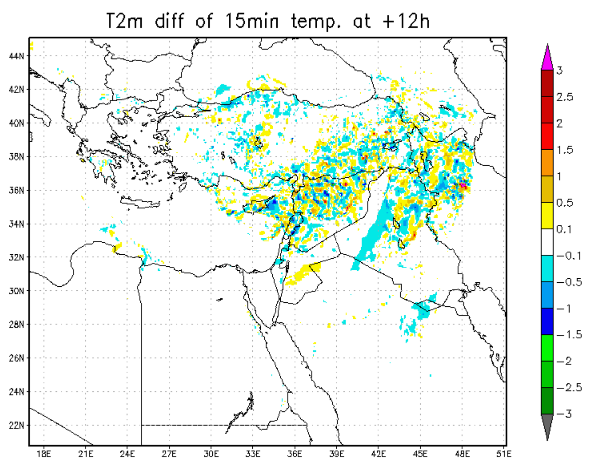






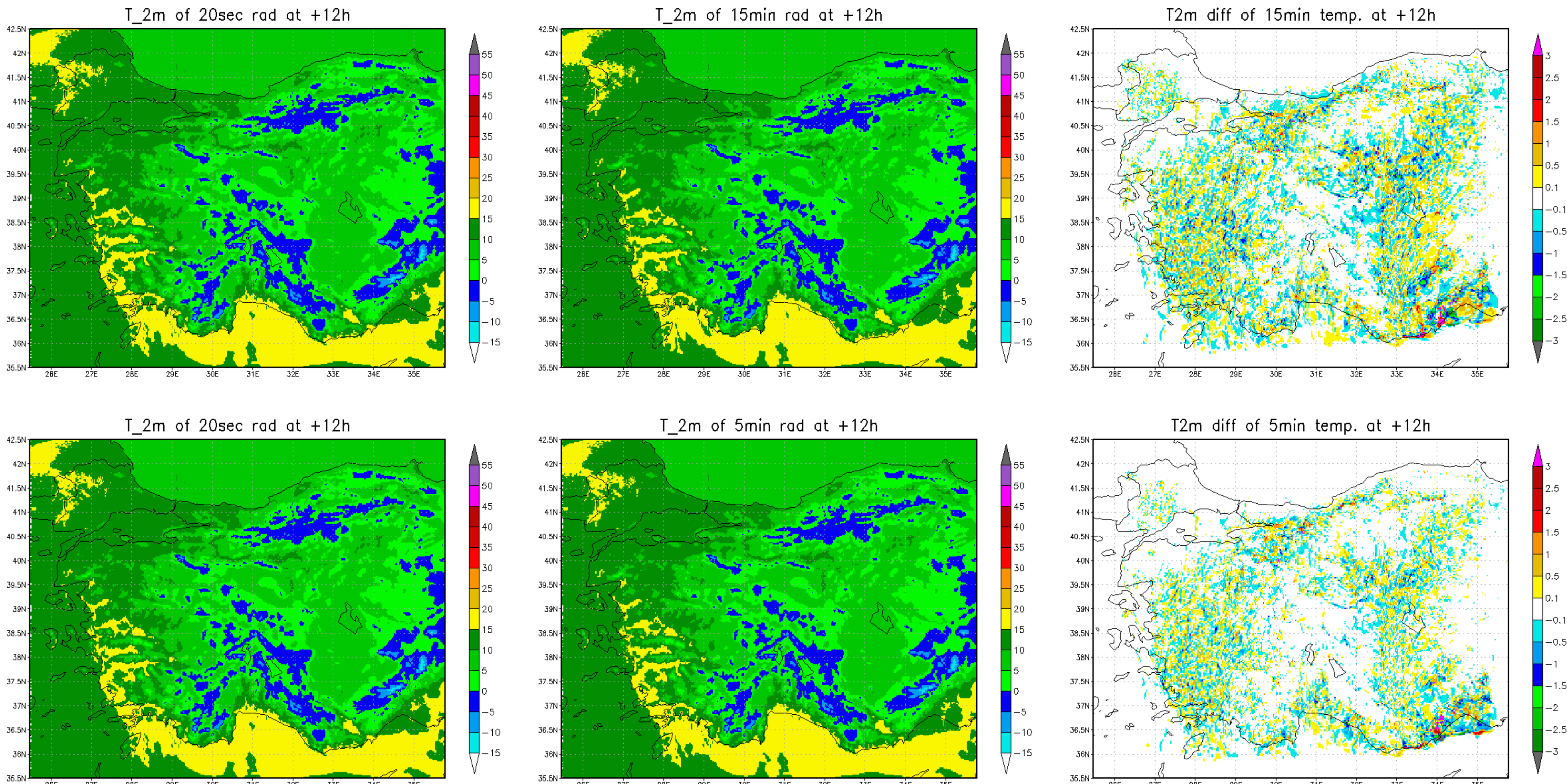






Optimizing Radiation scheme call time

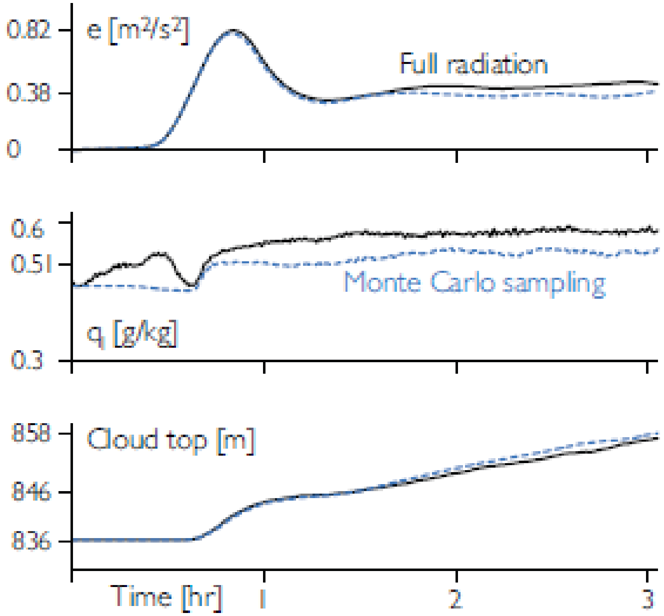
COSMO 2.8 km




Monte-Carlo
Spectral
Integration

Monte-Carlo Spectral Integration

- Bodo Ritter work started few years ago
- Bias free random sampling of the 8 spectral bands, instead of full spectral integration over every band in each radiation time step.
- The error introduced is substantial for individual samples but is uncorrelated in time and space.



Pincus & Stevens 2009

DP to SP

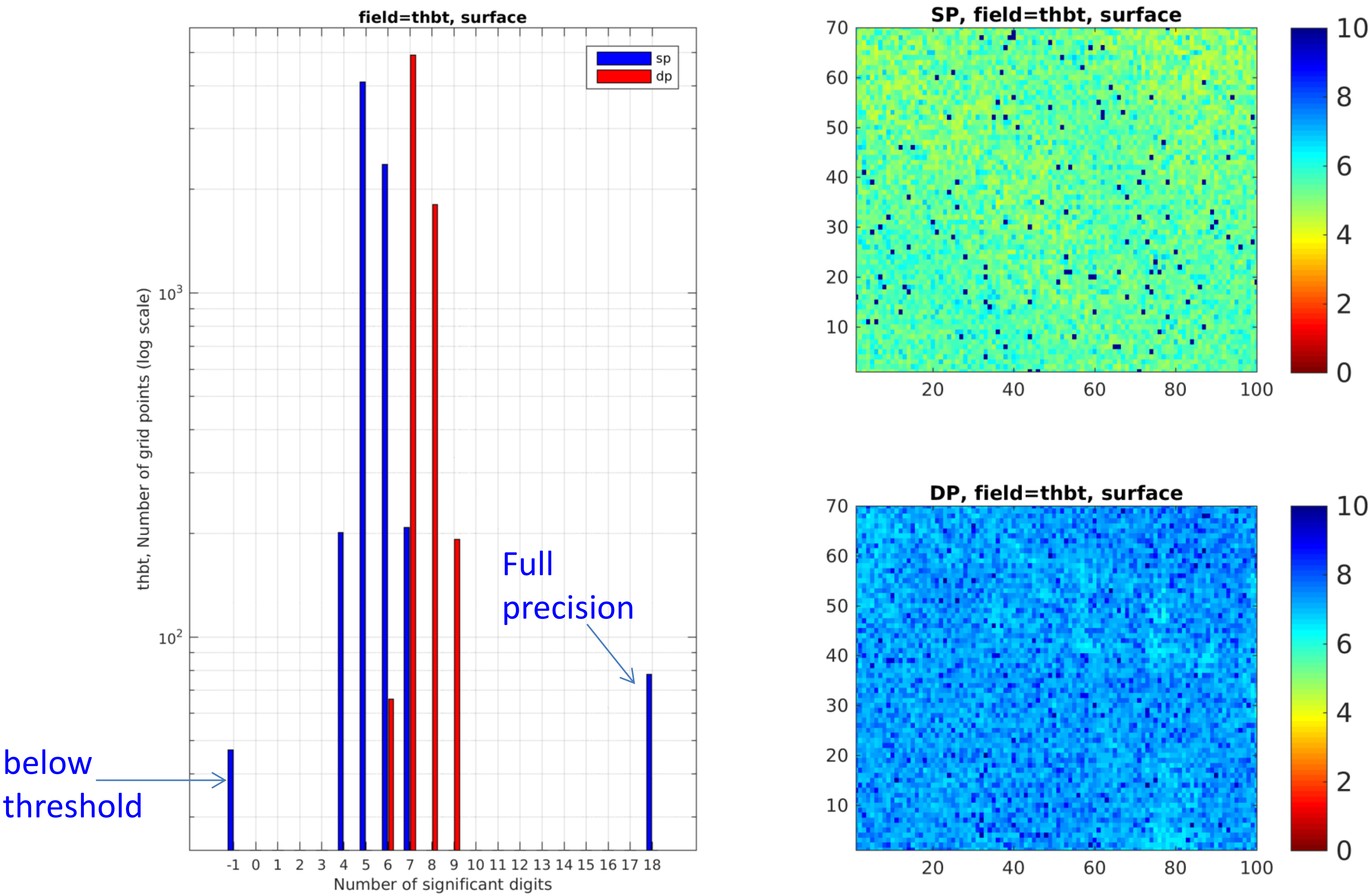
Switchable Single/Double Precision in Radiation Scheme

- In PP POMPA most parts of COSMO were re-written to enable SP/DP. Currently only radiation scheme is run on DP regardless of the WP (working precision)
- Perform several simulation with randomly perturbed data fields → Compute number of significant digits for each grid point

Name	Size	Decimal digits	Minimum number	Maximum number
half precision	2 Bytes	3.3	10^{-5}	10^{4}
single precision	4 Bytes	7.2	10^{-38}	10^{38}
double precision	8 Bytes	16.0	10^{-308}	10^{308}
quadruple precision	16 Bytes	34.0	10^{-4932}	10^{4932}

Fuhrer et al. 2014

Switchable Single/Double Precision in Radiation Scheme



thbt = thermal radiation at the upper boundary [w/m2] of the atmosphere

THANK YOU!