New PT:
$(RC)^2$ – Revised Cloud Radiation Coupling

**Ulrich Blahak (DWD), Pavel Khain (IMS), Harel Muskatel (IMS),
Marco Arpagaus (MeteoSwiss)**

Status

- Coupling of grid scale clouds and radiation is not consistent:
  - Only qc, qi are „seen“ by the radiation, qs, qr, qg are not
- Optical properties of qc, qi only depend on the mass density
  - Nowadays more modern parameterizations available, which have an explicit dependency on the effective radius R_eff
  - Allows for more consistent coupling of cloud microphysics and radiation, both for the 1-moment and 2-moment microphysics
- Factor „0.5“ to take into account the subgrid scale variability within a cloudy grid box
  - Value is appropriate for very much coarser models, but has to be increased for our applications
- Altogether there are different systematic biases in the incoming and outgoing radiation in different situations:
  - Very „thick“ clouds optically too „thick“
  - Intermediate clouds optically too „thin“
  - Cloud-free: too much extinction if using the old aerosol climatology

Status

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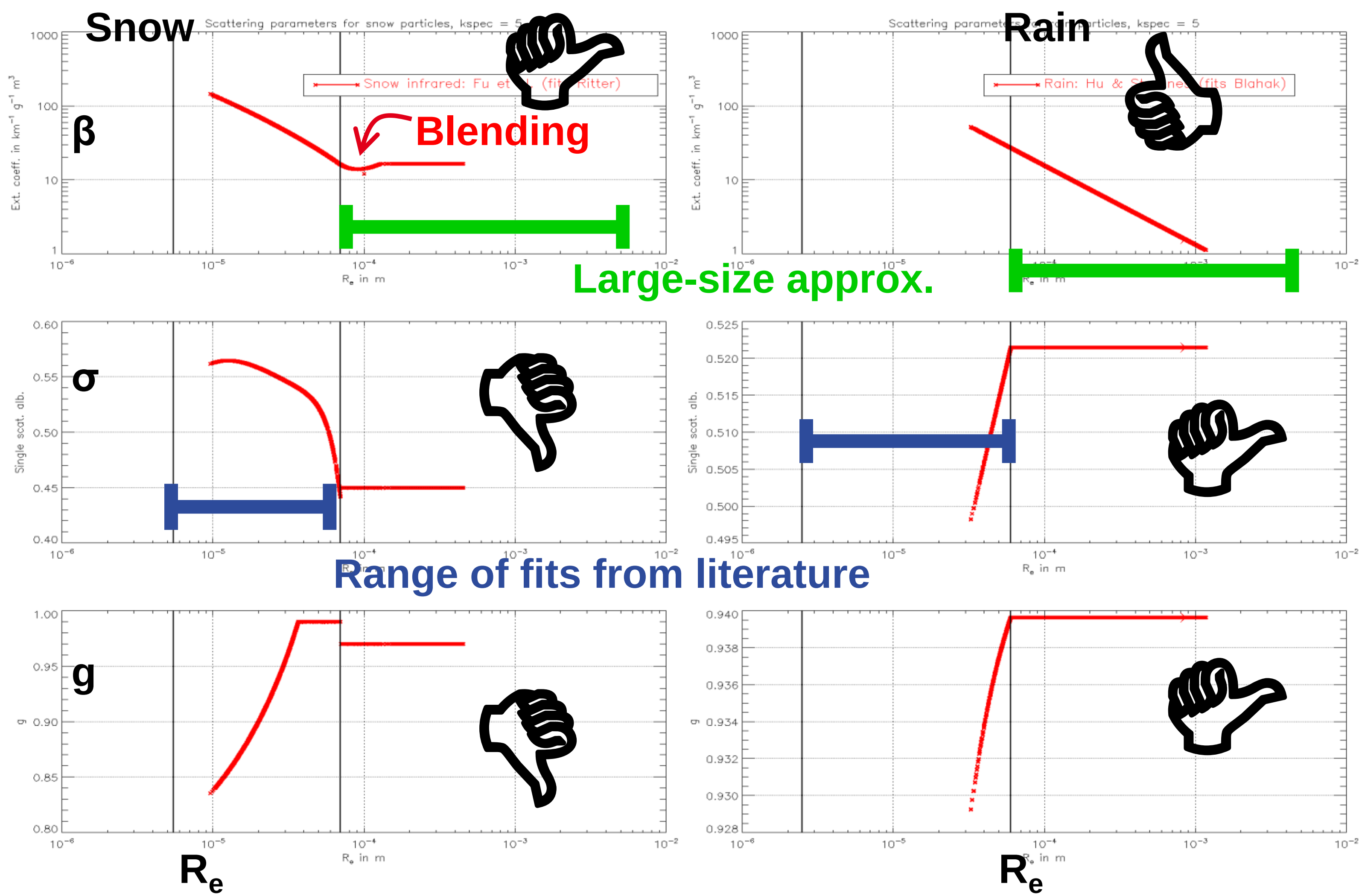
- **Test model version from UB available (based on COSMO 4.22):**
- Included qs, qr, qg in the radiation
- Optical properties depending on R_eff:
  - qc: based on Hu and Stamnes (1993)
  - qi: based on Fu et al. (1996, 1998)
  - qs, qr, qg: „Large size approximation“ by UB, ok for extinction but problematic for single scat. albedo and asymetry parameter
- ~20 new tuning parameters for, e.g.:
  - subgrid scale variability factor
  - cloud droplet number
  - subgrid scale cloud properties (water content, R_eff)
  - PSD parameters for cloud ice, snow, graupel
  - clipping of TQC, TQI, TQS
- Sensitivity studies based on COSMO-DE, but so far no further model tuning or evaluation!

Work packages for Priority Task

- **Priority Task (RC)² (2014 – 2015)**
  - Upgrade test code to the newest COSMO version **(→ UB)**
  - Getting familiar with the COSMO radiation scheme and with UB‘s test code together with the changes/ extentions contained herein **(→ PK, HM)**
  - Further revision of optical properties of ice hydrometeors (single scat. alb., asym. param.) based on a new parameterization of Fu et al. (2007) **(→ UB, HM)**
    (UB has visited Quiang Fu in Hamburg and initiated collaboration)
  - Review/ revise treatment of subgrid scale clouds in radiation **(→ PK, HM)**
    - E.g., decoupling of CLC diagnostic and radiation tuning; SGS clouds consistent to turbulence scheme?
  - Reduce number of tuning parameters **(→ PK, HM, UB)**
    - 1) Find insensitive parameters by case studies and set to constant values.
    - 2) Physically based closures. Examples:
      - Replace parameter *cloud_num* (number conc. of cloud drops) by a climatology. UB has developed a method for a similar parameter in the microphysics, based on Tegen et al. (1997) and Segal & Khain (2006), but not implemented in the radiation so far.
      - Replace *radqc_fact* by a PDF-based closure. Would be a new development and not clear if possible.
  - Case studies for different weather situations and different climates
  - Possible co-operation with a group from CLM-community for studies in longterm climate mode?
  - Participants: **UB (Ulrich Blahak), PK (Pavel Khain), HM (Harel Muskatel)**
  - Tentative PT leader: **UB**

Optical properties for large R_e to be revised



(spectral band no. 5)

Optical properties for large R_e: New data/parameterization of Quiang Fu

- Quiang provided an extended data set for β_{ext}, ω and g for R_e up to 3 mm. Need to do the spectral remapping to the RG92 wavelength bins.
- Fu (2007): Effective aspect ratio (AR) much better predictor of g than Re . Again, parameterization available up to size of 3 mm. **Distinction of smooth and rough surfaces (strong difference in scattering function)!** Need to implement calculation of AR and parameterization in COSMO and decide on assuming rough or smooth surfaces.

A New Parameterization of an Asymmetry Factor of Cirrus Clouds for Climate Models

QIANG FU

Department of Atmospheric Sciences, University of Washington,

(Manuscript received 6 September 2006, in final form 4 J

$$\mathrm{AR} = \frac{\int_{L_{\min}}^{L_{\max}} (D/L) A_c n(L)\, dL}{\int_{L_{\min}}^{L_{\max}} A_c n(L)\, dL}$$

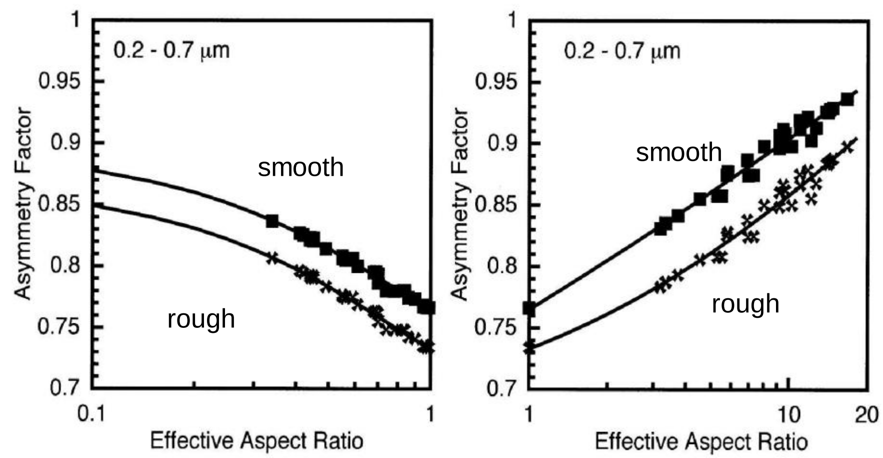


FIG. 4. Asymmetry factor vs the mean effective AR in the spectral interval 0.2–0.7 µm for (left) AR smaller than 1 and (right) AR larger than 1. The square and × symbols in each panel represent reference results from the geometric ray-tracing calculations using 28 measured ice crystal size distributions for ice particles with smooth and rough surfaces, respectively. The curves are from the parameterizations developed in this study.

To reduce tuning parameters

- radqcfact
- radqifact
- lrad_incl_qrqsqg
- itype_aerosol
- reff_ini_c
- reff_ini_i
- cloud_num_rad
- dz_oe_cloud_num_rad

- tqc_thresh_rad
- tqi_thresh_rad
- tqs_thresh_rad
- rhos_n0shigh_rad
- rhos_n0slow_rad
- n0s_low_rad
- rhoc_nchigh_rad
- rhoc_nclow_rad
- ncfact_low_rad
- rhoi_nihigh_rad
- rhoi_nilow_rad
- nifact_low_rad
- qvsatfact_sgscl_rad

To reduce tuning parameters

➔ Example: eliminate reff_ini_c by some physical parameterization

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

Relationships between cloud droplet effective radius, liquid water content, and droplet concentration for warm clouds in Brazil embedded in biomass smoke

Jeffrey S. Reid,[1] Peter V. Hobbs, Arthur L. Rangno, and Dean A. Hegg
Department of Atmospheric Sciences, University of Washington, Seattle

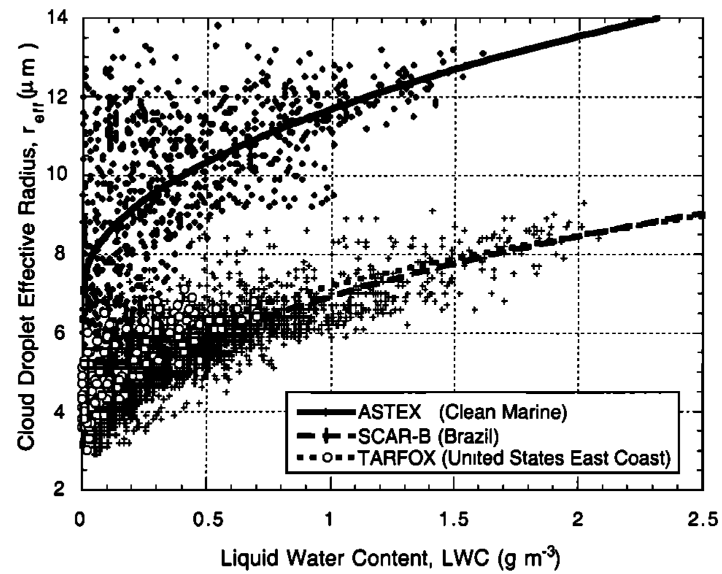


Figure 6. Cloud droplet effective radius (r_{eff}) versus liquid water content (LWC) for cumulus clouds in clean marine air over the northeastern Atlantic Ocean (diamonds, Atlantic Stratocumulus Transition Experiment (ASTEX)), in urban-industrial air off on the U.S. east coast (circles, Tropospheric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

Just an example on measurements of Re in water clouds, that are subscale to our models.

There are more papers on field experiments out there!

Something like that could replace the currently constant assumption for R_e in subgrid scale water clouds in the model!

To reduce tuning parameters

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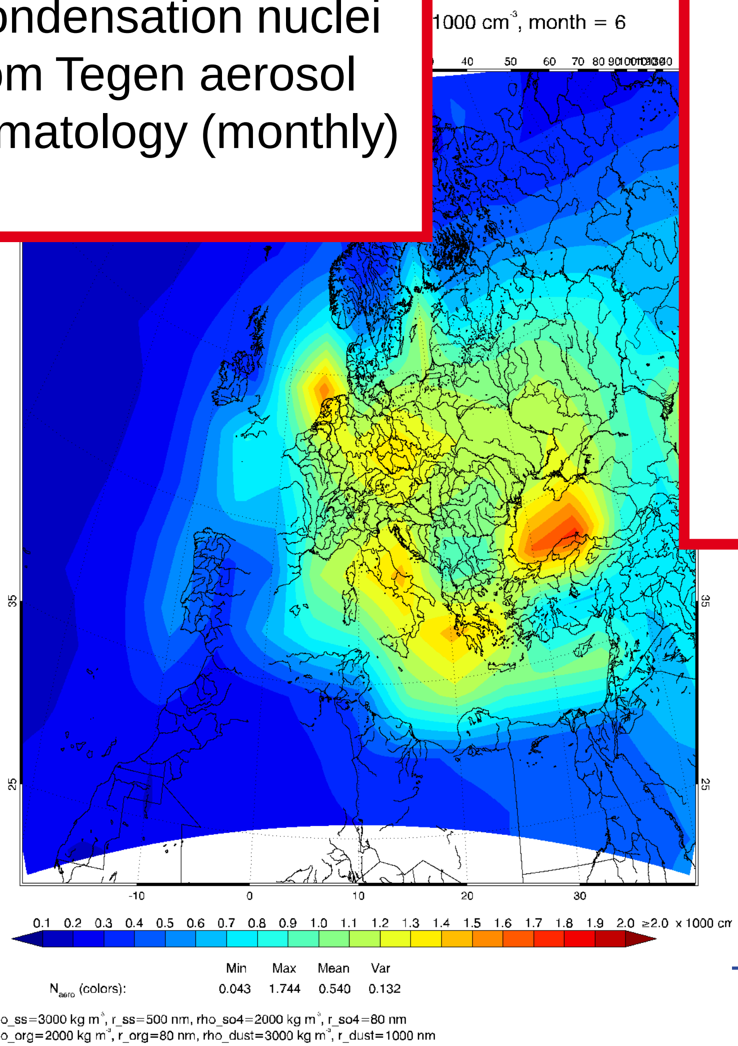
➔ Example: eliminate cloud_num by some physical parameterization

Condensation nuclei from Tegen aerosol climatology (monthly)



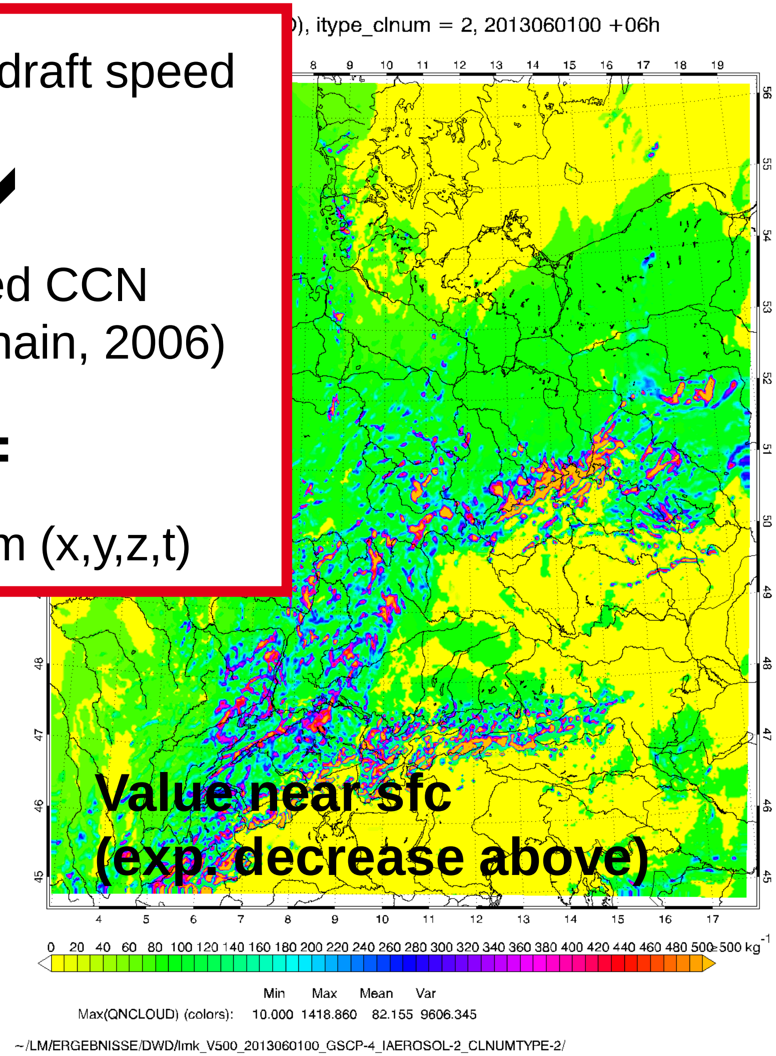
\+ model updraft speed

⬇

Activated CCN
(Segal & Khain, 2006)

=

cloud_num (x,y,z,t)



Value near sfc (exp. decrease above)

To reduce tuning parameters: identify and keep only the „sensitive“ ones

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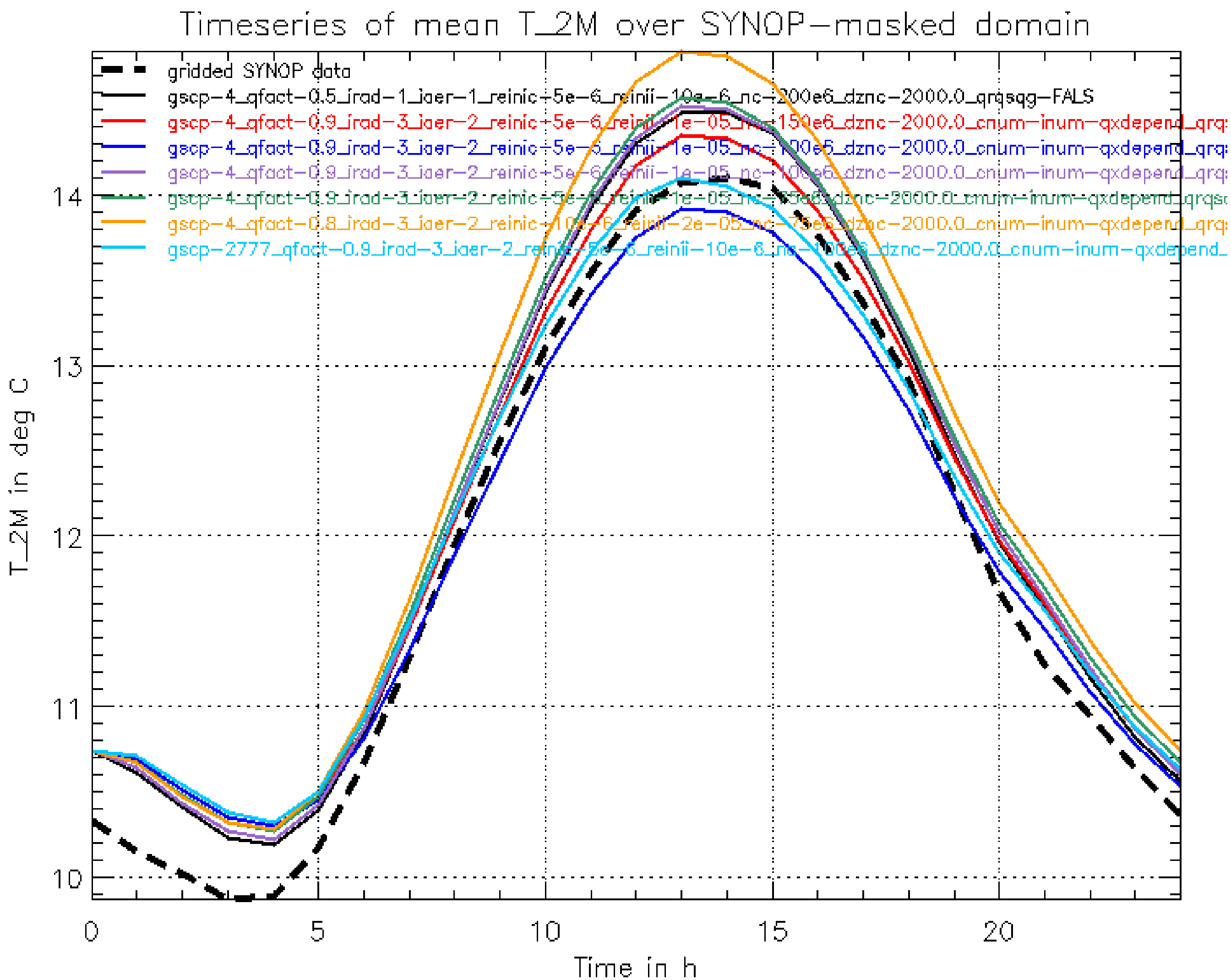

Control

„optimal tuning“ at k=0.9

+ doubling LWC and IWC of SGS clouds

+ halfing LWC and IWC of SGS clouds

+ halfing n_{c0}

+ halfing n_{c0} and doubling Re of SGS water clouds

2-moment scheme

FTEs

→ Ulrich Blahak	**0.3 FTEs**
→ Pavel Khain	**0.3 FTEs**
→ Harel Muscatel	**0.5 FTEs**

OUTLOOK: Tentative Work packages for a possible follow-up Priority Project

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- **Priority Project (2015-2017), first idea on working title: *T²(RC)² - Testing and Tuning of Revised Cloud Radiation Coupling***
  - Coupling of RRTM to COSMO (Common physics library) + Transfer of new cloud radiation coupling methods to RRTM
  - Extensive testing, model tuning and evaluation in different climates necessary!
    - Would be ideal for a collaborative COSMO effort (different model setups, different climates)
    - Needs help from people from different COSMO countries
    - Liase with PP CALMO for automatic tuning, after expert tuning has revealed the most sensitive tuning parameters?
  - Estimated duration: 2 years
  - Tentative PP leader: tbd (MA is ready to take the lead in case no one else wants to do it)