Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
nwp central europe

Scale dependency of 3MT closure and adaptive detrainment

ALARO Working Days, 12-14 May 2014

Problem of diurnal cycle

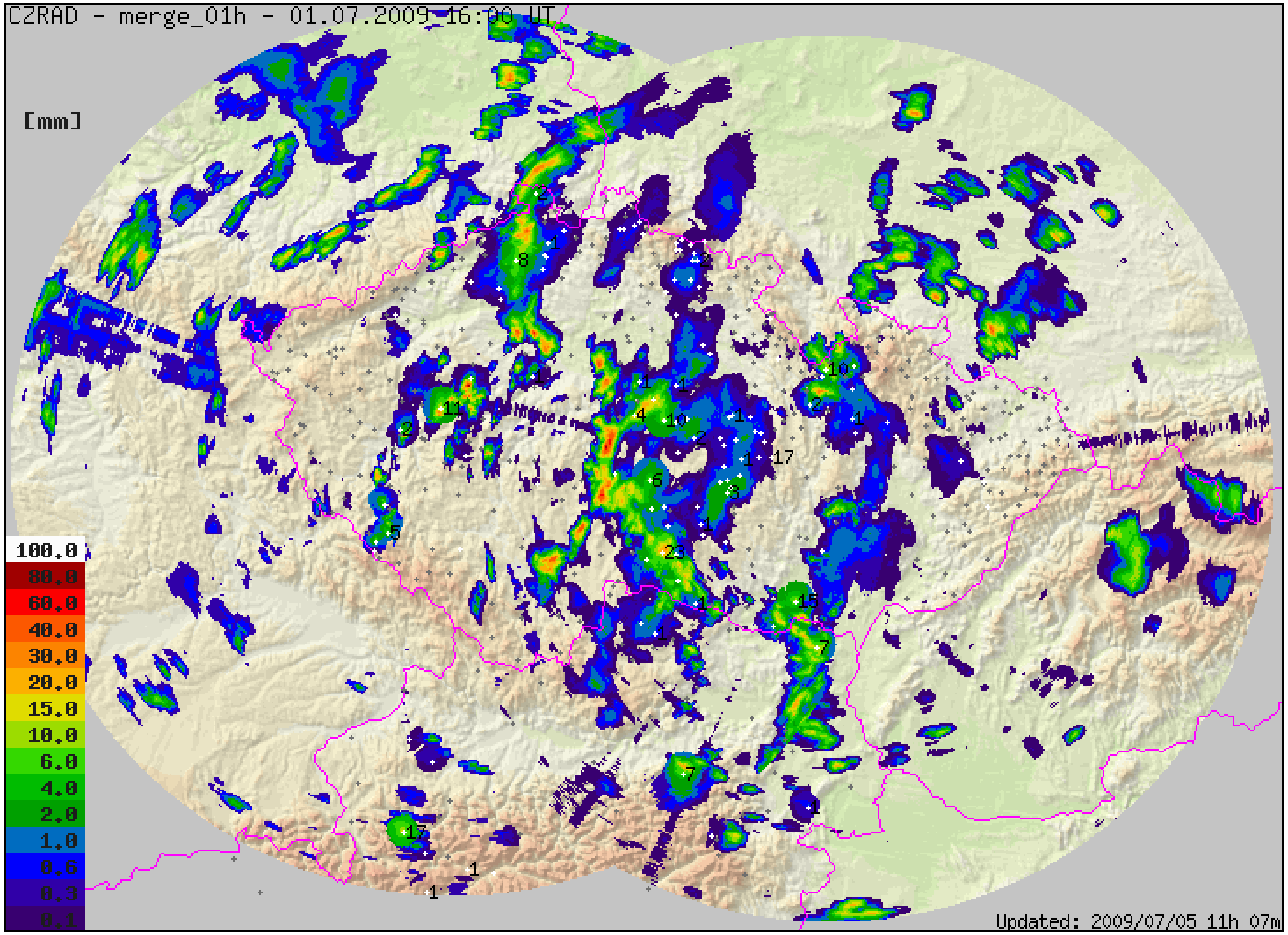
- Known weakness of parameterized moist deep convection:

  it starts couple of hours too early and decays too early.
- This is true also for a prognostic scheme like 3MT in its “standard” version (prognostic velocities and area fractions).
- A study: can we improve the diurnal cycle phase and intensity of convection by introducing more “memory” and “flexibility”?

Set-up of the study

- Period June-July 2009 in Central Europe with very strong convective activity every day;
- Well pronounced daily cycle of convection observed from 24 June to 4 July => period of 11 days;
- Hourly precipitation amounts were extracted from the merged observations from radars and gauges over territory of Czech Republic and surroundings.

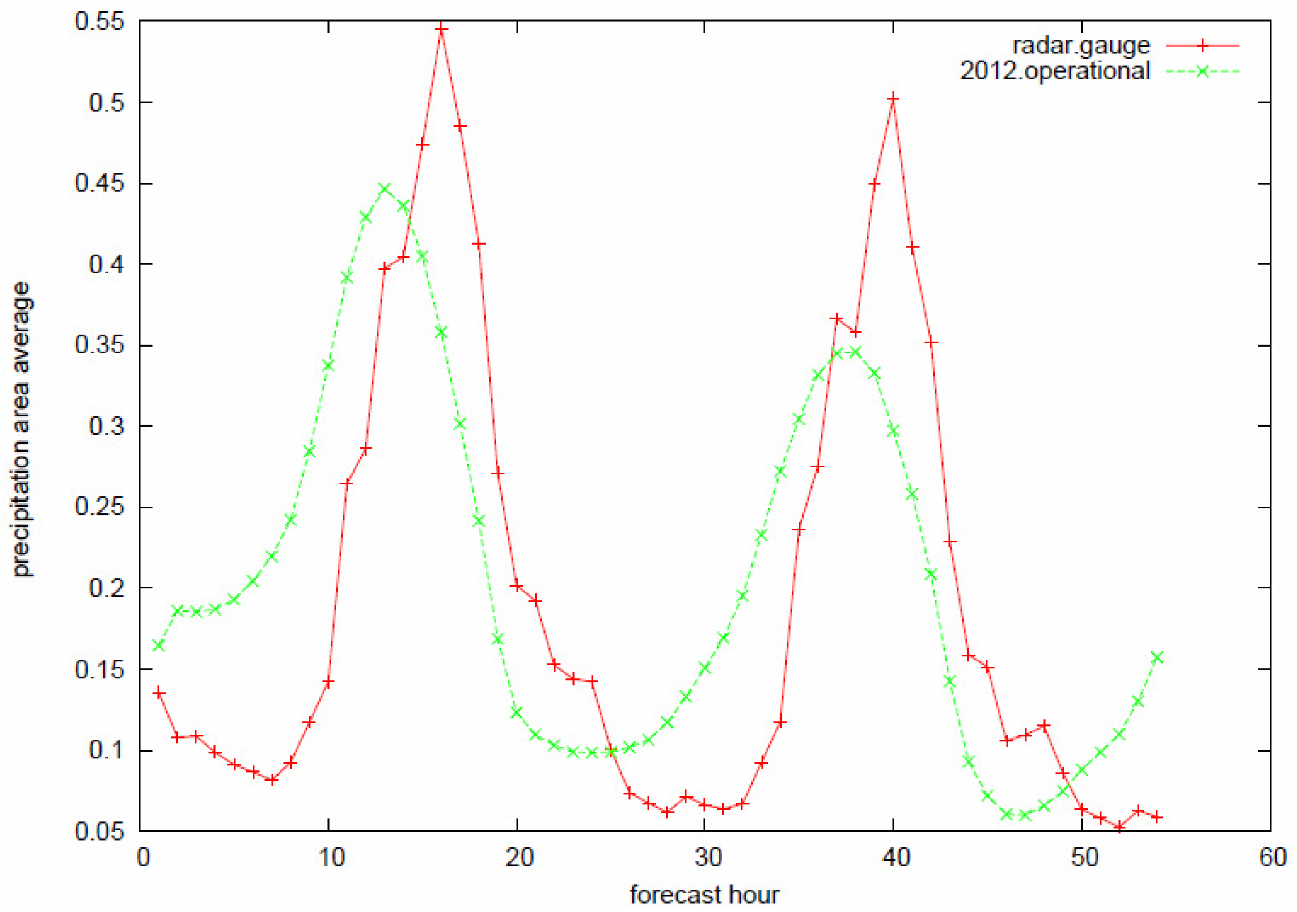
Availability of precipitation observations -area



Demonstration of the problem (1)

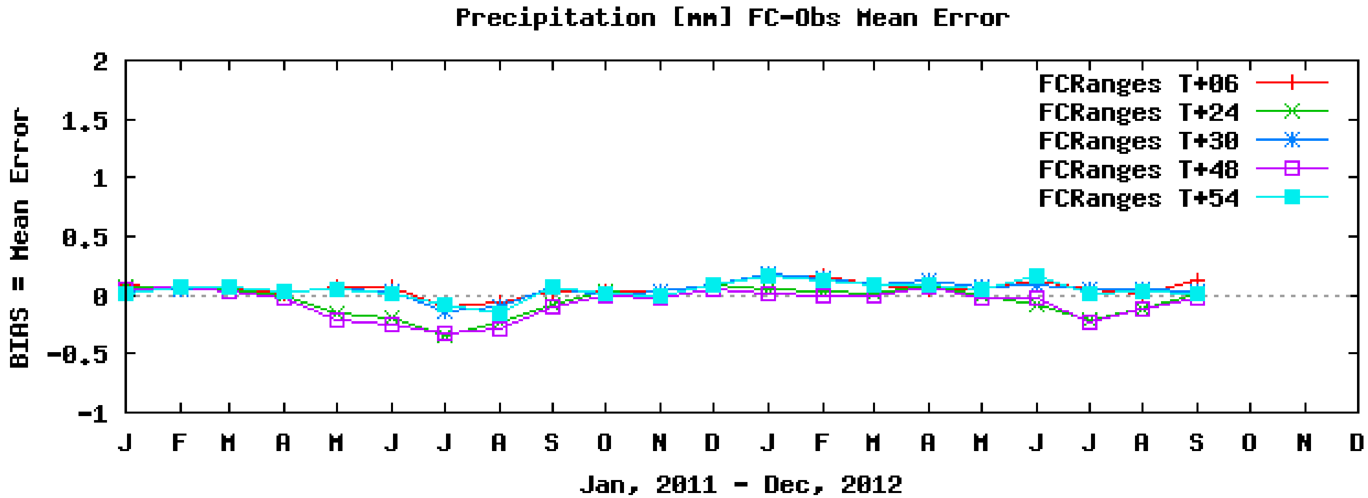
11 realizations' average of mean hourly precipitation over the area

- Model starts rain early;
- Early decay as well;
- Too much precipitation in the morning;
- Lack of precipitation in the late afternoon and in the evening.



Demonstration of the problem (2)

Verification scores – monthly mean over Central Europe in 2011 and 2012,
before ALARO-0 baseline



- Negative bias in summer for the forecast ranges 24h and 48h (rainfall sum between 18h and 24h UTC network time analysis: 0h UTC);
- Confirmation of the diurnal cycle problem.

Proposal (1)

- In the scheme, entrainment rate also depends on buoyancy (I_b):

$$Ent = f(\lambda_x, \lambda_n, \phi - \phi_b) \qquad \lambda_n = \frac{1}{1/E_n + \alpha I_b} \qquad \lambda_x = \frac{1}{1/E_x + \alpha I_b}$$

$$I_b = \int_{\phi_s}^{\phi} (h_{nea} - \bar{h}) d\phi$$

E_n, E_x and α are tuning parameters.

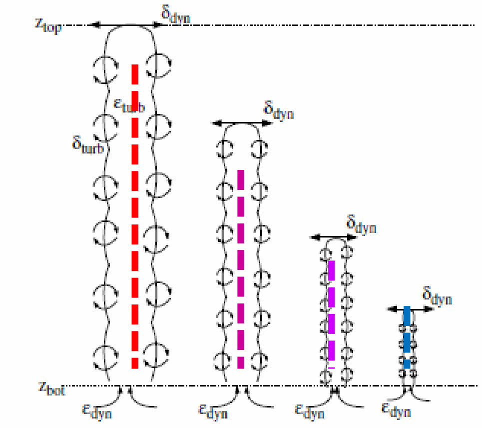
- Parameter α is proposed to depend on relative humidity of environment (idea of P. Bechtold applied to our case) - closer to saturation => lower entrainment:

$$\alpha^* = \alpha \frac{\int_{\phi_s}^{\phi} \overline{R_h} (h_{nea} - \bar{h}) d\phi}{I_b}$$

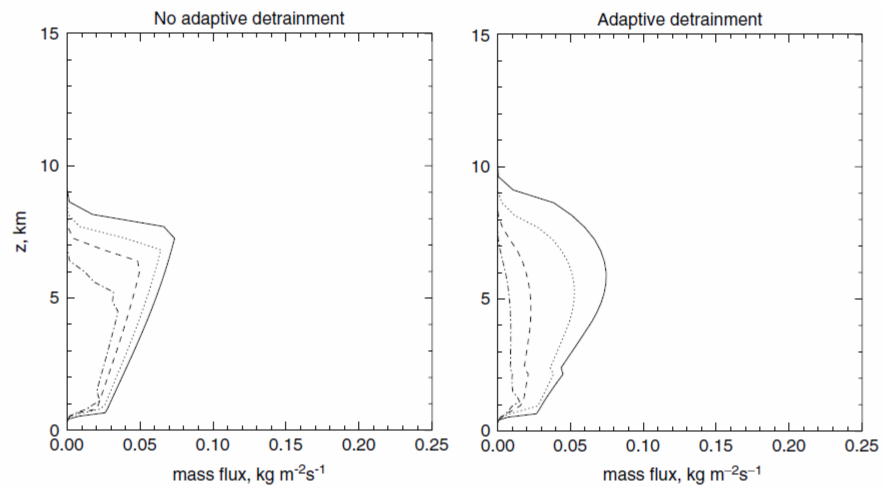
Proposal (2)

- Less entraining clouds get higher and are warmer; in the scheme, the equivalent cloud profile is computed by "reducing" layers' thickness to go up and relaxing moist static energy to non-entraining case via warmer conditions.

$$\Delta\phi' = \Delta\phi/\{1 + \nu\chi max(0, h_{nea} - h_u)\}$$



- Tuning parameter *ν* determines height and shape of profiles, similarly to illustration taken from Derbyshire et al., 2011.
- Left picture: as if *ν=0* ;
- Right picture: tuned value of *ν*.



Proposal (2)'

- In the proposal, tuning parameter *ν* is made dependent on previous precipitation activity – evaporation:

$$\nu = z\alpha/(z+\alpha) \qquad z = \frac{z^{t-\Delta t} + (\kappa E + \nu_{min})\Delta t/\tau}{1+\Delta t/\tau}$$

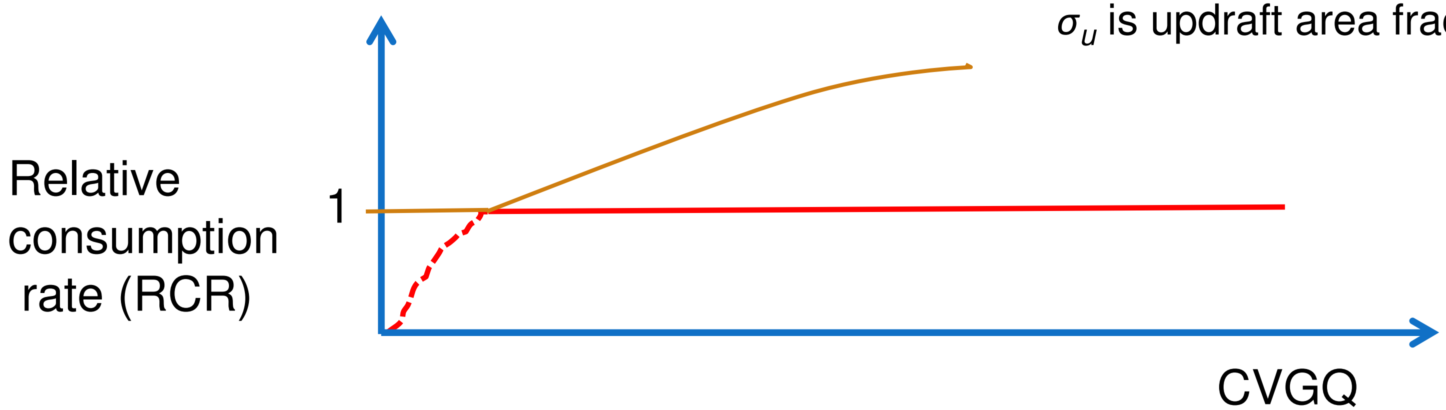
- Parameters *z* and *α* have the same physical dimension – inverse of geopotential.
- With *κ* and *τ* being tuning parameters, *E* is evaporation.
- More rain => more evaporation => higher clouds (thanks to 'cold pool effect') => convection activity is maintained longer.
- This proposal results from various attempts to cope with the entrainment dilemma (Mapes and Neale, 2011); the combination with *α* avoids too big values of *ν*.

Proposal (3)

- Closure, formulated in terms of moisture convergence, can have a modulation of a CAPE type (Luc Gerard).
- Converging moisture may be either all consumed in condensation (CVGQ closure only), or it is partly consumed, partly it charges moist static energy reservoir for a later "use" (mixed type of closure).

$$CVGQ' = CVGQ * MIN(1, \mu\ \sigma_u(CVGQ'))$$

σ_u is updraft area fraction

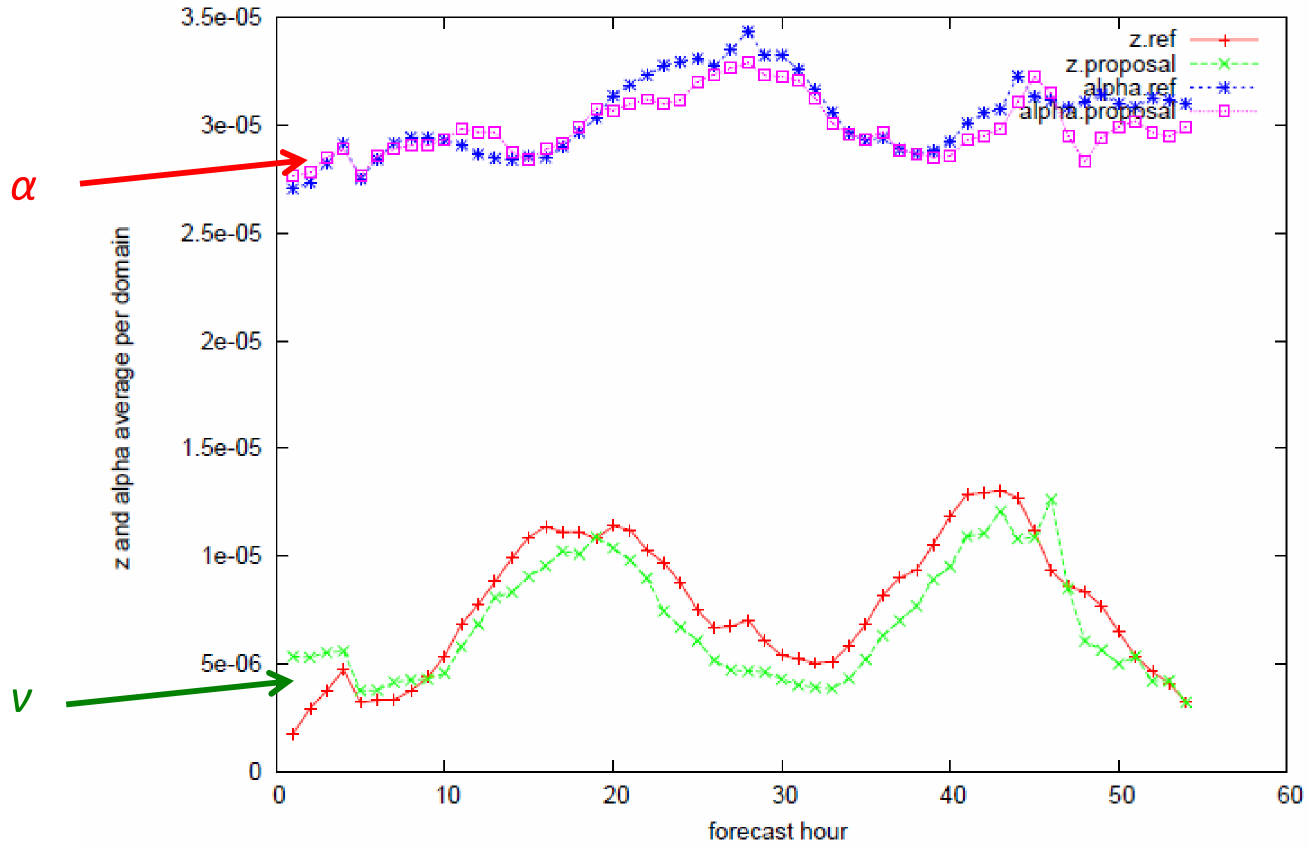


Tuning parameters of proposed modifications

- Entrainment parameters [all in s^2m^{-2}]:
  $\alpha = 4.5E\text{-}05$; $En = 5.E\text{-}06$; $Ex = 1.6E\text{-}04$;
- Evaporation "memory" time-scale:
  $\tau = 1/\Omega$;
- Minimum parameter $\nu = 0$;
- Tuning parameter $\kappa = 0.18$ [s^3kg^{-1}];
- Closure tuning parameter $\mu = 15$. – first tuning

- In between we developed a more sophisticated version (tested in the Grey Zone Project of WGNE), see later.

Entrainment cycle

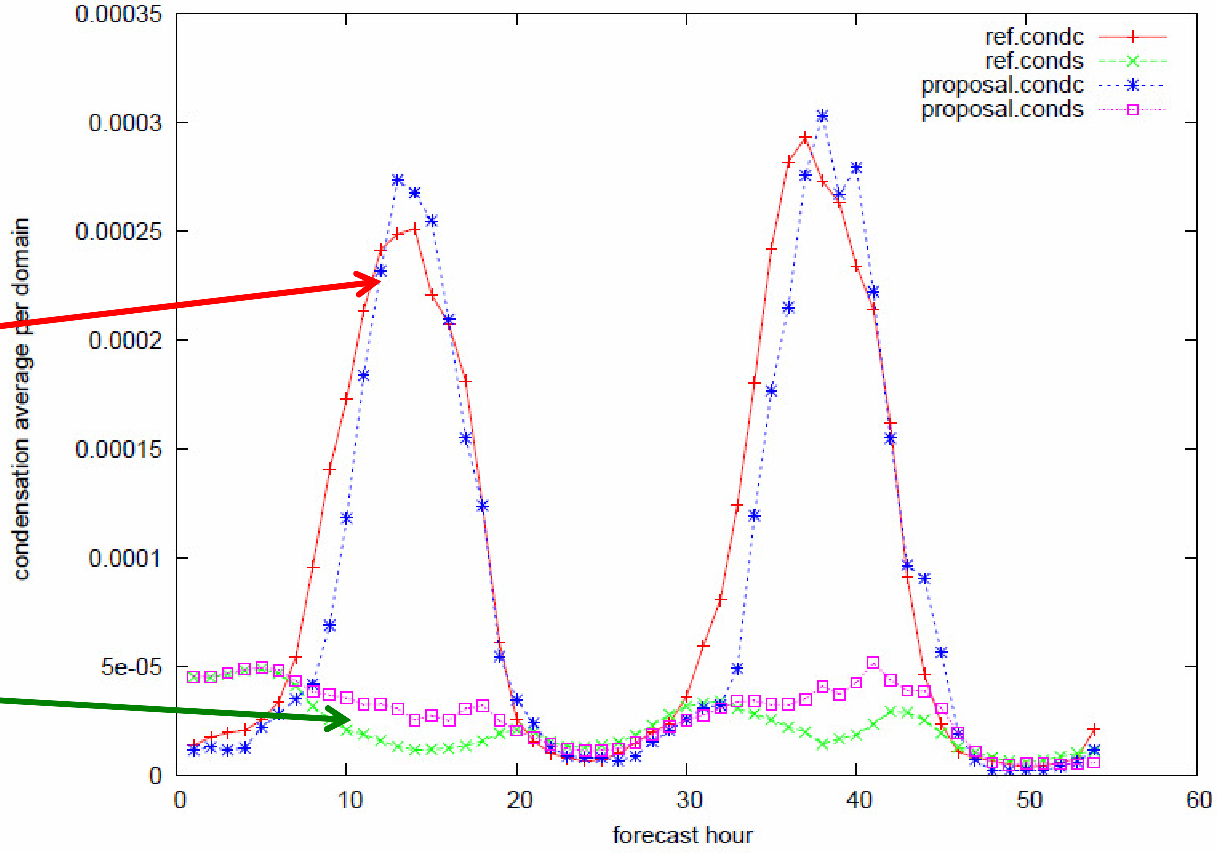


Diurnal cycle of entrainment for realisations with CVGQ closure and mixed closure - main pattern remains the same (orthogonal issues). RH-driven *α* does not have so pronounced cycle as evaporation driven *v*.

Condensation cycle – 4,7km

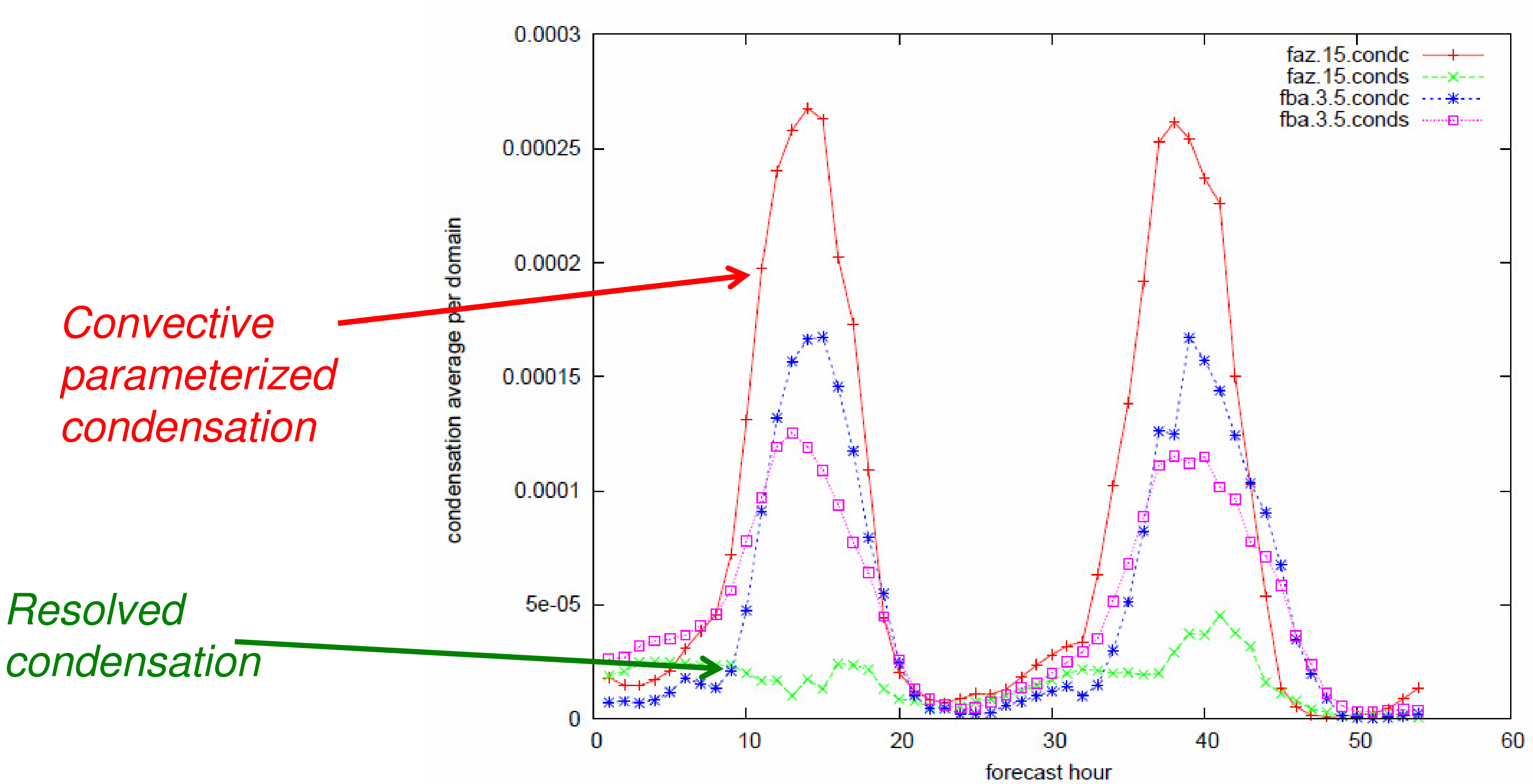
Convective parameterized condensation

Resolved condensation



Diurnal cycle of integral condensation fluxes. In the “proposal” case convective parameterized condensation is a bit delayed and resolved condensation is enhanc

Condensation cycle – 2,2km



Diurnal cycle of integral condensation fluxes. Tuning for 4,7km is not sufficient. Mesh box size dependency of the closure modulation must help to progressively pa parameterized drafts' activity to the resolved processes.

Closure modulation according to the mesh box size

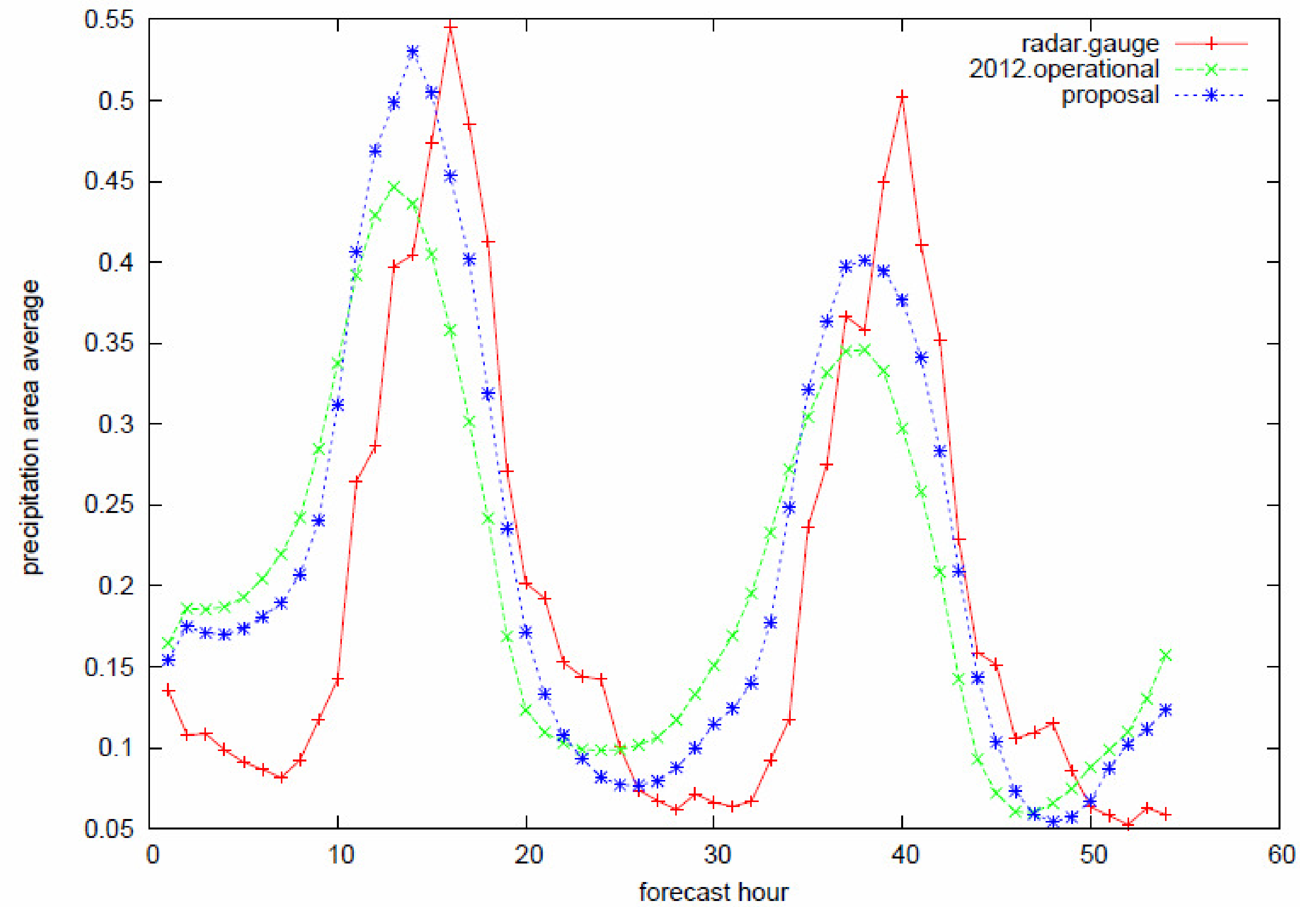
<u>New formulation, but not yet in the cy38t1_bf3:</u>
modulation of the closure is computed as a function of the mesh box size

$$\mu = min\left[25, \left(\frac{dx}{1200}\right)^2\right]$$

It was verified that the value 25 gives better results than 15 at 9km mesh size.

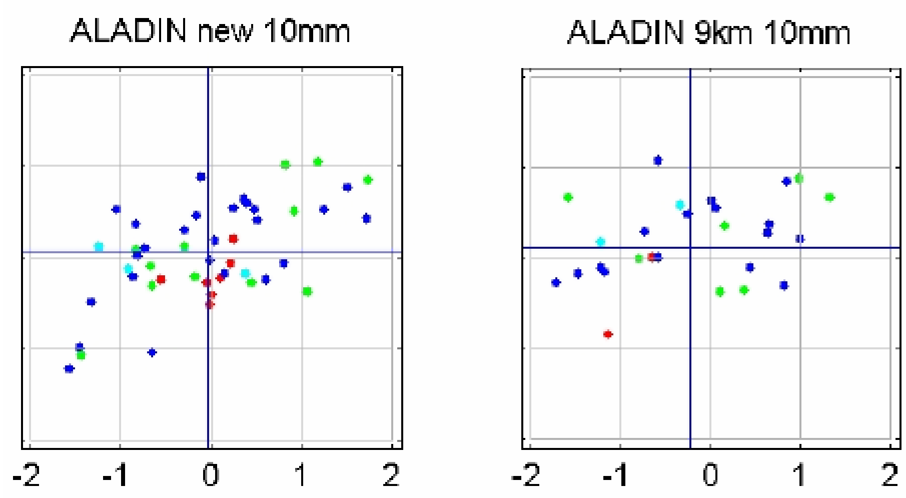
Impact on diurnal cycle – 4,7km

11 realizations' average of mean hourly precipitation over the area

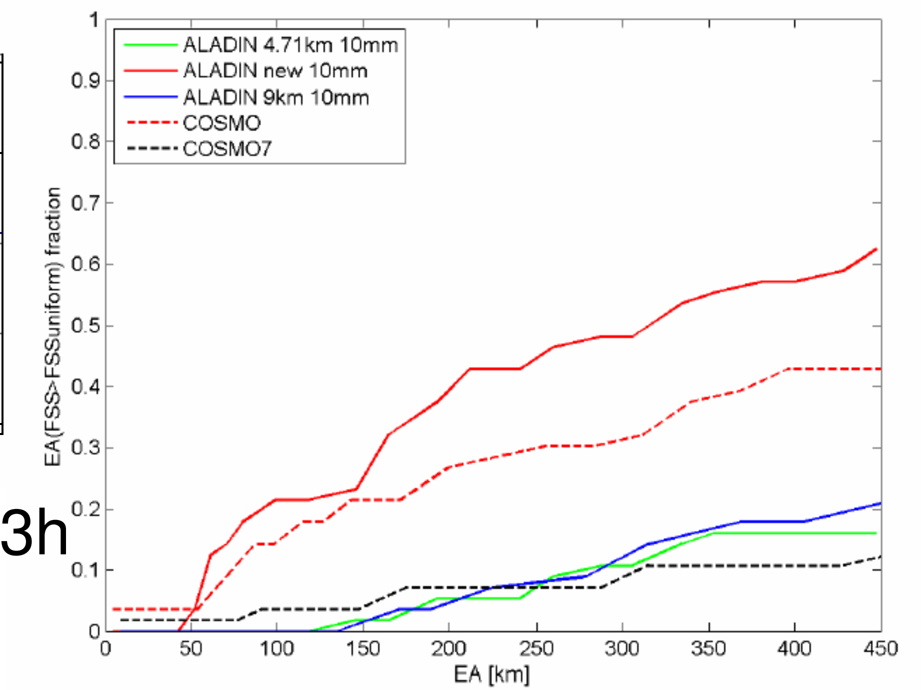


Some ALARO-0 results - precipitation

Verification over flash-flood period 21 June – 5 July 2009



SAL verification for RR>10mm/3h

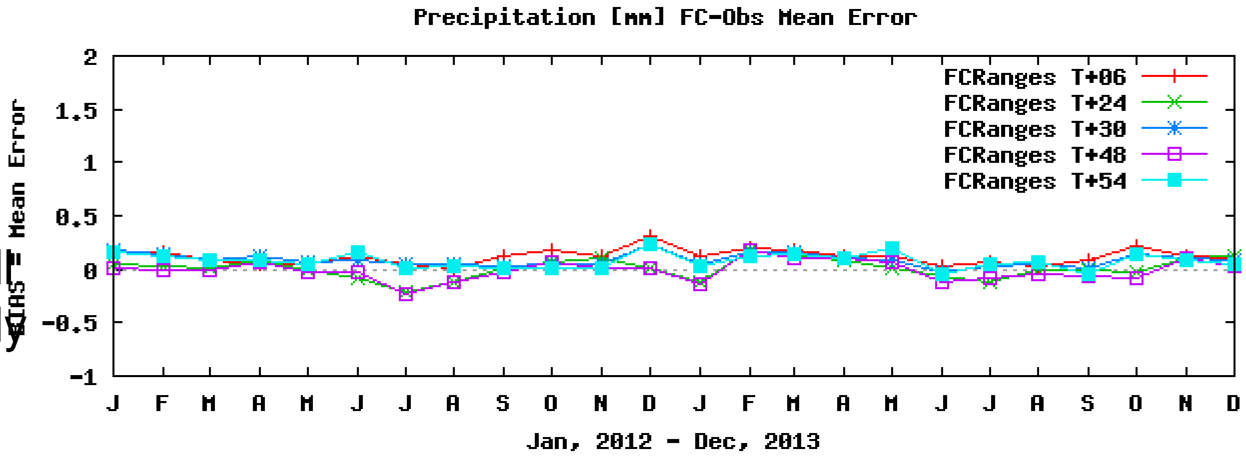


Structure component: horizontal axis
Amplitude component: vertical axis
Location: color (red – best L<0,1, green, blue, black for L>1)

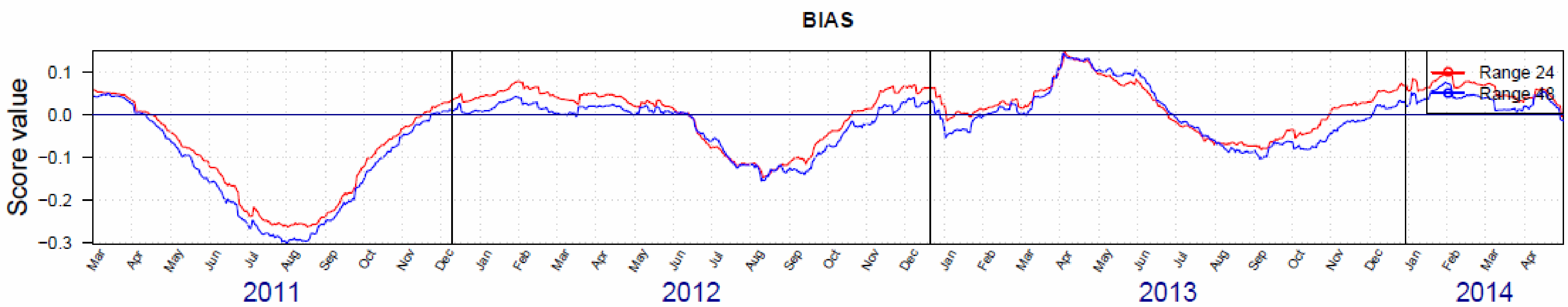
FSS verification for RR>10mm/3h

Precipitation bias

Monthly scores and
Quarterly moving average:
Summer evening precipitation bias got better, but there is still a slight underestimation – early decay of convection



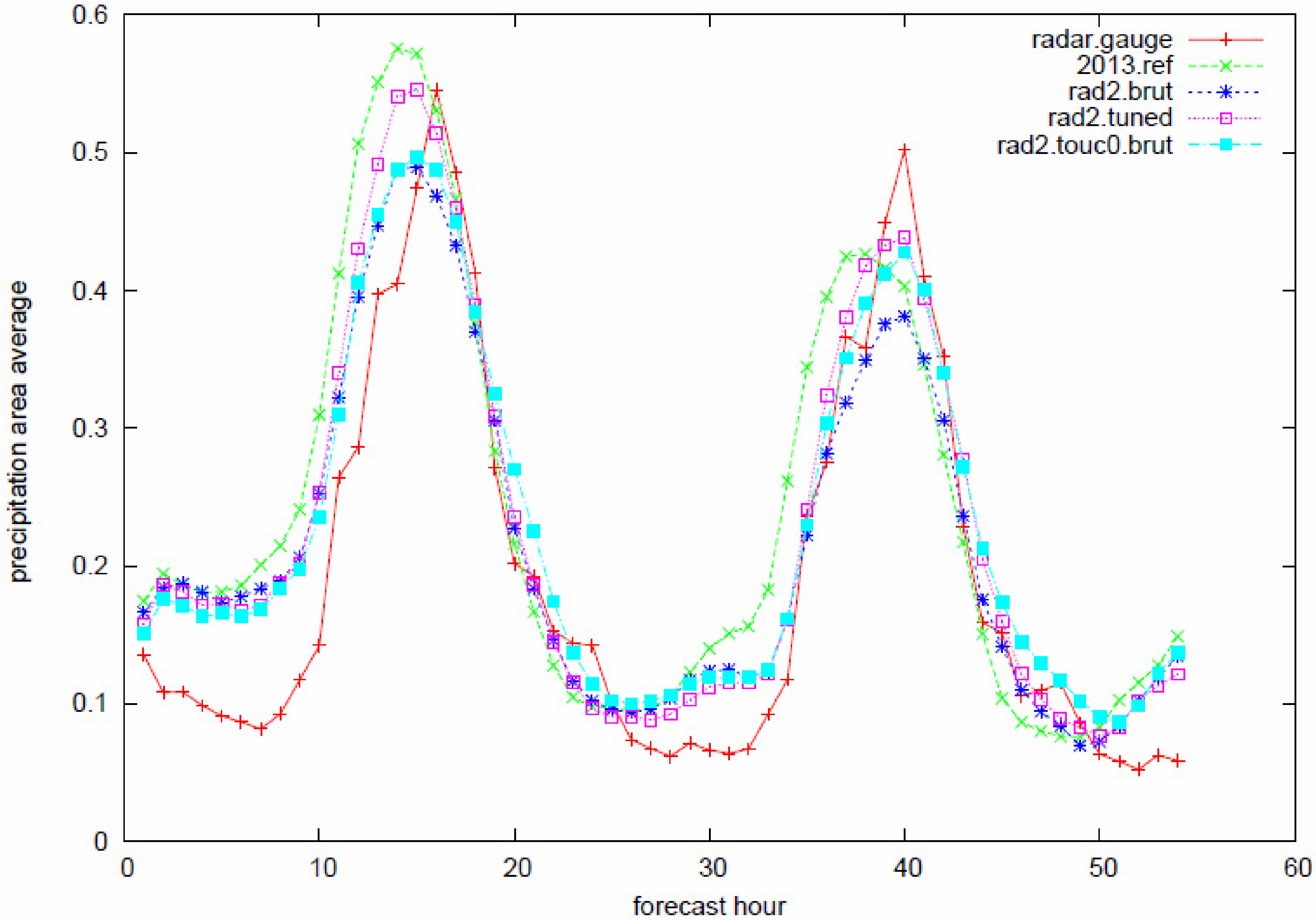
Quarterly moving average of basic scores for Precipiation[mm/6h]
Domain: LACE, Network: 00 UTC



Going with the study to ALARO-1

- Introduction of ACRANEB2
  - First complementary tunings were made in 3D tests, for summer 2009 and winter 2013 periods.
- Introduction of TOUCANS
  - Not yet complete (for instance without prognostic Total Turbulence Energy)
  - Conservative set-up (mixing length like in p-TKE)
  - No tunings yet
  - First trials in 3D together with ACRANEB2, again in summer 2009 and winter 2013.

Improved diurnal cycle of convection



Outlook

- 3MT scheme has the capacity to go progressively to convection permitting scales;
- Introduction of better radiation scheme ACRANEB2 and TOUCANS framework for turbulence further improves the diurnal cycle of convection;
- Additional refinements are expected from the non saturated downdraft.