The prognostic deep convection parametrization for operational forecast in horizontal resolutions of 8, 4 and 2 km

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Outline

- **Deep convection parametrization in NWP model ALADIN/ALARO**

  – **Parameterized processes, mass flux, interaction with resolved precipitation and turbulence**

- **Prognostic convective scheme 3MT (Modular Multi-scale Microphysics and Transport)**

- **Impact on precipitation forecast**

  – **Isolated convective cells**

  – **Persistent heavy rain with severe floods**

Convection in ALADIN

Shallow convection – contribution computed as the modification in the turbulence

Deep convection – develops due to moisture convergence and surface evaporation and produces precipitaiton, cloudines etc.
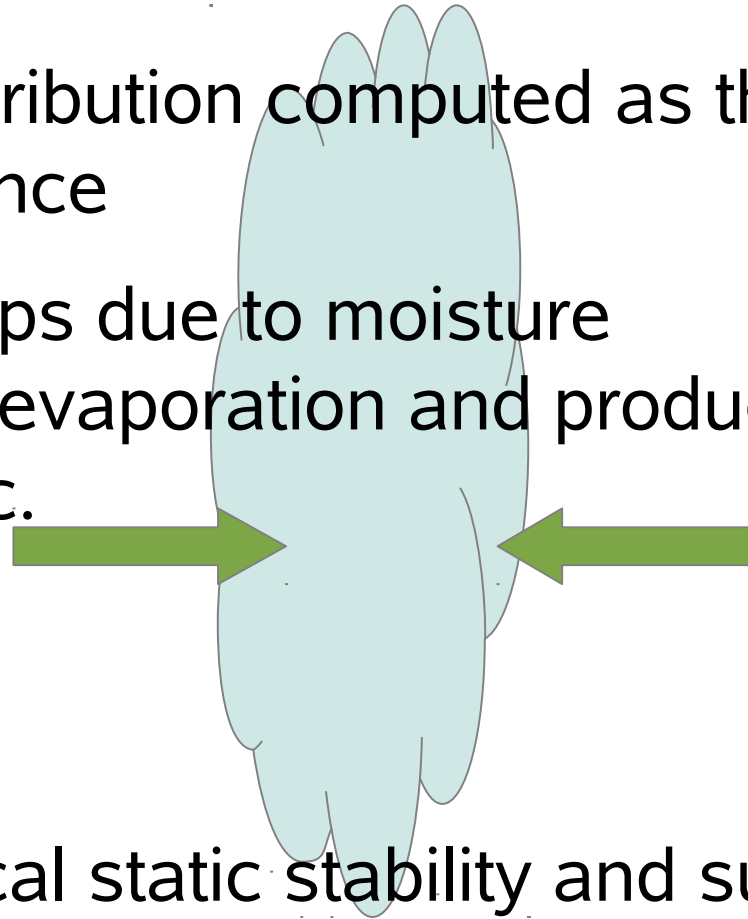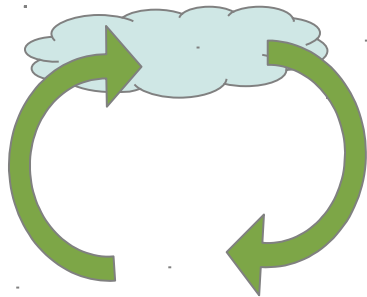
Moisture convergence, local static stability and surface evaporation feed convection that in turn redistributes heat, moisture and momentum in the vertical.

Only sub-grid precipitating clouds are parametrized.

Parametrized processes

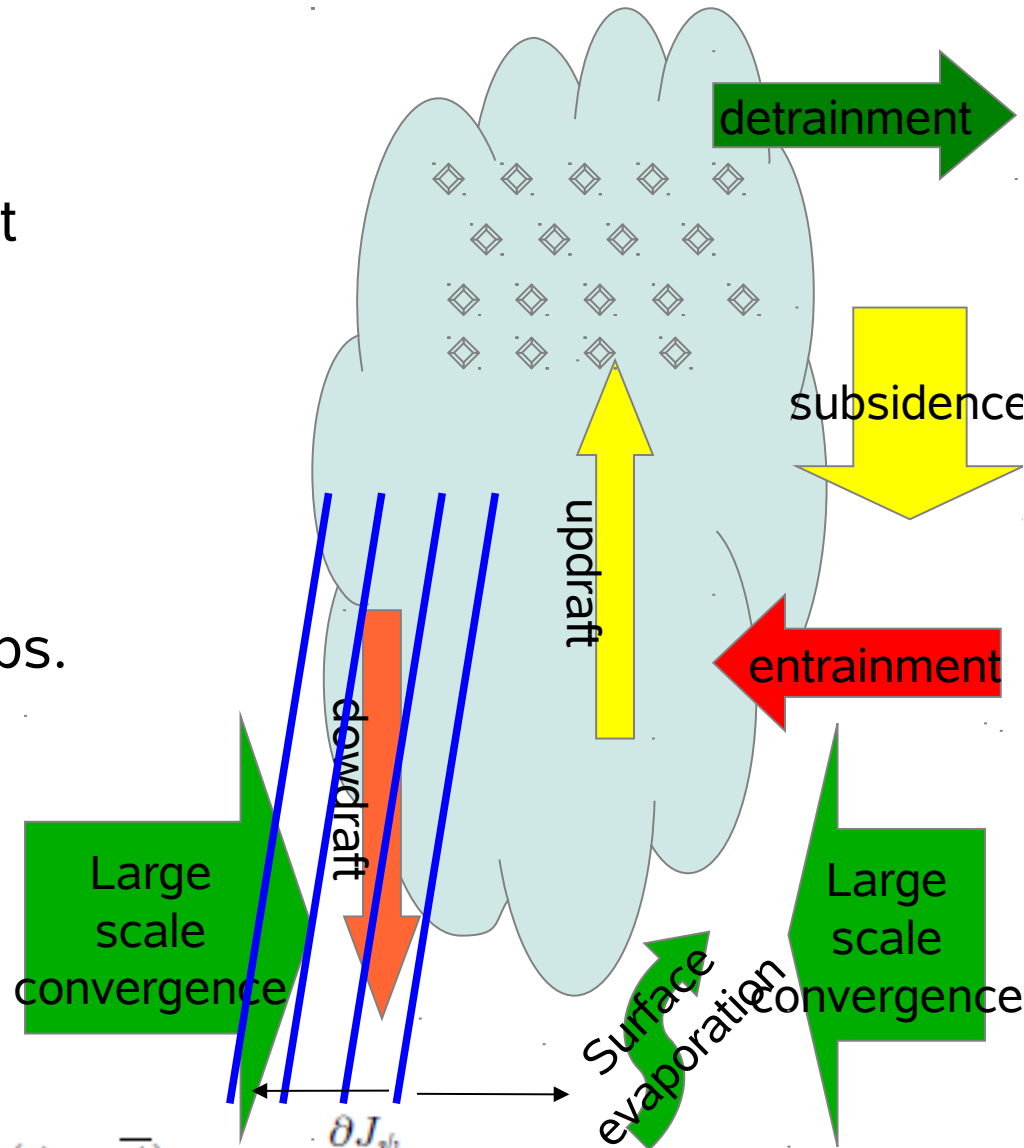Active elements are **updraft** and **downdraft**

Cloud **entrains** air from the environment and **detrains** into the environment

Updraft grows due to **moisture convergence** and **evaporation** of soil.

Upper portion of cloud consists of cloud ice and lower portion of cloud water drops.

Evaporation of precipitation **cools** the environment and initiates downdraft.

Cold air **increases pressure** close to surface and initiates wind gusts

detrainment

subsidence

updraft

entrainment

downdraft

Large scale convergence

Large scale convergence

Surface evaporation

$$\left(\frac{\partial \overline{\psi}}{\partial t}\right)_{conv} = \underbrace{\omega^{\hat{*}}\frac{\partial \overline{\psi}}{\partial p}}_{\text{pseudo subs.}} + \underbrace{K_u(\psi_u - \overline{\psi})}_{\text{Detrainment}} + \underbrace{\omega^{\vee}_{*}\frac{\partial \overline{\psi}}{\partial p}}_{\text{pseudo asc.}} + \underbrace{K_d(\psi_d - \overline{\psi})}_{\text{Detrainment}} + \underbrace{g\frac{\partial J_\psi}{\partial p}}_{\text{turb. vert. diffusion}}$$

Mass flux

Weather in a grid point represents and ensemble of weather on an area and in a layer of an atmosphere (volume). "ensemble mass flux" approach uses one equivalent cloud. Convective flux contains contributions from updraft (u), downdraft (d) and the environment (e).

$$\overline{\psi'\omega'} = \sigma_u \left.\overline{\psi'\omega'}\right|_u + \sigma_d \left.\overline{\psi'\omega'}\right|_d + \sigma_e \left.\overline{\psi'\omega'}\right|_e$$

Mass flux in an updraft $M_u \equiv -\sigma_u \cdot \omega_u$

where σ_u is updraft mesh fraction and ω_u is vertical velocity in an updraft (Pa/s)

Mass flux in a downdraft $M_d \equiv \sigma_d \cdot \omega_d$

where σ_d is downdraft mesh fractionand ω_d is vertical velocity in a downdraft (Pa/s)

Turbulence and resolved precipitation

With increasing resolution, more precipitation is resolved and less needs to be parametrized.

Turbulence and resolved precipitation redistribute moisture and contribute to moisture convergence.

$$\mathrm{CVGQ} \equiv -\mathcal{R}\left[\mathbf{V}\cdot\nabla q + \omega\frac{\partial q}{\partial p}\right] - g\frac{\partial J_q}{\partial p} - g\frac{\partial P_{\mathrm{LS}}}{\partial p}$$

J_q

P_{ls}

Large scale convergence

Large scale convergence

J_q

P_{ls}
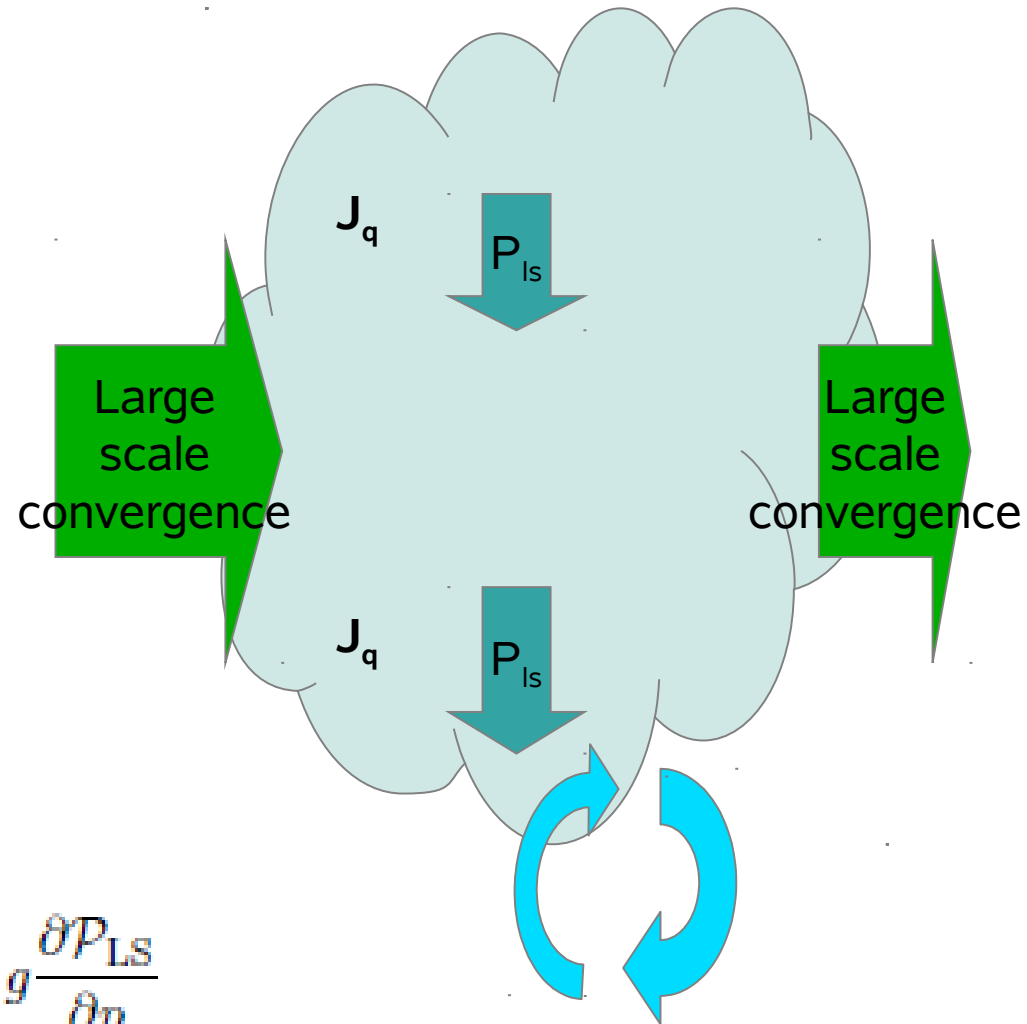
Diagnostic vs. prognostic scheme

Diagnostic scheme assumes **stationary state** with **balance** of buoyancy and dissipation and that updraft and downdraft occupy a **negliglible** portion of grid cell. There is **no memory** from previous time-step.

Prognostic scheme uses **prognostic** equations for **convective variables** that allow evolution of convection through time-steps and proper parametrization of **growing** and **dissipating clouds**. Updraft and downdraft mesh fractions are not neglected.

Prognostic deep convection

q_v – water vapour

q_i – cloud ice

q_l – cloud liquid water

q_s – snow

q_r – rain

σ_u updraft mesh fraction

ω_u updraft vert velocity

σ_d downdraft mesh frac

ω_d downdraft vert vel.

E entrainment

Cc conv. cloud
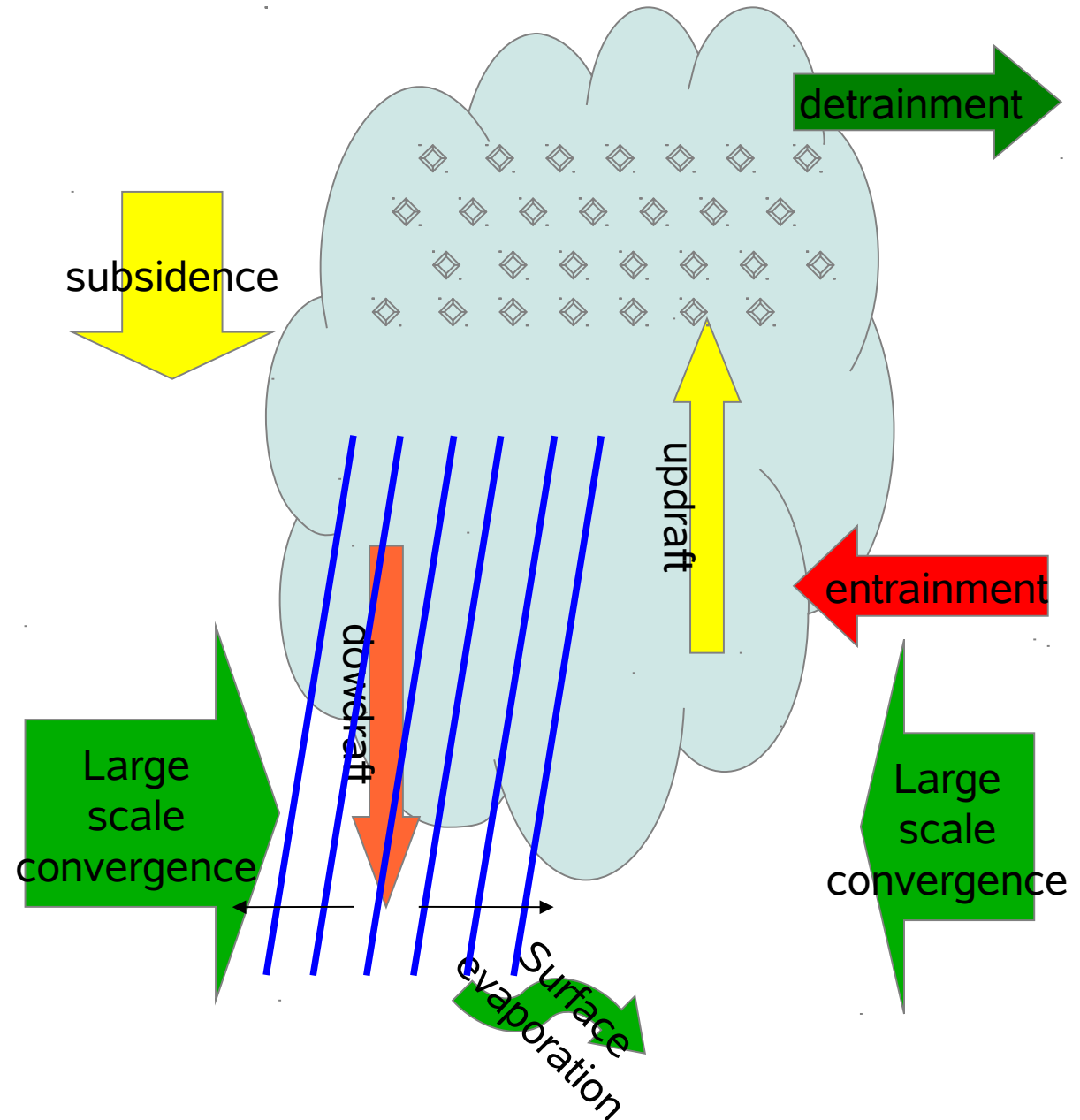
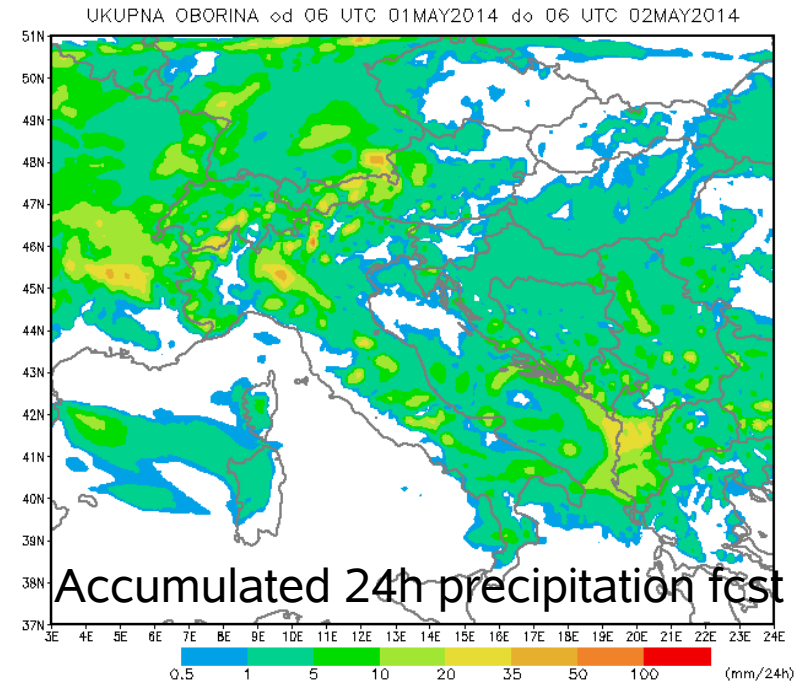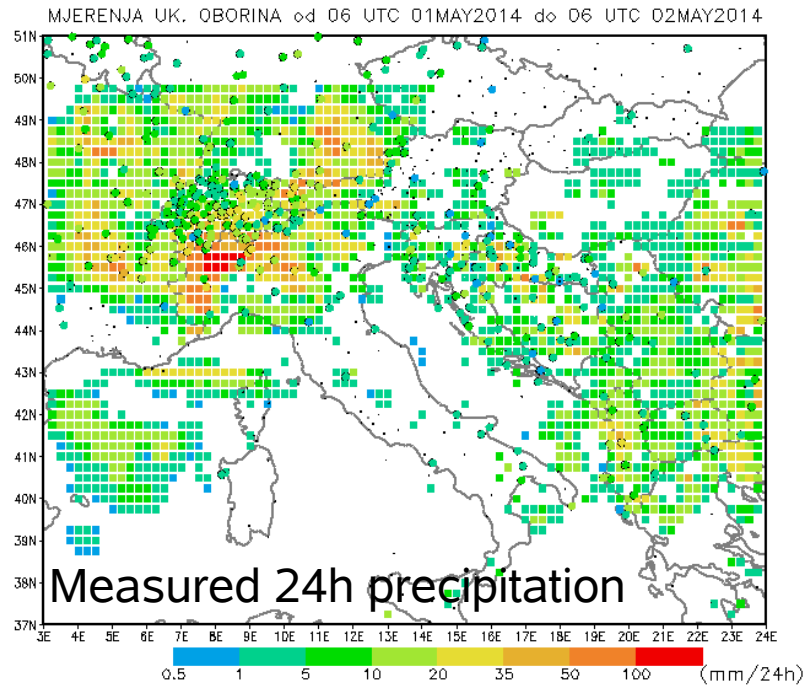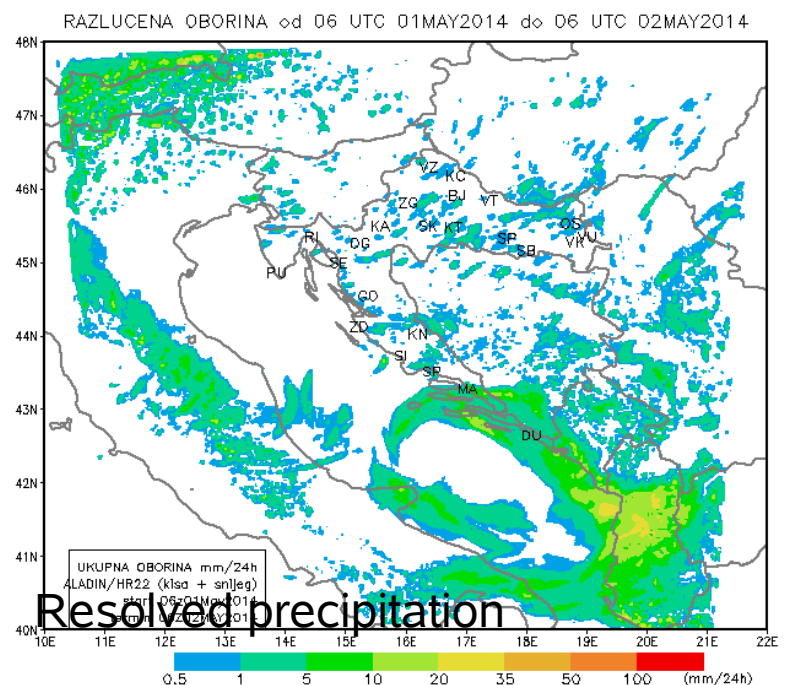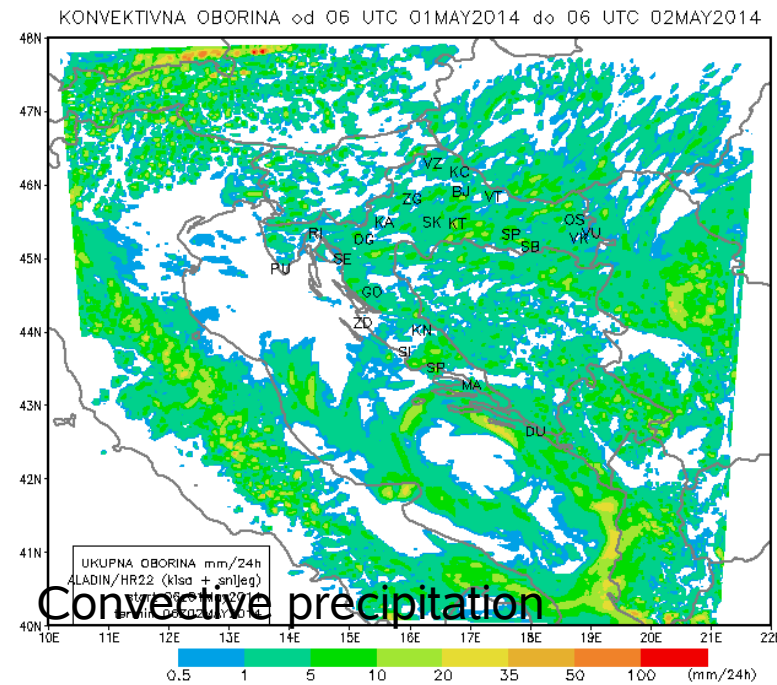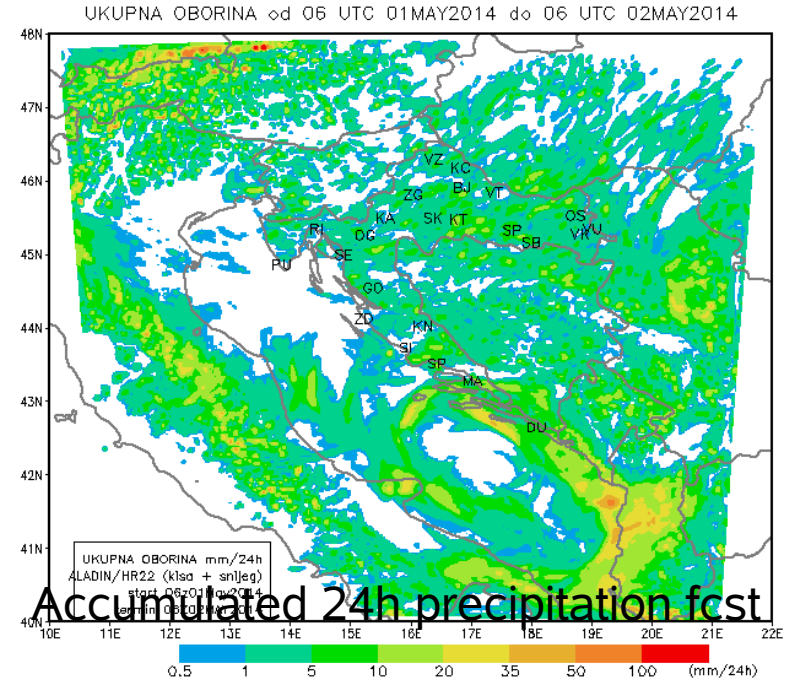# Small scale convective cells – radar reflectivity for 1st May 2014
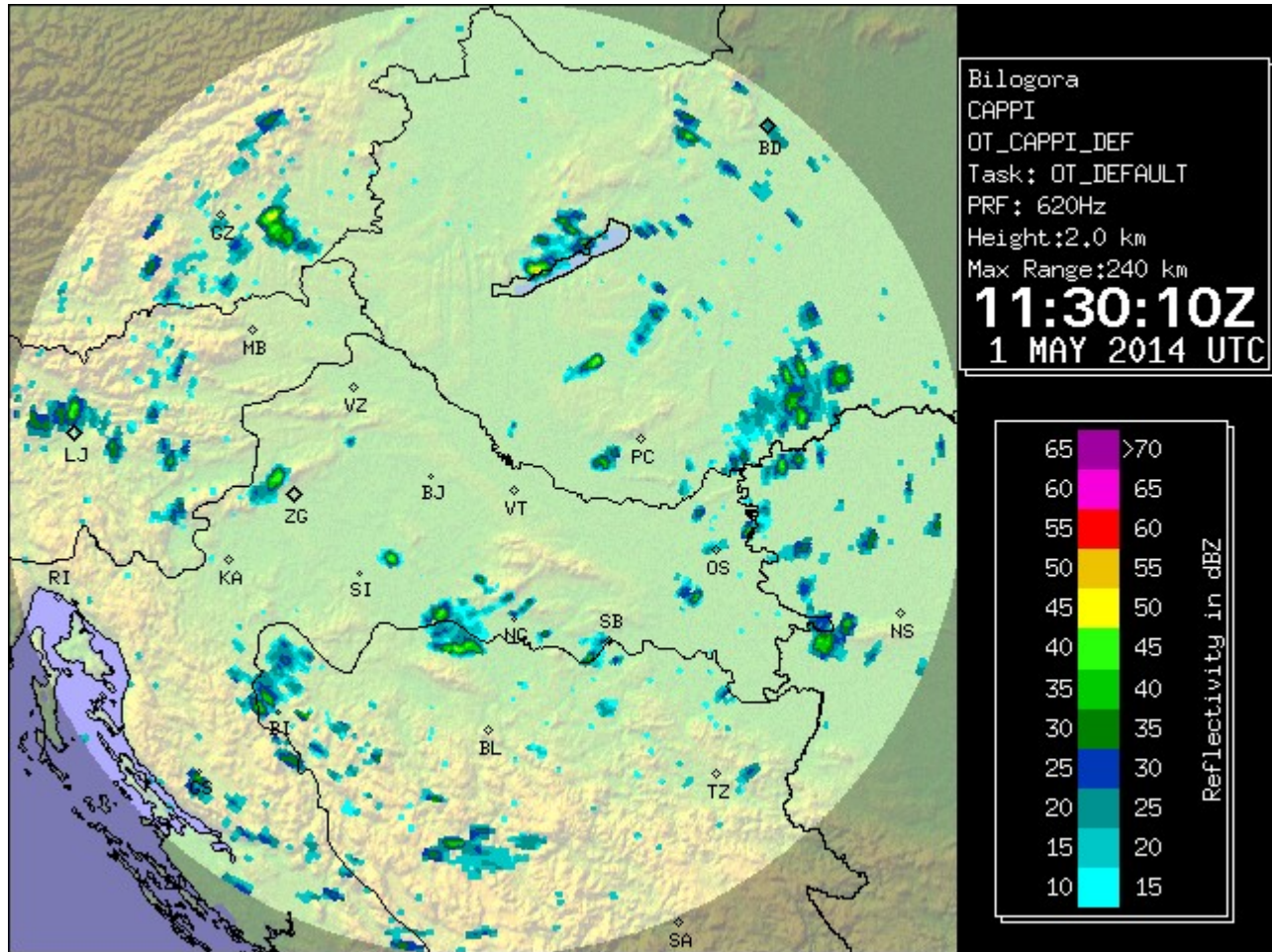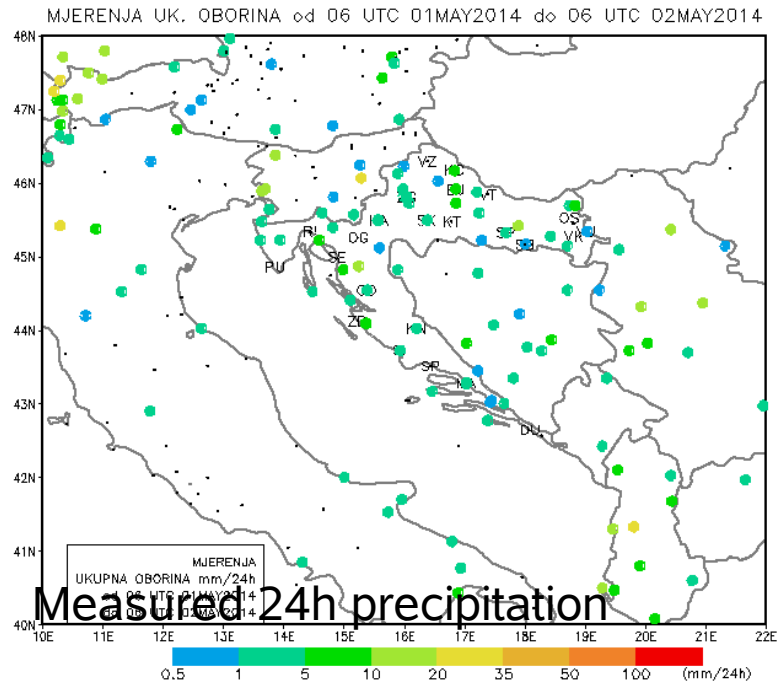
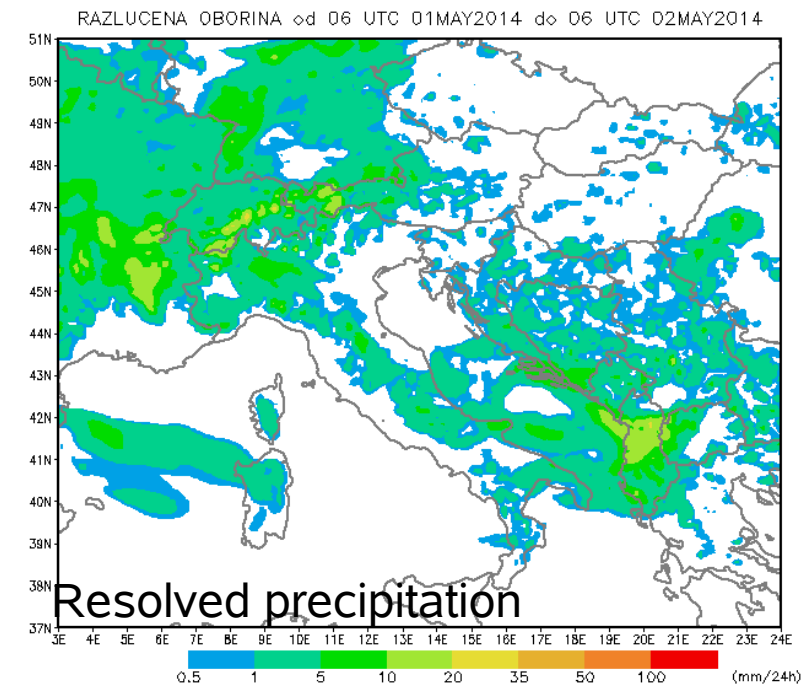# Small scale convective cells – radar reflectivity for 1st May 2014
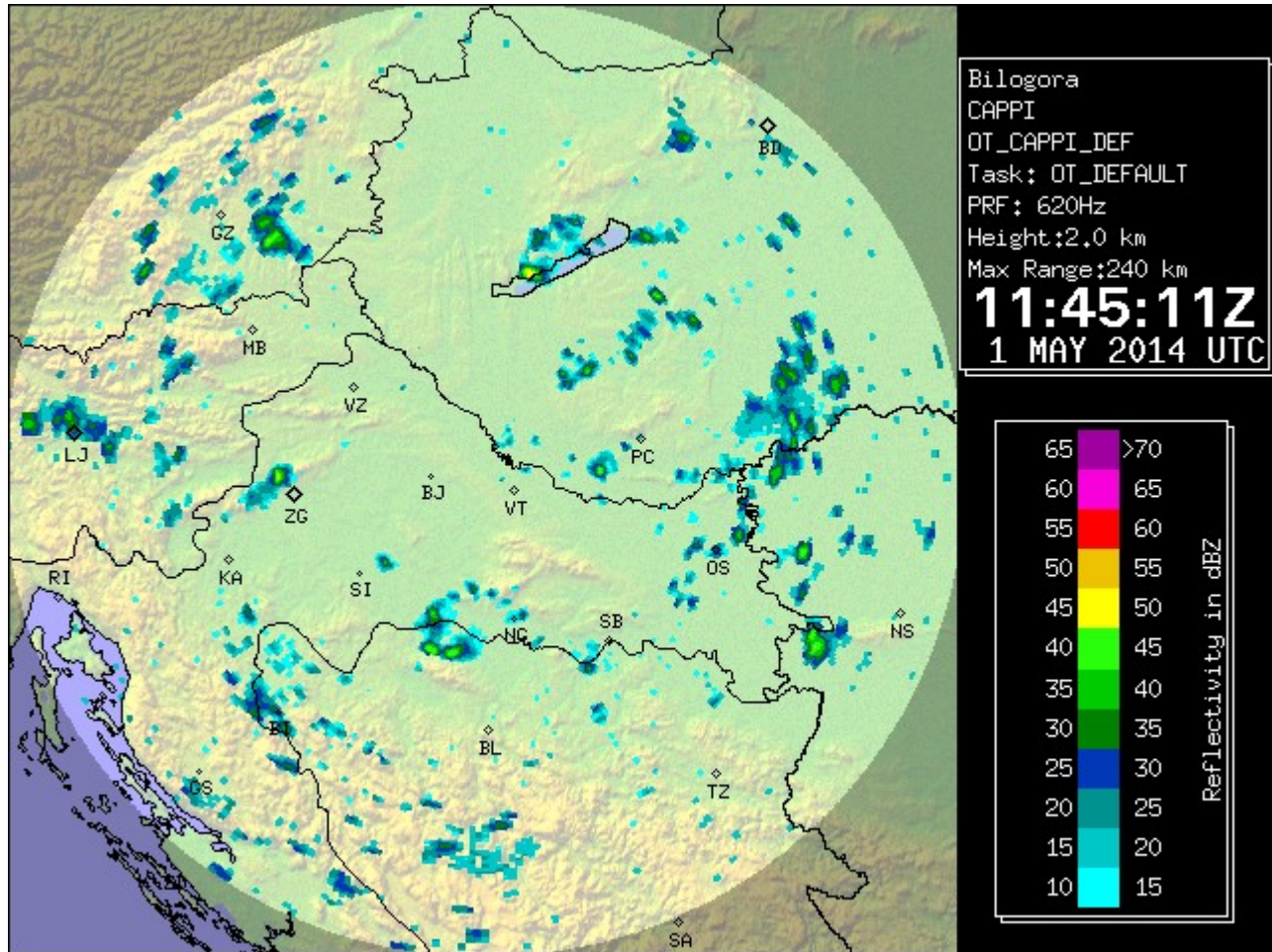
Small scale convective cells – radar reflectivity for 1st May 2014
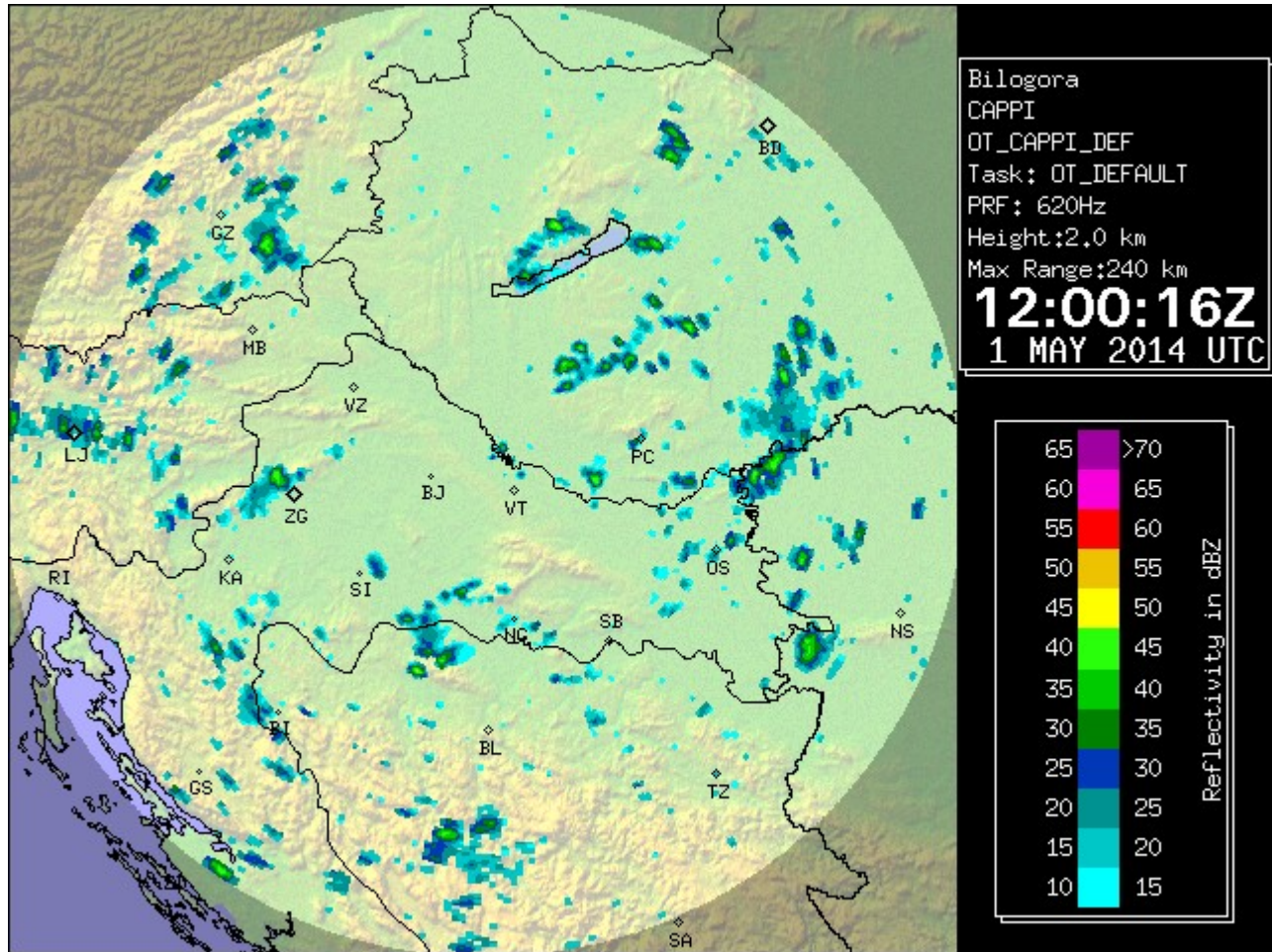
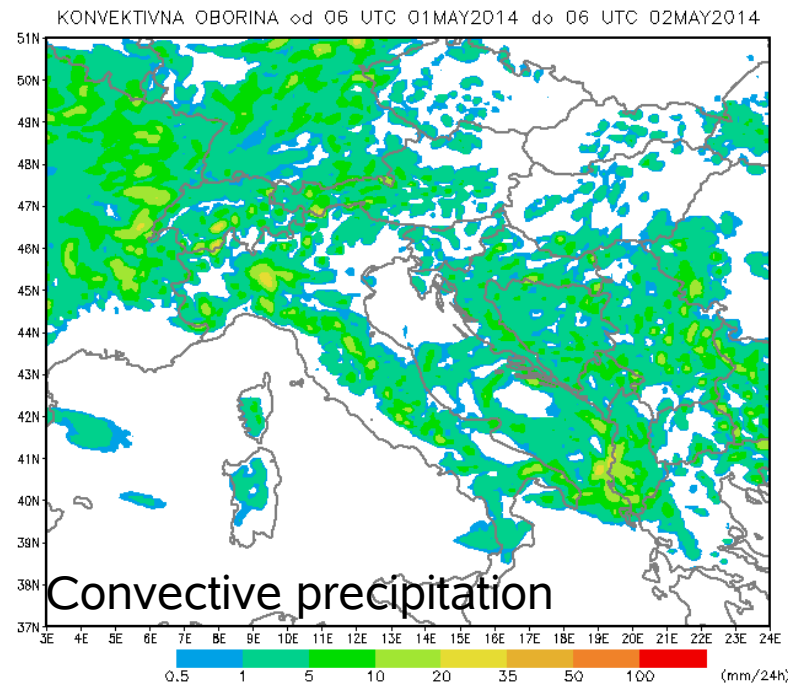# Small scale convective cells – radar reflectivity for 1st May 2014

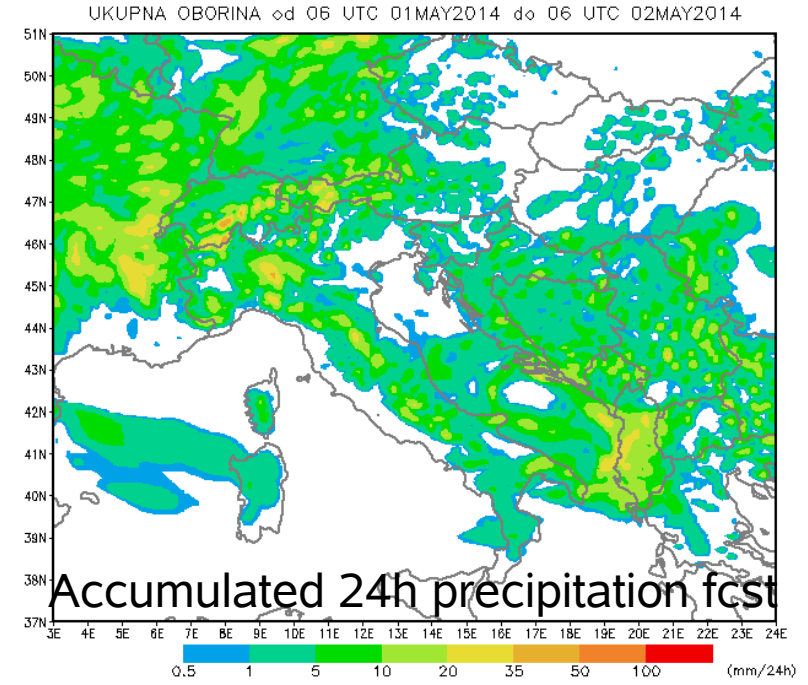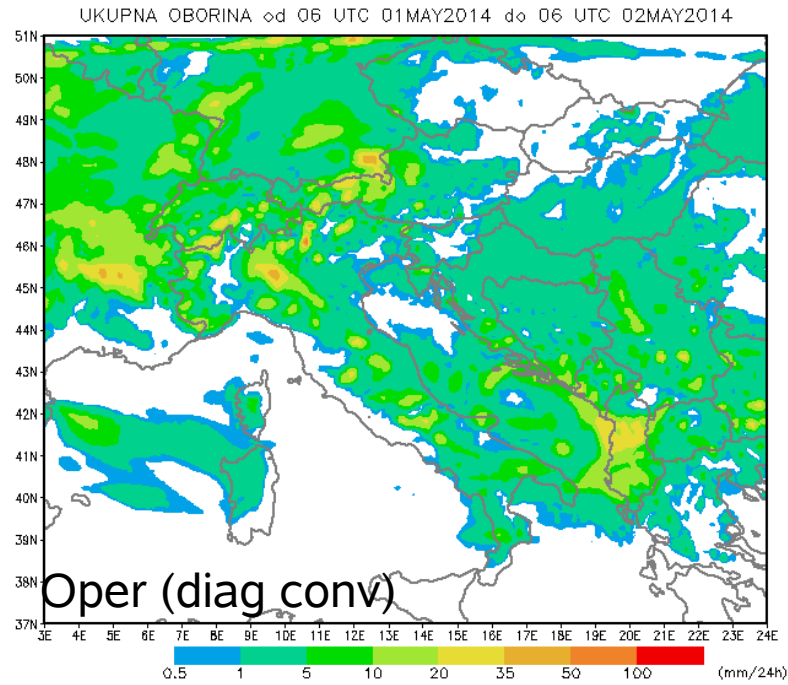# Small scale convective cells – radar reflectivity for 1st May 2014

Operational forecast, 8km res, HY, diagnostic convection

Measured 24h precipitation

Accumulated 24h precipitation fcst

Convective precipitation

Resolved precipitation

Operational forecast, 2km res, NH, prognostic convection (part)

MJERENJA UK. OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Measured 24h precipitation

UKUPNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Accumulated 24h precipitation fcst

KONVEKTIVNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Convective precipitation

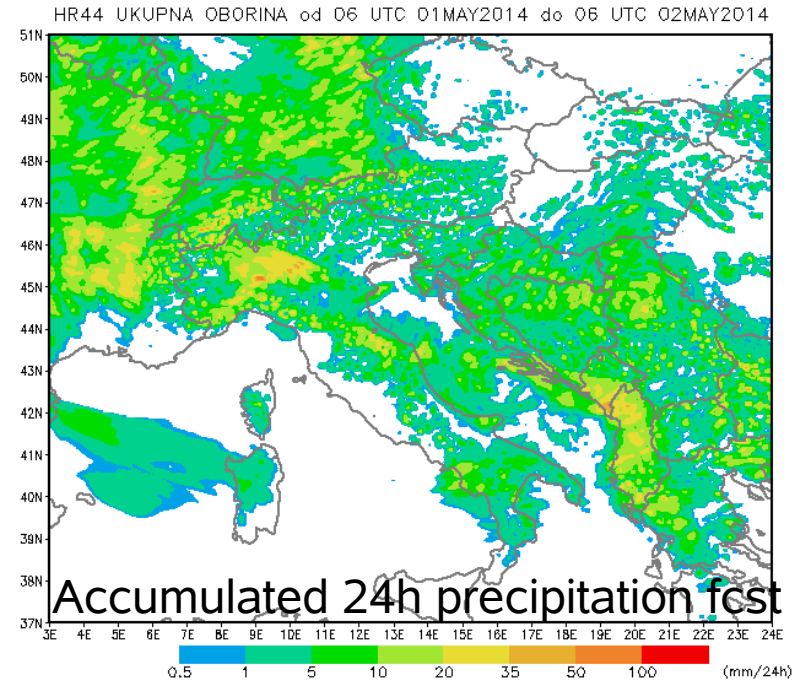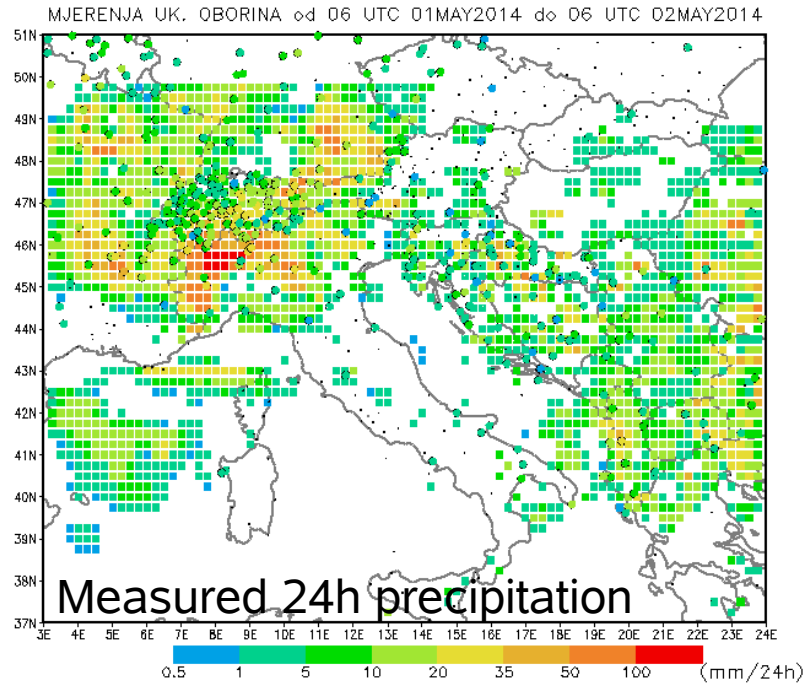RAZLUCENA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014
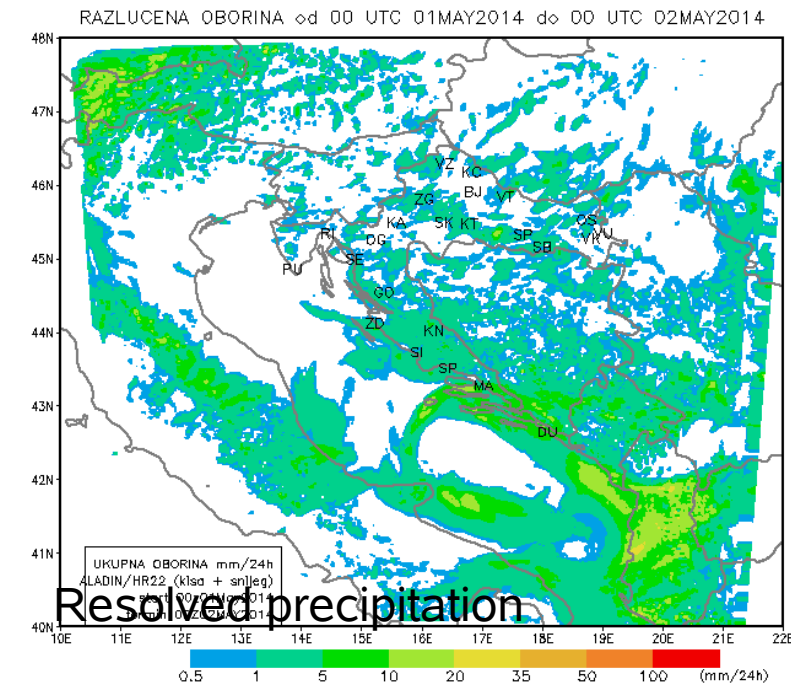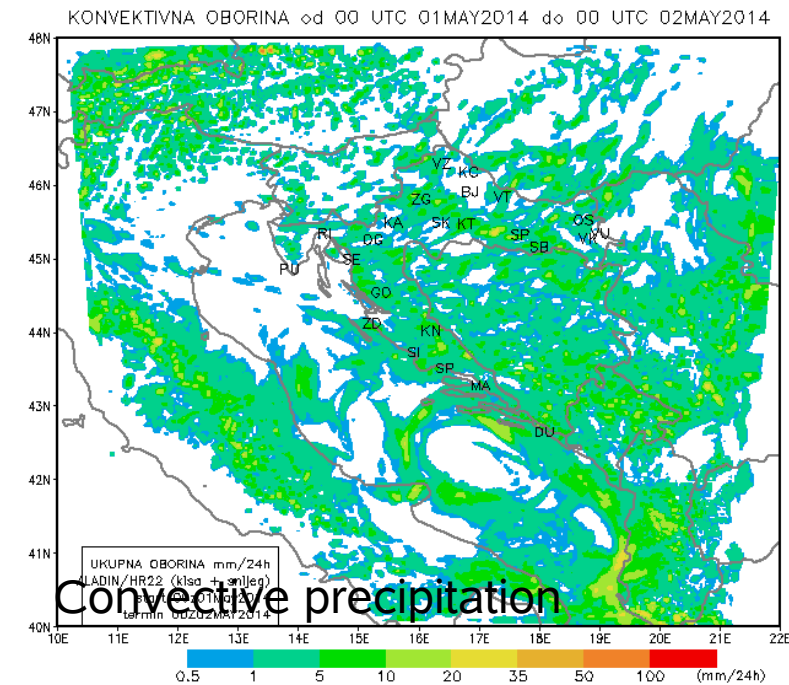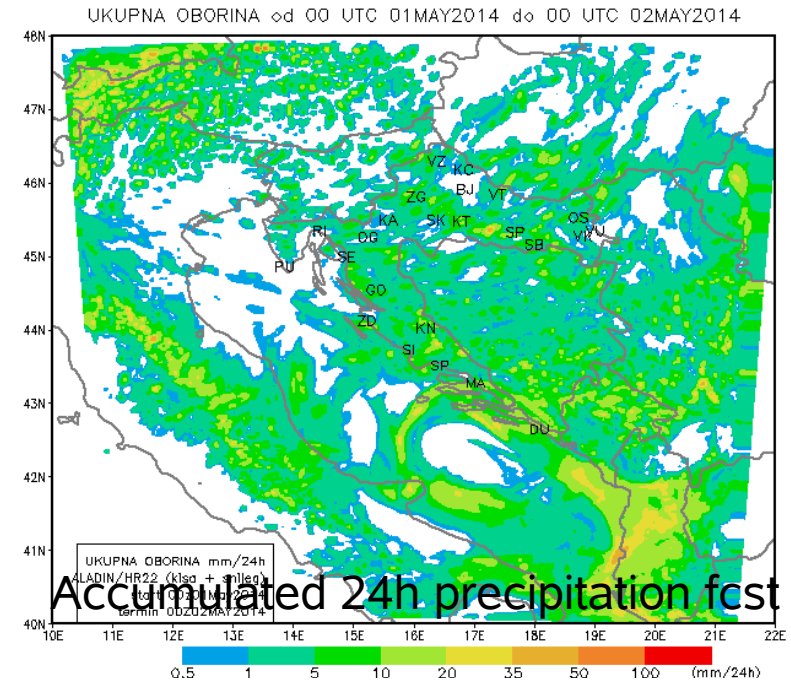
Resolved precipitation

AL38t1, **8km** res, HY, prognostic convection

UKUPNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Oper (diag conv)

UKUPNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Accumulated 24h precipitation fcst

KONVEKTIVNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Convective precipitation

RAZLUCENA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014
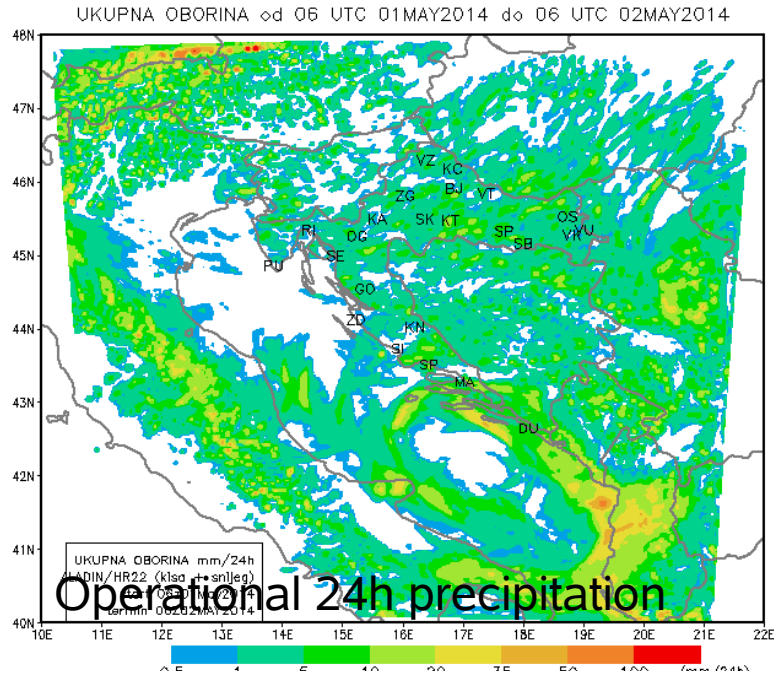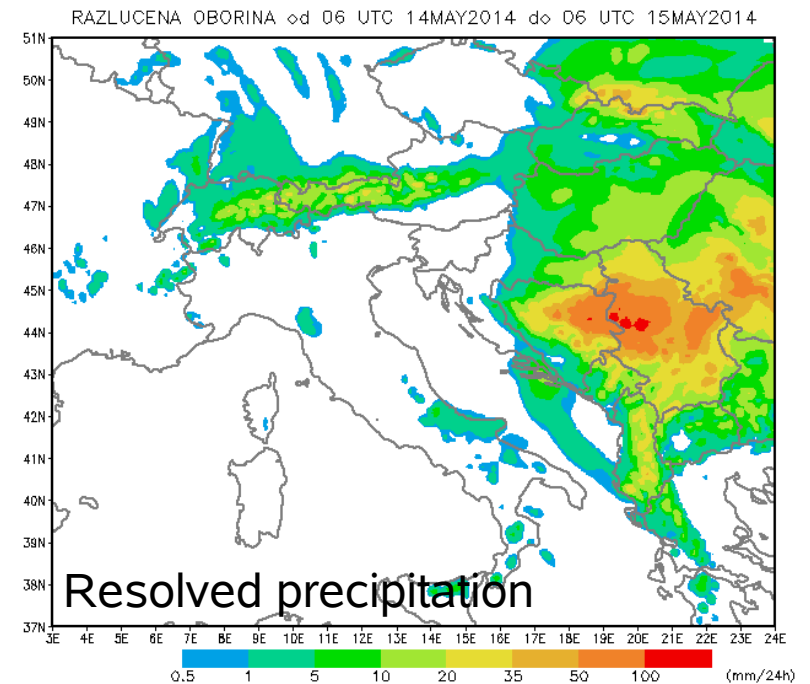
Resolved precipitation

AL38t1, **4km** res, HY, prognostic convection

MJERENJA UK. OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Measured 24h precipitation

HR44 UKUPNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Accumulated 24h precipitation fcst

HR44 KONVEKTIVNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Convective precipitation

HR44 RAZLUCENA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Resolved precipitation

AL38T1, **2km** res, NH, prognostic convection

UKUPNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Operational 24h precipitation

UKUPNA OBORINA od 00 UTC 01MAY2014 do 00 UTC 02MAY2014

Accumulated 24h precipitation fcst

KONVEKTIVNA OBORINA od 00 UTC 01MAY2014 do 00 UTC 02MAY2014

Convective precipitation

RAZLUCENA OBORINA od 00 UTC 01MAY2014 do 00 UTC 02MAY2014

Resolved precipitation

Operational forecast, 8km res, HY, diagnostic convection   Heavy flash flood case

Measured 24h precipitation

Accumulated 24h precipitation fcst

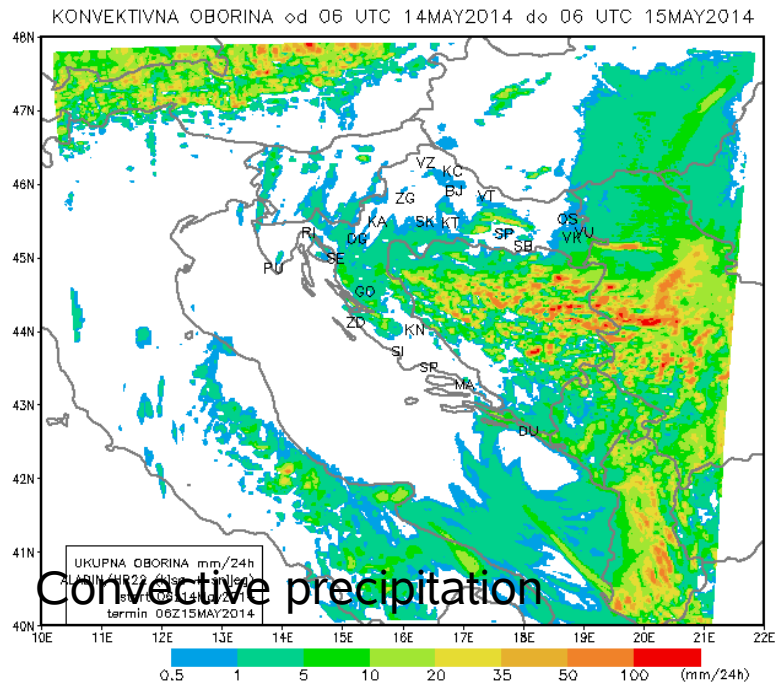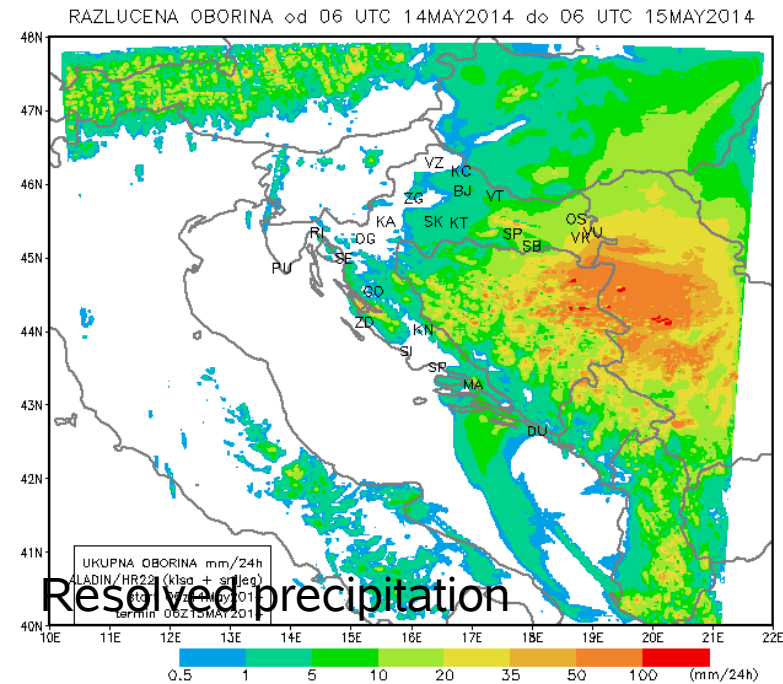Convective precipitation

Resolved precipitation
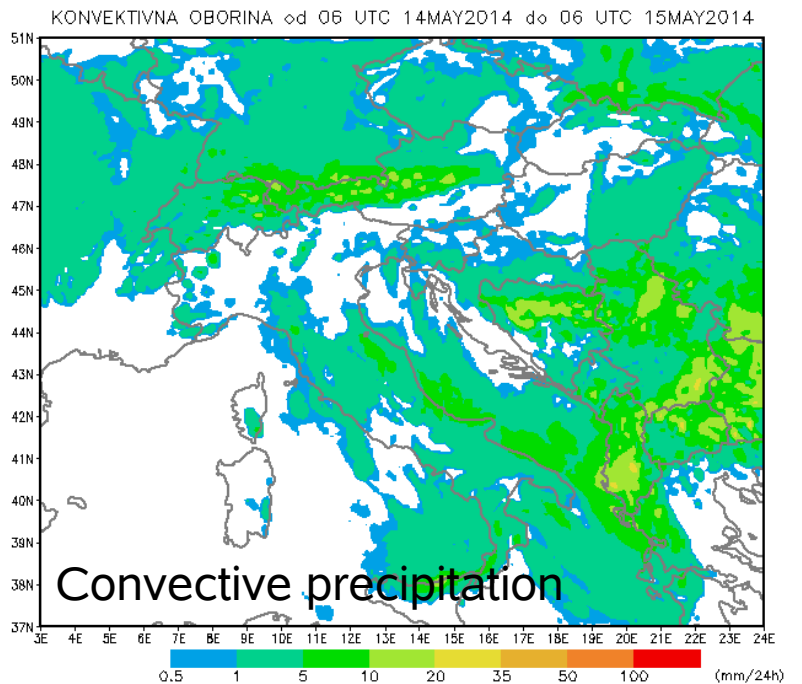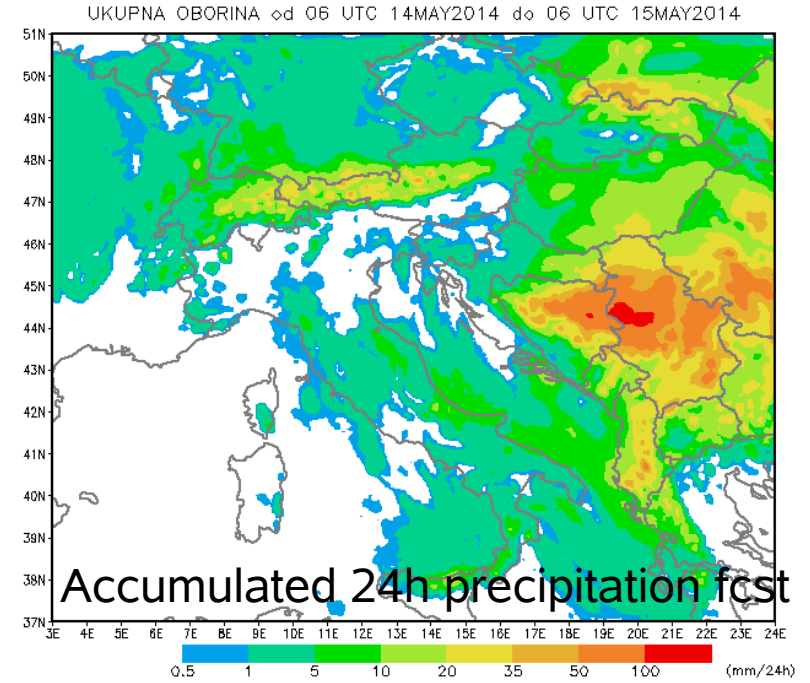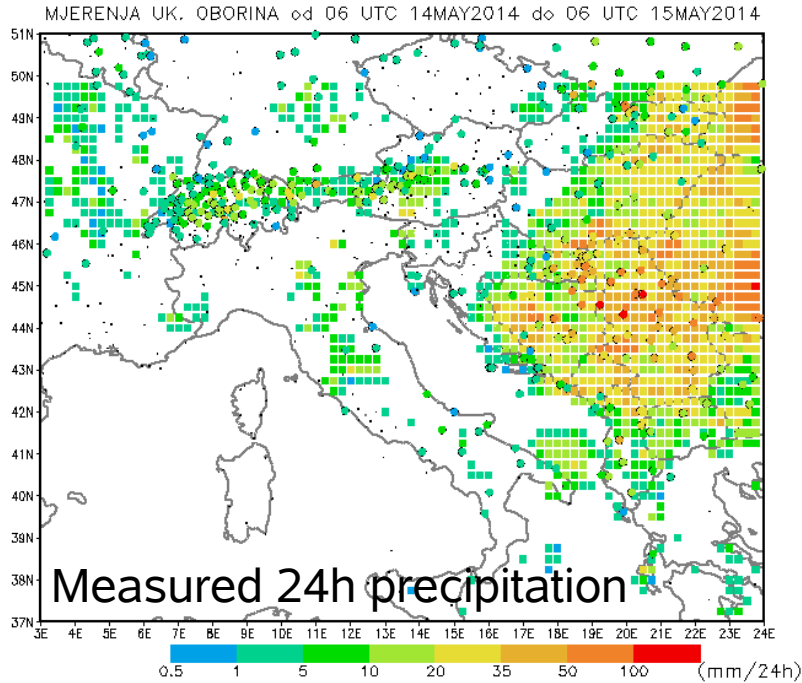
Operational forecast, 2km res, NH, prognostic convection (part)

Measured 24h precipitation

Accumulated 24h precipitation fcst

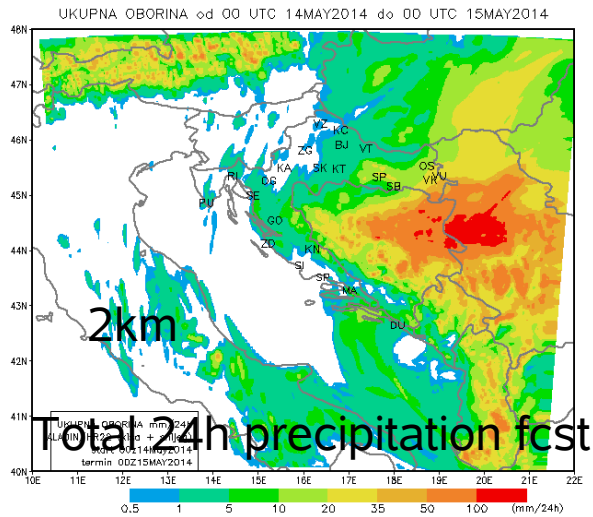Convective precipitation

Resolved precipitation

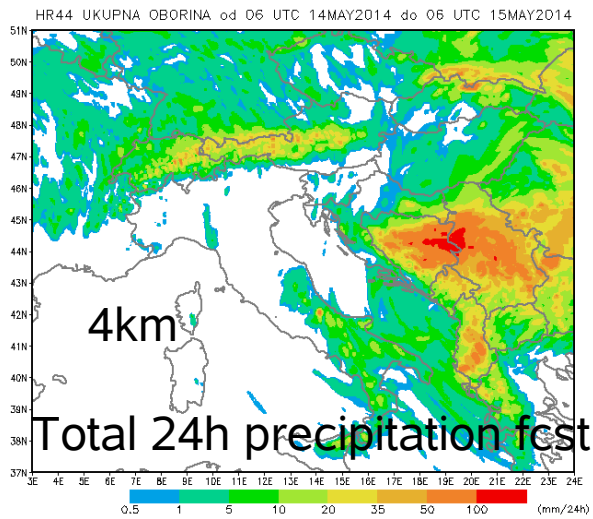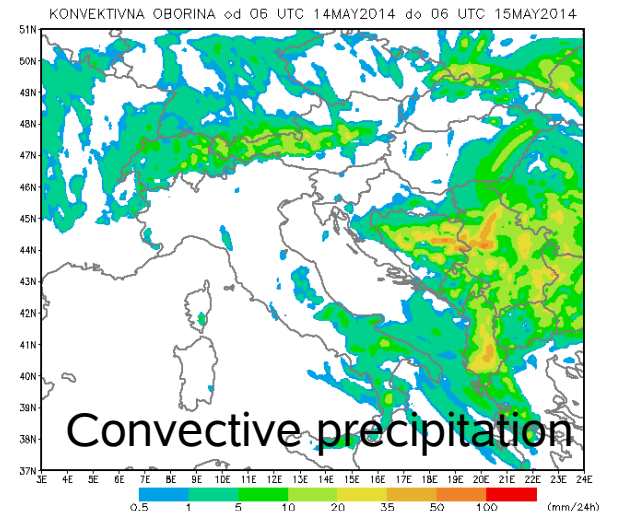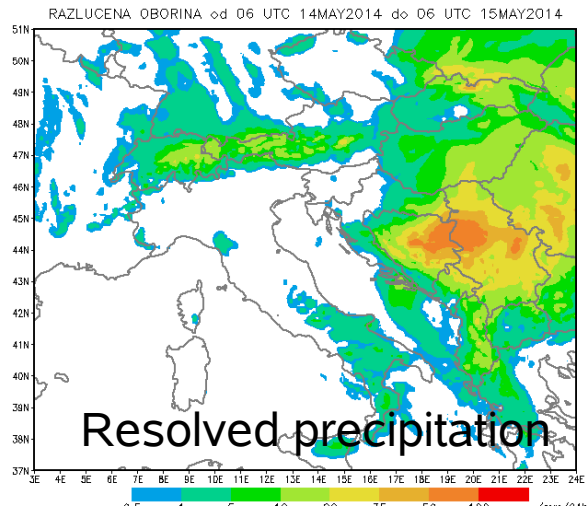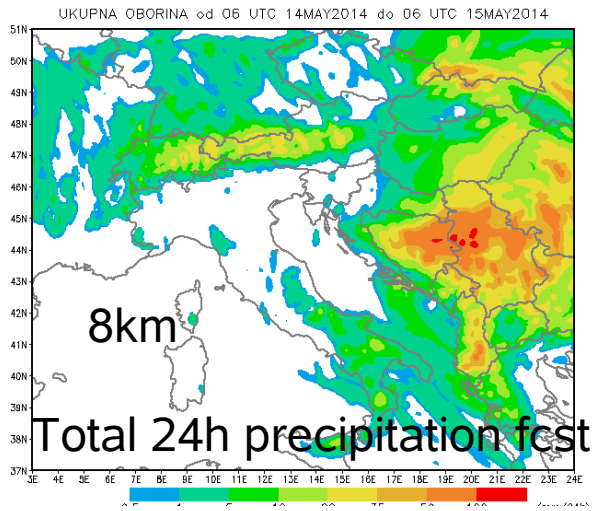UKUPNA OBORINA od 06 UTC 14MAY2014 do 06 UTC 15MAY2014
RAZLUCENA OBORINA od 06 UTC 14MAY2014 do 06 UTC 15MAY2014
KONVEKTIVNA OBORINA od 06 UTC 14MAY2014 do 06 UTC 15MAY2014

8km
Total 24h precipitation fcst
Resolved precipitation
Convective precipitation

HR44 UKUPNA OBORINA od 06 UTC 14MAY2014 do 06 UTC 15MAY2014
HR44 RAZLUCENA OBORINA od 06 UTC 14MAY2014 do 06 UTC 15MAY2014
HR44 KONVEKTIVNA OBORINA od 06 UTC 14MAY2014 do 06 UTC 15MAY2014

4km
Total 24h precipitation fcst
Resolved precipitation
Convective precipitation

UKUPNA OBORINA od 00 UTC 14MAY2014 do 00 UTC 15MAY2014
RAZLUCENA OBORINA od 00 UTC 14MAY2014 do 00 UTC 15MAY2014
KONVEKTIVNA OBORINA od 00 UTC 14MAY2014 do 00 UTC 15MAY2014

2km
Total 24h precipitation fcst
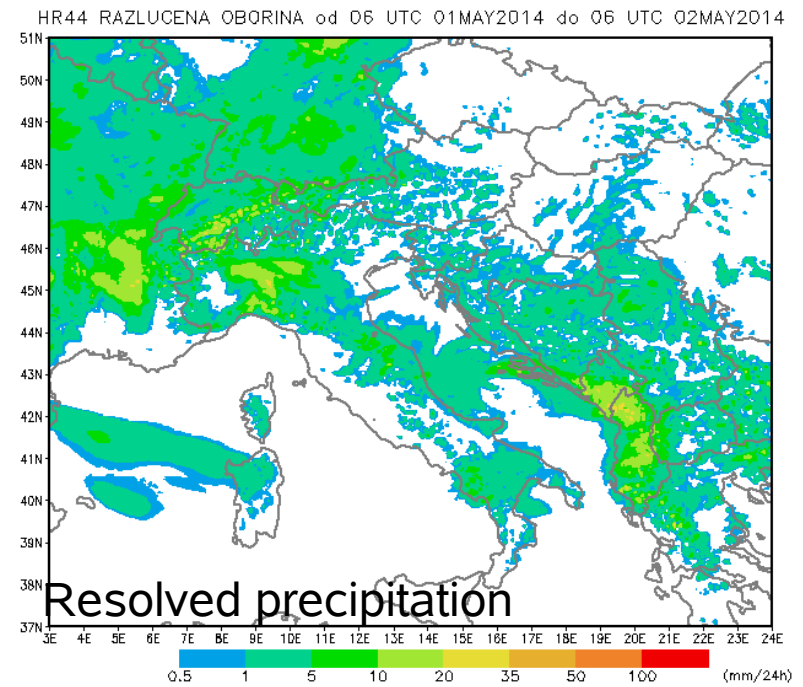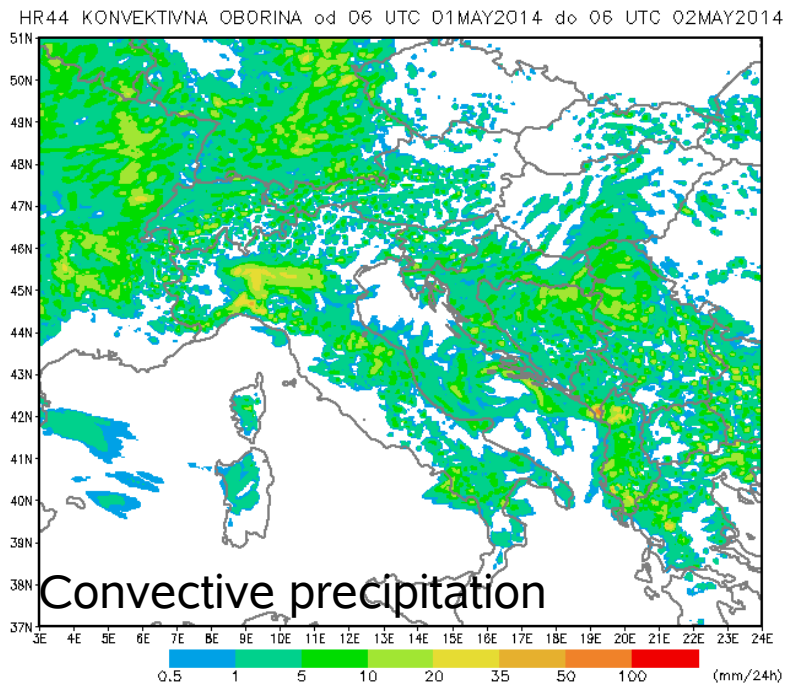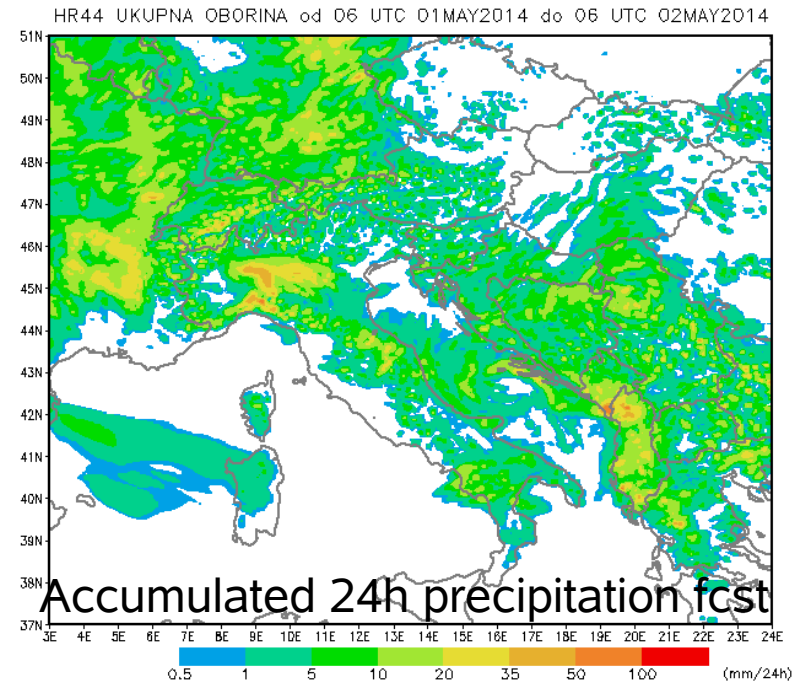Resolved precipitation
Convective precipitation

Summary

- Parametrization of deep convection in NWP model computes contribution of unresolved deep convective clouds to the evolution of resolved model fields and convective precipitation.

- Prognostic deep convection scheme uses 6 new forecast fields to introduce memory in convective processes.

- Increase in resolution moves rain from convective to resolved but very slowly.

AL38t1 forecast, 4km res, NH, prognostic convection

HR44 UKUPNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Measured 24h precipitation

Accumulated 24h precipitation fcst

HR44 KONVEKTIVNA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Convective precipitation

HR44 RAZLUCENA OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

Resolved precipitation

"Sub-grid" deep convection

Convective clouds are a source of heat and remove moisture from the atmosphere

Convective mass flux redistributes momentum, temperature and moisture along the vertical

Convective precipitation (unsaturated grid-point)

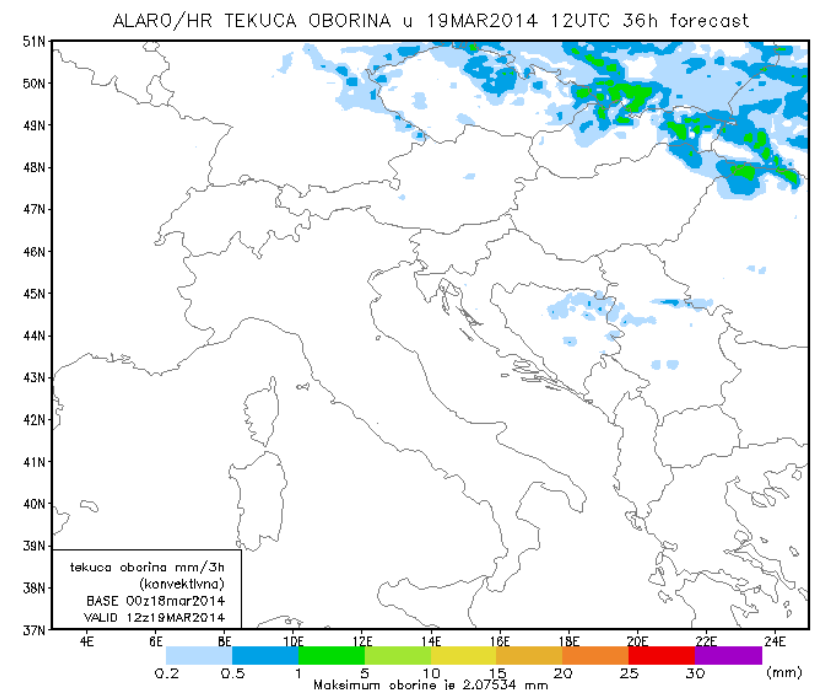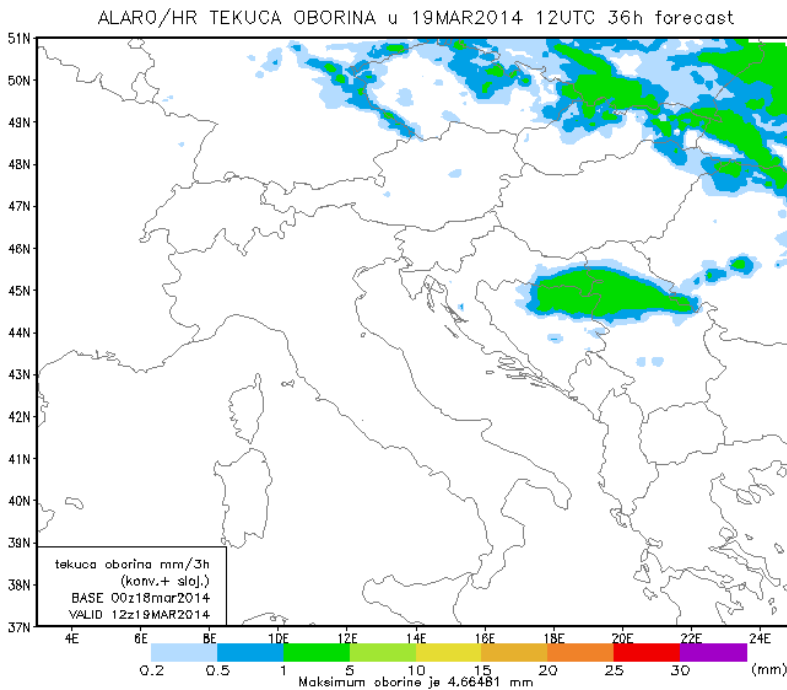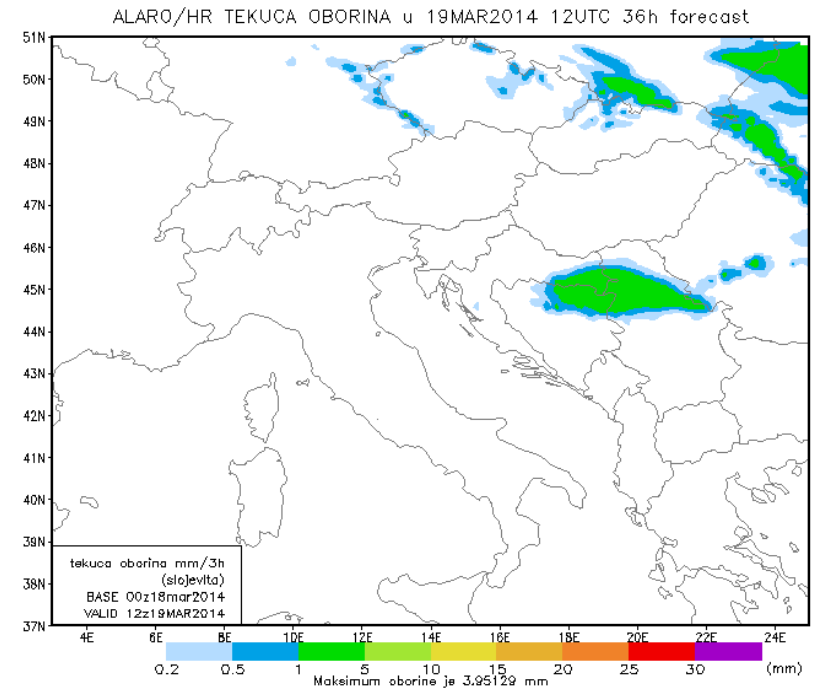Resolved precipitation (saturated grid-point)

front

Cold air
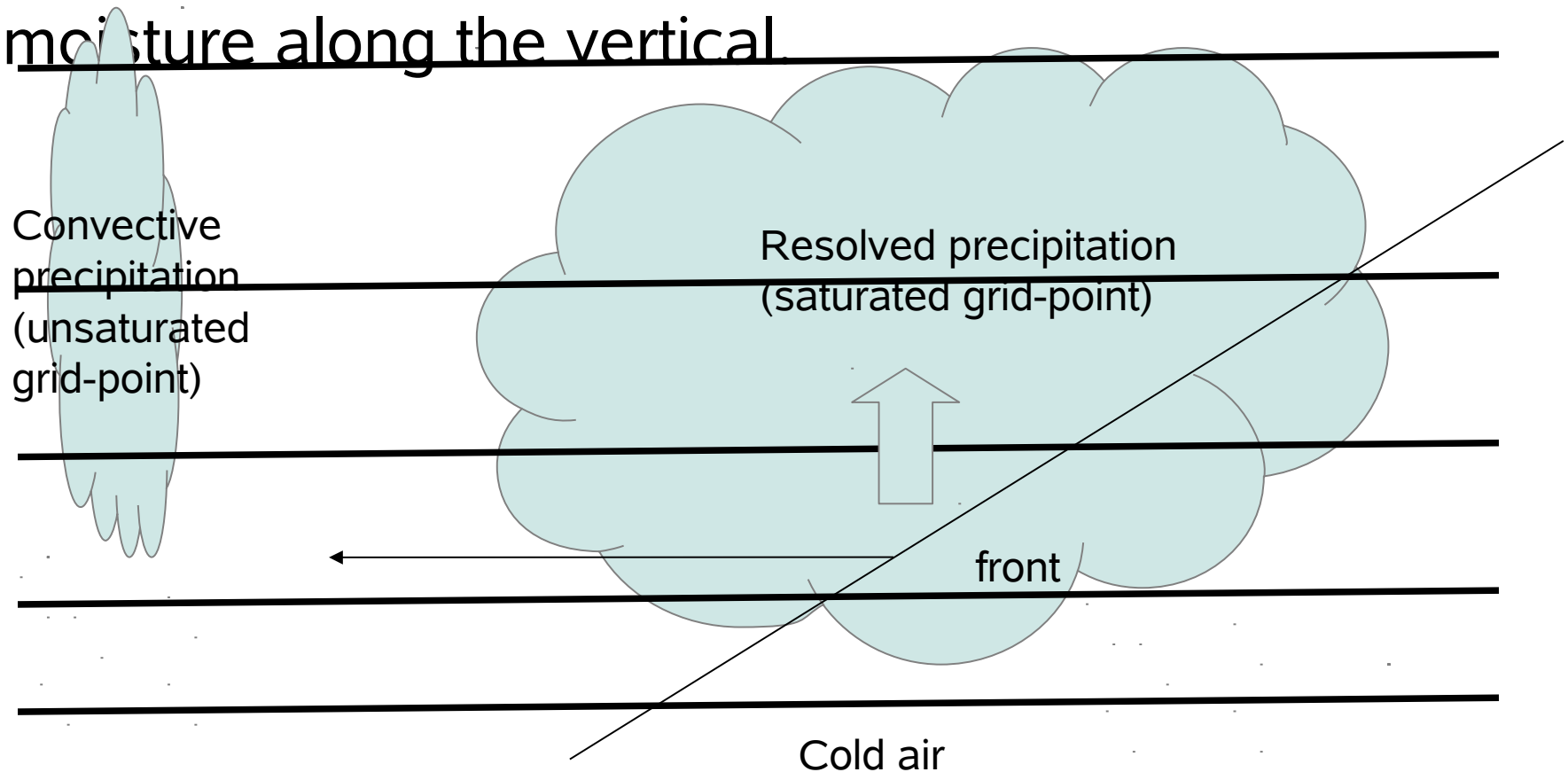
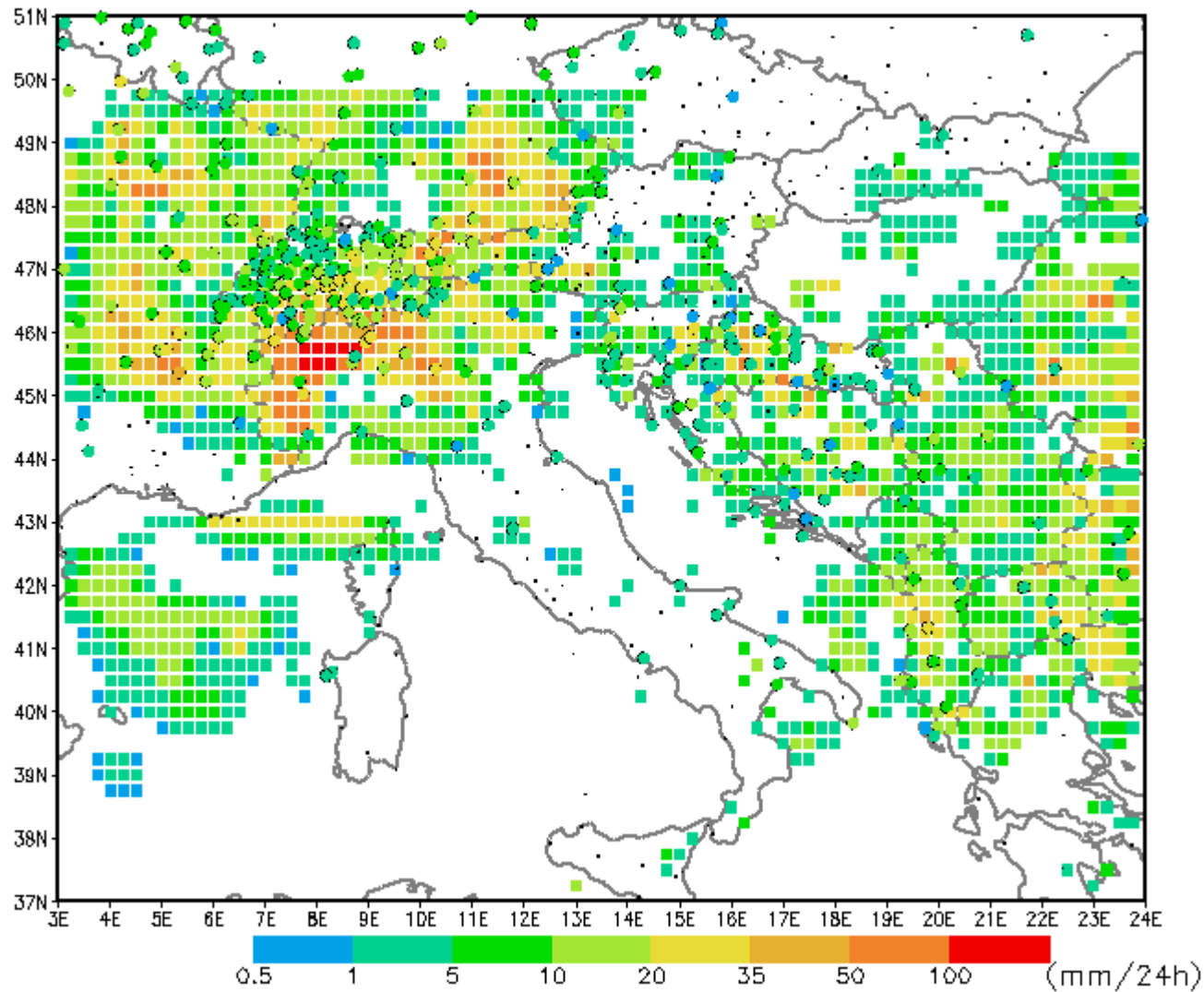Only sub-grid precipitating clouds are parametrized
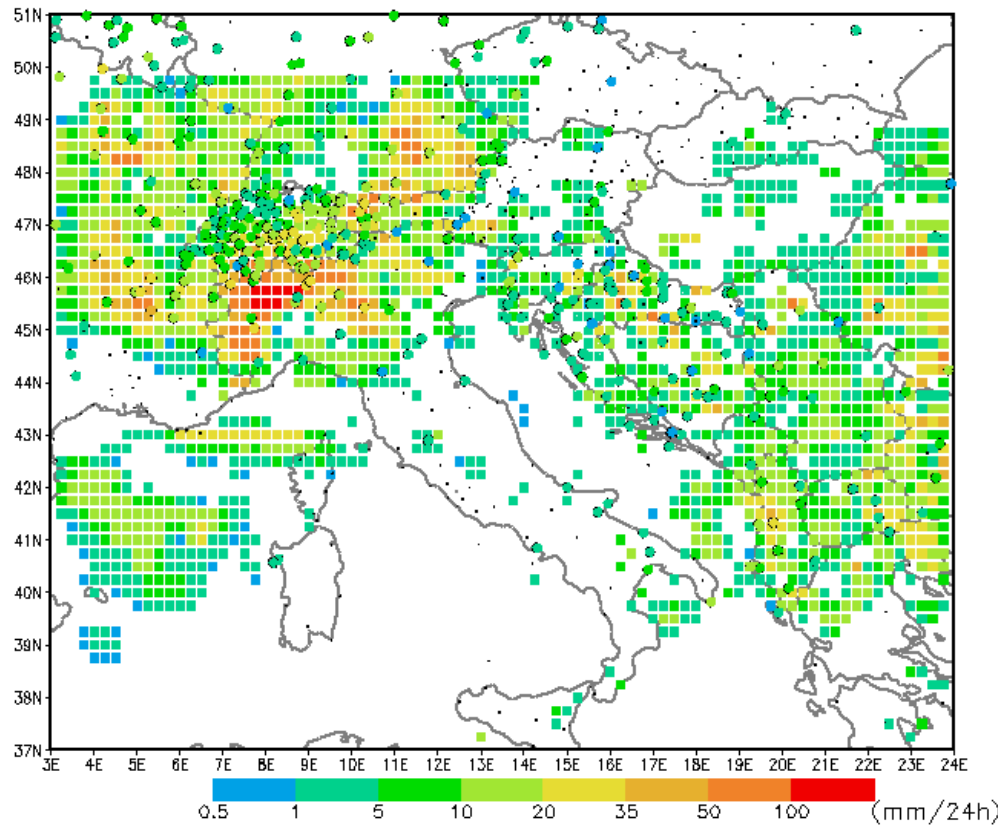
Convective precipitation

Total precipitation 3h (below), resolved (right) and unresolved convective (lower right) associated to a cold front.
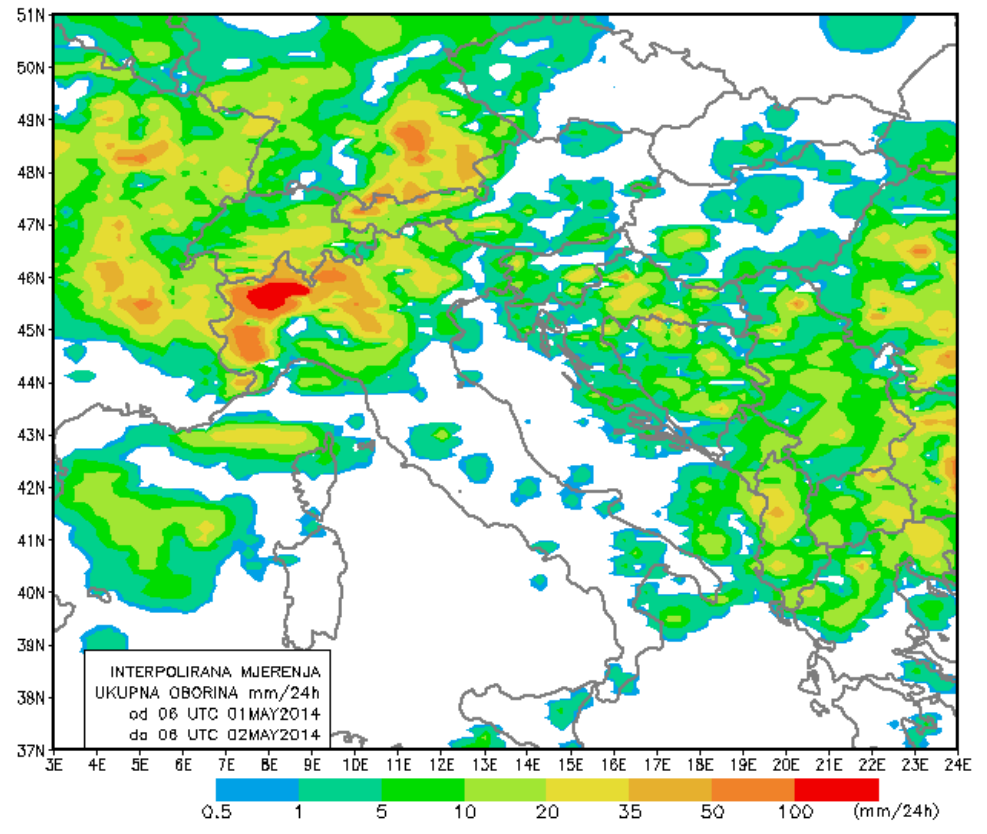
MJERENJA UK. OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

(mm/24h)
0.5   1   5   10   20   35   50   100

MJERENJA UK. OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014
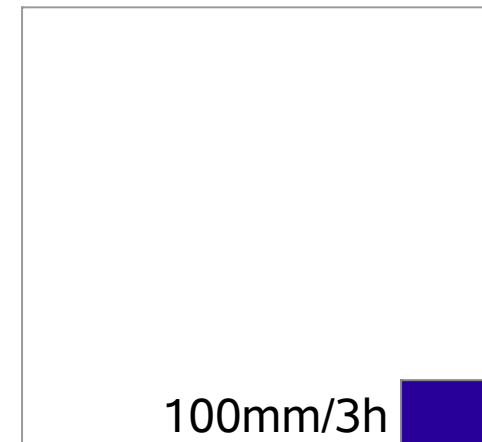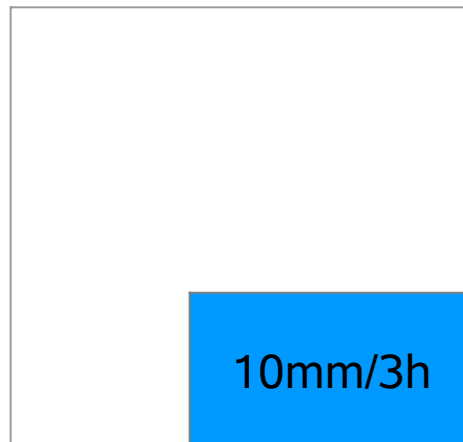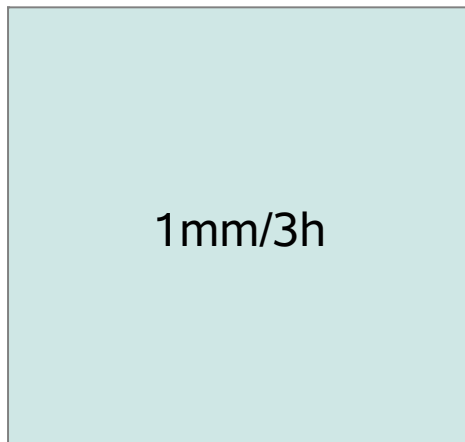
INTERP. MJ. UK. OBORINA od 06 UTC 01MAY2014 do 06 UTC 02MAY2014

INTERPOLIRANA MJERENJA
UKUPNA OBORINA mm/24h
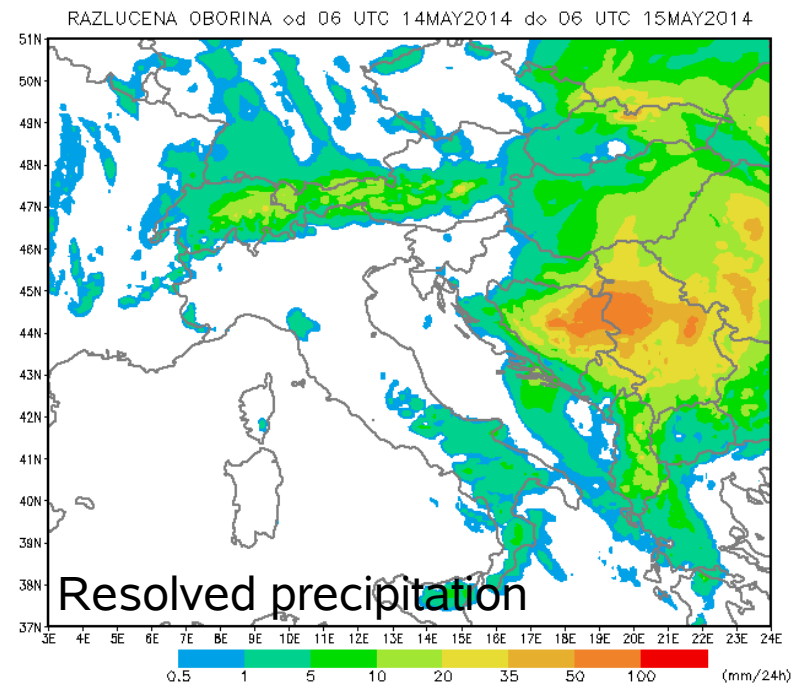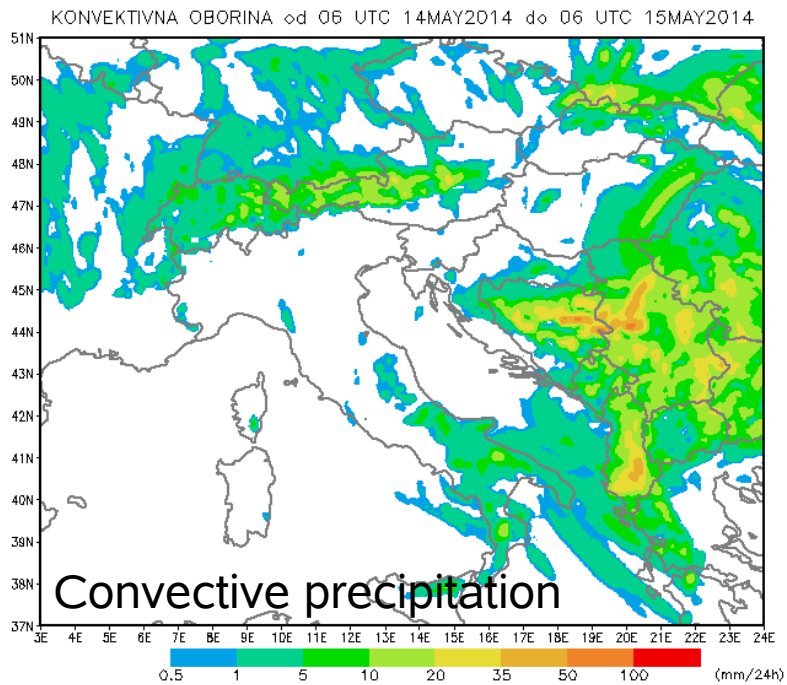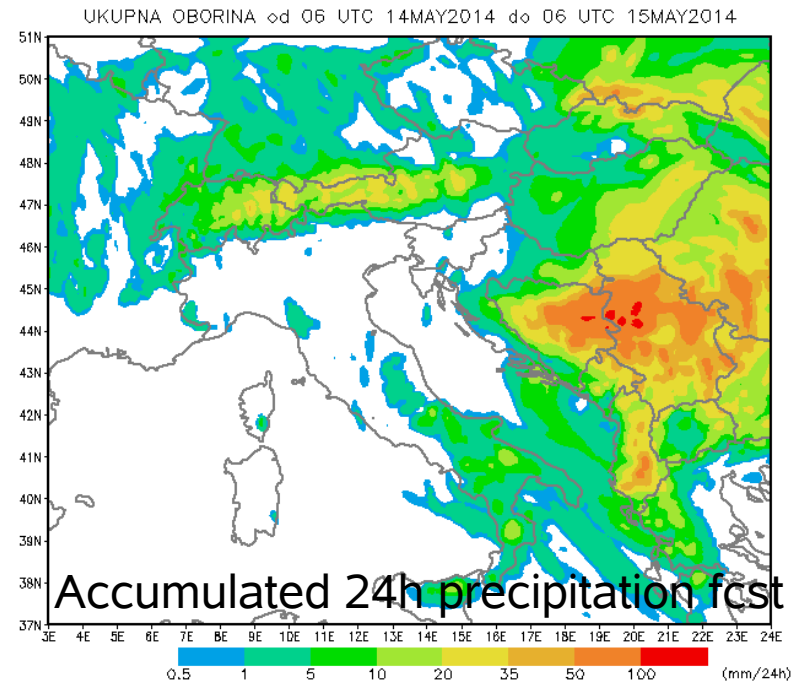od 06 UTC 01MAY2014
do 06 UTC 02MAY2014

Convective precipitation

Parametrization of deep convection computed precipitation that is added to the resolved precipitation and plotted on a map as total precipitation and lated validated against (in situ) measurements. But, it should be taken as subgrid variability in precipitation added to the resolved precipitation.
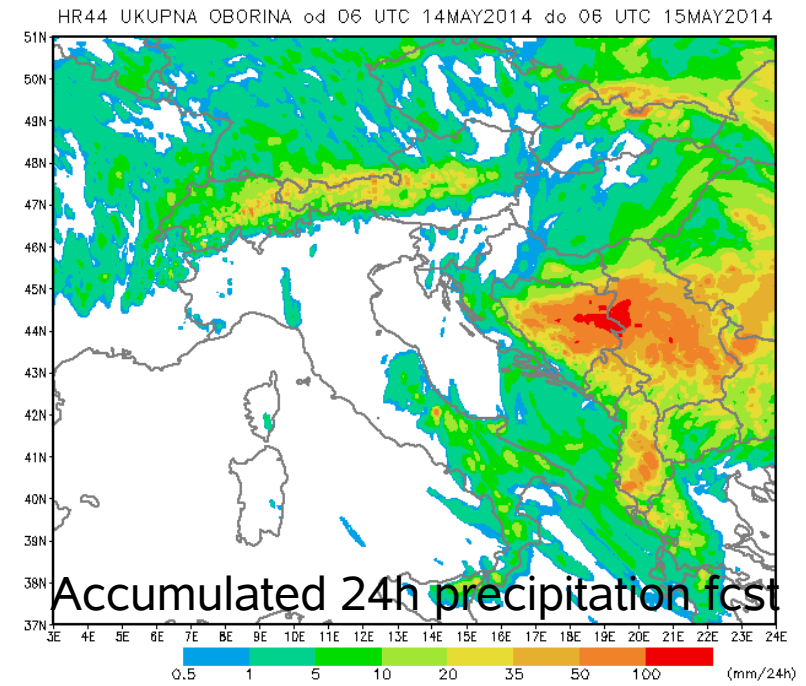
1mm/3h

10mm/3h

100mm/3h

AL38T1, 8km res, HY, **prognostic** convection

Measured 24h precipitation

Accumulated 24h precipitation fcst

Convective precipitation

Resolved precipitation

AL38T1, **4km** res, HY, prognostic convection

Measured 24h precipitation

Accumulated 24h precipitation fcst

Convective precipitation

Resolved precipitation

AL38T1, 2km res, NH, prognostic convection

UKUPNA OBORINA od 00 UTC 14MAY2014 do 00 UTC 15MAY2014

Measured 24h precipitation

Accumulated 24h precipitation fcst

KONVEKTIVNA OBORINA od 00 UTC 14MAY2014 do 00 UTC 15MAY2014

Convective precipitation

RAZLUCENA OBORINA od 00 UTC 14MAY2014 do 00 UTC 15MAY2014

Resolved precipitation