Cover

Flash floods as result of flow interactions in the atmospheric boundary layer over complex orography

ARPA FVG - CRMA
Regional **C**enter for **E**nvironmental **M**odeling
Palmanova, Italy

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Outline

- The class of atmospheric events
- The conceptual model
- Numerical simulations by means of LAMs
- Results

The class of investigated events

Heavy long lasting rain over the **same area** in **complex orography**

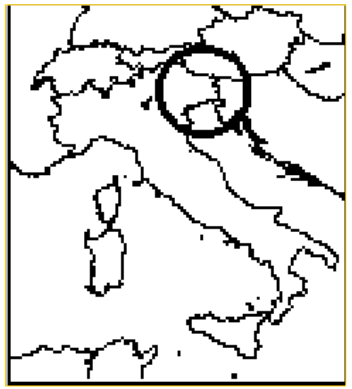
- **Heavy rain**: rain rates > 10 mm/5'
- **Long lasting**: continuous time series (> 1 hour) of heavy rain
- **Same area**: geographical surface about 5 km x 5 km or less
- **Complex orography**: steep mountains (h > 1000 m) and flat terrain

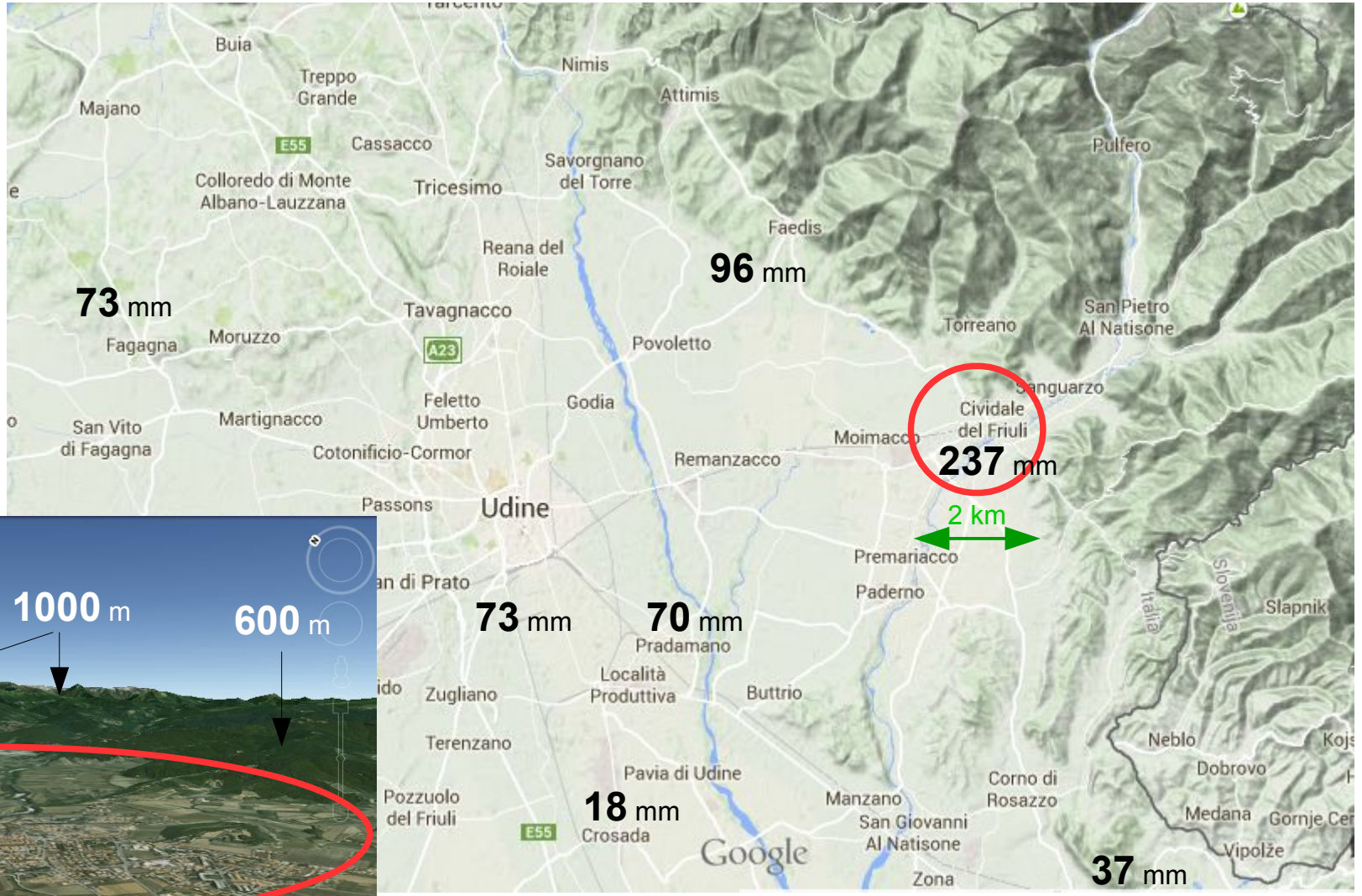
Why we are interested in this class of atmospheric events.

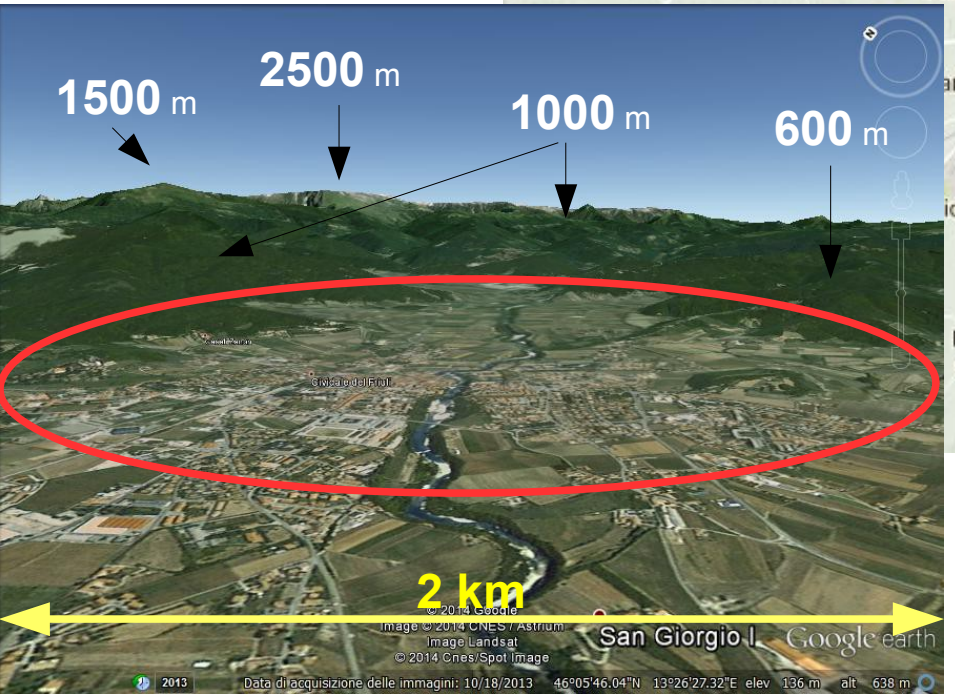
- Weather forecasts and risk management
- Knowledge of deep atmospheric convection and severe weather
- Weather numerical models reliability

A class element (a real event)

September 09, 2013 – Northeastern Italy



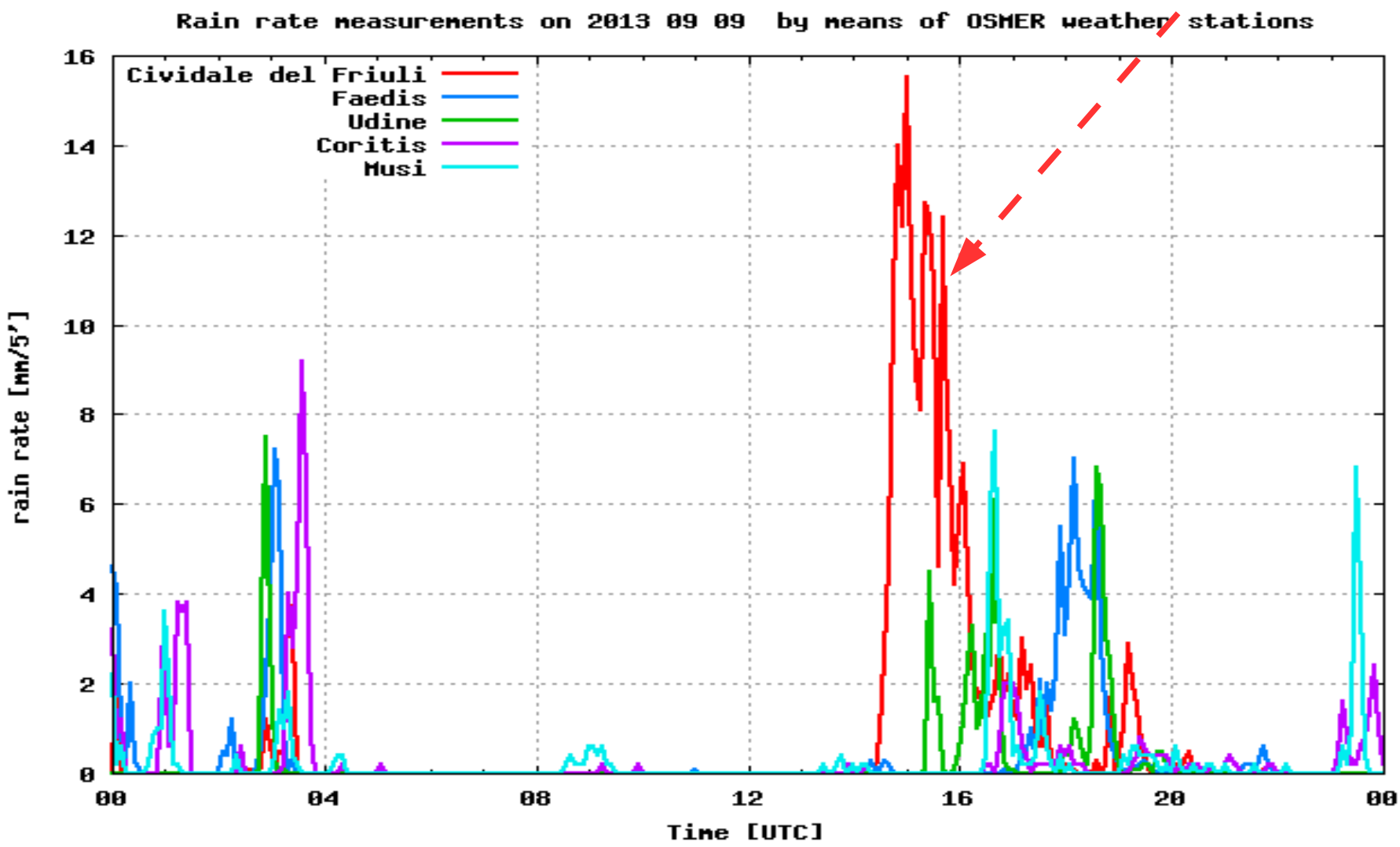




100 civil protection volunteers involved to help flooded people
1 MEuro of costs and damages
At leas **one event/year** in the area (100 km x 100 km)

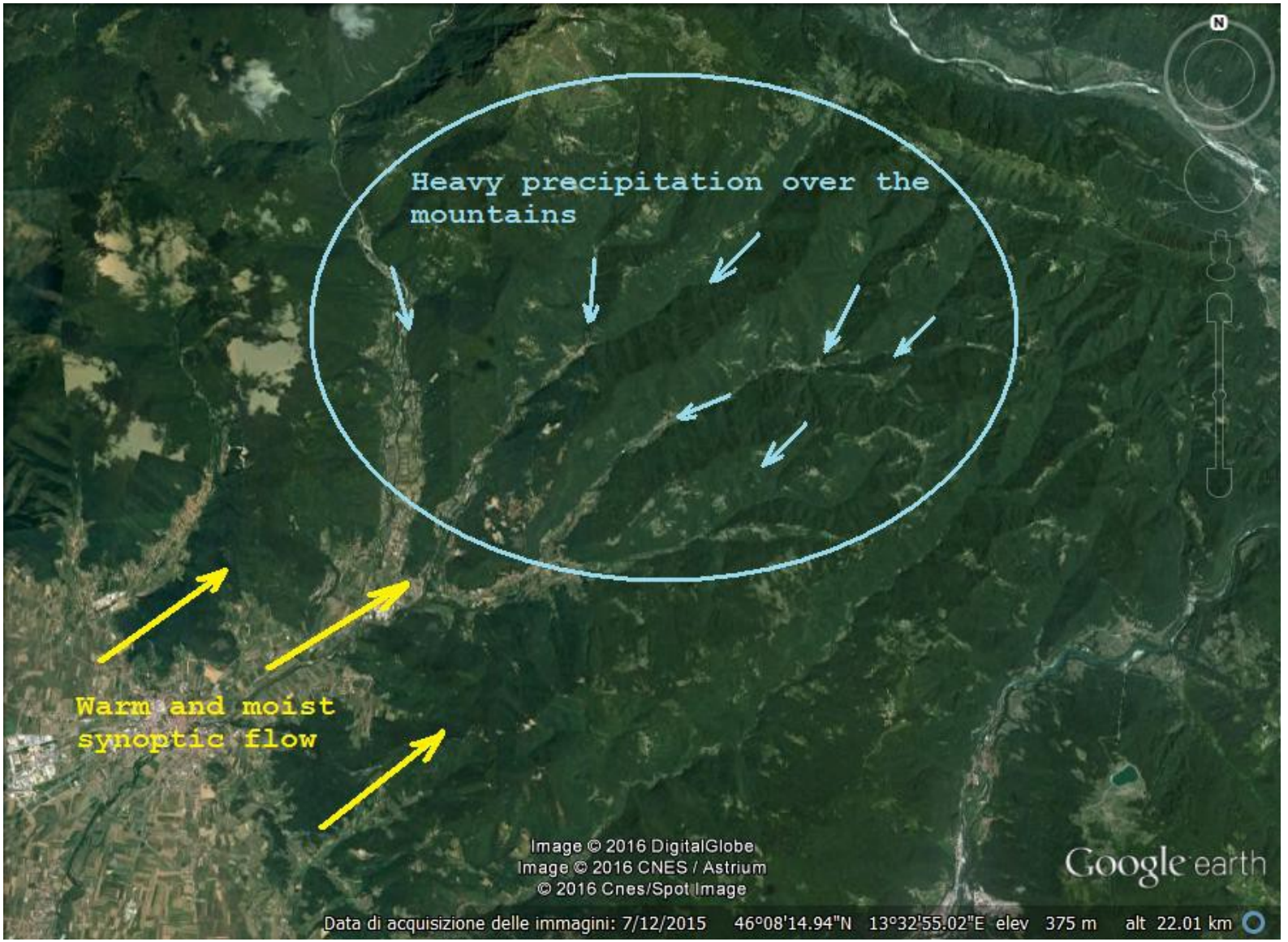
Stationary deep atmospheric convenction – a flash flood

- High efficiency in water vapor condensation and precipitation (> 10 mm/5')
- Persistence for more than one hour
- Large horizontal rain rate gradients (>100% change in about 2 km)



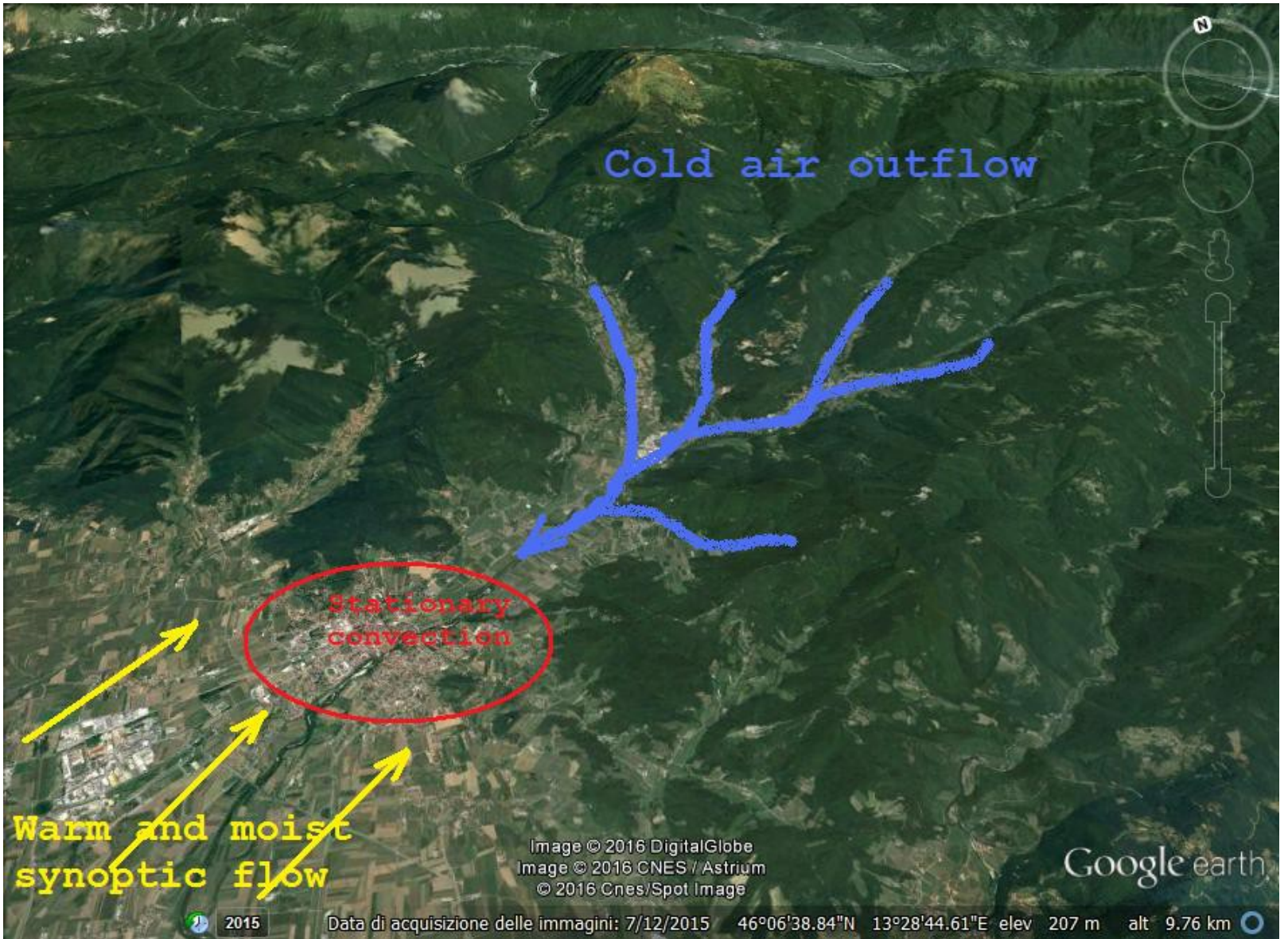
Conceptual model – phase a)

1) The synoptic flow interacts with orography and convection is initiated
2) Heavy precipitation over the mountains
3) Cold and dense air pools (downdrafts) flow at the valleys bottom



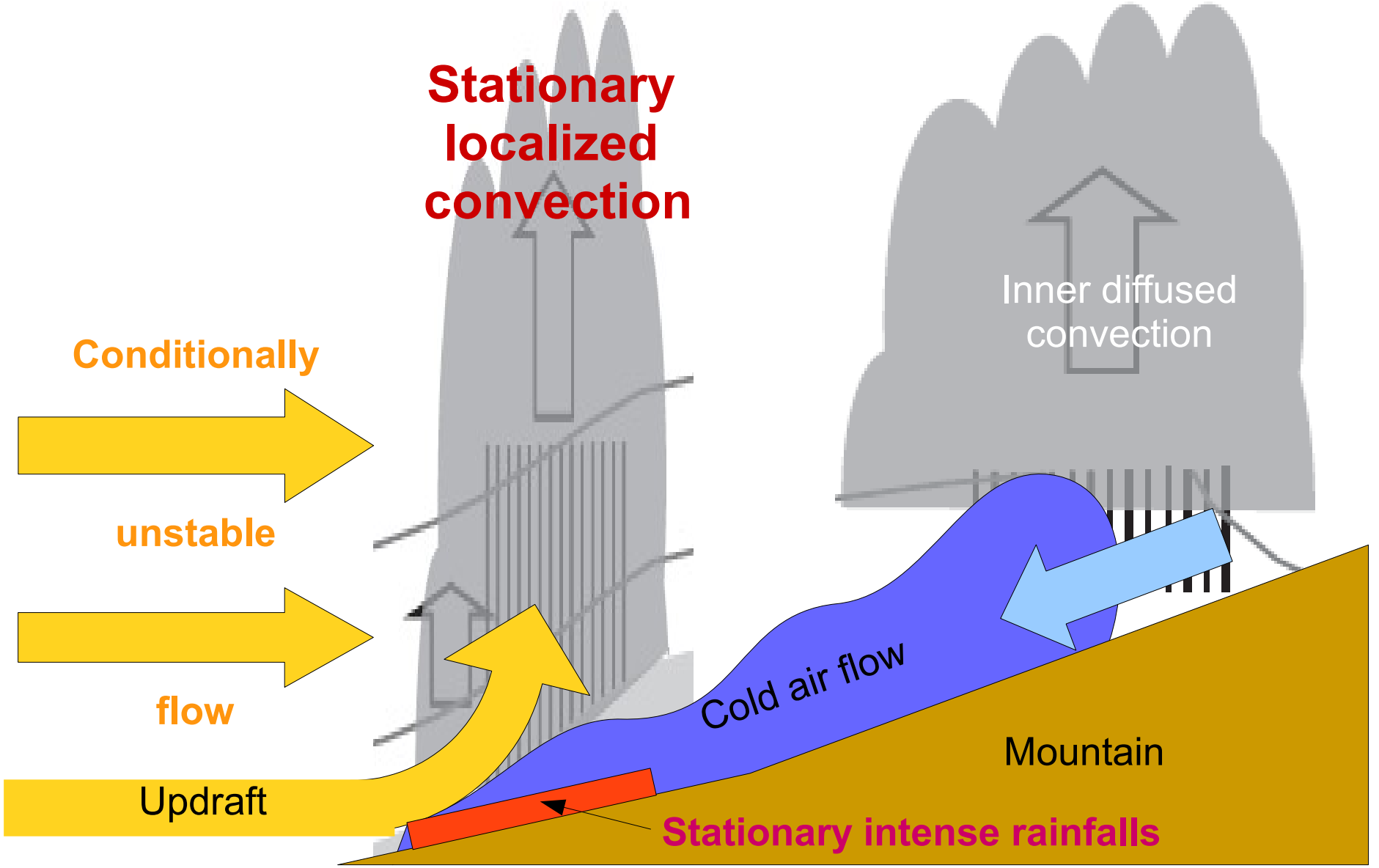
Conceptual model – phase b)

1) Dense air pools generate an outflow from the main valley into the the plane.
2) The boundary layer is completely changed in the area where outflow and synoptic flow interact; there the moist convection is initiated.



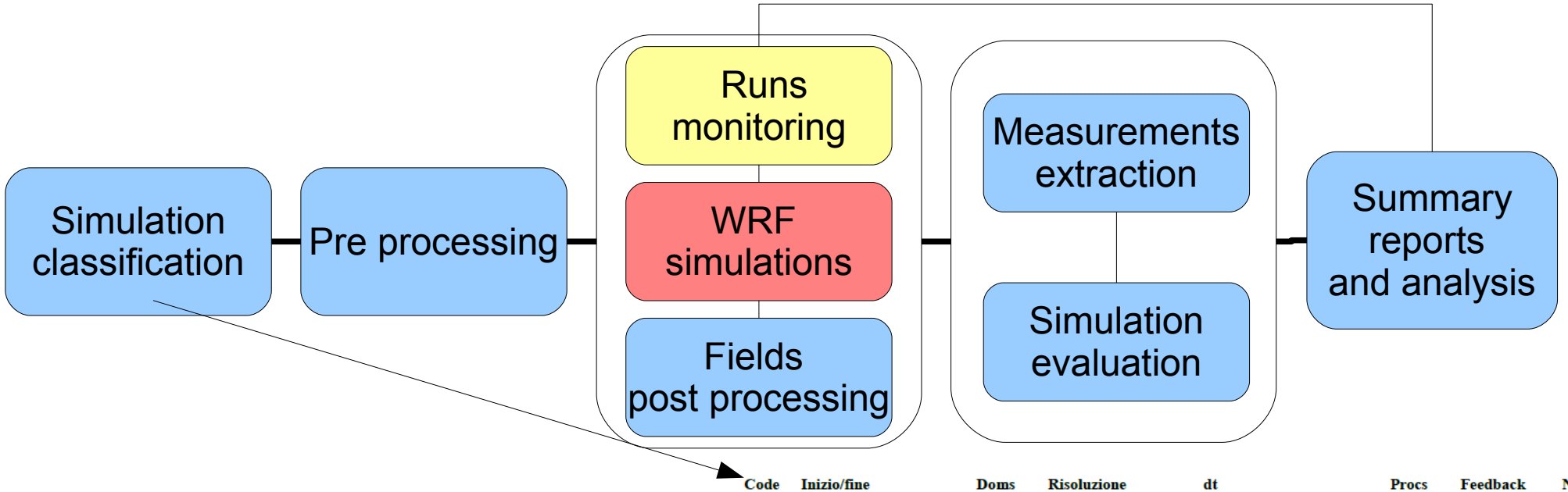
Conceptual model – phase c)

- Deep moist convection is maintained stationary



Numerical experiments to verify the conceptual model

- All numerical experiments are implemented as **workflows** composed by actions
- A new experiment workflow is defined by means of initialization files
- Simulation chains are run automatically according HPC resources availability



WRF rain sensitivity on:

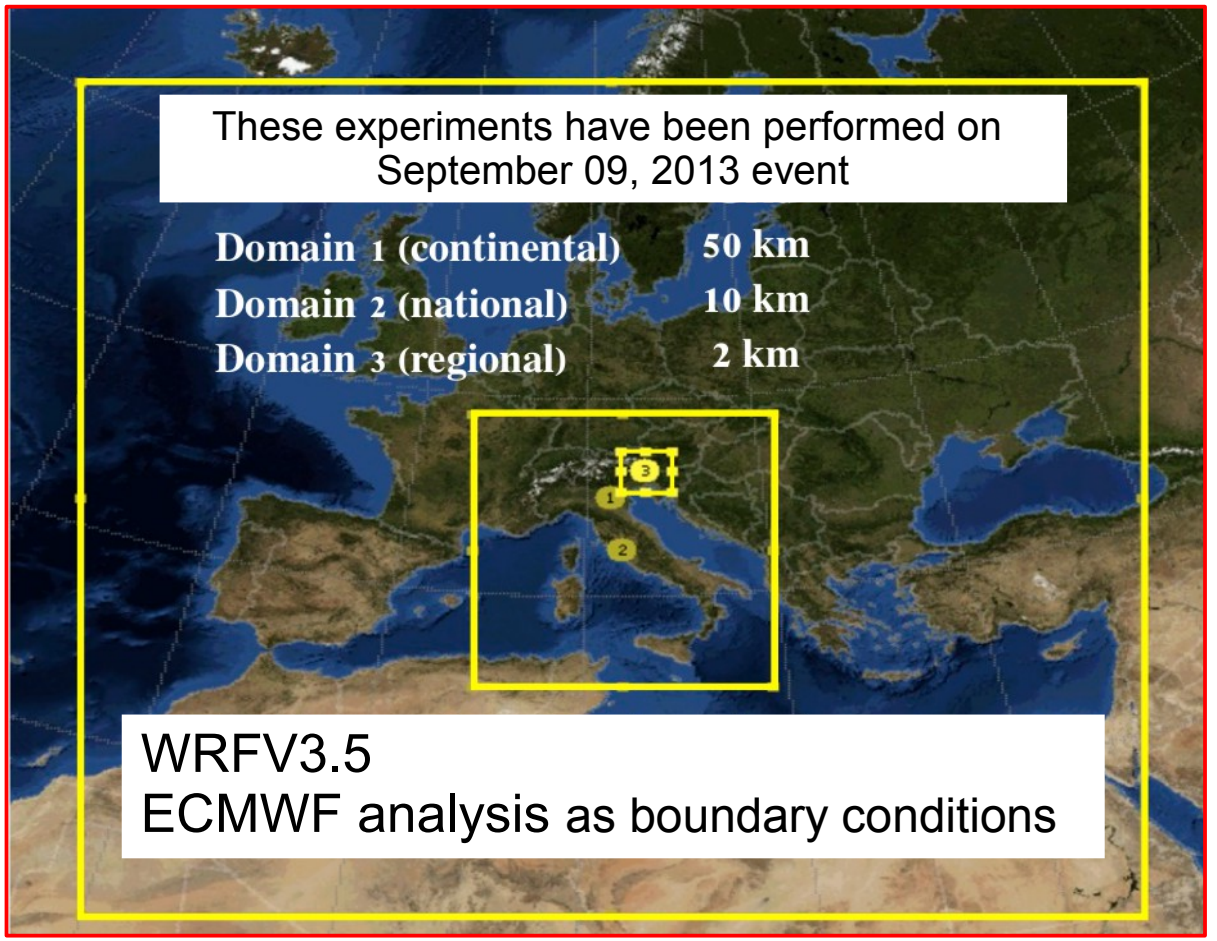
- Horizontal resolution
- Nested domains feedback effects
- Initial and boundary condition
- Boundary layer schemes

Code	Inizio/fine	Doms	Risoluzione	dt	Procs	Feedback	Note
AA	06-09-13/10-09-2013	3	50, 10, **2**	240, 40, 40/6	32	ON	Manca
AB	06-09-13/10-09-2013	4	50, 10, 2, 1	240, 40, 40/6, 40/12	32	ON	
AC	06-09-13/10-09-2013	3	50, 10, 2	240, 40, 40/6	32	OFF	Come .
AD	08-09-13/10-09-2013	4	50, 10, 2, 1	40, 40, 40/6, 40/12	16	ON	Come .
AE	08-09-13/10-09-2013	4	45, 9, 1.8, 0.6	180, 36, 6, 1	16	ON	Interro Il resta
AF	08-09-13/10-09-2013	5	45, 9, 1.8, 0.6, 0.3	180, 36, 6, 1, 0.5	16	ON	
AG	08-09-13/10-09-2013	4	45, 9, 1.8, 0.6	180, 36, 6, 1	16	OFF	
AH	08-09-13/10-09-2013	5	45, 9, 1.8, 0.6, 0.3	180, 36, 6, 1, 0.5	16	OFF	

Numerical Model and basic information

Are nowadays LAMs able to simulate such class of atmospheric events?

- Simulations with uniform flows and simple orography are known form literature.
- What about WRF model in real cases?



WRF is run operationally at ARPA FVG

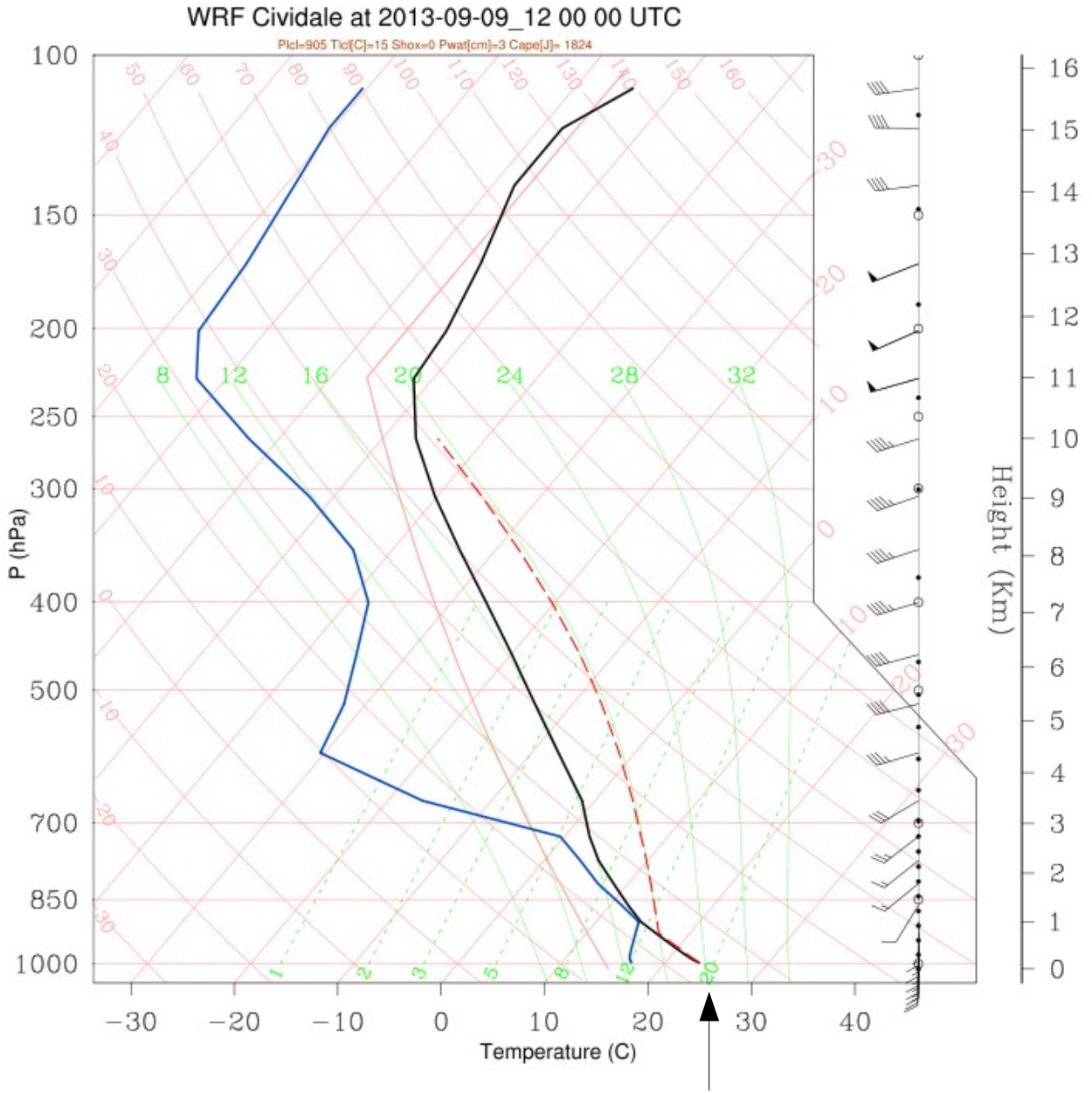
Boundary and initial conditions are ECMWF IFS

3 nested domains to reach 2 km resolution over NE Italy

Orography resolution 30”

HPC shared+distributed memory 32 x 4 cores

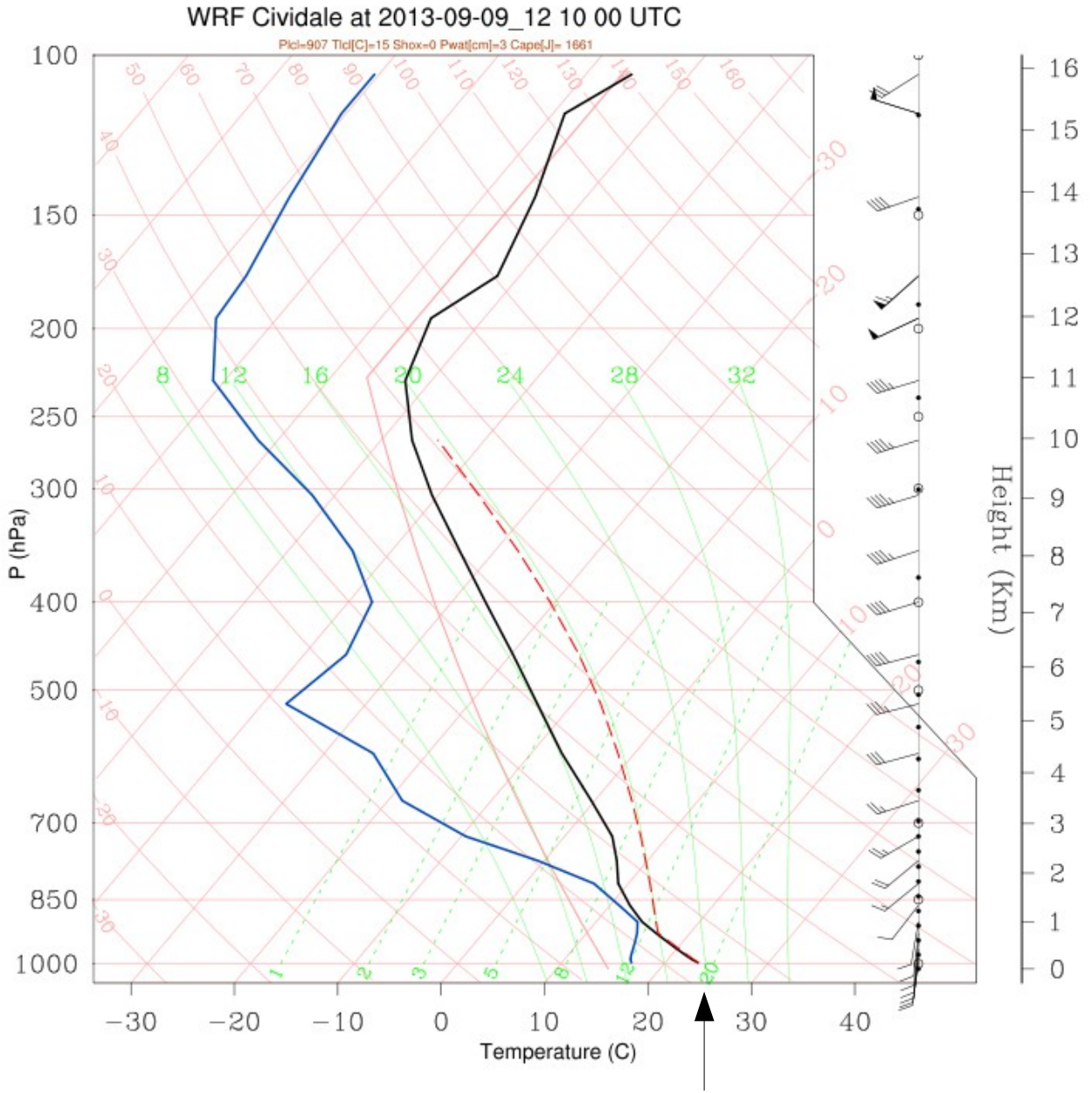
WRF simulation 0.6 km resolution- Cividale virtual sounding



Synoptic flow

Synoptic flow

WRF simulation 0.6 km resolution- Cividale virtual sounding



Synoptic flow

Synoptic flow

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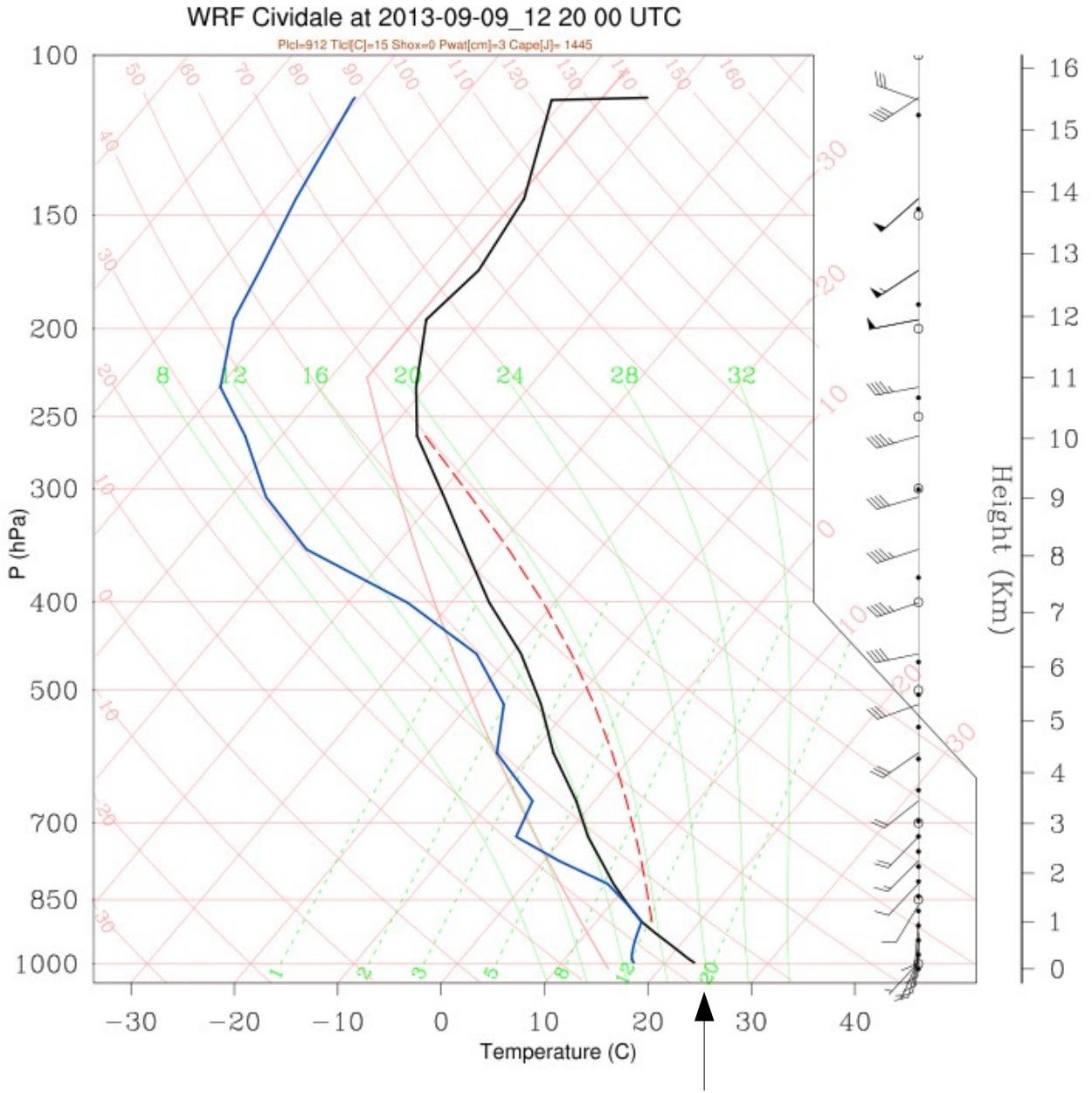

Synoptic flow

Synoptic flow

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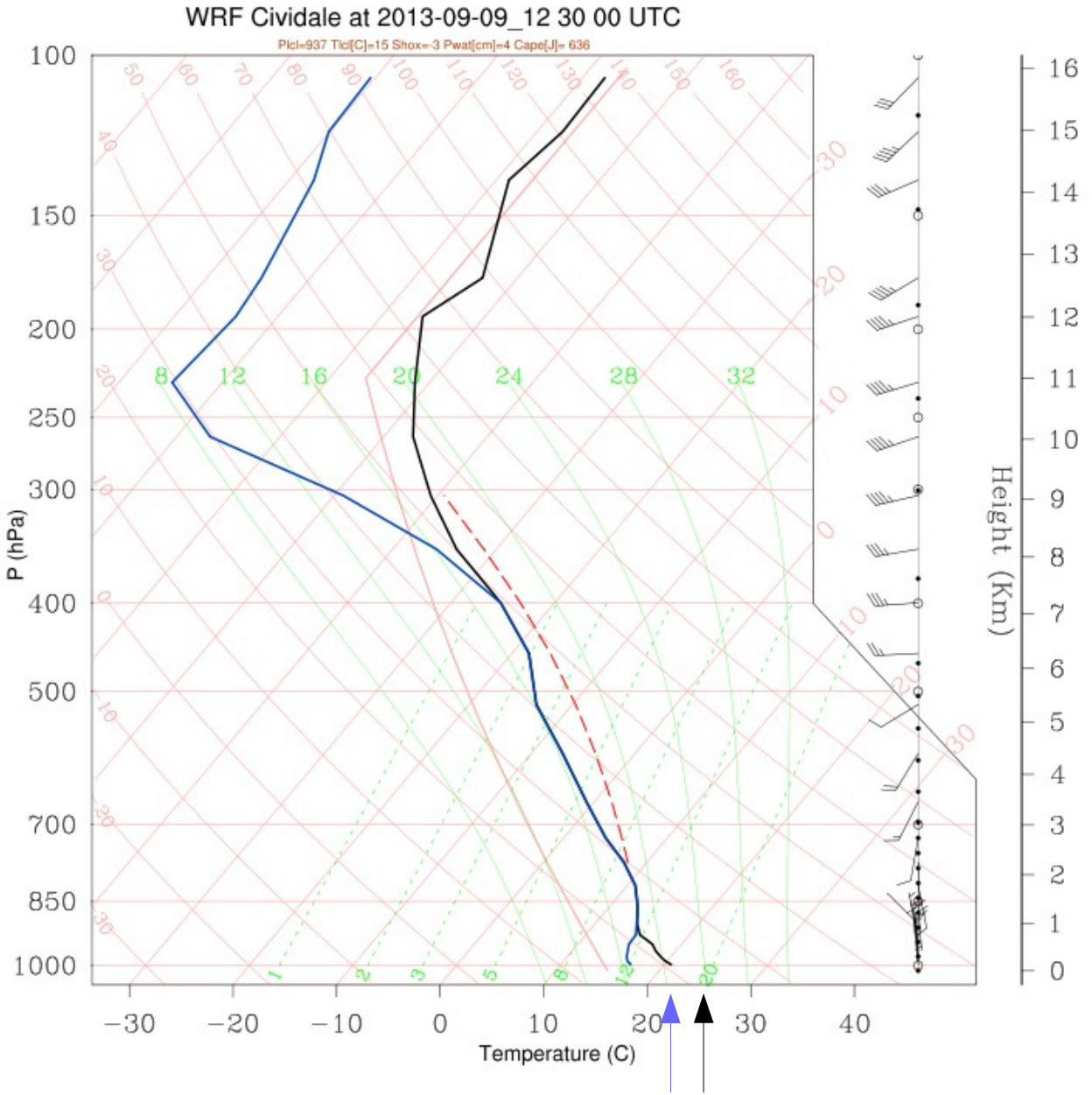
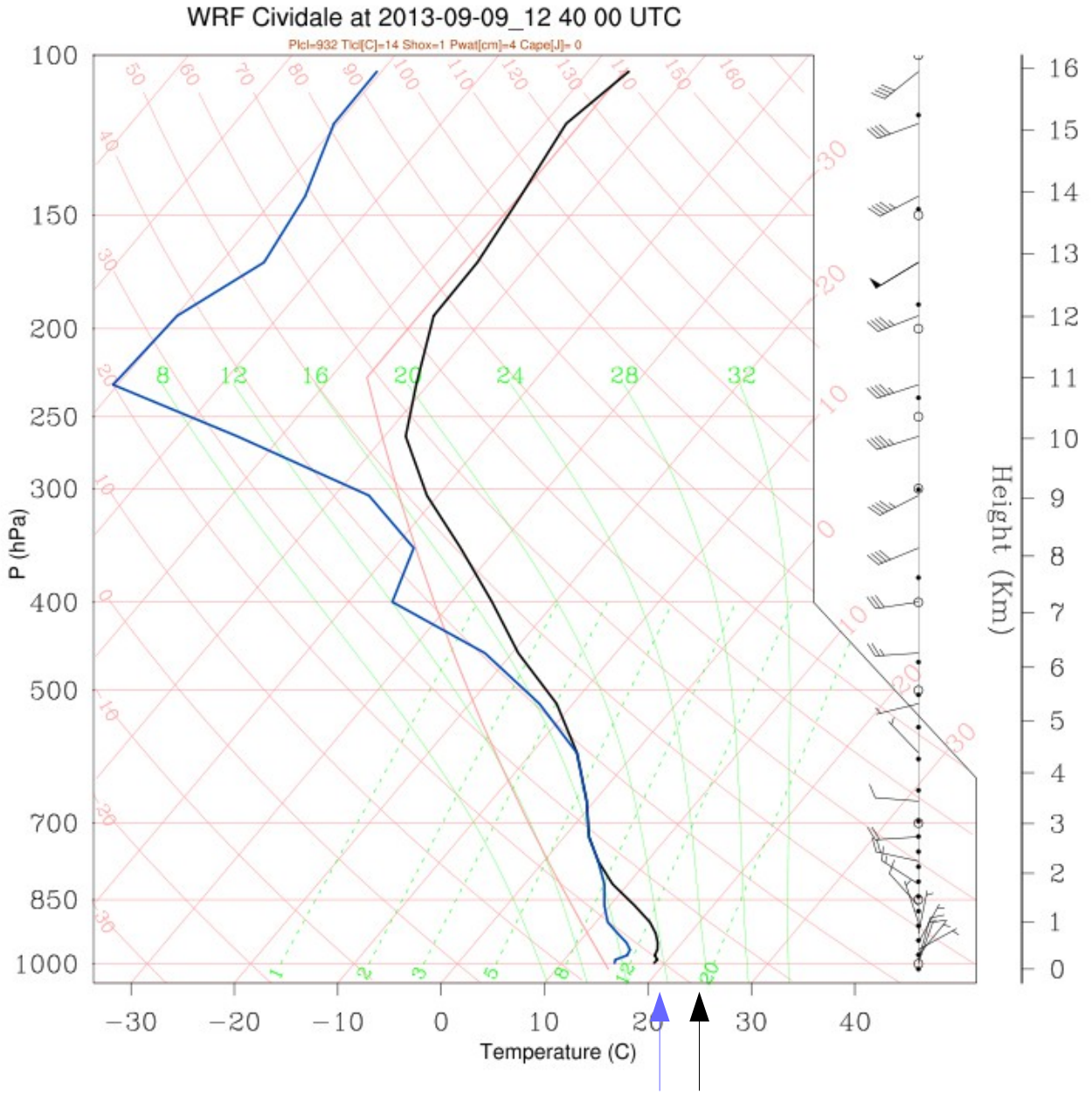


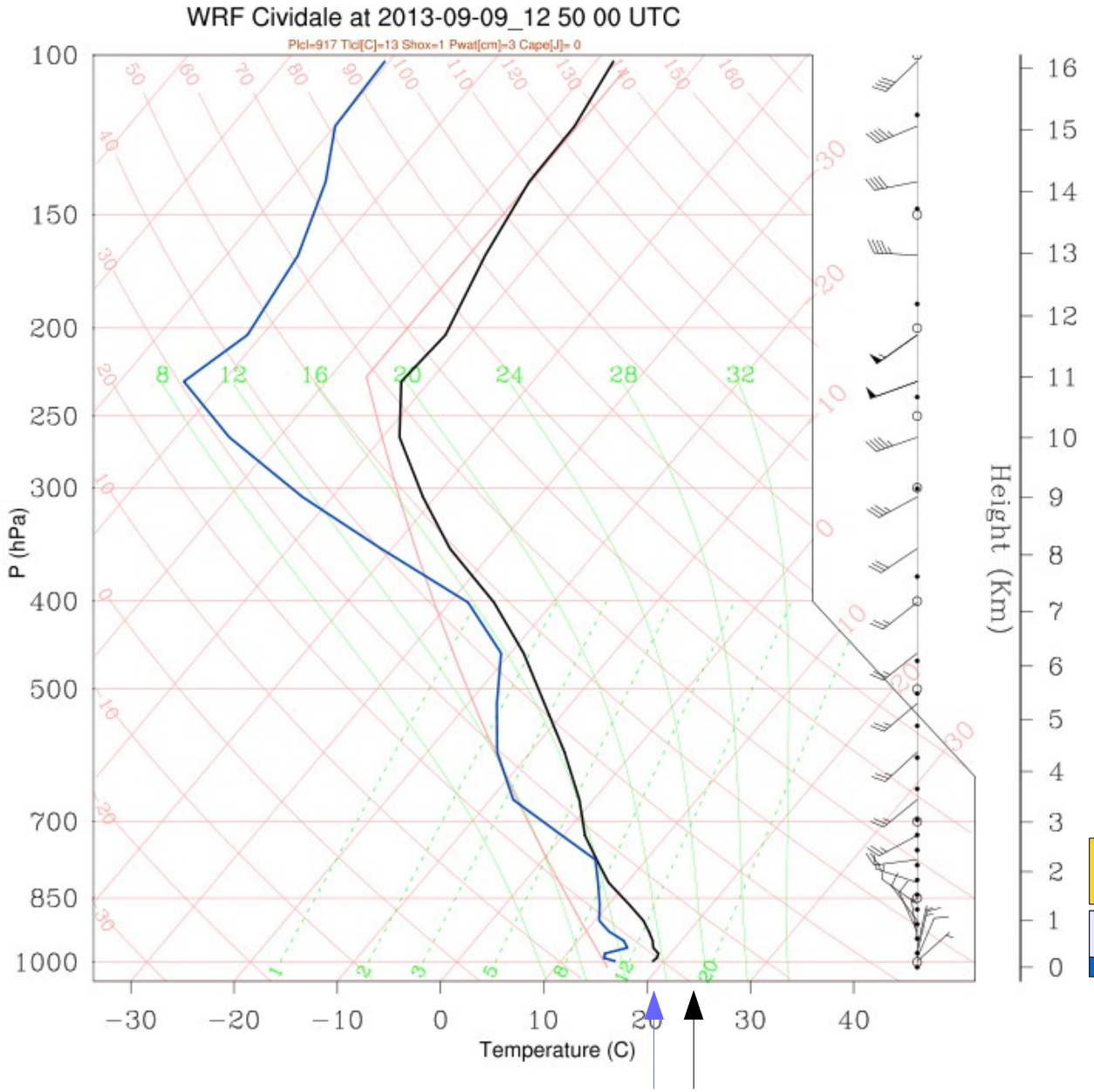
Synoptic flow

Out flow start

WRF simulation 0.6 km resolution- Cividale virtual sounding



WRF simulation 0.6 km resolution- Cividale virtual sounding



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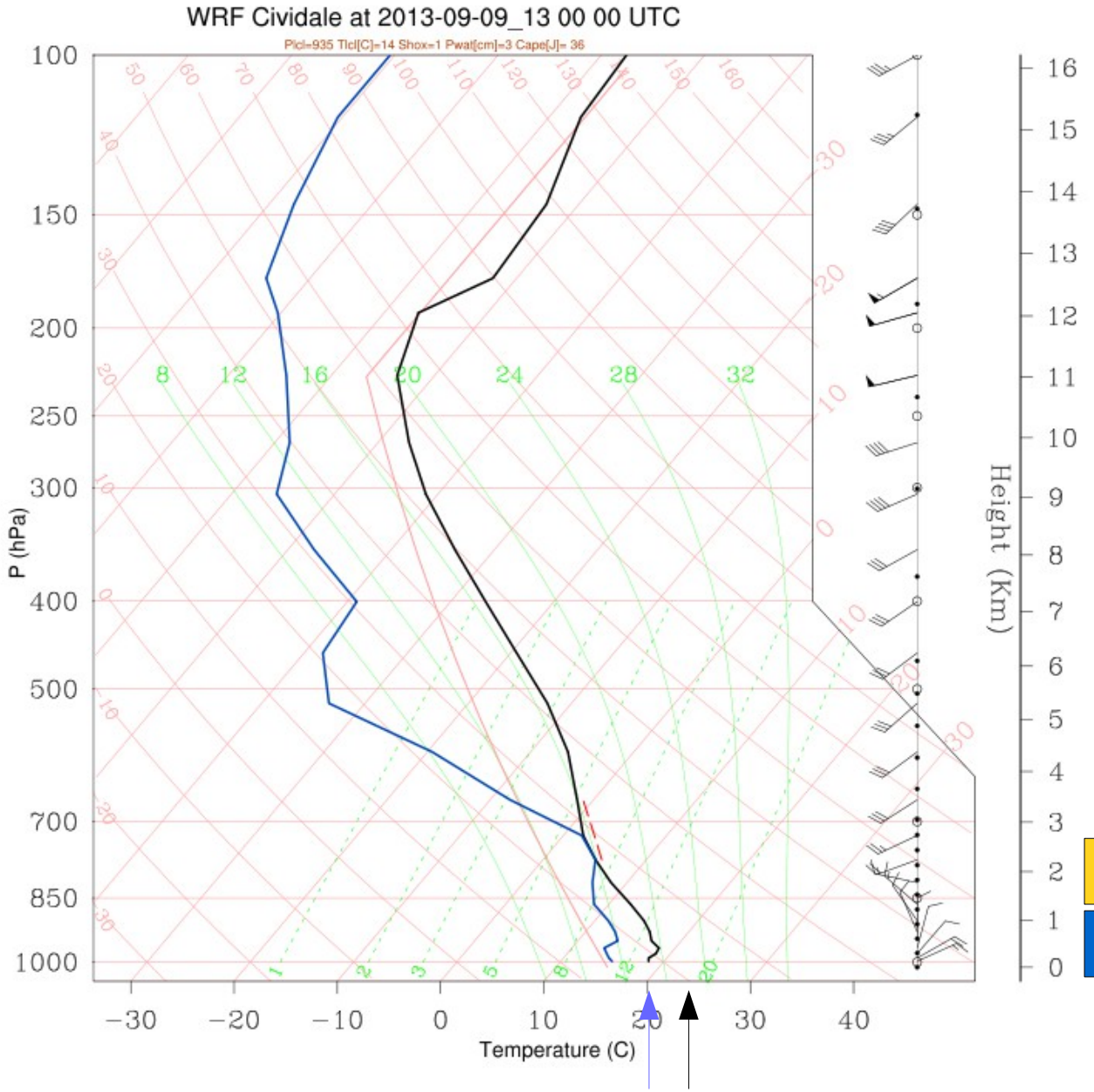

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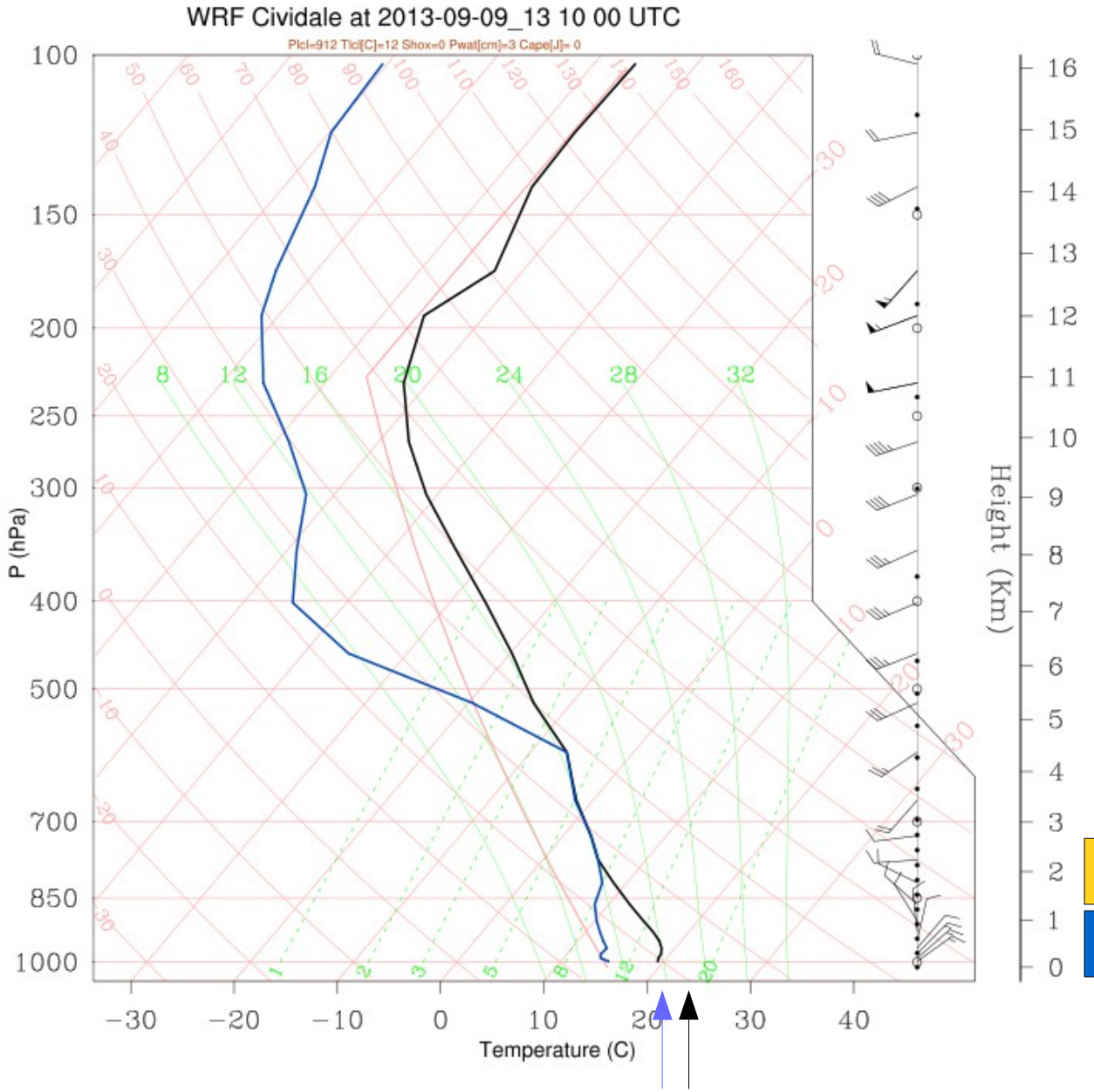

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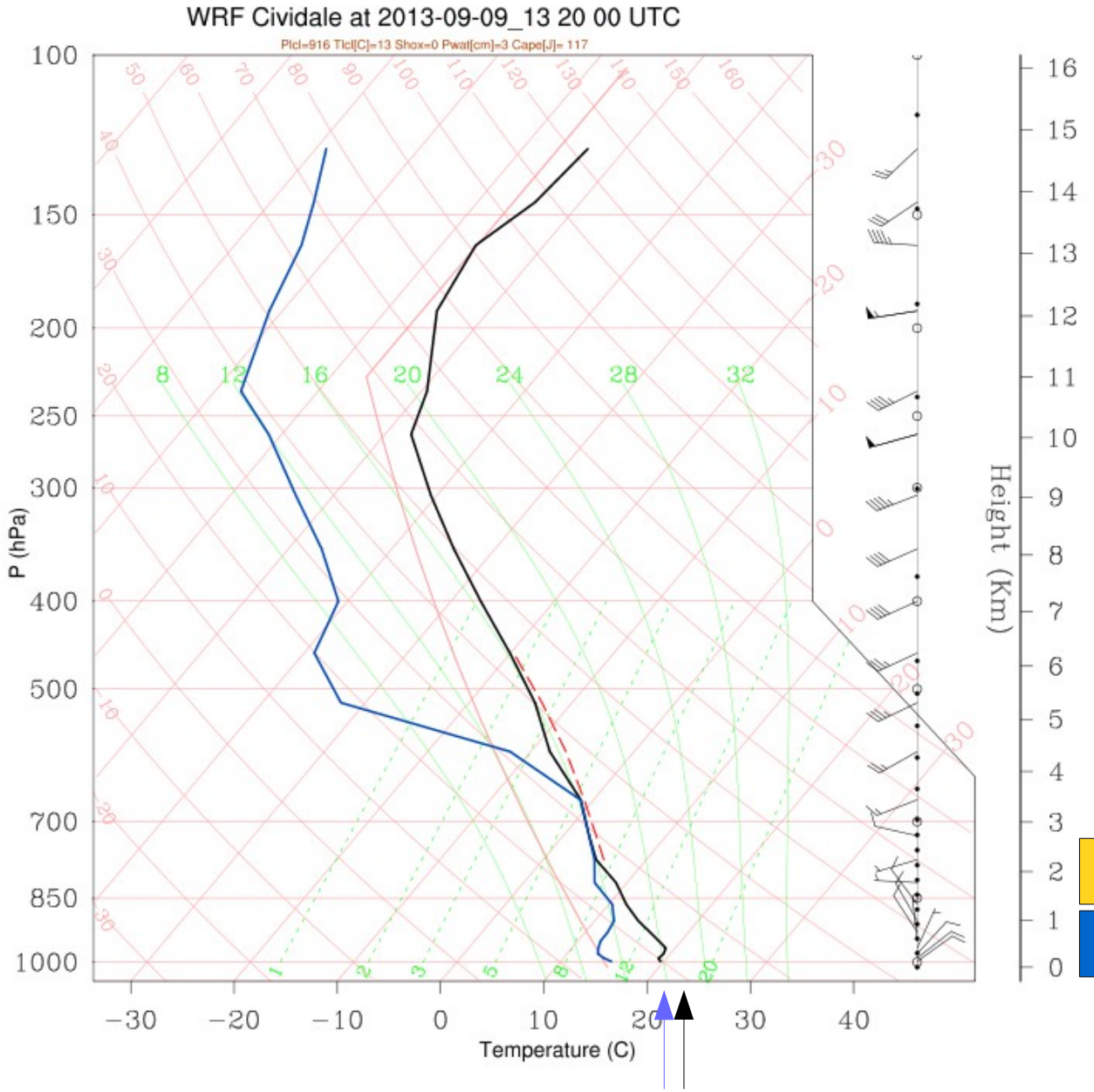

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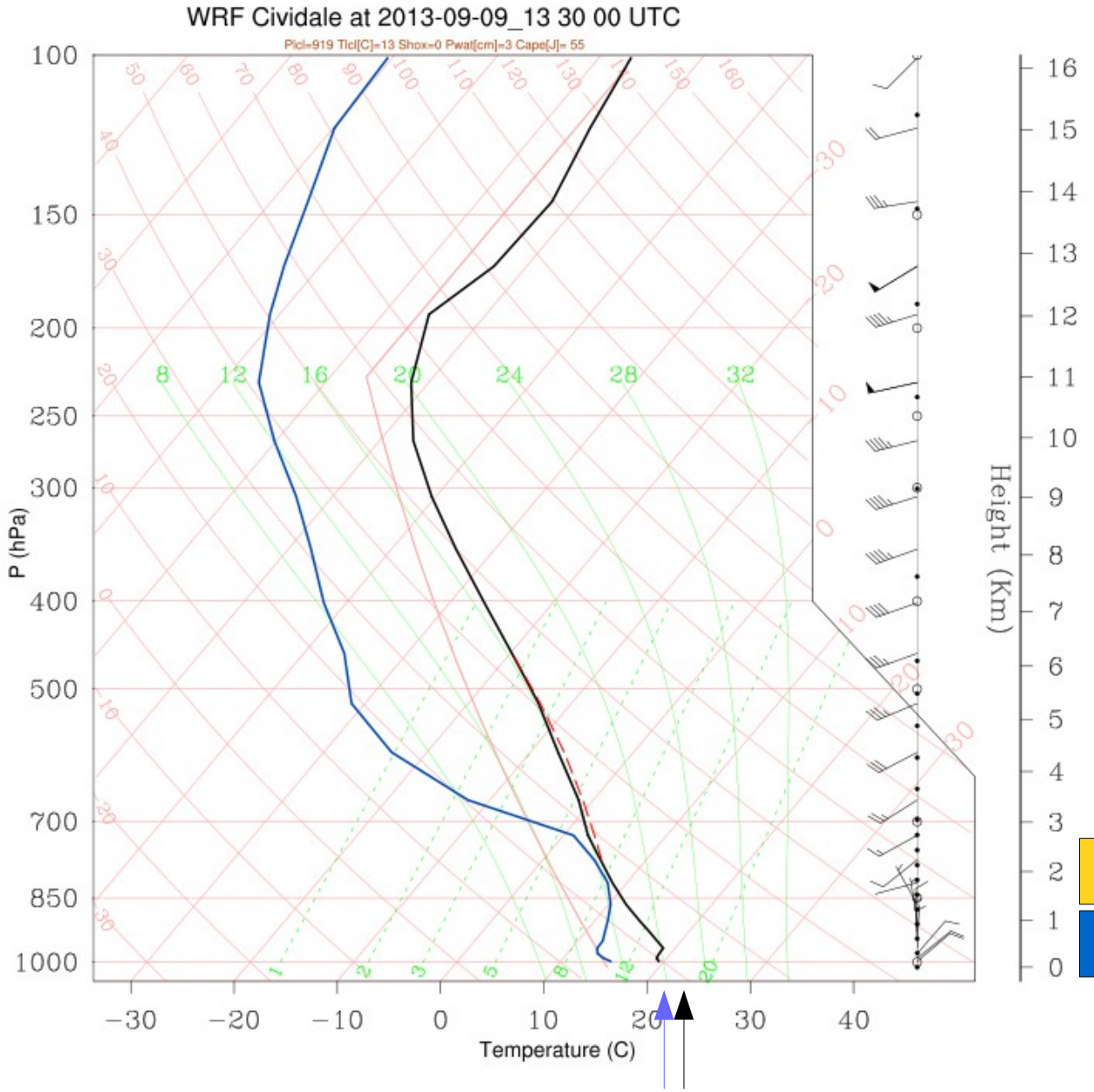
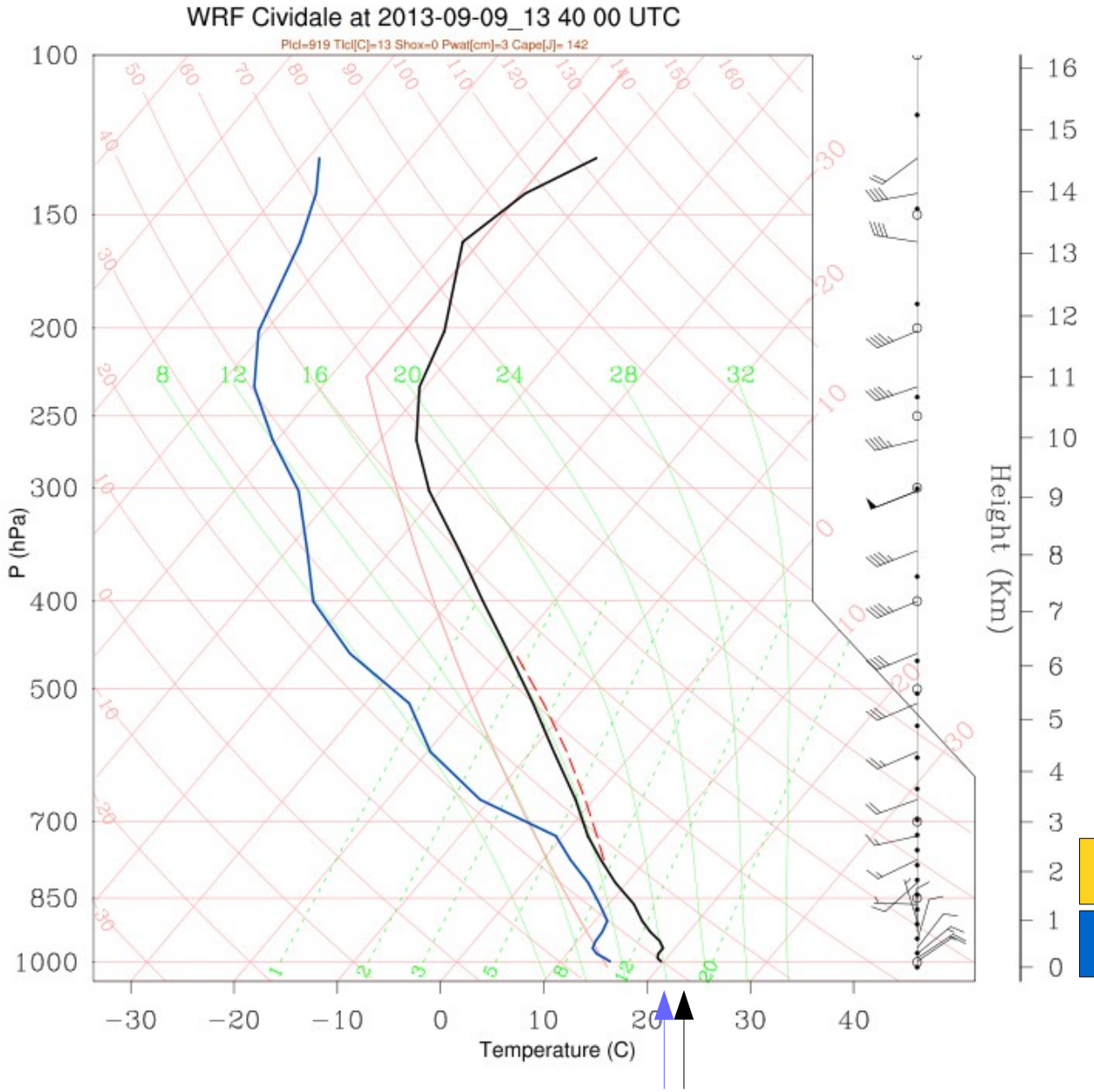


Synoptic flow

Out flow

WRF simulation 0.6 km resolution- Cividale virtual sounding



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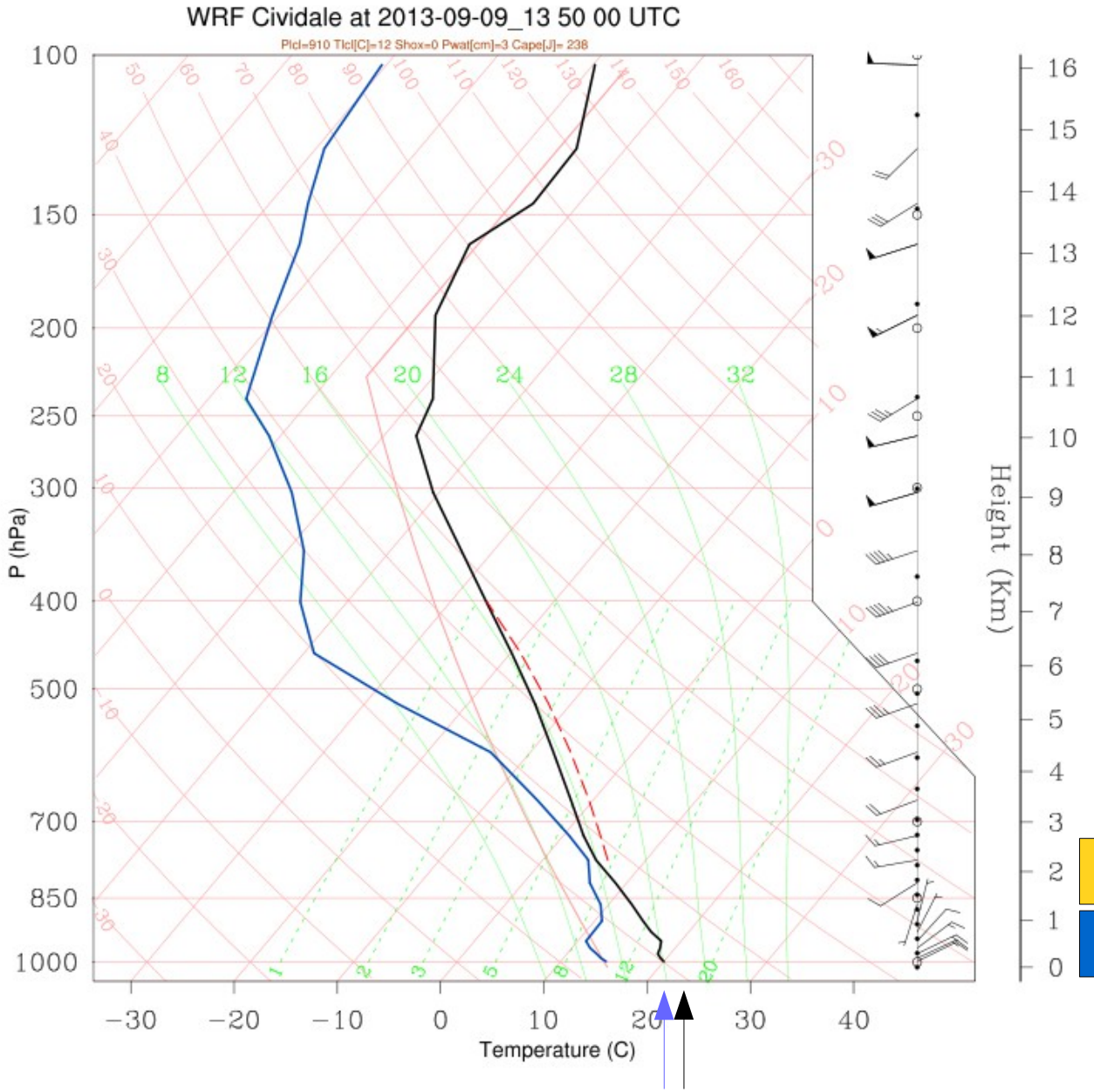

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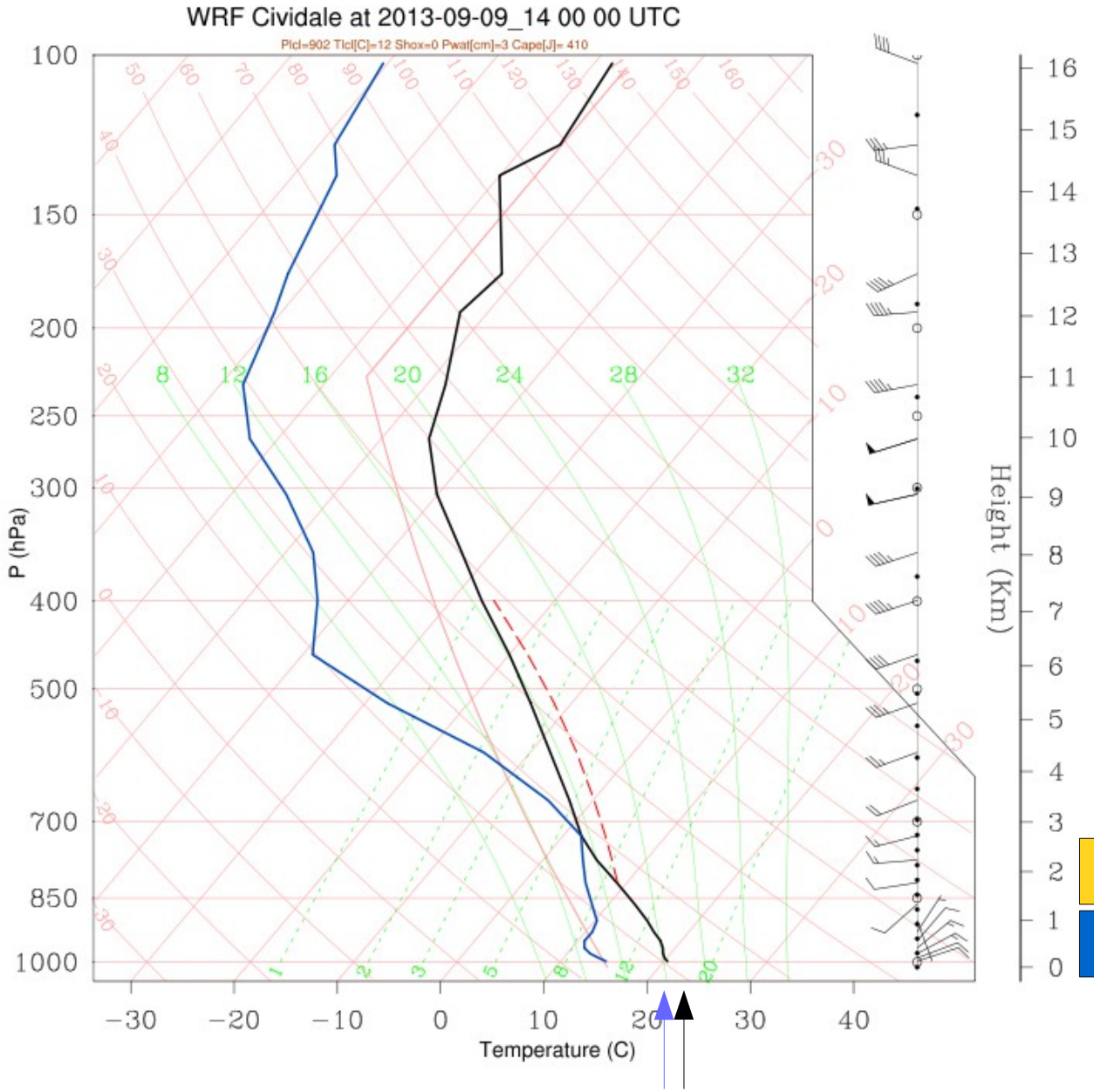

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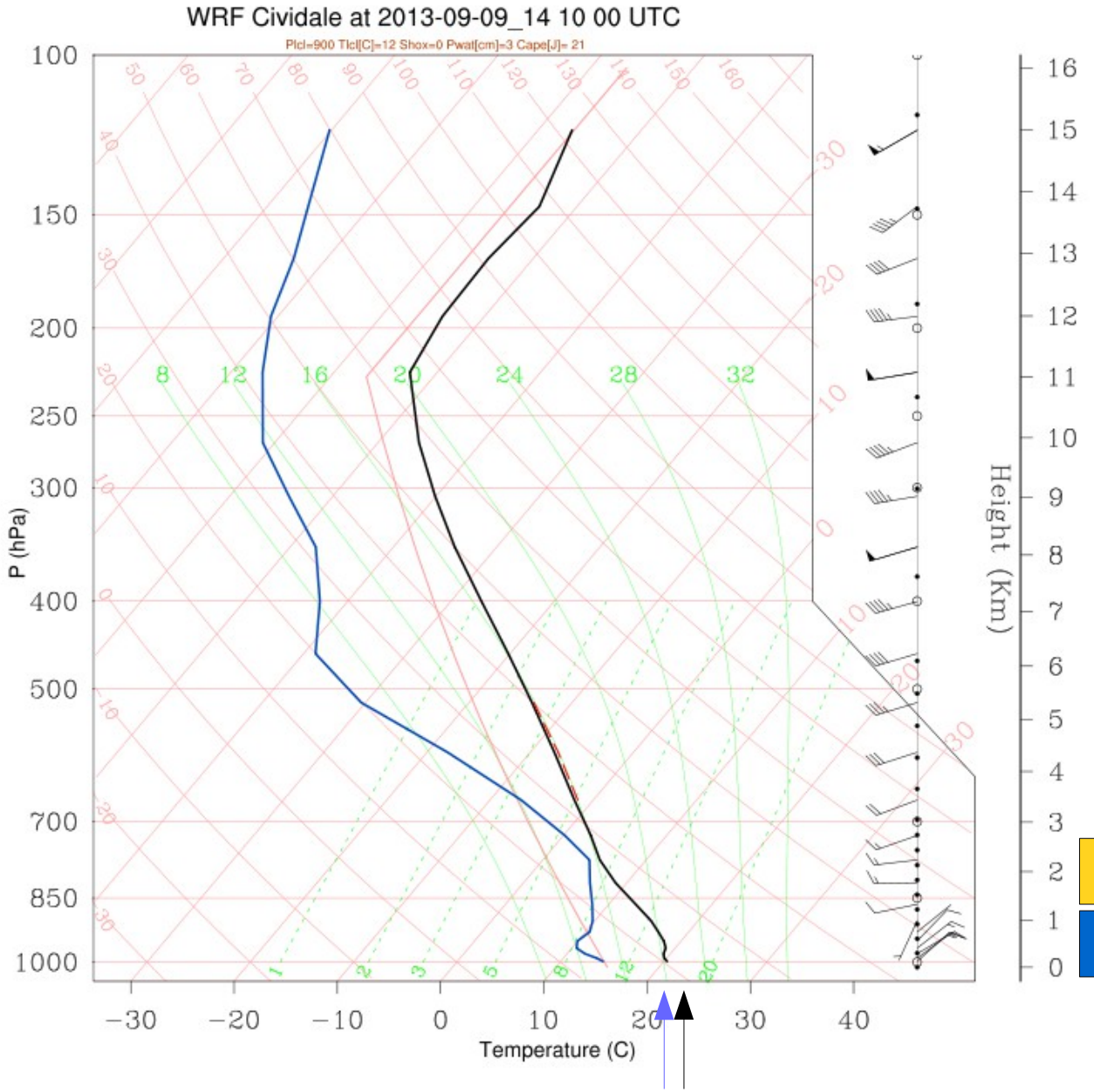

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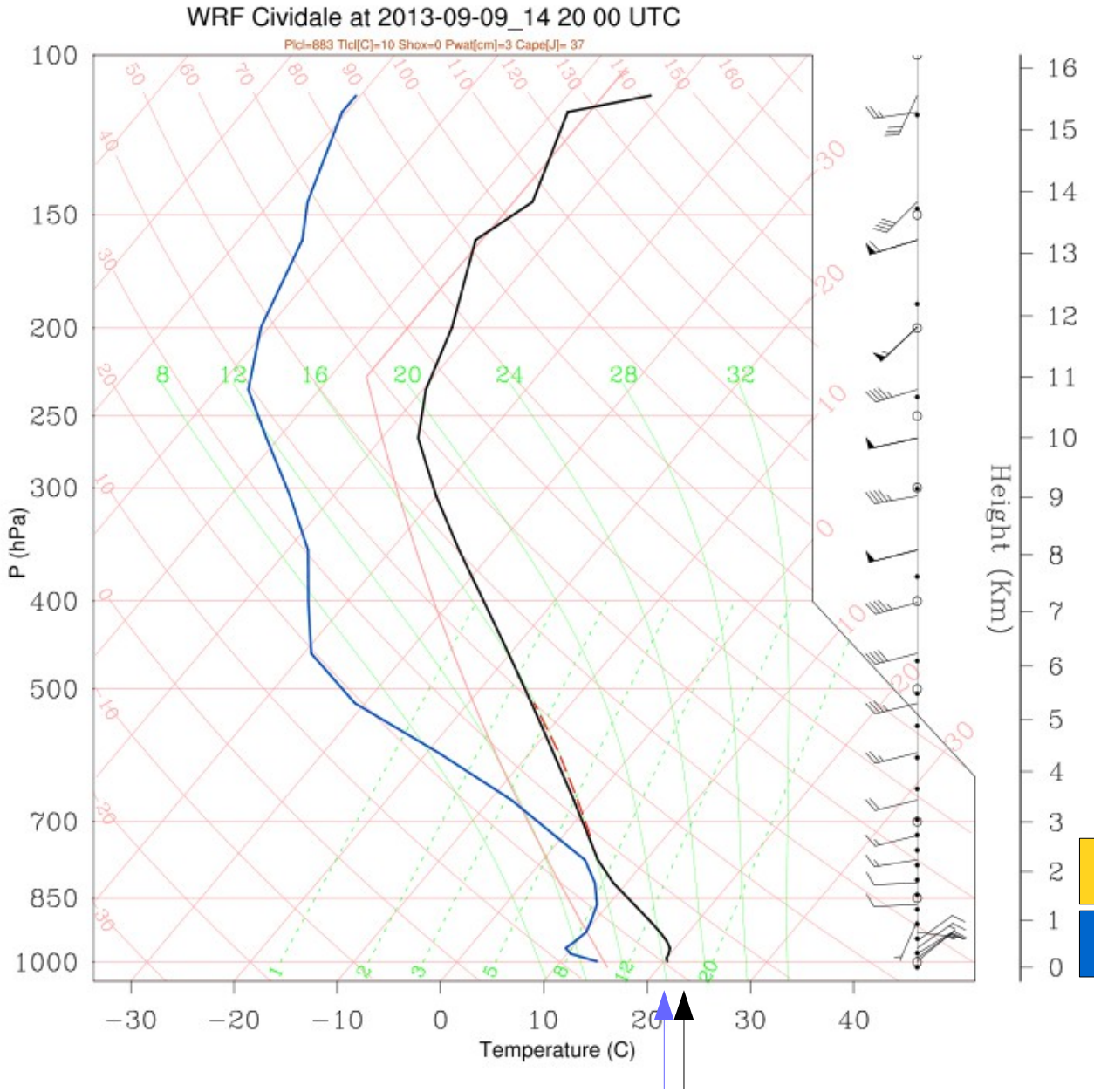

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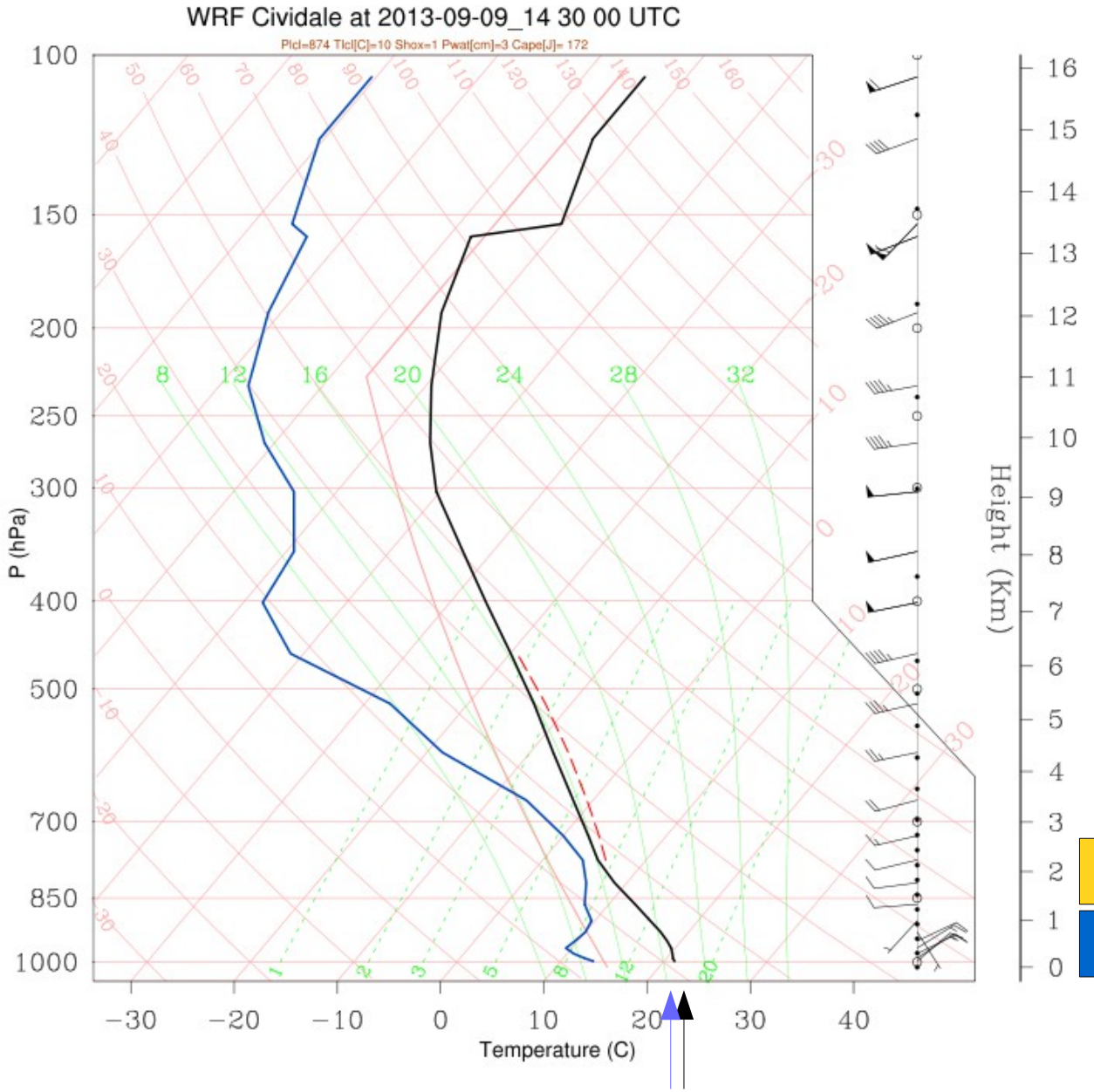
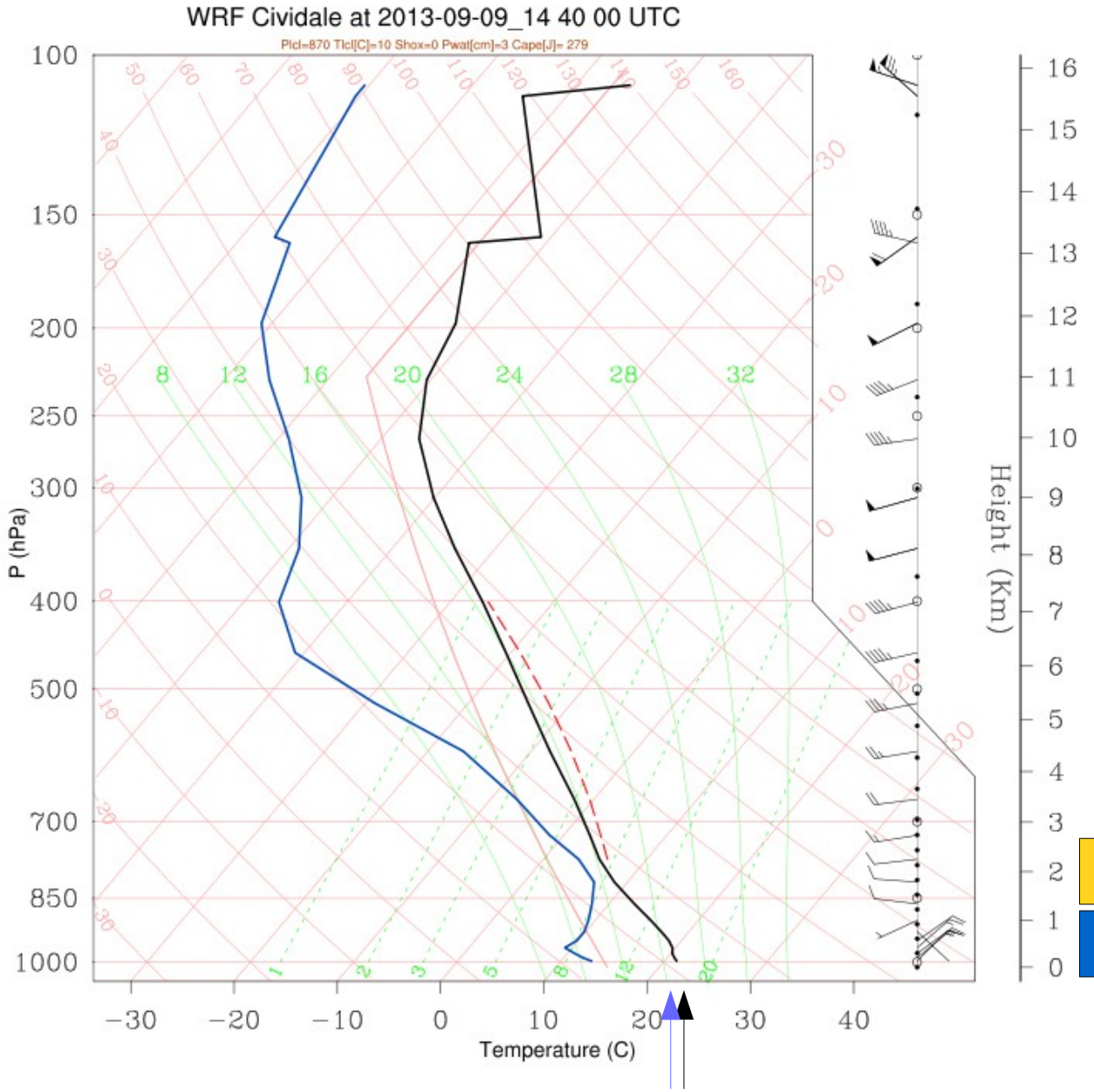


Synoptic flow

Out flow

WRF simulation 0.6 km resolution- Cividale virtual sounding



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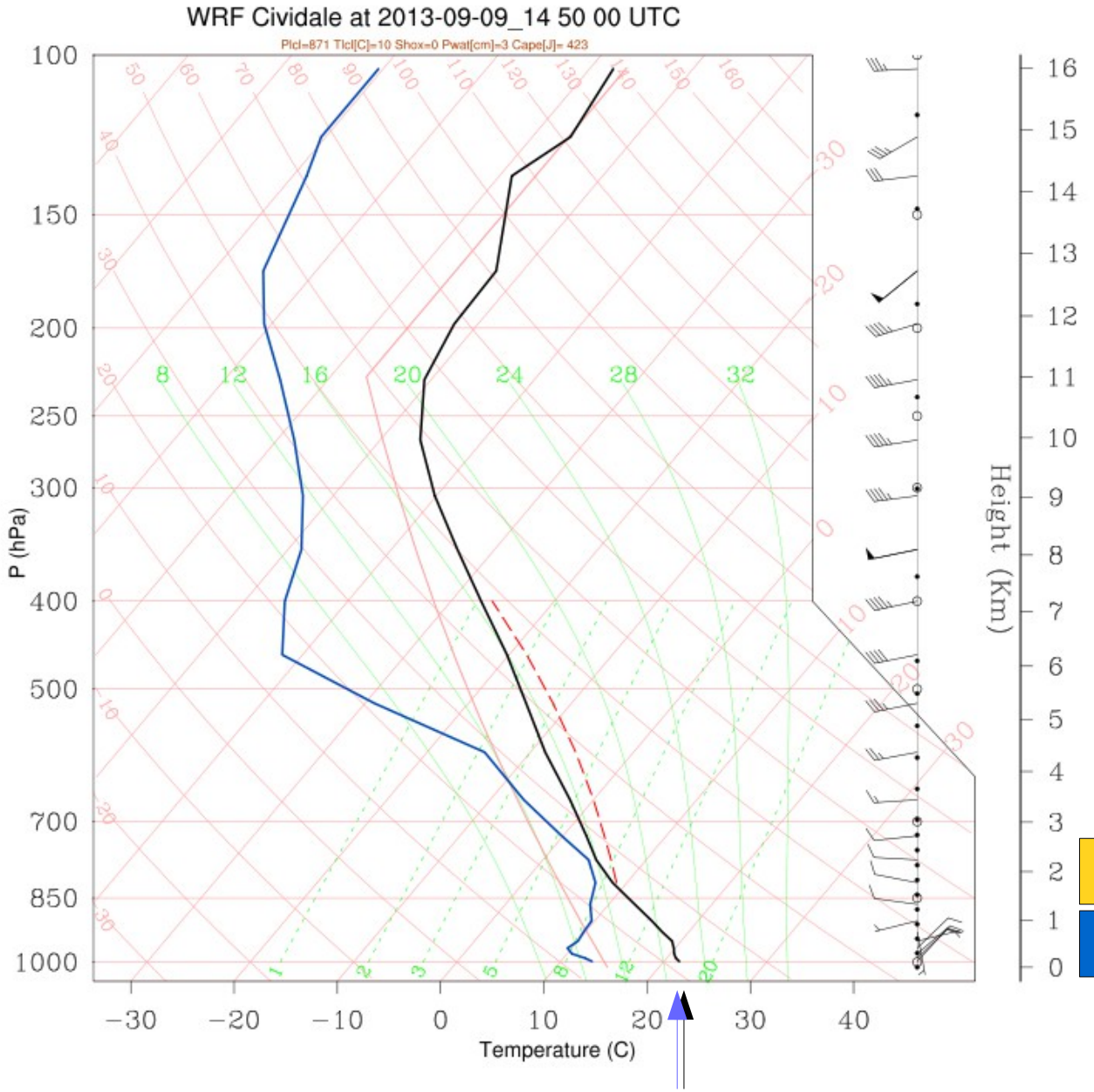

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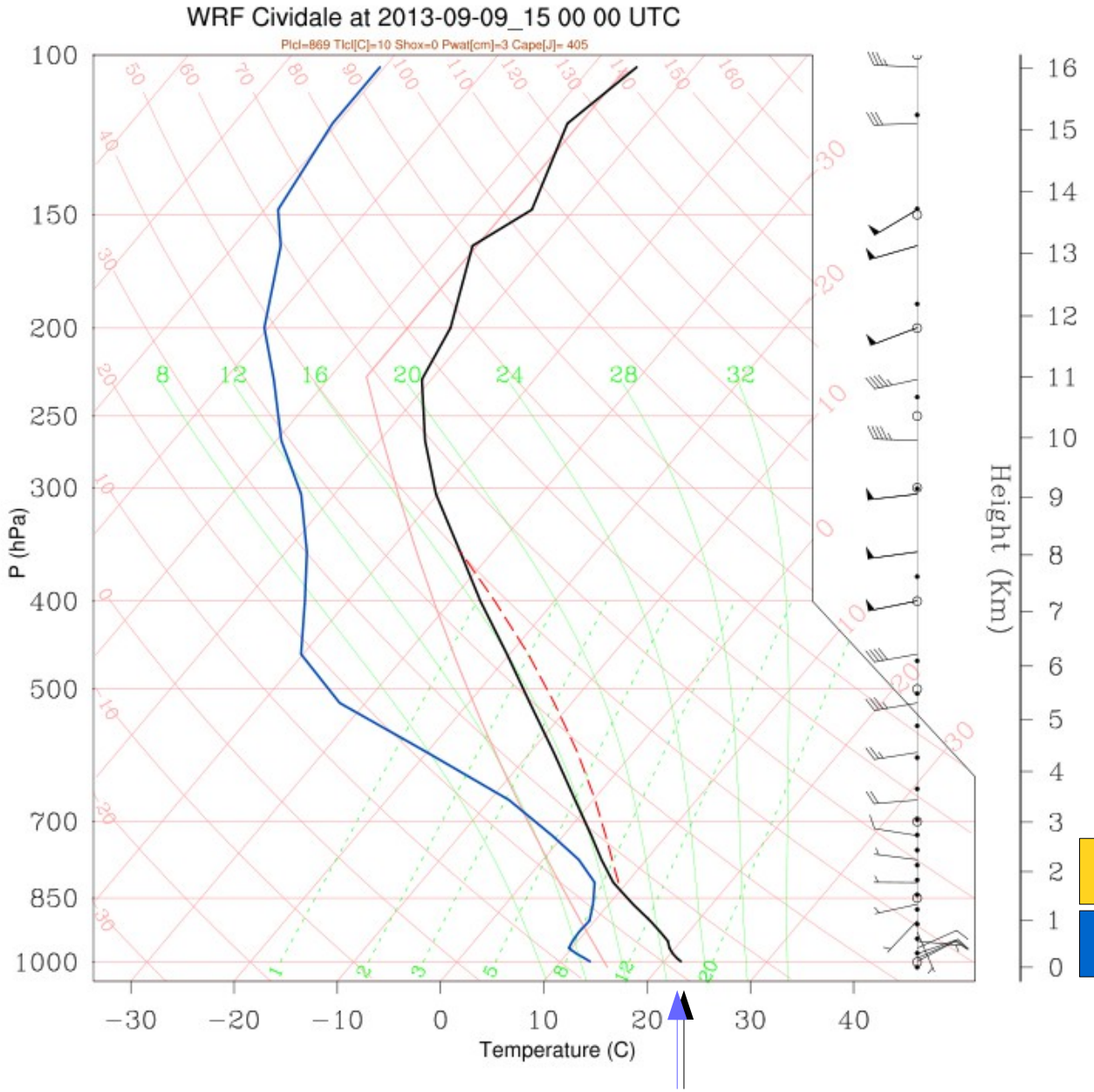

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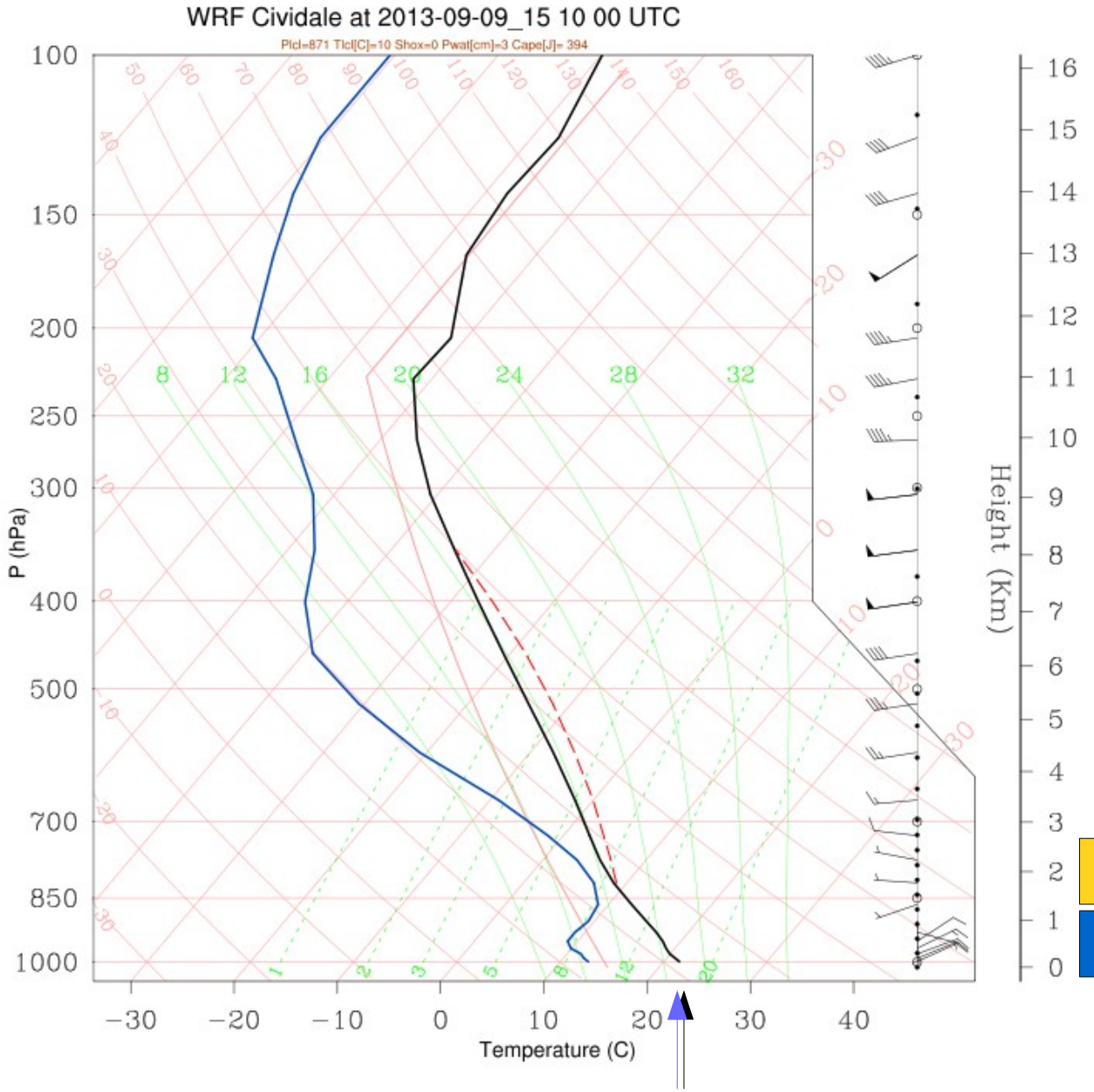
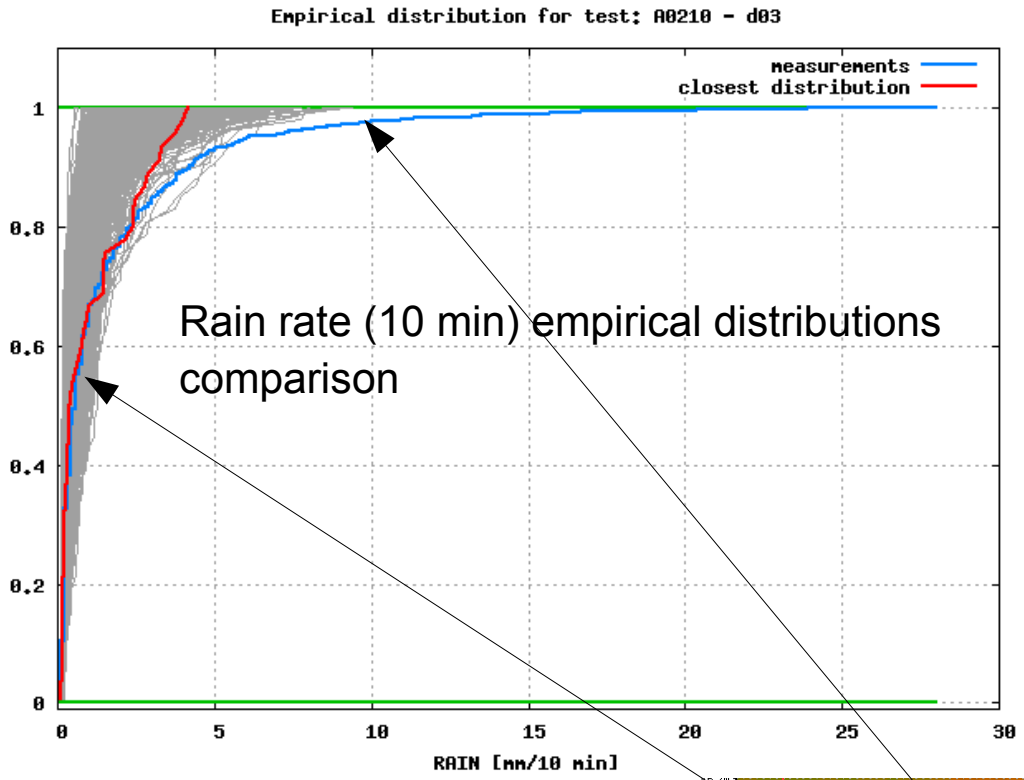
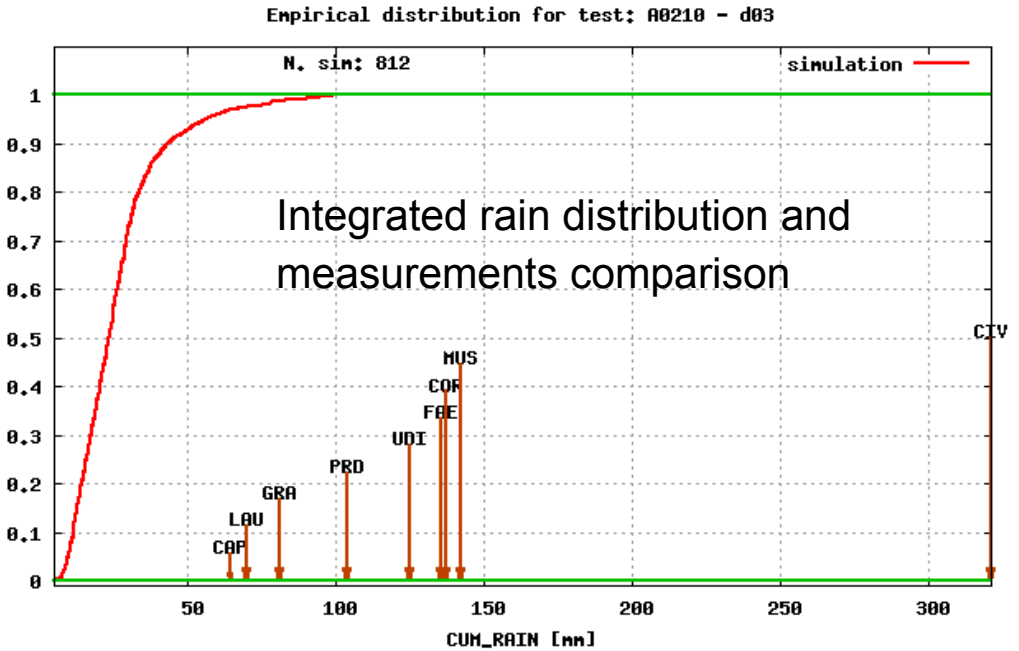


Precipitation rates

The main result is: the model gets close to the reality within the area/time window

Compare all grid points data with the corresponding measurements in the area/time window






```
# Simulations statistics
# Data ;min;0.01;0.05;0.1;0.5;0.9;0.95;0.99;max;ave
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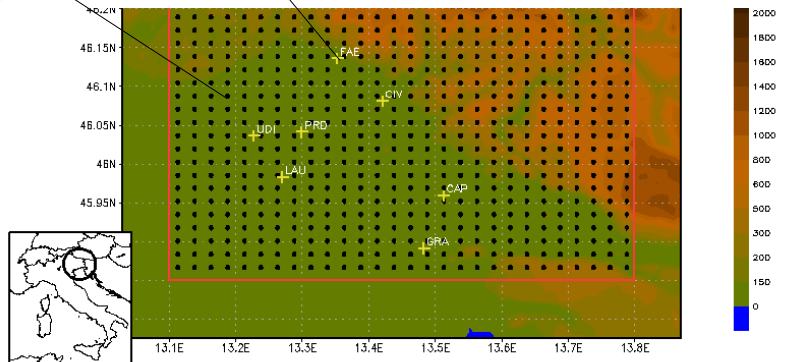


Quantitative statistical tests and statistical estimators are used as closeness measurement

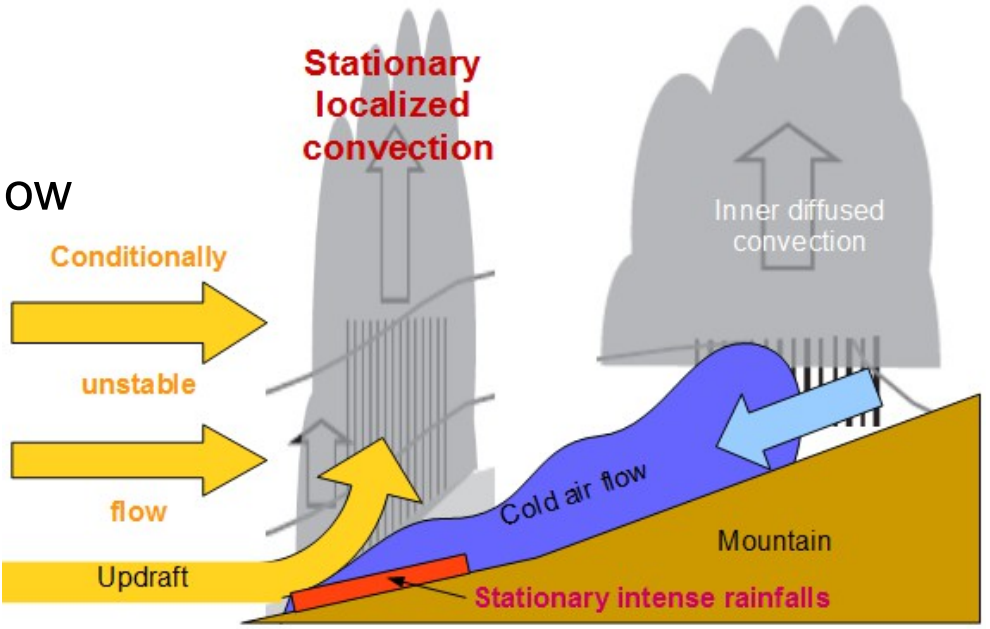
Conceptual model summary

LAMs (WRF) are able to generate simulations close to the reality and support the conceptual model for:

Deep atmospheric convection stationary over the same area

Mandatory elements

- Moist conditionally unstable synoptic flow
- Complex orography



Conceptual model

1. Conditionally unstable air impinging on mountains is lifted up to LFC
2. Deep convection take place and generates diffuse downdrafts
3. Downdraft flows are driven by orography in the boundary layer
4. In the boundary layer, synoptic flows and downdrafts interact lifting unstable air
5. The synoptic flow and the downdraft interact stationary in a restricted area

- The area interested by the interaction is a function or synoptic flow intensity, and stability, the cold air outflow and the orography shape.