Meteorologisches Institut
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DAQUA

Physical Initialization Bonn (PIB) Results using Identical Twin experiments

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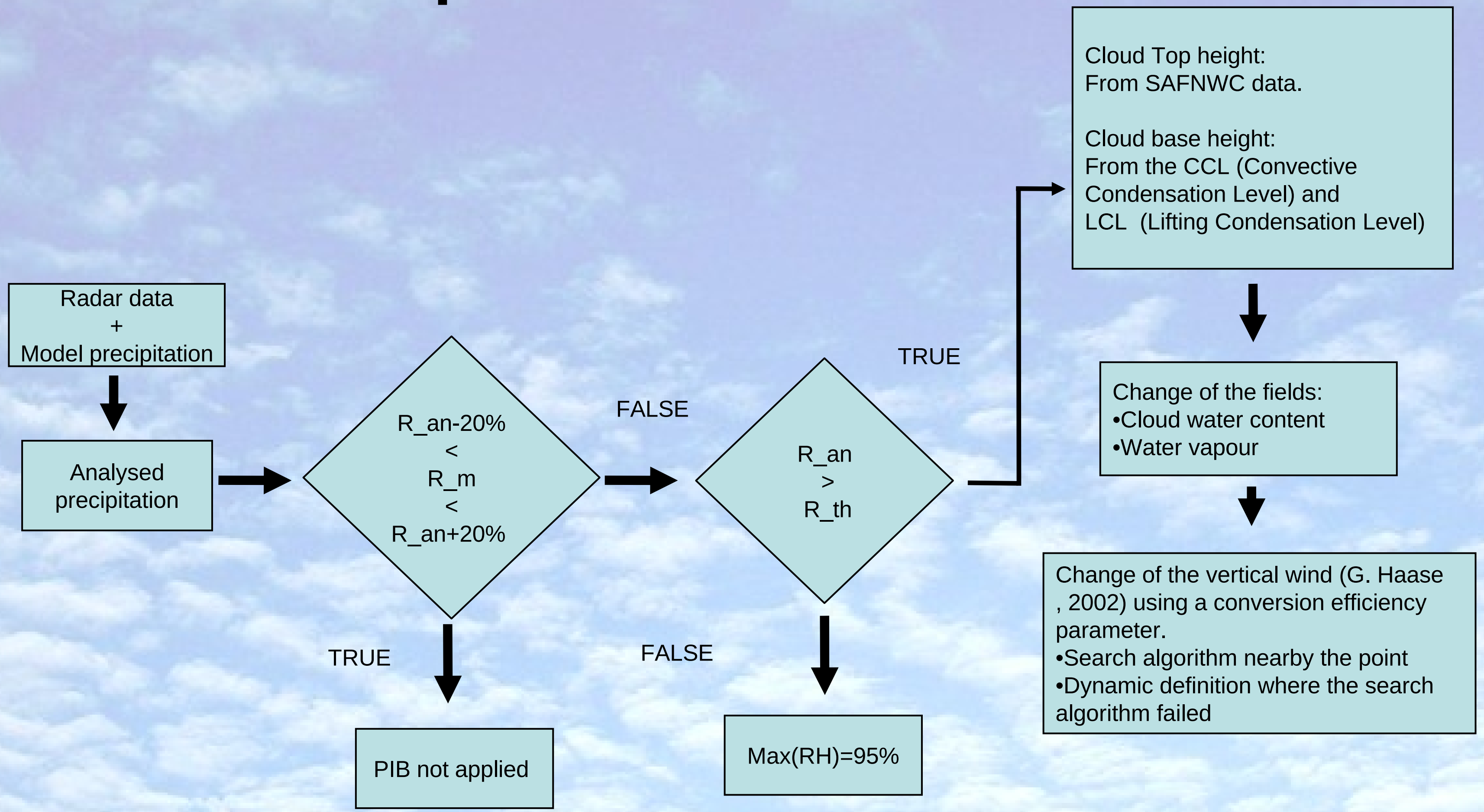
Motivation

- Work in DAQUA project. „Schwerpunkt programm“.
- Improvement of QPF.
- Reduction of spin up.
- Use in nowcasting and short range forecast.

Description of the scheme



R_an = analysed precipitation
R_th = threshold for the precipitation (0.1 mm/h)
R_m= model precipitation
RH = relative humidity

Simple cloud model

- Cloud top height:

The PIB uses the observation of Meteosat second generation (SAFNWC product form DWD).

- Cloud base height:
  - Search algorithm in the nearby points.
  - LCL (Lifting Condensaton Level) and CCL (Convective Condensation Level) often agree closely with one another (Rogers and Yau,1989).
  - Approximation for LCL.
  - Approximation for CCL.
  - Use the average and a correction for cloud thickness

Water vapour

The water vapour content is changed in this way:

- From the cloud bottom to the cloud top, the specific humidity is set to saturation.

- Below the cloud bottom the specific humidity is set to the saturation value of the cloud bottom. It is assumed that the specific water vapour content is a conservative quantity in the PBL, it is well mixed.

- Above the cloud top the specific humidity is set taking into account that the maximum of the relative humidity can be 95%.

Vertical wind

The vertical wind inside the clouds is changed using the following equation (*G. Haase, 2002*), with a do cycle from cloud top to cloud base:

$$\hat{w}_k = \left(\rho^*_{v,k}\right)^{-1}\left\{\rho^*_{v,k-1}\hat{w}_{k-1} - \left(z_{k-1} - z_k\right)\frac{R\left(z_{cb}\right)}{z_{ct} - z_{cb}}\left[1 - \frac{\pi}{2}\left(1 + \frac{1}{c}\right)\sin\left(\frac{\pi}{2}\frac{z_{k-1/2} - z_{cb}}{z_{ct} - z_{cb}}\right)\right]\right\}$$

with

$$c = \left.\frac{R}{\rho^*_v \hat{w}}\right|_{z=z_{cb}} \qquad [0.25,1]$$

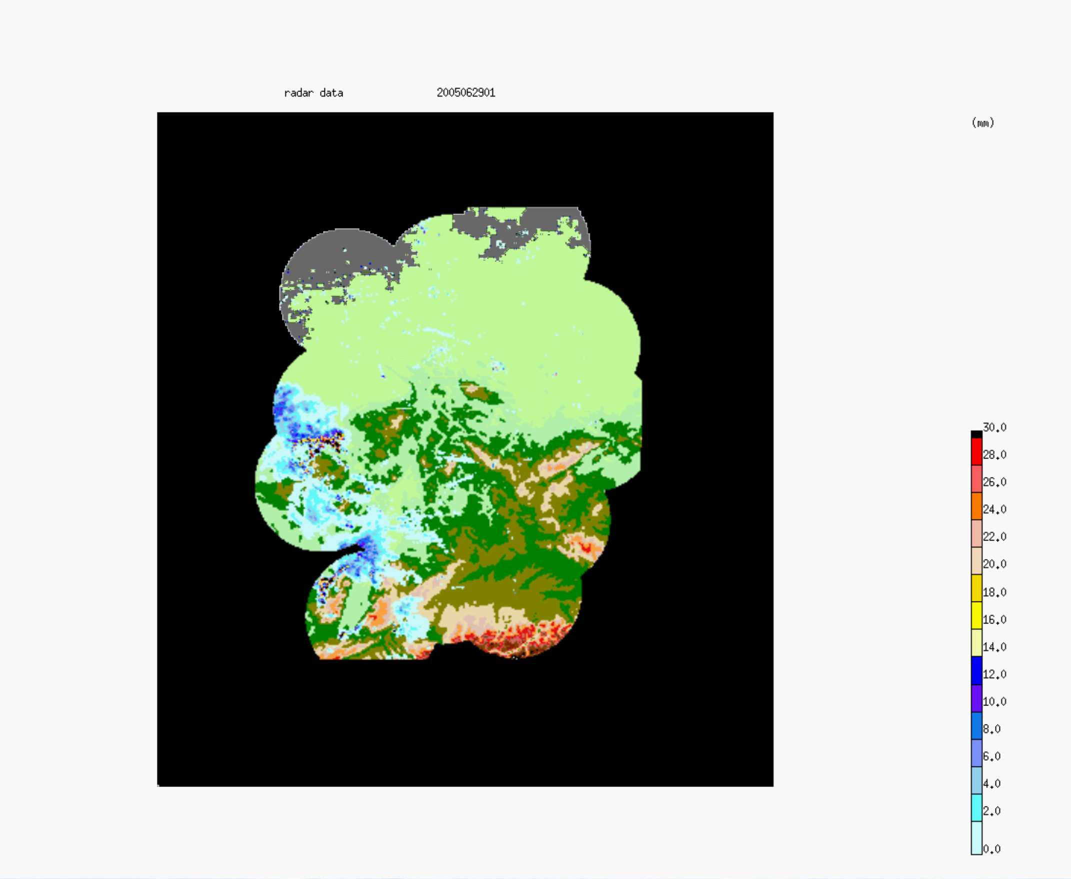
c conversion efficiency of saturated water vapour into rain water, ρ_ν^* partial densities of saturated water vapour, **R** precipitation flux, $\mathbf{z_{ct}}$ height of the cloud top, $\mathbf{z_{cb}}$ height of the cloud bottom and **w** vertical wind.

The c parameter is arbitrary at the first time step then adjusted taking into account the quality of the forecast.

Below the cloud the vertical wind is calculated with a linear interpolation.

Above the cloud the vertical wind is set to 0

29/06/2005



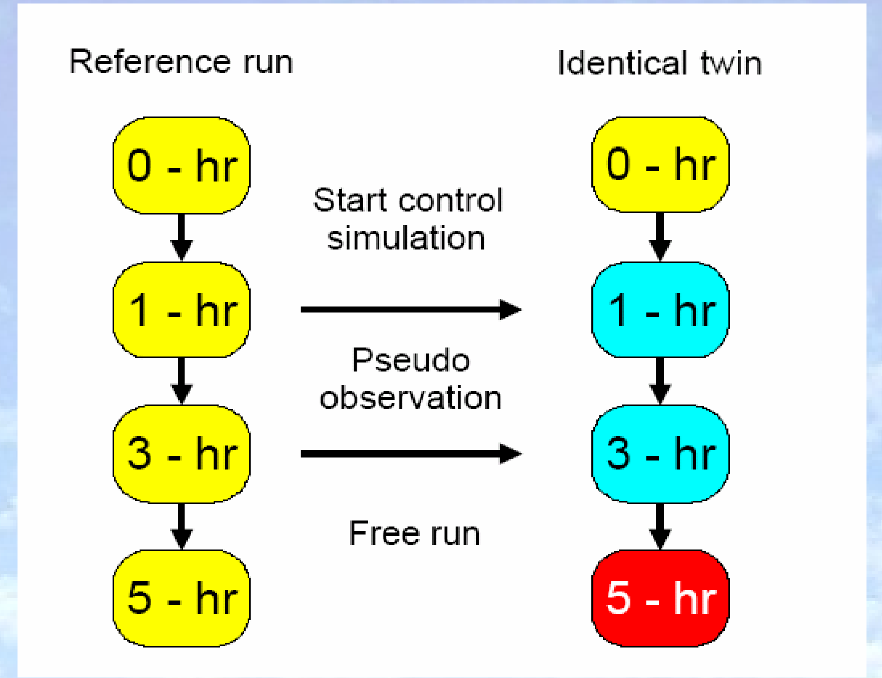
- Convective line moves across south and middle Germany.
- Event between 1 and 10 UTC.
- High temperature in southwest Germany in the afternoon of the day before.
- Very bad forecast for this event.

19/08/2005

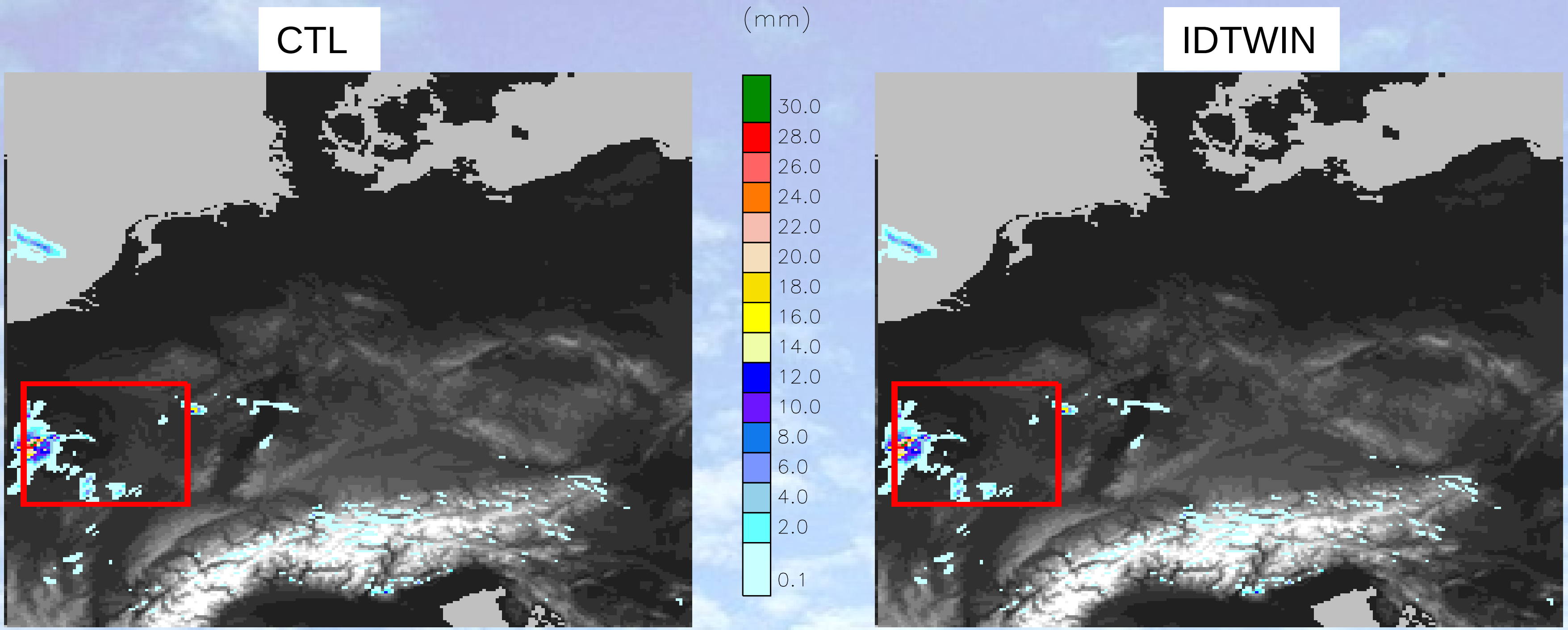
- Cold front in the west part of Germany.
- Precipitation during the day, from 12:00 to 21:00 UTC.
- Presence of multicells

Identical Twin

- The PIB scheme must be consistent with the NWP model. Cosmo model, the former LM3.15.
- Five hours control run. The reference simulation.
- The output from the control run (cloud top height and precipitation) is now the input of the new run. The reference simulation is assumed perfect.
- Run of LM with the use of PIB (the Identical Twin). 1hr control run, 2hr assimilation window, 2hr free forecast.
- PIB applied in all the points with precipitation, not only where the error is greater then 20%.

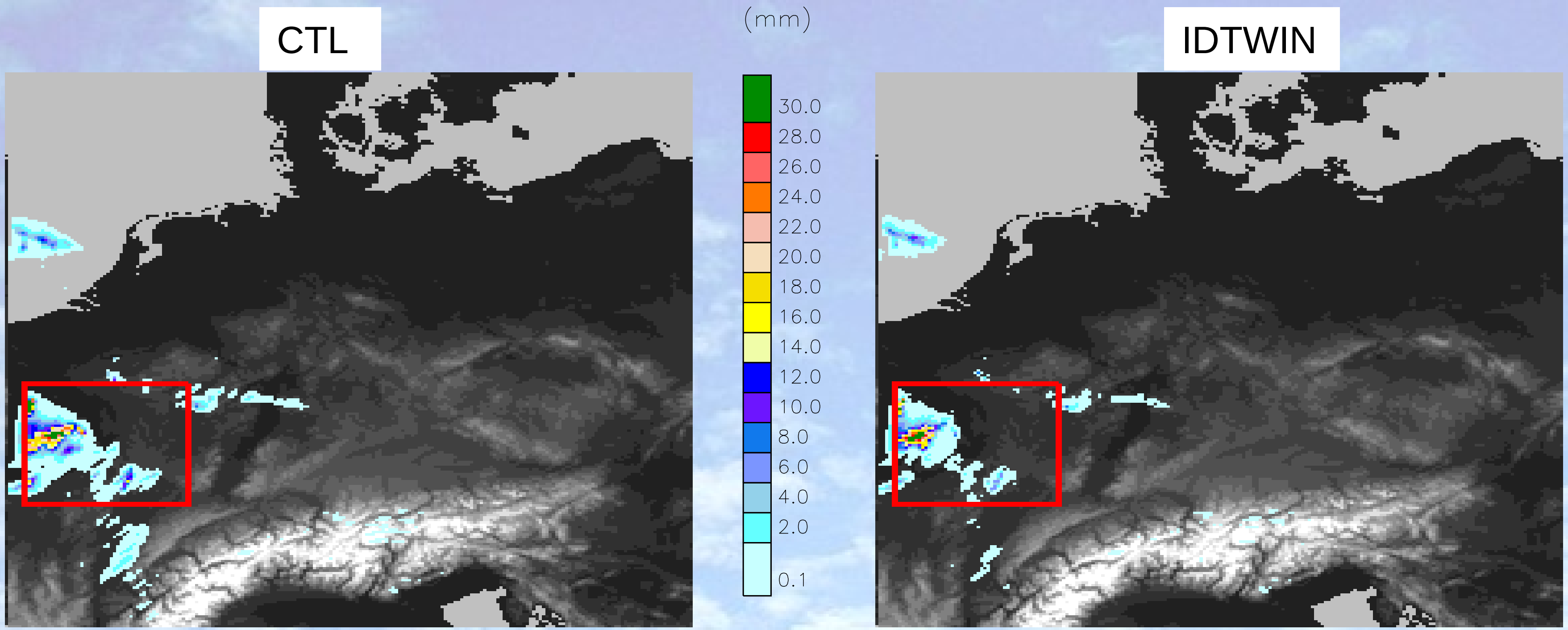


2005062902 Assimilation window



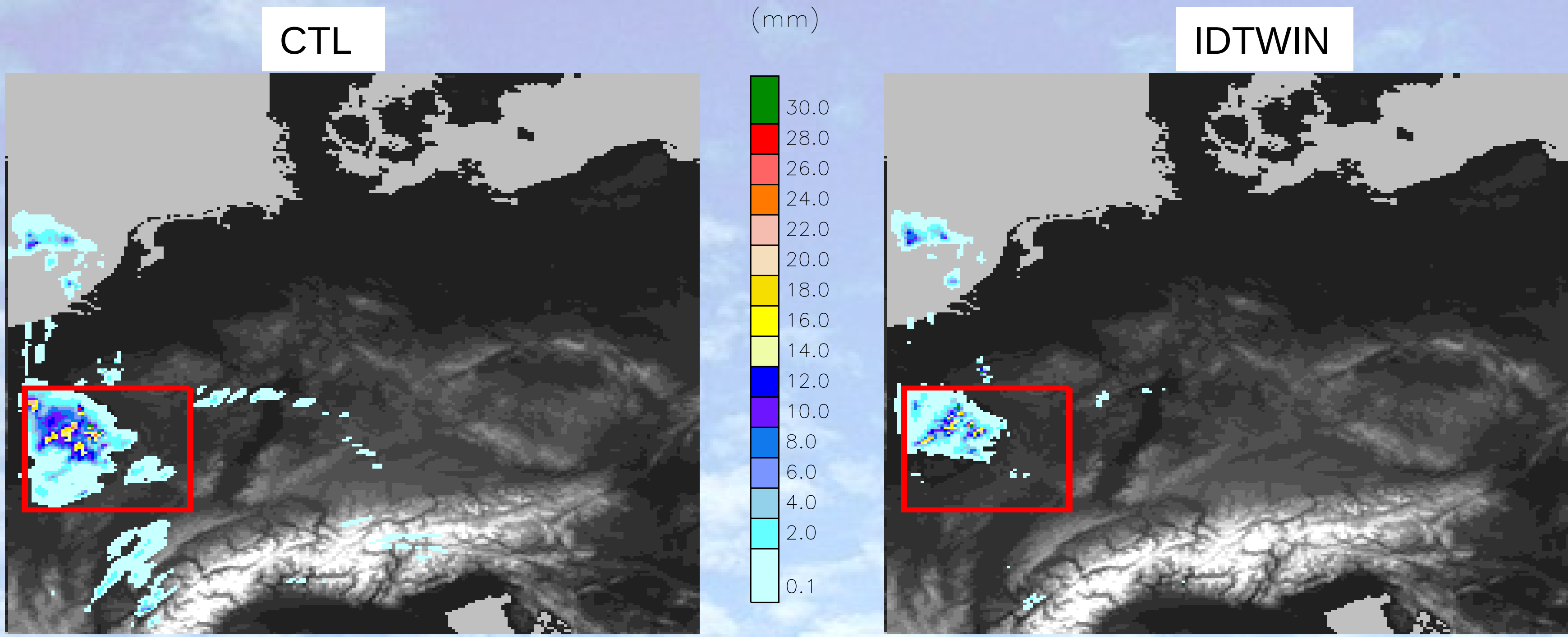
- Good performance for the precipitation area.
- Slight underestimation for the regions with low precipitation.

2005062903 Assimilation window



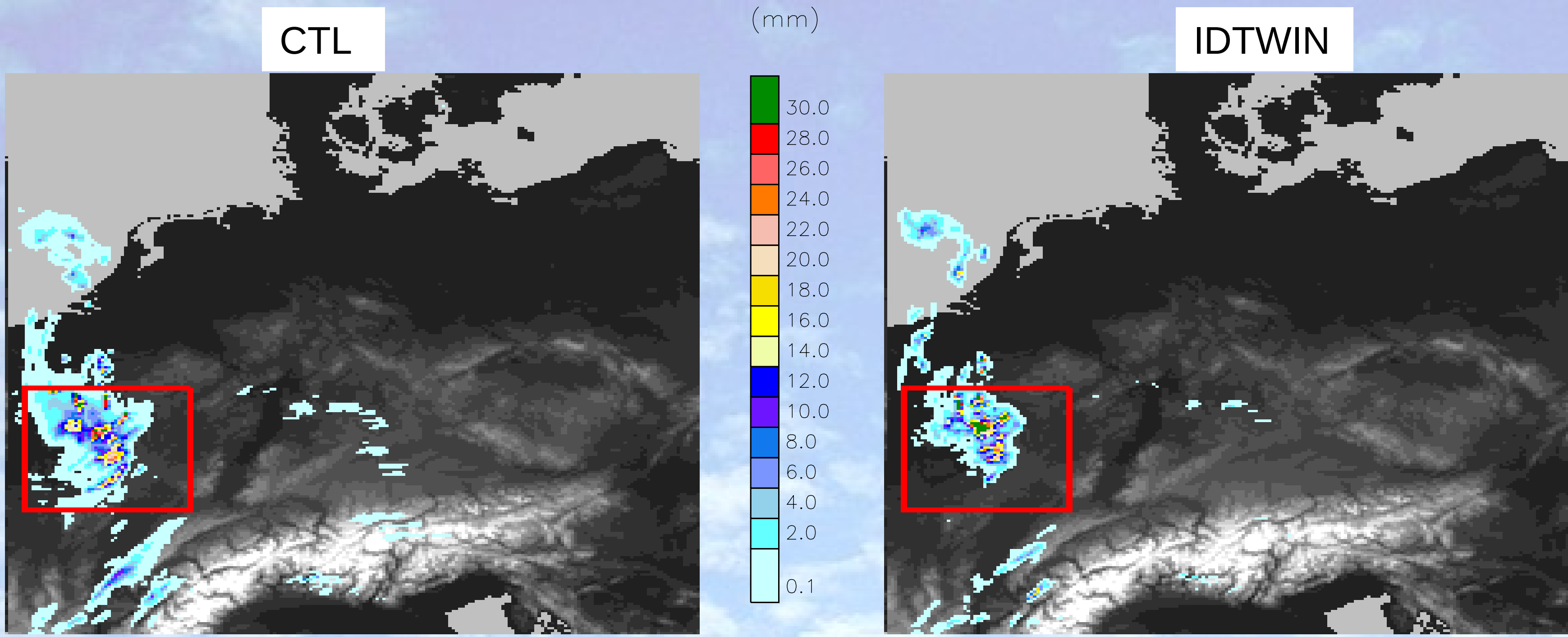
- Good performance for the precipitation area.
- Slight underestimation for the regions with low precipitation.

2005062904 Assimilation window



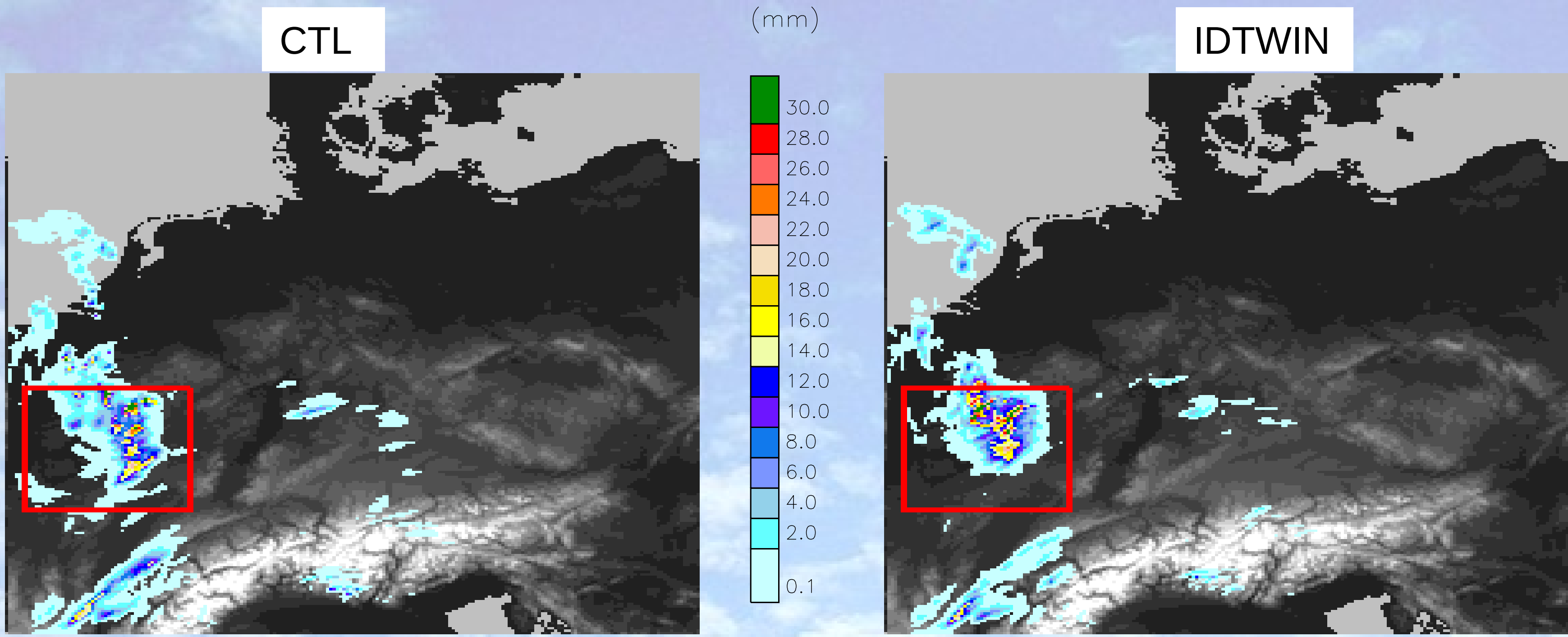
- Good performance for the precipitation area.
- Slight underestimation for the regions with low precipitation.

2005062905 Free run



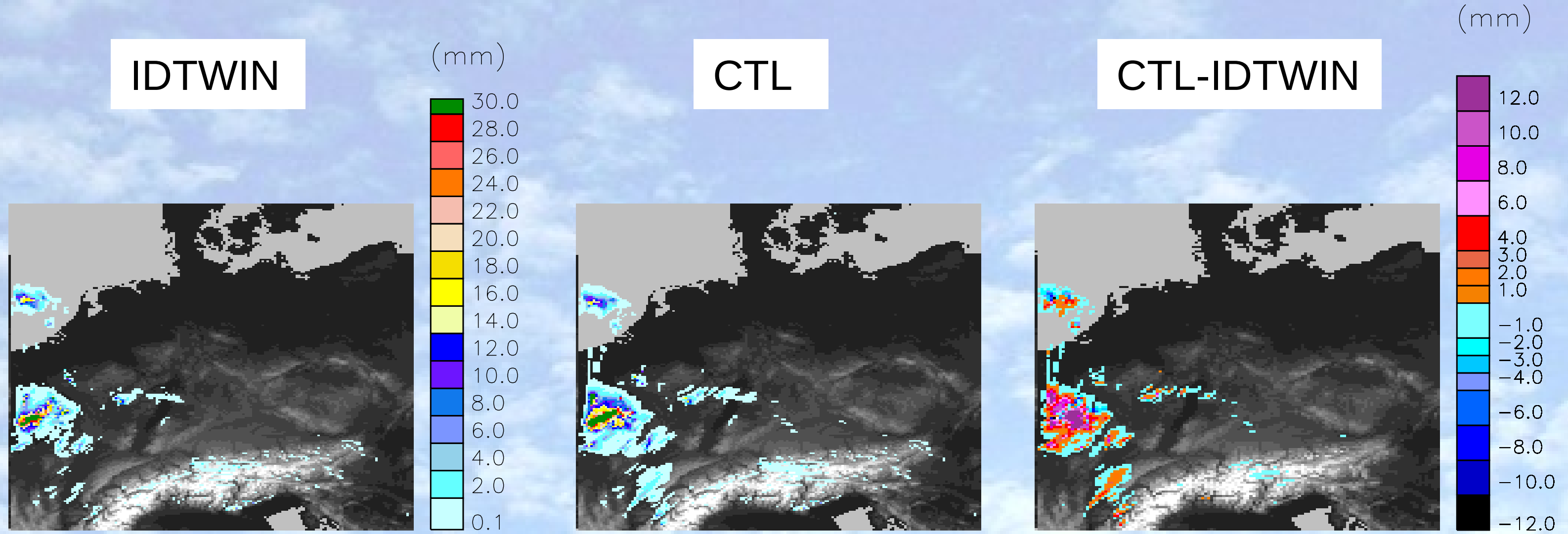
- Good performance for the precipitation area.
- Slight underestimation for the regions with low precipitation.

2005062906 Free run



- Good performance for the precipitation area.
- Slight underestimation for the regions with low precipitation.

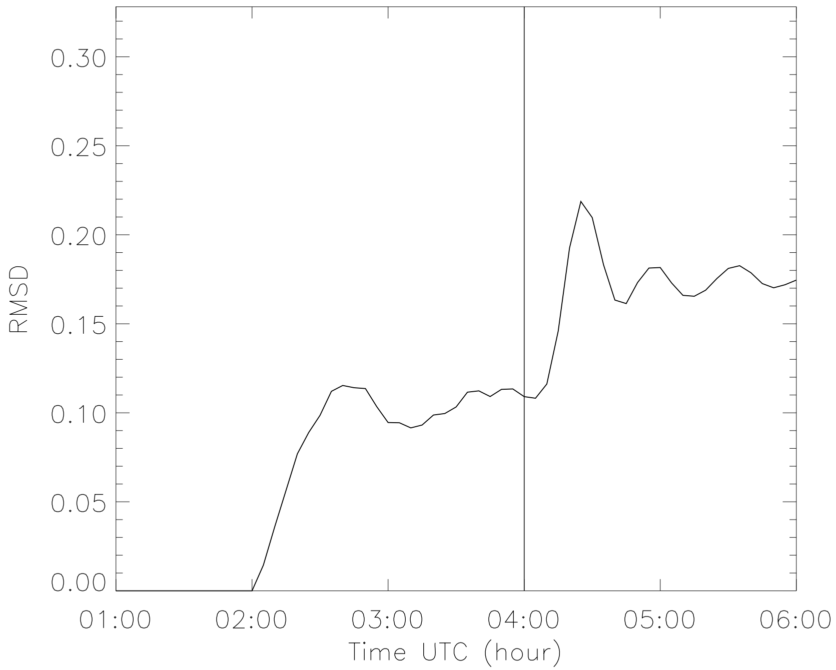
Precipitation in assimilation time



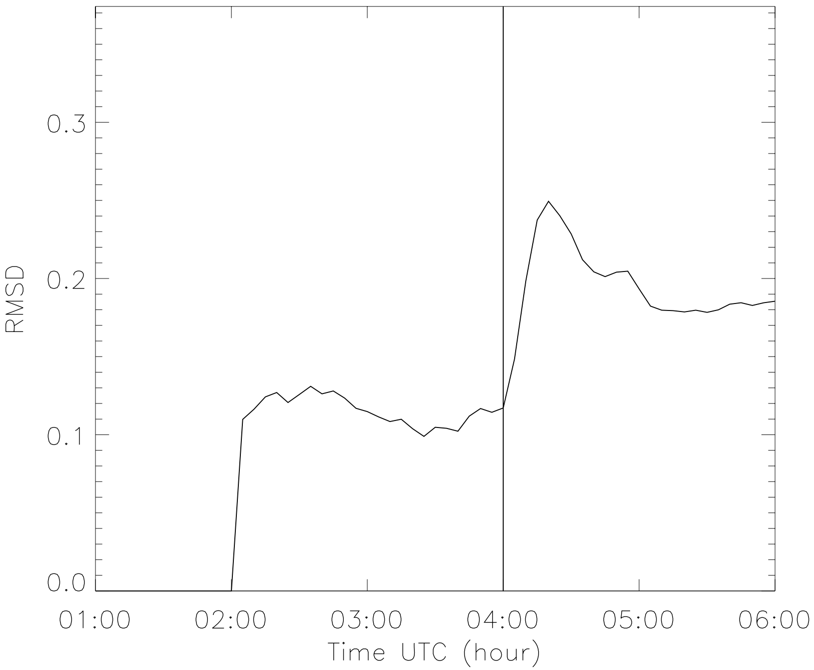
- Very good approximation.
- General underestimation of the precipitation.

RMSD

Precipitation

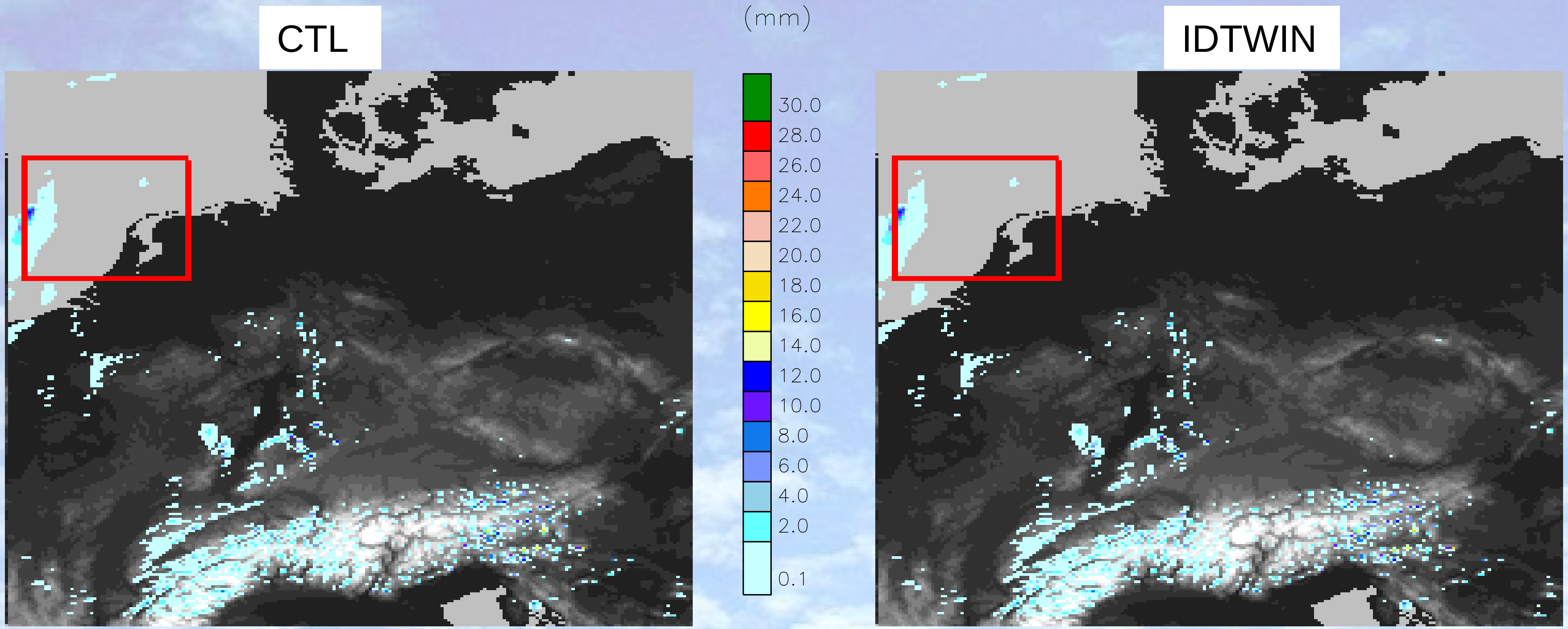


Vertical wind



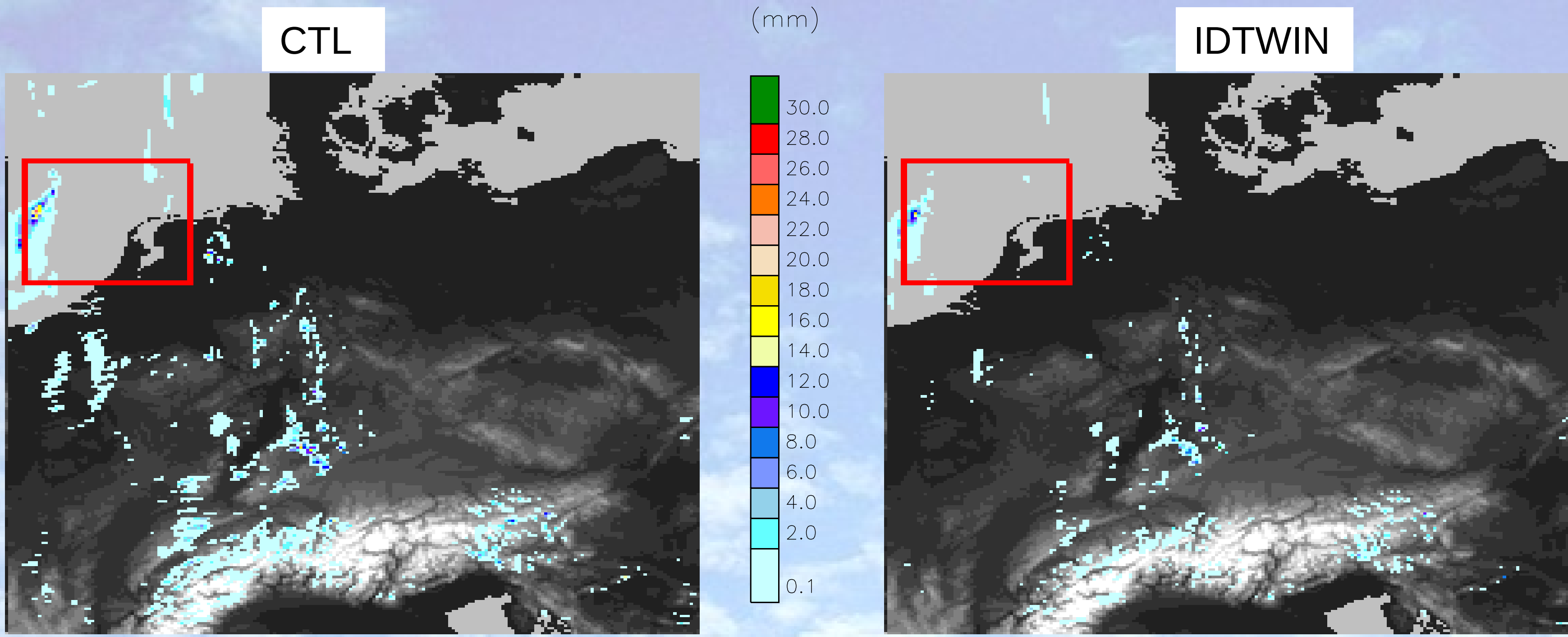
- Fast increase of the differences at the beginning of the assimilation.
- Peak after the assimilation window.

2005081913 Assimilation window



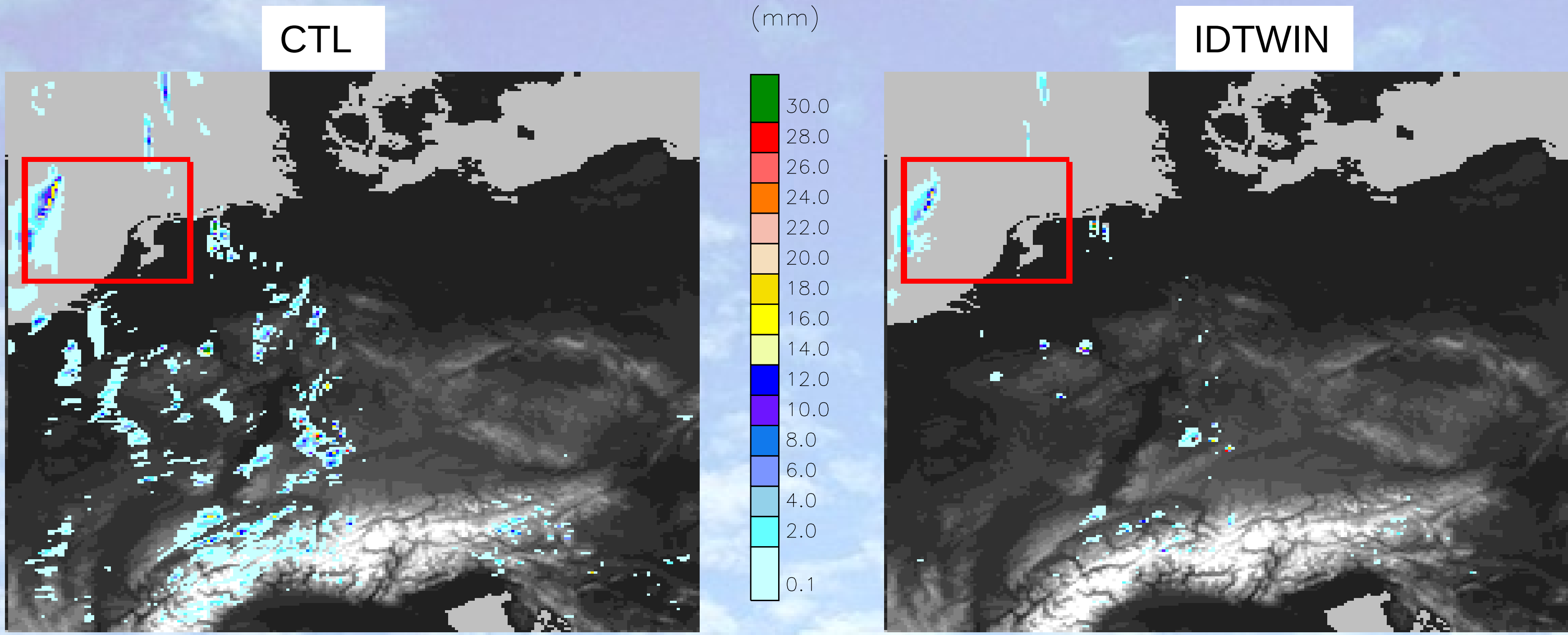
- We can assimilate the strong convection.
- Problems for the small isolated cells.

2005081914 Assimilation window



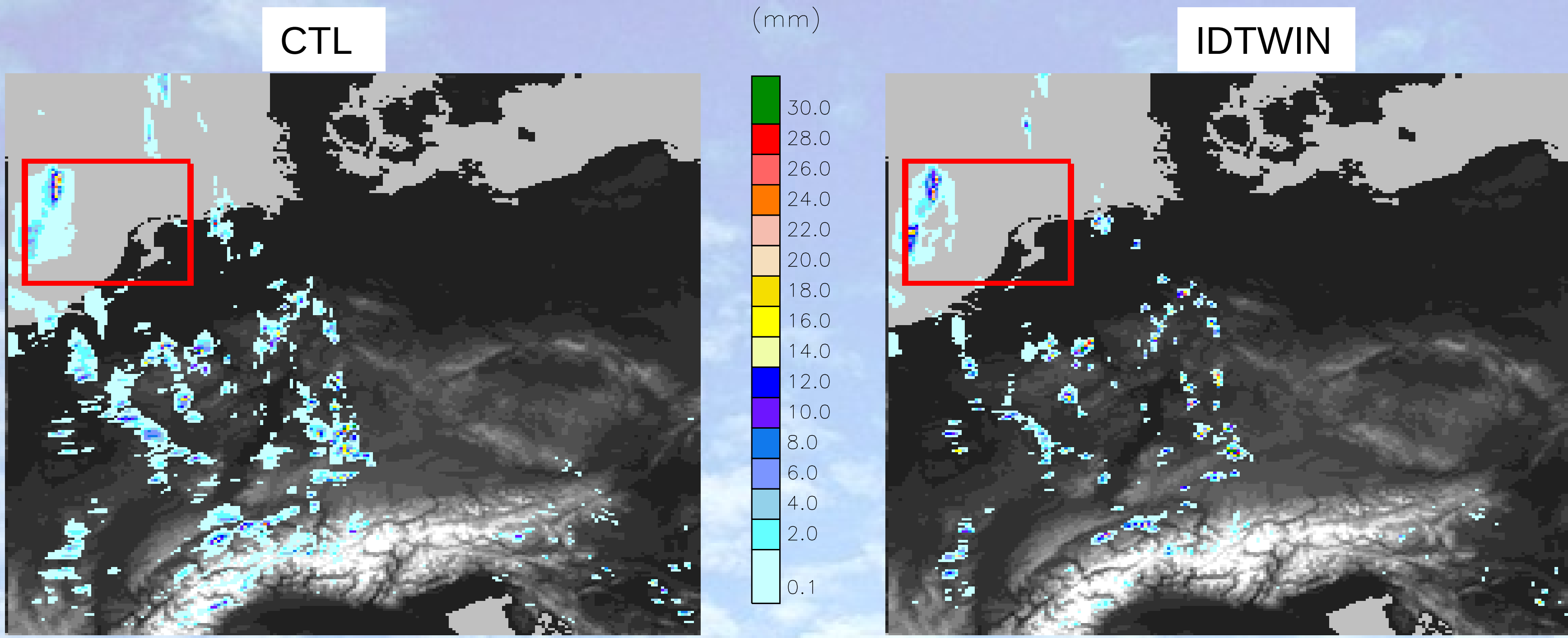
- We can assimilate the strong convection.
- Problems for the small isolated cells.

2005081915 Assimilation window



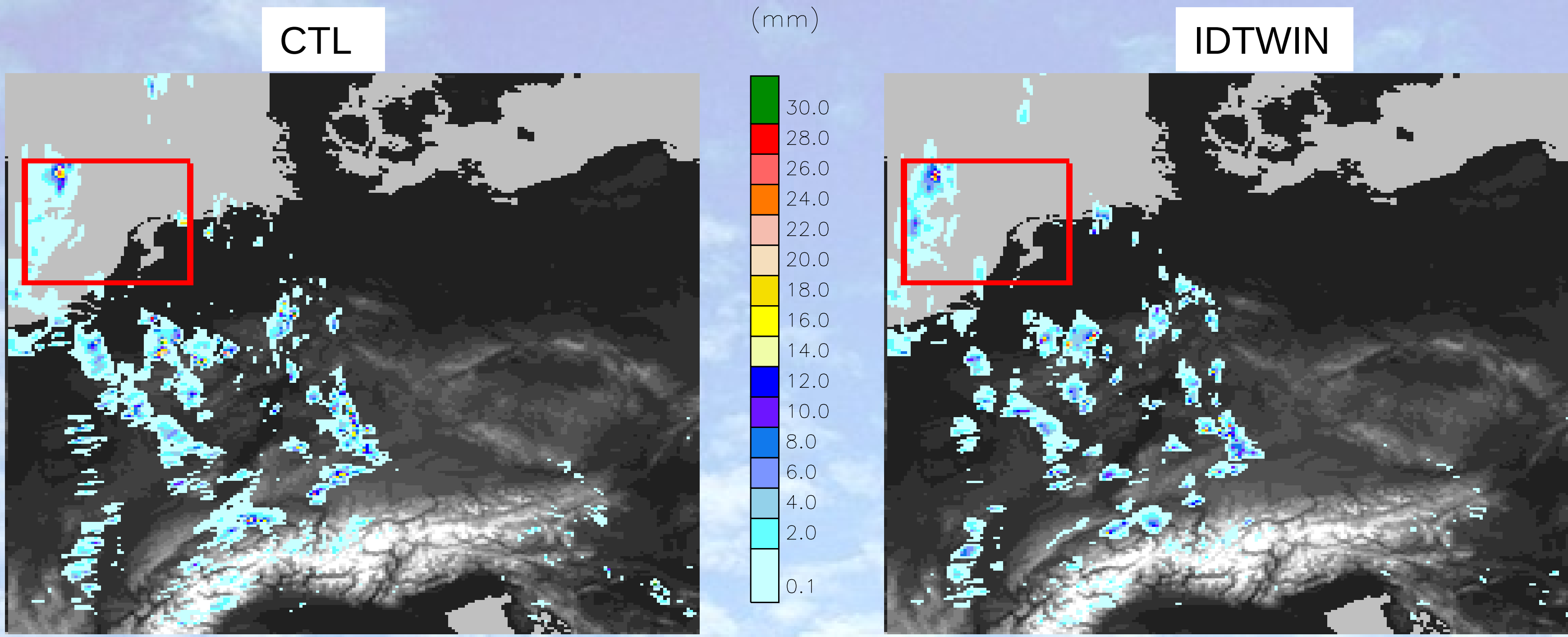
- We can assimilate the strong convection.
- Problems for the small isolated cells.

2005081916 Free run



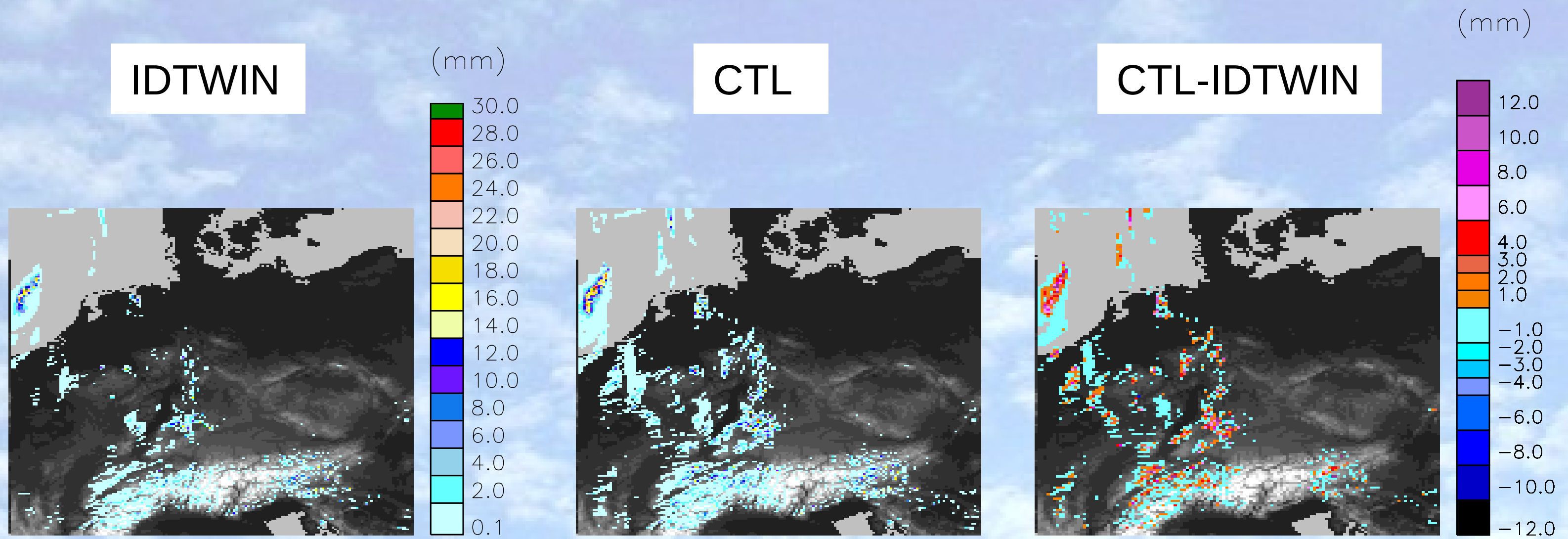
- We can assimilate the strong convection.
- Problems for the small isolated cells.

2005081917 Free run



- We can assimilate the strong convection.
- Problems for the small isolated cells.

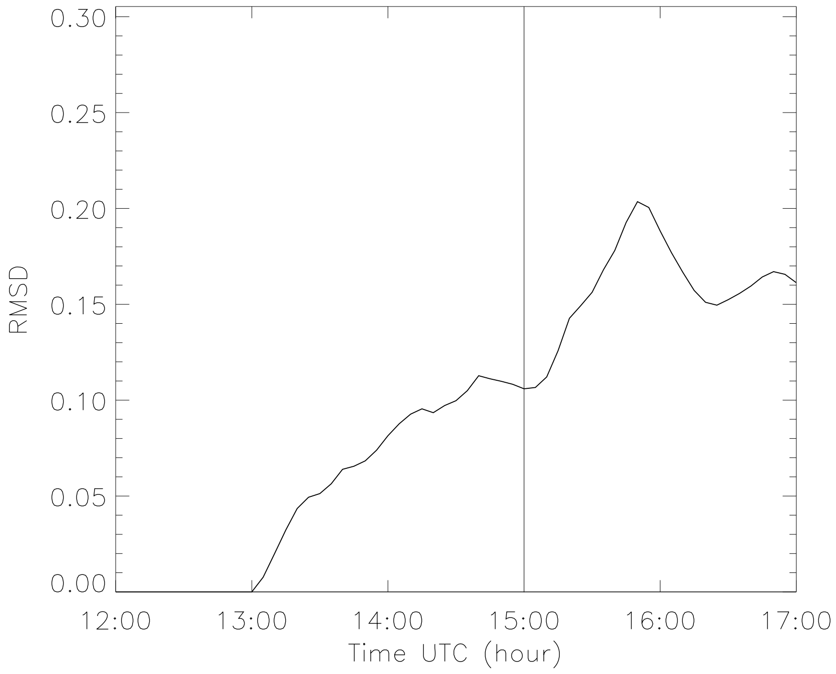
Precipitation in assimilation time



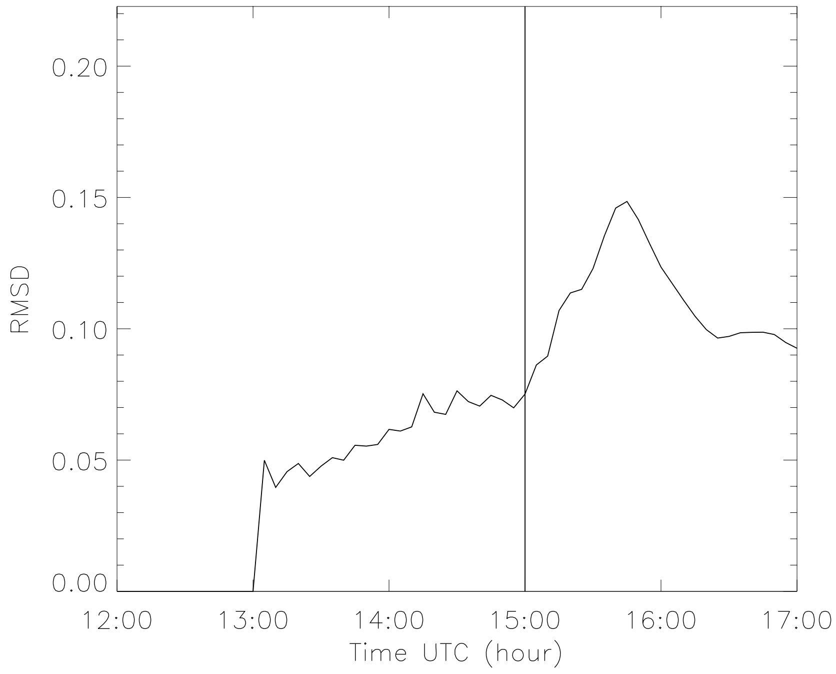
- Very good approximation.
- General underestimation of the precipitation. Problem in the assimilation of weak precipitation.

RMSD

Precipitation



Vertical wind

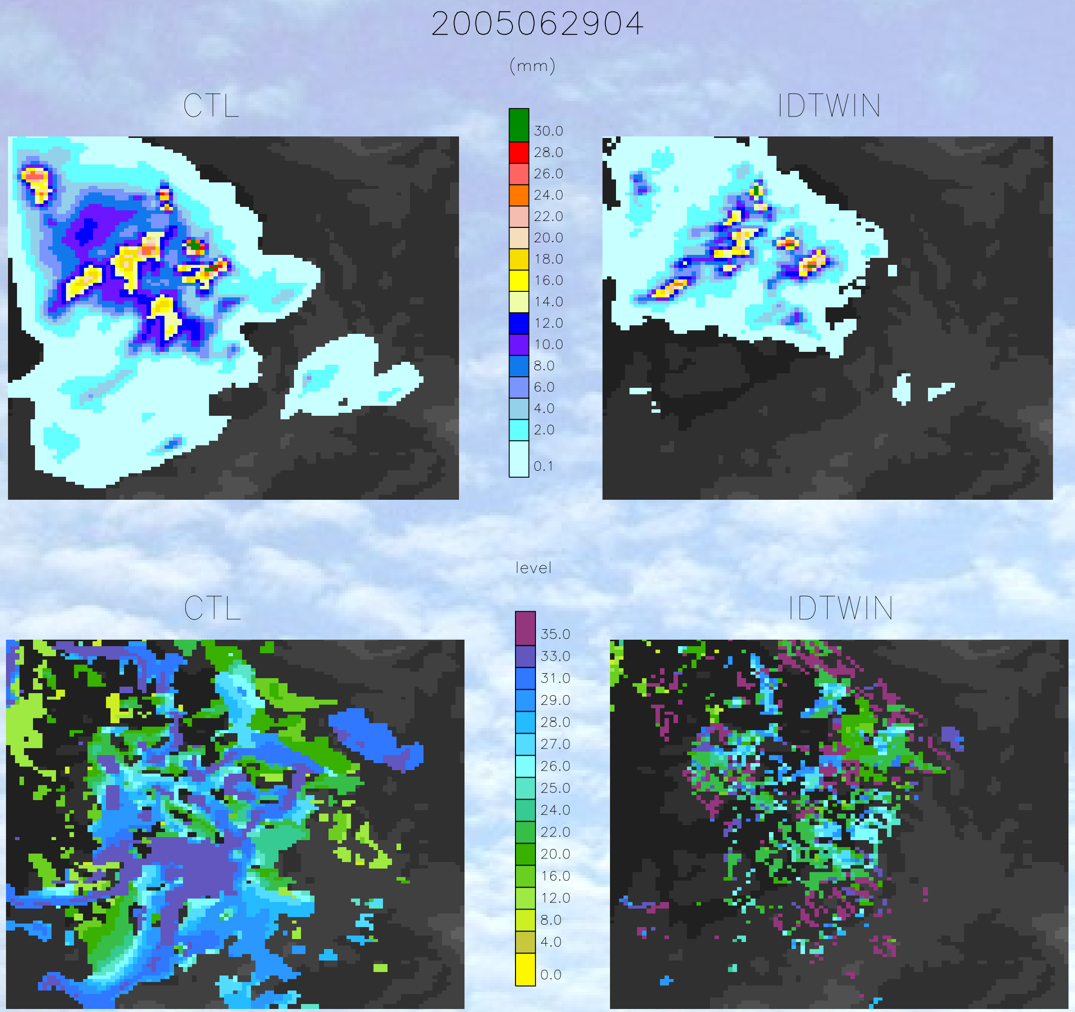


- Fast increase of the differences at the beginning of the assimilation.
- Peak after the assimilation window.

Cloud base

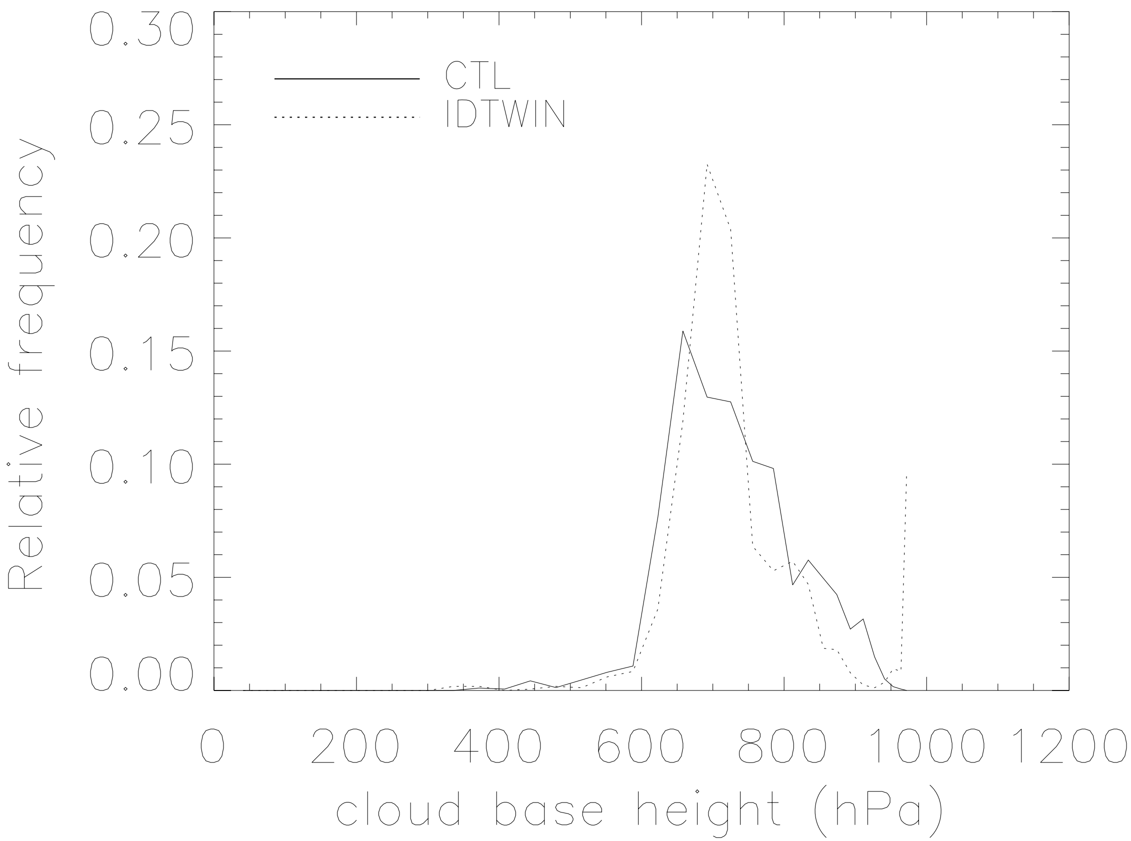
- A region with precipitation is chosen (in the red box).
- CAPE is very sensible to the cloud base position.
- The cloud base for the Identical Twin run is compared with the one for the reference run.

29/06/2005 cloud base level end of assimilation



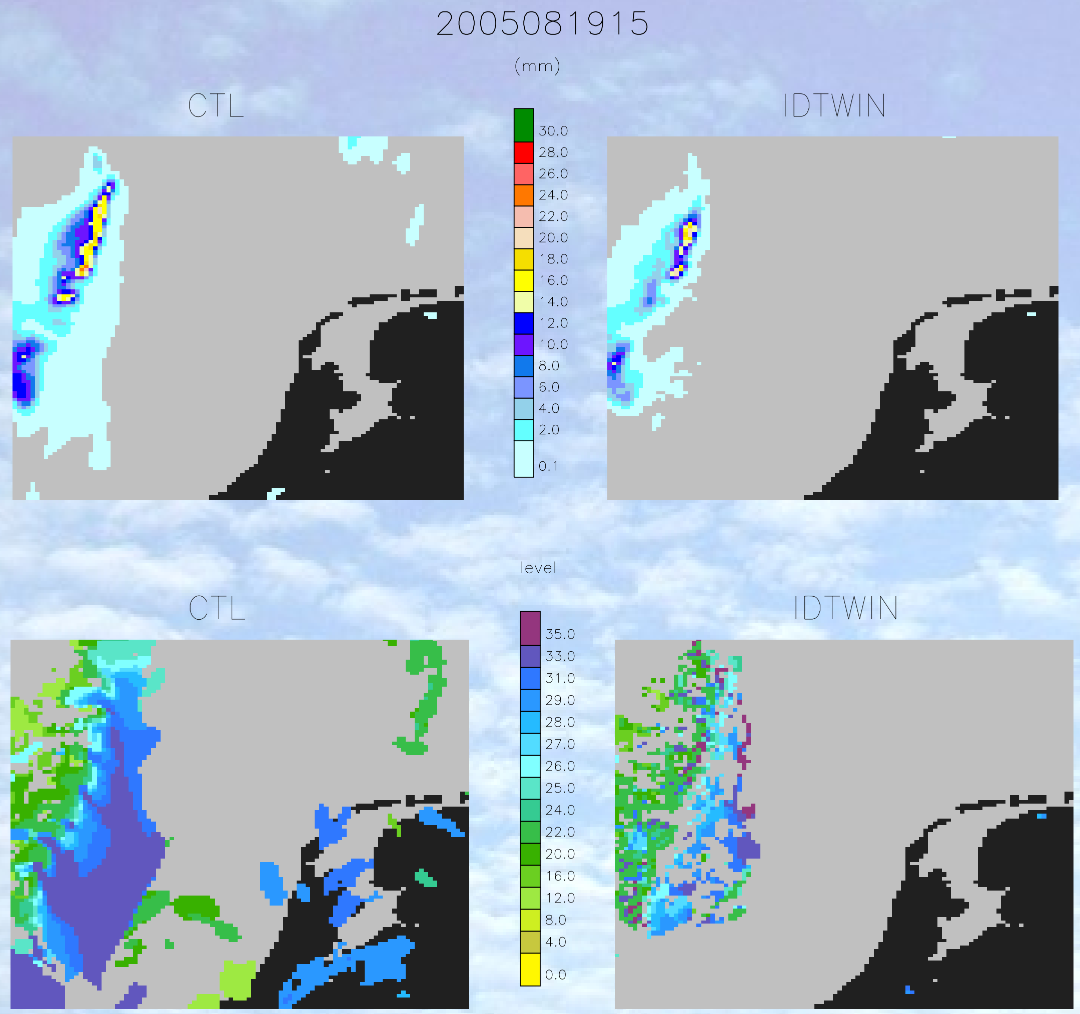
- Slight underestimation of precipitation.
- Quite good position of the cells.
- higher value for the cloud base level.
- scatter structure in the cloud base.

29/06/2005 Relative frequency of cloud base level at the end of assimilation window



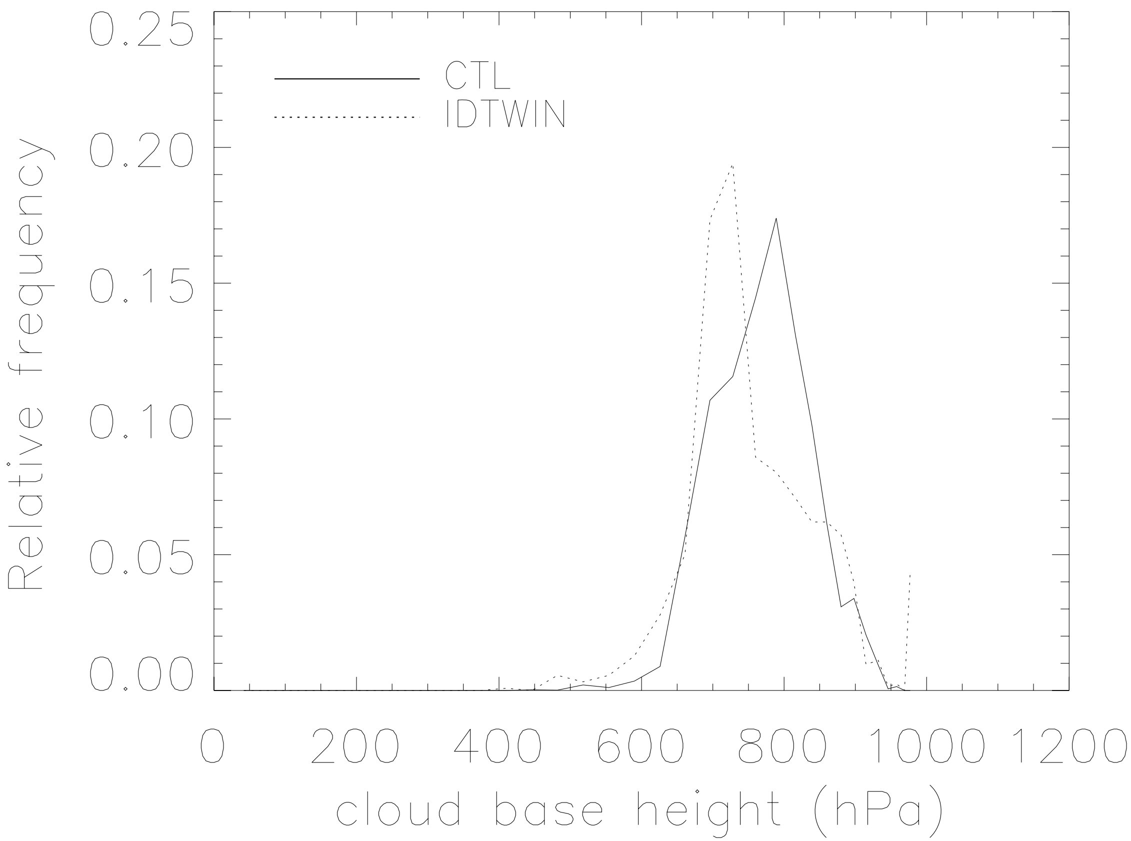
- Cloud base in the whole field.
- Overestimation of higher cloud bases.
- Underestimation of the lower cloud bases.
- Problem: about 9% of cloud base at the surface level.

19/08/2005 cloud base level end of assimilation



- Very good approximation.
- Good position.
- Cloud base level slightly overestimated.
- Scatter structure in the cloud base.

19/08/2005 Relative frequency of cloud base level at the end of assimilation window



- Cloud base in the whole field.
- Overestimation of higher cloud bases.
- Underestimation of the middle level cloud bases.
- Problem: about 4% of cloud base at the surface level.

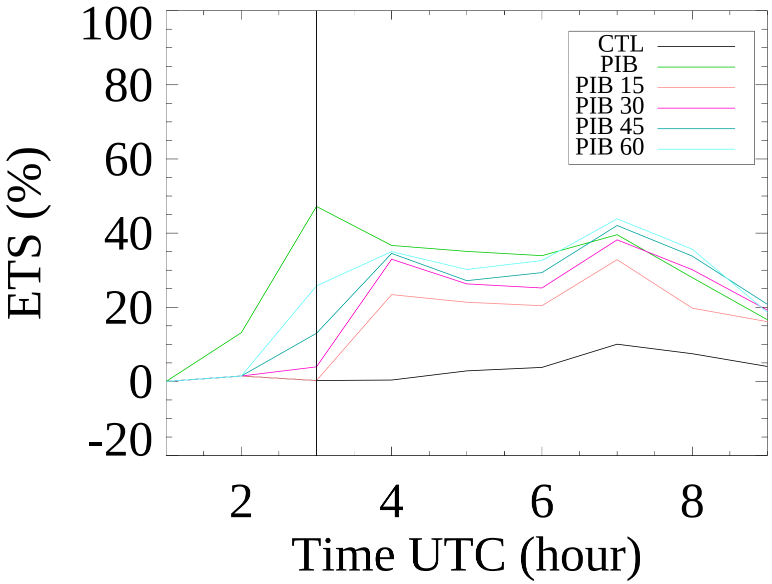
Change of the assimilation window

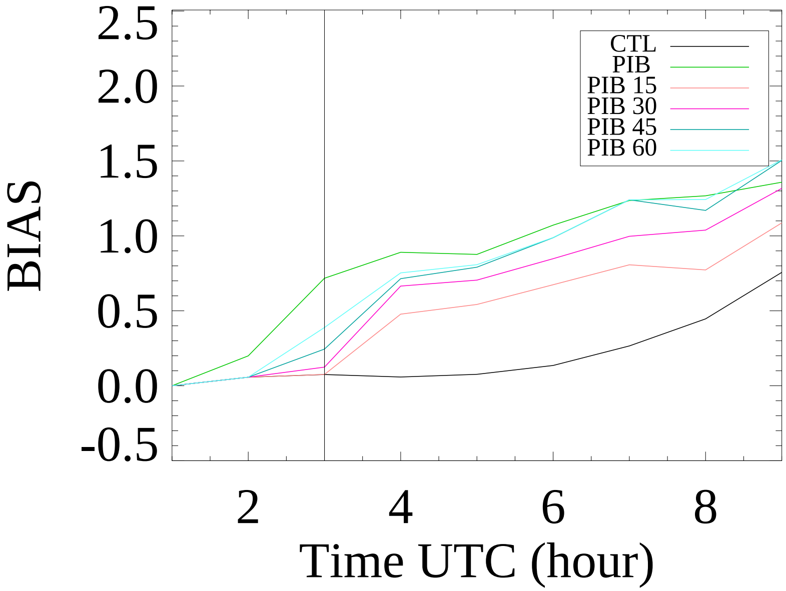
Different experiments with assimilation of real data:

- 2 hours
- 60 minutes
- 45 minutes
- 30 minutes
- 15 minutes

How the model reacts to the assimilation with a short or very short (15 minutes) assimilation window.

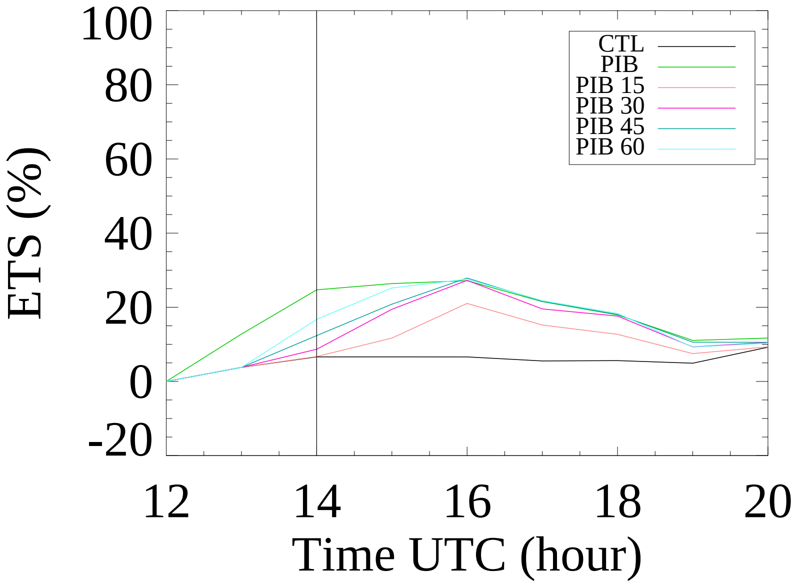
29/06/2005

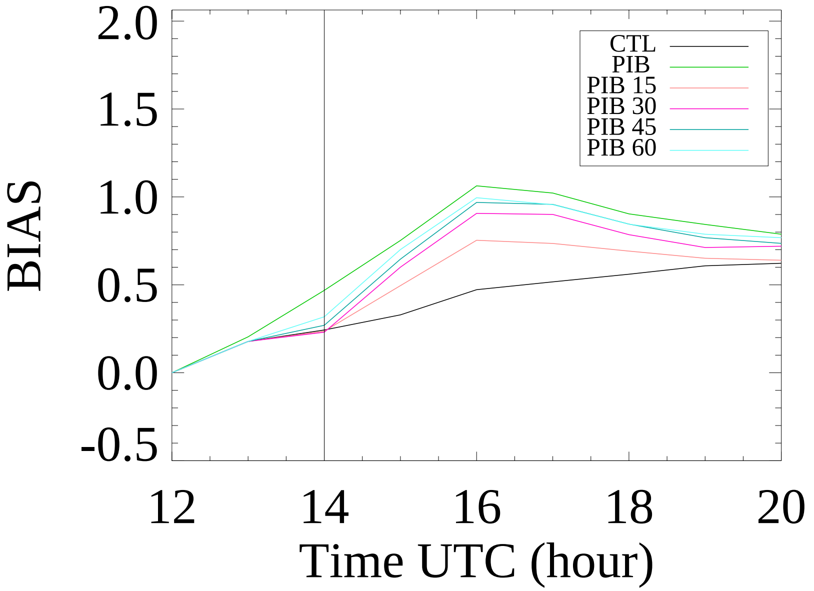




- Objective skill scores with a 0.1mm threshold. Equitable threat score and frequency BIAS.
- After 6 hours of free run the improvement due to the PIB is still visible.

19/08/2005





- Objective skill scores with a 0.1mm threshold . Equitable threat score and frequency BIAS.
- In this case the assimilation has a impact for about 4 hours.

CONCLUSIONS

- We can make a good forecast of the convective cells, at least for the bigger ones, in the first hours of forecast.
- The organization of the meteorological events is good represented.
- The method is very fast.
- From the results of the Identical Twin experiments the modification of the vertical wind seems to adjust also the horizontal wind field.

THANK YOU

- Deterministic runs
- Cloud top height
- Cloud base height
- Determination of the conversion efficiency
- Correction of cloud thickness
- LM3.15 choice of shall or deep convection
- CCL
- Future work
- Identical twin horizontal wind field.
- CAPE
- EPS
- Results without vertical wind adjustment
- Cloud base with TKE
- References
- Objective Evaluation
- Analysed precipitation

Deterministic runs

- 2.8 km horizontal resolution (421×461 points LMK area)
- 25s time step
- CFL:

$$|c|\frac{\Delta t}{\Delta x} \leq 1 \quad \Rightarrow \quad |c| \leq 112\, {}^{m}\!/\!{}_{s}$$

- 29th June 2005, from 01:00 UTC to 10:00 UTC
- 19th August 2005, from 12:00 UTC to 21:00 UTC

Cloud top height

The PIB uses the observation of Meteosat second generation to derive the cloud top height.

- Use of SAFNWC (Satellite Application Facilities for Support to Nowcasting and Very Short-Range Forecasting) .
  - products generated from DWD.
  - temporal resolution 15 min (for the year 2005)
- The high semitransparent clouds and the high semitransparent clouds above low or medium clouds are not taken in account.
- An Optimal Interpolation scheme (from Felix Ament) is used to fill the gaps, for the multi layer clouds.
- In case of precipitative points with no cloud, or cloud type not taken in account, the cloud top is fixed to the 14_{th} level ($\approx 8000m$)

↑

Cloud base height

LCL (Lifting Condensaton Level) and CCL (Convective Condensation Level) often agree closely with one another (Rogers and Yau,1989). We use an average for the two approximation. Correction of the cloud thickness for shallow and deep convection (Bechtold at al., 2001).

- LCL estimate
  - Mean temperature and dewpoint in a near surface layer, about 100 hPa deep *(Craven and Jewell, 2002).*
  - The temperature of the LCL is calculated using (Bolton, 1980):

$$T_L = \frac{1}{\frac{1}{T_D - 56} + \frac{\ln(T - T_D)}{800}} + 56$$

T_L temperature of the LCL, T mean temperature of the model levels near the soil. T_D mean dew point temperature calculated in the model levels near the soil.

- CCL estimate:
  - Mean specific humidity in the near surface layer (mixed layer).
  - Lift the surface air parcel adiabatically and check for buoyancy and saturation.

Search for the conversion efficiency and cloud base

- Definition of „good“ forecast:

$$\frac{1}{3} R_{ana} \leq R_{mod} \leq 3 R_{ana}$$

- For „good“ forecasted points not change (start value for c parameter 0.4).
- Otherwise search in the surrounding grid points for the one with the best fit (model consistent).
- If we find at least a point that satisfied our request we calculate the c parameter and the cloud base using the model variables.
- Otherwise use a dynamical determination of the conversion efficiency.

Dynamical determination of the conversion efficiency

The conversion efficiency parameter (*c*) is dynamically adjusted by the comparison between the model precipitation and the radar precipitation.

– For the considered grid point the parameter *c* at time step *n* is function of its value at the step n-1 , the analysed precipitation *R_an* and the model precipitation *R_m* :

$$c(n) = c(n-1) \bullet \left[1 - \sin\left(\frac{\pi}{2} \bullet \left(\frac{R\_an - R\_m}{R\_an + R\_m} \right) \right) \right]$$

With :

$$0.25 \le c(n) \le 0.8$$

Correction of cloud thickness

- Correction in case of the vertical extension of the cloud is not consistent with the model dynamics.
- Determination of shallow and deep convection using the algorithm for the Tiedke scheme in LM3.15.
- For deep convection the cloud thickness must be greater than 25000 Pa. Otherwise we put down the cloud base.
- For shallow convection the cloud thickness must be lower than 25000 Pa. Otherwise we put up the cloud base, until the cloud top with a minimum of one layer.

LM3.15 choice of shall or deep convection

From the LM3.15 in the Tiedke scheme:

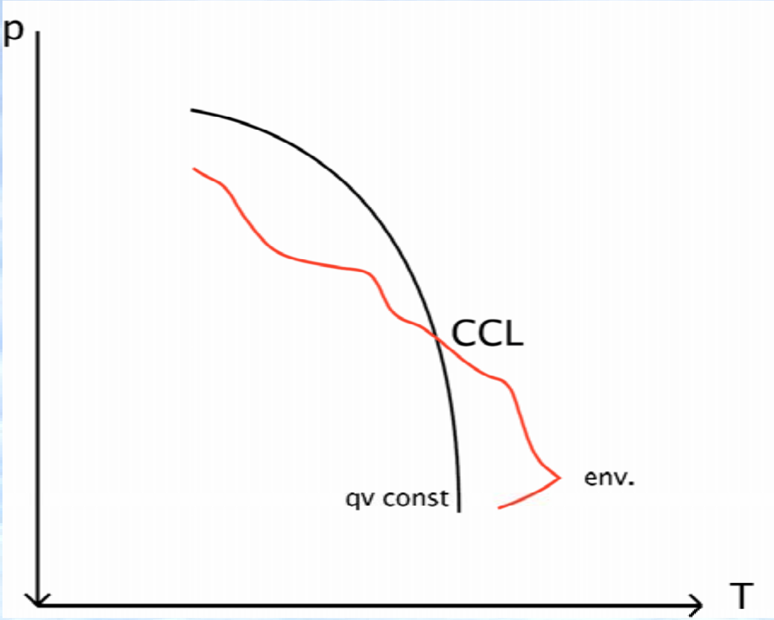
1. Calculation of three dimensional environment humidity convergence. Integration over the entire column.

2. Calculation of the turbulence humidity flux in the level nearest to the soil.

3. The deep convection is selected if the first term is greater than the second. Otherwise shallow convection.

Convective Condensation Level

- On a thermodynamic diagram, the point of intersection of a sounding curve (representing the vertical distribution of temperature in an atmospheric column, red line) with the saturation mixing ratio line corresponding to the average mixing ratio in the surface layer (black line).



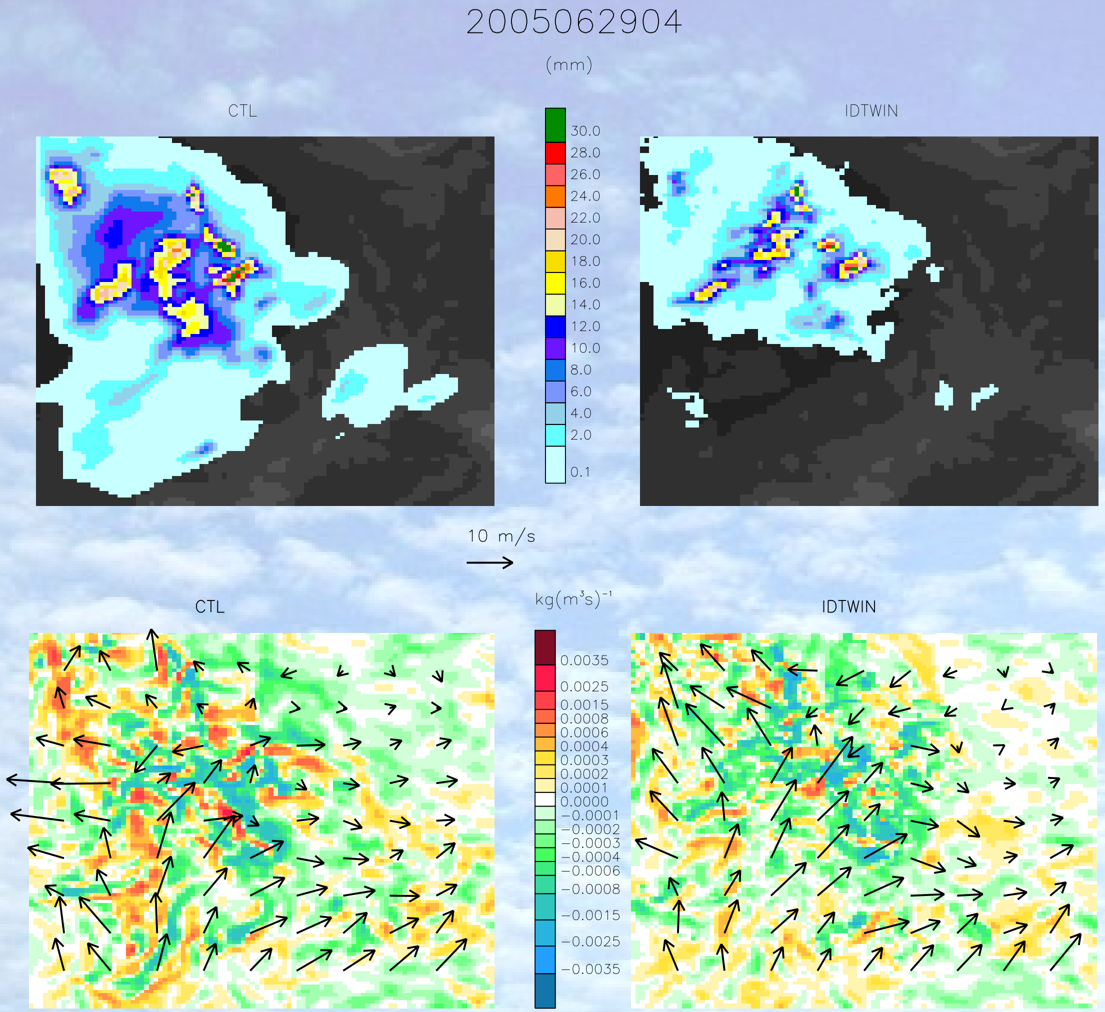
FUTURE WORK

- Combine the PIB with regional ensemble system generated by DLR. Find a way (parameter) to define the best member for the assimilation. In progress.
- Evaluation of PIB in different meteorological events in the LMK area.
- Reduction of the nudging period according to our resuls.
- Others Identical Twin experiments with the introduction of "observation errors".
- Use the EPS output for others identical twin experiment.
- Find a way to assimilate clouds without precipitation .

Horizontal wind field

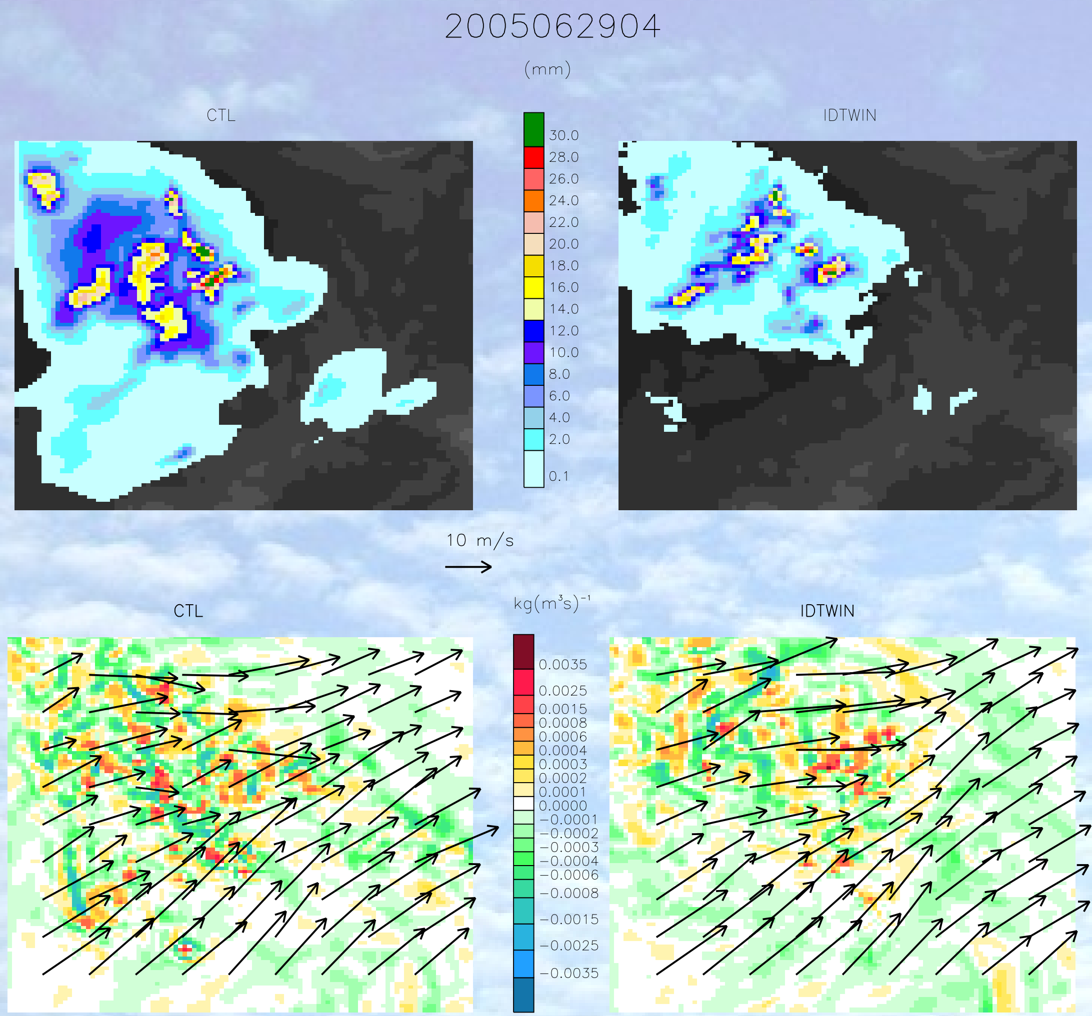
- We assumed that the modification of the vertical wind adjust also the horizontal wind field, from the mass conservation equation.
- We analyse this relationship in more detail.
- In case of convection a convergence band under the cloud base is present.
- Near the cloud top (model level 15) a mass flux divergence.
- In our plots the positive values are for the mass flux divergence.

29/06/2005 end of assimilation



- Horizontal mass flux divergence.
- Level 28 as cloud base
- General wind direction quite similar.
- Underestimation of divergence.
- For the identical twin run convergence in correspondence of the convective cells

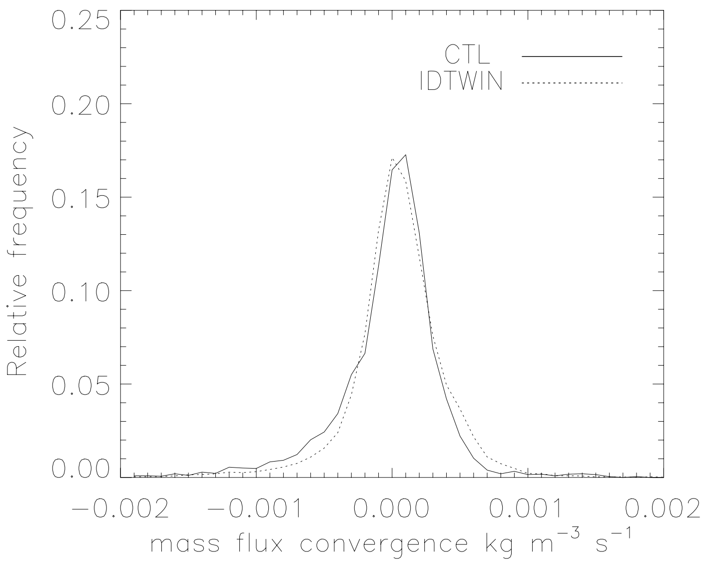
29/06/2005 end of assimilation



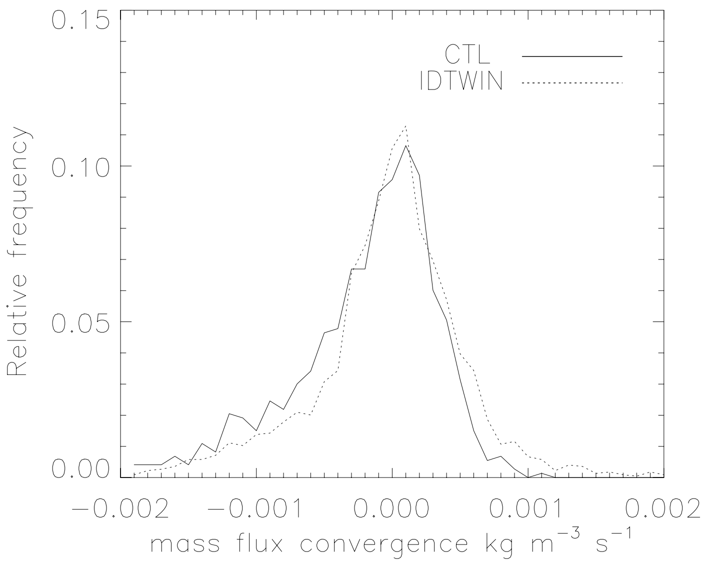
- Horizontal mass flux divergence.
- Cloud top level 15
- Same structure for the horizontal wind field.
- Slight underestimation of the divergence.

Total field (cloud base)

0.1 mm/h

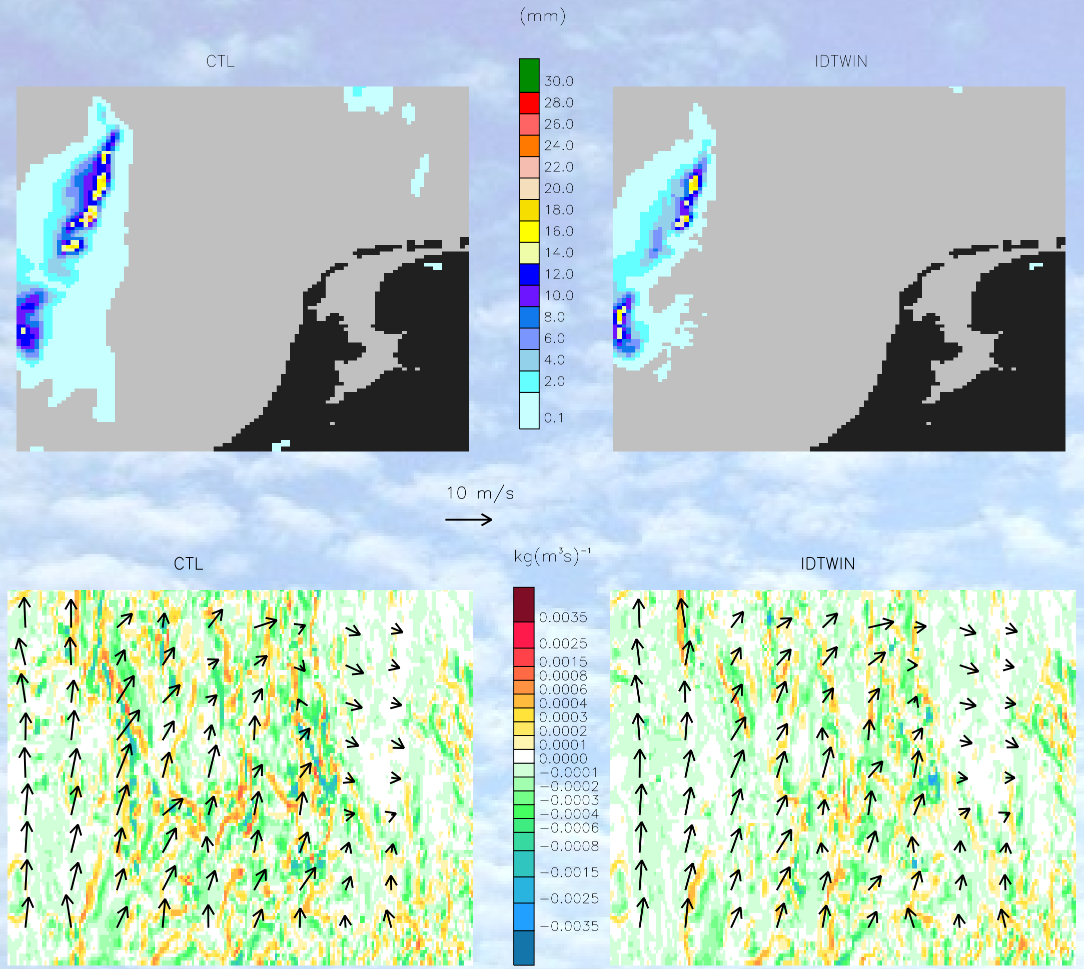


5 mm/h



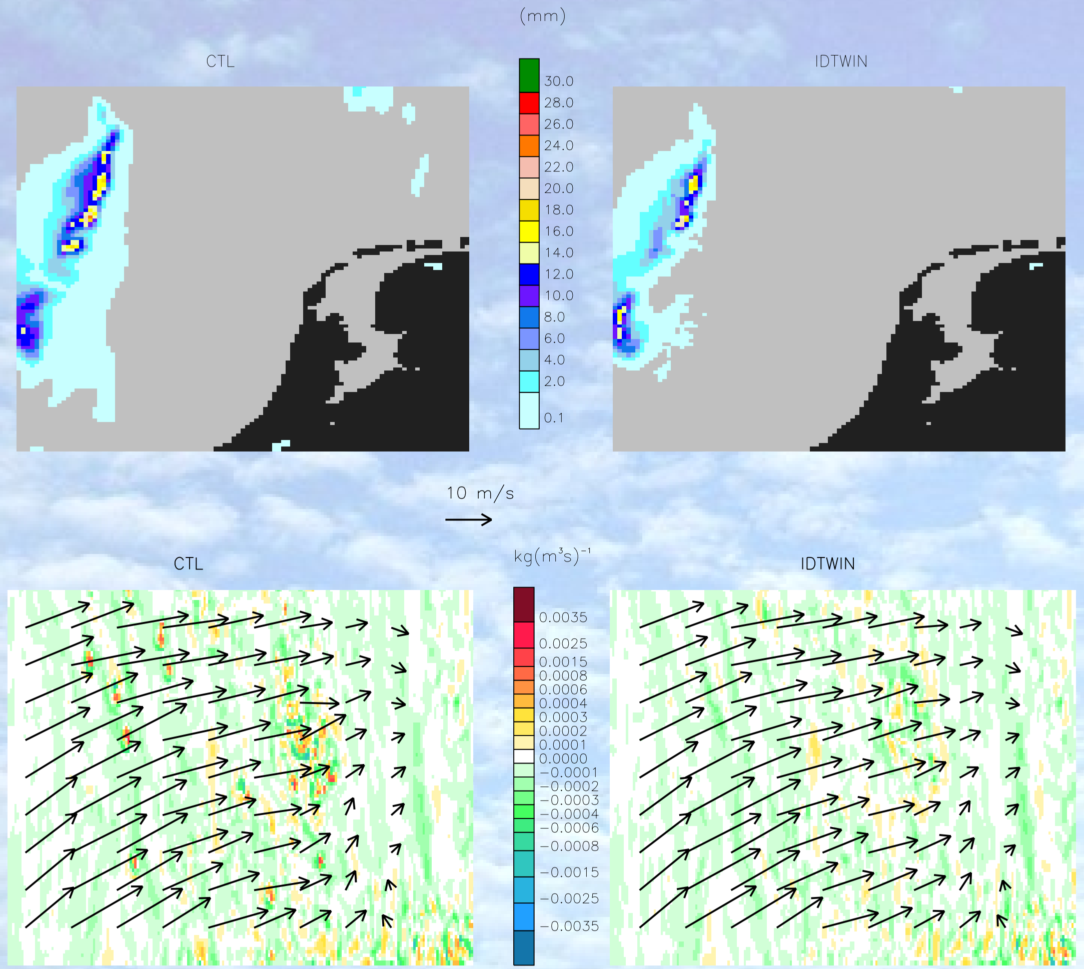
- Relative frequency in classes of $10^{-4}\,\frac{kg}{m^3 s}$
- Cloud base. Level 28.
- Total precipitation points. Good approximation.
- Points with precipitation greater than 5mm. Lower plot
- Slight overestimation (underestimation) of the divergence (convergence)

19/08/2005 end of assimilation



- Horizontal mass flux divergence
- Very low convergence
- Good approximation of the general wind direction
- Underestimation.

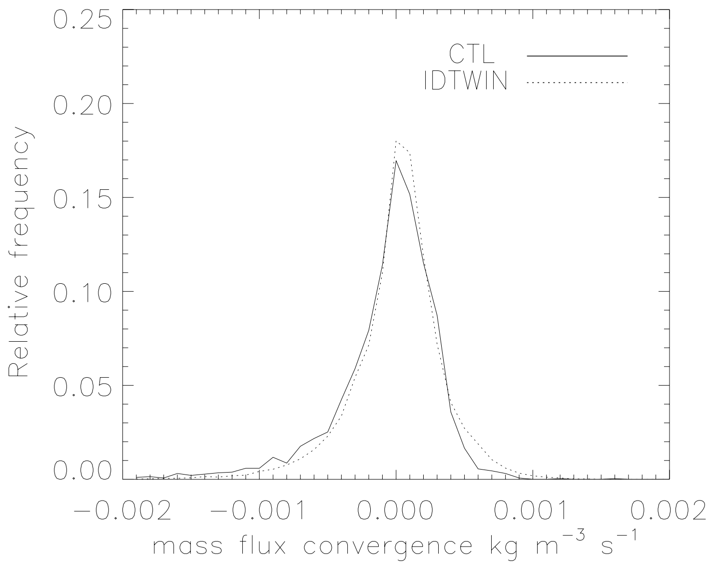
19/08/2005 end of assimilation



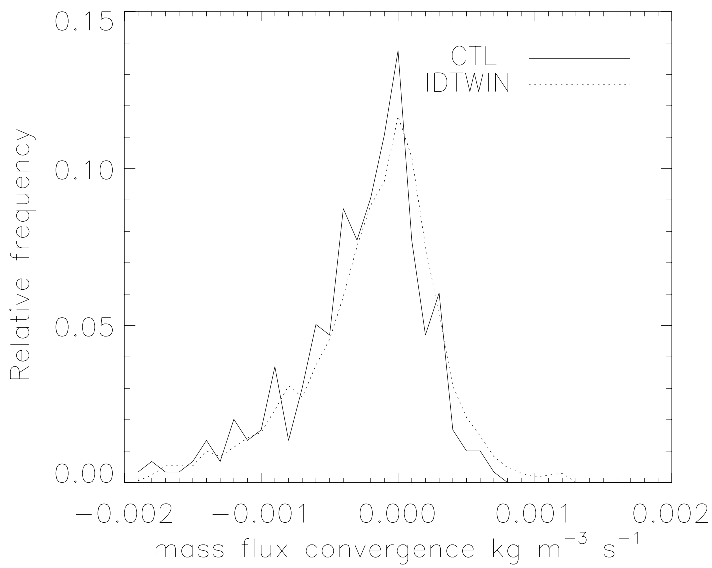
- Horizontal mass flux divergence
- Cloud top level 15
- Same structure for the horizontal wind field.
- No sign of divergence.

Total field

0.1 mm/h

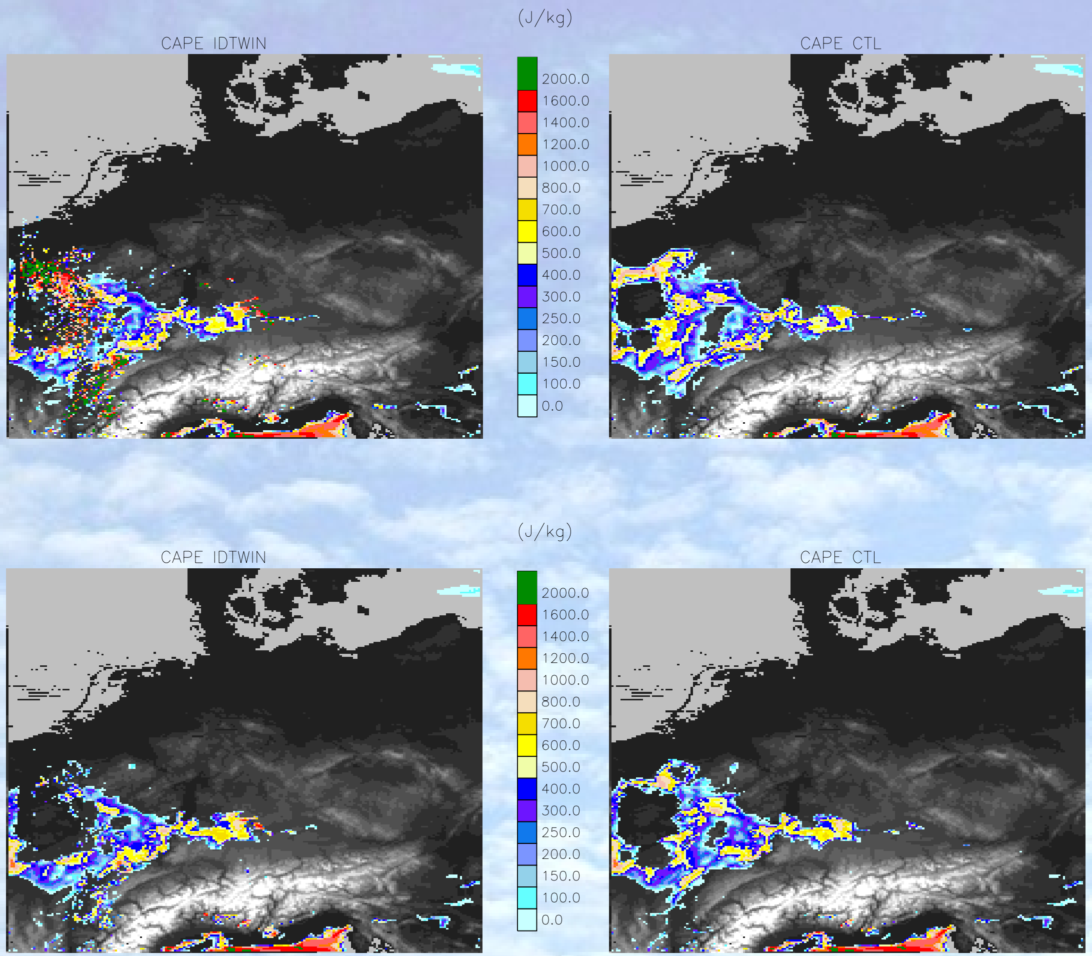


5 mm/h



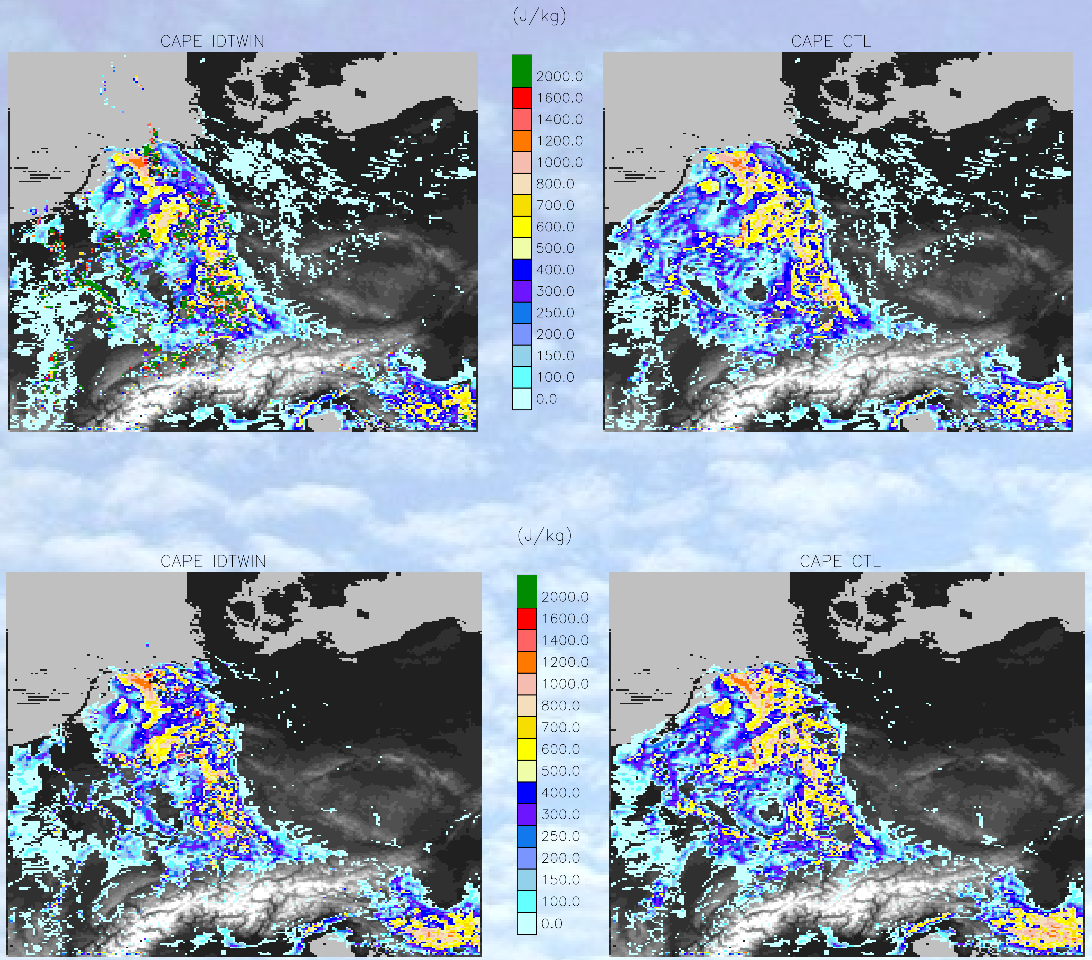
- Relative frequency in classes of $10^{-4}\,kg(m^3 \cdot s)^{-1}$
- Cloud base. Level 28.
- Total precipitation point. Upper plot, good approximation.
- Points with precipitation greater than 5mm. Lower plot, absence of some “structures”.

IDTWIN CAPE 29/06/2005



- CAPE at the end of the assimilation window.
- Enhancement in CAPE in convective region
- CAPE after an hour of free run
- Underestimation, a part of the CAPE is lost at the beginning of the free run.

IDTWIN CAPE 19/08/2005



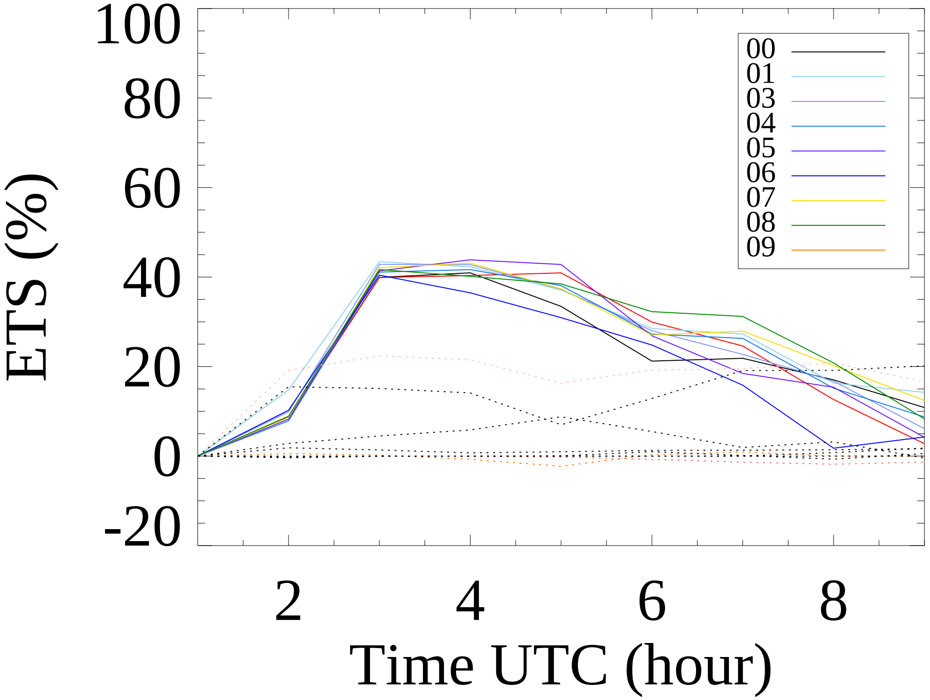
- CAPE at the end of the assimilation window.
- Good approximation
- CAPE after an hour of free run
- Slight underestimation.

Use of EPS

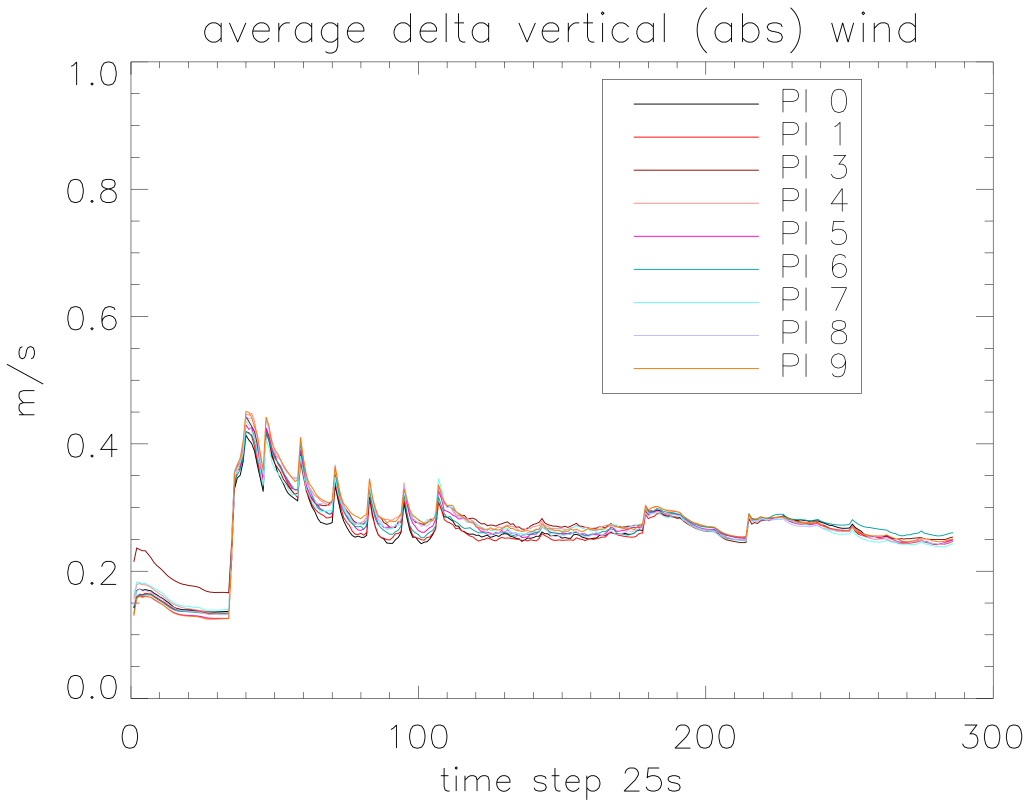
- A run is well initialized when after a period the initialization scheme changes the model less than at the beginning of the assimilation window.
- Check how the PIB changes the model variables:
  - Vertical wind
  - Specific humidity
- Take the “best” member.
- Create a new EPS from this member.
- New assimilation window.
- Forecast.

First EPS results (29/06/2005)

- Ten runs using boundary and initial conditions from the ten members of the EPS, two hours of assimilation comparison with CTL.

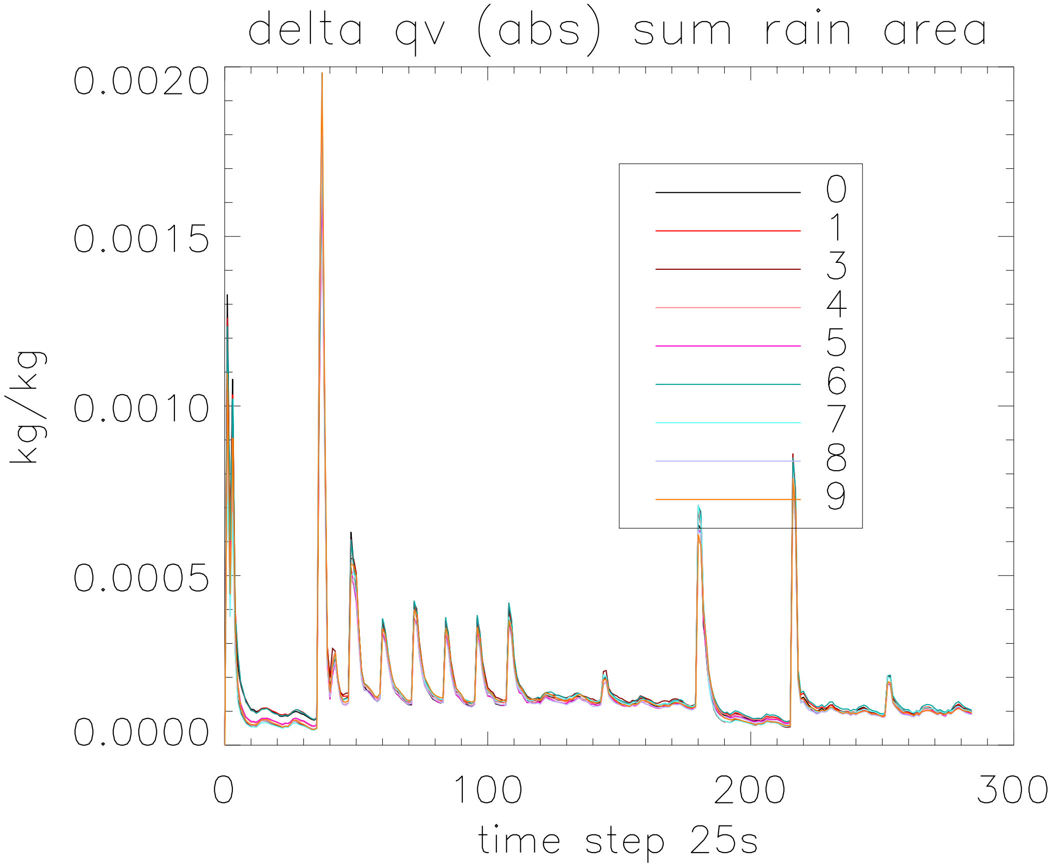


Vertical wind



- Difference between the model wind and the initialised wind.
- Average of the absolute value in the LMK area.
- Bigger energy input at the beginning.
- After less then 100 time steps the PIB adjustment is quite constant.
- The members are very similar.

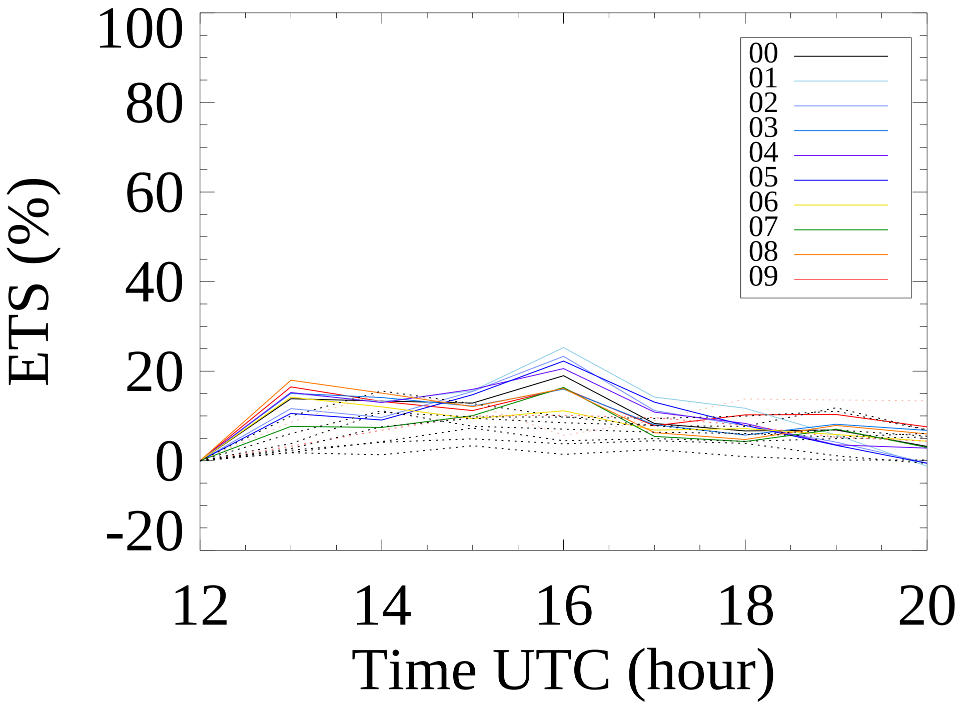
Specific Humidity



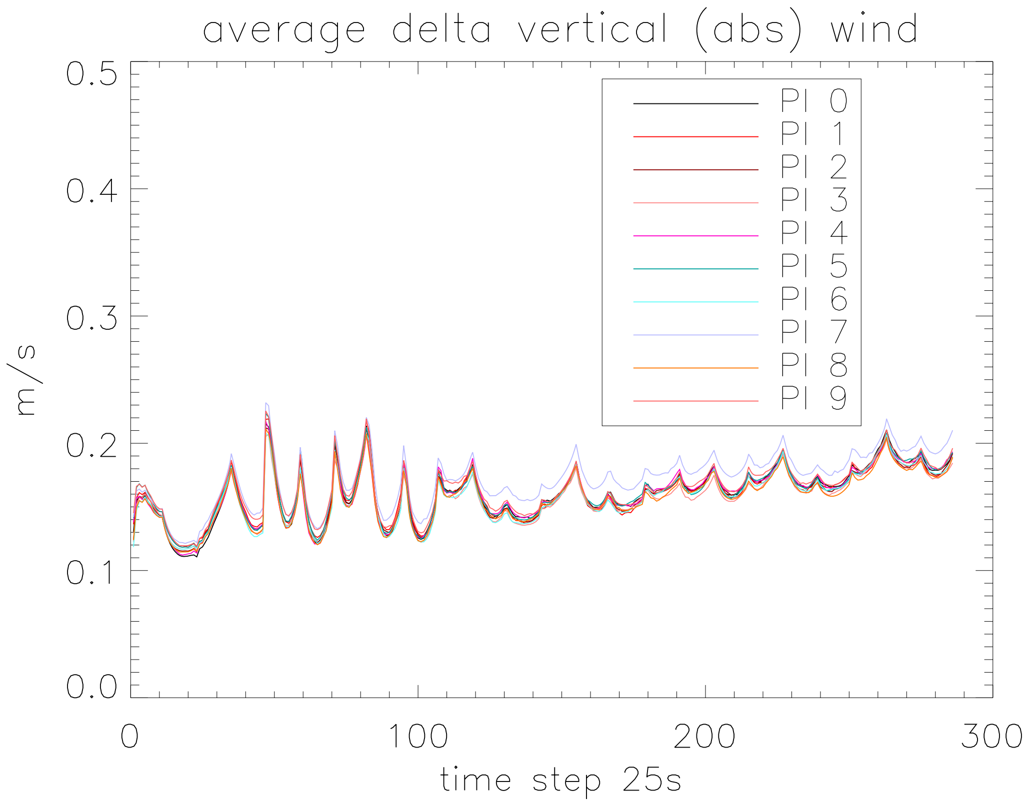
- Adjustment in terms of specific humidity for the raining points

First EPS results (19/08/2005)

- Ten runs using boundary and initial conditions from the ten members of the EPS, two hours of assimilation comparison with CTL.

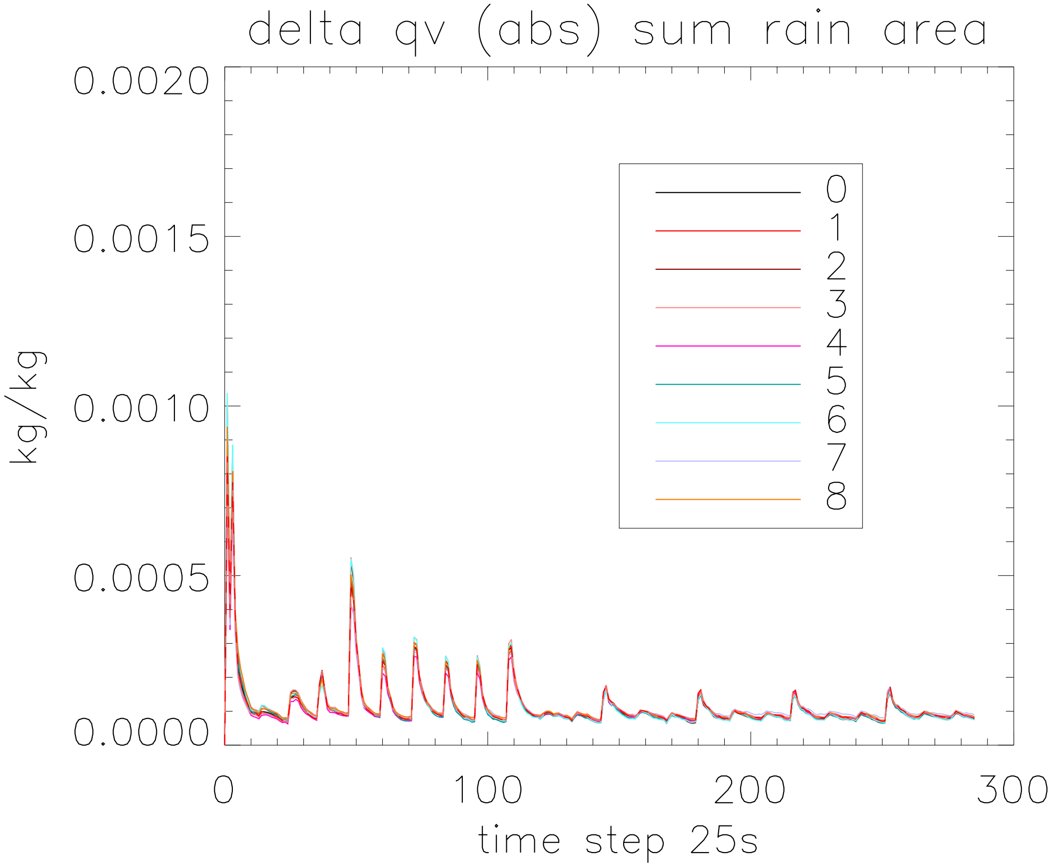


Vertical wind

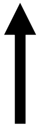


- Difference between the model wind and the initialised wind.
- Average of the absolute value in the LMK area.
- After less then 100 time steps the PIB adjustment is quite constant.
- The members are very similar.

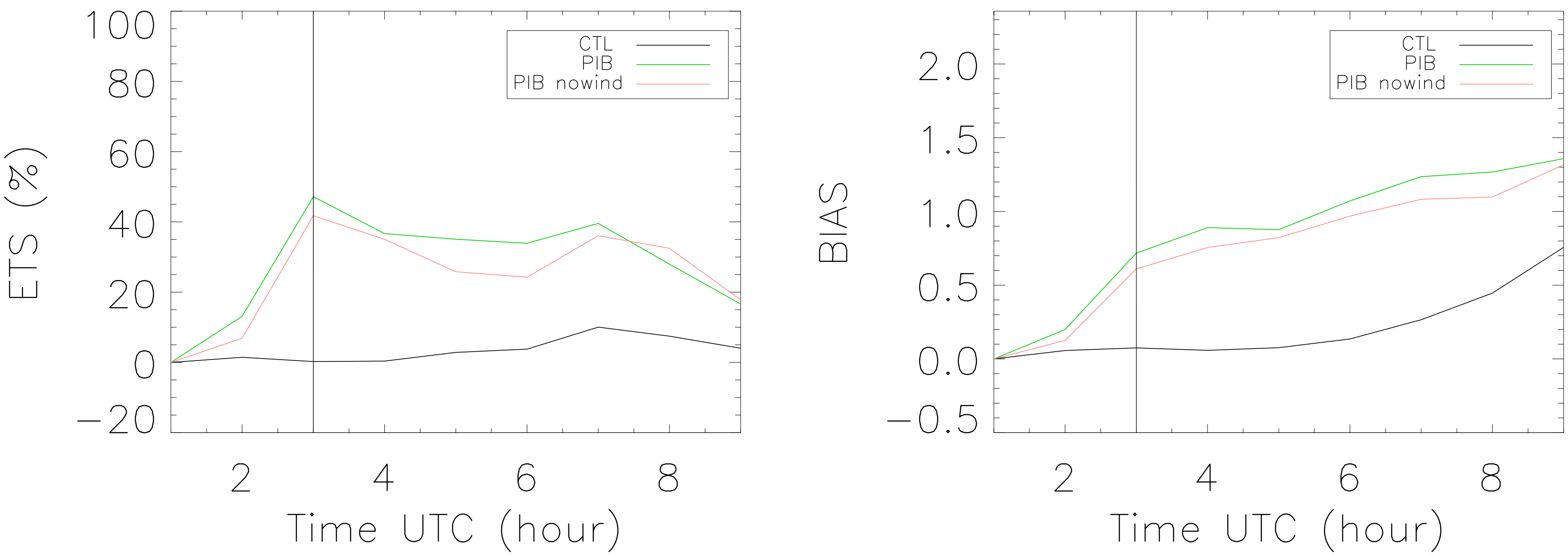
Specific Humidity



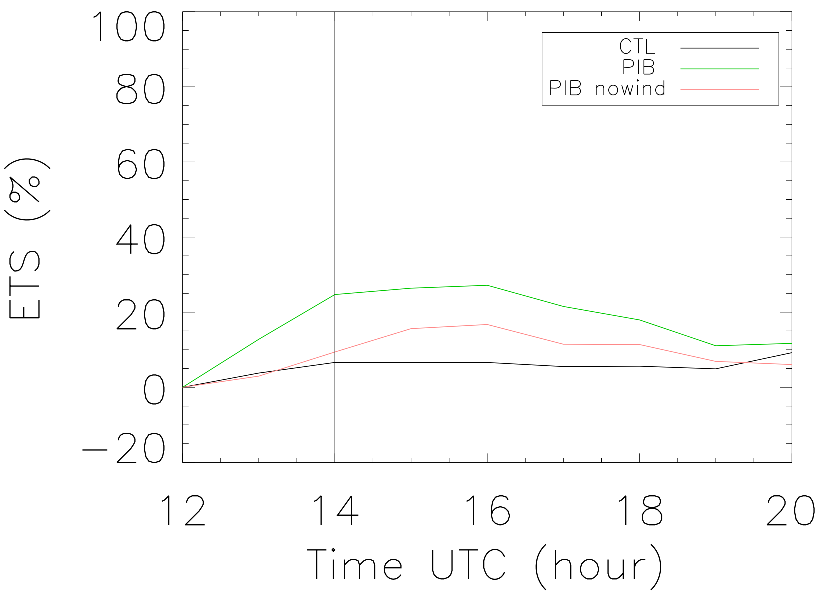
- Adjustment in terms of specific humidity for the raining points

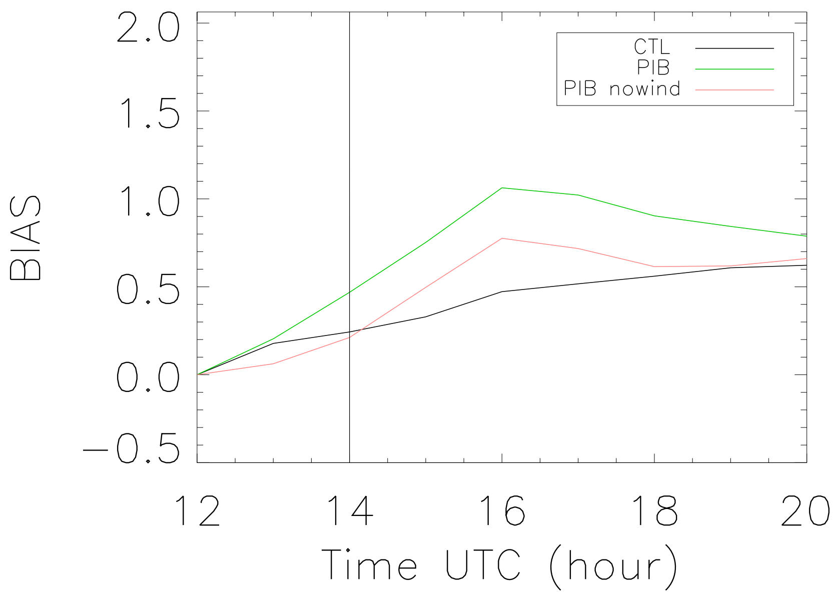


Results without vertical wind adjustment (case 1)



Results without vertical wind adjustment (case 2)





Cloud base with TKE

- The *buoyant production or cunsumption term* for the TKE in a convective boundary layer becomes negative near the cloud base (Stull, 1999).

$$\frac{g}{\overline{\theta_v}}\left(\overline{w'\theta_v'}\right)$$

$\overline{w'\theta_v'}$ the flux of virtual potential temperature

- Is it a good indicator?
- In statically stable conditions this term becomes negative.
- After the sun set.
- At the top of the mixed layer where warmer air entrained downward by turbulence opposes the descent because of its buoyancy. ↑

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OBJECTIVE EVALUATION

For an objective check of the forecast quality we can make a comparison with the radar data using:

•**FAR (**False alarm ratio, in %): *what fraction of observed "yes" events actually did not occur?*

•**TS** (threat score, in %): *How well did the forecast "yes" events correspond to the observed "yes" events?*

•**ETS** : (Equitable threat score, in %): How well did the forecast "yes" events correspond to the observed "yes" events (accounting for hits due to chance)?

•**BIAS score : (**frequency bias, 0 to infinity, perfect score 1), How did the forecast frequency of "yes" events compare to the observed frequency of "yes" events?

BENCHMARKS: Control run (without assimilation). All the runs are with the prognostic precipitation.

$$TS = 100\frac{d}{b + c + d}$$

$$FAR = 100\frac{c}{c + d}$$

$$BIAS = \frac{c + d}{d + b}$$

$$ETS = \frac{d - CH}{b + c + d - CH}$$

	R_{rad}<=R_{th}	R_{rad}>R_{th}
R_{LM}<=R_h	a	b
R_{LM}>R_{th}	c	d

$$CH = \frac{(d + b)\cdot(b + c)}{N_{TOT}}$$

Analysed precipitation

Temporal weight (α_t) : Linear interpolation in time

Spatial weight

$$R_{rad} > 0 : \alpha_s = 1 - 0.5\left(\frac{r_{rad}}{100} + \tanh\left(\frac{3r_{rad}}{100} - 3\right) - 1\right)$$

$$R_{rad} = 0 : \alpha_s = 1 - \tanh\left(\frac{3r_{rad}}{100} - 3\right)$$

R_{rad} rain rate from radar
r_{rad} distances to the closest radar site

Analyzed precipitation

$$R_{ana} = \alpha R_{rad} + (1-\alpha) R_{LM}$$

$$\alpha = \alpha_t \cdot \alpha_s$$