A novel displacement-based measure to assess the quality of mesoscale EPS forecasts

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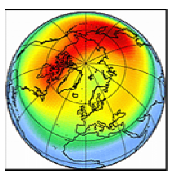
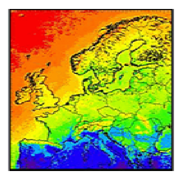
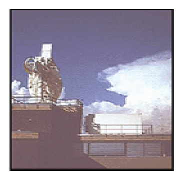
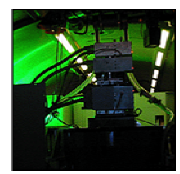
    

DLR

Institut für

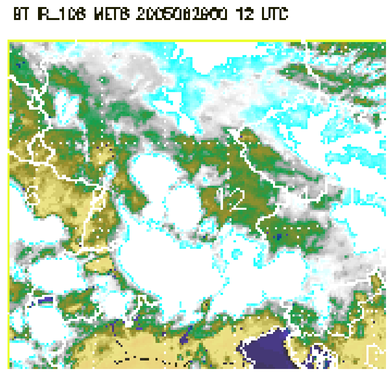
Physik der Atmosphäre

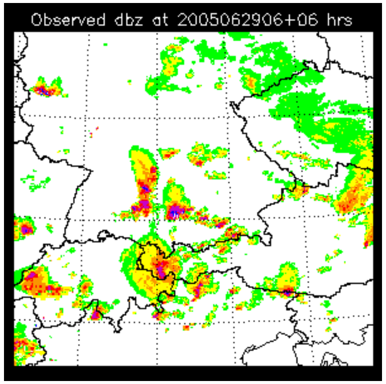
Motivation

Exploitation of spatio-temporal information contained in remote sensing imagery

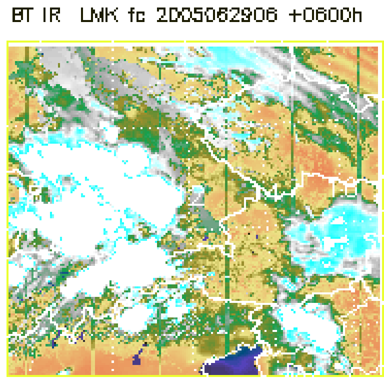
Meteosat 8 | Radar

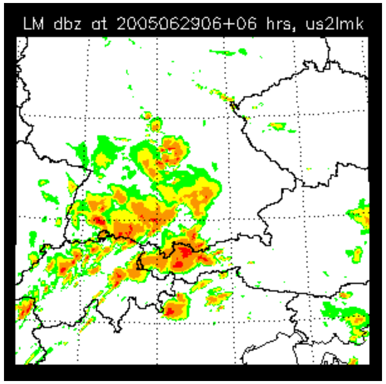
Observation





LMK Forecast
using forward operators





Pyramidal Matching Algorithm (Mannstein et al., 2002)

1. Project observed and simulated images to same grid

2. Coarse-grain both images by averaging of 2^F pixels onto one pixel element

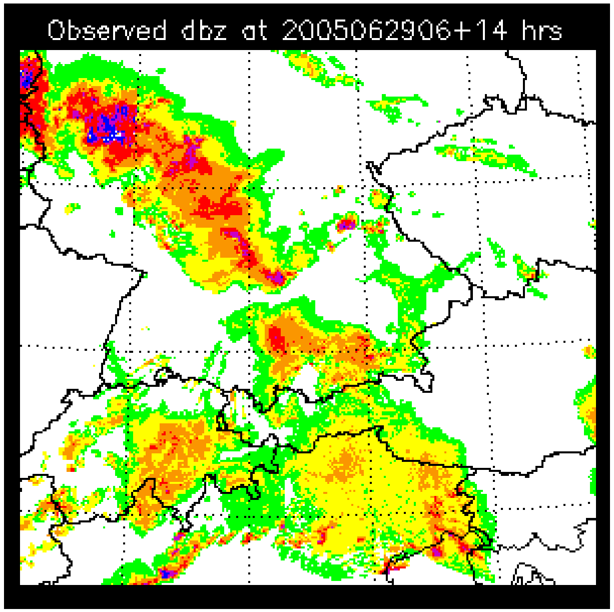
3. Compute a displacement vector field that minimizes the squared difference within the range of +/- 2 pixel elements

4. Repeat step 2 at successively finer scales

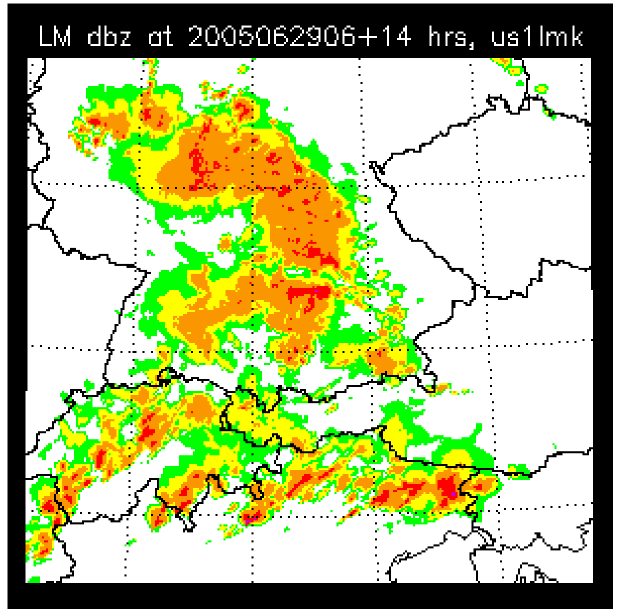
5. Displacement vector for every pixel results from the sum over all scales

Pyramidal Matching: Example with real data

1. Project observed and simulated images to same grid



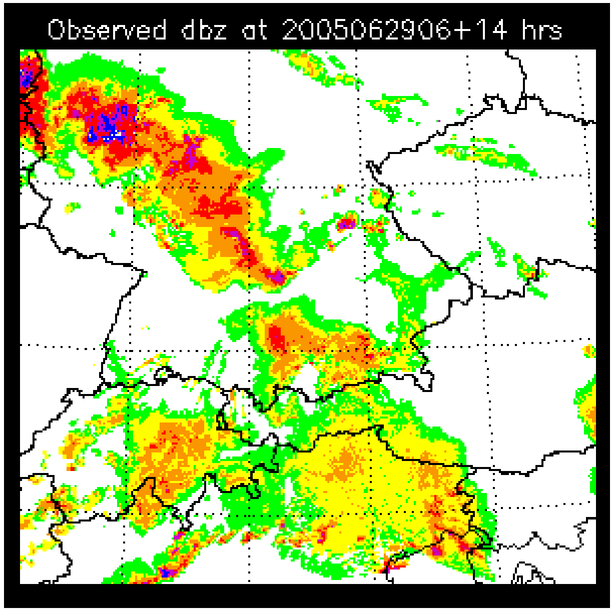
Observation

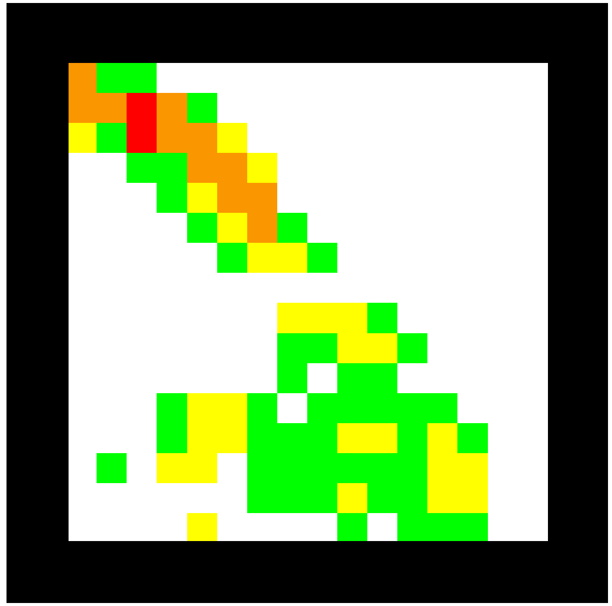


Forecast

Pyramidal Matching: Example with real data

2. Coarse-grain both images by pixel averaging



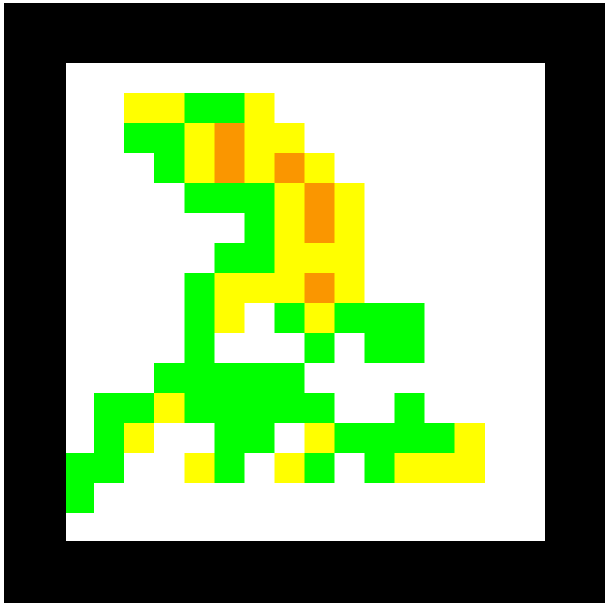


Observation

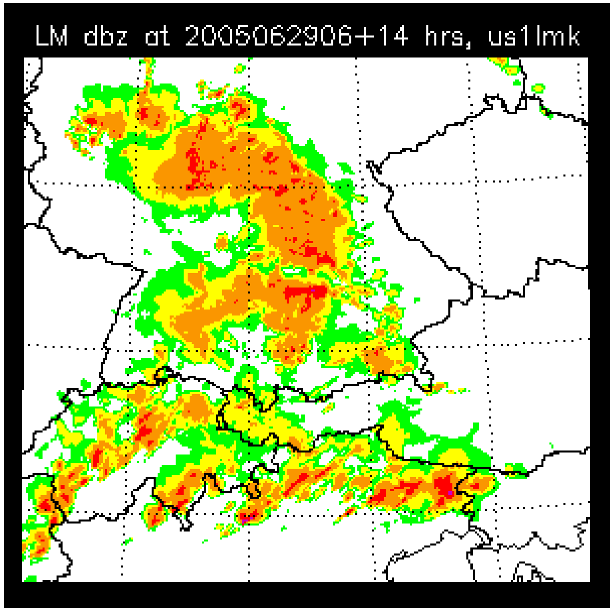
Coarse-grained observation

Pyramidal Matching: Example with real data

2. Coarse-grain both images by pixel averaging



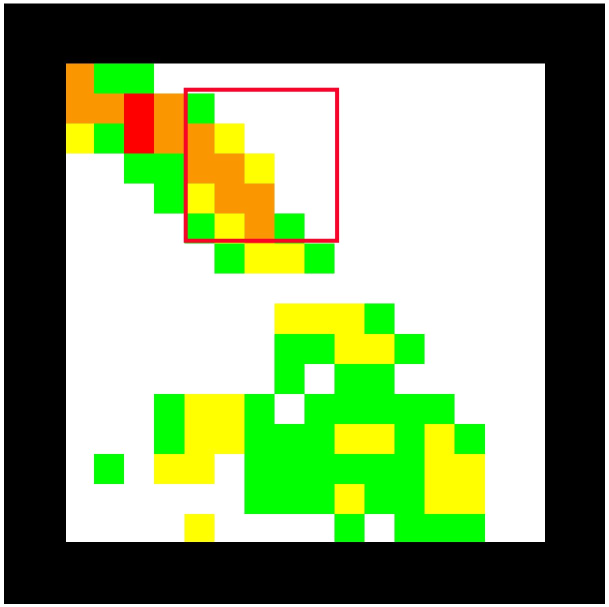
Coarse-grained forecast



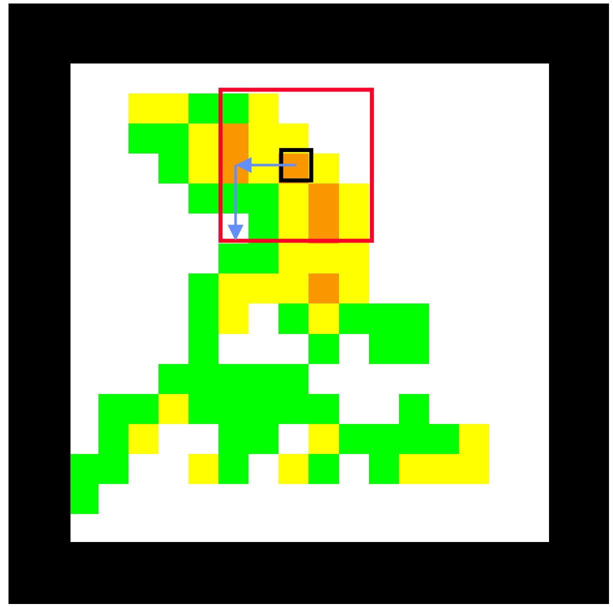
Forecast

Pyramidal Matching: Example with real data

3. Compute displacement vector field that minimizes the squared difference



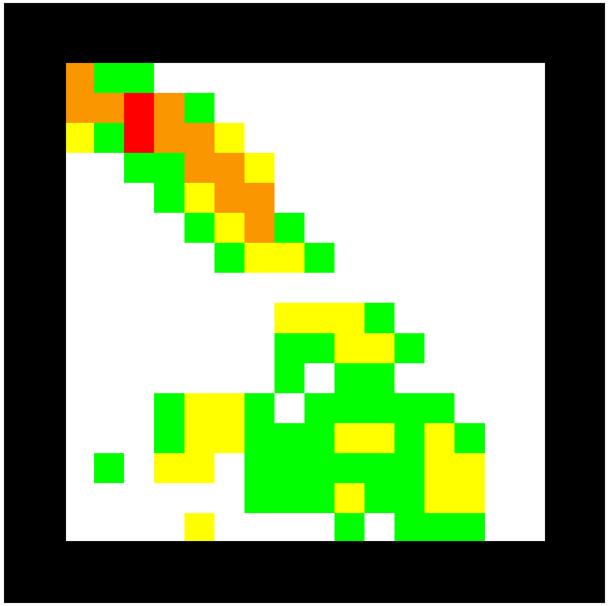
Observation



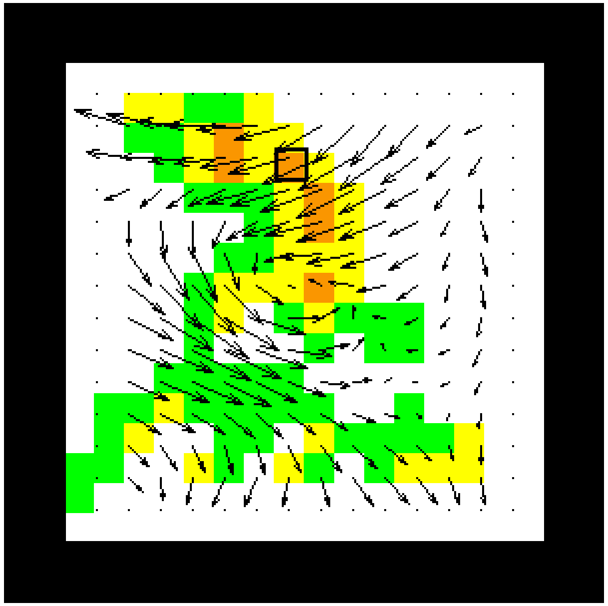
Forecast

Pyramidal Matching: Example with real data

3. Compute displacement vector field that minimizes the squared difference



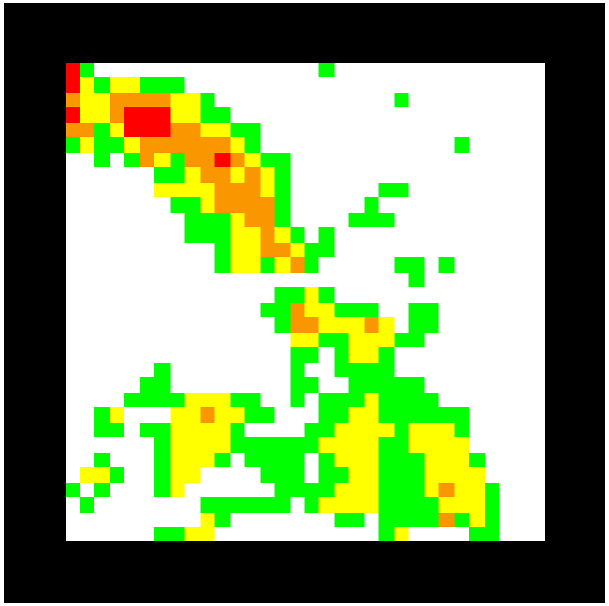
Observation



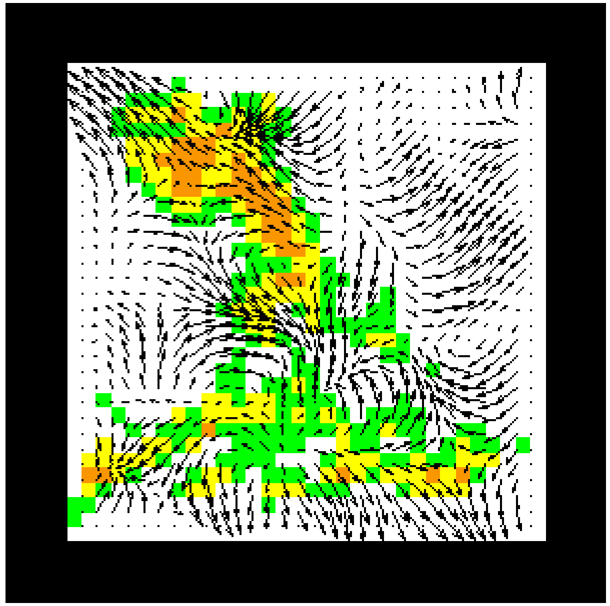
Forecast

Pyramidal Matching: Example with real data

4. Repeat step 3 at successively finer scales



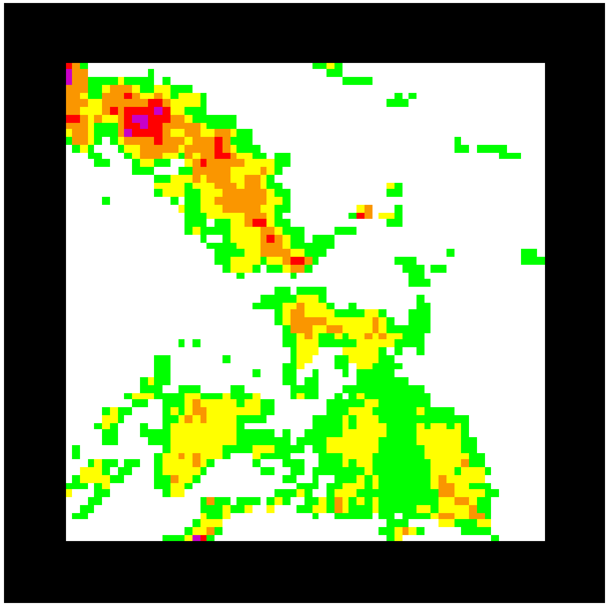
Observation



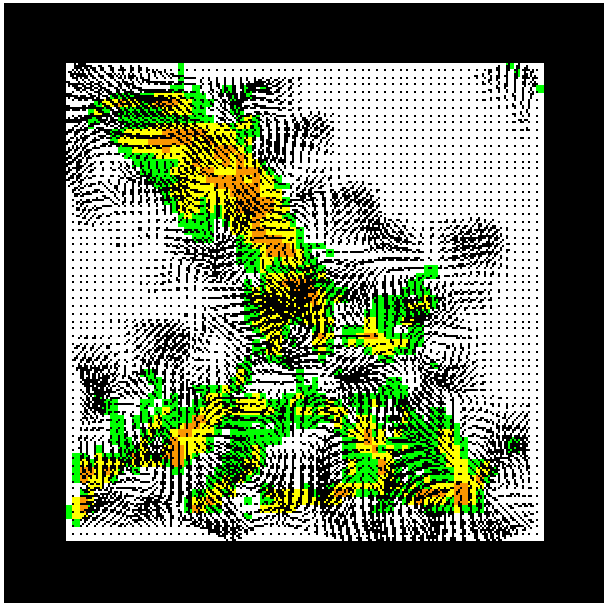
Forecast

Pyramidal Matching: Example with real data

4. Repeat step 3 at successively finer scales



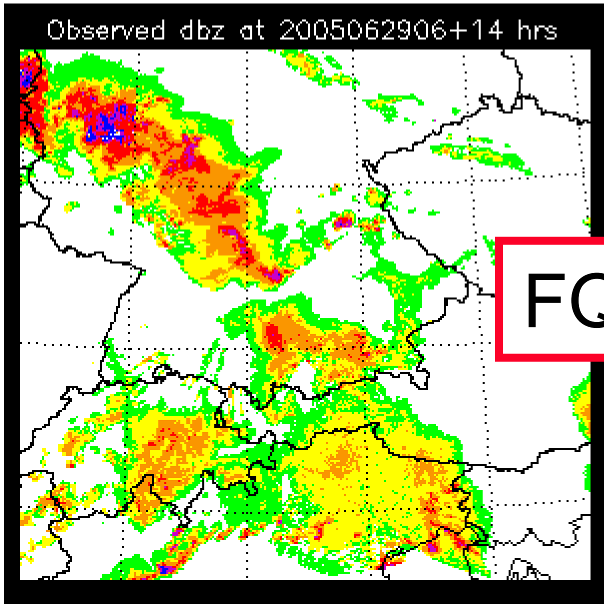
Observation



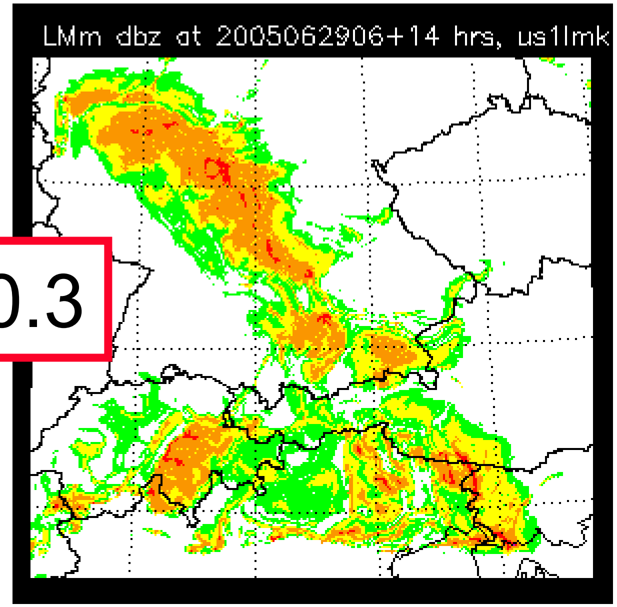
Forecast

Pyramidal Matching: Example with real data

5. Displacement vector for every pixel results from the sum over all scales



FQM = 0.3



Observation

Forecast

Forecast Quality Measure

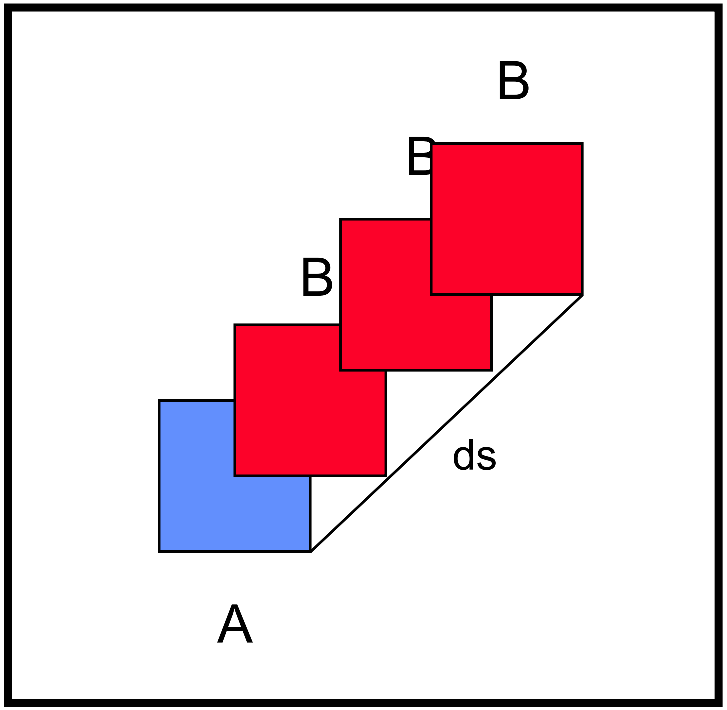
$$FQM = \frac{1}{A} \sum_{A} \max\left(c_1 \cdot DIS, c_2 \cdot LSE\right)$$

$$c_1 = DIS_{max}^{-1}$$

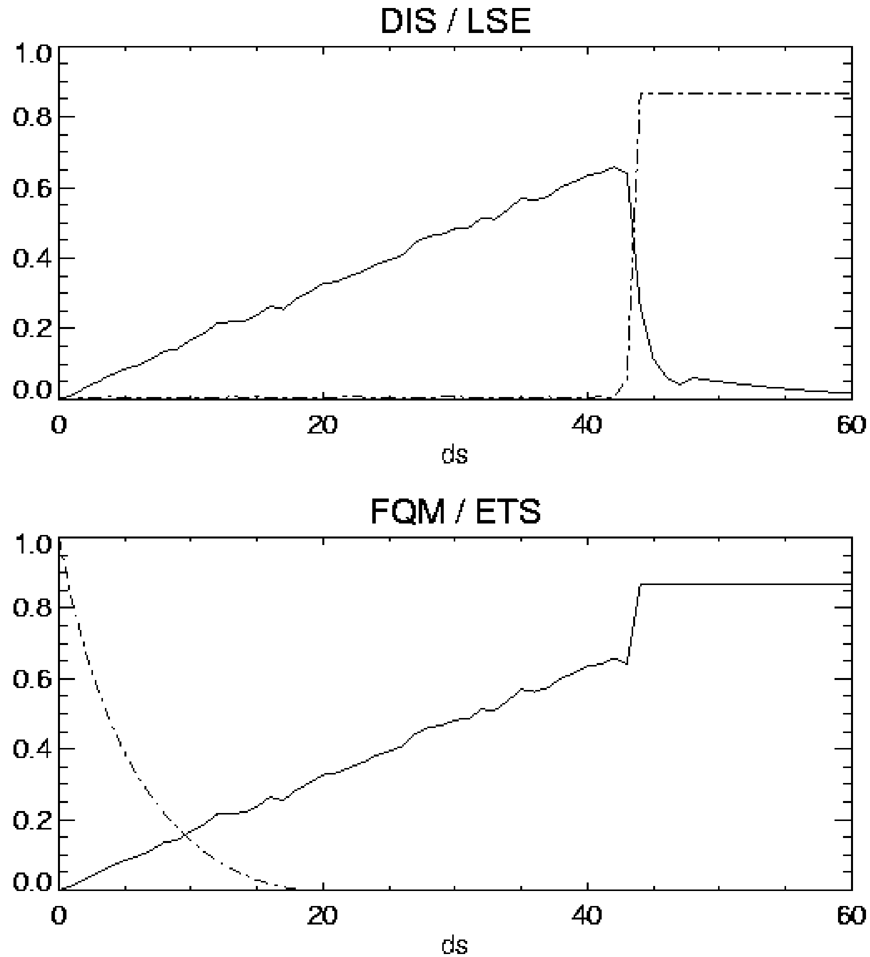
$$c_2 = \left(BT_{max} - BT_{min}\right)^{-2}$$

If forecast and observed features can be matched, the magnitude of the displacement vector DIS characterises forecast quality, whereas when matching features cannot be found within the search distance, the local squared error LSE between both fields is used.

Simplified case



2 identical features
increasingly separated

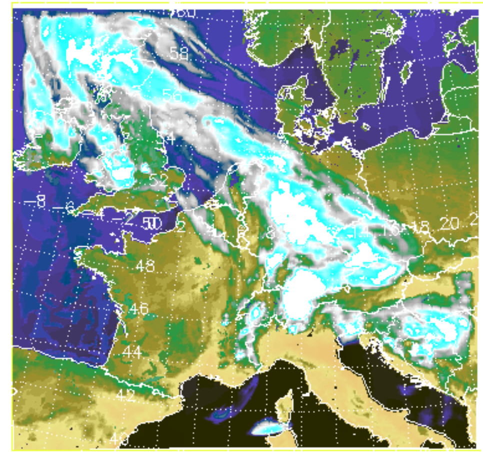


measures vs. separation distance

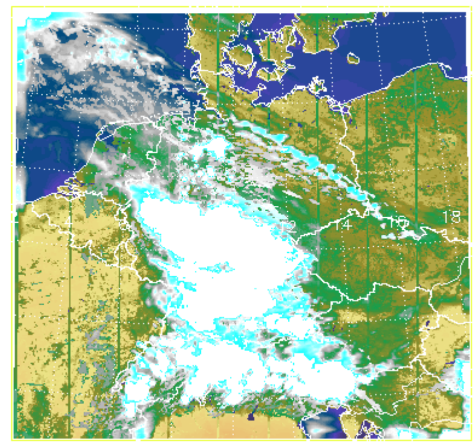
Applied in a Regional Ensemble Forecasting System

- COSMO-LEPS: based on ECMWF EPS providing initial and boundary conditions and Lokal-Modell (LM Δx=7km)
- LMSynSat: forward operator (RTTOV7) to compute synthetic satellite imagery in LM
- High resolution LMK experiments (Δx=2.8km) nested into representative members of COSMO-LEPS

BT IR_108 LM fc 2005062812 +032h



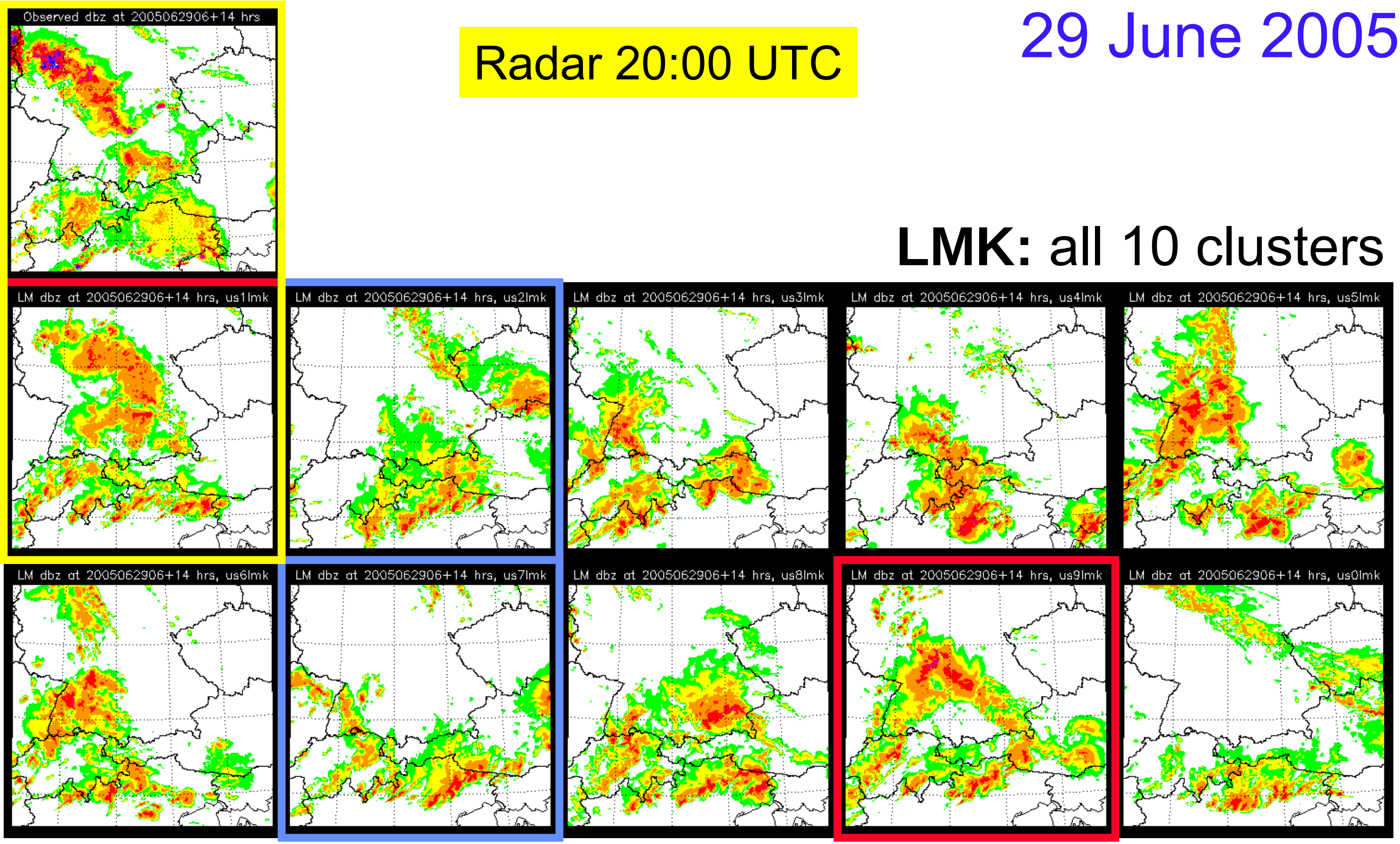
BT IR_108 LMK fc 2005062906 +014h

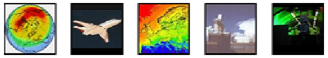


Applied in a Regional Ensemble Forecasting System on 29 June 2005

Radar 20:00 UTC

LMK: all 10 clusters

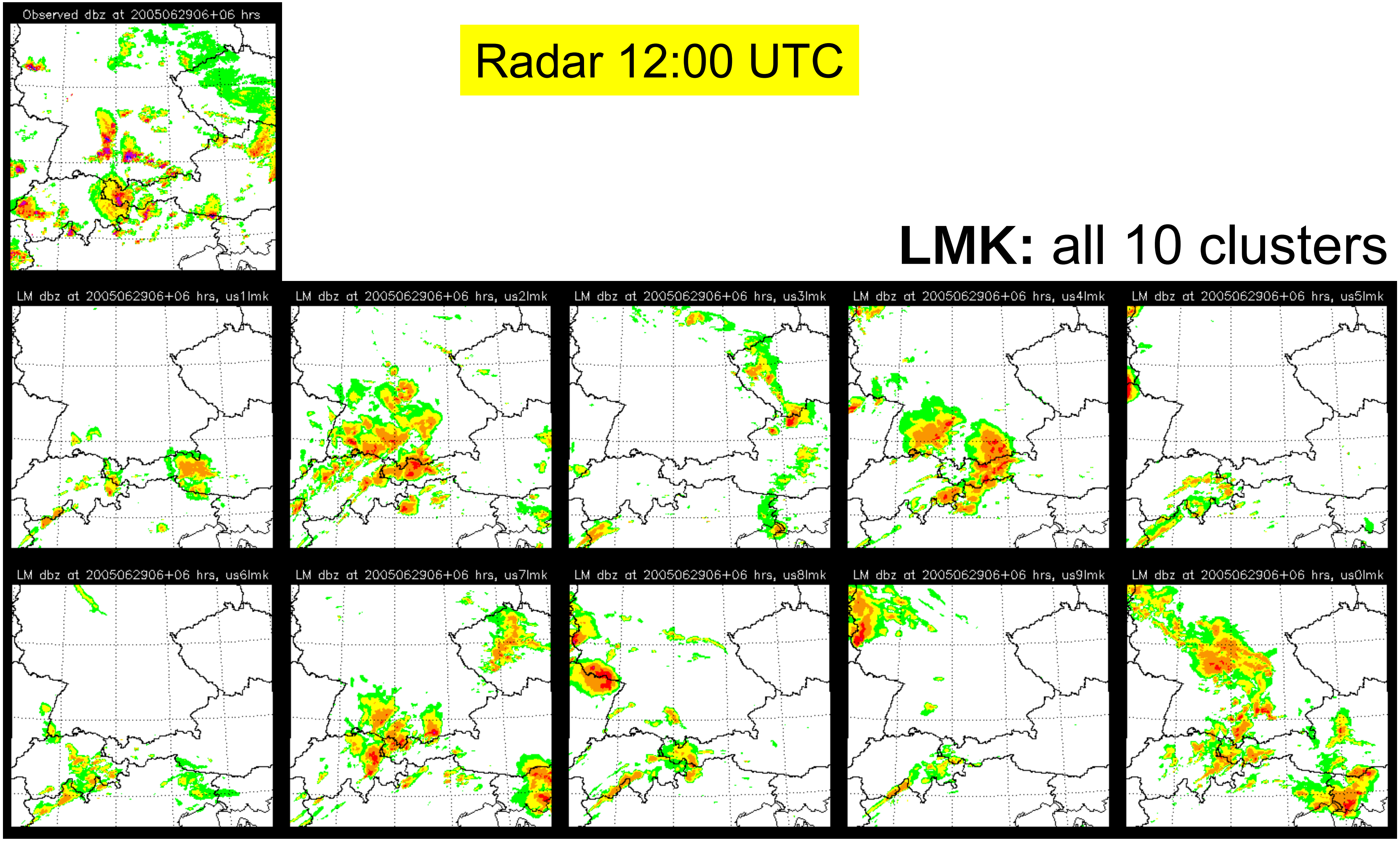




29 June 2005

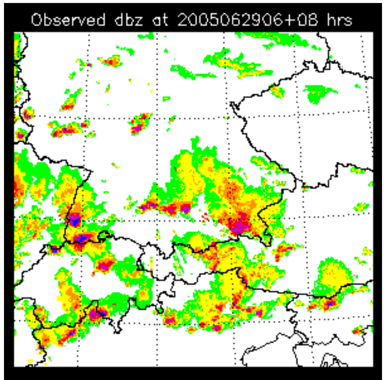
Radar 12:00 UTC

LMK: all 10 clusters

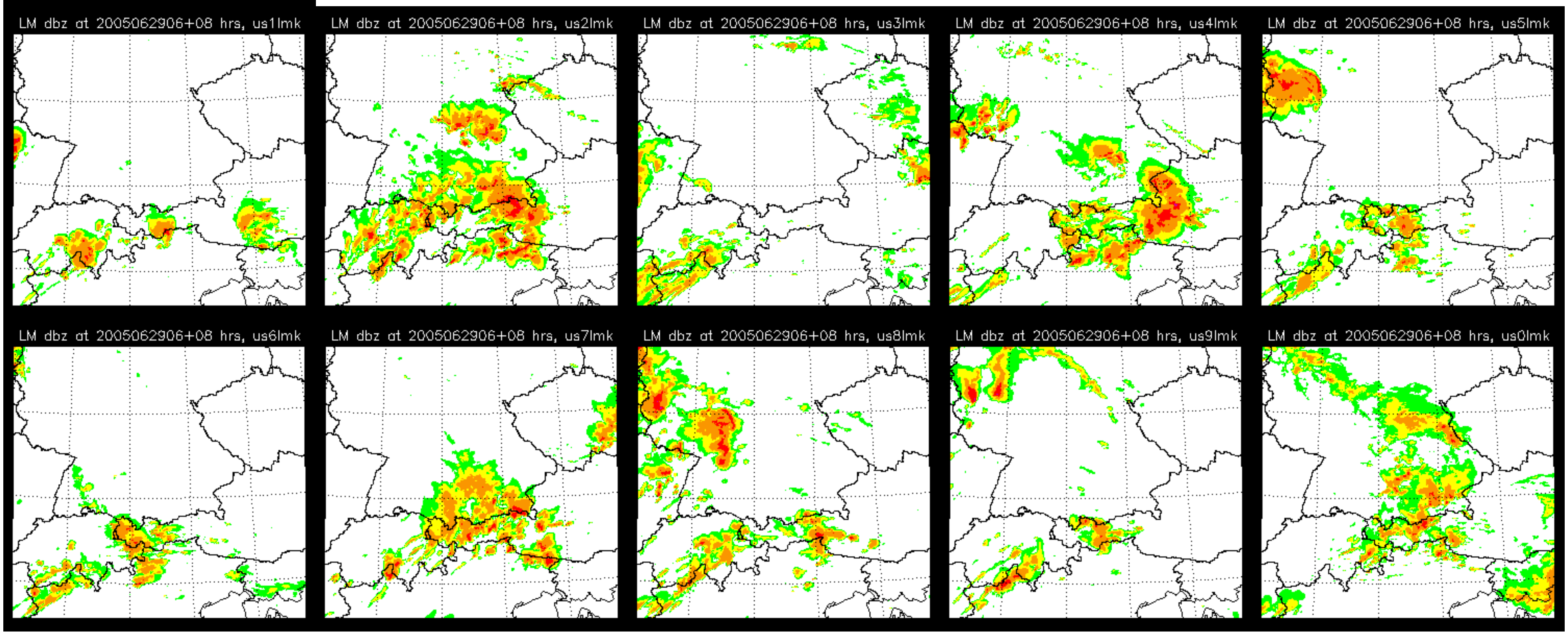


29 June 2005

Radar 14:00 UTC



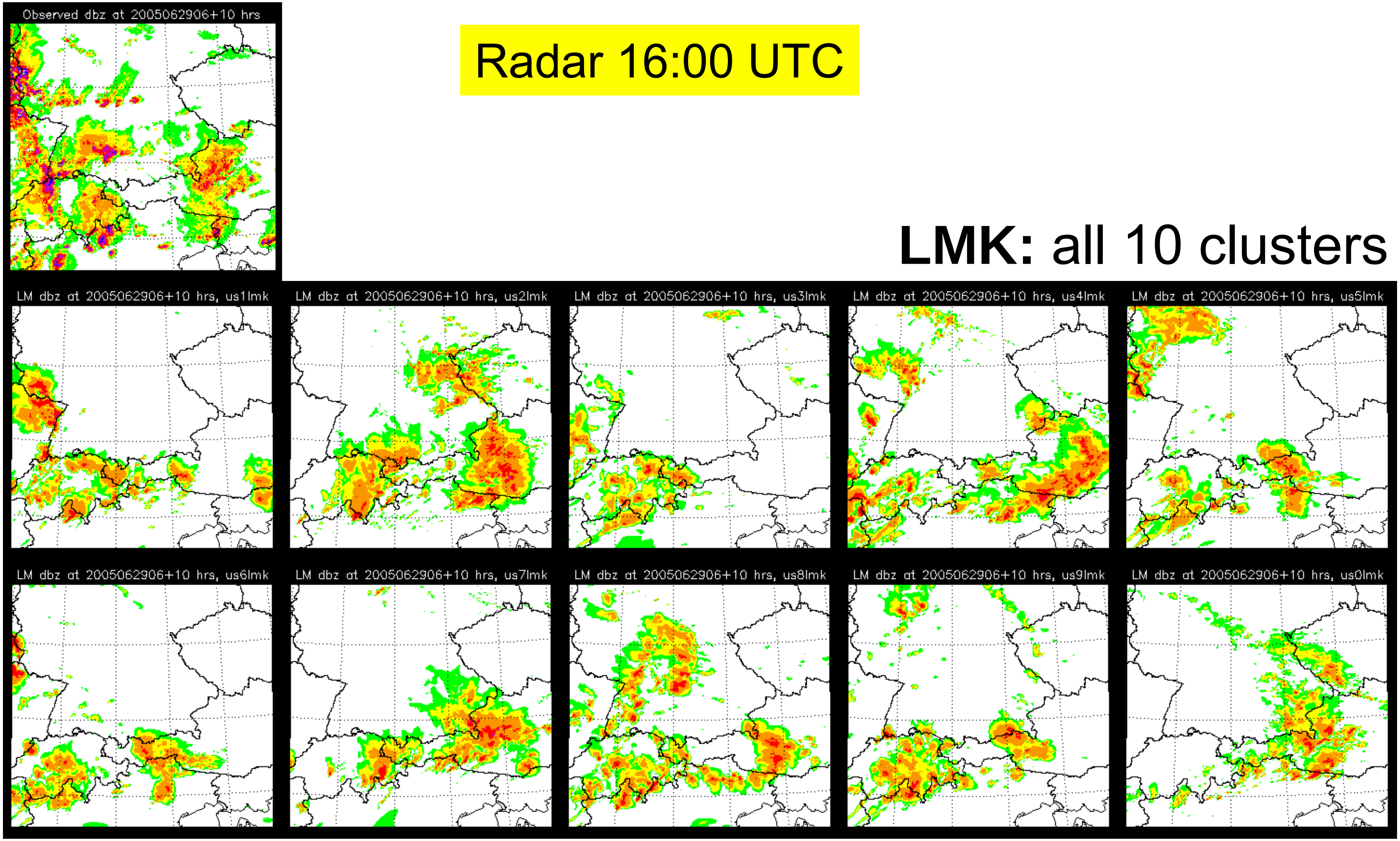
LMK: all 10 clusters



29 June 2005

Radar 16:00 UTC

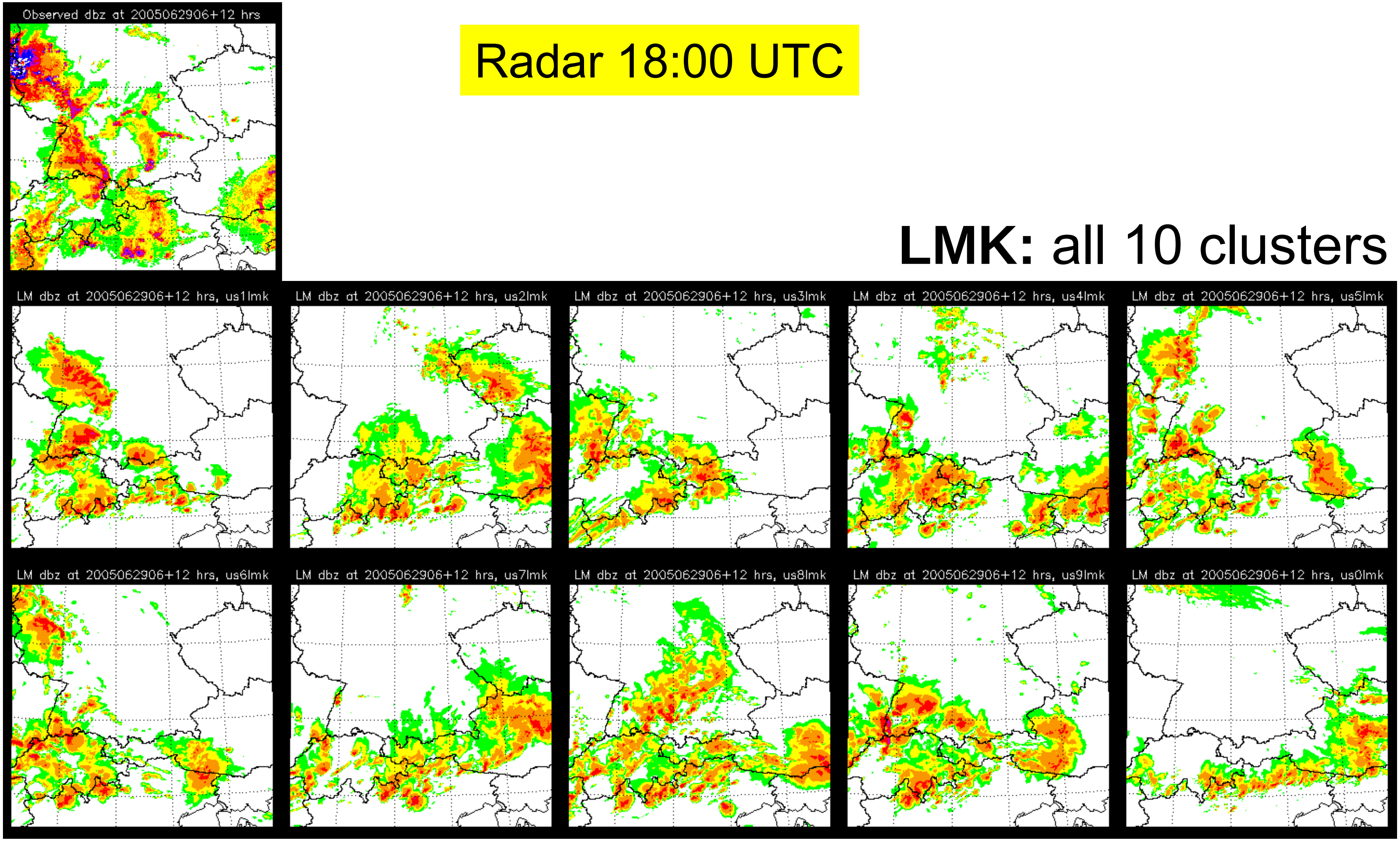
LMK: all 10 clusters



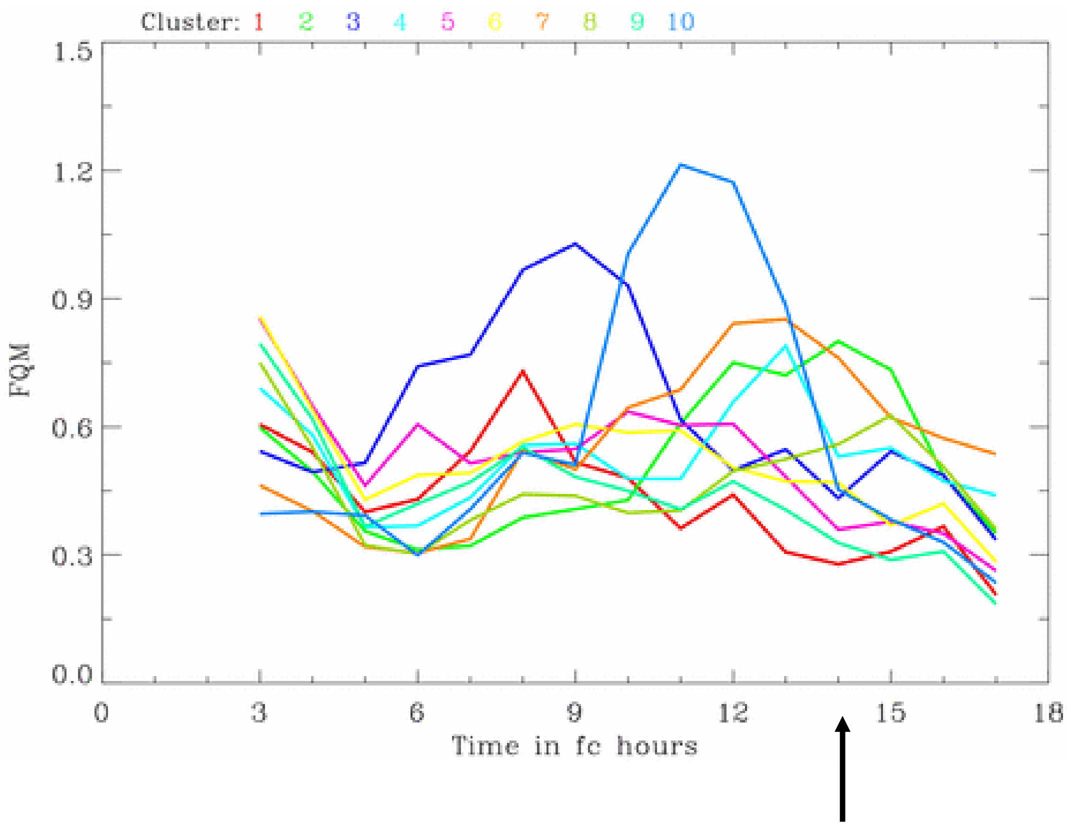
29 June 2005

Radar 18:00 UTC

LMK: all 10 clusters

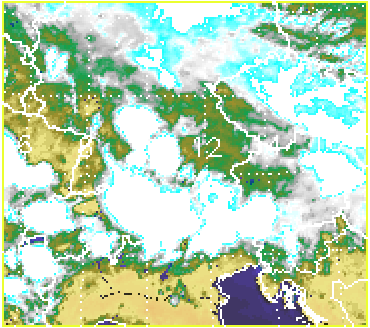


Forecast Quality of LMK based on Radar data



29 June 2005

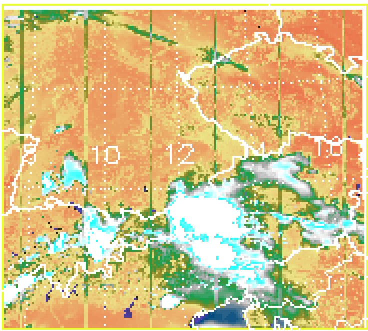
BT IR_108 MET8 2005062900 12 UTC



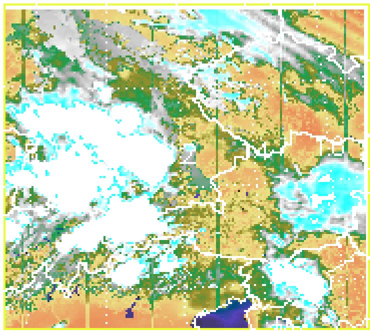
Meteosat 8 IR10.8 12:00 UTC

LMK: all 10 clusters

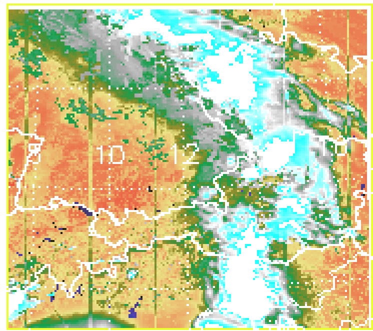
BT IR LMK fc 2005062906 +0600h



BT IR LMK fc 2005062906 +0600h



BT IR LMK fc 2005062906 +0600h



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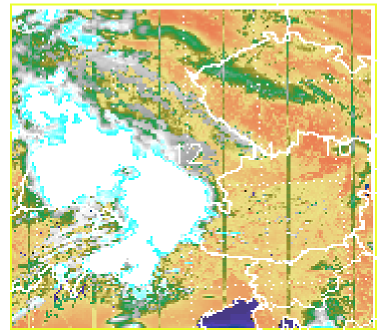
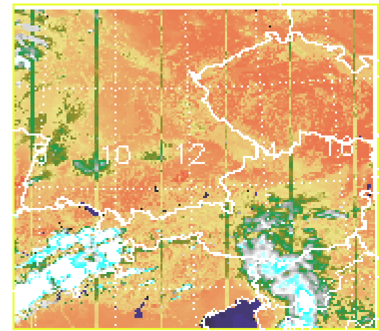


BT IR LMK fc 2005062906 +0600h



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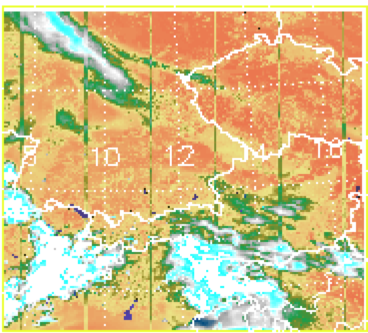
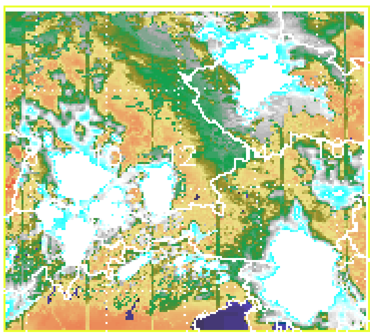


BT IR LMK fc 2005062906 +0600h



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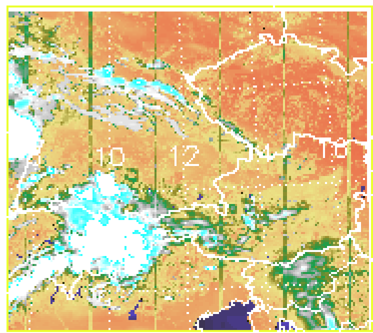

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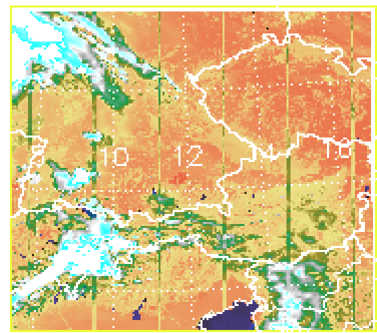

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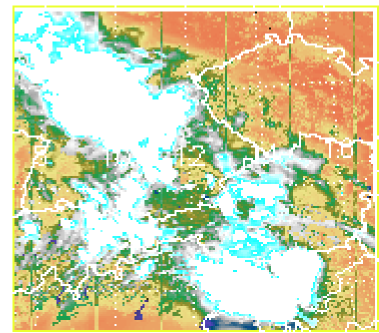
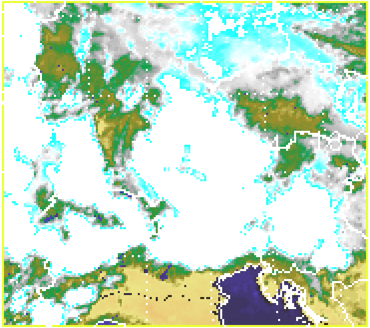


29 June 2005

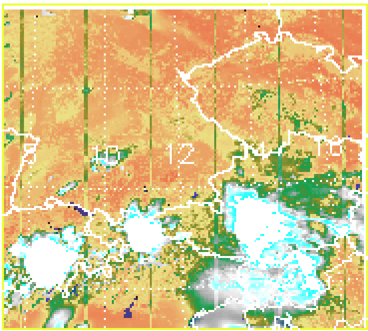
BT IR_108 MET8 2005062900 14 UTC



Meteosat 8 IR10.8 14:00 UTC

LMK: all 10 clusters

BT IR LMK fc 2005062906 +0800h



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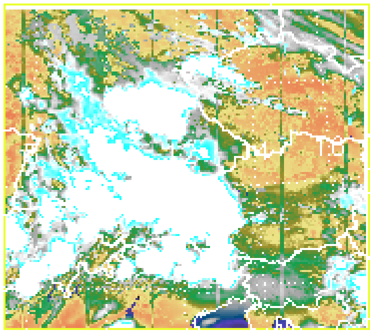

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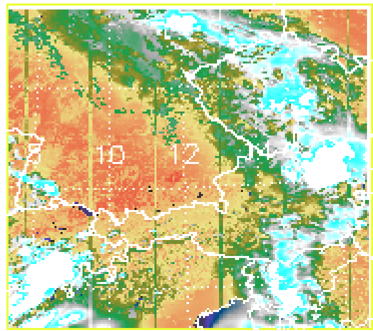

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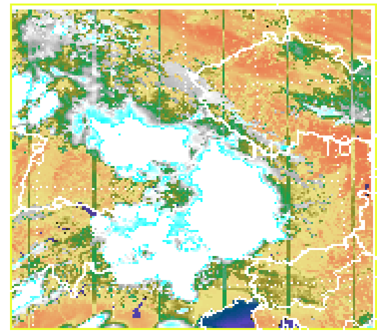

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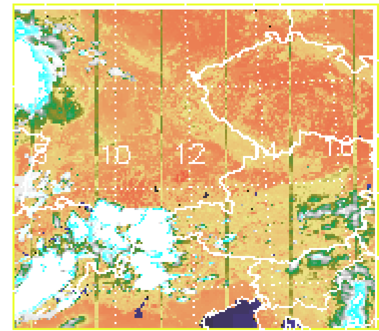

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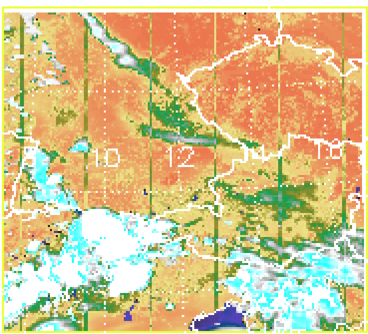

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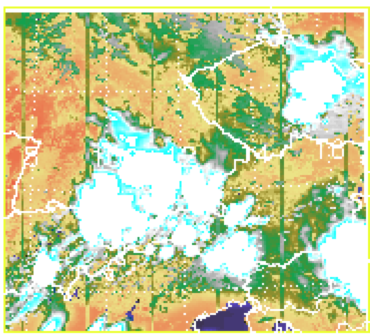

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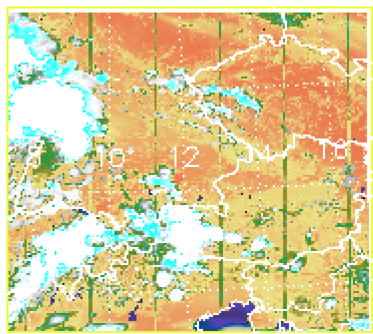

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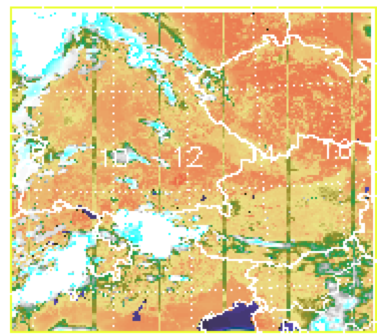
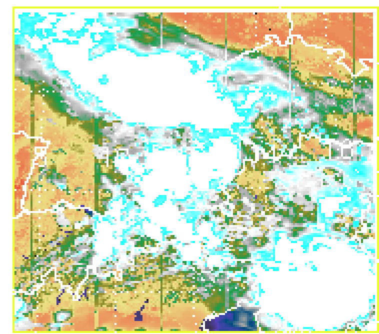
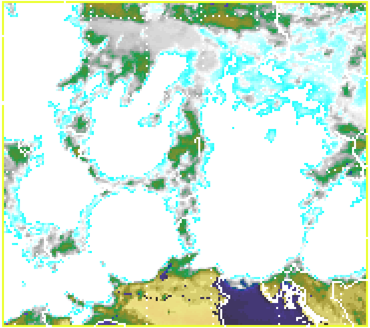


BT IR LMK fc 2005062906 +0800h



29 June 2005

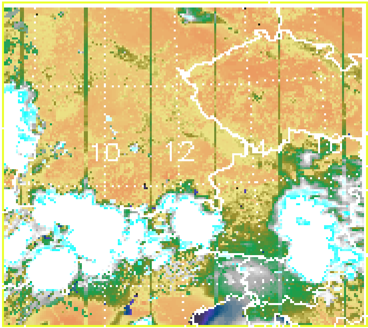
BT IR_108 MET8 2005062900 16 UTC



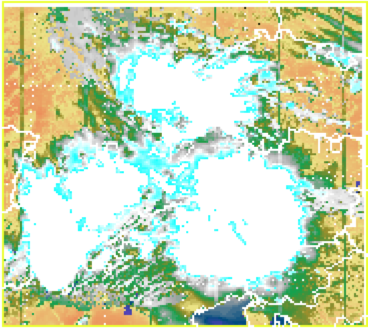
Meteosat 8 IR10.8 16:00 UTC

LMK: all 10 clusters

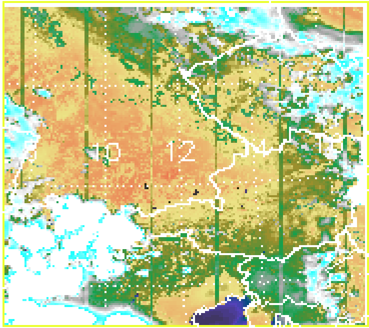
BT IR LMK fc 2005062906 +1000h



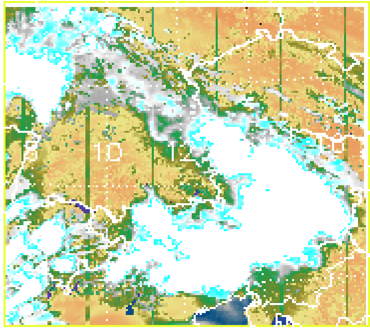
BT IR LMK fc 2005062906 +1000h



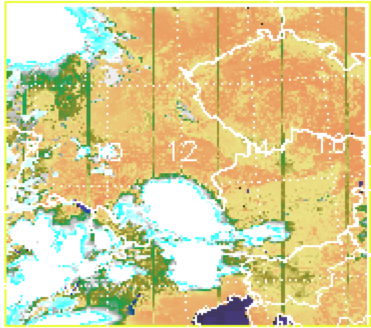
BT IR LMK fc 2005062906 +1000h



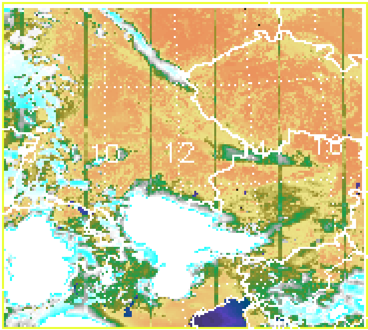
BT IR LMK fc 2005062906 +1000h



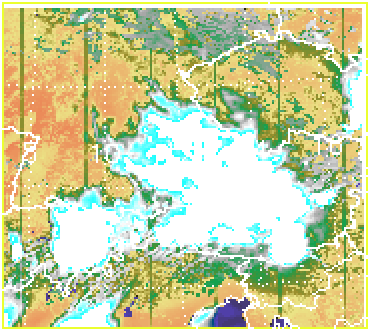
BT IR LMK fc 2005062906 +1000h



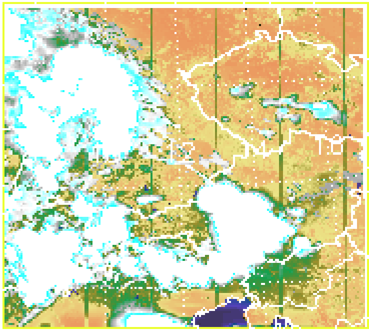
BT IR LMK fc 2005062906 +1000h



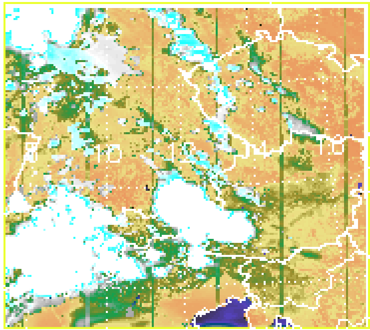
BT IR LMK fc 2005062906 +1000h



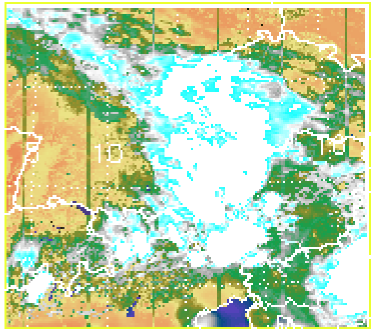
BT IR LMK fc 2005062906 +1000h



BT IR LMK fc 2005062906 +1000h

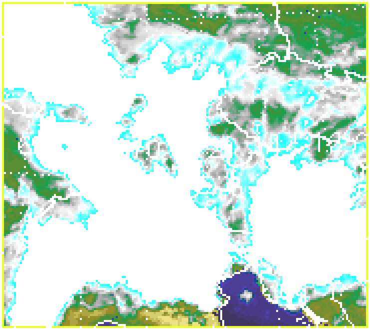


BT IR LMK fc 2005062906 +1000h



29 June 2005

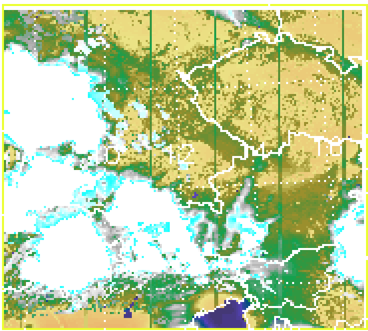
BT IR_108 MET8 2005062900 18 UTC



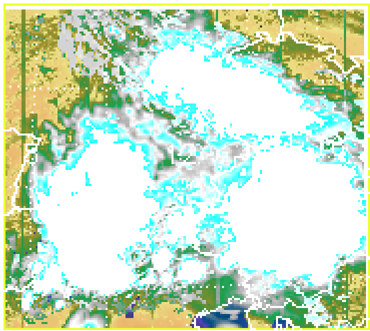
Meteosat 8 IR10.8 18:00 UTC

LMK: all 10 clusters

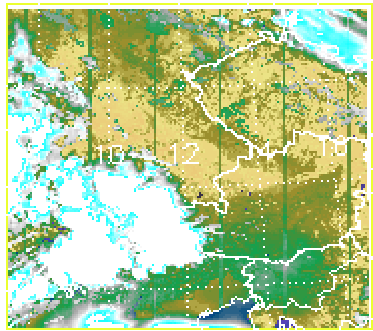
BT IR LMK fc 2005062906 +1200h



BT IR LMK fc 2005062906 +1200h



BT IR LMK fc 2005062906 +1200h



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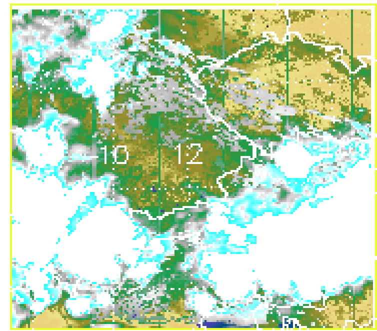

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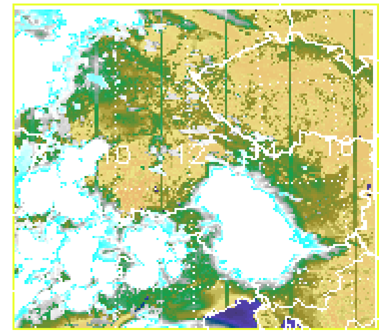
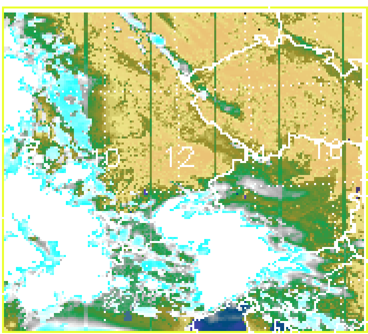
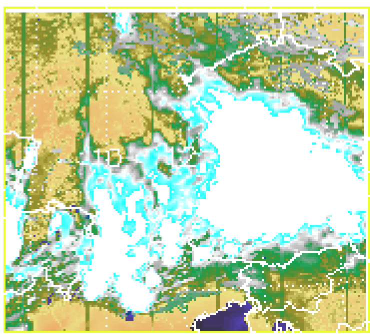


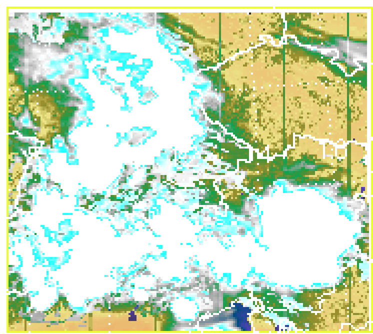
BT IR LMK fc 2005062906 +1200h



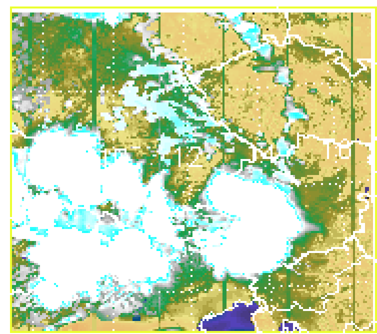
BT IR LMK fc 2005062906 +1200h



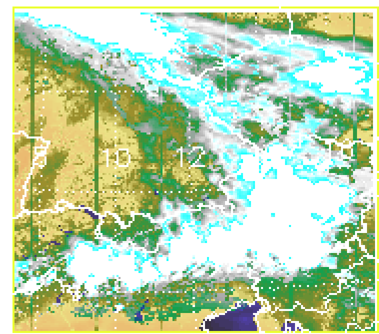
BT IR LMK fc 2005062906 +1200h



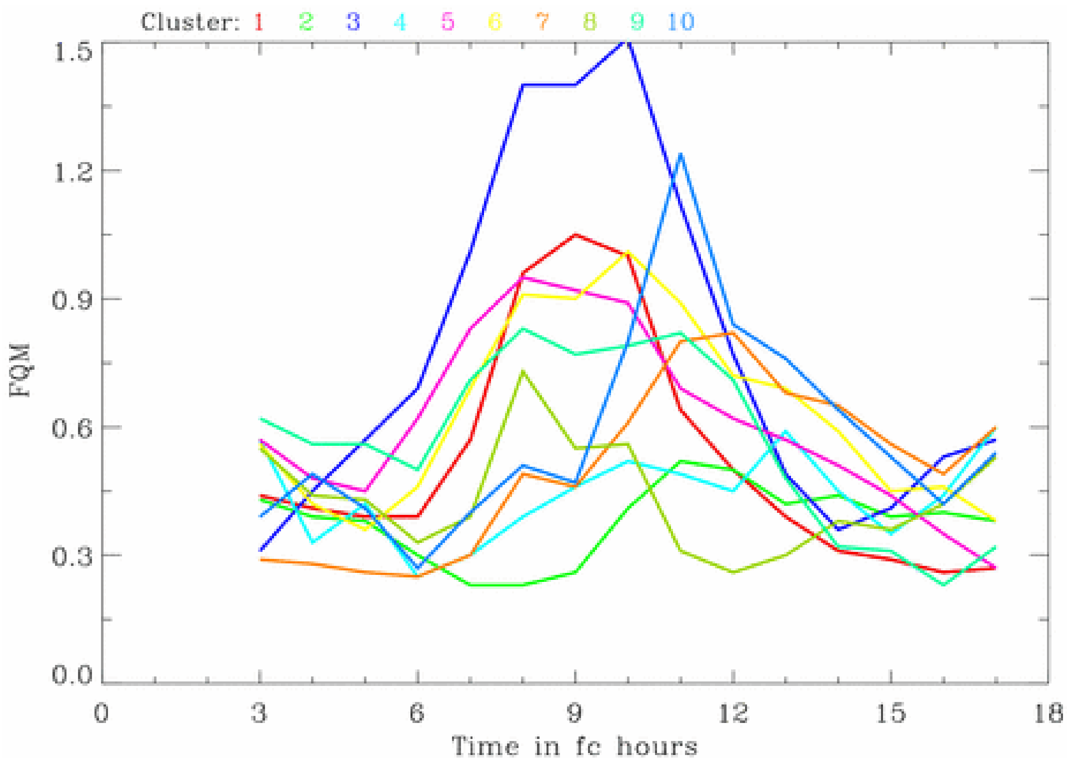
BT IR LMK fc 2005062906 +1200h



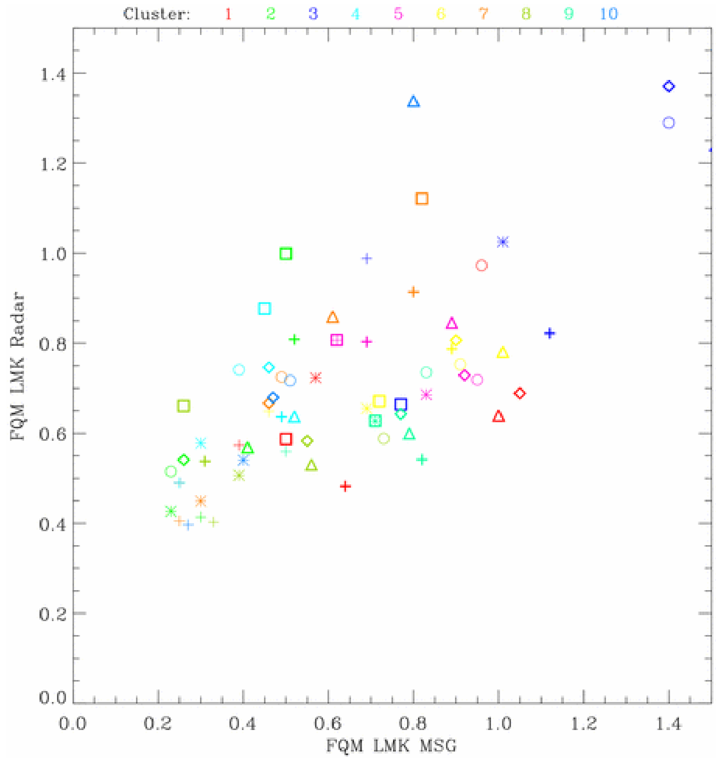
BT IR LMK fc 2005062906 +1200h



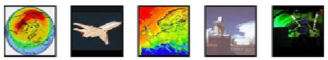
Forecast Quality of LMK based on Satellite data



Forecast Quality of LMK based on Satellite vs Radar data



Correlation FQM(MSG vs Radar) = 0.73



Summary, conclusions and outlook

- The novel Forecast Quality Measure allows an objective evaluation based on image comparison.

  Keil, C. and G. C. Craig, 2006: A Displacement-based Error Measure applied in a Regional Ensemble Forecasting System, *Mon. Wea. Rev.*, submitted.

- Comparison of Regional Ensemble Forecasts with Radar and Satellite data provides consistent results.

- Systematic evaluation planned during DOP in 2007

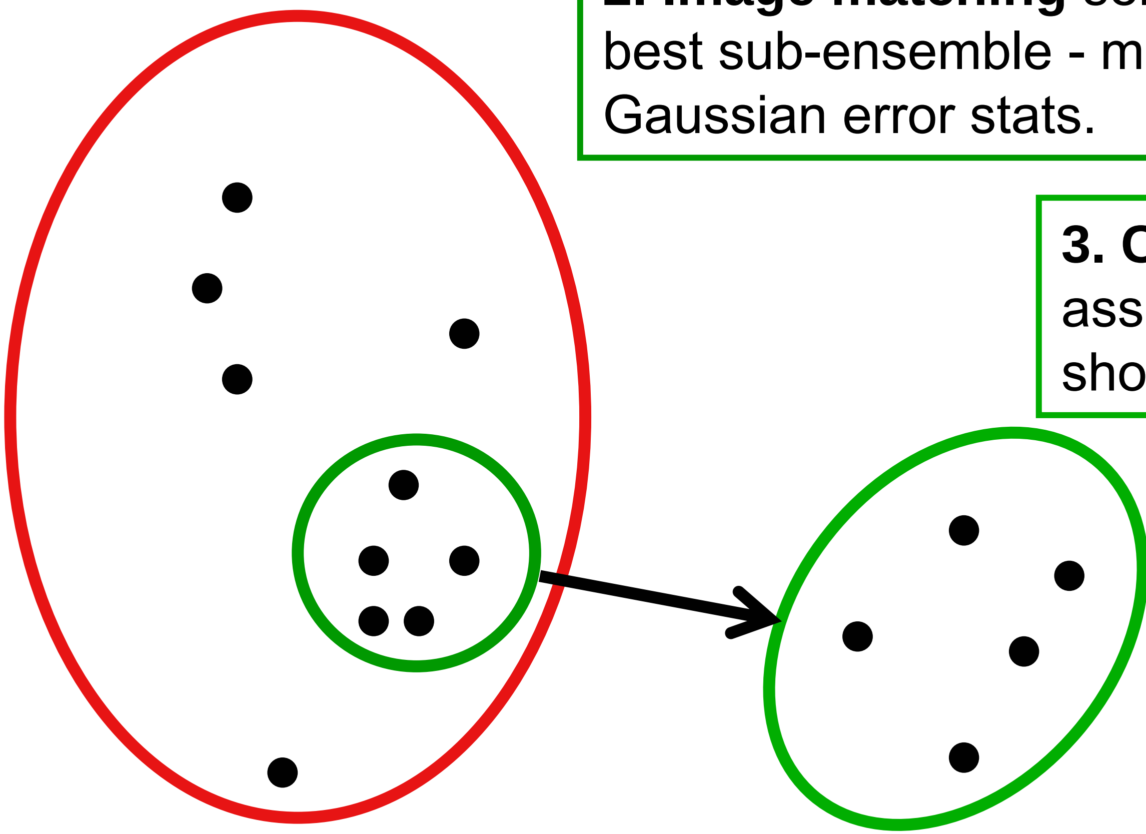
- Radar rainfall assimilation experiments in selected members which are favourable for convection (in collaboration with MeteoSwiss)

Goal: Image matching as pre-conditioner for DA

1. COSMO-LEPS ensemble forecast - highly non-Gaussian error stats.

2. Image matching selects best sub-ensemble - more Gaussian error stats.

3. Conventional DA assimilates most recent data for short-range forecast

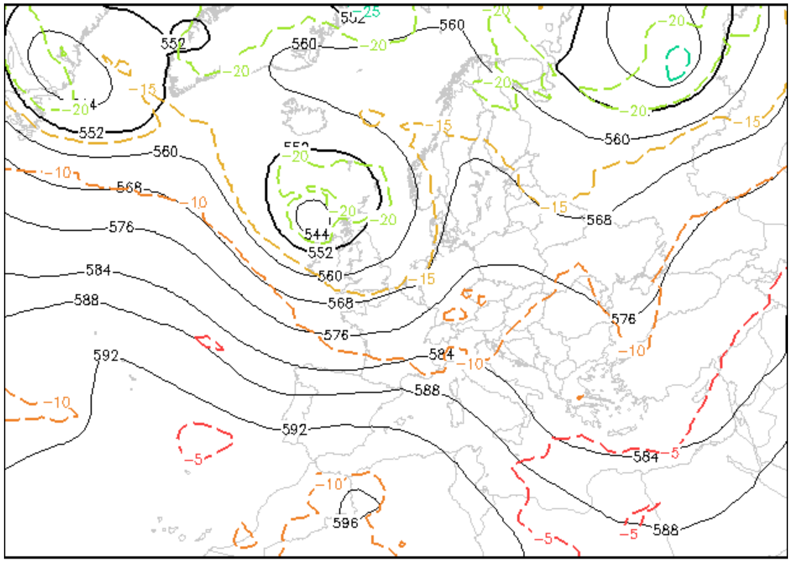


DAQUA Ensemble Experiments JJA 2006 (tbd)

- Type I: 31 July 2006 — Forced frontal
- Type II: 28 June 2006 — Forced non-frontal
- Type III: 13 July 2006 — Airmass convection

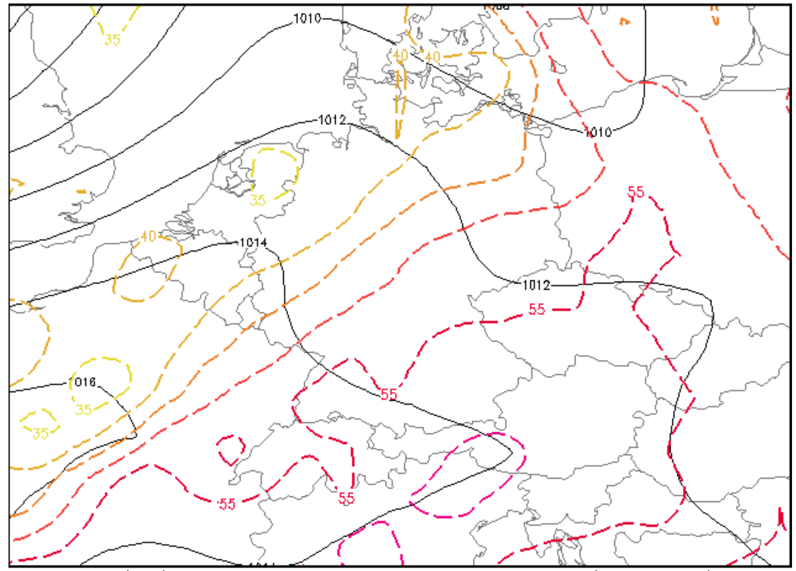
- [Type IIb: 28 August 2006 — Forced non-frontal]

Type I: 20060731



Hoehe 500 hPa GFS (gpdm)
Temperatur 500 hPa GFS (°C)

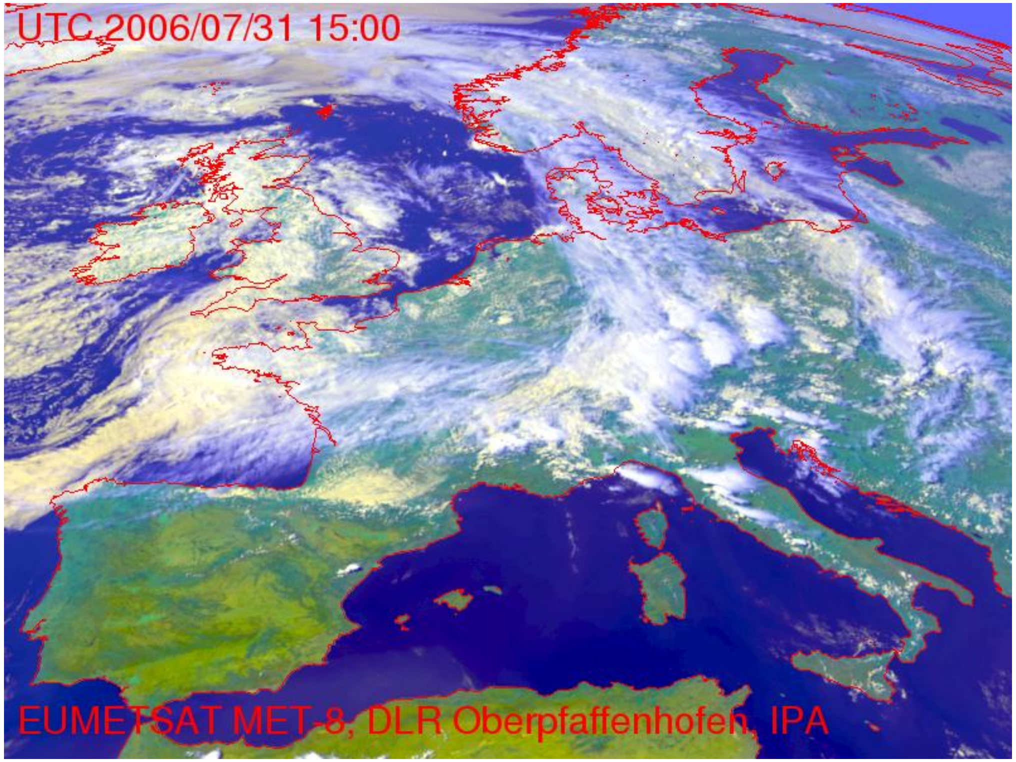
Mo 31.07.06 12 GMT (Mo 00 + 12)
WetterOnline

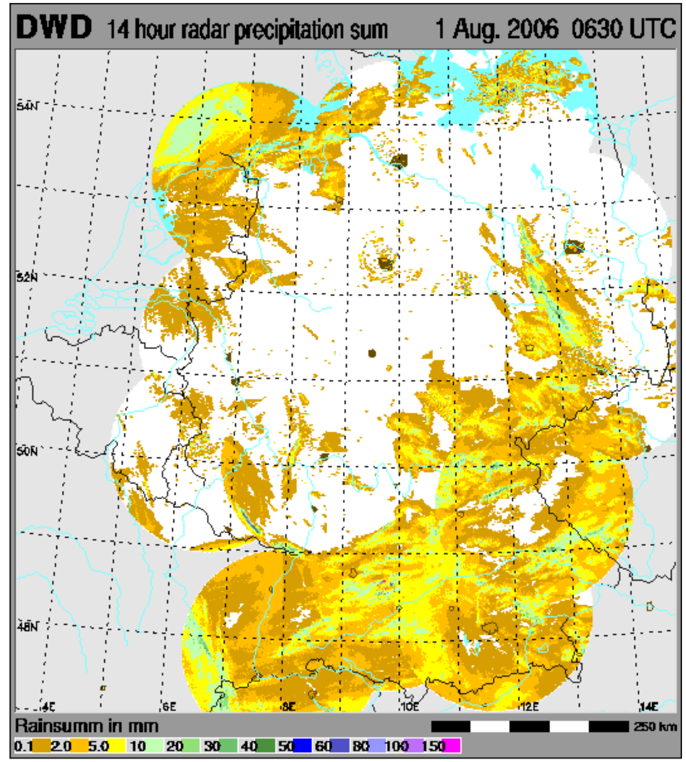


Bodendruck (hPa)
Equiv. Pot. Temp 850 hPa GFS (°C)

Mo 31.07.06 12 GMT (Mo 00 + 12)
WetterOnline

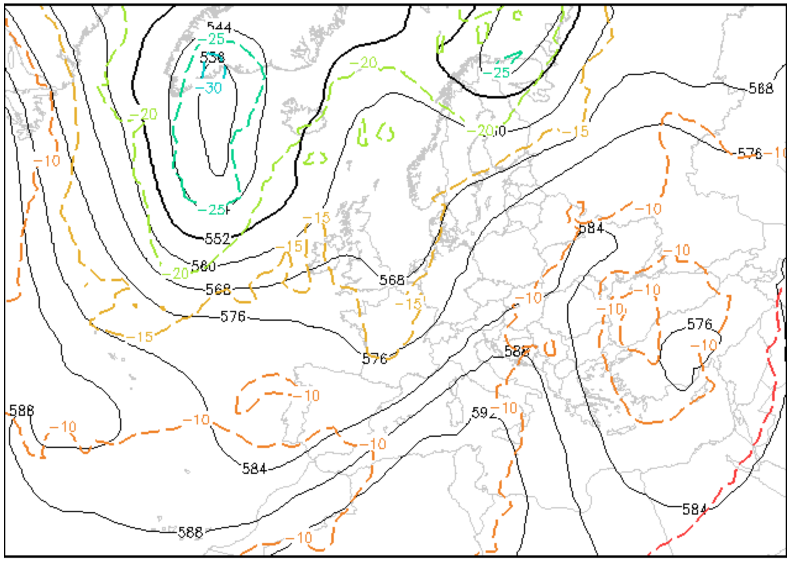
Type I: 20060731



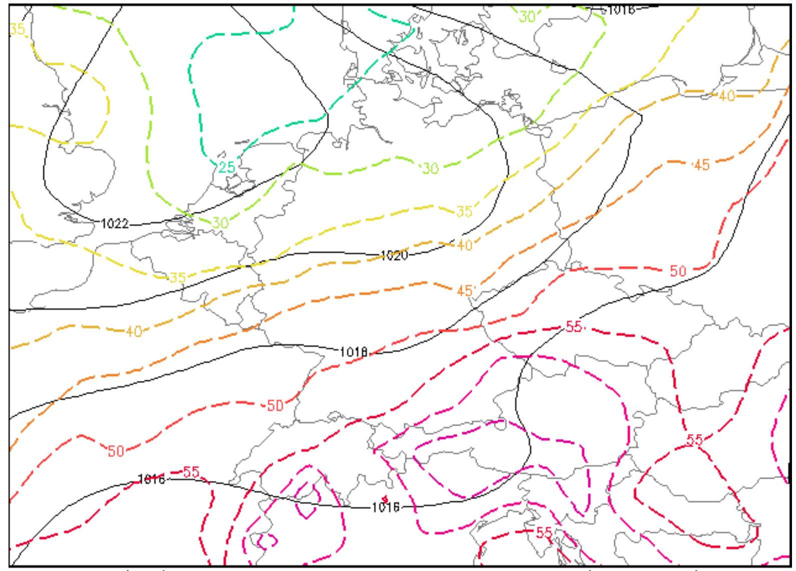


24h precip:	Feldberg	20 mm
	Freiburg	2 mm
	Freudenstadt	13 mm
	Klippeneck	27 mm

Type II: 20060628

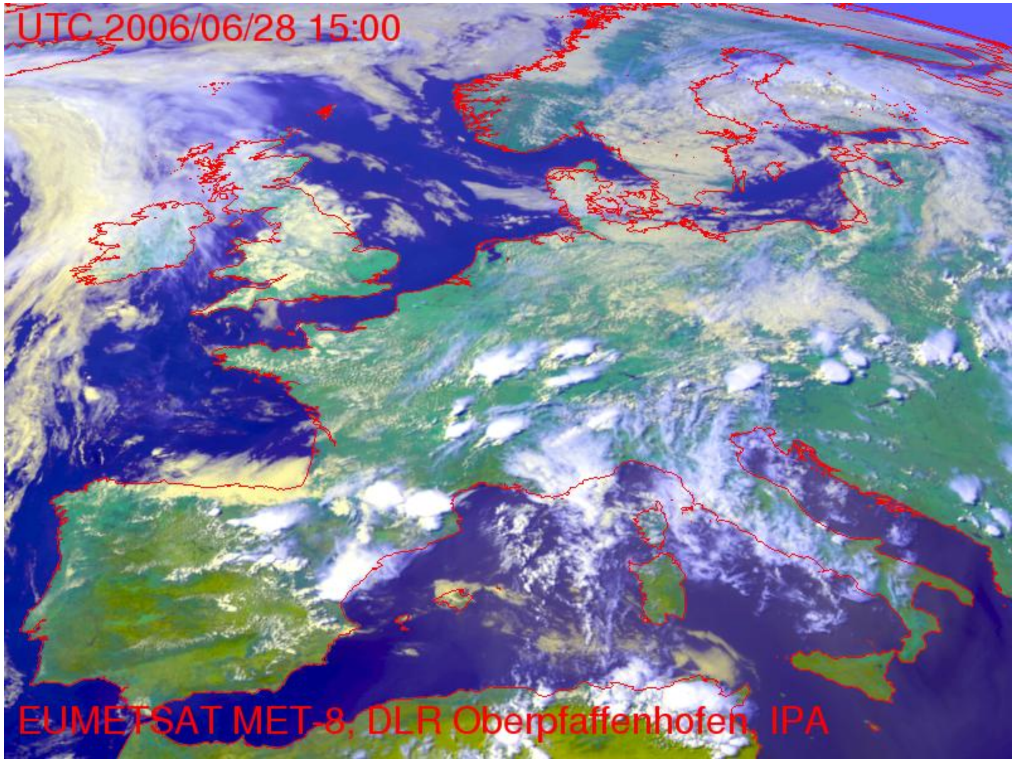


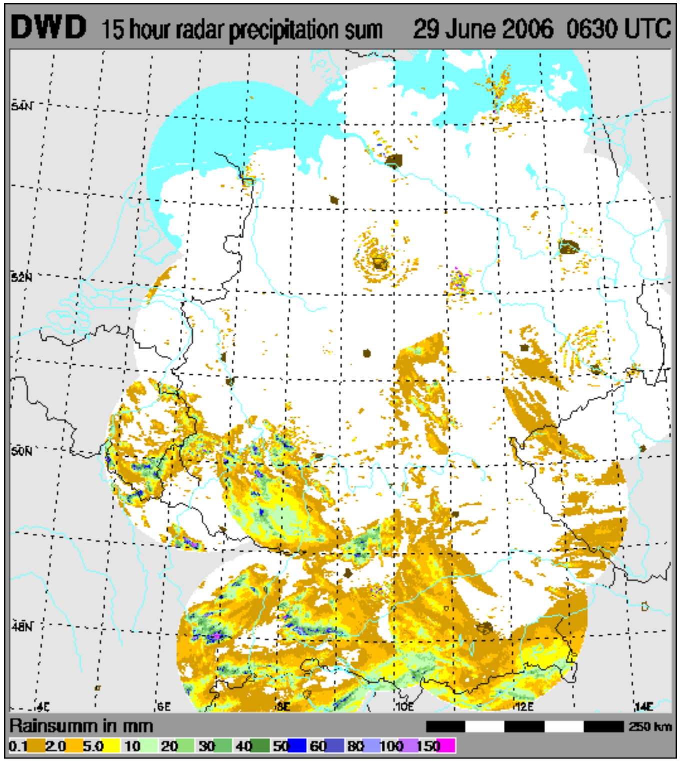
Hoehe 500 hPa GFS (gpdm)   Mi 28.06.06 12 GMT (So 00 + 84)
Temperatur 500 hPa GFS (°C)   WetterOnline



Bodendruck (hPa)   Mi 28.06.06 12 GMT (Mi 00 + 12)
Equiv. Pot. Temp 850 hPa GFS (°C)   WetterOnline

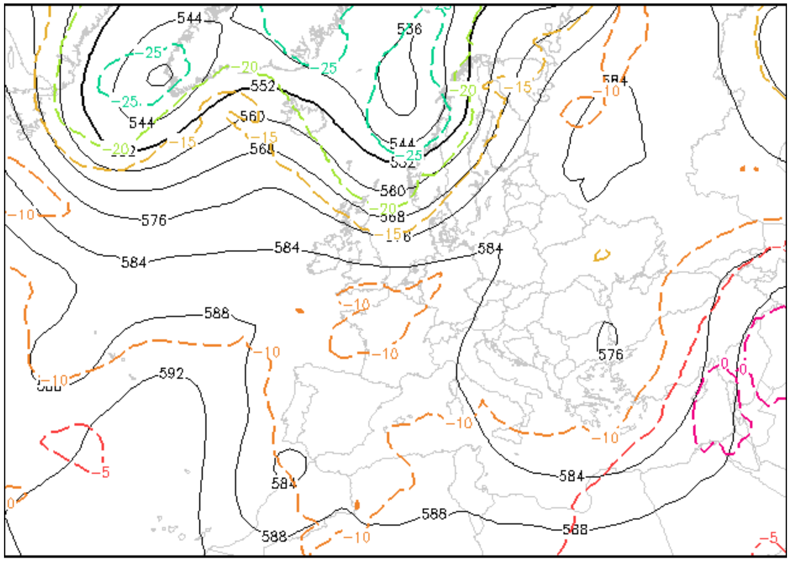
Type II: 20060628



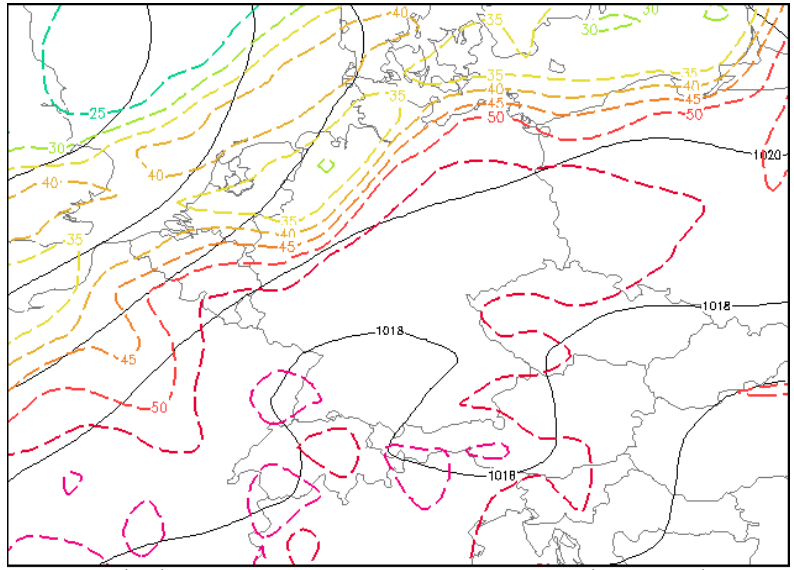


24h precip:	Feldberg	4 mm
	Freiburg	--
	Freudenstadt	13 mm
	Klippeneck	22 mm

Type III: 20060713

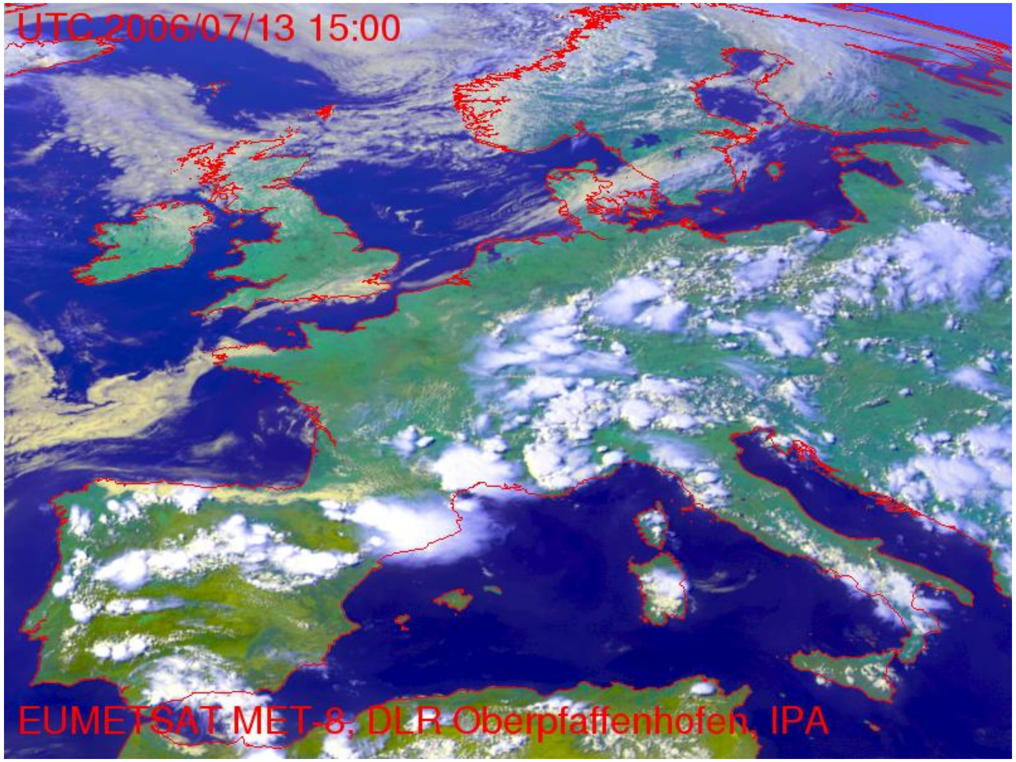


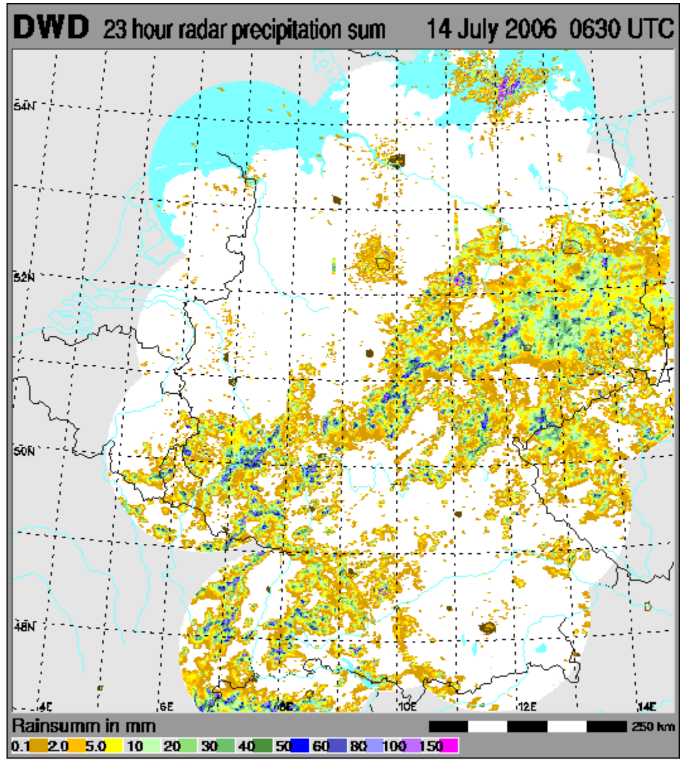
Hoehe 500 hPa GFS (gpdm)
Temperatur 500 hPa GFS (°C)
Do 13.07.06 12 GMT (Do 00 + 12)
WetterOnline



Bodendruck (hPa)
Equiv. Pot. Temp 850 hPa GFS (°C)
Do 13.07.06 12 GMT (Do 00 + 12)
WetterOnline

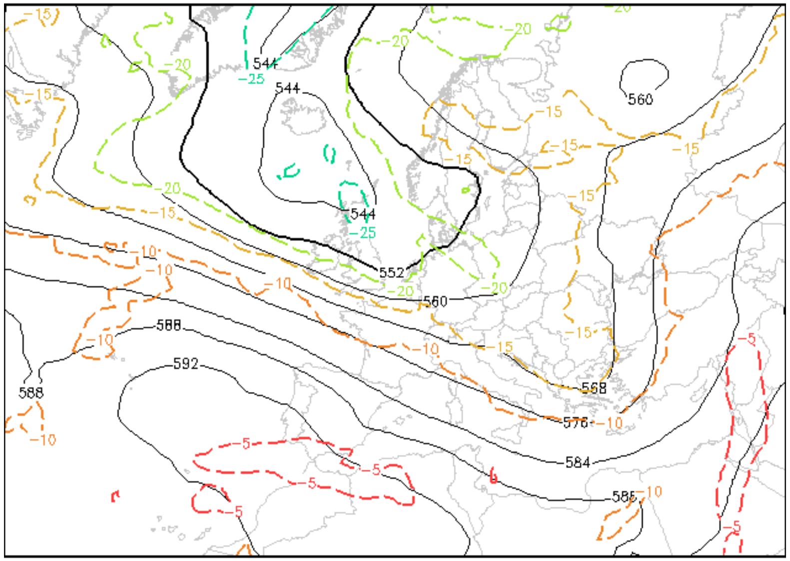
Type III: 20060713





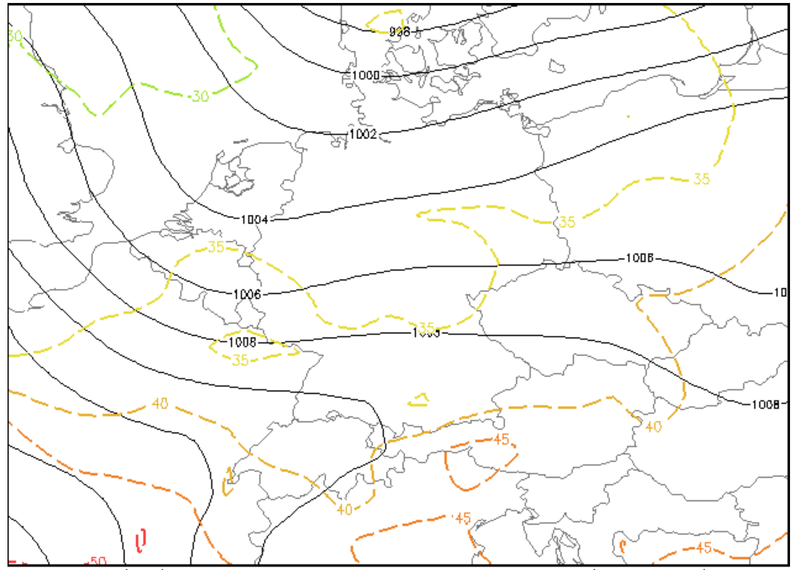
24h precip:	Feldberg	< 5 mm
	Freiburg	--
	Freudenstadt	--
	Klippeneck	< 5 mm

Type IIb: 20060828



Hoehe 500 hPa GFS (gpdm)
Temperatur 500 hPa GFS (°C)

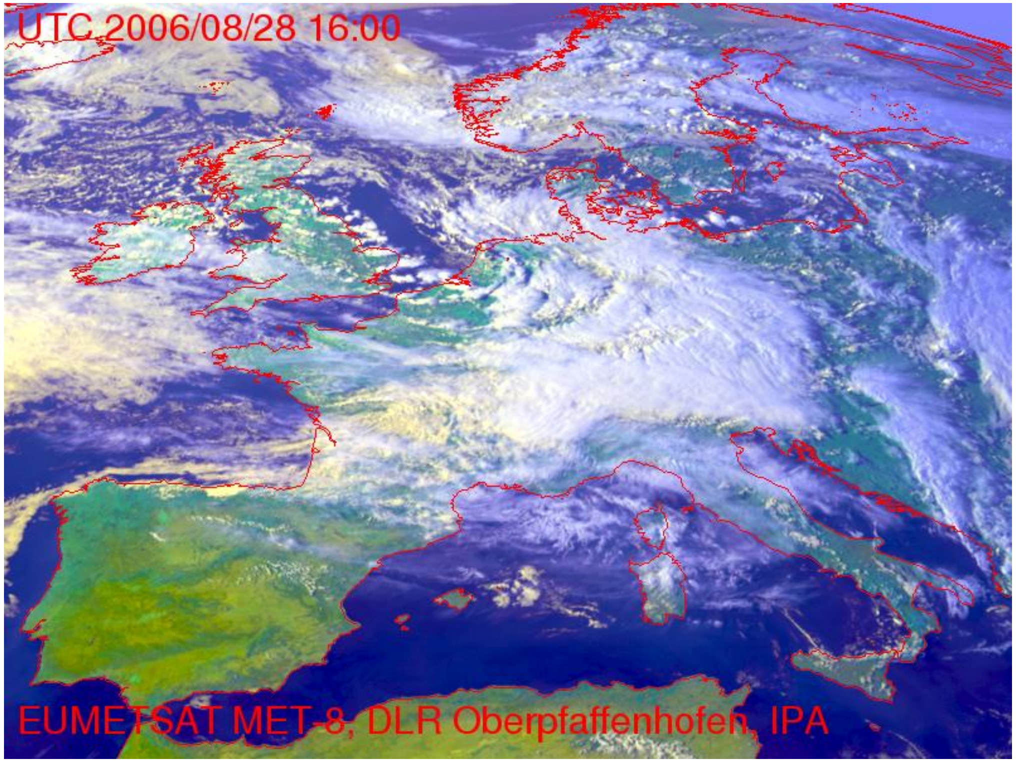
Mo 28.08.06 12 GMT (Do 00 + 108)
WetterOnline

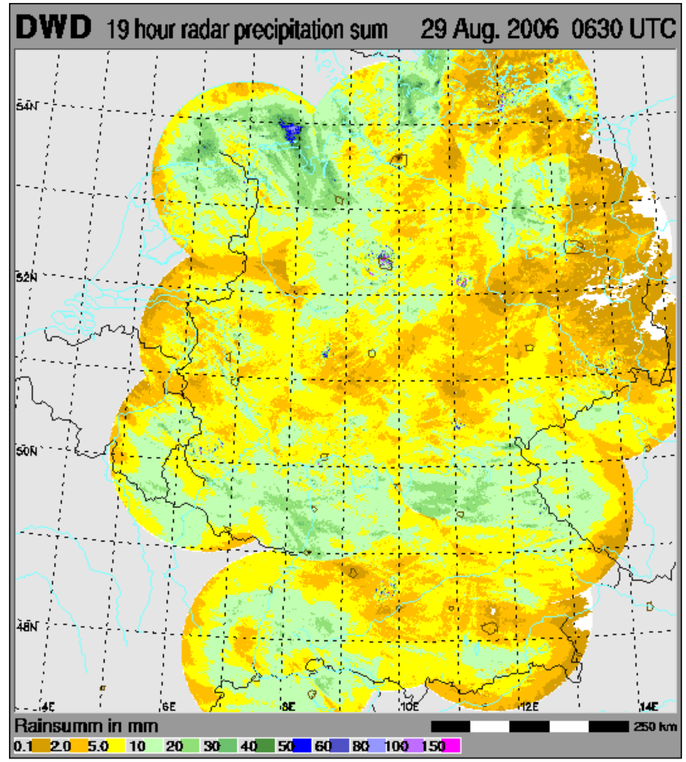


Bodendruck (hPa)
Equiv. Pot. Temp 850 hPa GFS (°C)

Mo 28.08.06 12 GMT (So 00 + 36)
WetterOnline

Type IIb: 20060828





24h precip:	Feldberg	38 mm
	Freiburg	14 mm
	Freudenstadt	28 mm
	Klippeneck	13 mm

Generation of synthetic satellite images in LM: LMSynSat

- RTTOV-7 radiative transfer model (Saunders et al, 1999)
- **Input**: 3D fields: T,qv,qc,qi,qs,clc,ozone

  surface fields: T_g, T_2m, qv_2m, fr_land
- **Output**: cloudy/clear-sky brightness temperatures for

  Meteosat7 (IR and WV channels) and

  Meteosat8 (eight channels)

(Keil et al, 2006)

Met-8 IR & Radar composite sequences