The role of synoptic dry-air intrusions on the West African monsoon onset using nudged climate simulations

and regional modelling

Illustration of the monsoon onset of 2006

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Context and Objective

1. **The monsoon onset over West Africa is characterized by a transitional phase of weakened convection and rainfall *(Sultan and Janicot 2003, Thorncroft et al. 2010)***

2. Extra-tropical dry-air intrusions have been detected over North Africa in summer *(Roca et al. 2005)* that could be associated with weakened convection over the Sahel *(Roca and Deme 2009).*

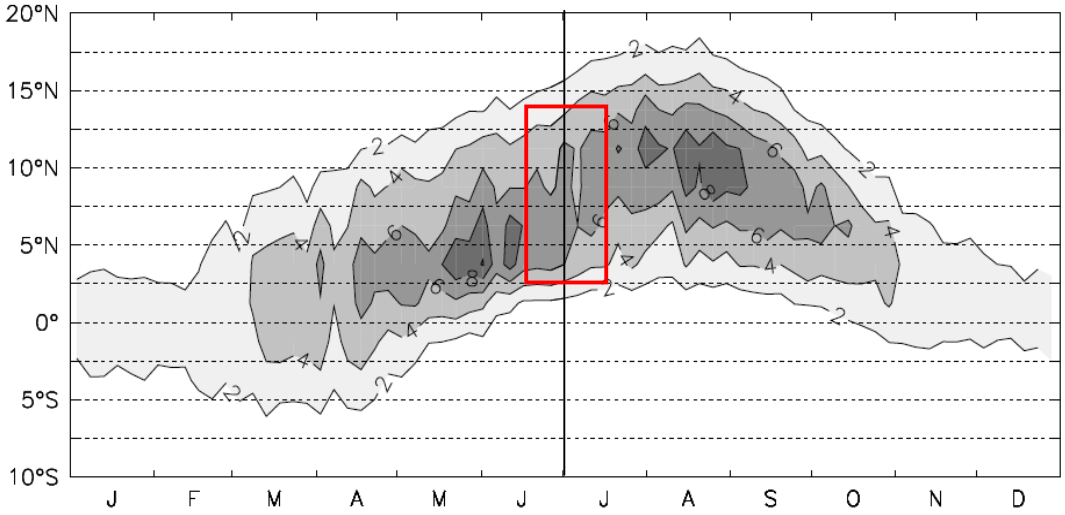
3. Westward moving Rossby wave is induced by convective activity over Northern India, warming atmosphere and inducing subsidence over North Africa and East Mediterranean *(Rodwell and Hoskins 1996, 2001)*

4. The Indian monsoon onset is instrumental in the seasonal increase of subsidence over East Mediterranean *(Rodwell and Hoskins 1996)*

5. The Indian monsoon onset occurs in average about two to three weeks before the West African monsoon onset

➢ (i) Could there be a dynamical link between the Indian and African monsoons ?
➢ (ii) Can dry-air intrusions over North Africa be an ingredient of the African monsoon onset ?

Latitude-time section over West Africa (10°W-10°E) of precipitation (GPCP mm/day 1998-2007) Nguyen et al. 2011



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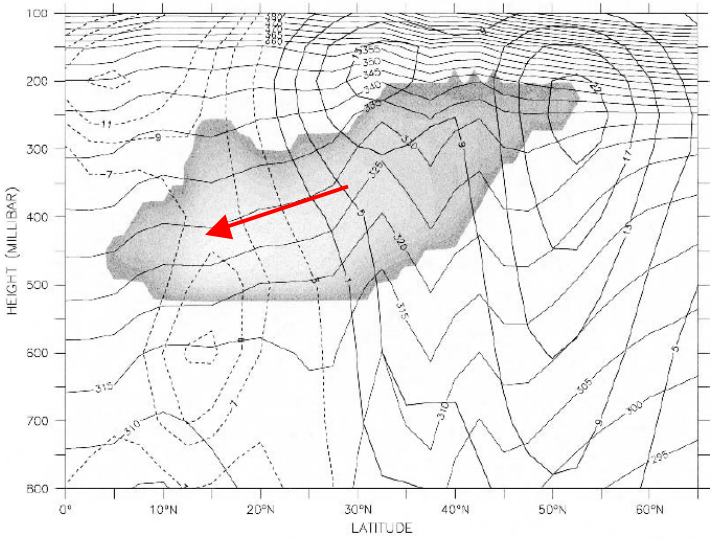

Trajectory density of air mass ending at 500hPa over the Sahel (12.5°N-17.5°N/10°W-10°E)
The lighter shading for the higher density

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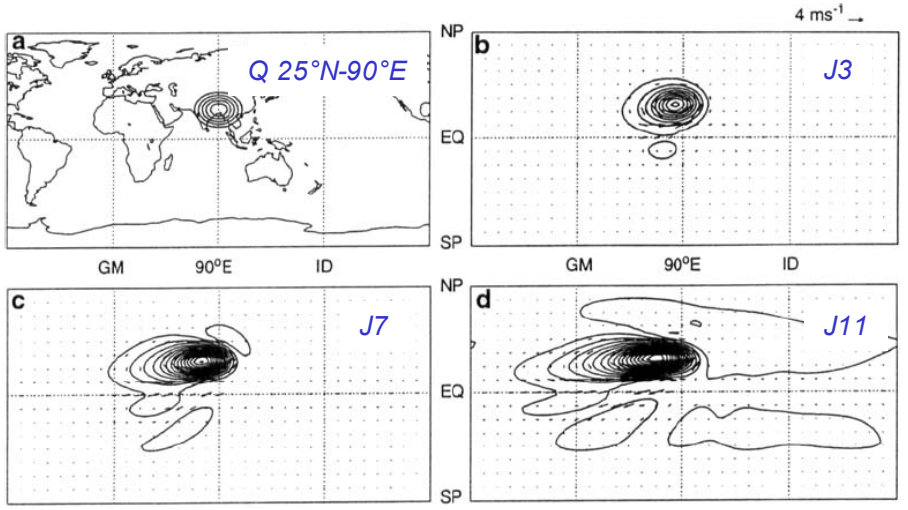
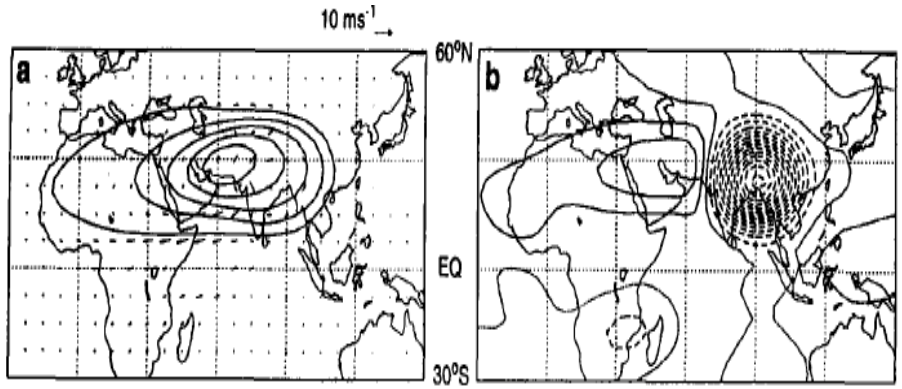


Q 25°N-90°E & Pressure surface - 887hPa



Pression iso-Θ 325K *ω 477hPa*

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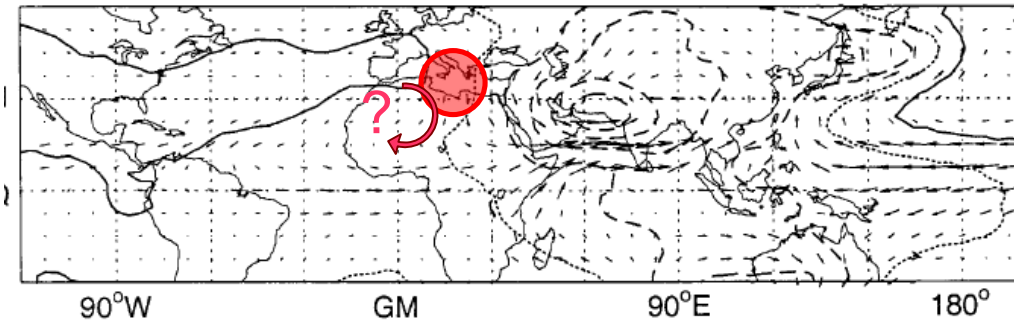
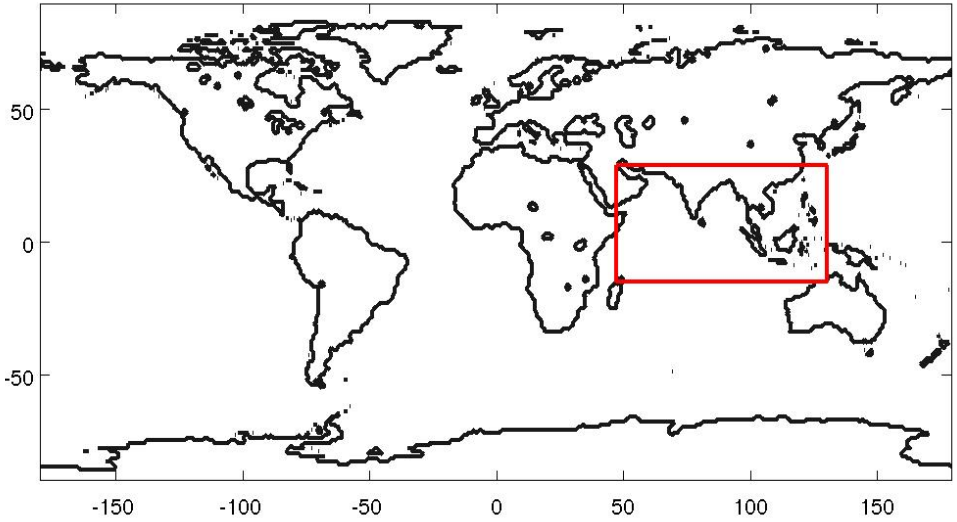


Q Asia & Pressure surface - 887hPa

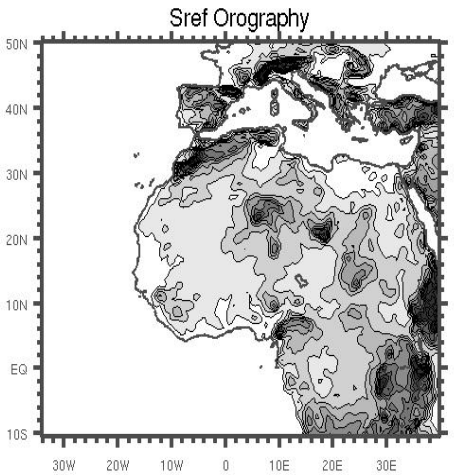
Using ensembles of AGCM simulations nudged over the Indian sector

- Data (June-September)
  - ✓ Daily NOAA OLR 1979-2008
  - ✓ Daily GPCP rainfall 1997-2008
  - ✓ Daily ERA-I 1989-2008
  - ✓ Daily ERA-40 1971-2000 & ERA-I 2001-2008



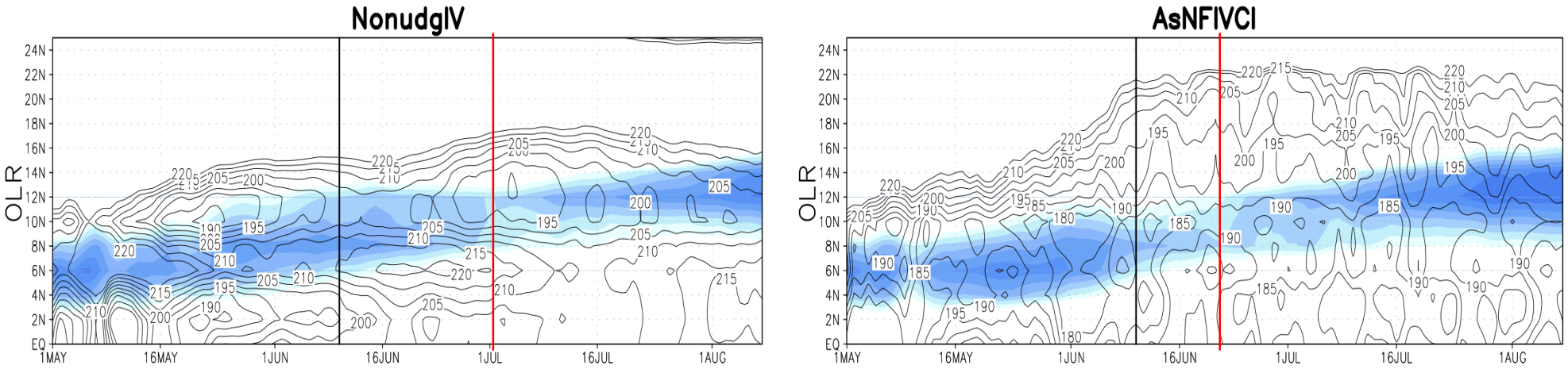
- Simulations AGCM LMDZ4
  - ✓ 3°-2° longitude-latitude
  - ✓ 19 vertical levels
  - ✓ Nudging
    - Area 47°E-130°E/15°S-29°N
    - Variables u,v,T (ERA-40 & ERA-I)
    - Relaxation time 30 mns
    - Ensemble of 10 simulations 1st May - 30th September 1971-2008
    - SST climatology or observed

- Dry-air intrusions (from Roca et al. 2005)
  - Back-trajectories over 10 days of air mass
  - arriving at 500 hPa over Sahel and Guinea
  - with a relative humidity lower than 20%
  - coming from a pressure level lower than 400 hPa



- WRF simulation of 2006 African monsoon season :

Nudging effect over India and link to Africa



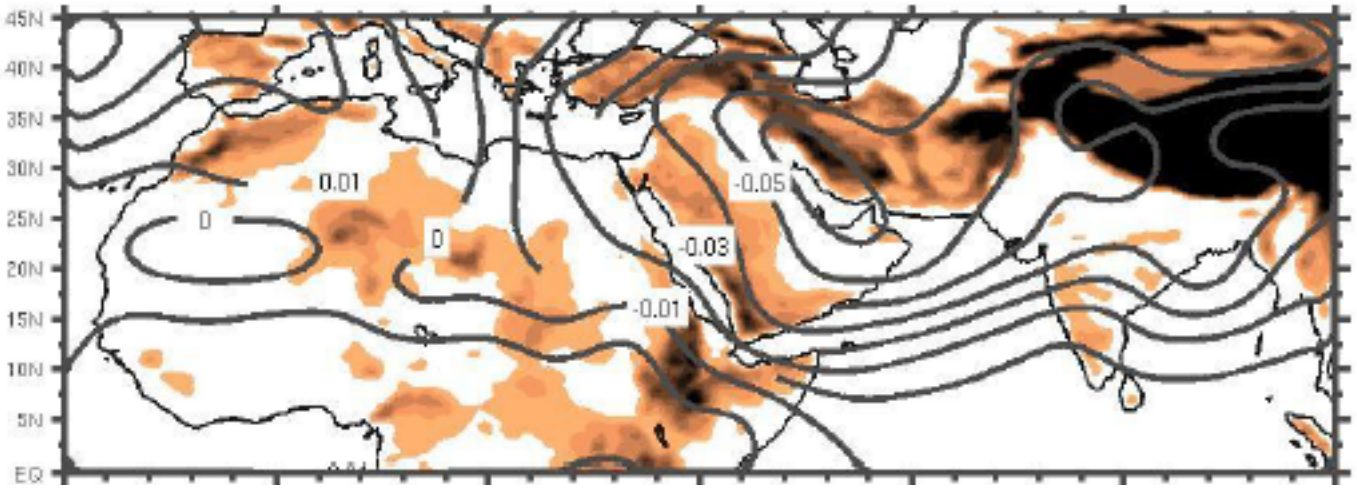
No Nudging ----------> Nudging

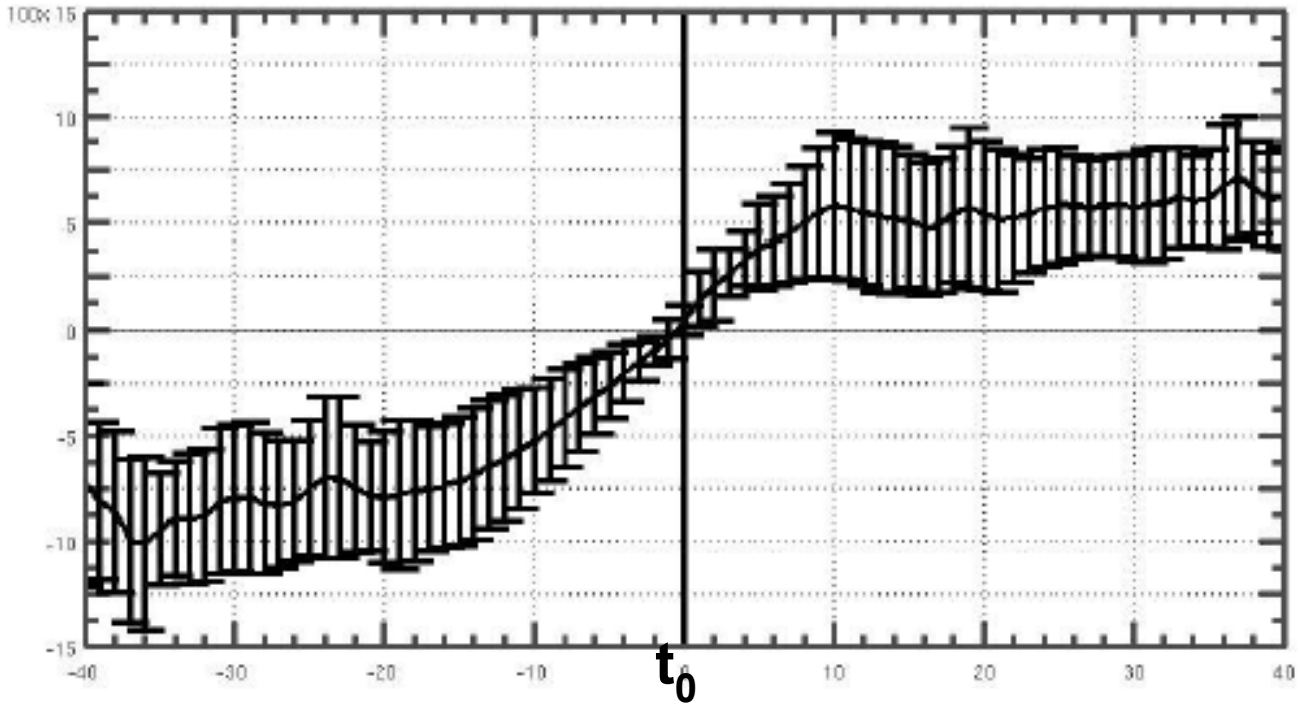
Contours : India ; Blue colors : West Africa ;

Vertical black line : June 10th ; vertical red line West African monsoon onset

- Clear impact of nudging on India convective regime
- India nudging leads to earlier onset over West Africa

EOF1 of Z925hPa ERA-I May-July 1989-2008





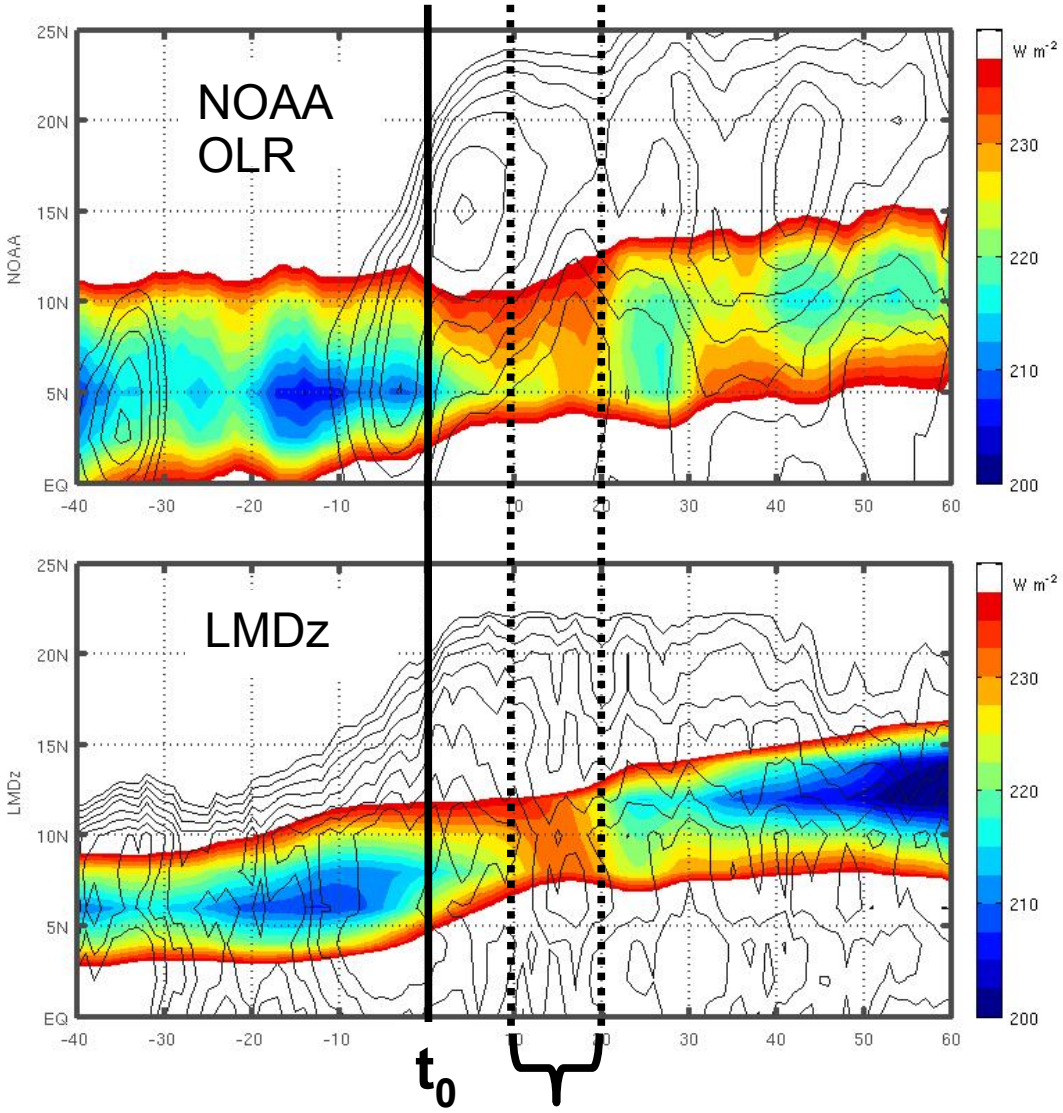
Composite analysis based on PC1 =0

Year	PC1 - day 0	Pai and Nair (2009)
1989	June 9	June 4
1990	June 10	May 18
1991	June 6	June 2
1992	June 15	June 5
1993	June 10	June 3
1994	June 1	May 28
1995	June 10	June 10
1996	June 13	June 9
1997	June 18	June 12
1998	June 18	June 3
1999	June 12	May 22
2000	May 26	June 1
2001	June 1	May 26
2002	June 8	June 9
2003	June 11	June 13
2004	June 12	June 3
2005	June 12	June 7
2006	June 22	May 26
2007	June 7	May 28
2008	June 5	

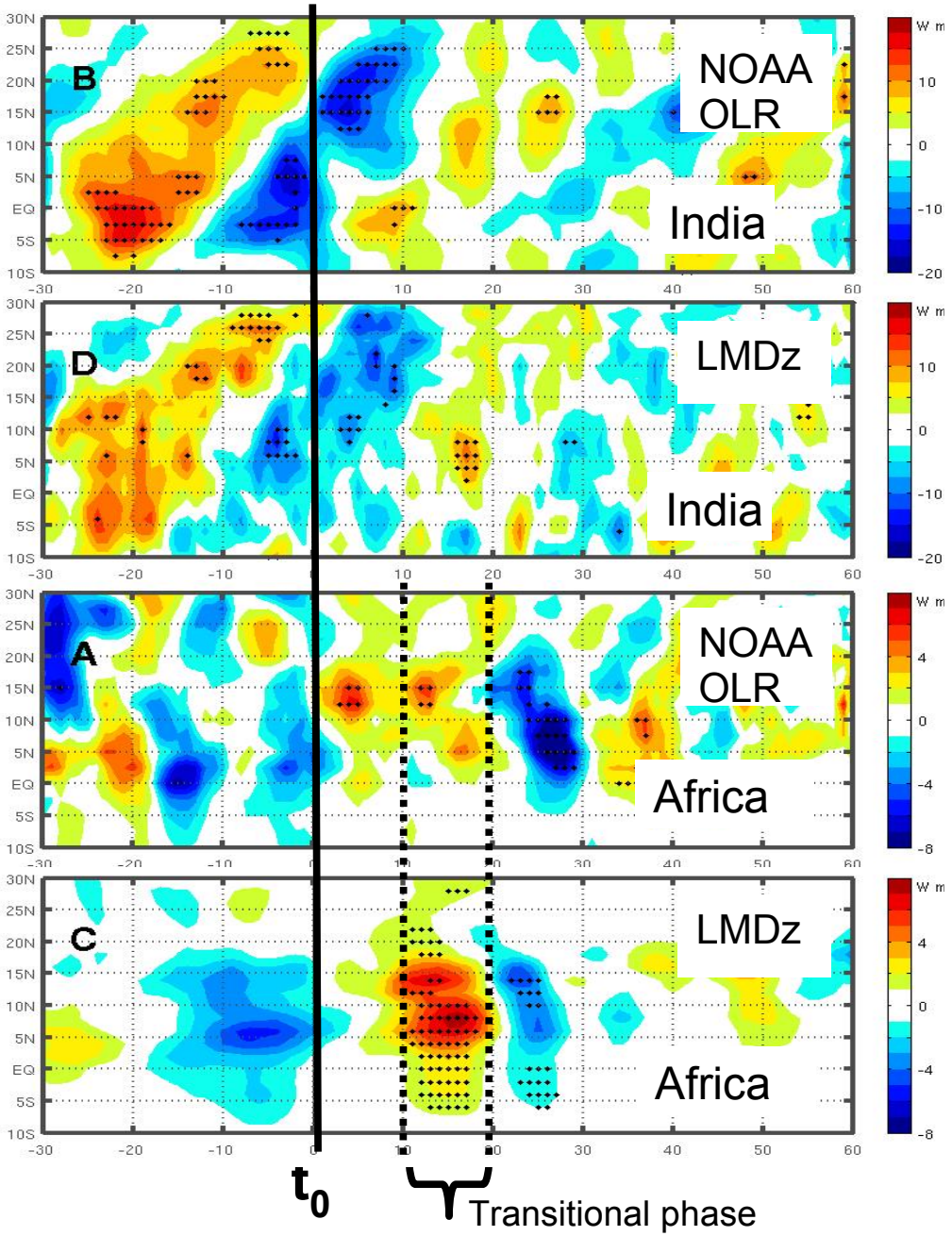
10th June 3rd June

Dates to PC1 & dates onset Indian monsoon

Composite time-latitude
OLR India (contours) &
Africa (colours)



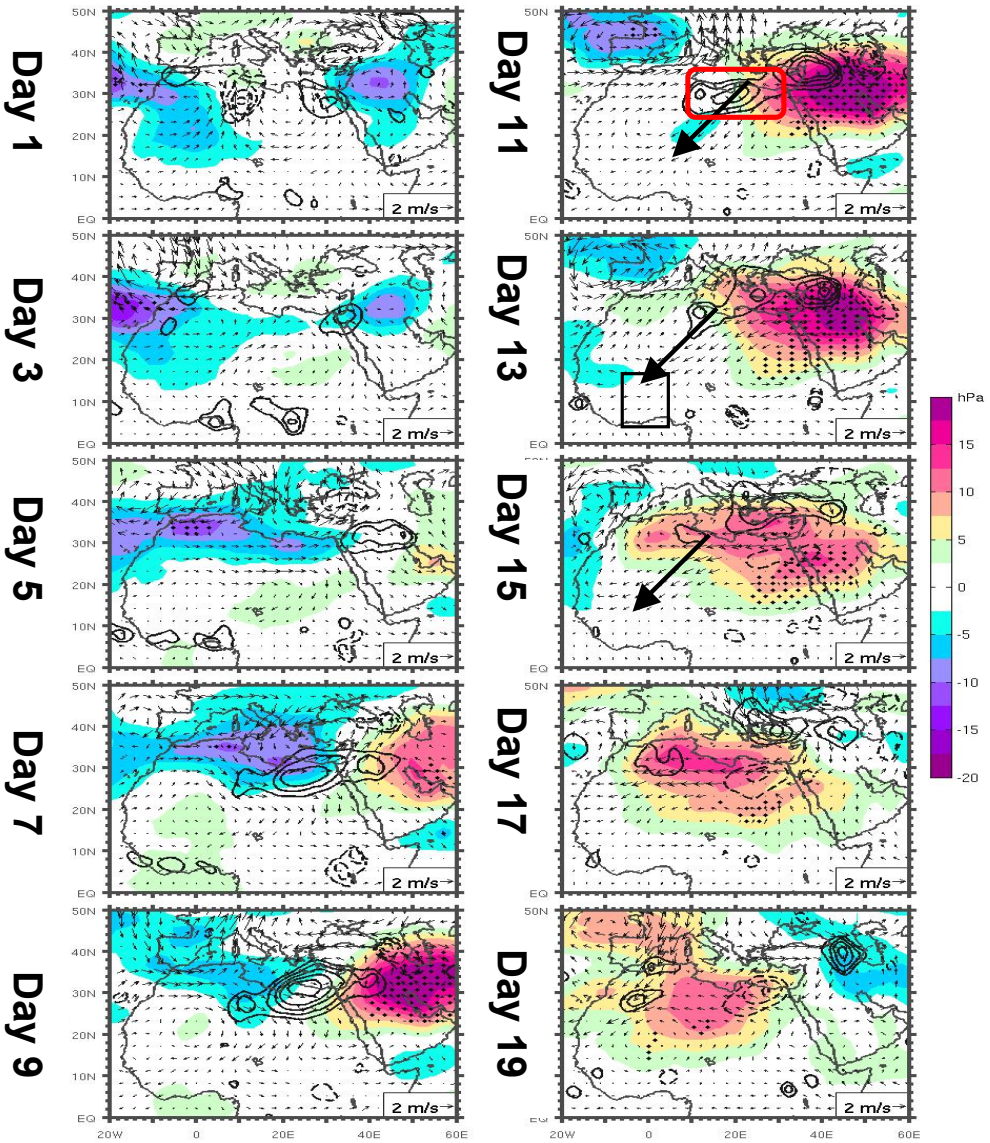
Composite time-latitude
OLR deseasonalized



Deseasonalized anomalies of vertical velocity (contours), wind, pressure (colours) on surface iso-Θ 330K

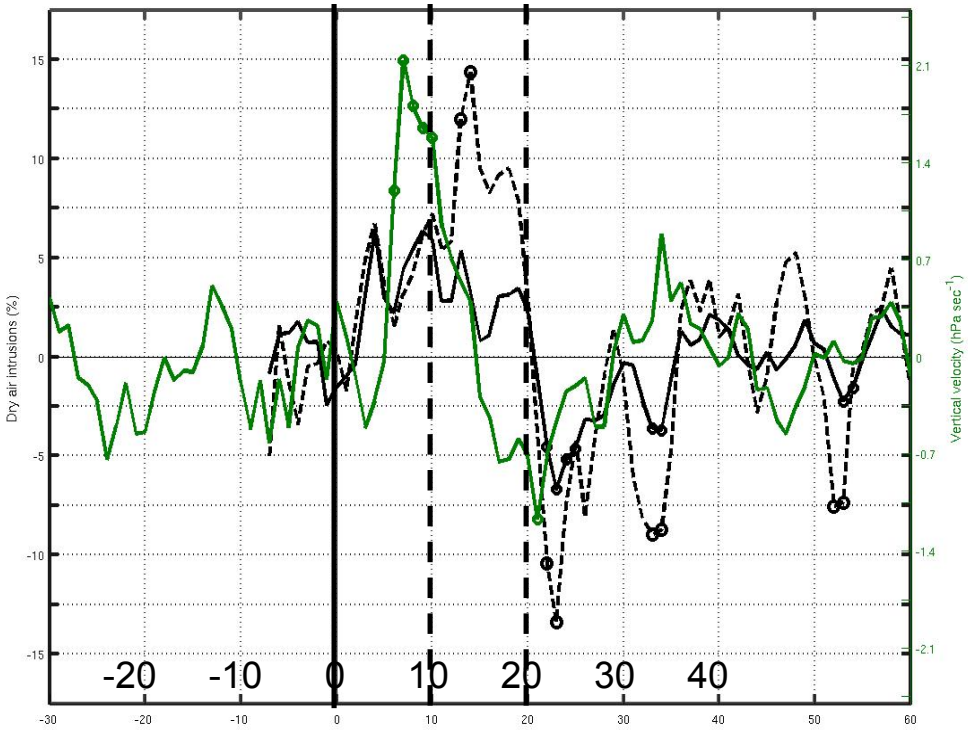
Days after Indian monsoon onset

ERA-I



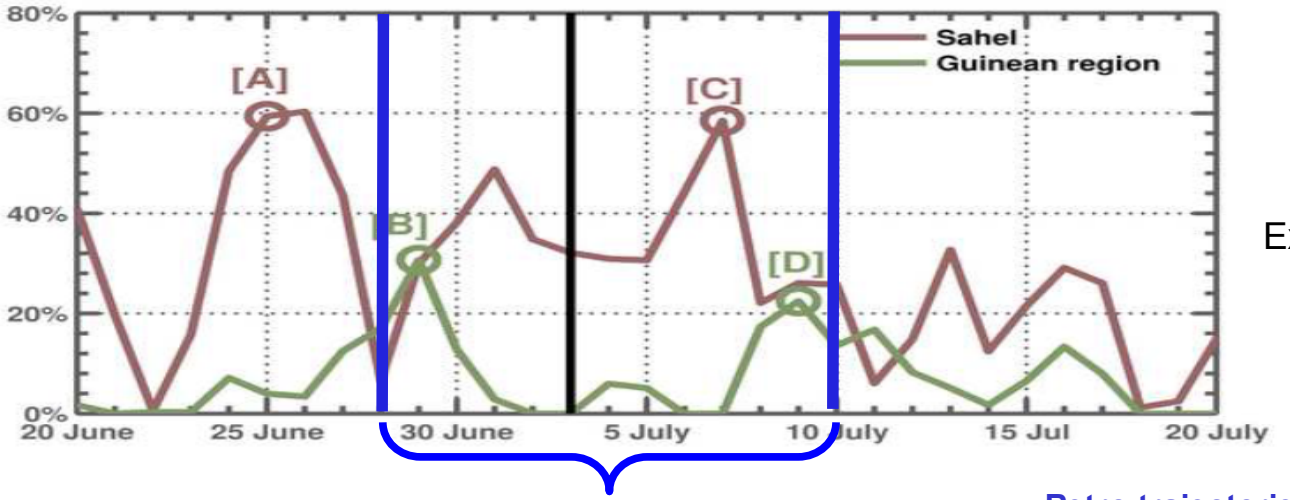
Subsidence over East-Mediterranean

Dry-air intrusions Sahel-Guinea



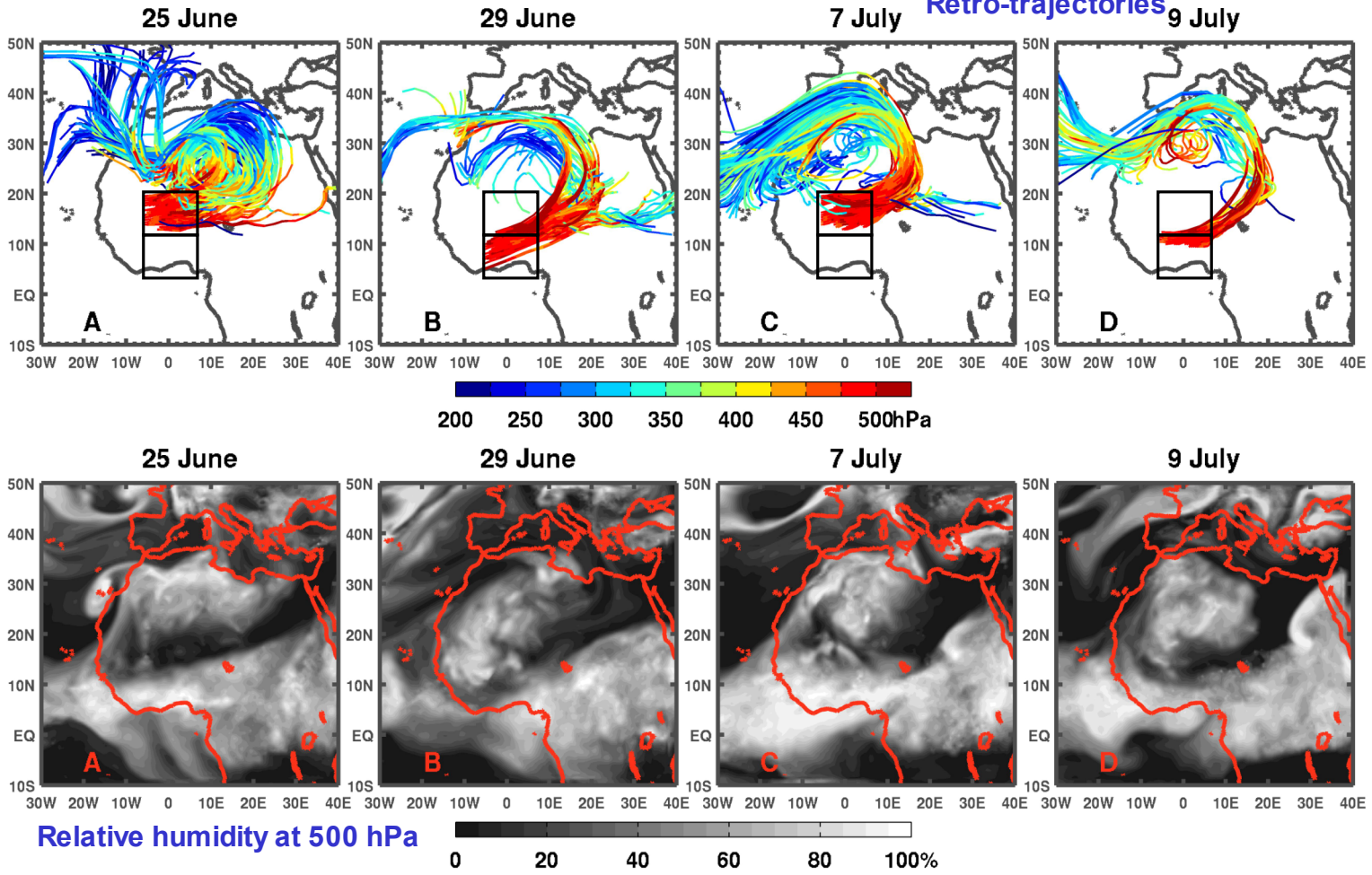
Vertical velocity 300hPa over East-Mediterranean

Dry air intrusion over Sahel (dashed line)
and Guinea (solid line)
% of grid mesh with relative humidity < 20% at 500 hPa

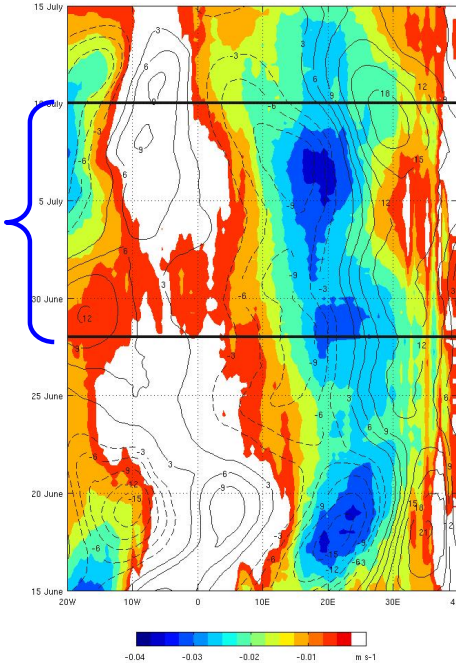


Dry-air intrusions

Example for 2006 during the transitional phase
WRF simulations
% of grid mesh of relative humidity < 40%



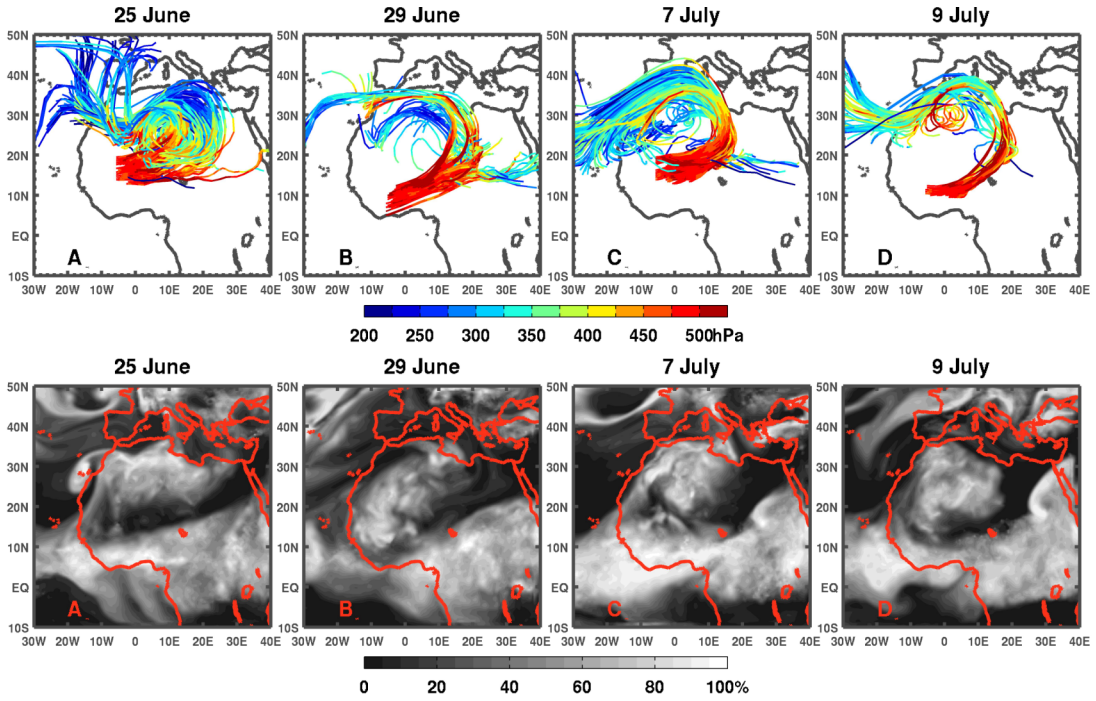
300hPa subsidence over Mediterranean
(highest value in blue)



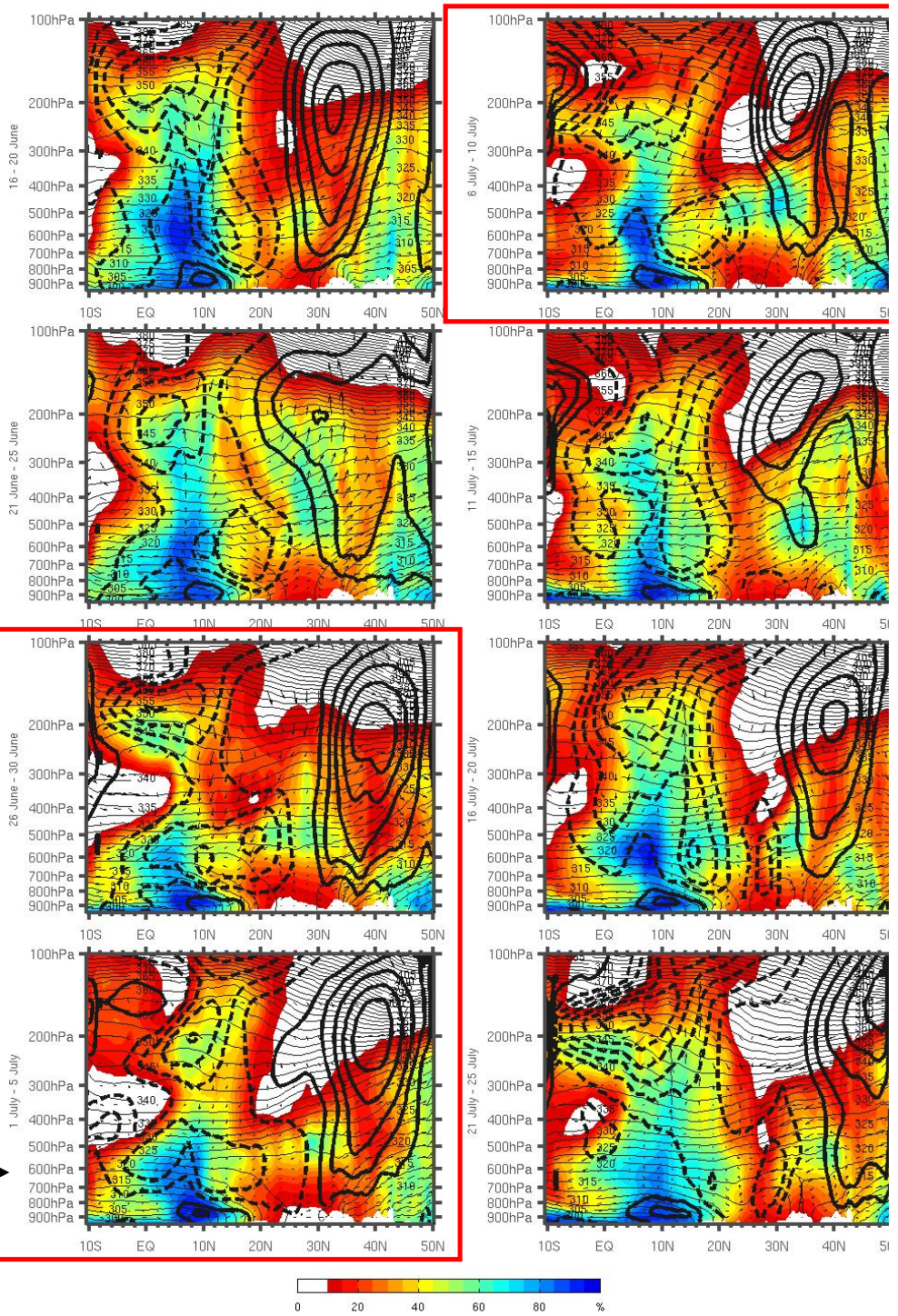
2006 : 16th-20th June to 21st-25th July

5°W-5°E

- relative humidity (%; colours)
- vertical/meridional wind
- zonal wind speed (thick contours)
- potential temperature (thin contours)



Vertical profile of relative humidity from WRF simulation in 2006
Also confirmed with sensitivity test of humidity impact on precipitation



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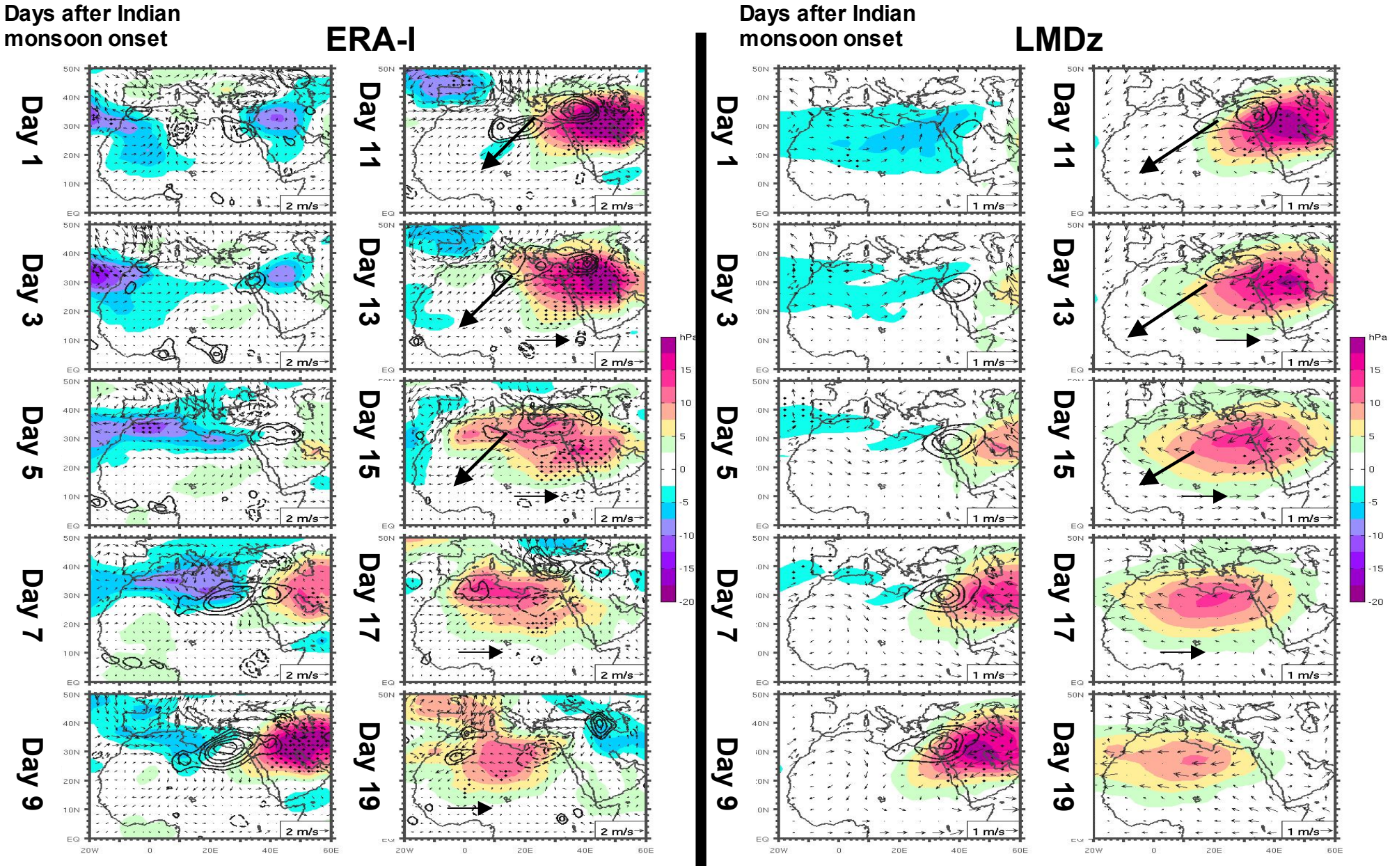
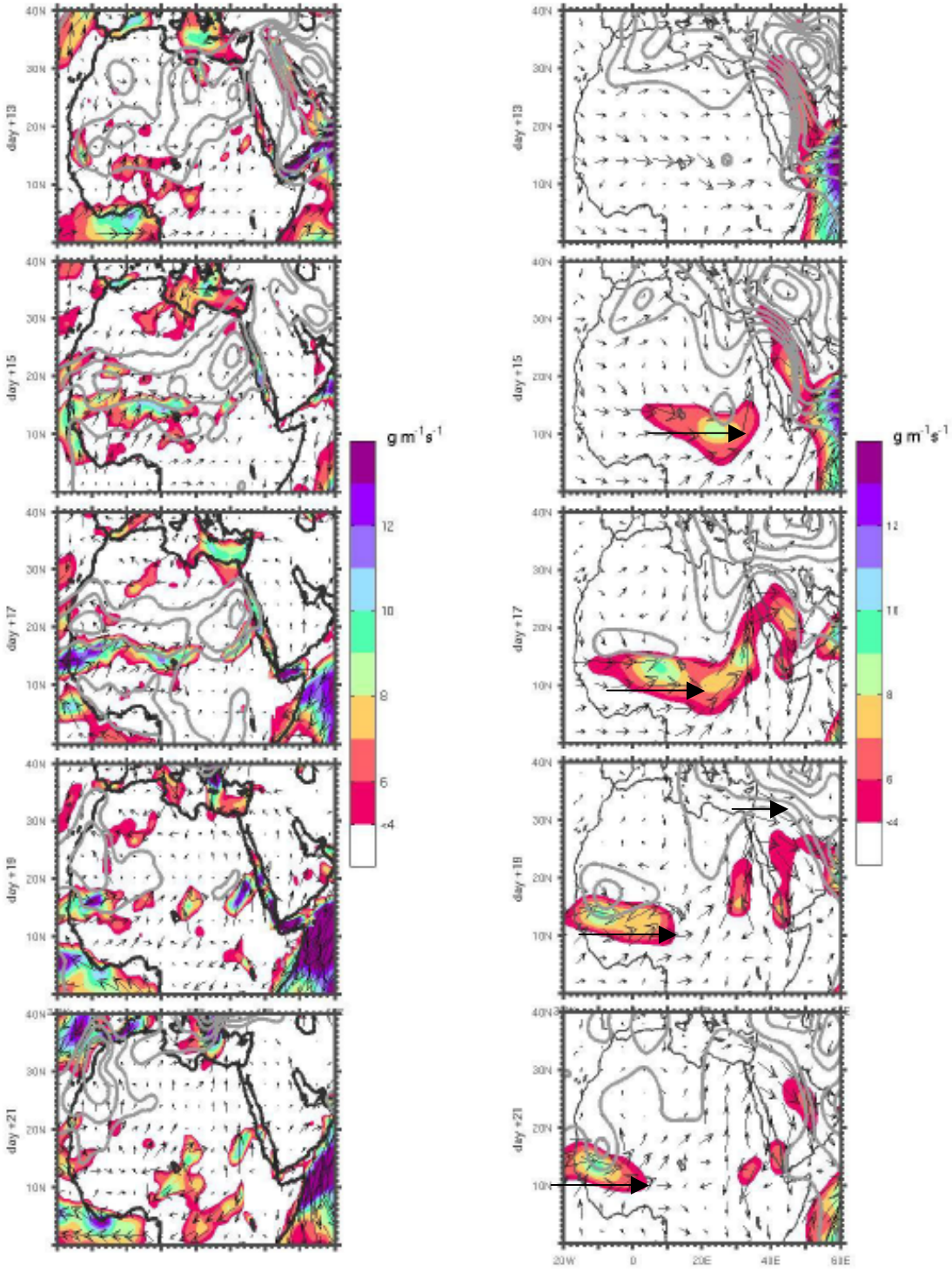


Integrated moisture flux between surface and 800hPa

Deseasonalized values
to+13 ---> to+21

ERA-I (left)
LMDZ (right)



Conclusion

1) The Indian monsoon onset leads to convection increase over Northern India and induces a westward Rossby wave
2) This wave induces subsidence ahead, and over East Mediterranean enhances dry-air intrusions towards West Africa
3) These dry air intrusions are associated with convection decrease over West Africa and the occurrence of the transitional phase of the African monsoon onset
4) During the second part of the transitional phase, induced low-level circulation increase moisture transport over the Sahel
5) Once the Rossby wave goes on westward and decreases, dry air intrusions vanish and thermodynamical conditions over the Sahel become favourable for convection, signing the end of the transitional phase.
6) *In this context one need to investigate more in details how dry-air intrusion impacts individual convective systems.*
7) Predictability of African monsoon onset seems possible but this is only one element among other mechanisms at the origin of African monsoon onset.

See also Poster W216A in Session C3 on Wednesday (Mohino et al.)

Flaounas, E., S. Janicot, R. Roca, S. Bastin, E. Mohino, L. Li, 2011. The role of the Indian monsoon onset on the African monsoon onset: observations and AGCM nudged simulations. *Climate Dyn. doi :10.1007/s00382-011-1045-x*

Flaounas, E., S. Janicot, S. Bastin, R. Roca, 2011. The West African monsoon onset in 2006: sensitivity to surface abedo, orography, SST and synoptic scale dry-air intrusion using WRF. *Climate Dynamics in revision*