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# Atmosphere-Land-Ocean Interaction at the Southwestern Edge of the Saharan heat low

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COSMO User Seminar 2009

Langen

10 March 2009

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# Outline

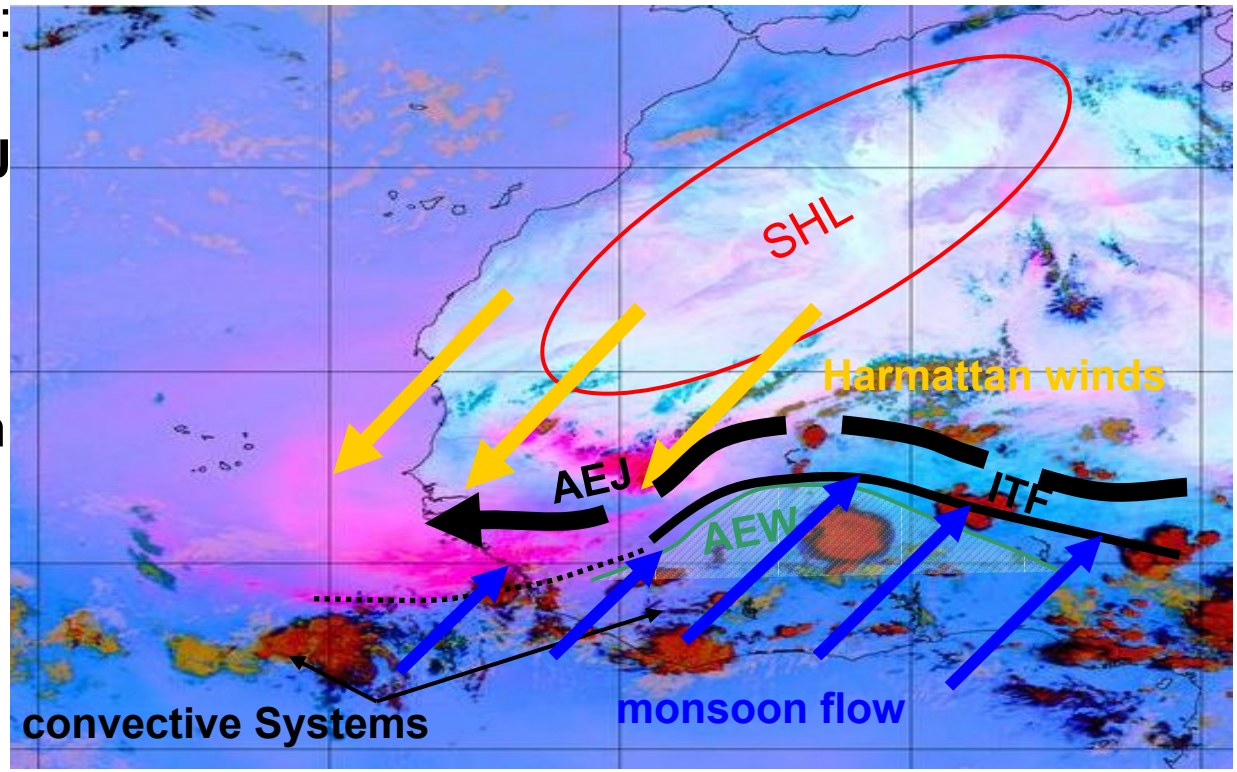
1. West African monsoon
2. GERBILS field campaign
3. COSMO validation
4. The Atlantic Inflow at the Mauritanian Coast
5. Future and current work

# 1. The West African Monsoon System – Main features



- northeastern tradewinds: **Harmattan**
- Southeastern tradewinds become Southwesterlies when crossing equator: **monsoon flow**
- Zone of convergence: Intertropical Front **ITF/ITD**, Inter Tropical Convergence zone →moist convection

- Saharan Heat Low **SHL**: Dry convection
- African Easterly Jet **AEJ** N-S temperature gradient, thermal wind balance
- Wave fluctuations within AEJ: African Easterly Waves **AEW**
- **Seasonal** phenomena (June-August)



# 1. The West African Monsoon System – Main features



- Moist convection: monsoon layer / ITD
- Dry convection at daytime: SHL region
  growing convective BL within residual BL

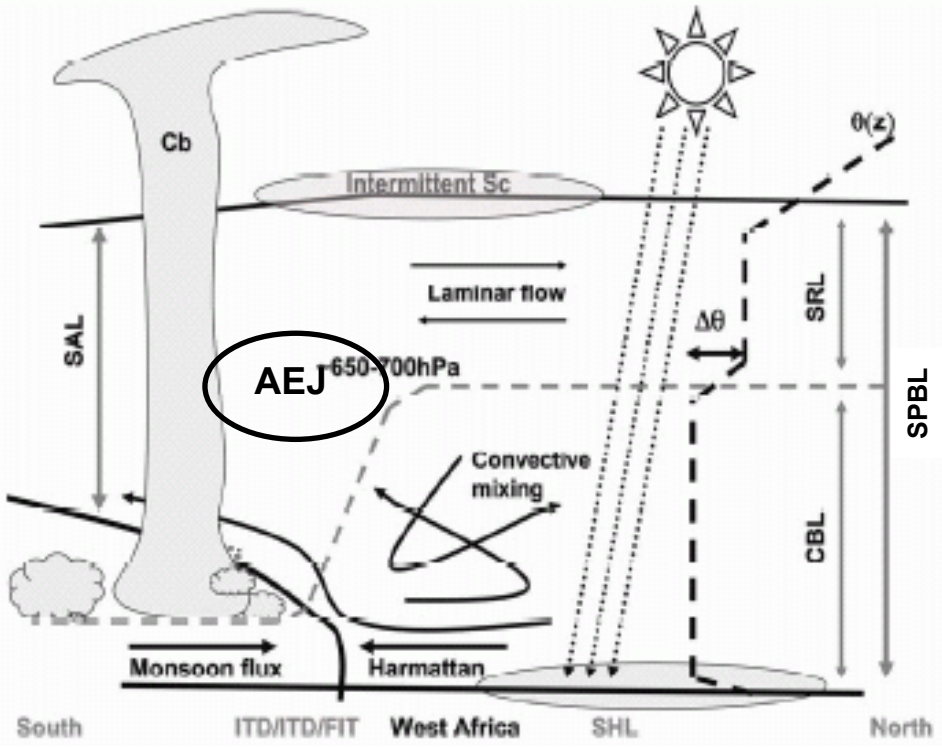
- Conv. Boundary Layer **CBL**

**+** Saharan Residual boundary layer **SRL**

**=** Saharan Planetary boundary layer **SPBL**

- Elevated and transported SPBL

**=** Saharan Air Layer **SAL**




**(Messager, 2007)**

# 2. The GERBILS campaign



**GERBILS** – GERB Intercomparision of Longwave and Shortwave radiation

- *Discrepancy in clear-sky top of atmosphere outgoing longwave radiation* (**OLRc**) over Sahara between model (UM) and satellite

- Three 2-leg flights with **FAAM BAe146** 2nd half of June 2007
- **dOLRc** maximum in June/July →
- western base Nouakchott, eastern base Niamey

- Flight track along 18°N over maximum dOLRc

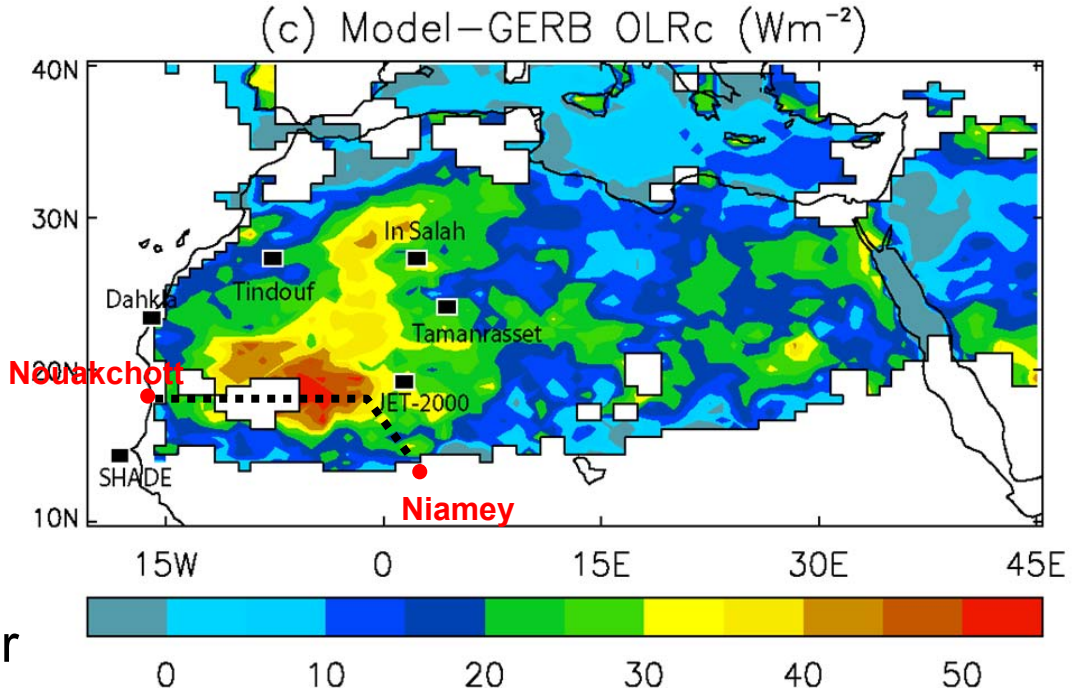


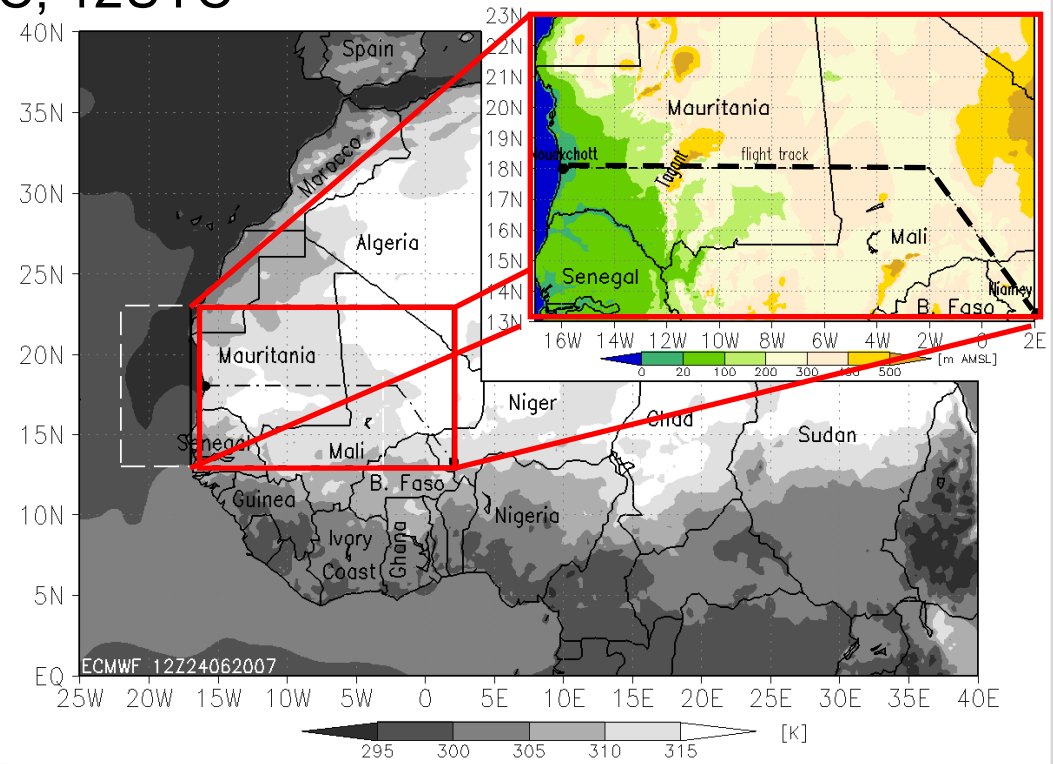

***Figure 1. An example of the OLR anomaly when comparing the UM against a) the GERB instrument on Meteosat 8 (Haywood, 2007)***

# Operational COSMO GERBILS V3.19 forecasts at IMK

- HP XC6000 Steinbuch Centre for Computing, KIT
- External data from DWD
- Initial / boundary data (3hourly) from IFS
- Initialised twice daily 00UTC, 12UTC
- Horizontal grid 305 x 161 gridpoints,17°W - 2°E, 13°N - 23°N, 0.0625°
- 35 vertical levels
- 18 June -30 June 2007

## After GERBILS

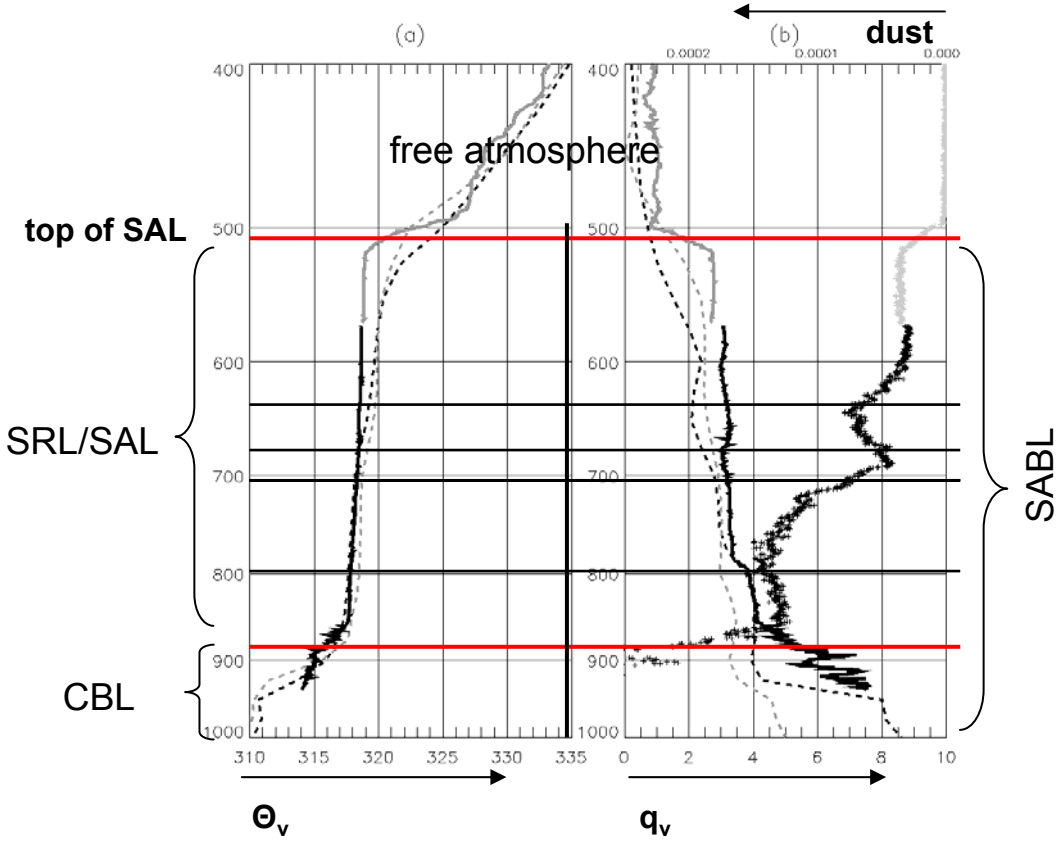
- Domain shifted
- Budget calculations



# 3. The COSMO model – Model validation

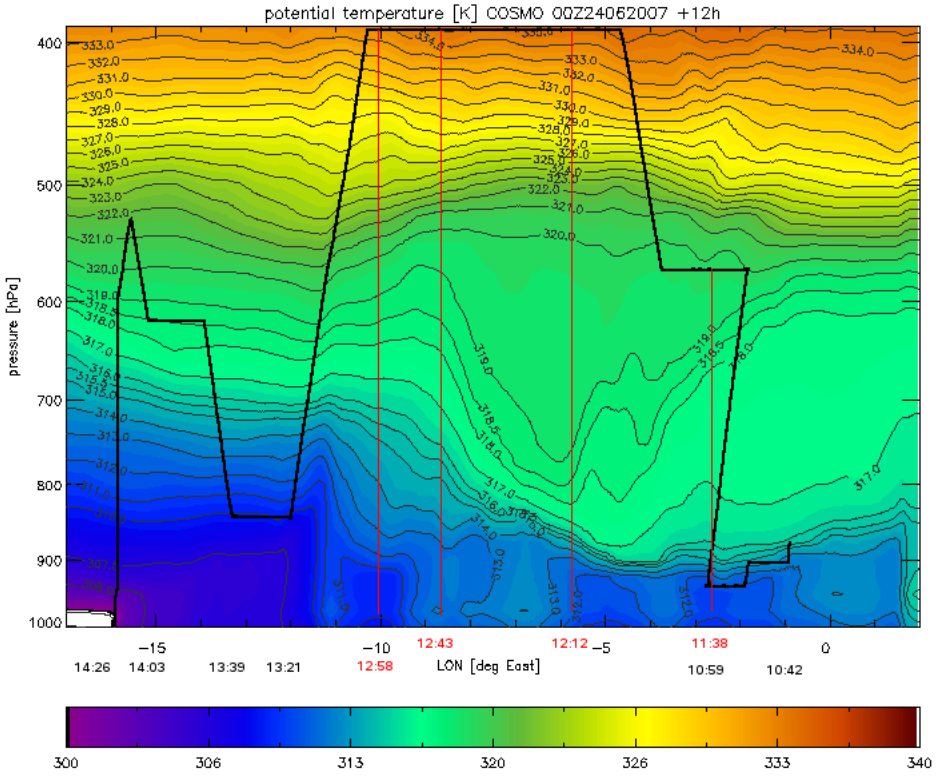


- Flight B299 24/06/2007: aircraft profile
  (profile 4&5, 2.7-4.6°W, 18°N, 1114-1202UTC)

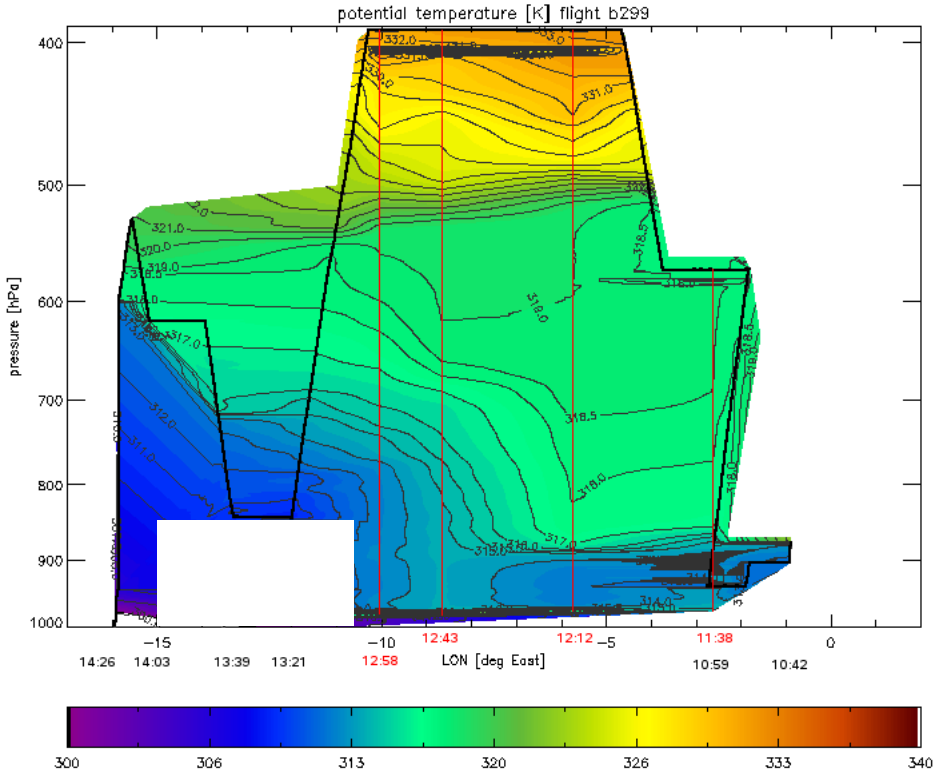


# 3. The COSMO model – Model evaluation

- Flight B299 24/06/2007: cross section of potential temperature at 18N

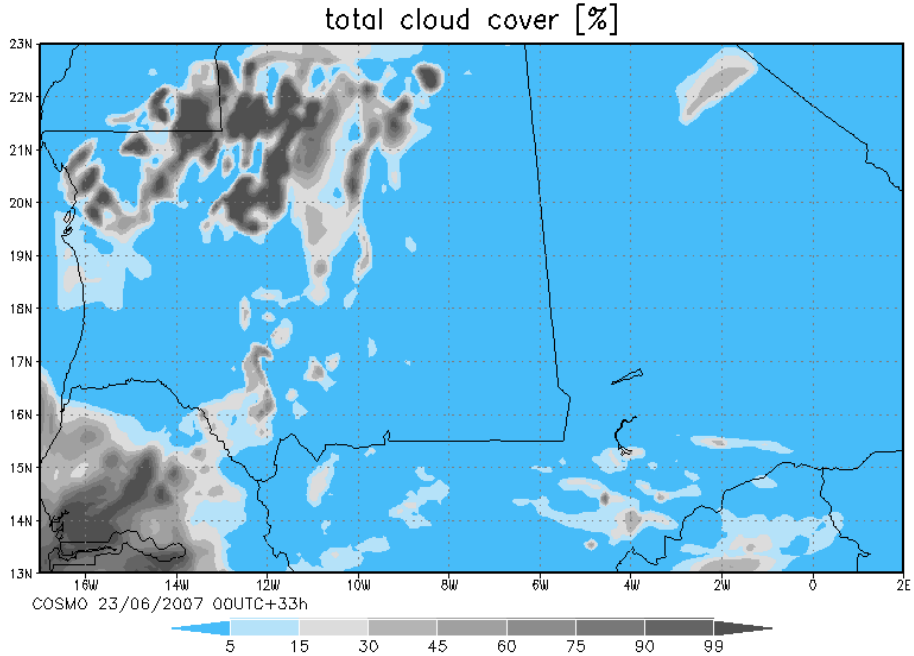



COSMO 24/06/2007 00UTC+12h

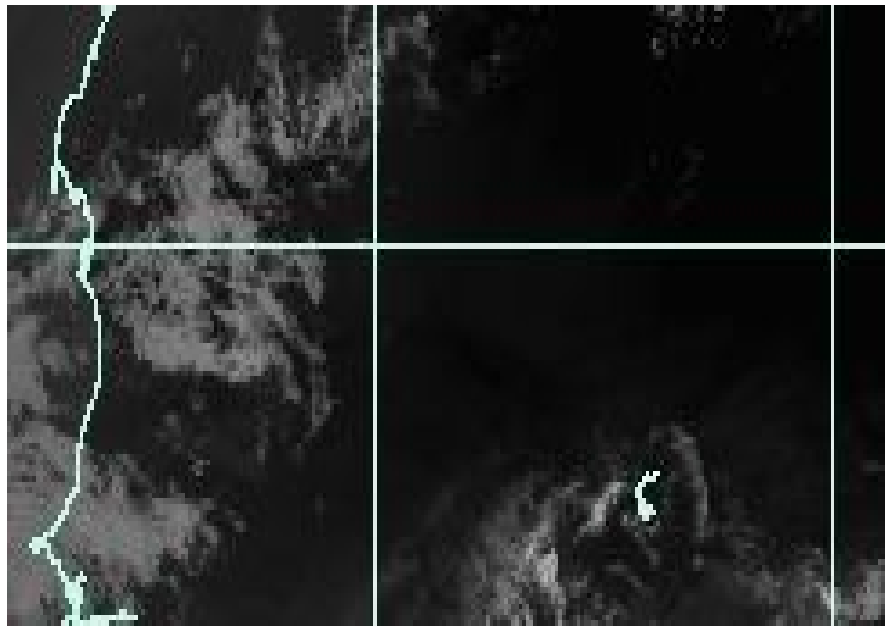



Dropsonde and Aircraft data

## Example: total cloud cover




COSMO 23/06/2007 00UTC+33h
forecast for 9 UTC 24/06/2007

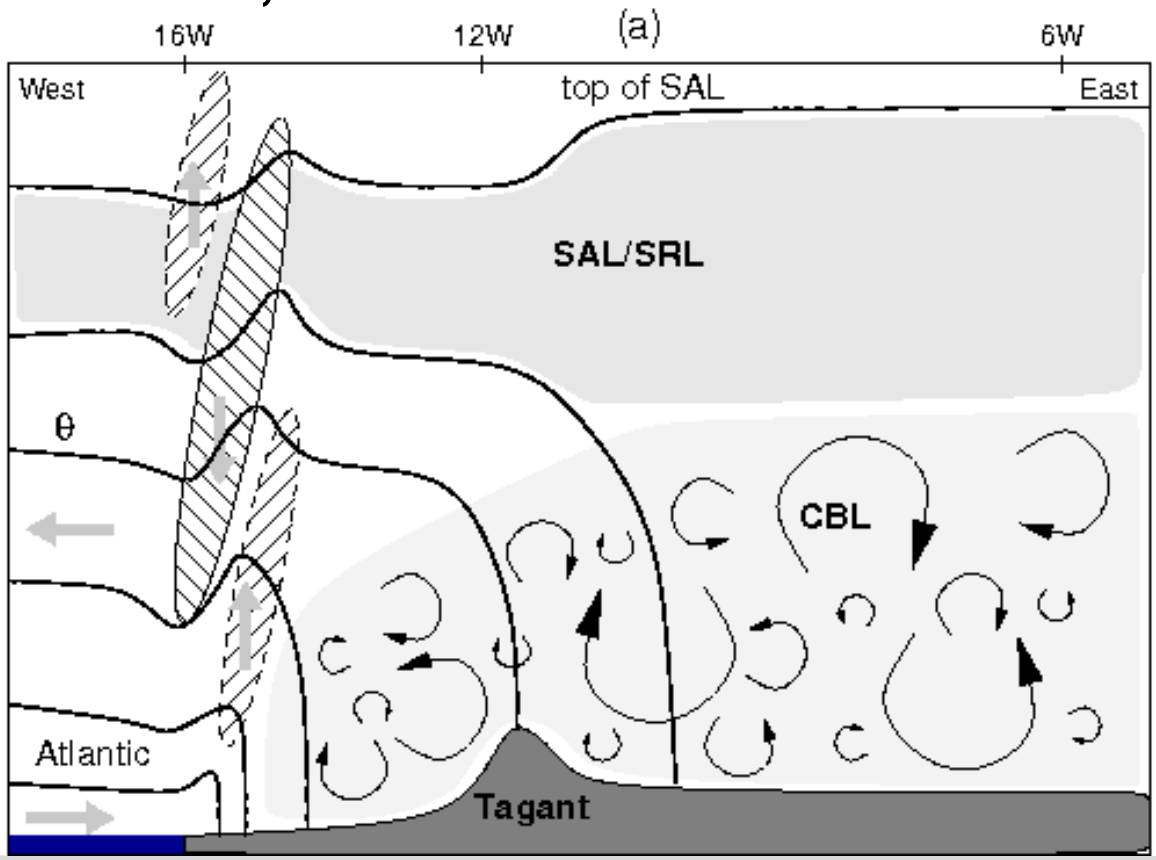


Meteosat IR10.8 µm 9 UTC 24/06/2007

# Atlantic Inflow:

- sea breeze/density current
- see breeze front
- frontal circulation
- gravity wave
- baroclinic zone
- diurnal cycle
- synoptic variability

} low-levels



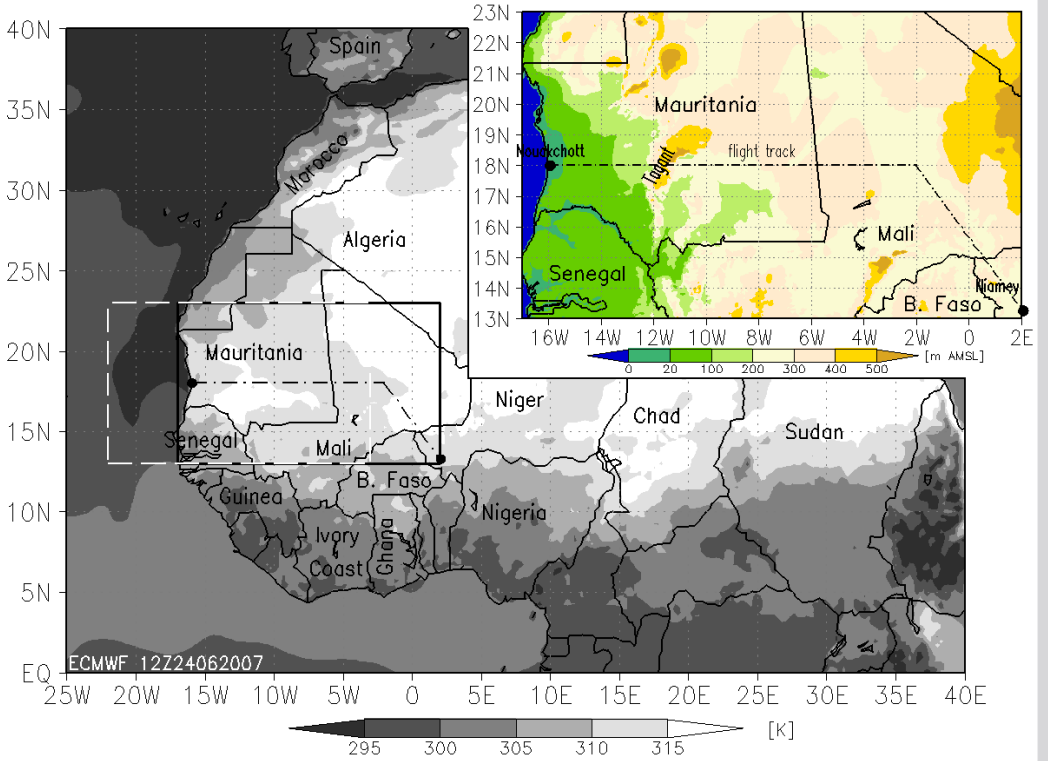
# Conditions in western Mauritania:

- land – sea temperature gradient:
  - cold canary current, upwelling deep waters
  - hot desert environment inland

$T_{SST} \approx 22°C$ $T_{2m} \approx 27°C$

$T_{sfc} > 45°C$ $T_{2m} > 42°C$

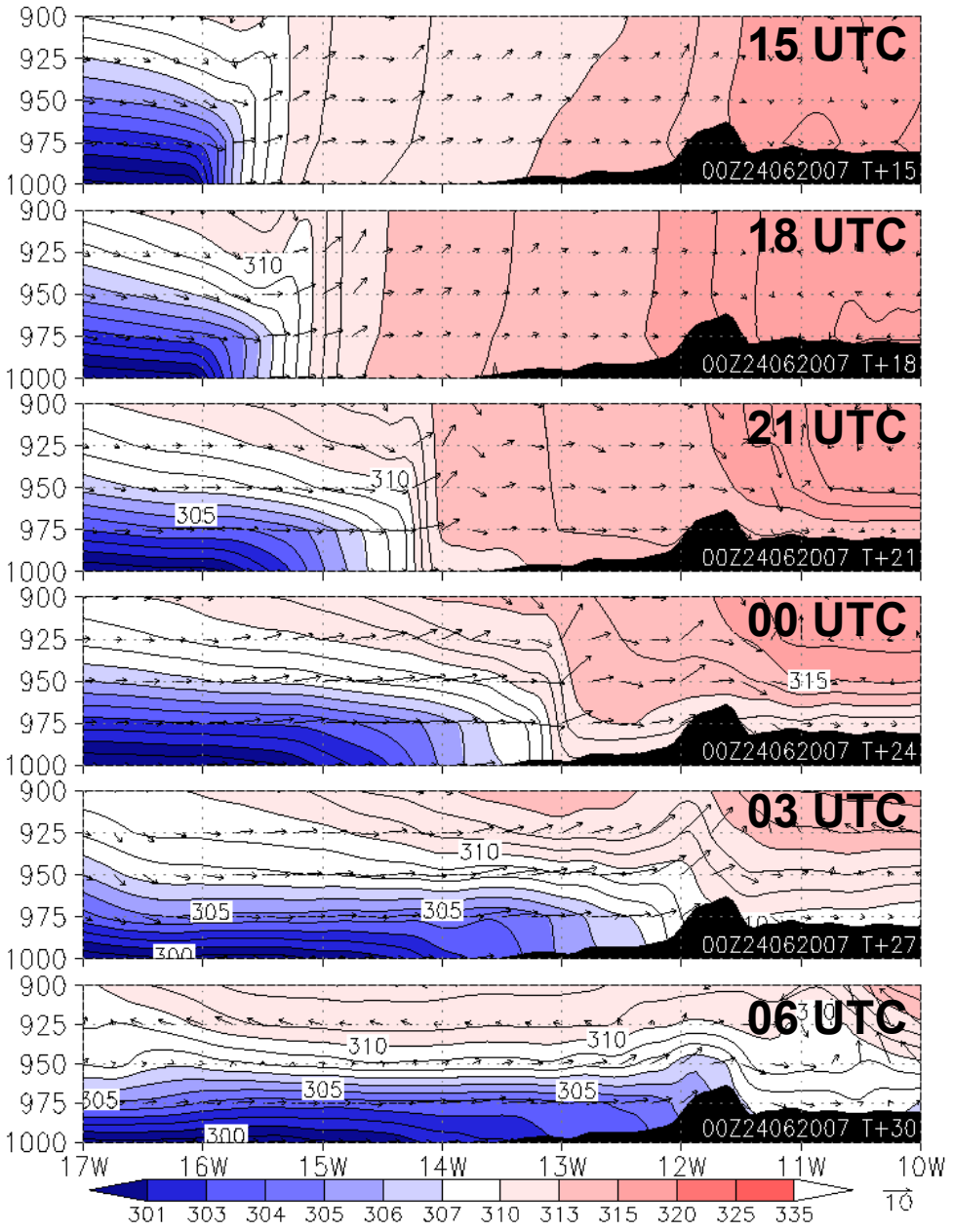
- SHL
  - dry convection
  - turbulent mixing
- coastal plain south of 20°N
- Tagant mountains 400km inland



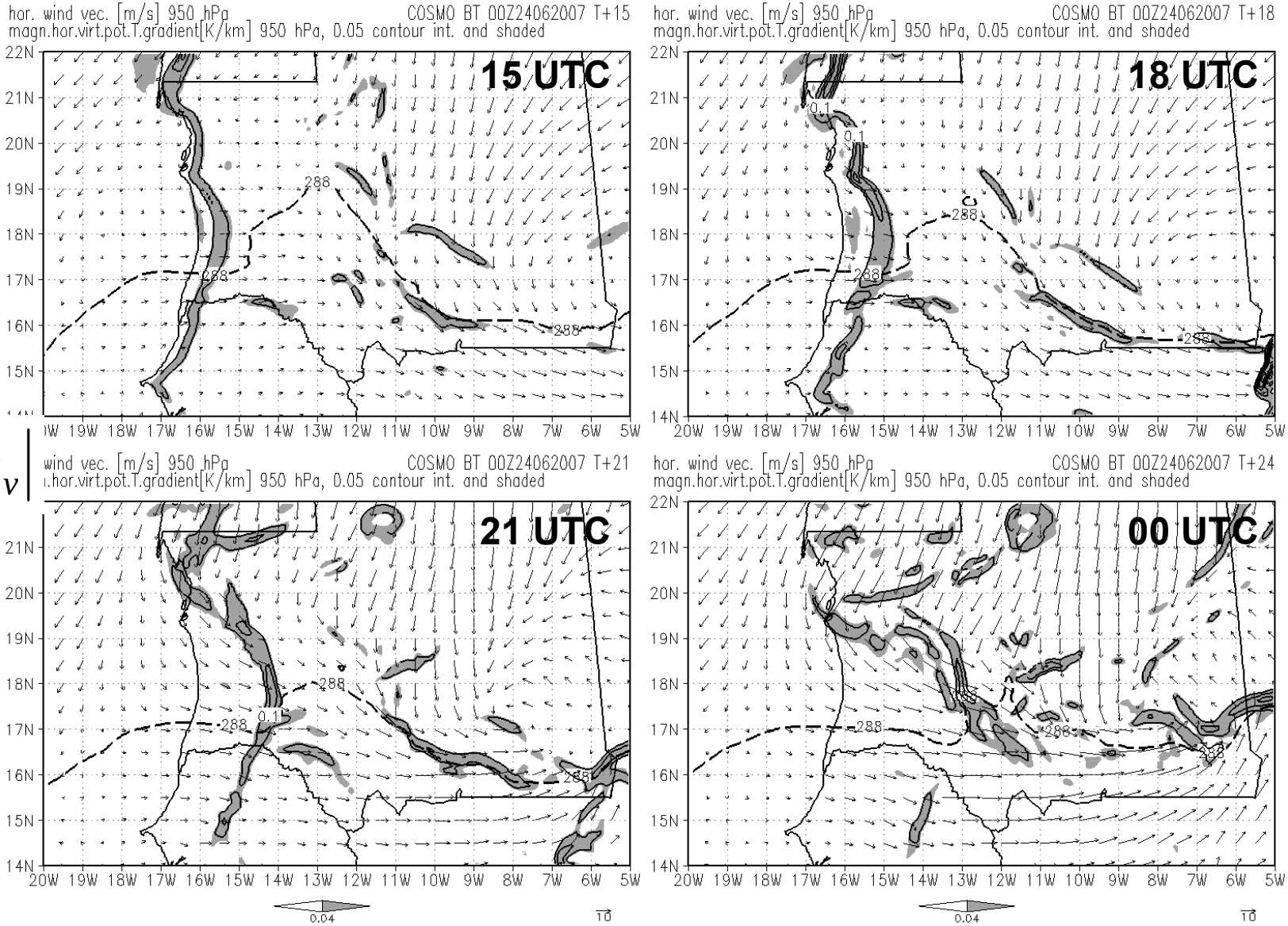
# Atlantic Inflow front:

(in lower troposphere)

- Separates maritime, cool and stably-stratified air in the West from dry and hot continental air
- Stationary coastal front at daytime
- Nocturnal propagation
- Coldpool in coastal plain next morning.



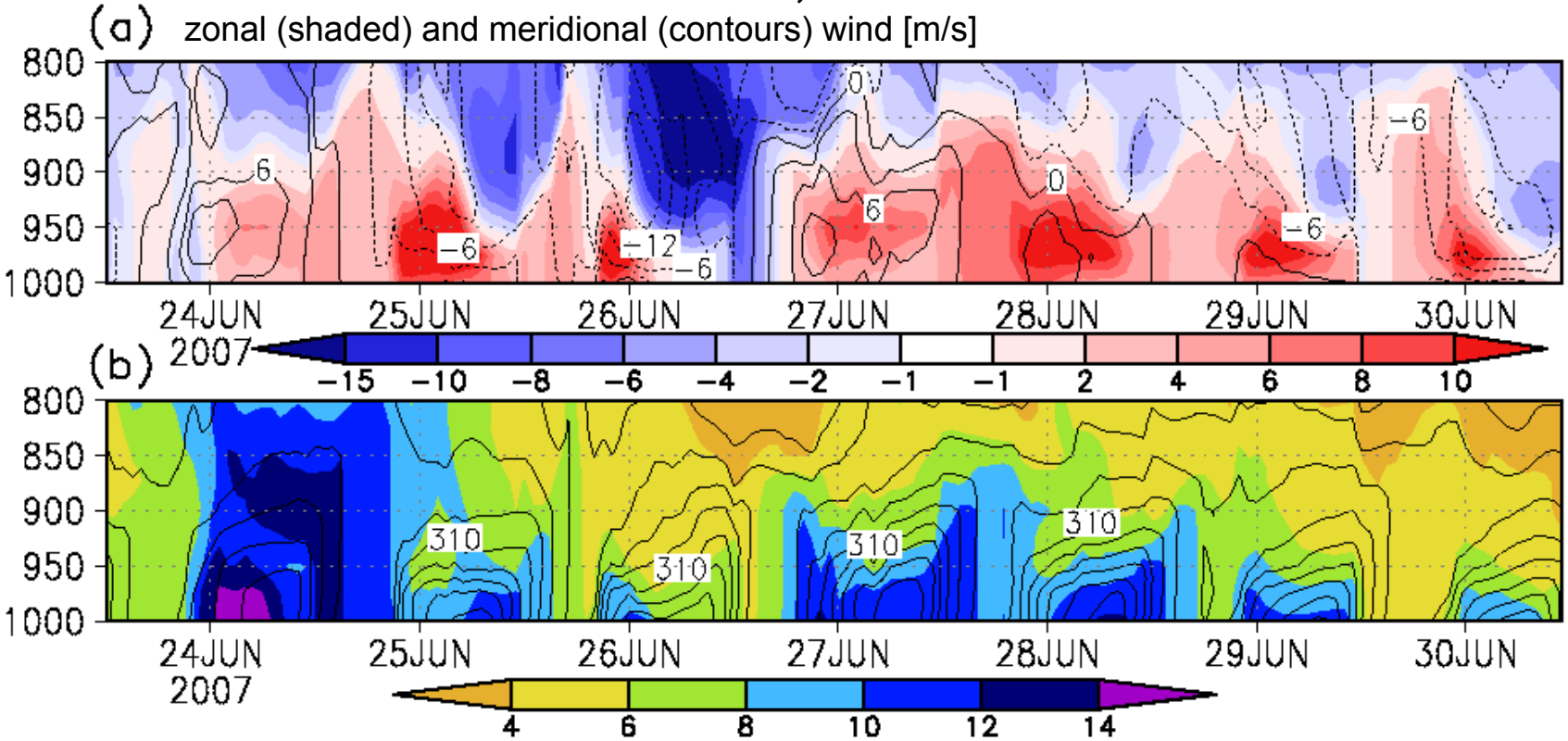
# 4. Atlantic Inflow – horizontal extent




$$\left|\nabla\Theta_v\right|$$

# 4. Atlantic Inflow – at a specific location

## 14°W,18°N



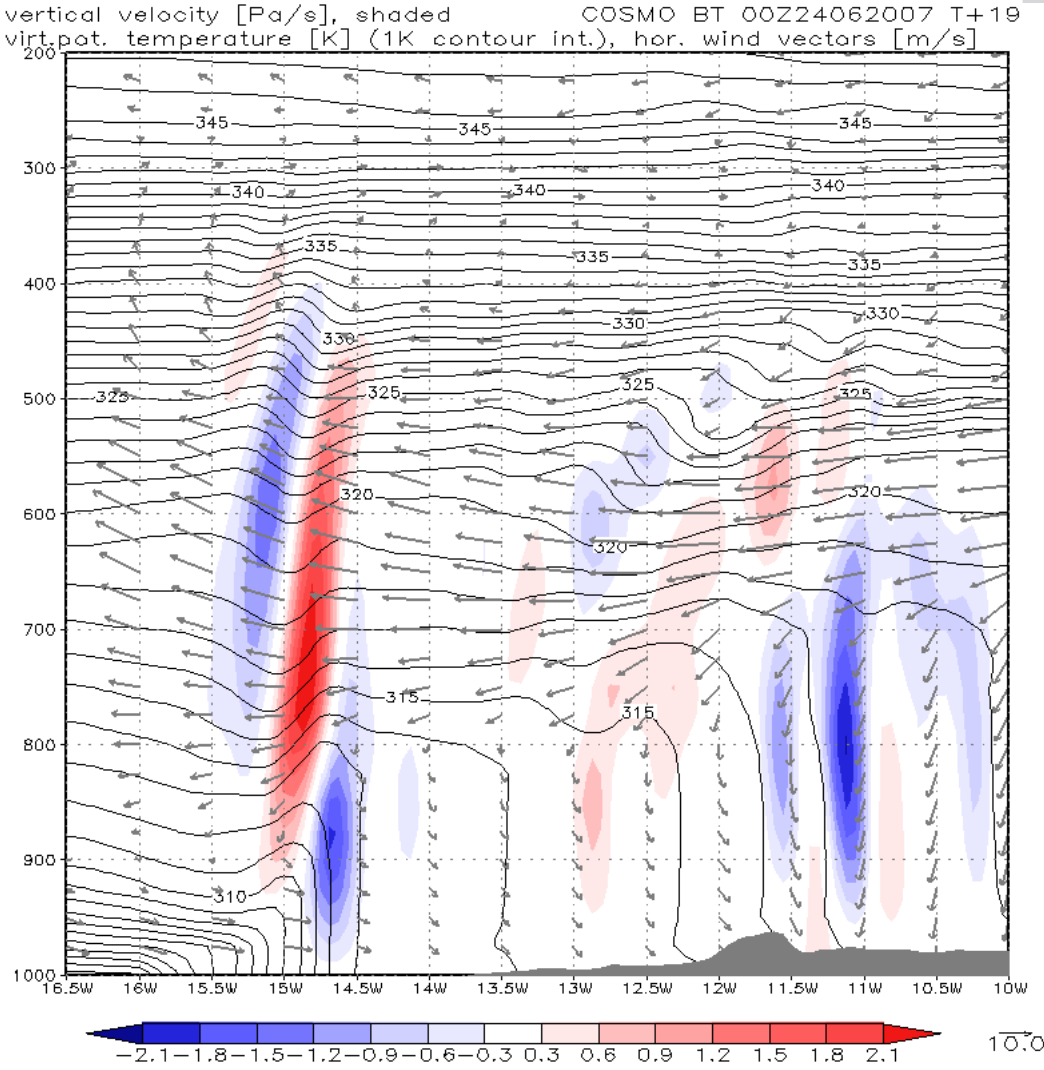

specific humidity [g/kg] (shaded) and virtual potential temperature [K] (2K contour interval)

- passage of coastal front at around 22UTC
- strong cooling and increasing of zonal wind component
- moist advection depending on synoptic conditions

# 4. frontal circulation and gravity wave



- Low-level density current lifts isentropes in stably-stratified mid-levels
- Crest-valley-crest wave combined with triplet of ascent-descent-ascent
- 10 m/s phase speed
- decouples from low-level front at Tagant



# COSMO Code adaptions:

- Output of individual contributions to tendency equations for temperature and humidity

- Tendency equation for potential temperature:

$$\frac{\partial \theta}{\partial t} = -\vec{v}_h \cdot \nabla_{h,p}\theta - \omega\frac{\partial \theta}{\partial p} + Q_\theta$$

$$Q_\theta = M_\theta^{TD} + M_\theta^{RAD} + M_\theta^{Sq} + M_\theta^{MC} + M_\theta^{comp}$$

- Tendency equation for specific humidity:

$$\frac{\partial q^v}{\partial t} = -\vec{v}_h \cdot \nabla_{h,p} q^v - \omega\frac{\partial q^v}{\partial p} + Q_{q^v}$$

$$Q_{q^v} = M_{q^v}^{TD} + M_{q^v}^{Sq} + M_{q^v}^{MC} + M_{q^v}^{comp}$$

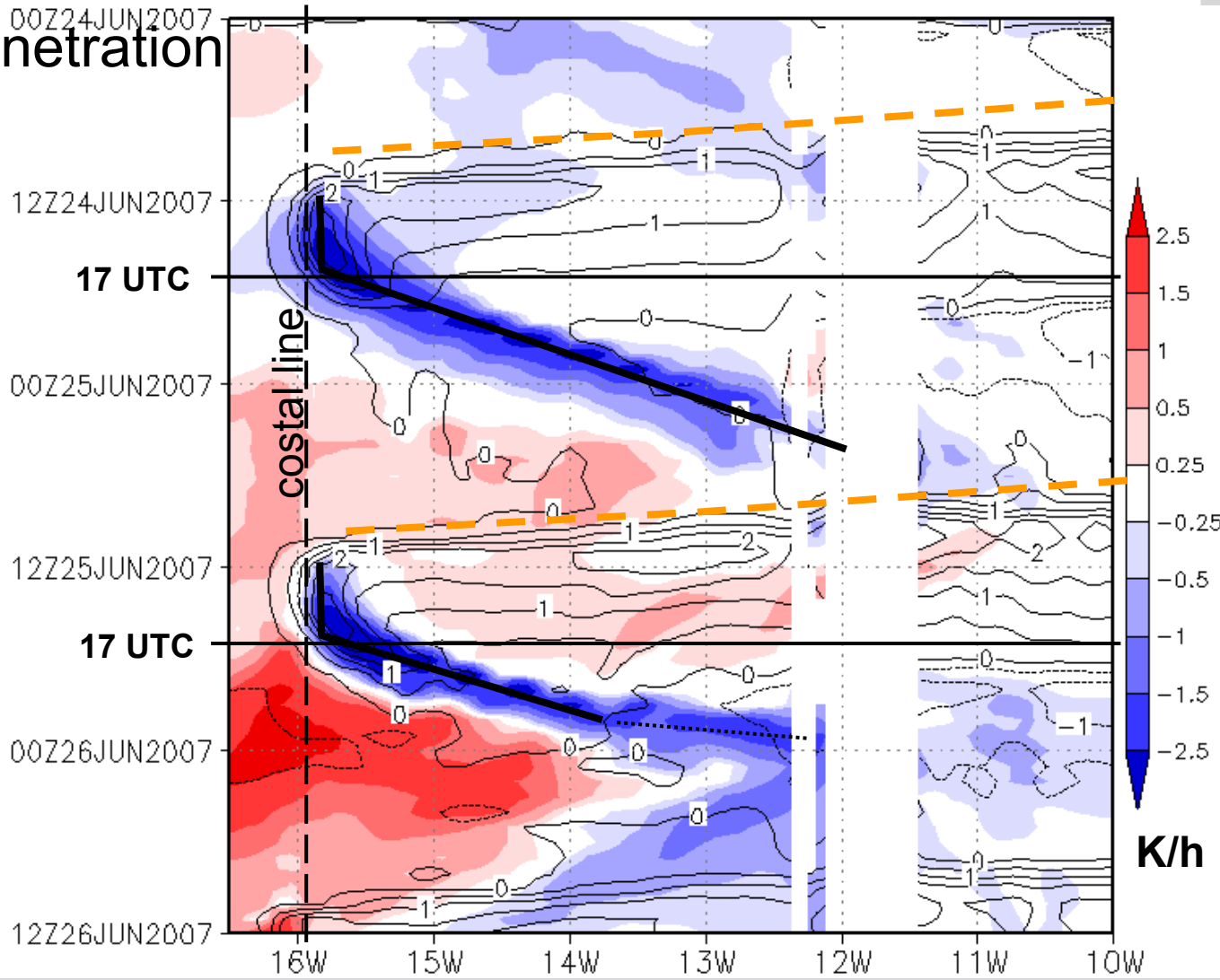
Contributions to the local tendency (RES) are from: horizontal (HADV) and vertical advection (VADV) , turbulent diffusion (MTD), radiation (RAD, only Θ), sub-grid scale moist convection (SQ), grid scale moist convection (MMC), computational effects (COMP).

# 4. Atlantic Inflow – mechanism



## Interplay of horizontal advection and turbulent diffusion governs inland penetration of coastal front

- Turbulence at daytime hinders inland penetration
- As soon as turbulence decays in the afternoon front starts propagating inland



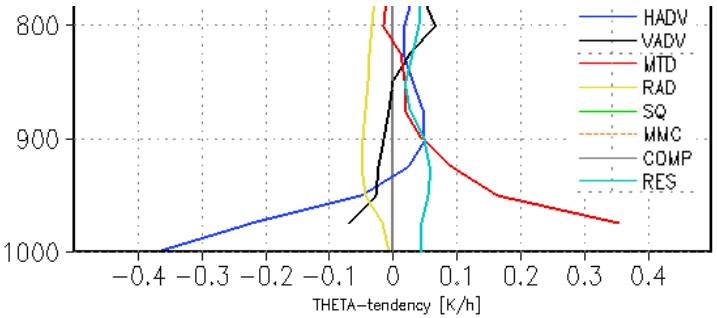
# 4. Impact on heat and moisture budgets

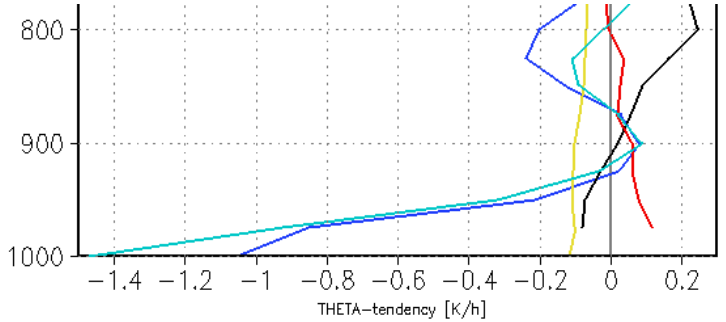


- Tendency terms areal averaged over box in Atlantic Inflow region
- Temporal average 0-48h: balance of horizontal advection and turbulence in heat budget, drying due to horizontal advection
- Temporal average for passage of the AI-front (18-22UTC): cooling and moistening due to horizontal advection!

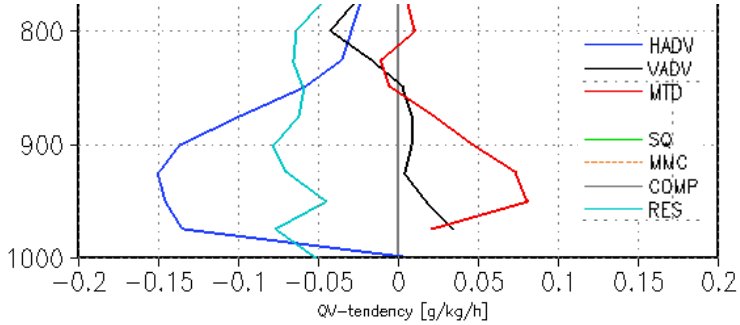
**0-48h** **18-22h**

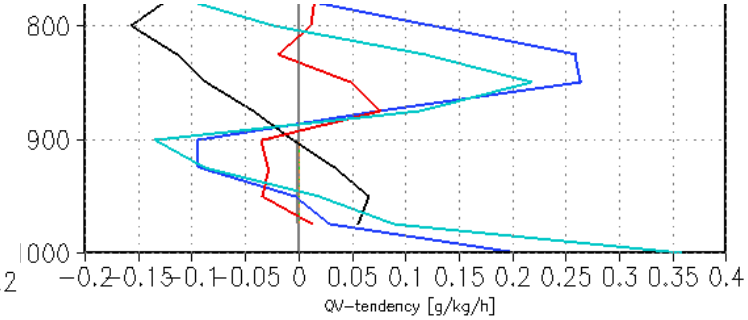
**Θ-tendencies**




**$q_v$-tendencies**



# 5. Summary



## Summary:

- SABL well represented in COSMO model
- Atlantic Inflow described as a mesoscale feature at the West African coast.
- Atlantic Inflow affects heat and moisture budget at the western flank of the Saharan heat low
- Frontal circulation could affect dust uplift

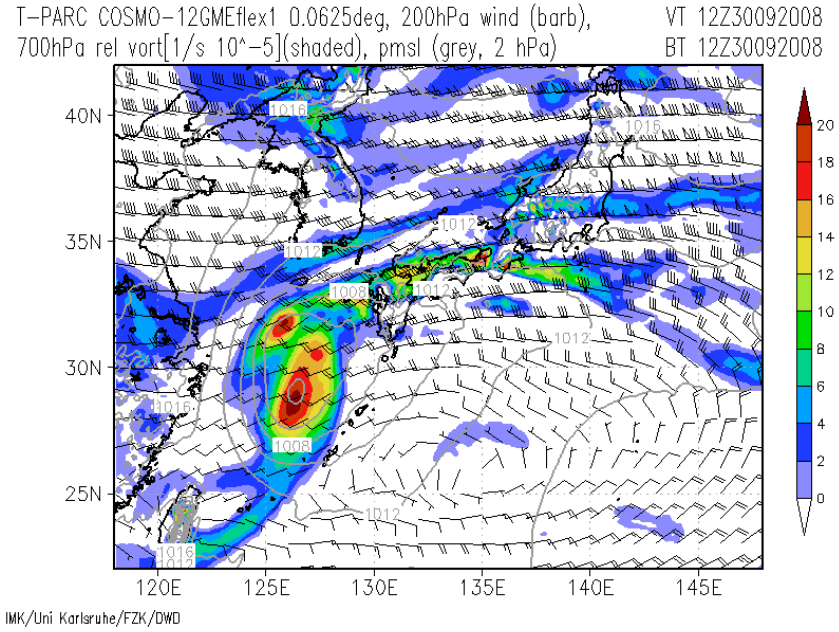
## Future work:

- Simulations including dust: COSMO-ART
- More detailed look at heat and moisture budgets

The Atlantic Inflow to the Saharan heat low: observations and modelling. Grams et al. (2009), accepted with minor revisions, *QJRMS Special Issue AMMA WP 2.1.*

# Extratropical transition of Tropical Cyclones in COSMO

- Operational COSMO forecasts in support of T-PARC 2008
  - Computed at HP XC4000 Steinbuch Centre for Computing, KIT
  - 0.025° and 0.0625° horizontal resolution, 51 vertical levels
  - GME and IFS as driving global models, 2 domains, 00Z, 12Z initial time
  - 16 forecasts per day, >700 forecasts from 1.8.2008-20.10.2008
- PV-diagnostics for COSMO model output
  - Calculation of balanced flow using PV-Inversion
  - Piecewise PV-Inversion
- Investigation of ET scenarios



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Homepage

http://www.imk.uni-karlsruhe.de/english/3841.php

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**Thank you for your attention!**

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