

Meteorology of Tropical West Africa: The Forecasters' Handbook

Chapter 1: Mean Climate and Seasonal Cycle - Lead Author, A. H. Fink

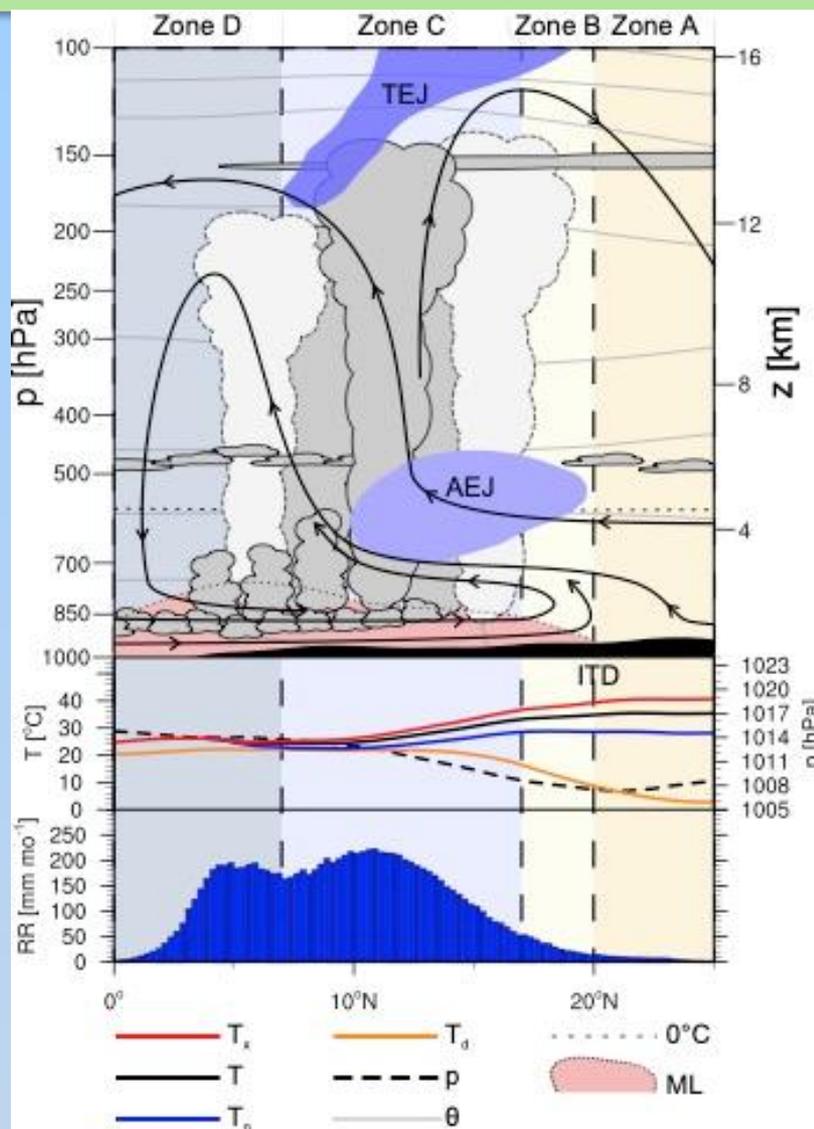


Figure 1.1: Schematic cross-section of the atmosphere between 10°W and 10°E in July and illustration of the weather zones A-D of the West African monsoon. Shown are the positions of the ITD, upper-level jet streams (AEJ, TEJ), the monsoon layer (ML) (as defined by westerly, i.e. positive zonal winds), streamlines, clouds, the freezing level (0°C isotherm), isentropes, minimum (T_n), maximum (T_x) and mean (T) and dew point temperatures (T_d), atmospheric pressures (p), and mean monthly rainfall totals (RR).

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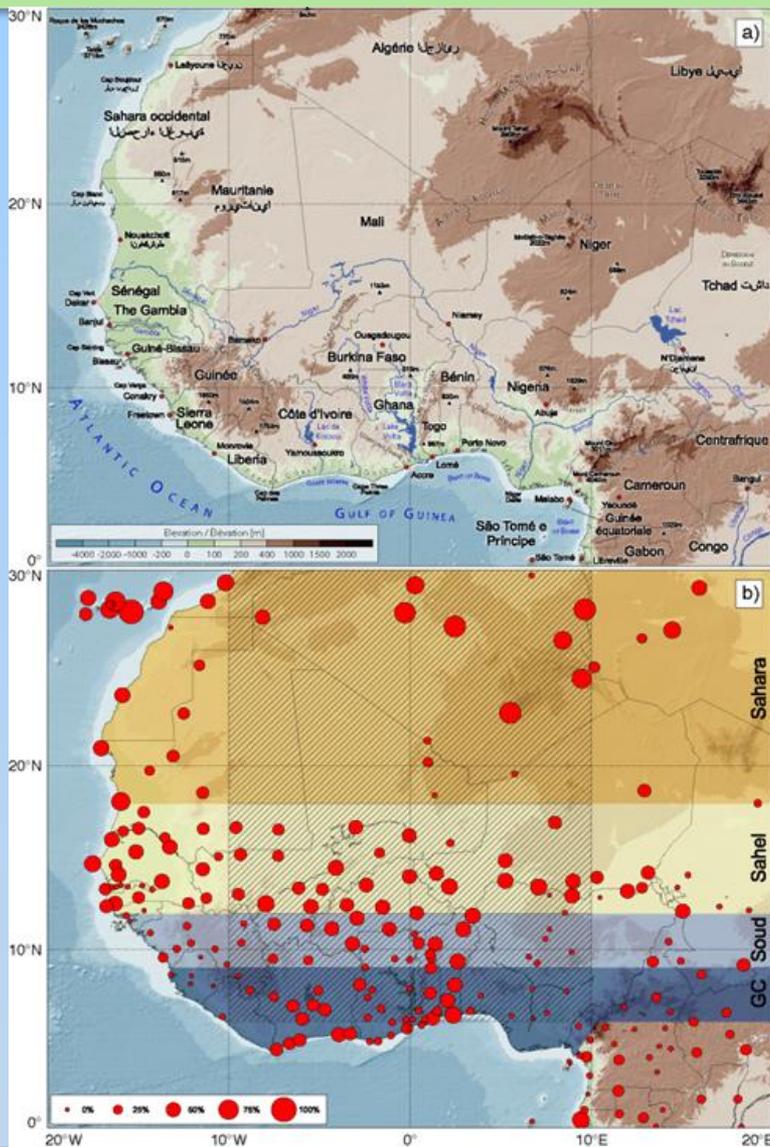


Figure 1.2: Maps of West Africa

a) West Africa is defined here as the region from the western coast to 20°E.

Source: Open Street

b) Location of synoptic stations and their reporting frequency to the Global Telecommunication System (GTS). The coloured areas indicate the positions of the climate zones: Guinea Coast (GC), Soudanian (Soud), Sahel, and Sahara. Hatched areas indicate the part of climates zones used in the Hovmoeller diagrams of Figures 1.4, 1.10, 1.12, and 1.23 and the cross-section in Figure 1.30.

Source: Met Office Integrated Data Archive System (MIDAS), 1981-2010.

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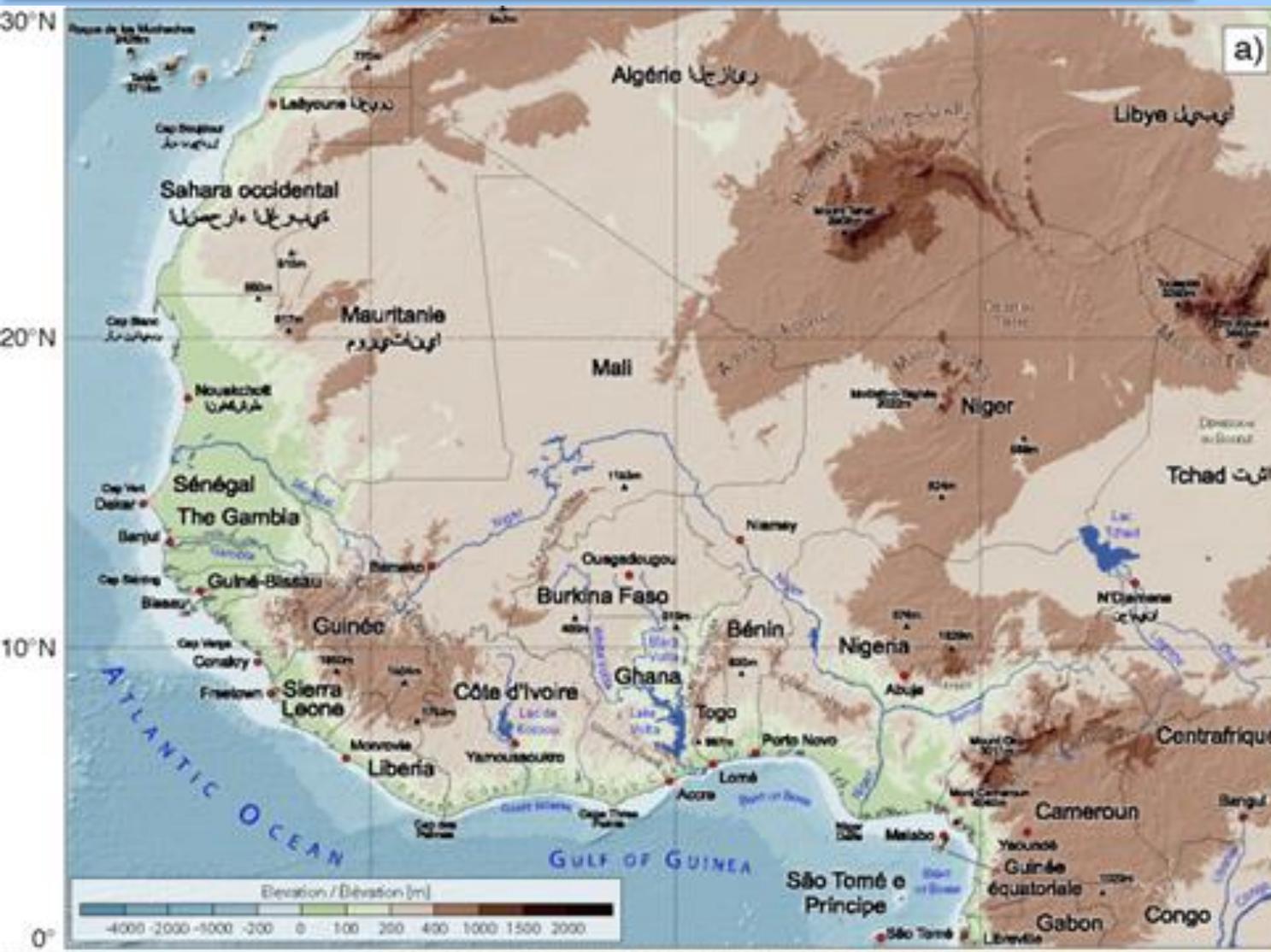


Figure 1.2a:
Maps of West Africa
West Africa is defined
here as the region
from the western coast
to 20°E.
Source: Open Street

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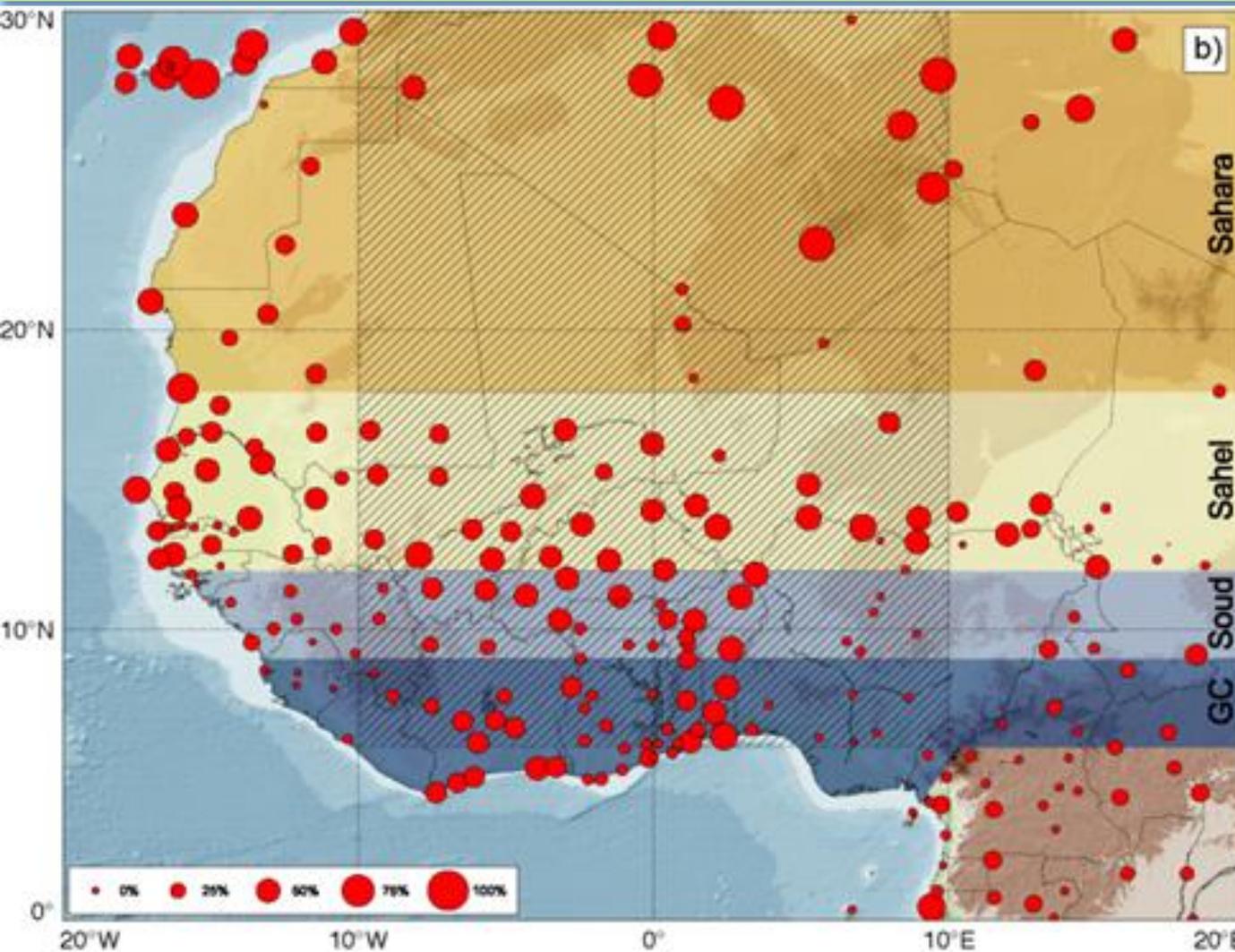


Figure 1.2b:
Maps of West Africa
Location of synoptic stations and their reporting frequency to the GTS. The coloured areas indicate the positions of the climate zones: Guinea Coast (GC), Soudanian (Soud), Sahel, and Sahara. Hatched areas indicate the part of climates zones used in the Hovmoeller diagrams of Figures 1.4, 1.10, 1.12, and 1.23 and the cross-section in Figure 1.30.

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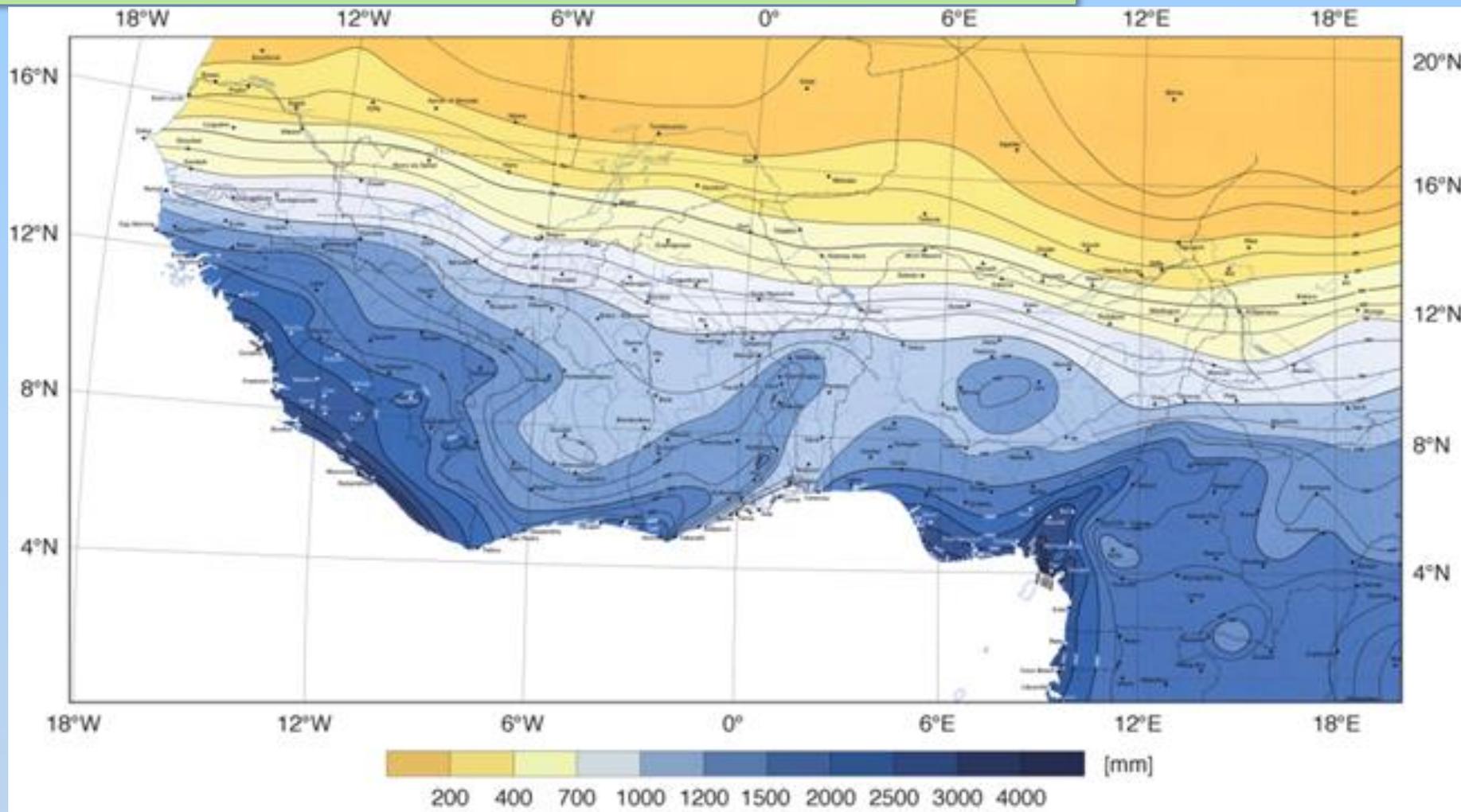


Figure 1.3: Mean annual precipitation for the period 1951–1989. The isohyets are based on 890 rainfall stations. (Source: Institut de Recherche pour le Développement (IRD))

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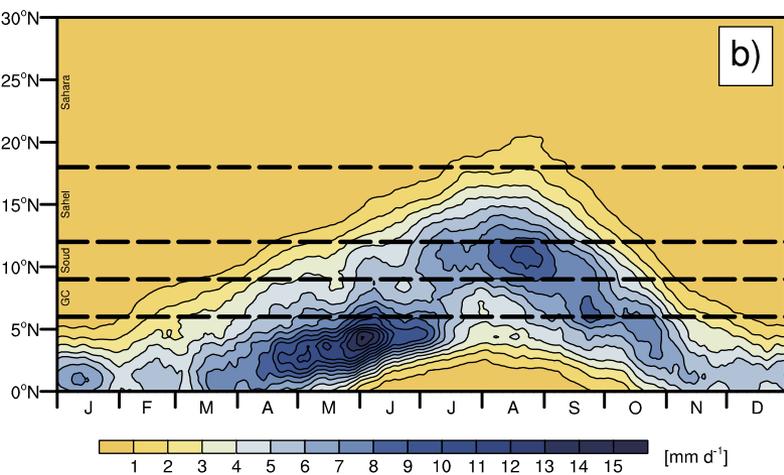
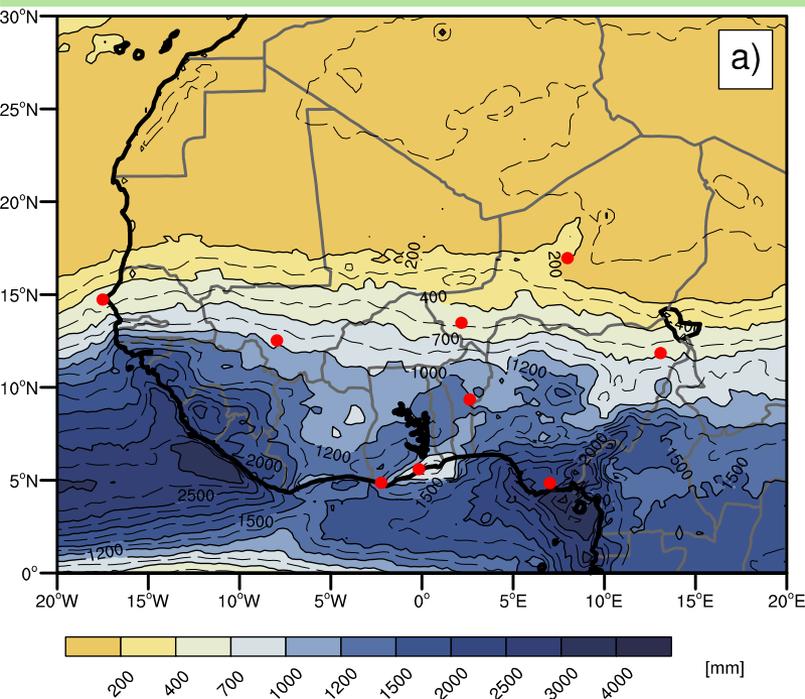


Figure 1.4: a) Mean annual precipitation. Red dots denote the positions of the stations shown in Figures 1.6 and 6. b) Hovmoeller diagram of the 15-day running mean of daily precipitation, averaged between 10°W and 10°E. Regions are shown in Figure 1.2b.

Source: Tropical Rainfall Measuring Mission (TRMM) 3B42 Version 7, 1998–2012.

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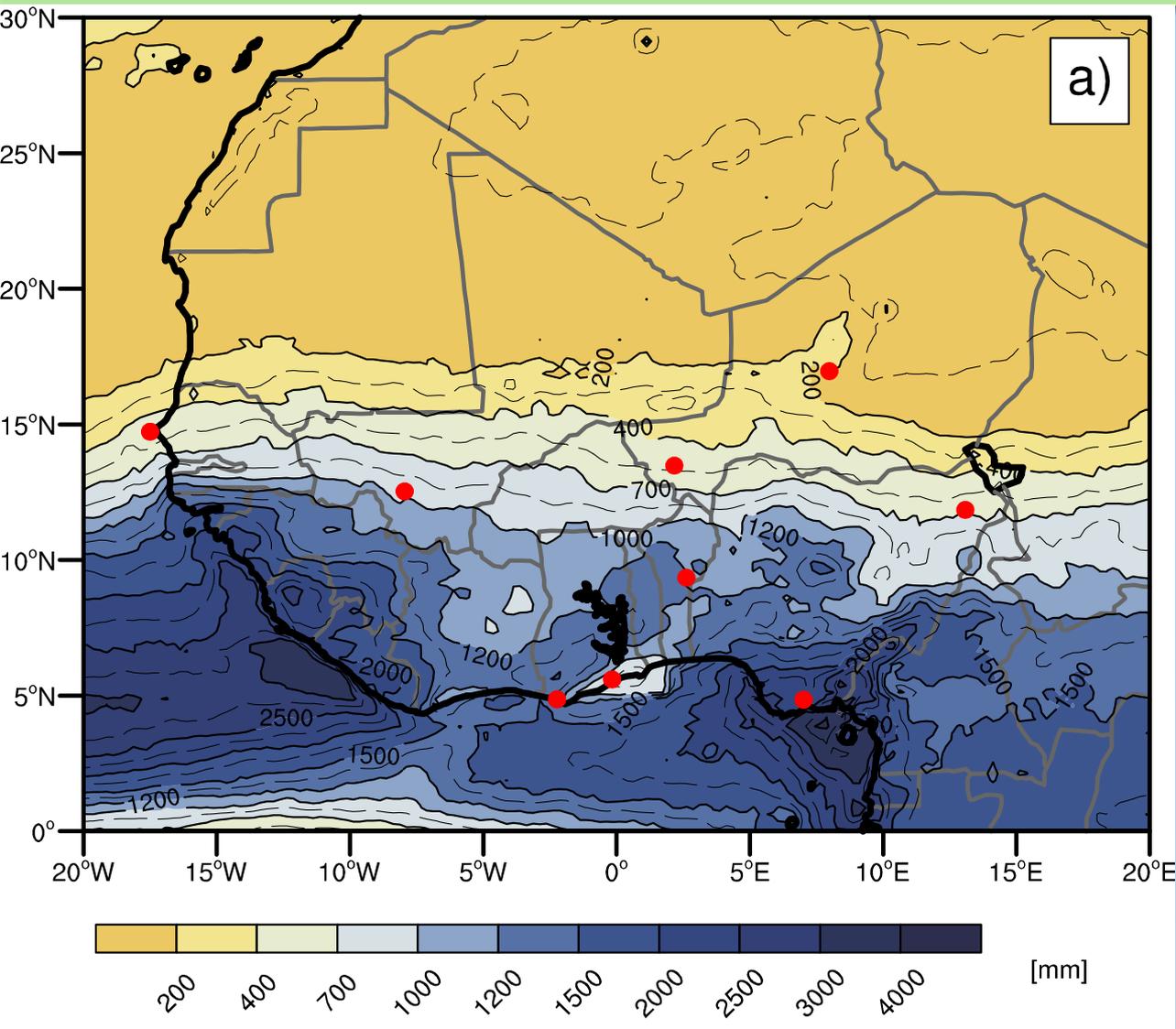


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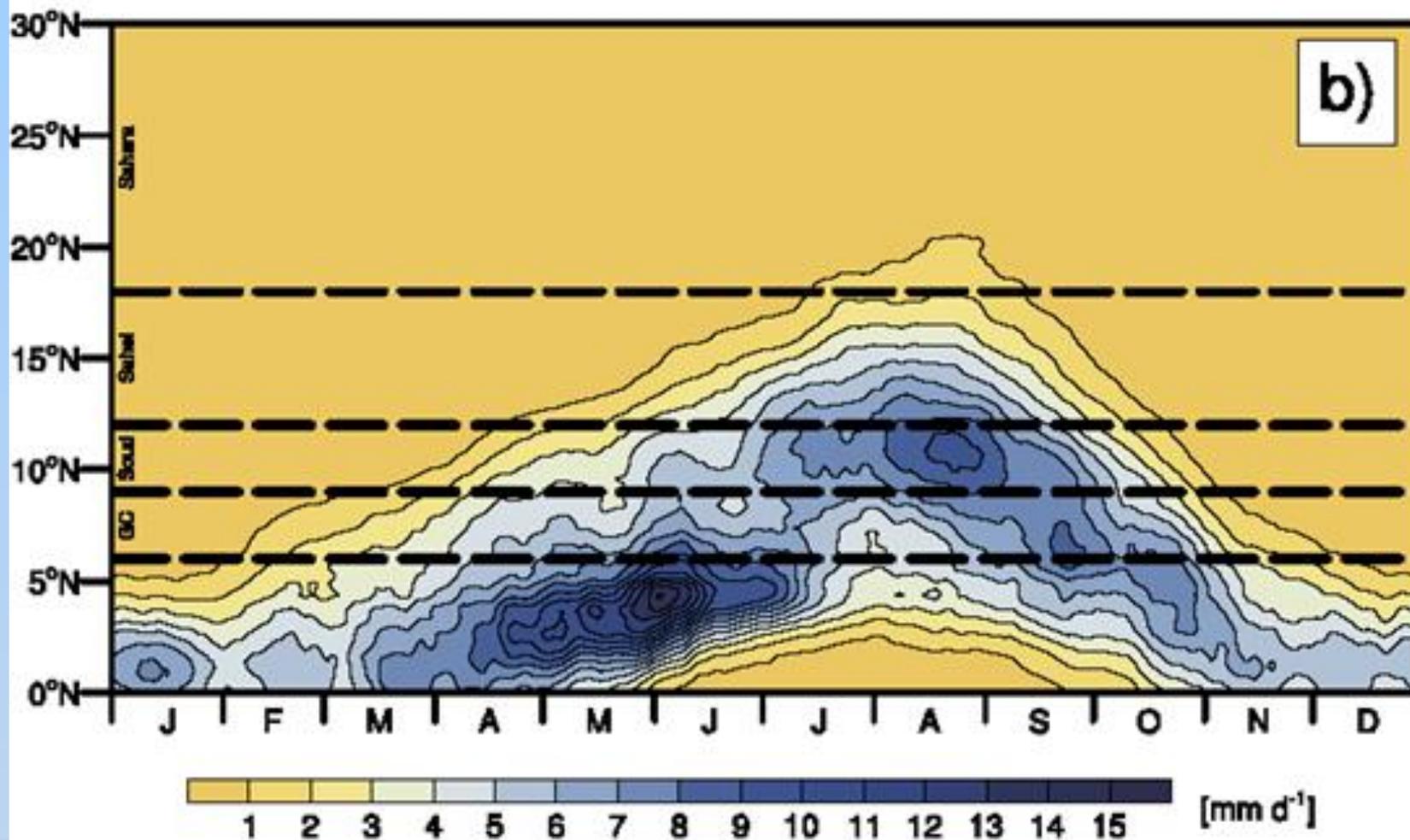


Figure 1.4: b) Hovmoeller diagram of the 15-day running mean of daily precipitation, averaged between 10°W and 10°E. Regions are shown in Figure 1.2b. Source: Tropical Rainfall Measuring Mission (TRMM) 3B42 Version 7, 1998–2012.

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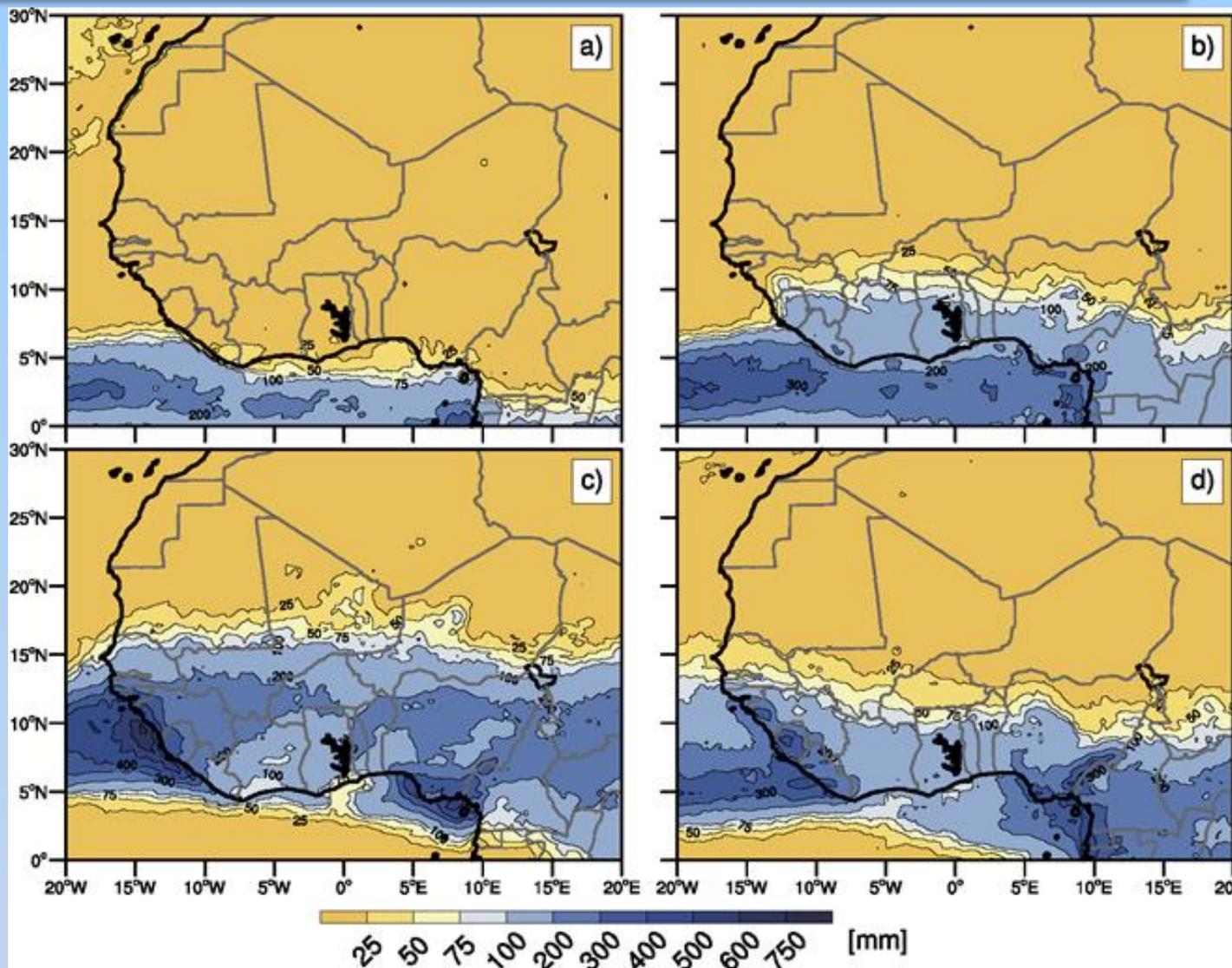


Figure 1.5: Mean monthly rainfall for , a) January, b) April, c) July, and d) October.

Source: TRMM 3B42
Version 7, 1998–2012

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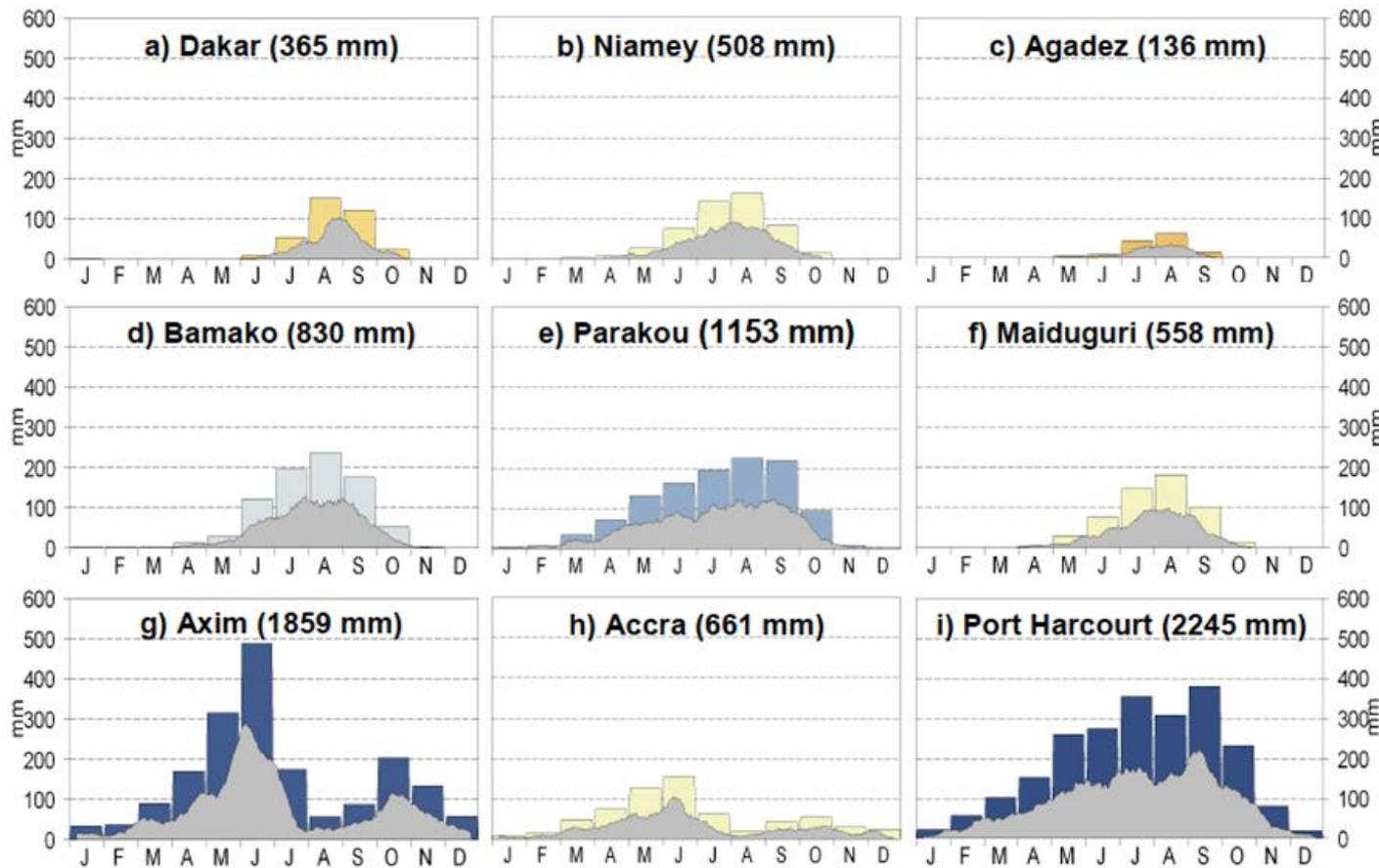


Figure 1.6: Colour bars: Mean monthly precipitation between 1981 and 2010 in mm (left and right axes) for:

- a) Dakar: 14.73°N, 17.50°W,
- b) Niamey: 13.48°N, 2.17°E,
- c) Agadez: 16.97°N, 7.98°E,
- d) Bamako: 12.53°N, 7.95°W,
- e) Parakou 9.35°N, 2.62°E,
- f) Maiduguri 11.85°N, 13.08°E,
- g) Axim 4.87°N, 2.23°W,
- h) Accra 5.60°N, 0.17°W,
- i) Port Harcourt 4.85°N, 7.02°E.

Figure 1.6: Grey areas: 15-day running mean precipitation amount between 1981 and 2010 in mm. Mean annual total is given at the top of the panel. Stations locations are shown in Figure 1.4a. Colours correspond to Fig. 1.4a.

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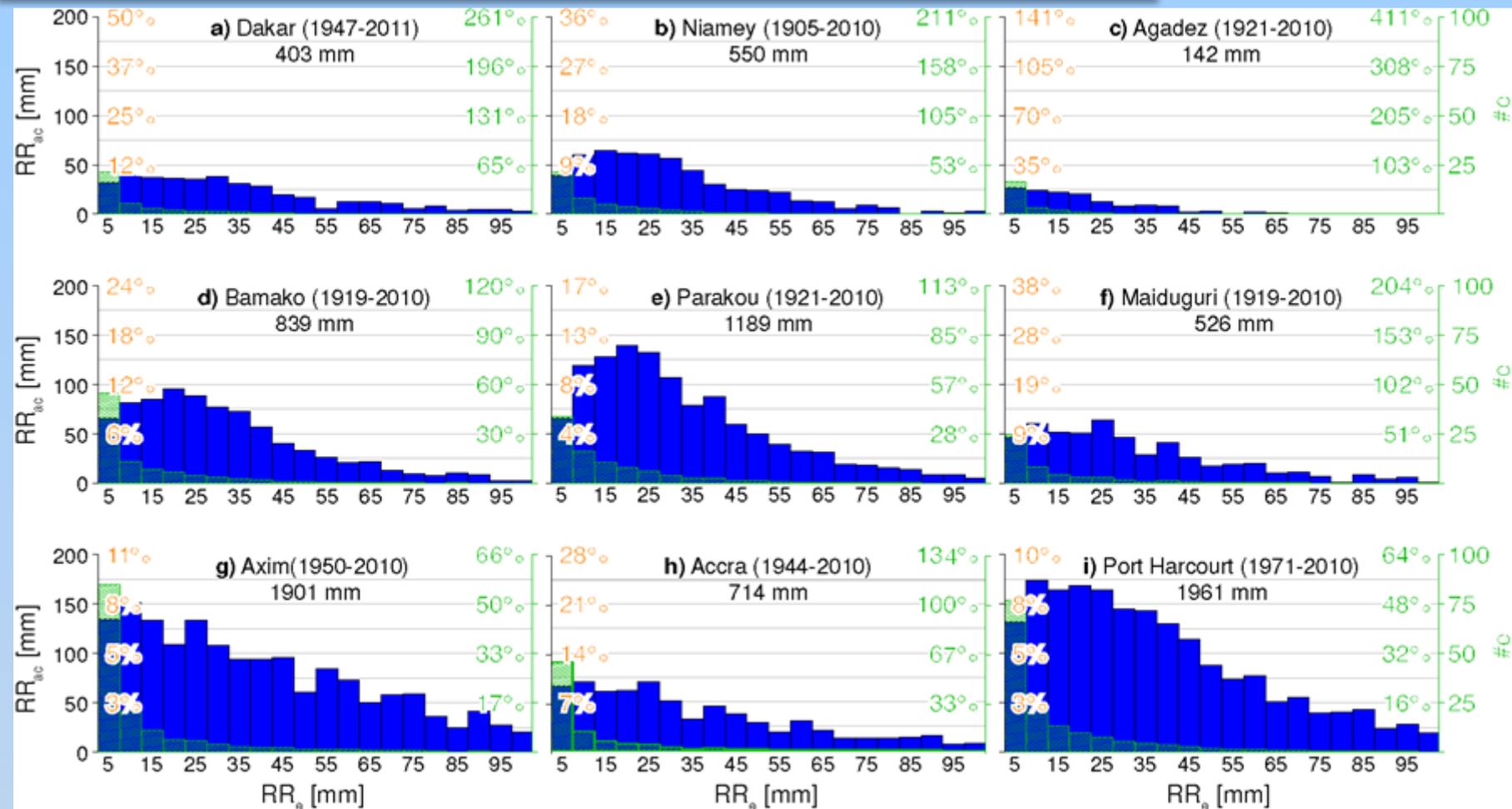


Fig. 1.7: Accumulated rainfall per 5 mm interval in mm and percentage of the annual total (blue, left axis). Number of rainfall events per 5 mm interval in % of total and number (green, right axis). Stations in panels (a – i) are the same as in Fig. 1.6. Reference period (as long as possible) and annual total is given at the top of the panel.

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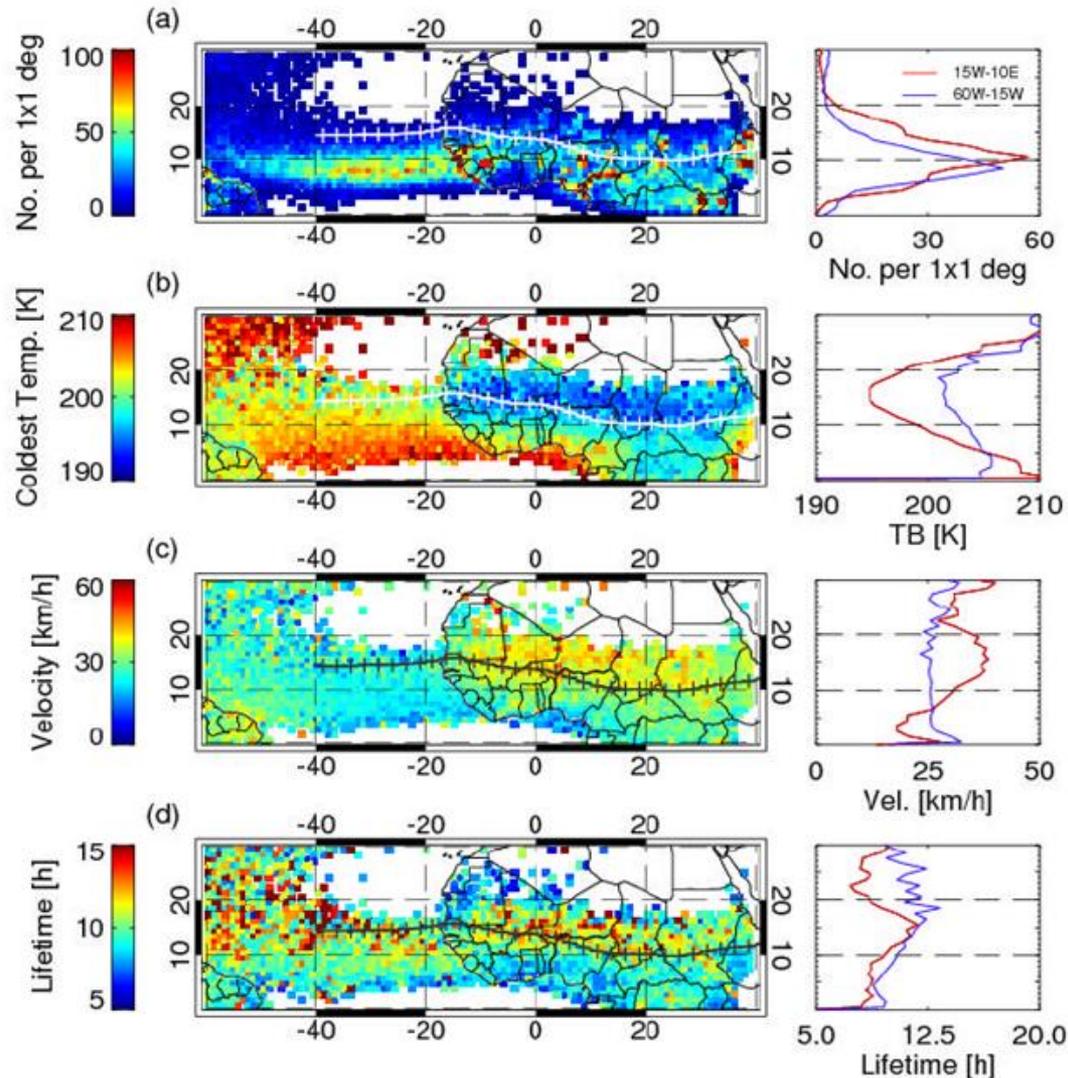


Figure 1.8: Mean features of convective systems derived from twenty years (1986–2005) of Meteosat Visible and Infra-Red Imager radiometer (MVI) observations. Data are binned in 1 x 1 degree boxes according to their origin. Figure taken from Bennartz and Schröder (2012).

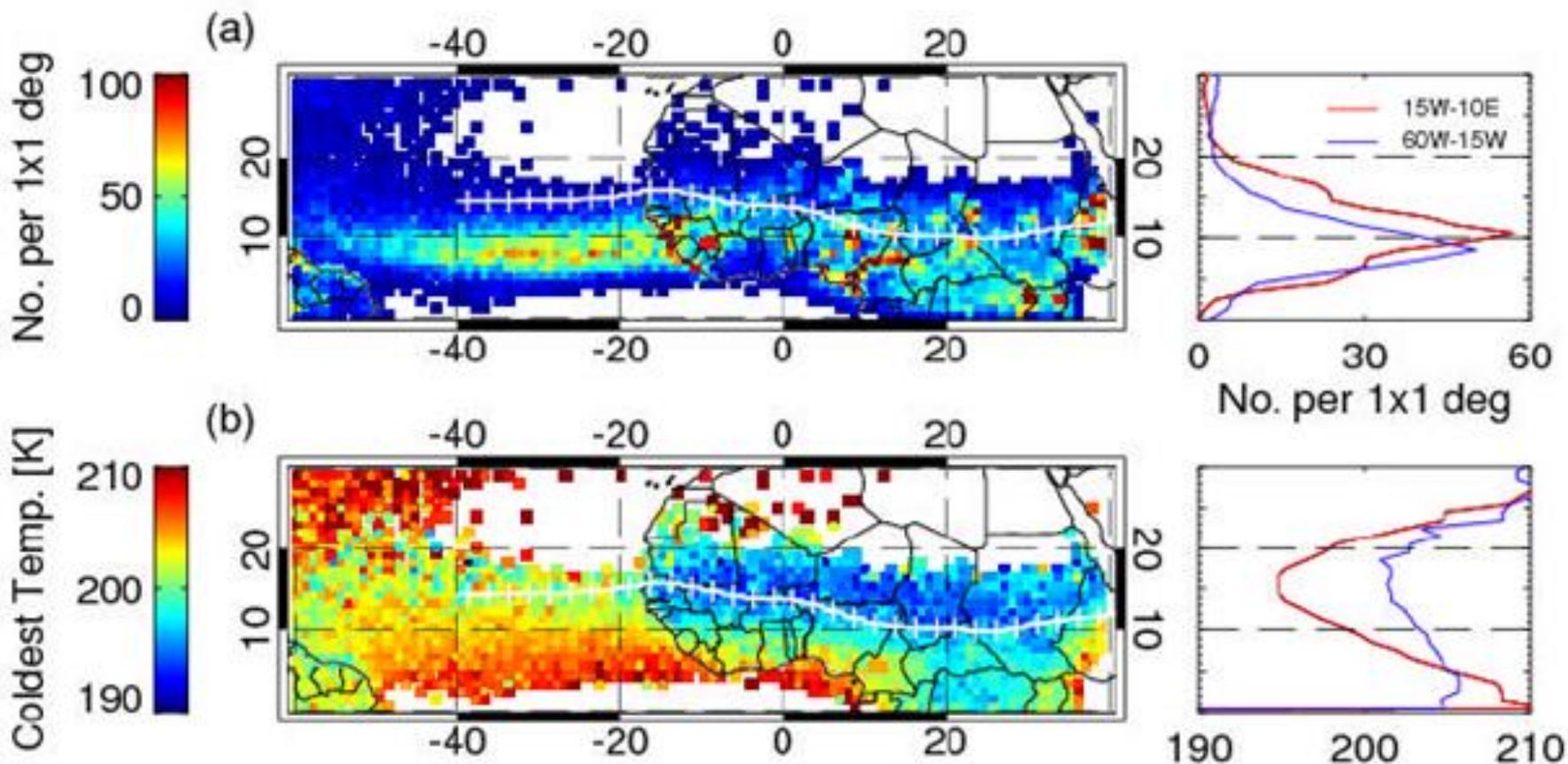


Figure 1.8: Mean features of convective systems derived from twenty years (1986–2005) of Meteosat Visible and Infra-Red Imager radiometer (MVIIR) observations. Data are binned in 1 x 1 degree boxes according to their origin. Figure taken from Bennartz and Schröder (2012).

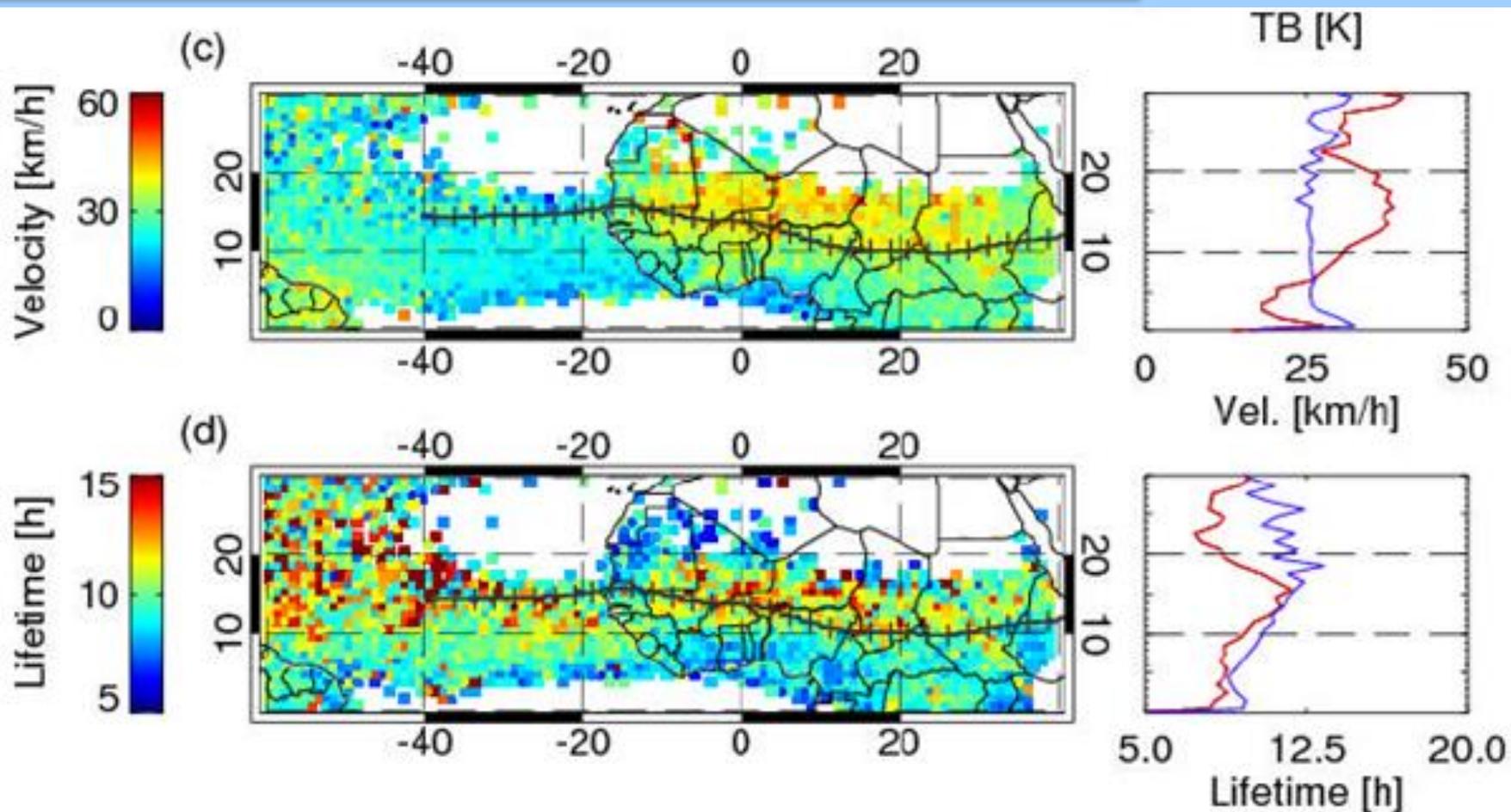


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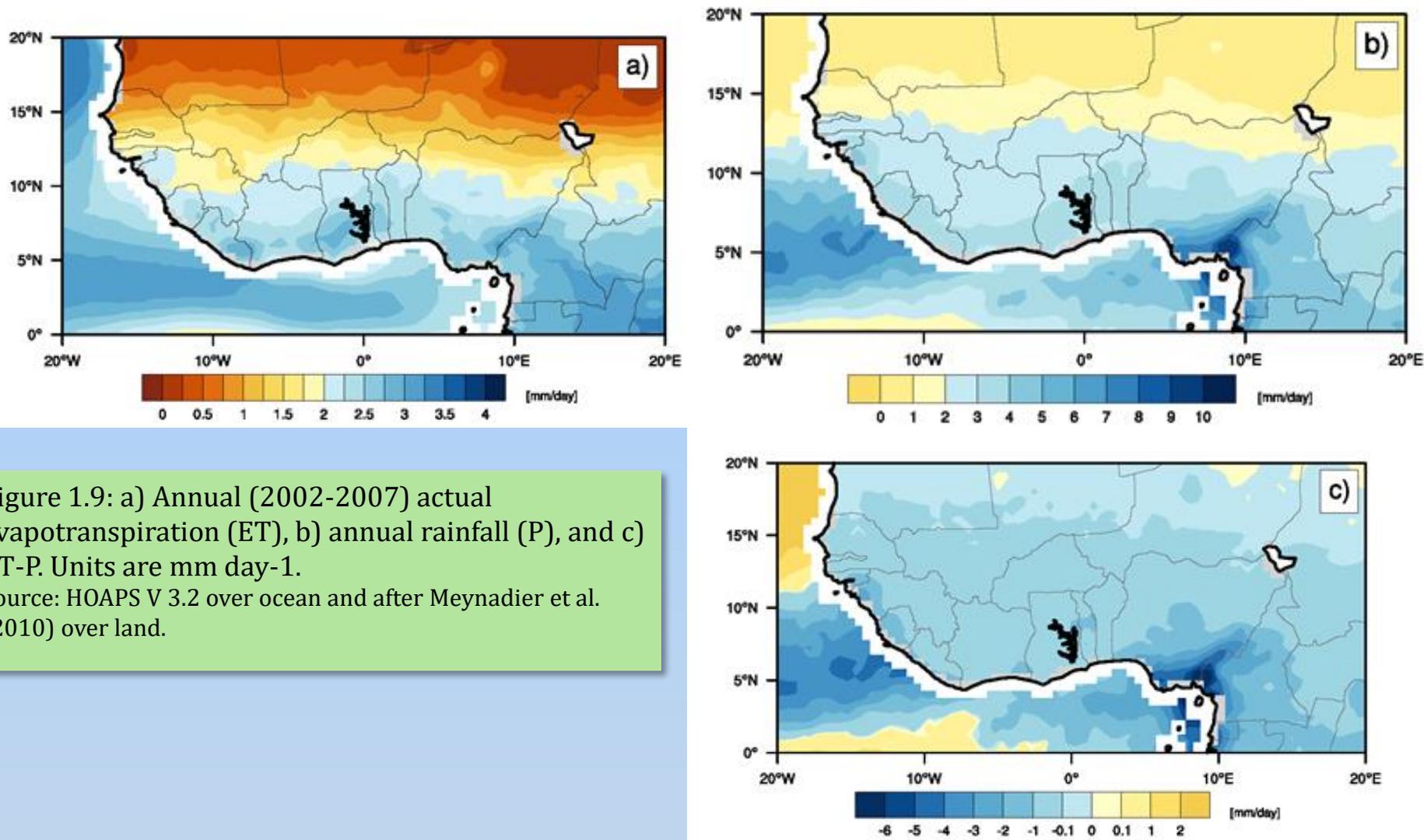


Figure 1.9: a) Annual (2002-2007) actual evapotranspiration (ET), b) annual rainfall (P), and c) ET-P. Units are mm day⁻¹.

Source: HOAPS V 3.2 over ocean and after Meynadier et al. (2010) over land.

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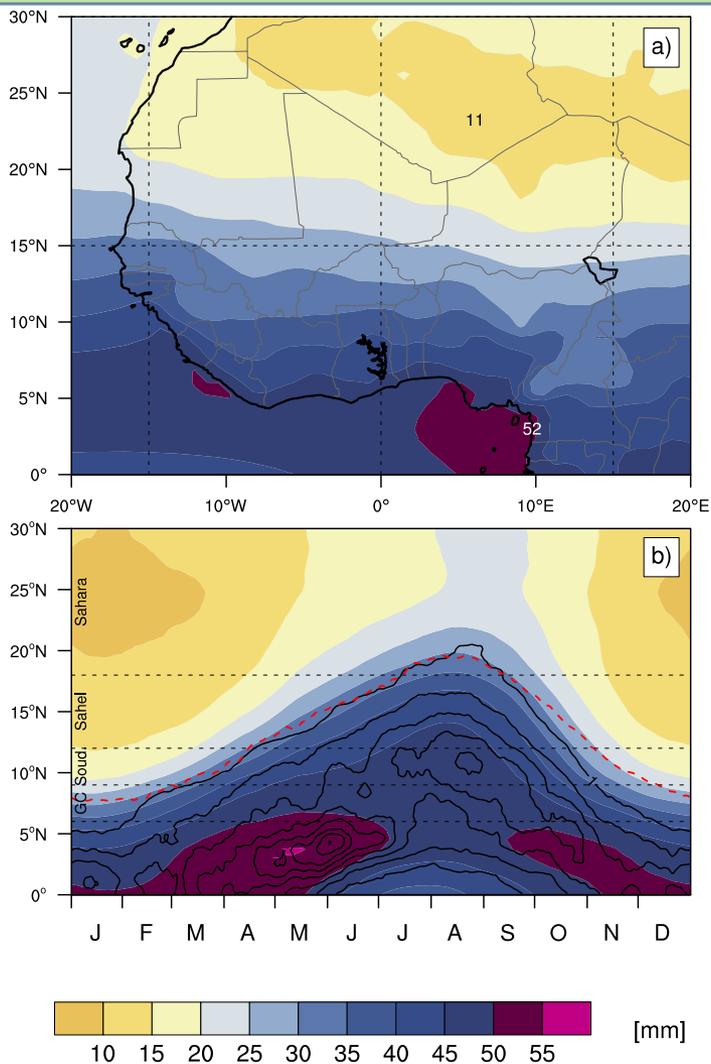


Figure 1.10: Integrated (1000-100 hPa) precipitable water (PW in mm).

a) Long-term annual mean.

b) Hovmoeller diagram of the 15-day running mean of PW and daily precipitation (contours, Source TRMM 3B42 Version 7, 1998–2012), averaged between 10°W and 10°E.

Dashed red line indicates the location of the Intertropical Discontinuity (ITD), inferred from the 14°C 2 m dewpoint isodrosotherm. Regions are shown in Figure 1.2b.

Source: ERA-Interim, 1981–2010.

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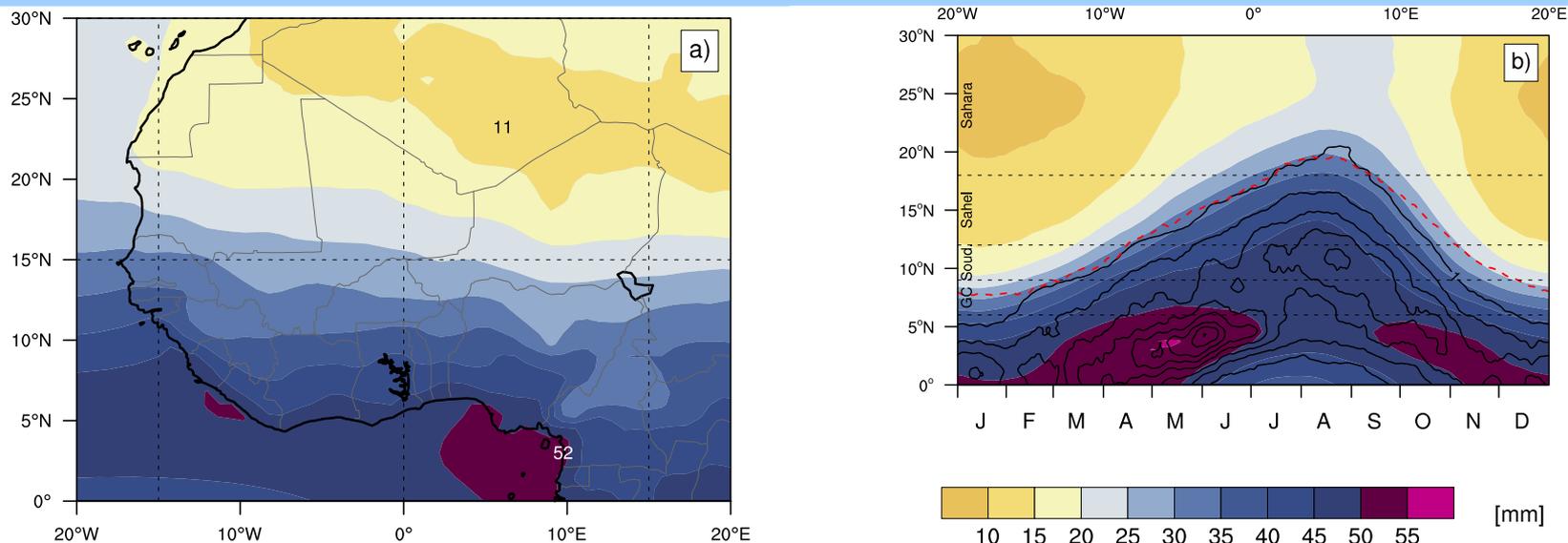


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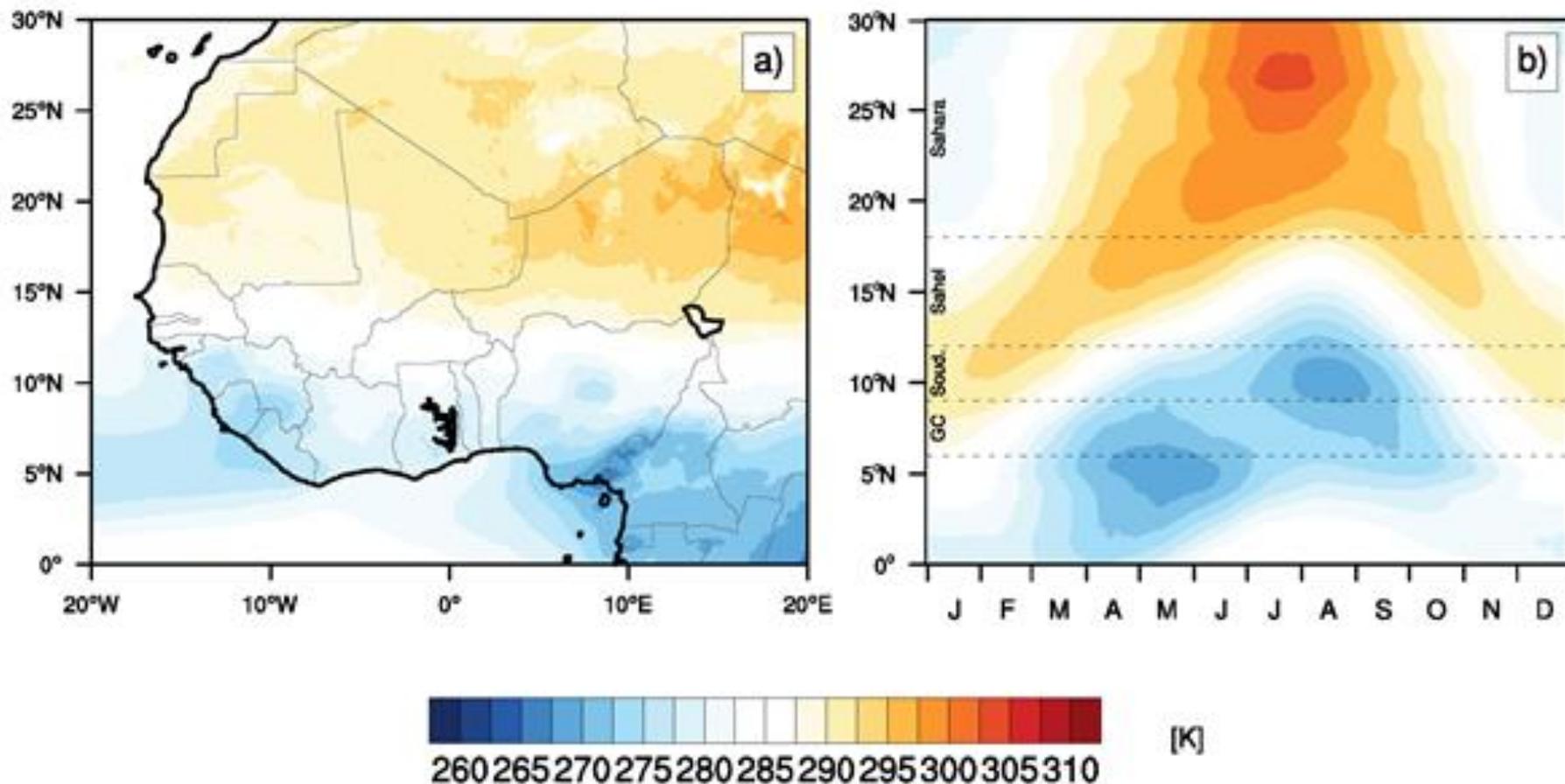


Figure 1.11: Infrared brightness temperatures in K, a) annual mean, b) 15-day running mean of daily brightness temperatures. Regions are shown in Figure 1.2b. Source: GridSat, 1983–2009, cf. Knapp et al. (2011).

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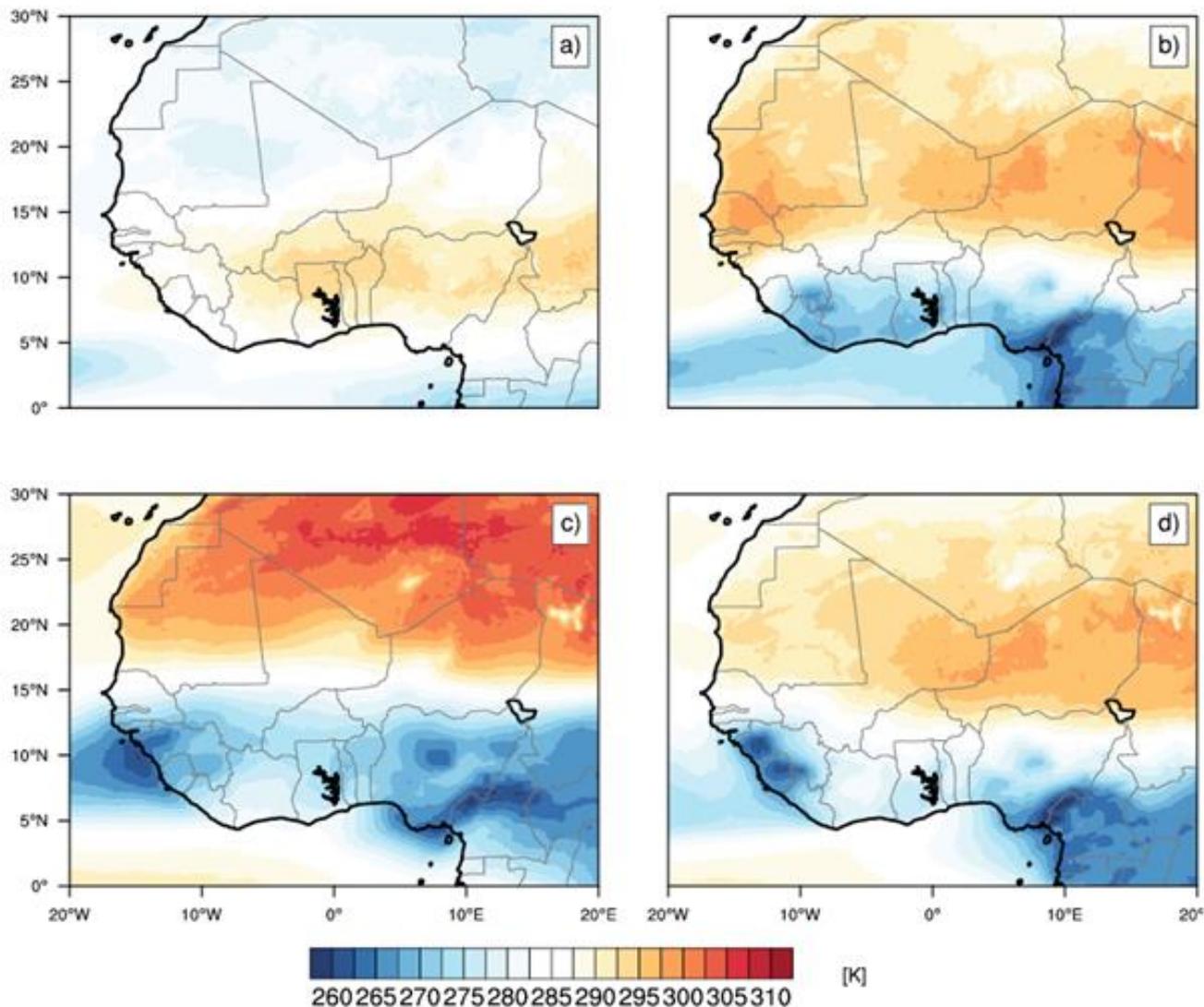


Figure 1.12: Infrared brightness temperatures in K for a) January, b) April, c) July, and October.

Source: GridSat, 1983–2009, cf. Knapp et al. (2011).

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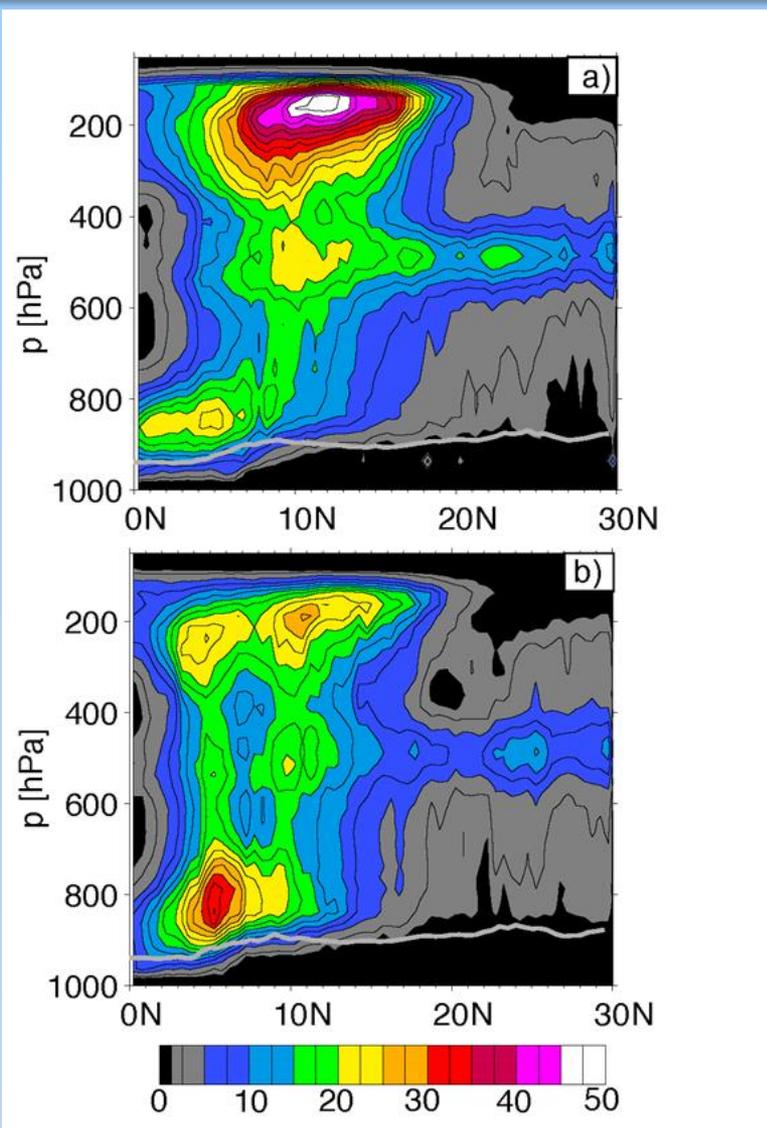


Figure 1.13: Cloud and precipitation fraction for June to September (2006–2010) observed by CloudSat and CALIPSO for a) night-time overpasses and b) daytime overpasses. Fractions are shown at 2.5% intervals at a resolution of 0.5° in latitude and 25 hPa in pressure, averaged over all observations throughout the period between 10°W and 10°E .

Values below 1.25% are shown in black with a thick grey line indicating the mean pressure at 600 m above the surface.

(amended from Stein et al., 2011)

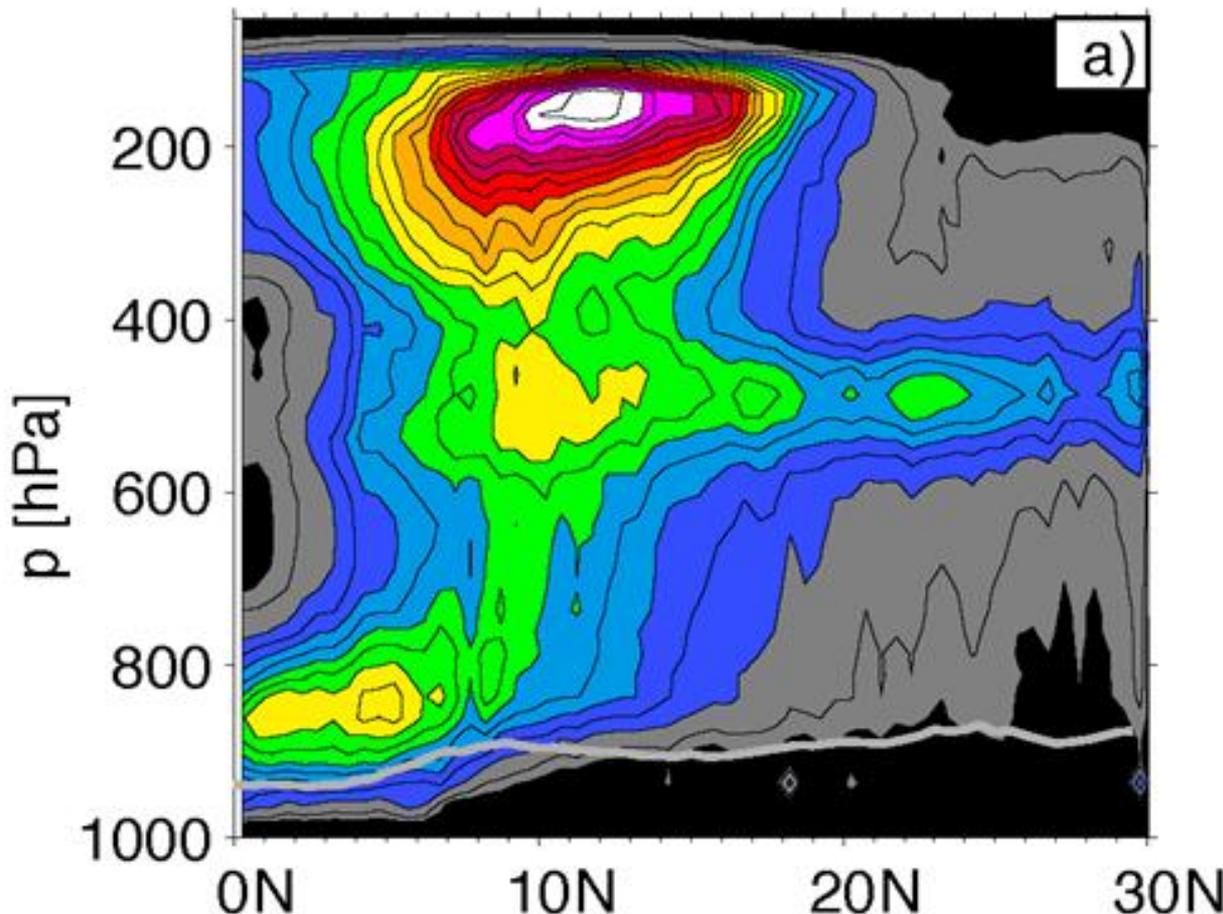


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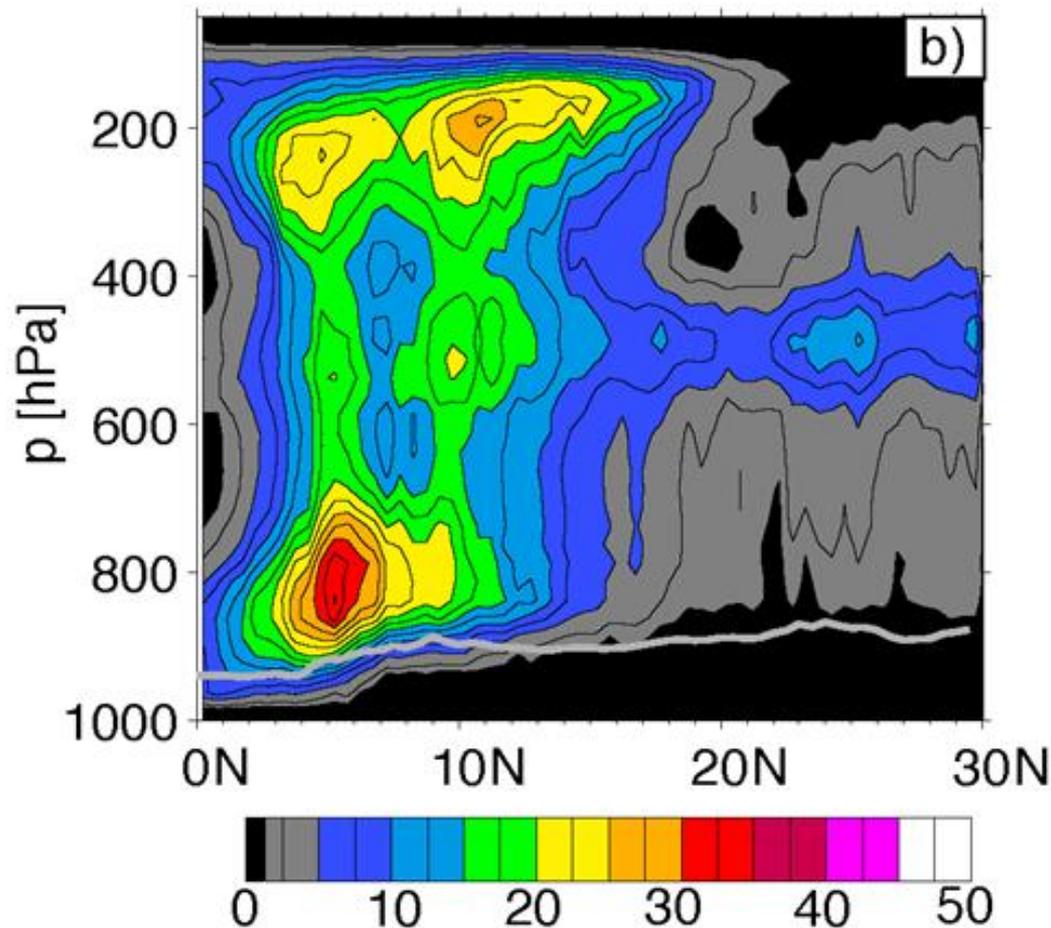


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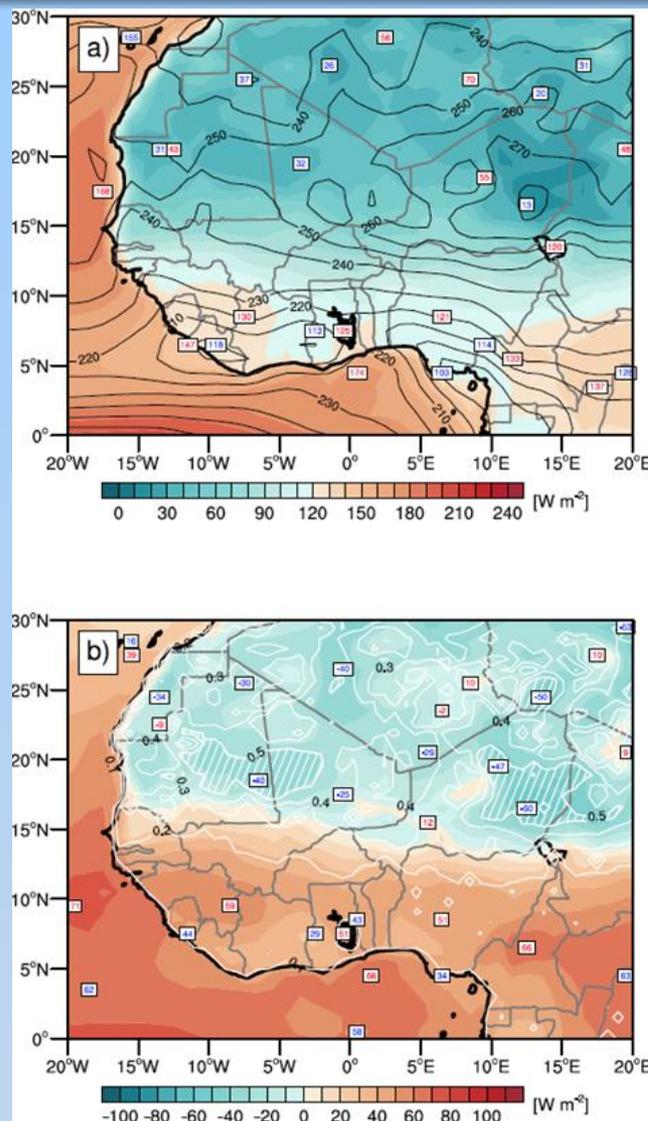


Figure 1.14: Mean annual net radiation at a) the surface and b) the top of the atmosphere.

Contours in a) and b) denote the incoming surface solar radiation and surface albedo, respectively. Boxed red (blue) numbers denote local maxima (minima) of net radiation at the surface in a) and at the top of the atmosphere in b).

Source: Global Energy and Water Exchanges Project (GEWEX), 1984–2007 and Global Inventory Modeling and Mapping Studies (GIMMS), 1982–2005.

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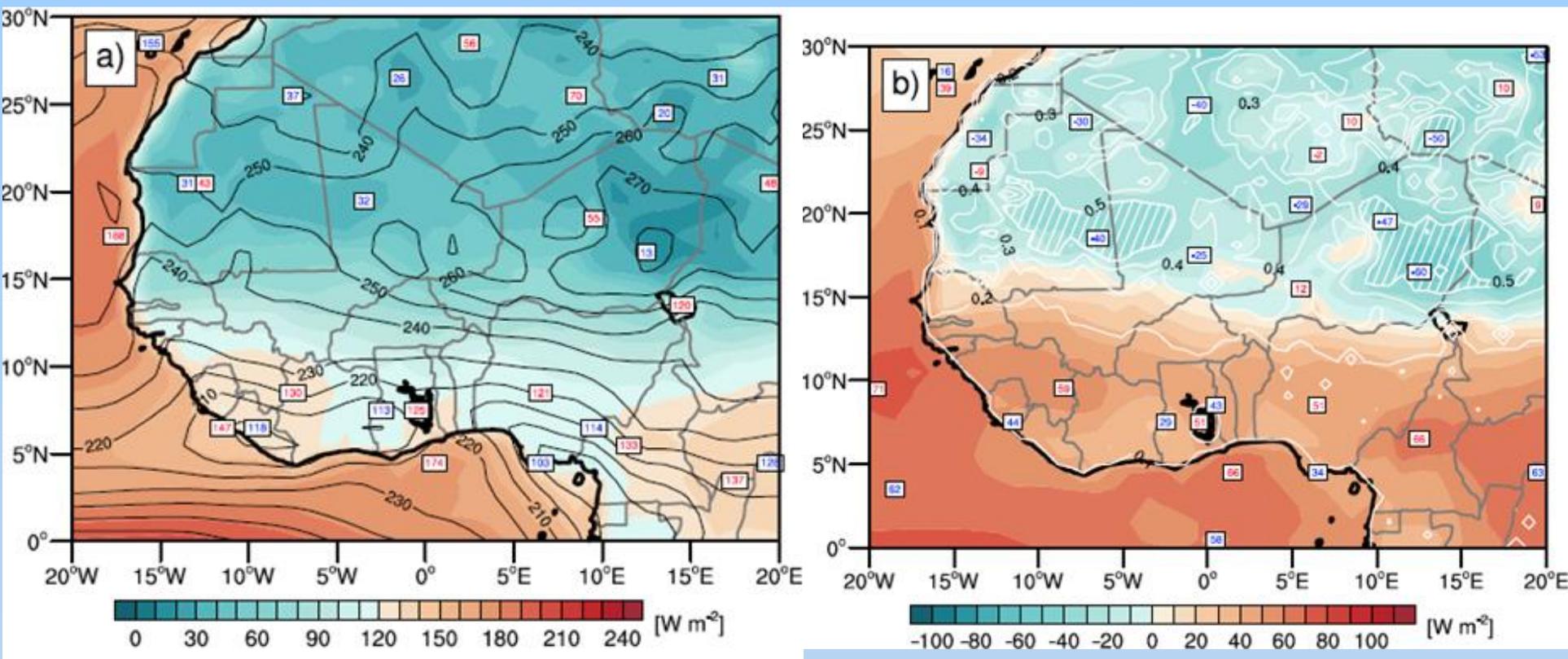


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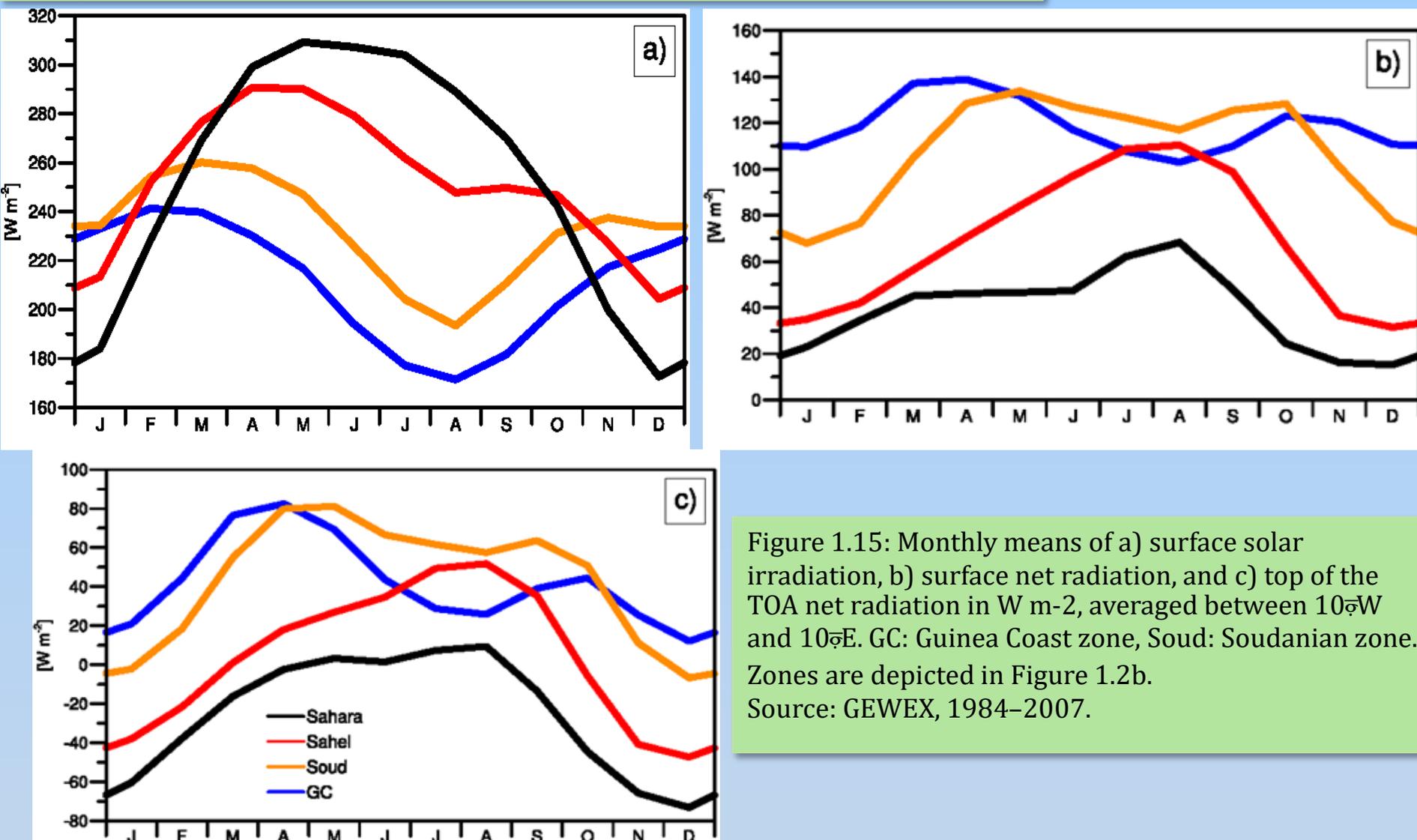


Figure 1.15: Monthly means of a) surface solar irradiation, b) surface net radiation, and c) top of the TOA net radiation in $W m^{-2}$, averaged between $10^{\circ}W$ and $10^{\circ}E$. GC: Guinea Coast zone, Soud: Soudanian zone. Zones are depicted in Figure 1.2b. Source: GEWEX, 1984–2007.

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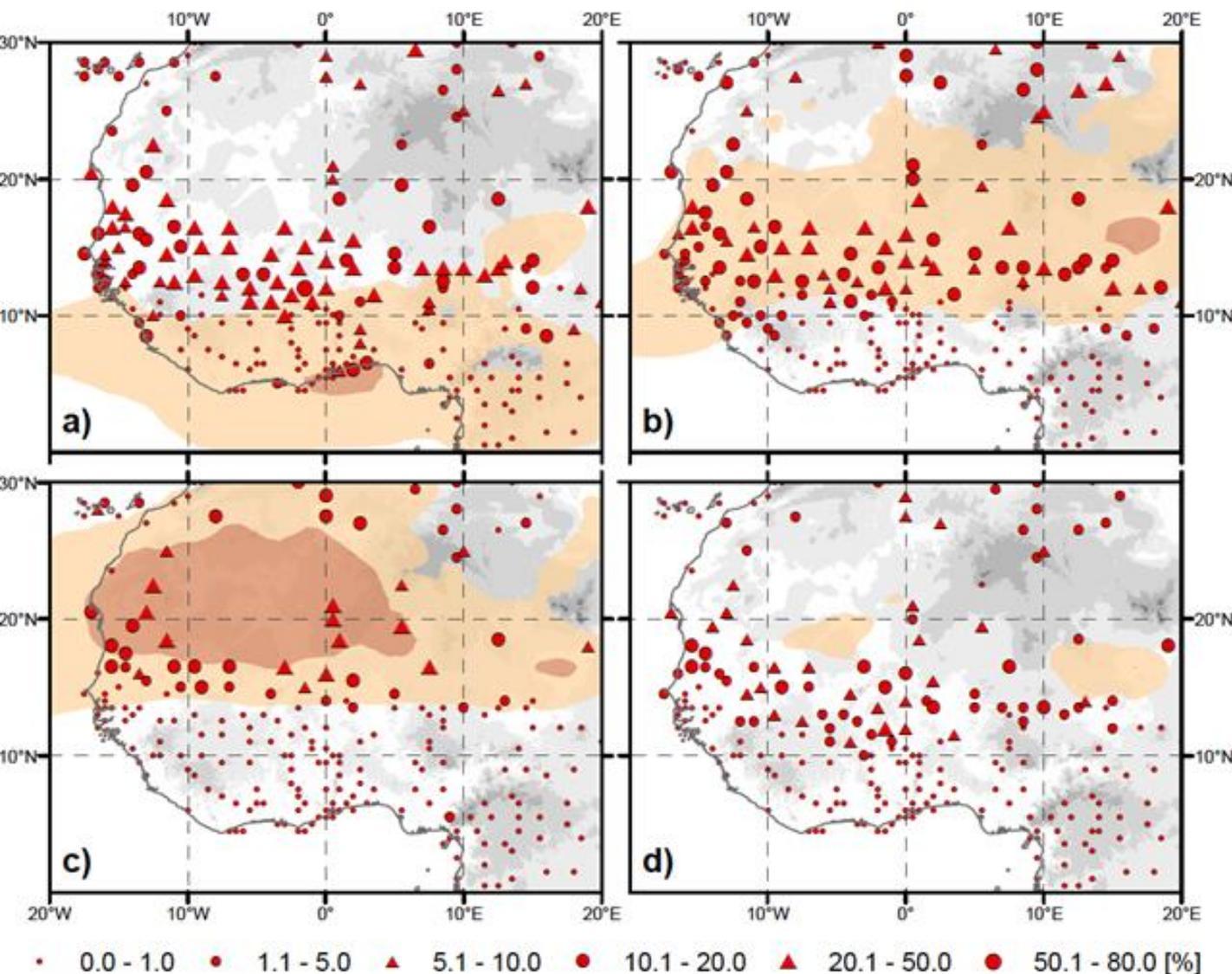


Figure 1.16: Frequency of dust weather in SYNOP reports for
a) January
b) April
c) July
d) October

Source MIDAS, 1983-2010; Yellow and orange areas indicate regions of monthly averaged TOMS/OMI AI for the analysis period exceeding an index value of 1.8 and 3, respectively

(updated from Klose et al., 2010).

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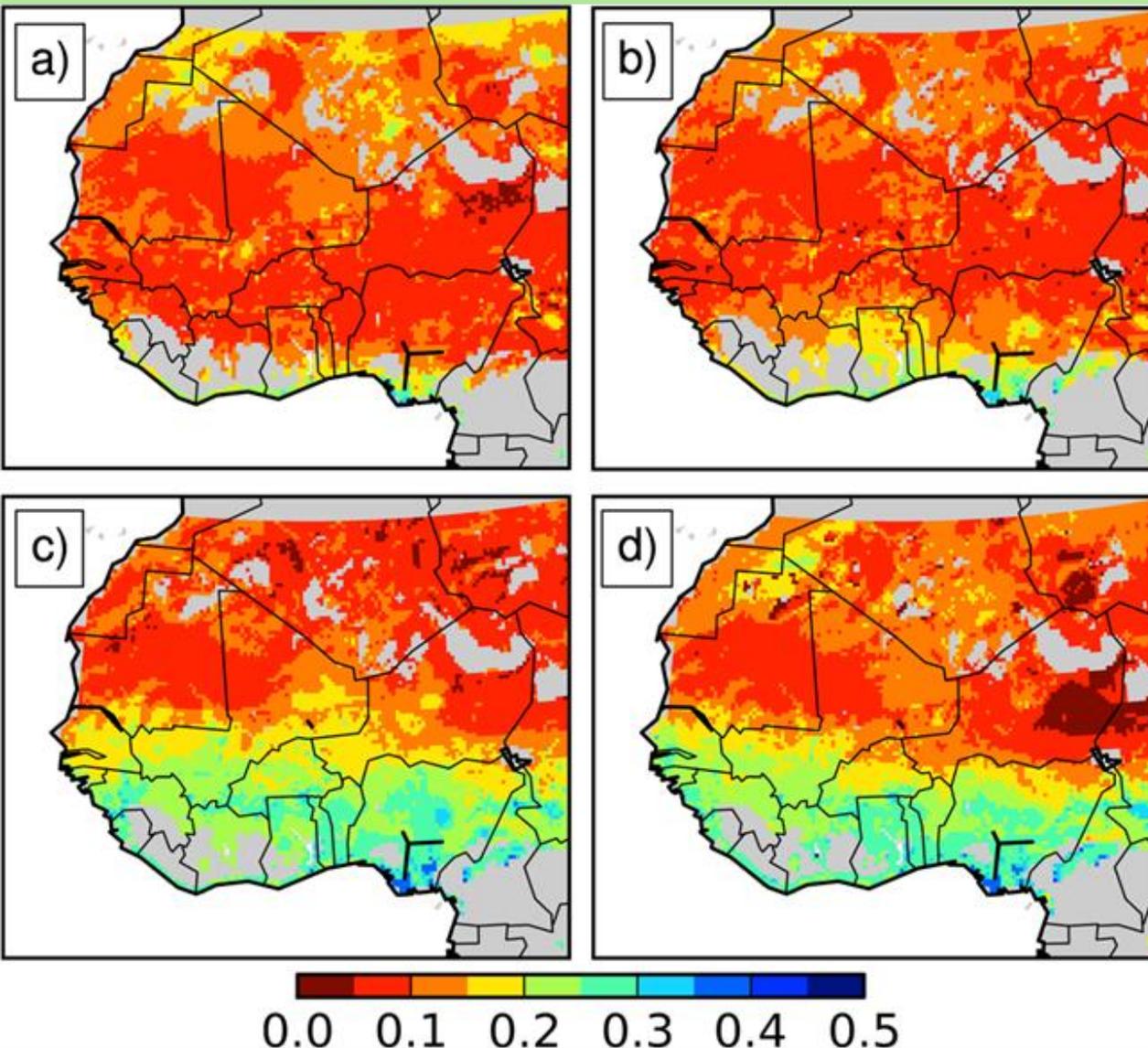


Figure 1.17: Climatology of volumetric topsoil moisture in $m^3 m^{-3}$ for
a) January
b) April
c) July
d) October
Grey areas depict regions where the vegetation density did not allow for a satellite assessment of topsoil moisture.

Source: Meteosat, 1983–2010.

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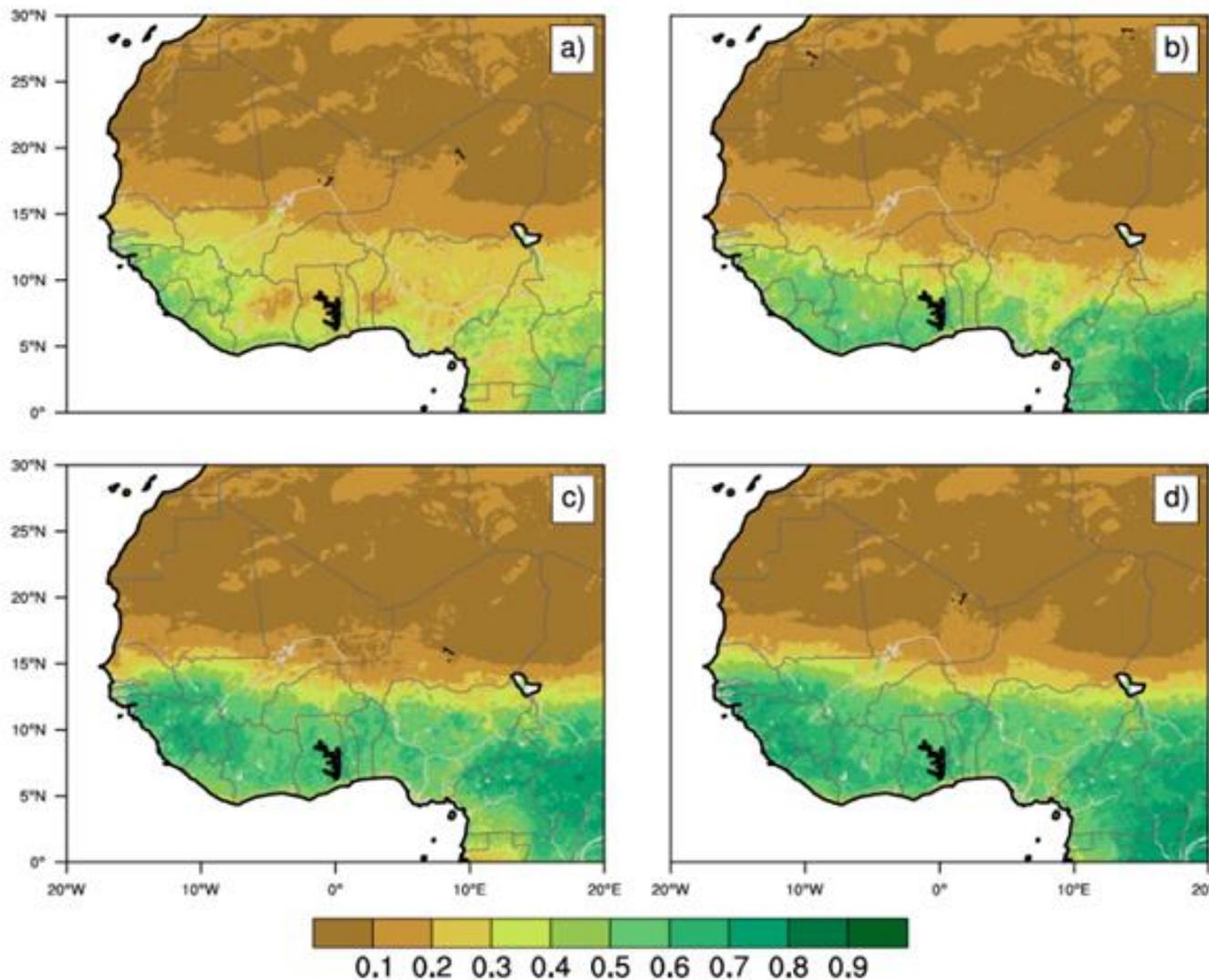


Figure 1.18: Mean Normalized Differential Vegetation Index (NDVI) for:
a) January
b) April
c) July
d) October

Source: GIMMS, 1982-2005.

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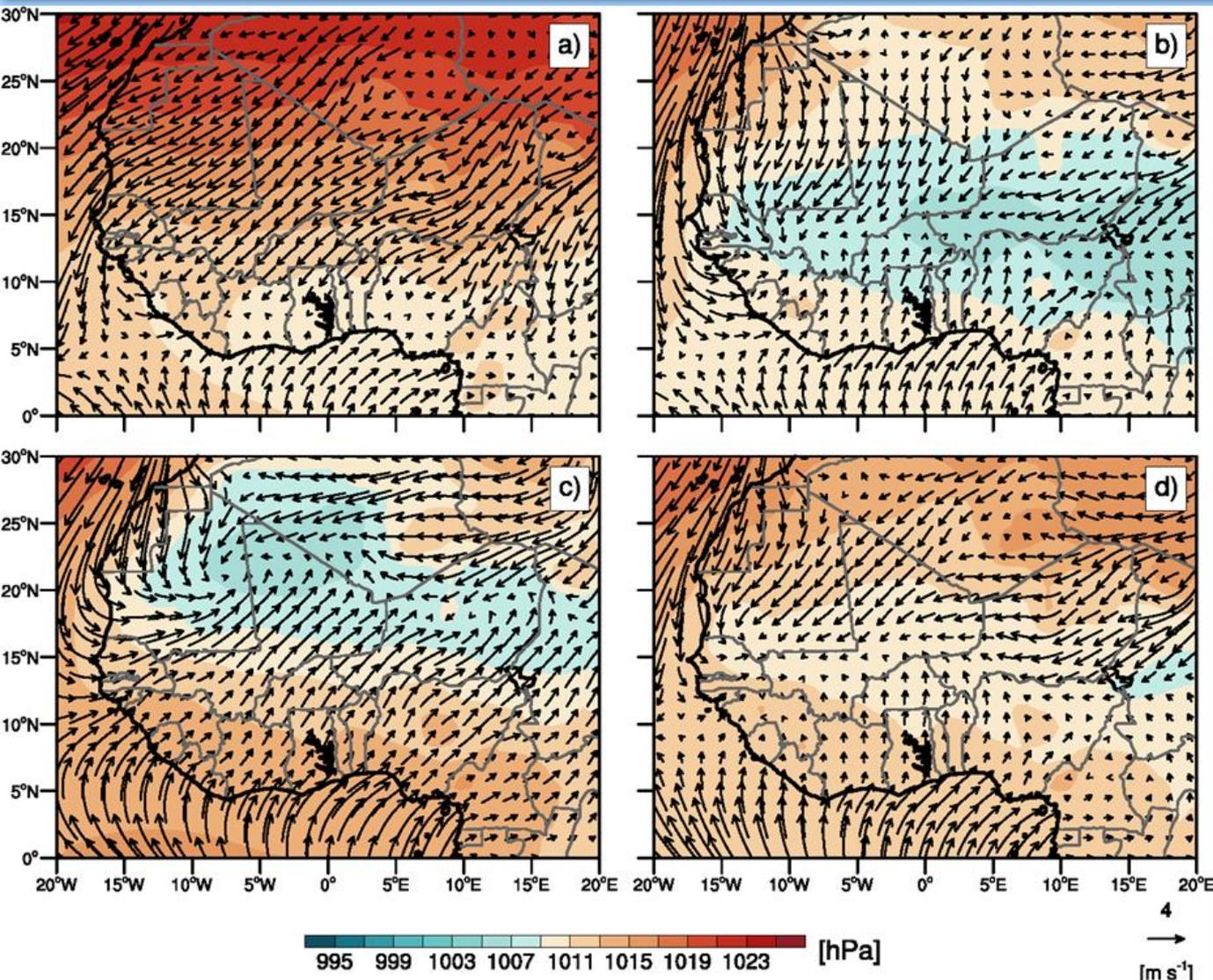


Figure 1.19: Monthly mean of mean sea level pressure (contours) and 10 m wind vectors for a) January, b) April, c) July, d) October

Source: ERA-Interim, 1981–2010.

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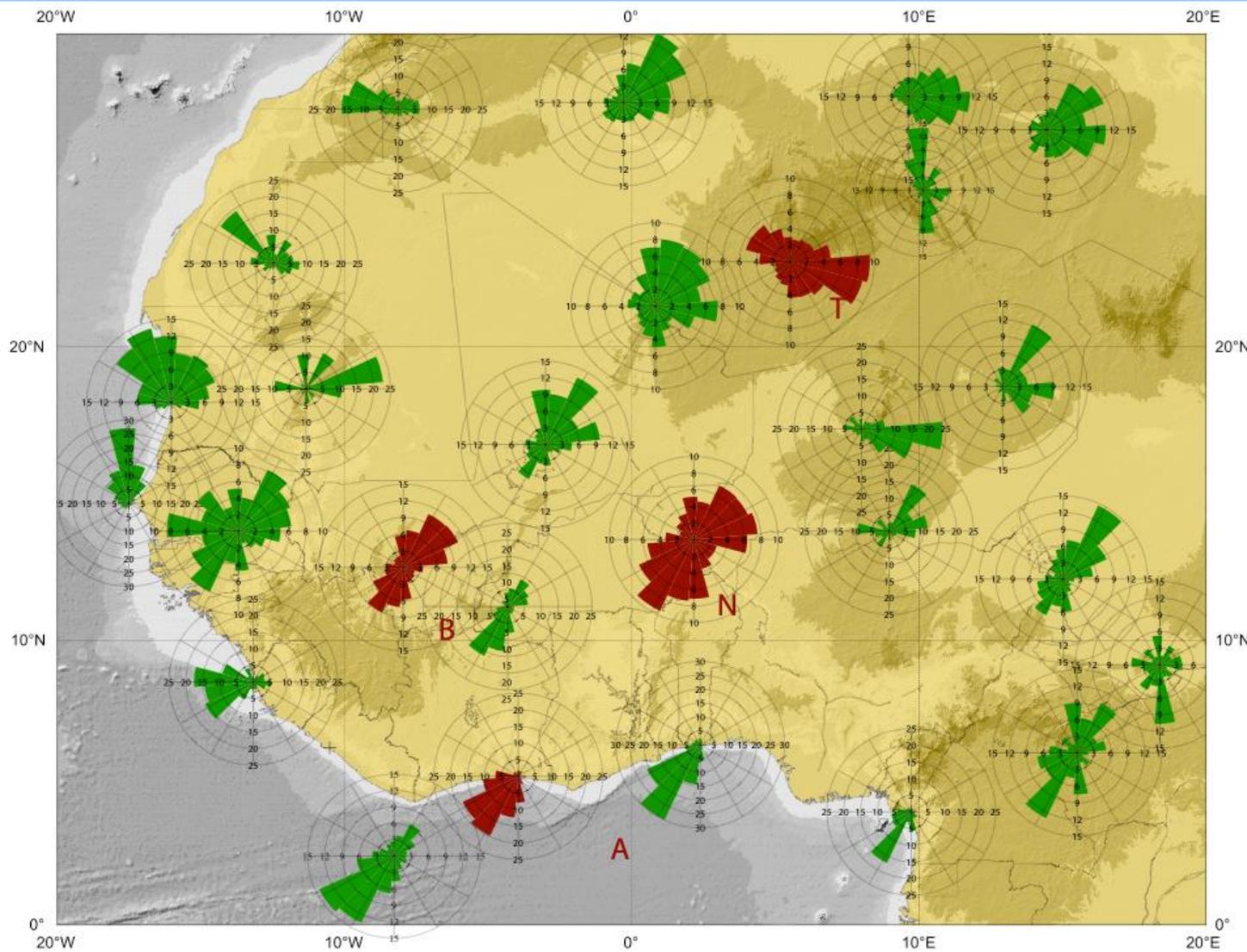


Figure 1.20: Wind roses from 28 West African synoptic weather stations.

Source: MIDAS and Integrated Surface Daily (ISD) data sets, 1981–2010.

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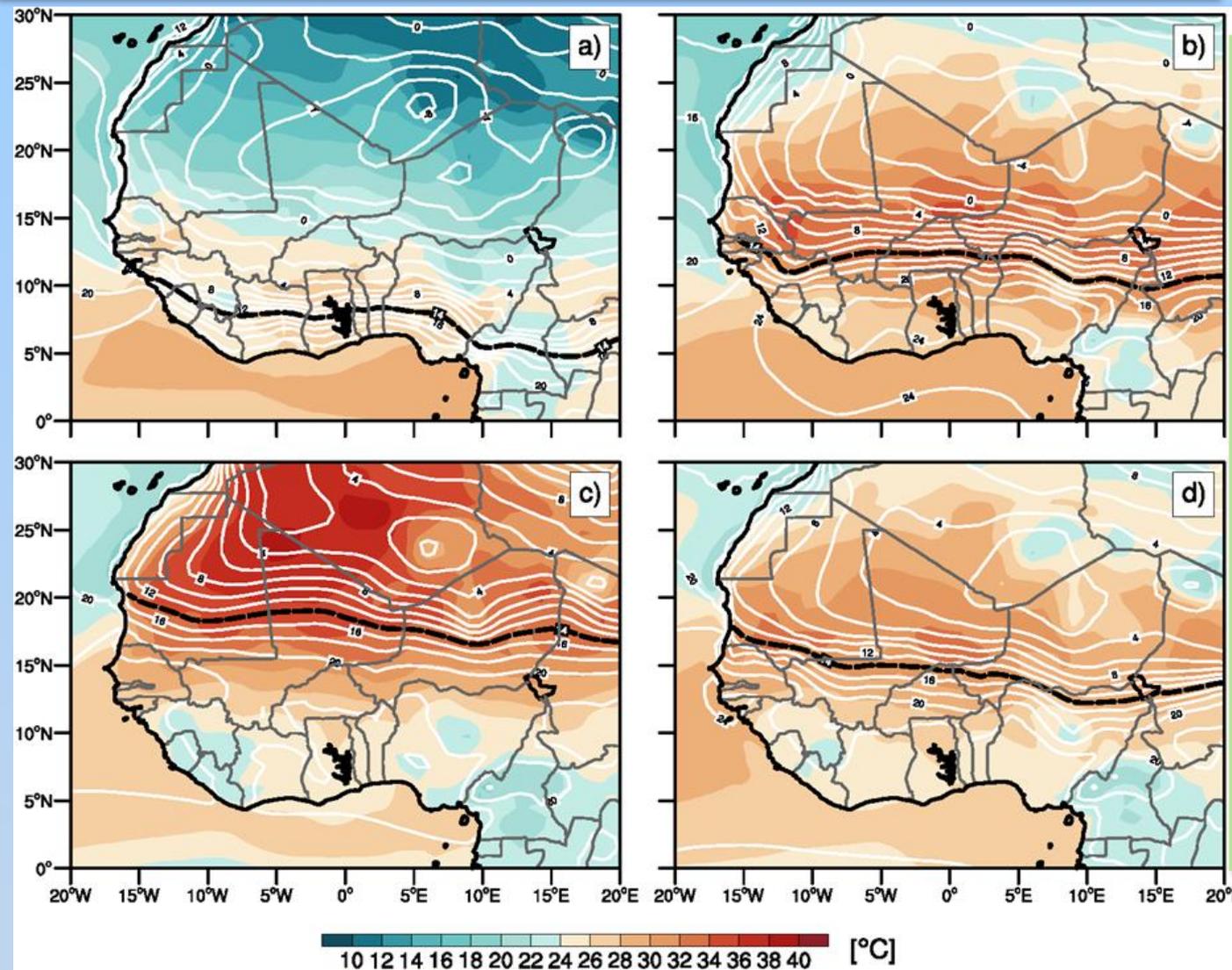


Figure 1.21: Mean monthly 2 m temperature and dewpoint temperature for a) January, b) April, c) July, and d) October. The Intertropical Discontinuity (ITD) is indicated by the black, dashed 14°C 2 m dewpoint temperature contour.

Source: ERA-Interim, 1981–2010. Over ocean the NOAA sea surface temperatures (SSTs), converted from the original 0.25°x 0.25° latitude-longitude resolution to the ERA-Interim resolution of 0.75°, are displayed for the period 1982–2010.

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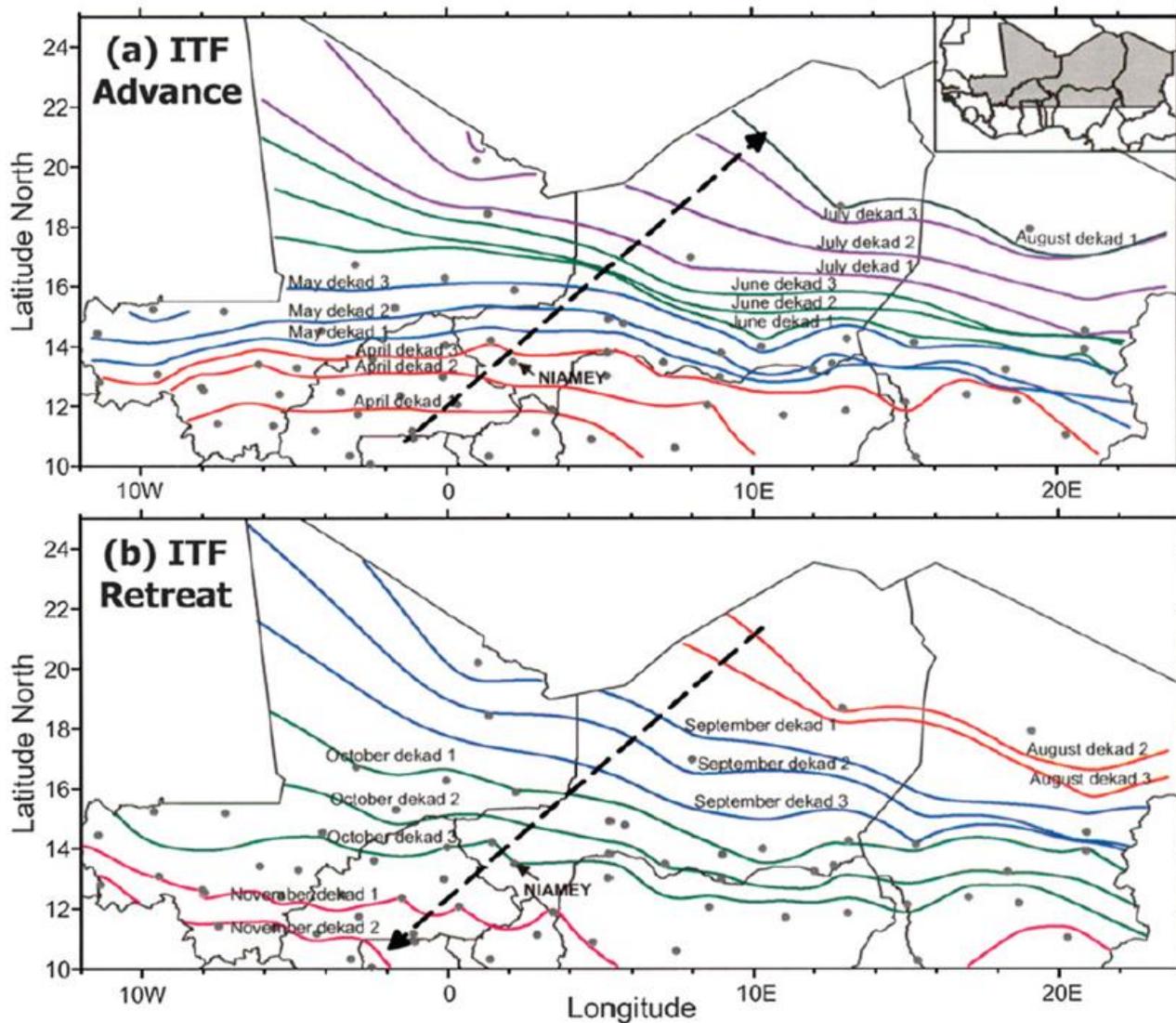


Figure 1.22: Long-term dekadal-average position of the West African ITD for 1974–2003 for a) the northward advance from early April until early August and b) the southward retreat from mid-August to mid-November. Boldface broken-line arrow indicates direction of advance and retreat for the central part of the study region. Dots locate synoptic stations from which daily minimum temperature and daily maximum relative humidity were employed to obtain daily dewpoint temperature and delineate the ITD using a 15°C dewpoint isodrosotherm. Location of Niamey station is indicated. (from Lélé and Lamb, 2010).

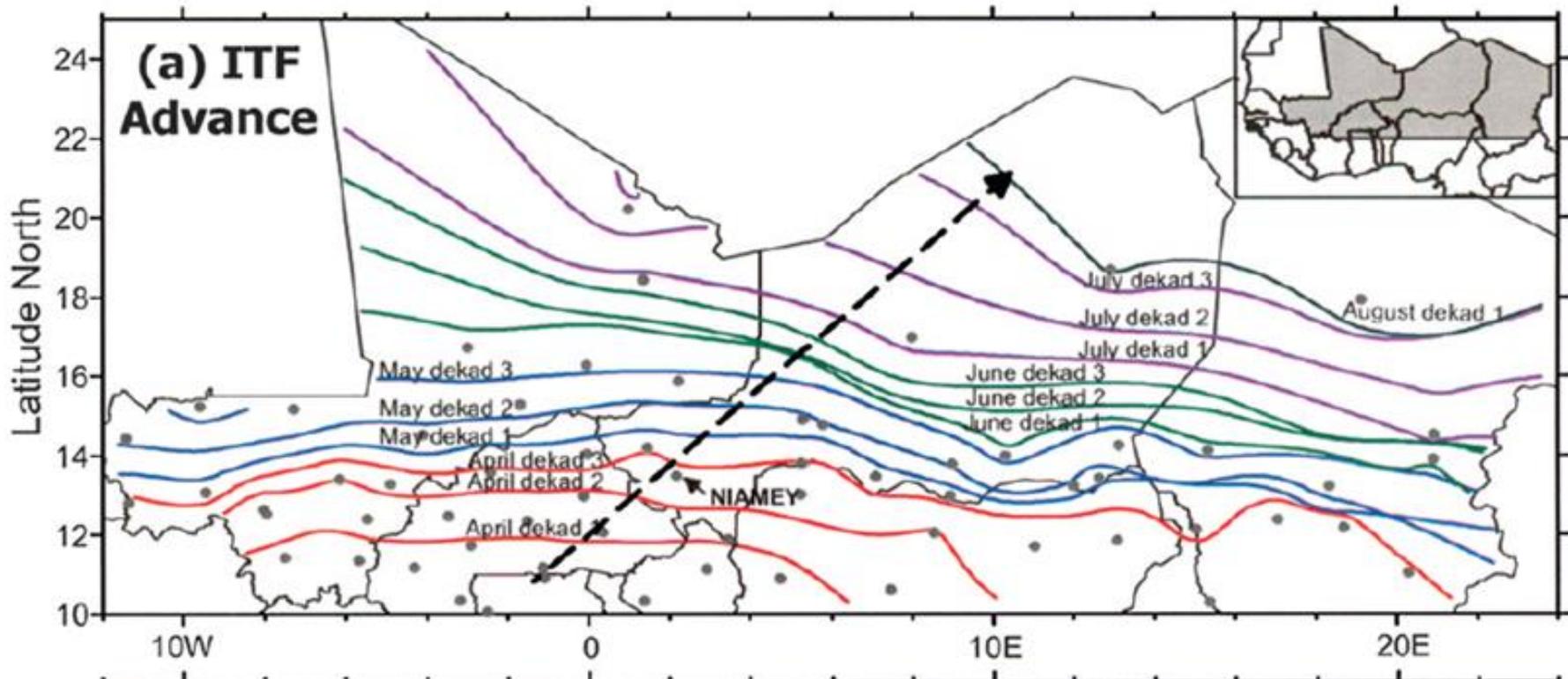


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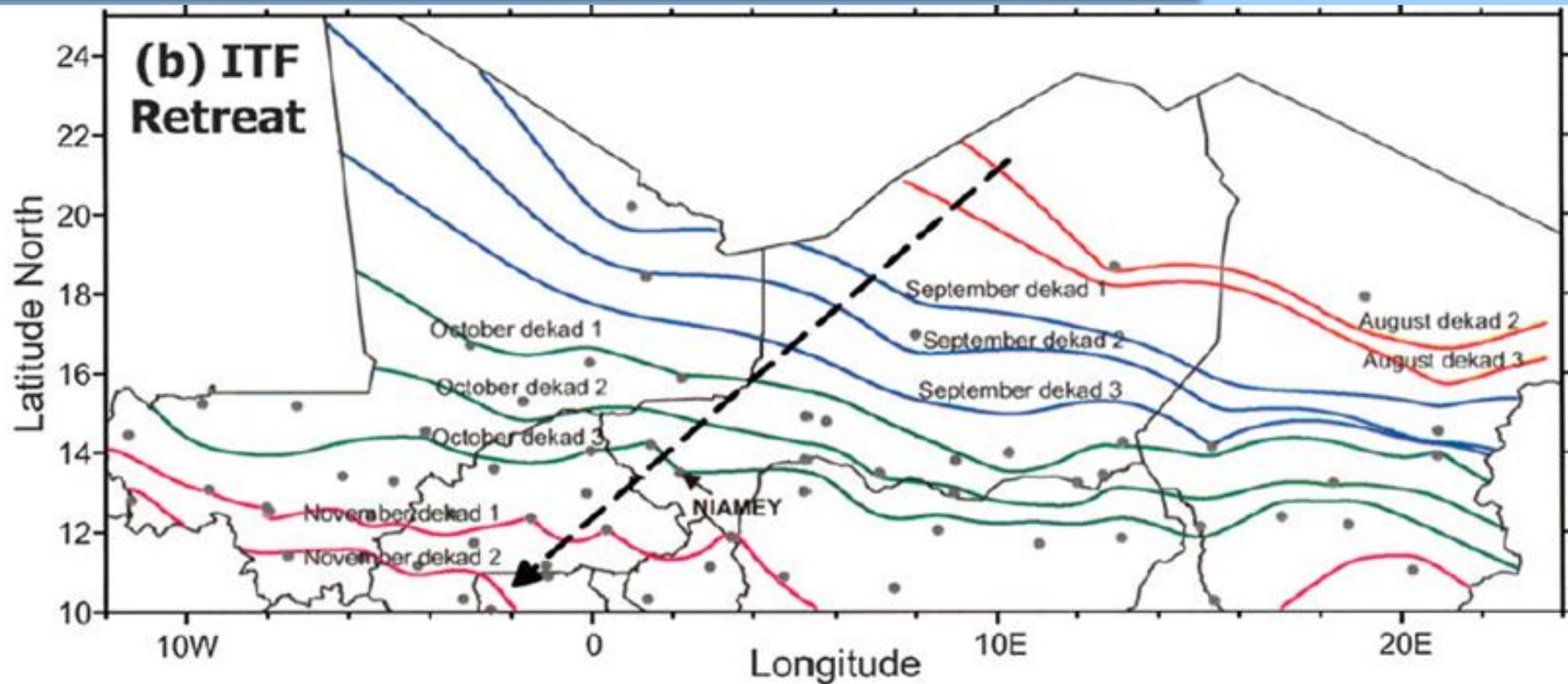


Figure 1.22: Long-term dekadal-average position of the West African ITD for 1974–2003 for b) the southward retreat from mid-August to mid-November. Boldface broken-line arrow indicates direction of advance and retreat for the central part of the study region. Dots locate synoptic stations from which daily minimum temperature and daily maximum relative humidity were employed to obtain daily dewpoint temperature and delineate the ITD using a 15°C dewpoint isodrosotherm. Location of Niamey station is indicated. (from Lélé and Lamb, 2010).

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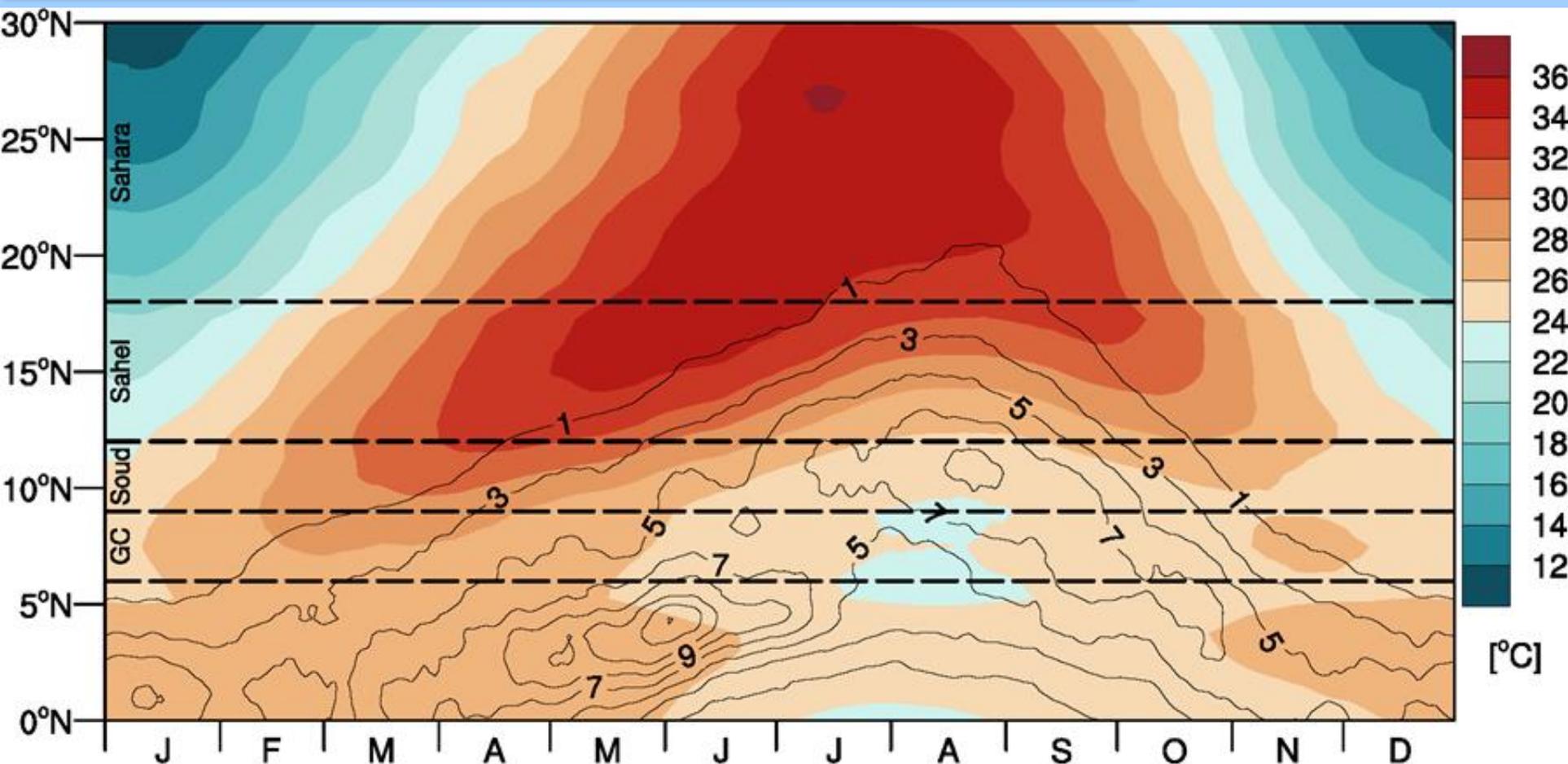


Figure 1.23: Hovmoeller diagram of the 15-day running mean of the daily mean temperature. Source: ERA-Interim, 1981–2010. Contours denote the 15-day running mean of daily precipitation. Source: TRMM, 1998–2012. Variables were zonally averaged between 10°W and 10°E. Zones are displayed in Figure 1.2b.

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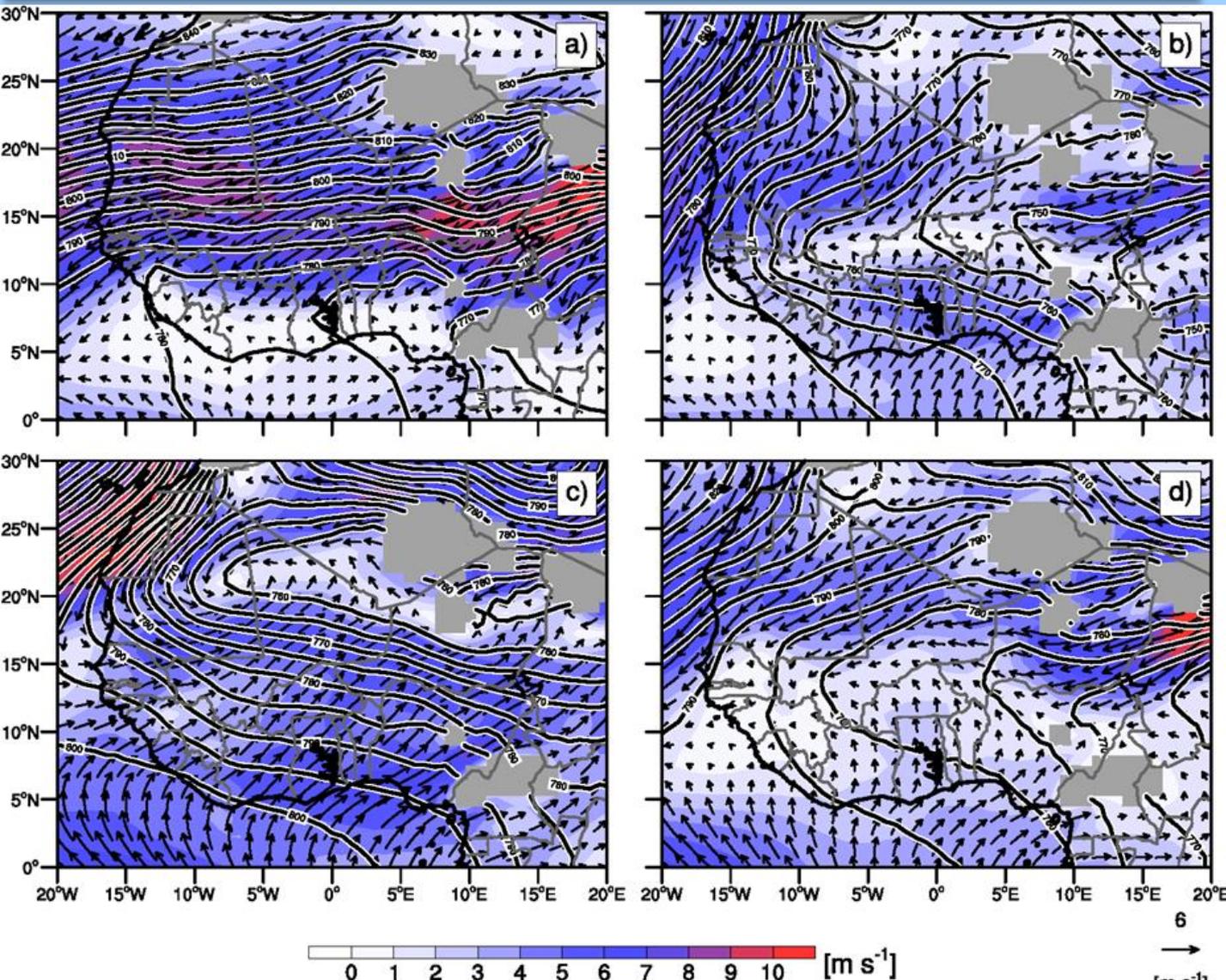


Figure 1.24: Mean monthly 925-hPa geopotential height (contours), wind vectors, and wind speed (colours) for a) January, b) April, c) July, and d) October. Grey areas show regions below ground level. Source: ERA-Interim, 1981–2010.

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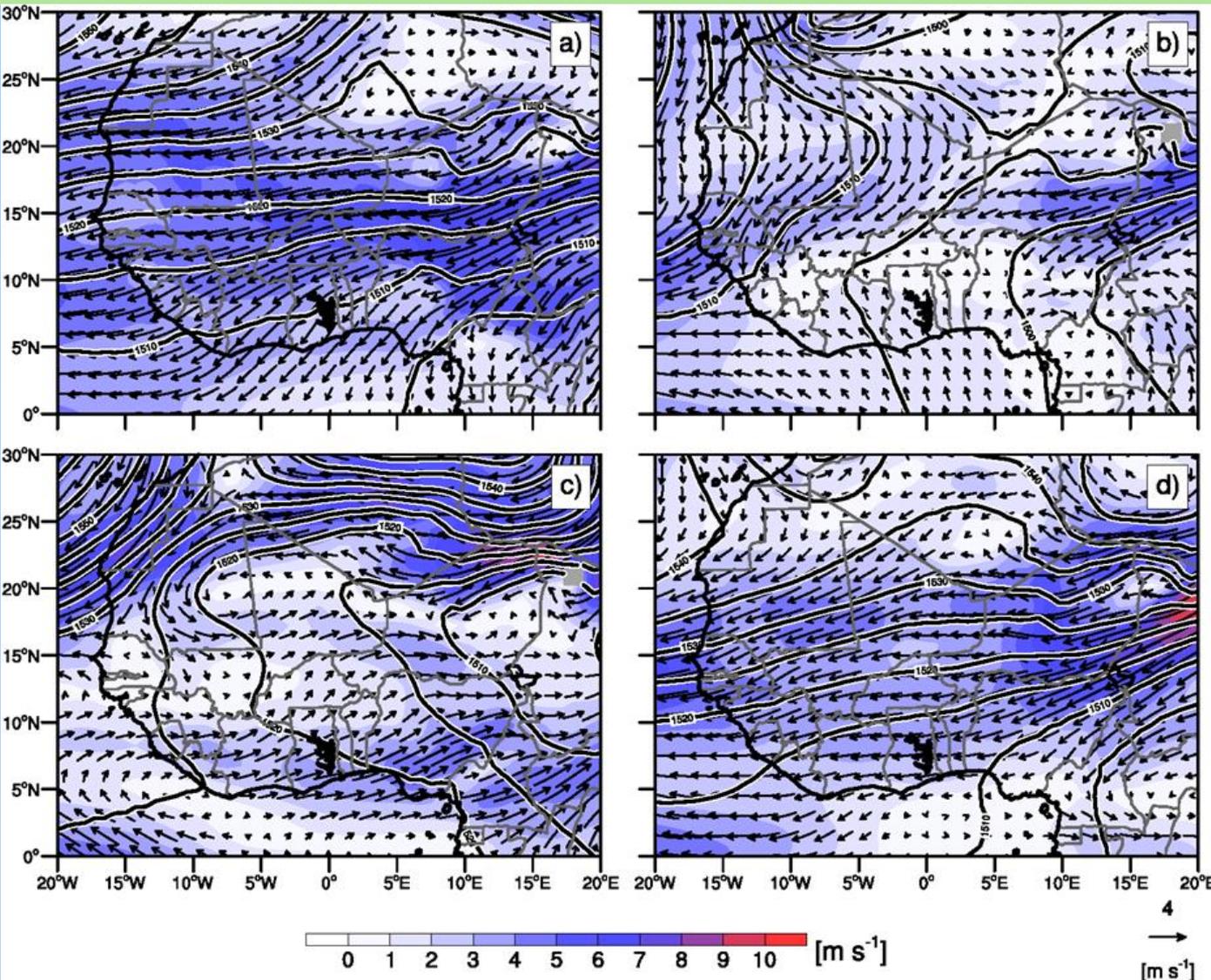


Figure 1.25: As in Figure 1.24, but for 850 hPa.

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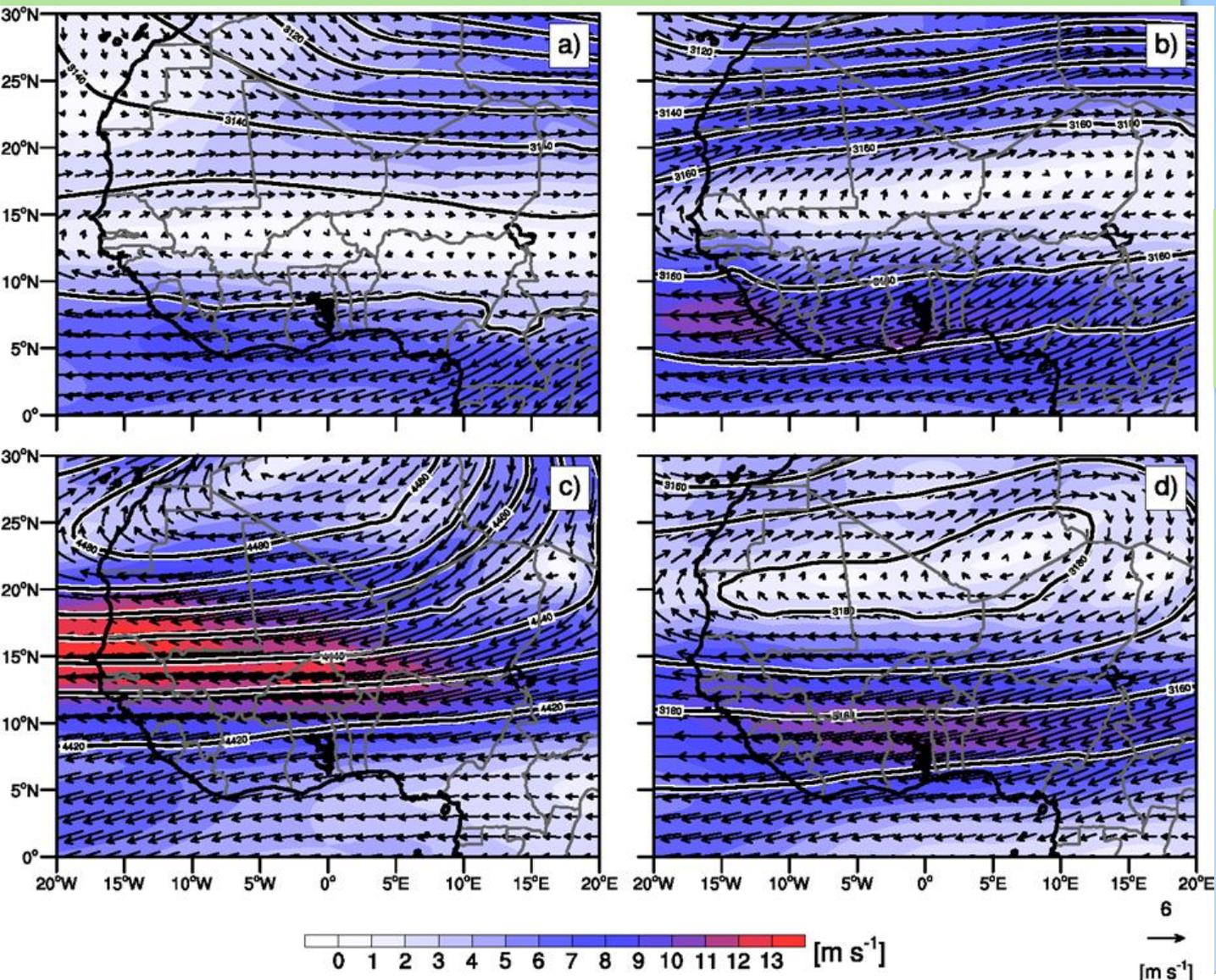


Figure 1.26: As in Figure 1.24, but for 700 hPa. For July the 600-hPa level is shown in (c).

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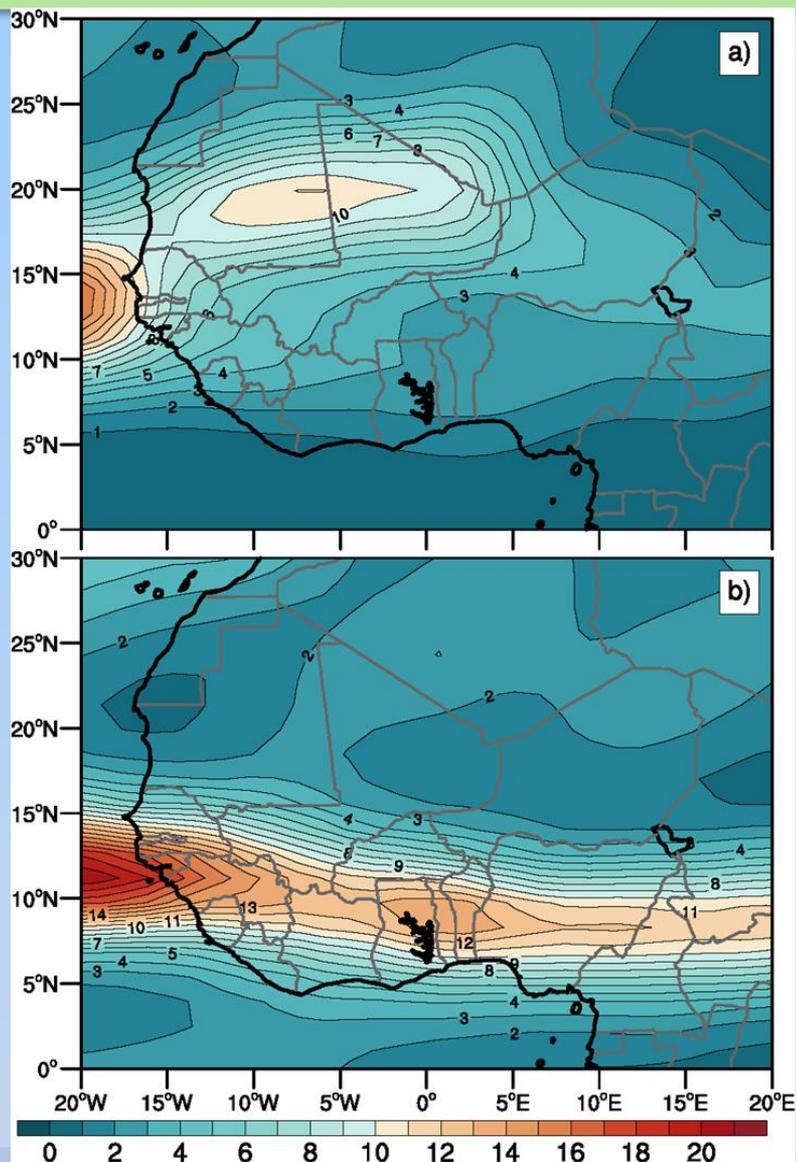


Figure 1.27: Track density climatology for AEWs for the June to October period between 1981 and 2010 based on the relative vorticity at a) 850 hPa and b) 600 hPa, from the ERA-Interim re-analysis. Units are number density per month per unit area, where the unit area is equivalent to a 5-degree spherical cap ($\sim 106 \text{ km}^2$).

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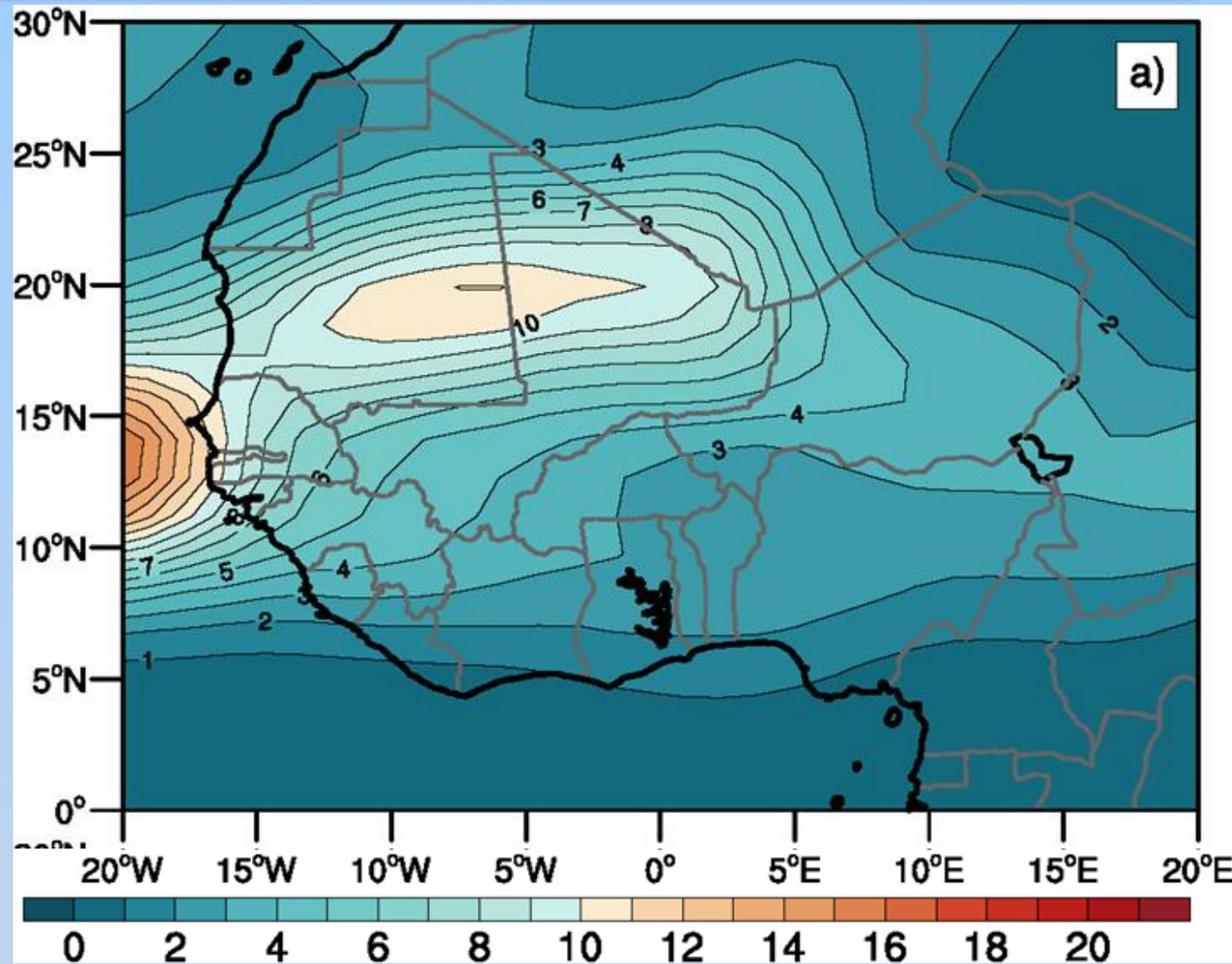


Figure 1.27: Track density climatology for AEWs for the June to October period between 1981 and 2010 based on the relative vorticity at 850 hPa from the ERA-Interim re-analysis. Units are number density per month per unit area, where the unit area is equivalent to a 5-degree spherical cap (~106 km²).

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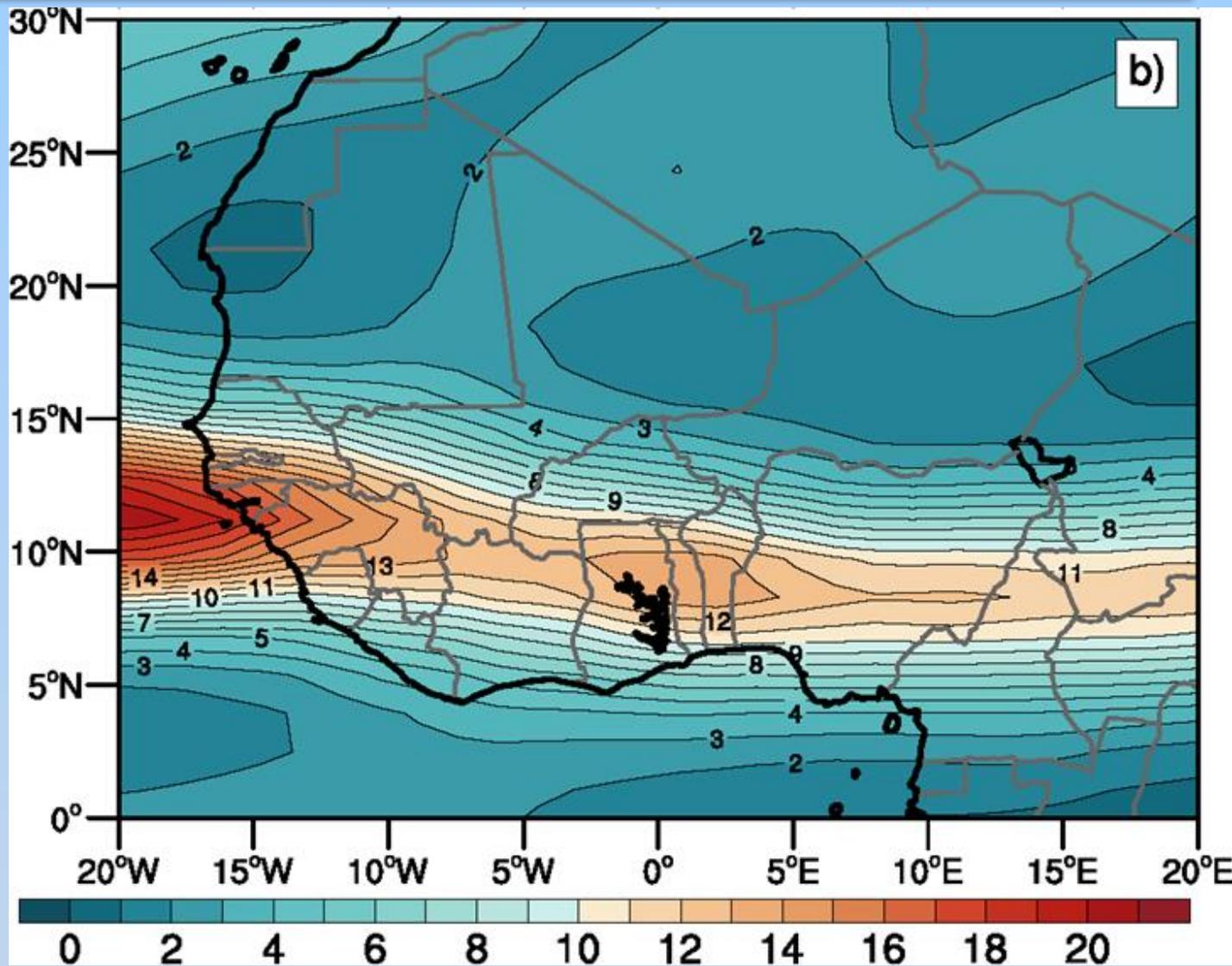


Figure 1.27: Track density climatology for AEWs for the June to October period between 1981 and 2010 based on the relative vorticity at 600 hPa, from the ERA-Interim re-analysis. Units are number density per month per unit area, where the unit area is equivalent to a 5-degree spherical cap (~106 km²).

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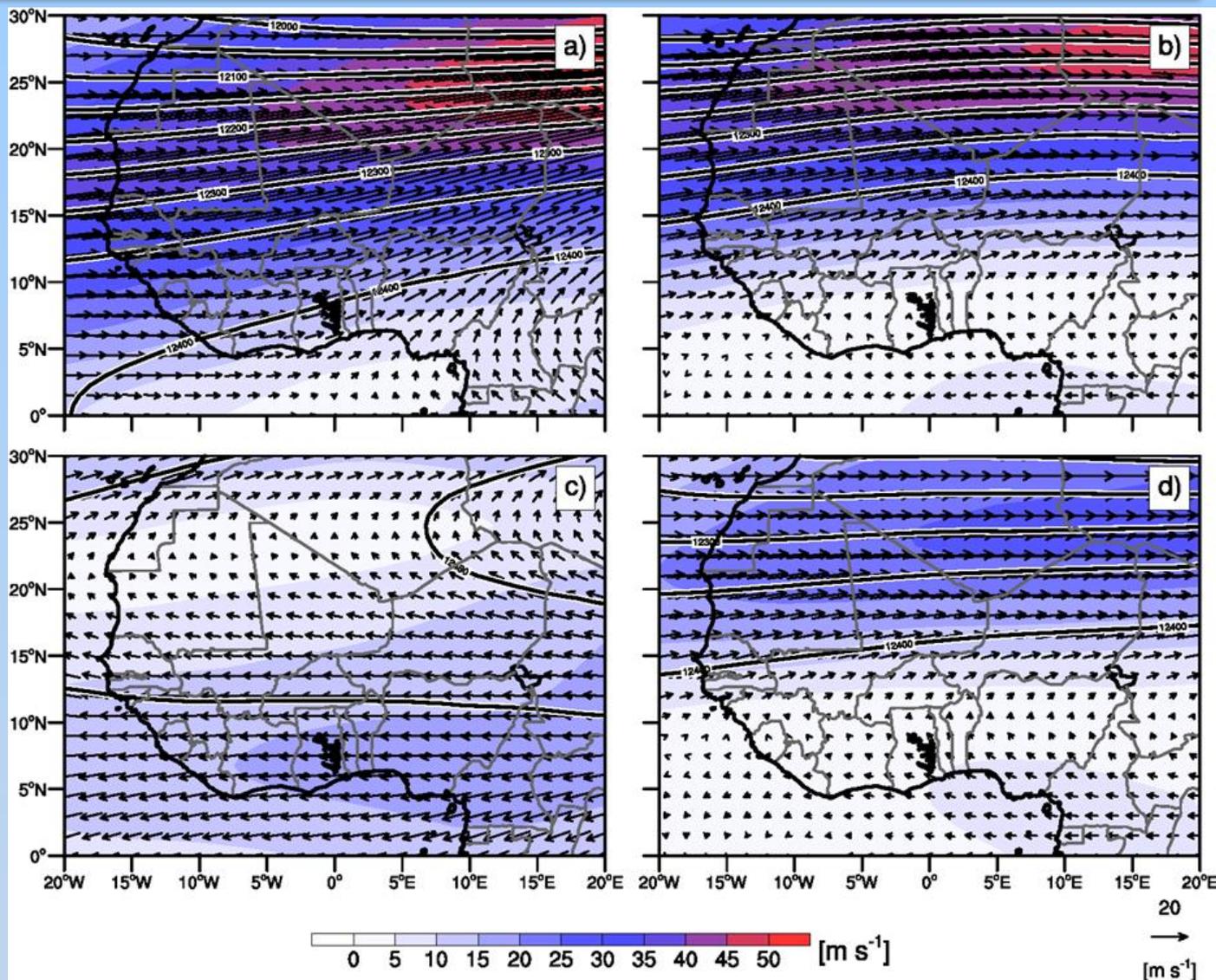


Figure 1.28: As in Figure 1.24, but for 200 hPa.

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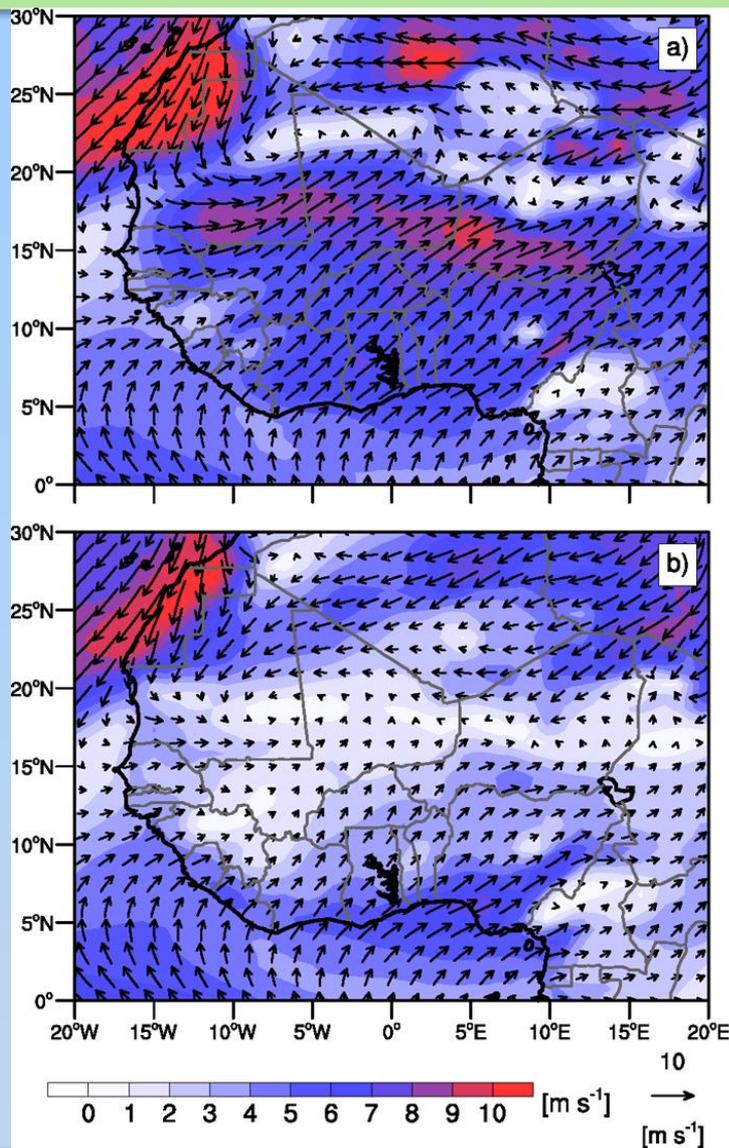


Figure 1.29: Mean 925 hPa winds for July at a) 0600 and b) 1800 UTC. Source: ERA-Interim, 1981–2010.

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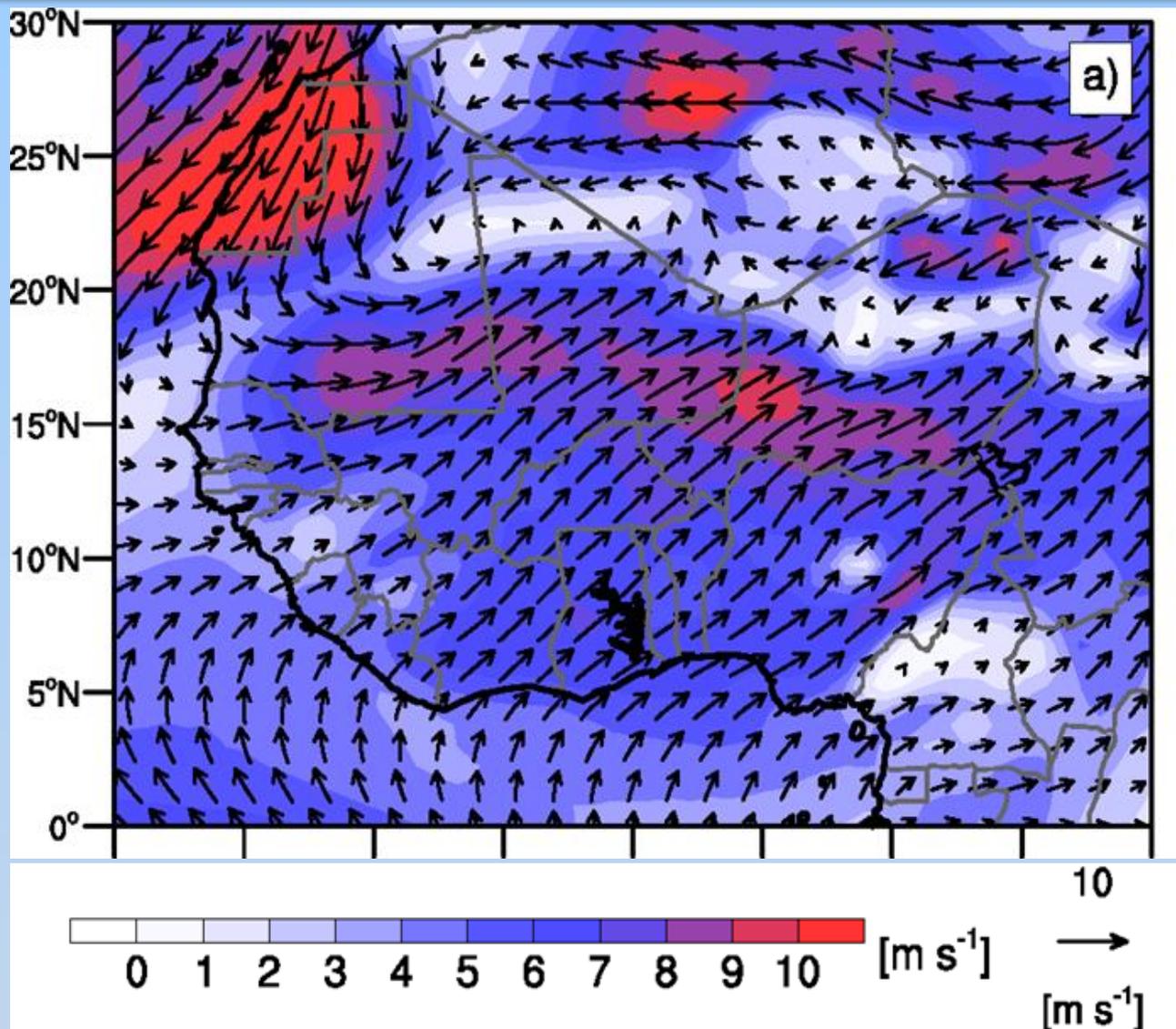


Figure 1.29: Mean 925 hPa winds for July at 0600 UTC. Source: ERA-Interim, 1981–2010.

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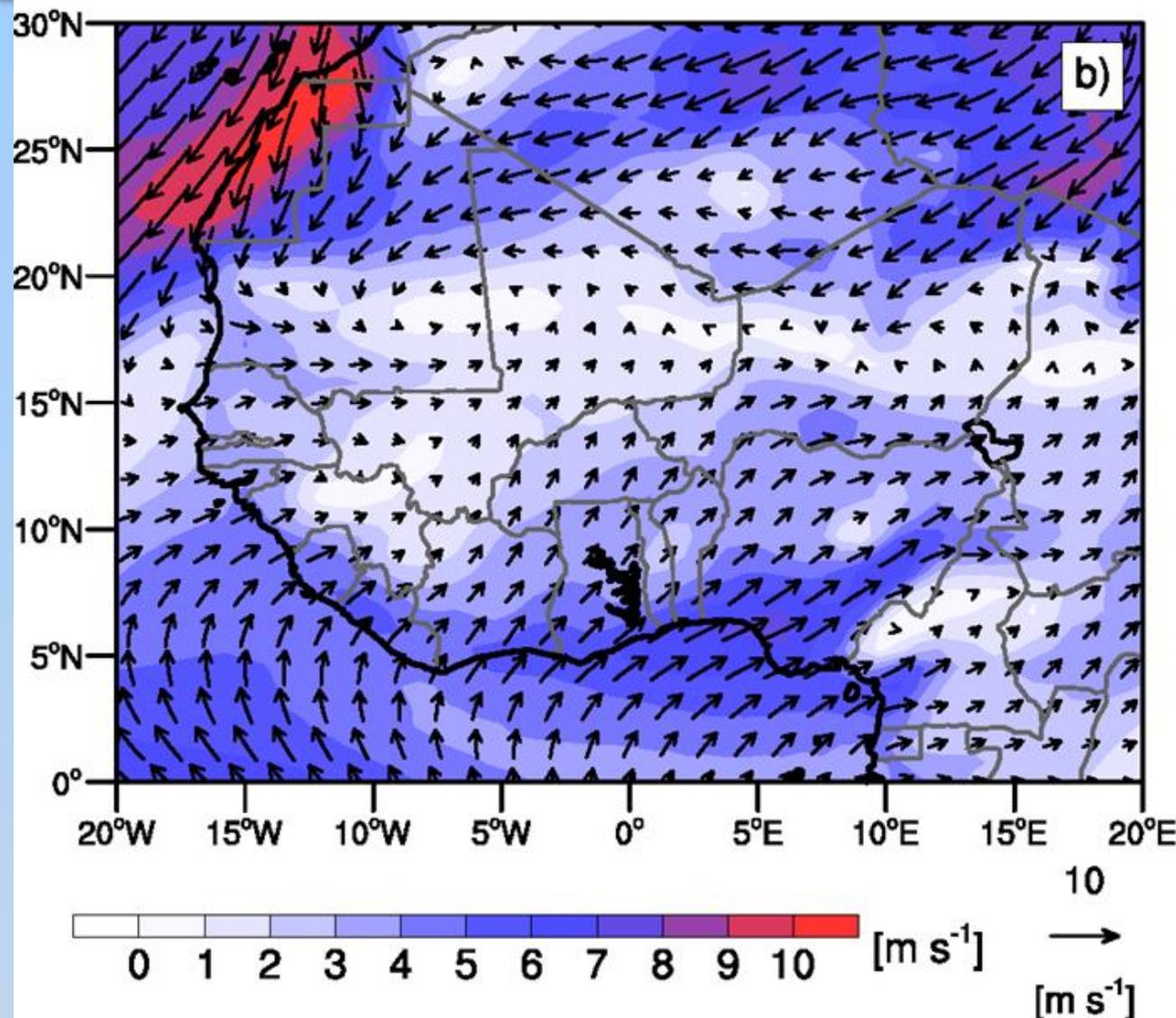


Figure 1.29: Mean 925 hPa winds for July at 1800 UTC. Source: ERA-Interim, 1981-2010.

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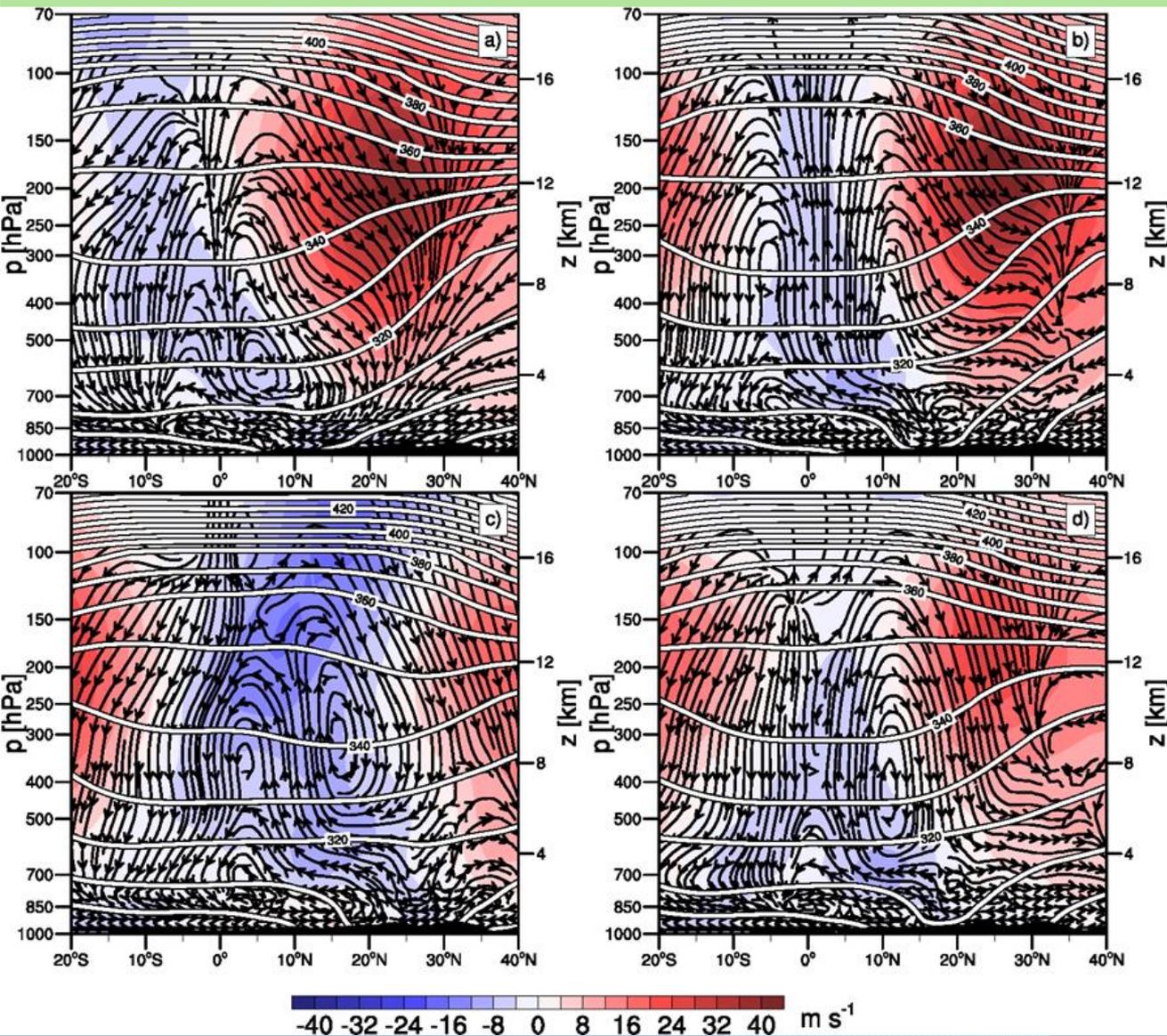


Figure 1.30: Mean monthly isentropes (contours), zonal wind speed (colours), and streamlines (v-wind, w-wind*1000) for a) January, b) April, c) July, and d) October, averaged between 10°W and 10°E. Source: ERA-Interim, 1981–2010.

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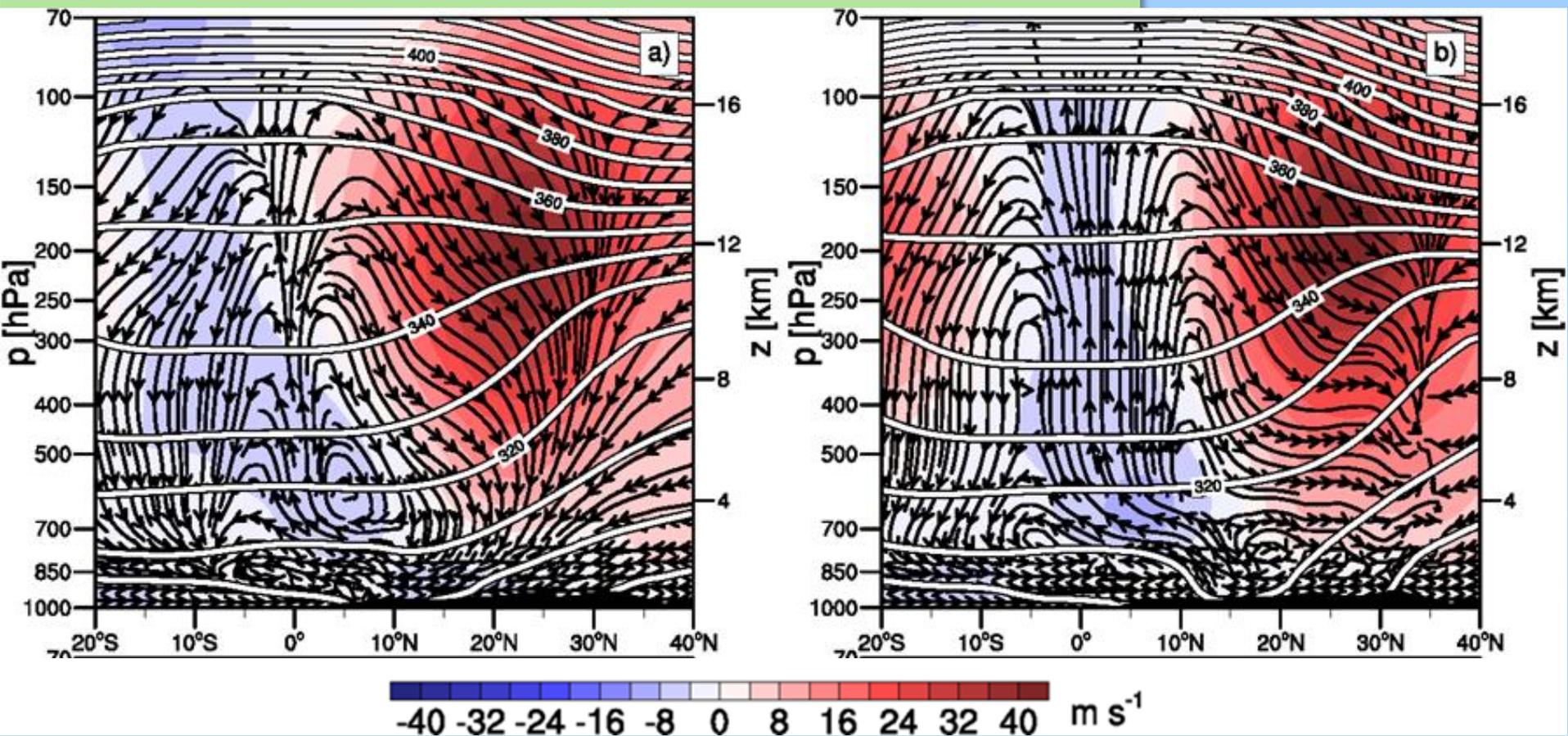


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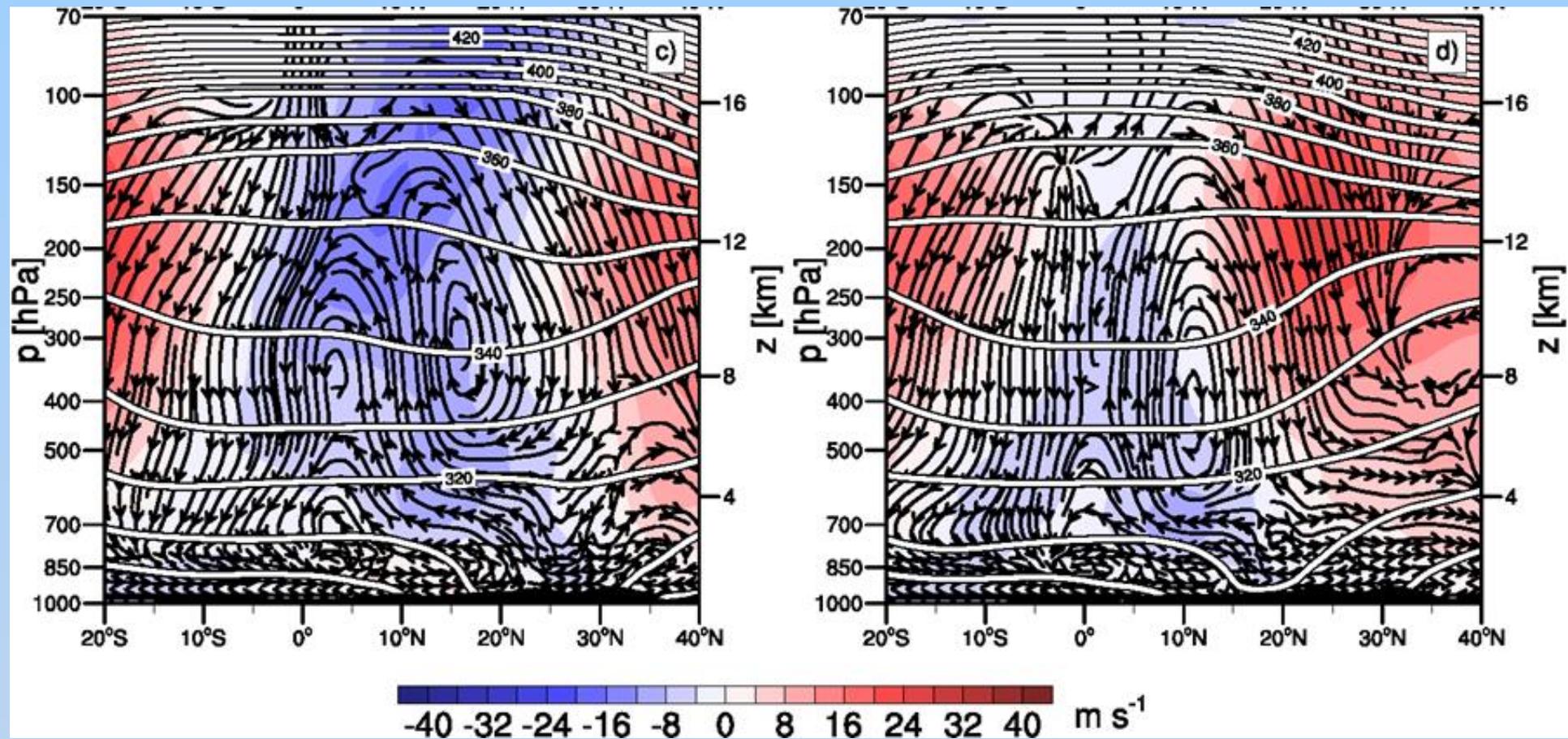


Figure 1.30: Mean monthly isentropes (contours), zonal wind speed (colours), and streamlines (v-wind, w-wind*1000) for c) July, and d) October, averaged between 10°W and 10°E. Source: ERA-Interim, 1981–2010.

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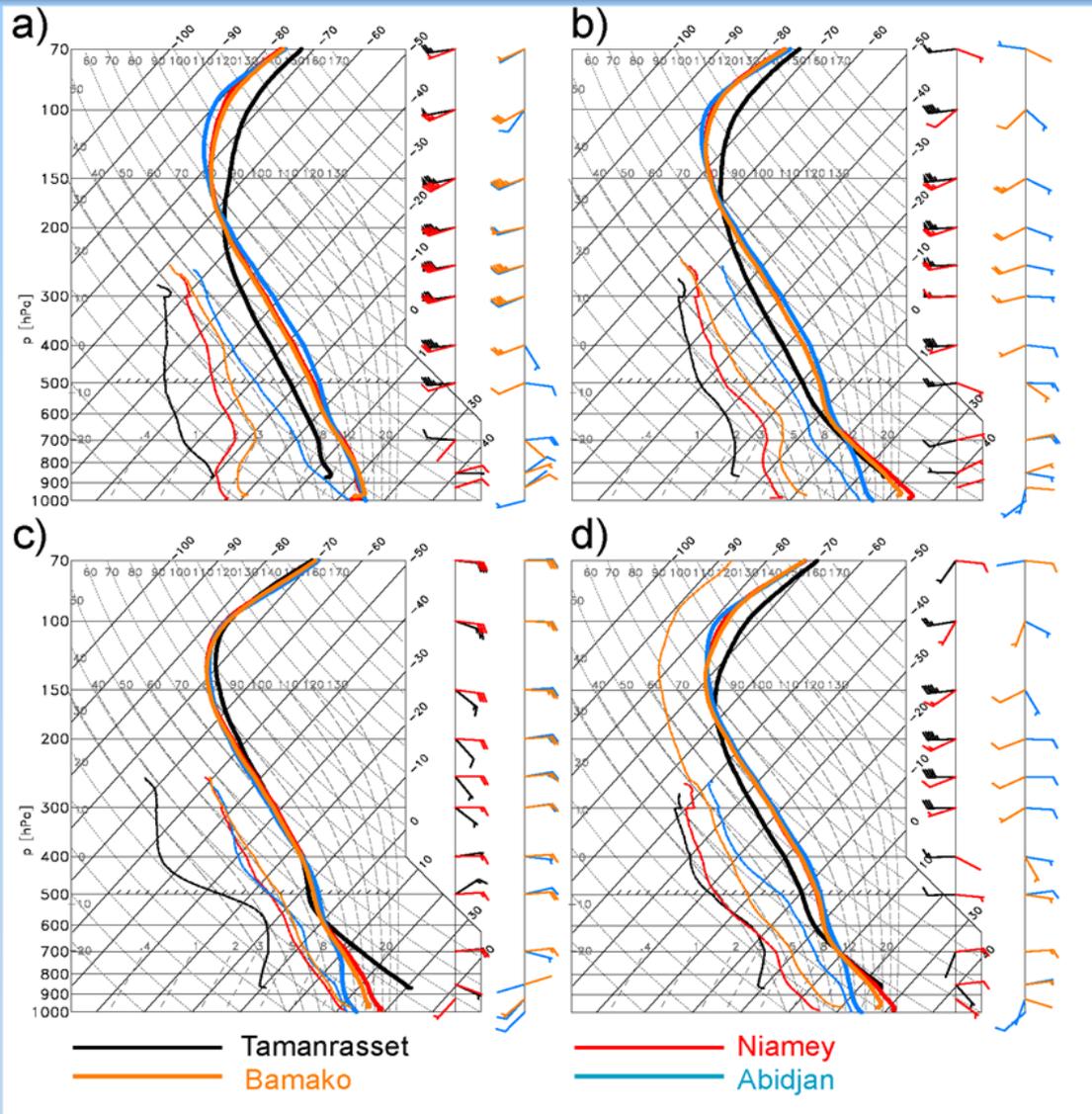


Figure 1.31: Composite radiosonde profiles between 1981 and 2010 from Tamanrasset (black lines and wind barbs), Niamey (red), Bamako (orange), and Abidjan (blue) for a) January, b) April, c) July, and d) October. Both the 0000 and 1200 UTC soundings were used for the climatology. The upper-air observations are displayed into a skew T-log-p diagram. Included are the measured air temperature (solid lines), dewpoint temperature (thin lines), and wind observations (wind barbs).

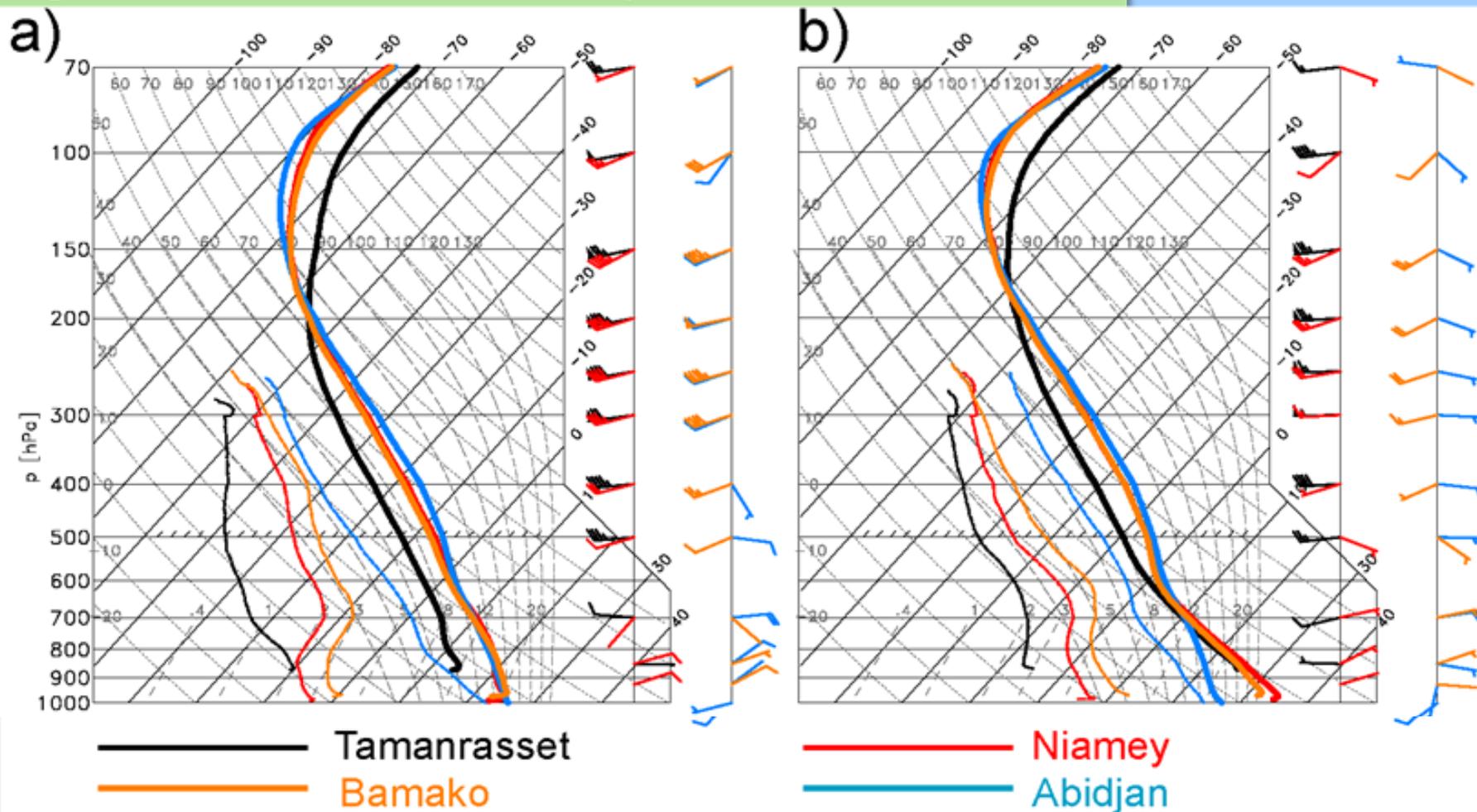


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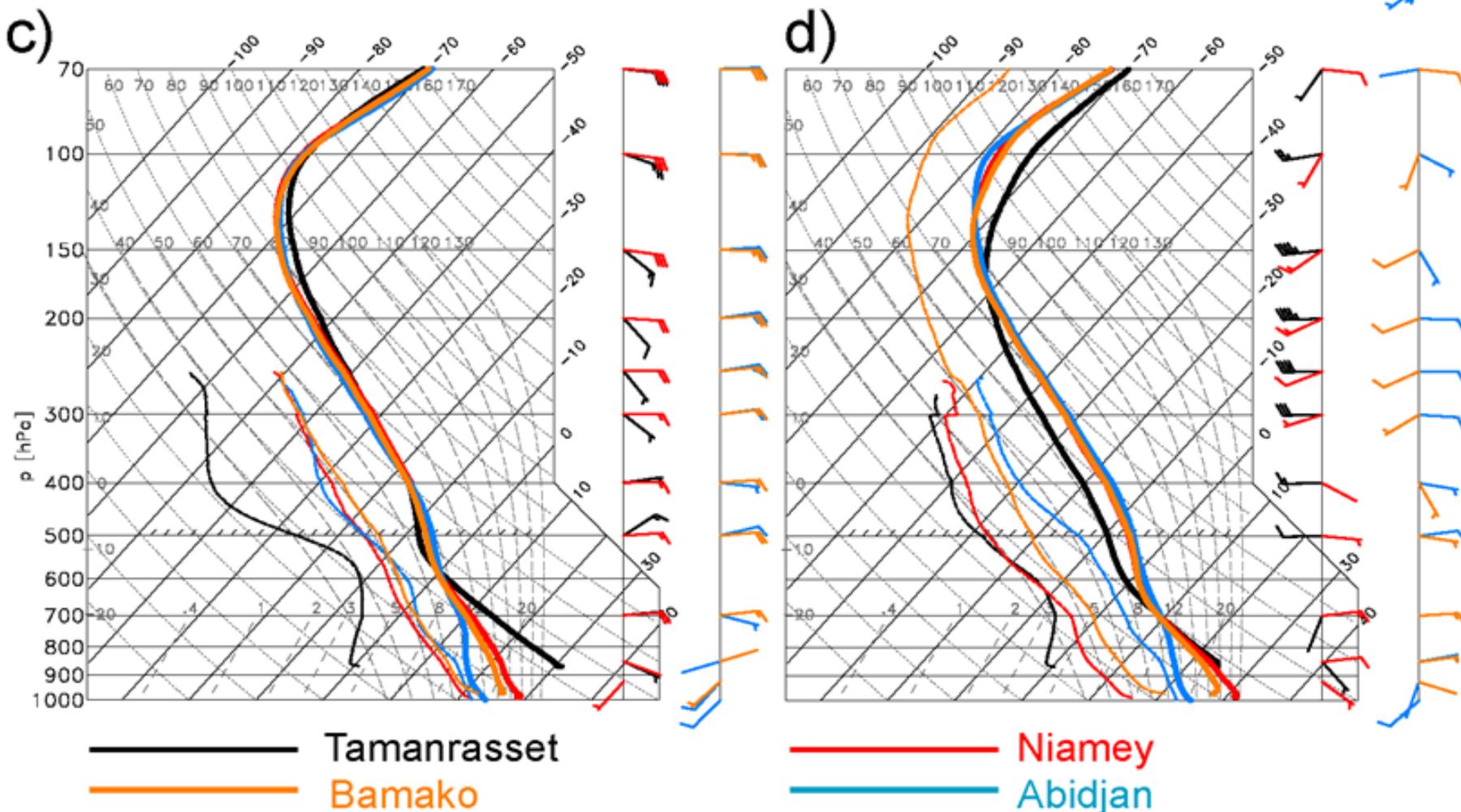


Figure 1.31: Composite radiosonde profiles between 1981 and 2010 from Tamanrasset (black lines and wind barbs), Niamey (red), Bamako (orange), and Abidjan (blue) for c) July, and d) October.

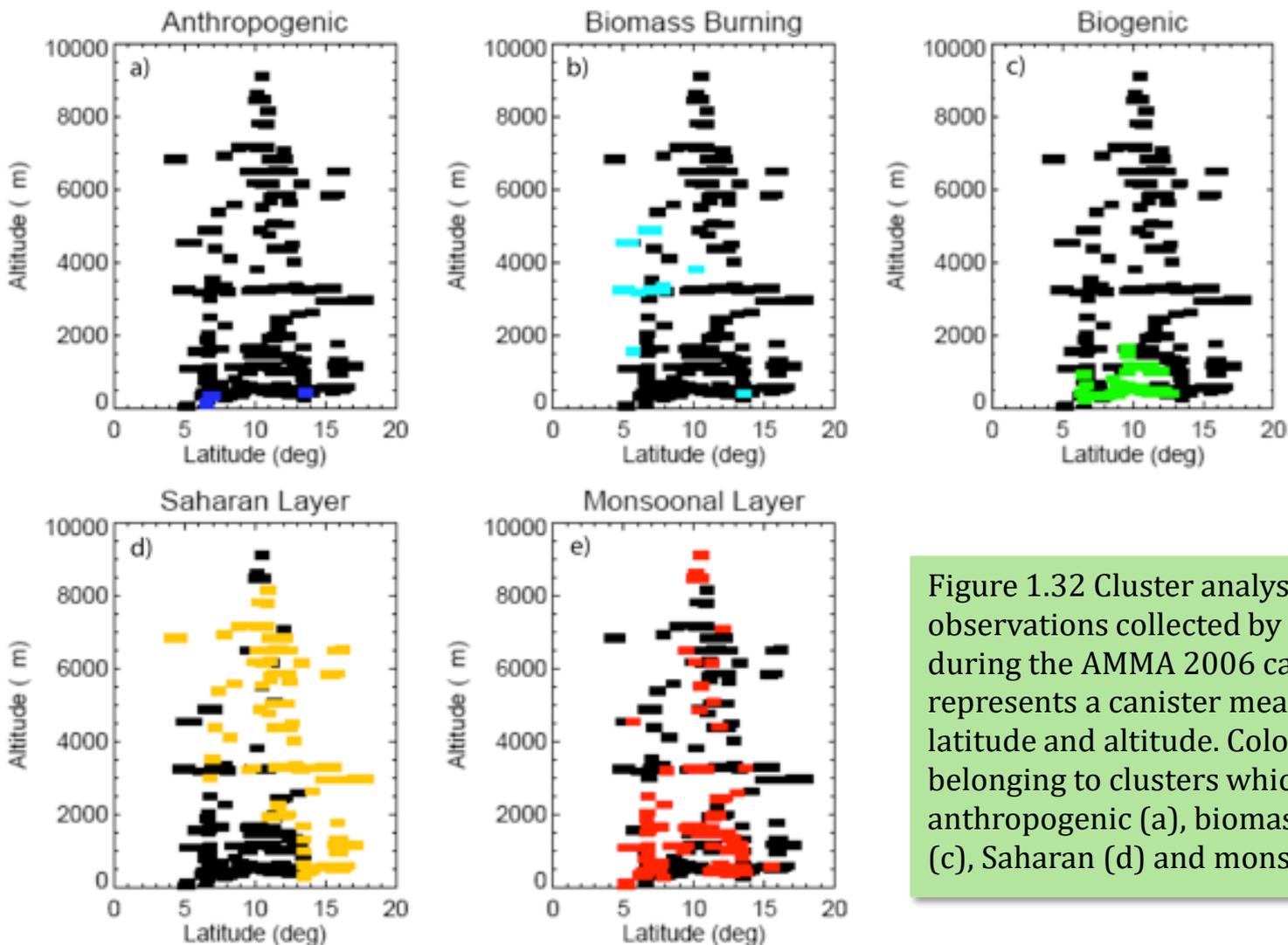


Figure 1.32 Cluster analysis of composition observations collected by the BAe146 aircraft during the AMMA 2006 campaign. Each rectangle represents a canister measurement, plotted by latitude and altitude. Colours represent samples belonging to clusters which are representative of anthropogenic (a), biomass-burning (b), biogenic (c), Saharan (d) and monsoon layer air masses (e).

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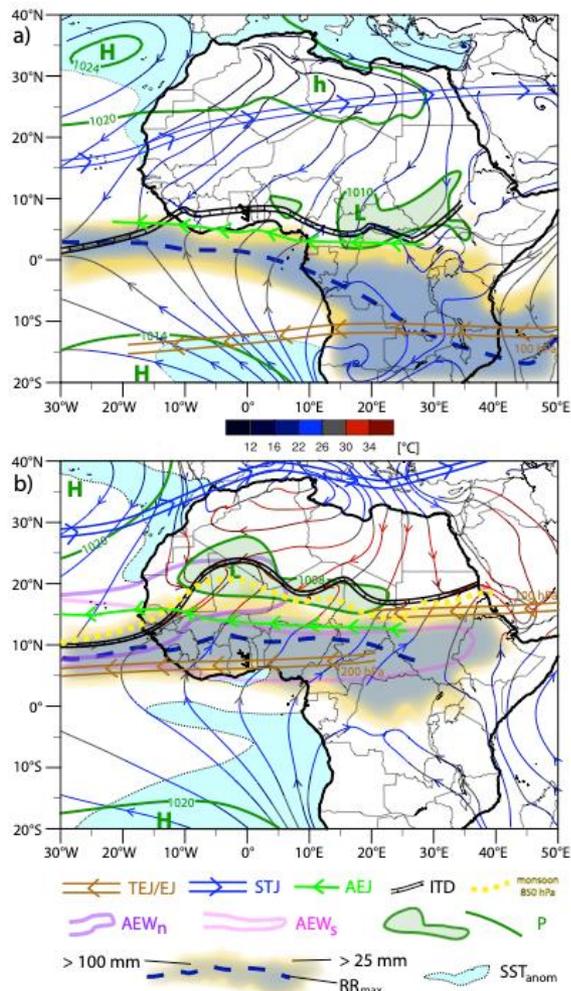


Figure 1.33: Schematic illustration of atmospheric and oceanic features determining the weather and climate of West Africa in a) January and b) July. Shown are the positions of the ITD, the monsoon trough, upper-level air streams (AEJ, TEJ/EJ, and STJ), surface winds coloured according to the 2 m air temperature (see colour bar), the tropical rain belt with the maximum axes of rainfall (RRmax), northerly and southerly AEW vortices propagation zones (AEW_n and AEW_s, respectively), areas with relatively cold sea surface temperatures (SST_{anom}), and example pressure lines marking the Azores ("H"), Libyan ("h") and Saint Helena ("H") Highs and the heat low ("L").

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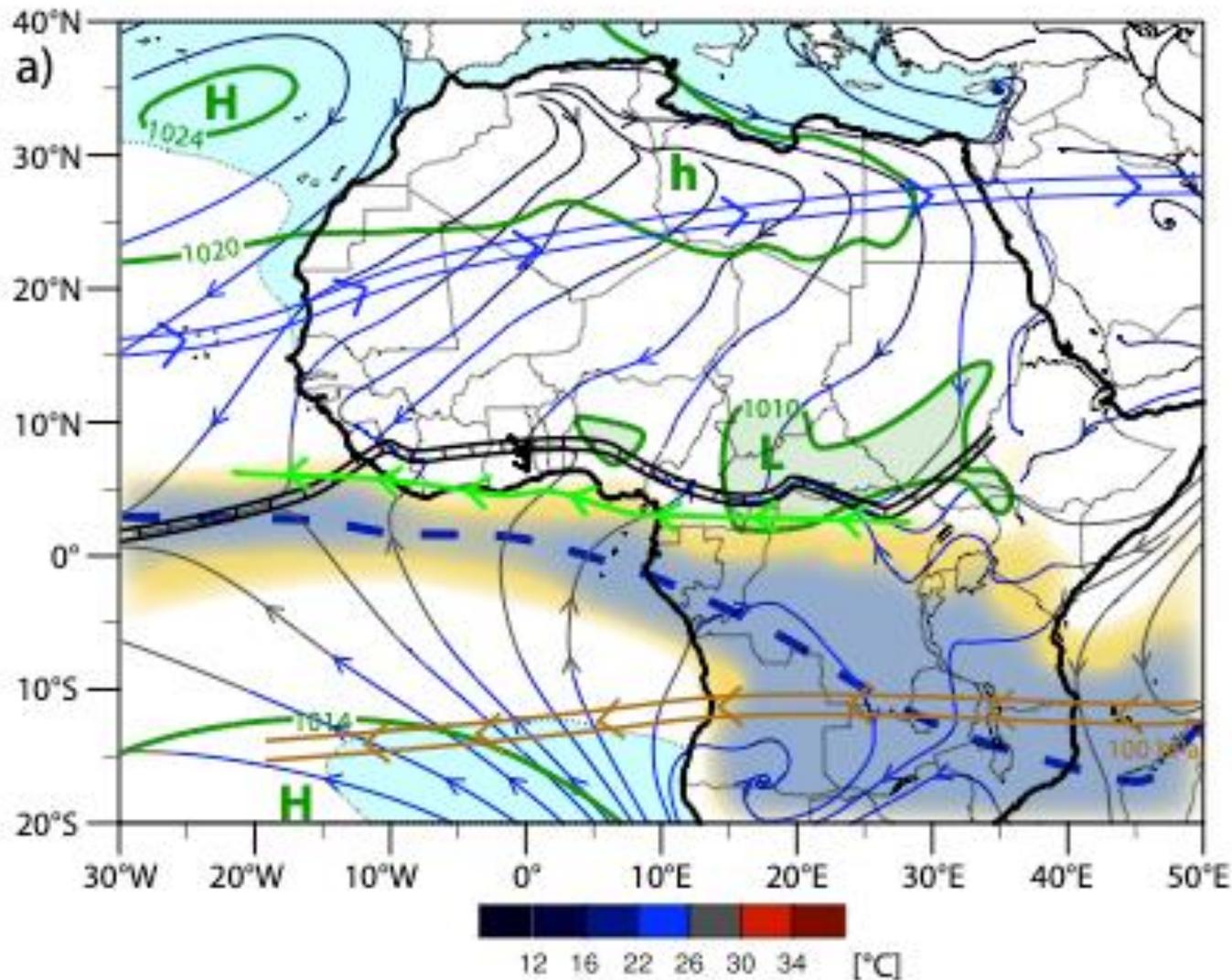


Figure 1.33: Schematic illustration of atmospheric and oceanic features determining the weather and climate of West Africa in January .

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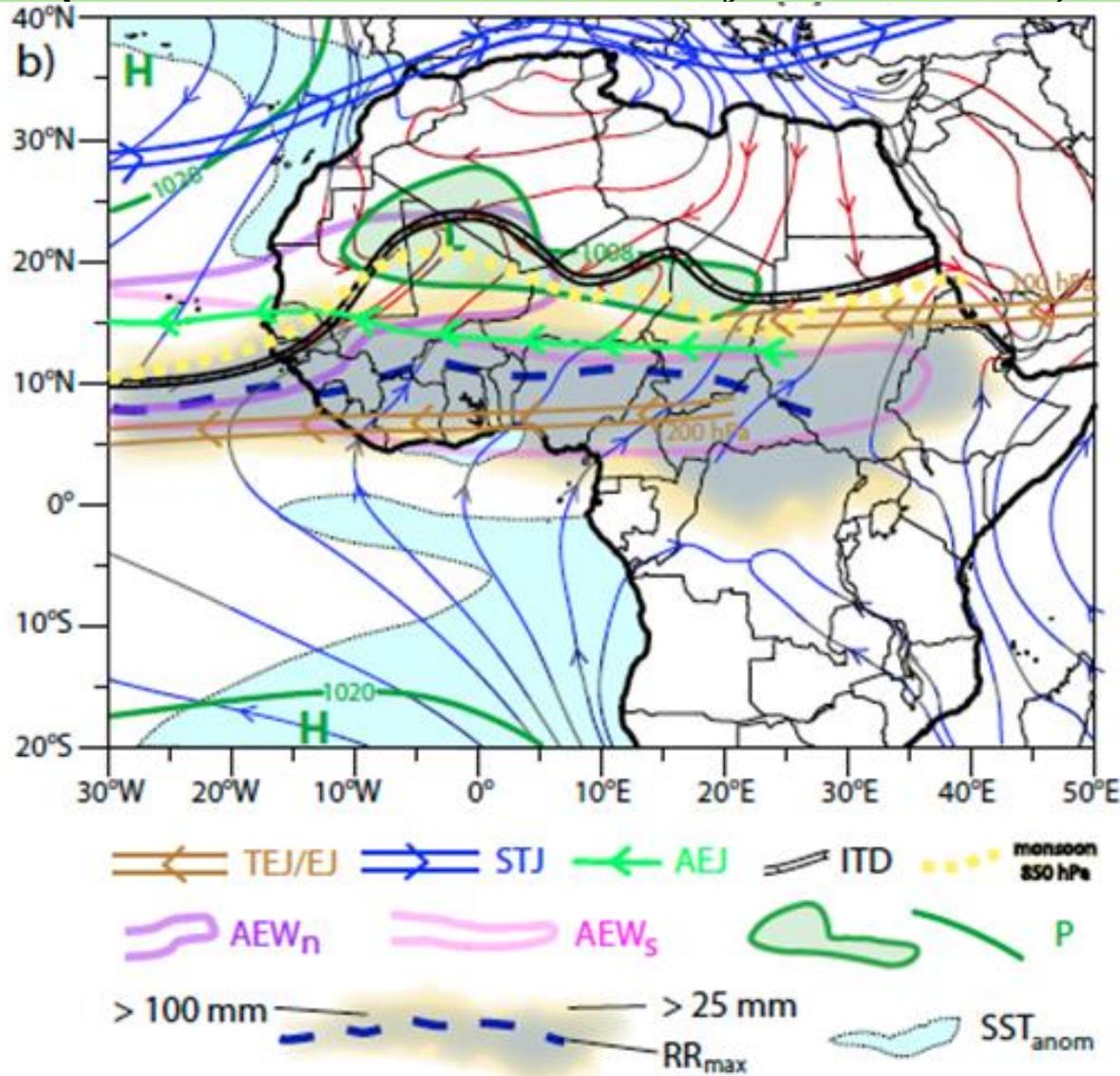


Figure 1.33: Schematic illustration of atmospheric and oceanic features determining the weather and climate of West Africa in July.

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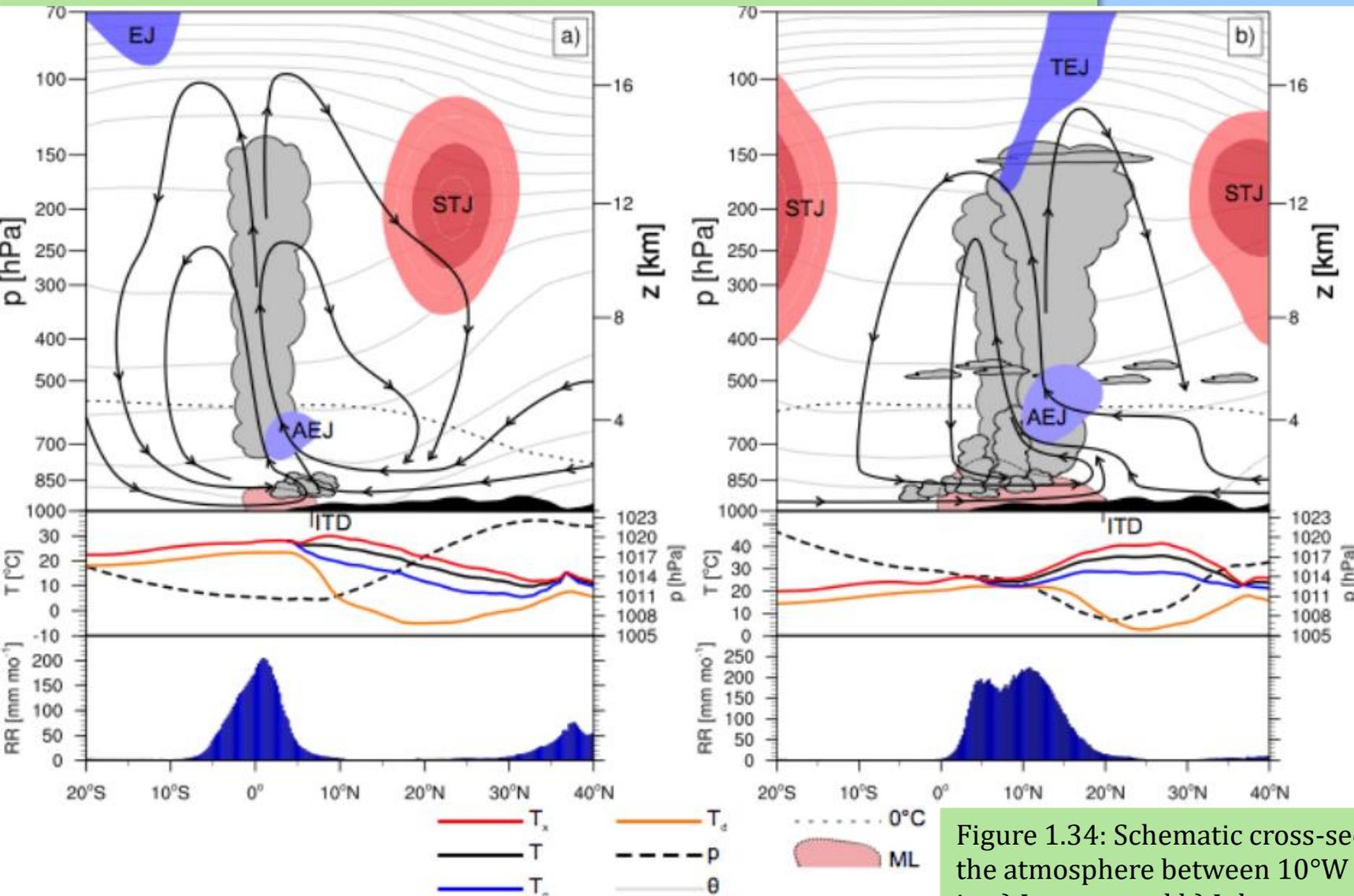


Figure 1.34: Schematic cross-section of the atmosphere between 10°W and 10°E in a) January and b) July.