

Opportunities and Challenges for Meteorology in Africa with a focus on West Africa: A Perspective from current ongoing UCAR projects

UNIDATA SEMINAR

15 October 2007

Boulder, CO

www.africa.ucar.edu

Africa Initiative Goal

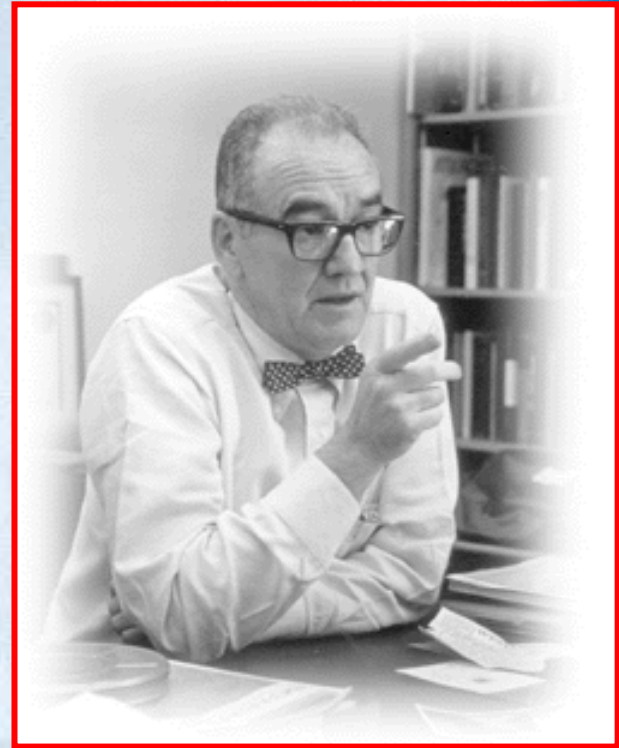
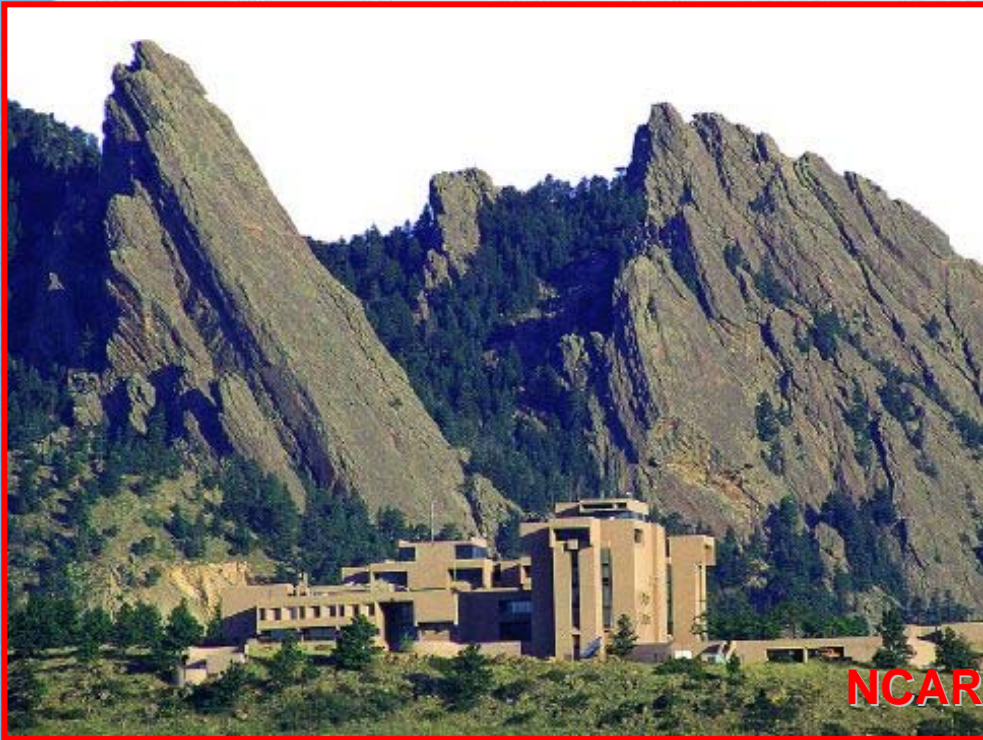


“African Solutions for African Problems”

An integrated end-to-end process, from research to impact

A partnership between Universities and UCAR for the benefit of the African people. The initiative envisioned will:

- Increase knowledge of the role of African weather, climate, and biogeochemical processes in the Earth system critical to Africa and important for the world
- Involve genuine collaboration with African institutions
- Develop research applications, operational systems, and dissemination strategies to improve lives in Africa
- **Enhance the capacity for atmospheric research in Africa by investing in sustainable infrastructure and education**
- Leverage the research infrastructure of NCAR/UCAR (and its partners) to add value to Africa research



“I have a very strong feeling that science exists to serve human welfare. It’s wonderful to have the opportunity given us by society to do basic research, but in return, **we have a very important moral responsibility to apply that research to benefiting humanity.”**

Walter Orr Roberts

Guiding Principles



- **Leveraging:** Focus on existing activities and coordinating pre-existing networks.
- **Develop research capacity while integrating research and education:** Contribute, in the long term, to developing local research capacity.
- **African Solutions for African Problems:** issues addressed should arise from an needs defined by local institutions, and focus on developing and enabling long-term strategies led by those institutions.

A very preliminary list of UCAR member universities with active atmospheric and related research in Africa



- Penn State (Many Researchers)
- Cornell (Kerry Cook)
- University at Albany - SUNY (Chris Thorncroft)
- Howard (Greg Jenkins)
- North Carolina State University (Fredrick Semazzi)
- Rutgers (Richard Anyah)
- Purdue (John Harbor)
- University of Illinois (Somnath Roy)
- University of Georgia (Carla Roncoli)
- Columbia University (Many Researchers, home of International Research Institute for Climate Prediction)

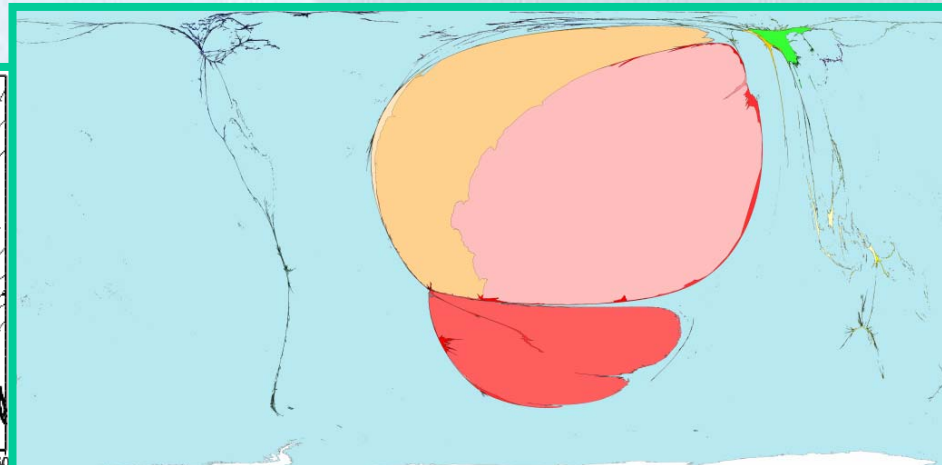
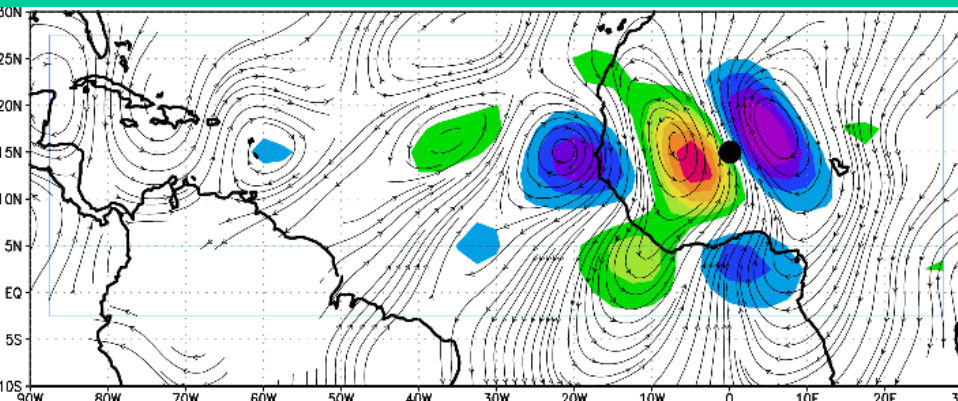
The importance of integration: Algerian Flood November 2001 : 737 Dead



“No warning to the population was raised and no measure taken to reduce the impact of the disaster, even though the meteorological office in Algiers announced two days earlier that a strong storm will arrive in Algeria on Friday night ...”

Global and Local Impact

- African easterly waves (AEW) create 90% of intense Atlantic hurricanes
- AEW's originate from traveling low-pressure systems that deliver essential precipitation in the Sahel
- The Sahel is subject to poorly understood variability in seasonal rains and frequent drought.



A guiding strategy

“any solution proposed for Africa must be based on the continent's own perception of its needs, and on the dynamics of its own economic and political environment.”

David Dickson, Director
SciDev.Net

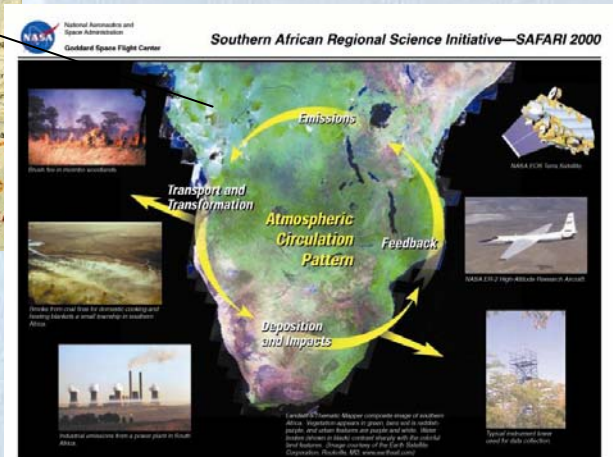
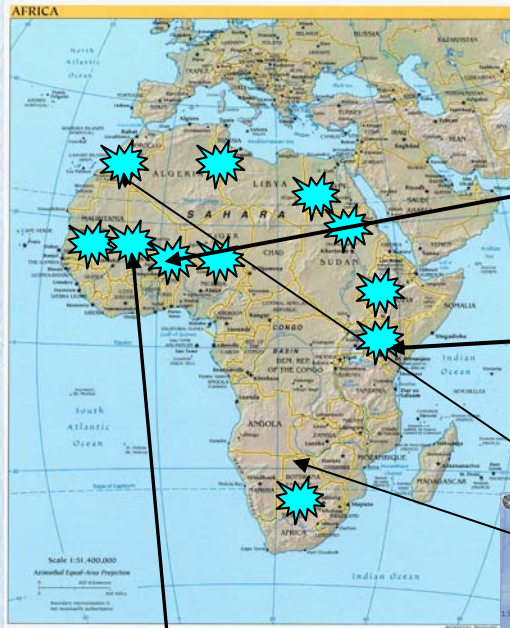
STEPS

- Identify and prioritize themes addressing local needs & global questions
- “Research for applications” around these priorities
- Integrate and coordinate existing activities to enhance collaboration and prevent overlap
- Broaden current activities to include regional and continental approaches
- Develop communities of practice with partners specializing in collaborating with stakeholders

Pilot and planned activities

- *Internal priority for capacity-building activities, aligned with identified priorities and partners*
 - *Pilot projects that enhance existing activities while allowing program development*
1. AAAS-UCAR African Scholars Program
 2. Educational Opportunities: April workshop in Ouagadougou, Burkina Faso
 3. Enhanced Observational Capacity: Radar network in West Africa
 4. Enhanced Modeling Capacity: WRF in Ghana

Africa Programs

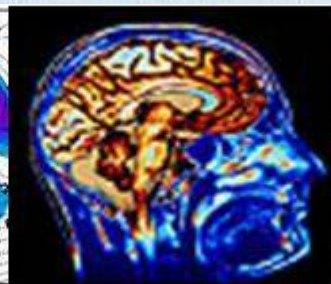
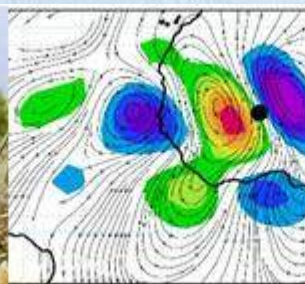
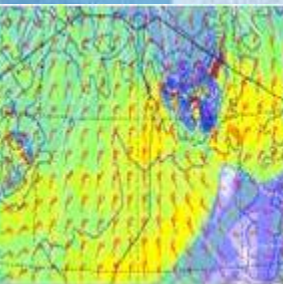
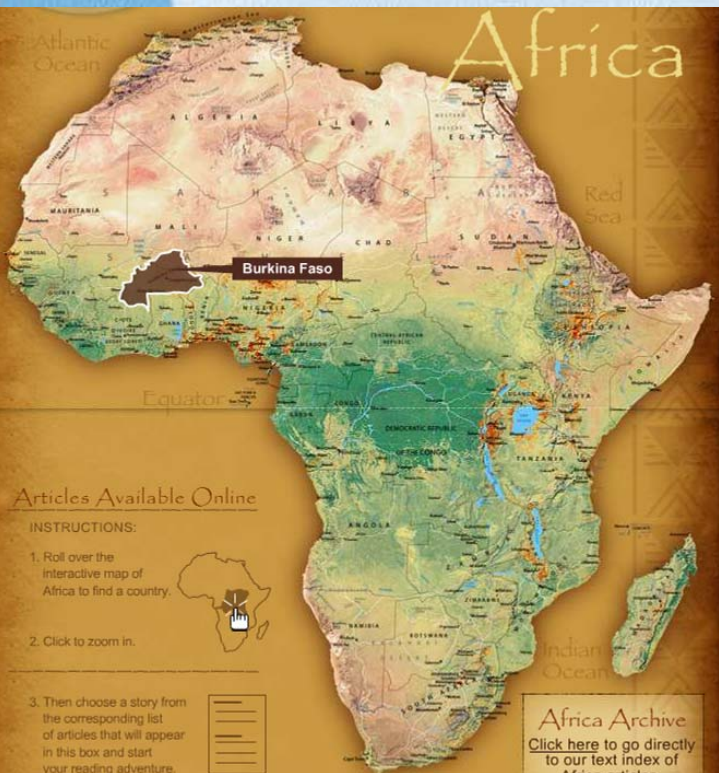


Supporting Capacity Building

Sahel Conference 2007

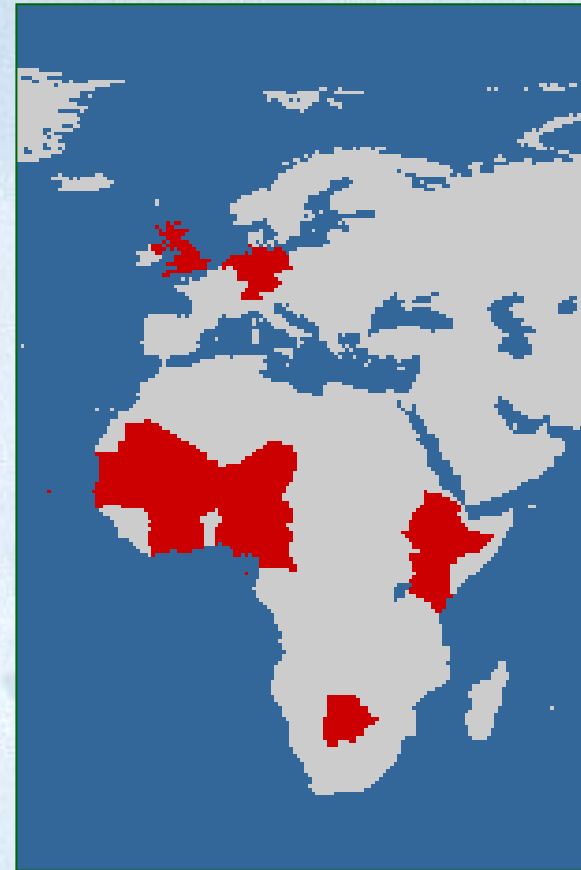
2-6 April 2007
Ouagadougou,
Burkina Faso

Co-hosted by CILLS,
Programme SAAGA



Participants

- Over 80 Participants from 18 countries
- Several regional alliances
- 10 participants from UOP, NCAR, and UCAR
- Unique mix of operational meteorologists, researchers, university faculty, military personnel, and program leaders



Conference Consensus



- Fundamental importance of training and education
- Long-term investment in Infrastructure (telecom)
- Development of NWP research and operations capability
- Free and open data exchange
- Regional approaches are fundamental to success



Conference Structure



- Informal Interaction
- Morning Plenary Session
 - Talks from African and International Participants
- Afternoon Hands-On Workshops
 - Unidata, EUMETSAT, RAL Radar Modules
- Friday Working Groups
 - Data Sharing Infrastructure & Telecommunications
 - Satellite, Radar, Observation Networks and Integration
 - Cloud Seeding
 - Numerical Weather Prediction



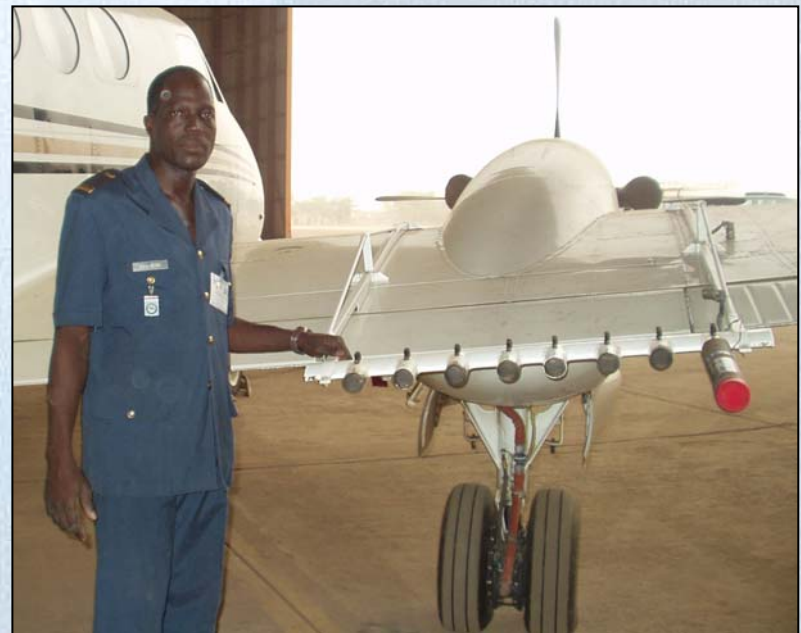
Education and Training

We underline the fundamental importance of **training and education** for meteorological personal. Budgets for training and education are fundamental to long-term program success.



Infrastructure

We call out the need for long-term investment in equipment and other infrastructure. The recommendation is that planning for the long-term maintenance of infrastructure be included in planning process



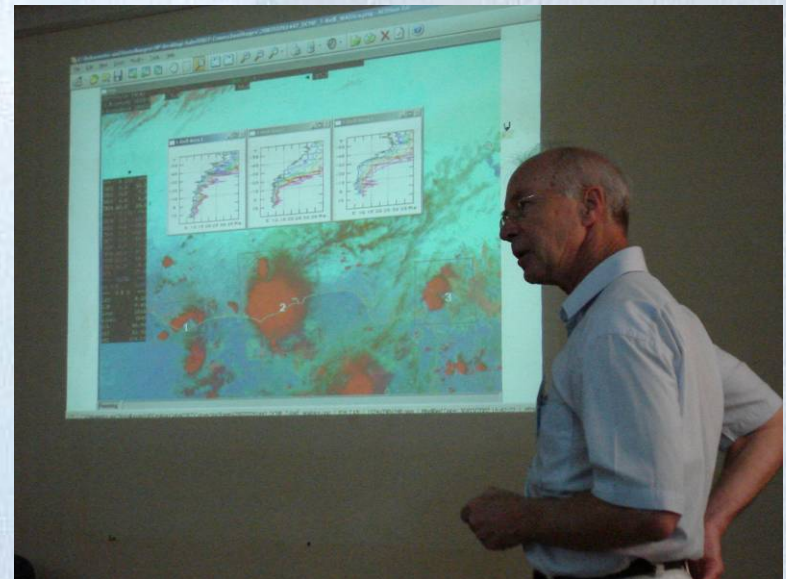
Weather Modification

- Controversial – A tentative consensus
 - Weather Modification should be accompanied by scientific research and optimization
 - Investment in rainfall enhancement capability produces other benefits



NWP

We propose the **development of numerical weather prediction research and operations capability**, and further recommend a **regional approach** that can extend the benefit of this capability to all Meteorological Services in the Sahel.



Sharing Data

We strongly endorse developing means to **share data freely** among all countries in West Africa, especially radar data, and for **developing a network of West African radars**



Potential Partnerships

- Unidata, EUMETSAT, African NMHS's collaborate to share and distribute products (e.g. composite rainfall from radar)
- Regional approaches to training, maintenance
- NWP with ACMAD, Senegal, Ghana, and Nigeria Weather Services
- Evaluation of Seeding
- CO₂ Monitoring in Kenya



Regional Approaches

In overall terms, we support the **sustained collaboration** between the various West African Meteorological Services and with centers like ACMAD, ASECNA, CILSS, etc.



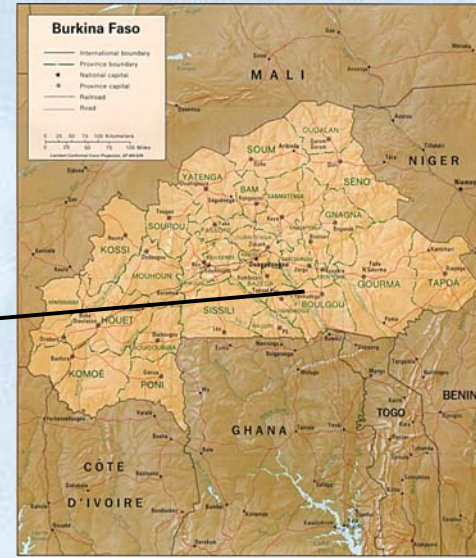
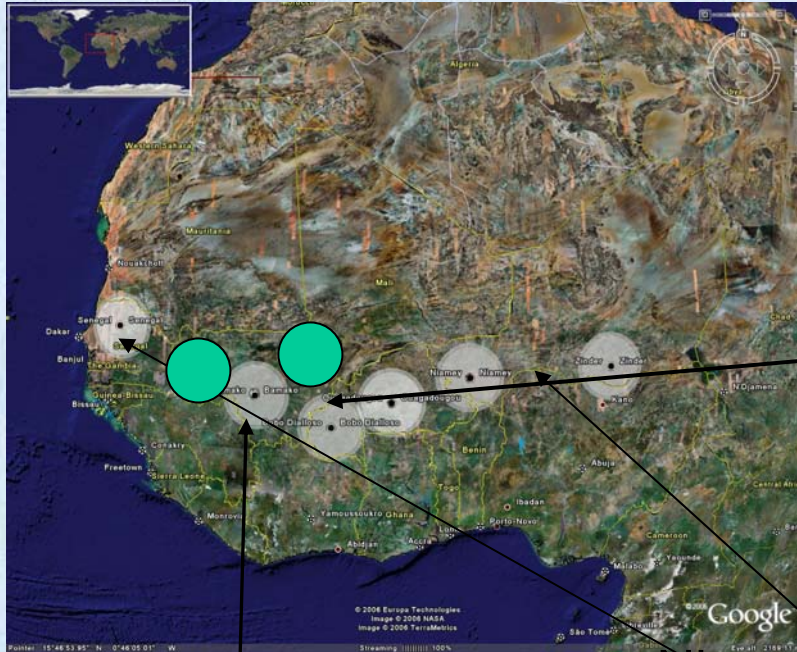
Participant Comments



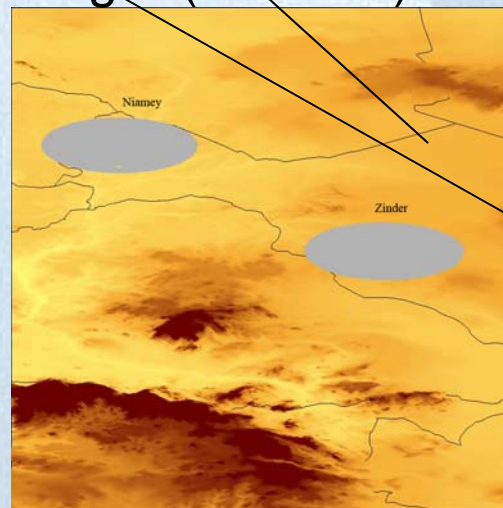
- good discussions
- African co-leadership
- good mix of operational weather forecasters and scientists
- intensive interaction with other participations with diverse backgrounds and experience which resulted in common areas and new areas for research

West African Radars

Burkina Faso (2 radars)



Niger (2 radars)



Mali (3 radars)



Senegal (one radar)



Burkina Faso infrastructure



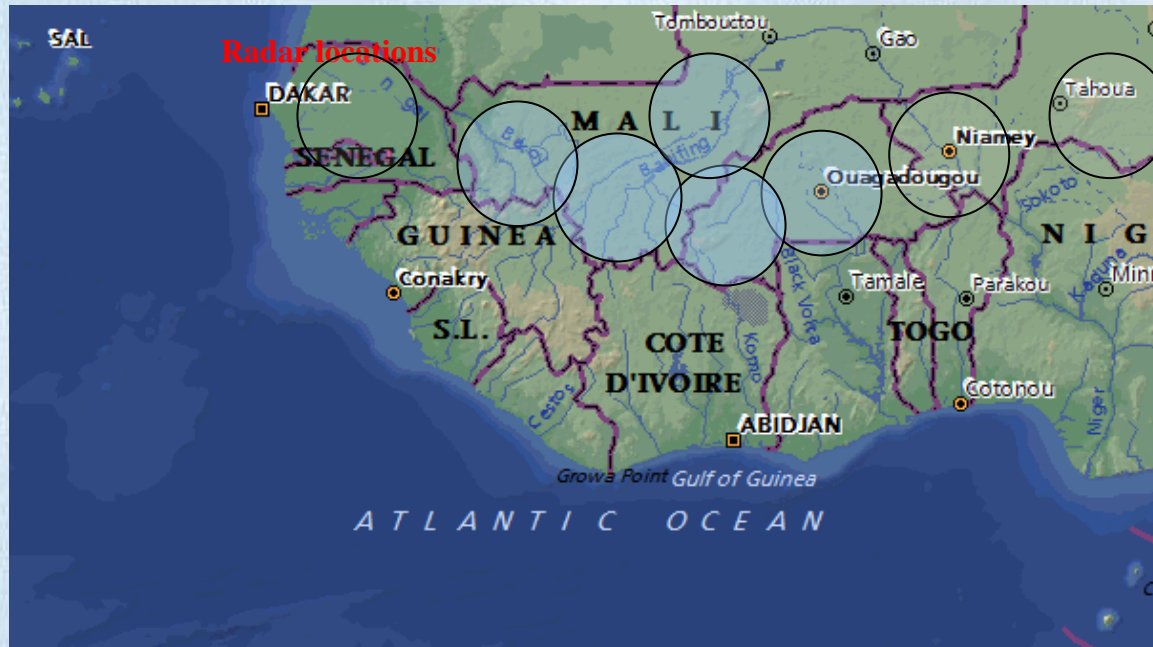
Radar installations in Ouagadougou and Bobo Dialloso, Burkina Faso

Mali

Mali radar infrastructure Bamako



Weather radar and project locations



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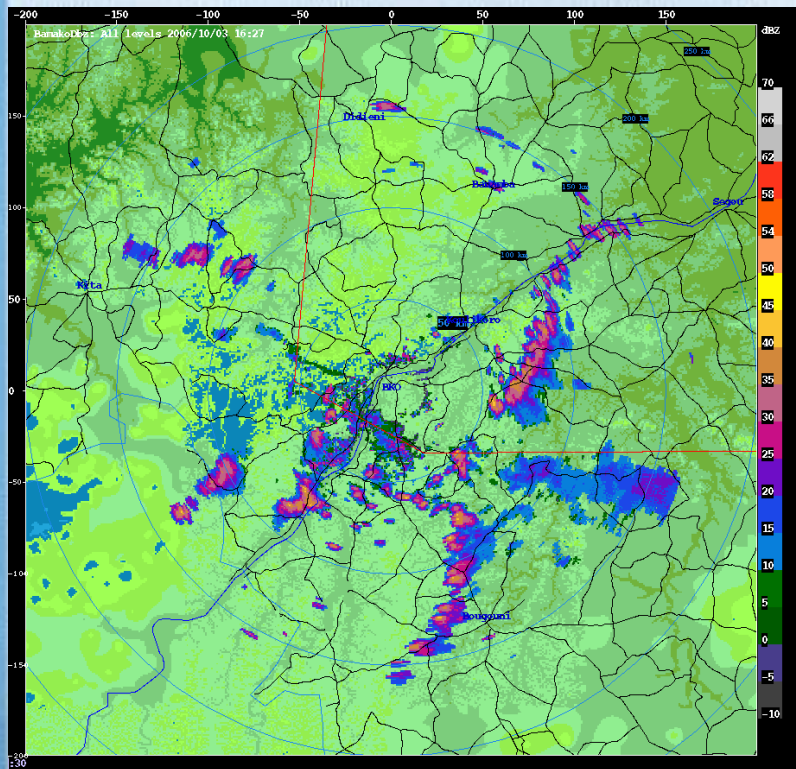
Burkina Faso, Mali (currently operational radars)
and potential Senegal and Niger radar locations
(not fully operational as yet).

Real-time data Bamako, Mali

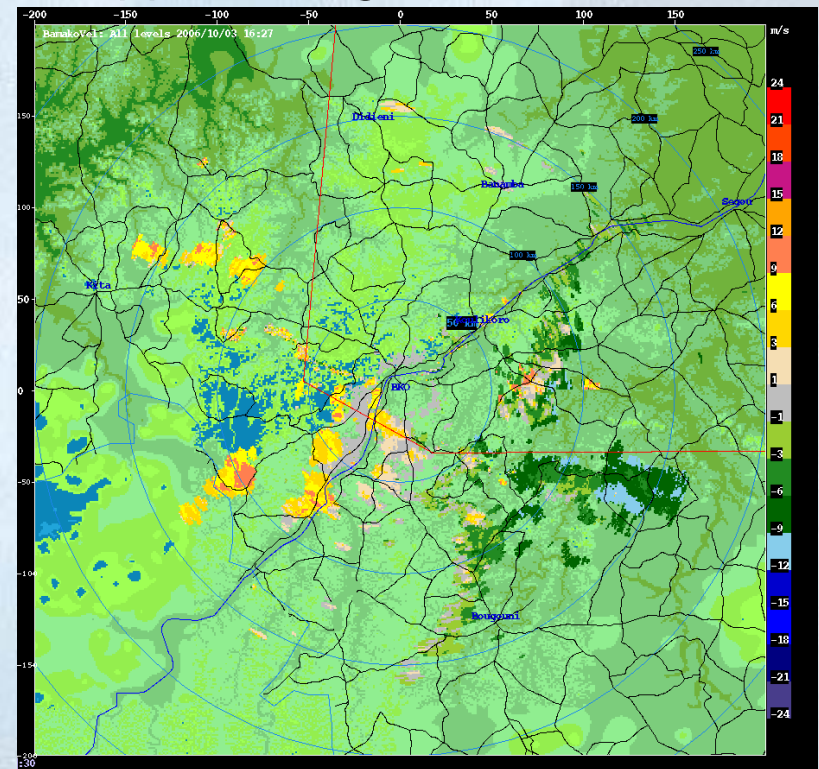


http://www.rap.ucar.edu/projects/westafrica/bamakorada_rdata/index.php

Convective line of storms approaching Bamako



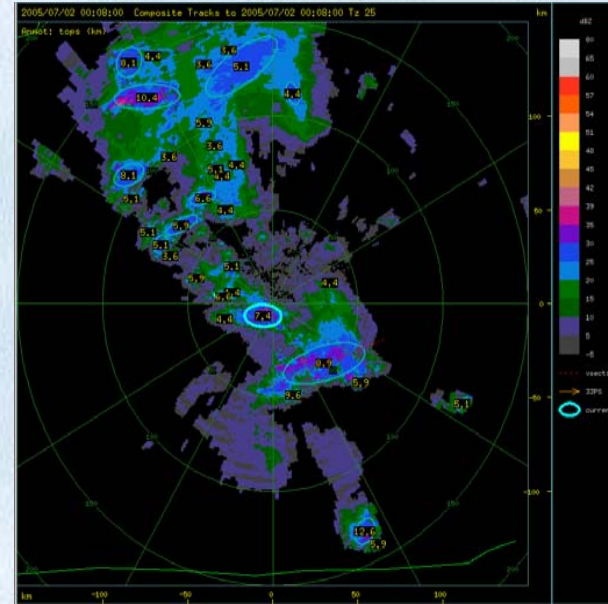
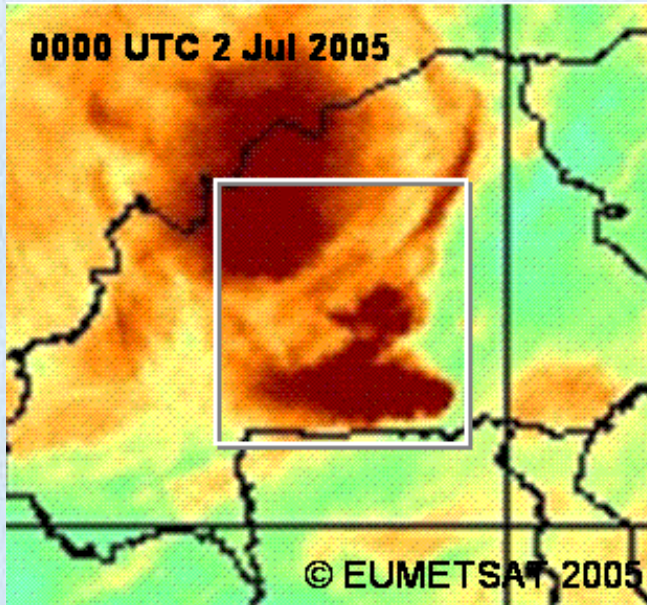
Reflectivity



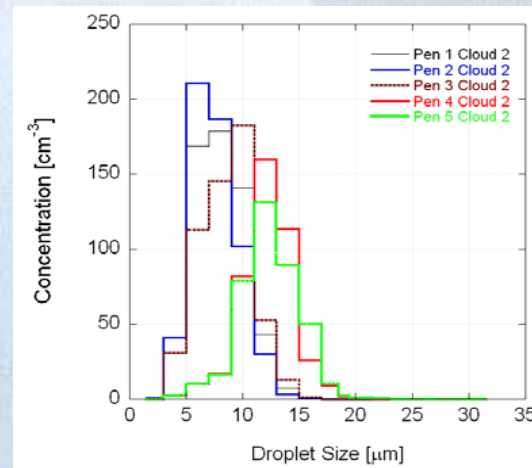
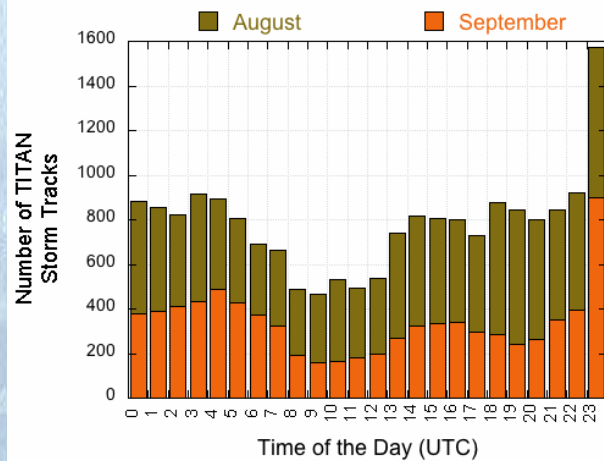
Radial Velocity

West Africa

Satellite image and Ouagadougou radar



Bamako diurnal variation of radar echoes and cloud droplet spectra in clouds



Current West Africa Activities



- Conducted calibrations of radars and upgraded software
- Networked the Mali radars
- Quality control of data
- Network Mali and Burkina Faso radars
- Stream data to UNIDATA and provide UNIDATA products for West African countries and universities
- Coordinate with EUMETSAT to integrate radar and satellite data

Proposed Future Activities

- Enhance network of radars by networking all West Africa radars starting with Burkina Faso and Mali and including the Senegal and potentially upgraded Niger radars.
- **Education and training** (3 people from Burkina Faso and two from Mali visited NCAR for training in October 2006).
- Future training in the integration of radars with other sensors and uses for different applications including assessment of rainfall enhancement programs, weather forecasting and nowcasting, aviation weather, water resources management and agriculture
- Follow-up SAHEL Workshops to enhance share experiences and enhance future collaborations, and to provide for sustaining current infrastructure

Western Africa NWP: The model and initial results

Ben Lemptley

Model Configuration

- MM5-based Real-Time Four Dimensional Data Assimilation (RTFDDA) system
- “Standard” model physics are currently used
- 6-hour cycles with 24 - 36 hr forecasts in each cycle, depending on the grid.
- Observations: Standard GTS/WMO surface and upper-air stations, plus MADIS (mostly AMDAR) and QuikScat sea-surface winds

Computing Resources

- NCAR Director GAU Reserve
7840 GAUs per month until May 1
- CISL Lightning Linux-cluster
18 dedicated dual-cpu nodes: 1 model master, 16 MPP and 1 spare
- Local post-processing and web service
RAL PC clusters

Domains

Three 2-way
nested domains

DX=
40.5/13.5/4.5 km

Dimensions

D1: 261x261x36

D2: 184x295x36

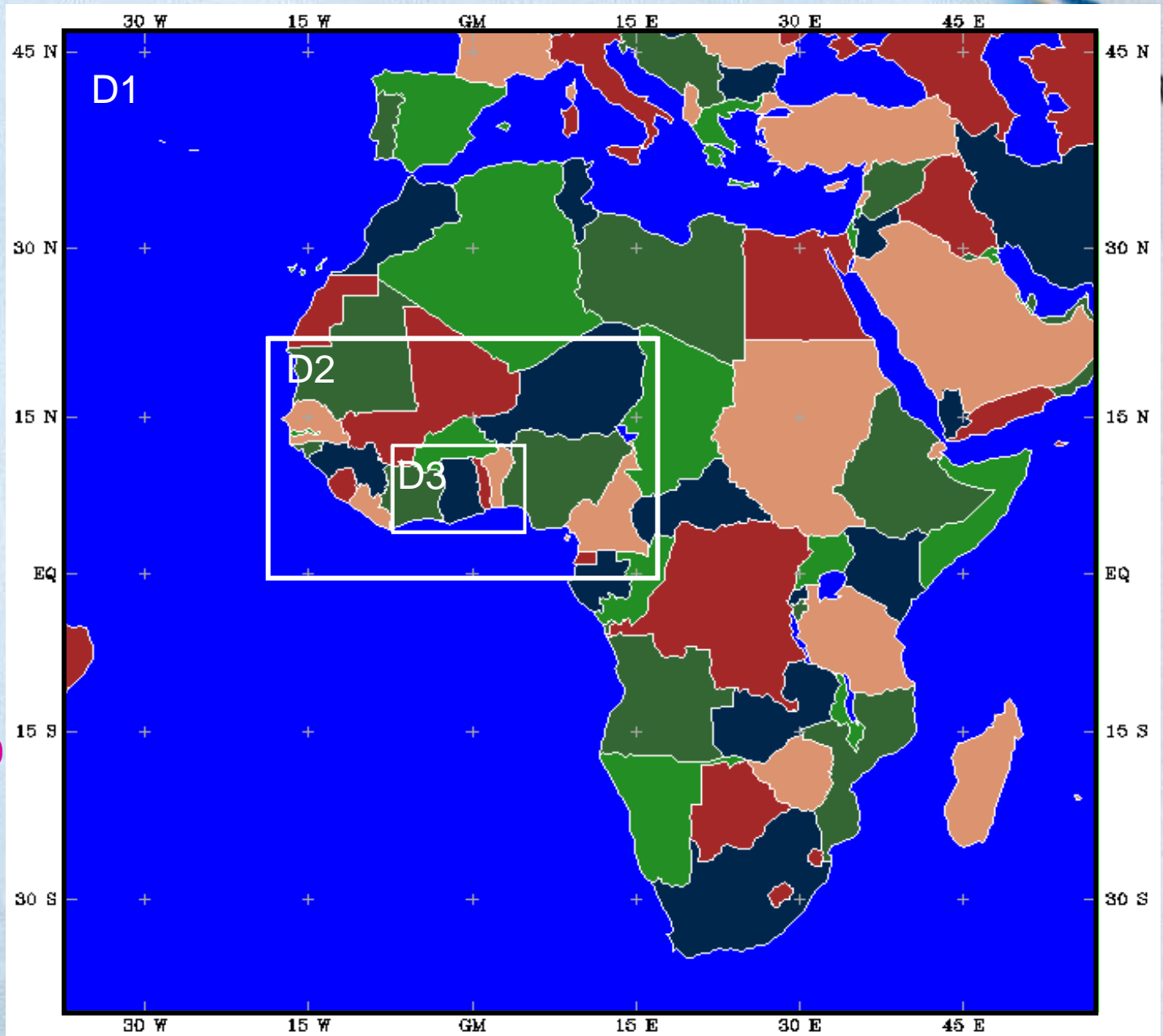
D3: 208x301x36

Sizes (km²):

D1: 10530x10530

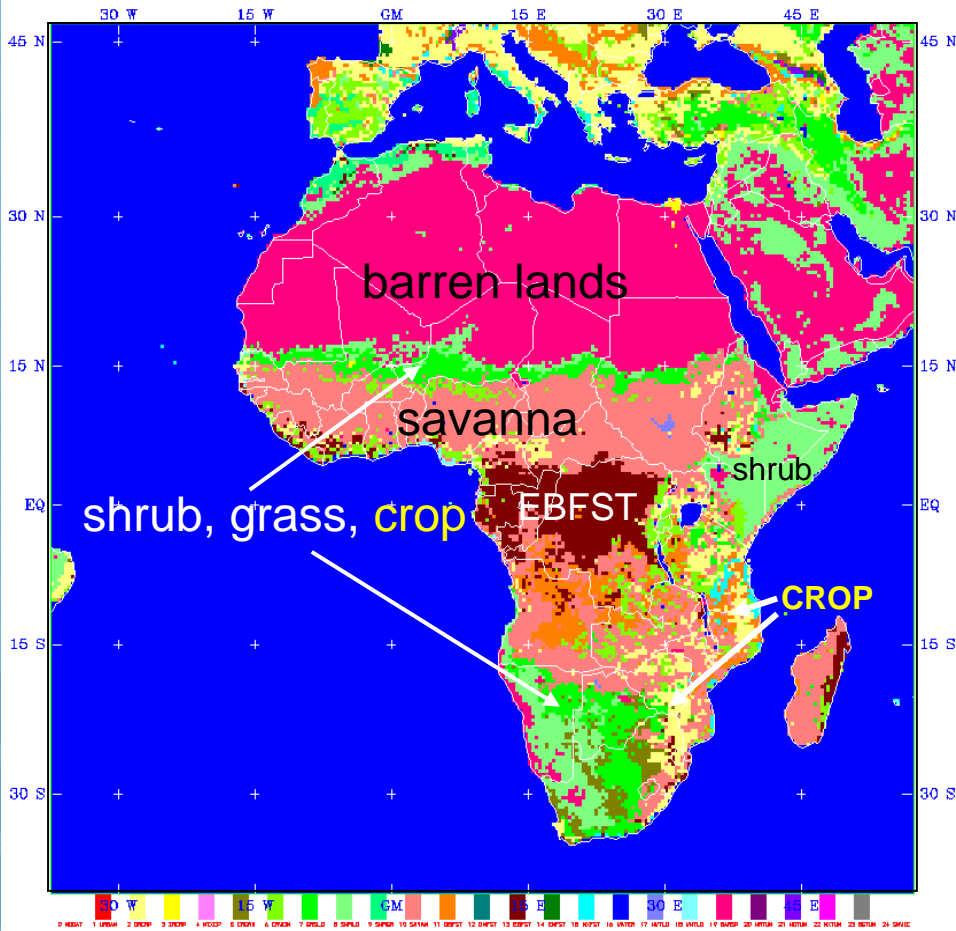
D2: 3969x2592

D3: 1350x931

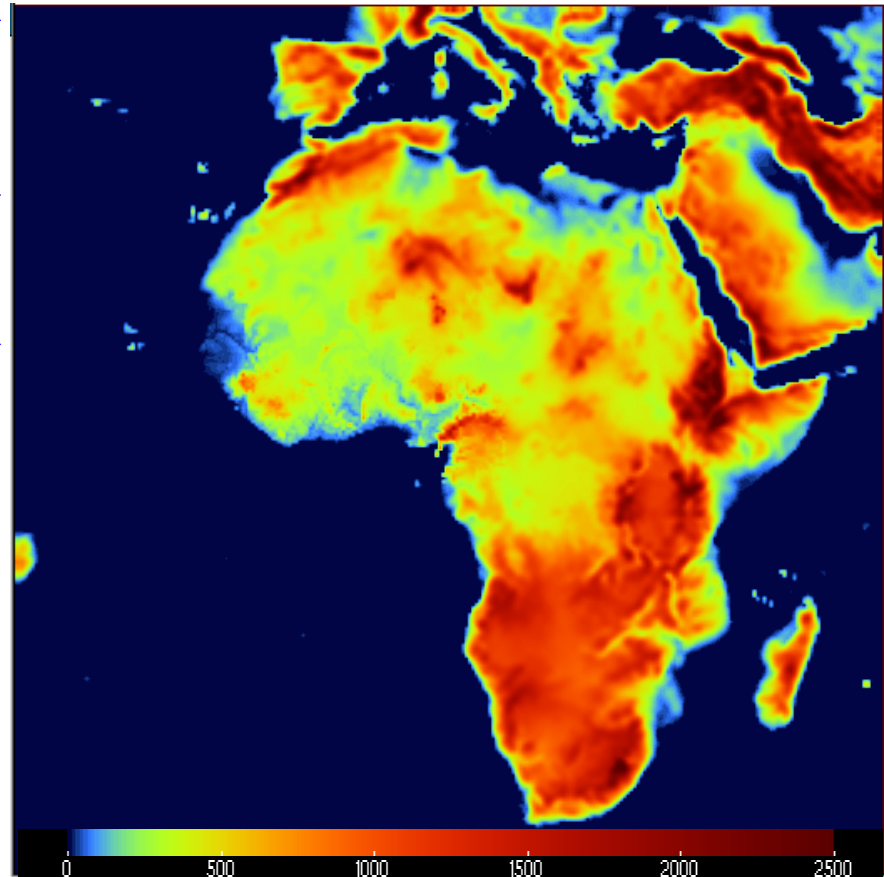


Land Use and Terrain Features

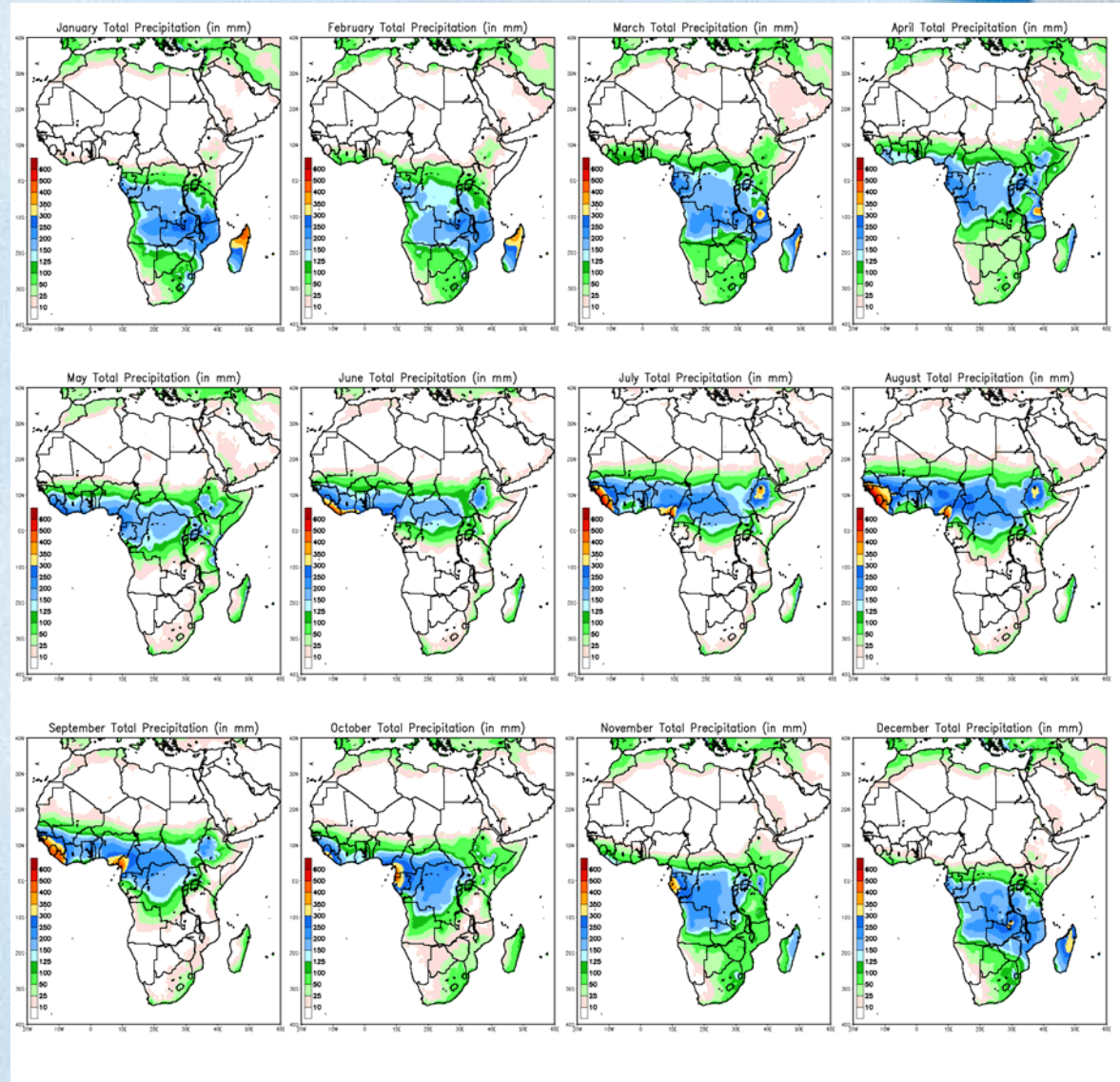
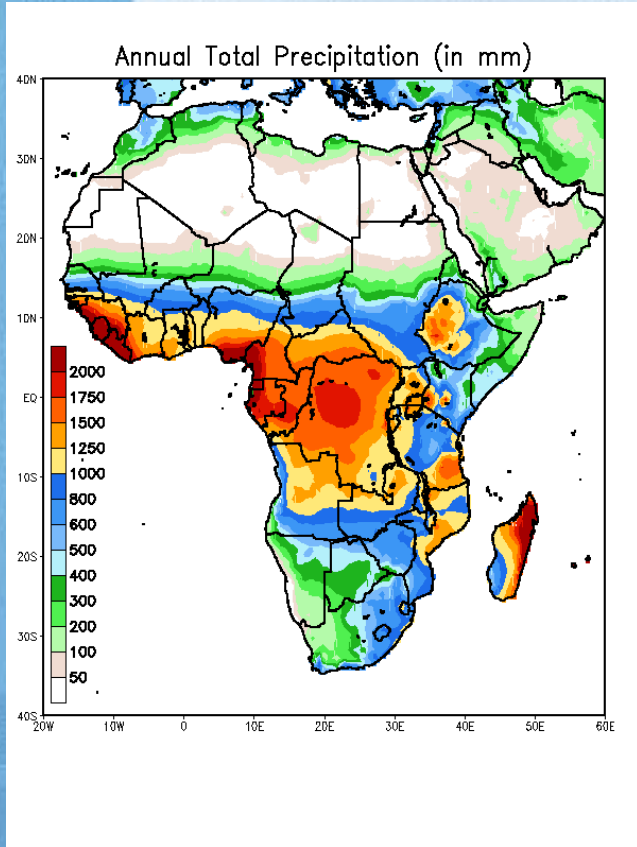
DOMINANT VEGETAT/NEW LANDUSE TYPE



TERRAIN HEIGHT (KM)

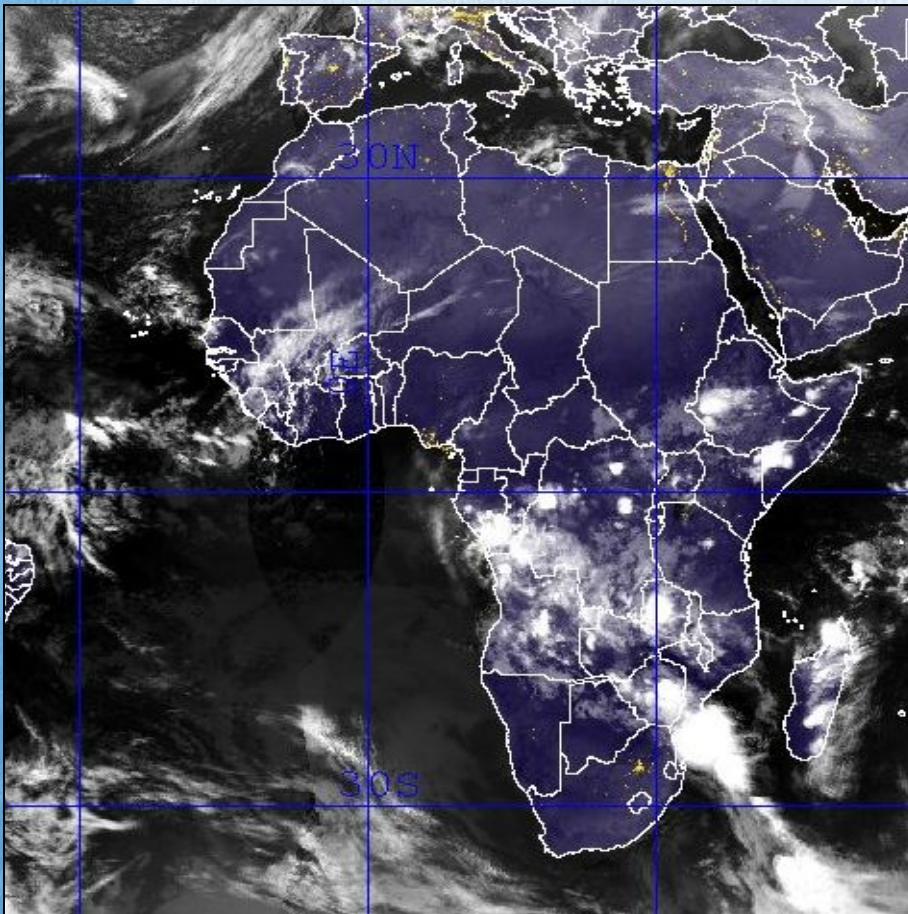


Precip. Climate (From UK/CRU)

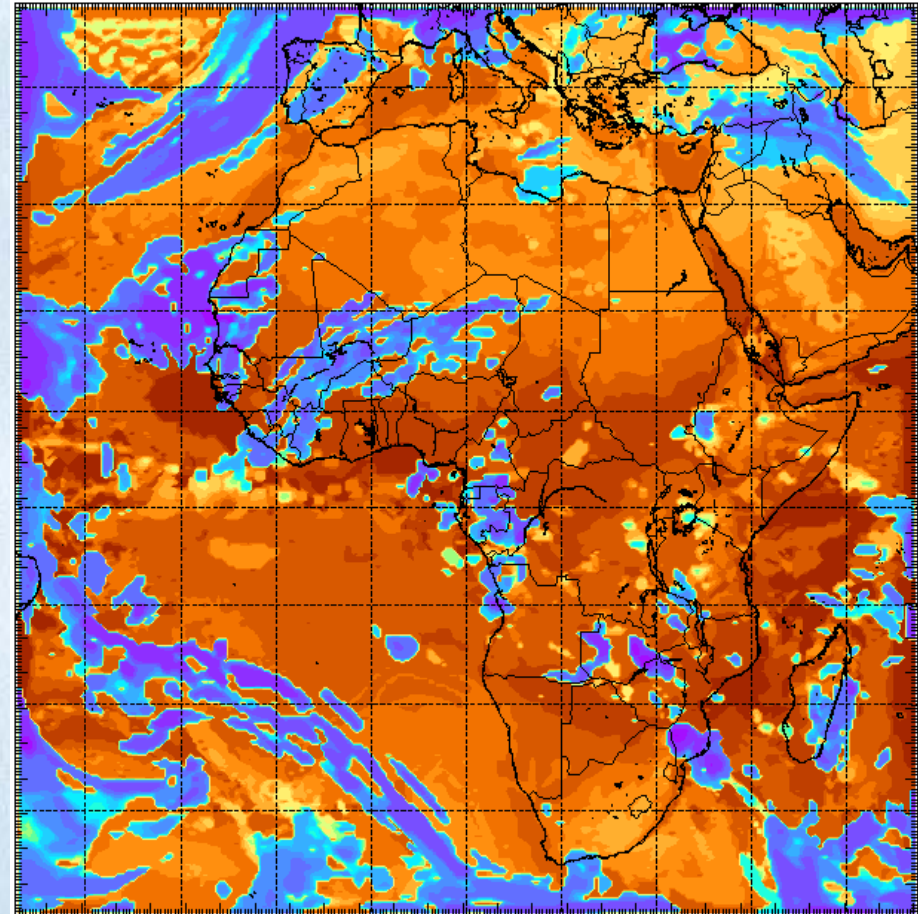


Verification of RTFDDA Forecasts of Cloud fields (Domain 1; valid at 00Z Dec. 5, 2006)

NRL DAY/NGT VIS/IR



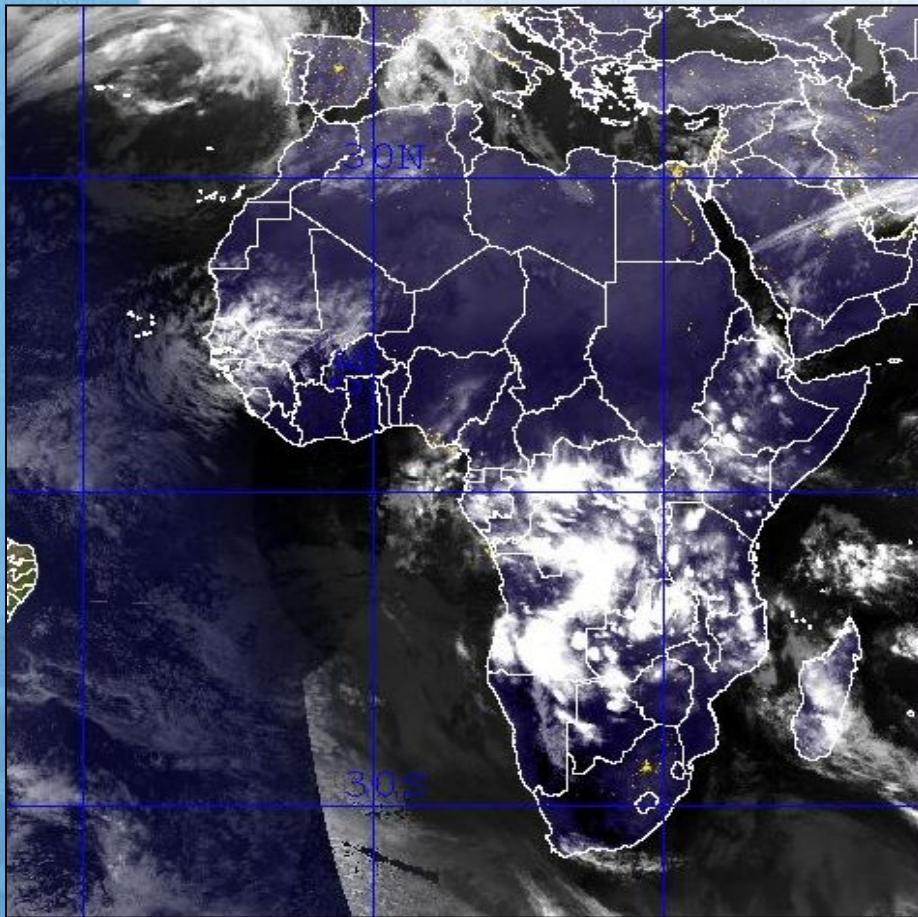
RTFDDA 6h FCST: Cloud Top T



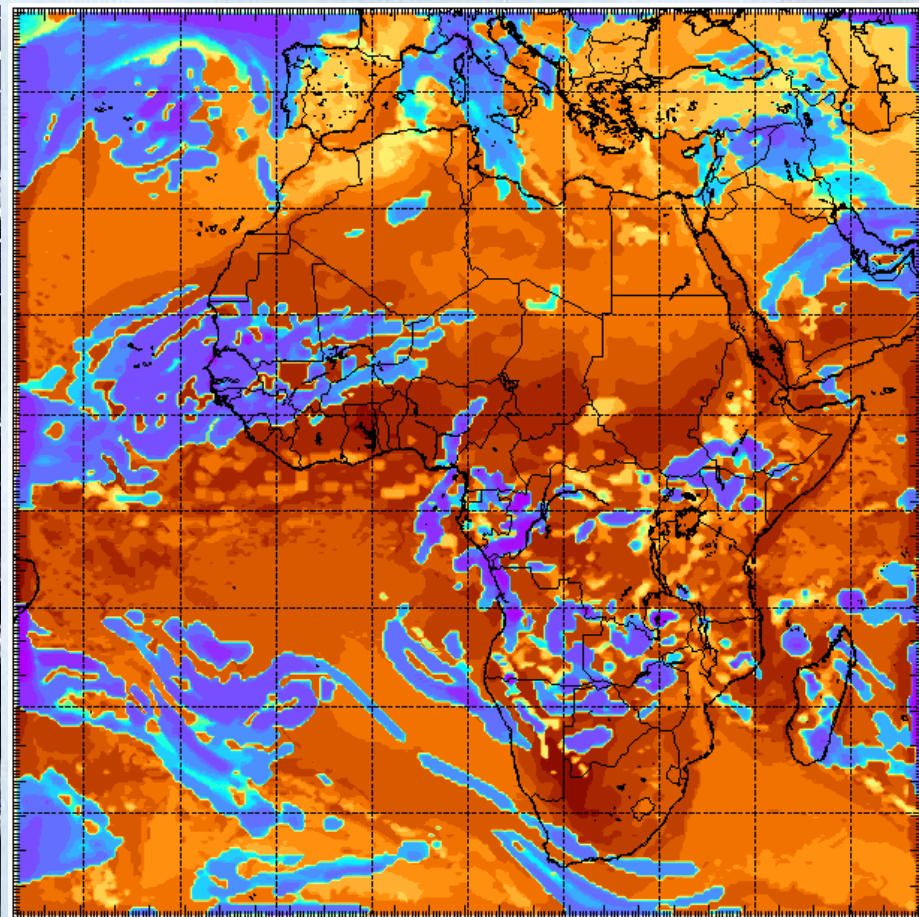
Verification of RTFDDA Forecasts of Cloud fields (Domain 1; valid at 18Z Dec. 6, 2006)



NRL DAY/NGT VIS/IR



RTFDDA 18h FCST: Cloud Top T

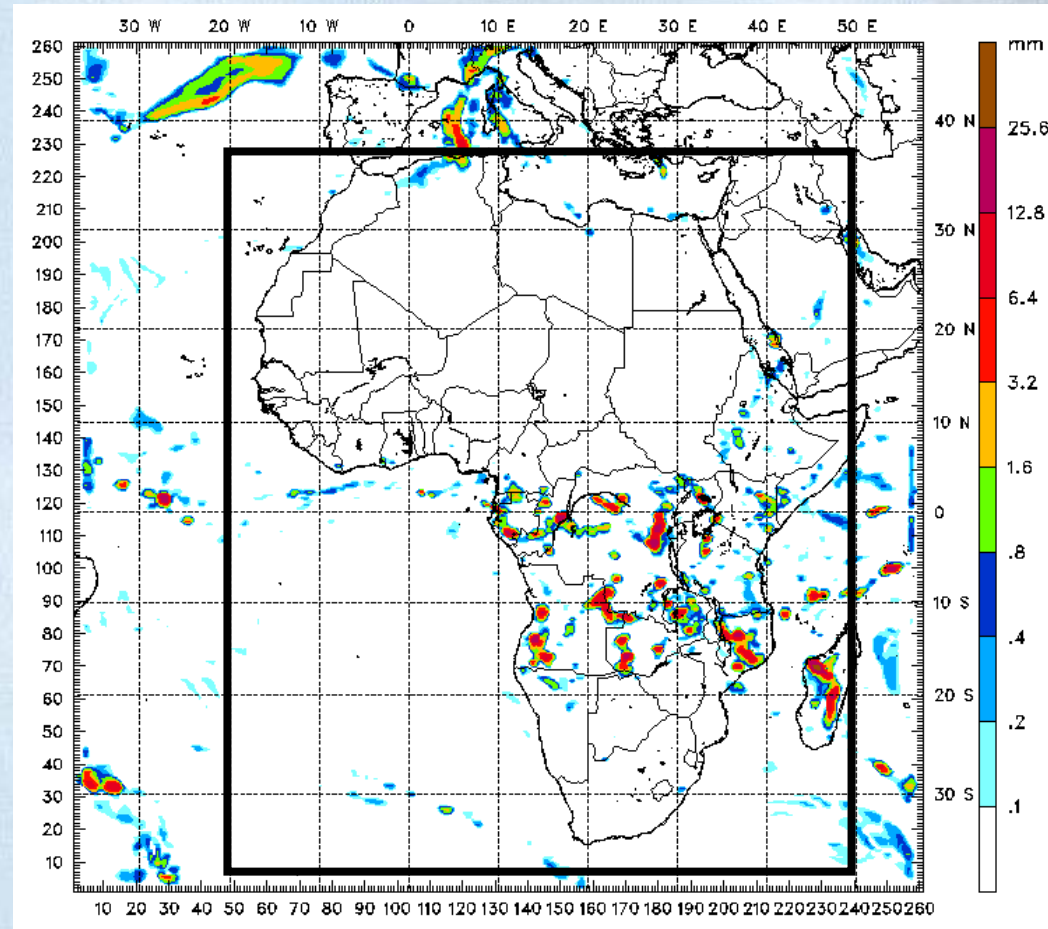
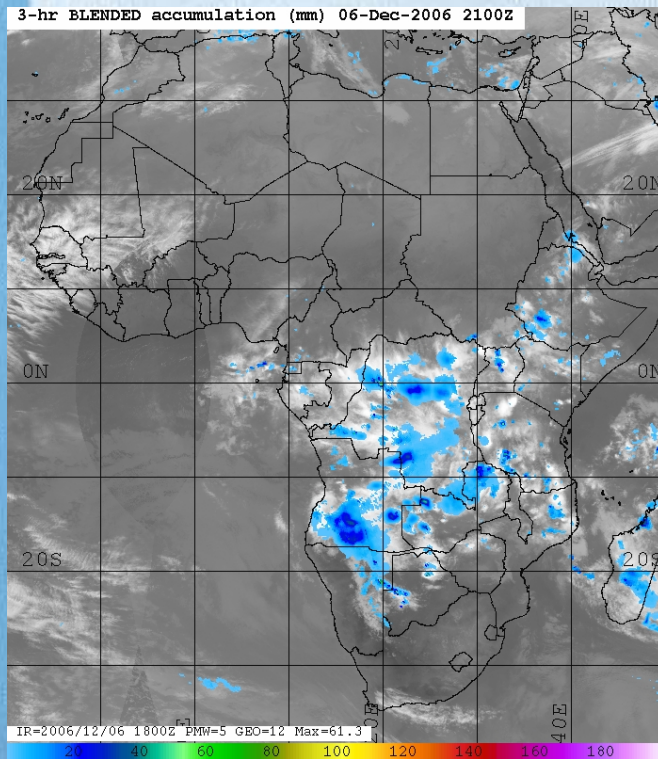


Verification of RTFDDA Forecasts of Precipitation (Domain 1; valid at 21Z Dec. 6, 2006)



NRL GEO-MV derived 3-h rain

RTFDDA 3h FCST: 1h rain



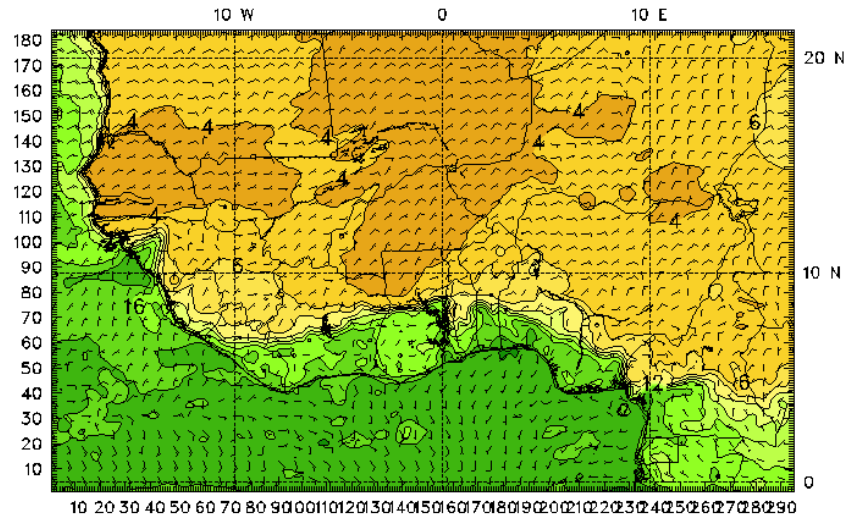
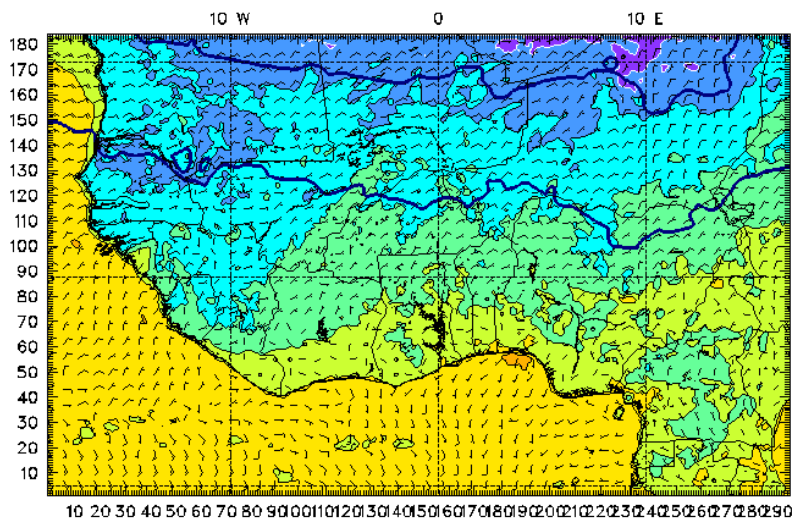
Domain 2

(Animated hourly, 07Z Dec. 4 – 18Z Dec. 5 2006)

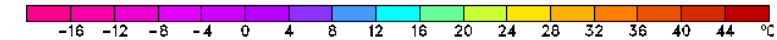
GRM RT-FDDA Domain 1 Cycle=2006120412 Init: 1800 UTC Sat 02 Dec 06 GRM RT-FDDA Domain 1 Cycle=2006120412 Init: 1800 UTC Sat 02 Dec 06
 Fcst: 37.00 Valid: 0700 UTC Mon 04 Dec 06 (0000 MST Mon 04 Dec 06) Fcst: 37.00 Valid: 0700 UTC Mon 04 Dec 06 (0000 MST Mon 04 Dec 06)
 Surface temperature Surface mixing ratio
 Surface horizontal wind vectors Surface horizontal wind vectors
 Sea-level pressure

Surface T and Winds

Surface Qv and Winds

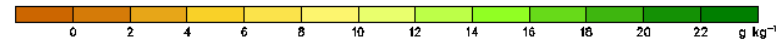


CONTOURS: UNITS=hPa LOW= 1016.0 HIGH= 1020.0 INTERVAL= 4.0000
 BARB VECTORS: FULL BARB = 5 m s⁻¹
 CONTOURS: UNITS=°C LOW= 12.000 HIGH= 44.000 INTERVAL= 4.0000
 CONTOURS: UNITS=°C LOW= -16.000 HIGH= 8.0000 INTERVAL= 4.0000



Model Info: V3.6.2 Grell MRF PBL Ralsner 1 14 km, 36 levels, 30 sec

BARB VECTORS: FULL BARB = 5 m s⁻¹



Model Info: V3.6.2 Grell MRF PBL Ralsner 1 14 km, 36 levels, 30 sec

Domain 3

(Animated hourly, 07Z Dec. 4 – 18Z Dec. 5 2006)

GRM RT-FDDA Domain 1 Cycle=2006120412

Fcst: 37.00

Surface temperature

Surface horizontal wind vectors

Sea-level pressure

Init: 1800 UTC Sat 01 Dec 06 GRM RT-FDDA Domain 1 Cycle=2006120412

Valid: 0700 UTC Mon 04 Dec 06 (0000 MST Mon 04 Dec 06)

Surface mixing ratio

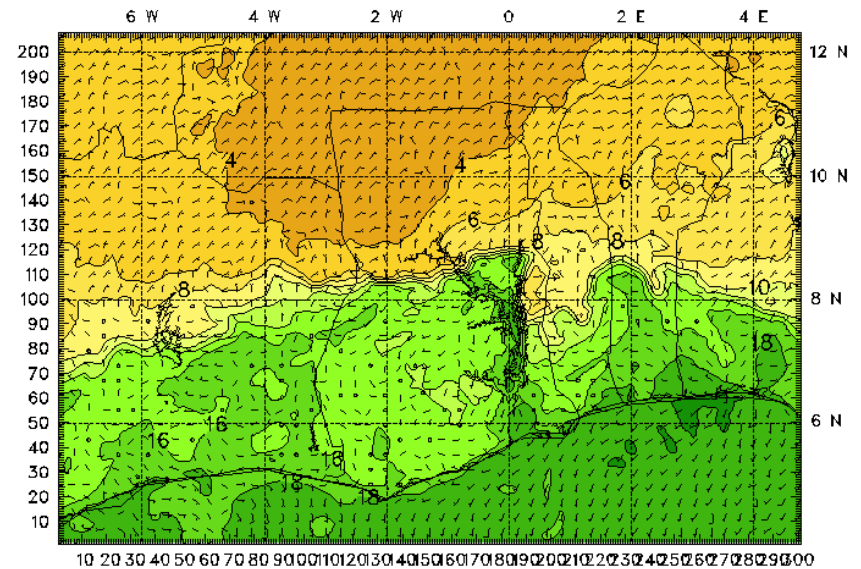
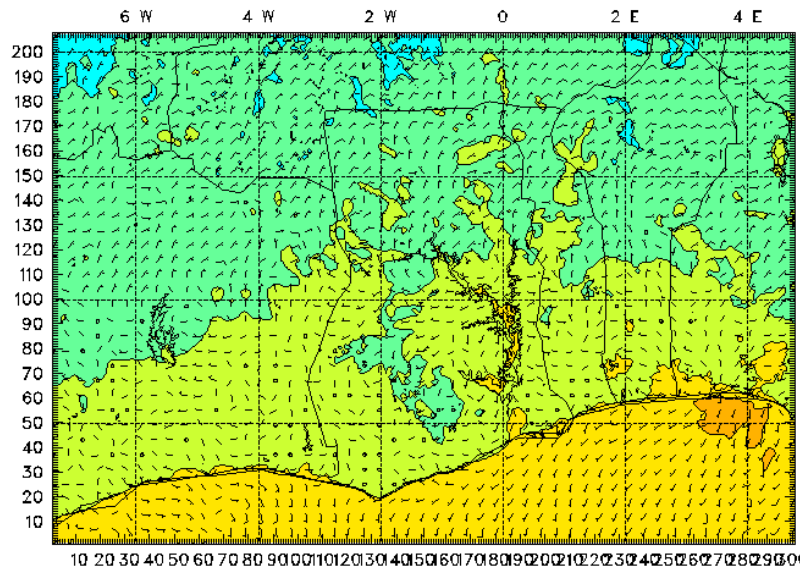
Surface horizontal wind vectors

Init: 1800 UTC Sat 02 Dec 06

Valid: 0700 UTC Mon 04 Dec 06 (0000 MST Mon 04 Dec 06)

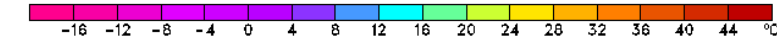
Surface T and Winds

Surface Qv and Winds



CONTOURS: UNITS=hPa LOW= 1016.0 HIGH= 1016.0 INTERVAL= 4.0000
 BARB VECTORS: FULL BARB = 5 m s⁻¹
 CONTOURS: UNITS=°C LOW= 12.000 HIGH= 44.000 INTERVAL= 4.0000
 CONTOURS: UNITS=°C LOW= -16.000 HIGH= 8.0000 INTERVAL= 4.0000

BARB VECTORS: FULL BARB = 5 m s⁻¹



Model Info: V3.6.2 No Cumulus MRF PBL Reisner 1 5 km, 36 levels, 10 sec

Model Info: V3.6.2 No Cumulus MRF PBL Reisner 1 5 km, 36 levels, 10 sec

Summary

- A demonstration modeling system has been set up for Africa, to support NCAR/UCAR capacity-building on that continent.
- The system is running at CISL for the next 5 months, providing high-resolution mesoscale NWP for African forecasters and stakeholders.
- A first look at the model results for arbitrarily selected cases is encouraging.
- Next year this system will transition to one running on a dedicated PC cluster in RAL.
- Considerable work needs to be done to verify the model forecasts, and improve the physics where needed.

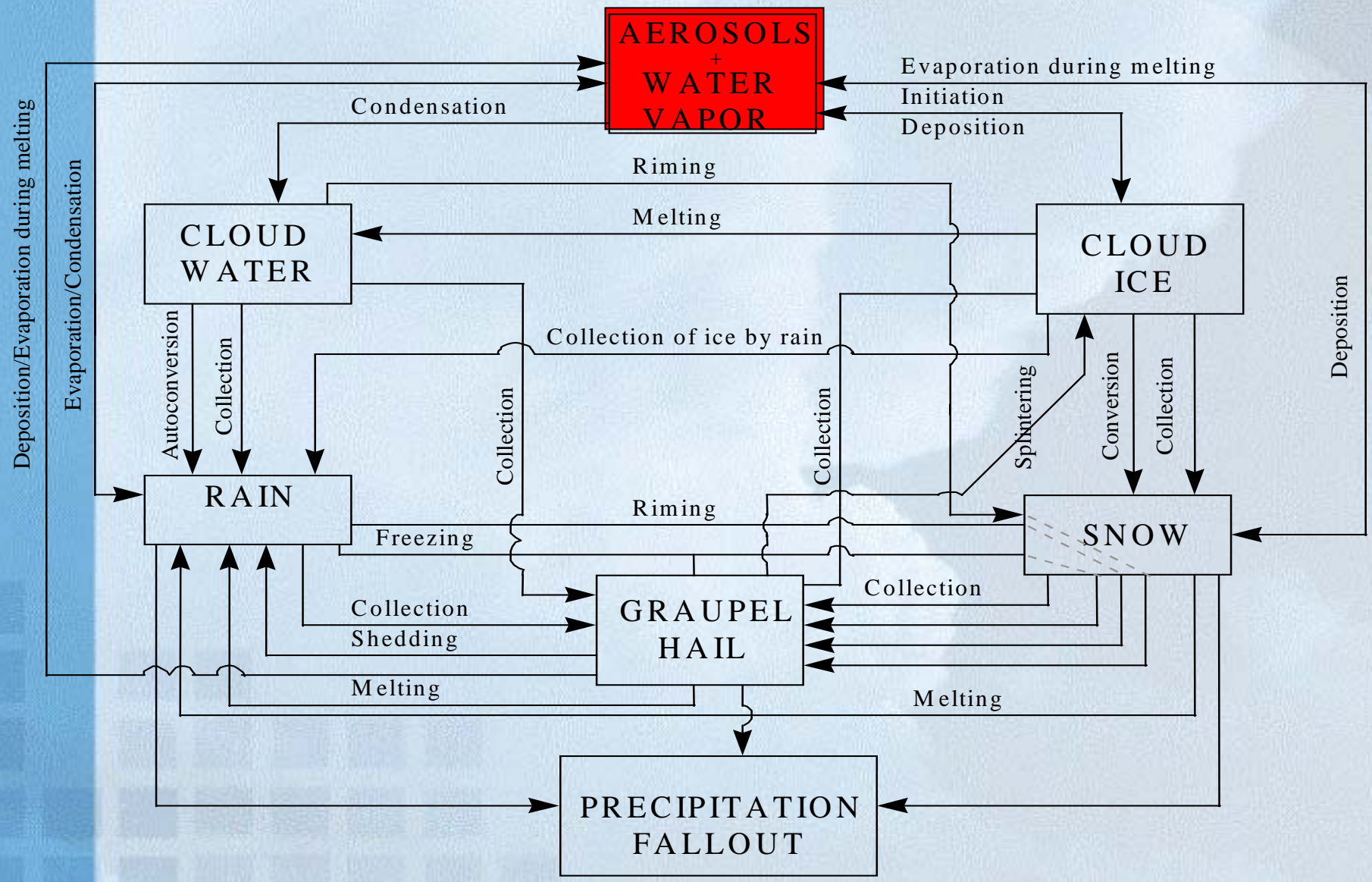
Weather Modification



- Controversial but consensus emerged
- Should be done very carefully
 - Controlled studies of effects
 - Quantification of conditions necessary for maximum effectiveness.
- Investment in rainfall enhancement capability produces other benefits
 - radars used to plan seeding can be used for civil aviation, agricultural planning, and even monitoring the movement of dust



Microphysical processes in precipitation development



INSTRUMENTED RESEARCH AIRCRAFT



Trace gases: SO_2 , O_3 , $\text{NO}_{x/y}$

Aerosols: CN, CCN, PCASP, filter pack sampler

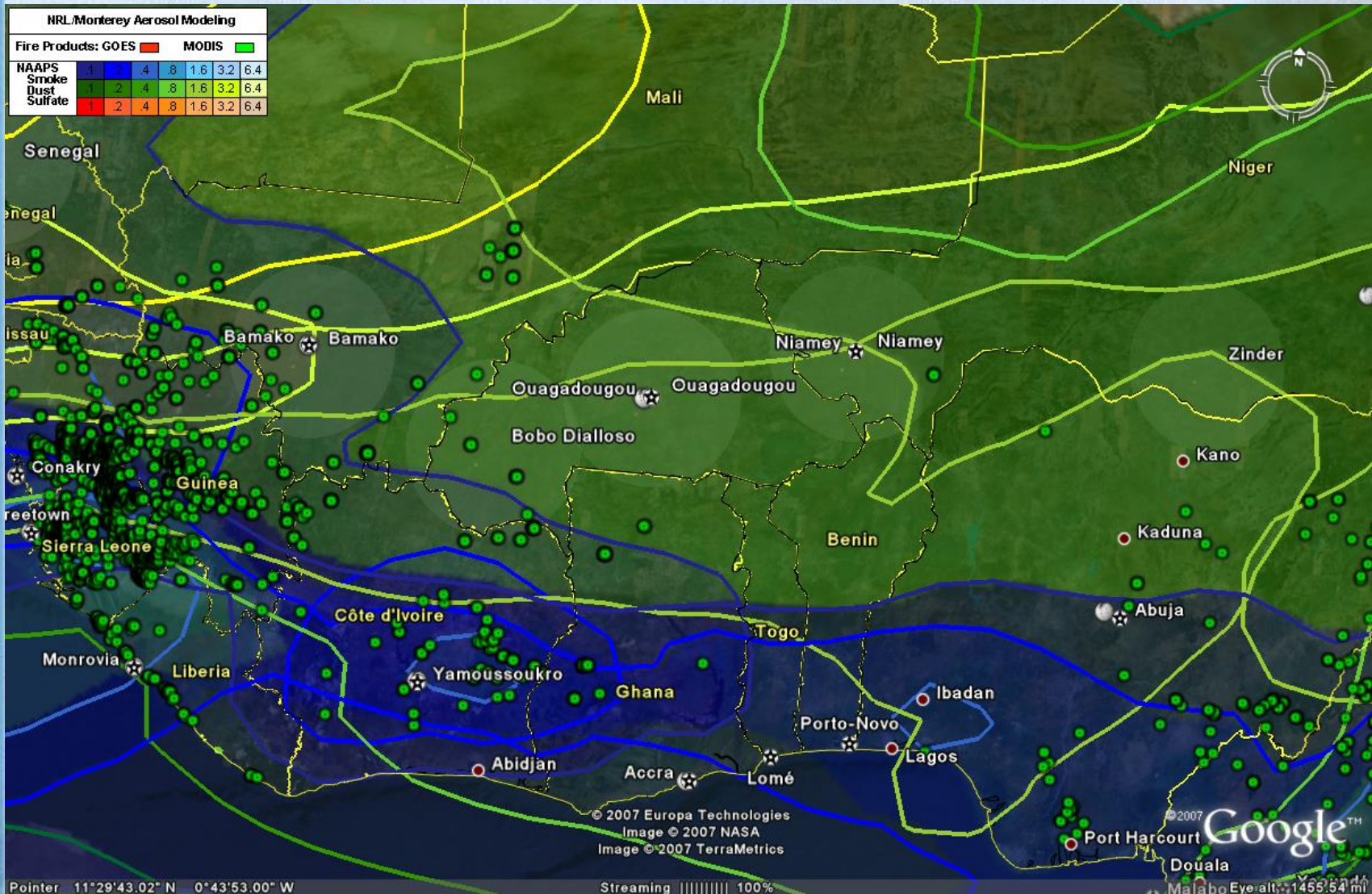
Missions: chemistry and aerosol mapping, cloud penetrations, seeding trials



Cloud physics: FSSP, 2D-C, 2D-P, (HVPS), LWC

State parameters: T, T_d , p, TAS, Hdg, GPS position, derived winds

West Africa Aerosols



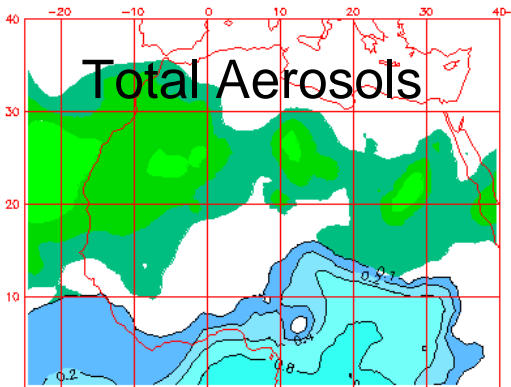
27 March 2007

Mali Aerosols Observations



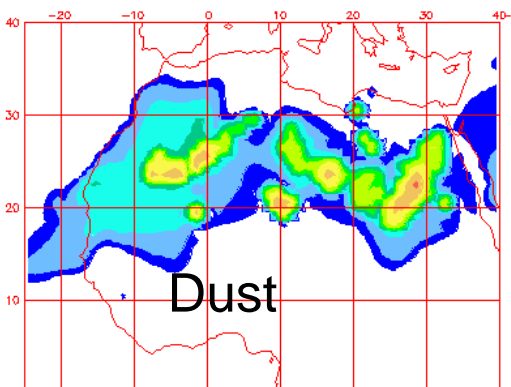
30 August 2006

NAAPS Optical Depth for 12:00Z 30 Aug 2006
Sulfate: Orange/Red, Dust: Green/Yellow, Smoke: Blue



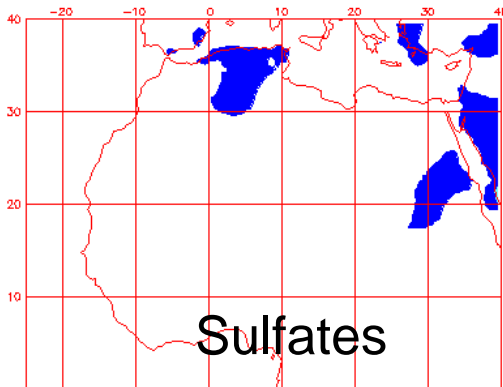
0.1 0.2 0.4 0.8 1.6 3.2 6.4 12.6
0.1 0.2 0.4 0.8 1.6 3.2 6.4 12.6
1.000E+01; 1.280E+01 [2.590E-01; 5.180E-01; 1.037E-01; UNITLESS
1.000E-01; 1.280E+01 [8.273E-03; 6.611E-01; 1.158E-01; UNITLESS

NAAPS Surface Concentration ($\mu\text{g}\cdot\text{m}^{-3}$)
for 12:00Z 30 Aug 2006 Dust



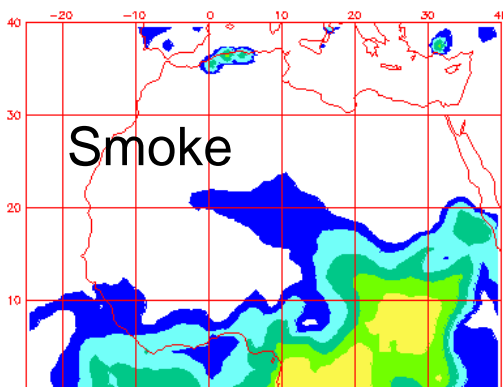
20. 40. 60. 160. 320. 640. 1280. 2580. 5120. 10240. 20480.
2.000E+01; 2.048E+04 [1.160E-25; 8.012E+03; 6.141E+01; NCRD-D/M**3

NAAPS Surface Concentration ($\mu\text{g}\cdot\text{m}^{-3}$)
for 12:00Z 30 Aug 2006 Sulfate

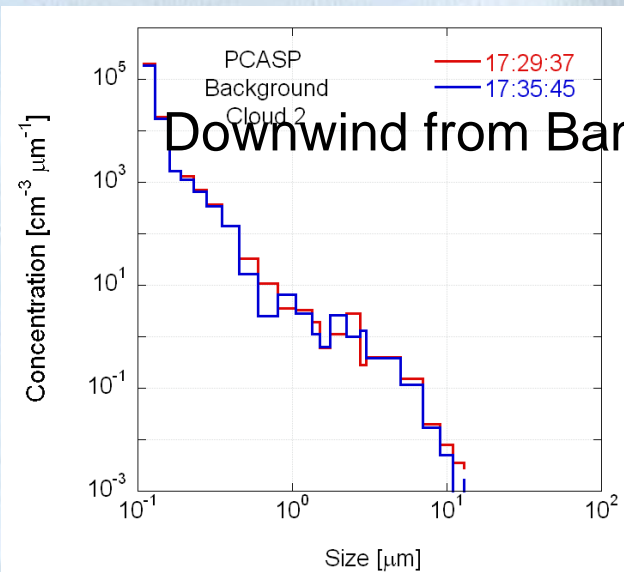


1. 2. 4. 6. 16. 32. 64. 128.
1.000E+00; 1.280E+02 [1.051E-02; 2.187E+00; 3.811E-01; NCRD-D/M**3

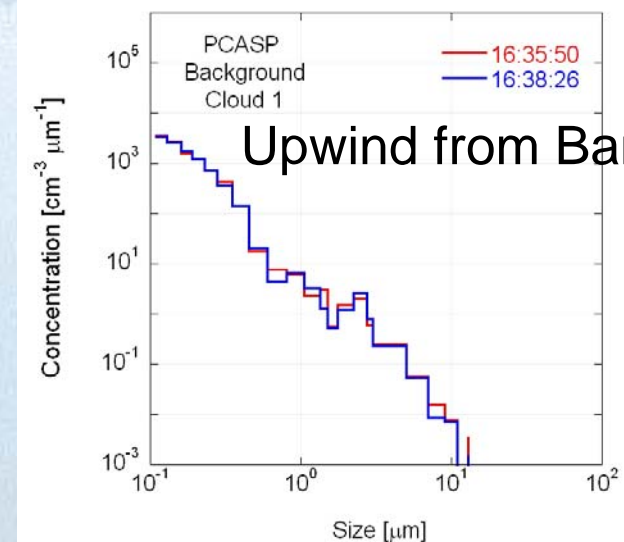
NAAPS Surface Concentration ($\mu\text{g}\cdot\text{m}^{-3}$)
for 12:00Z 30 Aug 2006 Smoke



1. 2. 4. 6. 16. 32. 64. 128.
1.000E+00; 1.280E+02 [4.753E-26; 2.550E+01; 2.188E+00; NCRD-D/M**3

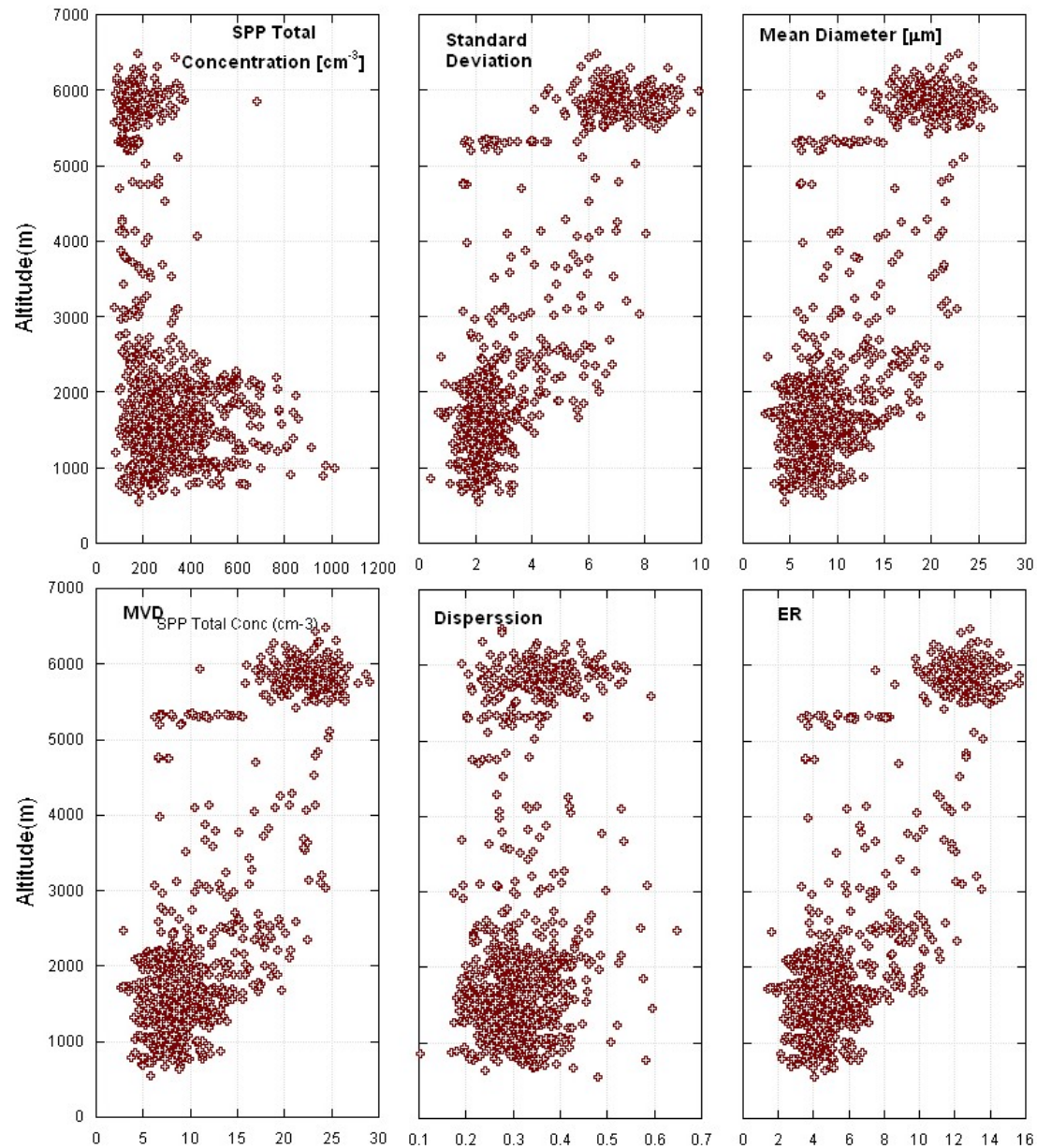


Downwind from Bamako



Upwind from Bamako

Cloud parameters



Summary



- Spatial and temporal changes in natural concentration, sizes, and chemical composition of aerosols change microphysical and precipitation processes
- Affects of anthropogenic and active seeding and may widely differ from one situation to the other.
- These effects may mask seeding effects in the evaluation of experiments unless stratified by these conditions
- New tools available to stratify these results

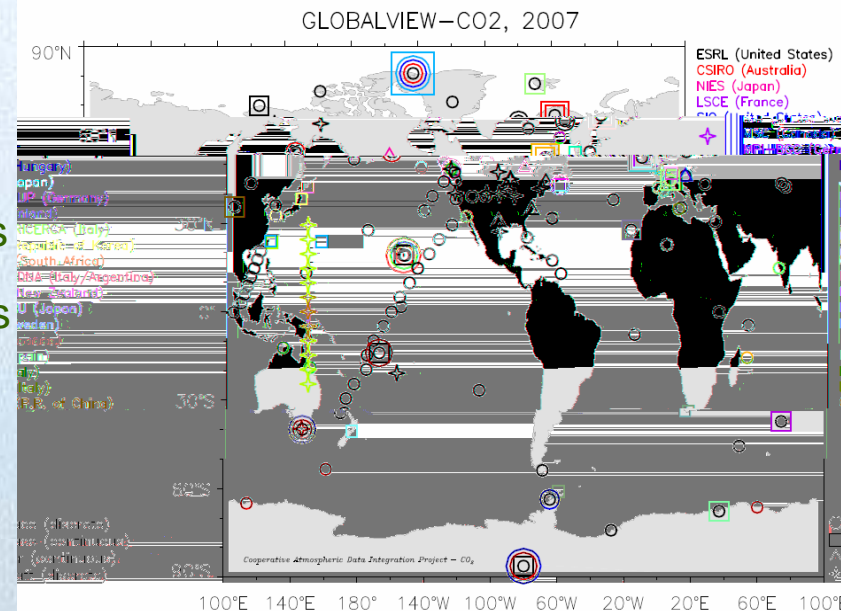
Improving regional-scale CO₂ flux estimates in Africa

NCAR

Sherri Heck, University of Colorado, sherri.heck@colorado.edu
Britt Stephens, NCAR, stephens@ucar.edu

Mt. Kenya site

- In cooperation with the University of Colorado, Kenya Meteorological Department and the University of Nairobi, Kenya
- Our CO₂ measurements will help to fill a key gap in available African CO₂ data
- CO₂ concentrations measured atop Mt. Kenya will use the AIRCOA (designed by Britt Stephens)
- Deployment in November 2007
- Estimation of regional-scale CO₂ surface fluxes will be determined using boundary layer techniques and by incorporating concentrations into inverse models
- These estimates can help improve African continental-scale and Indian Ocean fluxes





Improving regional-scale CO₂ flux estimates in Africa – Education and Outreach

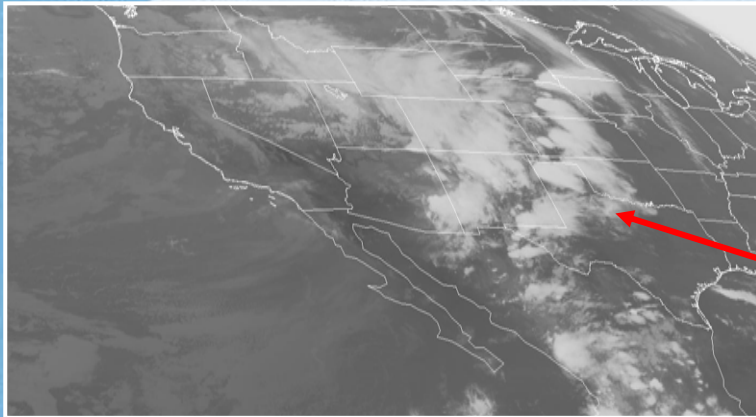
- Incorporating AIRCOA into Kenya Met Department/University of Nairobi Training Institute
- In cooperation with DLESE and Earth Exploration Toolbook, creating curriculum that utilizes CO₂ concentration data
- In conjunction with UCAR E&O and GLOBE, conducting physics and weather-related experiments in local schools and villages



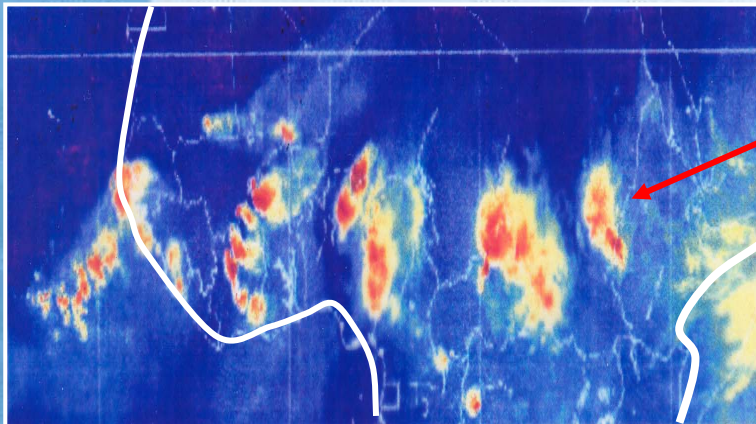
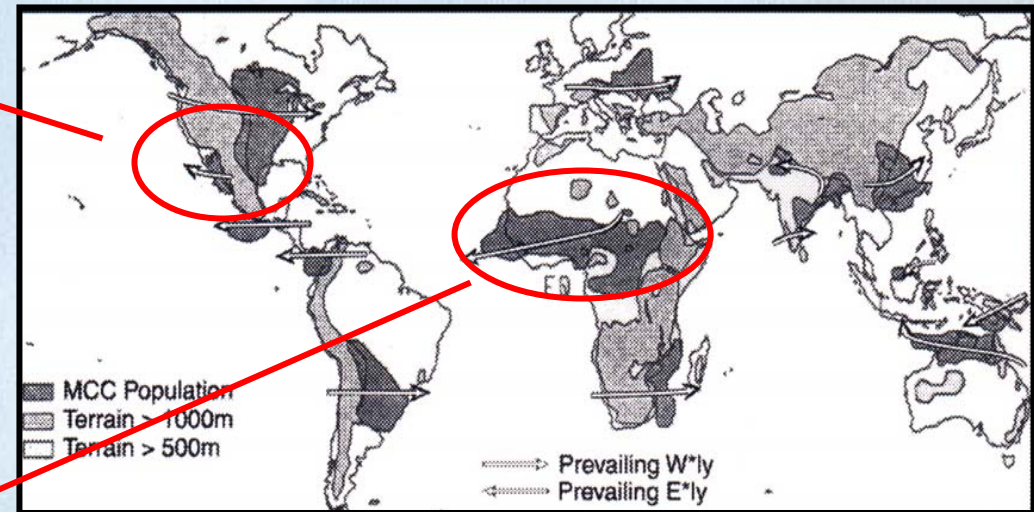
Fine-scale prediction in West Africa

- Step 1: Radar observations, Networking capabilities, and Training in radar interpretation
- Step 2: Develop real-time forecasting and downscaling capacity at NCAR; planning and training in Africa
- Step 3: Regional WRF in Africa

Global context for W. African traveling precipitating systems



Laing & Fritsch (1997)



Connecting principle: dynamics of orogenic convective systems in sheared environments

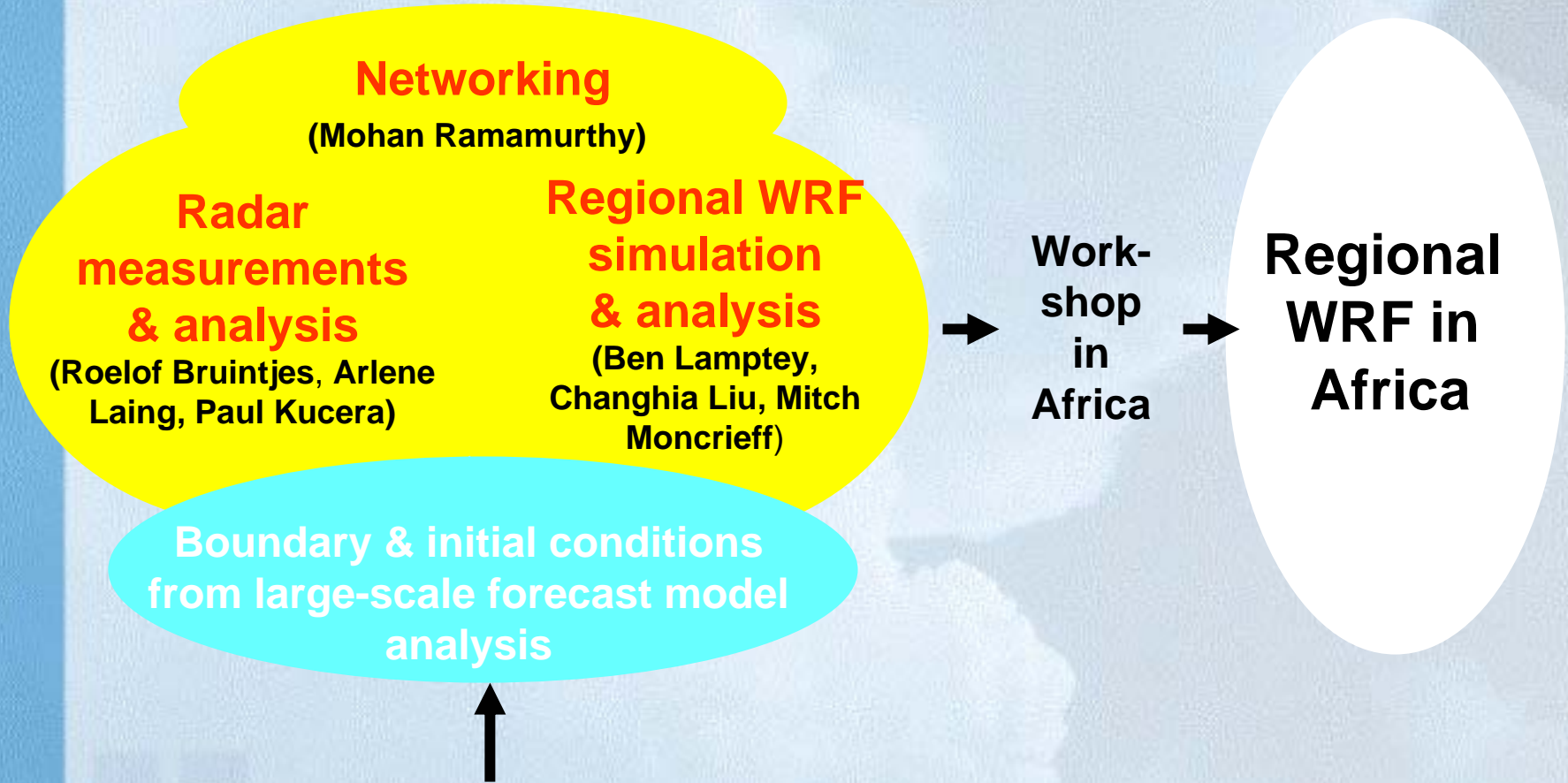
(Moncrieff & Liu 2006)

Long-term plan for the African Initiative



Research at NCAR

Application in Africa



Large-scale variability & teleconnection mechanisms

- Tropical easterly waves (~few days; AMMA Water Cycle Working Group)
- Planetary waves (week-2; THORPEX: TIGGE & Predictability & Dynamical Processes)

New integrated approach needed to study effects of aerosols on precipitation patterns



- Combined observational, modeling and theoretical approach
- Observations: Surface and in-situ, satellites and multi-parameter radar
- Models: Two-way interactive development of pollution and natural aerosol transport, chemistry, physics, cloud microphysical and precipitation processes
- Theory: Aerosol physics and chemistry and interaction with cloud and precipitation processes.

ISSUE

The world is a complicated place. Take a look outside.

Other partnerships

- National academies
- US-AID
- Gates Foundation
- U.S. State Department

The US National Academies project, the African Science Academy Development Initiative (ASADI), is about to hold its third Annual Meeting in Dakar, Senegal, from November 12-14. The Meeting's theme is Water and Health in Africa and I am attaching the most recent agenda for the meeting. This broad topic is being parsed into themes:

- **Access to Water.** This includes the provision of water for drinking, sanitation, and hygiene, and includes presentations on the engineering aspects as well as the behavioral and cultural ones.
- **Water and Diseases.** This session includes talks on infamous water-related diseases such as malaria and diarrhea, and it elevates the topic of water quality and links it with diseases.
- **Water-related disasters and catastrophes.** This session discusses primarily floods and droughts and takes a specific, case study look at the devastating floods that hit South Africa, Mozambique, and Botswana in 2000.
- **Water Resources Management and Governance.** Presentations in this session relate to water allocation, uses of water, and ways to govern the administration of water resources at the regional and national levels.

Ouagadougou dust
April 2007



Thank you

