Dynamics-Aerosol-Chemistry-Cloud Interactions in West Africa (DACCIWA) – An Introduction

Peter Knippertz & the DACCIWA Team
Outline

• **WHO is DACCIWA?**
  The 16 partners

• **WHY DACCIWA?**
  Motivation and background

• **WHAT is DACCIWA going to do?**
  Field campaign, modelling, data analysis, process understanding

• **HOW is DACCIWA organised?**
  Governance, workpackages, collaborations, timeline
Who is DACCIWA?

GERMANY
– Karlsruher Institute für Technologie (KIT)
– Deutsches Zentrum für Luft- und Raumfahrt (DLR)

UNITED KINGDOM
– University of Leeds (UNIVLEEDS)
– University of York (UoY)
– The University of Reading (UREAD)
– The University of Manchester (UNIVMAN)
– Met Office (MO)
– European Centre for Medium-Range Weather Forecasts (ECMWF)

FRANCE
– Université Paul Sabatier (UPS)
– Université Pierre et Marie Curie (UPMC)
– Université Blaise Pascale (UBP)
– Université Paris Diderot (UPD)
– Centre National de Réccherche Scientifique (CNRS) with Météo France (MF)

SWITZERLAND
– Eidgenössische Technische Hochschule Zürich (ETH Zurich)

WEST AFRICA
– Kwame Nkrumah University of Science and Technology (KNUST)
– Obafemi Awolowo University (OAU)
Why DACCIWA?
Why DACCIWA? Southern West Africa

Why DACCIWA? Background and Motivation

West Africa is a region affected by multiple stresses on food, water and health.

- Global climate change
- Land-use change
- Monsoon variability
- Population increase
- Economic growth
- Increase in anthropogenic emissions

Southern West Africa

West Africa is a region affected by multiple stresses on food, water and health due to: 

- Global climate change
- Land-use change
- Monsoon variability
- Population increase
- Economic growth
- Increase in anthropogenic emissions
Why DACCIWA? Climate Change

4° Turn Down the Heat
Climate Extremes, Regional Impacts, and the Case for Resilience

June 2013
A Report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics

THE WORLD BANK
Why DACCIWA? Change in Heat Waves

Large likelihood of unprecedented summer heat in 4° warmer world!

This is due to low natural variations in the deep tropics.

*World Bank Report, 2013*
Why DACCIWA? Aridity Change

Risk of increased aridity, even in 2° warmer world!

- Yield reduction, shift of ecosystem boundaries (also due to CO$_2$)
- Impacts on food security, poverty reduction, health, economic growth

*World Bank Report, 2013*
Why DACCIWA? Precipitation Change

Multi-model mean shows slight increase

No hatching indicates low confidence

Models struggle to realistically reproduce the West African monsoon (WAM)
Why DACCIWA? Background and Motivation

West Africa is a region affected by multiple stresses on food, water and health

- Global climate change
- Monsoon variability
- Land-use change
- Population increase / urbanisation
- Economic growth
- Increase in anthropogenic emissions

Southern West Africa

West Africa is a region affected by multiple stresses on food, water and health.
Why DACCIWA? Large decadal variability

Standardized precipitation indices

from Fink et al. 2010
Why DACCIWA? Background and Motivation

West Africa is a region affected by multiple stresses on food, water and health.

- Global climate change
- Monsoon variability
- Economic growth
- Increase in anthropogenic emissions
- Land-use change
- Population increase / urbanisation
Why DACCIWA? Population Increase & Urbanisation

Fig. I-2.1.1: Change in the fraction of rural to total population and increase in number and size of cities: (a) 1960, (b) 1990, and (c) 2020 (Source: ECOWAS-SWAC/OECD 2006).

UN 2011:
Current: 345M
+50% in next 20 yrs
Reach 743M in 2050
Why DACCIWA? Background and Motivation

West Africa is a region affected by multiple stresses on food, water and health.
Land-use Changes in Sub-Saharan Africa

- Substantial loss of biomass and biodiversity
- Shrinking forests along with expanding croplands, especially in the savannah regions of West Africa

Source: Born, IMPETUS
Why DACCIWA? Background and Motivation

West Africa is a region affected by multiple stresses on food, water and health.

- Global climate change
- Land-use change
- Monsoon variability
- Population increase / urbanisation
- Economic growth
- Increase in anthropogenic emissions

Southern West Africa
Why DACCIWA? Economic Growth

UN Economic Commission for Africa, 2010
Why DACCIWA? Background and Motivation

West Africa is a region affected by multiple stresses on food, water and health

- Global climate change
- Monsoon variability
- Economic growth
- Increase in anthropogenic emissions
- Population increase / urbanisation
- Land-use change

Southern West Africa

Land-use change
Population increase / urbanisation
Economic growth
Monsoon variability
Increase in anthropogenic emissions
Global climate change
Why DACCIWA? Air pollution

- increased emissions
- outdated technology
- intense photochemistry
- source mixing

➔ Respiratory deseases
➔ Increased cancer burden

Traffic and Domestic fire emissions: Assamoi and Lioussse 2010, Lioussse et al., 2013
Savanna fires: Lioussse et al. 2010
Dust: Marticoréna et al.
Why DACCIWA? Increase in road traffic

Figure 4 - Evolution of the number and composition of the pool motor vehicles in Burkina Faso
Why DACCIWA? Increase in emissions

Pollutants have tripled from 1950–2000 and are expected to triple again by 2030 (Lamarque et al. 2010, Liousse et al. 2013)

Figure 5 - NO₂ measurements in African capitals [Liousse and Galy-Lacaux, 2010].
(Also shown in Chapter 7 as Figure 15)
There is a need for further research on OA in order to reduce uncertainty of the role of aerosol in human health and climate.

Why DACCIWA? Secondary aerosol formation

Figure 5 - Sources of atmospheric aerosol [http://www.ems.psu.edu/~lno/Meteo437/ Figures437.html]
Why DACCIWA? Aerosols, clouds & radiation

IPCC draft, 2013
Why DACCIWA? Aerosols, clouds & radiation

Solar radiation
Terrestrial radiation
Surface-cloud couplings important for rapid-adjustments

IPCC draft, 2013
How well do we monitor this?

How well can we model this?

How well do we understand the mechanisms?
Why DACCIWA? Observational network

Networks that go beyond standard meteorological parameters are very sparse!
Why DACCIWA? Predicting the WAM

Precipitation trends from 2000 to 2050

Source: Paeth et al. 2011
Main players of the WAM: the equatorial cold tongue

New FP7 consortium PREFACE!
Main players of the WAM: the Saharan heat low

Focus of recent project FENNEC

Source: Fink et al., 2014, adapted
Main players of the WAM: Sahelian convection

Focus of AMMA programme

from Guichard/Kergoat (AMMA)
A new player? Monsoonal stratus

Meteosat RGB composite & SYNOP low-cloud cover 20 Aug. 2006

Knippertz et al. 2011
Stratus Occurrence Frequency

Source: van der Linden et al., 2014, in preparation
Difficulties to simulate low-level clouds in WAM

Mean summer (JAS) vertical profile of cloud cover IPCC models

Knippertz et al. 2011
What is DACCIWA going to do?
DACCIWA Focal Points

Concentrate on:

- **southern West Africa** (SWA; large increase in population and emissions)
- **summertime** (monsoon season, stratus and warm-rain showers)

⇒ ideal natural laboratory

- impacts on **human health in cities** directly affected by pollution increase
- impacts on **ozone concentrations downwind**, which affect health of rural population, agricultural productivity and ecosystem health
- impacts on aerosol generation and associated **modification of regional weather and climate** (clouds, precipitation, radiation, monsoon circulation)
DACCIWA Objectives in brief

1) Quantify atmospheric composition
2) Assess impact on human and ecosystem health and agricultural productivity
3) Quantify coupling between aerosols and cloud and raindrops
4) Identify controls on low-level stratiform clouds
5) Identify controls on precipitation
6) Quantify impacts on radiation and energy budgets
7) Evaluate and improve models and satellite retrievals
8) Analyse effect on West African monsoon circulation and water budget
9) Assess socio-economic implications of future changes
10) Effectively disseminate research findings and data
The DACCIWA field campaign (June–July 2015)

Base: Cotonou, Benin
The DACCIWA field campaign (June–July 2015)
The DACCIWA field campaign (June–July 2015)

Supersite Kumasi (Ghana)
Supersite Savé (Benin)
Obafemi Awolowo University
The DACCIWA field campaign (June–July 2015)

Re-activation of AMMA radiosonde stations at the Guinea Coast

after Schuster et al. 2013
Long-term monitoring: air pollution and health data

Cotonou (Dantokpa)

Abidjan (Côte d’Ivoire) with local partners
Cotonou (Benin) with local partners
Long-term monitoring of precipitation around Kumasi

Agromet (KNUST Campus)
Long-term monitoring: data digitisation

Collaboration with West African weather services:
- Nigeria
- Benin
- Ghana
- Côte d’Ivoire
Long-term monitoring: satellite data

Data from various sources will be combined to DACCIWA climatology!

DACCIWA field campaign data will be used to evaluate recently launched and future satellite retrievals (e.g., NPP, Megha-Tropiques, GPM)
**DACCIWA Modelling – Overview**

<table>
<thead>
<tr>
<th>Model</th>
<th>Run by</th>
<th>Run in</th>
<th>Period</th>
<th>Grid-spacing</th>
<th>Meteorology</th>
<th>Chemistry+aerosol species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESEARCH MODELS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCAR LES</td>
<td>UPS</td>
<td>WP1</td>
<td>IOP</td>
<td>10 m to 100m</td>
<td>Idealised</td>
<td>Just meteorology (may be possible to add chemistry)</td>
</tr>
<tr>
<td>UKMO LES</td>
<td>UNIVLEEDS</td>
<td>WP1</td>
<td>IOP</td>
<td>10m to 500m</td>
<td>Idealised</td>
<td>Just meteorology + idealised tracers aerosol and gas-phase chemistry/exposure/doses/impacts</td>
</tr>
<tr>
<td>RegCM4</td>
<td>UPS</td>
<td>WP2</td>
<td>Extended</td>
<td>1-50km</td>
<td>Regional</td>
<td>UKCA chemistry + multi-moment bulk aerosol, many runs may be online aerosol with offline chemistry</td>
</tr>
<tr>
<td>UM-UKCA</td>
<td>UNIVLEEDS</td>
<td>WP4</td>
<td>IOP</td>
<td>100m to 40km</td>
<td>Online, nested</td>
<td>Chemistry+aerosol, gases and aerosols fully interactive with radiations nd cloud physics</td>
</tr>
<tr>
<td>COSMO-ART/M7</td>
<td>KIT, ETHZ</td>
<td>WP4 &amp; 3</td>
<td>IOP</td>
<td>regional (10-50km)</td>
<td>Online, nested</td>
<td>Gas-phase and aerosols (bins resolved, anthro., bio, dust, fires)</td>
</tr>
<tr>
<td>Chimere</td>
<td>UPMC</td>
<td>WP3+4</td>
<td>Extended</td>
<td>IOP cases</td>
<td>Regional with WRF</td>
<td>Bin resolved aerosol + clouds</td>
</tr>
<tr>
<td>Bin-LES</td>
<td>UNIVLEEDS</td>
<td>WP4</td>
<td>IOP cases</td>
<td>10 m to 500m</td>
<td>Idealised</td>
<td>Bin resolved aerosol + clouds</td>
</tr>
<tr>
<td>Radiative transfer model</td>
<td>UREAD</td>
<td>WP5</td>
<td>IOP cases and Extended</td>
<td>200 m to 40 km</td>
<td>1D and 3D</td>
<td>meteorology +aerosol + cloud</td>
</tr>
<tr>
<td>Meso-NH</td>
<td>UPS</td>
<td>WP3 + 6</td>
<td>IOP cases</td>
<td>100 m to 1km</td>
<td>Online, nested</td>
<td>Chemistry + idealised tracers</td>
</tr>
<tr>
<td><strong>FORECAST MODELS</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>WRF</td>
<td>KIT</td>
<td>WP6</td>
<td>IOP cases + summer 2015</td>
<td>3 km</td>
<td>regional, self-nested, forced with ECMWF analysis</td>
<td>N/A</td>
</tr>
<tr>
<td>UM</td>
<td>UNIVLEEDS</td>
<td>WP7</td>
<td>Extended</td>
<td>regional+global</td>
<td>Global+nested</td>
<td>UKCA or none</td>
</tr>
<tr>
<td>ECMWF - MACC</td>
<td>ECMWF</td>
<td>WP7</td>
<td>Extended</td>
<td>global</td>
<td>Global</td>
<td>Aerosol and reactive gases</td>
</tr>
<tr>
<td>ECHAM</td>
<td>ETHZ</td>
<td>WP7</td>
<td>Extended</td>
<td>global</td>
<td>Global</td>
<td></td>
</tr>
<tr>
<td>Geos-Chem</td>
<td>UoY</td>
<td>WP3</td>
<td>IOP+extended</td>
<td></td>
<td>Global+regional</td>
<td>Offline, nested chem+Aerosol</td>
</tr>
<tr>
<td>UM</td>
<td>MO</td>
<td></td>
<td></td>
<td></td>
<td>Global + nested?</td>
<td>Dust</td>
</tr>
<tr>
<td>ECMWF-MACC</td>
<td>ECMWF</td>
<td></td>
<td></td>
<td></td>
<td>Global</td>
<td>Aerosol and reactive gases</td>
</tr>
</tbody>
</table>
DACCIWA Modelling – High-resolution on large domains

Cloud Number (/cm$^3$)

Aitken aerosol number mixing ratio

LWC (g/kg)

Accumulation aerosol number mixing ratio

Courtesy of Paul Field, MO
How is DACCIWA organised?
The DACCIWA Workpackages

WP 8 – Dissemination, Knowledge Transfer and Data Management

WP 2

WP 3

WP 4

WP 5

WP 6

WP 7

WP 9 & 10 – Scientific and General Management
WP1: Boundary Layer Dynamics

Leader: Norbert Kalthoff (KIT)
Participants: KIT, UNIVLEEDS, UPS, OAU, KNUST

Main Tasks and Deliverables
- Plan, install and operate ground sites
- Postprocess data
- Large-Eddy simulations
- Model evaluation
- Conceptual model development
WP2: Air Pollution and Health

Leader: Cathy Lioussse (UPS)
Participants: UPS, UoY, UPMC, UPD
+ University Houphouët Boigny, Abidjan, University of Cotonou

Main Tasks and Deliverables
- Emission inventories and scenarios (traffic, domestic …)
- Air pollution and health modelling
- Long-term measurements
- Census of respiratory diseases (epidemiology)
- Toxicological effect of combustion aerosol
- Inflammation risk maps

Lioussse et al., 2013
WP3: Atmospheric Chemistry

Leader: Celine Mari (UPS)
Participants: UPS, UoY, ECMWF, KIT, ETHZ, UPMC, UNIVMAN

Main Tasks and Deliverables
- Plan, install and operate field campaign
- Multi-scale modelling (LES-global)
- Modell assessment and validation
- Synthesis of field measurements
- Impacts on radiation
- Impacts on public health and ecosystems
- Future scenarios

Focus on short-lived pollutants: ozone and aerosols
Contrast emissions (anthropogenic, biogenic, biomass burning, ship plume, ...)

Equations 1.5 show the simplest pathway, the formation of O\(_3\) during the oxidation of CO. In addition, ozone and its precursors from large urban areas can be transported on hemispheric scales in the free troposphere and increase background levels of surface ozone such that the hemispheric transport may offset local mitigation strategies to reduce ozone levels [Jacob and Winner, 2009]. To fully understand the tropospheric O\(_3\) budget, a quantitative understanding of the identity and sources of its precursors, the numerous chemical reactions that constitute the atmospheric VOC oxidation processes, and transport processes that control background ozone and its precursor levels as well as stratospheric/tropospheric exchange must be incorporated into atmospheric models. Finally, tropospheric ozone is also a radiatively active trace gas, and thus impacts climate at regional and global scales.

Figure 4 - Physical and chemical processes affecting tropospheric ozone
[http://www.globalchange.umich.edu/gcte/Inquiries/Inquiries_by_Unit/Unit_9.htm]
WP4: Cloud-Aerosol Interactions

Leader: Hugh Coe (UNIVMAN)
Participants: UNIVMAN, UNIVLEEDS, KIT, DLR, UPMC, UBP, MO, ECMWF, ETHZ, CNRS

Main Tasks and Deliverables
- Plan, install and operate field campaign
- Evaluate existing models
- Synthesis of field measurements
- Process model studies
- Regional modelling

ACPM (Aerosol-Cloud-Precipitation Interactions Model) Manchester:

Process driven studies: ACPIM trajectory model

ADDEM: detailed aerosol thermodynamics

Coupled gas phase-aerosol scheme, considering activation.

Growth of precipitation mass-bins using moving centre grid

Growth of variable habit ice mass-bins using moving centre grid
WP5: Radiative Processes

Leader: Christine Chiu (UREAD)
Participants: UREAD, ECMWF, MO

Main Tasks and Deliverables
- Multi-satellite climatology
- Retrievals from field campaign data
- Evaluate current and future satellite products
- Aerosol and cloud radiative effects
- Model evaluation

Better estimates of aerosol and cloud radiative effects from combined DACCIWA and satellite obs.

courtesy of NASA
WP6: Precipitation Processes

Leader: Andreas Fink (KIT)
Participants: KIT, UNIVLEEDS, UPS, KNUST, OAU, UNIVMAN

Main Tasks and Deliverables
- Radiosonde campaign
- Rainfall types
- Role of land-sea breeze
- Monsoon-season climatology
- Case studies
- Model assessment of warm rain
- Evaluation of satellite rainfall products

Interaction between westward propagating Mesoscale Convective Systems (MCS), land-sea breeze and polluted coastal air not well understood

Source: SAFNWC/van der Linden/Fink
WP7: Monsoon Processes
Leader: Peter Knippertz (KIT)
Participants: KIT, ECMWF, ETHZ, KNUST, OAU, MO

Main Tasks and Deliverables
- Digitisation of station data
- Forecasts for field campaign
- Forecast evaluation
- Model evaluation
- Sensitivity experiments
- Scenario simulations

Mean summer (JJA) solar irradiance from satellite and ground stations (top) and CMIP3 models (bottom) (from Knippertz et al. 2011)
WP8: Dissemination, Knowledge Transfer & Data Management

Leader: Mat Evans (UoY)
Participants: UoY, KIT & all others

Main Tasks and Deliverables
- Website, newsletter, content
- Media communication, press releases
- Overview article
- Special sessions
- Special issue
- Stakeholder database
- Policy briefs
- Workshops
- Education
- Technical reports
WP9: Scientific Management
WP10: General Management

Leader: Peter Knippertz (KIT)
Project Manager: Roswitha Marioth (KIT)

Main Tasks and Deliverables
- Activity management
- Exchange with scientific partners
- Meeting organisation
- Internal communication (Share point)
- Financial management
- Legal management
- Reporting
- Gender equality
DACCIWA Technical Coordinators

Purpose
• Facilitate the flow of information and interactions between WPs
• Coordinate logistical, technical and data-management requirements

Areas
• Supersite Ghana: Barbara Brooks (UNIVLEEDS)
• Supersite Benin: Fabienne Lohou (UPS)
• Aircraft campaign: Cyrille Flamant (UPMC)
• Satellite data: Richard Alllan (UREAD)
• Modelling: John Marsham (UNIVLEEDS)
DACCIWA Advisory Board

Related international programs
• Peter Lamb (designated chair) – Sahel Cloud-Aerosol-Radiation Interaction Campaign (SCARIC)
• Serge Janicot – African Monsoon Multiscale Analysis (AMMA)
• Ulrike Lohmann (BACCHUS)
• Markus Rex (StratoClim)

Policy
• Georges Kouadio – Ministry of Environment, Health and Sustainable Development (Ivory Coast)
• TBD

Satellite
• Christina Hsu – Suomi-NPP
• Walt Petersen – Global Precipitation Measurement (GPM)

Modelling
• Leo Donner – Geophysical Fluid Dynamics Laboratory (GFDL)
• Sarah Jones – German Weather Service (DWD) (?)
Other International Collaborators

**European collaborators**
- West African Science Service Center on Climate Change and Adapted Land Use (WASCAL)
- African Climate Exchange (AfClix)
- Institut de recherche pour le développement (IRD)

**African collaborators**
- Direction de la Météorologie Nationale (Cote d’Ivoire)
- Ghana Meteorological Agency (Ghana)
- Direction Nationale de la Météorologie (Benin)
- Nigerian Meteorological Agency (Nigeria)
- AMMANET
- Université d’Abomey-Calavi (Benin)
- Pasteur Institute (Ivory Coast)
- Centre Suisse de Recherches Scientifiques en Côte d’Ivoire (CSRS)
- Ministry of Higher Education and Scientific Research (Ivory Coast)
Other International Collaborators

**Remote Sensing**
- Satellite Application Facility on Climate Monitoring (CM-SAF)
- University of Wisconsin (CloudSat group)
- Baseline Surface Radiation Network (BSRN)
- NASA Langley (CALIPSO group)

**Modelling**
- National Center for Atmospheric Research (NCAR)
- Pacific Northwest National Laboratory (PNNL)
- NASA Goddard Institute for Space Science (GISS)
THANK YOU!