CZO perspective in Central Africa: Ogooué River basin, Gabon

MAP = 2500 mm/yr
MAT = 26 °C
%humidity > 80%

- Silicated shield and Mesozoic terrains
- Thick regolith extremely weathered, ancient, comparable to a relatively large fraction of the Earth’s surface not yet represented in the CZO networks or sites
- Pristine watershed in fast mutation with a conservation policy
- Continuous hydro-climatic time-series 1953-1974 (20 stations monitored by ORSTOM/IRD)
Short to mid-term objectives

* **Water cycle**: Pilot hydro-climatic station at Oyem on Ogooué; combining high frequency in situ parameters with multisatellite data,

* **Biogeochemical cycles**: Set up a small experimental watershed in the LNP (carbon fluxes, nutriments, GHG emissions,…)

* **Weathering/erosion**: saprolite production versus soil breakdown; $\partial^7\text{Li}$, CRN, contemporary biogeochemical fluxes, …

* **Biosphere and forest dynamics**: Lidar, multisatellite data, …

* **Ecological functions and ecosystem services**
Kruger National Park, South Africa
Presented by Oliver Chadwick, UC Santa Barbara

Possible CZO building on existing research in:

- Geomorphology
- Surface and Groundwater Hydrology
- Lithologic Control on Ecosystem Ecology
- Savanna Response to Herbivores and Fire
- Animal – Plant and Animal – Animal Interactions
- Contrast with nearby Human Land use
Existing Kruger Infrastructure

SANParks Facilities
4 Designated “Research Supersites”
2 on Basalt, 2 on Granite - Paired by Rainfall
Groundwater Drilling
Soil and Vegetation Maps
High Resolution Lidar and other RS data
Controlled Fire Experiments
Long history of base-line data collection

Potentially Interested Partners
- SANParks
- SAEON (South African Environmental Observation Network)
- University of Cape Town
- University of Witwatersrand
- Max Planck Institute for Biogeochemistry
- UC Santa Barbara
- University of Oregon
- Arizona State University
(many others)

No Obvious Funding Source
What?
A multi-scale, regional observation system dedicated to long-term monitoring of water cycle, vegetation dynamics and their interactions with climate and resources in West Africa.

Why?
Global change → observations over the region are needed to:
• Understand the eco-hydrological main processes
• Improve Earth System Models,
• Detect trends and assess their impacts on living conditions

Who?
A team of 50 researchers and technicians in 4 countries (France, Mali, Niger, Benin) since 1990.
Member of RBV and e-LTER network

To know more: http://www.amma-catch.org

Rainfall anomaly 1950 to 2005
(Ali et Lebel 2009)
Observation strategy

\[ \rightarrow \text{Sample the \textbf{eco-climatic gradient}} \]

**MALI**
- Rainfall: 200 - 400 mm/year
- Pastoral land use

**BENIN**
- Rainfall: 1200-1300 mm/year
- Various crops (sorghum, yam...) and clear forest

**NIGER**
- Rainfall: 450-600 mm/year
- Pastoral use and crop (millet)

Critical zone Frontier Research Laboratory (CFRL)

• Principal Investigator: Dr. Jin-Yong LEE
• Investigators: Dr. Kideok KWON, Dr. Jung-Shin LEE, Dr. Kyoung-nam JO
• Today Speaker: Dr. Kyoung-nam JO

1Department of Geology, Kangwon National University
2Department of Molecular Bioscience, Kangwon National University
Research Scheme

Past
- Long term CZ responses to climate changes in the geologic past
- Changes in surficial & sub-surficial environments

Present
- CZ processes and dynamics in the present time
- Air - water - minerals - microbes interactions
  - Molecular Biology
  - Hydrogeology
  - Nano Mineralogy

Future changes?
- Fund: National Research Foundation (2.5 million USD/4.5 years)
- Launch: Sept., 2015
Themes & Topics

**Theme 1: Examining CZ changes and paleoclimatic condition**

**Topic 1:** The material transfer among precipitation, groundwater, and speleothem
- *natural laboratories of limestone caves* & meteoric stations

**Topic 2:** Reconstructing *paleo-CZ conditions*

**Topic 3:** Growth mechanisms of carbonate minerals in the CZ and cave environments

**Topic 4:** Paleo-biodiversity and climate conditions
- examining biodiversity in the past using metagenome analysis

**Theme 2: Examining present CZ changes**

**Topic 1:** Changes in *soil zone and groundwater* responding to precipitation patterns

**Topic 2:** *Exchanges of water & materials* and its effect in the GW-SW interface

**Topic 3:** Mineral reactivity in the hyporheic zone

**Topic 4:** Microbial diversity and activity change in the hyporheic zone

- **CZO design** -
  - Limestone and karst area
    - Undisturbed
    - Temperate

- **CZO design** -
  - Metamorphic rocks and punch bowl
    - Agricultural activities
    - Temperate
CZO perspective in the Western Ghats

**Aghnashini**
- Max Altitude 579m
- Mean Annual Precipitation - 5500mm (govt. sources)
  - 6457 mm (raingauges)
- Geology - belong to the Dharwar System, containing metamorphic rocks, considered one of the oldest in India
- Clayey-skeletal, kaolinitic – moderately deep well drained gravelly clay soil

**Nilgiris**
- Max Altitude 2600m
- Mean Annual Precipitation - 2390mm (govt. Sources)
  - 2807mm (raingauges)
- Composed of pre-Cambrian, mainly metamorphic rocks (gneisses, charnockites)
- Alfisols – fine mixed rhodic Paleudalfs - deep well drained clayey soil
Understand the spatial and temporal dimensions of ERE in the Western Ghats (WG) and relation to spatial patterns of land-cover and land-use.

- Time Frequency Plots from Wavelet Analysis; ground rainfall observations from tipping bucket rain gauges compared to the meteorological measures derived from satellite platforms

Determine the hydrologic and carbon dynamics consequences of existing land-cover and land-use including large scale forestation in the WG.

- Work linking response of extreme rainfall events with water quality dynamics

Assess the hydrologic and carbon vulnerability of ecosystems, natural, semi-natural and agro-ecosystems, to ERE at various spatial scales.

To prioritise sites in the WG for restoration under Green India Mission
Tochigi Site

Nested field observation

5m Contour based topographic partitioning
Climate station

Gauging station

K2-1
K2-2
K2-3
K2-4

Stream temp. was measured by Tidbit and TruTrack logger

Pre-thinning
Post-thinning

Increases stream flow
Mitigating stream temp changes

Perennial Channel
Headwater spring

30m bedrock well
Weathered sedimentary rock

Less groundwater contribution
Gaining groundwater infiltration

K2-1
K2-2
K2-3
K2-4

Relative height (m)
Relative distance (m)
Fukushima prefecture
Fukushima Dai-ichi Nuclear Power Plant

Iboriishi catchment
Stream water, Soil water, Groundwater

Ishidaira catchment
Stream water

Kotaishi catchment
Stream water, Soil water, Groundwater

Setohachi catchment
Stream water, Soil water, Groundwater

Cs-137 deposition (Bq/m²)

Photo 1 Sampling location of stream water in Kotaishi yama
Turkey offers climo-, litho-, biota-, chrono-, and anthro-sequences
Millennial-scale human-forcing with both a written and geologic history

Cappadocia, Turkey

Lake Iznik basin recent land use change

Agriculture: 1995 32% → 2013 47%
Urban: 1995 2% → 2013 5%
CZO-like acOviOes are ongoing in Turkey.
Institutes and Agencies in Turkey to coordinate CZO network

* Many others but no room to fit on to map.
The Qiantang-Hangzhou Coastal-Megacity Critical Zone Observatory: Science to underpin the Zhejiang Five Waters Program

Chen Zhu
Indiana University, USA
Zhejiang University, China

Michael Ellis
Director, Climate and Landscape Change
British Geological Survey
Coastal megacities: why choose this environment?

- Coastal megacities represent 80% GDP increase 2010-25, an environment particularly vulnerable because of climate change, urbanization, and intense human perturbation; yet not a CZO established in this type of environment.
- Strong policy driver: Zhejiang provincial government declares that water resources is the limit of economic sustainability and launched a 74 billion Yuan “five water” campaign.
  - Stop waste water discharge into rivers, streams, and lake waters;
  - Prevent flood (water) and improve forecast;
  - Upgrade the drainage water management
  - Secure potable water, including building backup resources;
  - Improve water use efficiency
- Long-term observational data available and an observational network
- Historic data available and cultural heritage to protect

Objective:
To develop an ability to assess the status and trajectory of freshwater ecosystem quality as mediated by organic and inorganic contaminants and macronutrients, and as signaled through holistic measures of toxicity and quality (e.g. via genetic mutations to Daphnia, status of lower trophic microfauna, biotoxicity).
UWA CZO - Avon River Catchment

Jason Beringer, Matthias Leopold and Deirdre Gleeson.
Main Range CZO, 
Australia

- MAT: 14.5 °C
- MAP: 1350 mm
- Elevation 1100 m
- Cool subtropical climate
- Dominant lithologies: basalts and shales
- Headwaters of catchment divide
- Sharp rainforest – open eucalypt forest ecotone
Research focus areas:

- Weathering and erosion rates on basalts, shales
- Impact of headwater biogeochemical processes on downstream water quality and quantity
- Factors controlling ecotone, sensitivity to climate and land use change
- Environmental drivers of microbial community structure and function, impacts on weathering
High resolution measurement infrastructure at Finse Alpine Research Center: LATICE-FLUX

Contact:
John F. Burkhart
Department of Geosciences, University of Oslo, Norway
john.burkhart@geo.uio.no

Practical details:
http://finse.uio.no
&
http://goo.gl/IPiKSU (INTERACT)
High resolution measurement infrastructure at Finse: LATICE-FLUX

• Flux/Climate Tower
  - Purchase equipment 2015/2016 winter
    * Met Norway Climate Reference Station (see right)
    * LATICE-FLUX adds eddy-covariance system
  - Installation Summer 2016

• WSN for snow observation

• Future: clouds, ecosystems, C-flux

- Wind in 10 m: GILL or Vaisala sonic wind sensor with at least 150 W heating power.
- Air temperature: Pt_100 element in MET screen in 2 and 8/10 m.
- Air Humidity; Vaisala HMP155 in MET screen in 2 m.
- Total radiation instrument: CNR4 in approx 4-5 m high (near eddy-cov instrument high).
- Ground surface temperature; IR sensor in approx 4-5 m high (e.g. Campbell SI-111).
- Snow depth sensor; Laser type HMS30 from LUFFT; in ab 5 m high (measure direction free with angle between 15 to 45 deg).
- Ground soil or rock temperature; Pt_100 element just below the surface; 2-5 cm deep depending on the surface consistency
- Precipitation amount sensor; Geonor weight sensor.
- Precipitation detector; Thies optical Yes/No sensor.
UK Capacity

Wide array of observing and research platforms linking atmospheric, terrestrial, freshwater and coastal science. Measurements across spatial and temporal scales - but most do not include the range of parameters both to depth and across scale a CZO requires.

Some such as CEH make available to wider UK and international community for fundamental and applied research to meet societal and economic benefit. Results used to test conceptual understanding & future resilience using a suite of models.

CEH has ca. 180 research platforms / observatories and an array of specialised and integrated national surveys across the UK. CEH ensure data, models and tools are made available in standardised & useable formats. These contribute to:

- national surveillance of environmental change;
- improved process understanding and model development;
- solving solutions for pressing environmental challenges.
- Inspire data compliant portals and modelling platforms

Many are part of UK or international networks (e.g. ECN, LTER, EMEP, EXPEER) which focus on different science questions and/or societal challenges.
CEH CZO possibilities

**Plynlimon (20km²): forestry**
- Marginal sensitive upland system
- Established in 1968 by CEH as a paired catchment experiment
- The first catchment-scale testing of effects of land use (forestry) on water budget
- 350 papers + books (5 Nature papers)

**Hillesden (10km²): arable**
- Commercial-heavy arable farm of 1000ha growing autumn-sown crops
- 15 x 50-60ha ‘farmlets’ = three treatments replicated 5 times
- 10 years of data collection covering crop, soil, water and species

**Conwy (520 km²) – Coastal**
- Sea level to 1000 m
- Rainfall 500-3500 mm
- Studies focussed in 5 sub-catchments (peatland, intensive and extensive farming, forestry)

**London and the Thames Valley (5,700 km²): Urban**
- Air quality, fluxes and source apportionment
- River quality
- Groundwater
- Flood and drought modelling
A source-to-sink CZO aimed at a human-dominated coastal-estuarine megacity and its catchment.

Builds on previously developed but isolated observatories

First 5-year focus is on water and air quality, mediated by the human-process
London – Thames (coastal megacity) CZO

Using the river to integrate both lateral and vertical dimensions of the critical zone

Complex land-use, policies (& history) mediates sediment and macronutrient flux

Airborne particulates and gases contribute to water and air quality

floodplain with urbanization (water management), legacy toxins, plastics, et al in sediments.

Complex sources, transport

Groundwater (at many levels, time-scales) contributes to river discharge, transports and mediates macronutrients et al

transient sink, remobilization

International parallel (and partner)

Chen Zhu (Indiana & Zhejiang)
The Krycklan/Svartberget Infrastructure

1. Water

Surface water monitoring

Lake-stream experimental area

Riparian observatory

Groundwater monitoring
2. Atmosphere

- ICOS Integrated Carbon Observation Systems
- 150 m tower with gradient system for water and CO2
- Eddy flux systems (20 m and 70 m)
- Many additional measurements

3. Forest

Forest/soil inventory

Forest development

Krycklan Needs You!

Data freely available at www.slu.se/Krycklan

Contact:
Hjalmar.Laudon@slu.se
Collaborative Research Center AquaDiva

- 13 research projects (23 PIs) with a common scientific question and shared infrastructure
- 12 year timeline
- Central measurements and data management system
- Graduate school
- Started October 2013
The Hainich Critical Zone Exploratory

- calcareous, highly fractured rock

HTU (Upper aquifer) is nearly anoxic
HTL (Lower aquifer) has higher O₂ levels

Forest  Meadow/Pasture  Agriculture
TUM Critical Zone Observatory

http://www.czo.wzw.tum.de/

**Ammer Catchment (S’ Munich)**
- Northern Limestone Alps (Flysch) and forelands
- alpine and pre-alpine area, glaciated during Ice Age
- 2,200-530 m a.s.l., 2,000-1,100 mm/a, M.A.T. 4-8° C
- high energy system
- sensitive climate system
- transhumance, grassland, arable farming, forest

**Otter Cr. Catchment (NNE’ Munich)**
- Bavarian Forest, crystalline setting (Granite, Gneiss)
- mid mountainous area, non-glaciated during Ice Age
- 350-700 m a.s.l., 800 mm/a, M.A.T. 7° C
- low energy system
- robust climate system
- arable farming, forest
Instrumentation

- Geophysics (ERT, GPR, SSR)
- Frequency Domain Reflectometry (FDR-probes)
- XRF, XRD field and lab based
- Numerical Age Dating (OSL) by NLLD Risoe, Denmark
- LIDAR and Remote Sensing
- NanoSIMS, gas chromat. etc.
- Eddy Covariance, Tunable Diode Laser, Closed Chamber

Major Science Questions

- 3D volumetric architecture of CZ, water pathways, slope water fluxes and storage, soil structure
- Physics and geochemistry of slope deposits as main factors for holocene soil genesis etc.
- Sink and source of land-use derived carbonatic sediments in slopes and floodplains
- SOC development under land use and climate change
- coupled C and N cycles between pedo-, bio- and atmosphere (CO₂, CH₄, N₂O, water vapour)
Santa Clotilde watershed, Southern Spain

Tom Vanwalleghem
Department of Agronomy, University of Cordoba, Spain
(ag2vavat@uco.es)

María P González-Dugo, Karl Vanderlinden
IFAPA, Junta de Andalucia, Spain
Environmental setting: Santa Clotilde watershed

Map of current CZOs and related sites (czo.org)

Santa Clotilde “pre-CZO”
- granite area
- 740 - 660 m a.s.l.
- Mediterranean climate
- semi-natural “dehesa”
- $T_{\text{mean}}$ 12.5-15 °C
- $P_{\text{mean}}$ 600-800 mm
- $A = 6.9$ and 41.0 km²
Instrumentation and science foci

Quantification of soil formation and weathering
- soil pits (n=10)
- full chemical weathering mass balance
- OSL: bioturbation + erosion

Spatial soil variability
- augerings (n=67) and geophysical methods
- tomography + corings

Oak savanna water, carbon and surface energy flux monitoring
- eddy flux tower (n=2)
- remote sensing

Soil moisture dynamics
- wireless soil moisture sensor network (n=2 → n=10)
- piezometers

Streamflow hydrology and chemistry
- flow gauges (n=2)
- automated sampler + analyzer

Test bank soil landscape models
- MILES2 (Vanwalleghem et al. 2013)
- LORICA (Temme and Vanwalleghem 2015)
- Soilgen (Finke et al. 2008)
- SSSPAM (Willgoose et al.)
CZO Mezquital Valley
Central Mexico

Chrisna Siebe and Blanca Prado
siebe@unam.mx/ bprado@geologia.unam.mx
Objective: to evaluate environmental effects of long-term (> century) waste water irrigation

- Semiarid climate (400-700 mm/ 18 °C)
- >90,000 ha irrigated with 52 m³/s:
  - 40 m³ s⁻¹ untreated sewage + 12 m³ s⁻¹ surface run-off
- Main crops: Maize (450000 t/year) and alfalfa (900000 t/year)
- Irrigation has led to an aquifer recharge of 6 m³ s⁻¹; this water is chlorinated and used for water supply of 500,000 inhabitants of the valley.
“Long term experiment”

1. Repeated sampling (1990 and 2009) of 21 to 24 fields irrigated for different lengths of time (4, 8, 16, 30, 65 and 80 years, i.e. soil chronosequence) with untreated waste water. And sampling of rain-fed maize fields, and natural vegetation (xerophytic shrubland).

**Soil proper<es**
- Soil organic matter
- Nutrients
- Heavy metals
- Emerging pollutants

**Crop quality:**
- Total biomass
- Nutrient contents
- Heavy metal take-up

**Sampling:**
1 soil profile (horizon samples)
4 composite samples: Soil: 0-30 cm; alfalfa, maize (corn)
2. Monitoring of selected irrigation events to follow:

- leaching into groundwater
- greenhouse gas emissions

Instrumentation of selected fields within a piedmont:

Along the piedmont:
- Deep piezometers (30 m)
- Medium depth piezometers (4-5 m)
- Observation wells (1.2 m)

Soil sensu stricto:
- Gypsum blocks, TDR probes, Pt electrodes,
- Sucoron cup lysimeters, Stac chambers
KONZA Prairie: Elucidating the impact of land cover and climate change on the evolution of the karst Critical Zone

PL Sullivan¹, P Kempton², GL Macpherson¹, M Kirk², N Brunsell¹, J Nippert², WK Dodds², J Blair²

¹ University of Kansas, Lawrence, KS
² Kansas State University, Manhattan, KS

KONZA is underlain by epikarst

60 Watersheds with different burning and grazing regimes

Woody Encroachment

<table>
<thead>
<tr>
<th>Year</th>
<th># of Fires</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>30</td>
<td>42 ha</td>
</tr>
<tr>
<td>2011</td>
<td>9</td>
<td>55 ha</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>24 ha</td>
</tr>
</tbody>
</table>

MAP = 835 mm
MAT = 12.5 °C

(Updated Briggs et al. 2005)
How is the Karst Critical Zone architecture responding to land cover and climatic changes?

Woody encroachment shifts system from C neutral to C sink

C₄ Grass (A. gerardii)

C₃ Shrubs (C. americanus)

Groundwater pCO₂ is increasing at faster rate than atmospheric pCO₂

(Woody Encroachment (4 yr Burn )
Grassland (Annual Burn)
(Logan and Brunsell 2015)

Woody plants rely on deeper water

(Nippert & Knapp 2007)
Fast kinetic reaction rates of carbonates combined with changes in land surface—atmospheric interactions can govern the evolution of the Karst Critical Zone.

Enhanced ET but similar P will alter ET:P

Warmer air temperature but more winter precipitation

Decline in soil moisture by the end of century

The vast infrastructure at KONZA makes CZ research possible
Shared Research Strategy (www.ars.usda.gov/)

Four Priority Areas of Concern

1) Agro-ecosystem Productivity;
2) Climate Variability and Change;
3) Conservation and Environmental Quality;
4) Socio-economic Viability and Opportunities.

Four Key Products

1) New knowledge of processes & systems;
2) New technologies & management practices;
3) Improved agro-ecological models;
4) Comprehensive, accessible data.

“...to sustain a land-based infrastructure for research, education, and outreach that enable understating and forecasting of our capacity to provide agricultural Goods and services under changing conditions.
Long Term Agro-Ecosystem Research Network

All occurs in the Critical Zone
Complimentary on Managed Lands
Long term focus
Common Experiment
Example of RCCZO/LTAR
Core sites
University of Cuenca, Páramo CZO

Páramo, Critical Andean Ecosystem

- Páramo Vegetation
  - High elevation
    - Upper forest line (3500 m) to snow line (5000 m)
- Extensive portions of 5 countries
- High Quality Water Supply
- Large Stores of carbon
- Currently under stress
  - Population
  - Alternative uses
  - Climate change
University of Cuenca, Páramo CZO

*Ongoing Long-term Research Site*

- Active Research Program
  - Long-term runoff, rainfall, soil water, meteorology/ET, isotopes
  - Recent additions of weather radar and eddy covariance
- Active collaboration
  - University of Marburg, Germany
  - Long standing work with Belgium
- Strong governmental support from the Ecuadorian government
- Potential extensions
  - Other paramo sites
  - Elevational gradient in two directions
- PhD program at Cuenca
- Support from Ecuador and Germany
- International collaboration
- Chapman Conference
Potential CZO: Pampas, Argentina
San Claudio Estancia
Ecohydrology. Biomanipulation of water and salt fluxes in a changing landscape.  
(Esteban Jobbagy, Marcelo Nosseto, Steve Loheide, Sam Zipper)

Biogeochemistry. C, N cycling. Atmospheric deposition. GHG emissions.  
(Gervasio Piñeiro, Tomas Della Chiesa, Danilo Carnelos, Laura Yadhjian)

Biodiversity and plant species interactions. Biological invasions.  
(Marina Omacini, Pedro Tognetti, Enrique Chaneton)

Institutions:  
Faculty of Agronomy, University of Buenos Aires-CONICET  
Environmental Studies, IMASL, Universidad Nacional de San Luis  
Civil and Environmental Engineering, University of Wisconsin - Madison
Bahía de Caráquez, Ecuador

Tropical Dry Forest