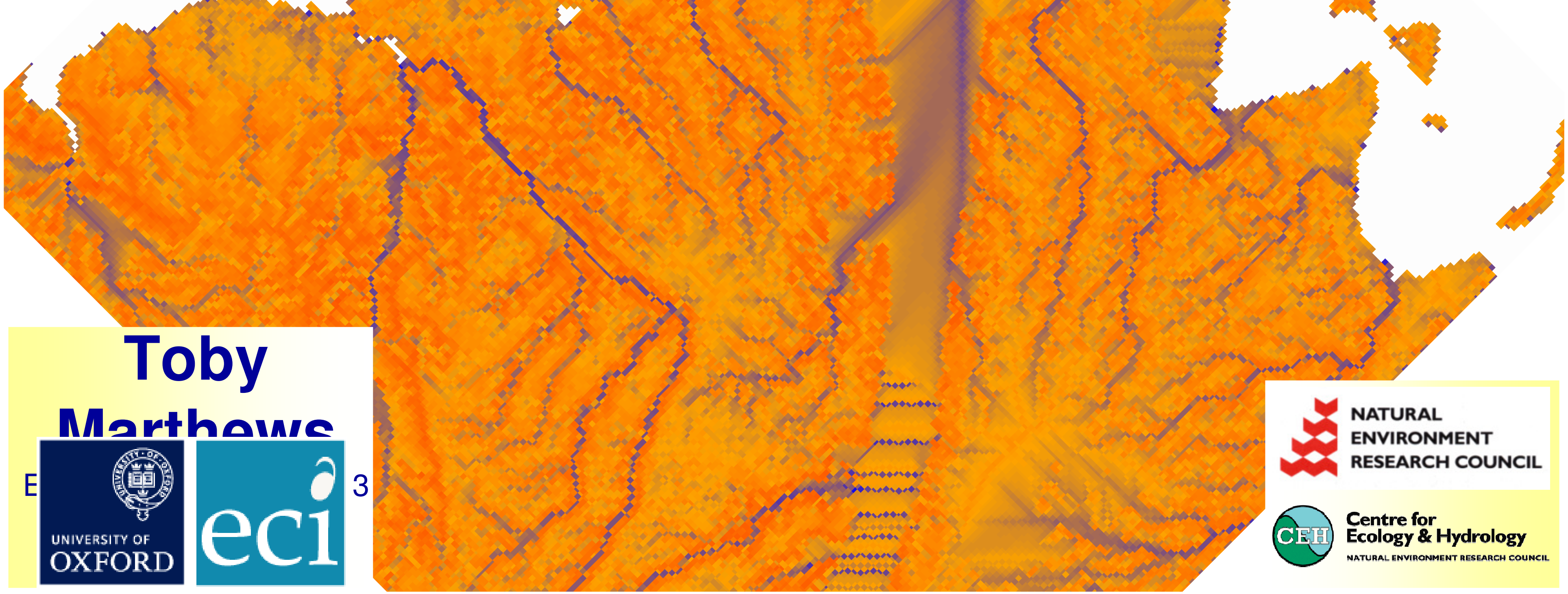
The TOPMODEL Topographic Index In *JULES*

Toby Marthews and Simon Dadson

Part of the NERC project:

Changing Land-Atmosphere Feedbacks in Tropical African Wetlands,

http://www.geog.ox.ac.uk/research/landscape/projects/africanwetlands.html



Toby Marthews

University of Oxford

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Research: Landscape Dynamics: Research Projects

Changing Land-Atmosphere Feedbacks in T
Wetlands

Proposed Research

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and climate. We will do this by implementing a dynamic wetla
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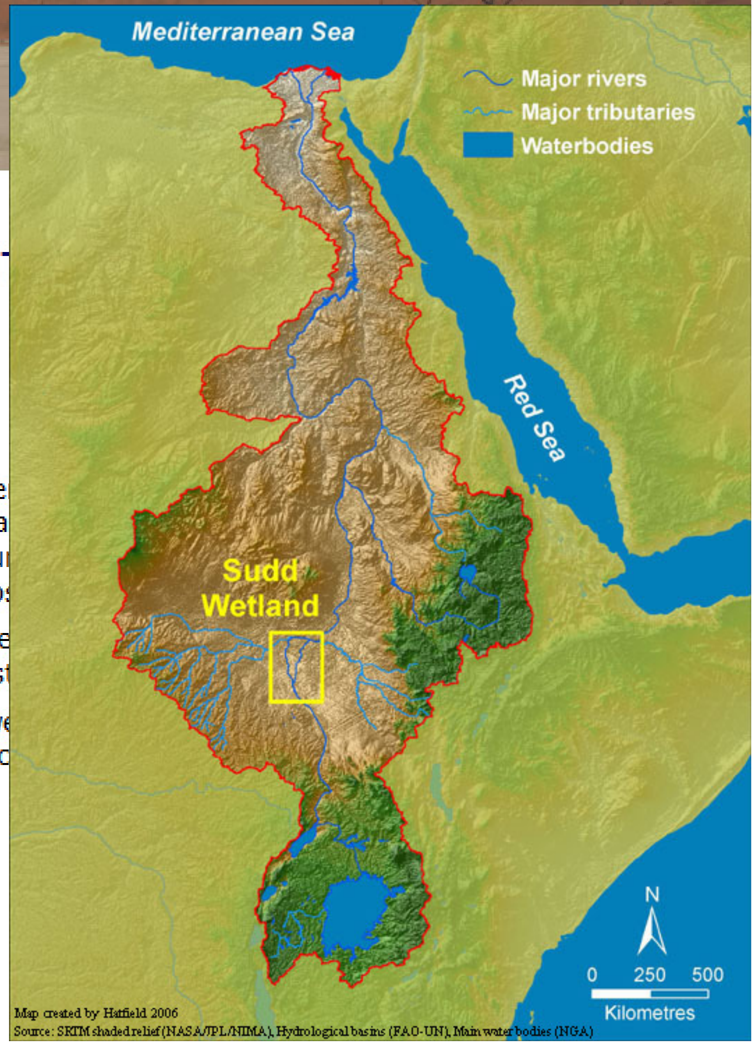

Dr Simon Dadson

- University Lecturer in Physical Geography
- Fellow of Christ Church, Oxford
- Academic Director, MSc in Water Science Policy and Management
- Member of the Climate Systems and Policy research cluster
- Member of the Landscape Dynamics research cluster

- Tel: +44 (0)1865 275866
- Email: simon.dadson@ouce.ox.ac.uk

Dr. Bernhard Lehner

Assistant Professor of Global Hydrology
Earth System Science Undergraduate Advisor
Director of the Geographic Information Center
Department of Geography
McGill University
Contact:
Burnside Hall, Room 612
Department of Geography
McGill University,
805 Sherbrooke Street West,
Montreal, QC H3A 2K6
Canada
Telephone: (1)514.398.8794
Fax: (1)514.398.7437
Email: bernhard.lehner@mcgill.ca

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4 MARCH 2008
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New Global Hydrography Derived From Spaceborne Elevation Data

PAGES 93–94

To study the Earth system and to better understand the implications of global environmental change, there is a growing need for large-scale hydrographic data sets that serve as prerequisites in a variety of analyses and applications, ranging from regional watershed and freshwater conservation planning to global hydrological, climate, biogeochemical, and land surface modeling. Yet while countless hydrographic maps exist for well-known river basins and individual nations, there is a lack of seamless high-quality data on large scales such as continents or the entire globe. Data for many large international basins are patchy, and remote areas are often poorly mapped.

In response to these limitations, a team of scientists has developed data and created maps of the world's rivers that provide the research community with more reliable information about where streams and watersheds occur on the Earth's surface and how water drains the landscape. The new product, known as HydroSHEDS (Hydrological Data and Maps Based on Shuttle Elevation Derivatives at Multiple Scales), provides this information at a resolution and quality unachieved by previous global data sets, such as HYDRO1k [*U.S. Geological Survey (USGS)*, 2000].

HydroSHEDS, which was developed by the Conservation Science Program of the World Wildlife Fund, is based primarily on elevation data obtained during NASA's Shuttle Radar Topography Mission (SRTM) [*Farr and Kobrick*, 2000]. At the most basic level, the kind of hydrographic information provided by HydroSHEDS will allow scientists and managers to create digital river maps and delineate watershed boundaries. These maps can then be coupled with a variety of other data sets or applied in computer simulations to perform more sophisticated analyses, such as the routing of river flow within hydrological models.

Data already have been completed for South and Central America, Asia, Africa, and Australia. These data are available for download from the USGS Earth Resources Observation and Science (EROS) Data Center. Data for the remaining landmasses of Europe and North America will be released within the next 6 months.

Data Development

The HydroSHEDS database contains both raster and vector layers describing the topography, drainage networks, and watersheds of the Earth's surface. The primary data source used in the development of HydroSHEDS was the SRTM digital elevation model, with ancillary data sources including the SRTM Water Body Data (see http://edc.usgs.gov/products/elevation/swbdguide.doc), the river networks of the Digital Chart of the World (DCW) [*Environmental Systems Research Institute (ESRI)*, 1993] and ArcWorld [*ESRI*, 1992], and the Global Lakes and Wetlands Database [*Lehner and Döll*, 2004].

The processing steps of generating HydroSHEDS are detailed in the data set's technical documentation [*Lehner et al.*, 2006]. Several of the procedures used in developing

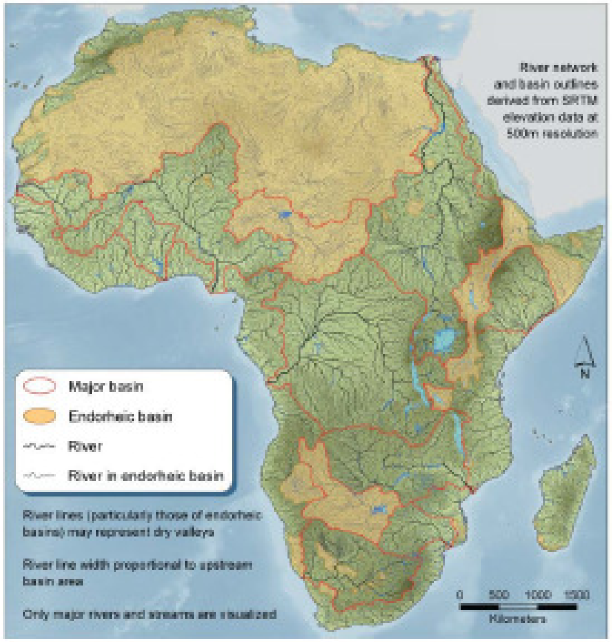


Fig. 1. HydroSHEDS river network and endorheic areas in Africa. Original color image appears at the back of this volume.

By B. Lehner, K. Verdin, and A. Jarvis

A calculator for the TOPOGRAPHIC INDEX, as used in the *TOPMODEL* model

Translated from various C and FORTRAN sources into R and then back into FORTRAN by Toby Marthews, 2012-13.

The topographic index is a parameter that was introduced as part of the fine-scale *TOPMODEL* hydrological model (Beven & Kirkby 1979, Beven 1997, 2012), arguably the most widely-used hydrological model.

Beven KJ & Kirkby MJ (1979). A physically based, variable contributing area model of basin hydrology. *Hydrological Sciences - Bulletin des Sciences Hydrologiques* 24:43-69.

Quinn P, Beven K, Chevallier P & Planchon O (1991). The prediction of hillslope flow paths for distributed hydrological modelling using digital terrain models. *Hydrological Processes* 5:59-79.

Wolock DM & McCabe GJ (1995). Comparison of single and multiple flow direction algorithms for computing topographic parameters in TOPMODEL. *Water Resources Research* 31:1315-1324.

Quinn PF, Beven KJ & Lamb R (1995). The $\ln(a/\tan\beta)$ index: how to calculate it and how to use it within the TOPMODEL framework. *Hydrological Processes* 9:161-182.

Beven K (1997). TOPMODEL: a critique. *Hydrological Processes* 11:1069-1085.

Ducharne A (2009). Reducing scale dependence in TOPMODEL using a dimensionless topographic index. *Hydrology and Earth System Sciences* 13:2399-2412.

Beven K (2012). Rainfall-Runoff Modelling The Primer (2nd ed.). Wiley-Blackwell, Chichester, UK.

A calculator for the TOPOGRAPHIC INDEX, as used in the *TOPMODEL* model

Translated from various C and FORTRAN sources into R and then back into FORTRAN by Toby Marthews, 2012-13.

The topographic index at any particular spatial point is basically log(*area*)/*slope* where *area* is the drainage area above that point.

There are various alternative ways of calculating the topographic index:

1.The *topmodel* R package, written in 2008 by Wouter Buytaert, Imperial College London (http://cran.r-project.org/web/packages/topmodel/index.html; programs *topidx.c* and *topidx.R*)

2.GRIDATB version 95.01 (program *gridatb.f*), originally written in 1983 by Keith Beven of the Hydrology Group, Lancaster University (revised for distribution 1993-95 by Paul Quinn and Jim Freer).

3.A simpler algorithm not based on an iterative search which I'll call *calcslope.f90*.

4.Using GRIDATB but with slopes calculated from steepest descent and using precalculated contributing areas from HydroSHEDS (Bernhard Lehner).

Following topidx.c

Inflow contour

Outflow contour

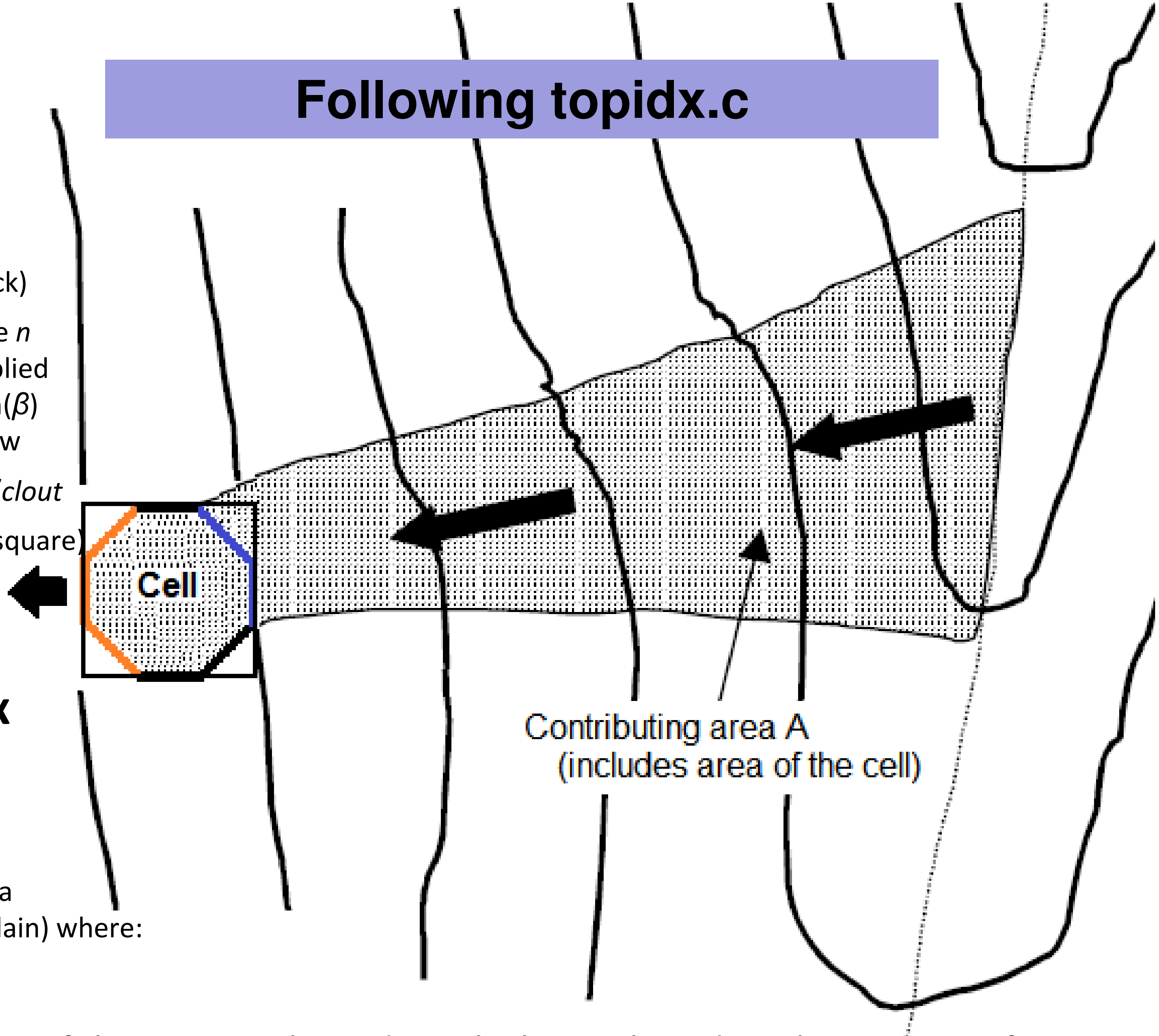
tan(*β*) = Average slope across outflow contour (orange)

tan(*β′*) = Average slope across non-outflow contour (blue+black)

clout = Weighted average of the *n* outflow (orange) lengths multiplied by *n*, where the weights are tan(*β*) for the slope across each outflow length.

a = Specific catchment area =*A*/*clout*

DX = Cell sidelength (the black square)



Topographic index for this cell

= ln(*a*/tan(*β*))

except if *clout*=0 (i.e. the cell is a depression/sink point or on a plain) where:
= ln(*A*/(2*tan(*β′*)))

This is a visual explanation of the topographic index calculation, based on the octagon of contour lengths shown in Quinn et al. (1991:Fig.1). Note that the default value will be undefined on any plain so I applied a minimum slope to all cells (from Hydro1k).

Following gridatb.f

Inflow contour

Outflow contour

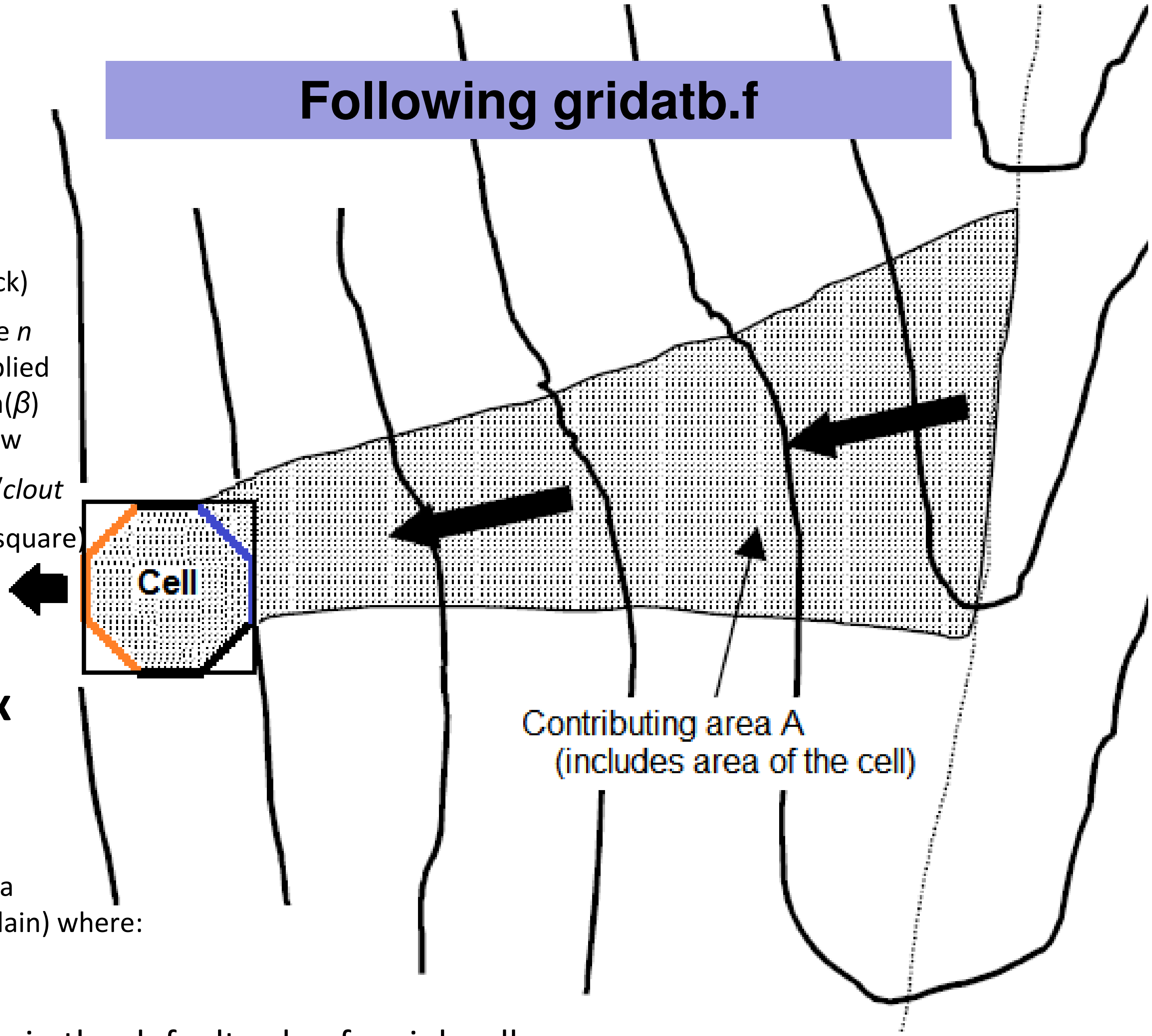
tan(*β*) = Average slope across outflow contour (orange)

tan(*β′*) = Average slope across non-outflow contour (blue+black)

clout = Weighted average of the *n* outflow (orange) lengths multiplied by *n*, where the weights are tan(*β*) for the slope across each outflow length.

a = Specific catchment area =*A*/*clout*

DX = Cell sidelength (the black square)



Topographic index for this cell

= ln(*a*/tan(*β*))

except if *clout*=0 (i.e. the cell is a depression/sink point or on a plain) where:

= ln(*A*/(2*DX*tan(*β′*)))

Note the small difference in the default value for sink cells.

Following calcslope.f90

Inflow contour

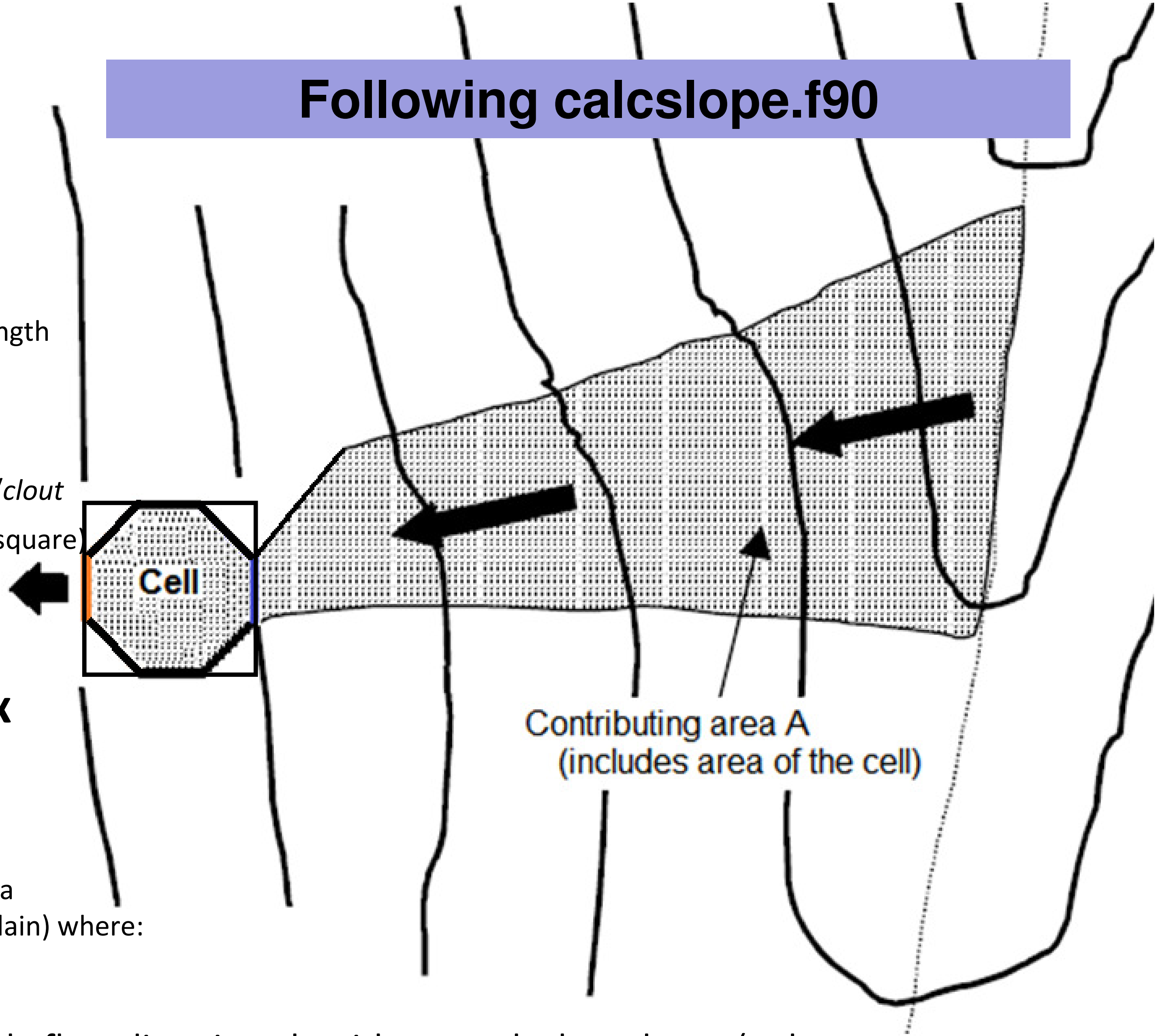
Outflow contour

tan(*β*) = Slope across outflow contour (orange)

clout = The outflow (orange) length

a = Specific catchment area =*A*/*clout*

DX = Cell sidelength (the black square)



Topographic index for this cell

= ln(*a*/tan(*β*))

except if *clout*=0 (i.e. the cell is a depression/sink point or on a plain) where:

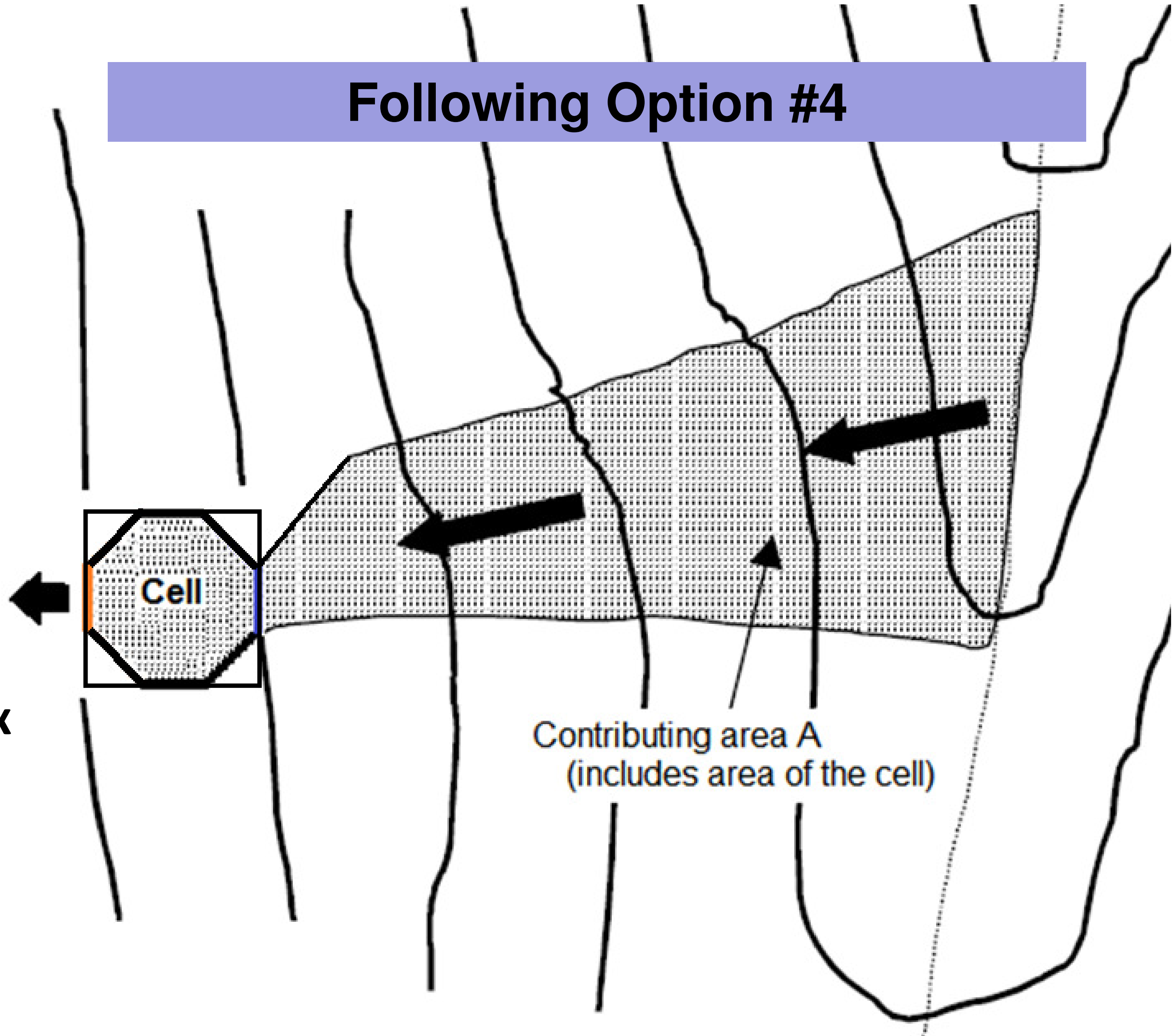
= [undefined]

This program used a single flow direction algorithm to calculate slopes (only one orange contour and one blue contour for each cell) and no default values for sink points.

Inflow contour
Outflow contour

Following Option #4

All as for GRIDATB inc. default values



Topographic index for this cell

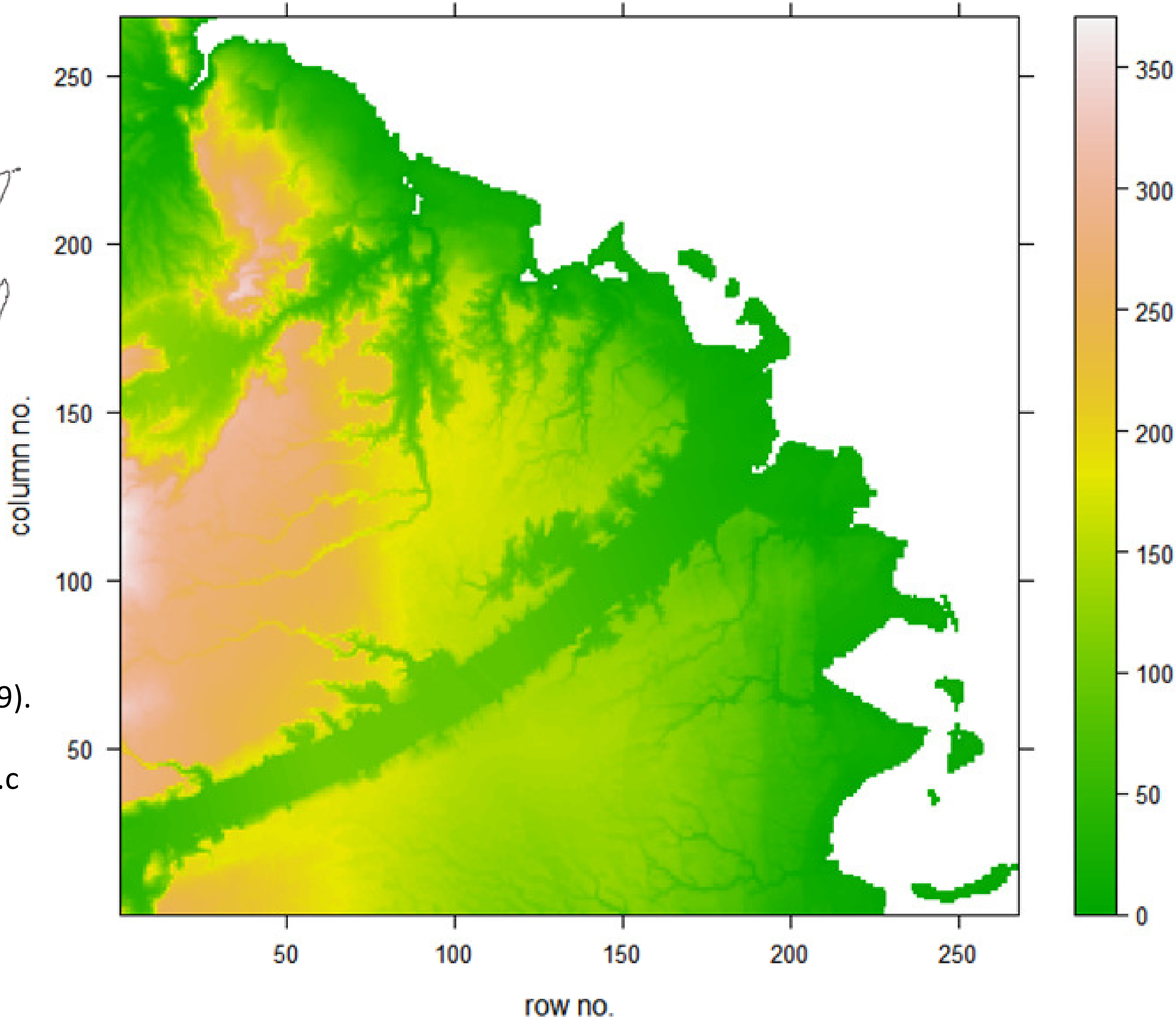
= ln(*a*/tan(*β*))

Single inflow and outflow, but contributing areas A are validated by HydroSHEDS to correspond more closely with more sophisticated routing models.

The resolution issue (Wolock & McCabe 1995, Ducharne 2009).

GRIDATB and topidx.c follow iterative searches, which are computationally demanding.

Input DEM for an area in SE Tanzania



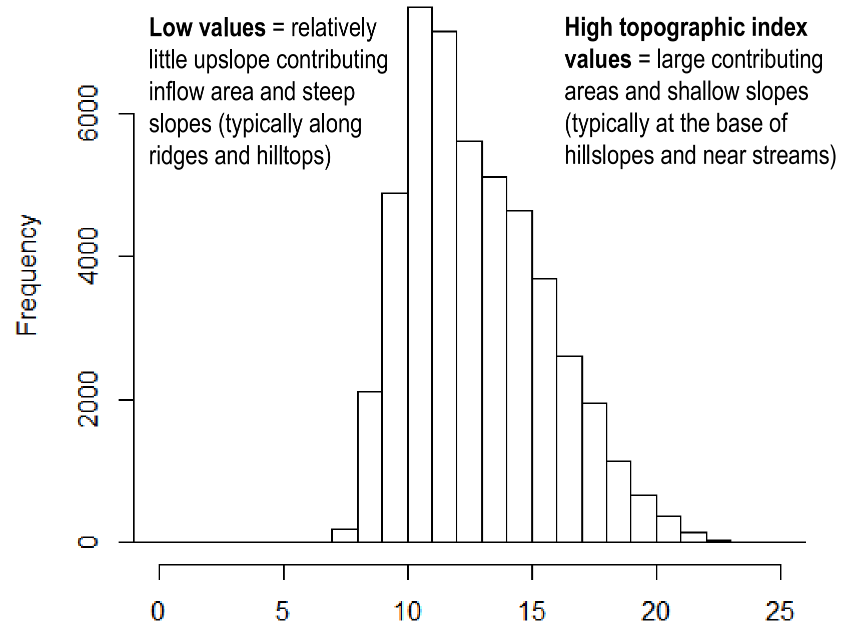
New Cluster for Oxford Supercomputing Centre

The Oxford Supercomputing Centre (OSC) is pleased to announce the availability of it's new cluster, "SAL". SAL is an SGI ICE cluster of the same type as the older OSC cluster 'HAL', but using the new Intel "Nehalem" generation of processors.

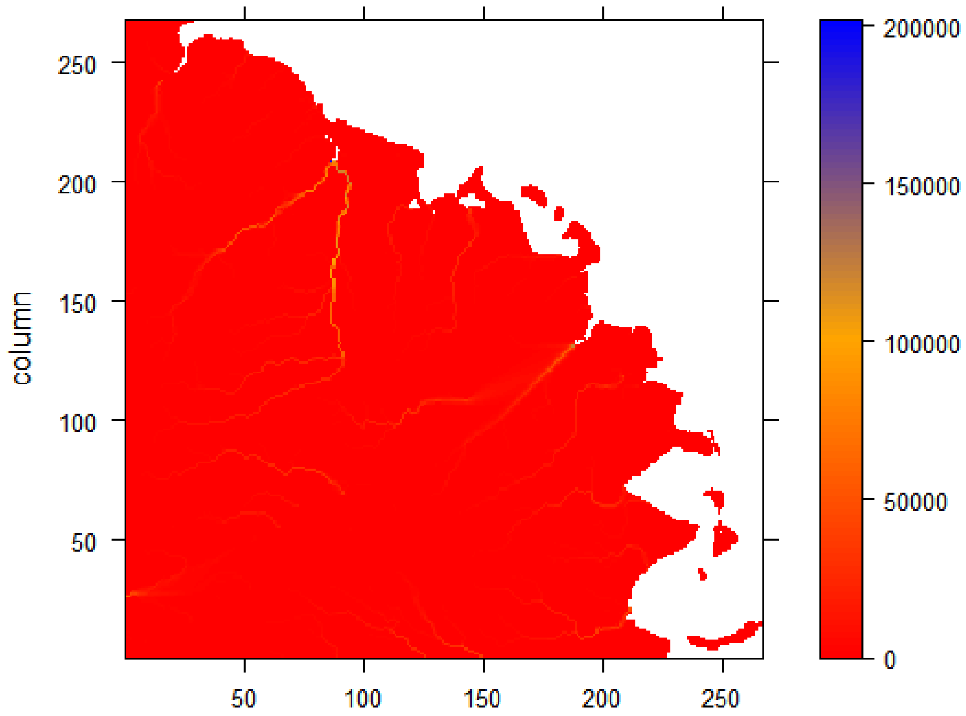
The system arrived on the 22nd of February and was running test jobs within a few days. SAL can be used in exactly the same way as the HAL system so there is generally no need to rebuild code which has previously been compiled on HAL. The two systems have the following specifications:

Component	HAL	SAL
Processors	2.8GHz Quad Core Harpertown	2.53GHz Quad Core Nehalem
Memory per core	2GB	3GB
Cores per node	8	8
Number of compute cores	512	640
Scratch space	12TB	12TB

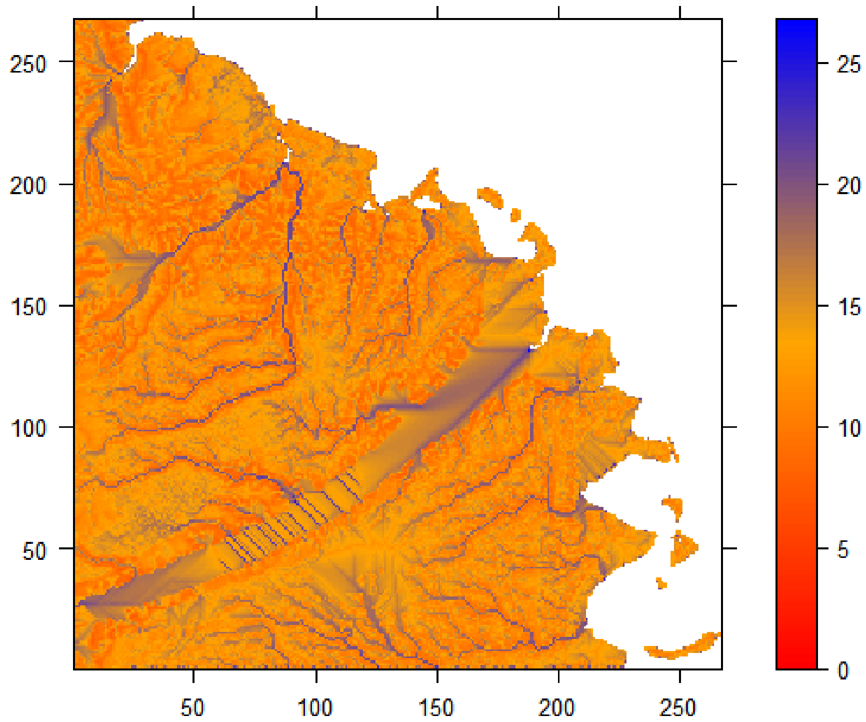
Here's what you get from topidx.c:



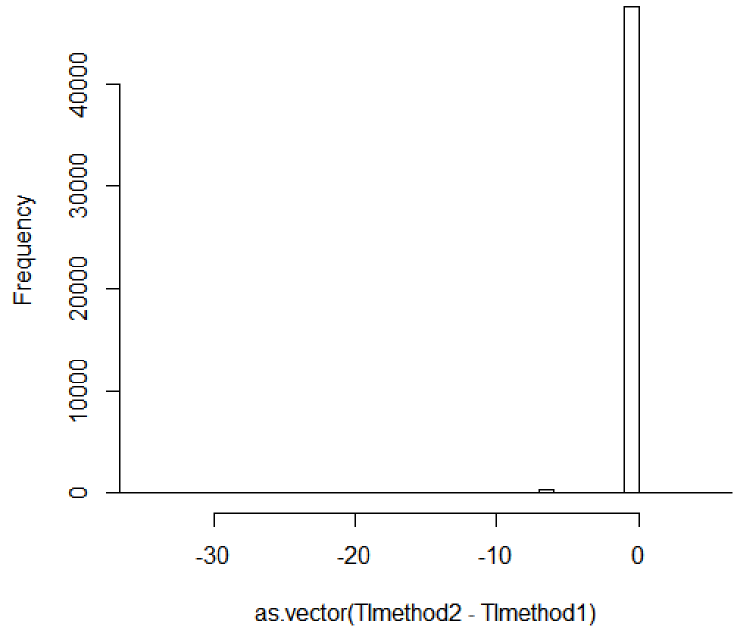
Contributing inflow area (ha) (calc. by topidx.c)



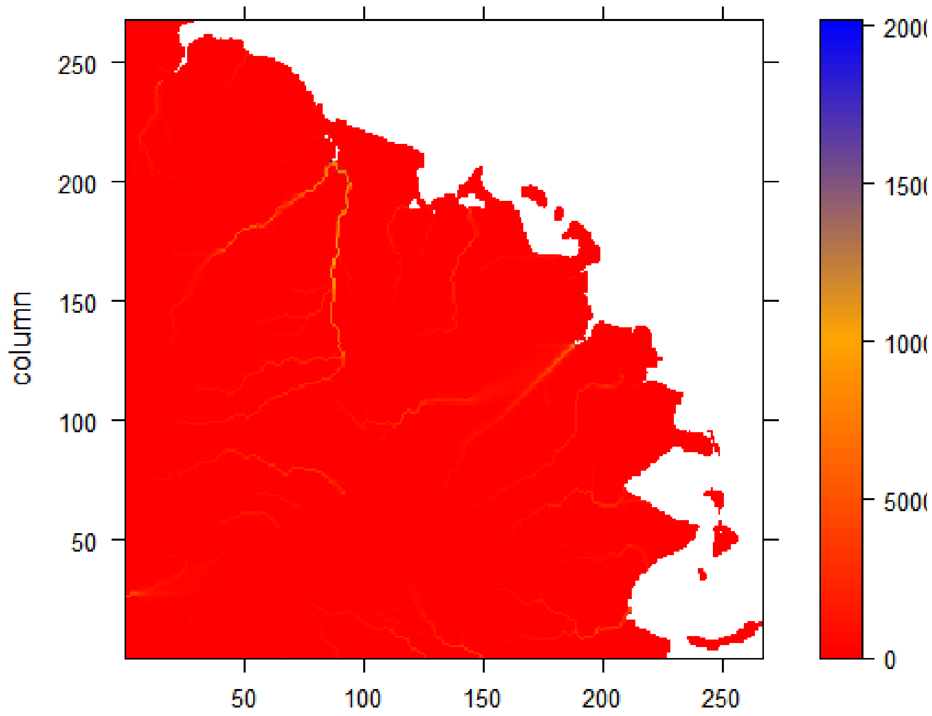
TOPMODEL Topographic Index (calc. by topidx.c)



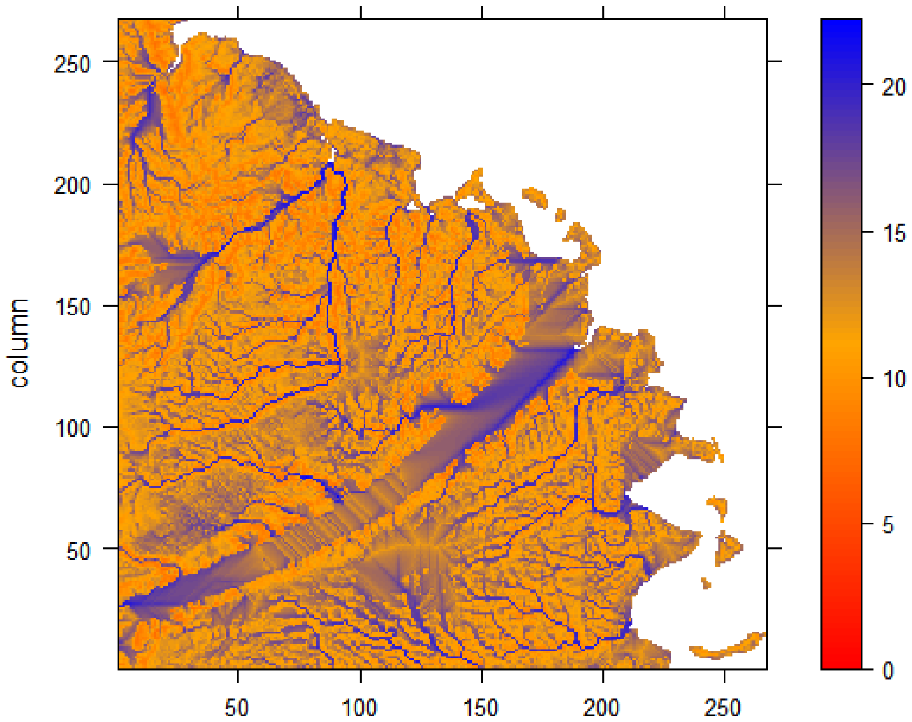
Here's what you get from gridatb.f:



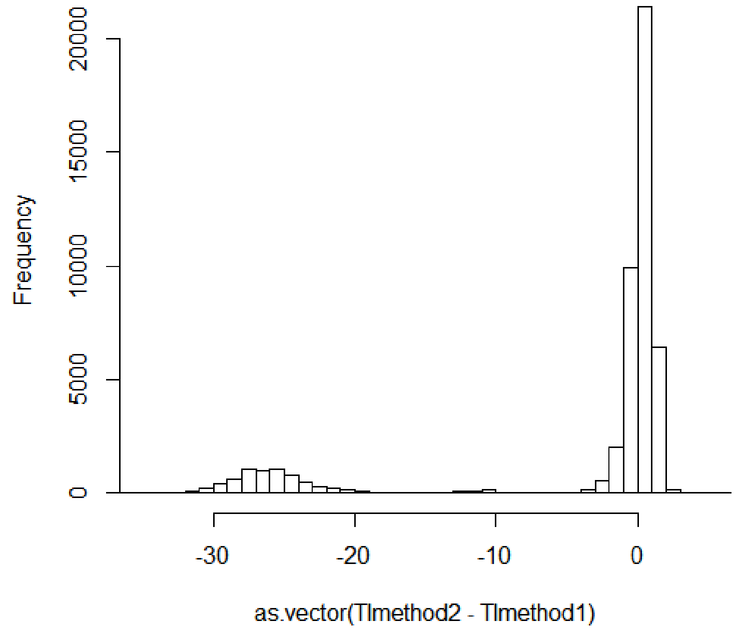
Contributing inflow area (ha) (calc. not by topidx.c)



TOPMODEL Topographic Index (calc. not by topidx.c)



Here's what you get from calcslope.f90:



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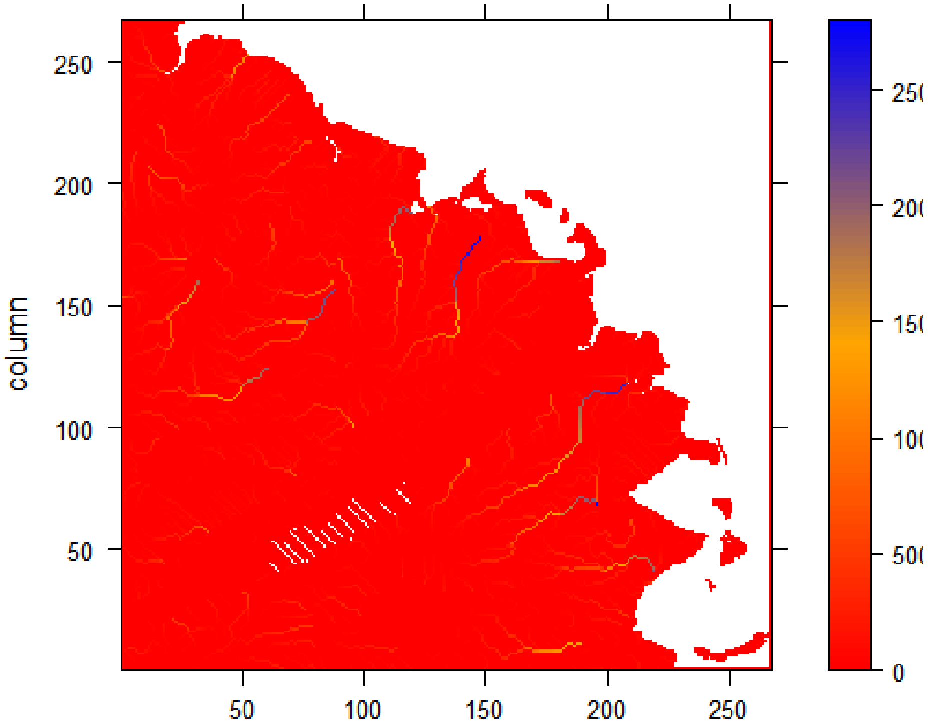

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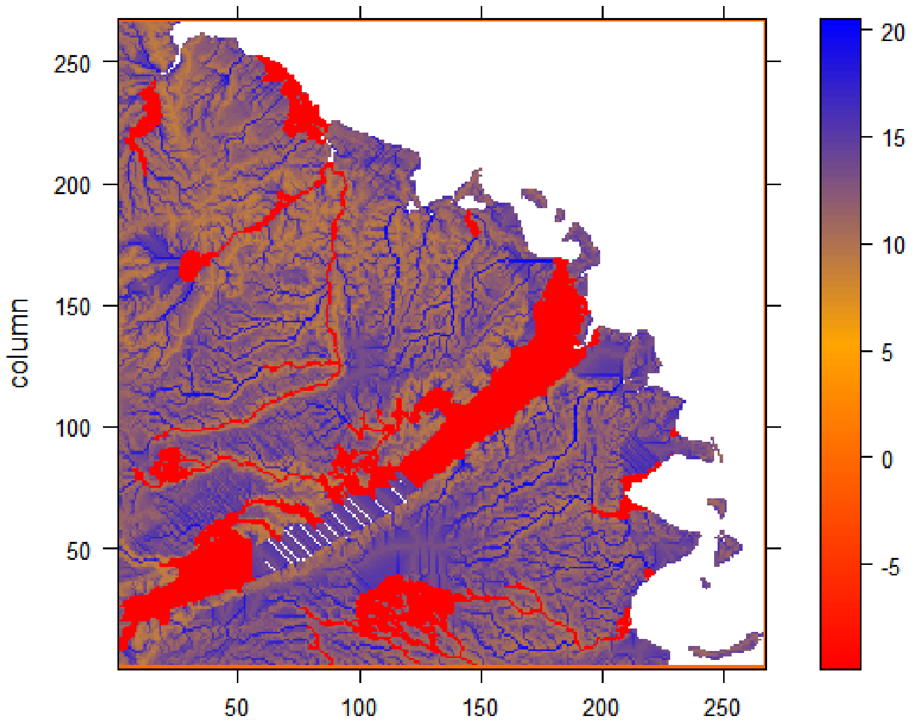
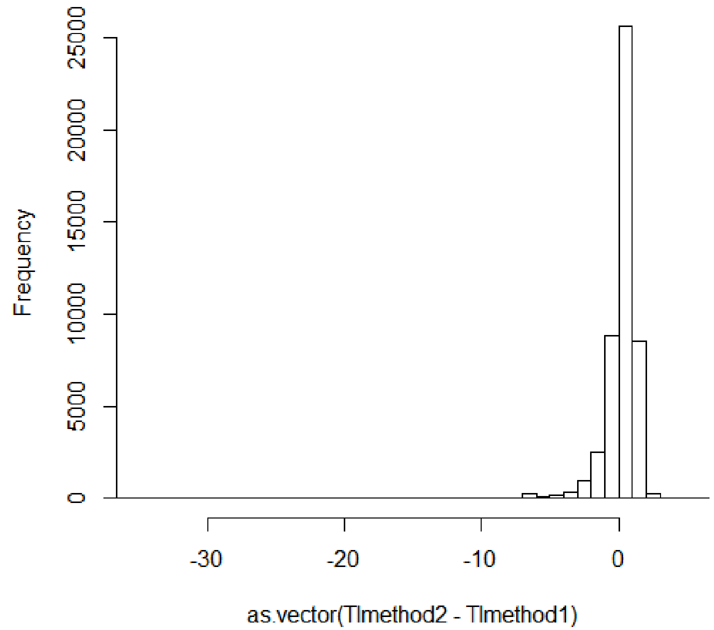
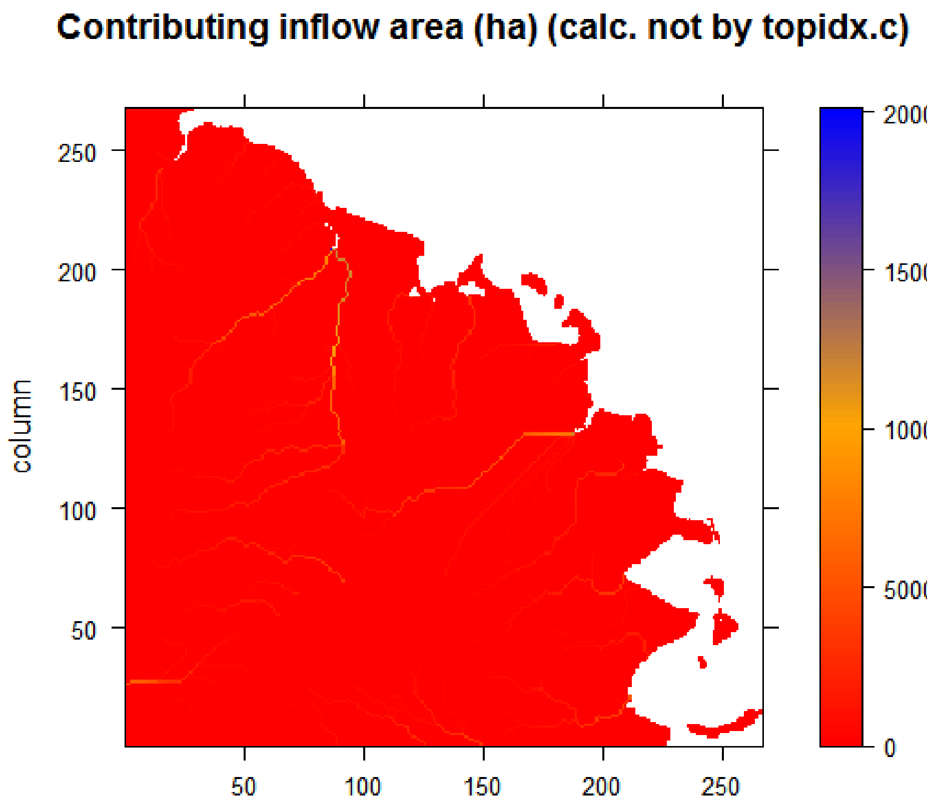
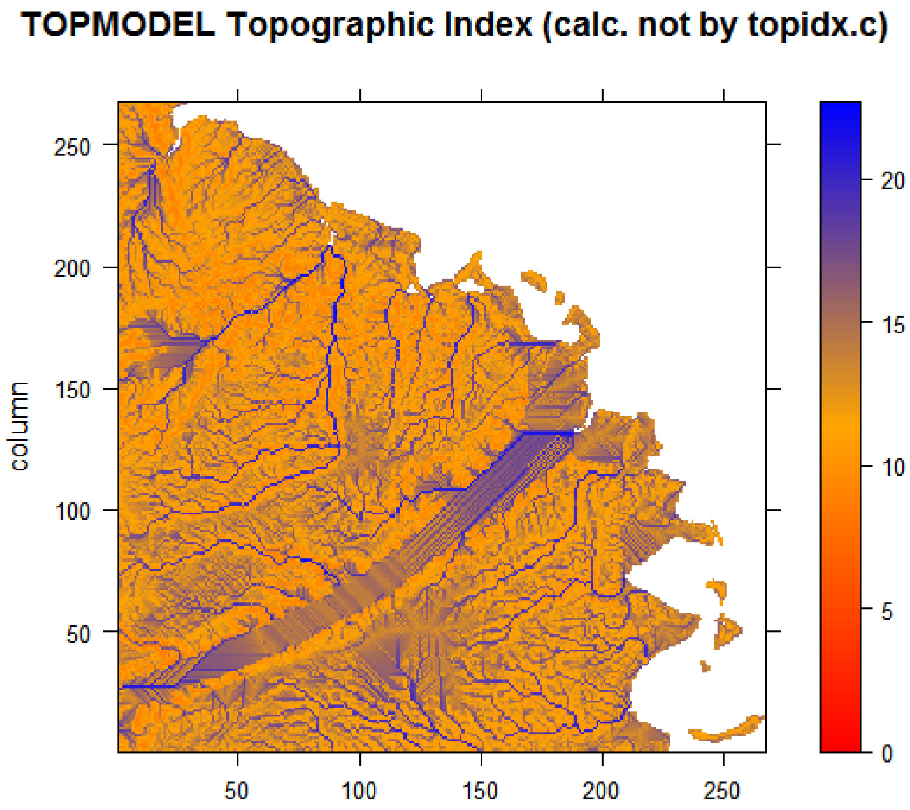
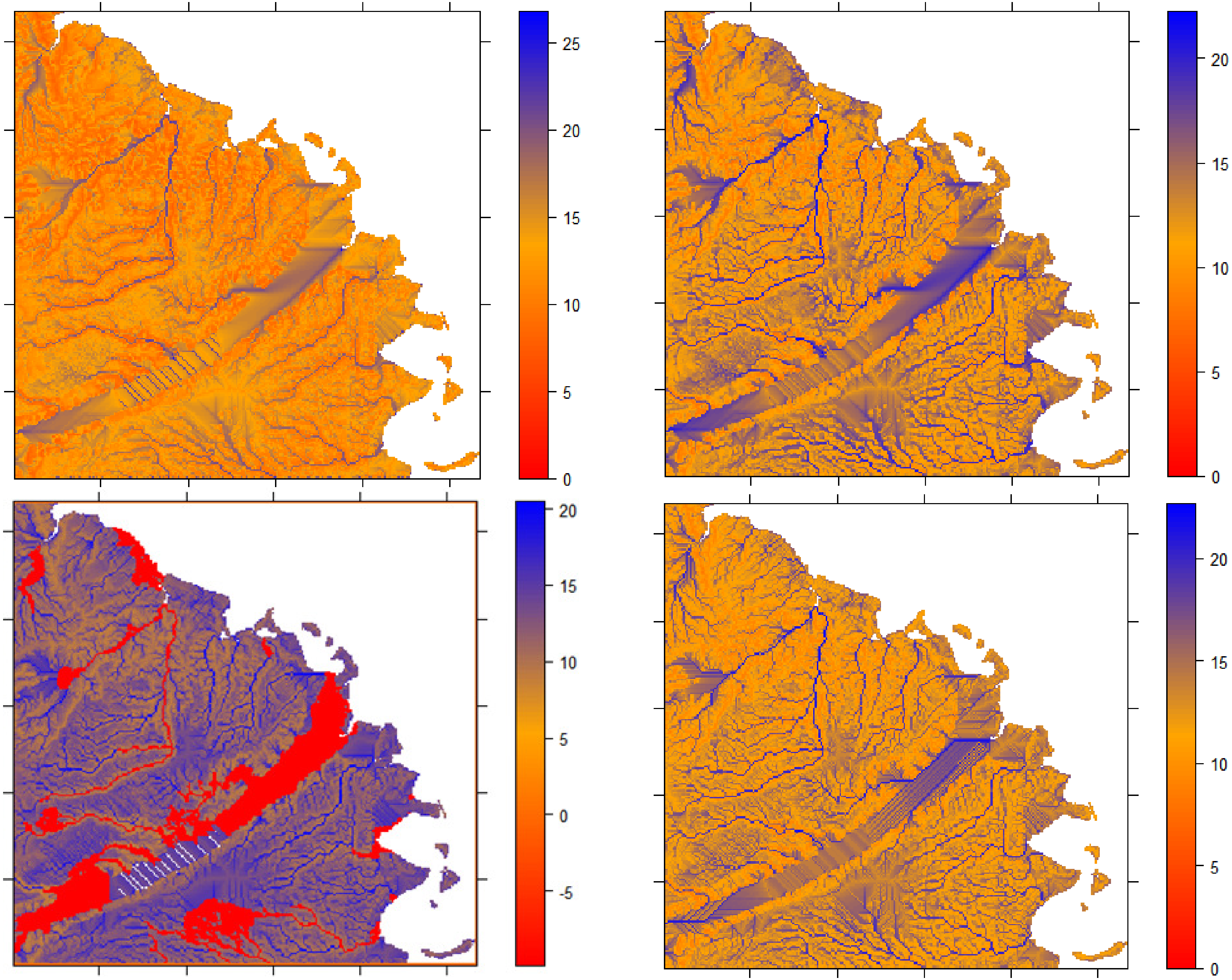


Here's what you get from Option #4:









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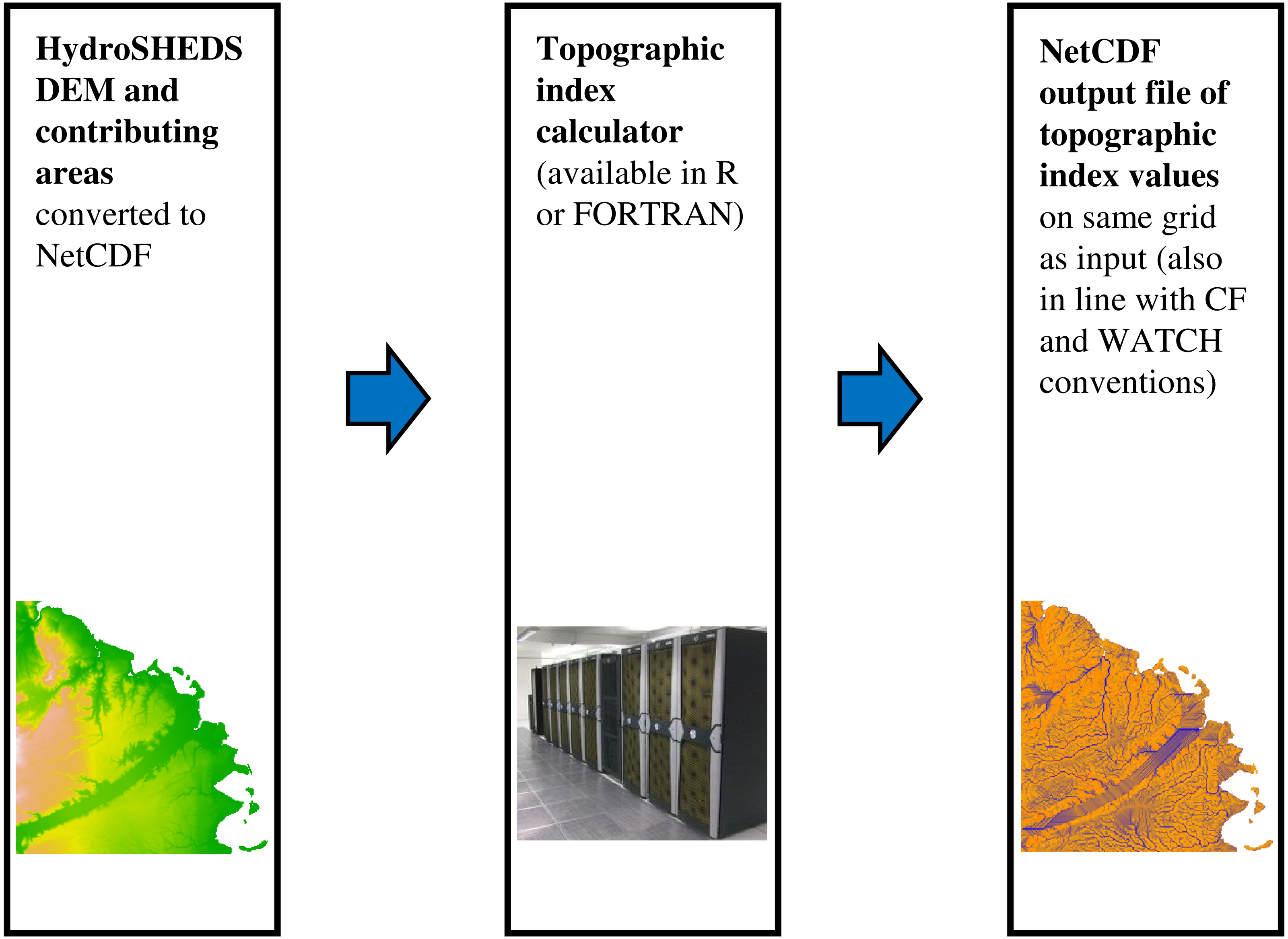
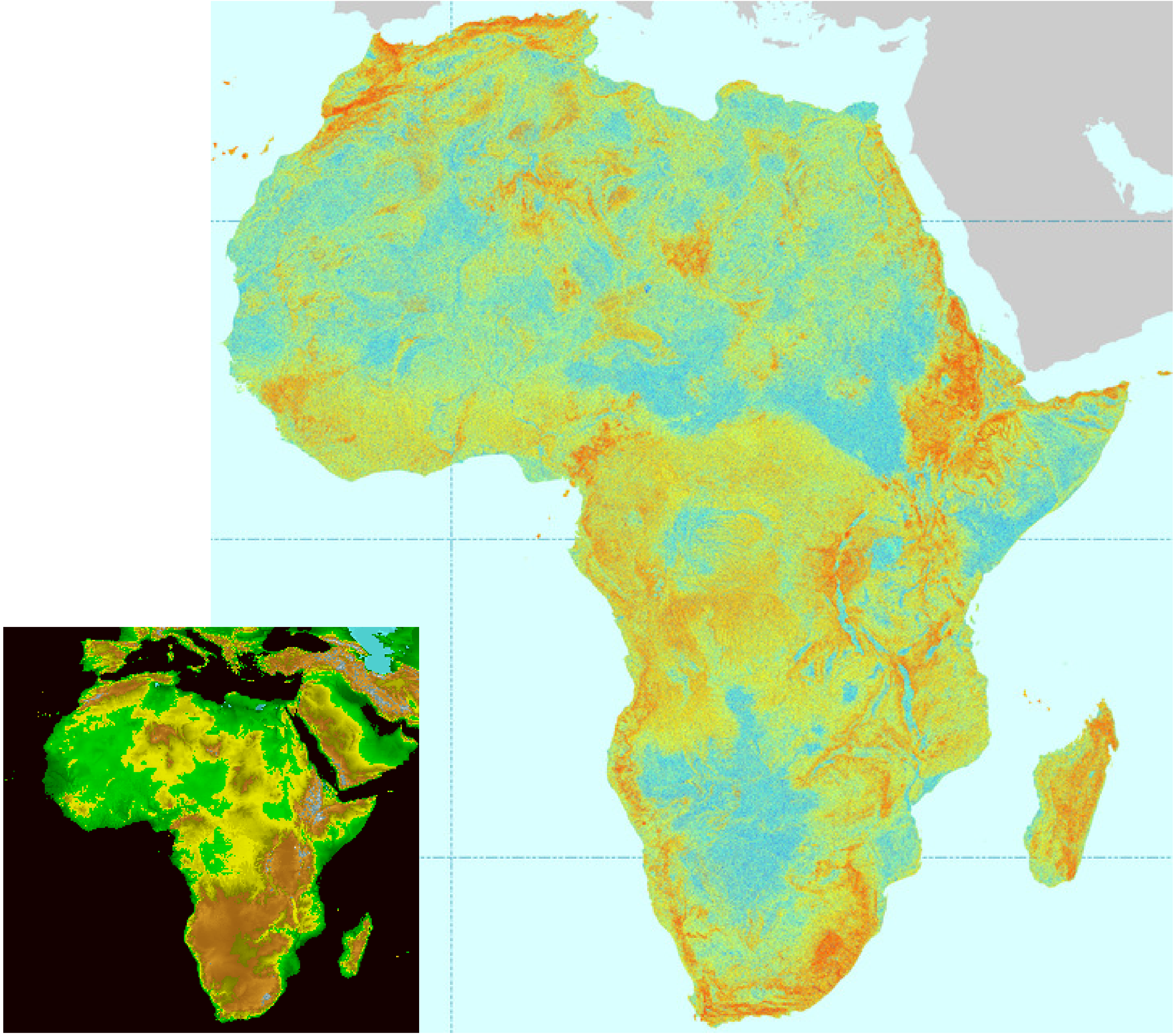
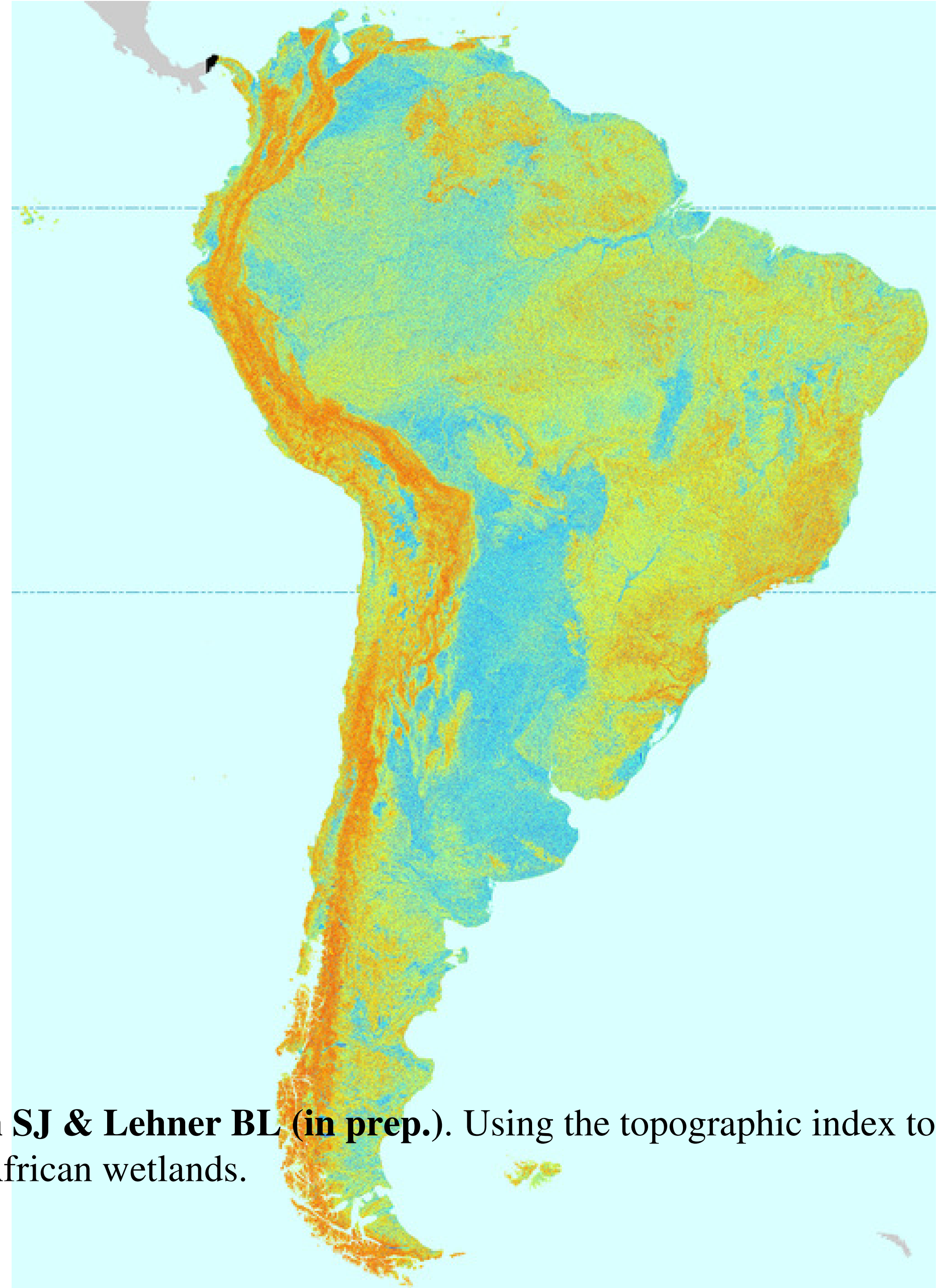

HydroSHEDS DEM and contributing areas converted to NetCDF
Topographic index calculator (available in R or FORTRAN)
NetCDF output file of topographic index values on same grid as input (also in line with CF and WATCH conventions)





Marthews TR, Dadson SJ & Lehner BL (in prep.). Using the topographic index to characterise overland and soil water flow in African wetlands.

Science Activities

Science

Climate Change

- Carbon Cycle
- Drought
- Vegetation Monitoring
  - Remote Sensing Phenology
  - VegDRI
  - Vegetation Condition

Landscape Dynamics

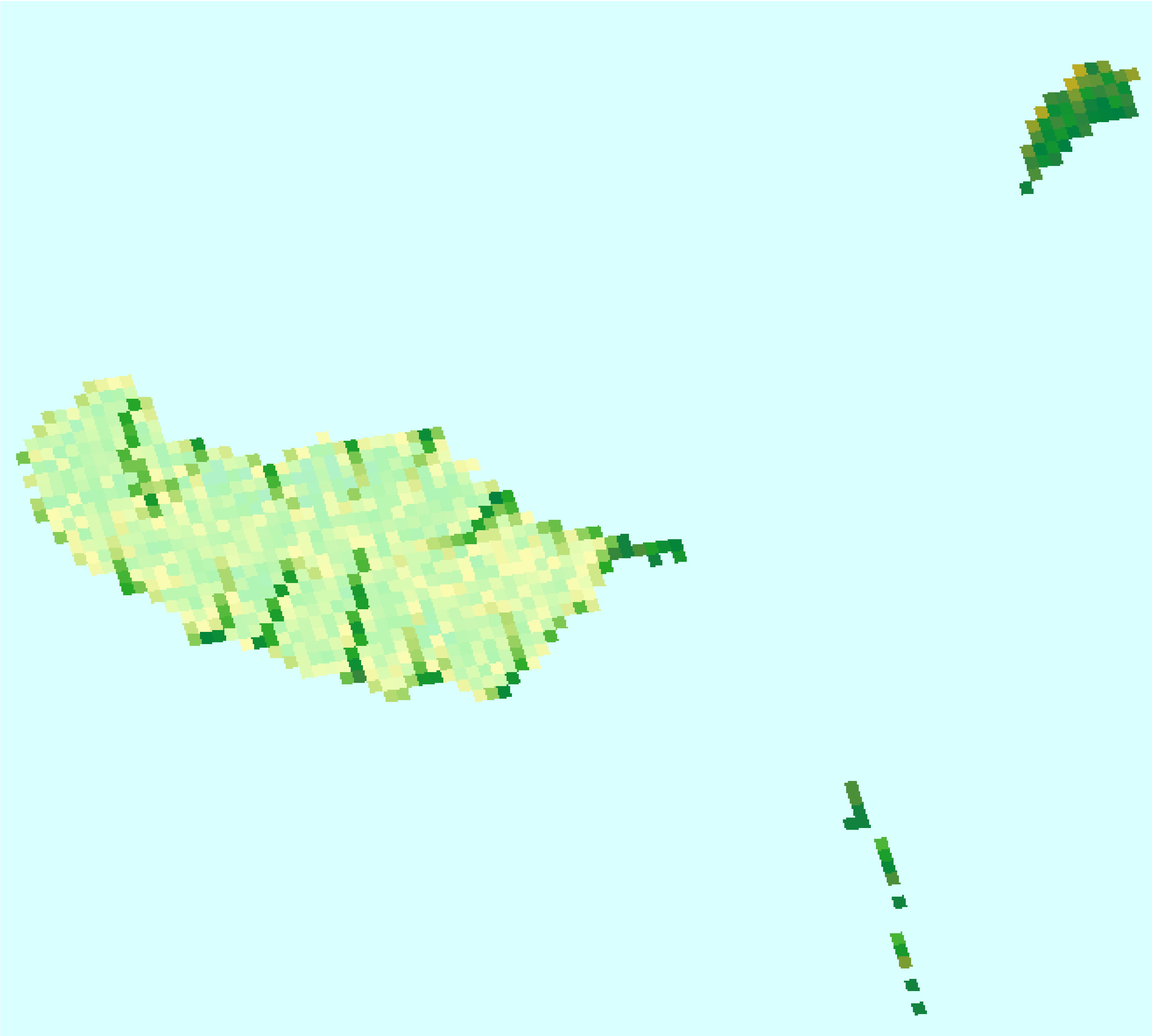
- Fire Science
- Land Cover/Land Use
  - Land Cover Trends
  - National Land Cover
  - Land Cover Institute
- Topographic Research

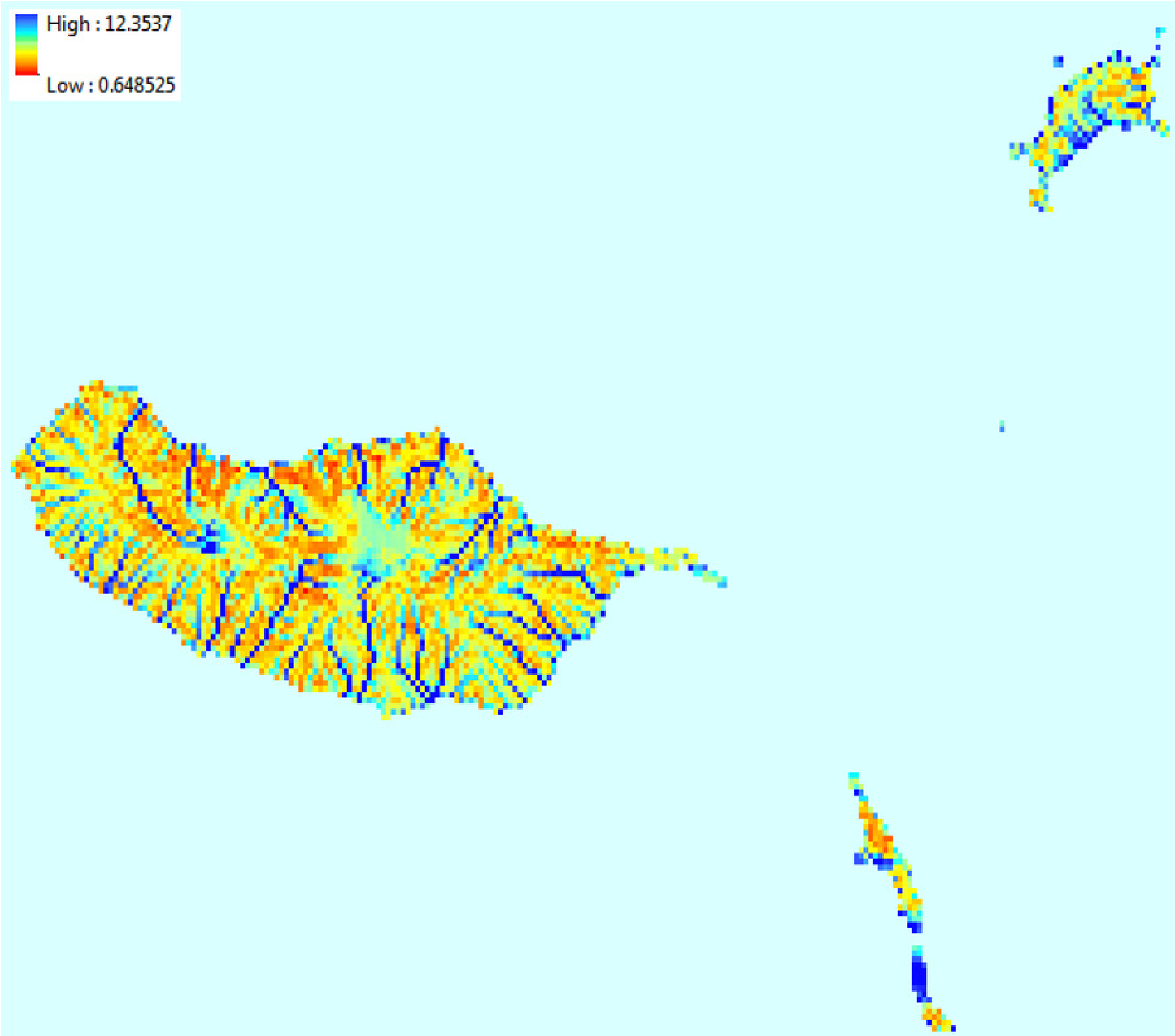
Hazards & Disasters

- Earthquakes
- Emergency Response
- Famine
- Flooding
- Human Health
  - Chemicals
  - Infectious Diseases
- Hurricanes
- Volcanoes

International Activities

- Afghanistan
- Famine Early Warning
- Flood Monitoring





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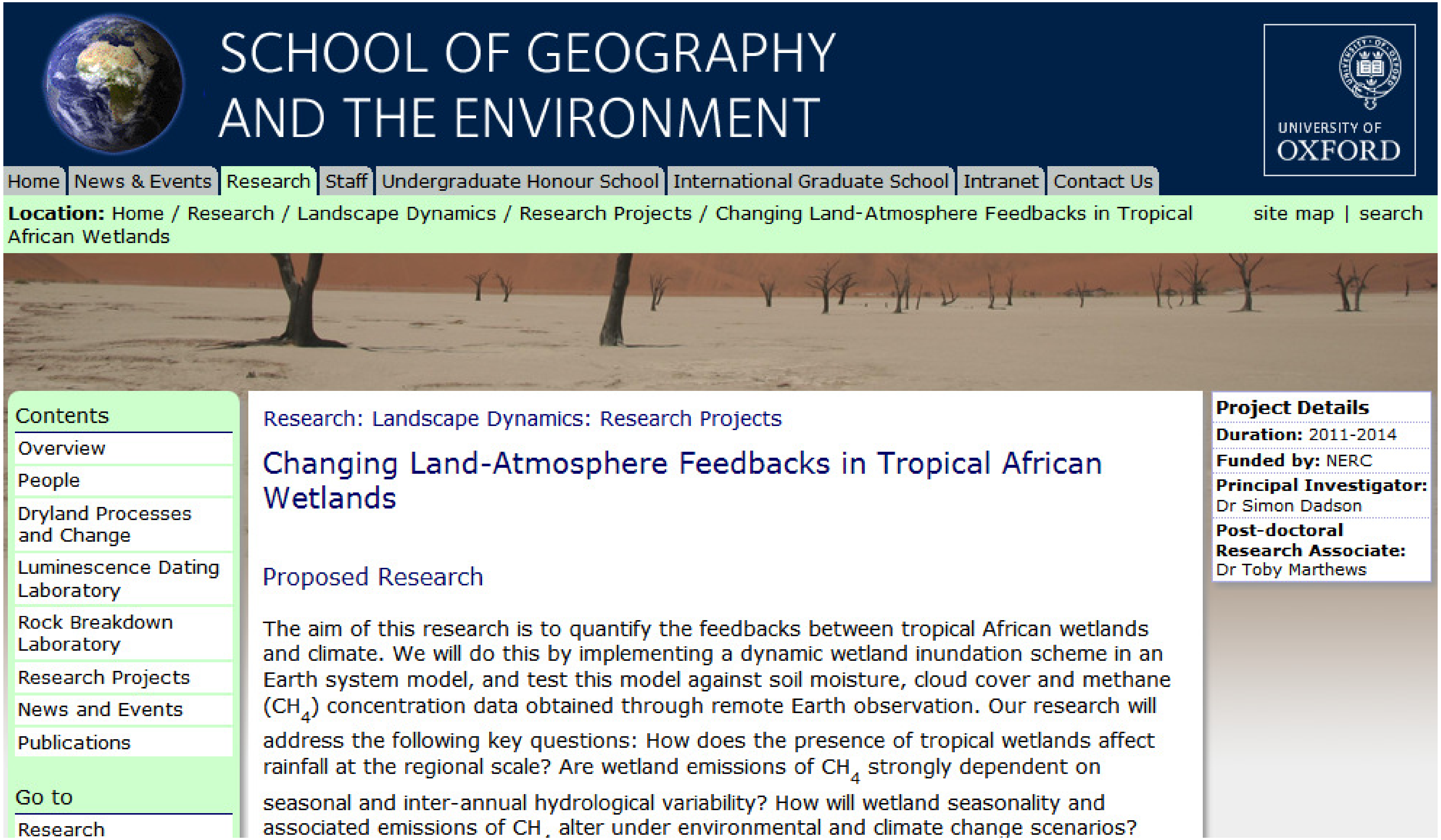
Low : 0.648525



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Research: Landscape Dynamics: Research Projects

Changing Land-Atmosphere Feedbacks in Tropical African Wetlands

Proposed Research

The aim of this research is to quantify the feedbacks between tropical African wetlands and climate. We will do this by implementing a dynamic wetland inundation scheme in an Earth system model, and test this model against soil moisture, cloud cover and methane (CH_4) concentration data obtained through remote Earth observation. Our research will address the following key questions: How does the presence of tropical wetlands affect rainfall at the regional scale? Are wetland emissions of CH_4 strongly dependent on seasonal and inter-annual hydrological variability? How will wetland seasonality and associated emissions of CH_4 alter under environmental and climate change scenarios?

Project Details

Duration: 2011-2014

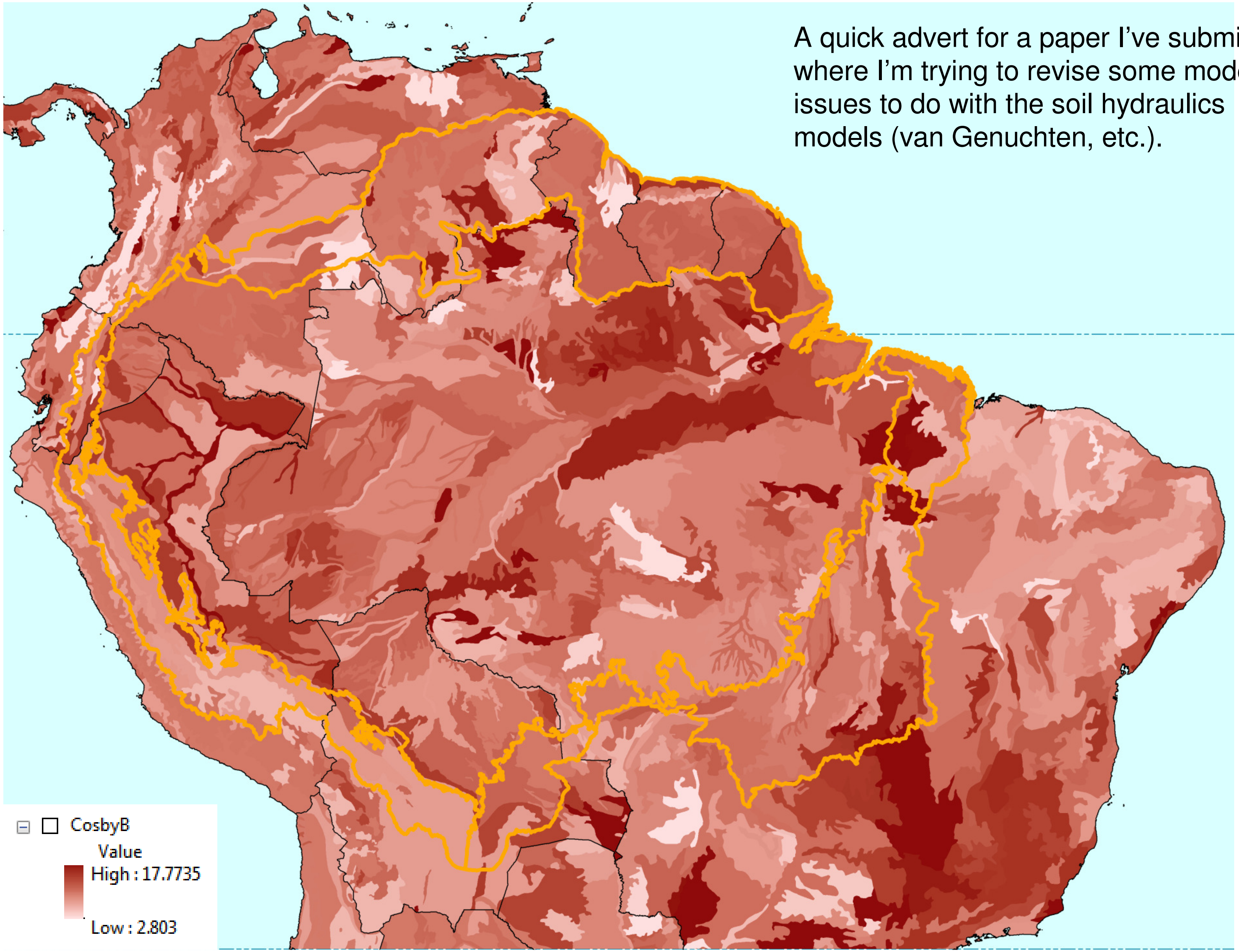
Funded by: NERC

Principal Investigator: Dr Simon Dadson

Post-doctoral Research Associate: Dr Toby Marthews

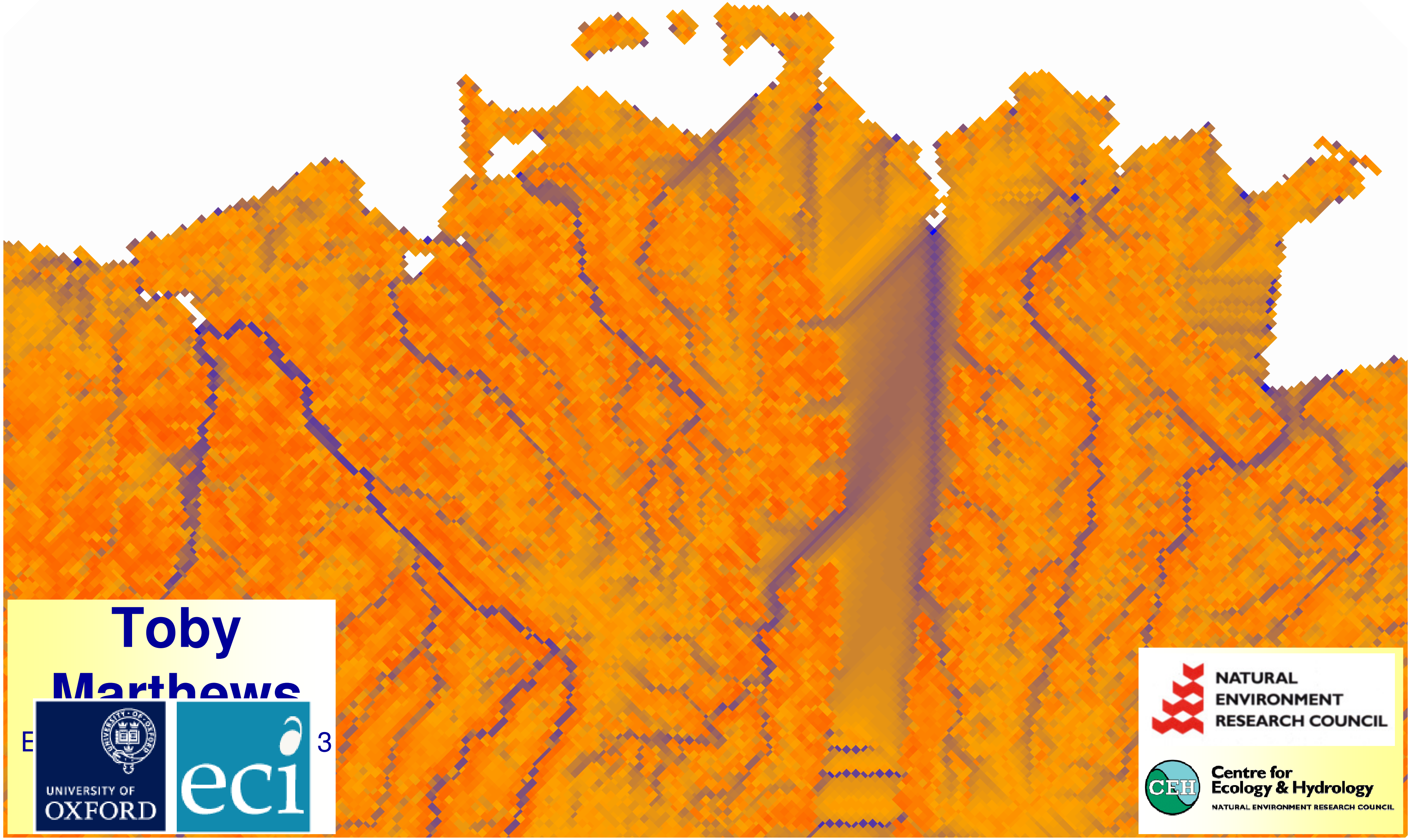
Marthews TR, Dadson SJ & Lehner BL (in prep.). Using the topographic index to characterise overland and soil water flow in African wetlands.

Marthews *et al.* (submitted). Hydraulic parameter maps of surface soils in tropical South America derived from locally-validated pedotransfer functions. *Water Resources Research.*



A quick advert for a paper I've submitted where I'm trying to revise some modelling issues to do with the soil hydraulics models (van Genuchten, etc.).

Thanks very much for listening.



Toby Marthews

UNIVERSITY OF OXFORD

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