Satellite rainfall retrieval: a climate modelling perspective

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Background

- Well-established that climate change will significantly alter climatic variability, as well as mean climate (e.g. Tegart et al. 1990)

- Changes in climate variability = changes in extreme climate events e.g. increasing frequency of flooding, drought, etc – likely to be of far more significance for environmentally vulnerable regions

- Changing climate variability may also result in change of other rainfall parameters e.g. a later start date of the wet season (e.g. Kniveton et al. 2007)

- Better understanding of extreme daily rainfall is important, because recent rainfall-related disasters e.g. Katrina have demonstrated impact of rainfall variability and extremes on society

- Generally agreed that developing countries suffer more from extreme rainfall events because, being environmentally and socio-economically vulnerable before occurrence of extreme event, developing countries are more sensitive to such disasters
Southern Africa

- Region of relative low and variable rainfall
- Dependence on rainfed agriculture
- High social pressures e.g.
  - Migration
  - Tourism
  - Population pressures
  - Economic/scientific underdevelopment
  - Widespread disease
  - Famine
  - Extreme poverty
  - Governmental corruption
  - HIV/AIDS crisis
  - Civil war
However……

Rainfall variability = function of scale, so high spatial and temporal resolution data needed to identify extreme rainfall events – as resolution increases, so too does ability to ‘see’ extremes

- Need for daily high spatial resolution rainfall data due to lack of gauge data
- Need for data set over prolonged period
Lack of consensus I: Climate models

HADCM3: SW Africa wet

CSIRO: SW Africa dry

M. Todd, pers. comm.
Lack of consensus II: High-resolution rainfall retrievals

20 November 2004

From: http://essic.umd.edu/~msapiano/PEHRPP/index.html
Microwave Infrared Rainfall Algorithm (MIRA)
Todd et al. (2001), Layberry et al. (2006)

Dataset of satellite-derived rainfall estimates, comprising 10 year’s worth of data, 1993-2002, covering Africa at 2-hourly resolution & at 0.1° lat/long. Validation for southern African half of dataset (0° – 34°S, 10° – 50°E) at daily resolution

Process:
1. For every grid cell (0.5°) for every month (1993-2002), Meteosat cloud top temperature and PM instantaneous rain rates from SSM/I sampled (when they occurred within 30 minutes of each other)
2. Histograms of both temperature and rain rate derived for each grid cell (where rainfall was present)
3. Histogram matching applied (e.g. assuming coldest temperature = highest rain). Thus temperature/rain rate relationship is established
4. Relationship applied to full resolution (2-hourly, 0.05°) Meteosat IR temperature data, then final rain rates averaged over each day and binned to 0.1° to make final dataset for validation
Data availability

- Southern Africa (south of Equator): daily rainfall data at 0.1 km spatial resolution from 1993-2002
- Northern Africa (north of Equator): daily rainfall data at 0.1 km spatial resolution from 1996-2002

Both available by request from d.r.kniveton@sussex.ac.uk
MIRA validation I: Comparison with GTS, for example year
MIRA validation II: Comparison with GPI, for example date

1 January 2000

MIRA vs. GPI on 1 January 2000.
MIRA validation III: Comparison with NCEP, for example event

Integrated rainfall between 16\textsuperscript{th} - 24\textsuperscript{th} January 2002 - a high rainfall event

MIRA

NCEP reanalysis

Kalnay \textit{et al.} (1996)
MIRA validation IV: Example score – HSS

<table>
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<th>MIRA/GTS</th>
<th>GPI/GTS</th>
<th>Gauges used (daily mean)</th>
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<tr>
<td>2000</td>
<td>0.47</td>
<td>0.40</td>
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</table>

- MIRA = significantly better than GPI for all years
- +ve correlation between skill of estimates and number of gauges: more gauges = greater agreement. Suggests remaining disagreement between MIRA/GTS may be due to low number of gauges as well as errors from MIRA?
MIRA / climate model comparison I: Method
Williams et al. (2007b)

- 10-year climate model integration, 1993-2001
- Model:
  - Global mode = HadAM3 (2.5° x 3.75°)
  - Regional mode = PRECIS (0.5° x 0.5°), run over southern African domain & driven at lateral boundaries by ERA-40

- Daily rainfall from model compared to MIRA, for full 1993-2001 period, monthly (January & July) and seasonally (Nov-April (NDJFMA) & DJF)
- Rainfall was firstly compared over entire domain as daily spatial averages, secondly at pixel scale as temporal means, & thirdly number/spatial distribution of extreme pixels

- Extreme rainfall investigated at pixel scale, with definition adapted from that used by Samel et al. (1999)
- Definition used here: extreme pixel (on any given day) = any pixel where rainfall > 1.5% of climatological total for that pixel
Means

Differences (MIRA-HadAM3) over southern Africa, 1993-2001. Mean differences in mm day$^{-1}$. Solid line = zero contour
MIRA / climate model comparison II: HadAM3 results (cont.)
MIRA / climate model comparison II: HadAM3 results (cont.)

Means

Mean differences in mm day\(^{-1}\). Solid line = zero contour

Standard deviations
Number of extreme pixels over southern Africa, 1993-2001 (top), and spatial patterns of total extreme pixels (bottom)

- MIRA = 19,645 extreme pixels
- HadAM3 = 14,233 extreme pixels
MIRA / climate model comparison III: PRECIS results

Means

Differences (MIRA-PRECIS) over southern Africa, 1993-2001. Mean differences in mm day$^{-1}$. Solid line = zero contour.
MIRA / climate model comparison III: PRECIS results (cont.)

Standard deviations

Number of extreme pixels over southern Africa, 1993-2001 (top), and spatial patterns of total extreme pixels (bottom)

- MIRA = 831,921 extreme pixels
- PRECIS = 567,218 extreme pixels
Possible conclusions from MIRA / climate model comparisons

1) HadAM3 reproduces both spatially averaged rainfall and rainfall at pixel scale (as shown by MIRA) with some accuracy
2) HadAM3’s ability to reproduce daily rainfall variability is spatially and temporally dependent – over wetter (drier) regions / during wet (dry) periods, HadAM3 underestimates (overestimates) rainfall variability relative to MIRA
3) HadAM3 reproduces the majority (~72%) of daily rainfall extremes highlighted by MIRA
4) Both MIRA and HadAM3 show a similar spatial distribution of rainfall extremes, with a higher number of extremes over subtropical Africa which decreases towards equator
5) Differences between PRECIS and MIRA are similar to those from HadAM3 integration (as expected, as essentially the same model but run at higher spatial resolution)
6) PRECIS identifies ~68% of rainfall extremes shown by MIRA, less than the ~72% identified by HadAM3 – may be because of the high spatial resolution of PRECIS which requires higher spatial accuracy
7) However, higher spatial resolution of PRECIS is important when identifying number of rainfall extremes, because many more extremes can be identified. Advantageous if, for example, extremes are then used as a basis for composite analysis within rainfall variability studies (e.g. Williams et al. 2007a)
Problematic regions

MIRA-HadAM3

MIRA-PRECIS

Difference in mean rainfall, January

Difference in total extreme pixels
Summary and future needs

• Need for high spatial/temporal resolution rainfall data in order to study rainfall extremes (particularly devastating for developing regions)

• Certain regions e.g. southwestern Africa = particularly problematic for both models and satellite-based rainfall retrieval methods, because:
  - Region of low/variable rainfall
  - Region of primarily convective and/or locally controlled rainfall (as opposed to large-scale), with which both models and rainfall retrievals have problems
  - Lack of rain gauges

Therefore, future data collection (from satellite-based rainfall retrievals) should focus on these regions
Thank you for your time.

Visit www.walker-institute.ac.uk
References


