Seasonal Forecasting of Ethiopian Spring rains

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University of Reading
Outline of the talk

- Large scale controls
- Homogeneous rainfall zones
- Predictors
- Forecasting Models
- Skill Assessment
- Conclusions
Large scale controls

Upper Level

Climatology (1969-2001) of wind at 200mb for FMAM season

Composite of wind at 200mb based on excess-deficit of zone IV rainfall

Low-Level

FMAM climatology (1969-2001) of wind at 850mb

Composite of wind at 850mb based on excess-deficit of zone IV rainfall
Identifying homogeneous rainfall zones

Determining and selecting of predictors

Model development

Skill Assessment
Seasonal Cycle

- **Graph:**
  - **X-axis:** Months (Feb, Apr, Jun, Aug, Oct, Dec)
  - **Y-axis:** Rainfall (mm)
  - **Legend:** Zone 1

- **Map:**
  - **Axes:** Longitude and Latitude
  - **Regions:** Marked with Zone 1 boundaries and data points

Africa group 2007 – p. 5/2
Seasonal Cycle

Rainfall (mm)

- Zone I
- Zone II

Month

Africa group 2007 – p. 5/2
Seasonal Cycle
Seasonal Cycle
Seasonal Cycle

Rainfall (mm)

Month

Zone I
Zone II
Zone III
Zone IV
Zone V
Zone VI

Longitude

Latitude

Africa group 2007 – p. 5/2
**Inter-annual variability (cross-correlation)**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Z I</th>
<th>Z II</th>
<th>Z III</th>
<th>Z IV</th>
<th>Z V</th>
<th>Z VI</th>
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![Map of Africa showing zones for inter-annual variability analysis](image-url)
Inter-annual variability (cross-correlation)

<table>
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Identifying homogeneous rainfall zones

Determining and selecting of predictors

Model development

Skill Assessment
Selection procedure

Four sets of Predictors (A’, B’, A and B) are created using:

- A’: stepwise regression and including predictors from contemporaneous season
- B’: stepwise discriminant analysis and including predictors from contemporaneous season
- A : stepwise regression and excluding predictors from contemporaneous season
- B : stepwise discriminant analysis and excluding predictors from contemporaneous season
Selected Predictors

Belg zone I predictors

Belg zone II predictors

Belg zone III predictors

Belg zone IV predictors

Belg zone V predictors

Stepwise regression  Stepwise discriminant analysis  Common to both  Including FMAM predictors

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Identifying homogeneous rainfall zones
Determining and selecting of predictors

Model development

Skill Assessment
Forecasting Models

**Multiple Linear Regression (MLR)**

\[
\Pr(Y|X) \sim N(\hat{Y}, \text{var}(\hat{Y})); \quad \hat{Y} = \hat{\beta}X; \quad \text{var}(\hat{Y}) = \sigma^2_o[1 + X'(X'X)^{-1}X]
\]

\(Y\) = Rainfall; \(X\) = predictors (SSTA); \(\beta\) = regression parameter

**Linear Discriminant Analysis (LDA)**

\[
Pr(W|X) = \frac{Pr(W_i)f_i(X)}{\sum_j Pr(W_j)f_j(X)} \ln(f_i(X)) = \alpha_1x_1 + \alpha_2x_2 + \ldots + \alpha_nx_n + \Gamma_i
\]

\[
Pr(W|X) = \frac{e^{d_i}}{\sum_j e^{d_j}} \quad \text{where} \quad d_i = \alpha_1x_1 + \alpha_2x_2 + \ldots + \alpha_nx_n + \Gamma_i + \ln(Pr(W_i))
\]

Where \(\alpha_{ij} = S_{ij}^{-1} \bar{x}_i\) and \(\Gamma_i = -\frac{1}{2} \bar{x}_i^T S^{-1} \bar{x}_i\)

d=discriminant score, \(Pr(W_i)\) = apriori probability, \(W\) = category, \(f\) = density function
Identifying homogeneous rainfall zones

Determining and selecting of predictors

Model development

Skill Assessment
Hindcast

leaving out 3 years cross-validation

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Training

Forecast

Omit
# Skill Assessment-I

1. **Relative Operational Characteristics (ROC) score**
   - compare with a random forecast
   - For a skillful forecast $\rightarrow$ ROC score $(0.5,1]$ 

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Dry</th>
<th>Normal</th>
<th>Wet</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>MLR</td>
<td>LDA</td>
<td>MLR</td>
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<tr>
<td>Set A’</td>
<td>0.87</td>
<td>0.84</td>
<td>0.69</td>
</tr>
<tr>
<td>Set B’</td>
<td>0.86</td>
<td>0.86</td>
<td>0.69</td>
</tr>
<tr>
<td>Set A</td>
<td>0.87</td>
<td>0.83</td>
<td>0.63</td>
</tr>
<tr>
<td>Set B</td>
<td>0.83</td>
<td>0.82</td>
<td>0.66</td>
</tr>
</tbody>
</table>

- Lower skill in the near Normal category
- Higher ROC score for models with predictors set B (including contemporaneous season)
2. Ranked Probability Skill Score (RPSS)

- compare with climatology
- For a skillful forecast → RPSS(0,1]

If we exclude contemporaneous predictors, the highest skill is over Zone V (where spring is the main rainy season)
Conclusions

- Due to high spatial variation forecasting should be done for each homogeneous rainfall zones separately.

- Linear approach yield a better skill compared to climatology or random forecast.

- The skill in the outer categories (above normal and below normal) is better that that of the inner one (near normal).

- Models with predictor set A’ and B’ (including contemporaneous season) have got higher skill than models with predictor set A and B (excluding contemporaneous season).

- The skill of the forecast is better for zone V where Spring is the main rainy season.
Future work

- Modify the seasonal forecast by using additional atmospheric parameter and compare with the one already done

- Carry out idealised SST experiments for different regions of oceans to understand the mechanisms
Thanks