Meteosat Flow Forecasting & Drought Monitoring

Andries Rosema
EARS Earth Environment Monitoring BV
Delft, The Netherlands
EARS Earth Environment Monitoring BV

• Remote sensing company since 1977
• Delft, the Netherlands
• Energy & Water Balance Monitoring
• Using geostationary meteorological satellites
• Climate, Water and Food applications:
  ✓ River flow forecasting
  ✓ Drought monitoring
  ✓ Crop yield forecasting
  ✓ Crop insurance
Energy and Water Balance Monitoring System
Meteosat
Energy en Water Balance

Radiation → Heat → Evaporation → Precipitation → Flow
Energy and Water Balance Monitoring System (EWBMS)

- Meteosat
- VIS & TIR

- Clouds
  - Rainfall processing

- Temperature
  - Albedo
  - Energy balance processing

- Precipitation

- Evaporation

- Radiation

- Hydrological model
  - River flow forecasting

- Drought processing
  - Drought monitoring

- Crop growth model
  - Crop yield forecasting
Rainfall product
Actual evapotranspiration product
Water balance validation

- SW Burkina Faso reported run-off: 2-8% (Mahe et al. 2008)
- EWBMS using Meteosat: 4.5%

**EWBMS rainfall & evapotranspiration**

![Graph of cumulative PREC/ET and ET vs. time]

**Same but cumulative**

![Graph of cumulative PREC/ET and ET vs. time with lines and formulas]

- EARS
  Satellite data for Climate Water and Food
Time series (daily, 10-daily)
Complete river basins
Flow Forecasting
Yellow River basin project (2006-2009)

Upper Yellow River

Wei River

Second largest river basin of China
GMS / FY2 precipitation data

1st quarter 2000

2nd quarter 2000

3rd quarter 2000

4th quarter 2000
Water balance validation

Upper Yellow River
Large Scale Hydrological Model (LSHM)

Land component:
2-dimensional diffusion process
Surface & sub-surface flow

*EWBMS Precipitation & Evapotranspiration*

River flow component:
Muskingum-Cunge routing

\[
Q(t) = Q_l(t) + Q_r(t)
\]
Wei River flow simulation

\[ R^2 = 0.75 \]
Vol. error = 4%

\[ R^2 = 0.80 \]
Vol. error = 11%
Wei River 24 hr forecast

RMSE = 110 m$^3$/s  RRMSE = 0.37
COE = 0.75  $R^2$ = 0.79
Upper Yellow River flow simulation

<table>
<thead>
<tr>
<th>Station</th>
<th>$R^2$</th>
<th>Volume difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jimai</td>
<td>0.80</td>
<td>+17.9 %</td>
</tr>
<tr>
<td>Maqu</td>
<td>0.82</td>
<td>- 0.61%</td>
</tr>
<tr>
<td>Jungong</td>
<td>0.80</td>
<td>+ 0.61%</td>
</tr>
<tr>
<td>Tangnaihai</td>
<td>0.80</td>
<td>- 0.67%</td>
</tr>
</tbody>
</table>
Upper Yellow River 24 hr forecast

RMSE = 161 m$^3$/s
RRMSE = 0.17

COE = 0.84
$R^2 = 0.93$
High level interest at the 2nd International Yellow River Forum
Zhengzhou, October 2005
Yellow River project evaluation

- By a Chinese high-level scientific commission
- Classification: “World Leading Level”
- 2nd Prize China Ministry of Water Resources

- Niger Basin Authority, Niamey, Niger
- Operational implementation
- Drought monitoring
- River flow forecasting
Project components

- Meteosat receiver
- PC network
- Software
  - Pre-processing
  - EWBMS
  - LSHM
  - Utility GIS
- Validation
- Calibration
- Training
Meteosat antenna
Receiving and processing office
Training
Drought monitoring
EARS Satellite data for Climate Water and Food

EWBMS drought information

- Meteorological drought
  - SPI

- Hydrological drought
  - EP = P – E_a

- Agricultural drought
  - RE = LE_a / LE_p

- Climatic drought (> 1 yr)
  - Climatic Moisture Index (UNEP)
    - CMI = P / LE_p
  - Environmental Moisture Index
    - EMI = LE_a / LE_p
Evapotranspiration & crop growth

- Evapotranspiration ≈ transpiration
- CO₂ uptake proportional to crop growth

\[ 1 - R_Y = k^*(1 - R_E) \]

Doorenbos & Kassam (1979)
“Yield Response to Water”
FAO Irrigation & Drainage Paper 33
Relative evapotranspiration (RE)

Agricultural drought index used for:
• Irrigation scheduling / water allocation
• Crop yield forecasting
• Agricultural drought insurance

\[ \text{Difference evapotranspiration (DE)} \]
\[ DE = \frac{(RE - RE_{avg})}{RE_{avg}} \]
Drought monitoring East Africa

• DE East Africa
• Vuli season (Dec-Jan)
• Scale -30% to +30%
• Extreme drought in 2006
Irrigation patterns Niger delta
Start of 2014 growing season W-Africa
2014 Crop yield forecast
Long time series for index insurance design

- Location of growing season (starting window)
- Quality of growing season (RE)
- Historic risk assessment → insurance premium
Index insurance

- Crops and livestock
- Drought and excessive precipitation
- In 10 African countries
- A dozen of insurance partners
- 23,000 farmers insured in 2013
- Target next 6 year: 1 million farmers
Conclusions

- Satellite based climate monitoring system
- Precipitation and evapotranspiration data
- Daily temporal resolution
- 3-5 km spatial resolution
- Distributed, transboundary
- Uniform
- Objective
- Validated
- Cost effective
- River flow forecasting
- Drought monitoring and water allocation
- Crop yield forecasting and crop insurance
What about India?
Cumulative precipitation first dekad of September
Thank you for your attention

andries.rosema@ears.nl
www.ears.nl
Rainfall processing

- Meteosat TIR
- Cloud top temperature
- Cloud level
- Cloud level durations (CD_i)
- GTS rain gauge data (R)
- Regression:
  \[ R = a_0 + a_1 CD_1 + a_2 CD_2 + \ldots \]
- Calculate rainfall field
Evapotranspiration processing

Hourly TIR

TIR, VIS

Cloud?

Atm.corr.

T₀, Tₐ, A₀, t

TIR, VIS

Hourly VIS

Radiation

Iₙ = (1 - A₀) I₇ - Lₚ

Potential evaporation

LEₚ = 0.8 Iₙ

Sensible heat flux

H = α (T₀ - Tₐ)

Actual evaporation

LE = Iₙ - H

Rel. evaporation

RE = LE / LEₚ

LE = 0.8 * RE * Iₙ

constant “Bowen ratio”