Nick Chappell

Interaction between Hydrological and Meteorological Processes in S E Asia

CRES Hydrology & Fluid Dynamics Group
IENS, Lancaster University, Lancaster LA1 4YQ

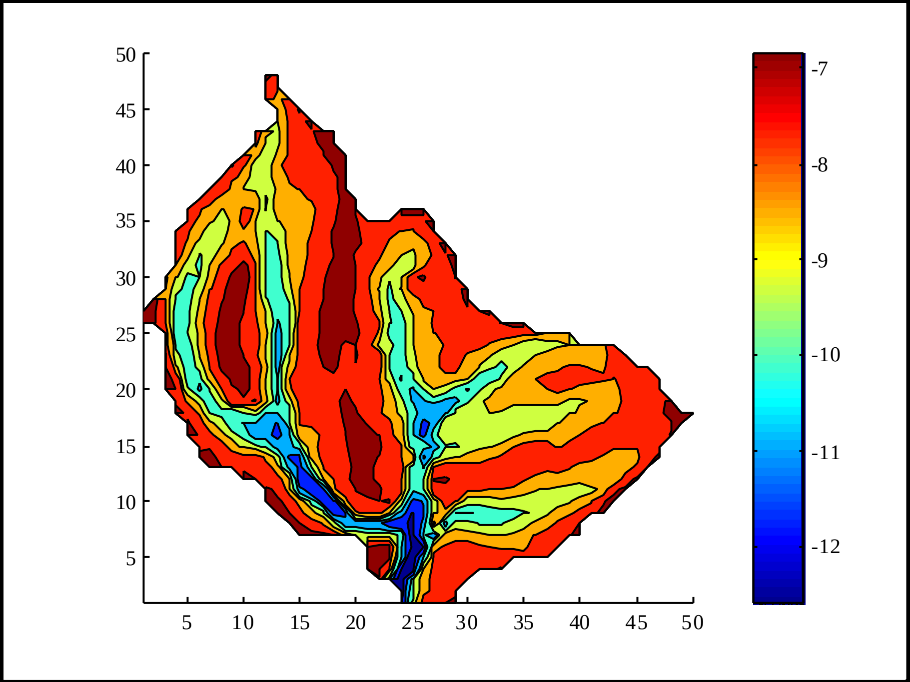
- **Tropical hydrology : current research questions**
  … need new meteorological input

- **Tropical meteorology (partic GCM studies)**
  … need new hydrological input

Illustrate with some of our work in tropical S E Asia

Tropical Hydrology: Need For New Meteorological Input

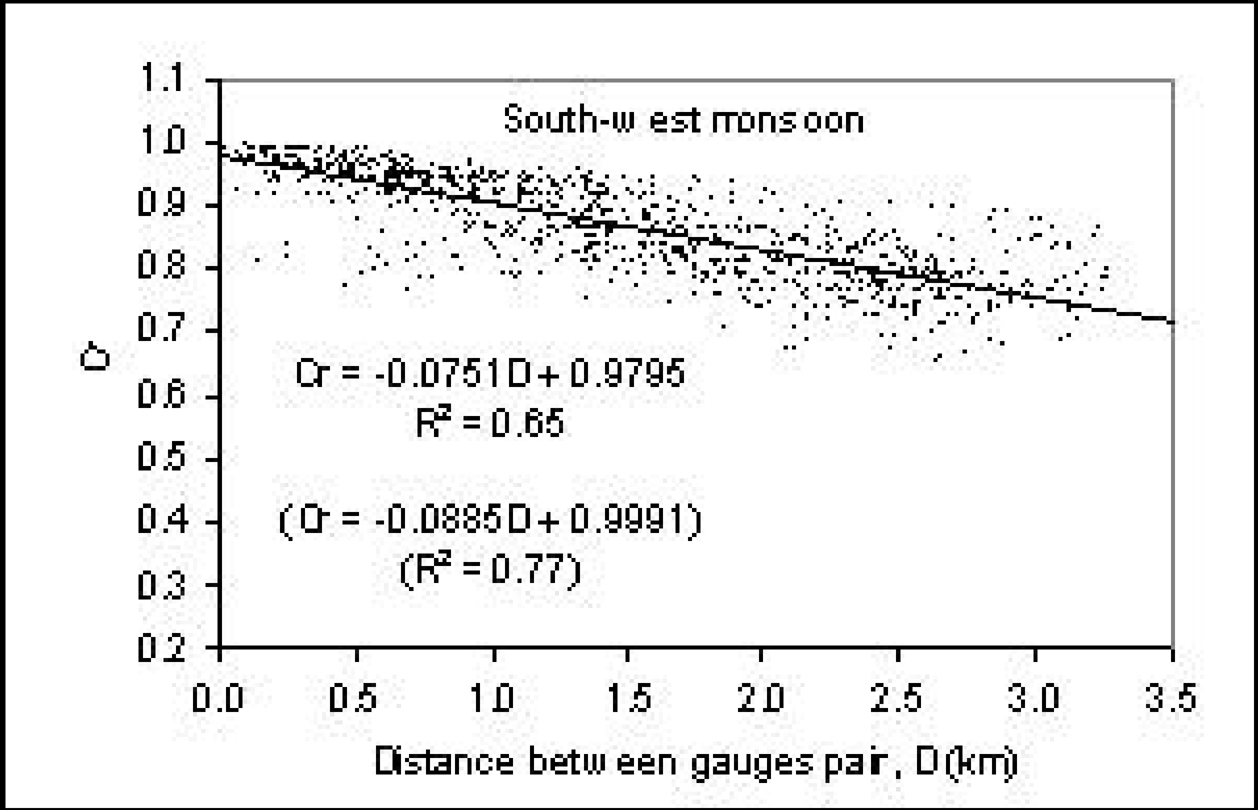
- **rainfall-runoff processes within (tropical) catchments**



Spatially distributed processes within 0.1-10 km^2 exp catchments

e.g., wetness index 0.44 km^2 Baru catchment, Borneo (Chappell *et al.*, 1998 *Hydrol. Process.)*

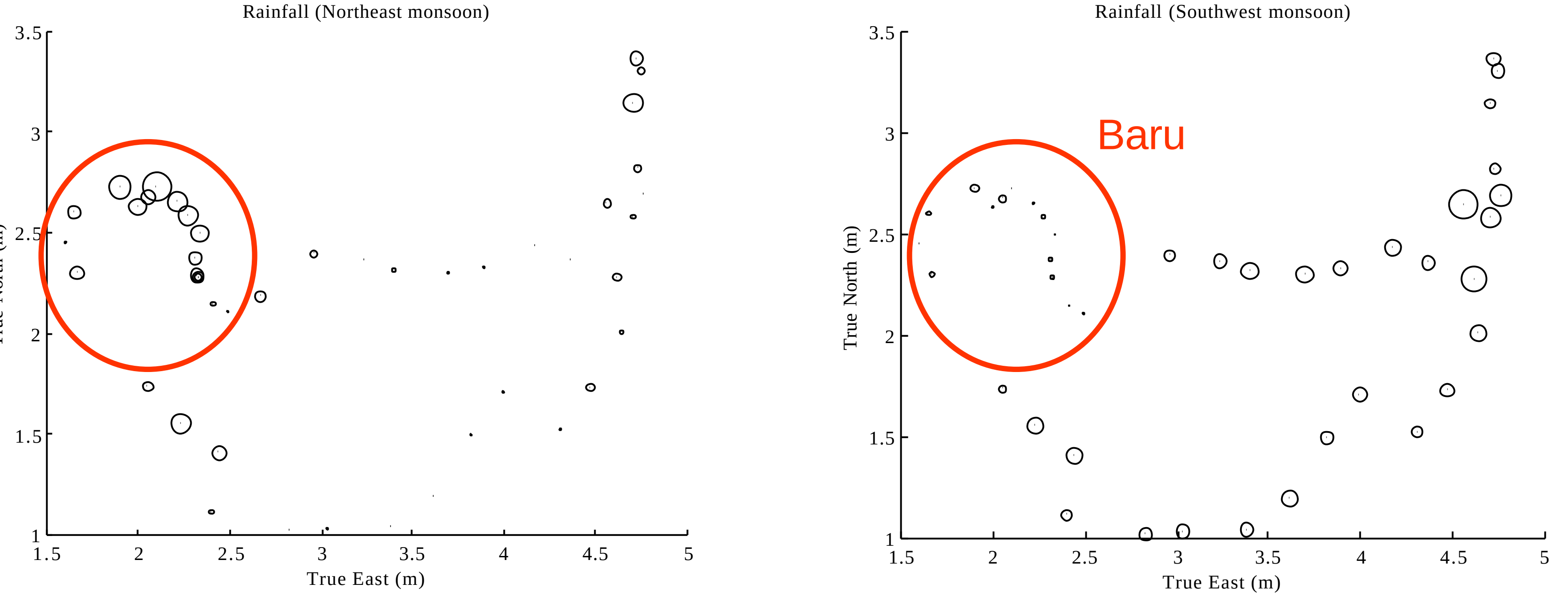
Now see rainfall not lacking structure a fine-scales ...



Stochastic (distance-related) structure

4 km^2 Sapat Kalisun Exp. Catchment, incl. Baru (K Bidin PhD thesis)

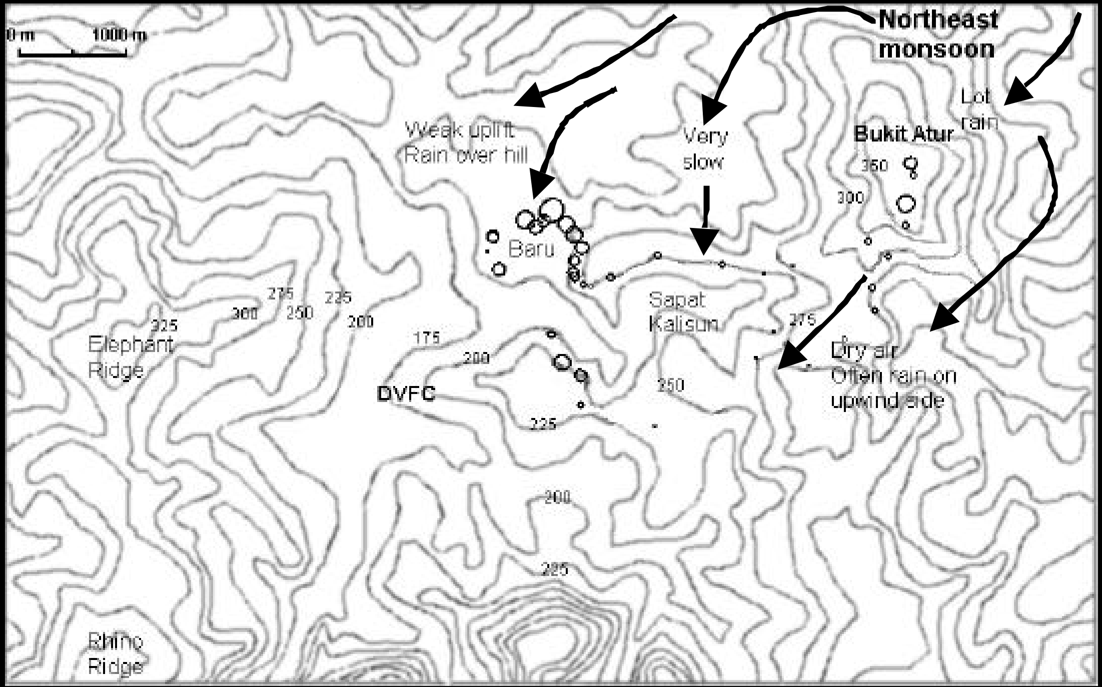
Deterministic (topography-related) structure
seen with monsoonal changes in wind direction



NE monsoon (Nov-Apr)

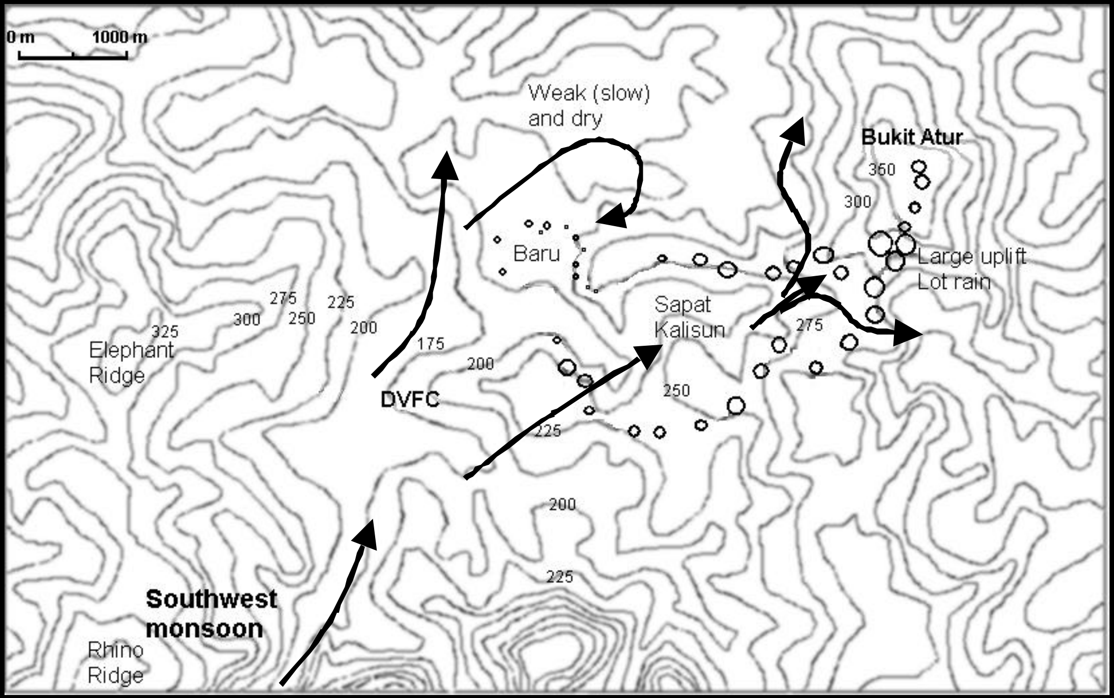
SW monsoon (May-Oct)

Circles on map are proportional to 6-month rainfall totals
NB axes are in kilometers, not metres



NE monsoon (Nov-Apr)

Possible windfield giving rise to rainfall pattern
Bidin, Chappell, Dalimin and Sinun, submitted, *Hydrol. Earth Syst. Sci.*



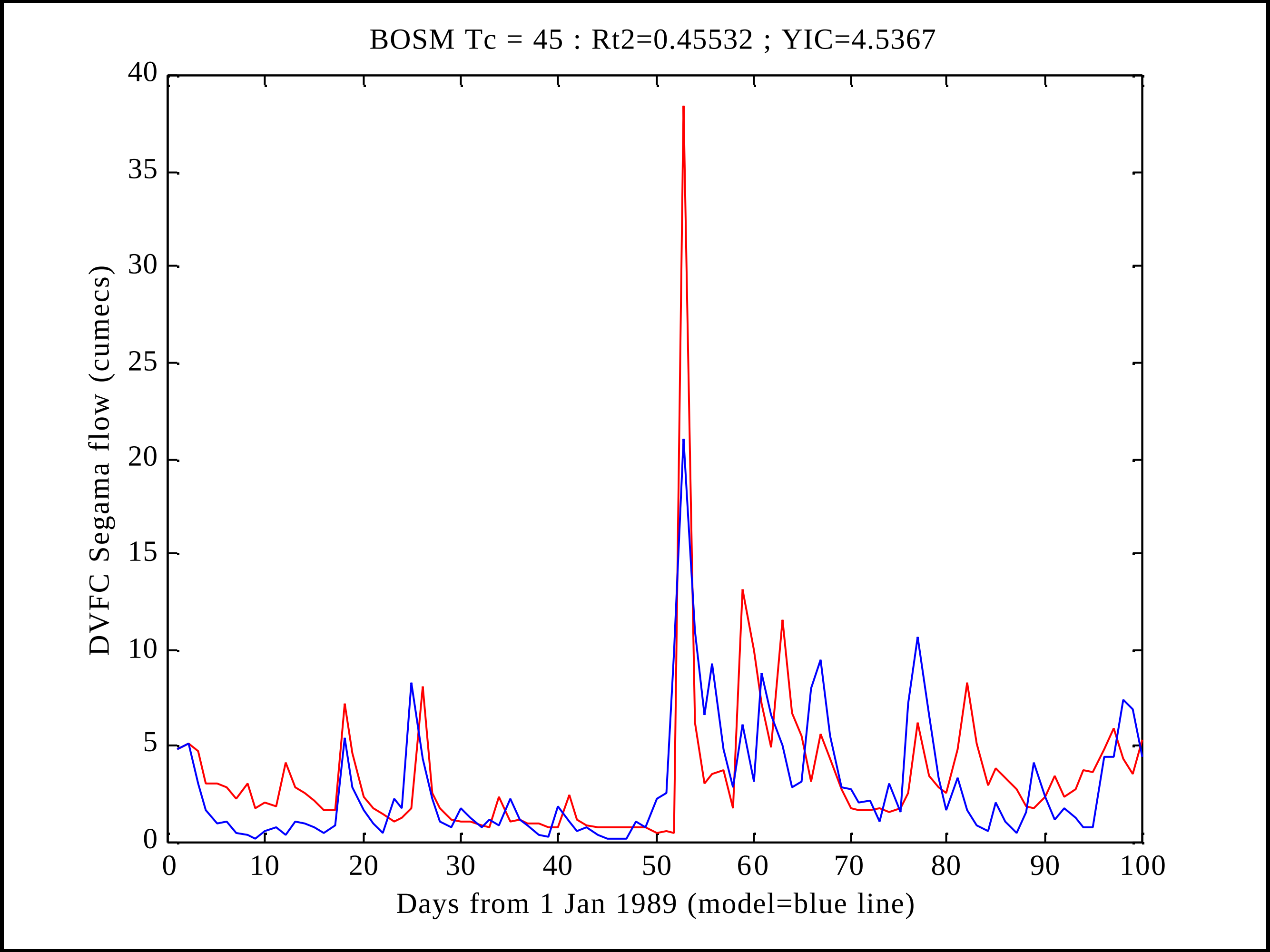
SW monsoon (May-Oct)

need more meteorological input to catchment studies

- **represent (tropical) R-R processes over larger scales**

Describe R-R processes at 100-5,000 km^2 scale …understand changes in dominant process with scale changes

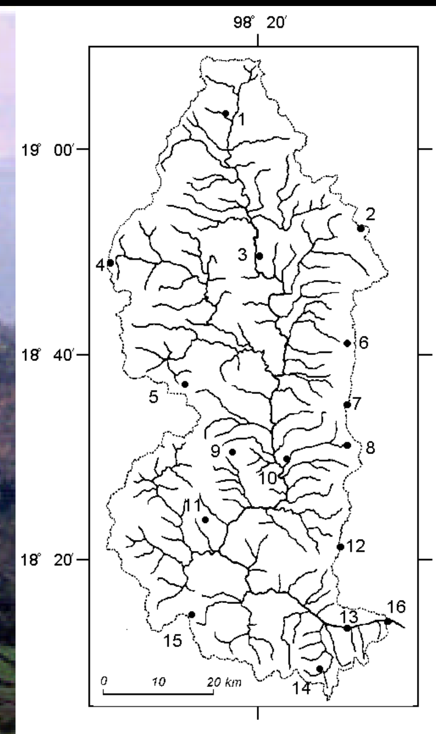
Problem of sparse raingauge networks when modelling rainfall - riverflow of large tropical catchments



One raingauge / 721 km^2: only 46 % explanation of riverflow using Data-Based-Mechanistic model (with non-linearity)

S Vongtanaboon, PhD programme: Hydrology of large tropical catchments

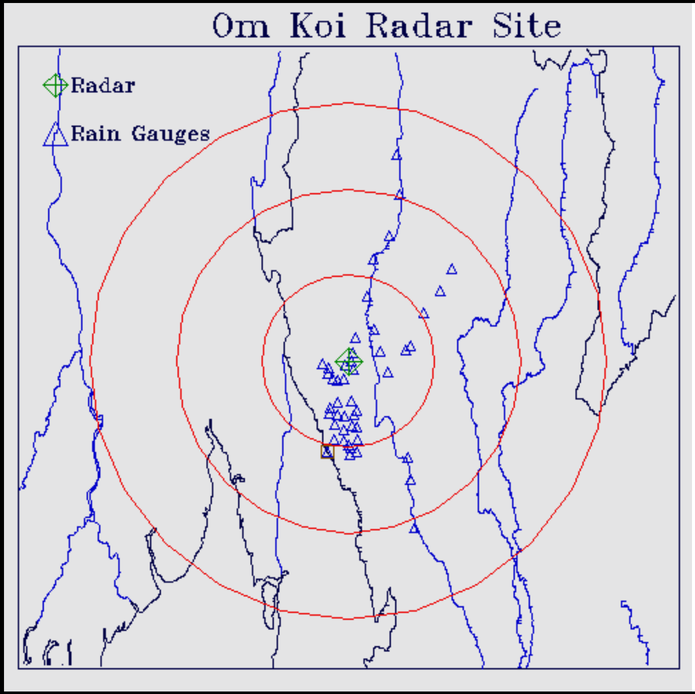
Multiple, nested catchments throughout Thailand,
including 3,853 km^2 Mae Chaem catchment (below)



- scale effects with changing scale
- **process / model structure ID (with DBM), dependent on rainfall sampling density**

Also using same Mae Chaem catchment is the GAME-T programme
potential value of obtaining regional (1,000 km^2) rainfall from ...

Calibrated radar



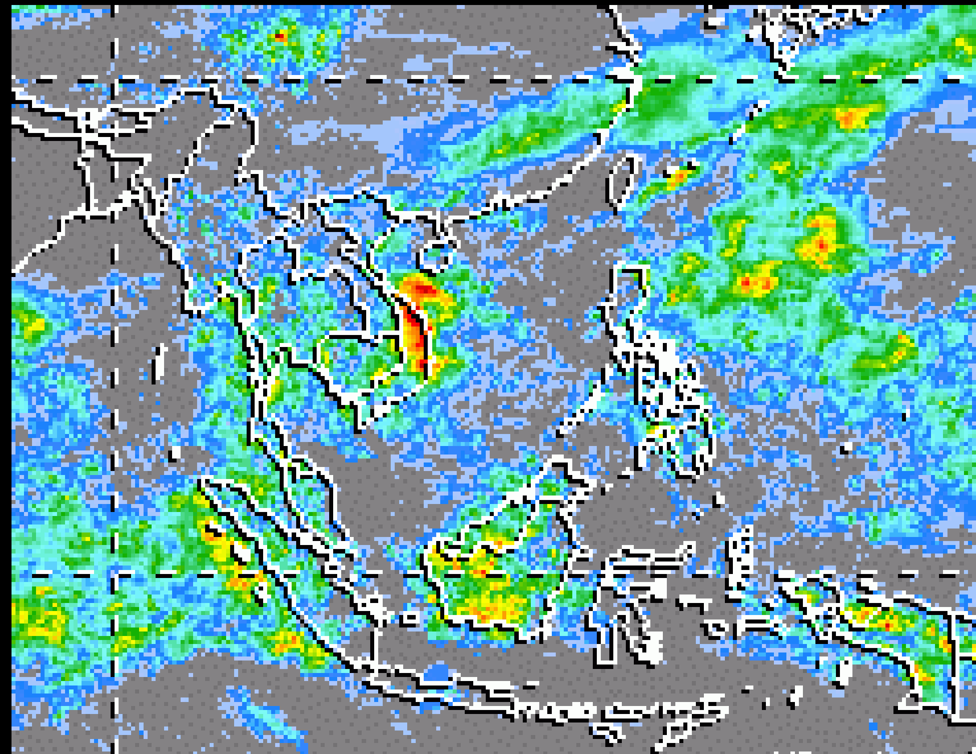
GAME-Tropics: GEWEX Asian Monsoon Experiment

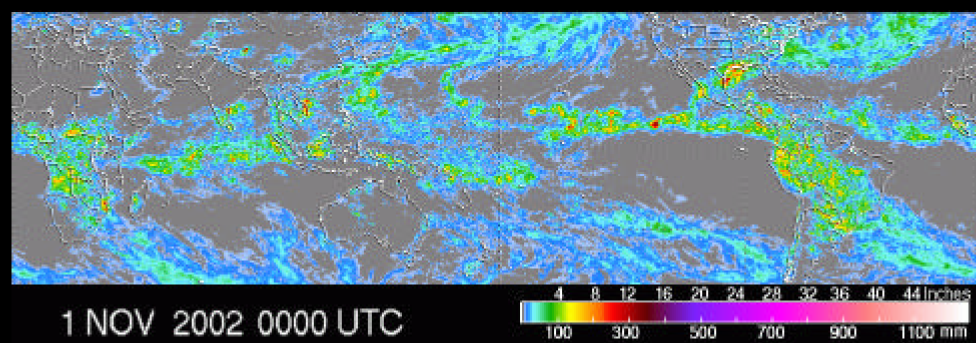
Improving resolution satellites (?)

e.g., TRMM

Tropical Rainfall Measuring Mission

NASA (USA)
NSDA (Japan)

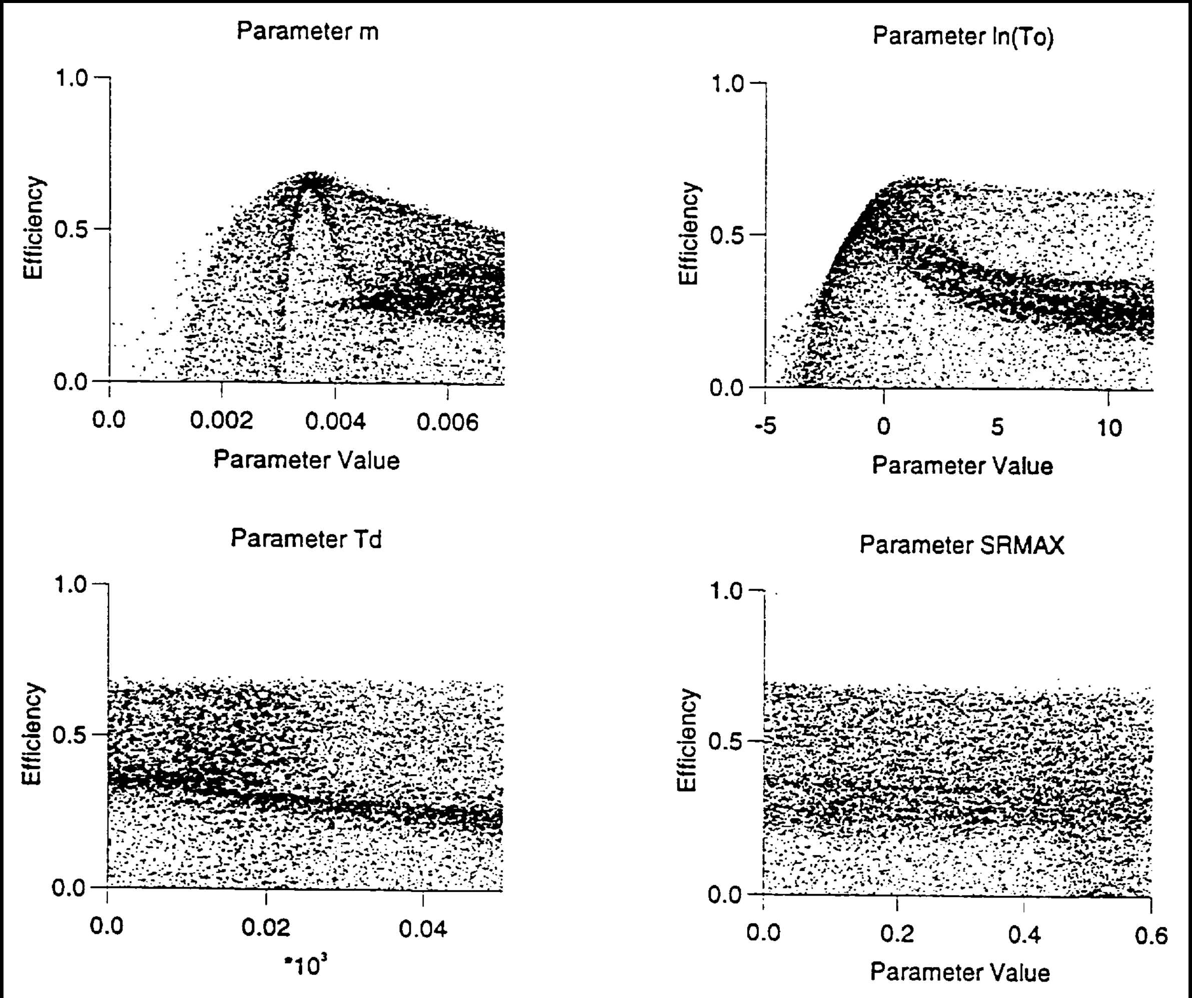




ref. Martin Fowell
PhD programme

- **land-use change impacts on (tropical) hydrological processes**

River flashiness, evapotranspiration, river turbidity, river chemical quality etc



(1) Modelling:

Utility of physically based modelling of catchment rainfall-runoff relationships is limited due to **parameter uncertainty** during the calibration process

e.g., Beven (2001) *Hydrol. Earth Syst. Sci.*

Left: Efficiency vs possible parameter values in a 4-parameter model, Baru catchment (Chappell *et al.*, 1998 *Hydrol Process*)

(2) Empirical field studies:

Too few land-use change case studies for tropics (Chappell *et al.,* 2002b, *CUP*)

partic as sensitive to time undertaken during natural climatic cycles & trends

Rainfall-driven phenomenon of suspended sediment flux

e.g., Segama catchment

(partly disturbed by commercial, selective logging)

8-year record

analysed using

Dynamic Harmonic Regression (DHR) model

Young, Pedregal & Tych (1999)

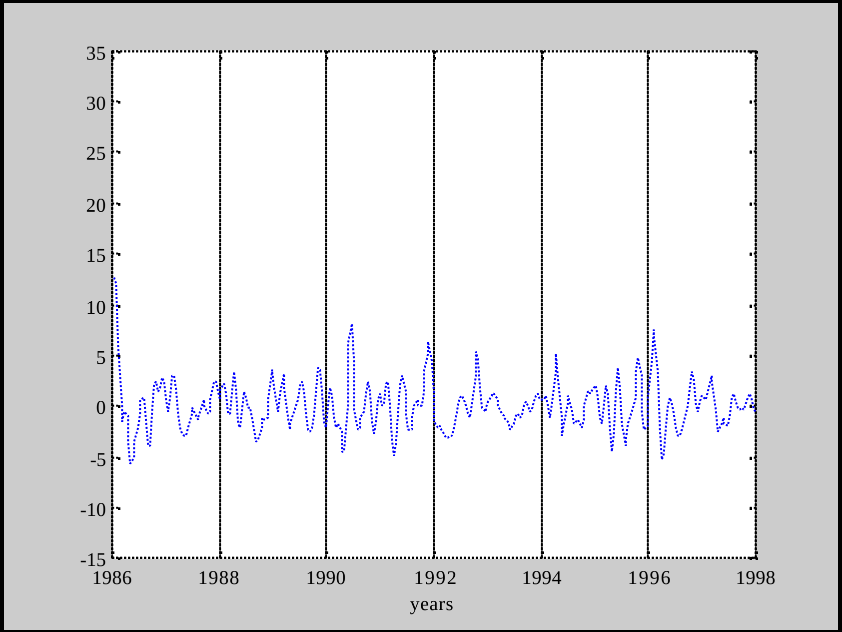
recursive interpolation, extrapolation and smoothing algorithm for non-stationary time-series

$$SS_{(t)} = T_t + S_t + e_t$$

- T_t trend, incl. inter-annual cyclicity & longer-term drifts
- S_t within-year cycles or seasonality
- e_t white noise

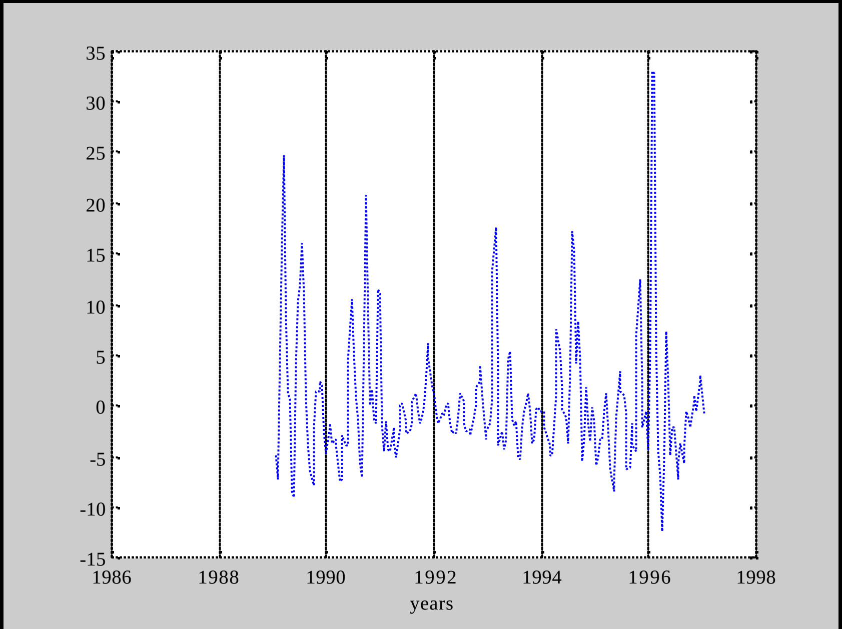
Seasonal rainfall cycles magnified

Rain



within-year cyclicity 3 to 5 mm day^{-1}
rainfall equivalents

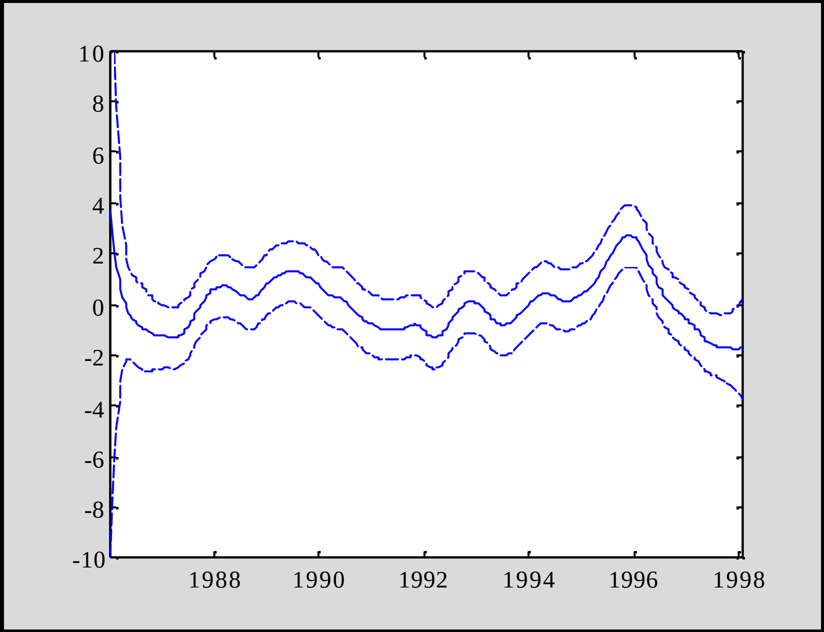
SS flux



within-year cyclicity 5 to 20 mm day^{-1}
rainfall equivalents

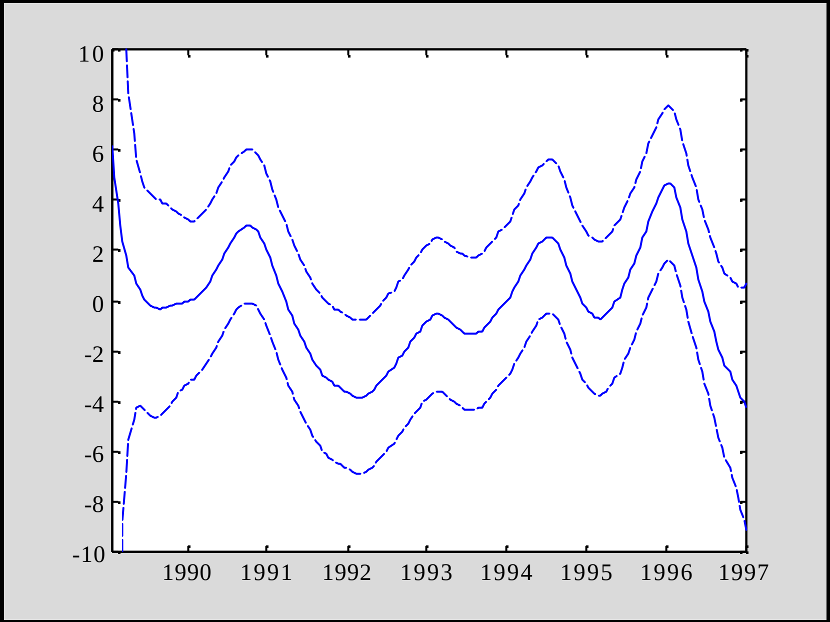
Inter-annual rainfall cycles (e.g., ENSO) magnified

Rain



inter-annual cyclicity ≈ 2 mm day^{-1}
rainfall equivalents

SS flux



inter-annual cyclicity ≈ 4 mm day^{-1}
rainfall equivalents

(Chappell *et al.*, 2002b, *CUP*)

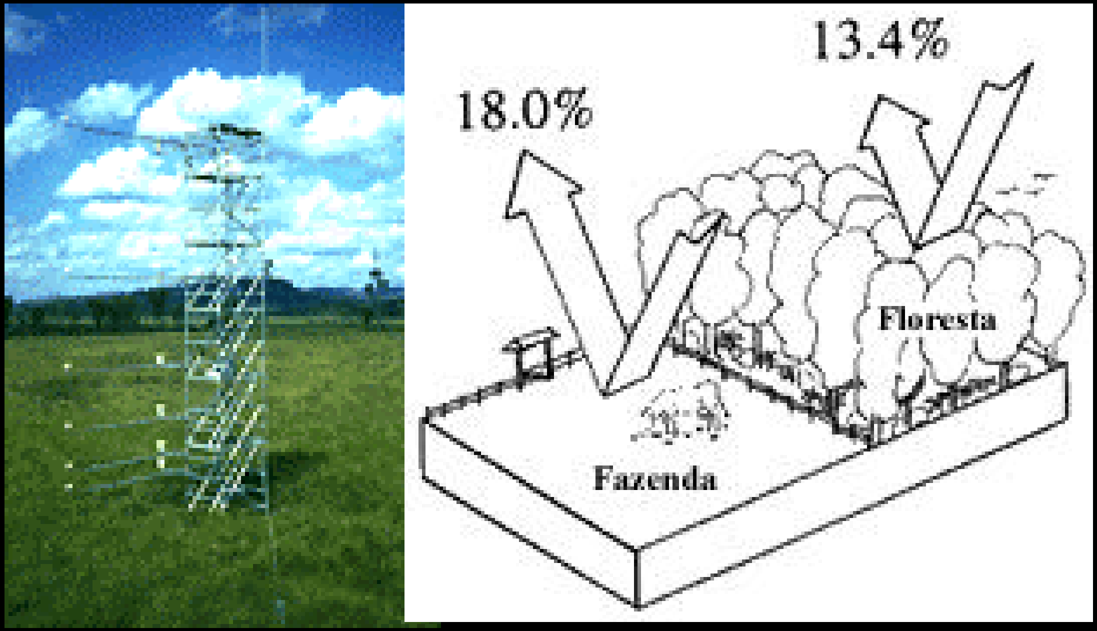
Effects seasonality & ENSO much greater impact on annual sediment budgets than expected from dynamics in rainfall

thus relative impact of partic land-use changes (e.g., forestry) strongly dependant on season & position in ENSO cycle activities take place ('paired studies' do not account for all effects)

e.g., road constr & harvesting conducted at peak in La Nina period greater rel impact same operations in El Niño period

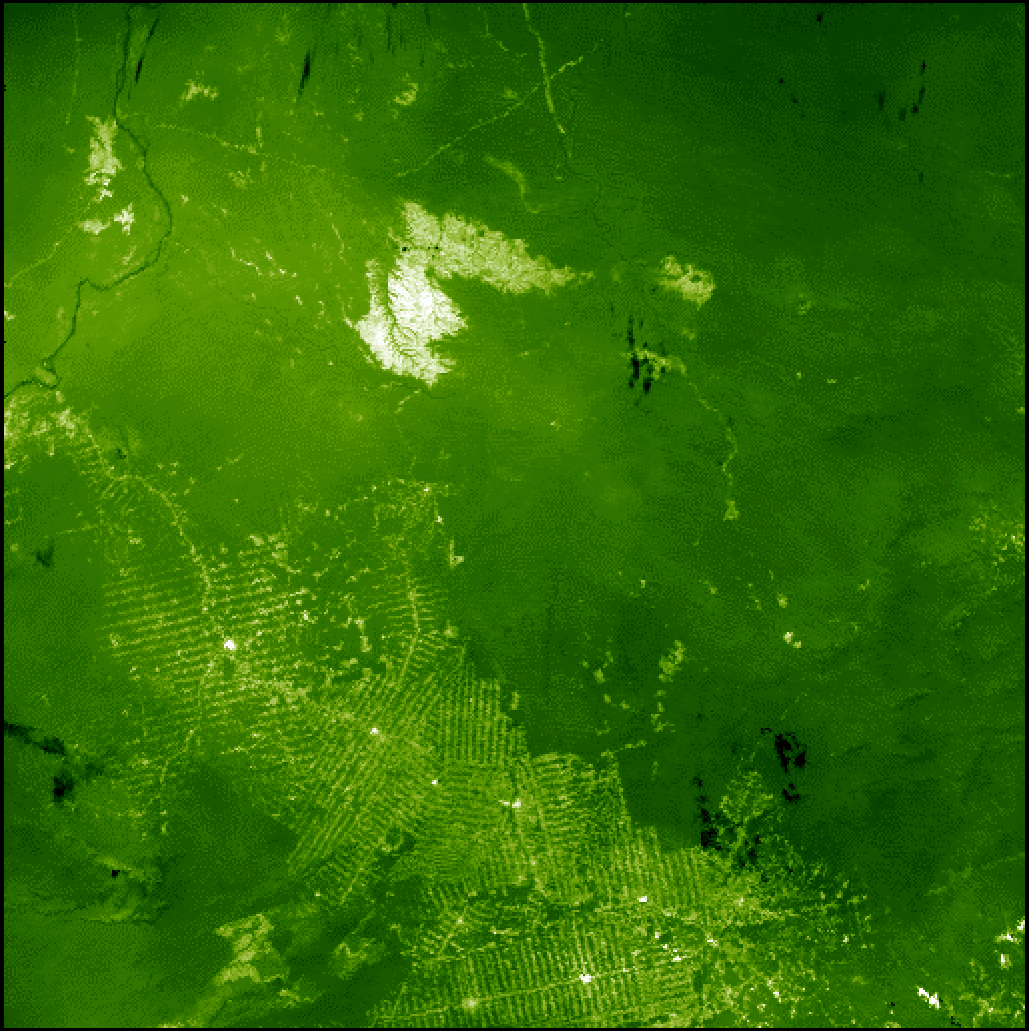
Tropical Meteorology:
Need For New Hydrological Input

- **land-cover change impacts on regional evaporation**



Good field studies (e.g., Gash *et al*., 1996, *Wiley*) & GCM land-use change simulations (e.g., Zhang *et al*., 1996 *J. Clim.*) **based on very simple vegetation covers**

A key land-cover in SE Asia - selectively managed forest, is alone highly complex



Even forest loss in the Amazon now thought
to be complex (Drigo, 2002, *CUP*)

clearfelling in humid tropics

red evapotranspiration is well attested by field studies (Oyebande, 1988; Bruijnzeel, 1990; 1996; 2001)

A. selective logging (localised disturbance)

- smaller gaps where:

(i) new growth of pioneer trees,
(ii) accelerated growth of younger & smaller commercial trees, &/or
(ii) vine growth takes place

- **red ET by removal of climax trees partly offset by rapid growth of water demanding pioneer trees & vines**

e.g., High rates of transpiration from:

- vines in secondary Amazonian forest (Restom & Nepstad, 2001)

- pioneer trees in E. Malaysian rainforest (Eschenbach *et al.*, 1998)

- also some types of canopy damage can give inc wet-canopy-evap (Bidin, 2001; Chappell *et al.,* 2001)

B. Large, largely unexplained, range in rates in wet canopy evaporation for different locations (Bruijnzeel, 1990; 1996; 2001)

Gash *et al*., (2002, *CUP*) hypothesis of strong inland vs coastal effects rather than purely vegetation differences

Difficult to derive regional estimates of evapotranspiration from assemblages of observed field data

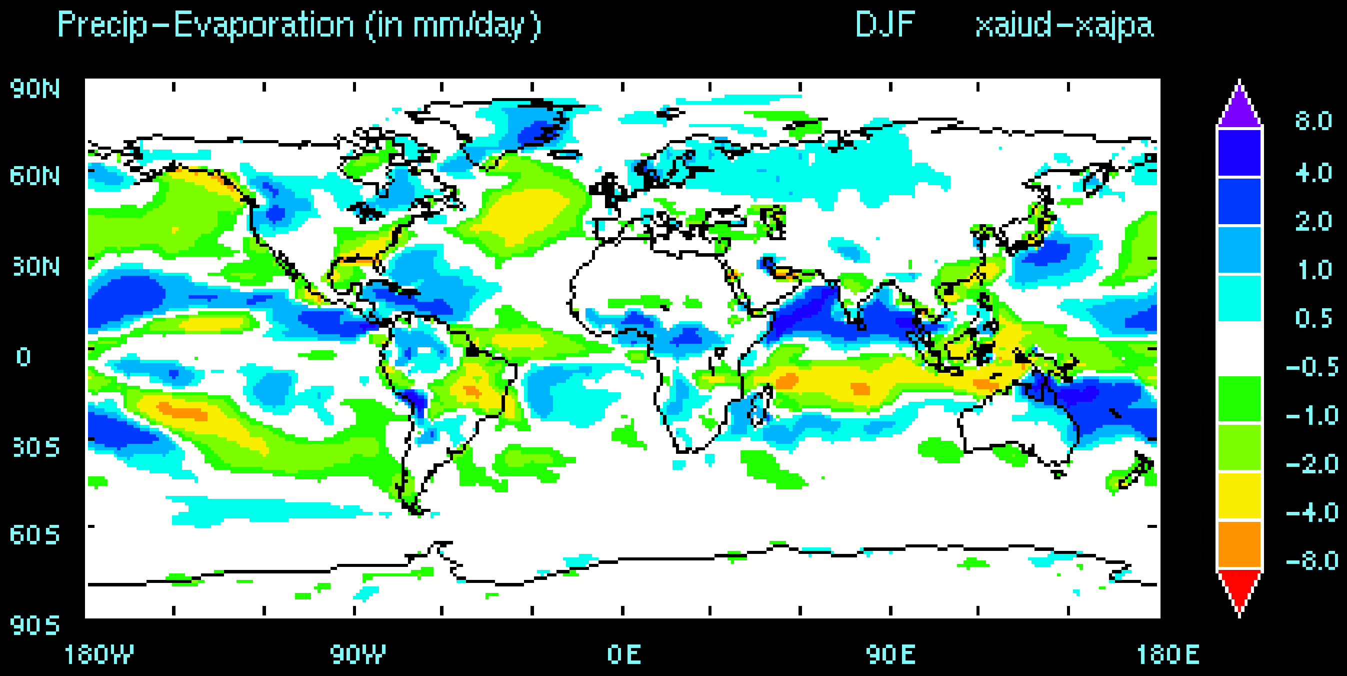
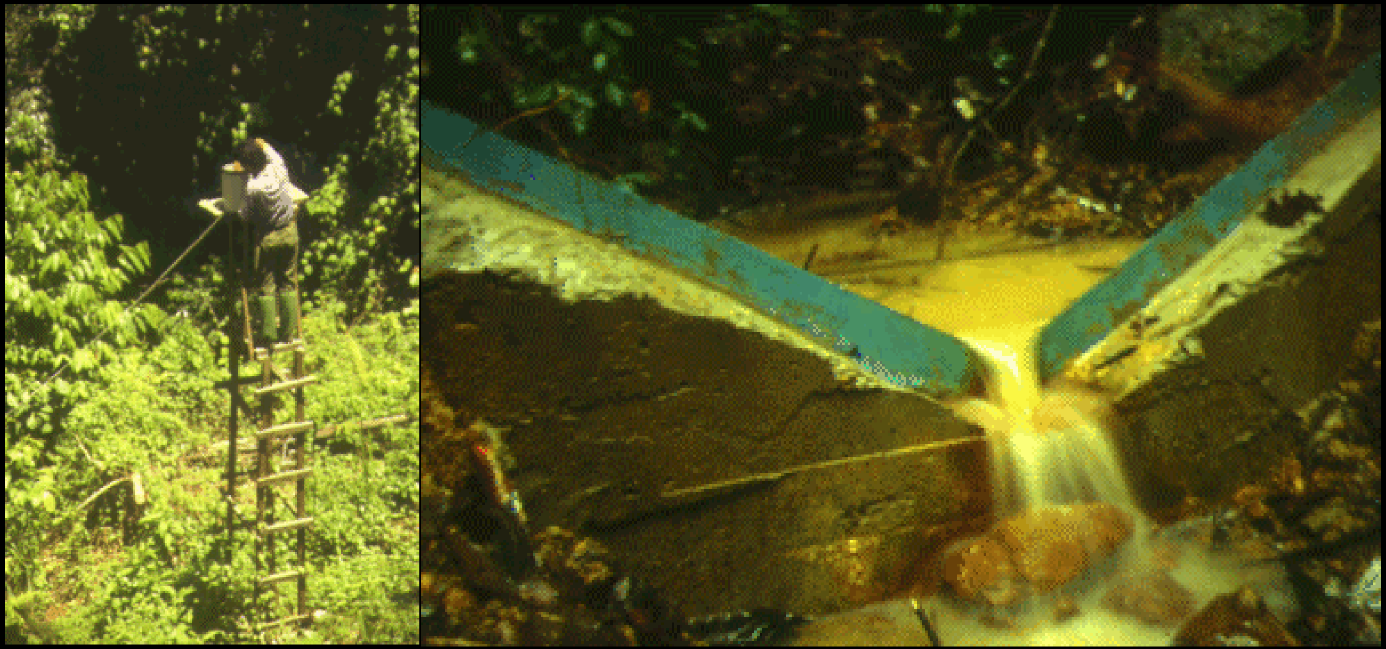


diagram from Hayward *et al*. (1999)

how do we judge / validate GCM simulations of evapotranspiration ?

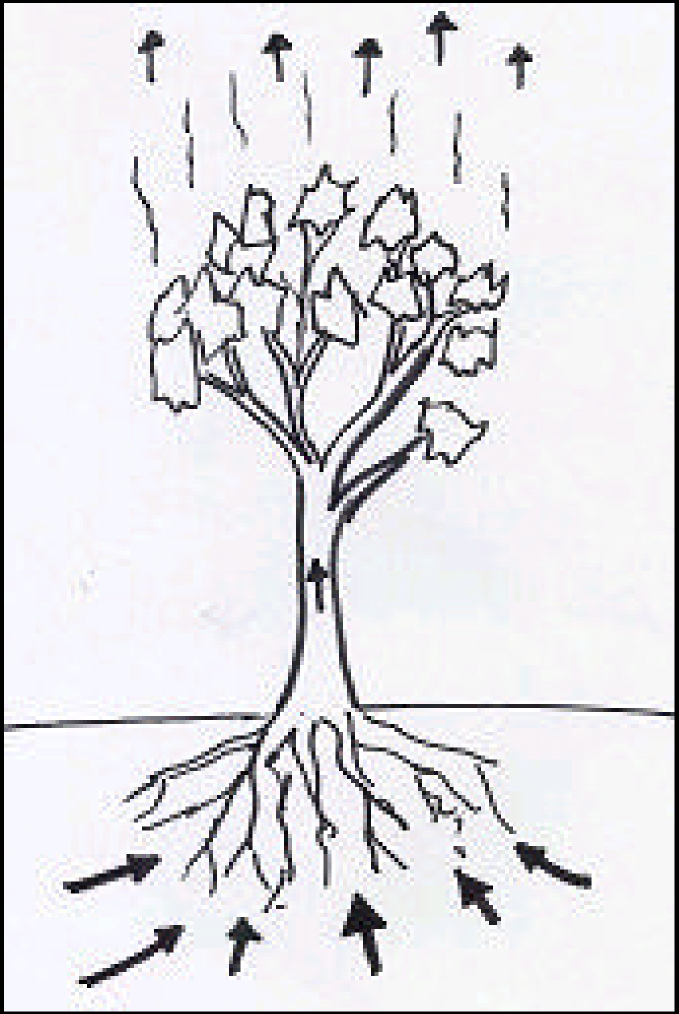
● **rainfall-runoff pathways in GCMs affecting vapour transfer to atmos**



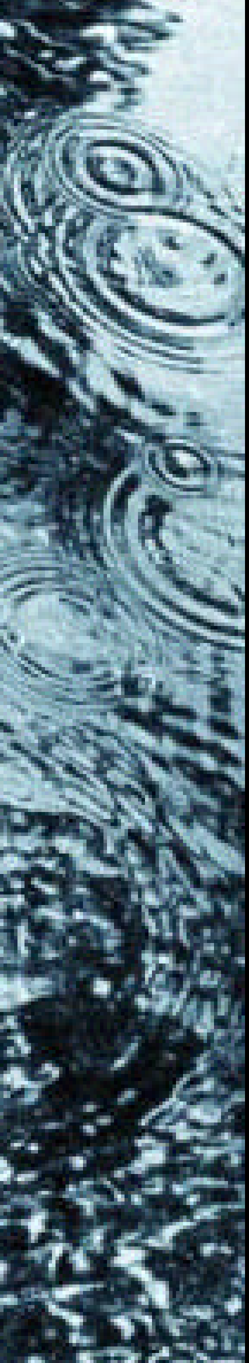
Common belief that most rainfall that generates tropical hydrographs is from purely overland flow, and that this increases dramatically with terrain disturbance during deforestation. Also seen within some GCM simulations (e.g., Lean *et al*., 1996 *Wiley*)

Field data does not support this…

tropical rainforest slopes in Africa (e.g., Dabin, 1957, *DPBS*), S America (e.g., Cailleux, 1959, *MSCG*) & SE Asia (e.g., Chappell *et al.*, 1999a, *Phil. Trans. R. Soc. Lond. B*.) usually generate **only a few % overland flow** per unit slope area



This means there is **more soil-water (& deeper sources) available to sustain transpiration**



Conclusions

Catchment hydrologists would benefit from greater meteorologist involvement…

- nature of the **catchment rainfall distribution** (the driver for most tropical hydrological processes)
- new techniques providing more accurate **regional rainfall**
- underling the importance of **natural dynamics of the climate** when hydrologists attempt to identify land-use change impacts

GCM simulations of tropical climate or predictions of land-use impacts on climate would benefit from hydrologists

- providing more robust estimates of the components of **regional evapotranspiration**
- disseminating current **evidence & theories of flow pathways** within the tropical biosphere