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Detecting periodic climate fluctuations in vegetation patterns from satellite image time series

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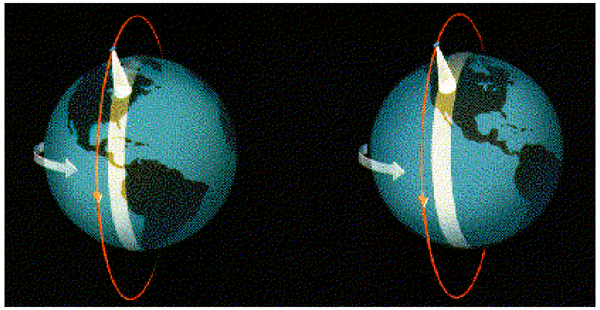
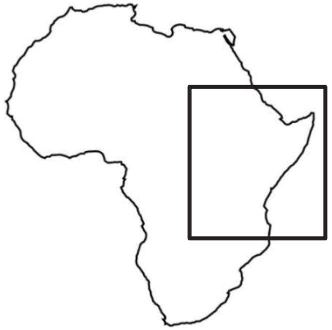
Intro: Earth Observation data



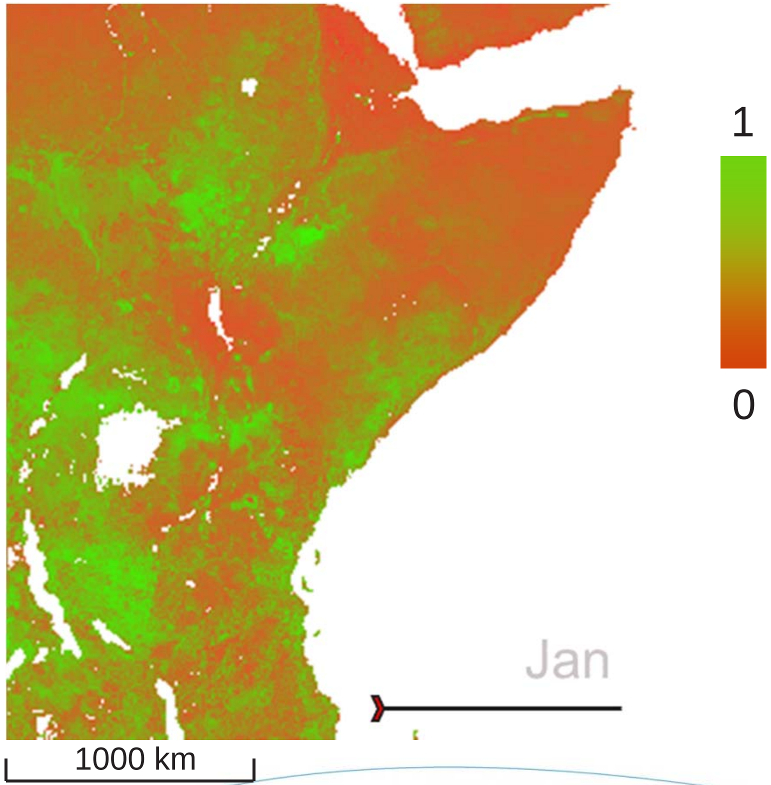
- Global land surface monitoring (nearly daily coverage!)

Source: EUMETSAT

Intro: Satellite image time series



- Temporal changes in vegetation cover
- NDVI index
  - NOAA-AVHRR (1981-1999)
  - SPOT-VGT (1998-2014)
  - Proba-V (2013- present)
- 4km/1km/300m spatial resolution
- 10-daily synthesis



$$NDVI = \frac{Refl_{NIR} - Refl_R}{Refl_{NIR} + Refl_R}$$

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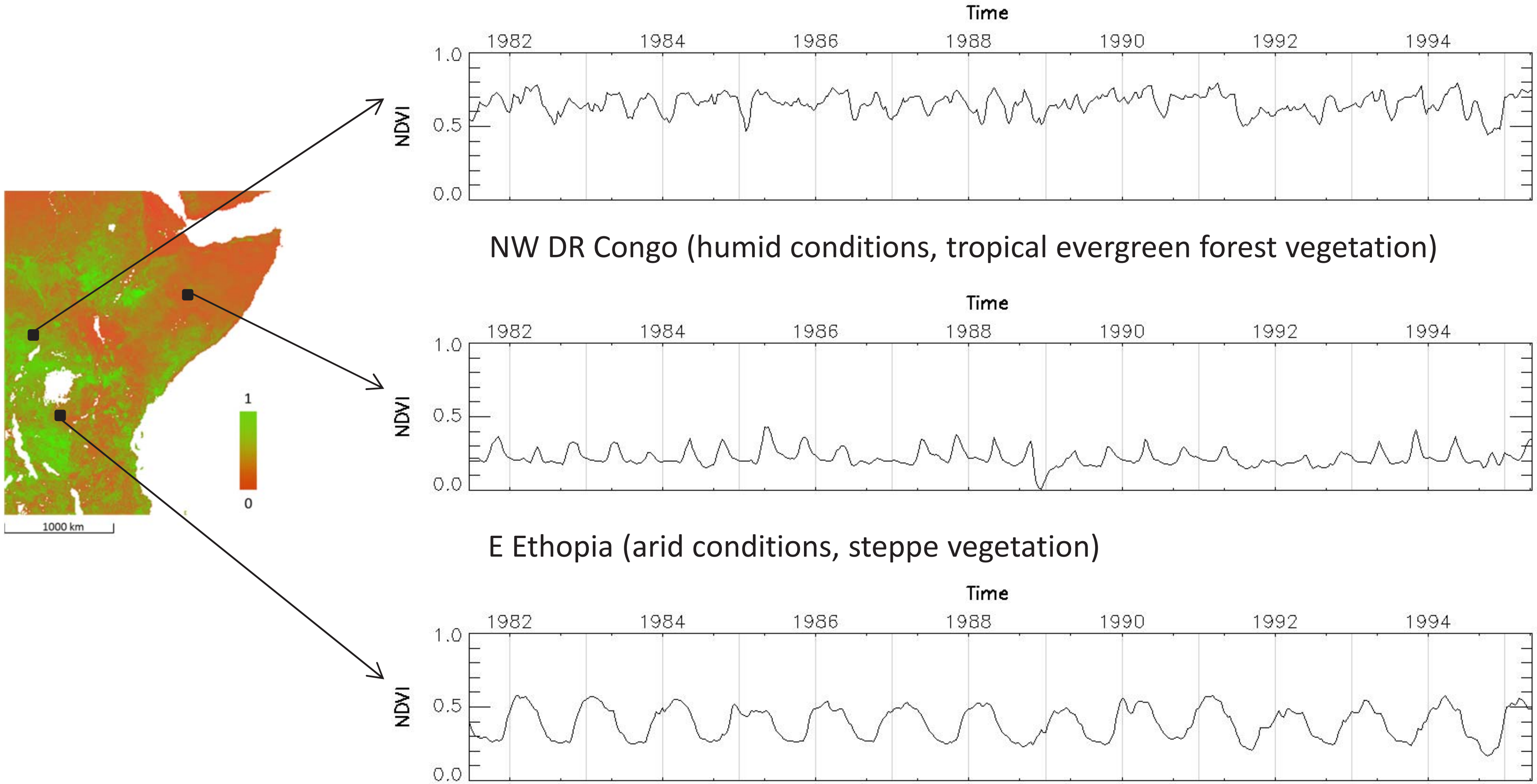
Intro: Satellite image time series

» Temporal changes in vegetation cover



NW DR Congo (humid conditions, tropical evergreen forest vegetation)

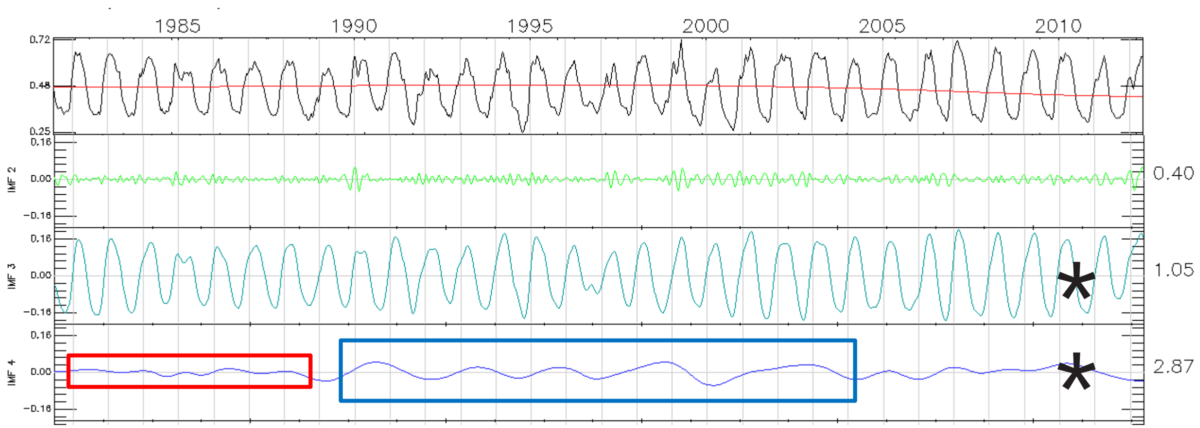
E Ethopia (arid conditions, steppe vegetation)

N Tanzania (sub-humid conditions, grassland/woodland savanna)

esearch questions

Which time scales (other than the annual season) are present in long-term vegetation index time series ?

» Decomposition, evaluation of components

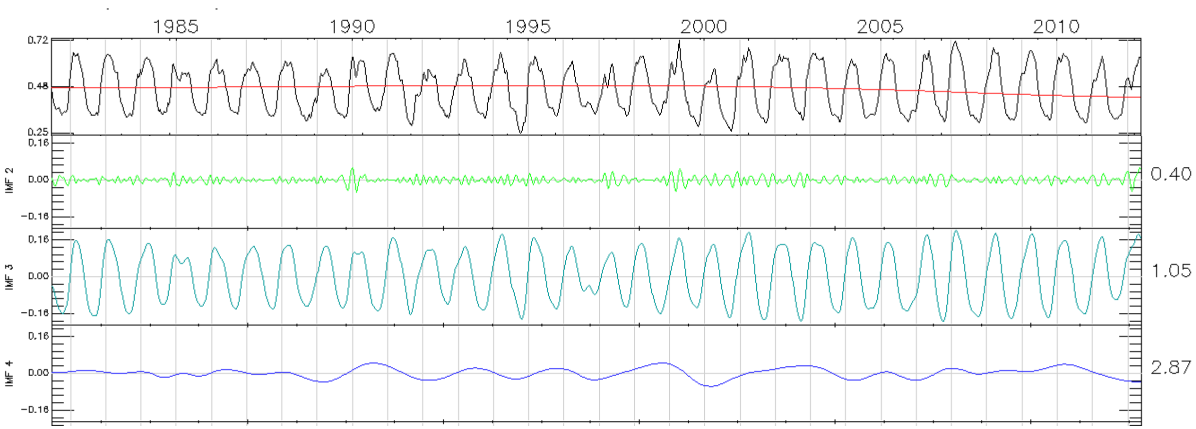


How do inter-annual climatic components behave over time ?

» Testing for switching regimes

ethods : Decomposition model

Requirements



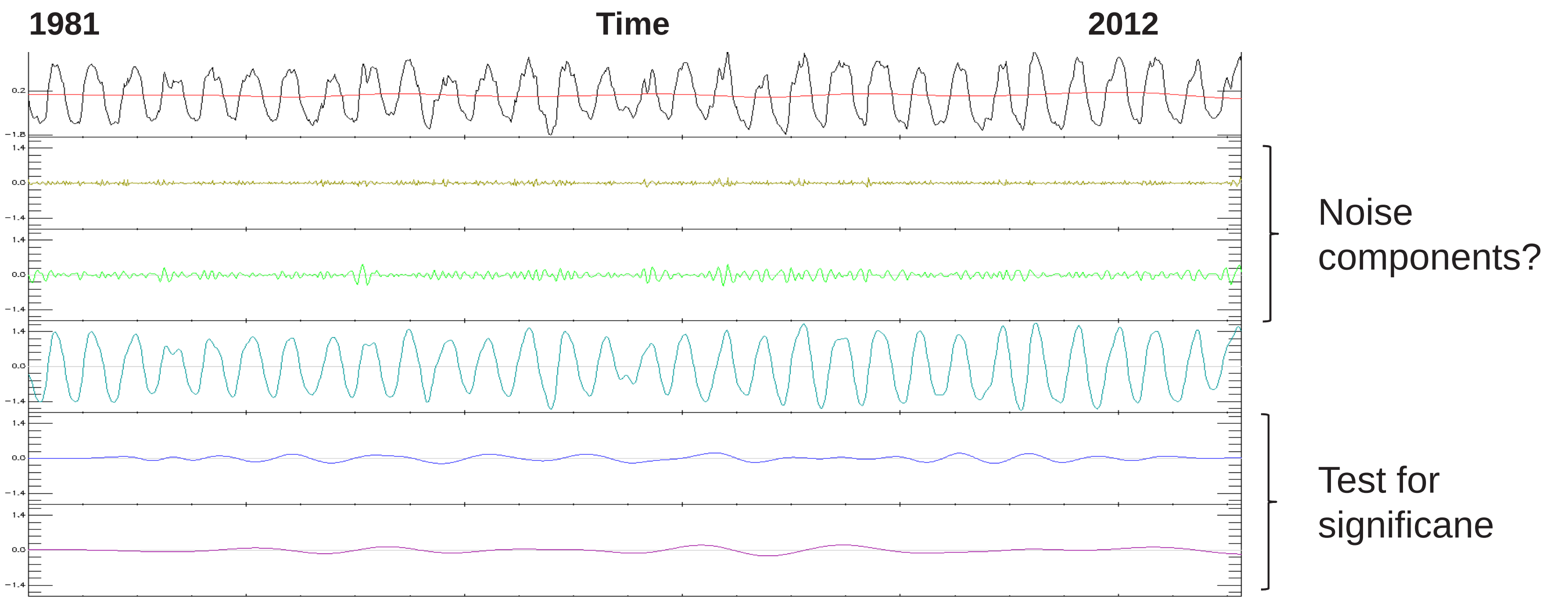
1) Non-stationarity
2) Data-adaptive basic functions
3) Periodicities unknown a priori

Empirical Mode Decomposition (EMD, Huang et al., 1998)

ethods : EMD decomposition

terative filtering process (in the time domain!)

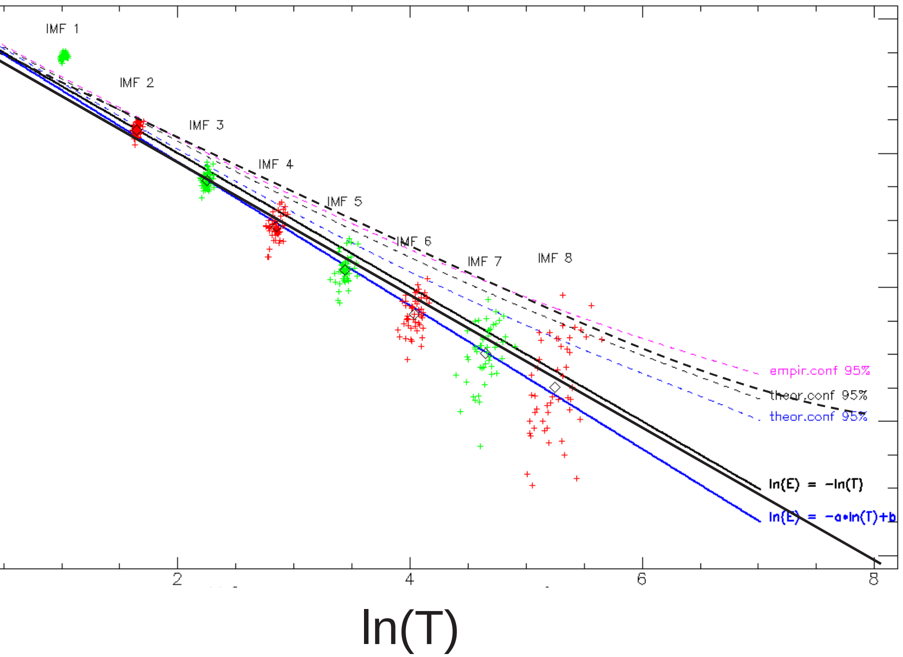
3ased on Min/Max in data

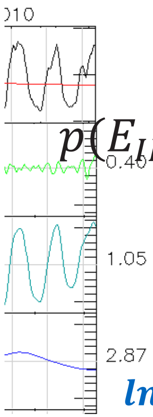


Yields ‘Intrinsic Mode Functions’ (IMFs)

ethods : Period-energy relationship

Theoretical study of EMD of white noise (Wu and Huang, 2004)





$$\ln\left(E_{IMF_i}\right) = -\ln\left(T_{IMF_i}\right)$$

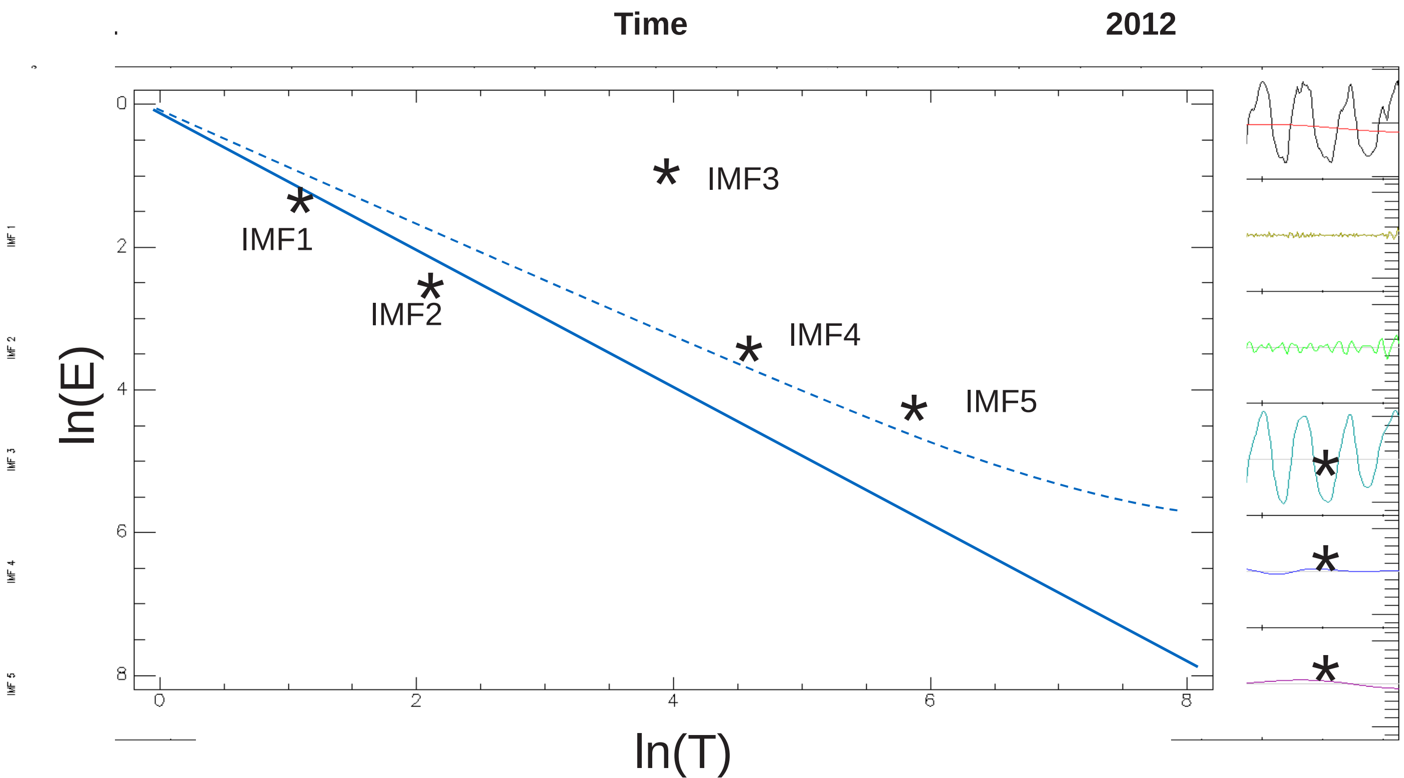
$$p\left(E_{IMF_i} | T_{IMF_i}\right) = {\chi^2}_{mod}\left(E_{IMF_i}\right)$$

MC verification

$$\boldsymbol{ln\left(E_{IMF_i}\right) = -1.07\, ln\left(T_{IMF_i}\right) + 0.01}$$

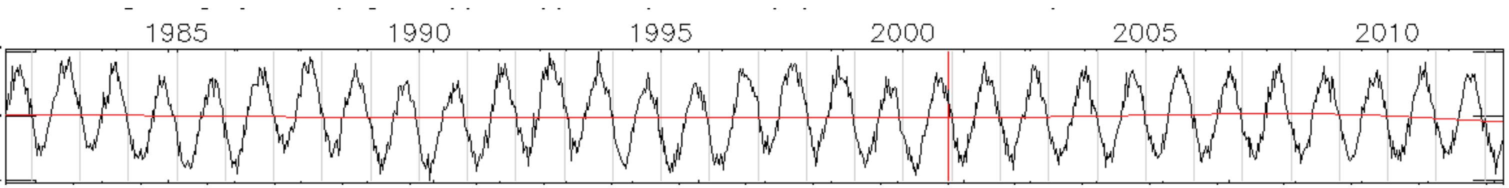
$$\boldsymbol{p_{95\%\_MC} \sim p_{98\%\_theor}}$$

ethods : Global significance of IMFs

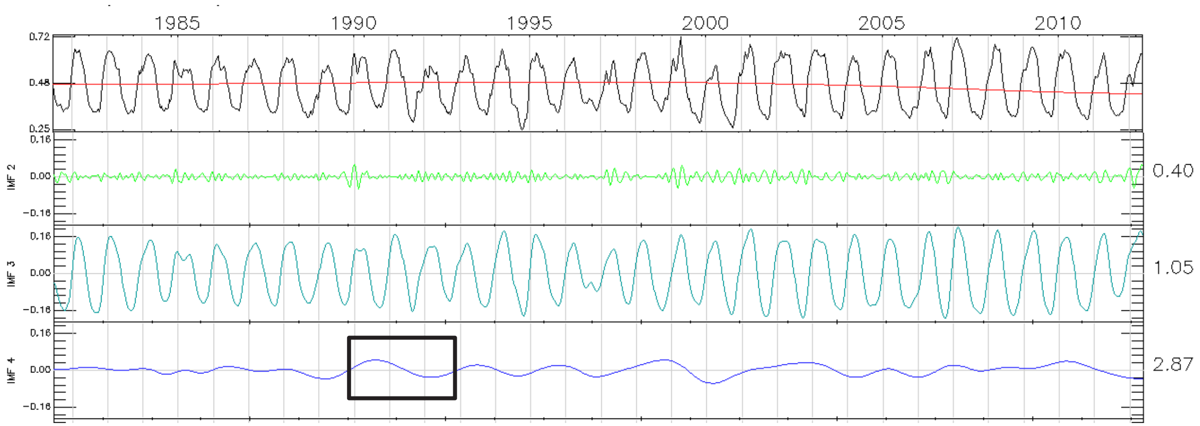


ethods : A local significance test?

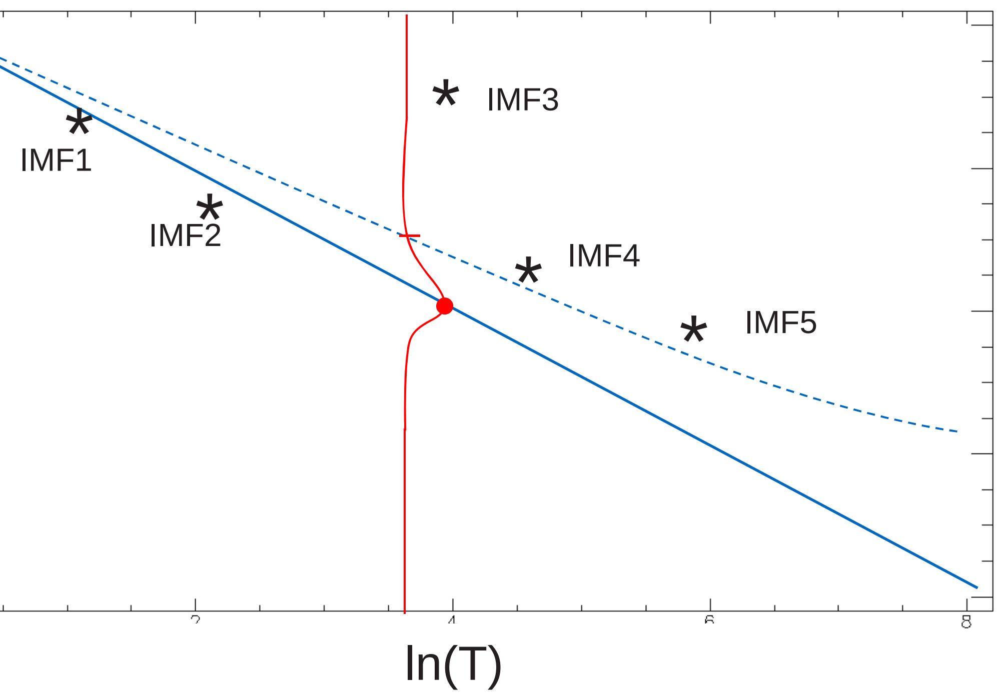
Regime change ?

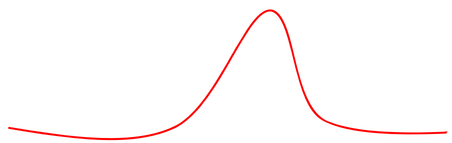


How local ?



ethods: Derivation of local sig.level



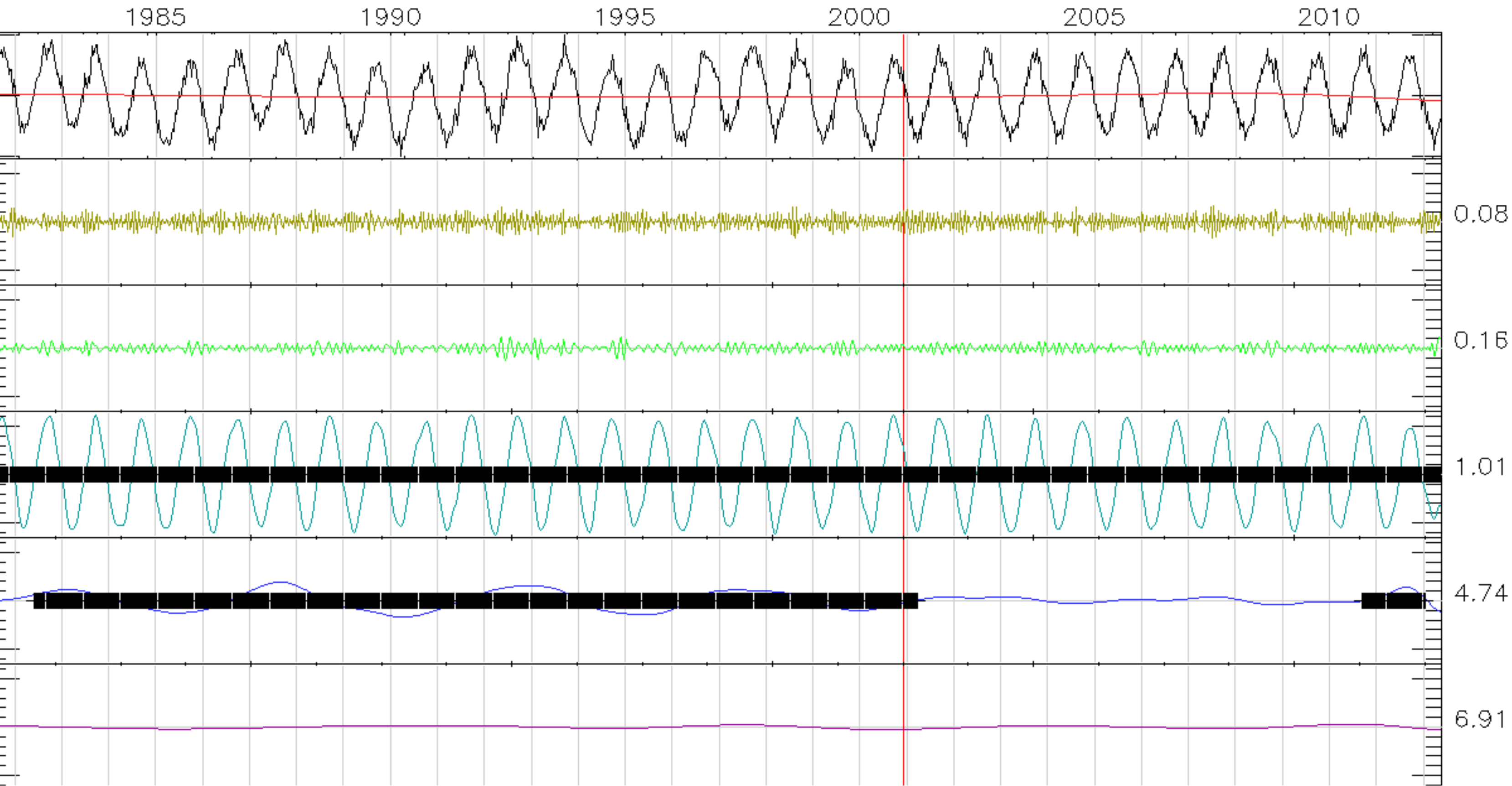


$$\chi^2_{mod}\left(E_{IMF_i}\right) = N.k^{N.\hat{E}_{IMF_i}/2-1}.e^{-k/2}$$

$$N = series\ length$$
$$k = d.f. = N.E_{IMF_i}$$

substitute cycle length
for series length T_{IMF_i}

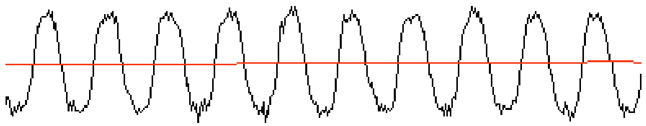
ethods: MC verification of local sig.level



periment: Synthetic time series

Known components ~ knowledge of studied phenomena

- Annual seasonal component



  - mean historic season / fit as.Gaussian / random phase modulation
- ± 5-yearly ENSO events

  - regular sequence / historic sequence (NOAA data) / two historic events
- Decadal mode (9y)

- Breakpoint in ENSO mode

- Varying amplitudes

periment: measures of success

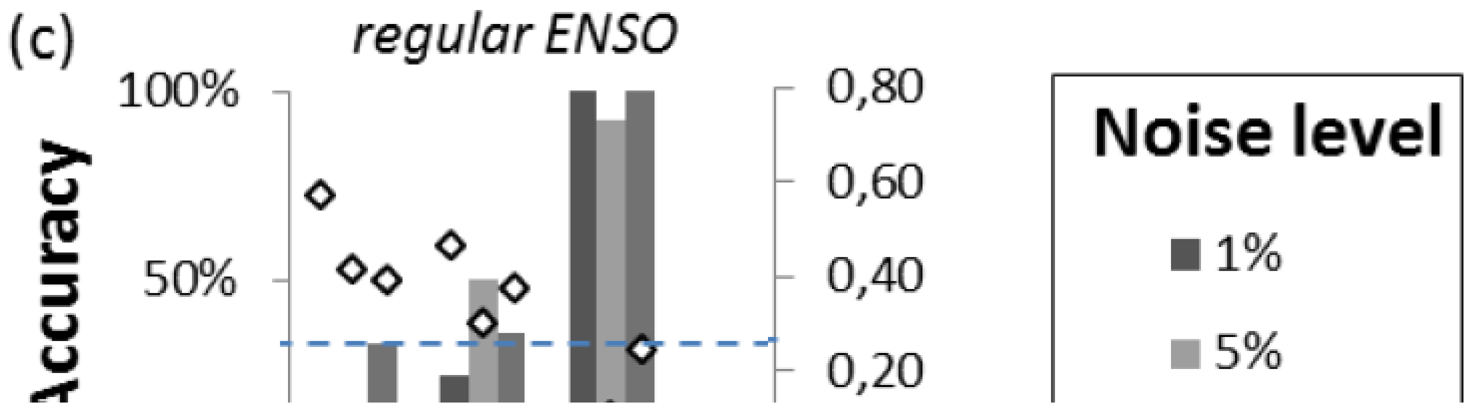
Match IMFs with known input patterns

input:	4.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0
IMF:	3.8	3.8	3.8	3.8	4.7	4.7	4.7	4.7	4.7	4.1	4.1	4.1	3.6

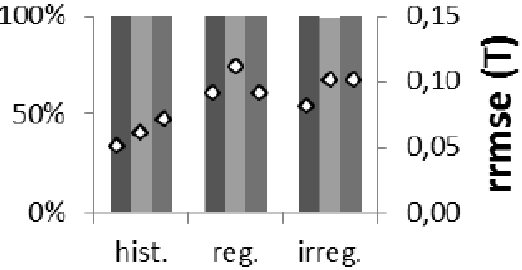
rmse

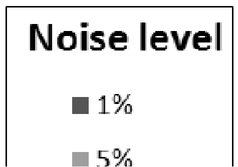
Accuracy : % correctly detected (0/1)

rmse : reconstruction of time scale



periment: results

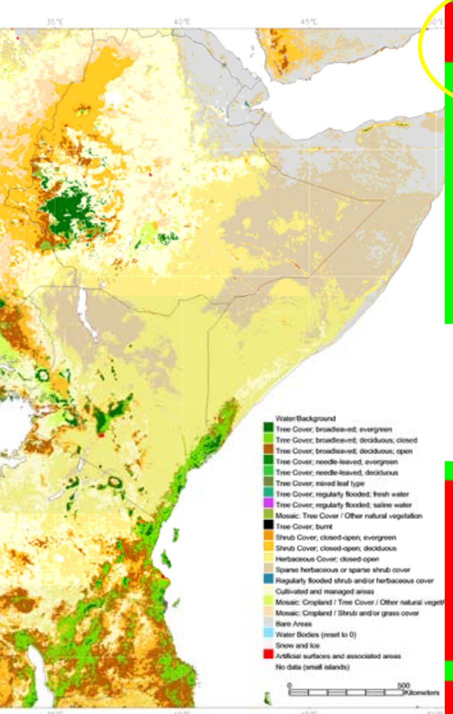


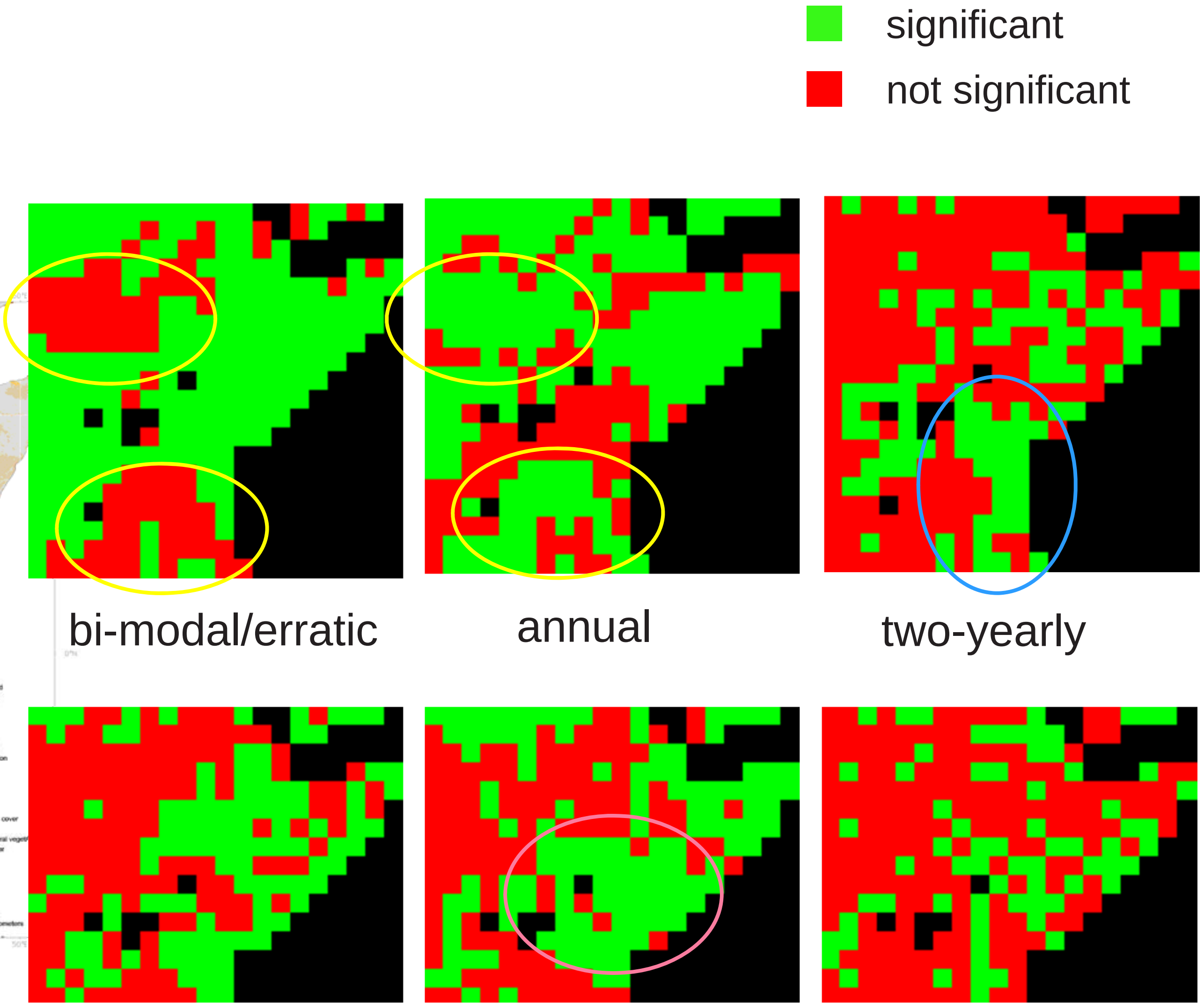


periment: discussion

- Relative scaling problem (-> false negative detections)
- Low sensitivity to noise
- Pre-filter with global significance test
- Relatively sharp localization of breakpoints

utlook




significant
not significant
bi-modal/erratic
annual
two-yearly

anks for your attention

and for questions and comments !