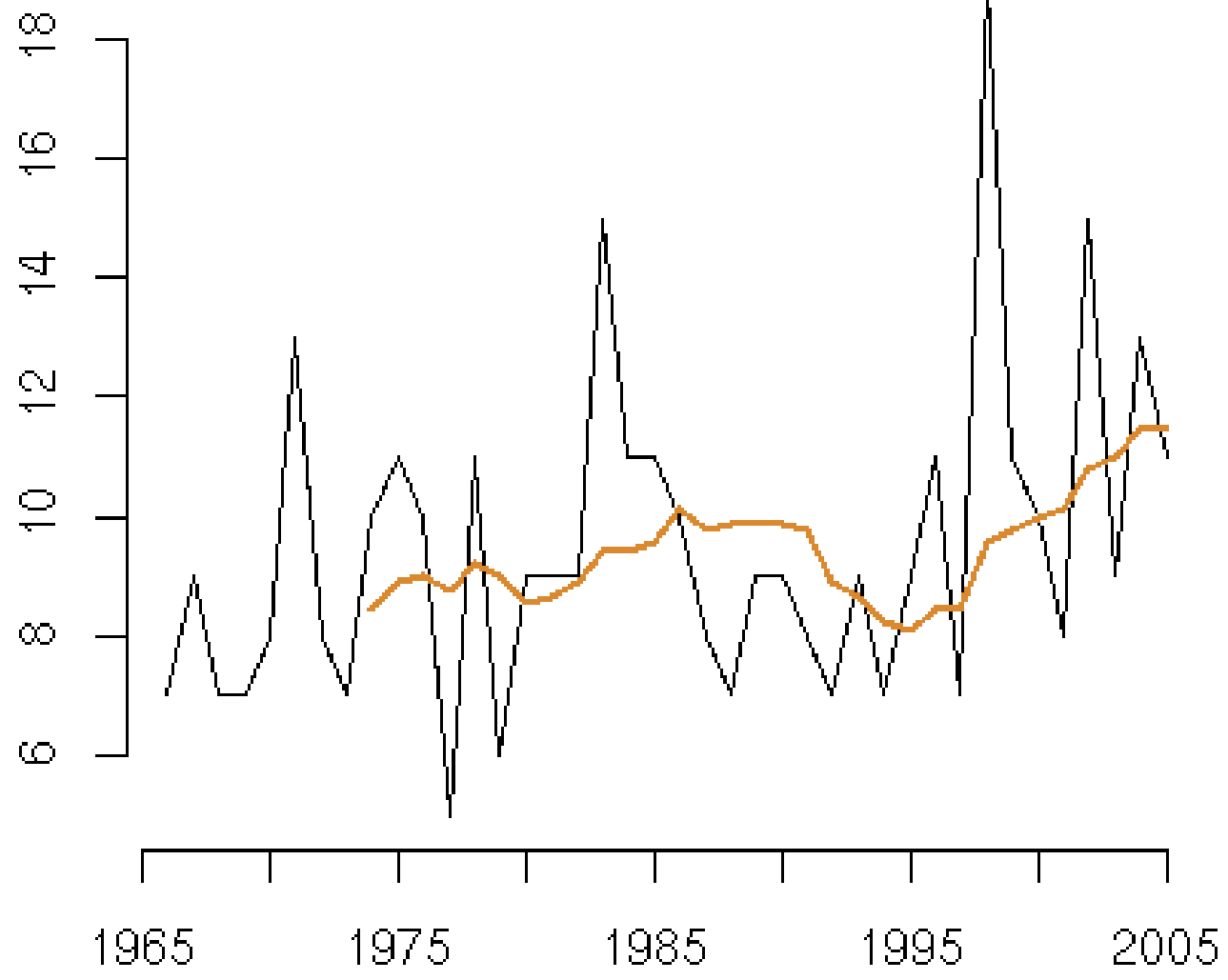


Have the number and intensity of tropical cyclones increased?

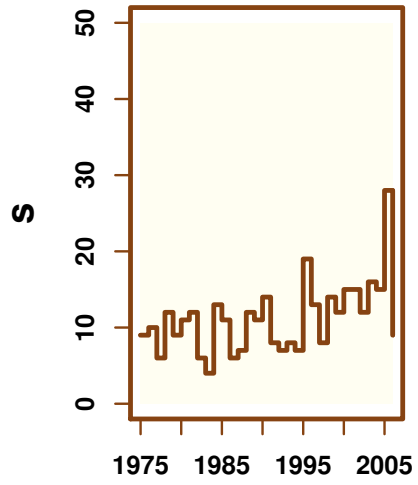
William M. Briggs

New York

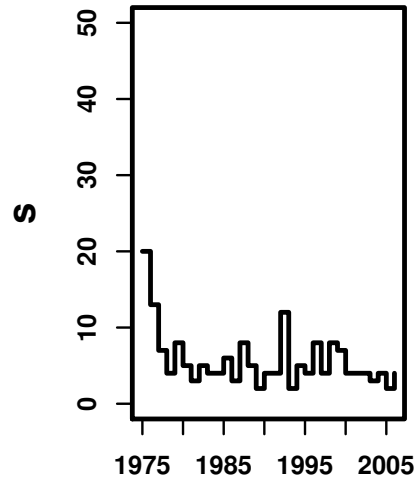
22 January 2008



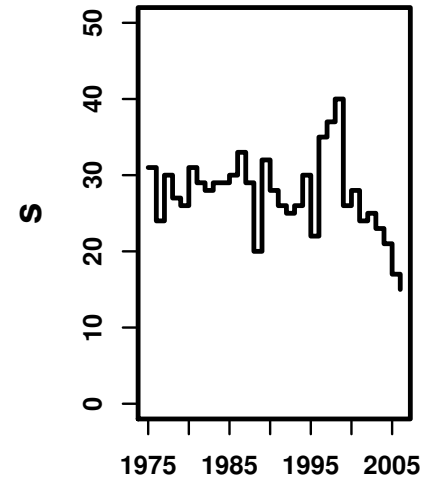
North Atlantic



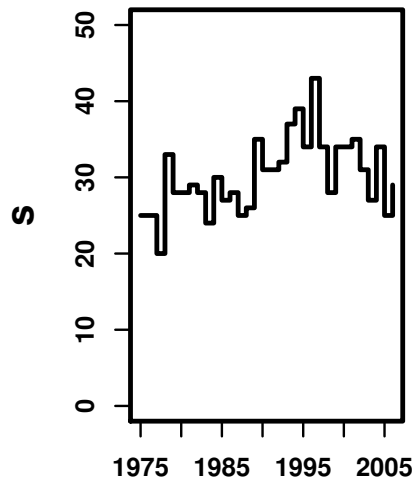
North Indian



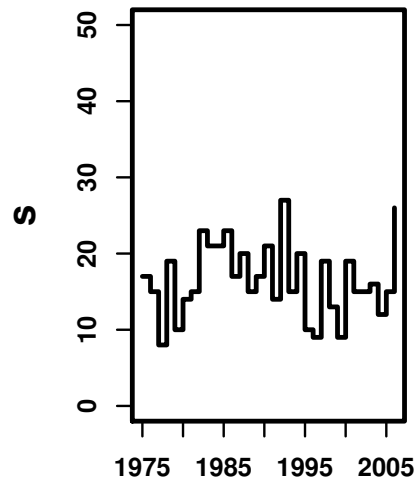
South Indian



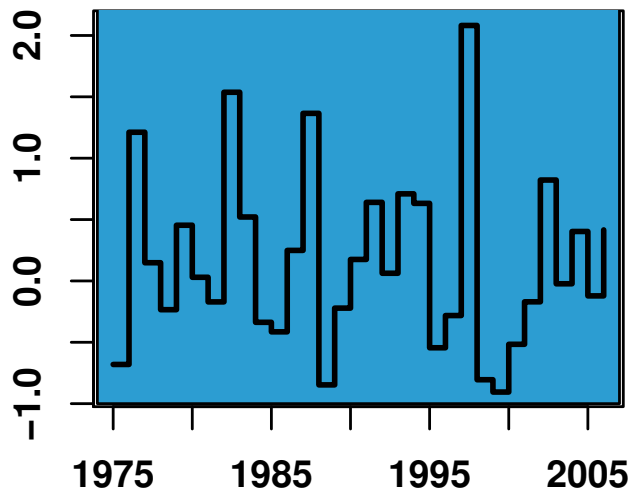
West Pacific



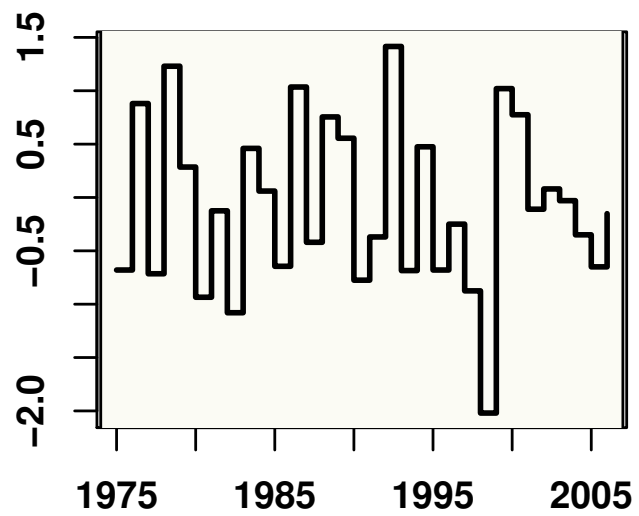
East Pacific



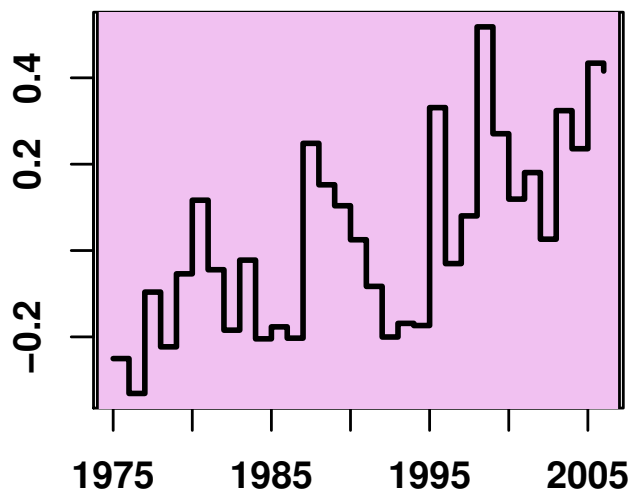
CTI



NAOI



AMO



$$s_{ij} \sim \text{Poisson}(\lambda_{ij}), \quad i = 1 \dots 5, \quad j = 1 \dots n$$

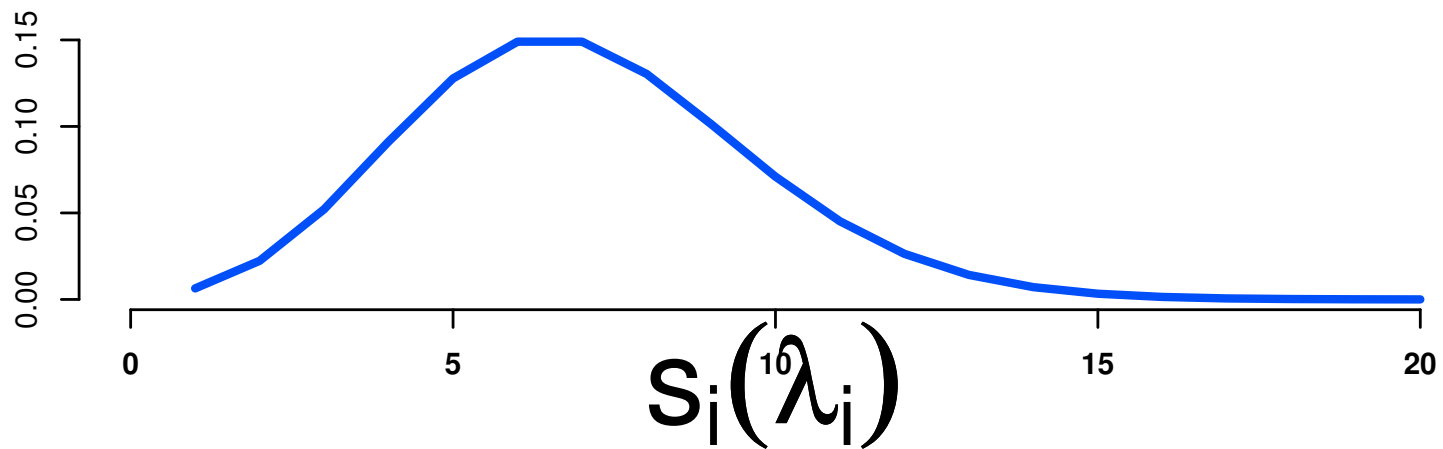
$$\begin{aligned} \log(\lambda_{ij}) = & \beta_{0i}^s + \beta_{1i}^s t_j + \beta_{2i}^s \text{CTI}_j + \beta_{3i}^s \text{NAOI}_j \\ & + \beta_{4i}^s \text{AMO}_j \end{aligned}$$

$$\beta_{ki}^s | \gamma_k^s, \tau_k^s \sim \text{N}(\gamma_k^s, \tau_k^s), \quad k = 0, 1, 2, 3, 4$$

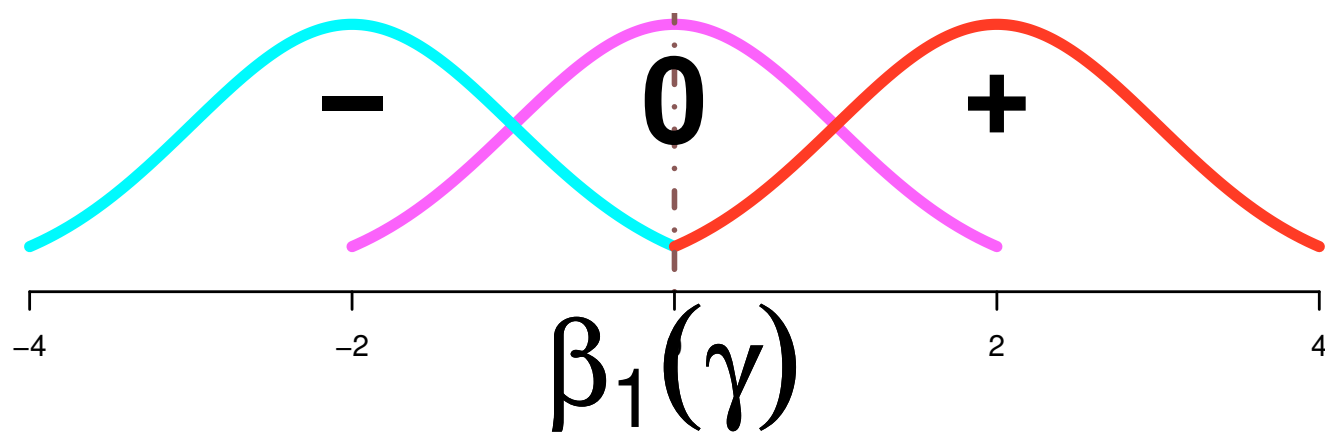
$$\gamma_k^s \sim \text{N}(0, 1e - 6)$$

$$\tau_k^s \sim \text{Gamma}(.001, .001)$$

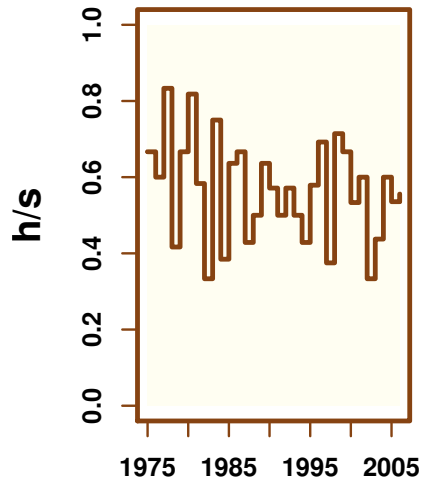
interest in γ_1^s, β_{1i}^s



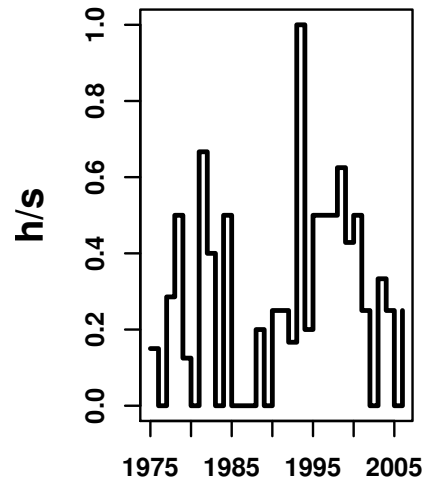
$$\log(\lambda_i) = \beta_{0i} + \beta_{1i}t + \dots$$



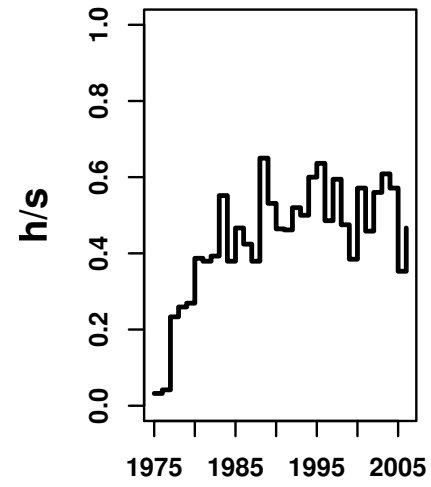
North Atlantic



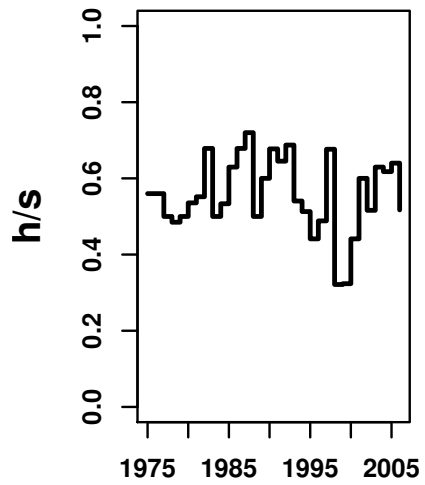
North Indian



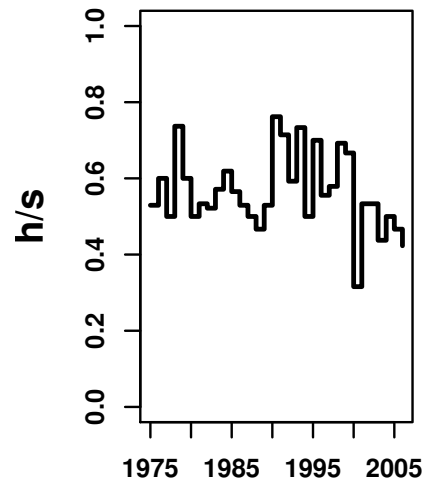
South Indian



West Pacific



East Pacific



$$h_{ij} | s_{ij}, \theta_{ij} \sim \text{Binomial}(s_{ij}, \theta_{ij})$$

$$\text{logit}(\theta_{ij}) = \beta_{0i}^h + \beta_{1i}^h t_j + \beta_{2i}^h \text{CTI}_j + \beta_{3i}^h \text{NAOI}_j + \beta_{4i}^h \text{AMO}_j$$

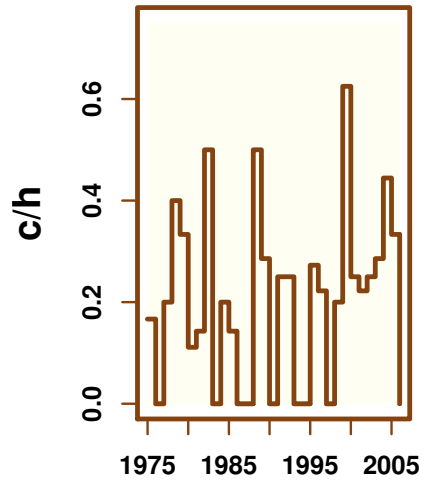
$$\beta_{jk}^h | \gamma_k^h, \tau_k^h \sim \text{N}(\gamma_k^h, \tau_k^h), \quad k = 0, \dots, 4$$

$$\gamma_k^h \sim \text{N}(0, 1.0E - 6)$$

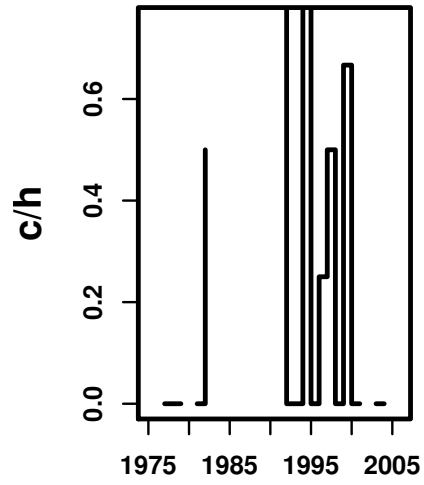
$$\tau_k^h \sim \text{Gamma}(.001, .001)$$

interest in γ_1^h, β_{1i}^h

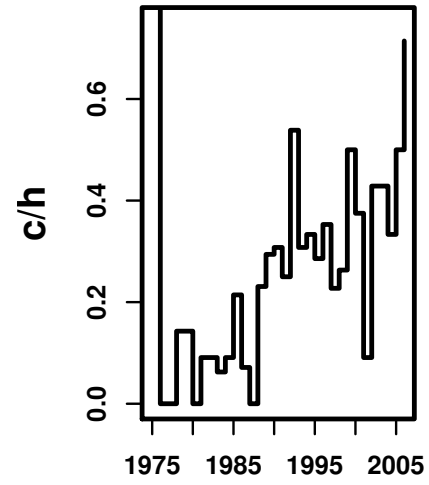
North Atlantic



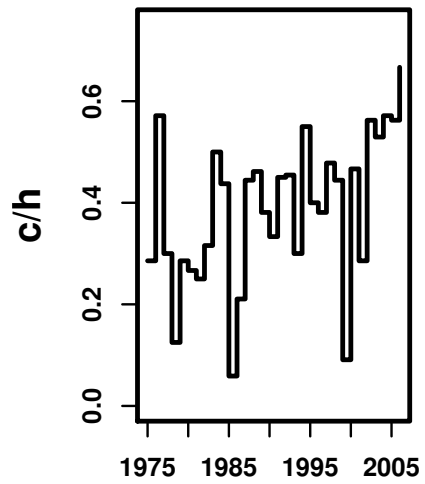
North Indian



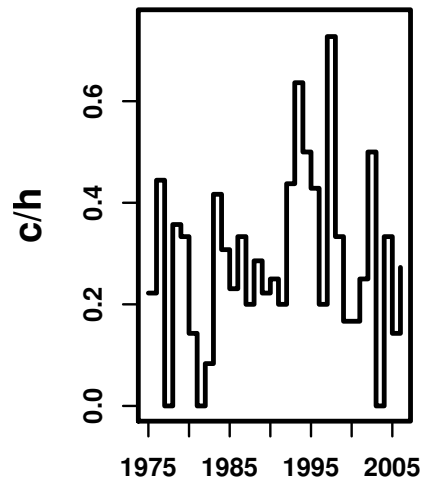
South Indian



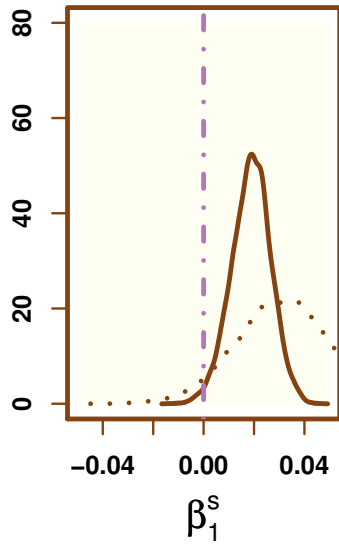
West Pacific



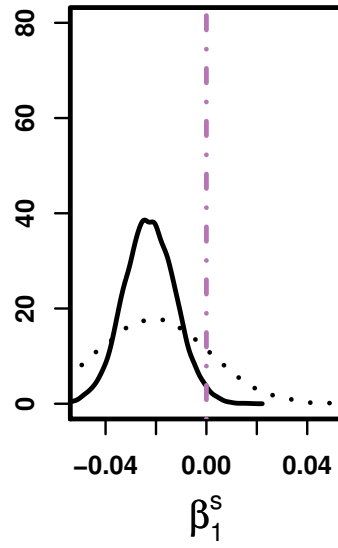
East Pacific



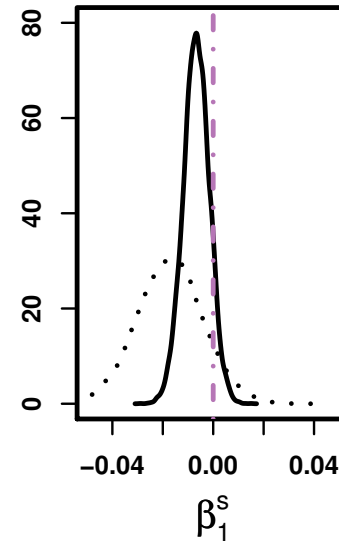
North Atlantic



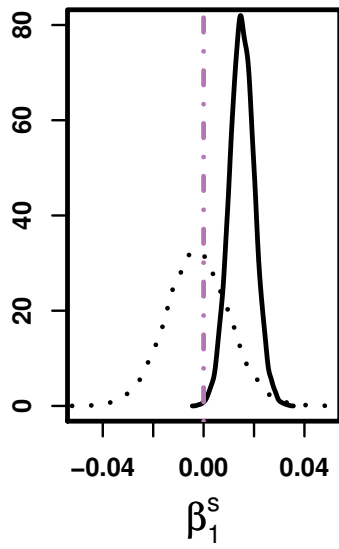
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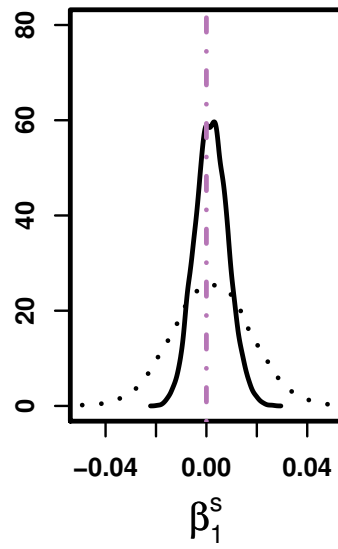
South Indian



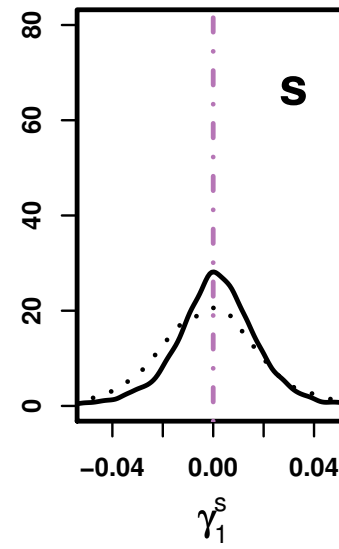
West Pacific



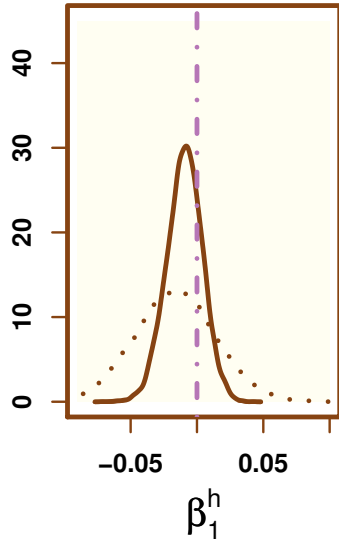
East Pacific



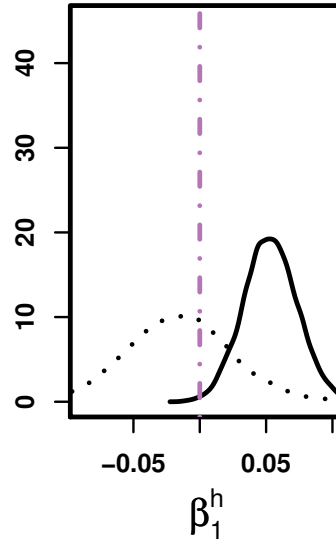
Overall



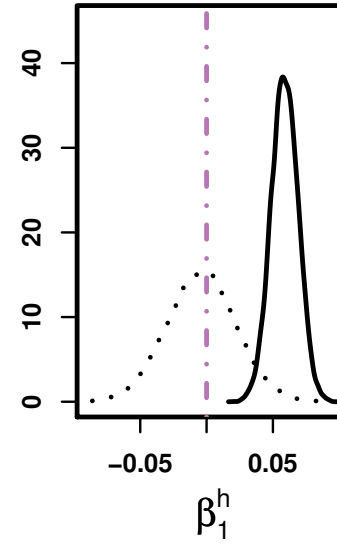
North Atlantic



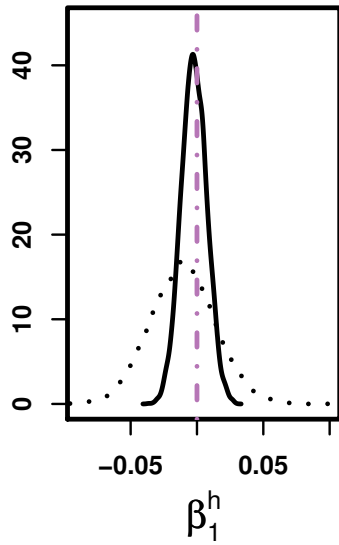
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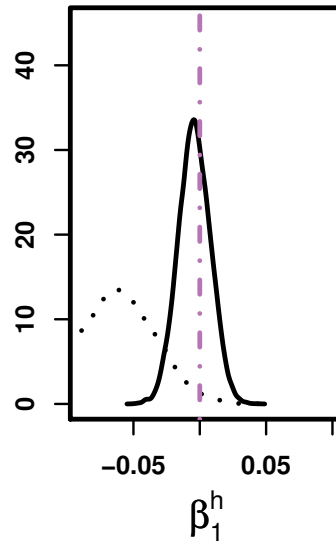
South Indian



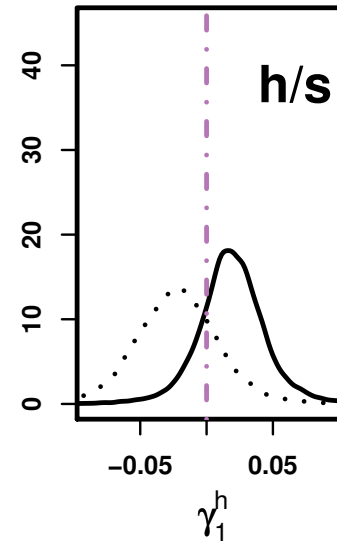
West Pacific



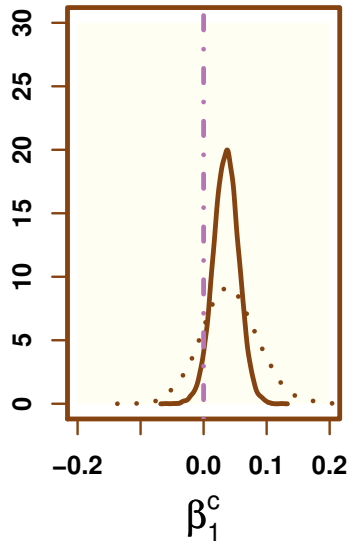
East Pacific



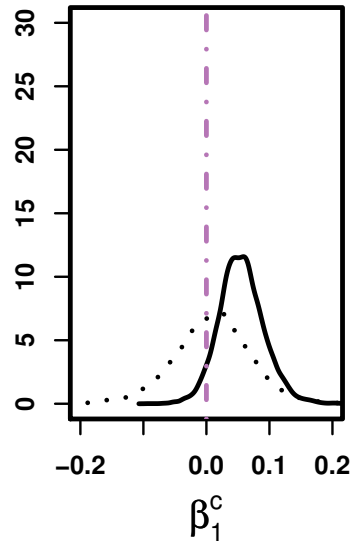
Overall



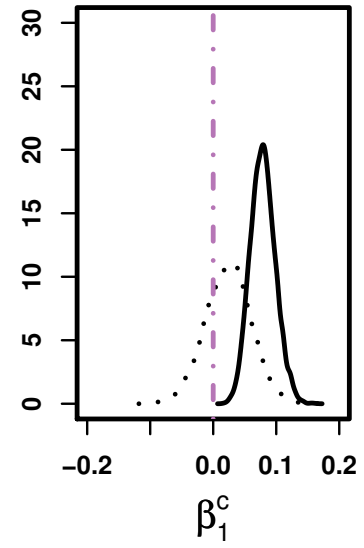
North Atlantic



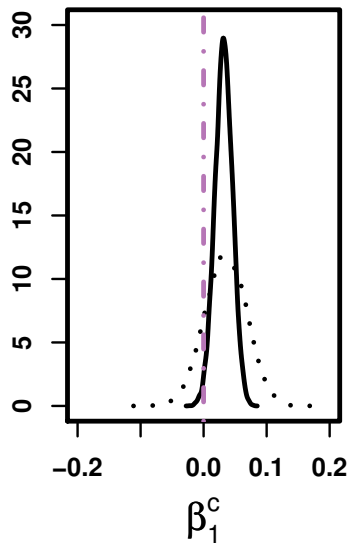
North Indian



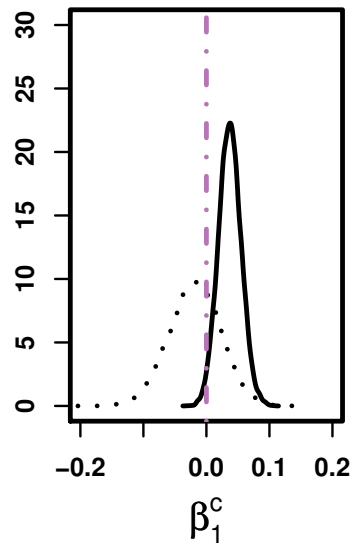
South Indian



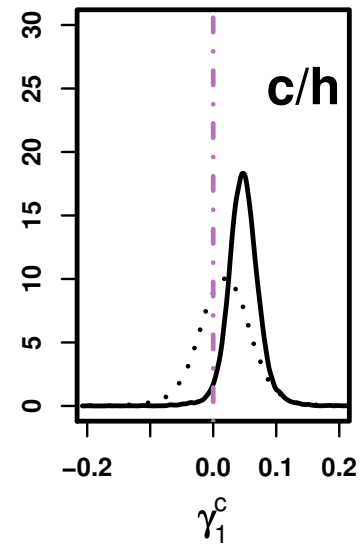
West Pacific



East Pacific



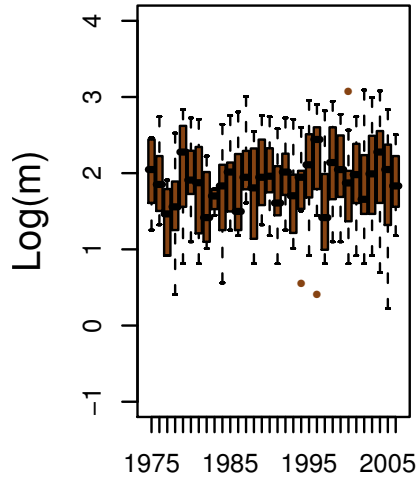
Overall



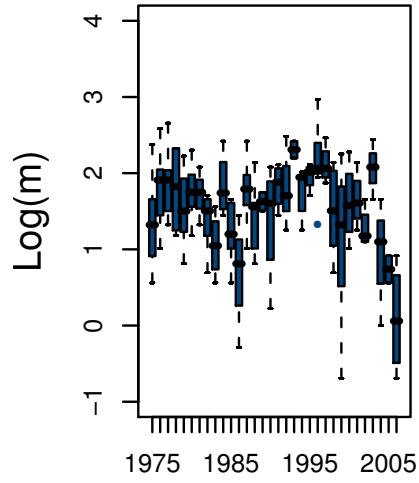
Effects of CTI/NAOI/AMO

Ocean	2.5%	50%	97.5%
<hr/> <hr/> β_2^s : CTI <hr/>			
NA	-0.36	-0.18	-0.03
<hr/> β_2^h : CTI <hr/>			
WP	0.01	0.21	0.42
<hr/> β_2^c : CTI <hr/>			
WP	0.06	0.32	0.59
EP	0.03	0.38	0.74

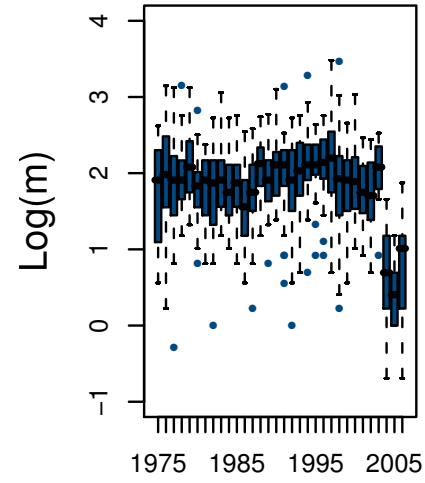
North Atlantic



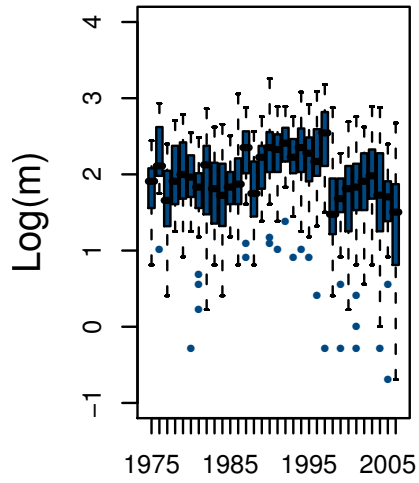
North Indian



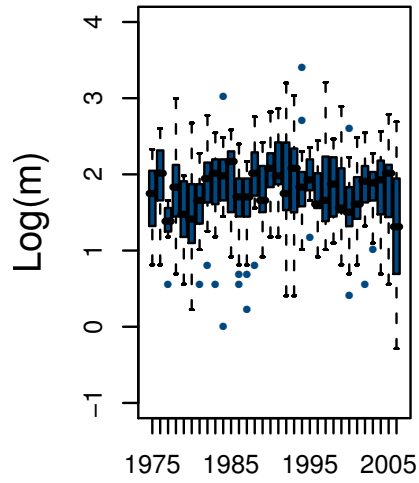
South Indian



West Pacific

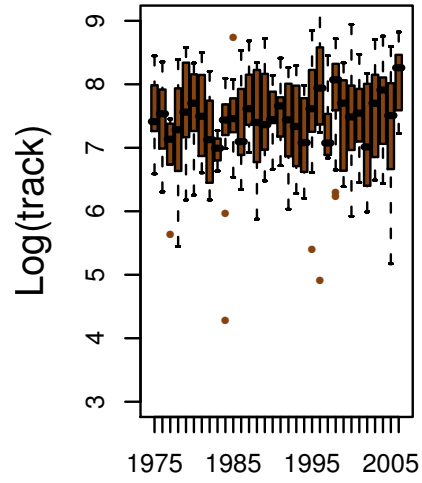


East Pacific

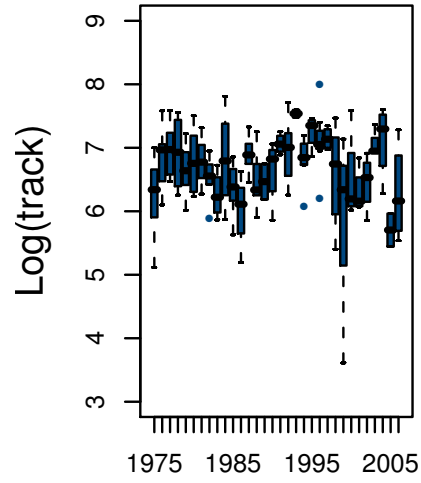


**Storm
Days**

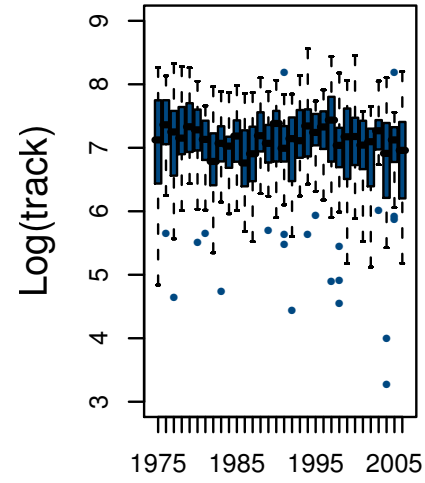
North Atlantic



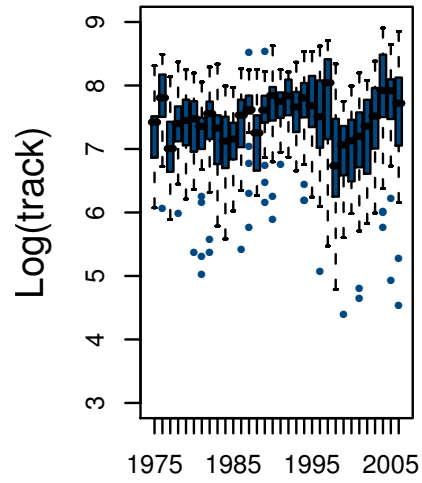
North Indian



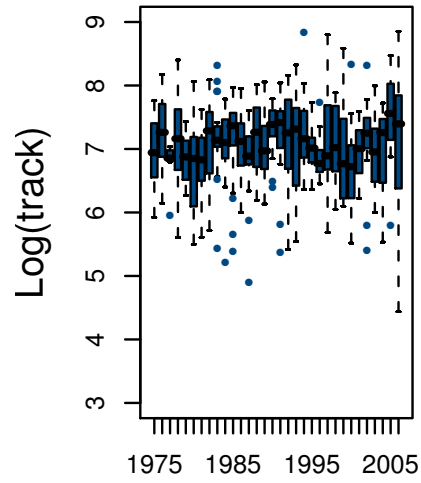
South Indian



West Pacific

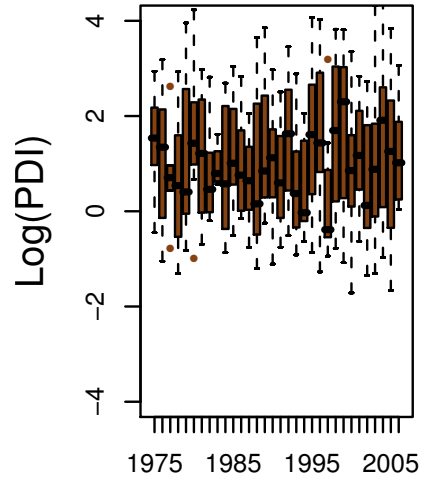


East Pacific

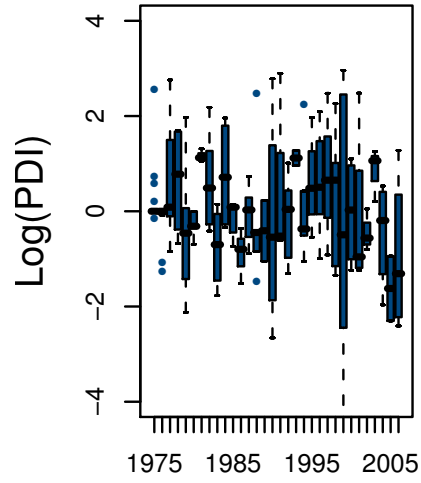


Track

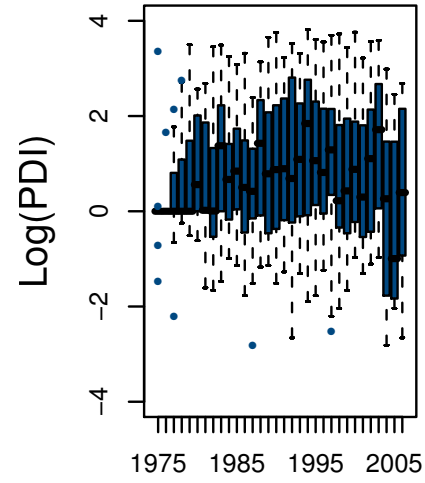
North Atlantic



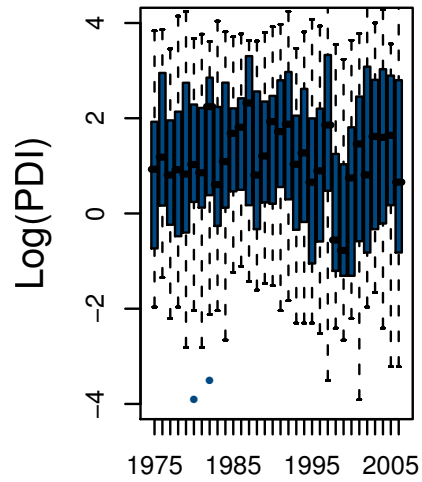
North Indian



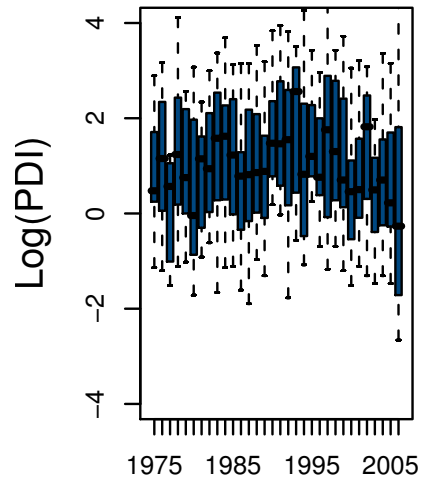
South Indian



West Pacific



East Pacific



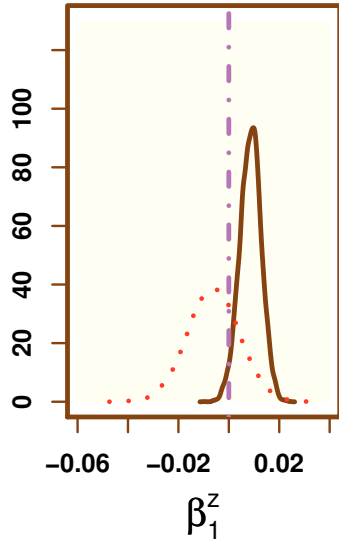
PDI

$$y_{ijk} = \begin{pmatrix} \log(m) \\ \log(\text{track}) \\ \log(\text{PDI}) \end{pmatrix}_{ijk}$$

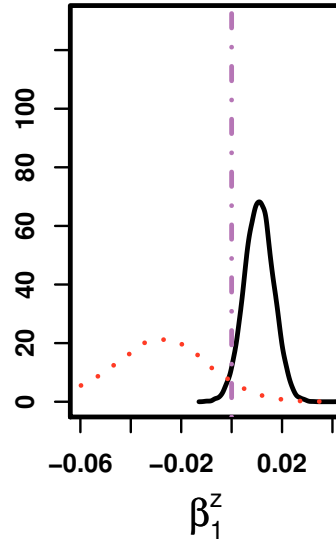
$$y_{ijk1} = \log(m)_{ijk} \text{ etc.}$$

$$y_{ijk} \sim \text{MVN}(\mu_{ijk}, \Lambda_{ij})$$

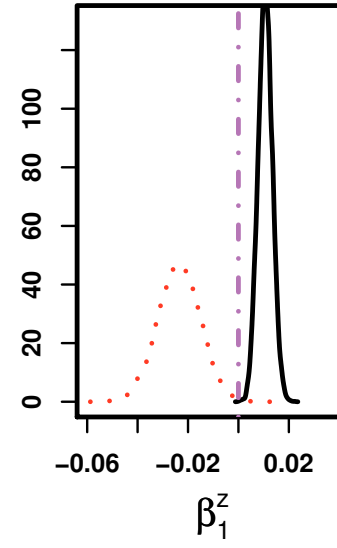
North Atlantic



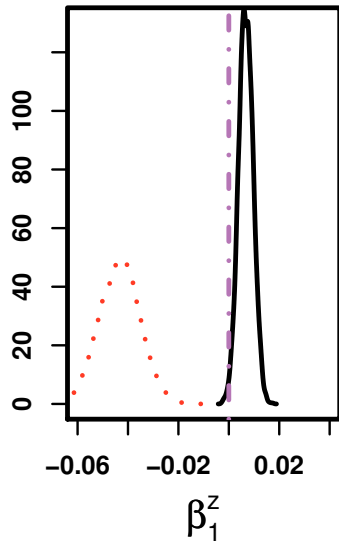
North Indian



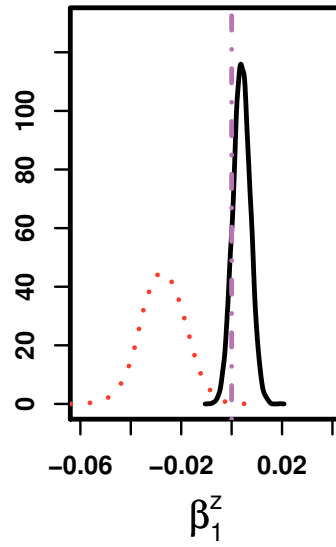
South Indian



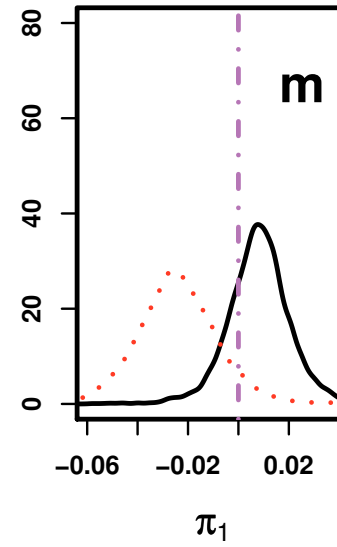
West Pacific

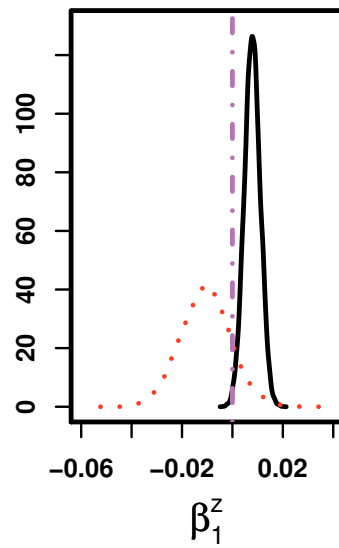
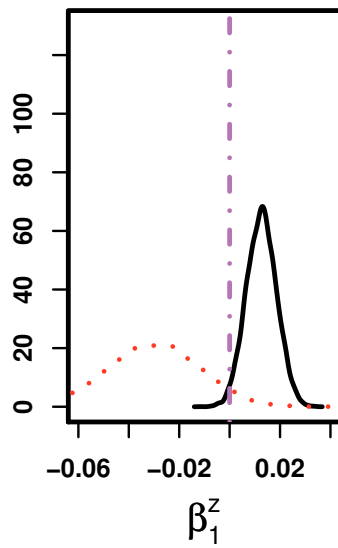
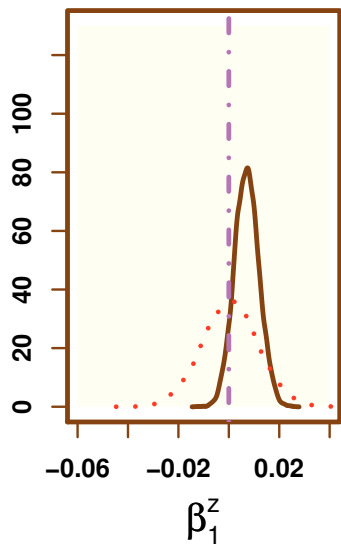


East Pacific

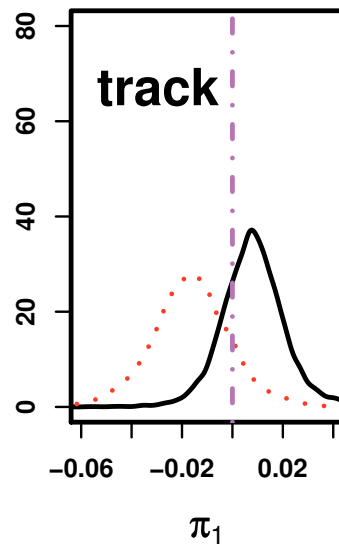
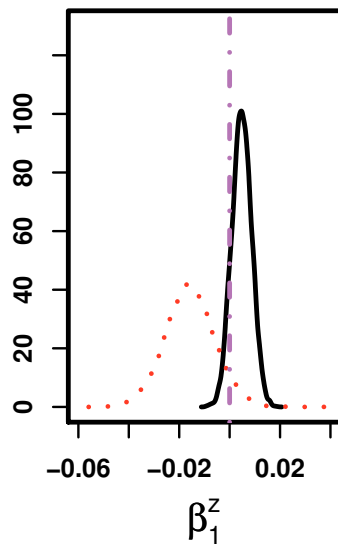
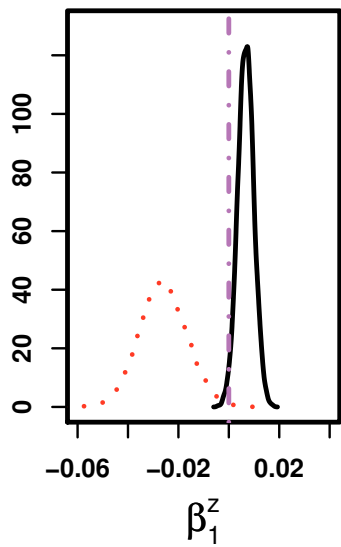


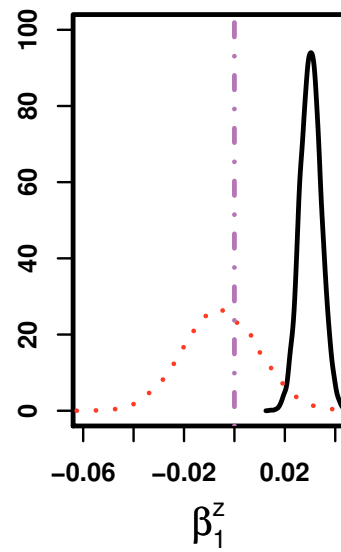
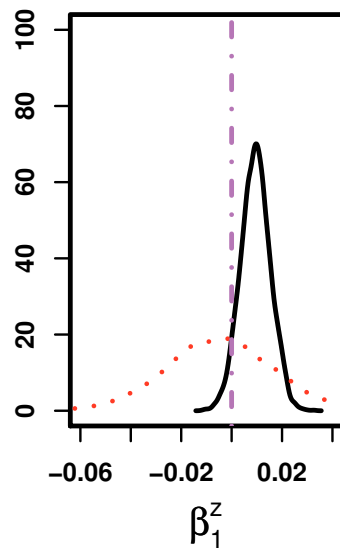
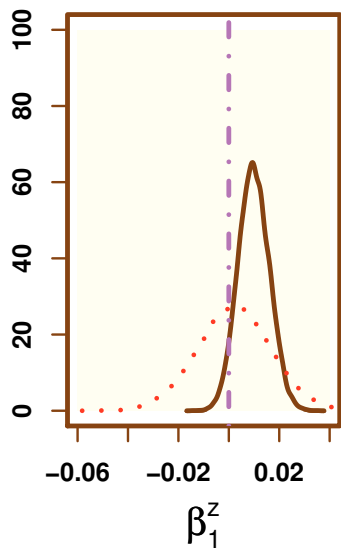
Overall



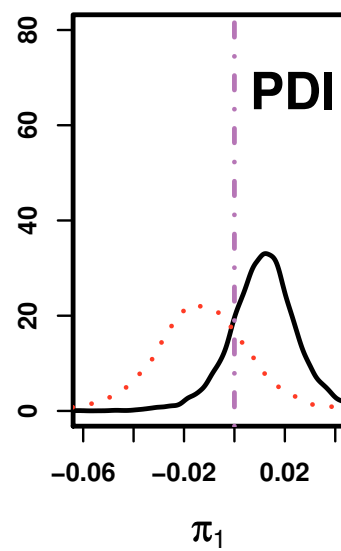
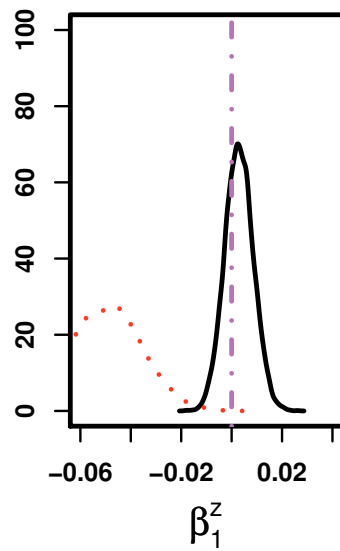
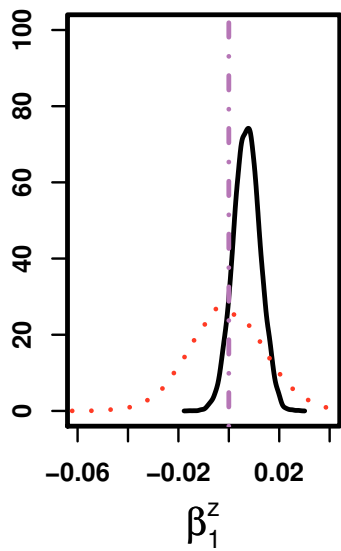


Overall

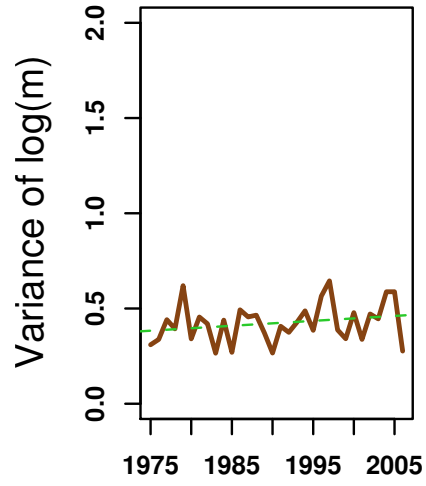




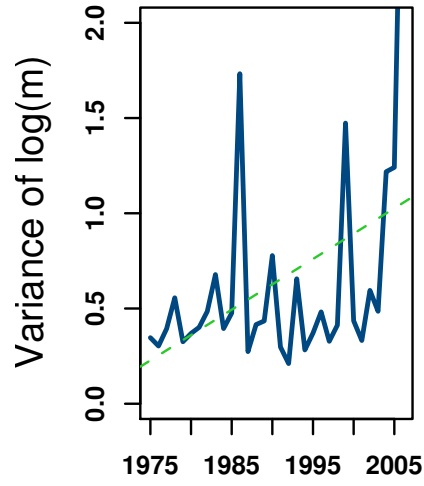
Overall



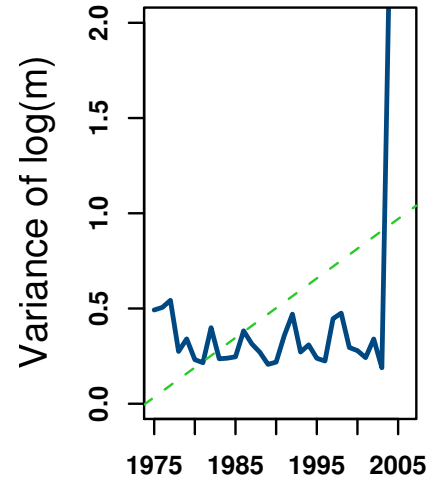
North Atlantic



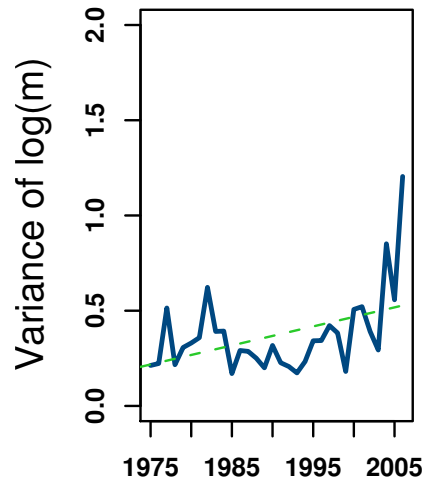
North Indian



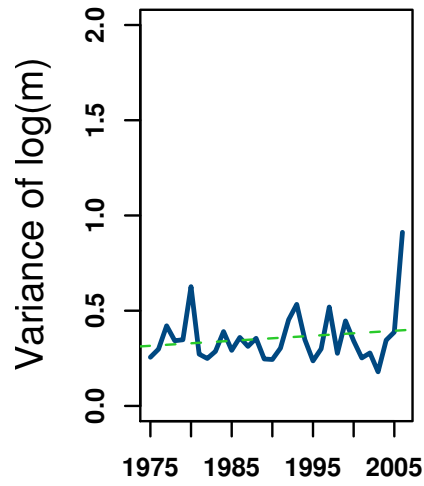
South Indian



West Pacific

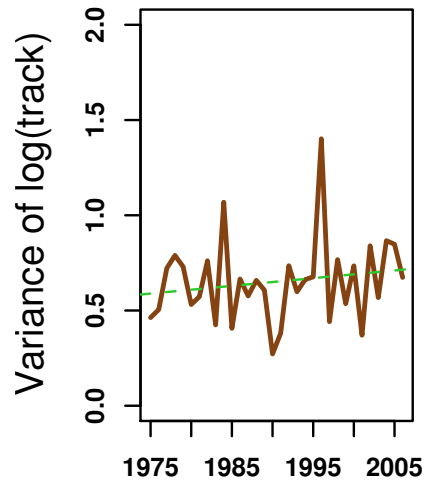


East Pacific

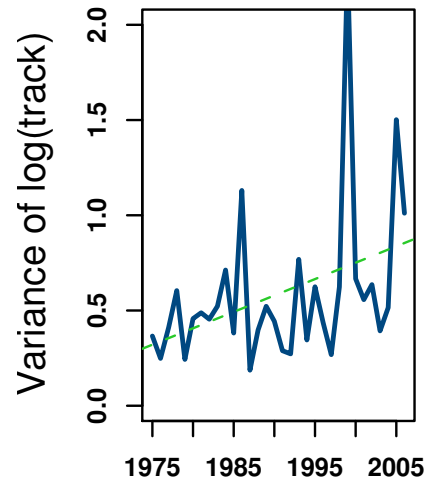


m

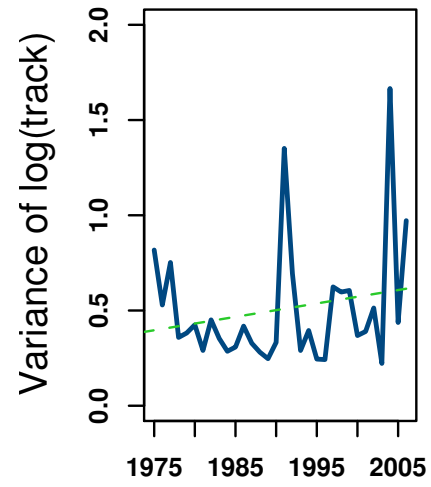
North Atlantic



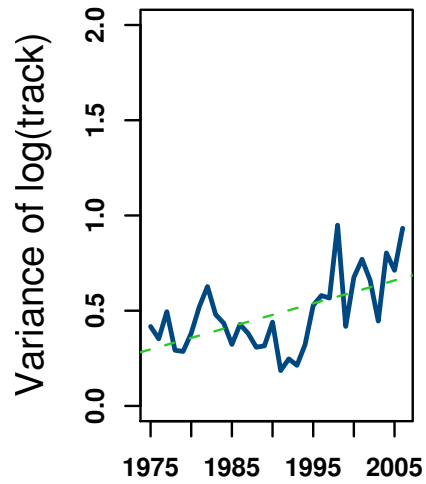
North Indian



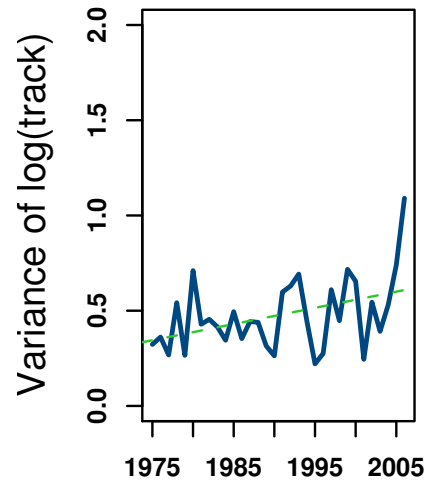
South Indian



West Pacific

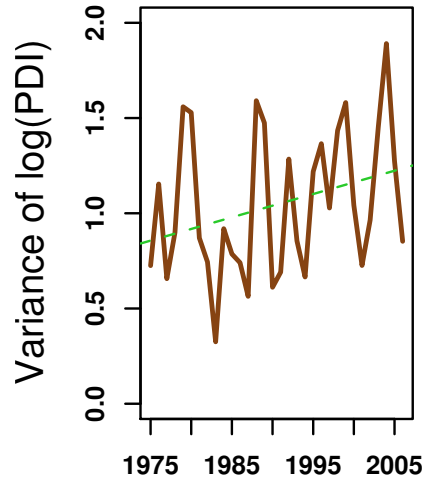


East Pacific

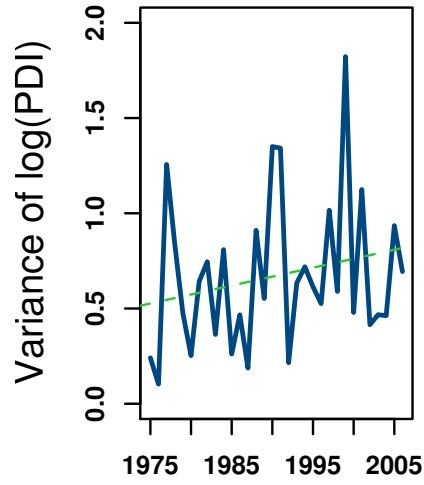


track

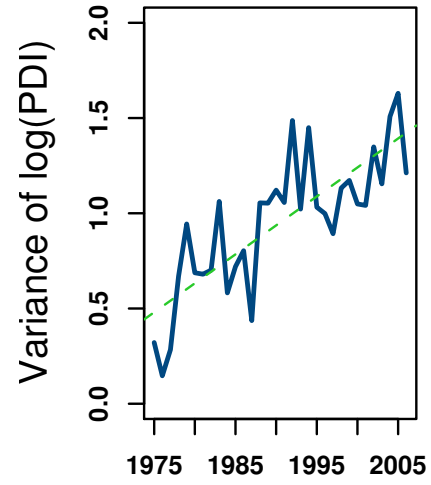
North Atlantic



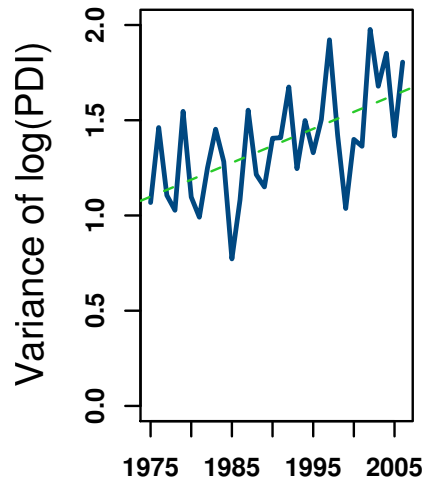
North Indian



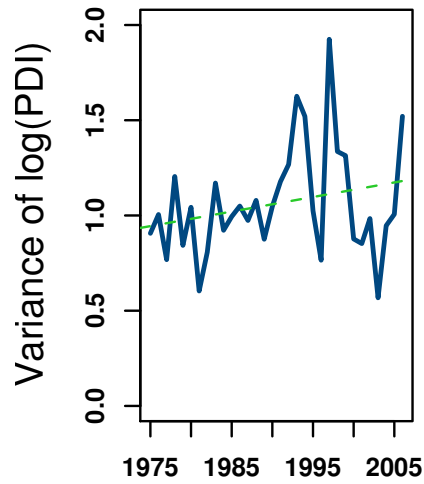
South Indian



West Pacific



East Pacific



PDI

Effect of CTI/NAOI/AMO

Ocean	2.5%	50%	97.5%
<hr/>			
	$\log(m) : \beta_2^z : \text{CTI}$		
WP	0.10	0.16	0.22
<hr/>			
	$\log(\text{track}) : \beta_2^z : \text{CTI}$		
NI	0.05	0.15	0.26
WP	0.13	0.21	0.28
<hr/>			
	$\log(\text{PDI}) : \beta_2^z : \text{CTI}$		
WP	0.13	0.25	0.37

Conclusions

1. Likely that neither storms nor mean intensity have increased; variance has.
2. Data quality is always suspect.
3. It all depends on where you start looking.