Long-term trends of HCH and PCB in soils in India and air-soil exchange of POPs under the influence of the monsoon

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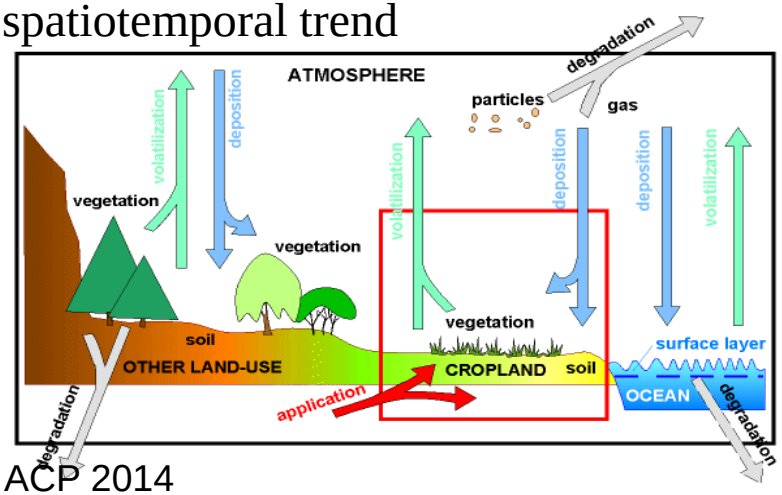
Motivation:

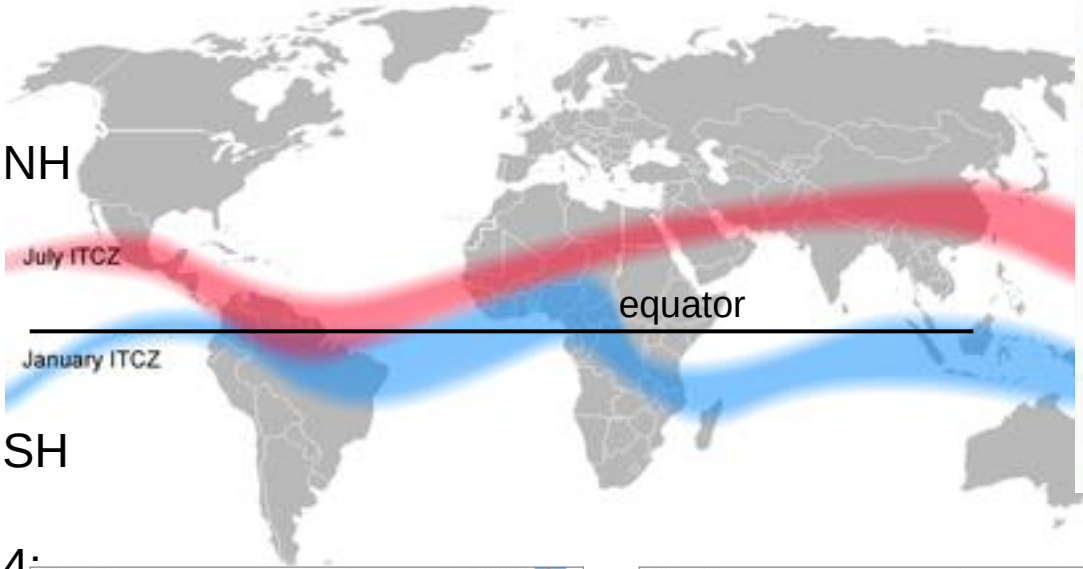
- Understand chemodynamics of persistent semivolatile substances (which are bio-accumulative and toxic)
- which are re-volatilising from ground compartments (multi-hopping)

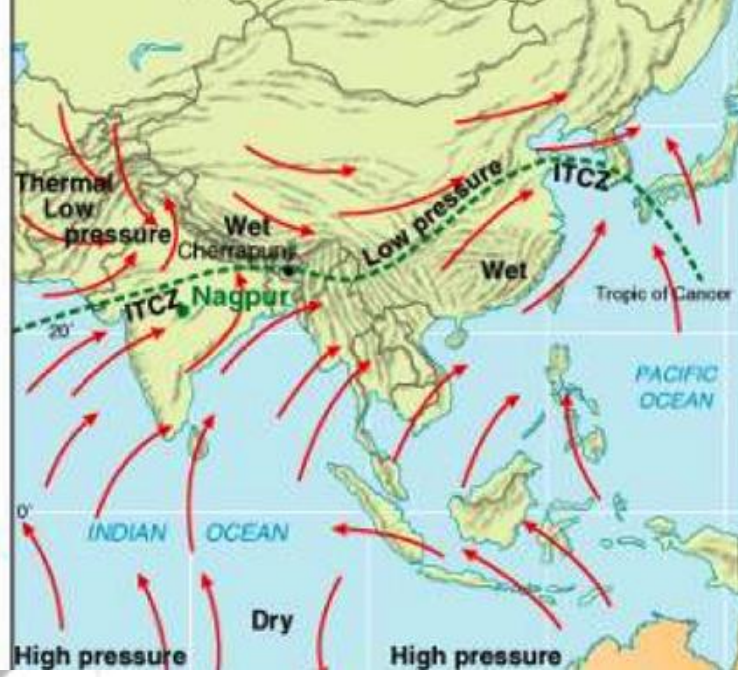
→ study the processes and understand large scale spatiotemporal trend



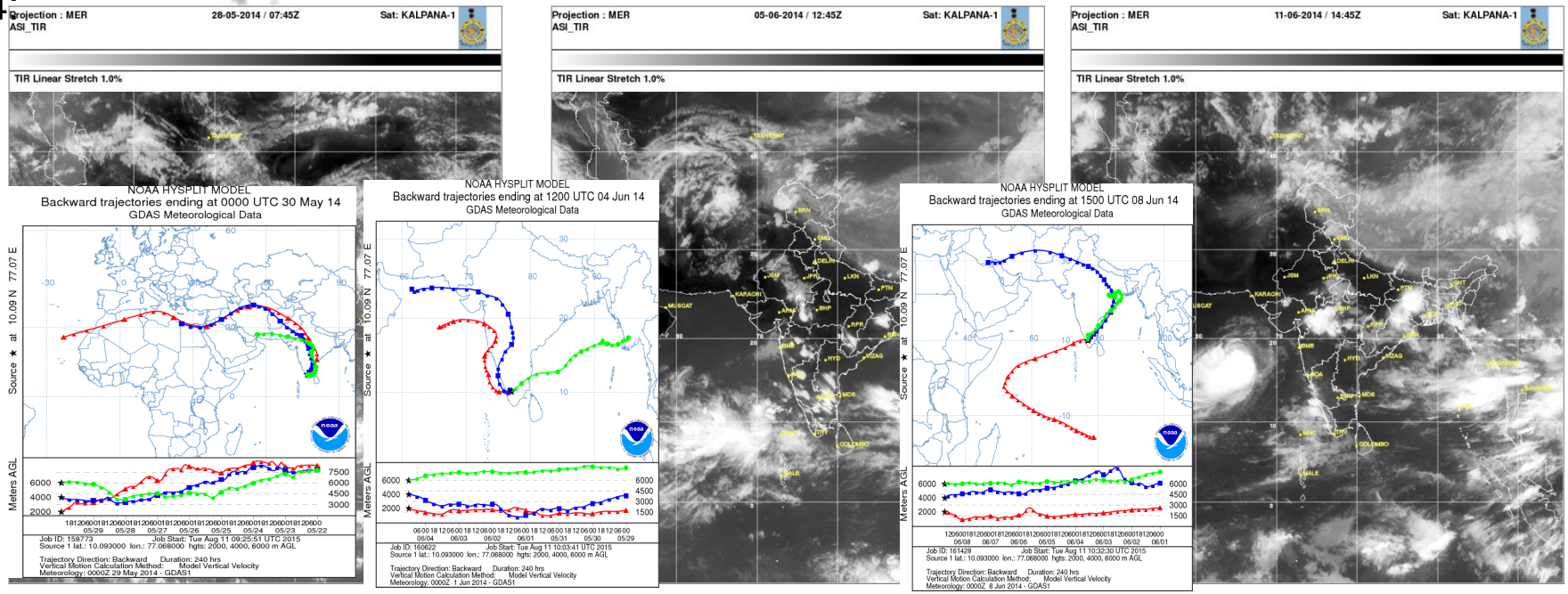
Air-sea	E Mediterranean	2010	seasonal	Mulder et al ACP 2014
	E Mediterranean	2012	episode	Lammel et al ACP 2016
Air-soil	W Balkans	2008	episode	Lammel et al. J Env Mon 2011
	Pannonian Plain	2013	episode	Degrendele et al. EST 2016
	India	2014	seasonal	

India southwest (or ‚summer') monsoon 2014 - Clean SH air

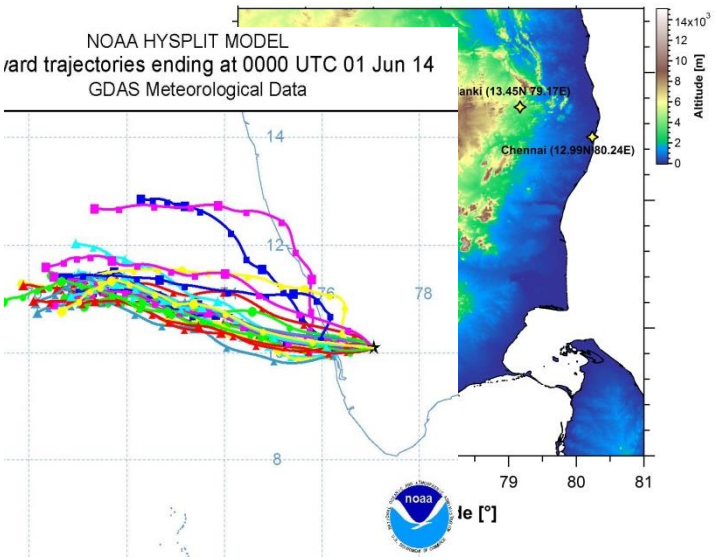




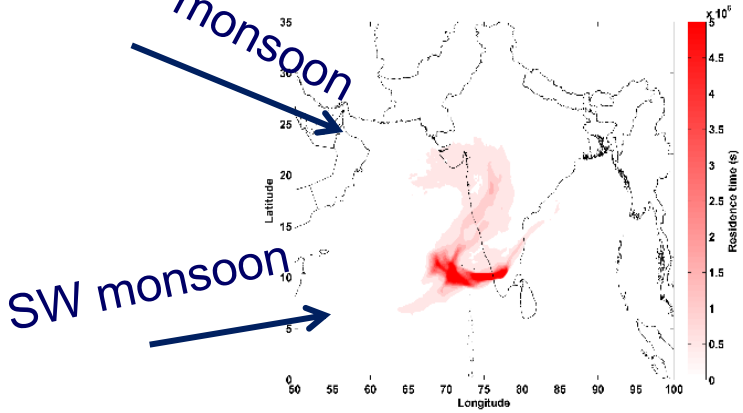
2014:

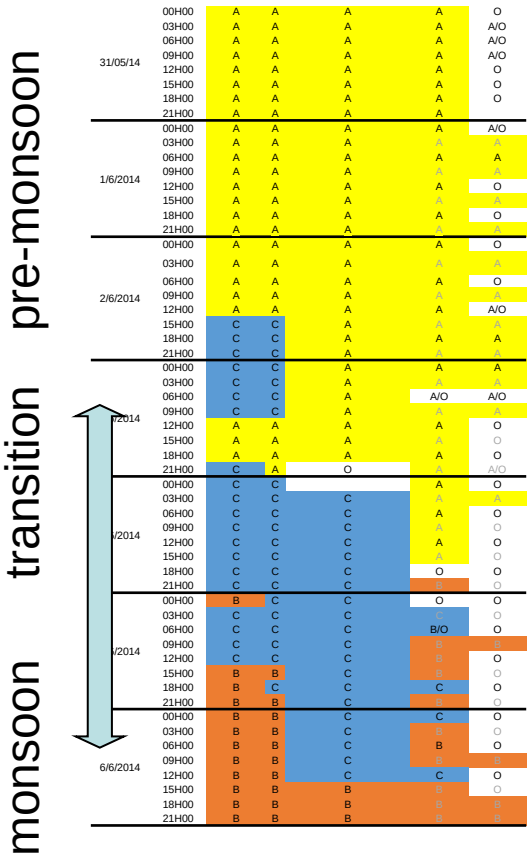


Munnar, Kerala, May-June 2014

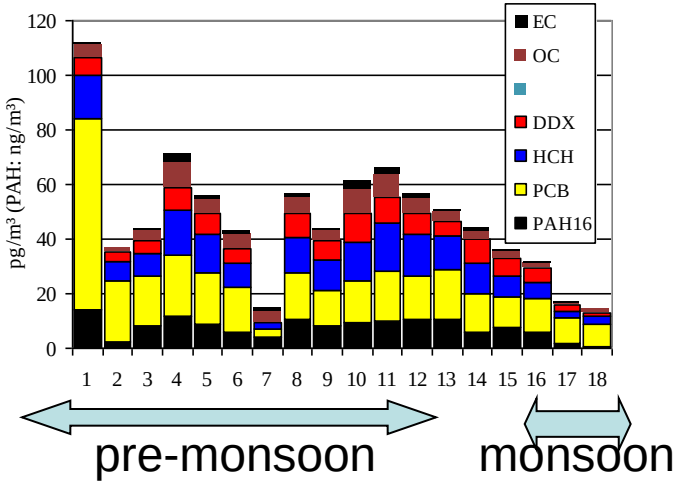


Origin of air masses (Lagrangian dispersion modelling i.e. FLEXPART)





high-volume air samples (n = 24)



2. Air-soil exchange of trace gases ?

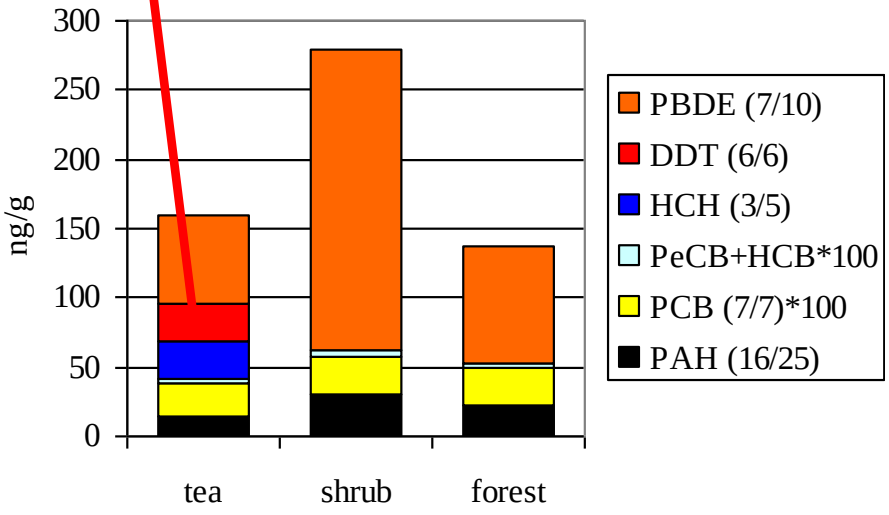
Canopy and soil at 3 soil sampling plots. Soil type: nitisol (GOI, 1985; FAO, 2014)

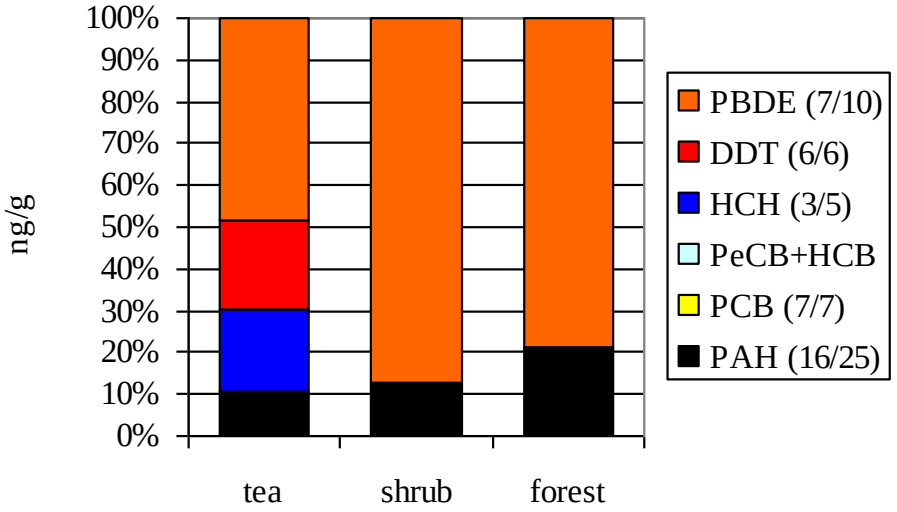
Tea garden
TOC = 4.4%

Shrub
10.7%

Forest
4.0 %

o,p'-DDE	1.84
p,p'-DDE	12.13
o,p'-DDD	0.49
p,p'-DDD	0.17
o,p'-DDT	11.34
p,p'DDT	1.90



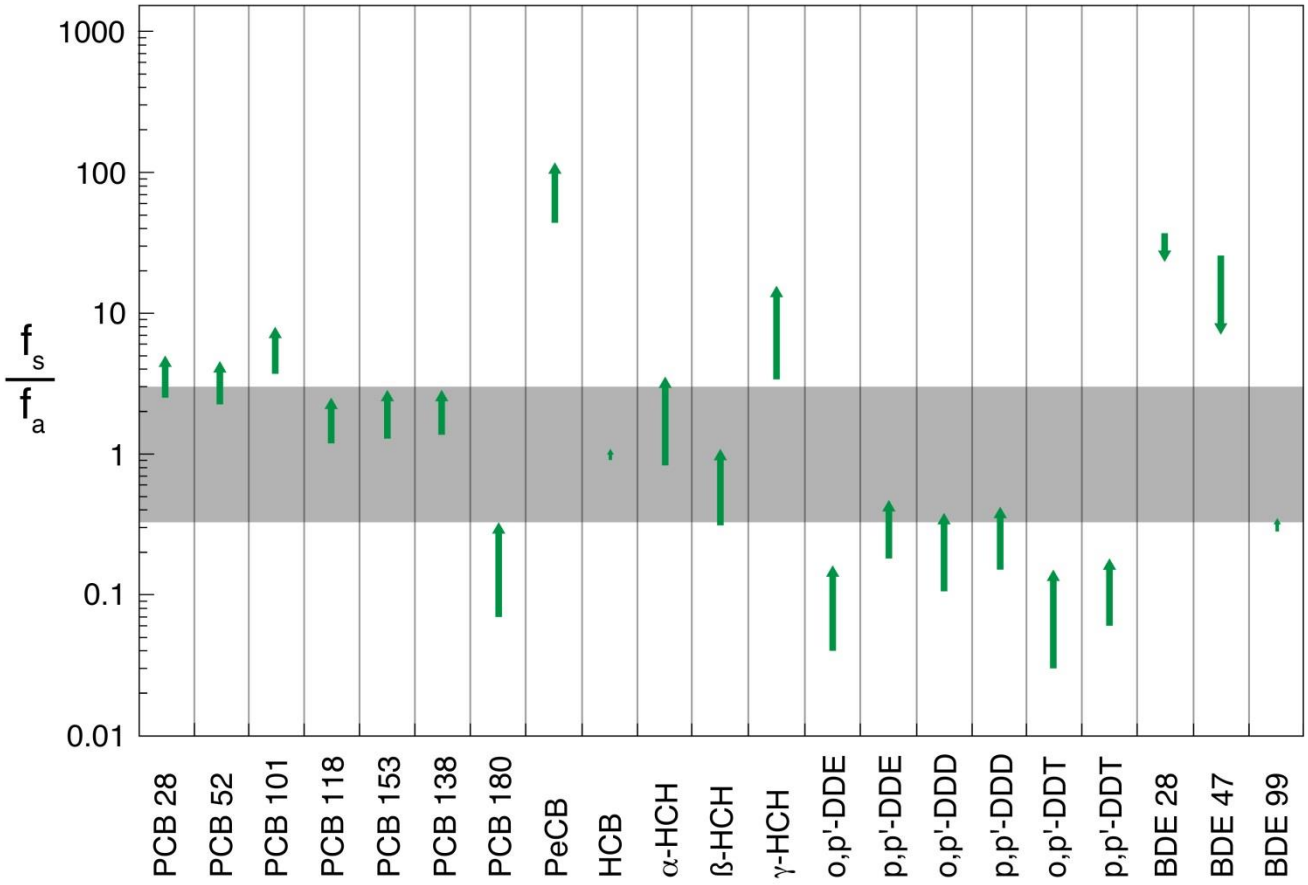


Air-soil exchange India before and during onset of SW monsoon 2014

Change of **air-soil fugacity ratio** (2-film model; *Harner et al., 2001)*,

$f_s/f_a = c_s\, H(T) / (0.411\, \phi_{OM}\, K_{OW}) / [c_a\, R_g\, T]$, with the onset of SW monsoon in 3 land-use categories:

in forest:



↑ upward: PCB28 (forest), α-HCH (tea, forest) and γ-HCH (all)

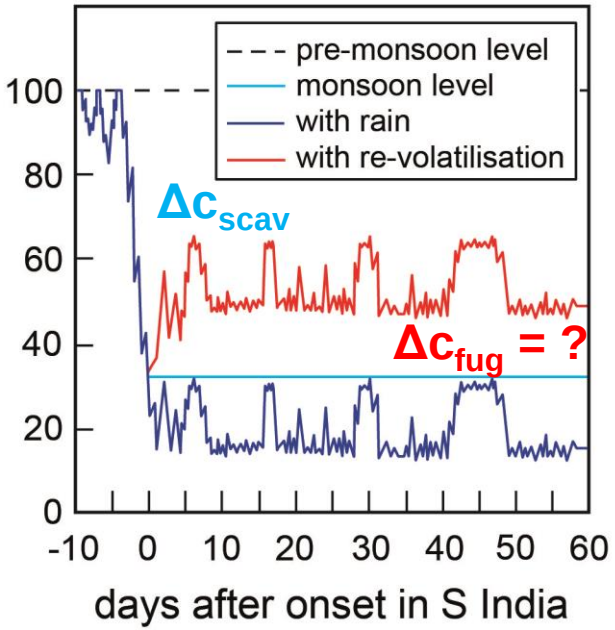
↓ predominantly downward: (g) PHE, FLT, PYR, α- and γ-HCH, BDE47 and -99

Results:

• almost all pollutants addressed were found in air, but not in soil (LOQ too high for many OCPs and PAH derivatives)

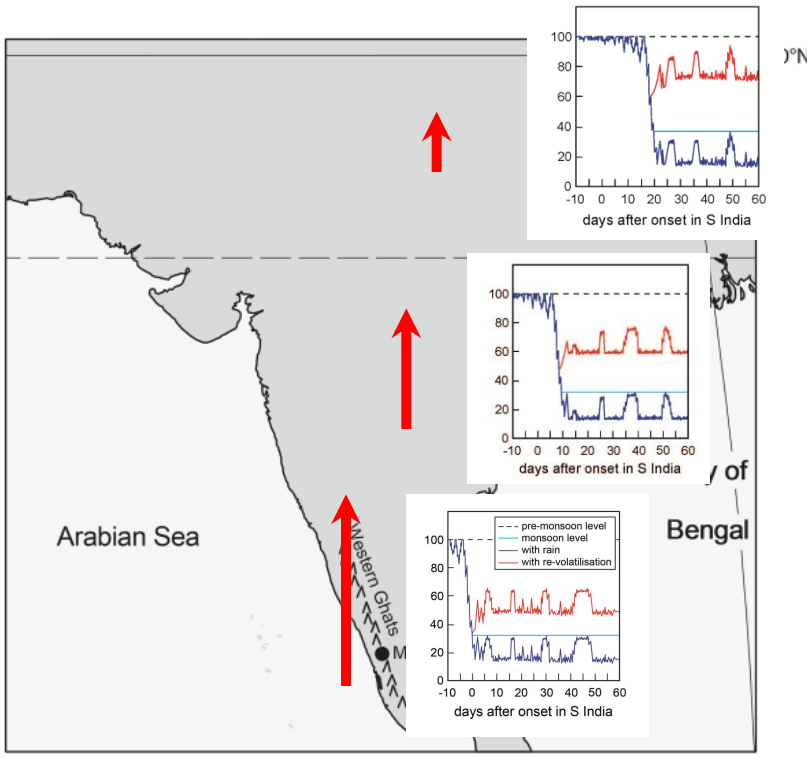
• direction of vertical flux of some OCPs and PCBs may change with onset of monsoon from downward to upward

→ seasonal flux fluctuation, determined by the large-scale advection pattern ?



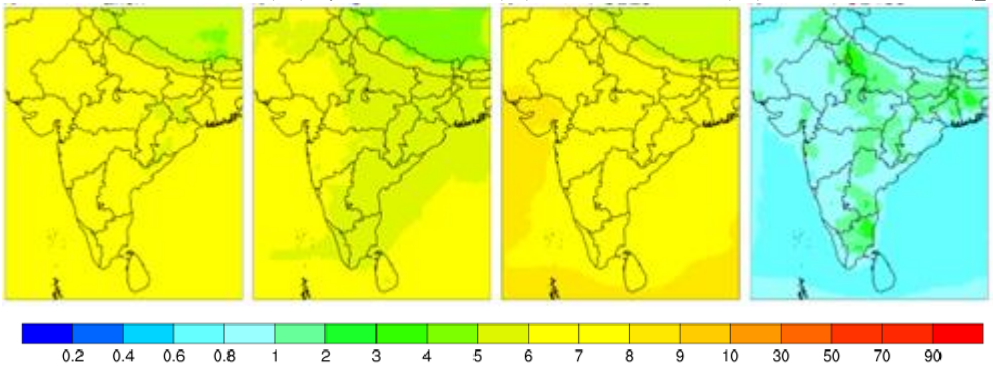
Hypothesis:

When propagating northward, the SW monsoon in India advects air which carries **secondary emissions** of semivolatile pollutants previously **stored in soils, the more the further it propagates** and - triggered by itself ! - ?



Volatilisation triggered by the drop of air pollution levels ?
→ Modelling the chemodynamics

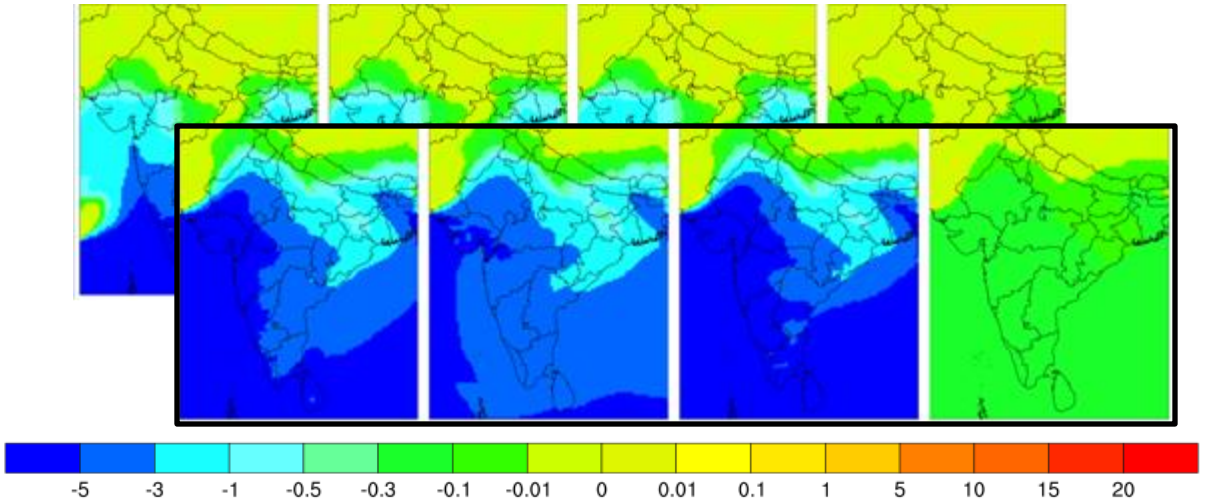
$c_{pre\ monsoon}$ in air (ground level, mean of 1-3 June)
(a) α-HCH, (b) γ-HCH, (c) PCB28, (d) PCB153 (pg m



(%)	S India (Munnar, 9°N)	
	$\Delta c_{obs}/c_{obs}$ [a]	$\Delta c_{pred}/c_{pred}$
***α*-HCH**	-83	-79
***γ*-HCH**	-87	-83
***pp*-DDT**	-73	-42
***pp*-DDE**	< -75	-99.8
PCB28	-55	-79
PCB153	-55	-38

Response of the air-soil sub-system to meteorological and chemical changes in advection: episode simulation WRF/Chem model with soil compartment

Air pollution drop due to advection of SW monsoon air (exp-ctrl) 8-10, then 28-30 June 2014



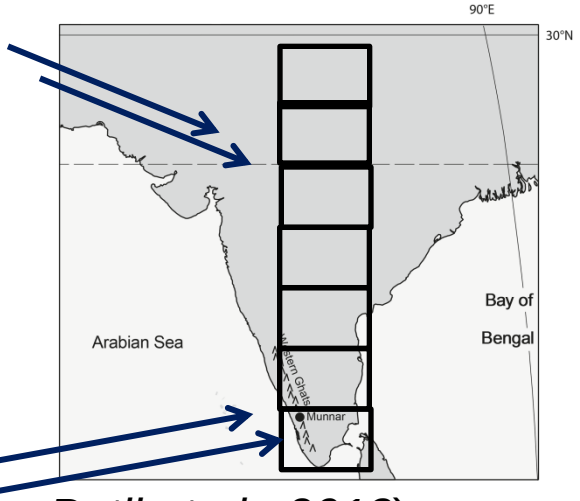
→ In S India the change of pollutant level reflects the drop in the advected, clean air, while with propagation northward the signal decreases

40-year simulation - Input data spatiotemporal variations:

c_{OH} interpolated from 3-monthly climatological data (*Spivakovsky et al 2000*)

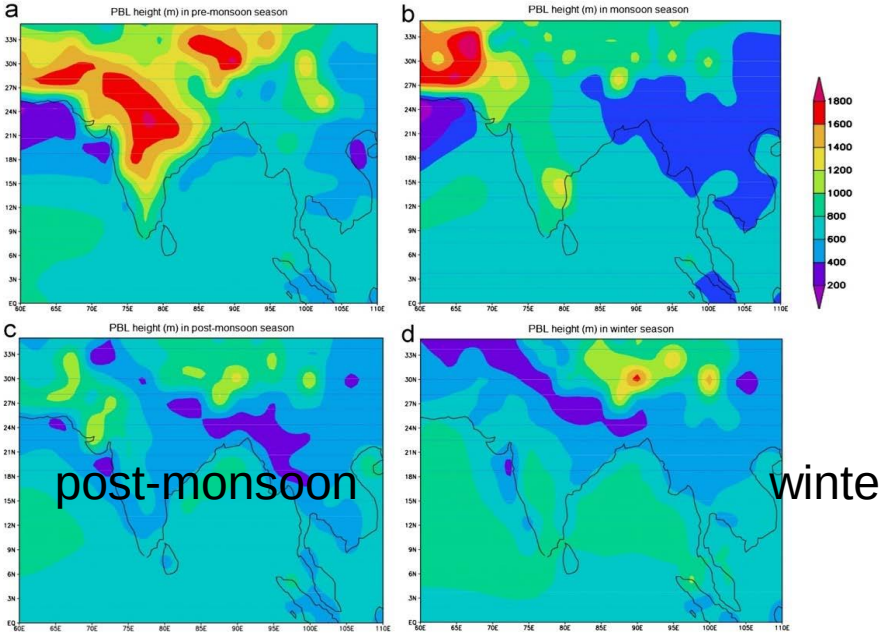
$h_{boundary\ layer}$ 37-year mean (1965-2002) monthly data (ERA40, ECMWF)

W_t scaled from atmospheric burden and $F_{wet\ dep}$ of global MCTM output (*Lammel et al 2012, Stemmler & Lammel 2012, Semeena et al 2006*),

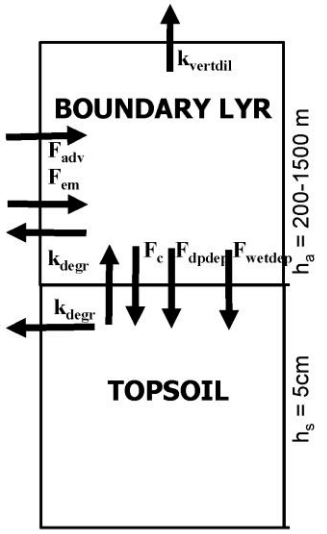


Seasonal (40 year-) mean PBL heights (ERA-40 data; *Patil et al., 2013*)

pre-monsoon monsoon



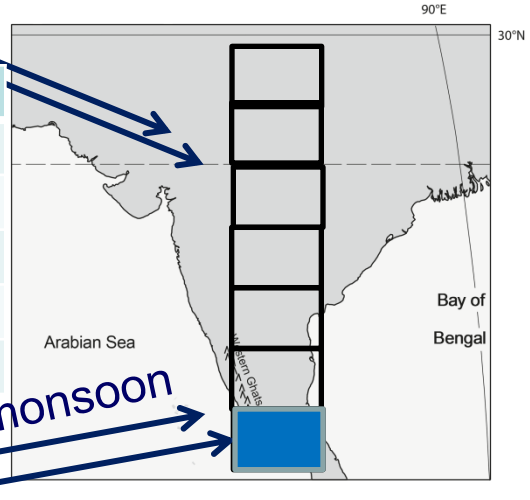
post-monsoon winter



2. Long-term regional scale response of soil compartment to atmospheric pollution and the monsoon cycle ?

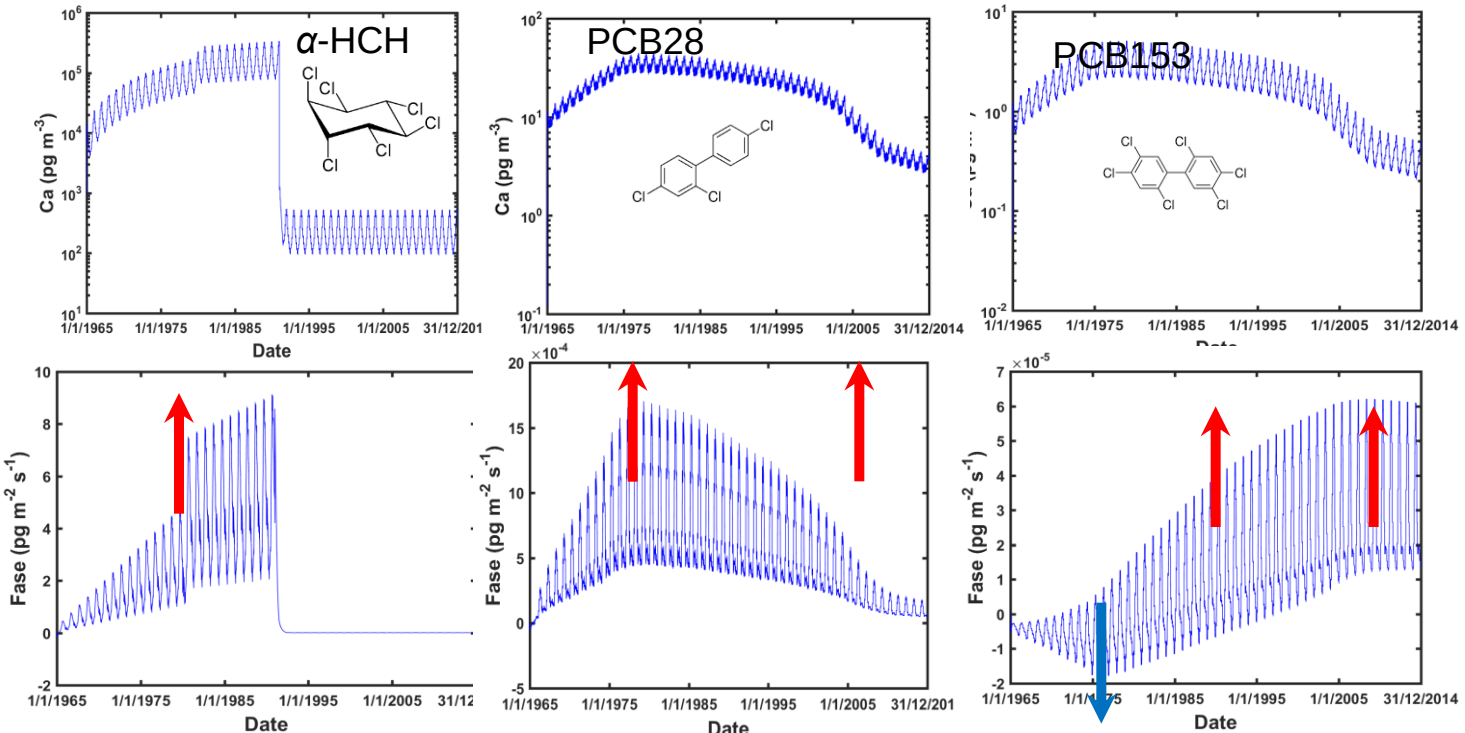
Non-steady state 2-compartment box modelling 1965-2014: Model predicted concentrations in air and top soils in 7 zones (boxes), N to S

	Air (pg m^{-3})				Soil (pg g^{-1})	
	Pre-monsoon 2014		Monsoon 2014		2014	
	Obs'd	Mod'ld	Obs'd	Mod'ld	Observed	Mod'ld
PCB28	10.5	3.0	5.5	3.0	54-60	1.9
PCB153	0.47	0.22	0.21	0.24	34-40	21
***α*-HCH**	7.7	118	1.3	114	10-36	18



southernmost (measurement) box:

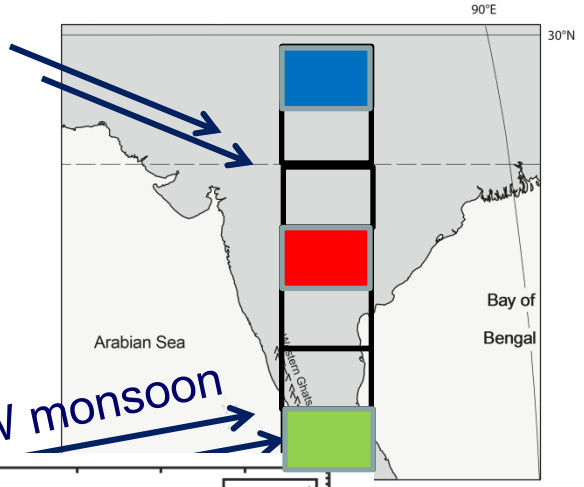
Air



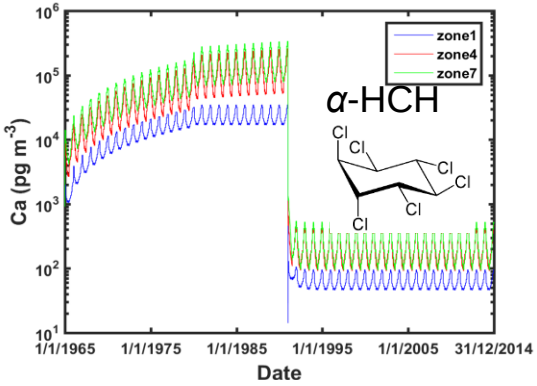
Long-term regional scale response of soil compartment to atmospheric pollution and the monsoon cycle ?

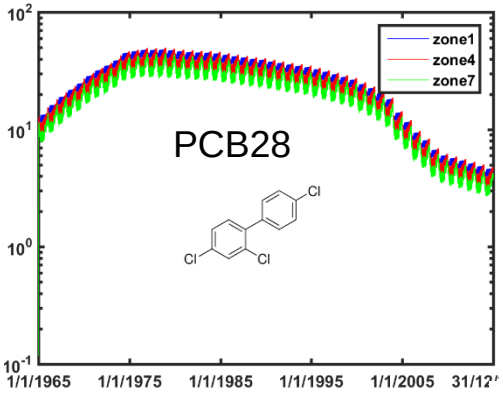
Non-steady state 2-compartment box modelling 1965-2014:
Model predicted concentrations in air and top soils in 7 zones (boxes), N to S

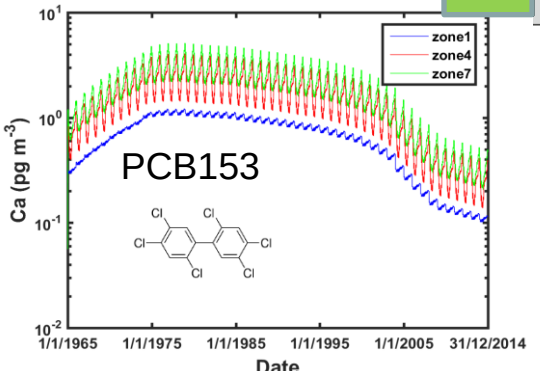
Southernmost, central and northernmost boxes:

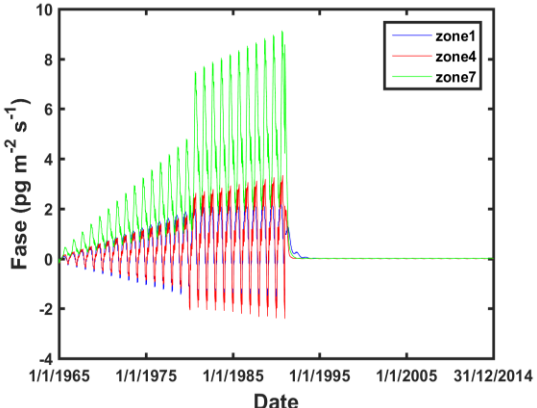


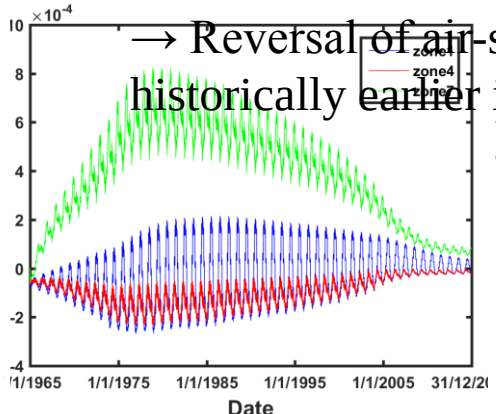
Air

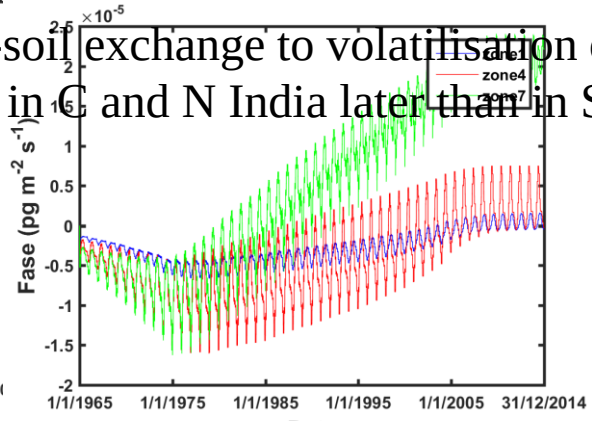












→ Reversal of air-soil exchange to volatilisation of PCBs historically earlier in C and N India later than in S India

Main results and conclusions

- HCH, DDT and PCB are re-volatilising from soil at a S India background site 2014
- Pollution drop in air (when SW monsoon arrives) enhances re-volatilization of some of the POPs from soils (the deeper the drop, the more)
- Monsoon air arriving in N India is expected to be less clean than in S India due to mobilisation of pollution stored in soils (besides other pollution sources)
- *So far:* Seasonality of air-soil exchange flux not explained by box modelling / for only part of the substances studied

… thank you for your attention!

acknowledgements:

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