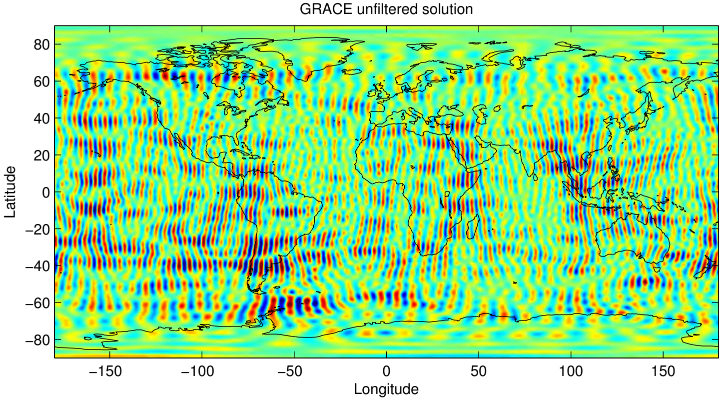
Data driven approach to minimize effects of filtering on GRACE

Bramha Dutt Vishwakarma [1],
Balaji Devaraju [2] and Nico Sneeuw [1]

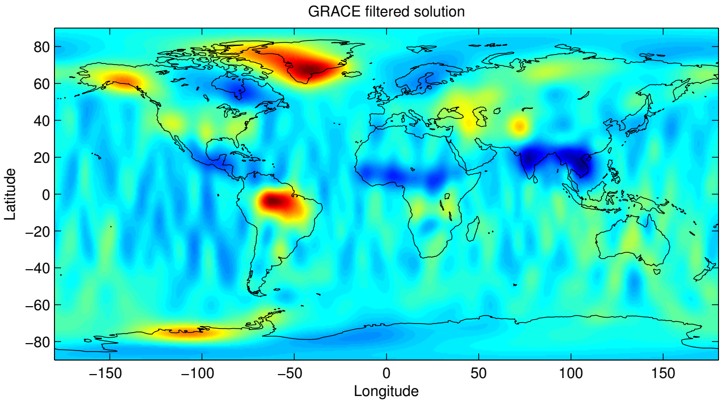
[1]Institute of Geodesy, University of Stuttgart

[2]Institute of Geodesy, Leibniz University of Hannover

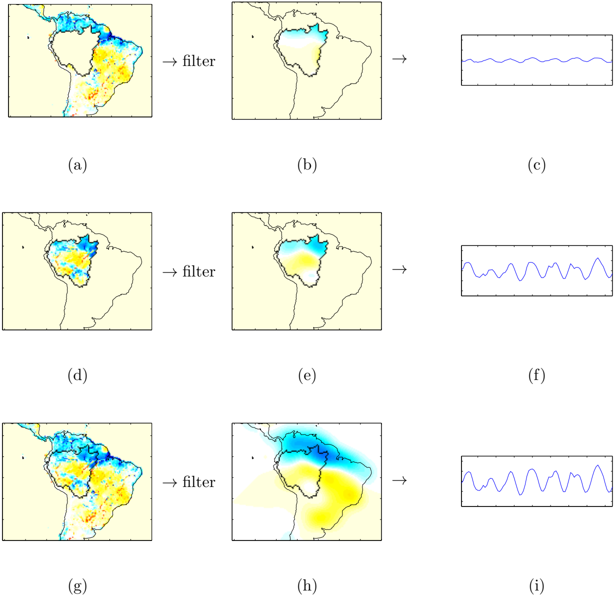
GRACE, level 2 observation for month of May 2005



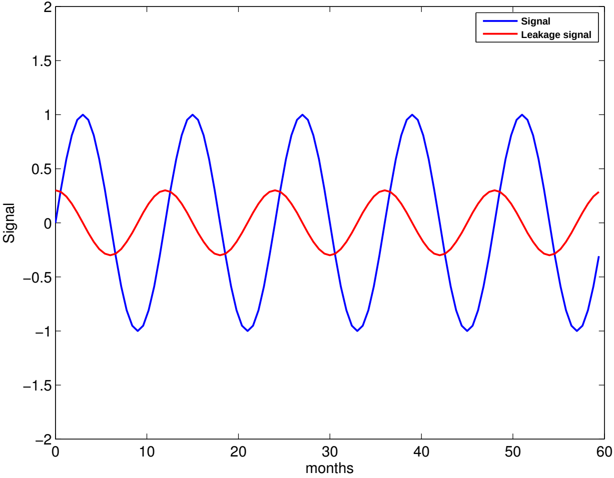
Filtered observation (May 2005)



Breaking the problem



How 2 waveform with different amplitude and phase interact



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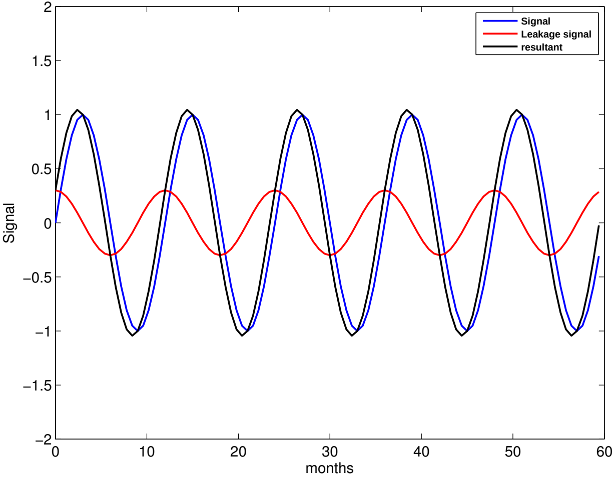

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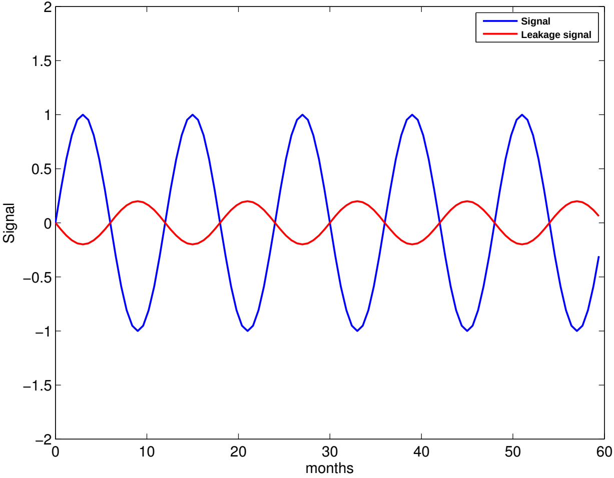

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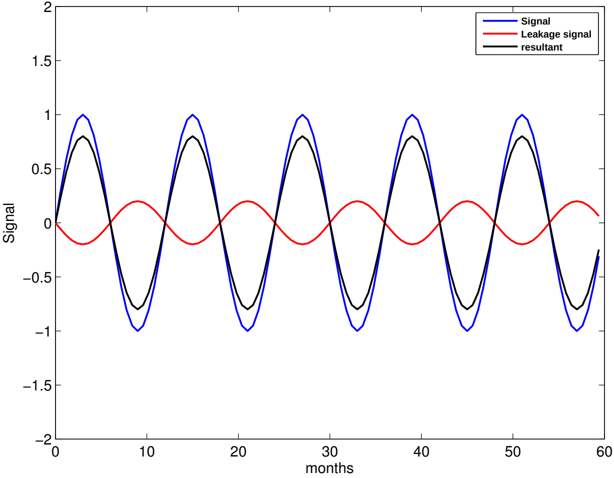

Resultant phase and amplitude

Let the resultant time series be $\bar{\alpha}\cos(\omega t + \bar{\phi})$. The amplitude $\bar{\alpha}$ and phase $\bar{\phi}$ of time-series for a catchment can be computed from the following relations,

$$\bar{\alpha} = \sqrt{{\alpha_a}^2 + {\alpha_l}^2 + 2\alpha_a\alpha_l\cos(\phi_a - \phi_l)}, \tag{1}$$

$$\tan(\bar{\phi}) = \frac{\alpha_a \sin\phi_a + \alpha_l \sin\phi_l}{\alpha_a \cos\phi_a + \alpha_l \cos\phi_l}. \tag{2}$$

Attenuated time-series: $\alpha_a\cos(\omega t + \phi_a)$.
Leakage time-series: $\alpha_l\cos(\omega t + \phi_l)$.

Phase shifts after filtering (absolute)

Basin	**Phase shift** ($1^\circ \approx 1$ **day**)
Amazon	0.6°
Parana	2.18°
Indus	0.25°
Ganges	2.60°
Orinoco	2.67°
Brahmaputra	12.75°
Highlands of Tibet	22.55°
Rio Tapajos	11.27°
Godavari	2.12°
Krishna	11.92°
Mag dalena	4.66°
Arravali	5.63°

Table: Analysis with WGHM model as field.

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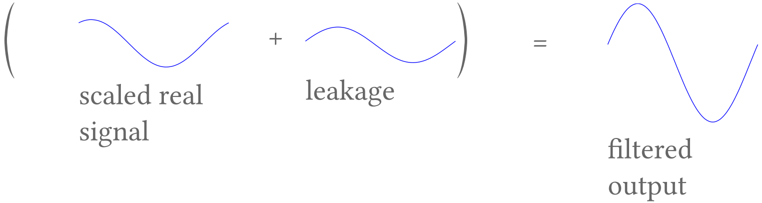
How can we get back the real time-series ?



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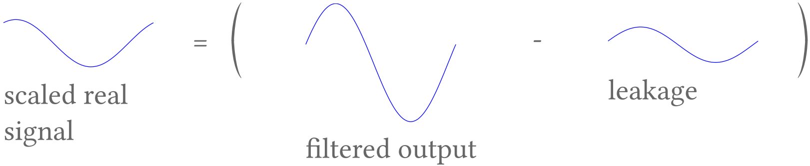

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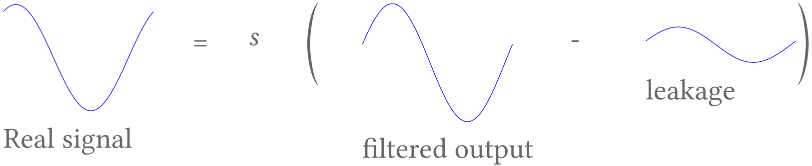


Mathematical relation

$$f_c = s(\bar{f}_c - l_c). \tag{3}$$

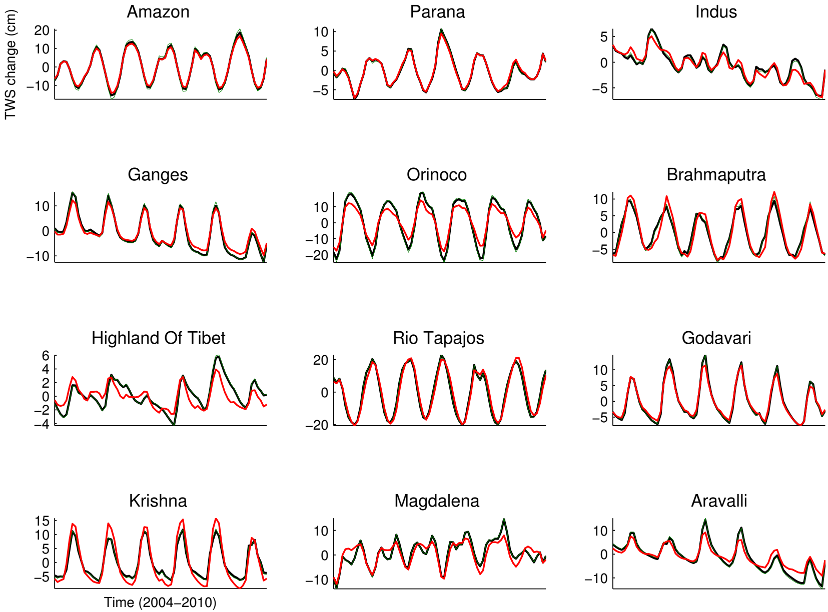
$$s = \frac{\int_\Omega R(\theta,\lambda)\mathrm{d}\Omega}{\int_\Omega \bar{R}(\theta,\lambda)R(\theta,\lambda)\mathrm{d}\Omega}. \tag{4}$$

The true time-series over a catchment c is denoted by f_c, time-series from filtered global field by $\bar{f}_c$, leakage time-series by l_c and the scale factor for the region and a filter kernel by s. Where R is the region mask (1 inside the catchment we are interested in and 0 outside), $\bar{R}$ is the filtered mask.

Scale factors for catchments treated with gaussian filter (400 km)

Basin	Scale factors
Amazon	1.40
Parana	1.65
Indus	2.16
Ganges	2.26
Orinoco	2.27
Brahmaputra	3.12
Highlands of Tibet	2.96
Rio Tapajos	4.01
Godavari	4.10
Krishna	4.84
Magdalena	4.86
Arravali	6.86

Validation in closed loop (WGHM as input field)



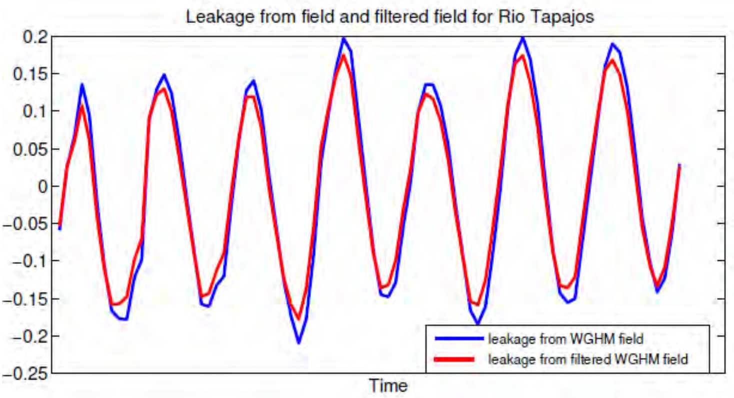
Can we apply it to GRACE ?

- Remove leakage and then scale the time-series.
- To get leakage, we need knowledge of real field distribution!
- GRACE is too noisy and when we compute leakage from unfiltered field, we have noise components.

$$\bar{G}_{\mathrm{c}} = \frac{1}{s}(f_{\mathrm{c}} + n_{\mathrm{c}}) + l_{\mathrm{c}} + n_{\mathrm{c}}^{l}, \quad (5)$$

where $\bar{G}_{\mathrm{c}}$ is the catchment aggregate of filtered mass change observed from GRACE, n_{c} is the damped noise estimate over the catchment only, n_{c}^{l} is the noise term in the leakage field computed from unfiltered GRACE observations. f_{c} is real time-series, and l_{c} is leakage.

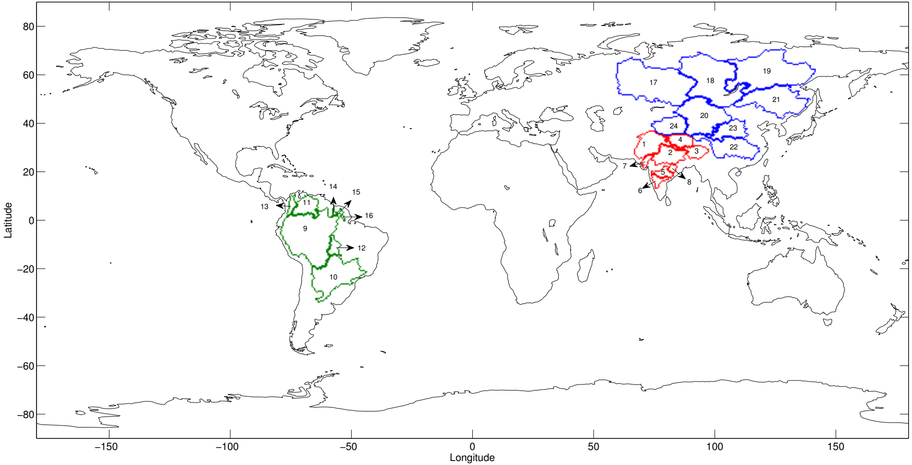
Leakage from field and it's filtered version (in cm)



Proposed methodology

- Compute leakage from once filtered field ($\bar{l}$) and twice filtered field($\bar{\bar{l}}$).
- Get phase difference between the two time series $\bar{l}_c$ and $\bar{\bar{l}}_c$.
- Shift the leakage ($\bar{\bar{l}}_c$) by the phase difference, and compute the ratio between them.
- Shift the leakage ($\bar{l}_c$) by the phase difference and apply the ratio to get leakage (l_c).
- Remove this leakage from filtered field, and apply scaling factors to get near true estimates.

Catchments under investigation



Catchments under investigation

Index	**Catchment**	**Area (in square** km)
1	Indus	1122836.00
2	Ganges	906200.81
3	Brahmaputra	521828.69
4	Highland of Tibet	521596.41
5	Godavari	308695.09
6	Krishna	254875.20
7	Aravalli	179980.91
8	Mahanadi	123744.50
9	Amazon	4672876.00
10	Parana	2645738.00
11	Orinoco	836021.50
12	Rio Tapajos	366842.69
13	Magdalena	254778.70
14	Corantijn	67876.95
15	Maroni	61706.62
16	Rio Jari	46354.74
17	Ob	2926321.00
18	Yenisei	2454961.00
19	Lena	2417932.00
20	Gobi	2099470.00
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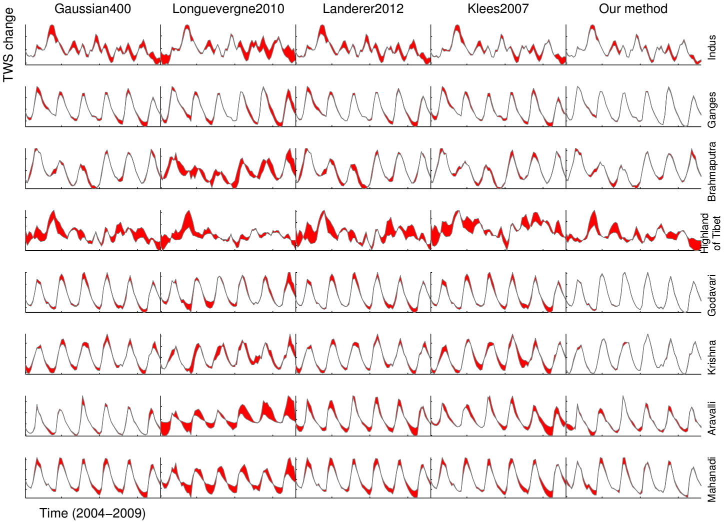
GLDAS as input and WGHM as model



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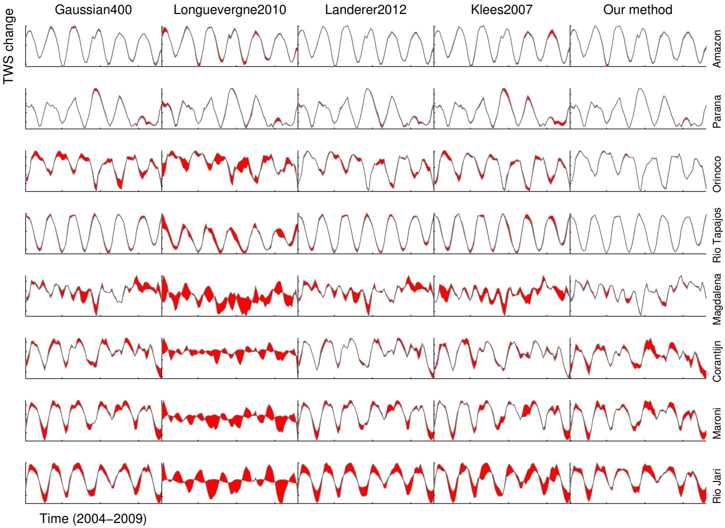

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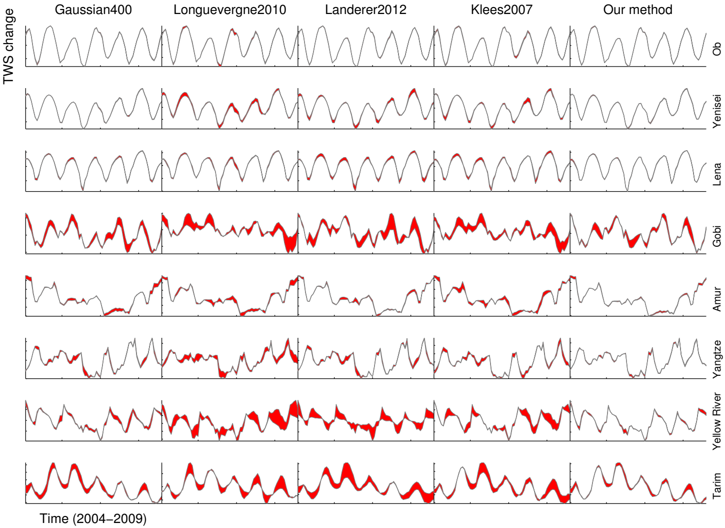
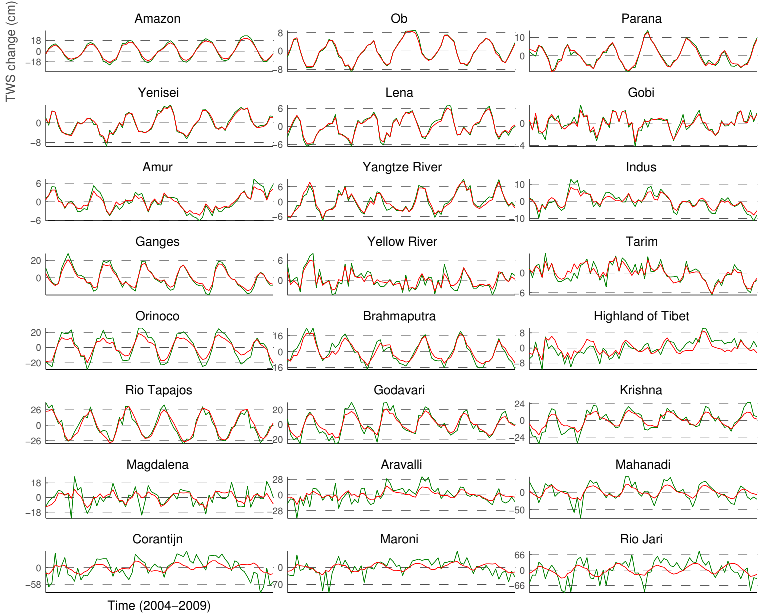


GRACE data processed with our method



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- Correcting GRACE observations with help of models can be erroneous.
- The application of our strategy in closed loop environment shows promising results.
- Computation of leakage from filtered field with better accuracy would enhance performance.
- GRACE can be independent of models.

Thank you

Acknowledgement

- DAAD for financial support.
- Matthew Rodell and Hiroko Kato Beaudoing, NASA/GSFC/HSL (12.01.2013), GLDAS Noah Land Surface Model L4 monthly 1 x 1 degree Version 2.0, Greenbelt, Maryland, USA: Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed October 2014, doi:10.5067/342OHQM9AK6Q
- Doell et al (2014) for WGHM hydrology data.

Questions and Suggestions