EGSIEM

European Gravity Service for Improved Emergency Management

# WP4. Scientific Combination Service

## Combination of GRACE Monthly Gravity Field Solutions

**Yoomin Jean**

Astronomical Institute, University of Bern

**EGSIEM Progress Meeting # 3**

**GFZ, Potsdam**

**June 02 – 03, 2016**

Horizon2020

# Introduction

- In WP4 at AIUB
  - Scientific Combination Service :

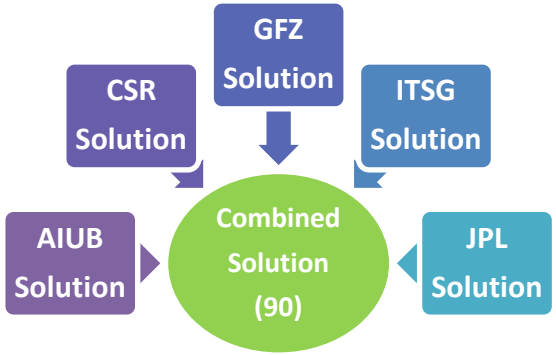
    Combination of GRACE Monthly Gravity Field Solutions

- Contents
  - Review:
    - Comparison and Combination of GRACE Monthly Solutions on Solution Level
    - Validation of a Combined Solution: Hydrology, Cryology, GIA, GPS Loading
  - Simulation Study on the Combination
  - Combined Solution using New Weighting Schemes

# Review (1/2): Combination of GRACE Monthly Solutions

- GRACE Monthly Solutions
  - The solutions available at ICGEM website


- Comparison
  - Signal: MEWH of river basins
  - Variability: wSTD over the oceans
  - Spherical Harmonic Coefficients



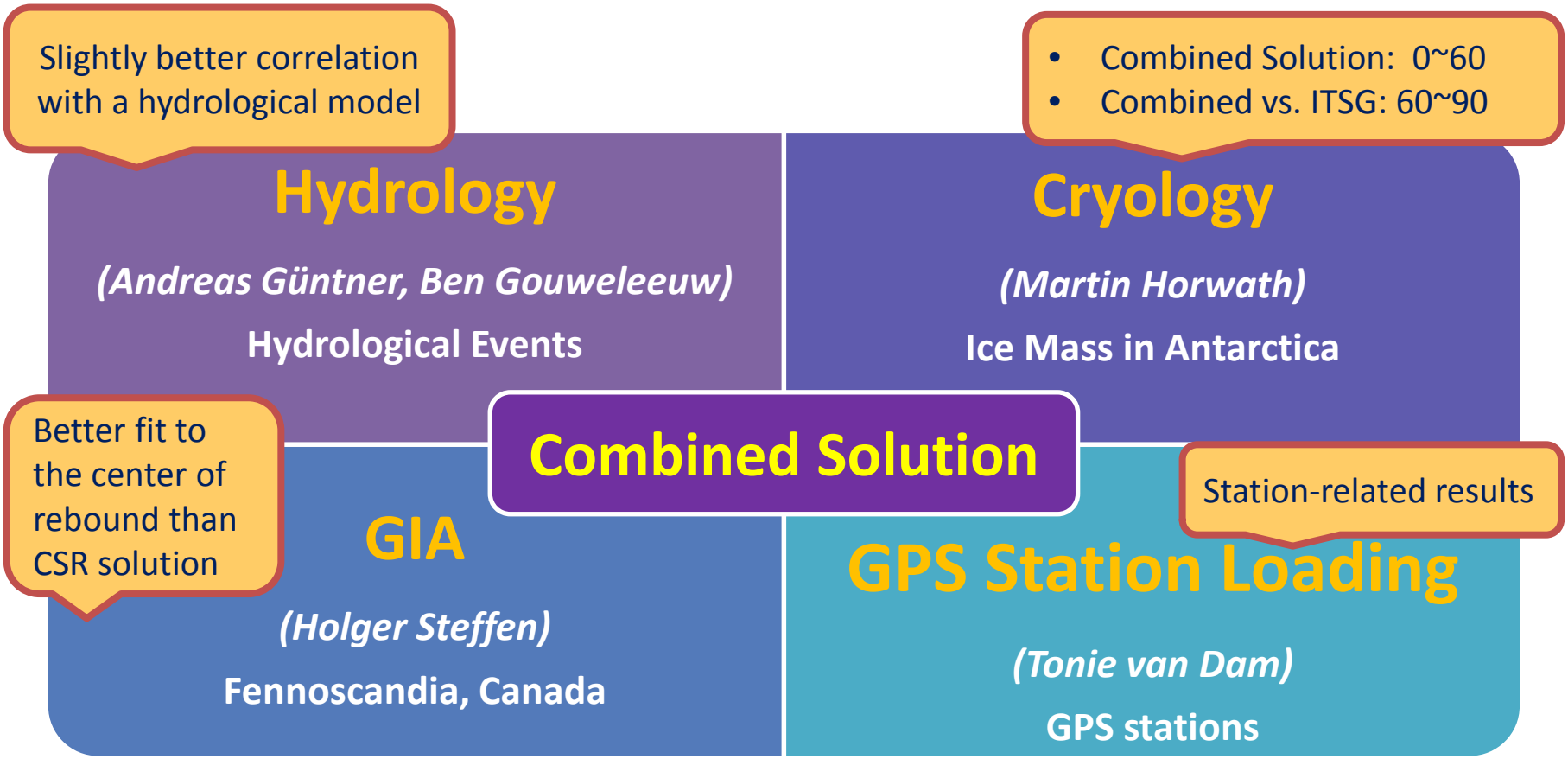

- Combination
  - Weighting schemes: $1/(\text{Solution} - \text{Arithmetic Mean})^2$
  - Weighted combined solutions:

    One weight/month/gravity field

# Review (2/2): Validation of Combined Solutions

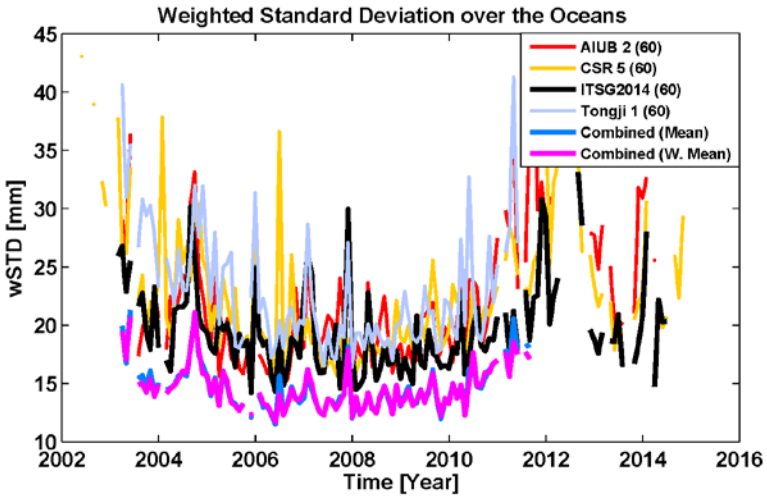
- Combined solution: Single weight/month/gravity field (degree 90)

  : in gfc file format and L3 grids (Thanks to *TU Graz*'s prompt conversion assistance)

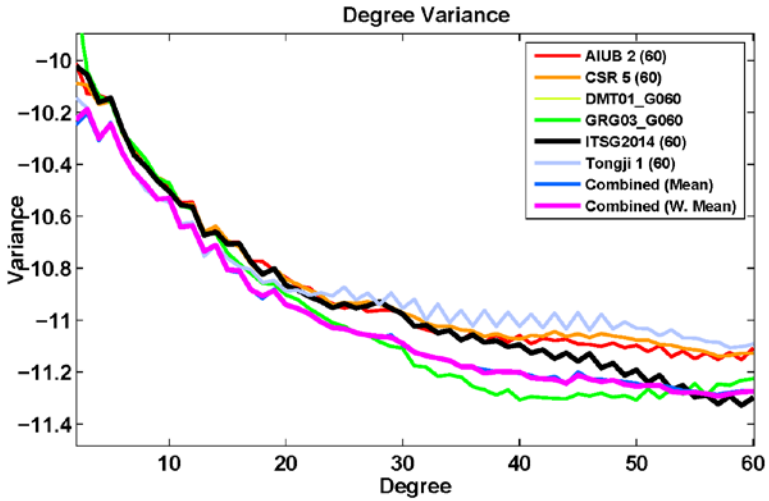


# [Simulation Study] Motivation

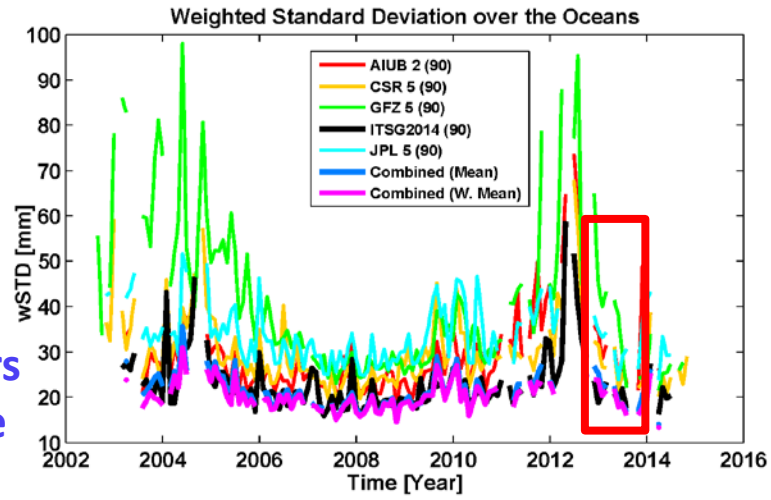
## Degree 60

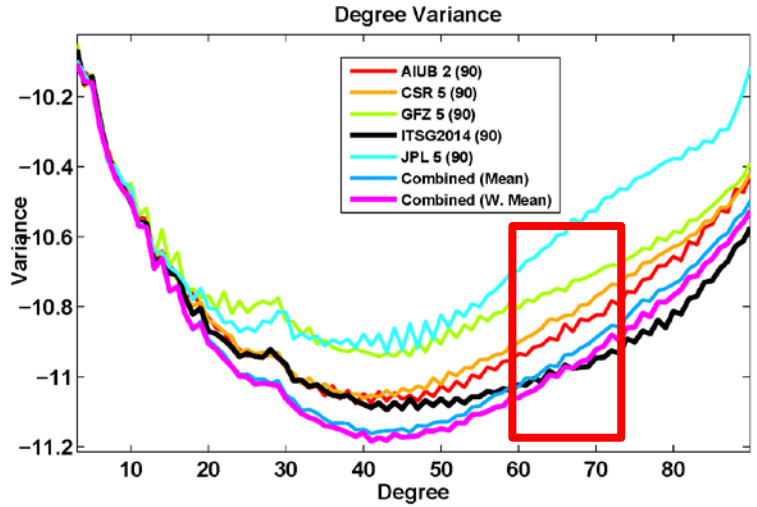



**Median of time series of**




## Degree 90




**Strange behaviors in degree 90 case**

# [Simulation Study] Objectives

- To investigate
  - **Impact of an Individual Solution** with
    - Very different levels of noise
    - Attenuated Signal
  - **Weighting schemes**
    - Another weighting scheme to overcome the limitations of current weighting schemes
- Presented in *EGU General Assembly 2016* (April 2016)

# A Newly Tested Weighting Scheme

- In the last meeting, about the limits of current weighting schemes
  - Assumption: the ***arithmetic mean*** is close to the truth.
  - However, the ***reality*** may be not like that.
  - How to ***improve*** the weighting scheme?

- **Variance Component Estimation (VCE)**
  - Iterative process
  - Replacing **Arithmetic Mean → Weighted Mean**
    in computation of weights in each iteration step
  - Updating weights in each iteration step

# [Simulation Study] Simulated Gravity Field Solutions

- **Reference gravtiy field**: extracted from a model

$$\hat{X}_{lm}(t) = \underbrace{a_{0_{lm}}}_{\text{Offset}} + \underbrace{a_{1_{lm}}\Delta t}_{\text{Trend}} + \underbrace{a_{2_{lm}} \sin \omega \Delta t + b_{2_{lm}} \cos \omega \Delta t}_{\text{Annual Signal}}$$

- **Simulated Individual Solutions**

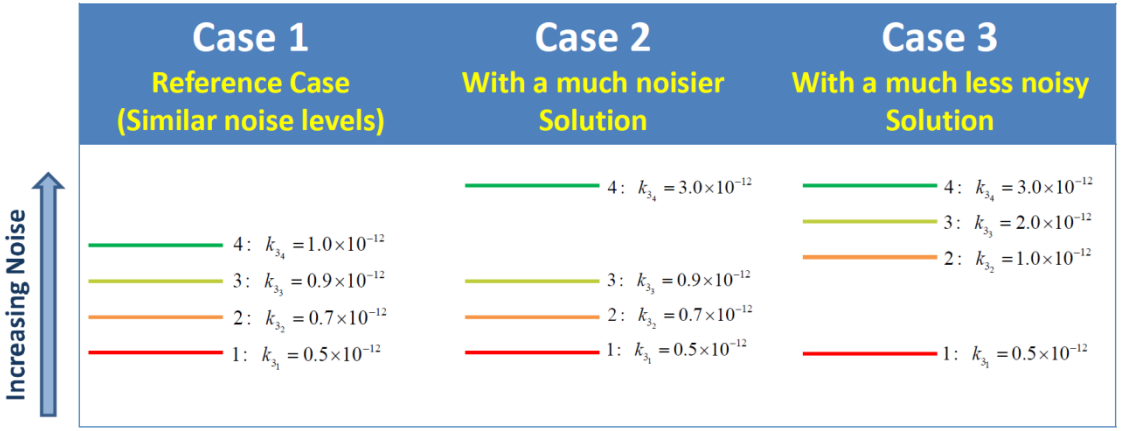
$$X_{i_{lm}}(t) = \mathbf{k_0} a_{0_{lm}} + \mathbf{k_1} a_{1_{lm}} \Delta t + \mathbf{k_2}(a_{2_{lm}} \sin \omega \Delta t + b_{2_{lm}} \cos \omega \Delta t) + \mathbf{k_3} \epsilon$$

| Coefficient | Term | Scale Factor | In the simulation |
|---|---|---|---|
| $a_0$ | Offset | $k_0$ | Fixed |
| $a_1$ | Slope (Trend) | $k_1$ | Fixed |
| **$a_2$, $b_2$** | **Annual Signal** | **$k_2$** | **Varied** |
| **1** | **Random Error** | **$k_3$** | **Varied** |

# [Simulation Study] Cases (Four Indiv. Simul. Solutions / Case)

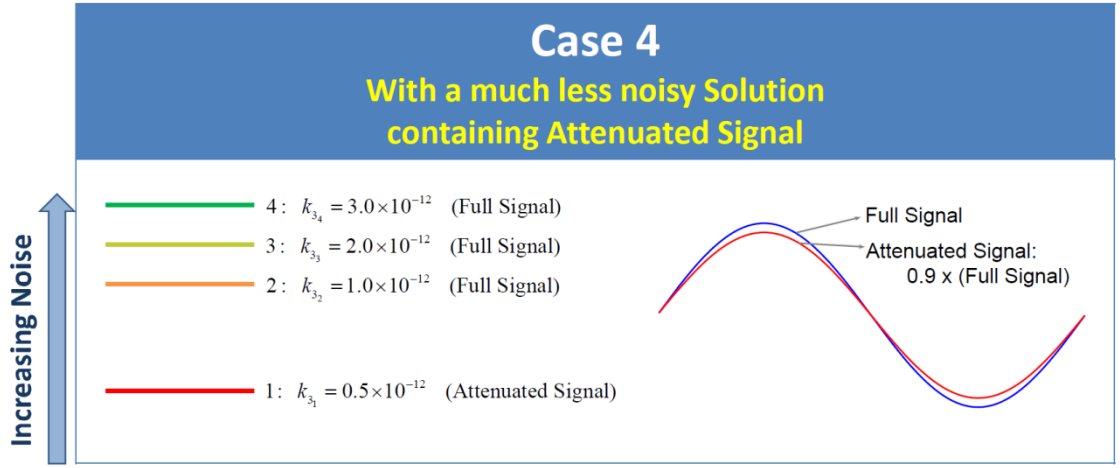
## Noise :

Deviated Level of Noise

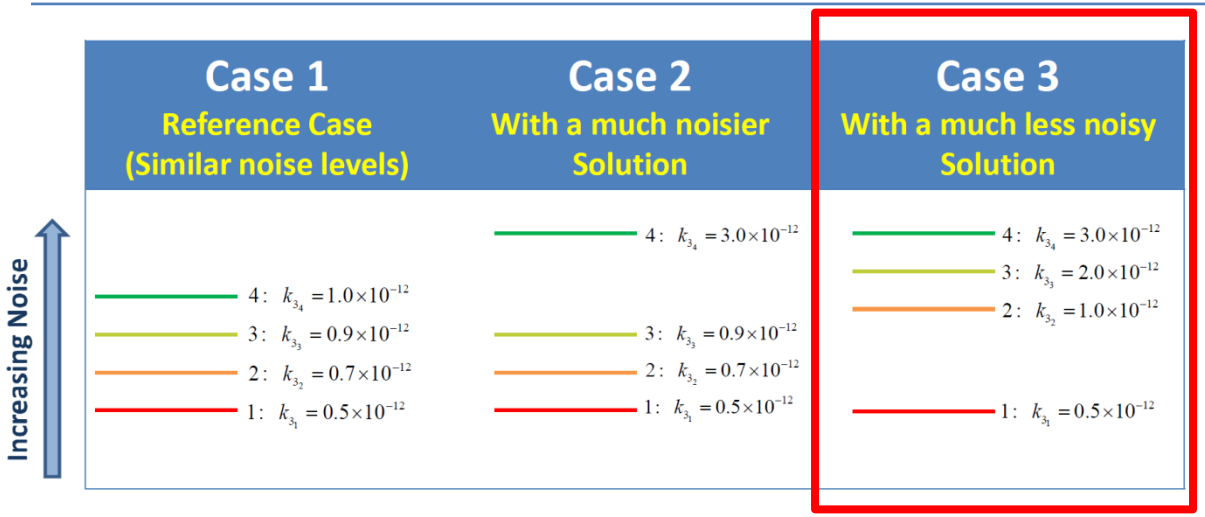



## Systematic Error :

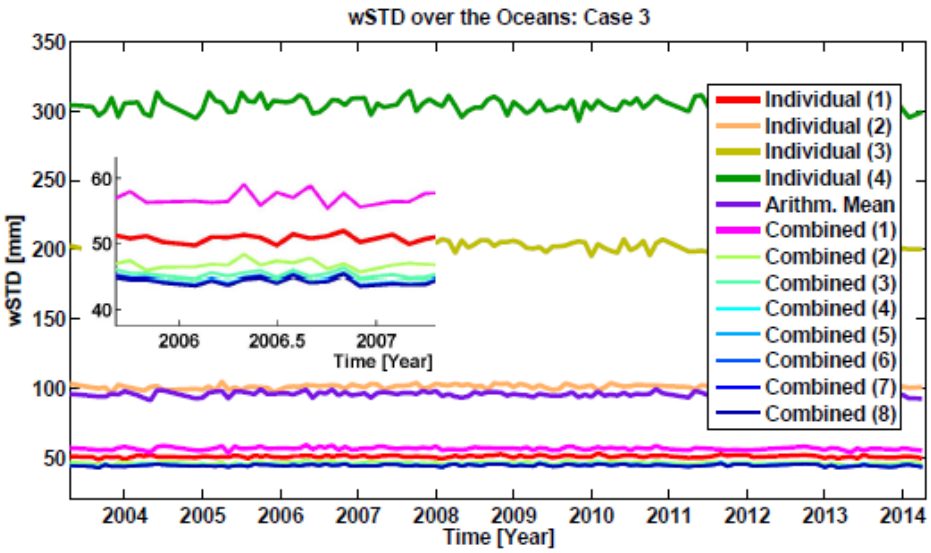
Attenuated Signal

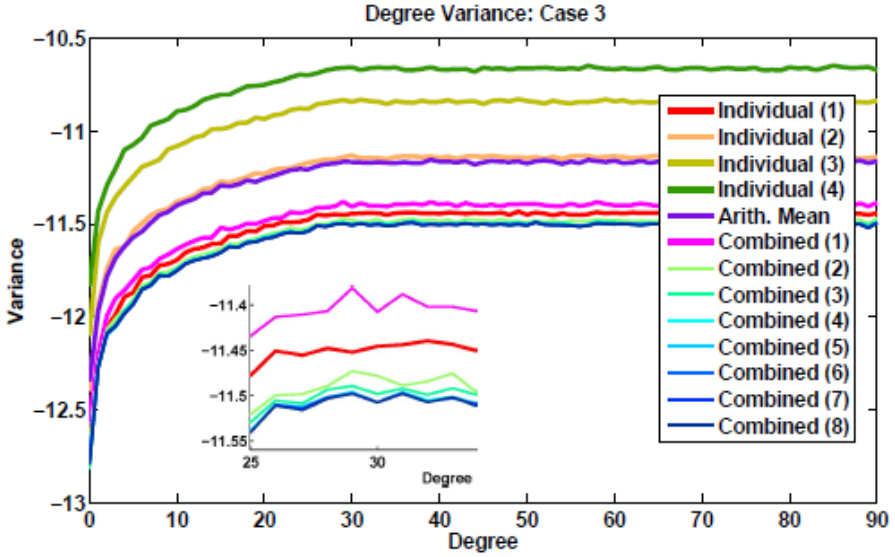


# Case 3: With a Much-Less-Noisy Solution

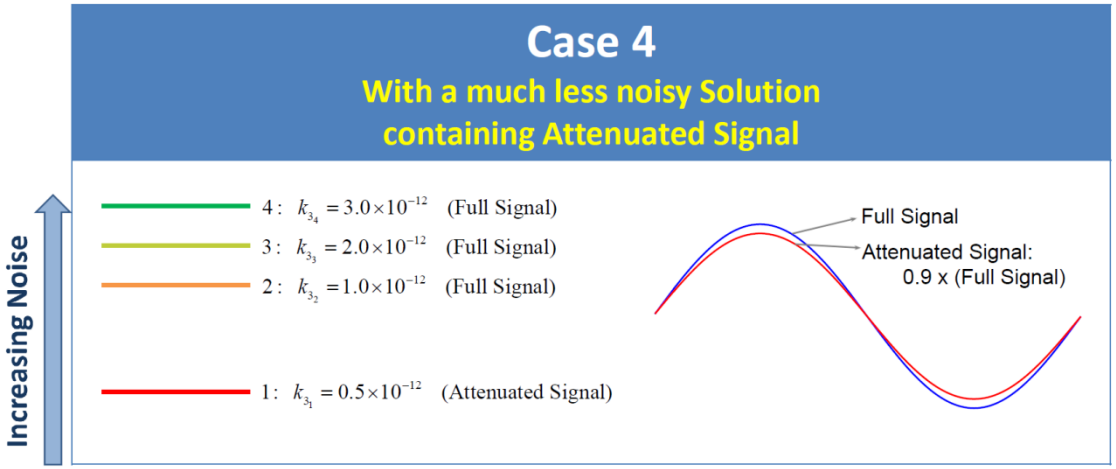



- Combined solutions after iterations have less noise than the individual solution with the least noise.

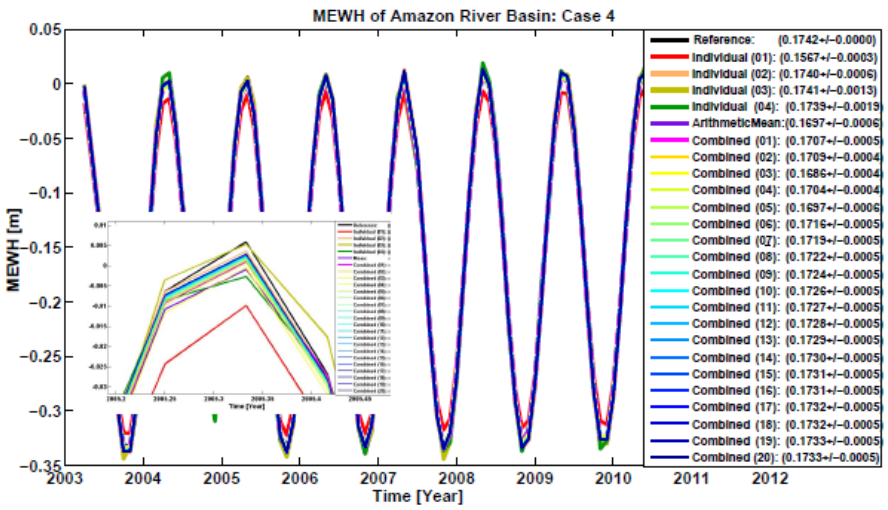


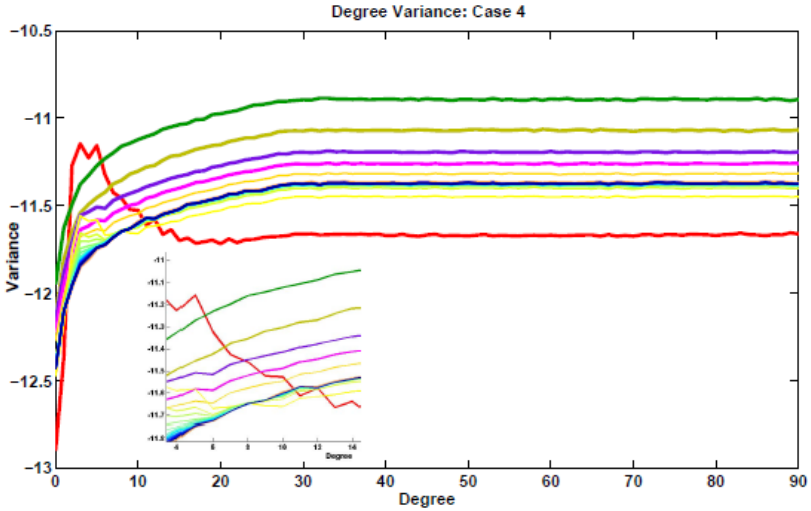



# Case 4: Attenuated Signal



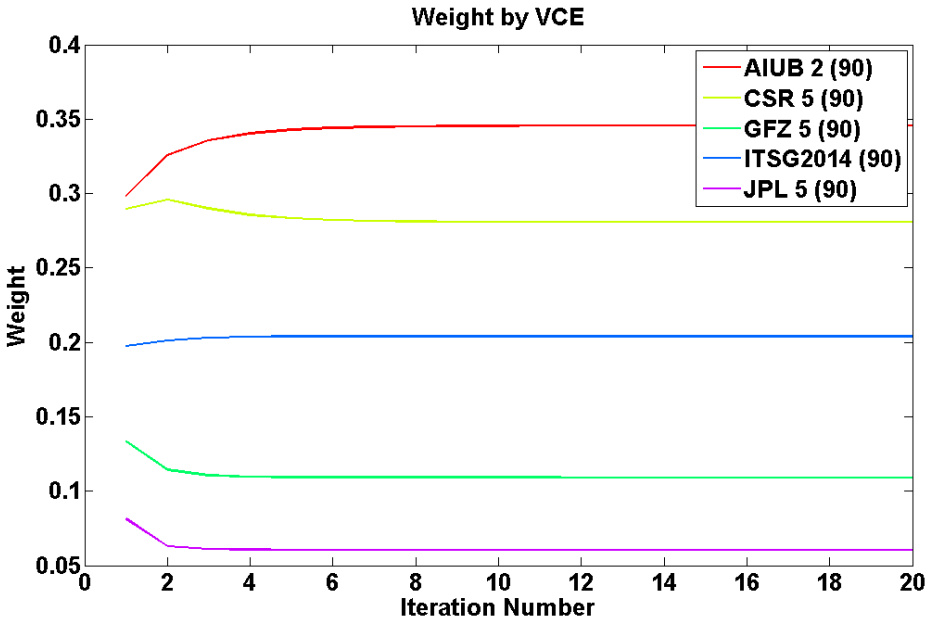

- Combined solutions after iterations have less noise than the individual solution with the second least noise.

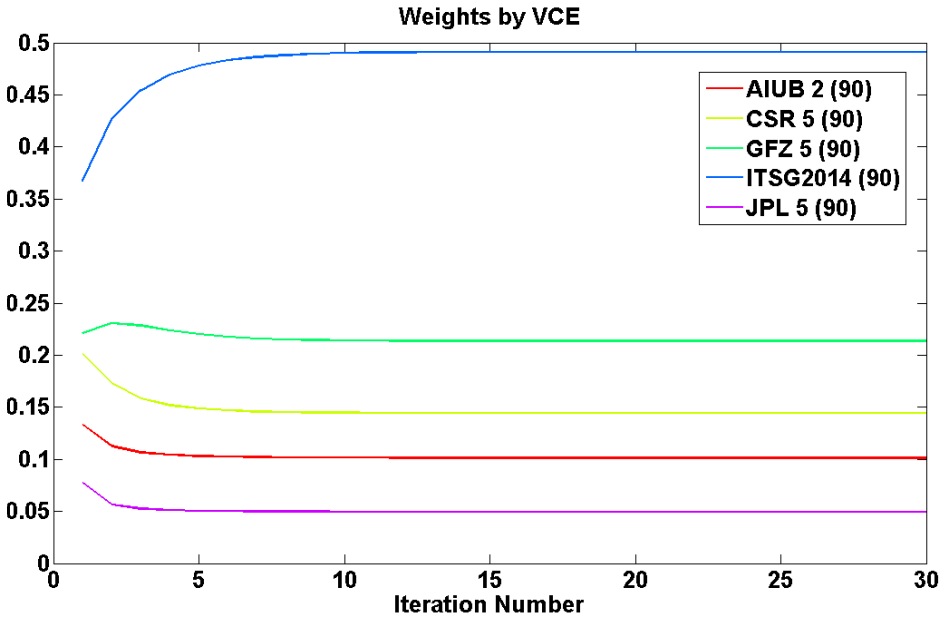


# Real Combined Solutions using *VCE* Weighting Scheme

- Weights: (almost) Converging

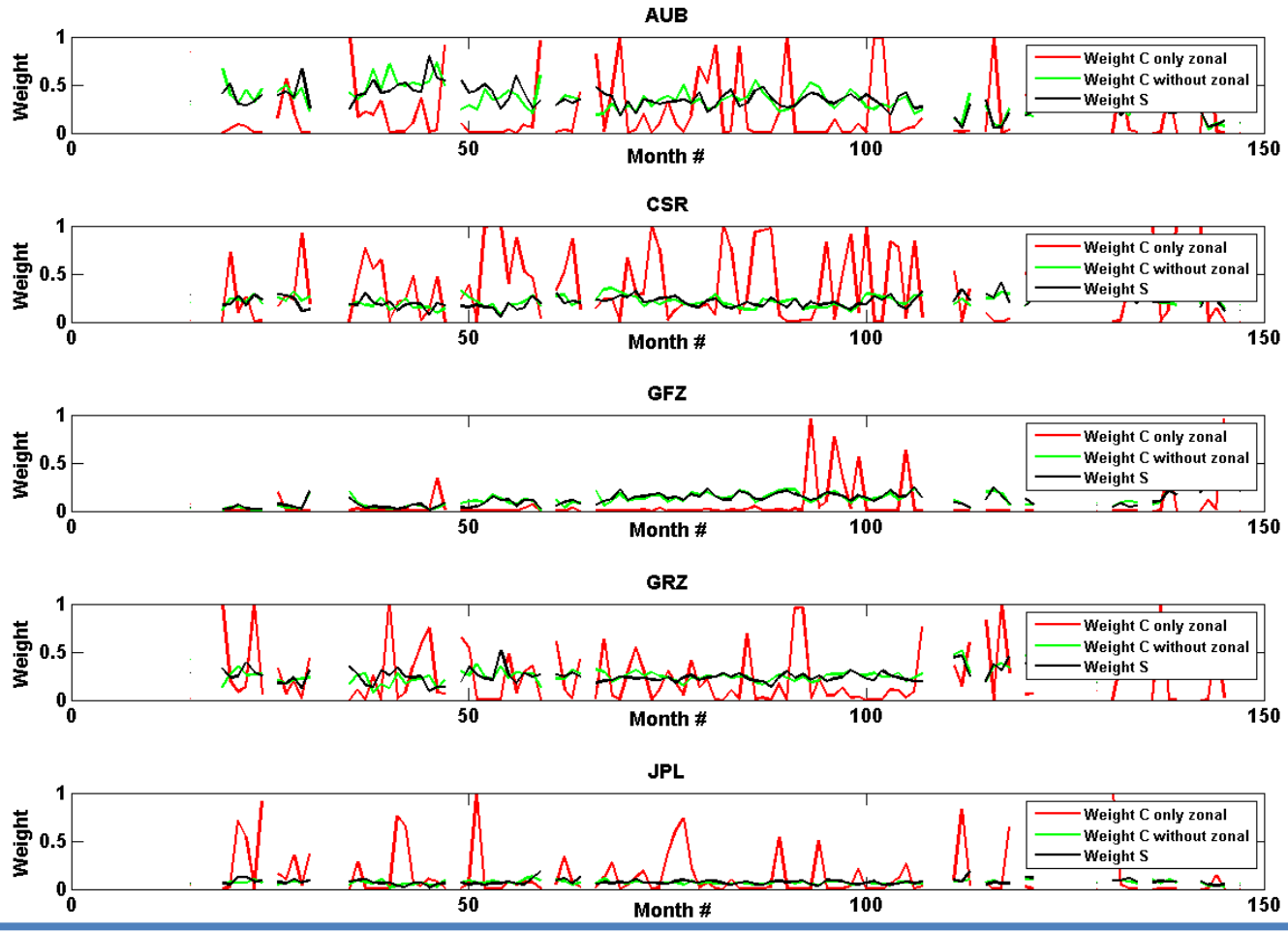


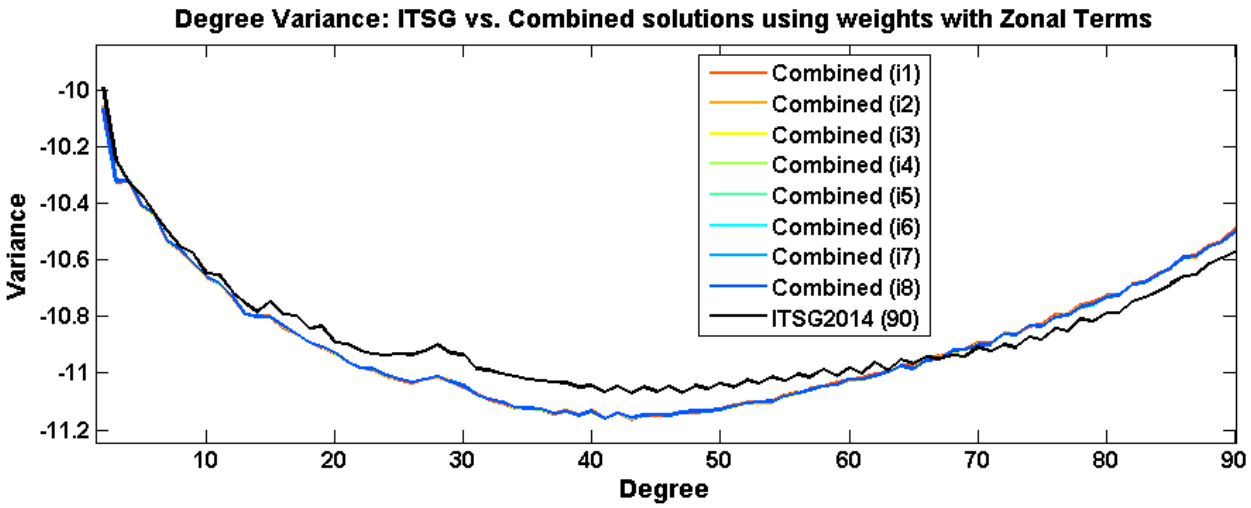

**2007/08** **2014/03**

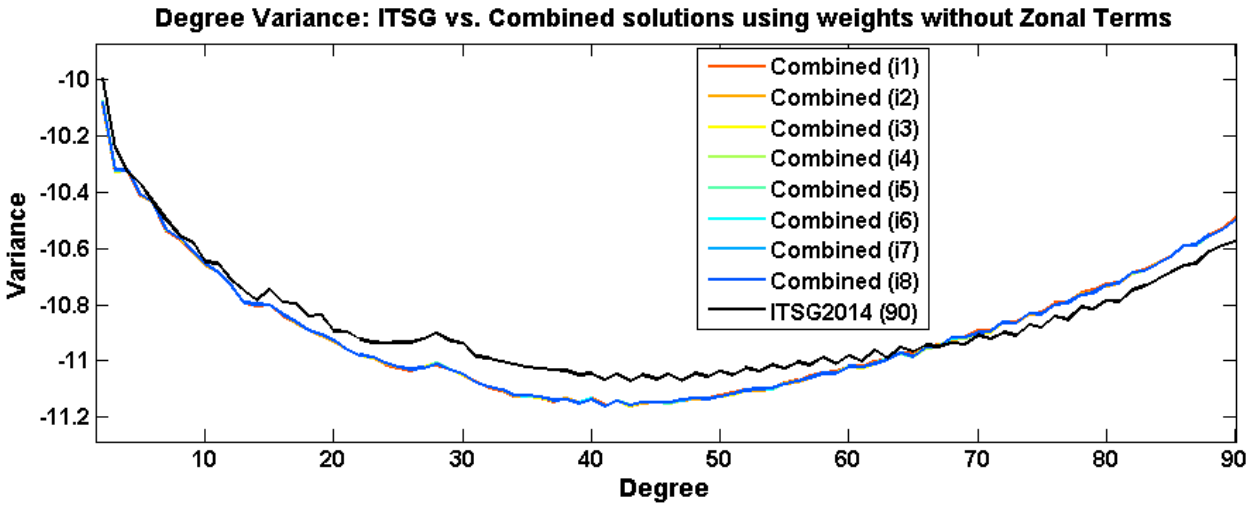
# Weights using (*Only C*), (*Only S*), (*Only Zonal Terms*)

- Weights by **C coefficients (w/o Zonal Terms)** and that by **S coefficients** are similar.
- However, the **weights by only zonal terms** are very different.

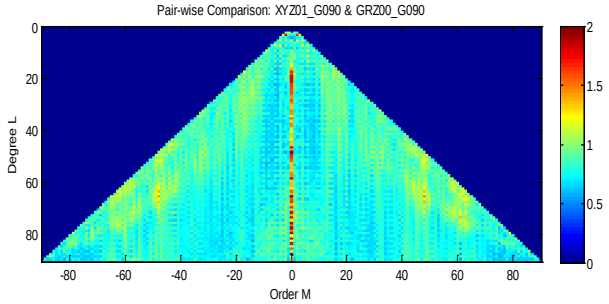


# Weights *with* and *without* Zonal Terms



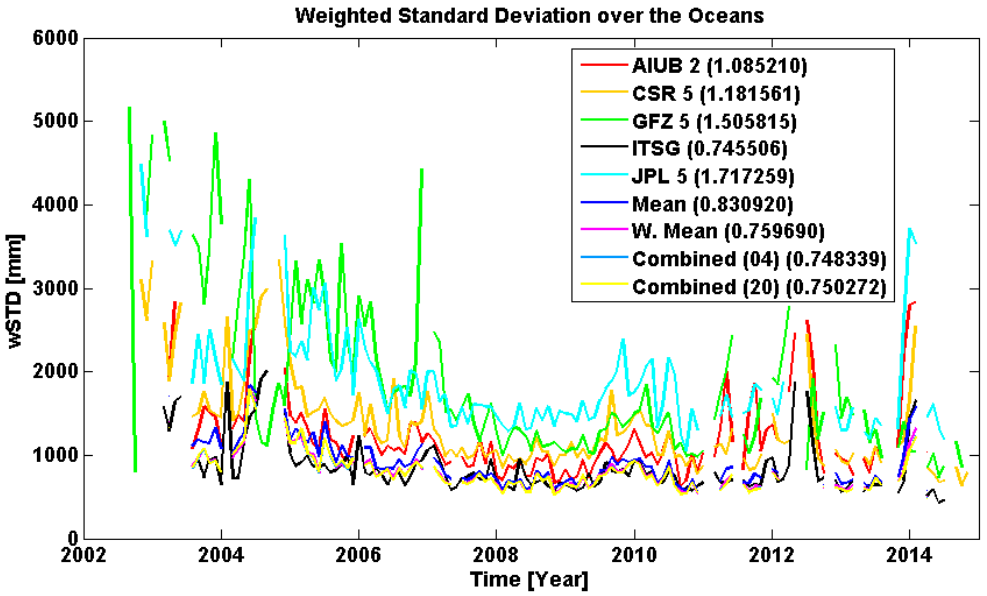



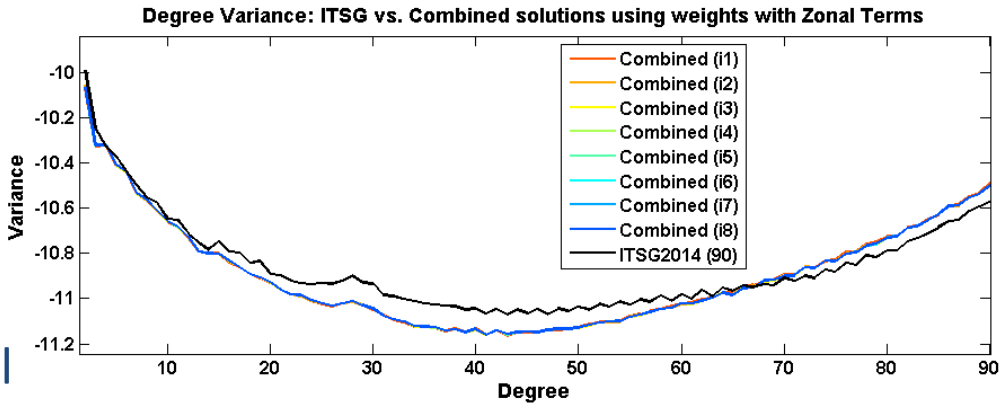

- Almost similar
- # of zonal coefficients: ***90***
- # of whole coefficients: ***4186***



# Real Combined Solutions using VCE

| Solution | Median of wSTD over the Oceans |
|---|---|
| AIUB | 1.085210 |
| CSR | 1.181561 |
| GFZ | 1.505815 |
| **ITSG** | **0.745506** |
| JPL | 1.717259 |
| Combined 01 | 0.756438 |
| Combined 02 | 0.750095 |
| Combined 03 | 0.750446 |
| **Combined 04** | **0.748339** |
| Combined05 | 0.748382 |

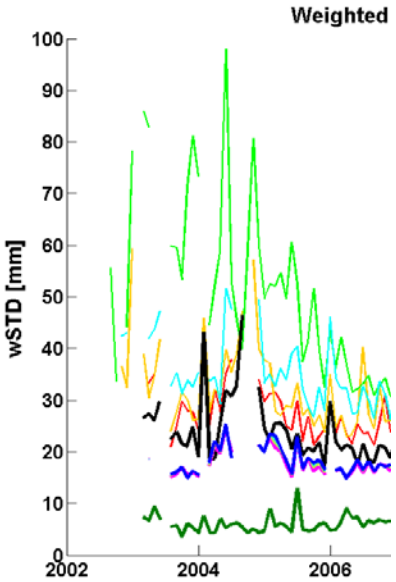


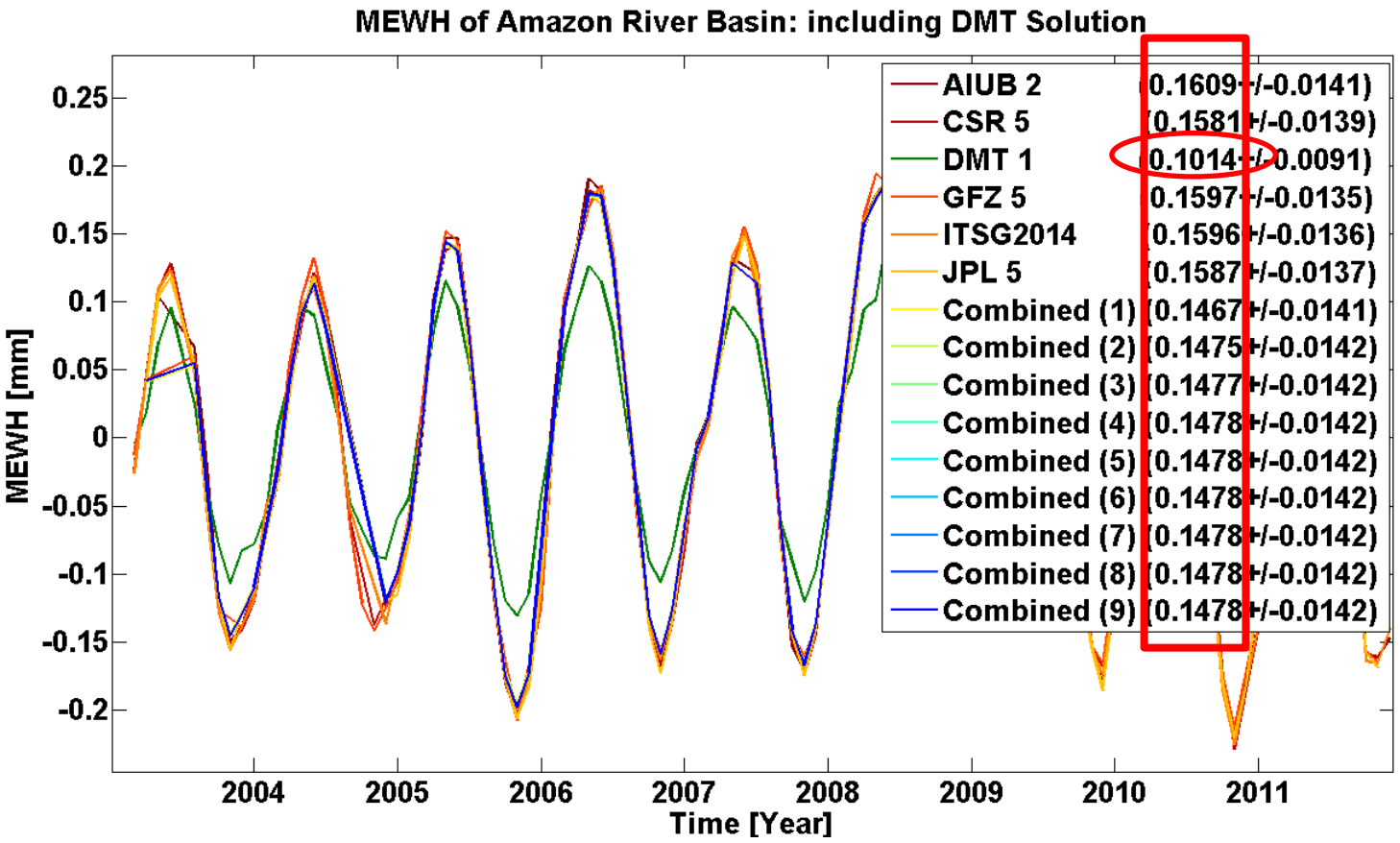




Combined solution using rough empirical weights (before optimization): **0.648336**

# Inclusion of DMT Solution in Combination

- In *Simulation*: the attenuated signal could be recovered by VCE.
- In *this real case*: the attenuated signal cannot be fully recovered by VCE.



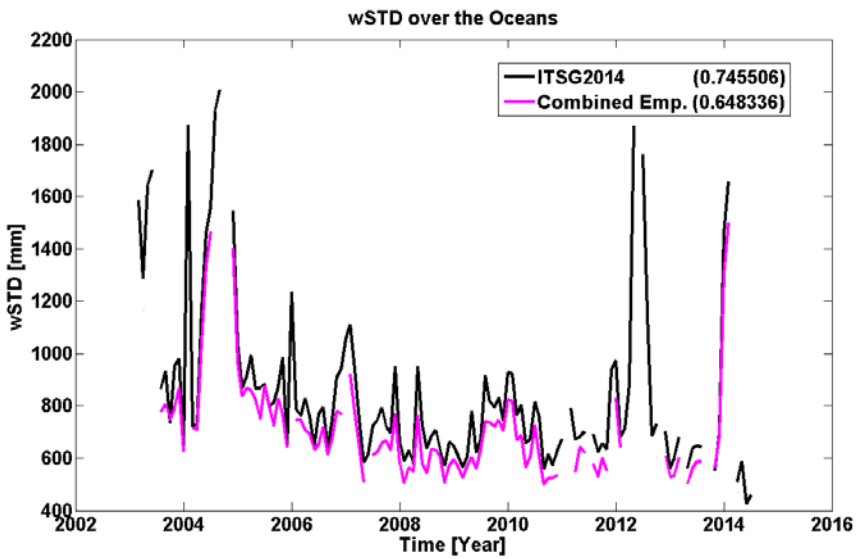



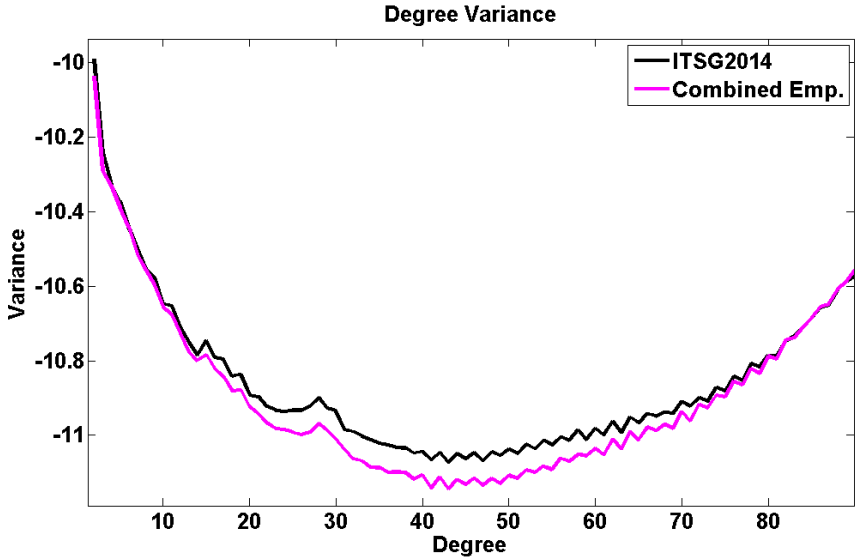
# Conclusions: in Simulation and in Reality

- A solution containing attenuated signal can
  - cause strange behavior from certain degree: cross point

- Weighting scheme
  - In simulation study, the VCE works well. (only white noise)
  - In real case, benefits of VCE are limited due to systematic effect in noise.

# Combined Solution using Rough Empirical Weights

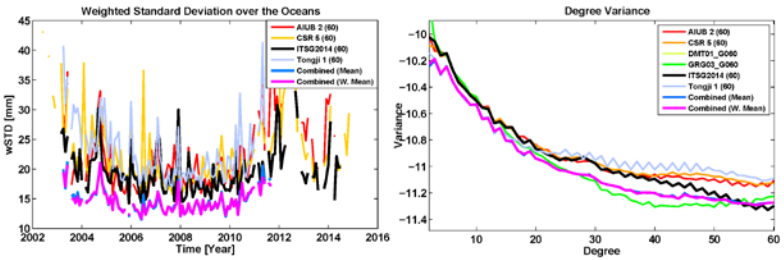


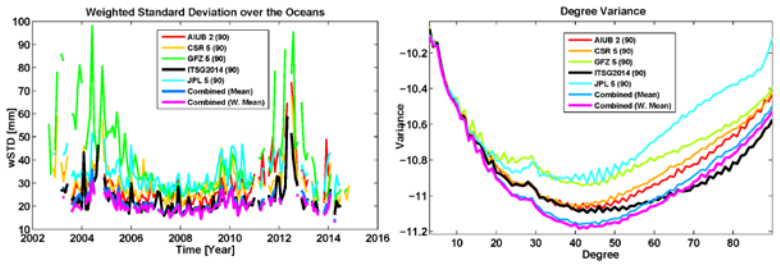




- Even before optimization:
  ***0.745506*** vs. ***0.648336***

- Degree 90 combined solutions can be further improved.

- Mathematics + Signal contents



# Final Report of WP 4.1 (~M18)

- Content related to **combination on solution level**
  - Availability and Preprocessing of GRACE Monthly Solutions
  - Comparison of GRACE Monthly Solutions
  - Combination of GRACE Monthly Solutions
  - Evaluation of GRACE Monthly Combined Solutions

# Presentations / Publications

- Presentation in the EGU 2015 (Apr. 2015)
- Presentation in the Geodätische Woche 2015 (Sep. 2015)
- Contribution to presentation by Prof. Adrian Jäggi in the AGU meeting 2015 (Dec. 2015)
- Presentation in the EGU 2016 (Apr. 2016)

In progress:

- Manuscript for a journal article (to be submitted in the first half of 2016)
- Final Report of WP4.1 (until M18: End of June 2016)