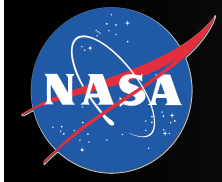

Improved estimates of regional mass change: Mascons, forward models, and iteration

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GRACE Science Team Meeting

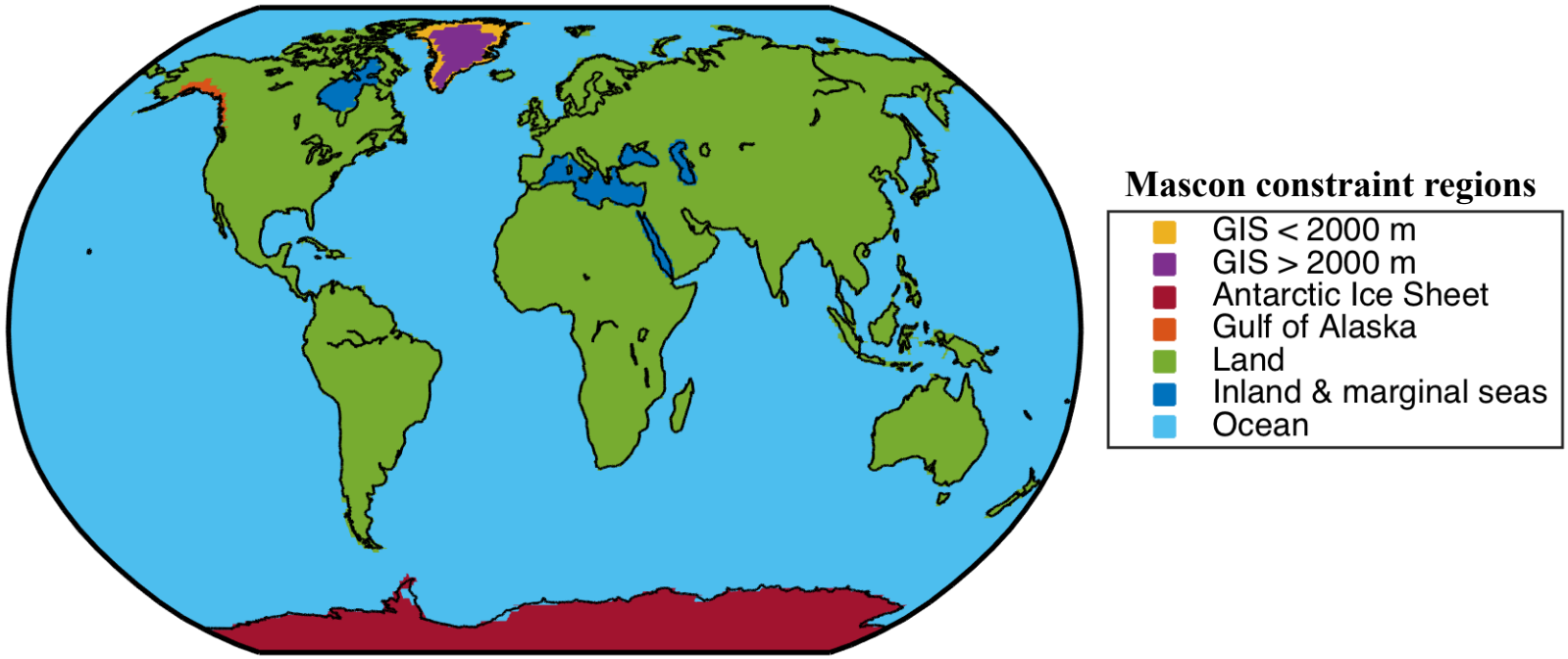
Sep 21– Sep 23, 2015

Austin, TX

NASA GSFC global mascons

New GSFC global mascon solution is available:

- Improved iteration procedure: Re-adjustment of arc parameters and stepped relaxation of constraint damping parameters
- Latitude-dependent constraints account for sampling; e.g. [Wahr et al., 2006]
- Improved mascon region definitions; separate constraint regions for largest inland and marginal seas: Mediterranean, Black, Red, Caspian, & Hudson Bay



Motivations

Motivation for mascon technique:

- Apply regularization in the least-squares parameter adjustment to leverage full covariance information towards the optimal reduction of noise
- Removes need for the end user to select, design, and apply a post-processing filtering method, which can have uncertain effects on results and scientific interpretation

Motivation for forward modeling & iteration:

- Reduces magnitude of KBRR residuals, Δ gravity, and signal leakage
  - GSFC: Forward model hydrology; 2°×2° Gulf of Alaska mascons [Luthcke et al., 2006]
  - GSFC: Forward model hydrology; 2°×2° global mascons [Sabaka et al., 2010]
  - GSFC: Forward model hydrology/GIA & iterate; 1°×1°global mascons [Luthcke et al., 2013]
  - CSR: Forward model GRACE trend+annual; 1°×1° global mascon: [Save et al., 2014]

Motivation for this work: How to validate the mascon solutions?

- Compare to independent data sets; useful to a point but GRACE data is unique
- Compare to unconstrained Stokes to ensure mascon regularization is not over-constraining the solution; requires reliable method to analyze Stokes — **This work**
- Forward model independent data sets and various solutions in L1B processing: KBRR residuals directly assess solution quality — **AGU**

Motivations

Objective: Validate GSFC mascon regional mass changes with GSFC unconstrained Stokes

L2 Stokes filtering methods to compute regional mass change:

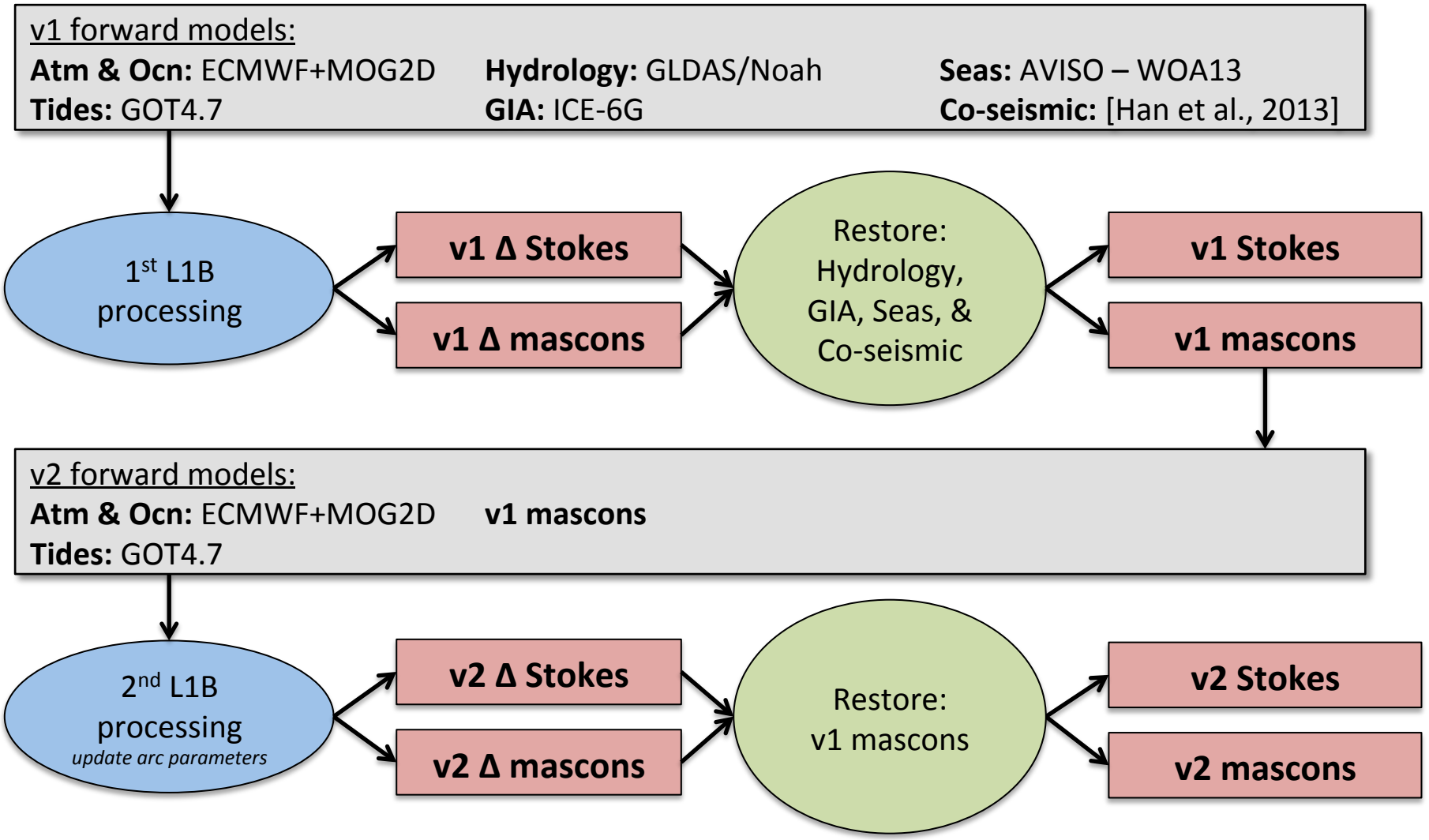
- Gaussian convolution averaging kernels [Swenson and Wahr, 2002]
- Weighted Gaussian convolution averaging kernels [Wahr et al., 2014]
- "Mascon" estimation from L2 product [Jacob et al., 2012; Xu et al., 2015]
- Slepian functions [Harig and Simons, 2012]
- EOF/PCA [Chambers and Willis, 2008; Schmidt et al., 2008]

Problem: Which technique to use? They give different answers for small regions

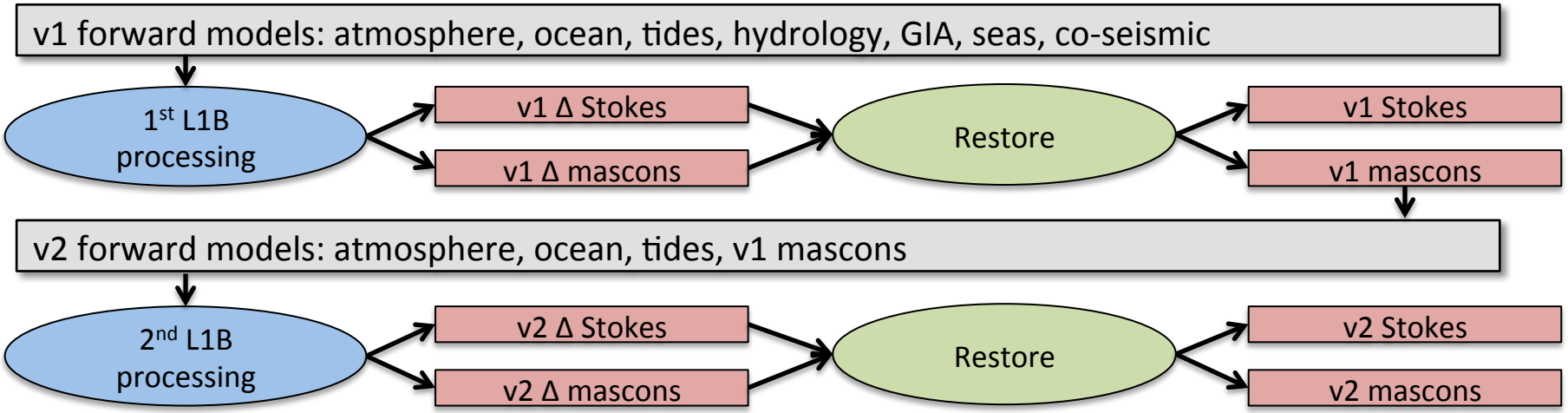
Solution: Apply filter to the Δ Stokes computed during mascon iteration

- Filtering the iterated Δ Stokes (instead of usual L2 Stokes) reduces effect of filtering choice and design which reduces technique-related uncertainty
- Regularized mascon solutions are successfully validated to un-regularized Stokes verifies that the constraints are not over-damping solution while removing noise

GSFC processing flow and solution method



GSFC processing flow and solution method



<u>Four different ways to compute regional mass change from Stokes coefficients:</u>

1. Filter **(v1 Stokes)**
2. Filter **(v1 Δ Stokes)** + v1 forward models
3. Filter **(v2 Stokes)**
4. Filter **(v2 Δ Stokes)** + v2 forward models

- Ideally all four cases would give the same answer, but they don't
- Results can be highly-dependent on choice of post-processing method for Cases 1-3

Results

Regions analyzed:

- Hydrologic basins: Amazon, Fraser, California
- Land ice: GIS, East AIS, West AIS, AIS Peninsula, Gulf of Alaska
- Inland and marginal seas: Mediterranean, Black, Red, Caspian, Hudson Bay

GSFC mascons compared to Stokes filtering methods:

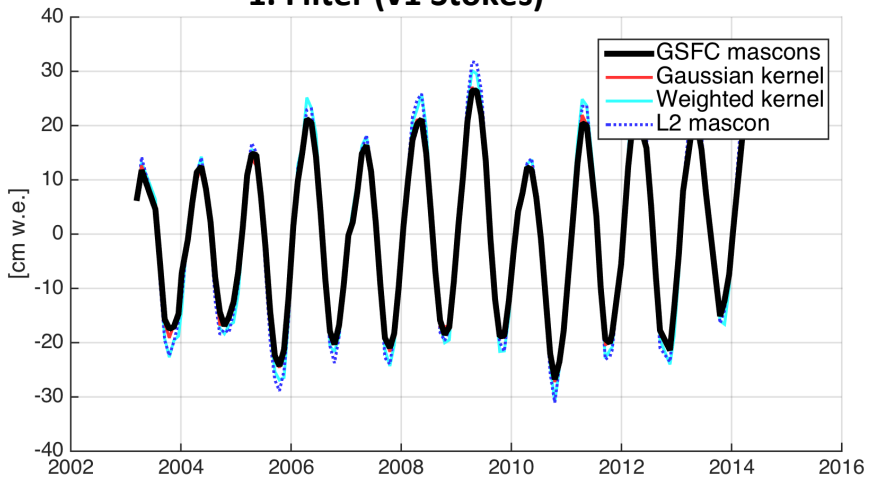
1. Gaussian convolution averaging kernels
2. Weighted Gaussian convolution averaging kernels
3. "Mascon" estimation from L2 Stokes

Stokes solutions:

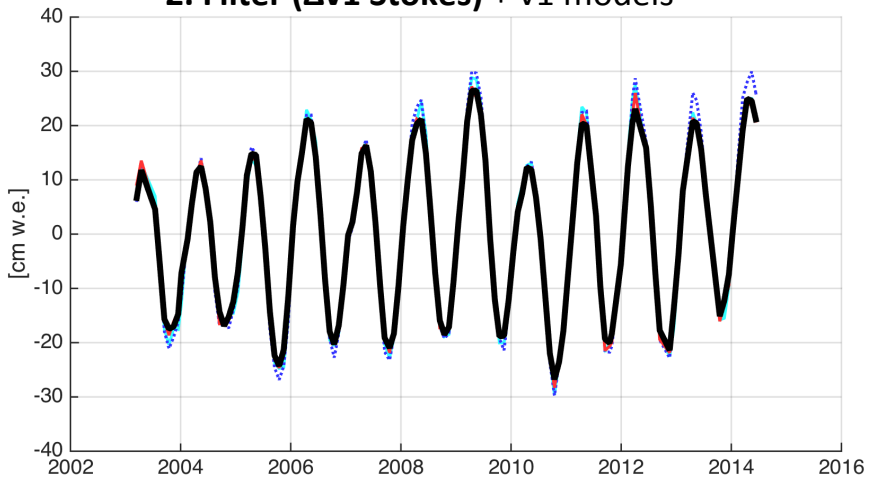
1. Filter **(v1 Stokes)**
2. Filter **(v1 Δ Stokes)** + v1 forward models
3. Filter **(v2 Stokes)**
4. Filter **(v2 Δ Stokes)** + v2 forward models

Results: Amazon basin

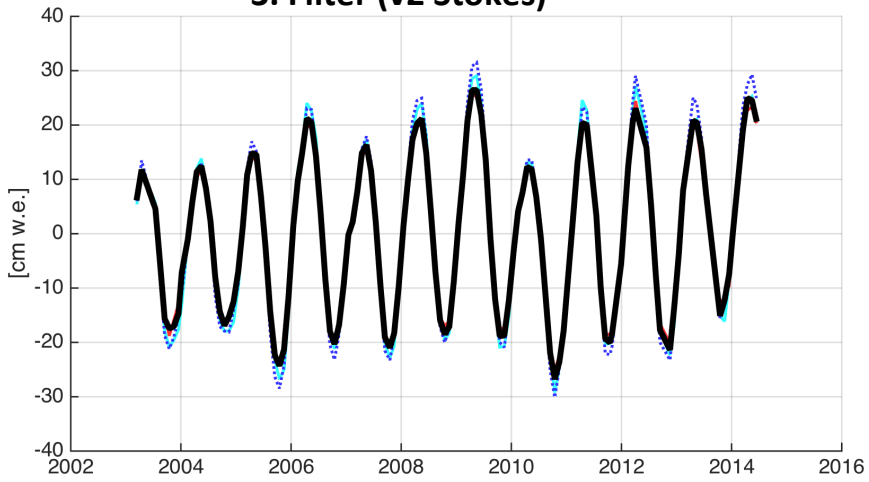
1. Filter (v1 Stokes)



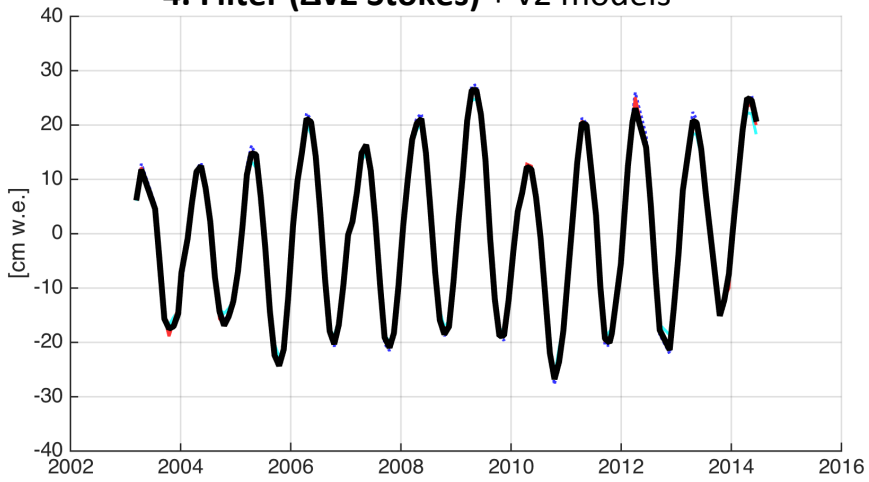
2. Filter (Δv1 Stokes) + v1 models



3. Filter (v2 Stokes)

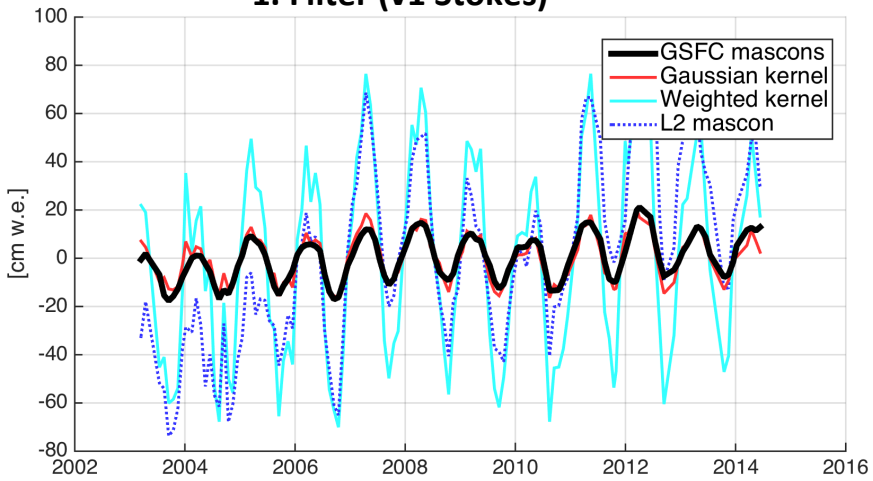


4. Filter (Δv2 Stokes) + v2 models

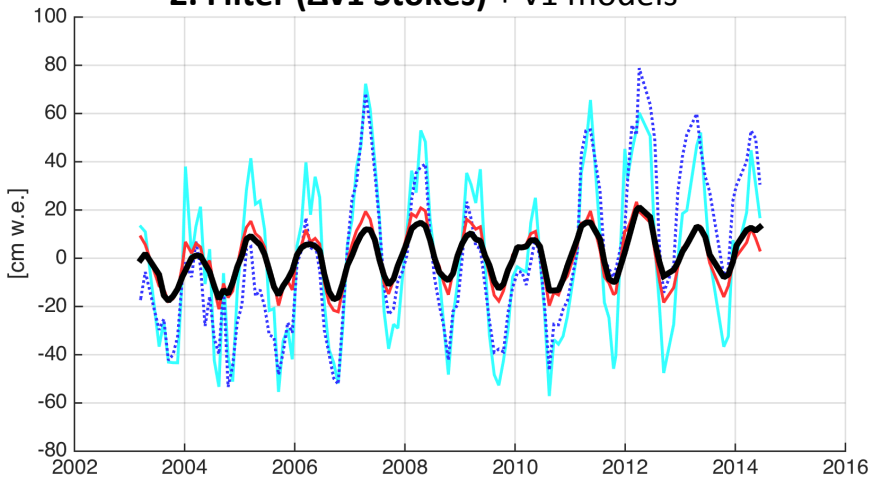


Results: Fraser basin

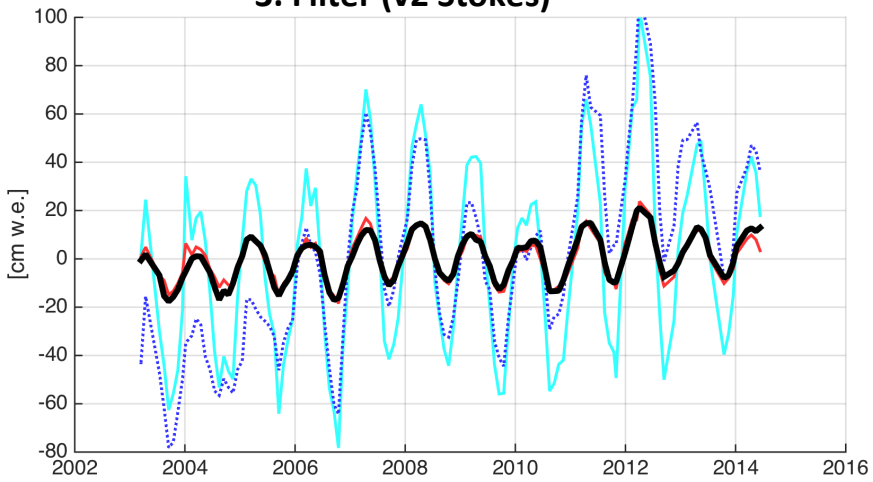
1. Filter (v1 Stokes)



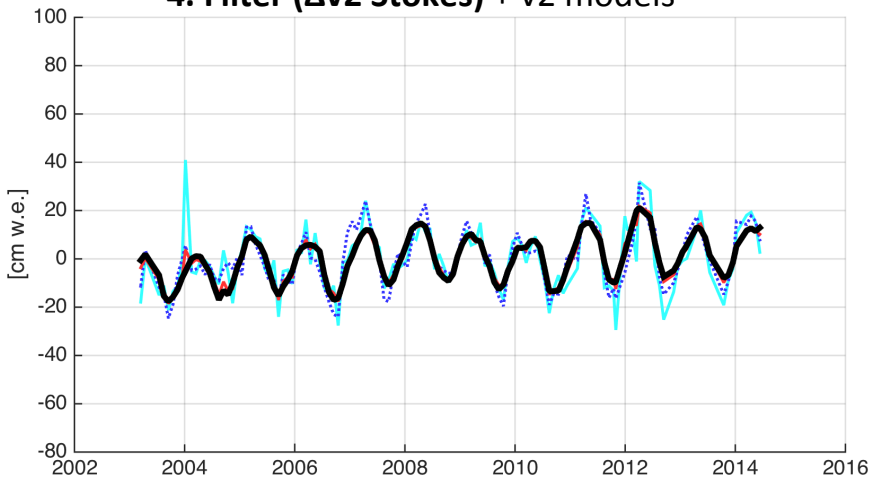
2. Filter (Δv1 Stokes) + v1 models



3. Filter (v2 Stokes)

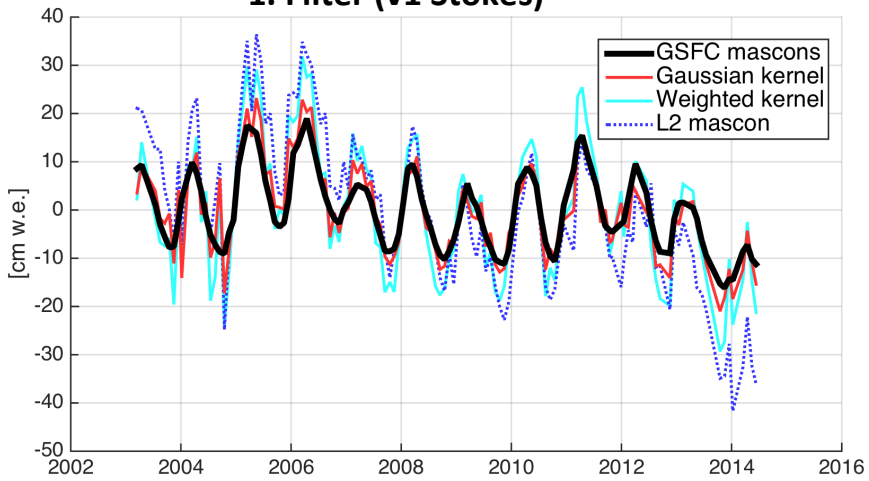


4. Filter (Δv2 Stokes) + v2 models

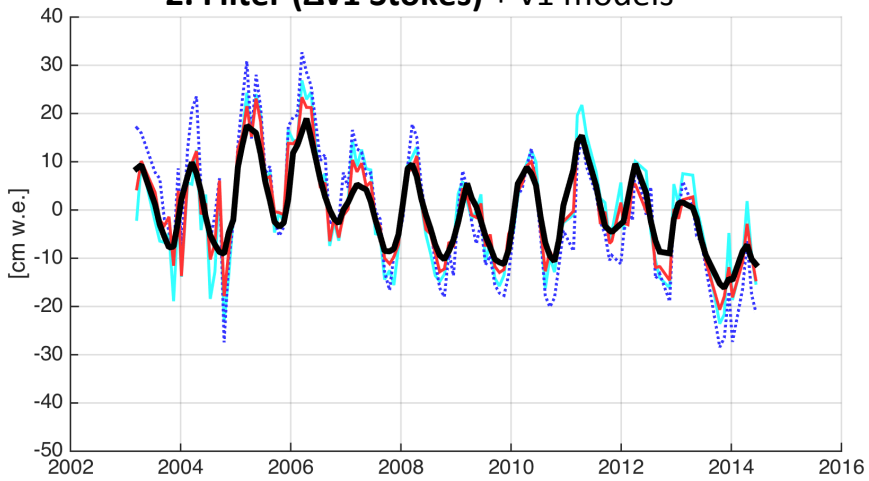


Results: California

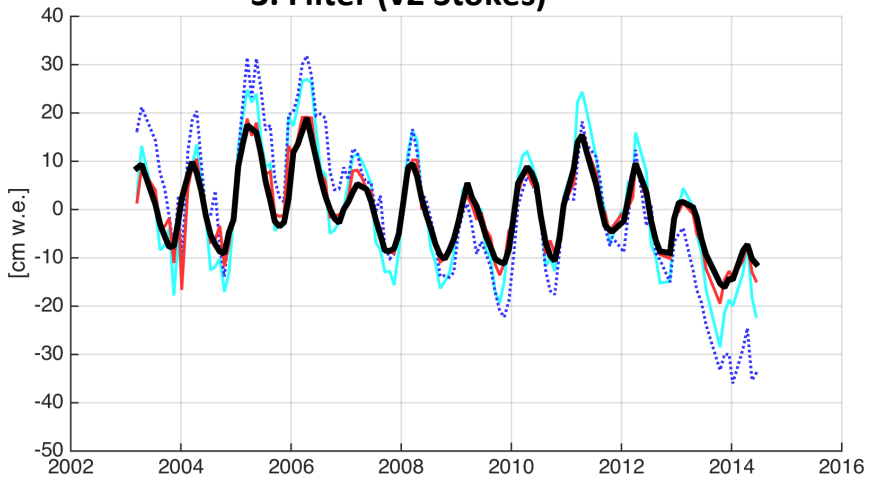
1. Filter (v1 Stokes)



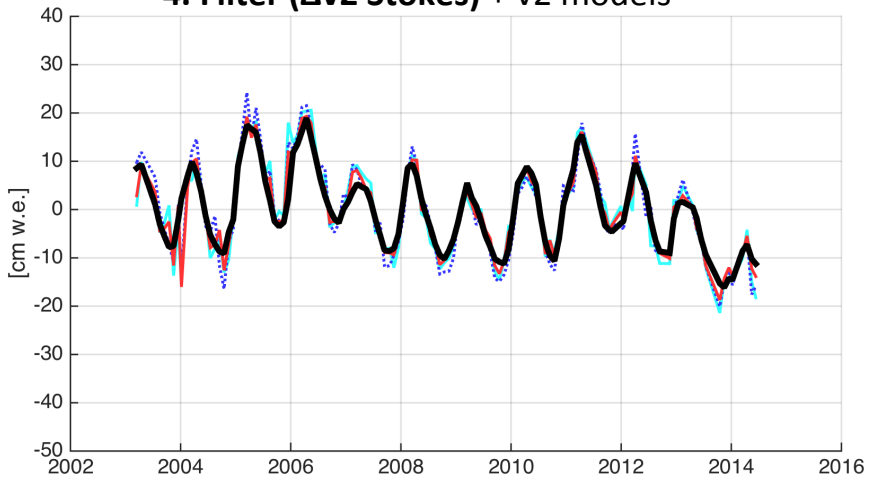
2. Filter (Δv1 Stokes) + v1 models



3. Filter (v2 Stokes)

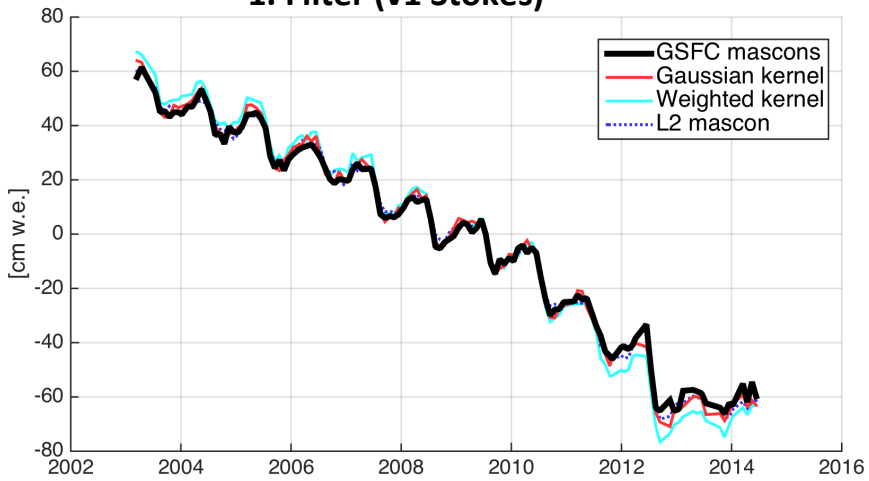


4. Filter (Δv2 Stokes) + v2 models

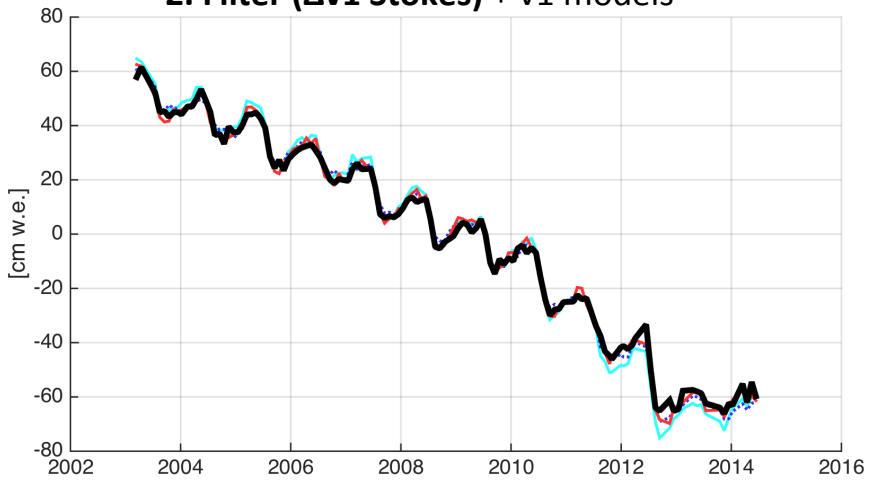


Results: Greenland Ice Sheet

1. Filter (v1 Stokes)



2. Filter (Δv1 Stokes) + v1 models

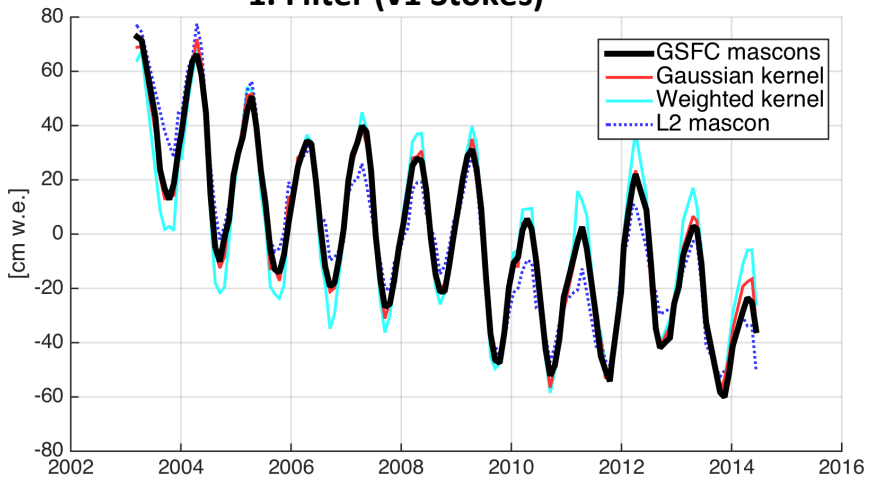


3. Filter (v2 Stokes)

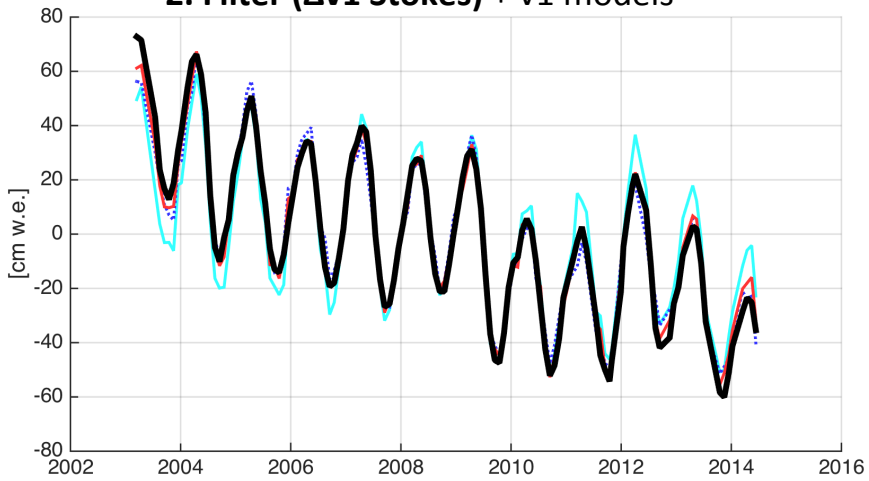
4. Filter (Δv2 Stokes) + v2 models

Results: Gulf of Alaska

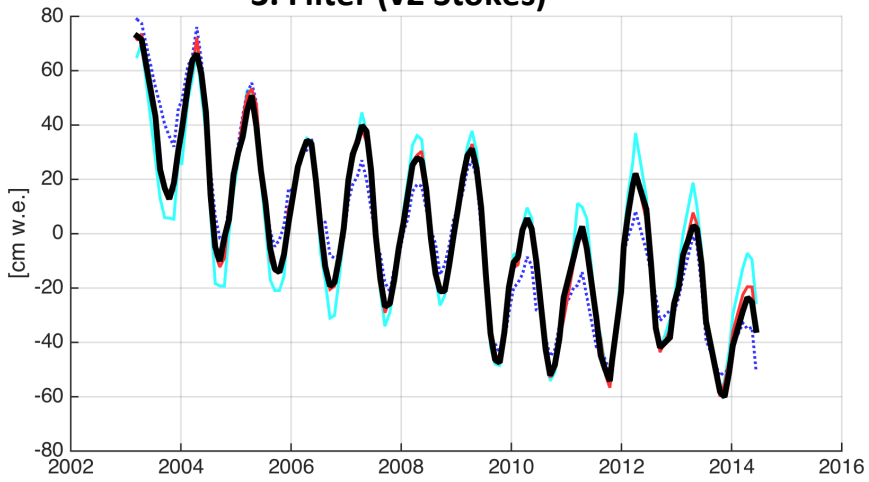
1. Filter (v1 Stokes)



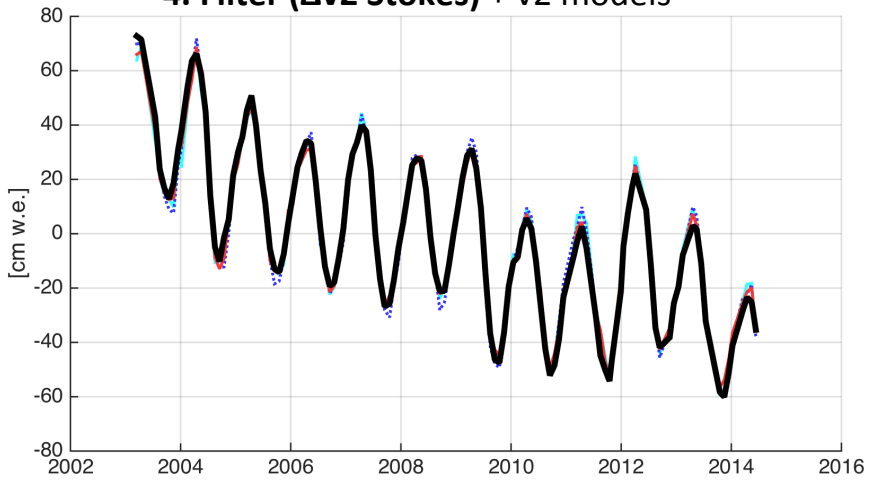
2. Filter (Δv1 Stokes) + v1 models



3. Filter (v2 Stokes)

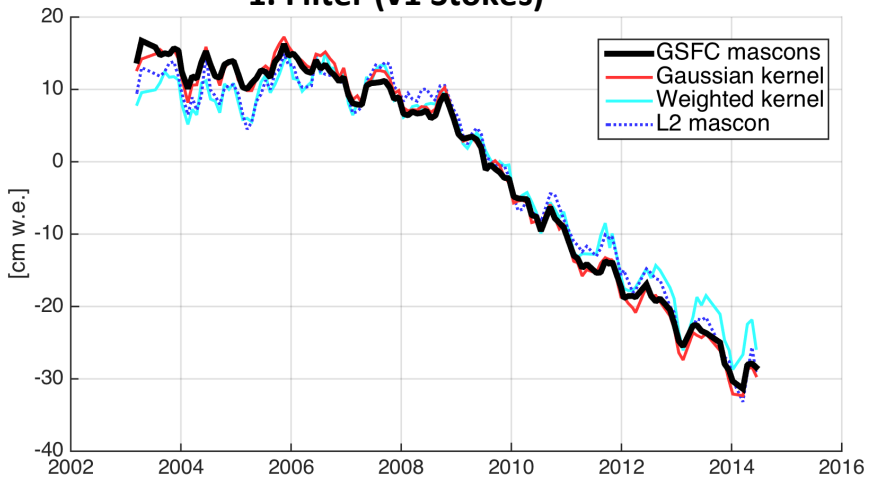


4. Filter (Δv2 Stokes) + v2 models

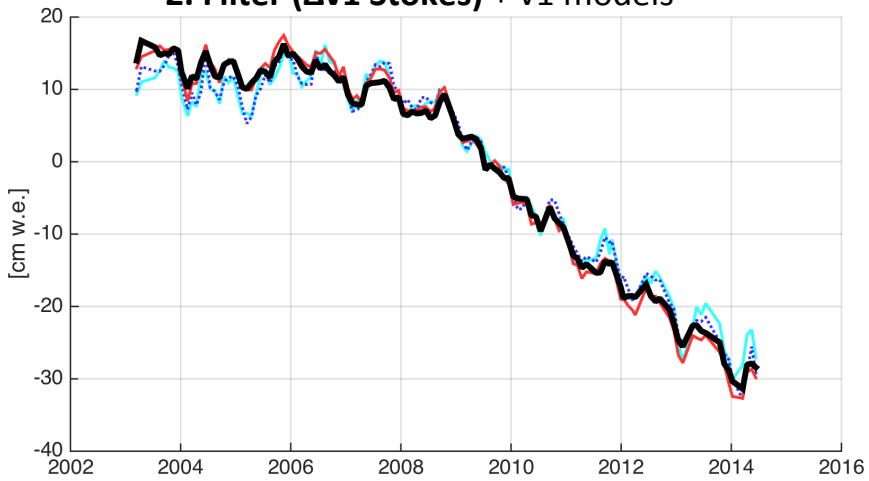


Results: West Antarctic Ice Sheet

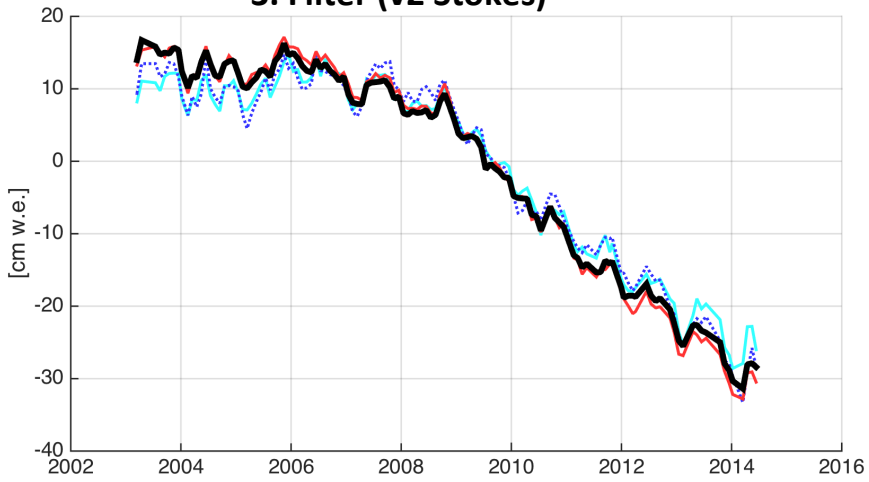
1. Filter (v1 Stokes)



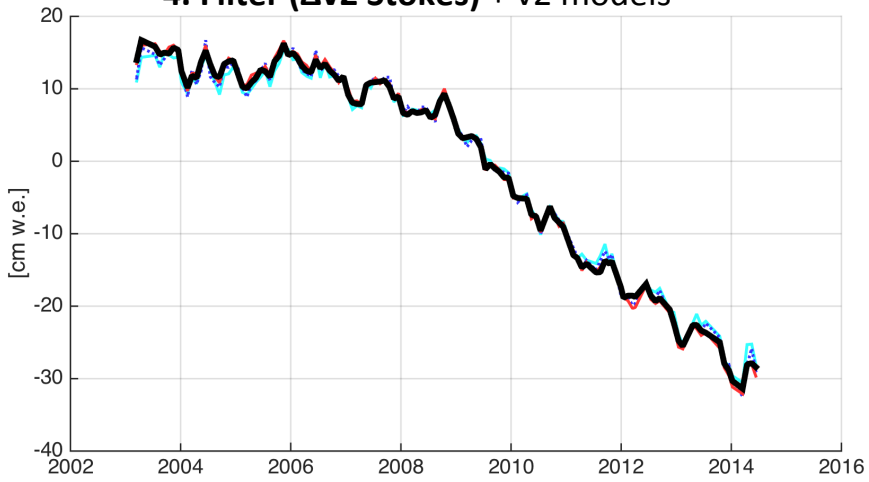
2. Filter (Δv1 Stokes) + v1 models



3. Filter (v2 Stokes)

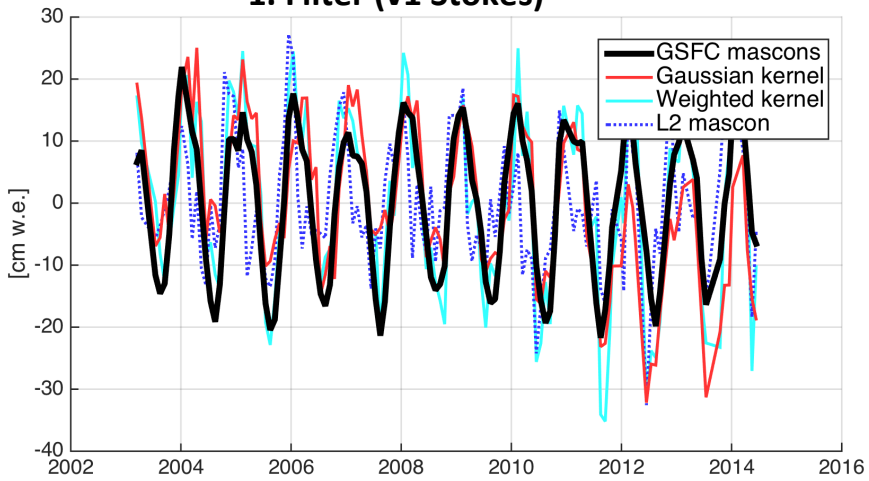


4. Filter (Δv2 Stokes) + v2 models

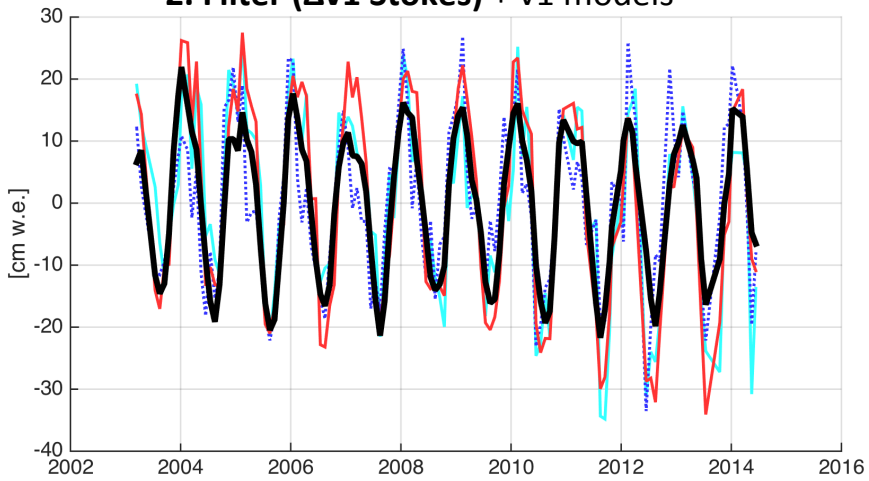


Results: Red Sea

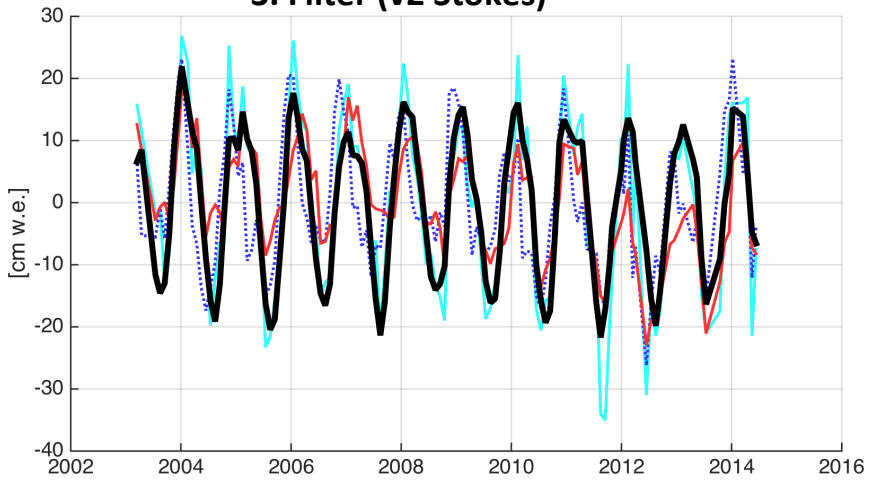
1. Filter (v1 Stokes)



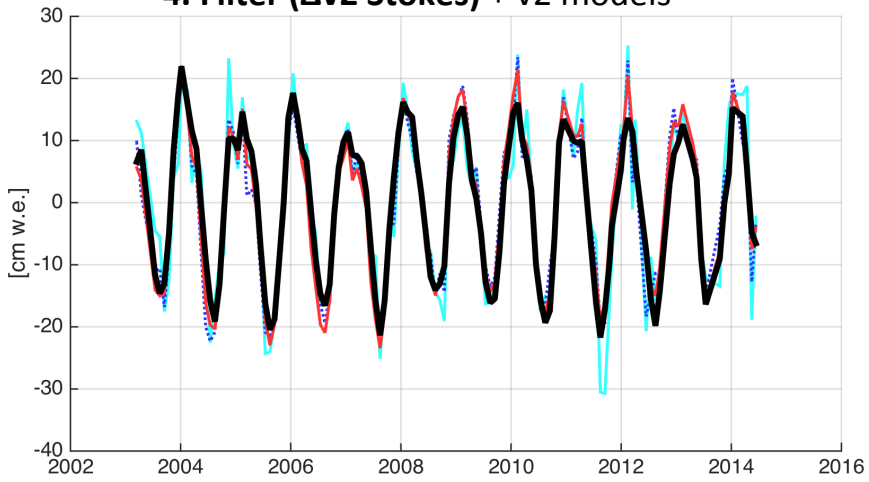
2. Filter (Δv1 Stokes) + v1 models



3. Filter (v2 Stokes)

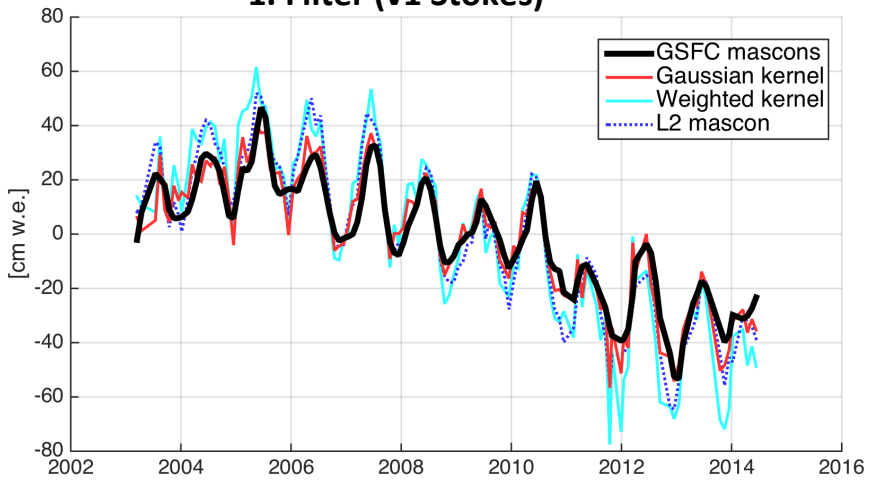


4. Filter (Δv2 Stokes) + v2 models

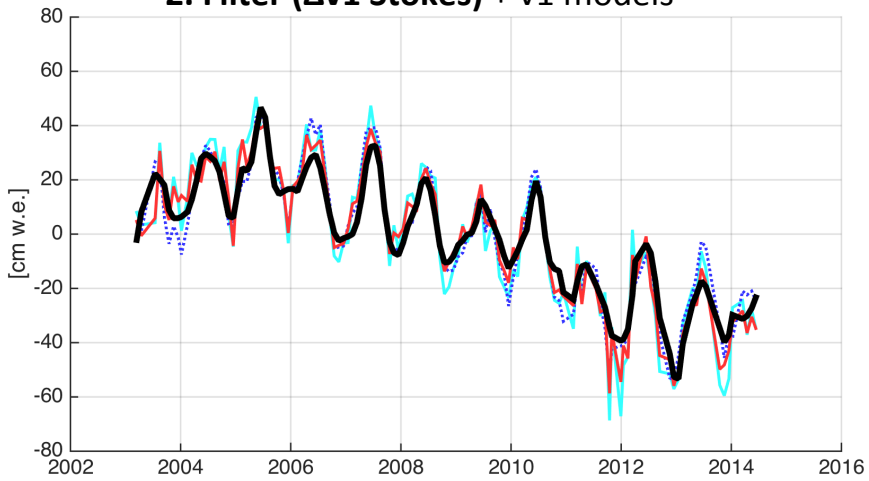


Results: Caspian Sea

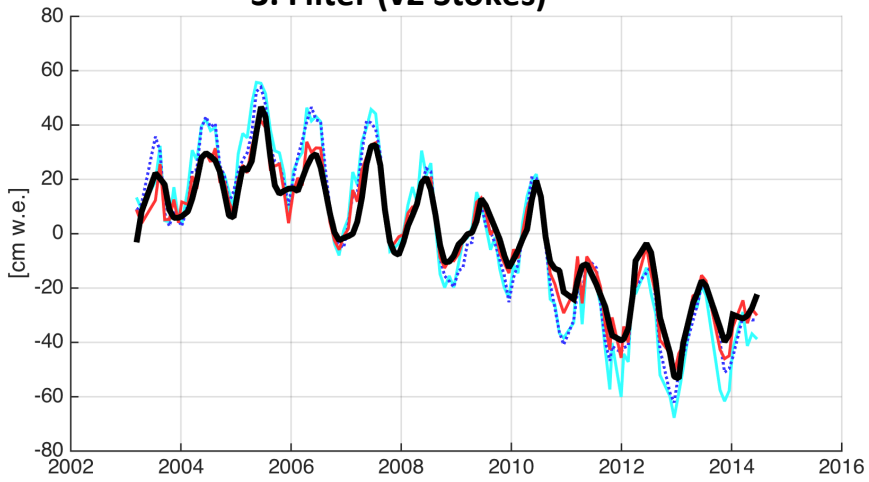
1. Filter (v1 Stokes)



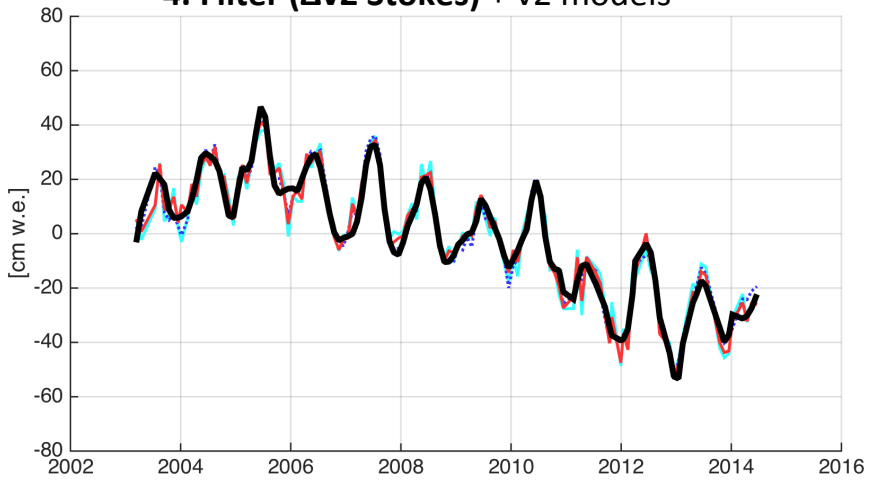
2. Filter (Δv1 Stokes) + v1 models



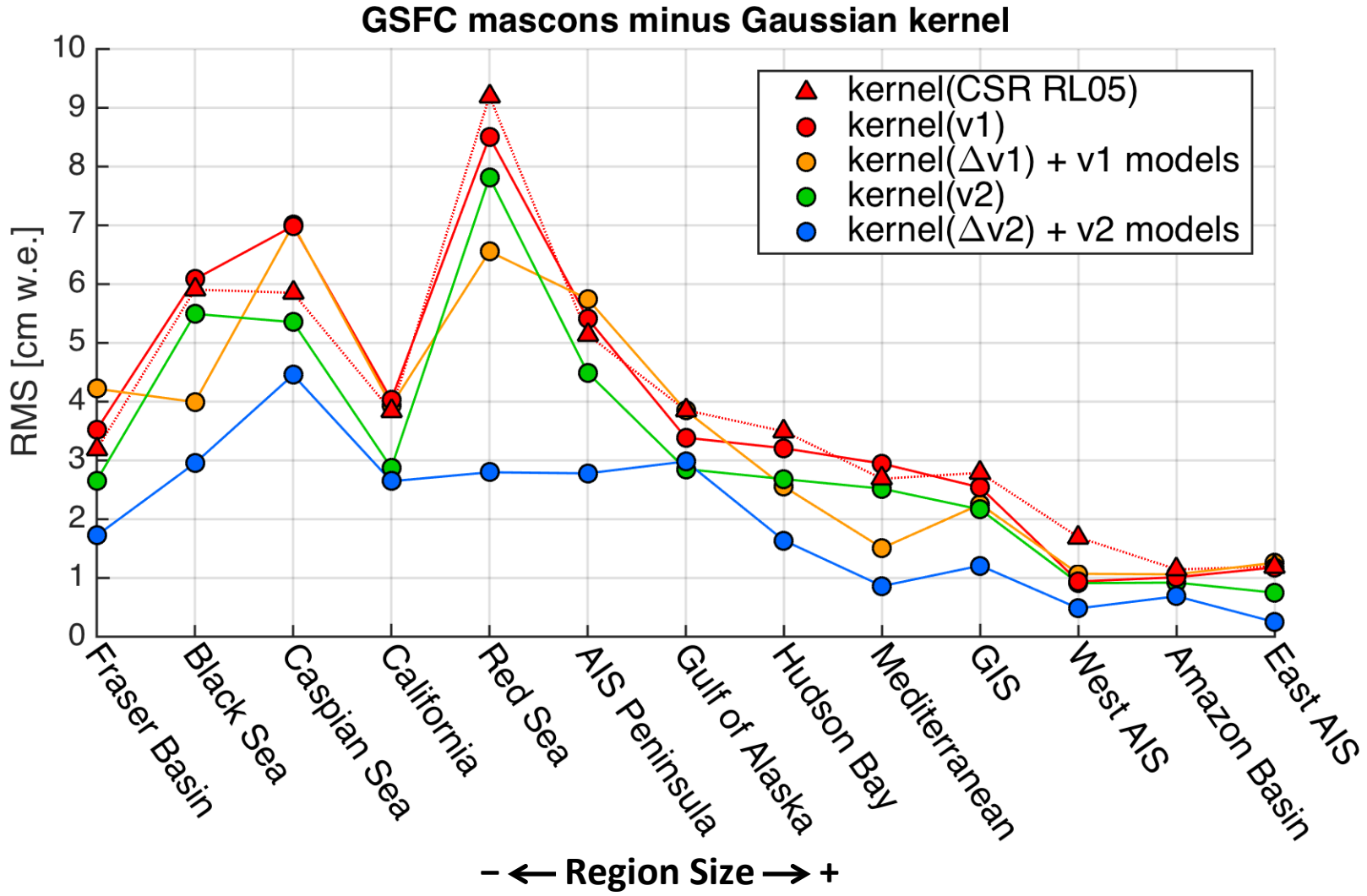
3. Filter (v2 Stokes)



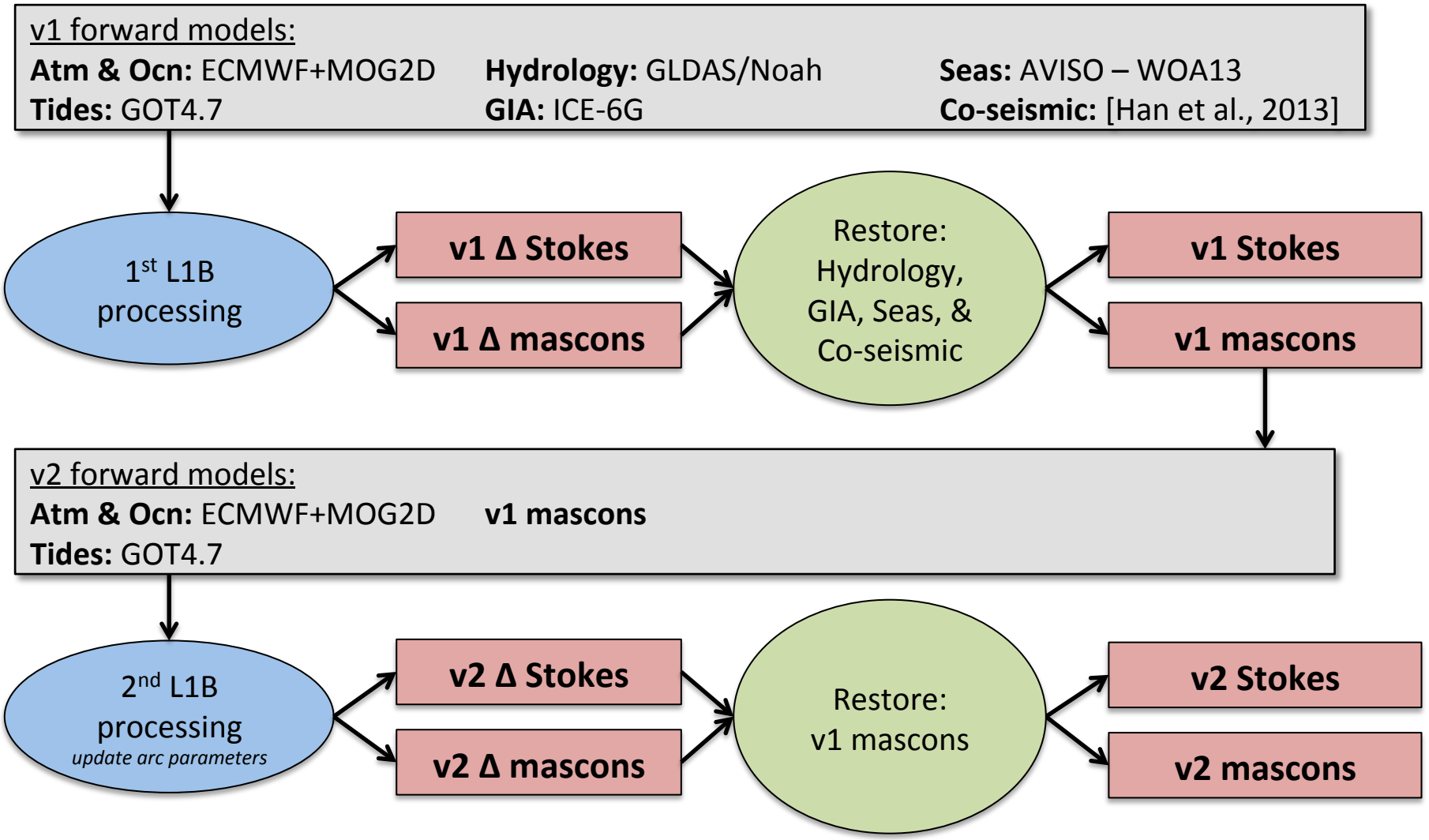
4. Filter (Δv2 Stokes) + v2 models



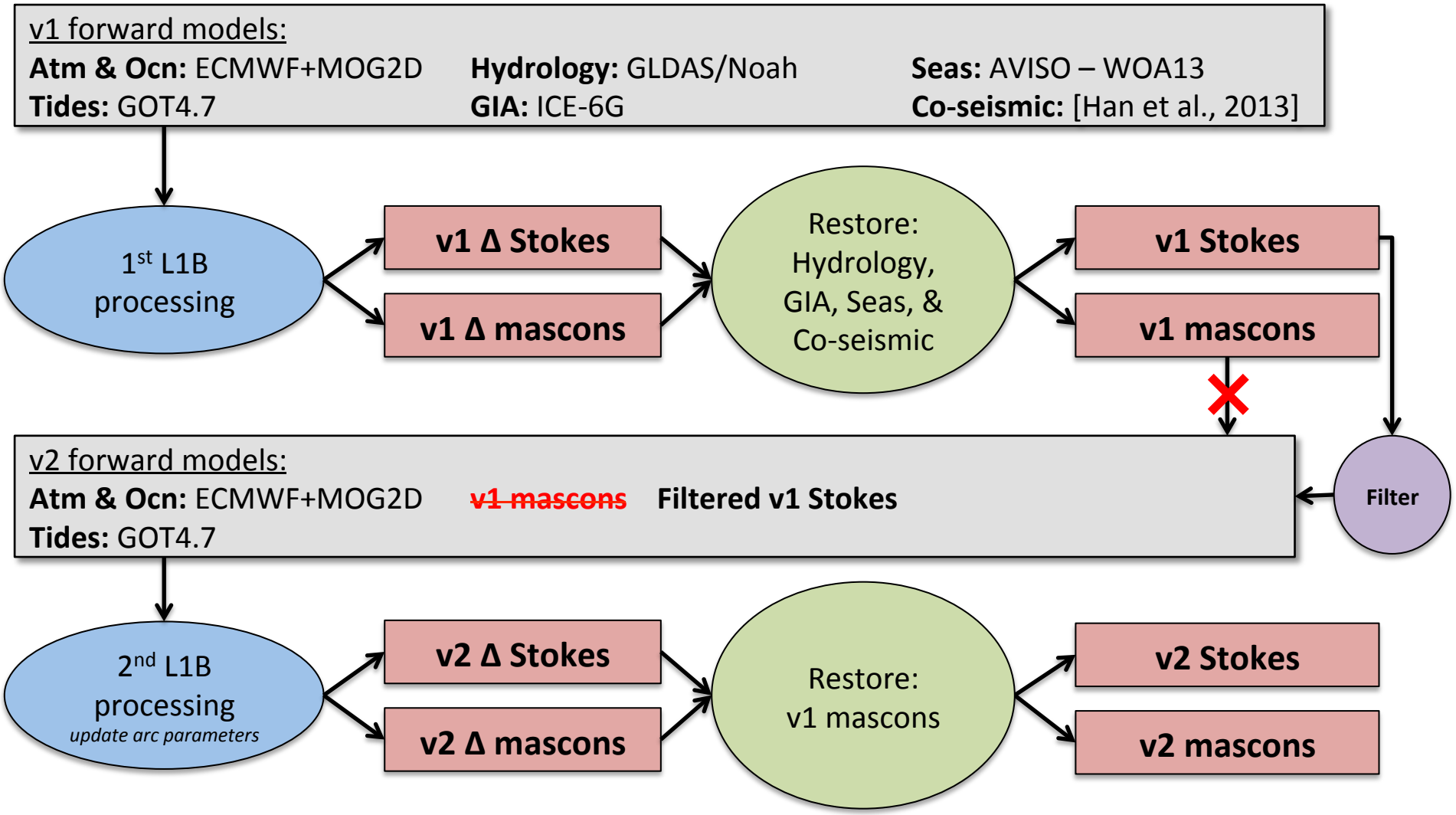
Results: Regional summaries



Solution iteration with Stokes?



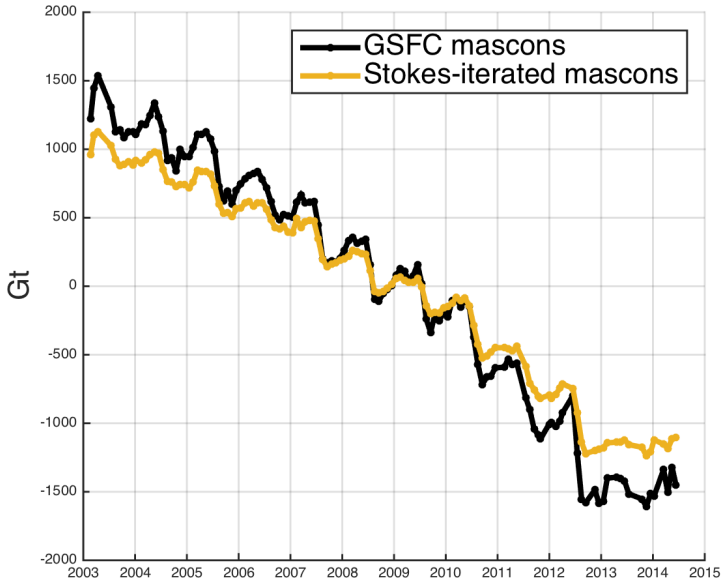
Solution iteration with Stokes?



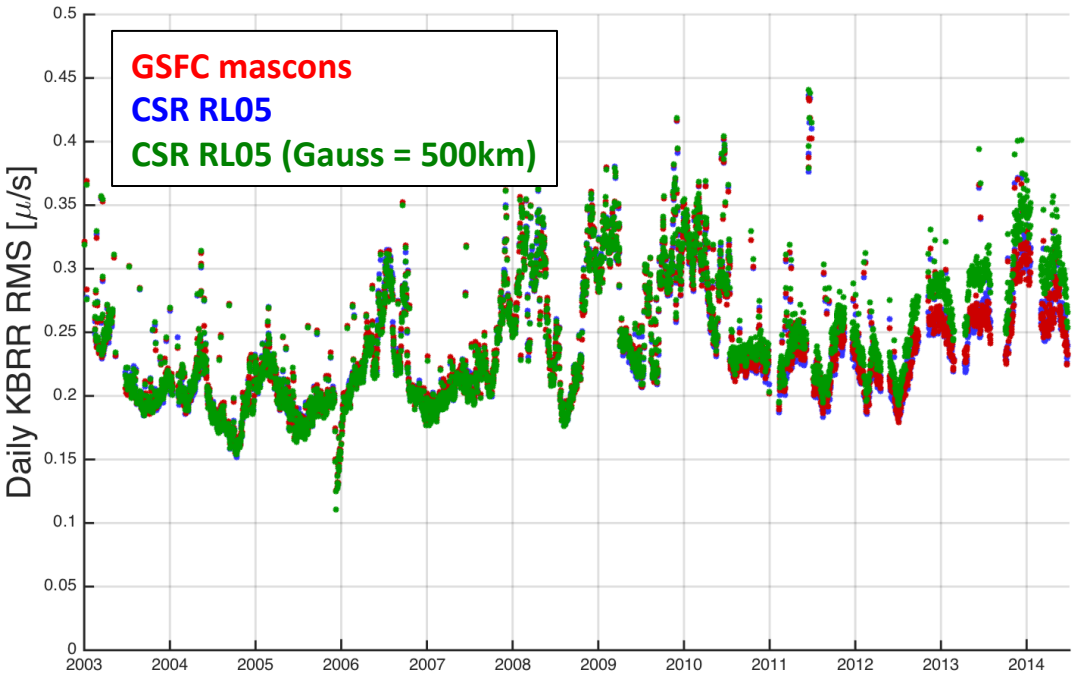
Solution iteration with Stokes?

- Iterating filtered Stokes does not work, despite small difference in KBRR fits
- The signal leakage from smoothing was not recoverable with iteration

Greenland Ice Sheet



Post-fit KBRR residuals



Conclusions

Summary:

- Improved accuracy of mass change estimates are achieved with:
  1. Well-designed mascon regularization
  2. Solution iteration/forward modeling
  3. Application of filtering to Δ Stokes (rather than full signal Stokes)
- GSFC mascon regularization strategy is successfully validated to un-regularized Stokes solutions: Final solution is not over-constrained

Future work:

- Finalize mascon validation by forward modeling the v2 mascons in the L1B data reduction: If any signal structure remains in KBRR residuals we will iterate again
- Utilize our rapid processing capabilities for iterative geophysical model assimilation: surface-mass balance, hydrology, etc.

Data access: e-mail Scott Luthcke @ scott.b.luthcke@nasa.gov

- We work directly with many researchers to provide application-specific solutions
- Public access soon via PO.DAAC and GSFC website