



SEA LEVEL VARIATIONS IN THE BLACK SEA FOR 1993-2007 PERIOD FROM GRACE, ALTIMETRY AND TIDE GAUGE DATA

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OUTLINE

1. INTRODUCTION

2. DATA & PROCESSING

a. Sea Water Mass Variations from GRACE and Land Hydrology Model

b. Sea Water Mass Variations from Altimetry and Hydrodynamic model

3. SEA LEVEL COMPARISON

a. Seasonal Scales

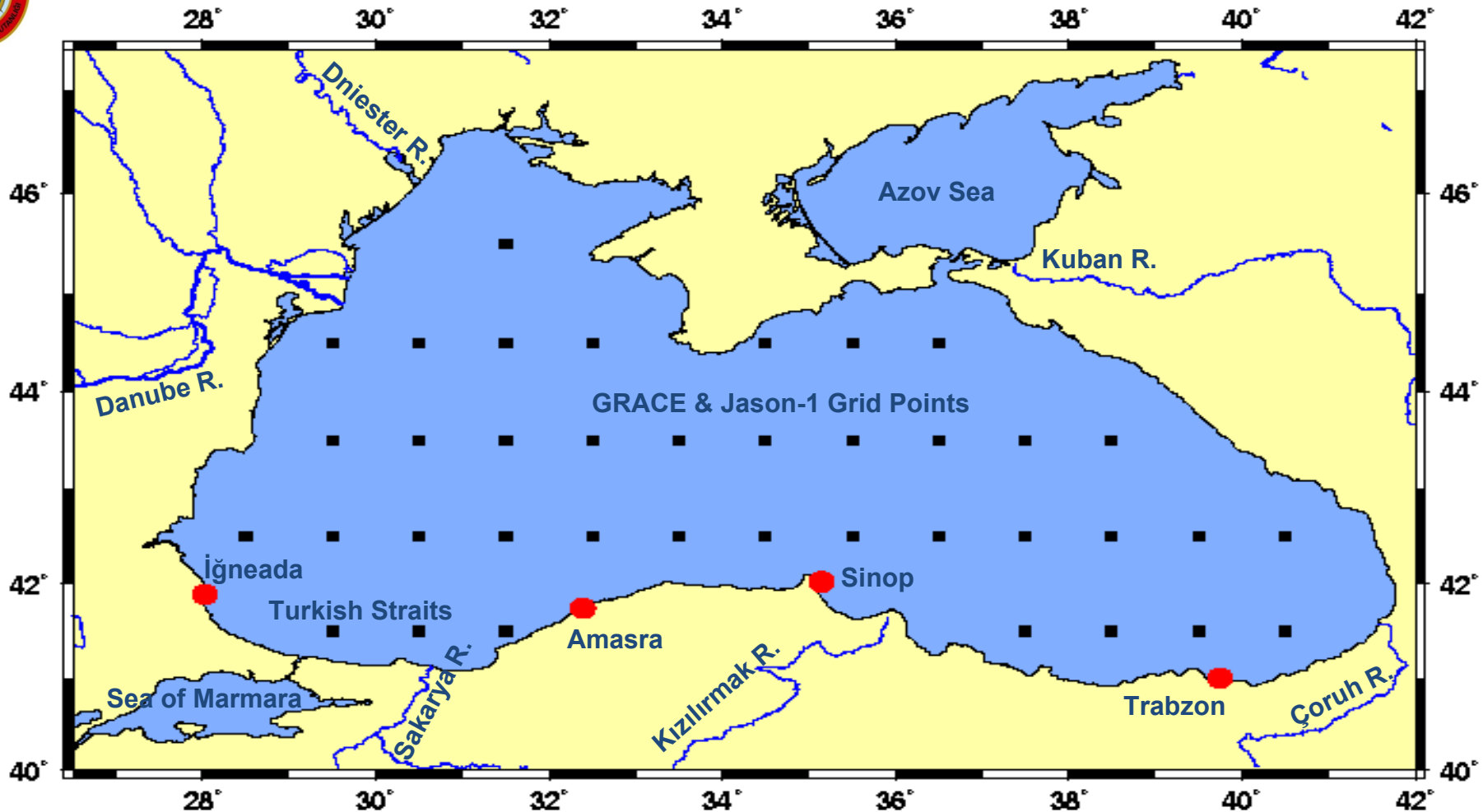
b. Interannual Scales

4. COMPARISON WITH TIDE GAUGE DATA

5. SUMMARY



INTRODUCTION



Surface area : 423,000 km²

Total volume : 547,000 km³

Maximum depth : ~2200 m.

Major shelf region: northwestern shelf with discharges from three of Europe's largest rivers

Precipitation (~300 km³ yr⁻¹)

Runoff (~350 km³ yr⁻¹)

Evaporation (~350 km³ yr⁻¹)



DATA

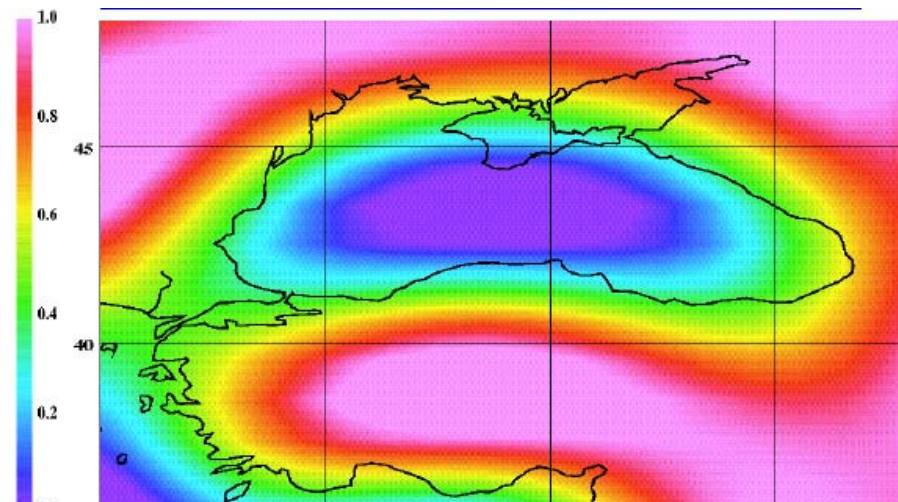
GRACE : BGI / CNES global GRACE constrained solutions [Lemoine et al. \(2007\)](#), 176 global solutions, Temporal resolution: 10 days

ALTIMETRY : RADS database, T/P and Jason-1 satellites (1993 to 2007), Standard corrections, Ocean Tides (GOT00), No inverse barometer correction. AVISO IB corrected merged data is also used for comparison for interannual sea level variation.

STERIC SEA LEVEL : World Ocean Atlas 2005 (WOA05) ([Locarnini et al., 2006](#); [Antonov et al., 2006](#)), Steric height is relative to the 100 m level. SST anomaly data set from NOAA, NCEP Optimally Interpolated weekly SST version 2 data set ([Reynolds et al., 2002](#)).

LAND HYDROLOGY : Monthly soil moisture changes from the Land Dynamics Model (LadWorld) ([Milly and Shmakin, 2002](#))

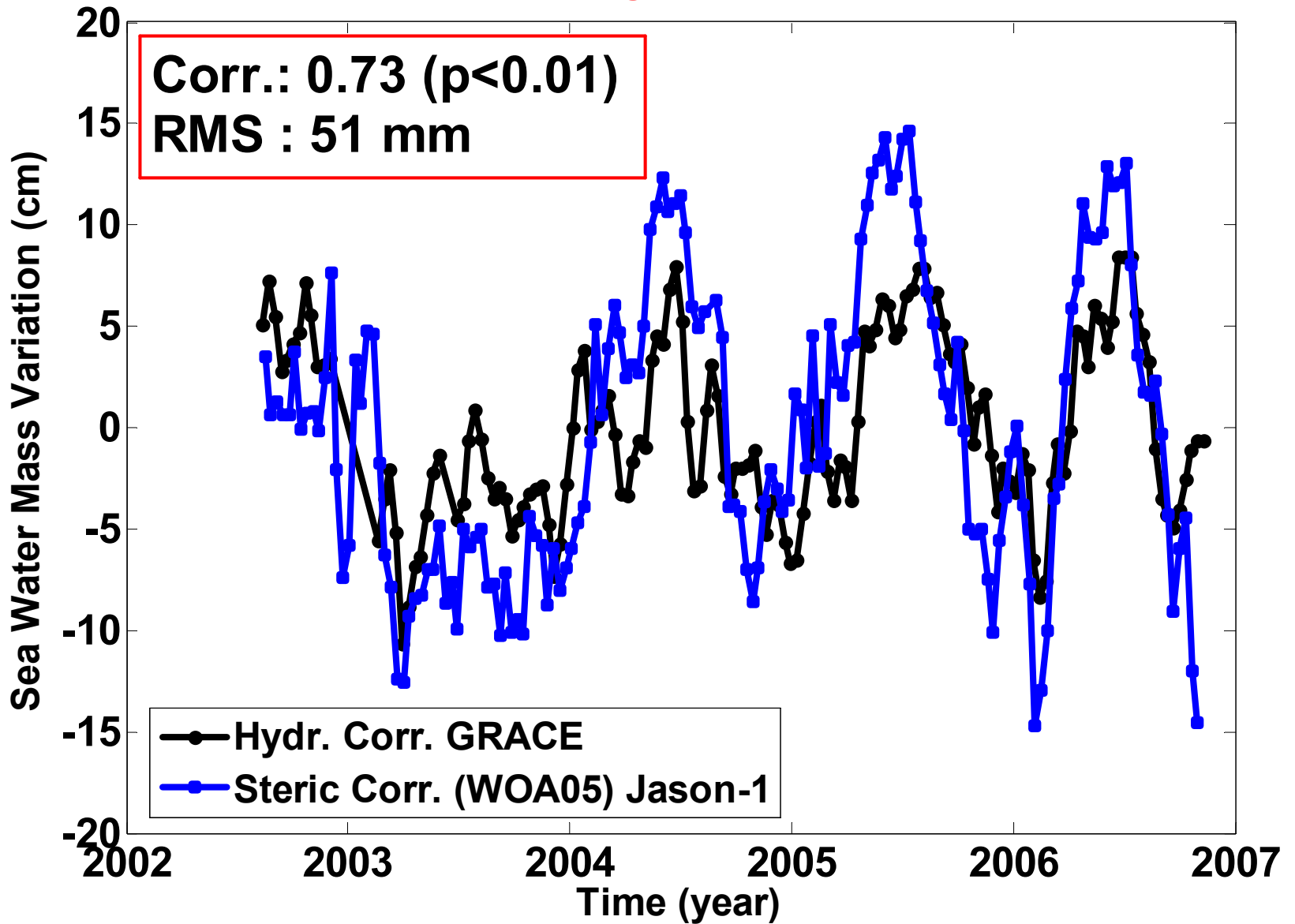
Smoothing applied to All datasets:
Spherical harmonic expansion to degree and order 2 to 50 degree (1 and 0 terms omitted)





BASIN AVR. SEAWATER MASS COMPARISON

Seasonal Signals Included





BASIN AVR. SEASONAL SEAWATER MASS VARIATIONS

Field	Annual Amplitude (mm)	Annual Phase (days)
GRACE-LAD (2002.615 - 2006.858)	33 ± 5	194.6 ± 7.5
$SLV_{\text{Mass}} = SLV_{\text{Total}} - SSL_{\text{WOA5}}$ (2002.625-2006.833)	55 ± 7	157.3 ± 7.2
$SLV_{\text{Mass}} = SLV_{\text{Total}} - SSL_{\text{SST}}$ (2002.625-2006.833)	57 ± 7	151.5 ± 6.8

Seasonal signal:

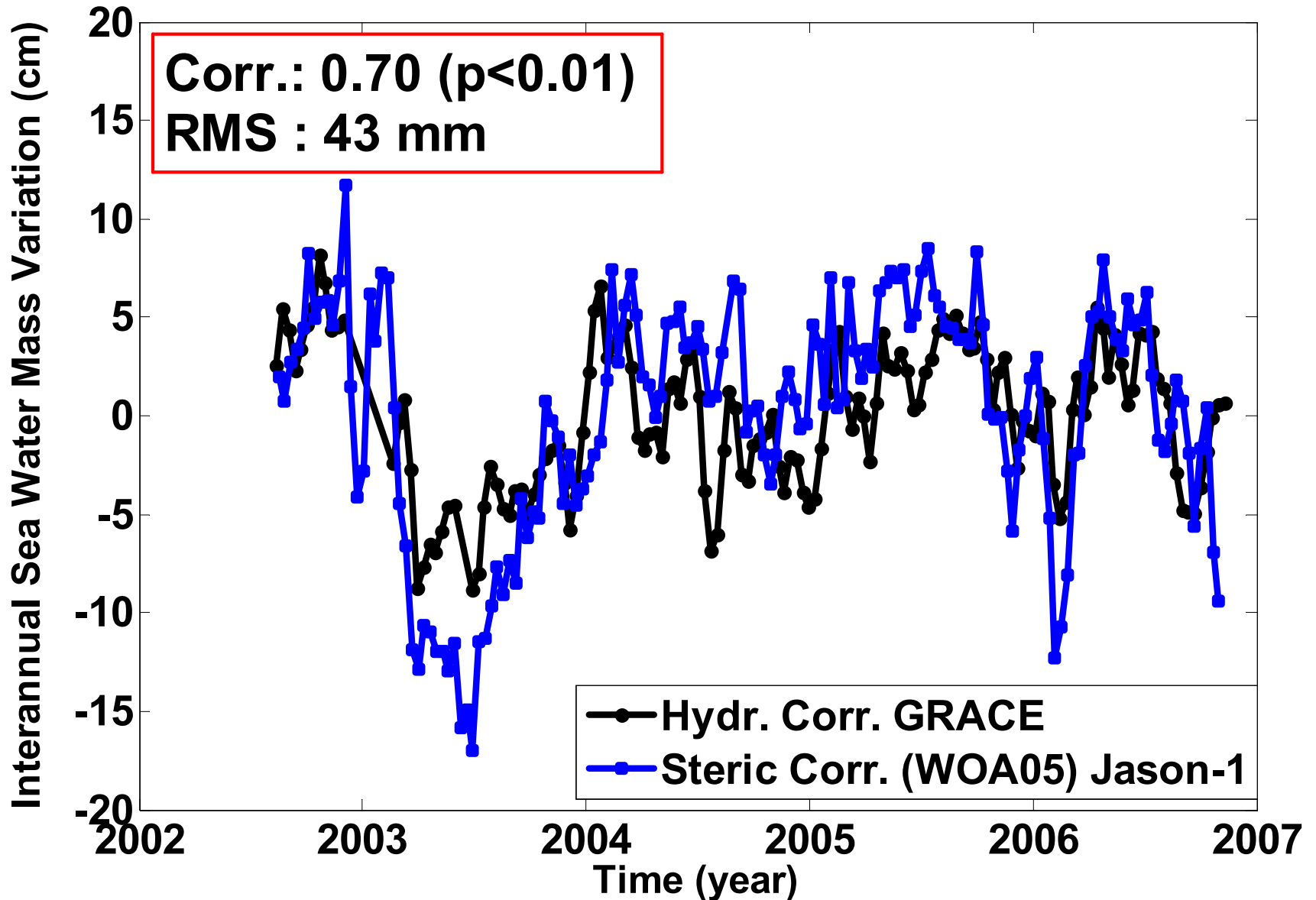
GRACE - LAD(land hydrology) annual peaks in July

Steric-corrected altimetry peaks in June.



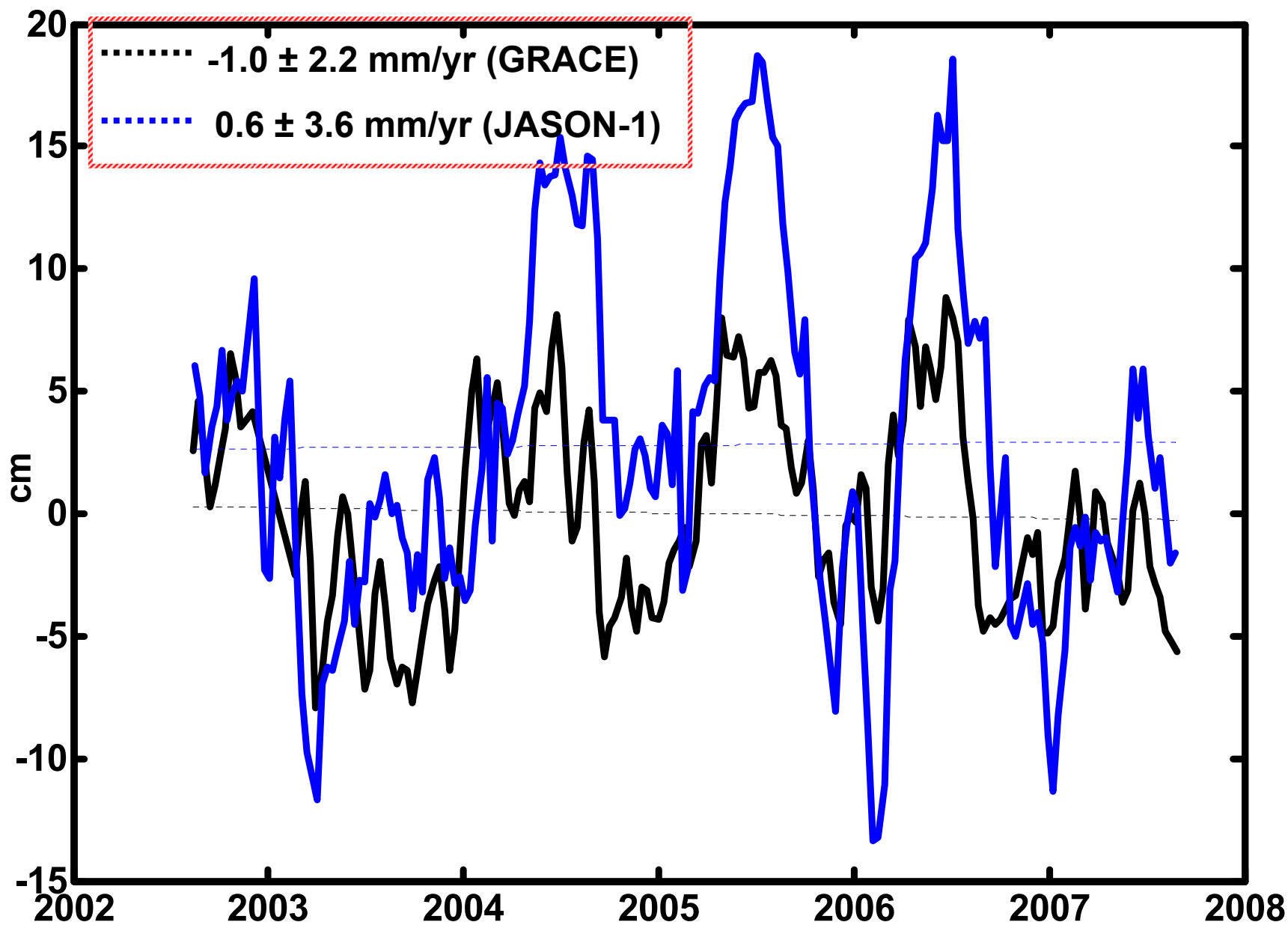
BASIN AVR. SEAWATER MASS COMPARISON

Seasonal Signals Removed



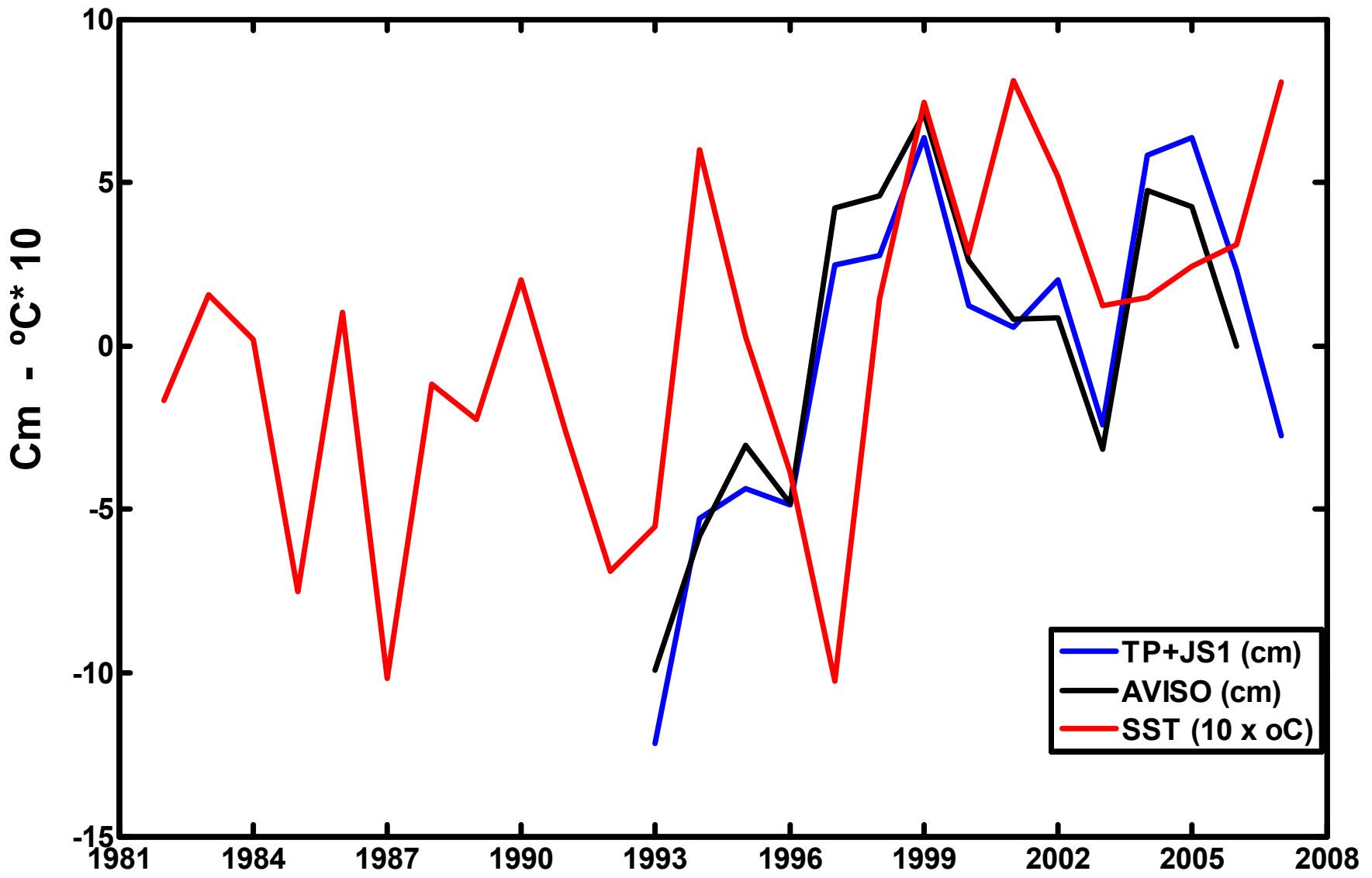


BASIN AVG. GRACE & JASON-1 TRENDS





BASIN AVG. ANNUAL SEA LEVEL (1993-2007)



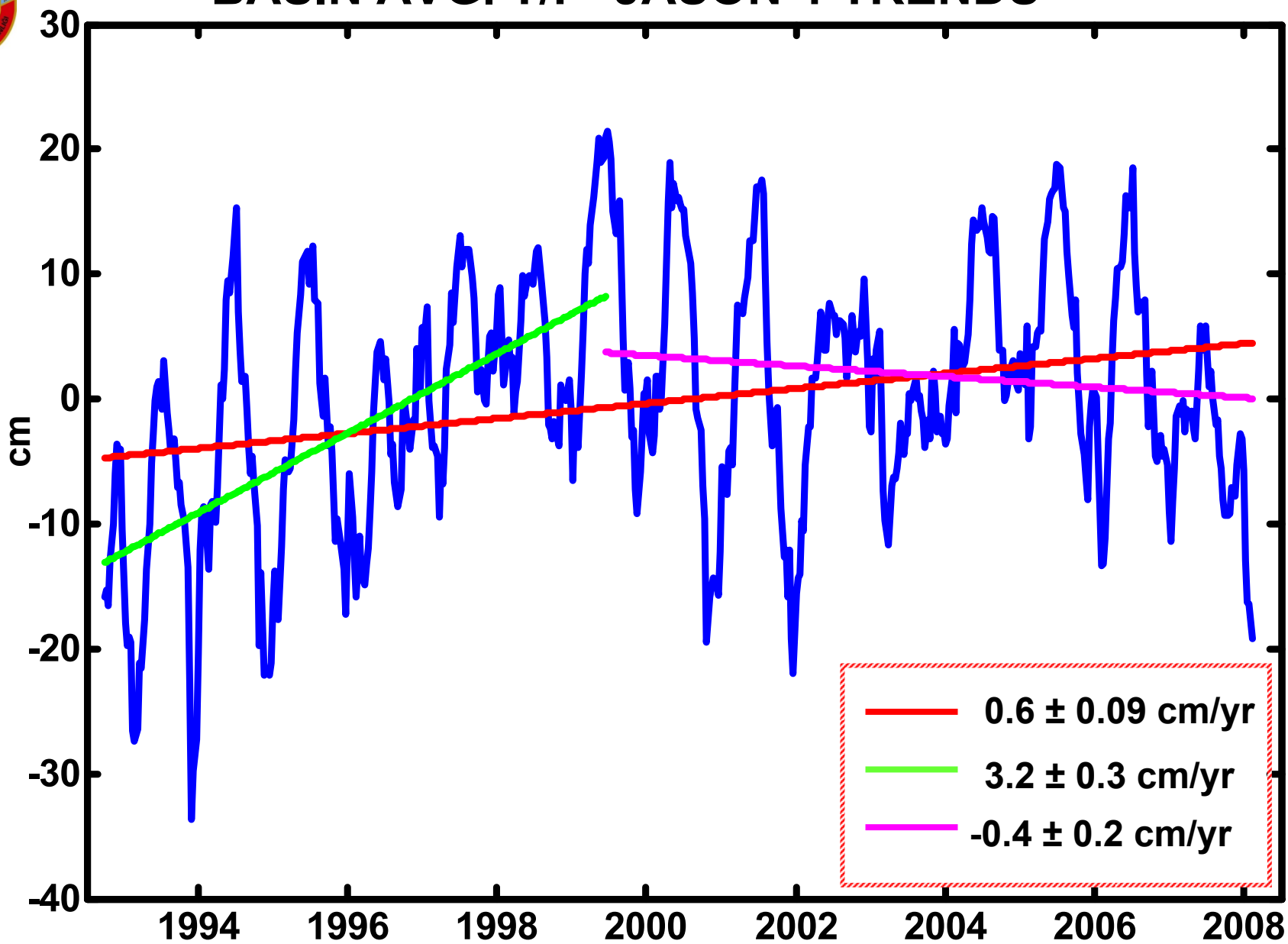


BASIN AVG. DECADAL SEA LEVEL CHANGES

Period	SST (°C/yr)	AVISO (cm/yr)	TP+Jason1 (cm/yr)
1993-2007	0.05 ± 0.03	0.64 ± 0.28 (1993-2006)	0.66 ± 0.26
1993-1999	0.07 ± 0.1	2.82 ± 0.40	2.80 ± 0.38
1999-2007	-0.02 ± 0.04	-0.40 ± 0.51 (1999-2006)	-0.30 ± 0.47



BASIN AVG. T/P+JASON-1 TRENDS

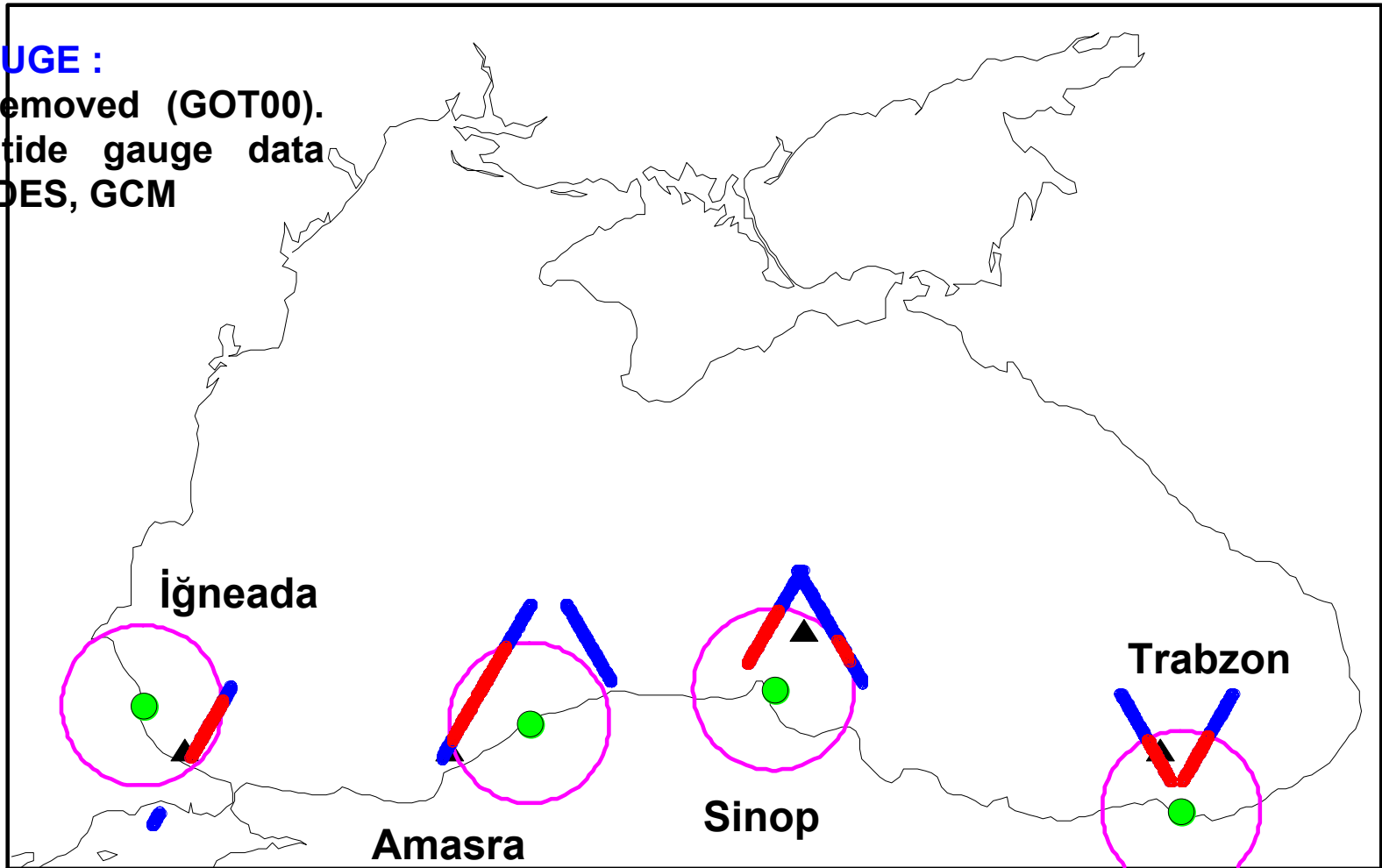




COMPARISONS OF JASON-1 & GRACE AT NEAREST GRIDS TO TIDE GAUGES AT NEAREST GRIDS TO TIDE GAUGES

TIDE GAUGE :

Tides Removed (GOT00).
Hourly tide gauge data
from TUDES, GCM



- ▲ Nearest Altimetry Grid Point
- Tide Gauge
- Buffer Frame
- Along Track Altimetry Points in Buffered Area
- Along Track Altimetry Points outside Buffered Area



COMPARISONS OF JASON-1 & GRACE AT NEAREST GRIDS TO TIDE GAUGES

Tide Gauges	Jason-1 Altimetry		GRACE (Gridded)
	Gridded	Along Track (75 km radius)	
İğneada (2002.6-2007.6)	0.56	0.65	0.47
Amasra (2002.6-2007.6)	0.62	0.49	0.50
Sinop (2005.4-2007.6)	0.70	0.65	0.47
Trabzon (2002.6-2007.6)	0.59	0.51	0.32

All the correlations are significant at 99% confidence level



SUMMARY – ANNUAL CHANGES

- **GRACE (Land hydrology corrected) is able to detect sea water mass variations in the Black Sea with an annual amplitude of 33 ± 5 mm peaking in July,**
- **Steric corrected altimetry are larger (annual amplitude of 55 ± 7 mm peaking in June approximately 38 days before the hydrology corrected GRACE data).**
- **Temporal correlation of Basin Avg. GRACE-LAD and Steric Corrected ALTIMETRY is around 0.7**



SUMMARY – INTER-ANNUAL CHANGES

- **Mean sea level trends from (T/P+Jason-1) and AVISO Merged+Gridded Data are consistent over 1993-2007 period.**
- **Sea level at the end of 2007 is getting closer to sea level of early 1993. Support interdecadal changes with periodicity in the 15 to 30-year band by Oğuz et al. (2006) from hydro-meteorological and biochemical records.**
- **Altimetric Sea level trend sensitive to record length. Support that changes are caused by decadal variability.**
- **1993-2007 Sea surface temperature is increasing. Support Stanev et al. 2000 + Tsimplis et al. 2004, that sea level changes are dominated by freshwater changes.**
- **GRACE 2002-2007 does not give definite mass change estimates (-1 mm/year +/-2.2 mm/year)**