Large-Scale Terrestrial Water Storage Change from GRACE

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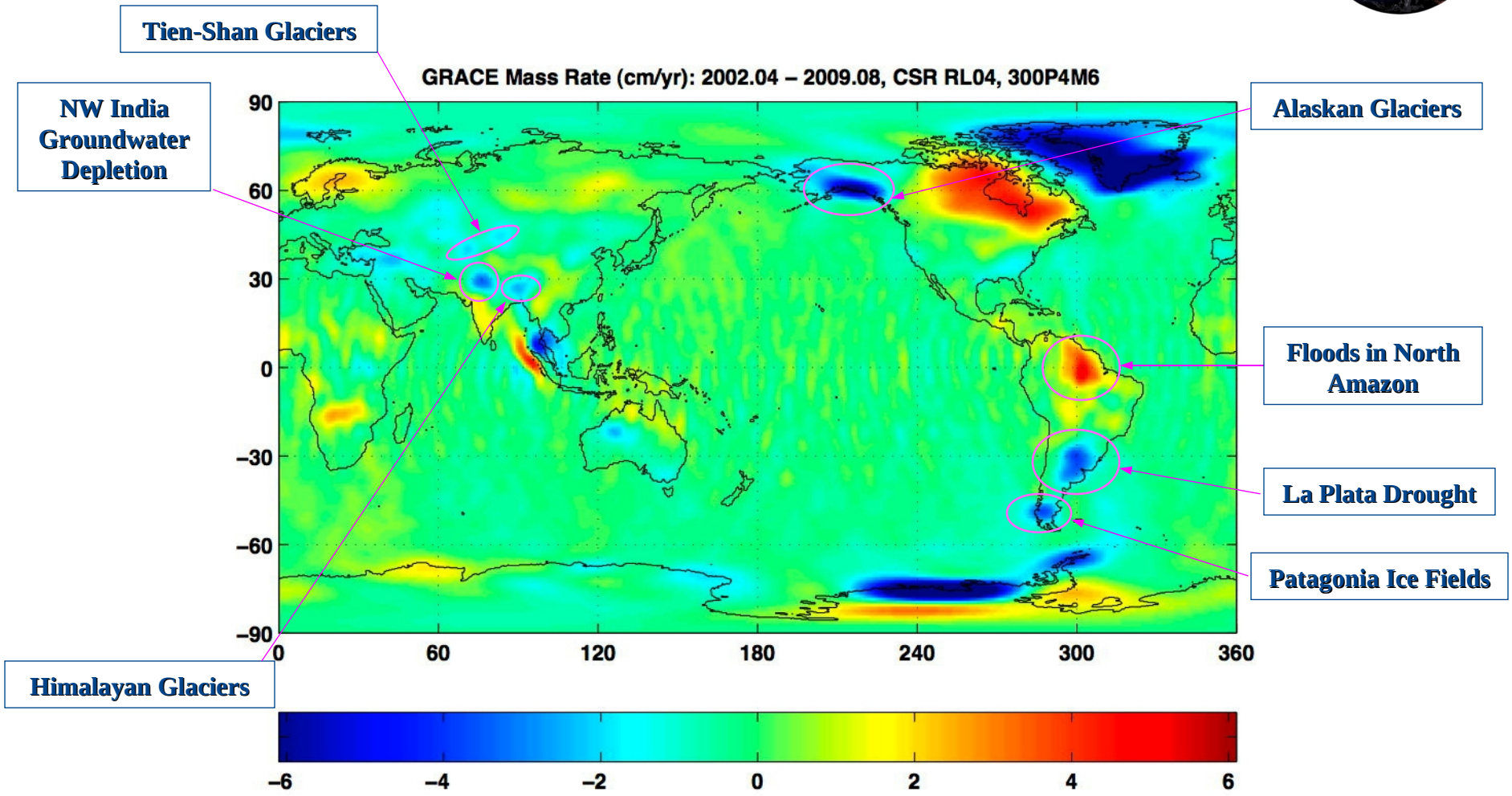
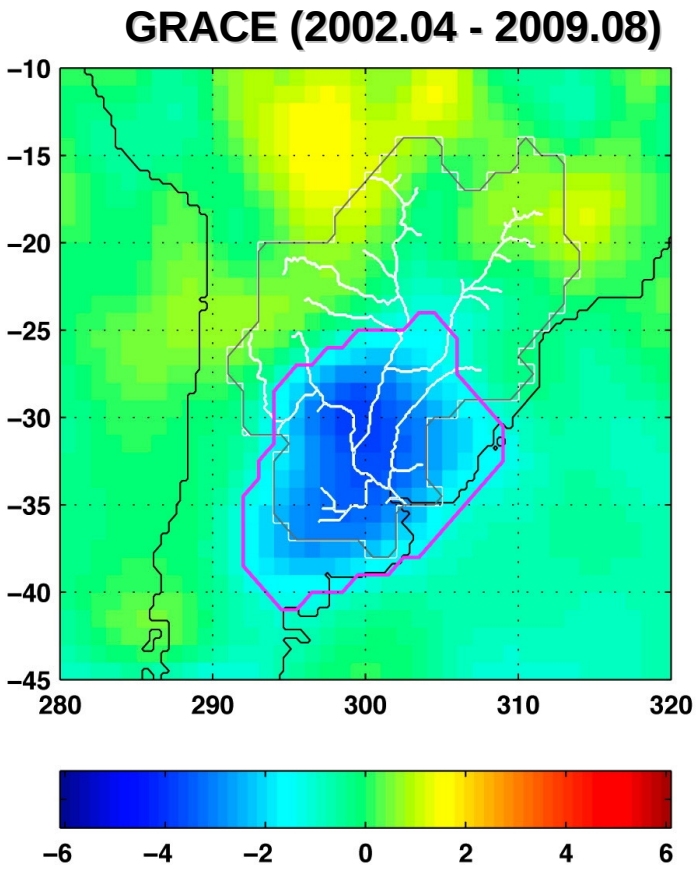
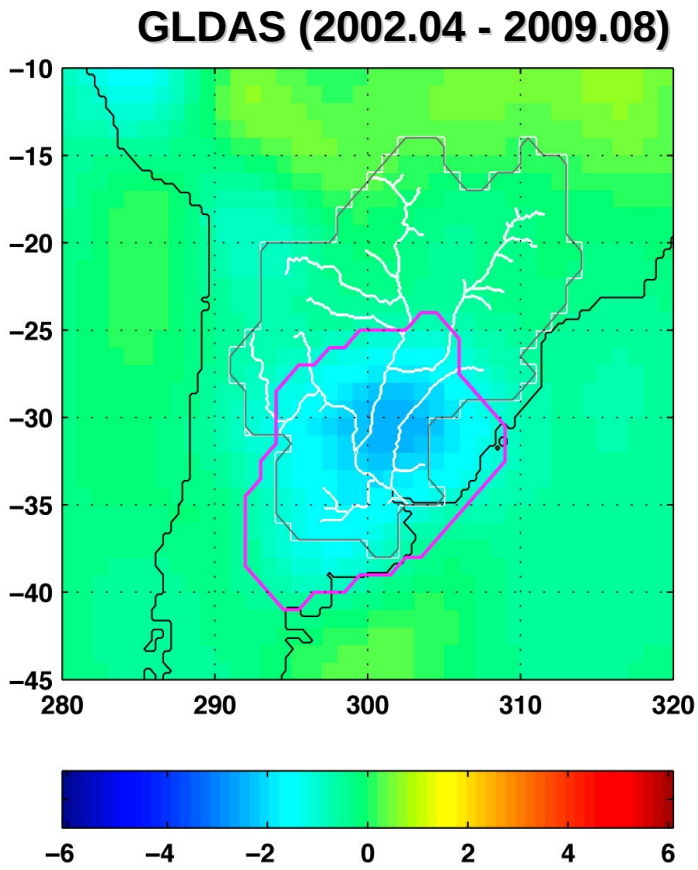
Climate Change Signatures from GRACE

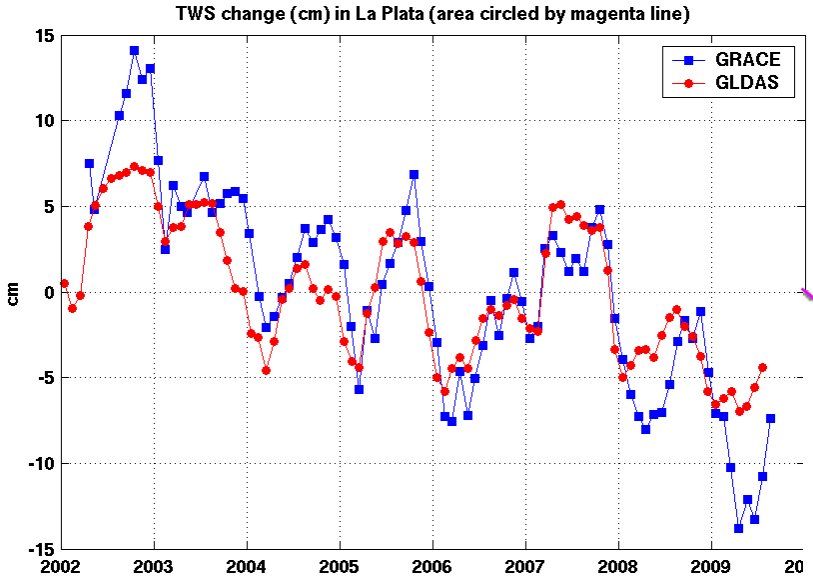


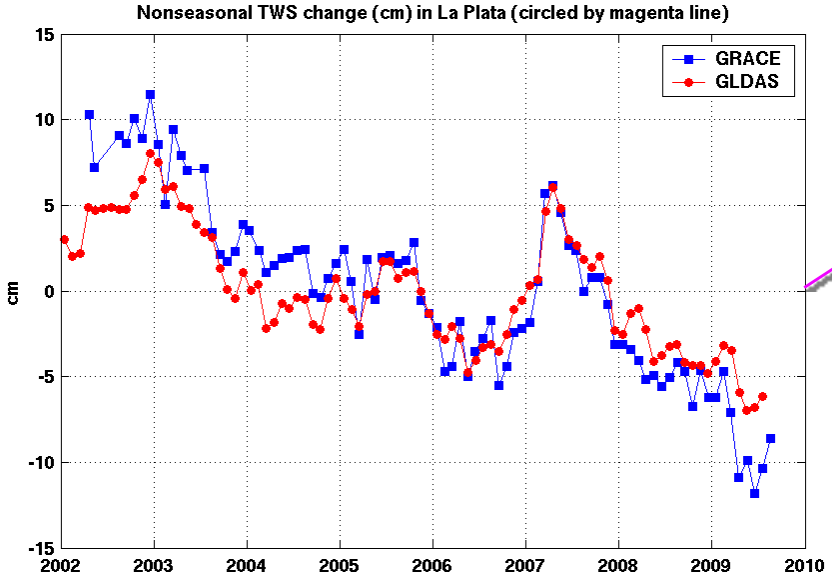
Extended Drought in the Lower La Plata Basin

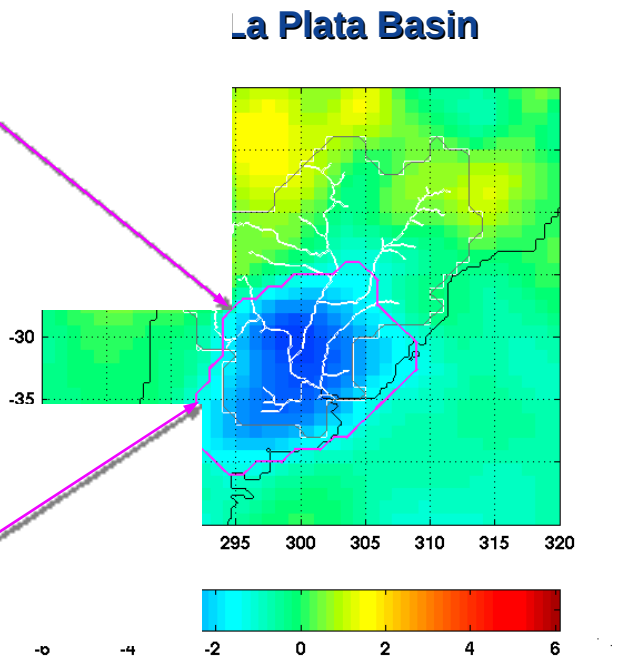


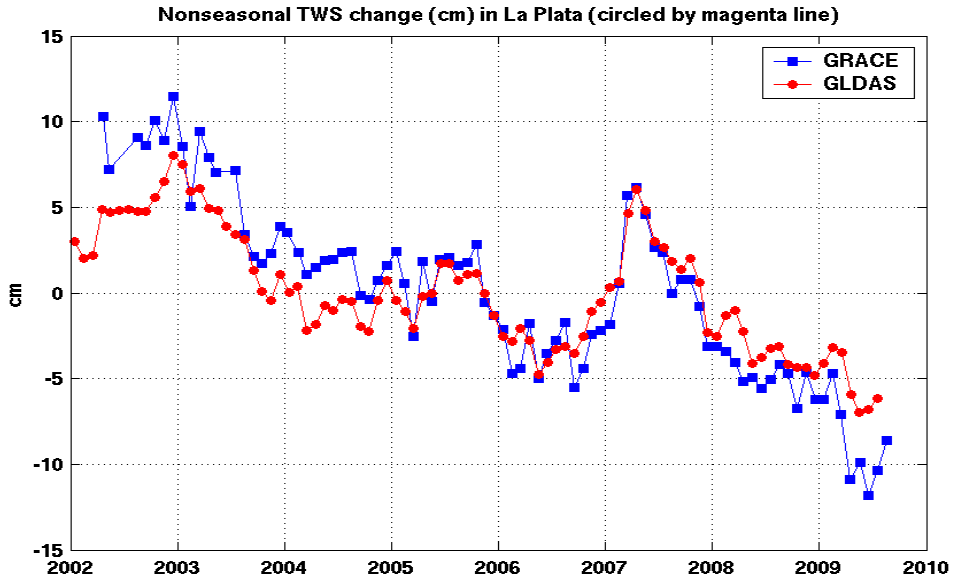


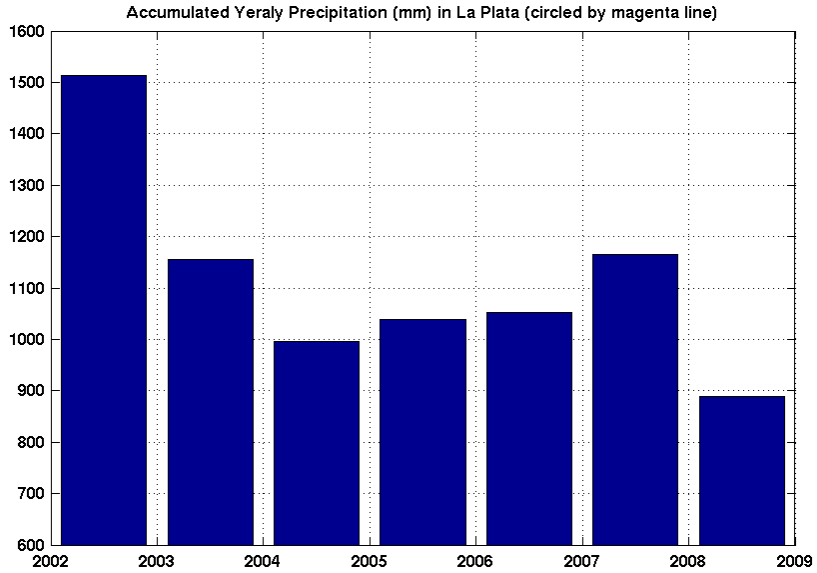
(Units: cm/year of equivalent water height)


TWS change (cm) in La Plata (area circled by magenta line)
GRACE
GLDAS
cm
15
10
5
0
-5
-10
-15
2002
2003
2004
2005
2006
2007
2008
2009
20


Nonseasonal TWS change (cm) in La Plata (circled by magenta line)
GRACE
GLDAS
cm
15
10
5
0
-5
-10
-15
2002
2003
2004
2005
2006
2007
2008
2009
2010

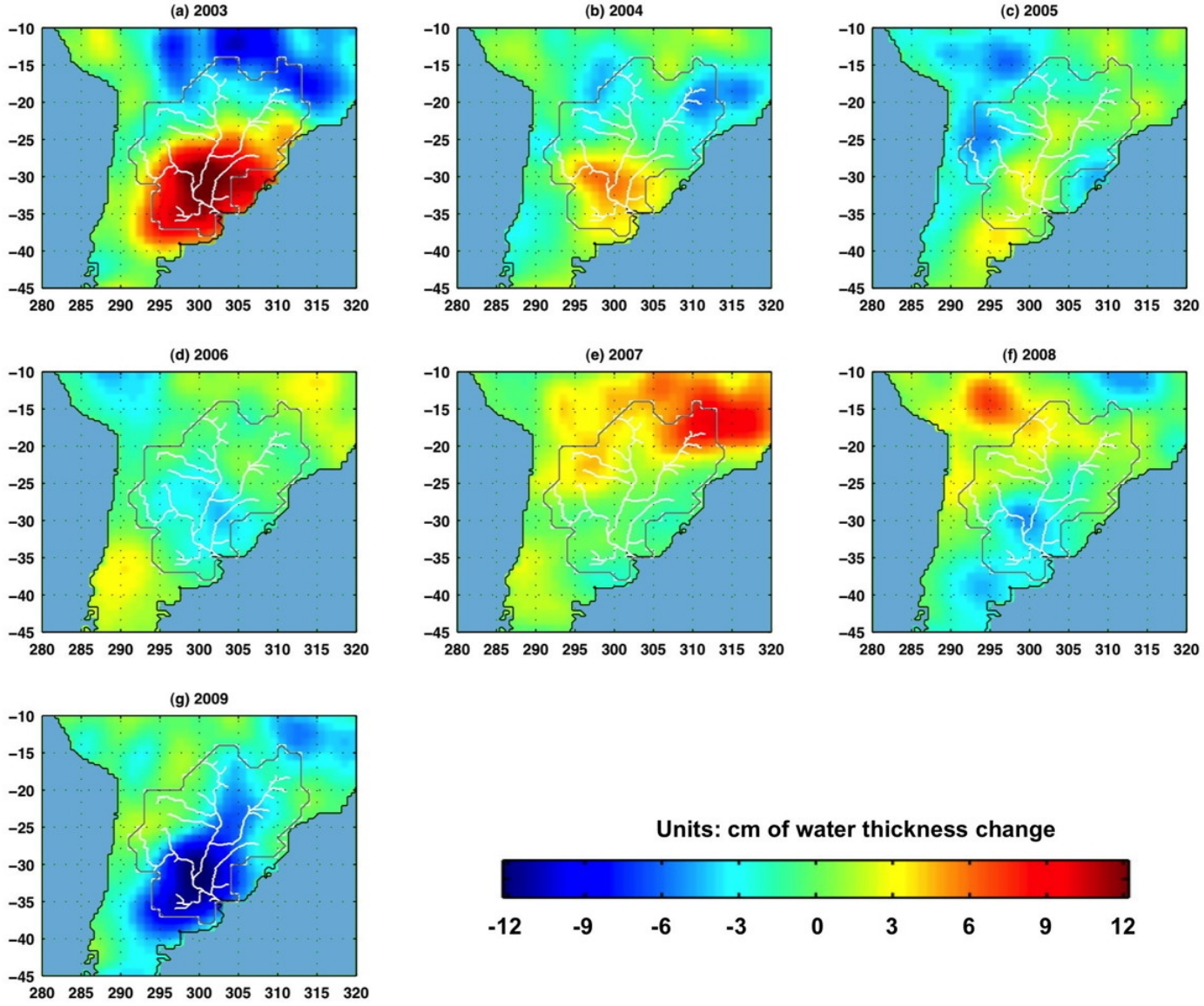

La Plata Basin
-30
-35
295
300
305
310
315
320
-6
-4
-2
0
2
4
6



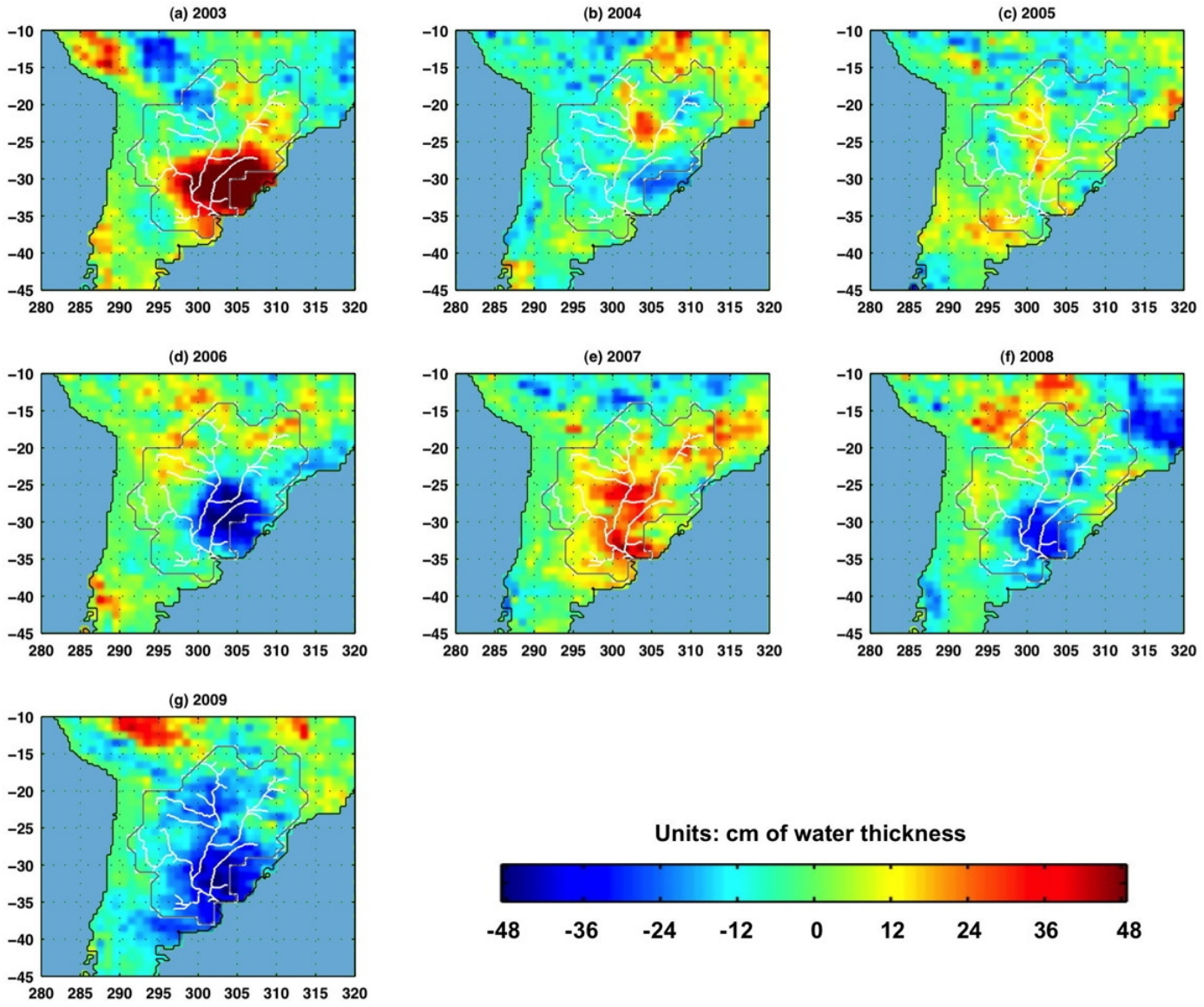


Accumulated Annual Precipitation in the Lower La Plata Basin (from GPCP)

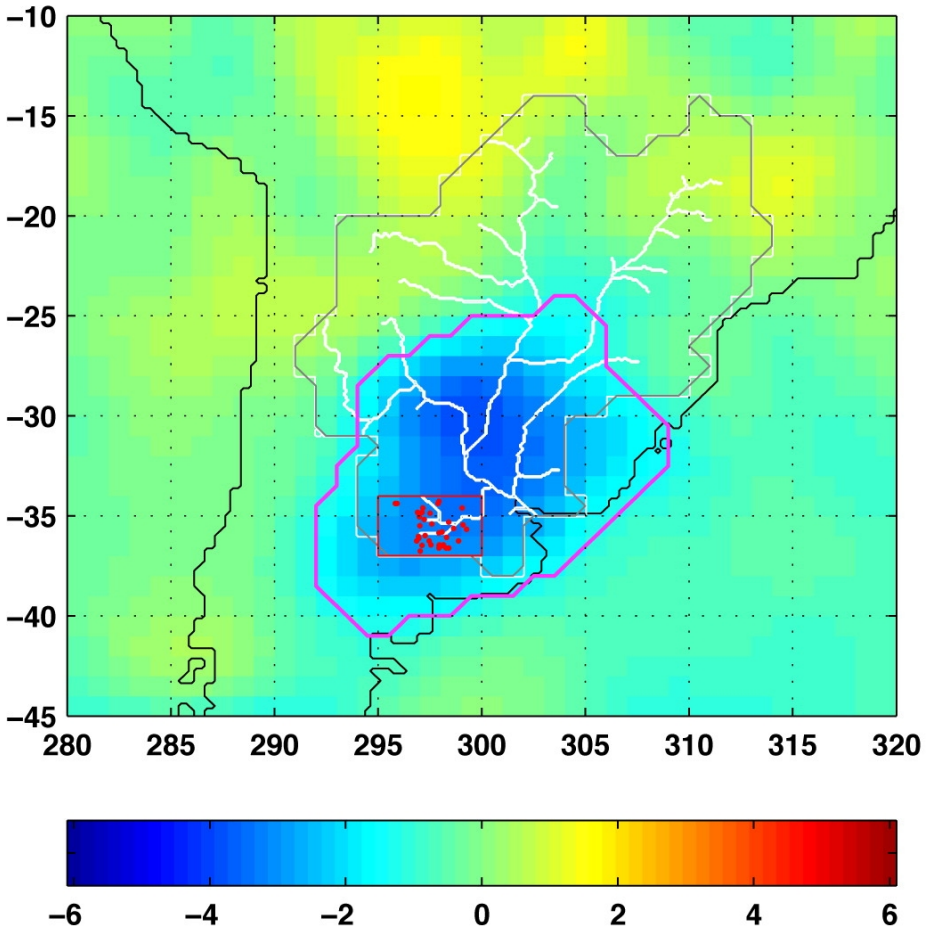
GRACE Yearly TWS change (Yearly = Average from July of the previous year through June)



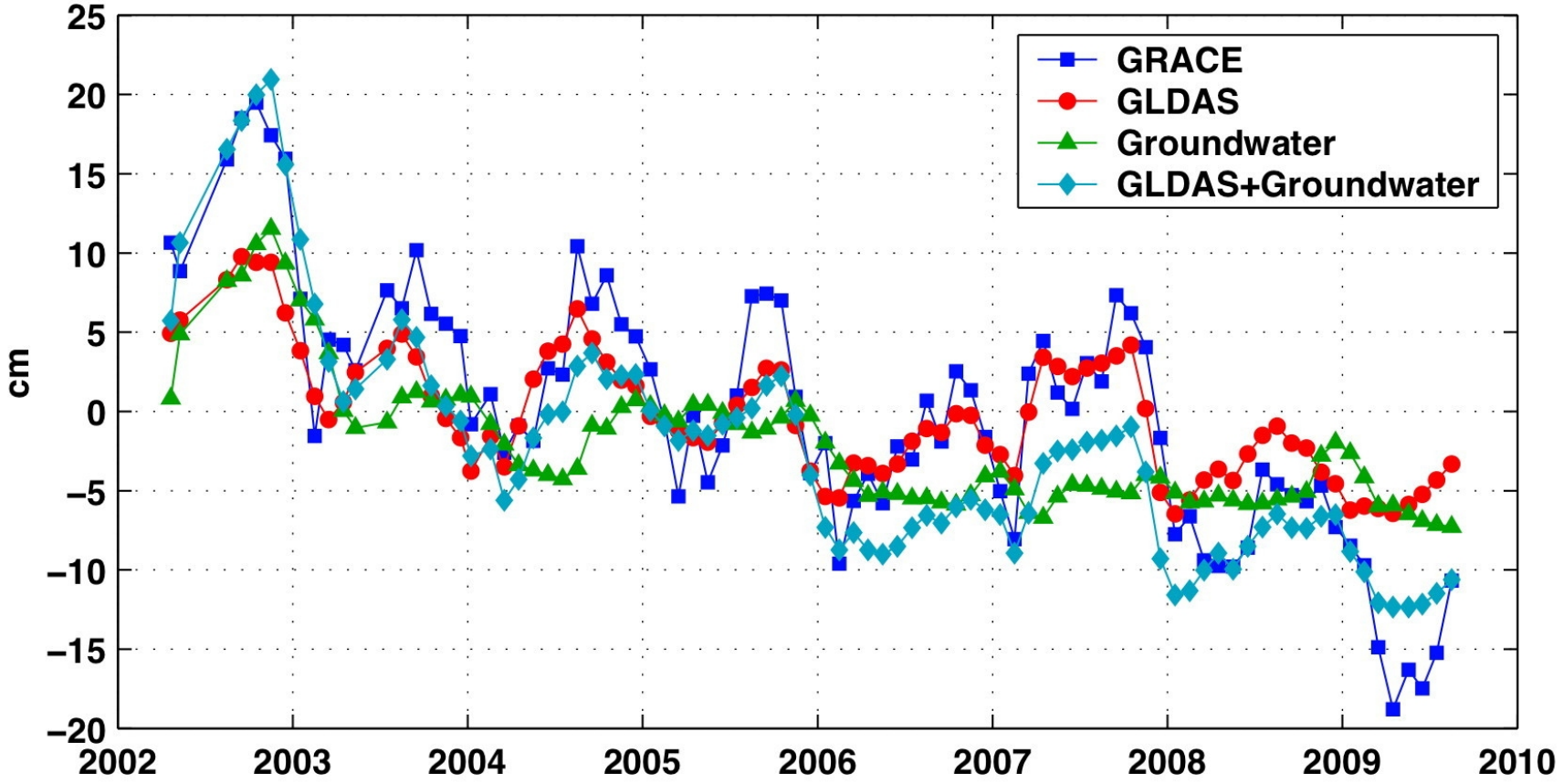
GPCP Yearly Precipitation Anomaly (Yearly = Average from July of the previous year through June)

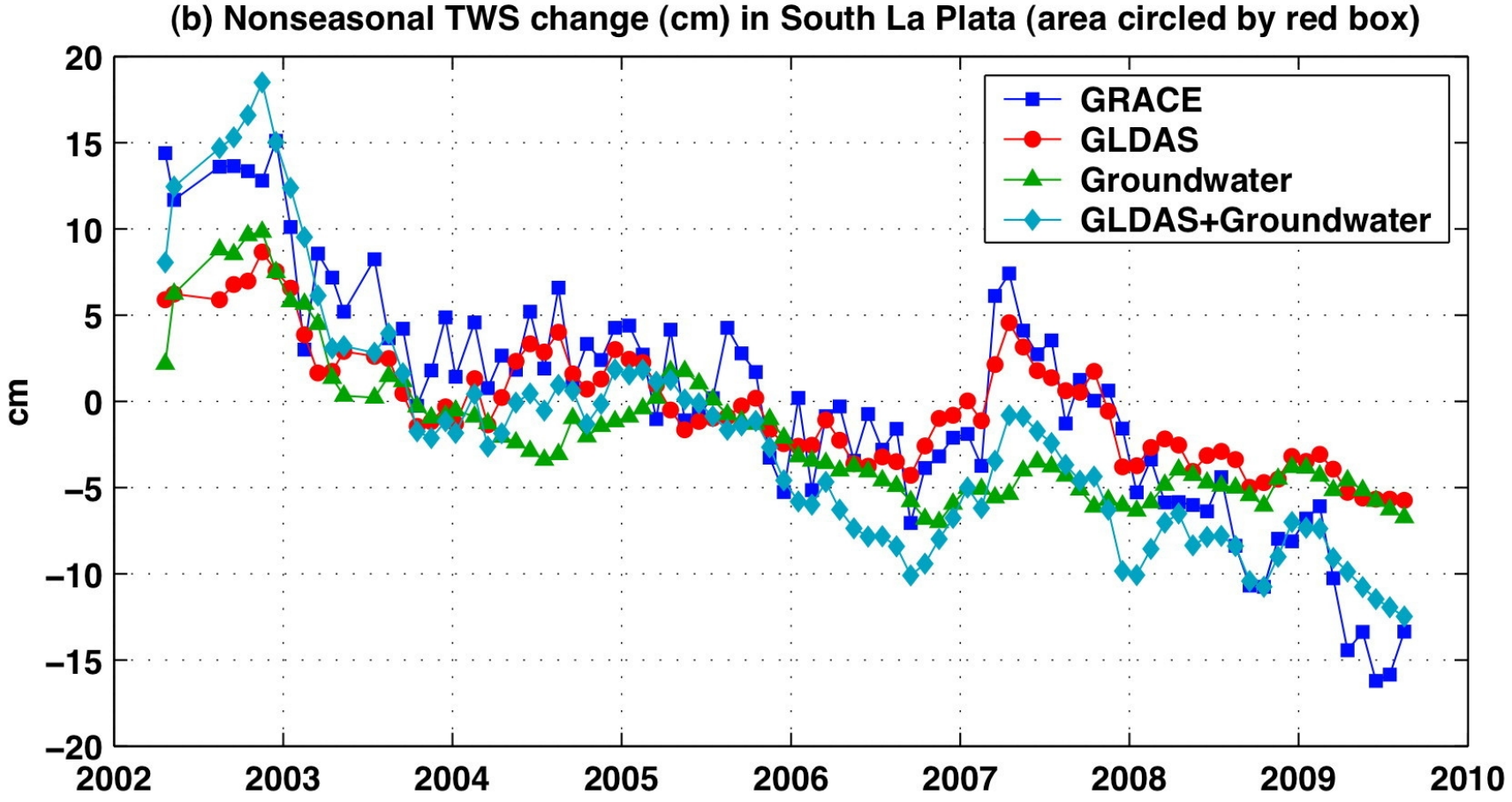


Groundwater Change in the Lower La Plata Basin



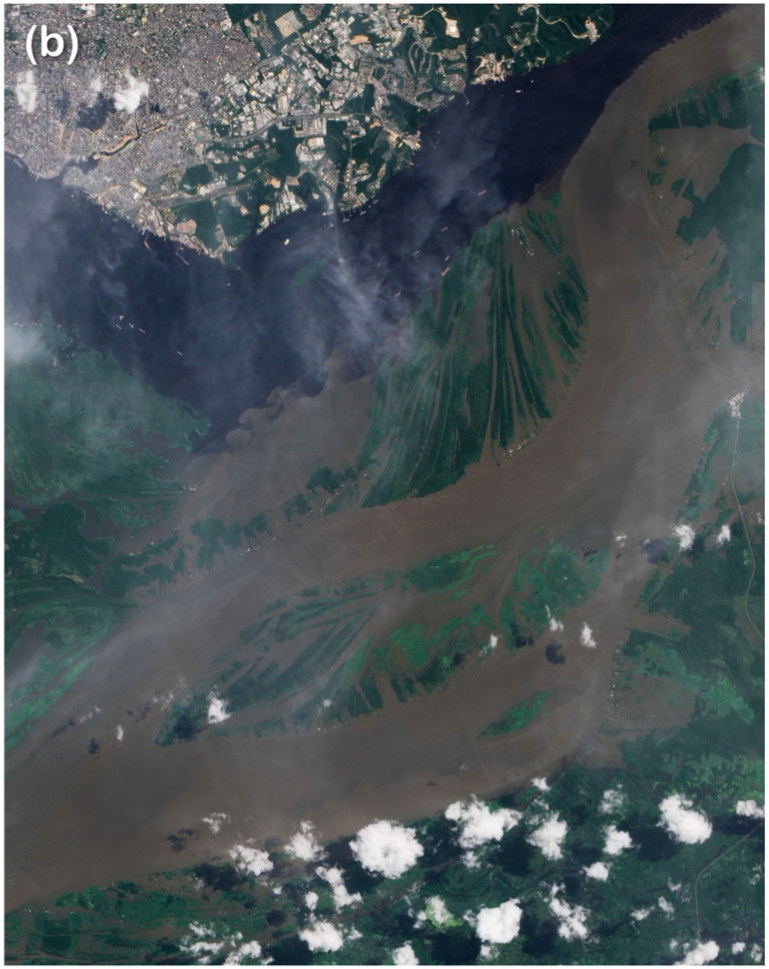
(Groundwater level data from 27 wells in the south La Plata basin)


(a) TWS change (cm) in South La Plata (area circled by red box)
cm
25
20
15
10
5
0
−5
−10
−15
−20
2002
2003
2004
2005
2006
2007
2008
2009
2010
GRACE
GLDAS
Groundwater
GLDAS+Groundwater


(b) Nonseasonal TWS change (cm) in South La Plata (area circled by red box)
GRACE
GLDAS
Groundwater
GLDAS+Groundwater
cm
20
15
10
5
0
−5
−10
−15
−20
2002
2003
2004
2005
2006
2007
2008
2009
2010

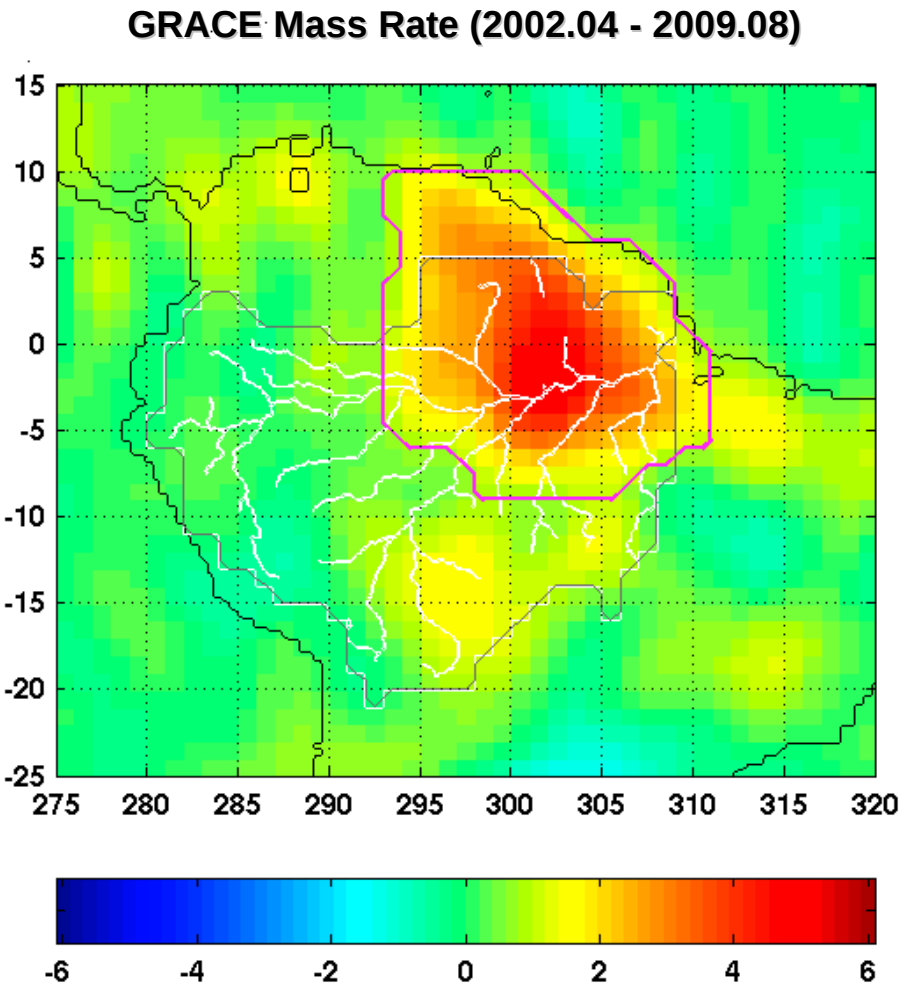
The 2009 Exceptional Flood in Lower Amazon

June 7, 2004

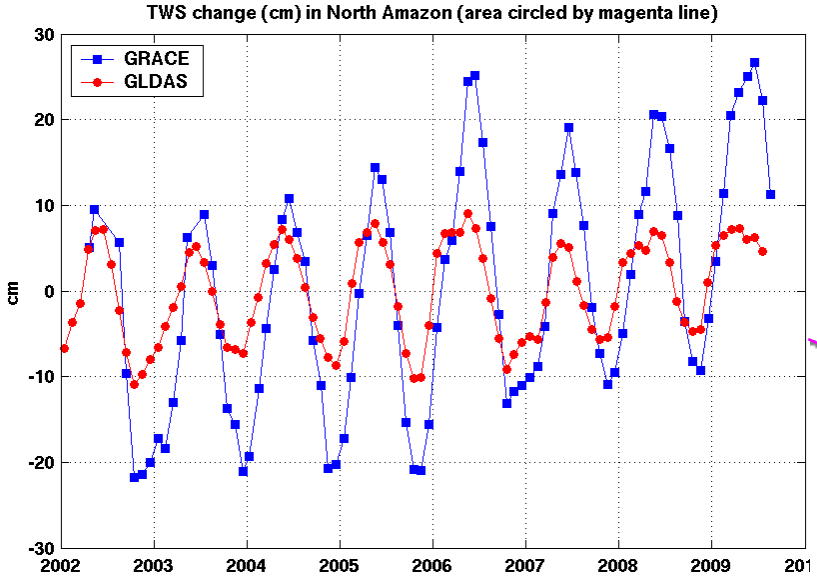


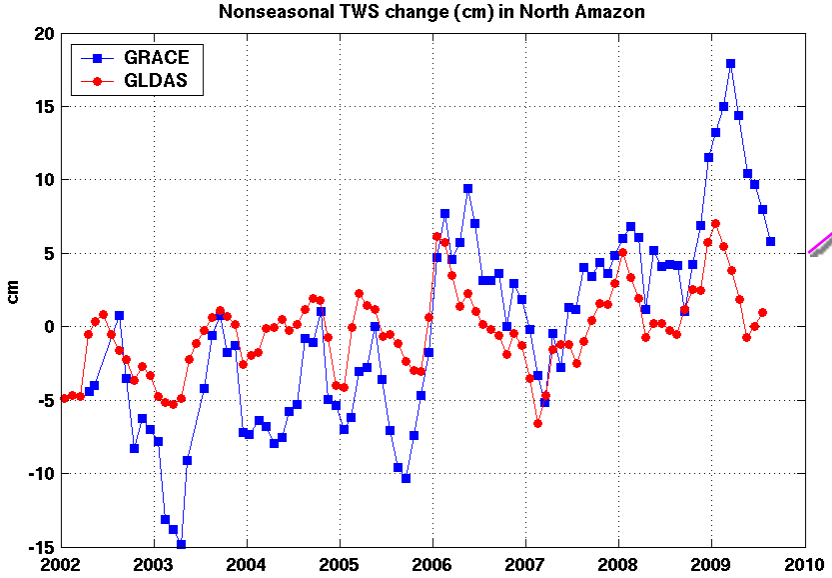
June 29, 2009

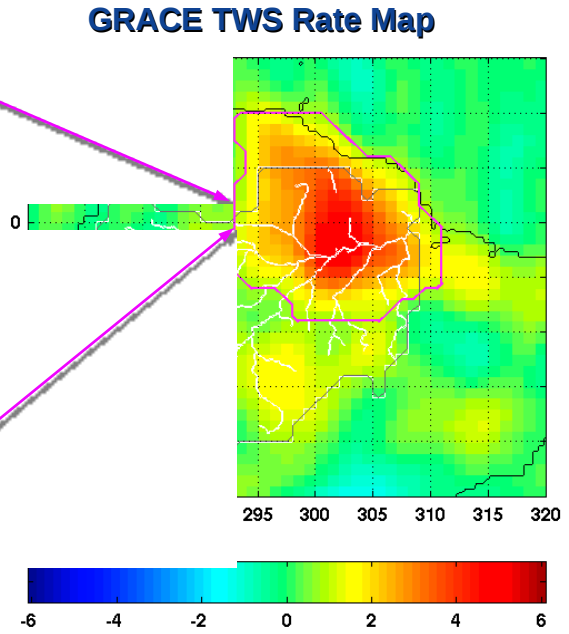
The 2009 Exceptional Flood in Lower Amazon

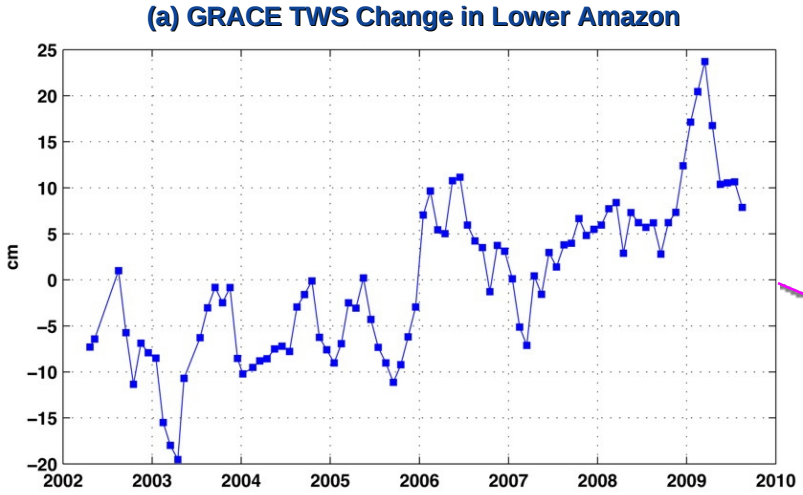


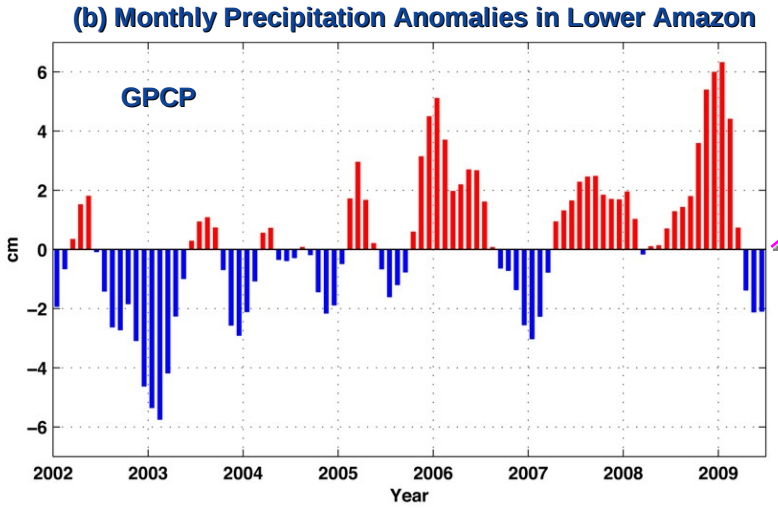
(Units: cm/year of equivalent water height)

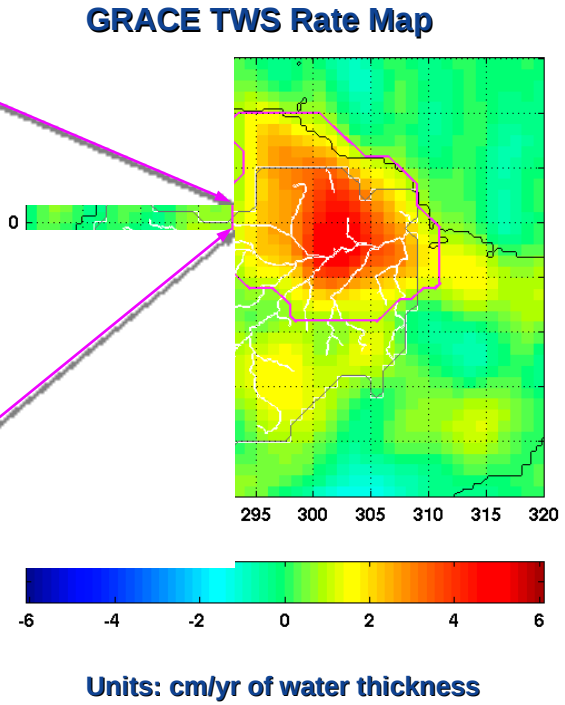

TWS change (cm) in North Amazon (area circled by magenta line)
GRACE
GLDAS
cm
30
20
10
0
-10
-20
-30
2002
2003
2004
2005
2006
2007
2008
2009
201

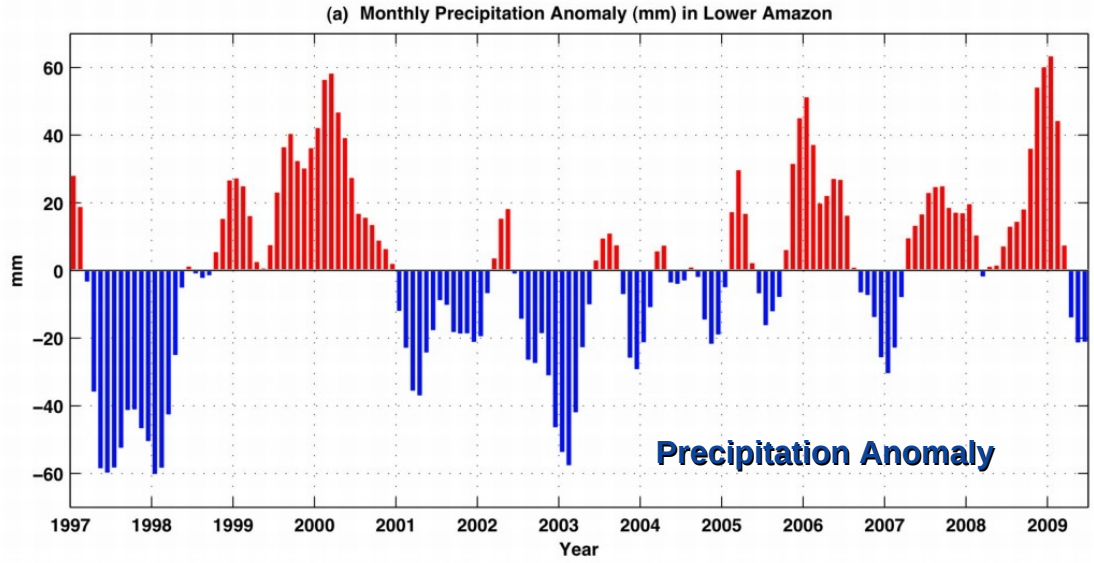

Nonseasonal TWS change (cm) in North Amazon
GRACE
GLDAS
cm
20
15
10
5
0
-5
-10
-15
2002
2003
2004
2005
2006
2007
2008
2009
2010

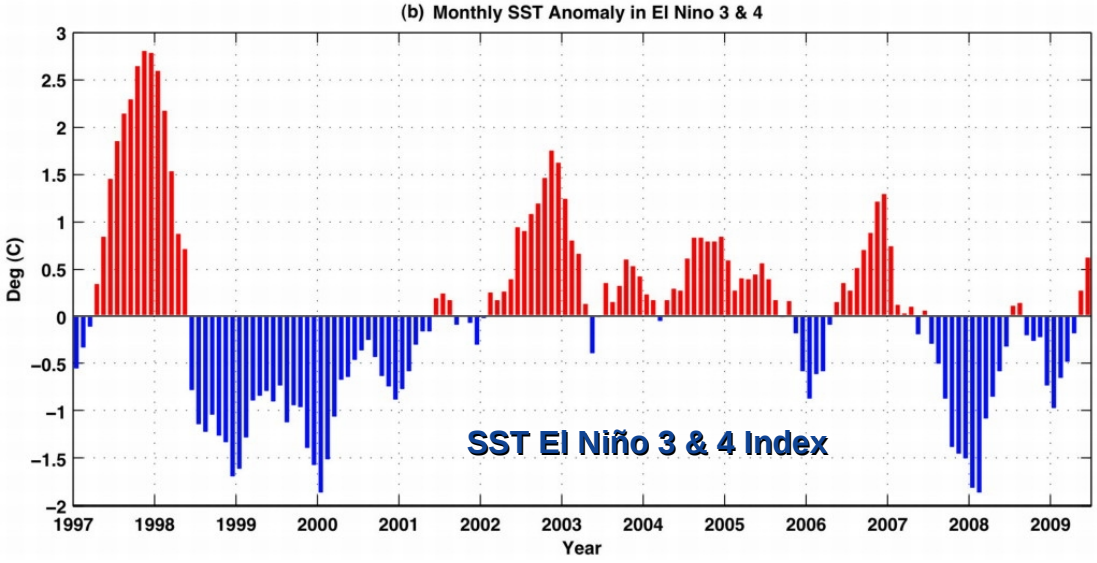

GRACE TWS Rate Map
0
295
300
305
310
315
320
-6
-4
-2
0
2
4
6
Units: cm/yr of water thickness


(a) GRACE TWS Change in Lower Amazon
cm
25
20
15
10
5
0
−5
−10
−15
−20
2002
2003
2004
2005
2006
2007
2008
2009
2010

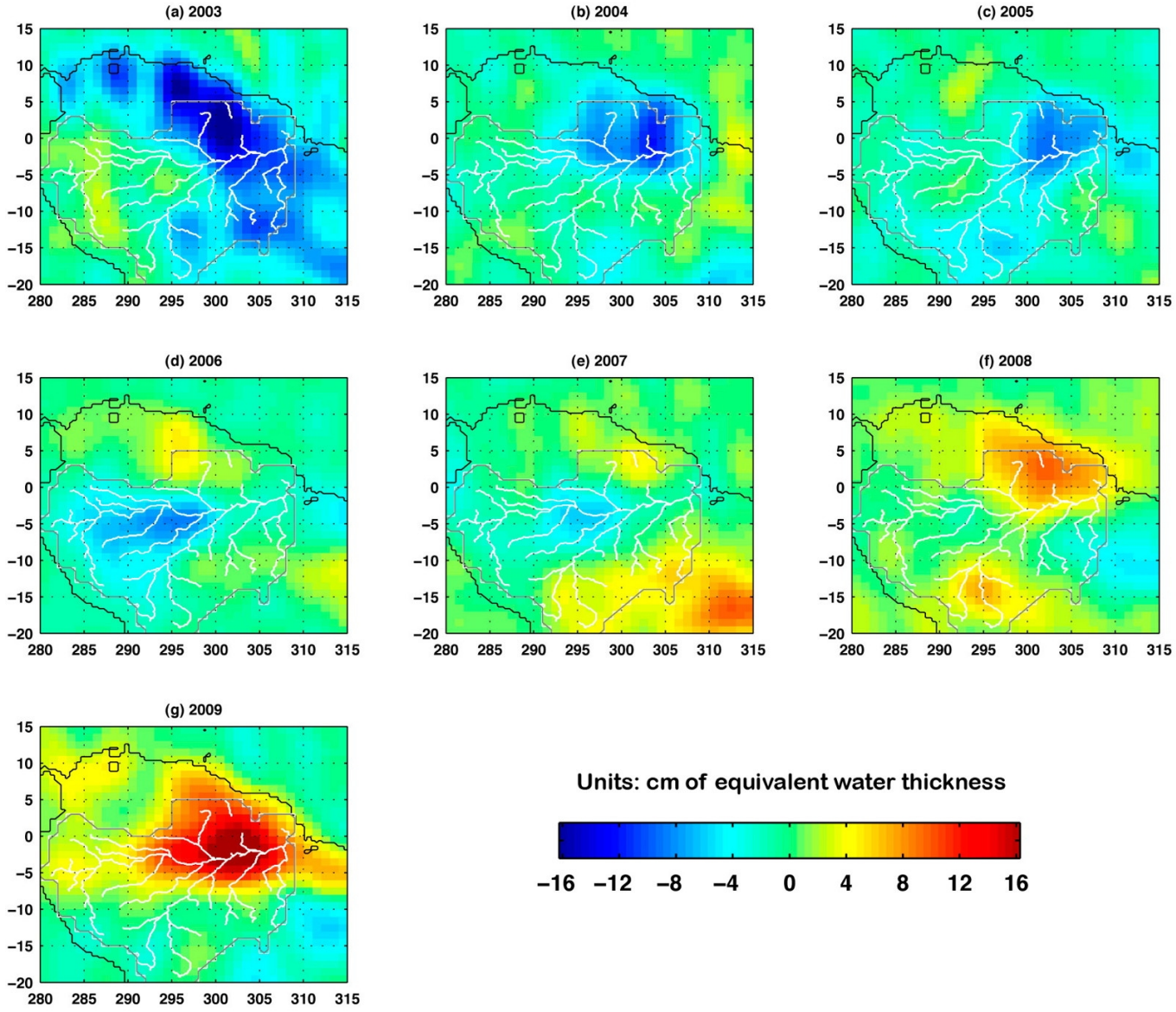

(b) Monthly Precipitation Anomalies in Lower Amazon
GPCP
cm
6
4
2
0
−2
−4
−6
2002
2003
2004
2005
2006
2007
2008
2009
Year


GRACE TWS Rate Map
0
295
300
305
310
315
320
-6
-4
-2
0
2
4
6
Units: cm/yr of water thickness

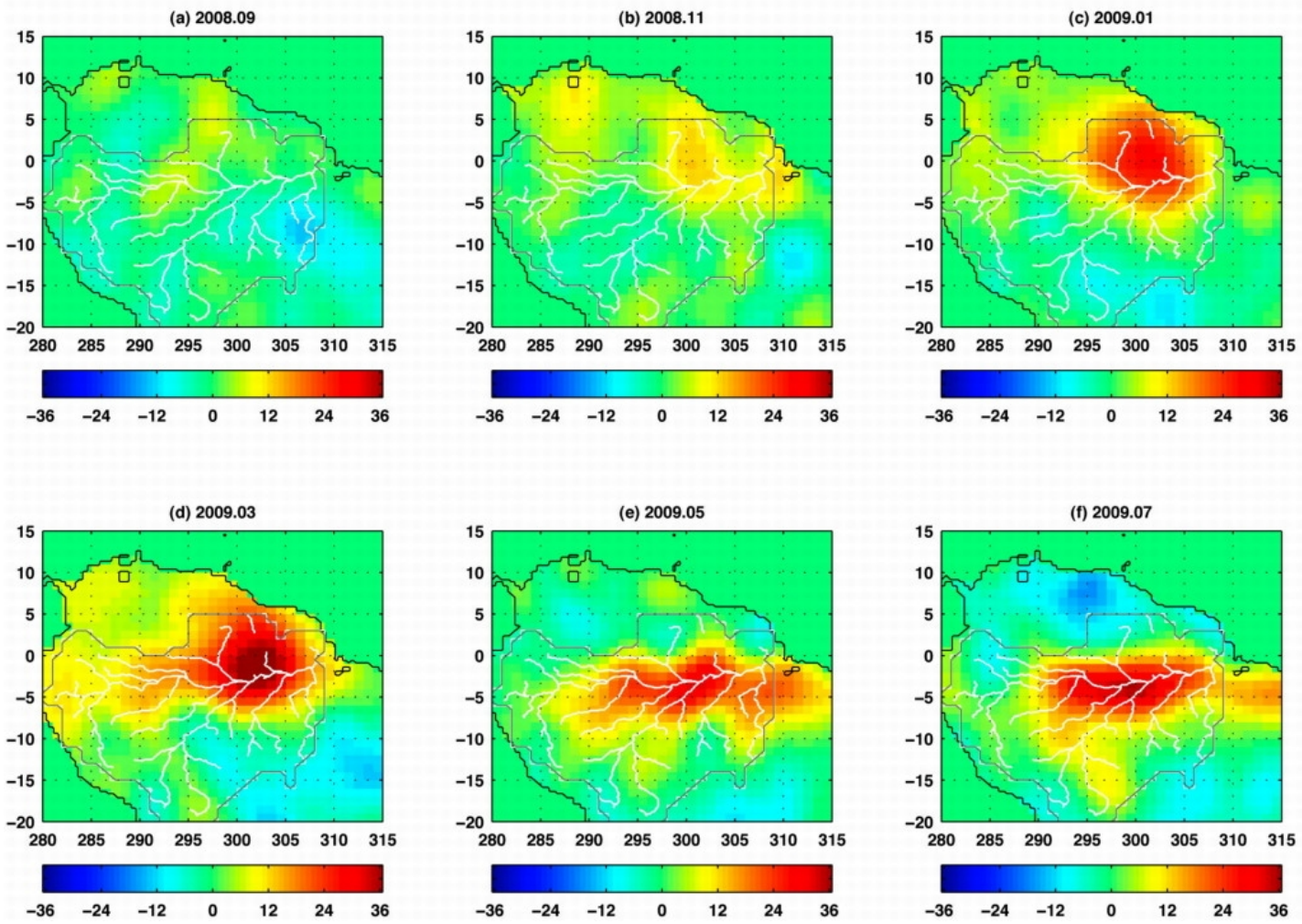

(a) Monthly Precipitation Anomaly (mm) in Lower Amazon
mm
60
40
20
0
−20
−40
−60
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year
Precipitation Anomaly


(b) Monthly SST Anomaly in El Nino 3 & 4
Deg (C)
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year
SST El Niño 3 & 4 Index

GRACE Yearly TWS change (Yearly = Average from July of the previous year through June)



Development of the exceptional 2009 Amazon flood from GRACE



GRACE observed monthly TWS anomaly (seasonal signal is removed)

Major Conclusions:

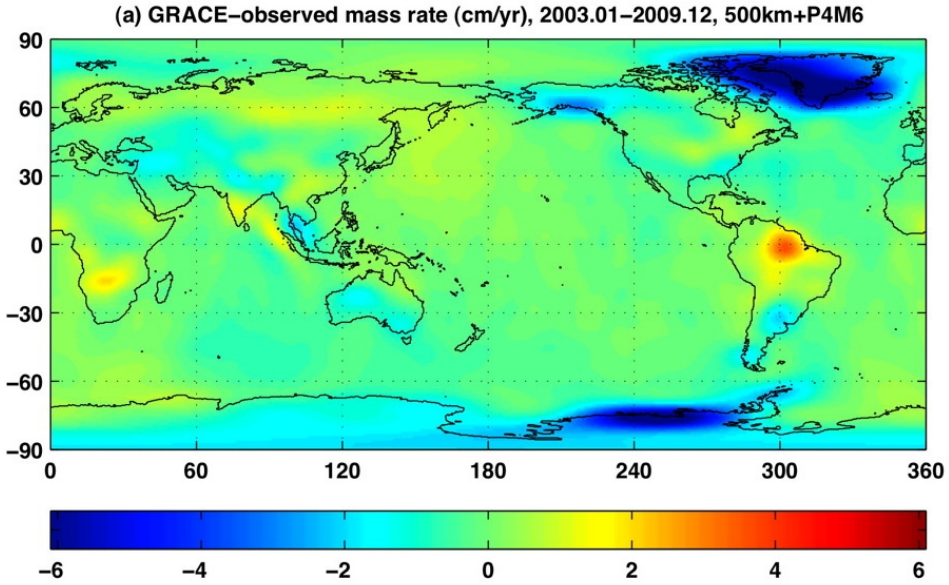
- GRACE time-variable gravity data have captured various interesting large-scale climate change features.
- The extended drought condition in lower La Plata basin is clearly captured by GRACE.
- GRACE has also captured the exceptional 2009 Amazon flood and its temporal and spatial evolutions.
- GRACE observations are supported by precipitation data.
- TWS changes in the La Plata and Amazon basins are closed correlated with El Niño and La Niña events.

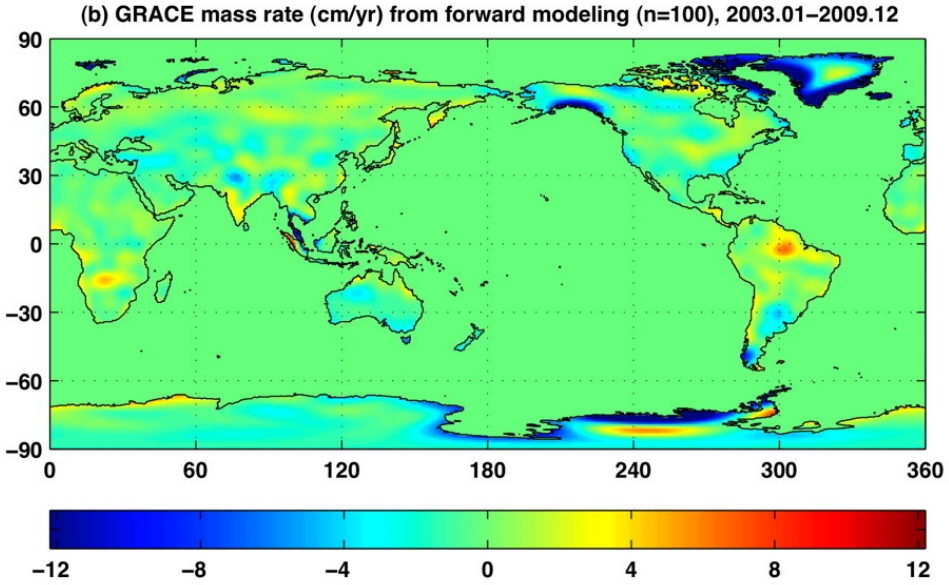
Major challenges to GRACE :

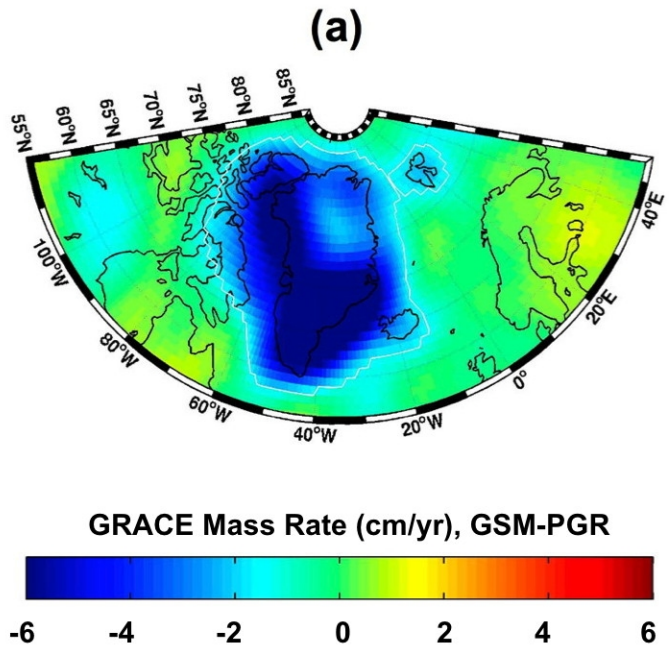
- **Low spatial resolution (300 – 500 km)**
- **Spatial leakage due to needed spatial filtering and use of limited degree and order of spherical harmonics.**
- **Signal attenuation associated with spatial leakage**
- **Residual errors in GRACE gravity solutions**
- **Missing geocenter terms (C11, S11, C10)**
- **Lack of *in situ* data for validation**

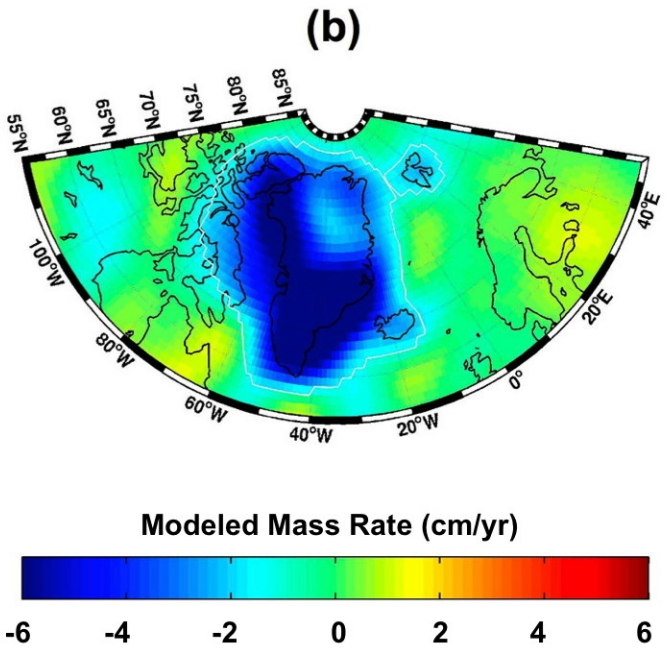
…

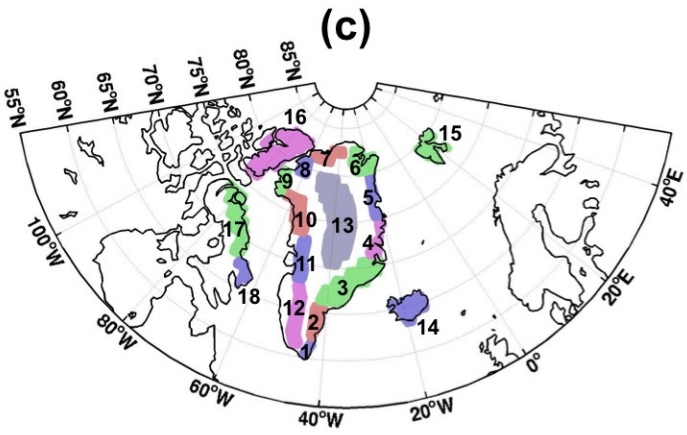
Forward Modeling of Global Long-Term Mass Rates



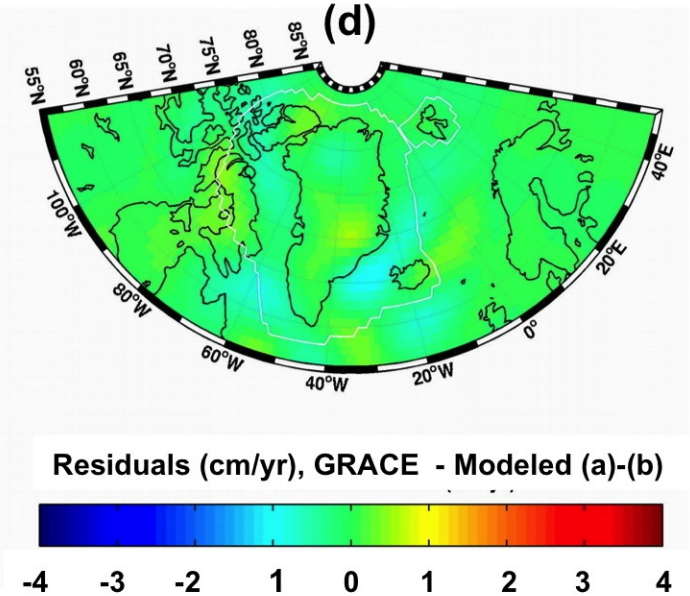




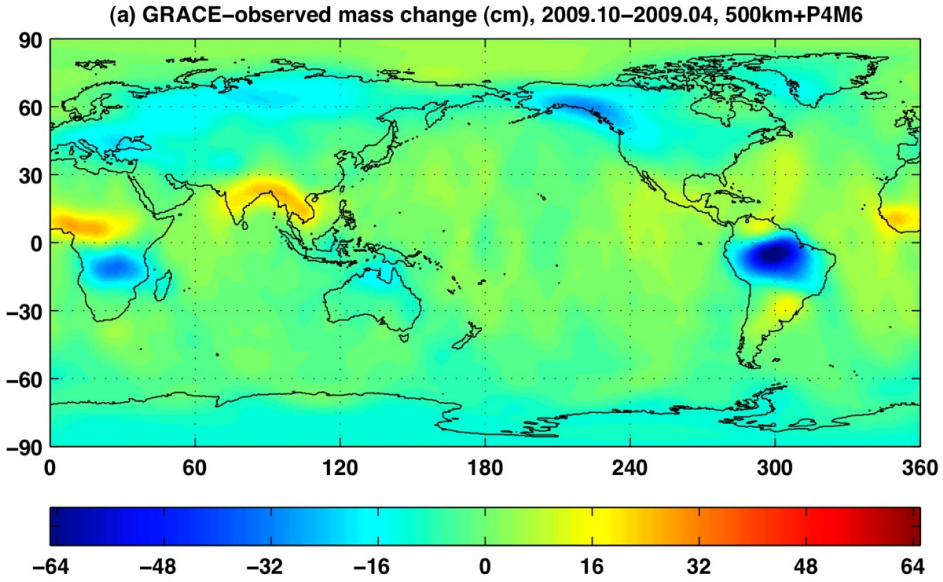


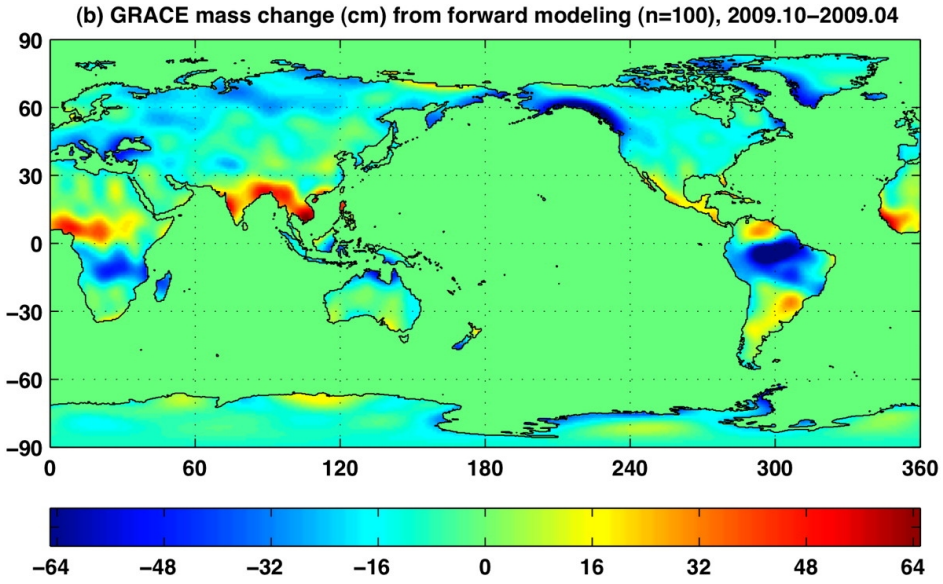


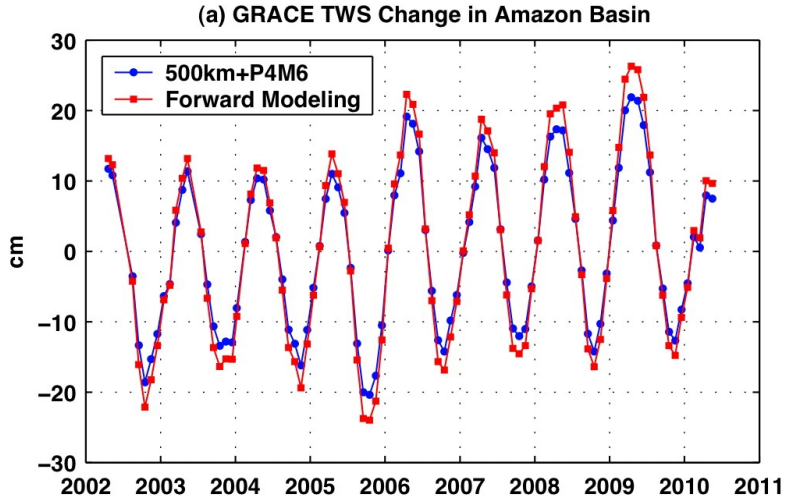
Area #	Mass Rate (Gt/yr)
1	–19.7
2	–29.9
3	–51.0
4	–9.4
5	– 9.8
6	–8.4
7	–10.6
8	+2.3
9	–13.6
10	–32.1
11	–30.2
12	–10.4
13	+3.9
14	–14.2
15	–9.2
16	–26.7
17	–25.9
18	–7.8

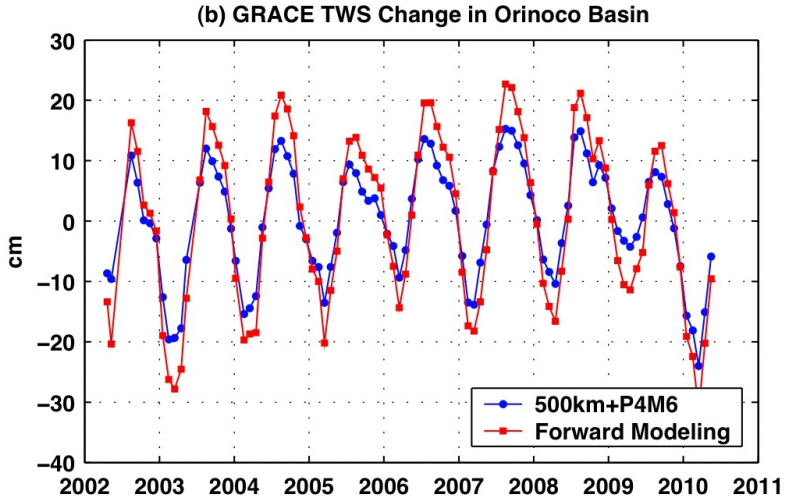


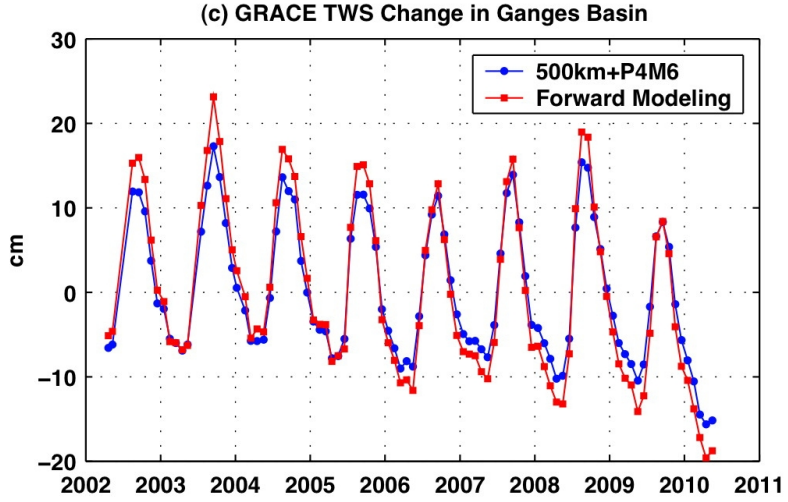
Forward Modeling of Global Monthly Mass Change (2009.10-2009.04) (cm)

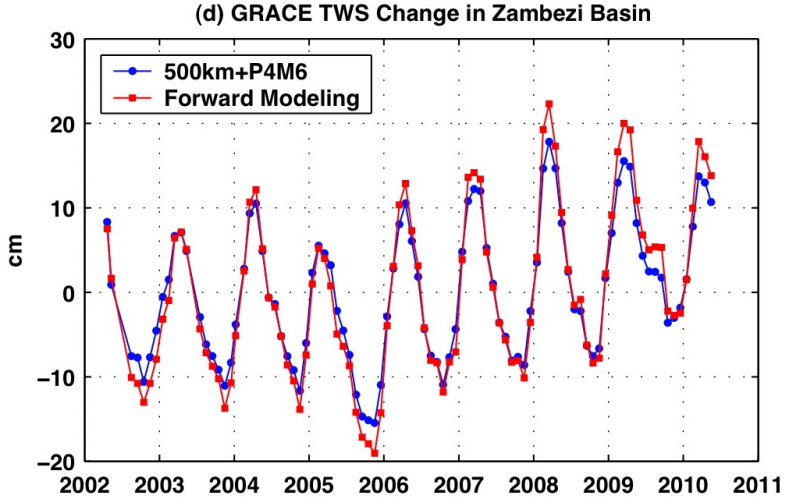





(a) GRACE TWS Change in Amazon Basin
500km+P4M6
Forward Modeling
cm
30
20
10
0
−10
−20
−30
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


(b) GRACE TWS Change in Orinoco Basin
500km+P4M6
Forward Modeling
cm
30
20
10
0
−10
−20
−30
−40
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


(c) GRACE TWS Change in Ganges Basin
500km+P4M6
Forward Modeling
cm
30
20
10
0
−10
−20
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


(d) GRACE TWS Change in Zambezi Basin
500km+P4M6
Forward Modeling
cm
30
20
10
0
−10
−20
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011