Consistency of Estimated Global Water Cycle Variations Over the Satellite Era

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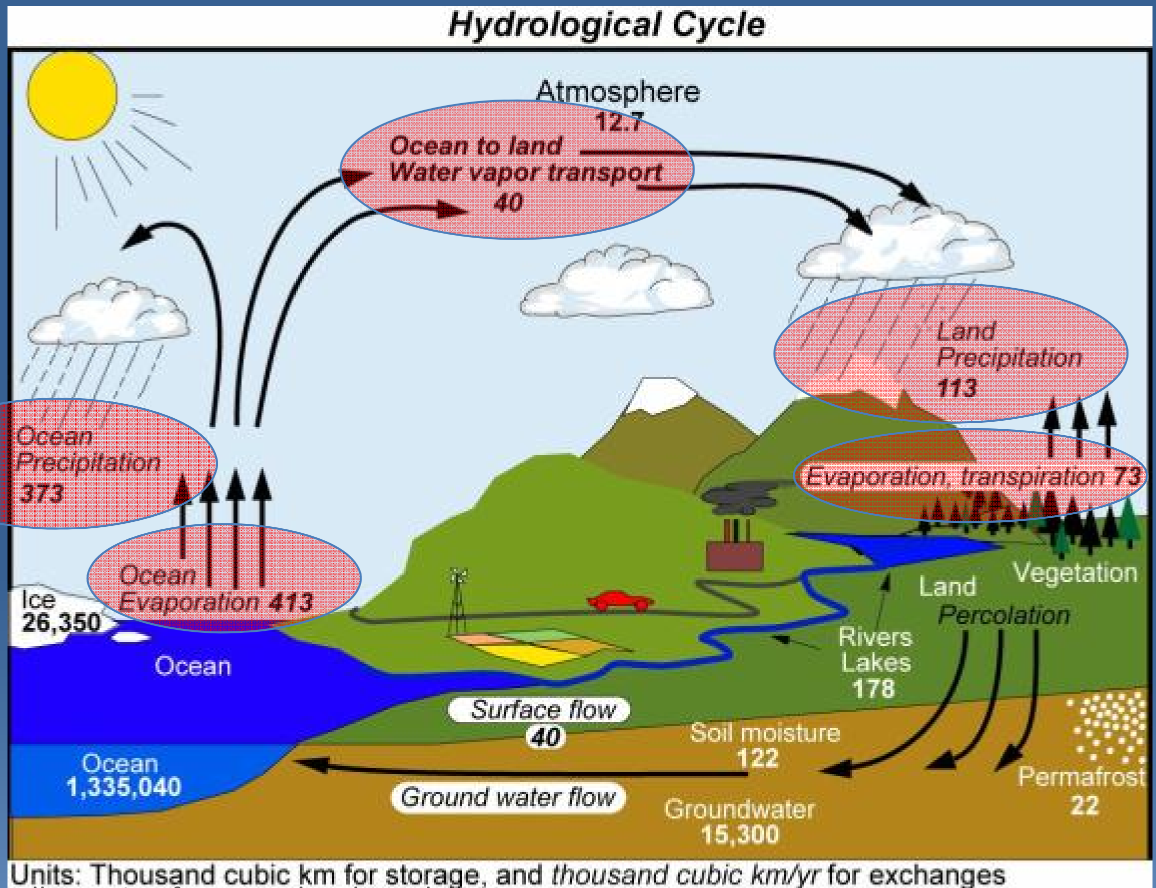


Illustration from Trenberth et al., 2007

Focus of the present work is on the
VARIABILITY of atmospheric P, ET and Transport processes

$$-\nabla \cdot \widehat{qV} = P - ET + \widehat{\partial q / \partial t}$$

Questions…

- ❑ How consistent are signals in the variability of P-ET over global land, E-P over ocean, and the implied net transport during the satellite era (Interannual Variability, Decadal-scale Shift)?

- ❑ Can we point to priorities for improvements in these retrievals or reanalyses needed to detect climate variability signals?

Approach:

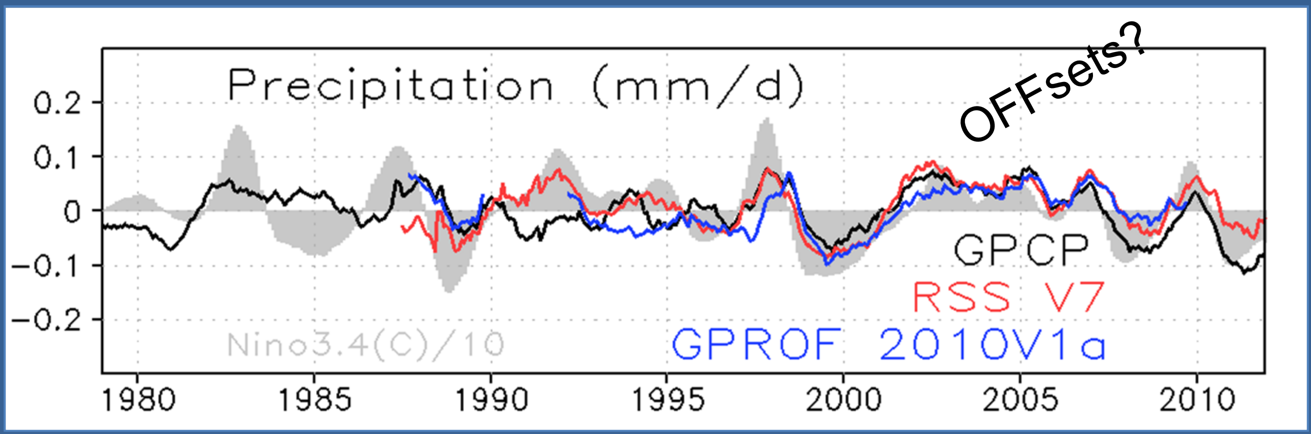
- ➢ Integrate a wide variety of satellite P, E retrievals, reanalysis vertically-integrated moisture flux divergence (over land), observationally-driven Land Surface Models.

$$-\nabla \cdot \widehat{qV} = \mathrm{P} - \mathrm{ET} + \widehat{\partial \mathrm{q} / \partial \mathrm{t}}$$

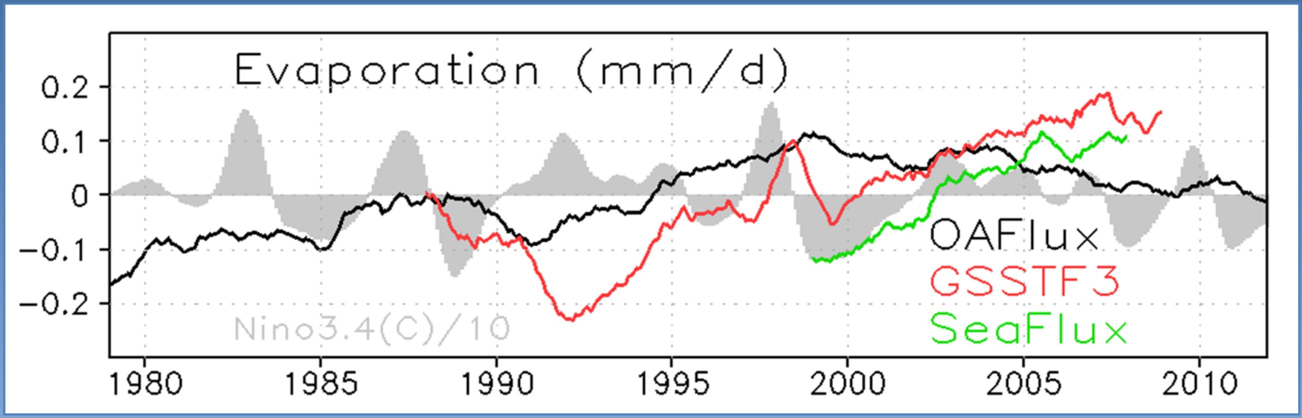
- ➢ Focus on monthly anomalies around climatology.
- ➢ Domains are near-global land and ocean area averages (60 N/S).
- ➢ 13-mo filter applied for time series display only

	Data Set	Native Resolution	Physical Basis	Reference	Comments
Remotely Sensed Precip	GPCP	2.5 deg global 1979-present	Passive micowave emission calibrates IR	Adler et al, 2003; 2012	Tied to GPCC over land
	RSS V7	0.25 deg ocean only Jul1987- present	Unified passive mico	Hilburn and Wentz, 2008	
	GPROF 2010 V1a	0.25 deg global Jul1987- 2009	Bayesian passive microwave	Kummerow et al, 2001; 2010	Lookup table uses TRMM PR
Remotely Sensed Ocean evap	OAFlux	1.0 deg 1959-present	OI blend of reans, satellite w/ buoy constraints	Yu and Weller, 2007; 2008	
	GSSTF3	1.0 deg Jul1987- 2009	Passive microwave drives COARE 3.0 bulk aero model	Shie et al, 2009; 2012	
	SeaFlux	0.25 deg 1998-2007	Neural net retrievals drive COARE 3.0 bulk aero model	Roberts et al, 2010; Clayson et al, 2013	
Obs Driven Land Surface Models	GLDAS-2 Noah	0.5 deg 1948-present	Driven by Sheffield et al, 2006 "Princeton Forcing"	Rodell et al., 2004	
	GLDAS VIC	1.0 deg 1948-2006	Driven by earlier version of "Princeton Forcing"	Sheffield et al. (2006) and Sheffield and Wood (2007)	
	MPI-BGC	0.5 deg 1982-2011	Scaling-up of FLUXNET via machine learning algorithm	Jung et al., 2009; 2010	GPCC precip used
	GPCC	0.5 deg	67,200 gauges world-wide	Schneider et al (2011; 2013)	Gauge only
	MERRA-Land	0.625 lon 0.5 lat	Offline version of MERRA Catchment LSM	Reichle et al, 2011; 2013	CPCU precip
Reanalyses (Land Only)	MERRA	0.625 lon; 0.5 lat	GEOS 5 Model; Incremental Analysis Update	Rienecker et al, 2011	Vert.-integ moisture flux diverg as corrected by NCAR/CAS (Trenberth et al., 2011)
	ERA-Interim	1.0 deg 1979-2010	ECMWF Integrated Forecast Model (IFS Cy31r2)	Dee et al, 2011	
	CFSR	1.0 deg 1979-2010	Weak ocean / atm coupling	Saha et al, 2010	

Ocean Area Average E, P Anomalies (mm d^{-1})



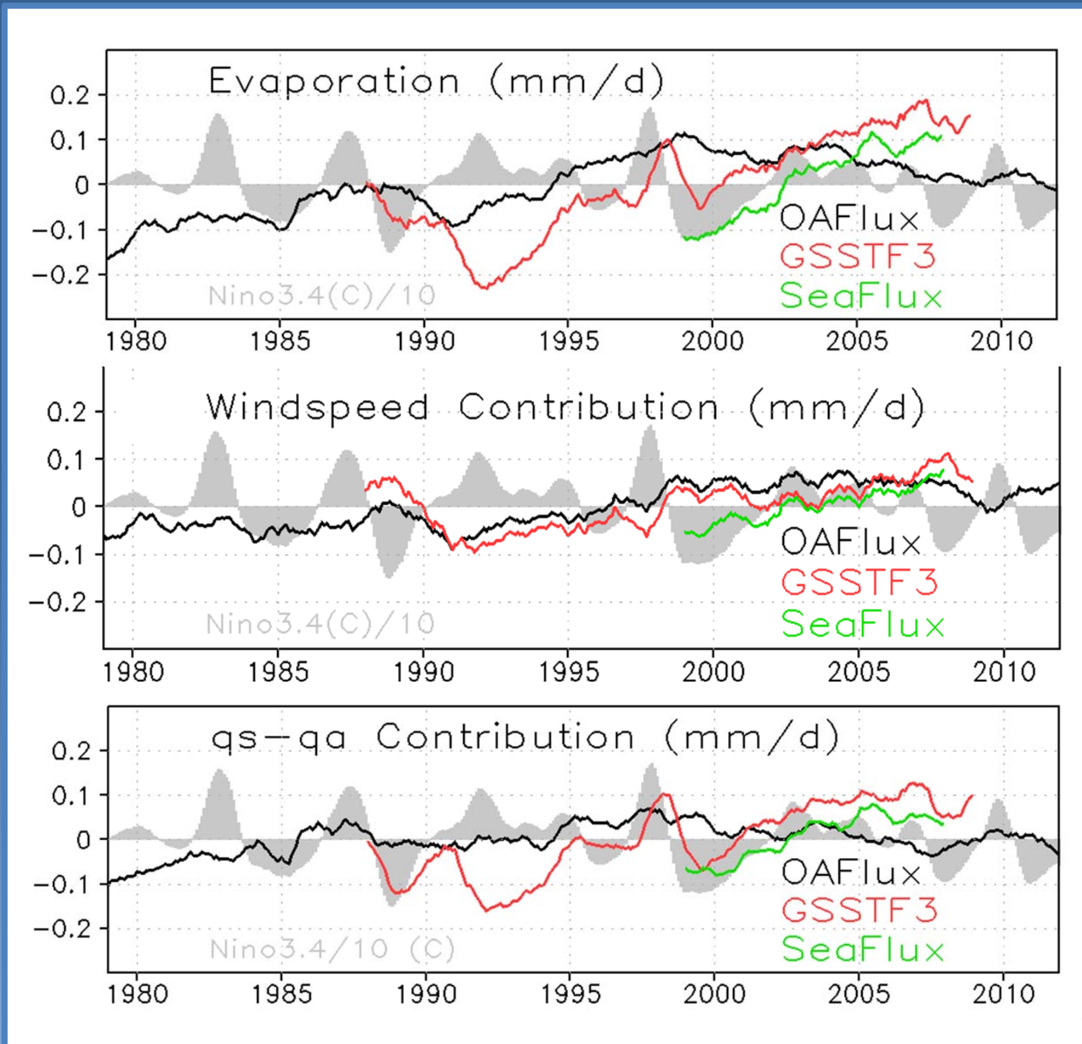
Correlation 1992 / 2009
(gpcp, rss) = .72
(gpcp, gprof) = .66
(gprof, rss) = .80



Correlation 1998 / 2007
(seaflux, oaflux) = .05
(gsstf3, oaflux) = .18
(seaflux, gssstf3) = .89

1988/2008
(gsstf3, oaflux) =.61

Wind Speed and Saturation Deficit Controls On Ocean Evaporation



Bulk Formula:

$$E = C_E \rho_a U(q_s(SST) - q_a(T_a))$$

Taylor Series Expansion:

$$\delta E = \frac{\partial E}{\partial q}\delta q + \frac{\partial E}{\partial U}\delta U + \frac{\partial E}{\partial C_E}\delta C_E$$

Moisture Deficit Sensitivity — *Wind Speed Sensitivity* — *Exch Coefficient Sensitivity*

Sensitivities:

Wind

$$\partial E/\partial U = \rho_a C_E(q_s(SST) - q_a(T_a))$$

Moisture Deficit

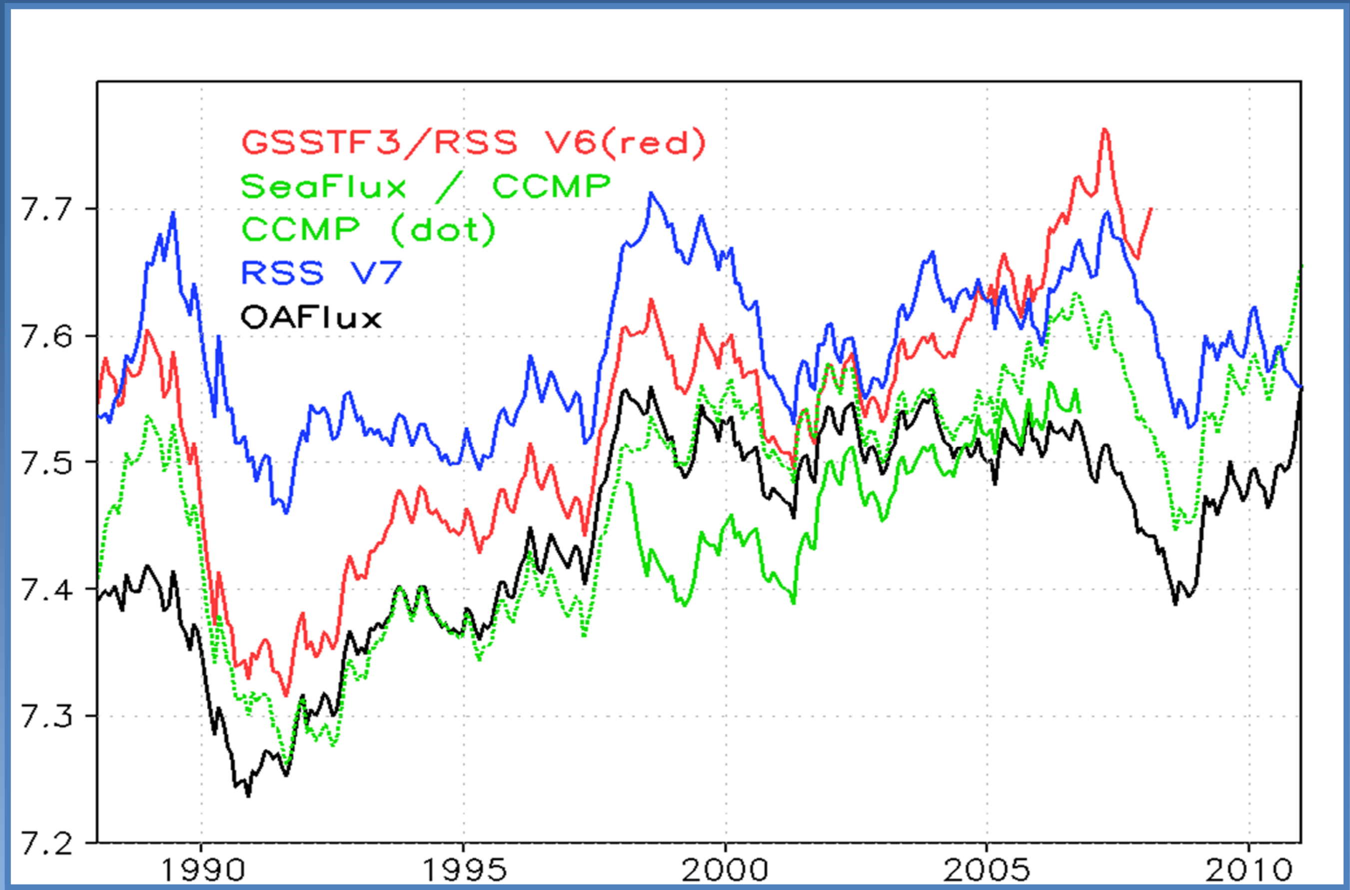
$$\partial E/\partial C_E = \rho_a U(q_s(SST) - q_a(T_a))$$

Exch Coefficient

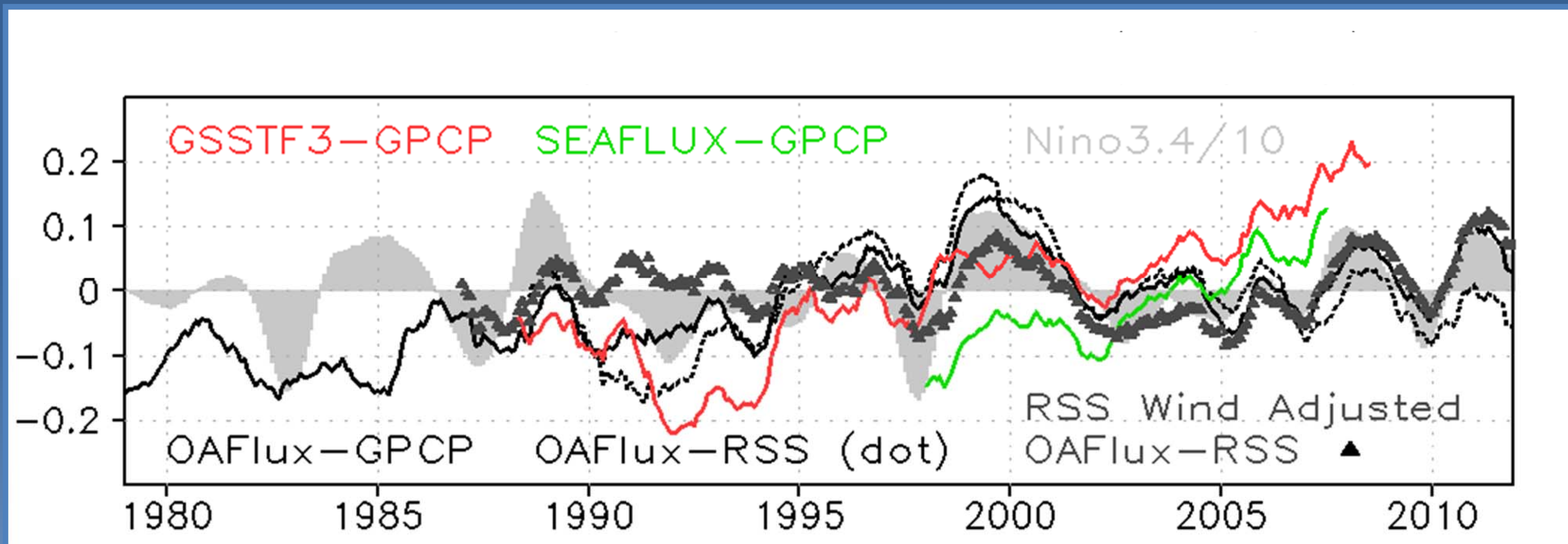
$$\partial E/\partial \Delta q = C_E \rho_a U$$

Differences Among 10m Ocean Wind Speed Products

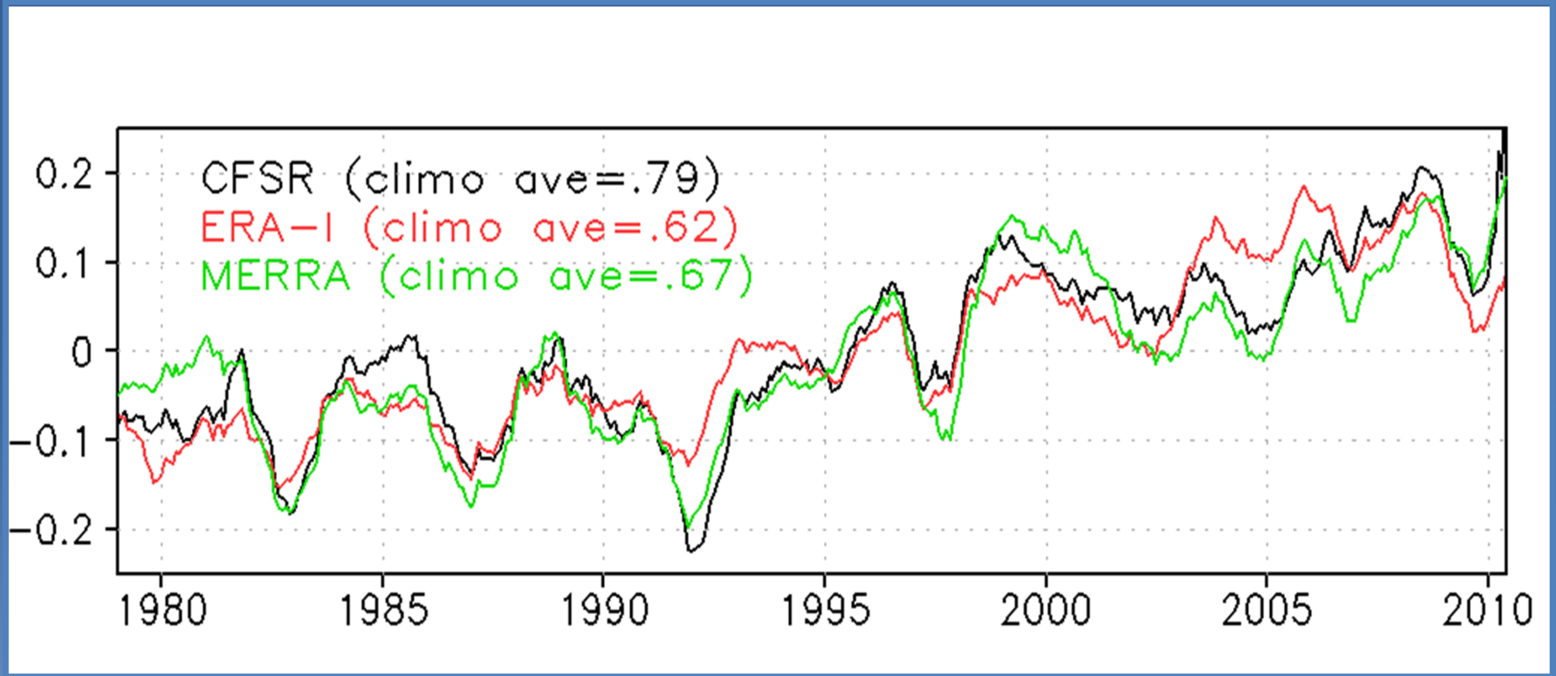
RSS V7 SSMI winds account for spacecraft Earth Incidence Angle variations (pitch/yaw/roll) and result in substantially les upward trend in speed than in earlier versions.



E-P Estimates (mm/d)from Combined Satellite Products
Ocean Area-Average 60 N/S

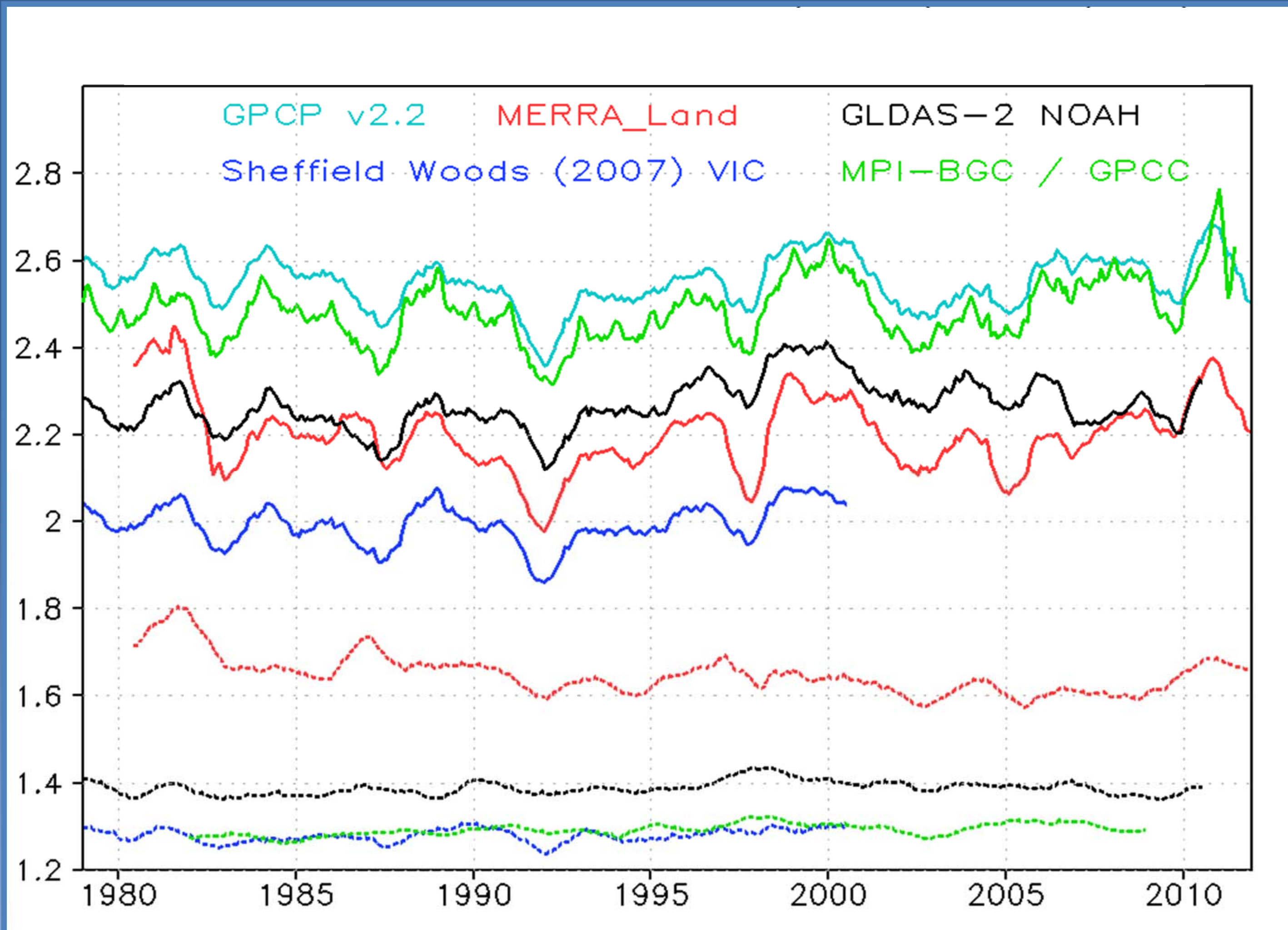


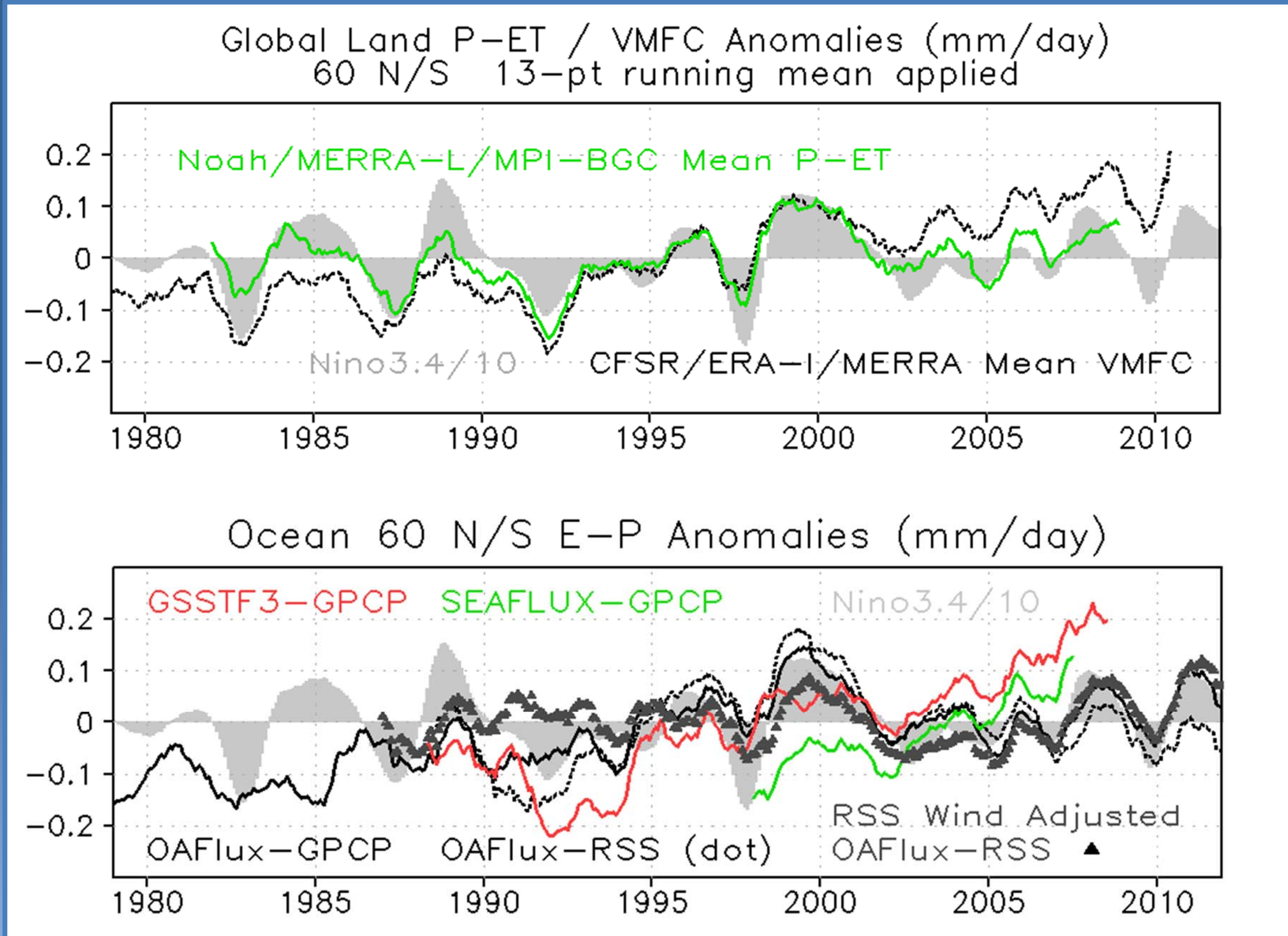
Reanalysis Vertically-Integrated Moisture Flux Convergence Anomalies (mm/d) 60 N/S



__Correlation 1979 / 2011:__ (erai, cfsr) =.85 (erai, merra)=.83 (cfsr, merra)= .88

60 N/S De-seasonalized (anomaly + mean) Land P (solid) and ET (dotted) mm/d

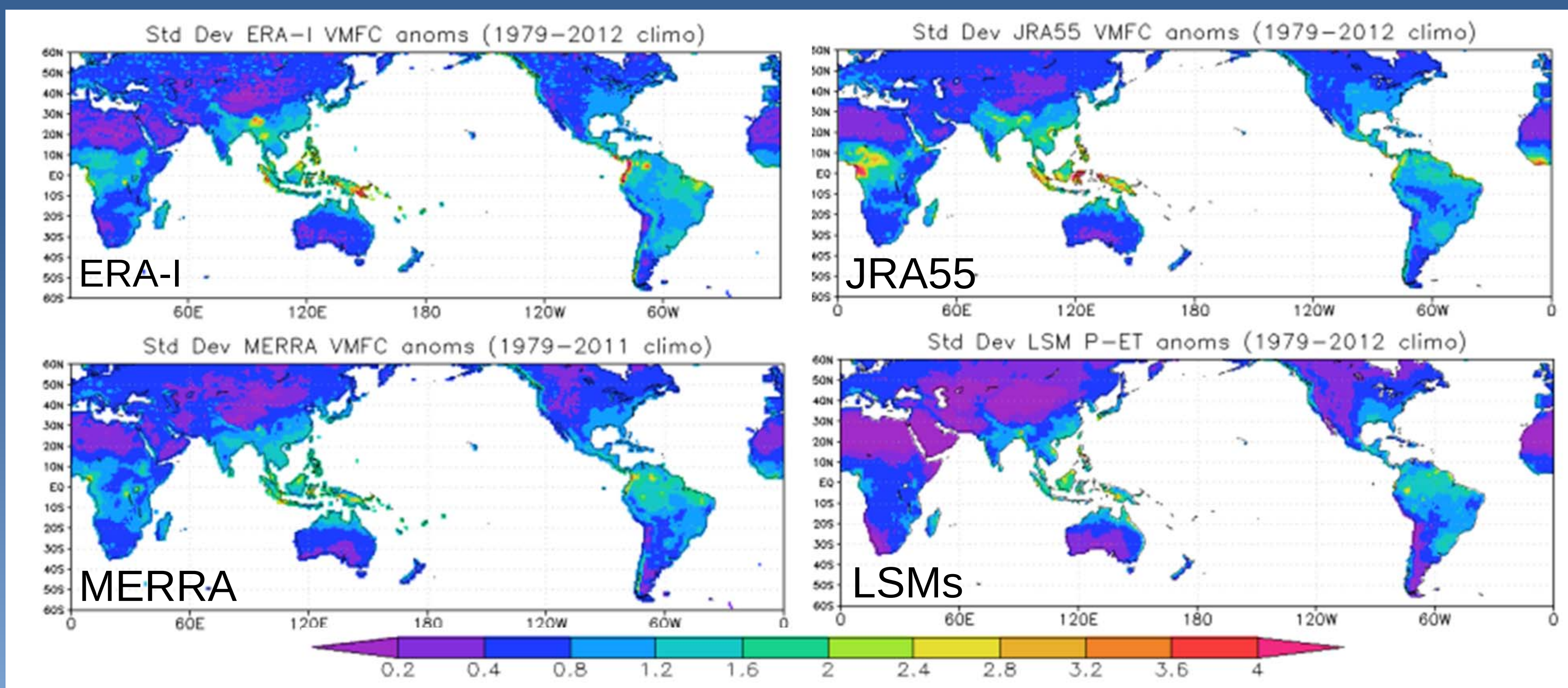



Global Land P−ET / VMFC Anomalies (mm/day)
60 N/S 13−pt running mean applied
Noah/MERRA−L/MPI−BGC Mean P−ET
Nino3.4/10
CFSR/ERA−I/MERRA Mean VMFC
0.2
0.1
0
−0.1
−0.2
1980
1985
1990
1995
2000
2005
2010
Ocean 60 N/S E−P Anomalies (mm/day)
GSSTF3−GPCP
SEAFLUX−GPCP
Nino3.4/10
RSS Wind Adjusted
OAFlux−GPCP
OAFlux−RSS (dot)
OAFlux−RSS ▲

Std Dev of Monthly P-ET Anomalies (mm/d) 1979 to Present

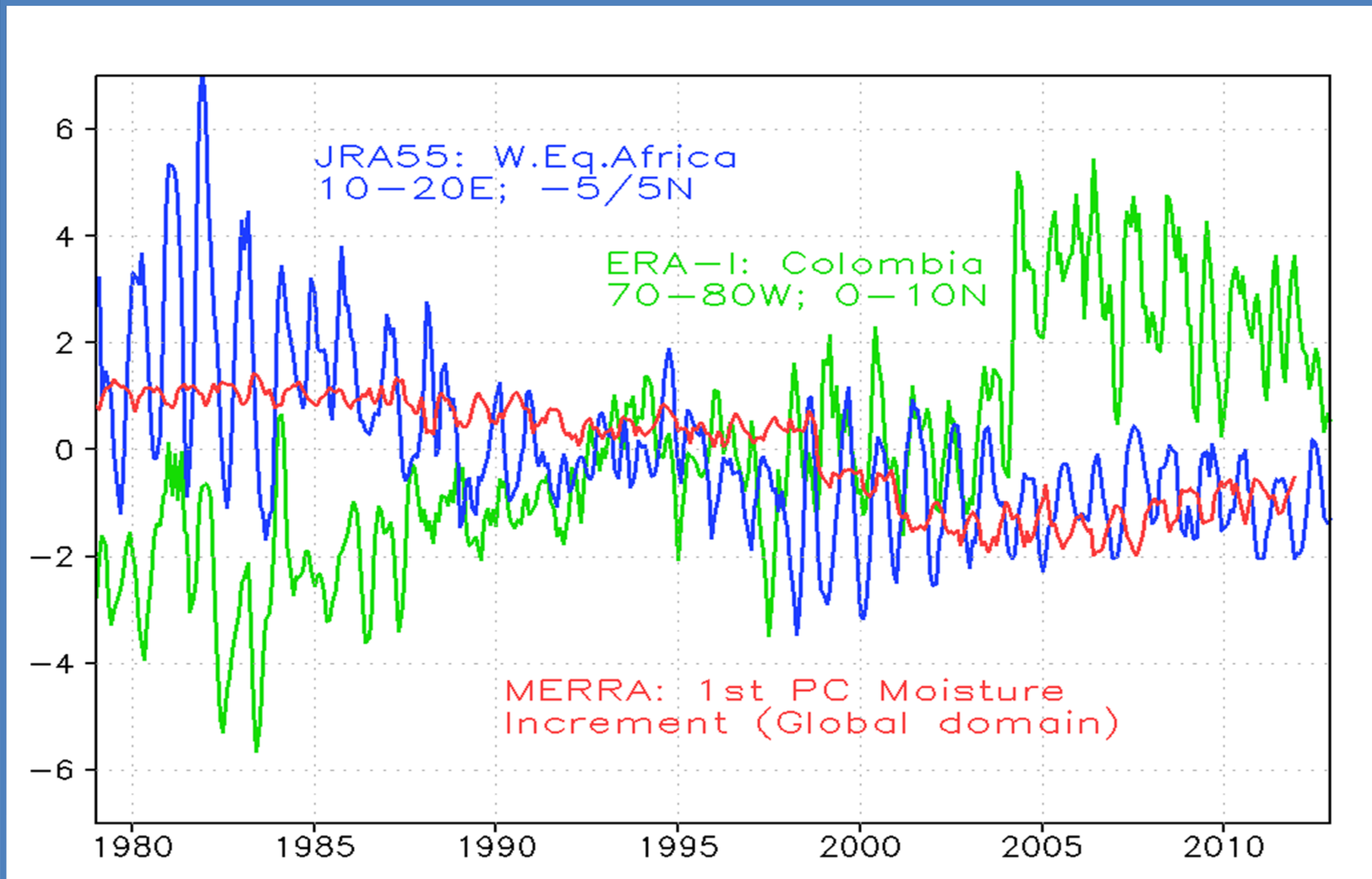
- LSM is mean of GLDAS-2 Noah, MERRA-Land and MPI-BGC ET w/GPCC precip.
- Reanalyses are vertically-integrated moisture flux convergence ($-\nabla \cdot q\mathbf{V}$).

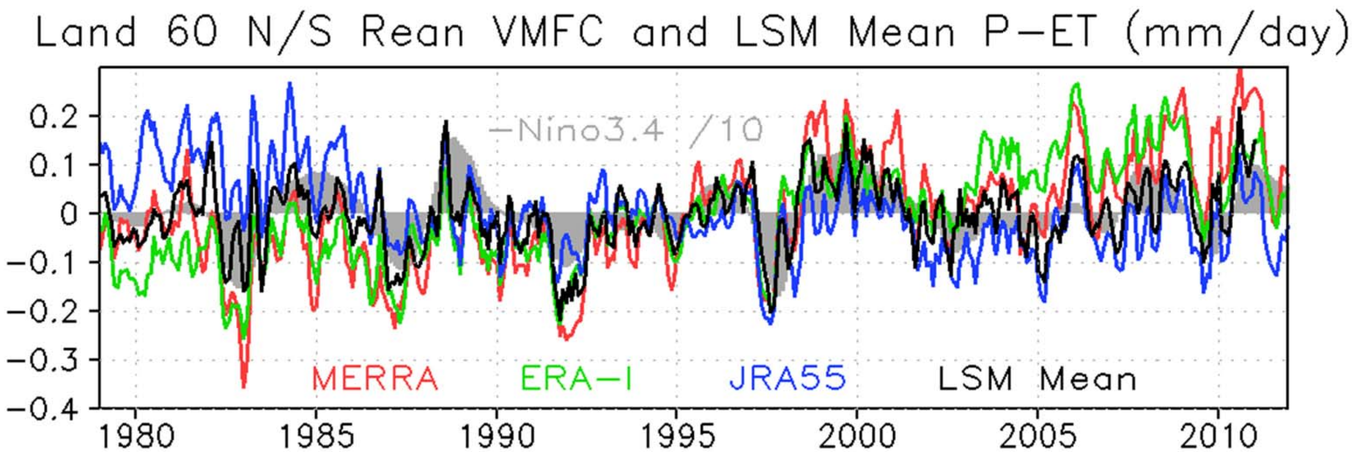
Significant differences between LSMs and reanalyses are apparent over central Africa

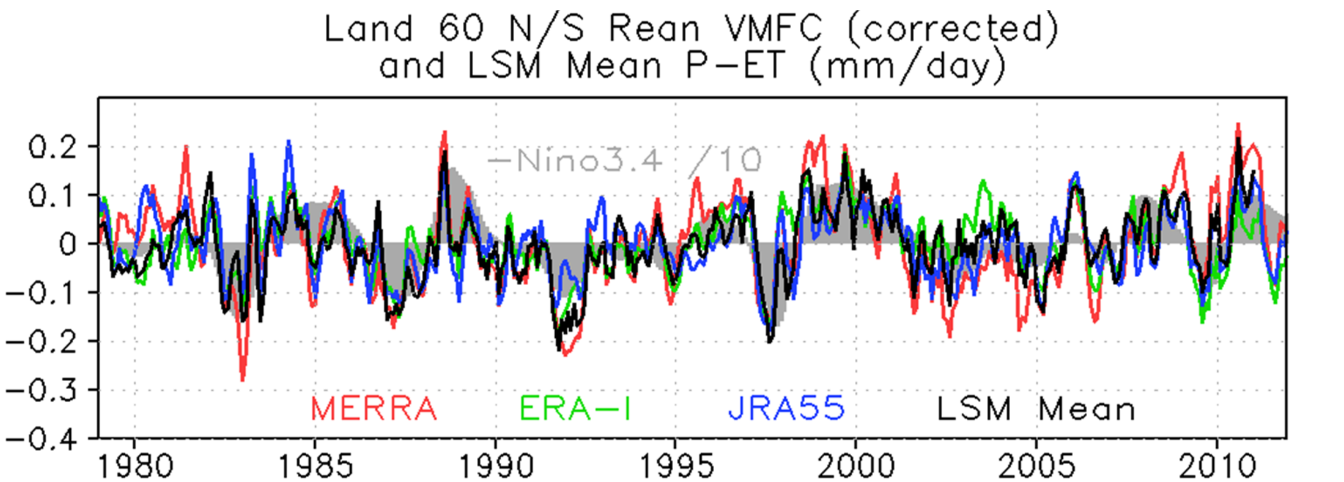


Leading $-\widehat{\nabla \cdot qV}$ Artifacts in Reanalyses

ERA-I and JRA 55 units (mm/) MERRA PC1 is non-dimensional




Land 60 N/S Rean VMFC and LSM Mean P–ET (mm/day)
–Nino3.4 /10
MERRA
ERA–I
JRA55
LSM Mean
0.2
0.1
0
–0.1
–0.2
–0.3
–0.4
1980
1985
1990
1995
2000
2005
2010


Land 60 N/S Rean VMFC (corrected)
and LSM Mean P–ET (mm/day)
–Nino3.4 /10
MERRA
ERA–I
JRA55
LSM Mean
0.2
0.1
0
–0.1
–0.2
–0.3
–0.4
1980
1985
1990
1995
2000
2005
2010

Conclusions

1. Ocean LHF uncertainties from satellite-derived component qs-qa and wind speeds combine with remaining problems in P retrievals to prevent P-E estimates with sufficient accuracy to monitor decadal changes in land /ocean moisture transport variations. *However, prospects for improved retrievals by accounting for spacecraft EIA variations are very good.*

2. Reanalysis VMFC have systematic errors arising from input data inconsistencies that induce erroneous trends. To first order these can be identified and removed. *Resulting VMFC variations over global land show substantial agreement with largely independent, observationally-forced LSMs.*

3. Using monthly data the largest signals in the land ➔ ocean moisture transport (P-ET) are those of ENSO with net transport decreasing (increasing) during warm (cold) events. *Transport variations are consistent with both IA as well as lower frequency ENSO signals.*

4. Further work on the fidelity of important regional pattern variations and trends is underway.