SATELLITE-DERIVED CLIMATE DATA RECORDS OF AIR-SEA FLUXES:

PROGRESS AND ISSUES

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with

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Turbulent heat fluxes from satellite

- Over the ocean: from satellite we estimate the fluxes from the bulk equations, e.g.:

$$Evaporation = r\,\overline{w'q'} = r(U_a - U_s)C_E(q_a - q_s)$$

- Subscripts a and s denote values pertaining to the atmosphere at height z_h and at surface

- C_E: bulk transfer coefficients: coefficients of water vapor exchange (also called Dalton number)

- Thus to calculate evaporation correctly we need: U_a, U_s, q_s, q_a and an appropriate model of C_E

Datasets

- Satellite
  - SeaFlux-v3: includes SSM/I, SSMIS, and other passive microwave data; OISST + diurnal SST; neural net retrievals of Qa, Ta, U
  - HOAPS 4.1: includes SSM/I, SSMIS. AVHRR-only OISST, uses 1D-Var scheme for wind speed; Qa is from Bentamy (2003) linear regression
  - IFREMER v4.1: winds combination of scatterometer retrievals; Qa retrieval dependent on SST, stability (from ICOADS and ERA-I).
  - J-OFURO3 V1.1: winds combination of passive microwave and scatterometer; SST from ensemble of 12 analyses; Qa comes from SSM/I brightness temperatures plus information from integrated water vapor, ERA-I reanalysis.
- RedObs: Reanalyses that withhold satellite data: JRA55C, CERA-20C, NOAA ESRL 20CR
- OAFlux: assimilates buoys, satellite, ERA-I, ships
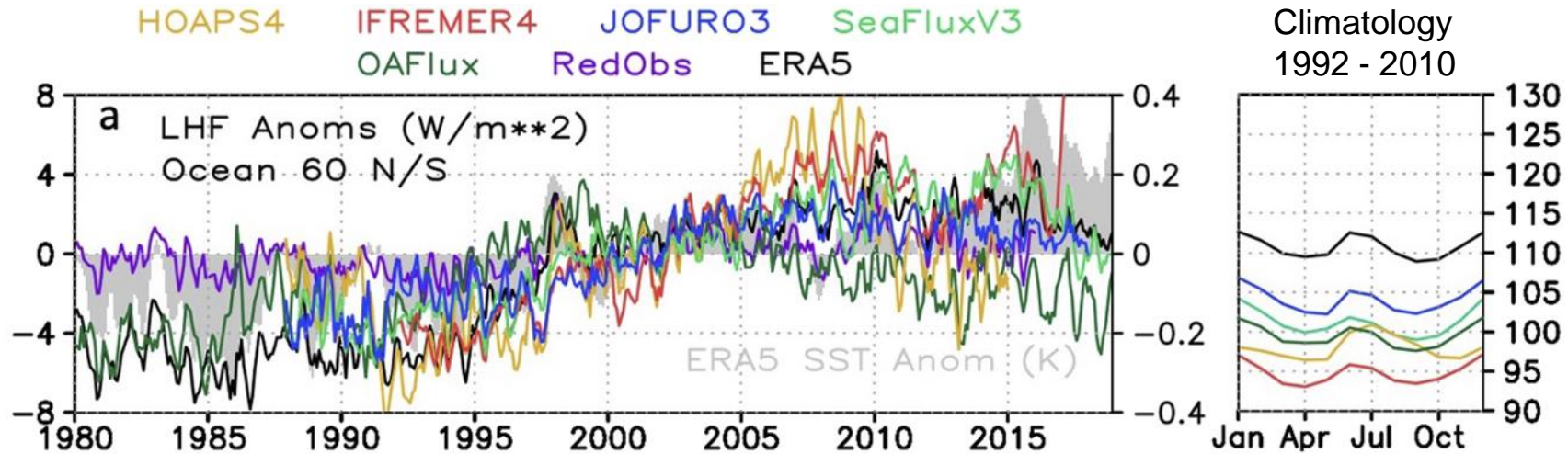- ERA5

Turbulent fluxes from satellite product SeaFlux v3

- Data is hourly at a 25-km equal area grid from 1988 – 2018
- 31-year mean values of Qa, Ta, Ua, SST, and LHF and SHF (colors) with the corresponding mean uncertainty shown as contours with labeled

| Variable	Global mean	Global mean uncertainty
LHF (W m^{-2})	95.4	4.2 (4.4%)
SHF (W m^{-2})	19.5	1.0 (5.3 %)
Windspeed (m s^{-1})	7.44	0.057 (< 1%)
Qa (g kg^{-1})	11.0	0.083 (< 1%)
Ts (^{o}C)	18.2	0.11 (< 1%)
Ta (^{o}C)	16.7	0.047 (<1%)
Ts - Ta (^{o}C)	1.56	0.06 (<1%)
Qs - Qa (g kg^{-1})	3.73	0.15 (4.1%)
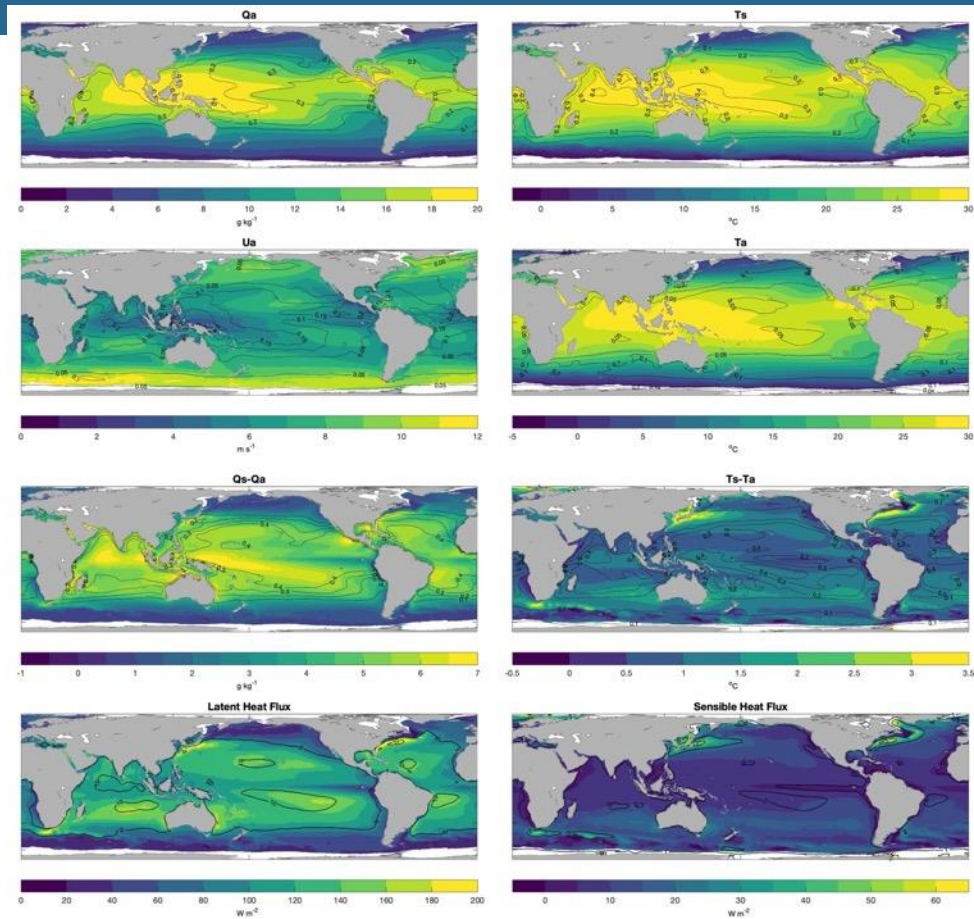
What is the global trend in ocean evaporation?

- ☐ Globally different satellite products have varying ocean evaporation trends

HOAPS4   IFREMER4   JOFURO3   SeaFluxV3
OAFlux   RedObs   ERA5

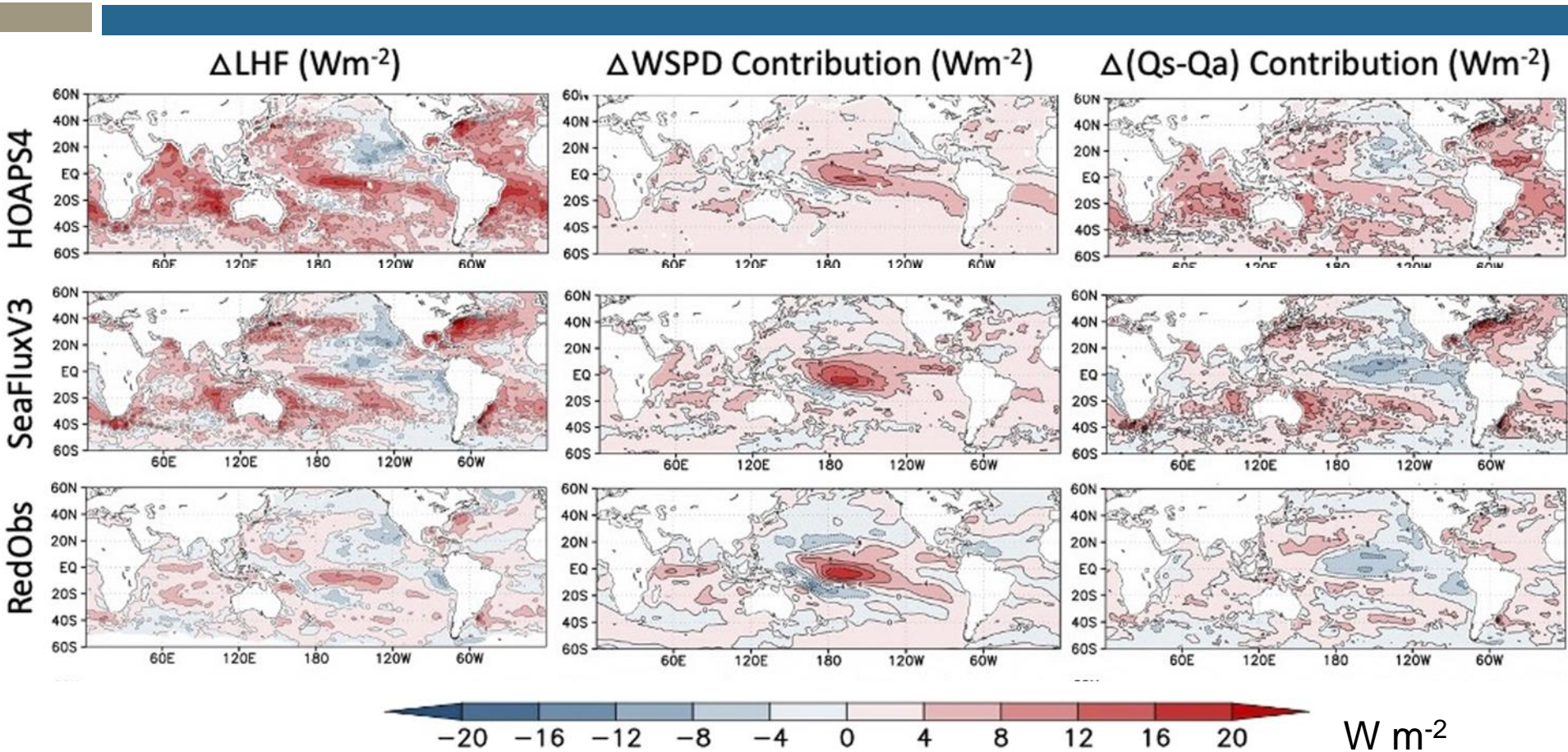Climatology 1992 - 2010

(Robertson et al. 2020)

How does this differ from model estimates?

- Globally different satellite products have varying ocean evaporation trends
  - Models with no satellite data (RedObs) have quite similar trends to each other (but not necessarily to satellite)
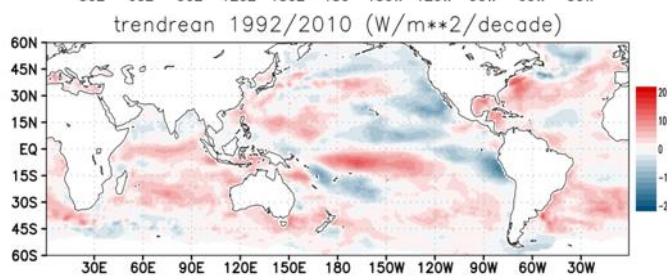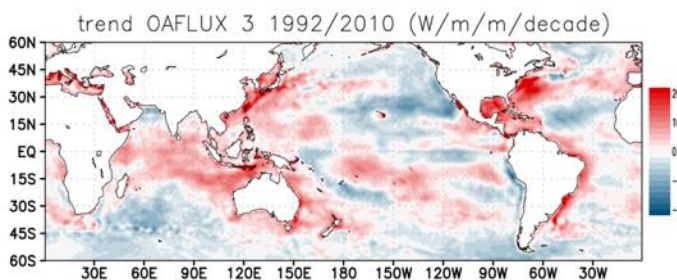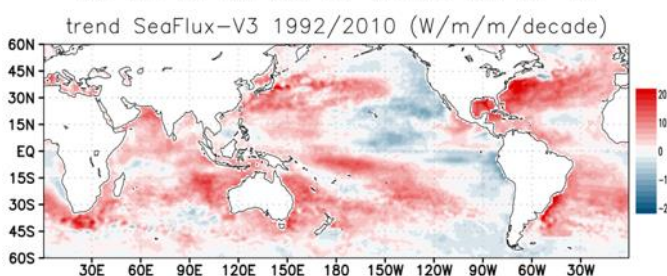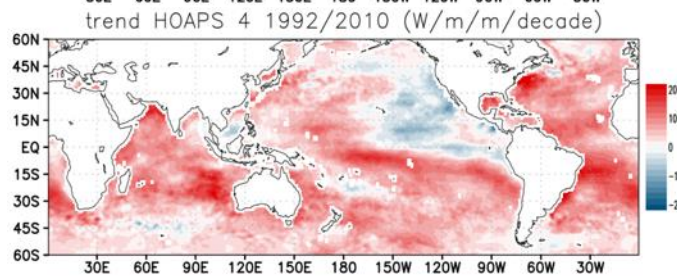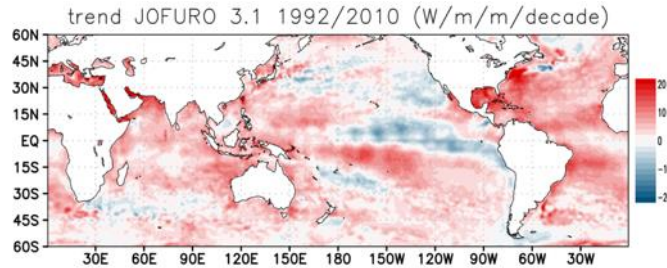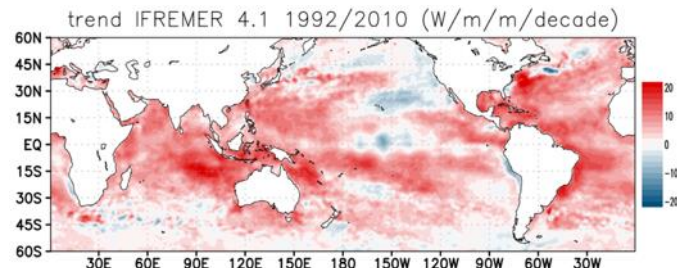

Climatology 1992 - 2010
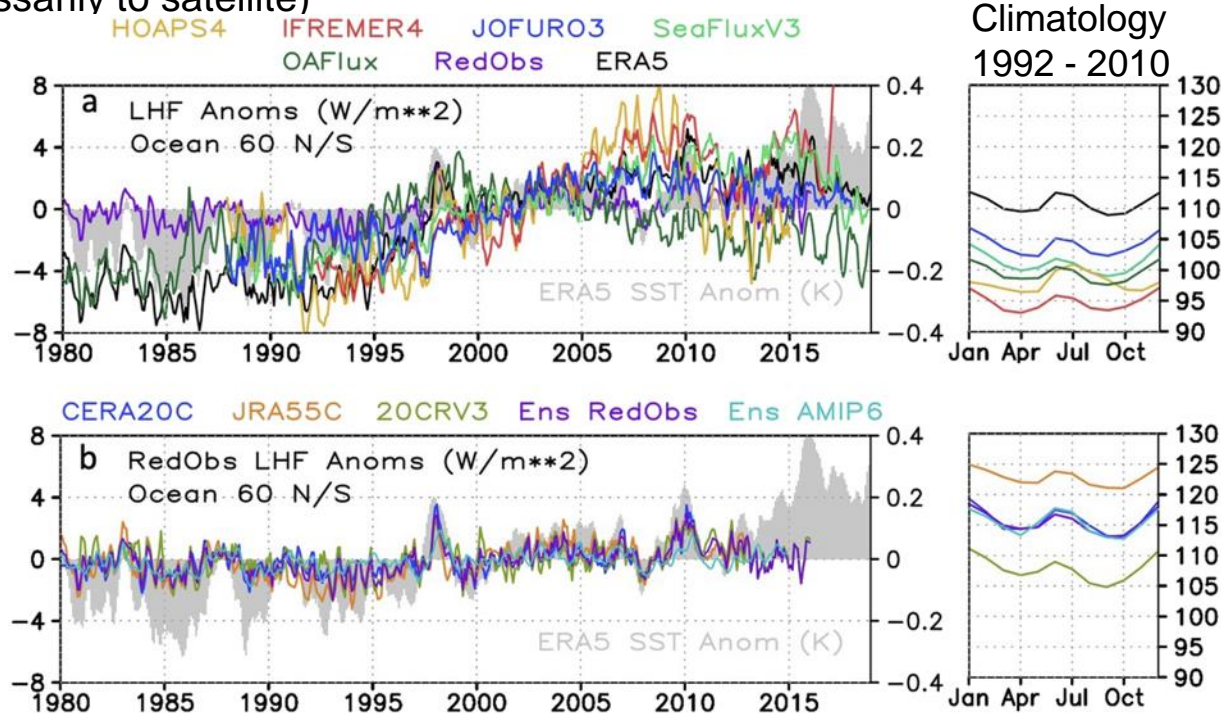
(Robertson et al. 202...)

Trends in winds vs. trends in humidity difference

LHF trends (1992/1999 to 2000/2010)

trend IFREMER 4.1 1992/2010 (W/m/m/decade)

trend JOFURO 3.1 1992/2010 (W/m/m/decade)

trend HOAPS 4 1992/2010 (W/m/m/decade)

trend SeaFlux−V3 1992/2010 (W/m/m/decade)

trend OAFLUX 3 1992/2010 (W/m/m/decade)

trendrean 1992/2010 (W/m**2/decade)

- All estimates indicate positive globally averaged trends but with downward trends over the eastern Pacific and within the SPCZ.
- IF4 and HO4 have systematically much larger trends than SFV3, JOF3 or RedObs owing to a combination of wind speed, qs(sst).
- JOF3 and IF4 show presence of TAO buoy data effects b/c they use ERA-I moisture data in their qa estimates.
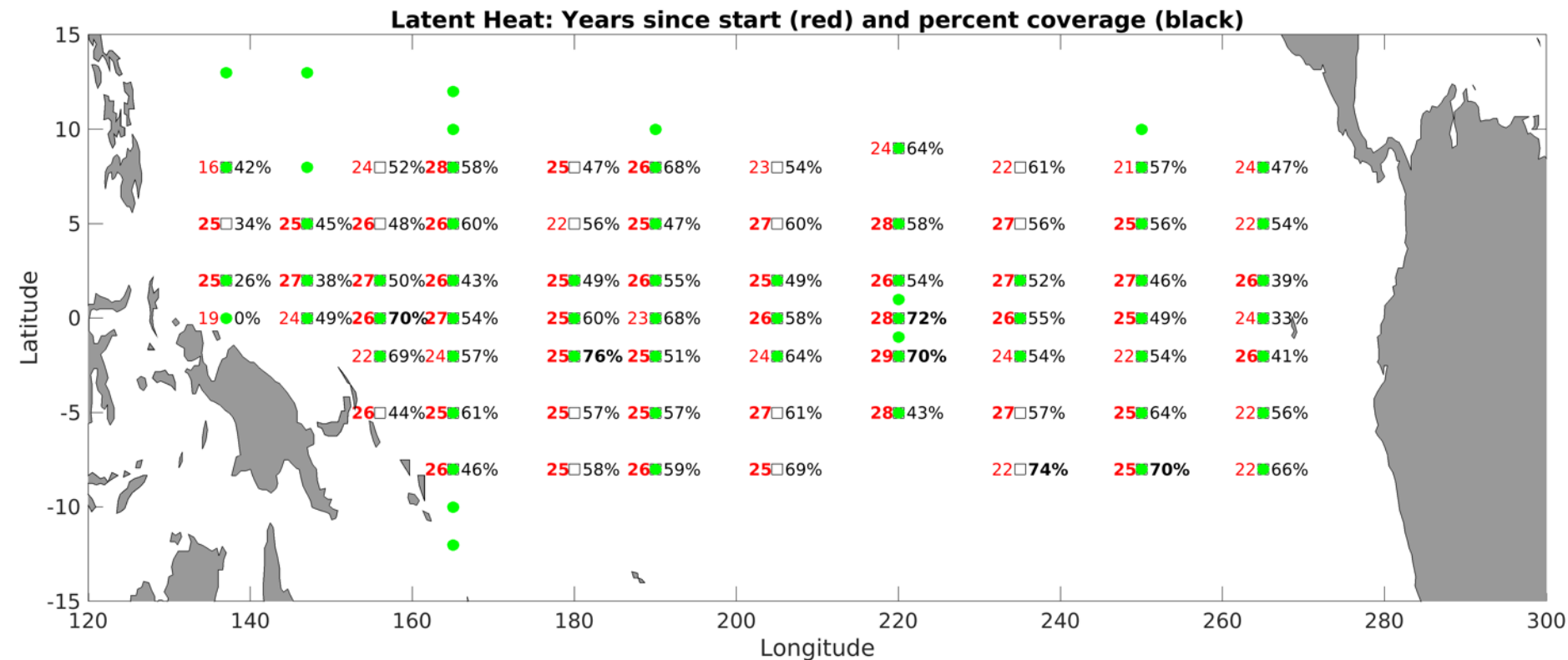
Tropical Pacific LHF Trends
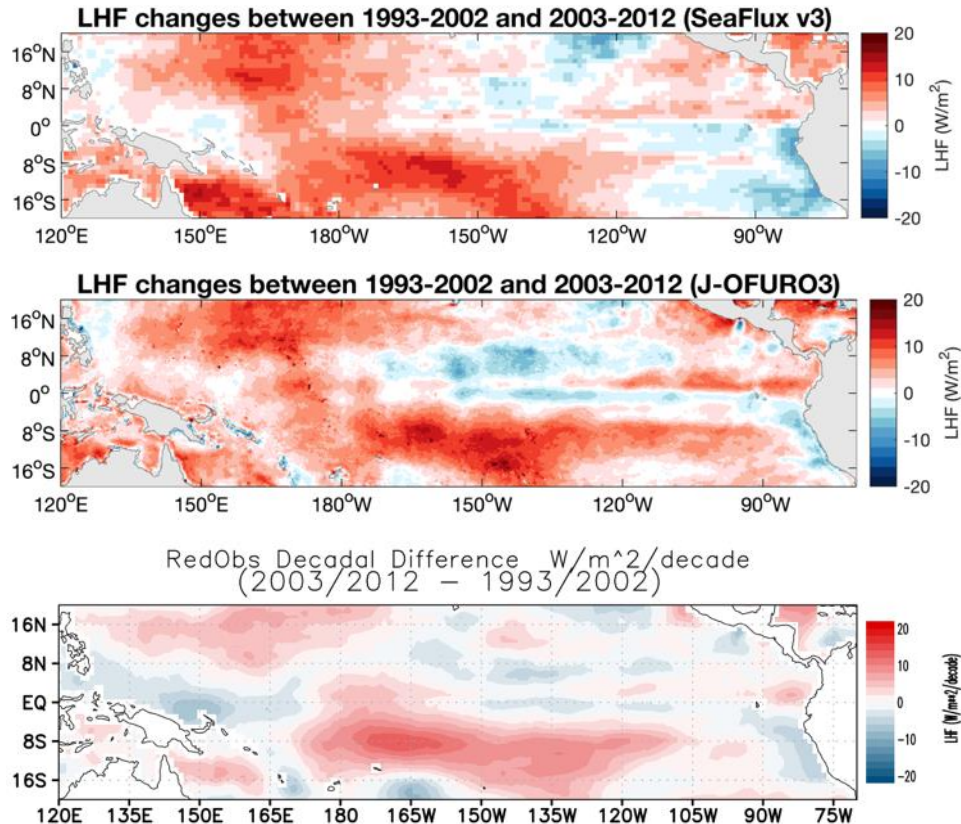
What can buoys tell us?

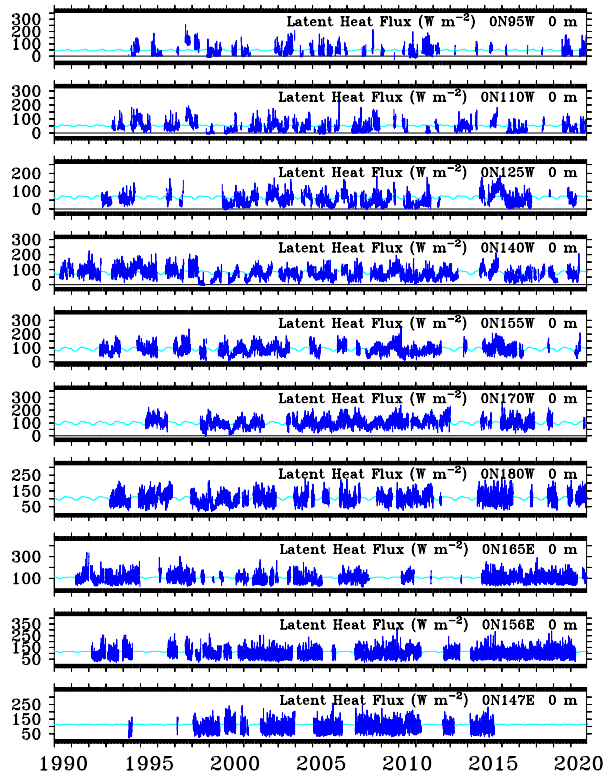☐ The conclusion first: some information but only after very careful analysis

(TPOS Second Report)

What can buoys tell us?

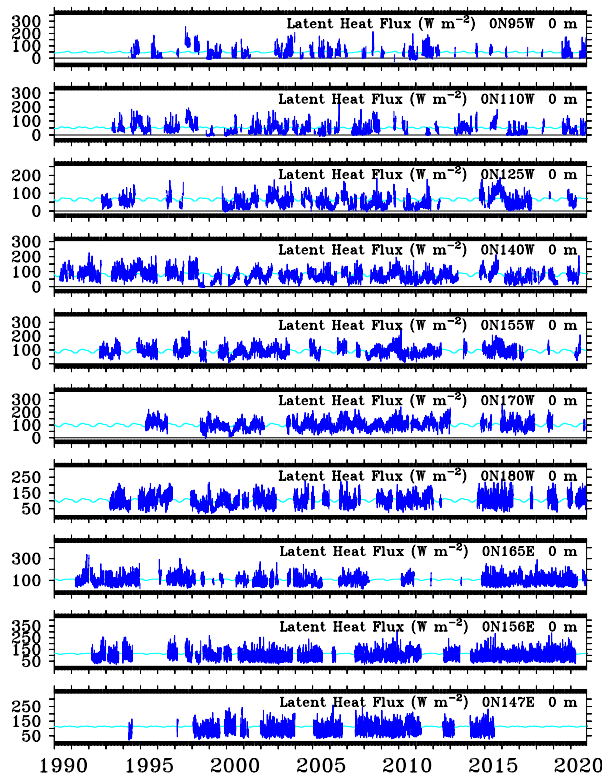*(TPOS Second Report)*
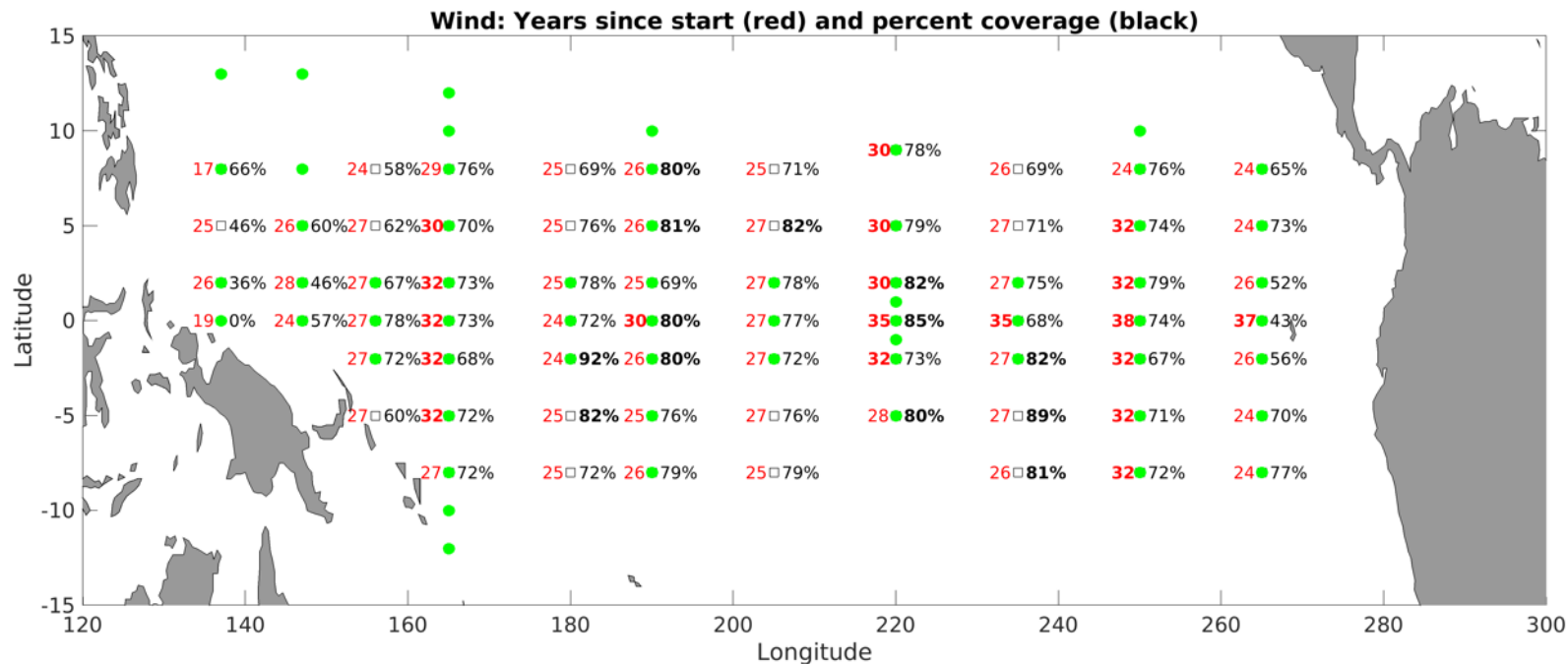
Example of temporal coverage

Daily Data

- Daily data: fluxes calculated from daily averages of winds, temperatures, humidities

- Percentages are months with > 75% data since start of individual buoy record
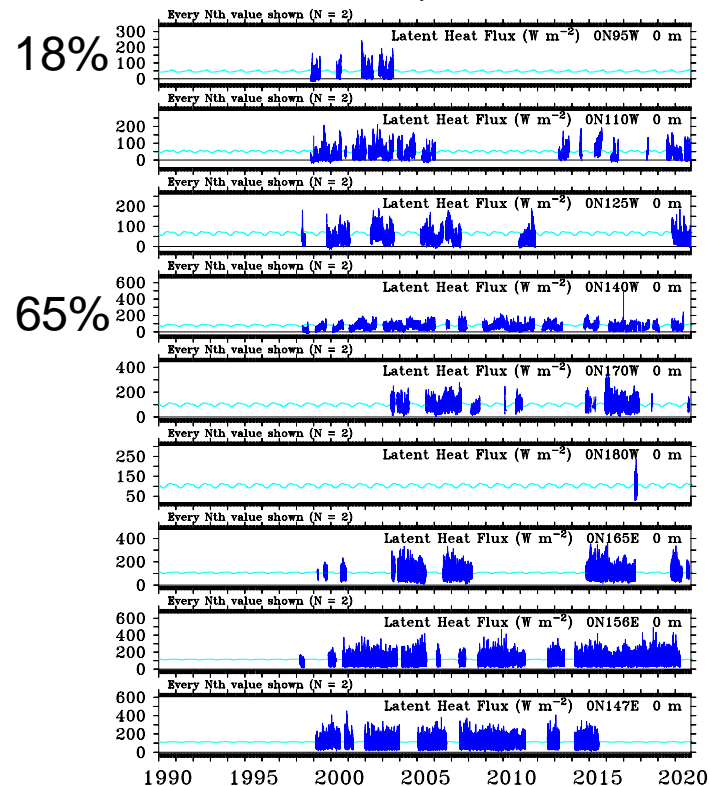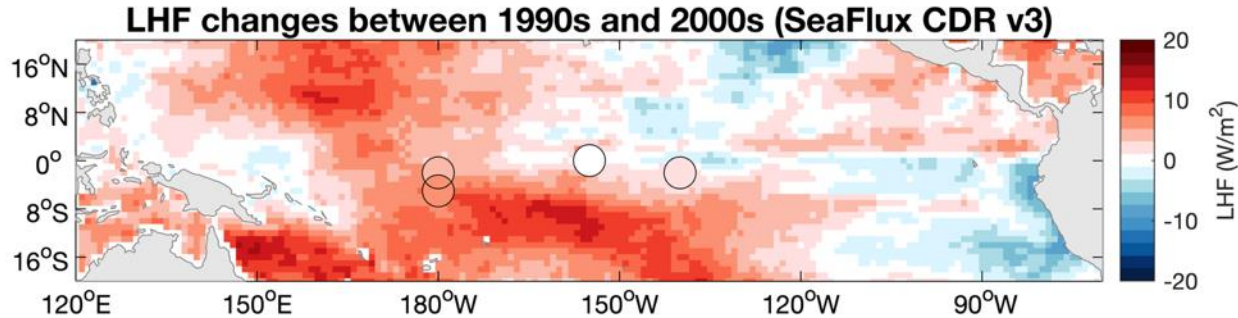
Example of temporal coverage

Daily Data

Hourly Data

39%

18%

72%

65%

Tropical Pacific Variability

LHF changes between 1990s and 2000s (SeaFlux CDR v3)
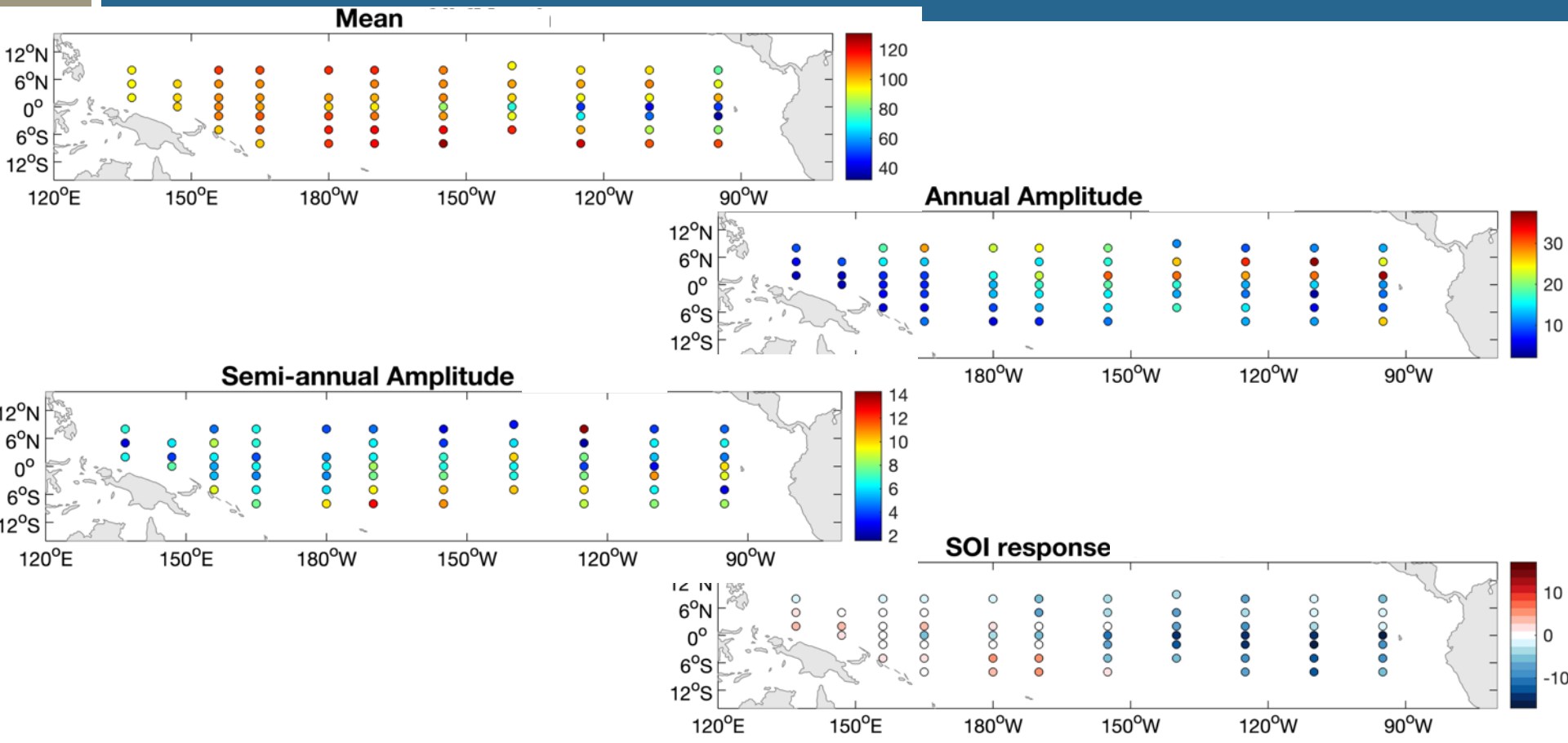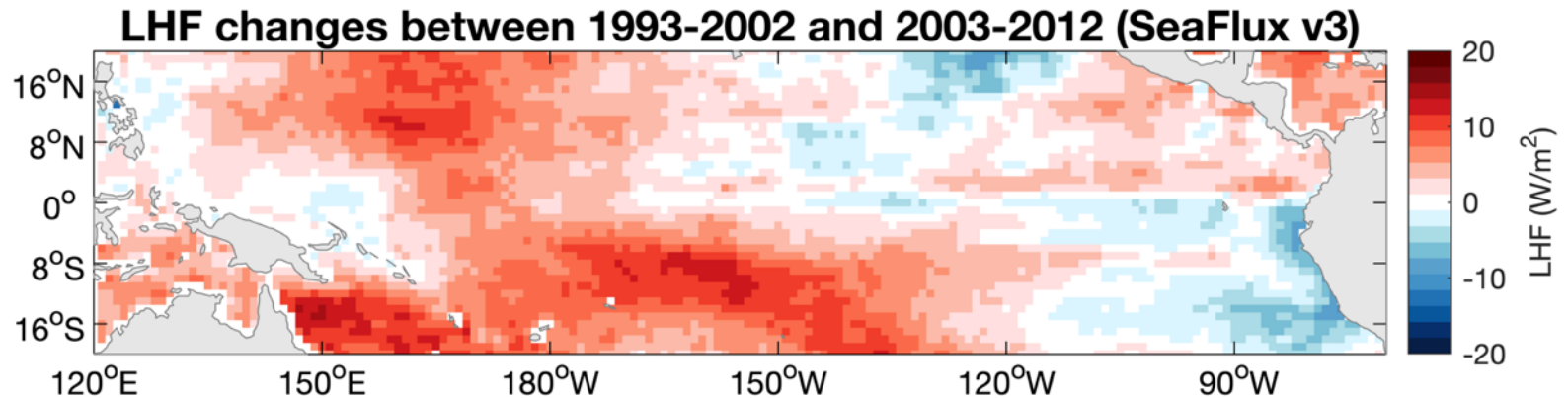
- Buoy monthly means only calculated for buoys with more than 70% data in a given month
- Buoy decadal values only calculated for buoys with more than 70% of the months

LHF cycles and trends from buoy data

Linear Change/decade

LHF changes between 1993-2002 and 2003-2012 (SeaFlux v3)

Tropical Pacific LHF Trends

LHF changes between 1993-2002 and 2003-2012 (SeaFlux v3)

Linear Change/decade for LHF

RedObs Decadal Difference W/m^2/decade
(2003/2012 − 1993/2002)

Other buoy issues: quality of trends

8n155w 10m Neutral Buoy/Scat speed (blues) and direction(red) bias . = ASCAT o=Quickscat

Ratio of wind speeds Buoy to satellite

Difference in direction Buoy to satellite

Analysis by TPOS Wind Team (O'Neill, Wijffels, McGregor, Farrar, Cla

Other buoy issues: quality of trends

8n155w 10m Neutral Buoy/Scat speed (blues) and direction(red) bias . = ASCAT o=Quickscat

8n155w Corrected 10n Buoy/Scat speed ratio (blues), direction difference(red) . = ASCAT o=Quickscat

Ratio of wind speeds Buoy to satellite

Difference in direction Buoy to satellite

Errors correlated with dynamical regimes

Figure 1. Mean differences (product minus observations) are shown for (a) JOFUROv2, (b) JOFUROv3, (c) GSSTFv3, (d) IFREMERv4, (e) HOAPSv3.2, and (f) SEAFLUXv2 over the common period 19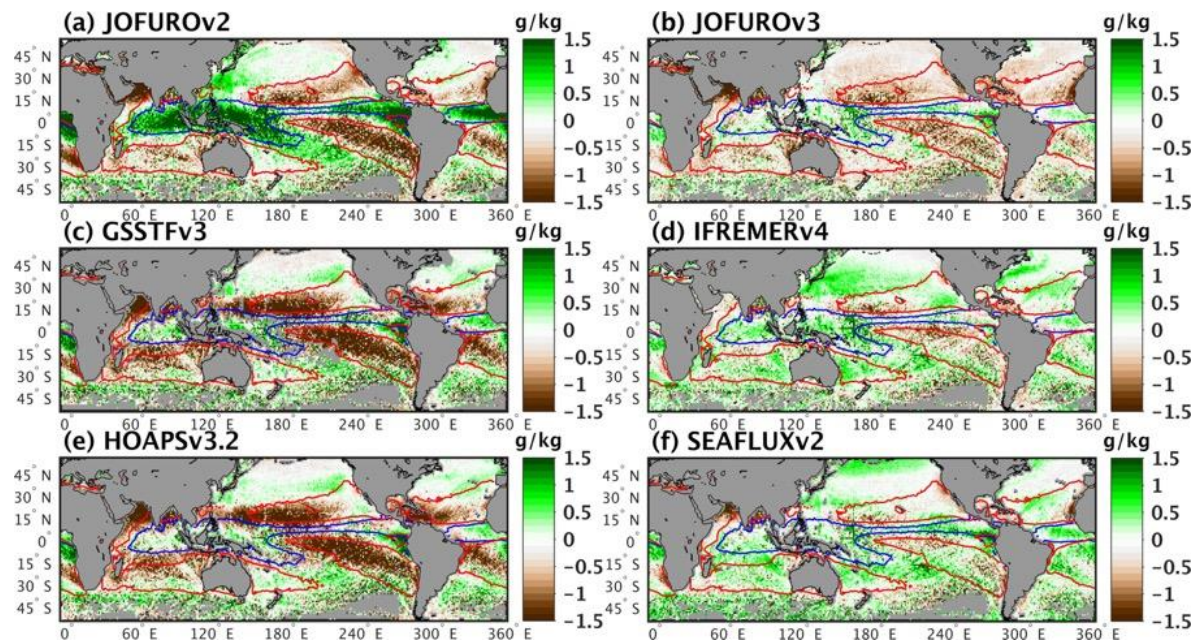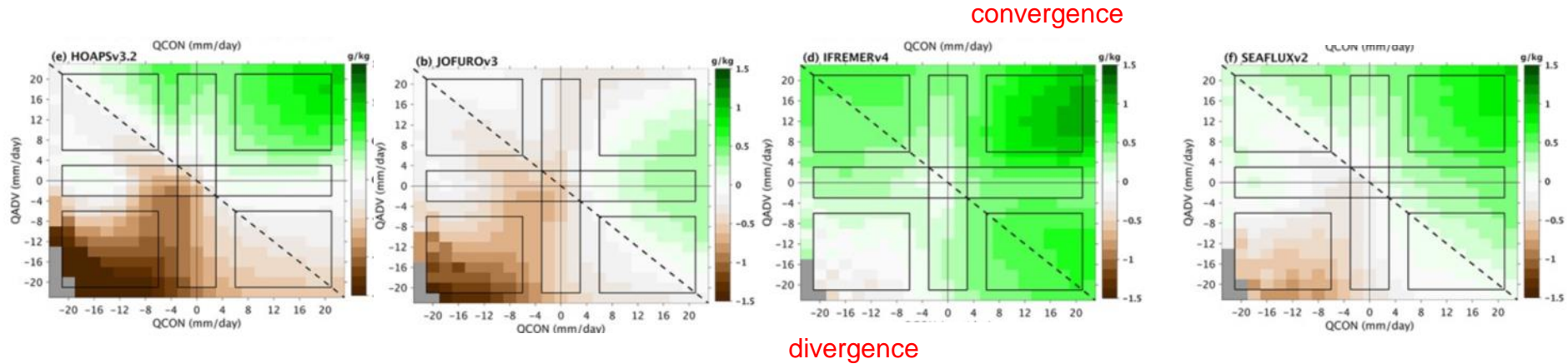99-2008. Red (blue) contours outline the 15% relative frequency of occurrence regions for the subtropical inversion layer/A0C- (deep convective/A0C+) dynamical regimes.

Roberts et al. 2019

Impact of columnar and BL water vapor

☐ Issues with retrievals dependent on boundary layer water vapor fraction (currently we use MERRA for this value in SeaFlux)

Roberts et al. 2019

Gains in consistency

Evolution of Pssive Microwave LHF Retrievals (W/m/m)

SeaFlux—V3 (V2 dot)   HOAPS4.1 (V3 dot)
IFREMER4.1 (V3 dot)   JOFURO3 P04 (V2 dot)
RedObs   OAFlux   GSSTF3 (dot)   ERA5
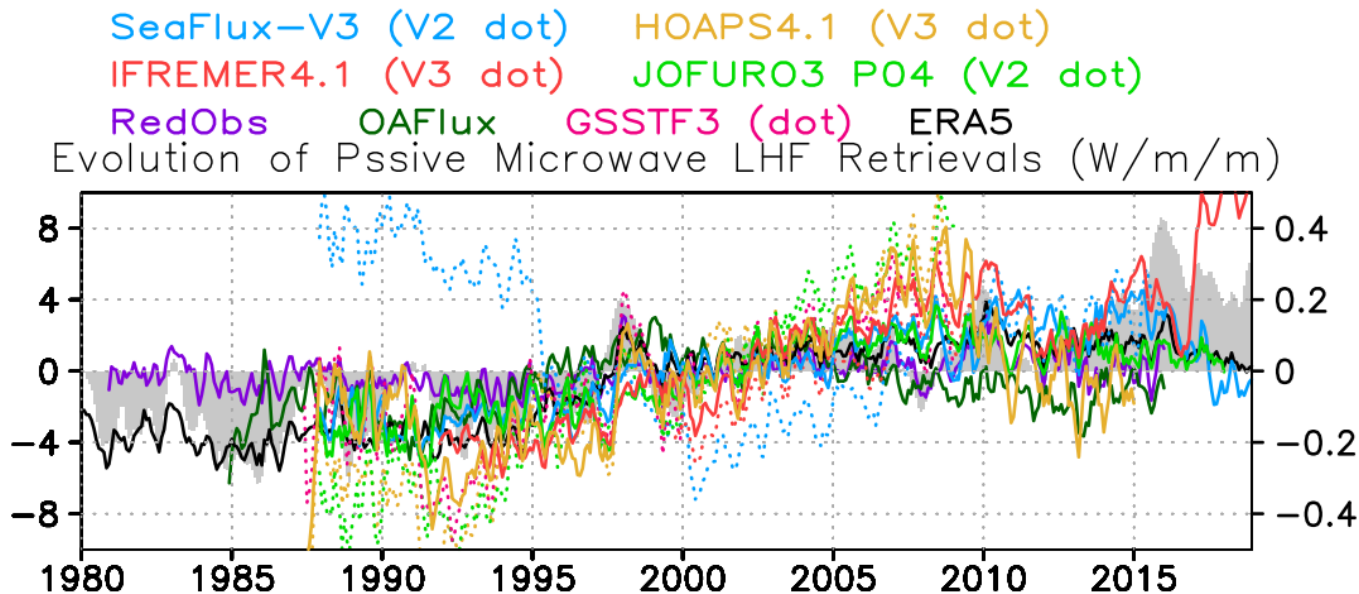
- Newer versions of datasets beginning to converge in global trends
- Improvements in datasets differ

Conclusions

- Continued convergence of satellite datasets in terms of global evaporation trends
- However:
  - Differences in trends remain across all components of bulk parameters, not just Qa (the usual suspect)
  - SSMIS issues affect products
  - Improvements vary between products
  - Switching of FCDRs without changes in algorithms proves problematic
- In situ datasets (i.e., buoys) can provide some information but data outages require very careful analysis to eliminate biasing
- Regime dependencies complicate understanding of trends across regions
  - Require ancillary data
  - Newer retrievals take dependencies into account: but reanalysis data used has its own set of trend issues
- Still using satellites from various times of day, varying resolutions, and mixing all together – see next talk!