Air-sea Fluxes:
OCEAN-model needs from Re-analyses

Michele Rienecker, Robin Kovach
Global Modeling and Assimilation Office,
NASA/GSFC

Ocean analyses

- Sensitivity to surface forcing estimates

Air-sea Flux Products

- Some new products
- Comparison with re-analyses
- Buoy data

Atmosphere & Ocean Re-analyses

- Workshop recommendations
  - Ongoing Analysis of the Climate System (August 2003)
  - Coupled Data Assimilation Workshop (April 2003)

• Surface Fluxes have a significant impact on ocean estimates, even in assimilation mode
• Important for ocean reanalysis - paucity of the historical ocean obs

Assimilation Sensitivity Tests

Poseidon V4 quasi-isopycnal ocean model, 1/3° x 5/8° x 27 layers
"quasi-global" : (no Arctic Ocean)

Assimilation scheme: OI
Sensitivity: forcing + treatment of salinity
Period: 1993-2003

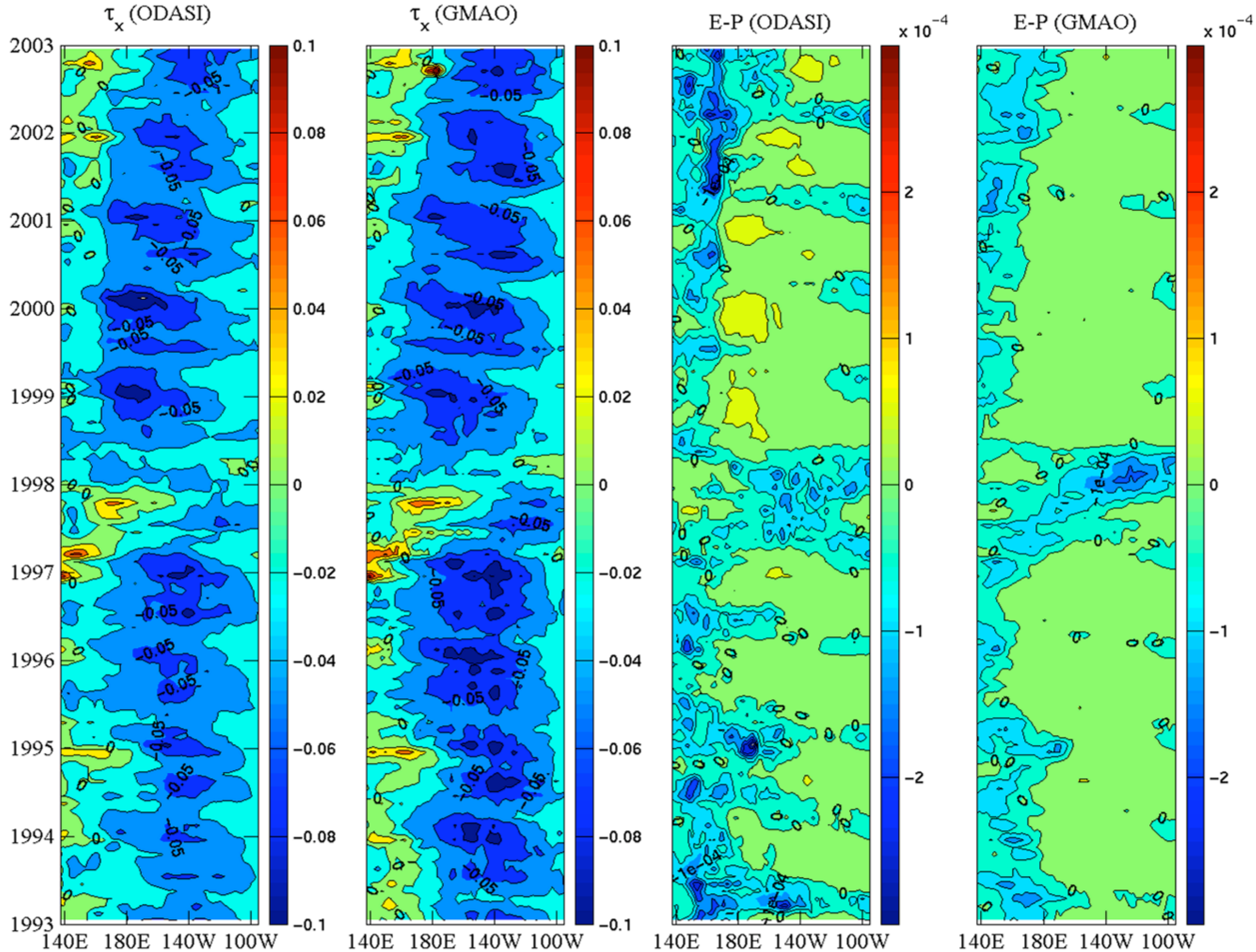
Surface Forcing

ODASI forcing:

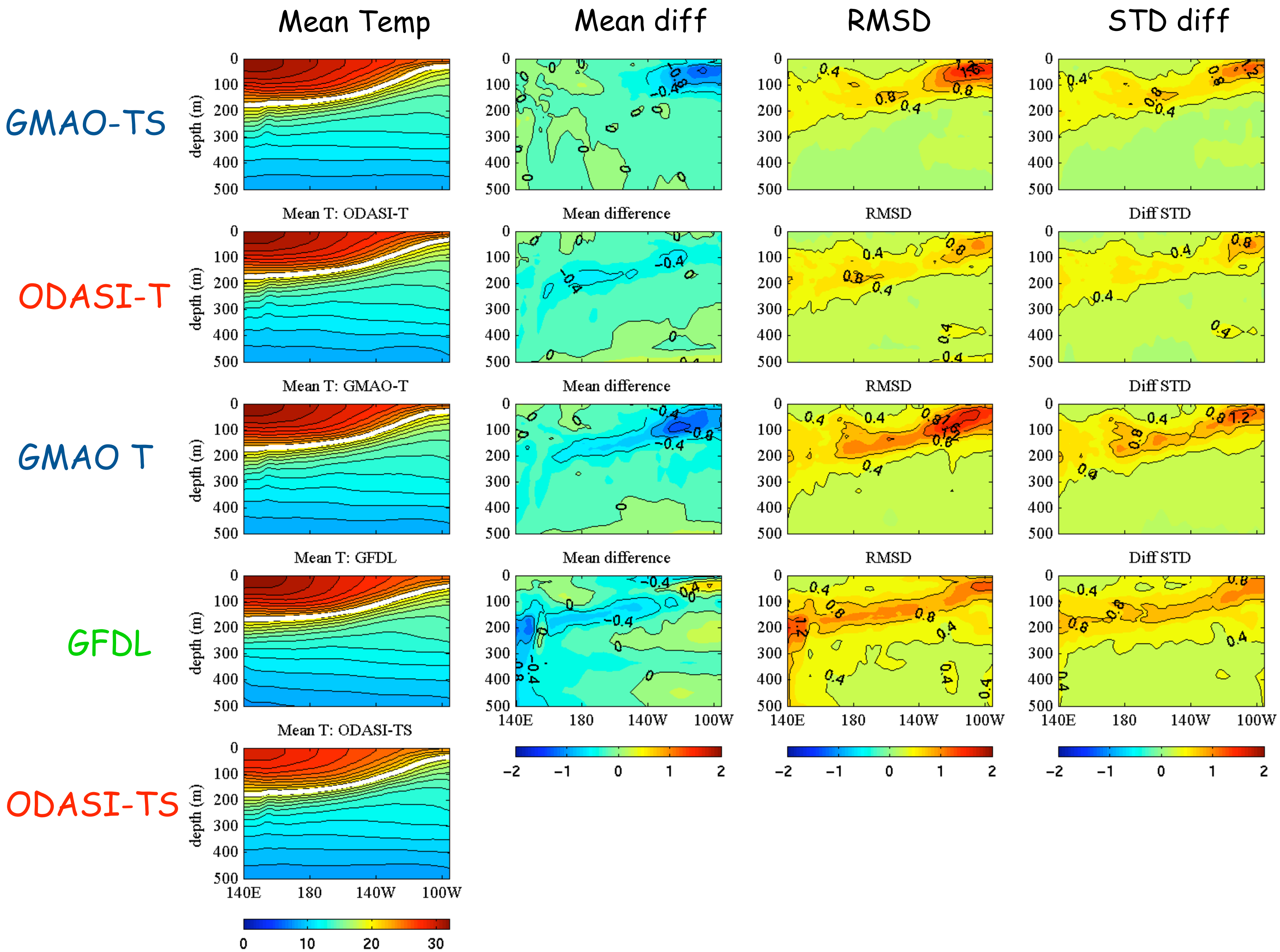
- NCEP CDAS forcing, wind stress climatology replaced by Atlas/SSMI analyses - relaxation to Reynolds weekly SST and Levitus salinity.

GMAO forcing:

- Atlas/SSMI time varying wind stress
- GPCP monthly mean precipitation
- NCEP CDAS SW (for penetrating radiation) & LH (for evaporation)
- relaxation to Reynolds SST



τx (ODASI)
τx (GMAO)
E-P (ODASI)
E-P (GMAO)
x 10^-4
x 10^-4
2003
2002
2001
2000
1999
1998
1997
1996
1995
1994
1993
140E 180E 140W 100W
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1
2
1
0
−1
−2



Mean Temp
Mean diff
RMSD
STD diff
GMAO-TS
ODASI-T
GMAO T
GFDL
ODASI-TS
Mean T: ODASI-T
Mean T: GMAO-T
Mean T: GFDL
Mean T: ODASI-TS
Mean difference
RMSD
Diff STD
depth (m)
140E
180
140W
100W

Surface Flux Product Comparisons

- NCEP1
- GFDL - NCEP2/CDAS
- CORE (NCAR - Large & Yeager)

  Common Ocean-ice Reference Experiments for CLIVAR/WGOMD

  http://data1.gfdl.noaa.gov/nomads/forms/mom4/CORE.html
- WHOI (OAFlux - Yu & Weller)

  Objectively Analyzed air-sea FLUXes

  http://oaflux.whoi.edu/data.html
- ERA-40

Large & Yeager (2004)

- Use Bulk formulae -- use Ocean Model SST (vs observed SST)
- Correct fields so that long-term mean fluxes are in balance

- Turbulent fluxes - shift temperature and humidity to height of wind - shift coefficients to this height and atmospheric stability

- Radiative fluxes - use consistent products for both components (cloud compensation)

- Precipitation data - highly uncertain - need breakdown in terms of rain and snow

- Runoff (distributes net P-E over land into runoff)

- Relaxation to observed SST - negative feedback helps contain the accumulation of flux errors
- Precipitation does not depend on salinity - no feedback to contain the flux errors

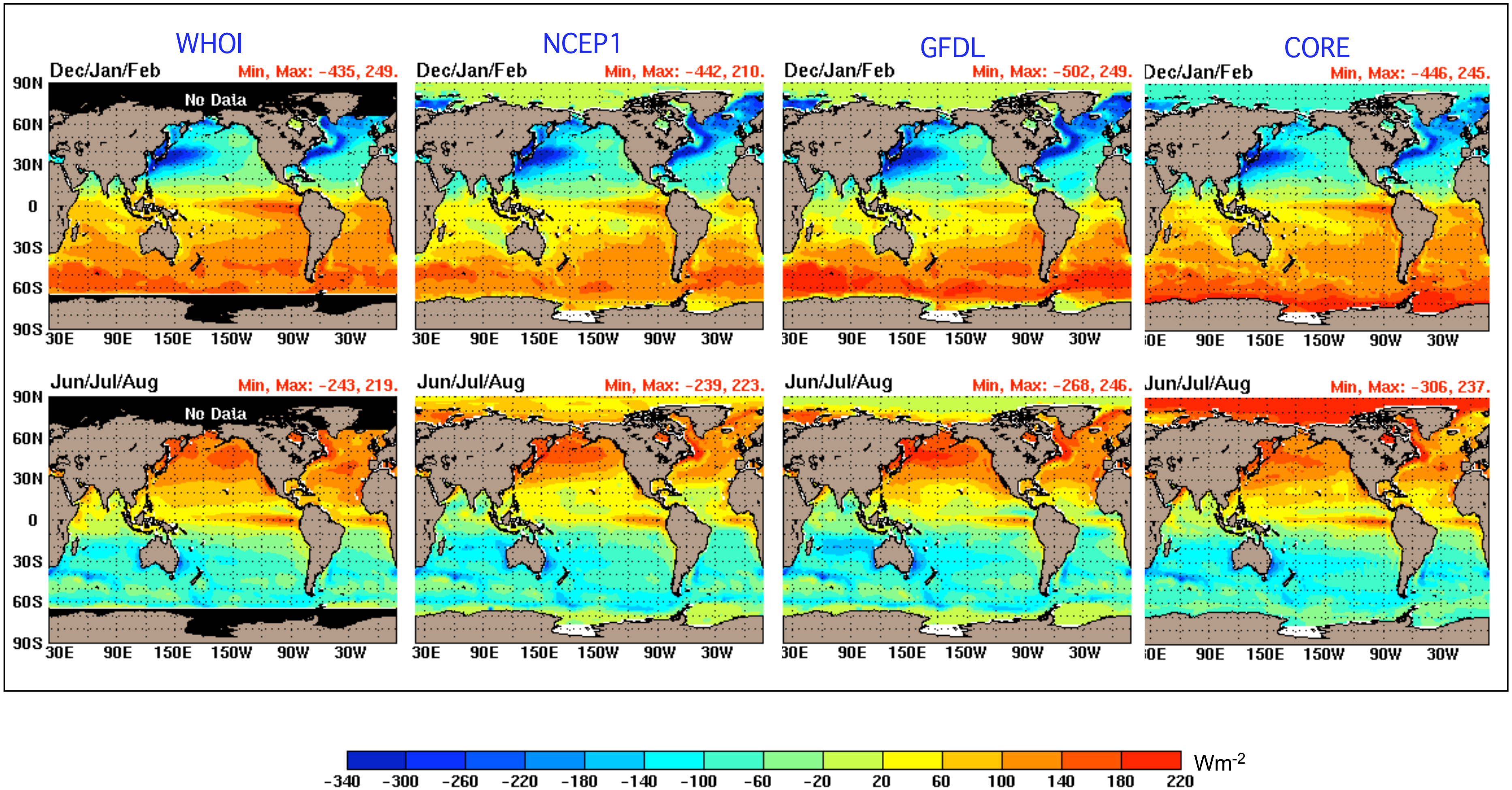
- Ice-ocean fluxes - use a sea-ice model

- NCEP; ISCCP
- Precipitation - blend of GPCP (tropics) and Xie-Arkin (GPCP/Serreze data in polar regions)
- SST and SSS data sets for relaxation

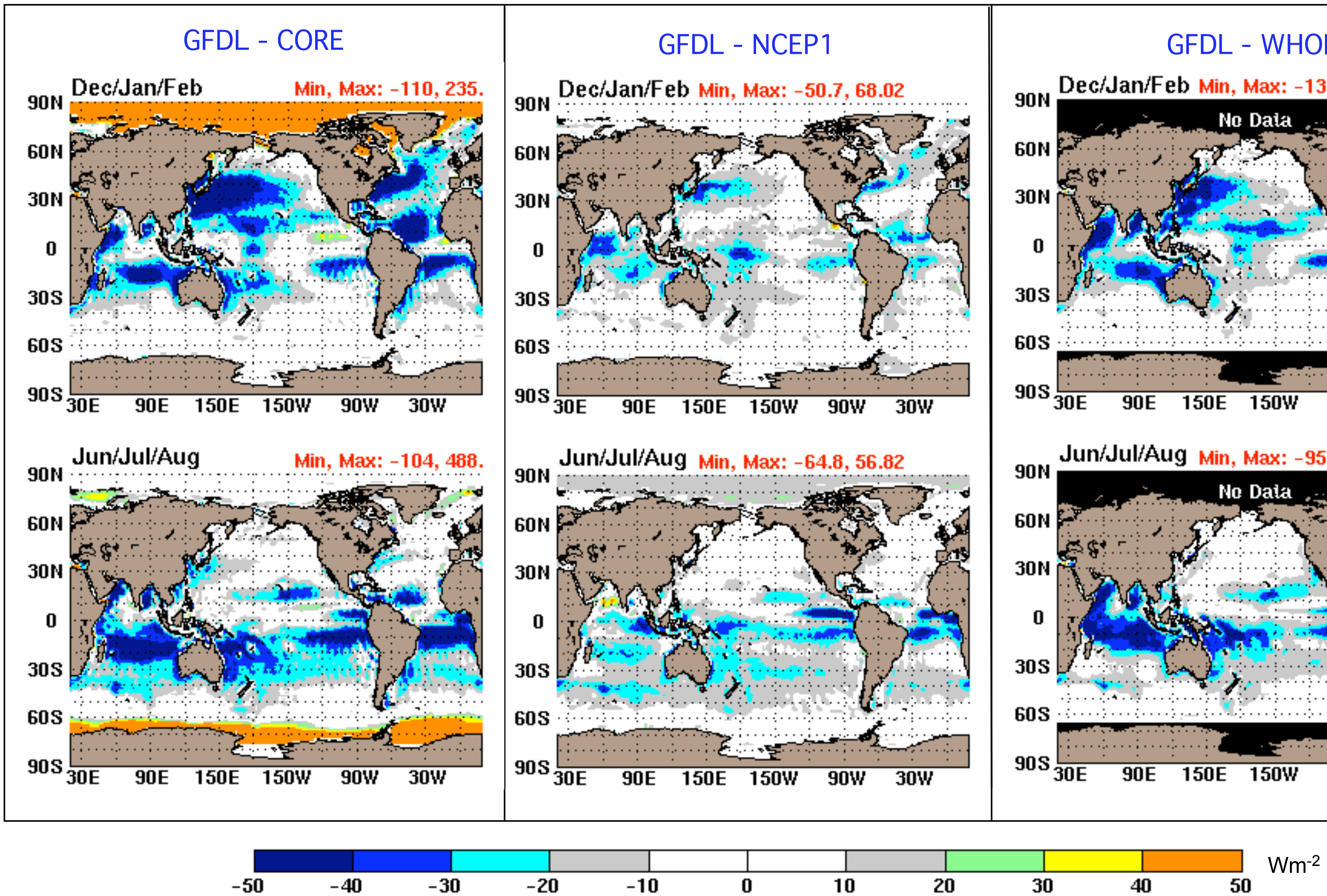
Flux corrections:

- SW (ISCCP c.f. other products)
- Qscat → corrections in wind speed
- LH → corrections in specific humidity → changes to P
- Global imbalances reduced to 1 Wm-2 and -0.1mg/s/m2

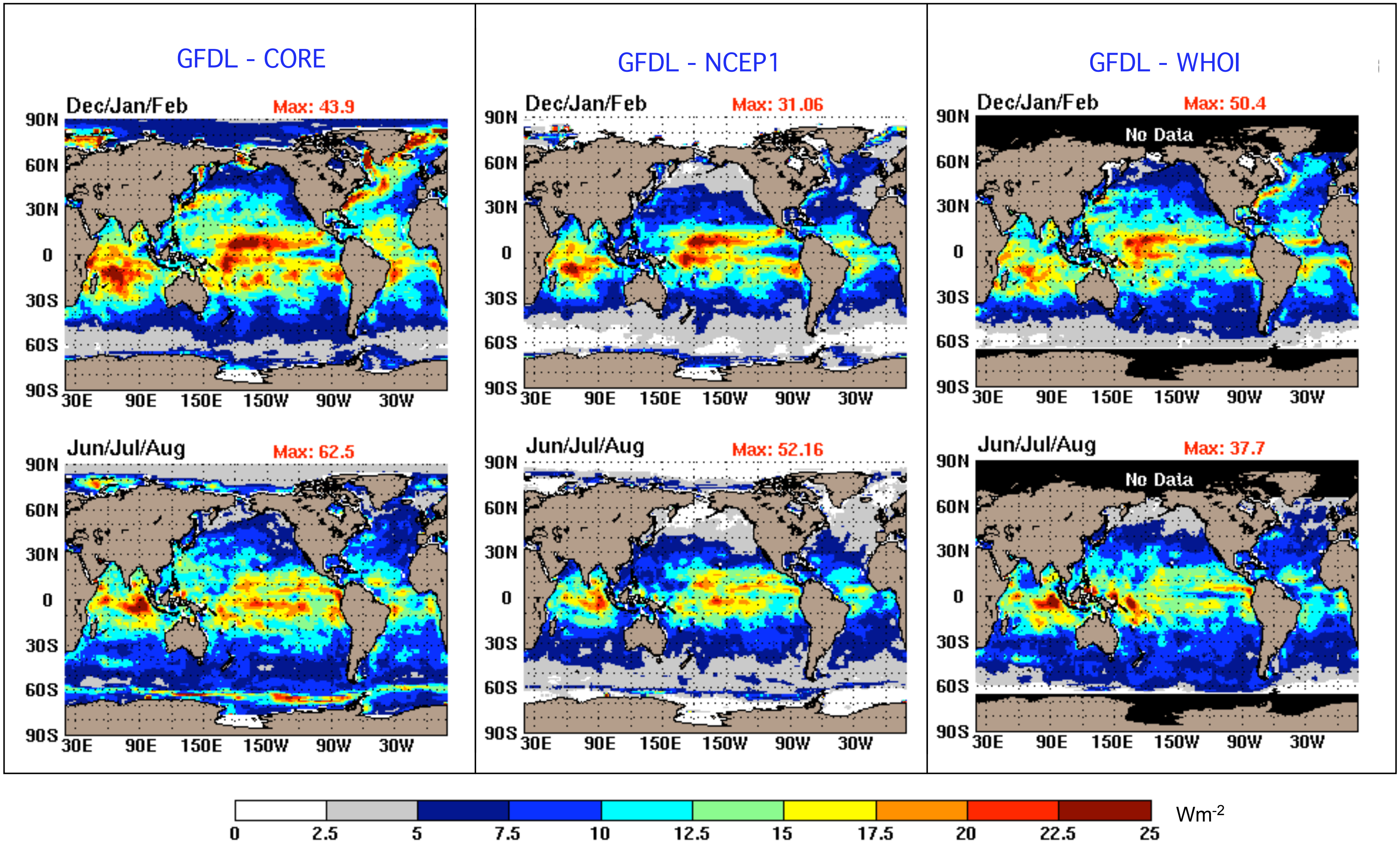
Qnet
Seasonal Means

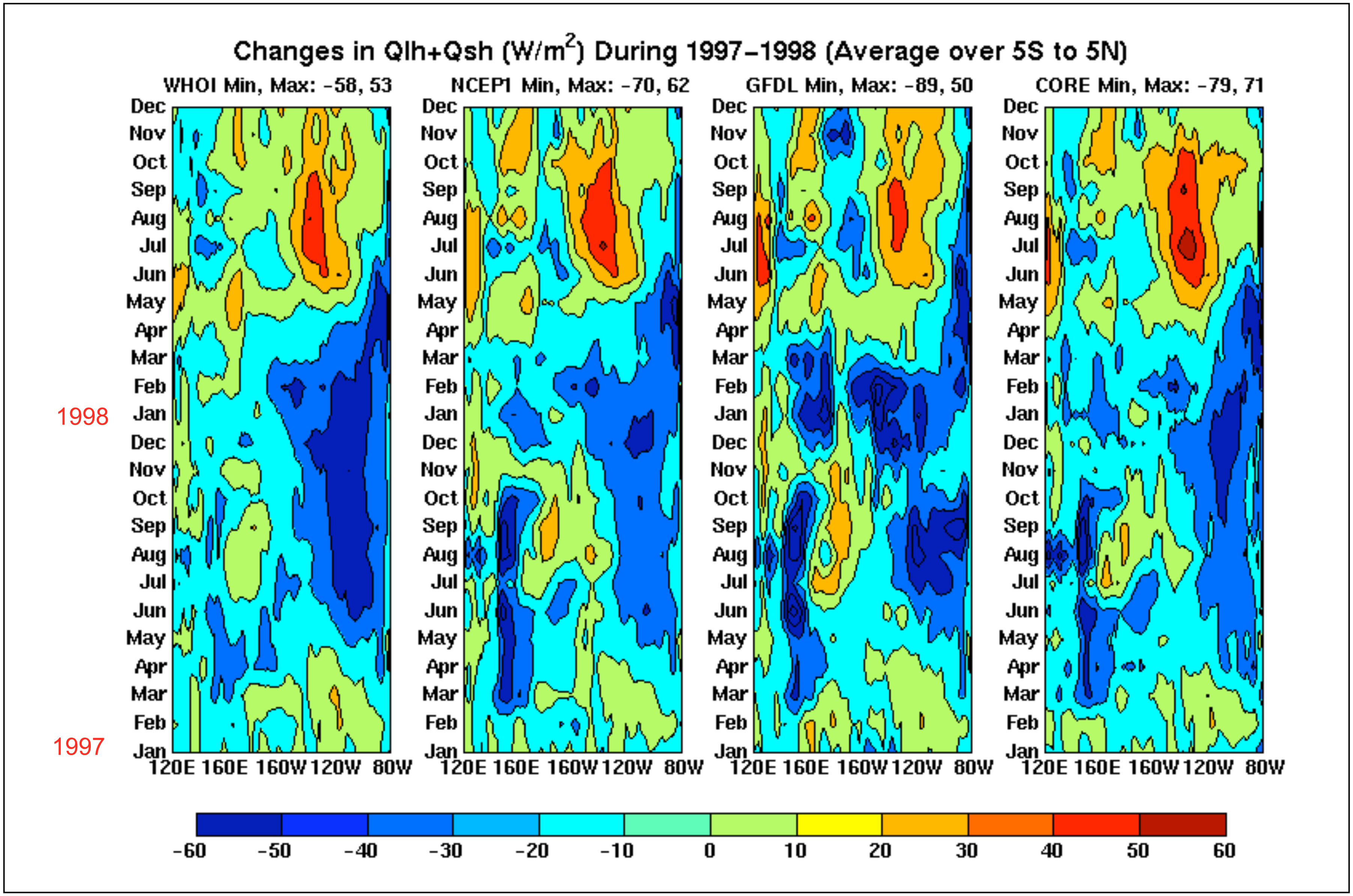


Latent Heat Flux Differences
Seasonal Mean



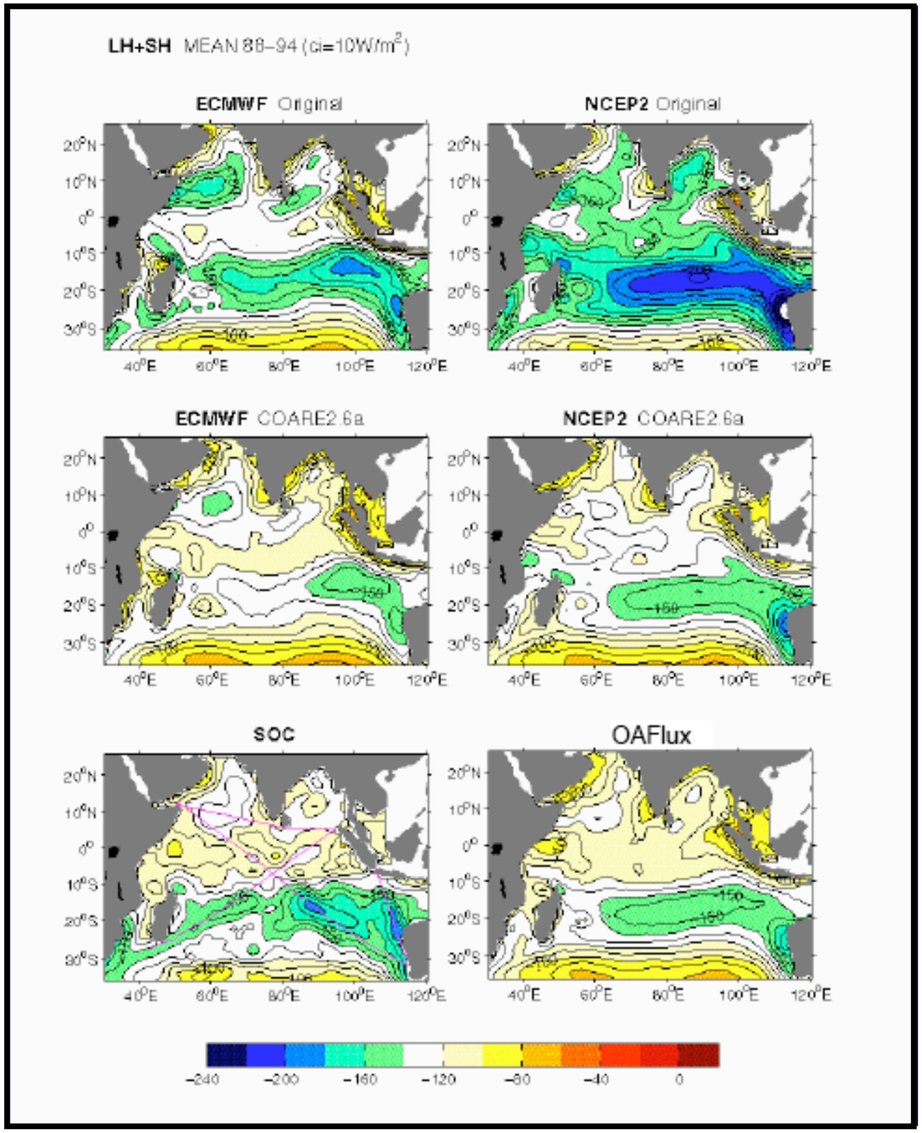
Latent Heat Flux Differences
Seasonal STD





Changes in Qlh+Qsh (W/m2) During 1997–1998 (Average over 5S to 5N)
WHOI Min, Max: -58, 53
NCEP1 Min, Max: -70, 62
GFDL Min, Max: -89, 50
CORE Min, Max: -79, 71
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan
1998
1997
120E 160E 160W 120W 80W
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60

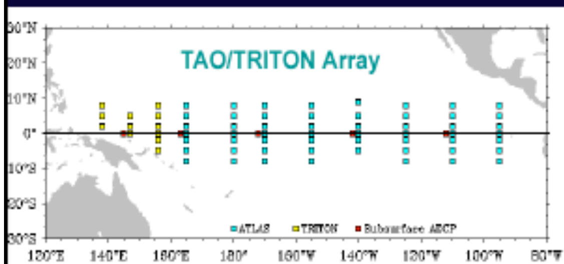
Why is it difficult to get the flux correct? Data? Algorithm?



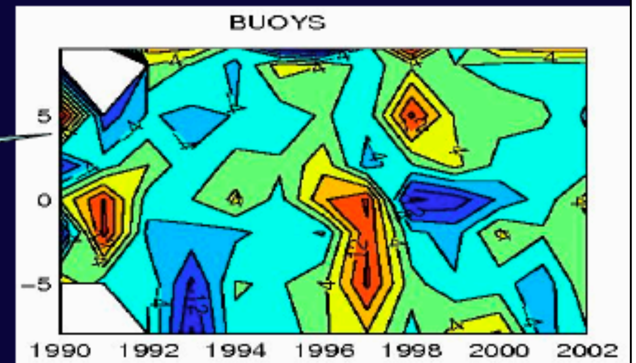
Yu & Weller

Problems in model humidity

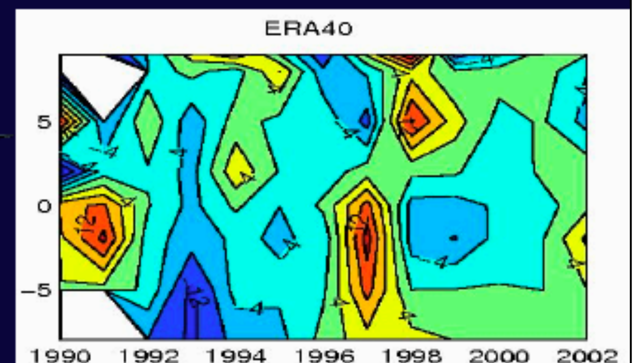
Year-to-year variations of zonally averaged latent heat flux from TAO buoys and ERA40



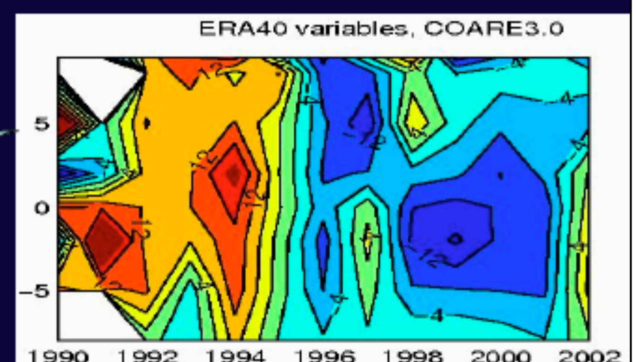
Buoy Q_{LH}



ERA40 Q_{LH}

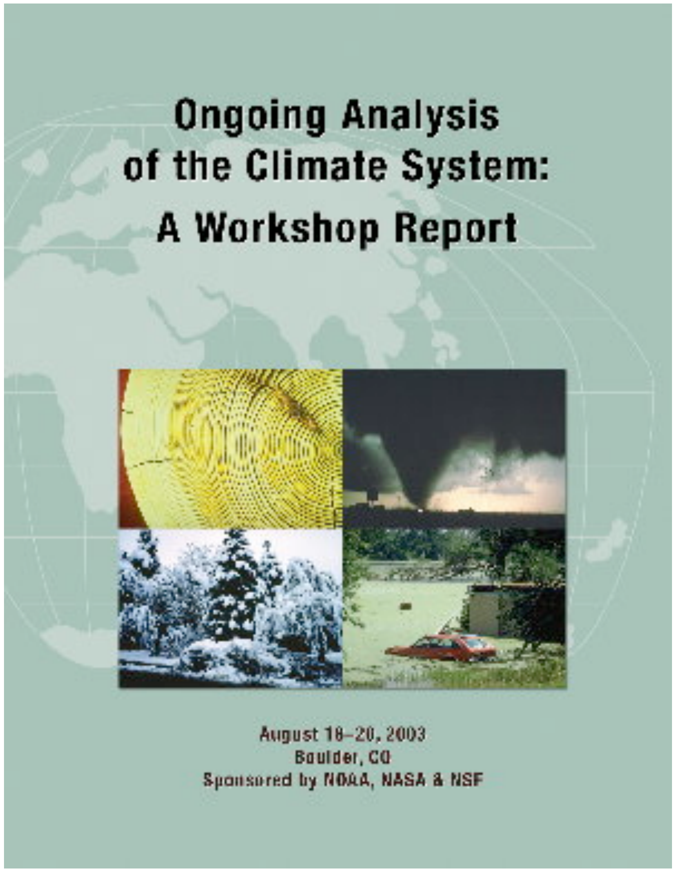


ERA40 variables COARE algorithm



Positive (negative) flux anomalies indicate more (less) latent heat loss from the ocean.

Yu & Weller



Surface Flux Panel

Background:

• Fluxes between the atmosphere and the ocean, land surface, sea-ice are important for understanding climate variability

• Surface forcing is a major source of error and uncertainty for ocean and land surface products

• Need better products and information on error statistics as input to ocean and land surface data assimilation

Findings :

• Current Reanalysis surface flux products are not adequate for climate analyses (not accurate, budgets don't close) or to force ocean and land surface models (not accurate).

• Of particular note: significant biases in precipitation and radiation.

• We need accurate surface fields more than accurate fluxes so that we can calculate our own surface fluxes. We replace reanalysis fields with corrected fields or other observational analyses (such as satellite-based surface radiation) when needed. Corrections for humidity are problematic.

Recommendations (1):

- Atmosphere, Ocean, Land Surface, Sea-ice analyses and the fluxes for each should be "synchronized" - coordinated programmatically
- Atmospheric analyses for climate purposes (such as CDAS) should be kept current
- Analysis should be best estimate of the state - that's what we measure
- Surface analyses should encompass:

  realistic variability in the modern era down to 1 degree resolution globally, resolving diurnal cycle

Recommendations (3):

- R&D priorities:
  - Improve cloud & PBL (atmosphere and ocean) representations so that analyses can produce realistic fluxes.
  - Develop assimilation for coupled systems
  - Improve assimilation methods so as to use surface observations more effectively

Coupled Data Assimilation

NOAA/OGP-funded Workshop, 21-23 April 2003

How should the problem be approached from theoretical and practical aspects? What are the first steps that could/should be taken?

- A loosely coupled system is the proper first step (NCEP, FNMOC)
- An incremental approach (e.g., atmosphere coupled to mixed layer; hybrid coupled models)

Summary

- Need better products <u>and</u> information on error statistics as input to ocean data assimilation
- Need long time-series and for analyses to be kept current
- Need consistent analyses of atmosphere and ocean - Coupled?
- Requirements (SCOR, Taylor, 2000): high quality flux products, 3hrly, 50km, errors of a few Wm^{-2}, consistency and continuity