Intermediate to full complexity coupled models: Experiences from ECMWF

Franco Molteni,

ECMWF, Reading, U.K.

in collaboration with
Fred Kucharski (ICTP) and Kristian Mogensen (ECMWF)

Experiences from the 1990's: EPS perturbations

- Development of a 3-level, T21 Quasi-Geostrophic model for predictability research
- Computation of fastest growing QG perturbation in a finite time interval (singular vectors, SVs) by constructing the linear propagator in matrix form
- Ensemble experiments with the ECMWF atmospheric model, using QG SVs interpolated to T63, 19-level model grid
- Comparison with QG results helped debugging the code to compute SVs in the primitive-equation model

The ICTP-NEMO coupled model

- **Atmosphere**: ICTP AGCM (Speedy) v 41, T30 L8, including simple slab models for land and sea-ice
- **Ocean**: NEMO v 2.0 with ECMWF modifications, ORCA-2 grid (2-deg with equatorial refinement to ~ 1/3 deg)
- **Coupler**: OASIS-3 with additional code by K. Mogensen

Coupling option with the ICTP AGCM ver.41

- Uncoupled AGCM runs with prescribed SST (either climatology or observed time-evolving field)
- One-way coupling (AMIP-forced runs): observed SST used by AGCM, ocean model driven by atm. model fluxes
- Two-way full coupling: exchange of SST and surface fluxes with no bias corrections
- Two-way anomaly coupling: AGCM uses SST with anomalies from ocean model, ocean model driven by fluxes recomputed w.r.t. ocean-model SST
- Pacemaker experiments: two-way anomaly coupling, but AGCM uses observed SST anomalies in selected regions (eg tropical Pacific)

Ocean model runs forced by (re-)analysis data

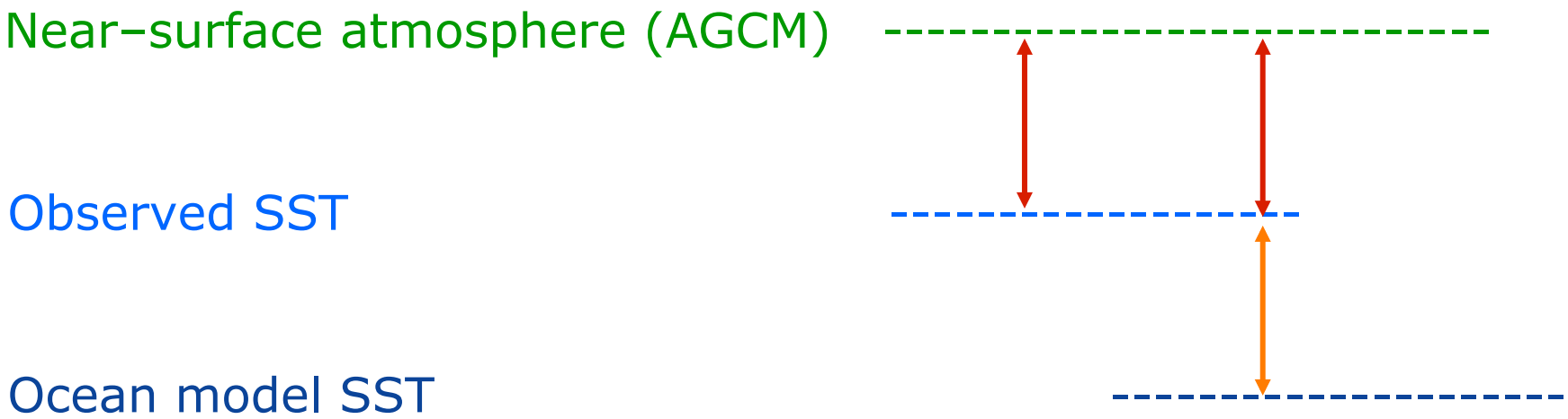
- **Bulk formula approach**: near-surface atmospheric variables (wind, temperature, humidity, SLP) are passed to the ocean model and fluxes are computed using bulk formula
- **Flux approach**: surface fluxes are taken from (re-)analysis, but heat fluxes are corrected by adding a relaxation term towards observed SST

Even when the flux approach is used with the same AGCM cycle used for the analysis, the forced-ocean climatology differs from the coupled climatology wherever the near-surface response to SST anomalies in the AGCM differs from the observed atmospheric response (esp. in terms of surface wind).

AMIP-forced ocean integrations in IFS-HOPE

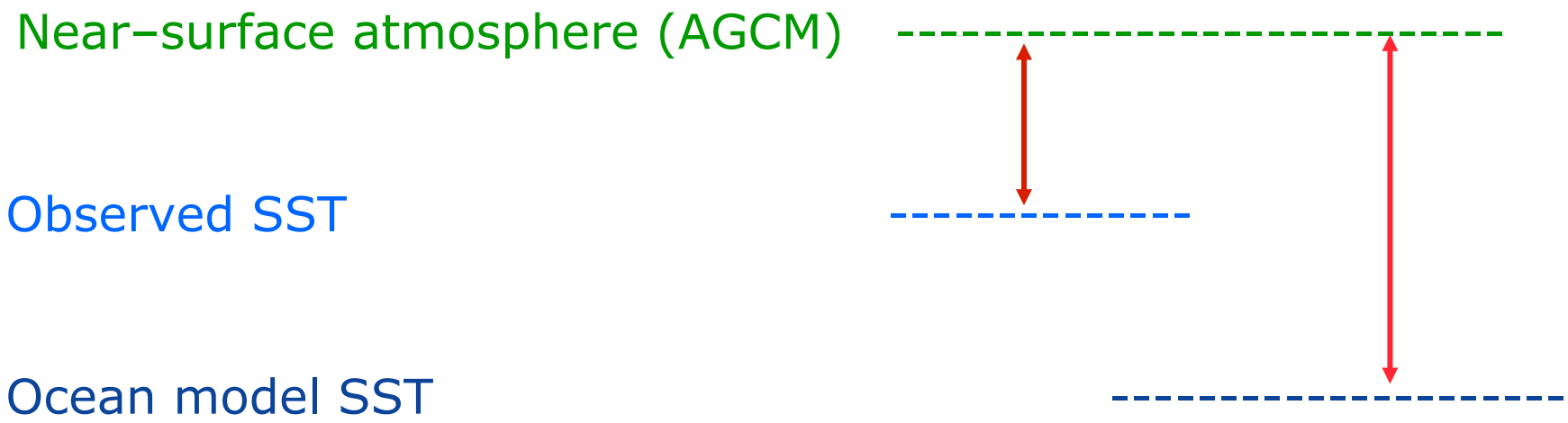
- Surface fluxes of heat/momentum/water are computed in AGCM from observed SST
- Heat fluxes are corrected by adding a linear relaxation of ocean-model SST towards observed SST:

$$HF' = HF + (dQ/dT)\,(SST_{ob} - SST_{om})$$



AMIP-forced ocean integrations in ICTP-NEMO

- Surface fluxes of heat/momentum/water are computed in AGCM from observed SST (= observed climatology + observed anomaly)
- Heat fluxes (SHF, LHF, SLR) are re-computed with respect to ocean-model SST to drive the ocean model



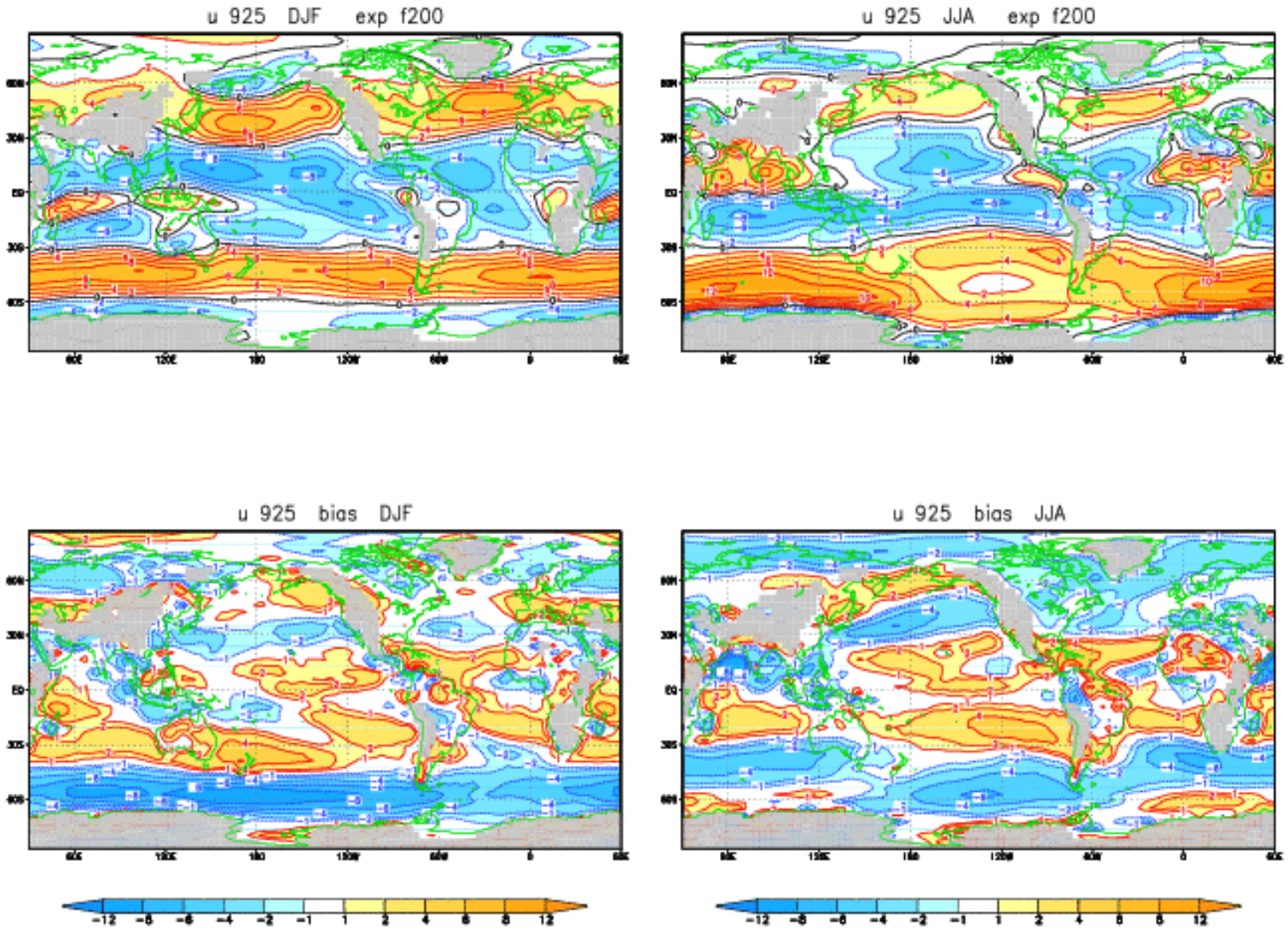
52-year integration driven by HadISST (1950-2002)

Anomaly-coupled integrations in ICTP-NEMO

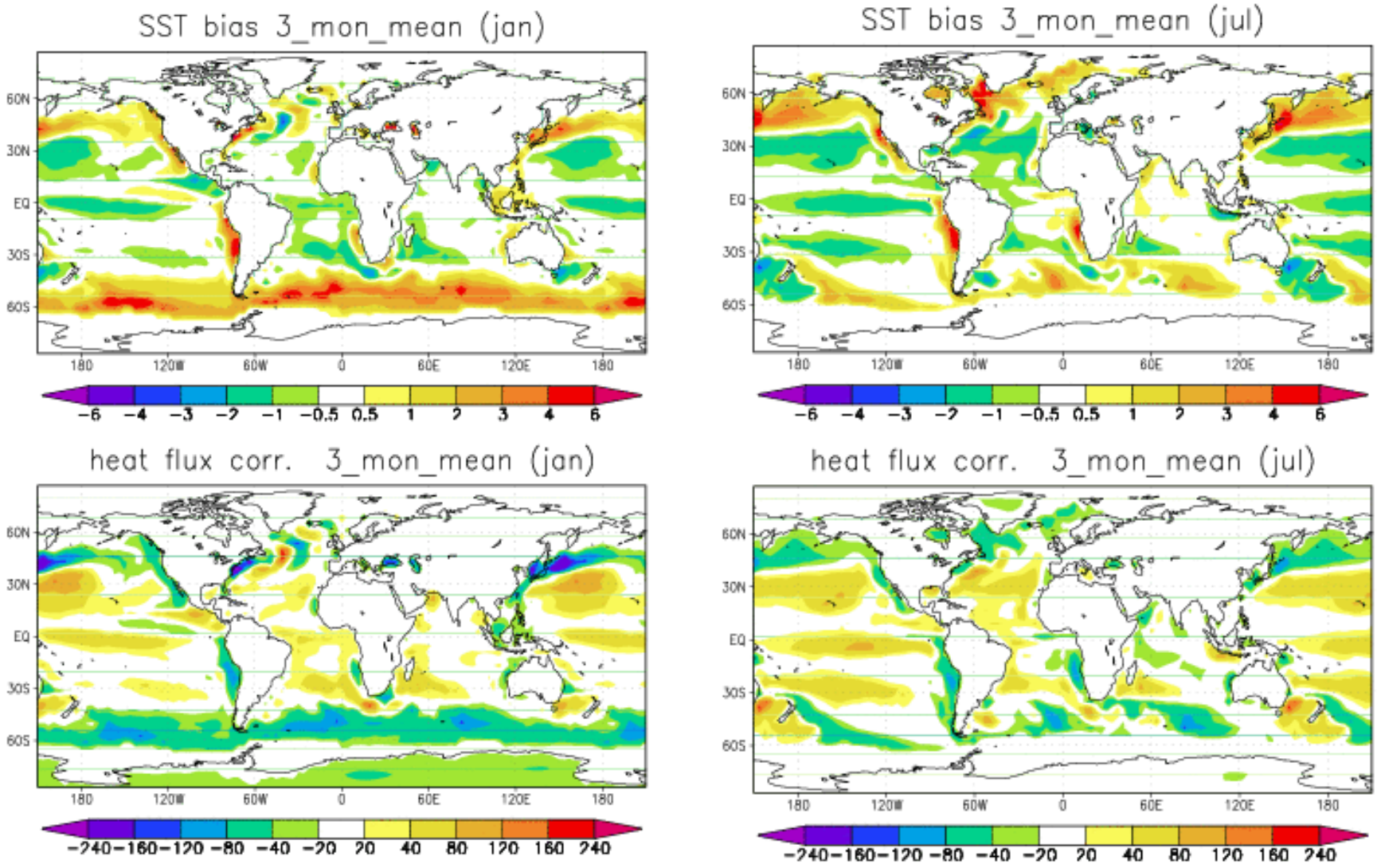
- Surface fluxes of heat/momentum/water are computed in AGCM from bias-corrected SST = observed climatology + NEMO anomaly
- Heat fluxes (SHF, LHF, SLR) are re-computed with respect to ocean-model SST to drive the ocean model

Because of the consistency with AMIP-forced methodology, the ocean model climatology in coupled and AMIP-forced runs is similar, so NEMO SST anomalies can be computed w.r.t. SST climate from AMIP run

925 hPa u-wind clim./bias in ICTP AGCM (1981-2000)

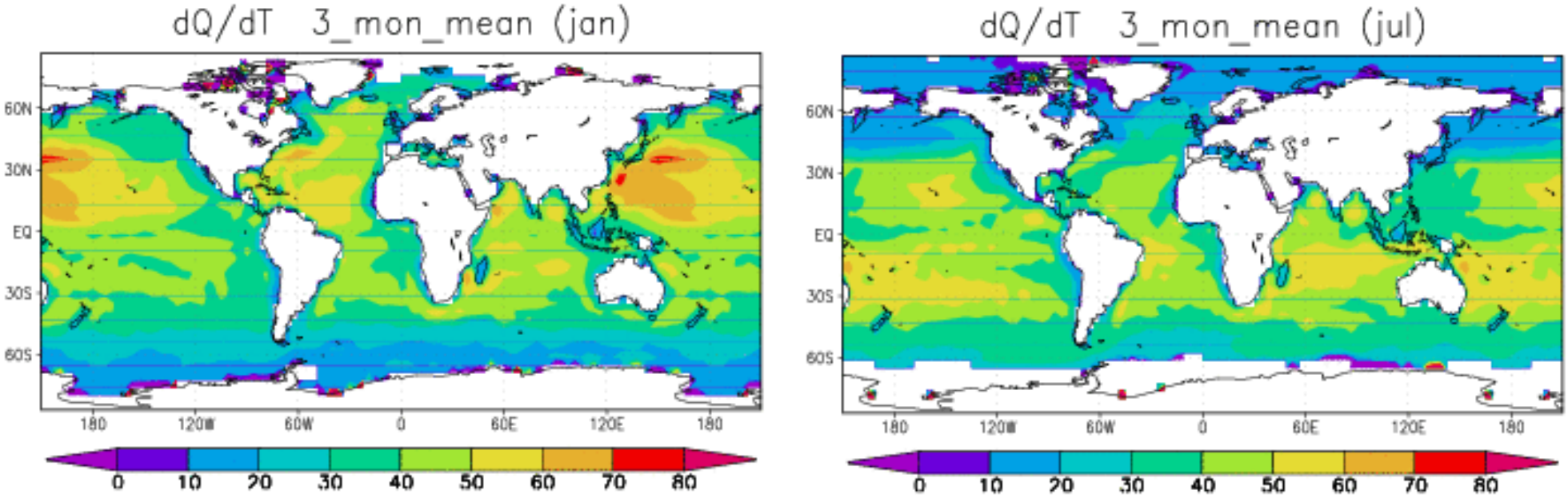


SST bias (NEMO – OBS) and heat flux corr. in 52-yr run



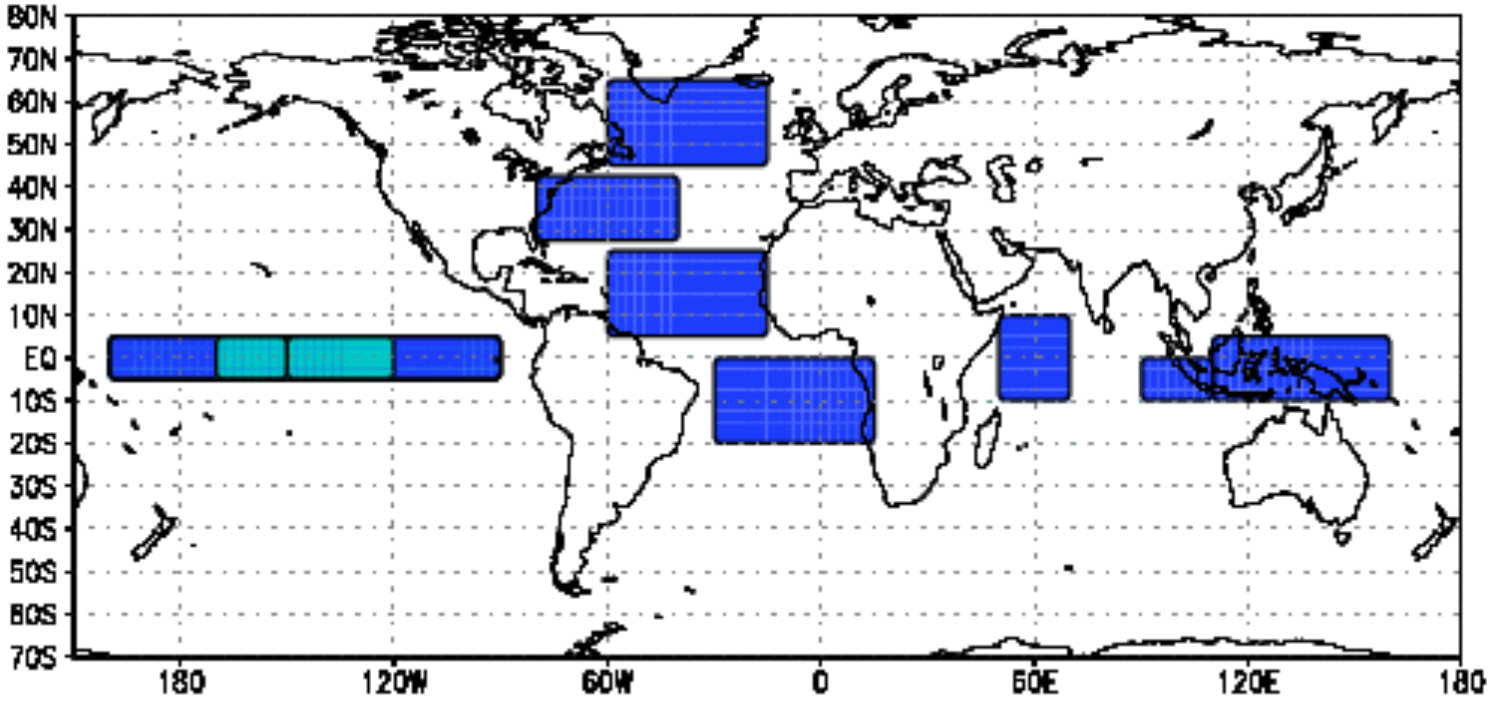
Regression of Δ heat flux vs. Δ SST (dQ/dT)

$$\Delta HF = C_{SHF} (SST_{ob} - SST_{om}) + C_{LHF} [q_{sat} (SST_{ob}) - q_{sat} (SST_{om})] + C_{LWR} (SST_{ob}^{4} - SST_{om}^{4})$$



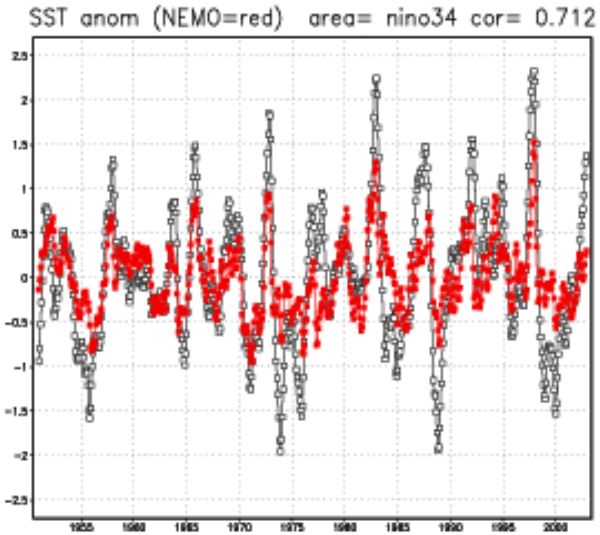
Time series of NEMO vs. OBS SST anomalies (1950-2002)

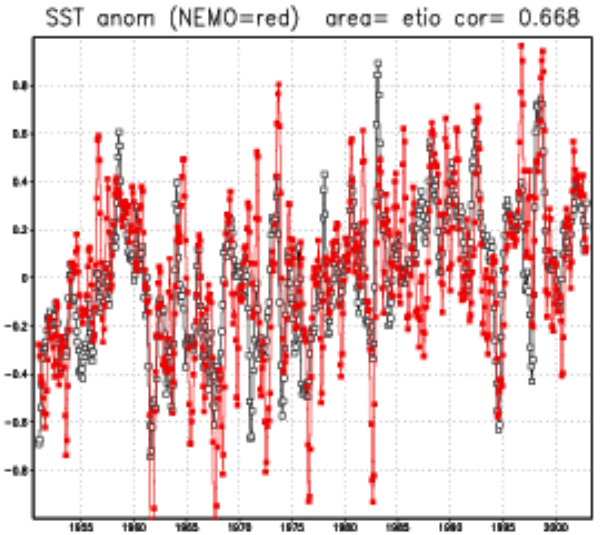
3-month running means of area-averaged SST anomalies from 52-year AMIP-forced runs



Time series of NEMO vs. OBS SST anomalies (1950-2002)

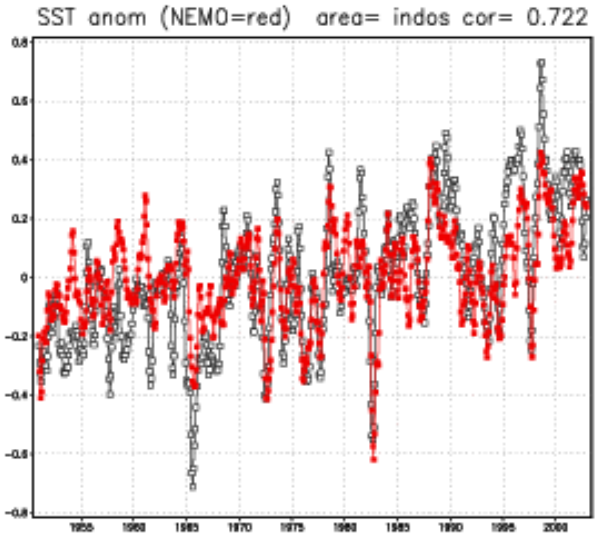
Nino3.4
Cor = .71

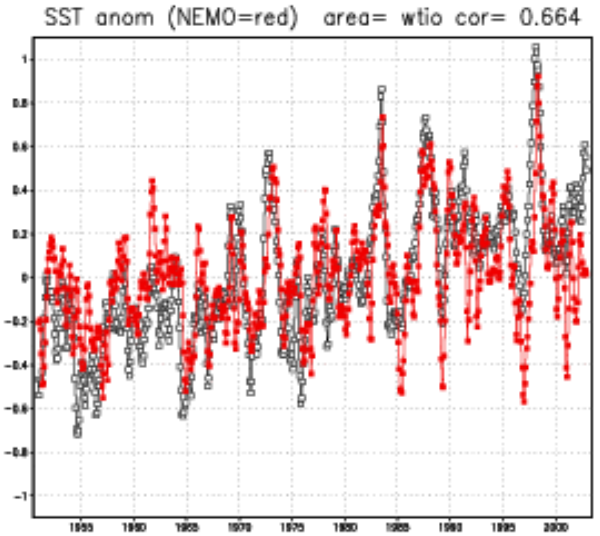




East. Trop.
Indian Oc.
Cor = .67

Indonesian
Seas
Cor = .72

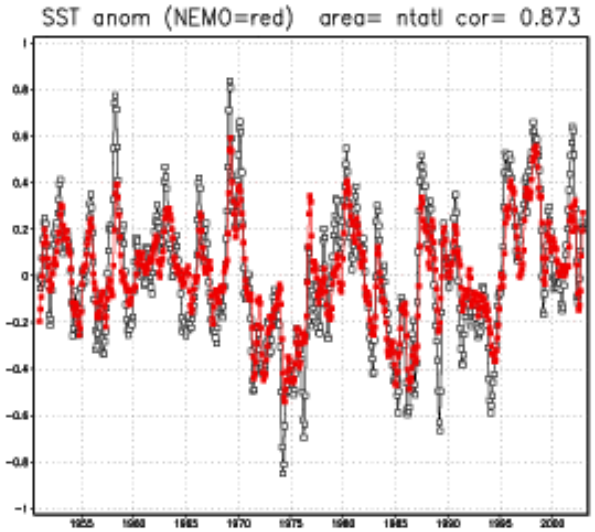


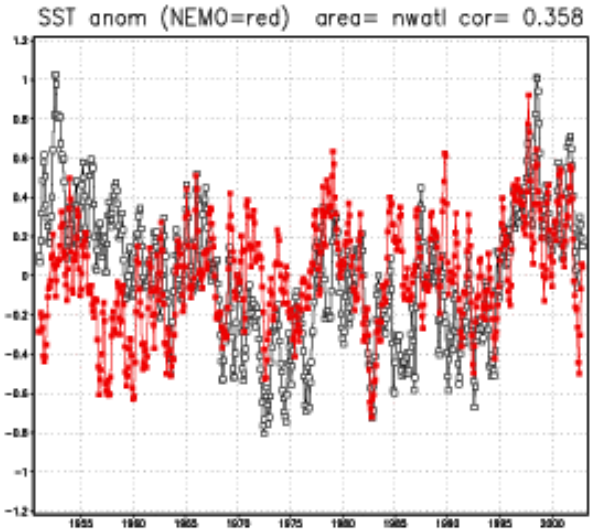


West. Trop.
Indian Oc.
Cor = .66

Time series of NEMO vs. OBS SST anomalies (1950-2002)

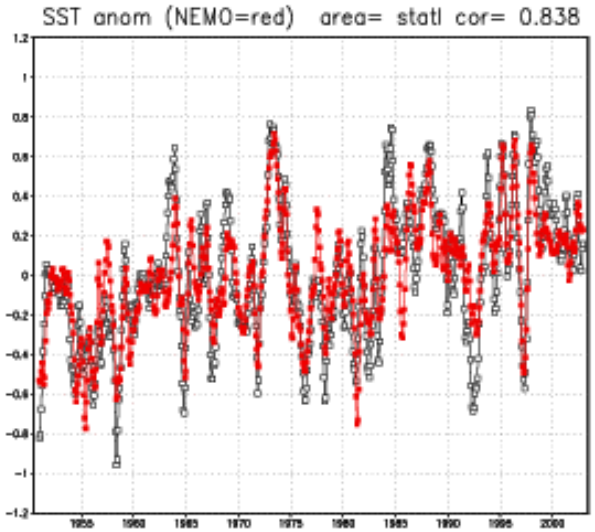
N. Trop. Atlantic Cor = .87

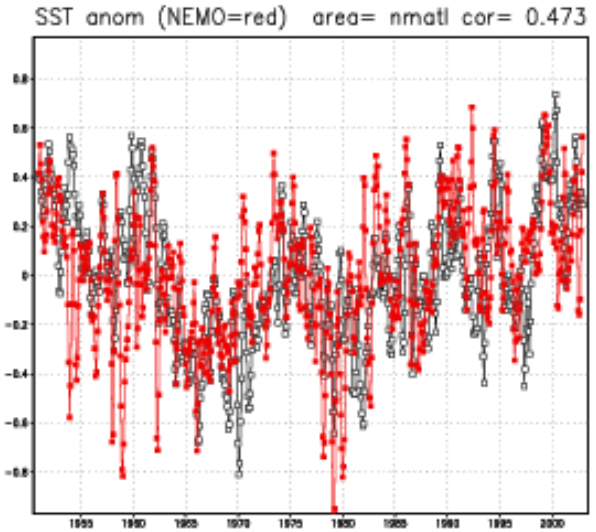




N. West Atlantic Cor = .36

S. Trop. Atlantic Cor = .84





N. Mid-lat. Atlantic Cor = .47

Proposed implementation in IFS-NEMO

- Replace linear relaxation to SST (constant dQ/dT) with non-linear heat flux correction, consistent with NEMO bulk formulae or IFS PBL formulation
- Run AMIP forced multi-decadal simulation as a diagnostic tool (e.g. AGCM relaxation experiments)
- Store SST bias and test coupled configuration where observed SST is gradually replaced by bias-corrected model SST (possible use in medium-range and monthly ensemble predictions)