Satellite-based air-sea heat fluxes using GHRSST data

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Contents

Air-sea heat exchange

- Occurs via a number of processes
  - Solar insolation (Qs) and net longwave (Ql) radiation
  - Conductive and convective transfer (Hs - *sensible heat*)
  - Evaporation (Hl - *latent heat*)
  - Net heat flux, Qnet = Qs + Ql + Hs + Hl

- Air-sea heat fluxes are key variables for:
  - Analyzing the upper ocean heat budget
  - Initializing ocean models
  - Diagnosing atmospheric models
  - Evaluating numerical weather prediction

Flux measurement

Sensible heat flux

$$Hs = p_a C_p \overline{w'\theta'}$$

- Air density
- Specific heat of air at constant pressure
- Covariance between vertical velocity and potential temperature

Latent heat flux

$$Hl = p_a L_v \overline{w'q'}$$

- Air density
- Latent heat of vaporization
- Covariance between vertical velocity and specific humidity

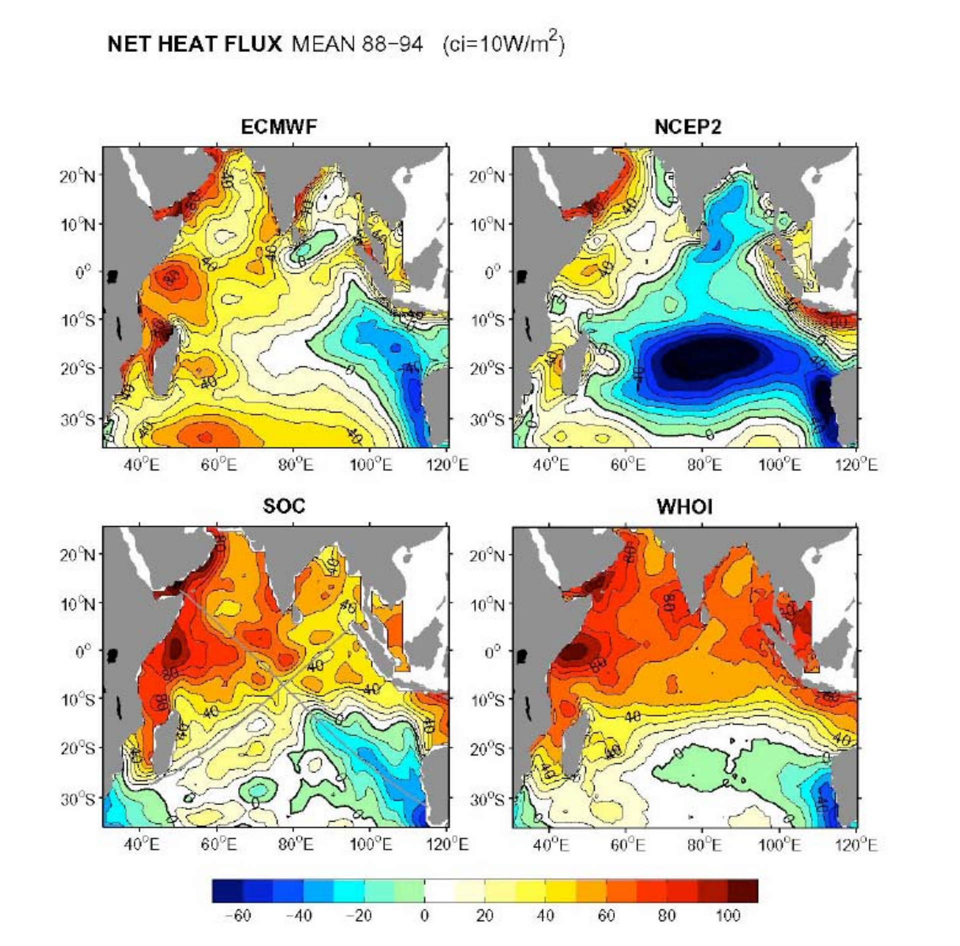
- Direct measurement via covariance method/inertial dissipation
  - Horizontal wind components (stress) - Sonic Anemometer/Rawinsonde
  - Temperature (sensible heat) – Thermometer/Thermistor/Sonic Anemometer
  - Moisture (latent heat) – IR Hygrometer
- High frequency direct measurements subject to many corrections/sampling errors e.g. platform motion etc...
- Requires complex suite of sensors, hence amount of research quality data is small.

Parameterization

- Fluxes can be directly related to average meteorological measurements through turbulent exchange coefficients.
- We rely on bulk parameterization of the air-sea fluxes as functions of surface meteorological variables – u10, Ta, SST, Qs, Qa etc...
- Measurements of these flux-related variables are readily available from marine surface weather reports from voluntary observing ships (VOS) and buoys/research ships.
- Atmospheric re-analyses from numerical weather predication (NWP) centers e.g. NCEP and ECMWF
- Problems include: incomplete global coverage, relatively short timescales, systematic bias and random error
- Comprehensive global coverage is only possible from an analysis incorporating satellite measurements.

Existing problems

- Flux related variables are available from NWP models e.g. NCEP-NCAR reanalysis and 40-yr ECMWF Re-Analysis (ERA-40).
- These can contain systematic biases. In some regions (e.g. the Arabian Sea and Bay of Bengal).
- The biases can be so large that the NWP net heat fluxes have a sign opposite to those of in situ measurements.
- Biases in NWP products/analyses cause errors in ocean/land simulations.
- **Remote sensing – an attractive alternative due to good spatial and temporal resolution.**



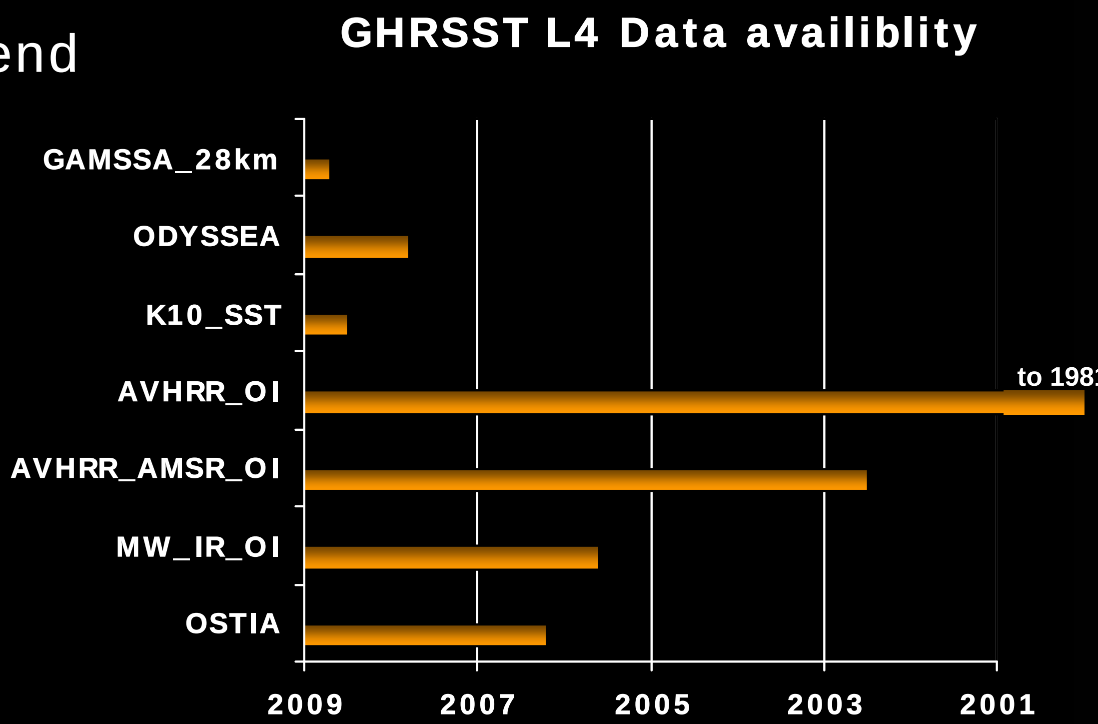
Peter Taylor and Bob Weller, OOPC 8 (2003)

Group for High Resolution SST (GHRSST)

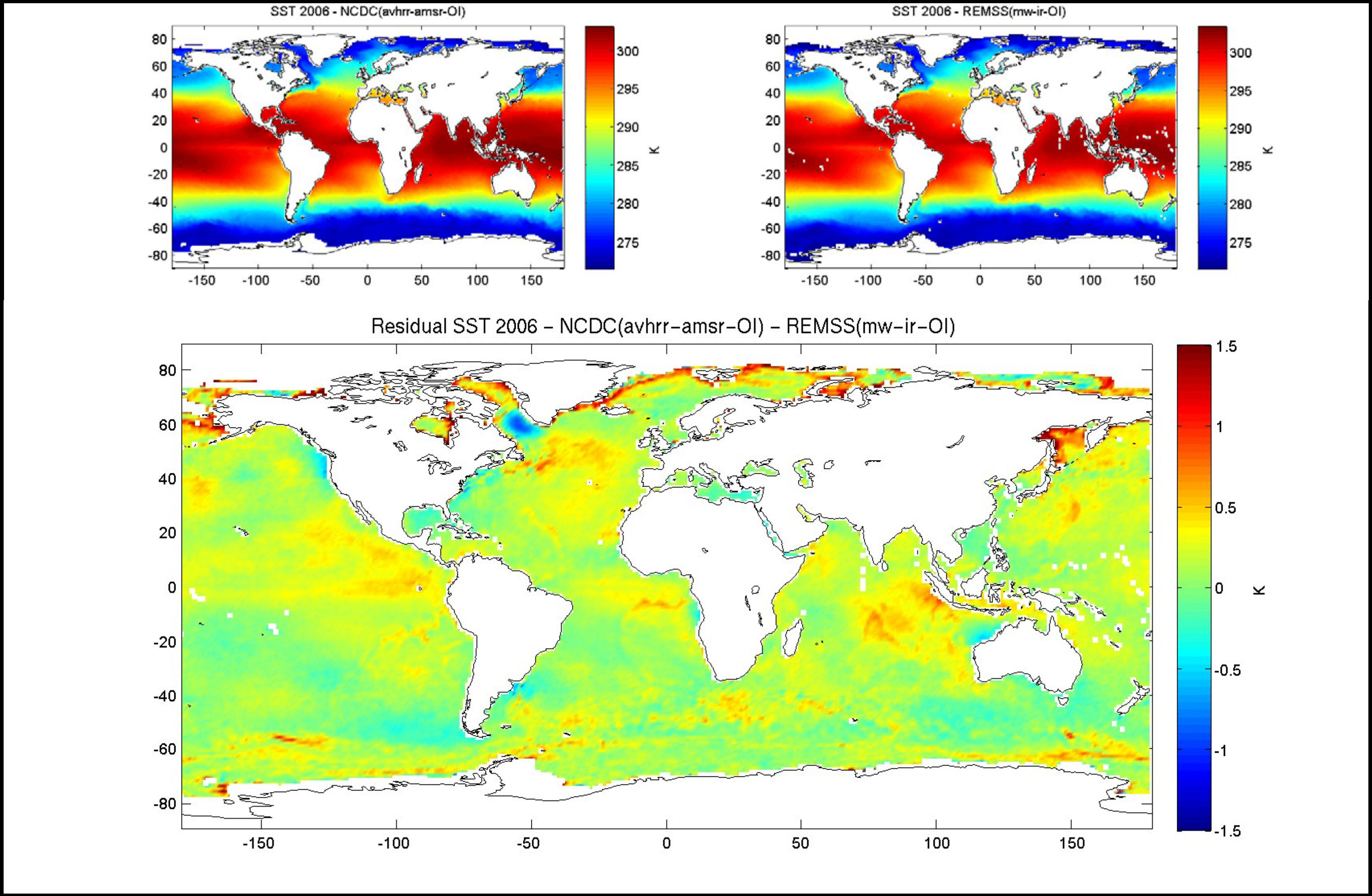
- SST – key variable for air-sea flux calculation, as well as weather prediction and climate [*Donlon et al., 2007*].
- Sea-air humidity difference is a function of SST – important for latent and sensible heat fluxes.
- NODC maintains the long term archive
  - GHRSST Archive (LTSRF) *http://www.nodc.noaa.gov/SatelliteData/ghrsst/*
- GHRSST Products combine several complementary satellite and in situ SST data streams.
  - designed to provide the best available estimate of the SST.
  - L2, L3 and L4 SST climate data record analysis products.
- Multiple data providers using different input data/algorithms to generate analysis products e.g. NCDC, REMSS, UKMO.
- Initially seek to utilize L4 high resolution SST products to improve estimates of air-sea fluxes.

LSTRF at NODC

- GHRSST data in common format, adhere to specifications.
- Easy to swap multiple SST datasets.
- Plans to reprocess/extend datasets e.g. OSTIA.
- GCOS SST-SI intercomparisons.



GHRSST L4 SST differences



Aims

- Create satellite derived heat flux products using high resolution SST data and other satellite based variables.
- Evaluate impact of new SST analysis products e.g. GHRSST
  - Through intercomparison of SSTs and subsequent fluxes
  - Comparison with existing flux datasets e.g. OAflux, GSSTF, NCEP/NCAR, ECMWF.
- Feedback into GHRSST processing
- Validation with in situ observations e.g. TOGA-COARE buoys and/or NOCS surface flux climatology.
- Initial testing using single year of data at 1x1 degree res.
  - Daily fluxes
  - L4 GHRSST data

Bulk flux algorithm

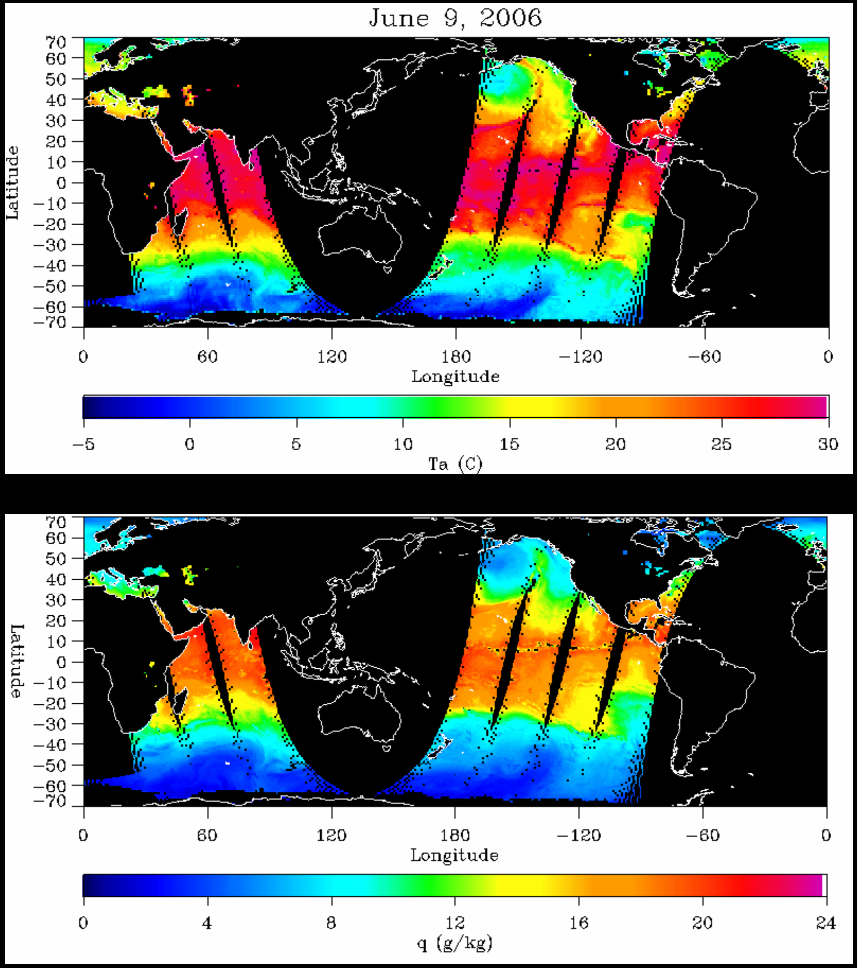
- COARE 3.0 Bulk aerodynamic formulae derived from M-O similarity theory [*Fairall et al., 1996*] .
- Mean and turbulent properties of the dynamical variables can be scaled by combinations of the surface fluxes, and their height dependence can be described by the ratio of the height above the surface to the M-O length.
- Monin-Obukhov (M-O) length related to friction velocity and potential temperature.
- Several algorithms available – differences in the treatment of transfer coefficients.
- COARE 3.0 algorithm determined to be one of the least problematic for computing ocean surface fluxes [*Brunke et al., 2003]*
- 4 independent variables needed to calculate Hs and Hl
  - SST, u10, Ta and Qa.
  - These can all be acquired by remote sensing.
  - Additional variables derived from these e.g. Qs = f(SST)
- Include the radiative fluxes to estimate net heat input into ocean.

Preliminary testing

- Input data re-gridded to daily 1x1 degree resolution
- Daily, 3-day, weekly, monthly fluxes for 2006.
  - Take advantage of parallel computing on cluster machines
  - Processing 1 month ~13x faster using 16 Matlab workers.
- COARE 3.0 bulk flux algorithm used to compute Hs and Hl
- Two L4 GHRRST datasets used so far for SST
  - NCDC – avhrr_amsr_OI
  - REMSS – mw_IR_OI
- Other inputs (Qa, Ta, u10, LWR, SWR) fixed
- Comparison with WHOI OAflux data for 2006 [*Yu and Weller, 2007*].

Air specific humidity and air temp.

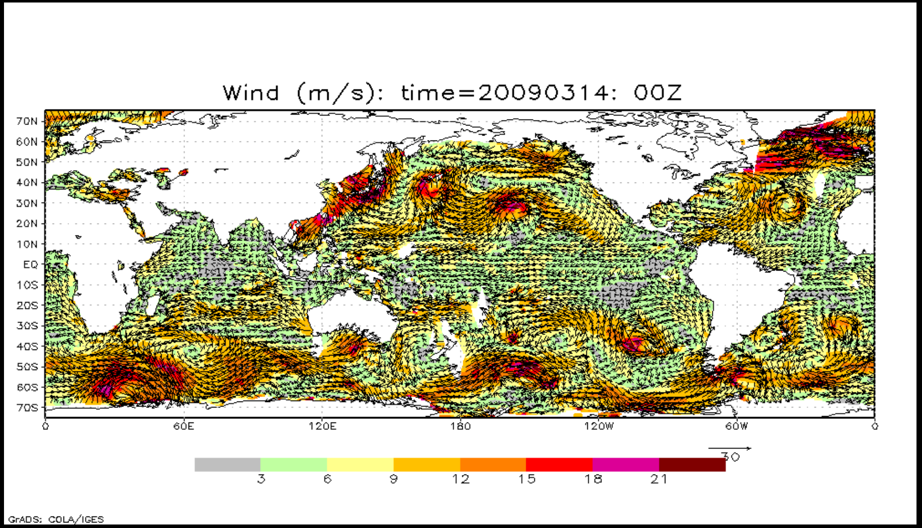
- Air specific humidity (QA) and air temperature (TA) derived from the AMSU brightness temperatures onboard NOAA POES.
- Experimental products, being developed at NCDC [*Shi and Zang, 2008*].
- TA uses AMSU-A, QA uses AMSU-A and –B.
- Neural network approach using a full year of training data
  - Global retrieval algorithm
  - Co-located AMSU and buoy/ship data from 70N-70S.
- 6 hourly data available.
  - 2001-present.



[*Shi and Zang, 2008*].

Blended Seawinds

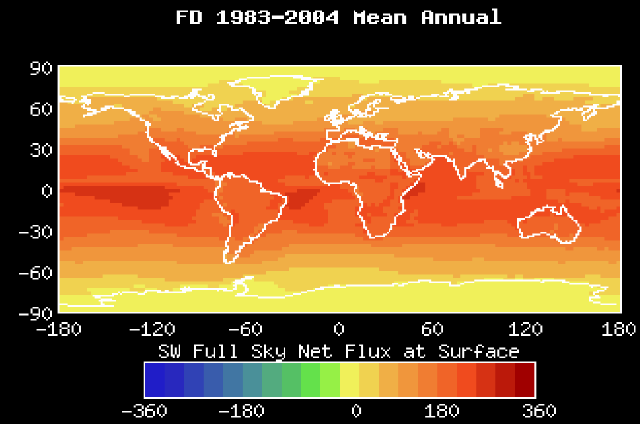
- Uses multiple-satellite obs. to fill in the data gaps (in both time and space) of the individual satellite samplings.
- Up to 6 satellites including AMSR-E, QSCAT, TMI.
- Reduces the sub-sampling aliases and random errors.
- U10 – Blended Sea Winds global 0.25 degree.
  - July 1987-present
  - 6 hourly, daily and monthly

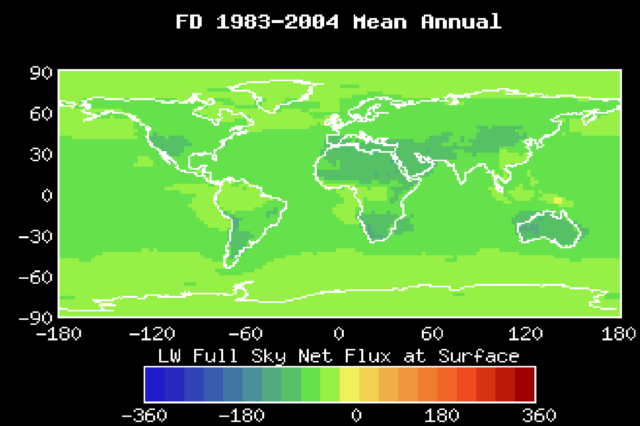


http://www.ncdc.noaa.gov/oa/rsad/seawinds.html [*Zang, 2006*].

Surface radiation – ISCCP FD SRF

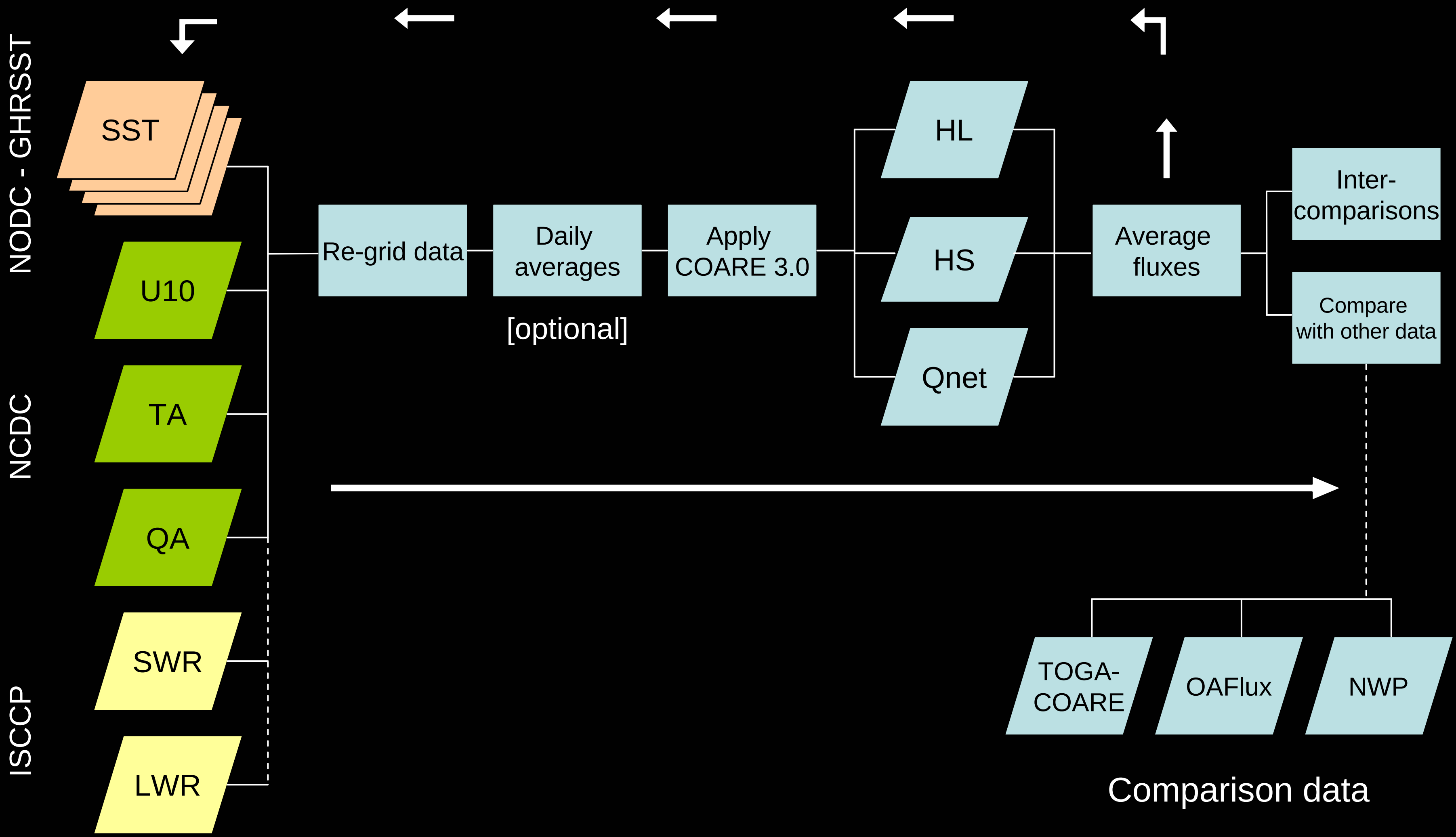
- Surface shortwave and longwave radiative fluxes available for 1983-2006 *[Zhang et al., 2004].*
- Global 280 km equal area, 3-hourly resolution.
- Full, clear and overcast sky.
- Using a complete radiative transfer model from the GISS GCM.
  - Uses cloud data from ISCCP



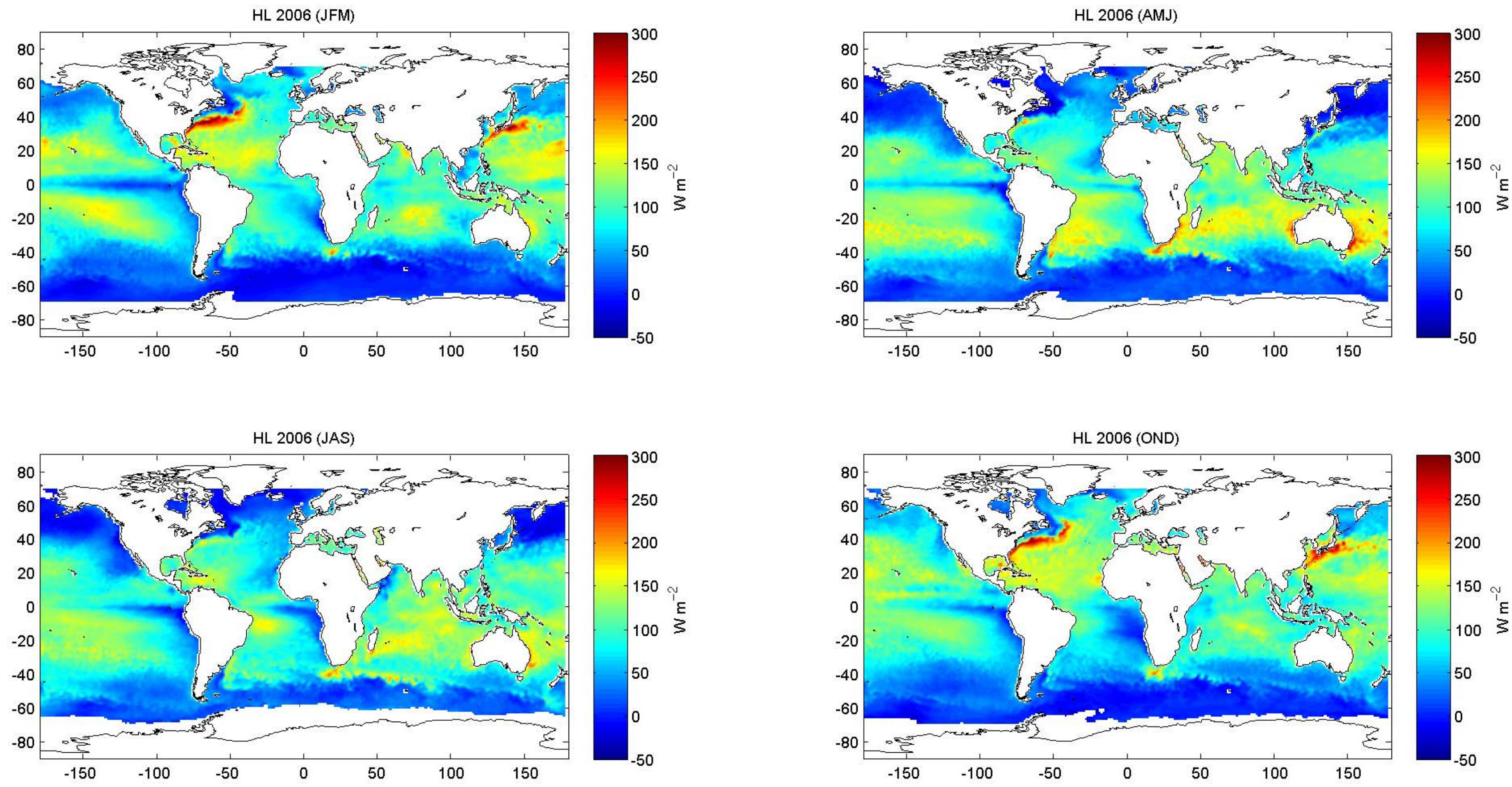


[*http://isccp.giss.nasa.gov/projects/browse_fc.html, 2009*].

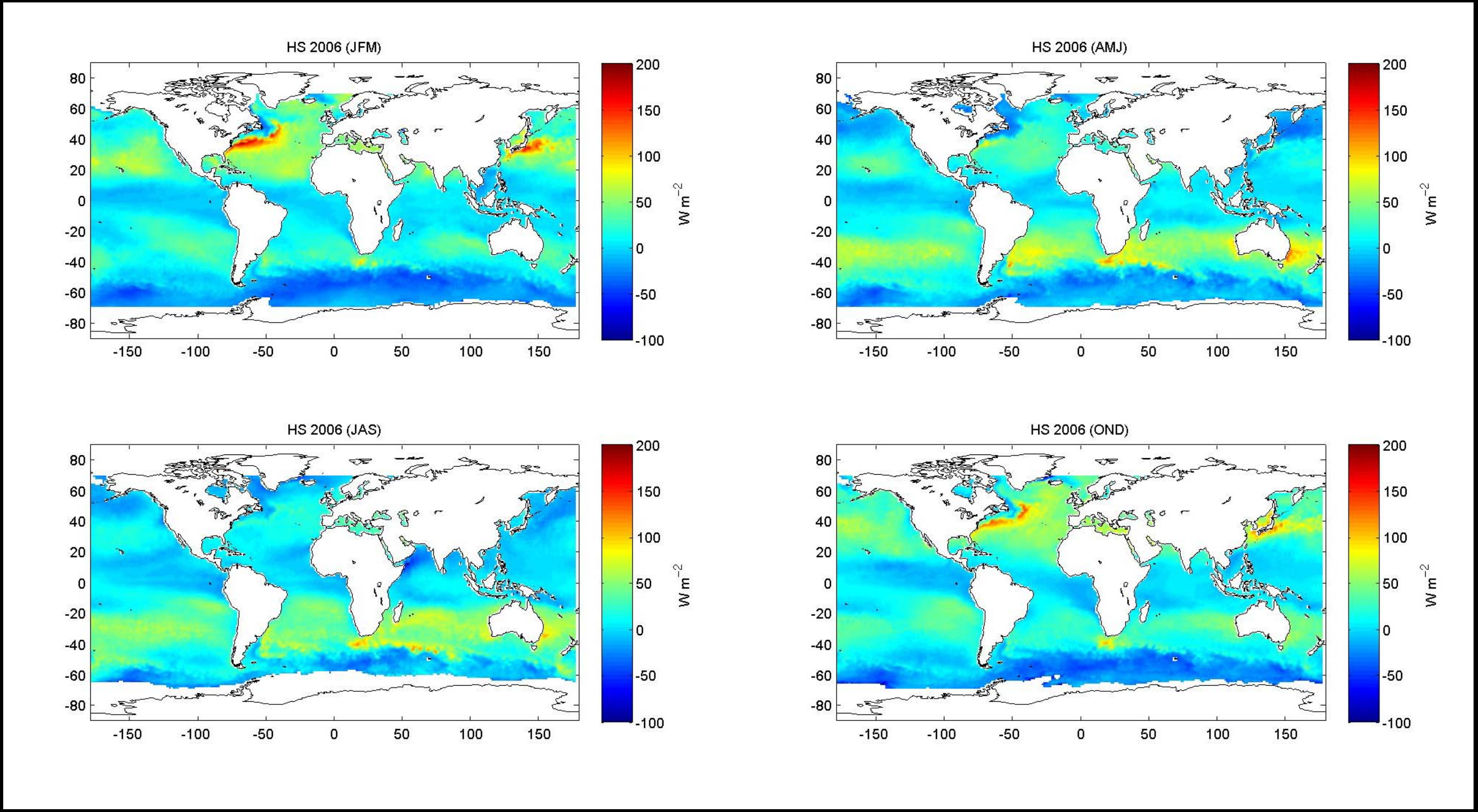
Simple outline



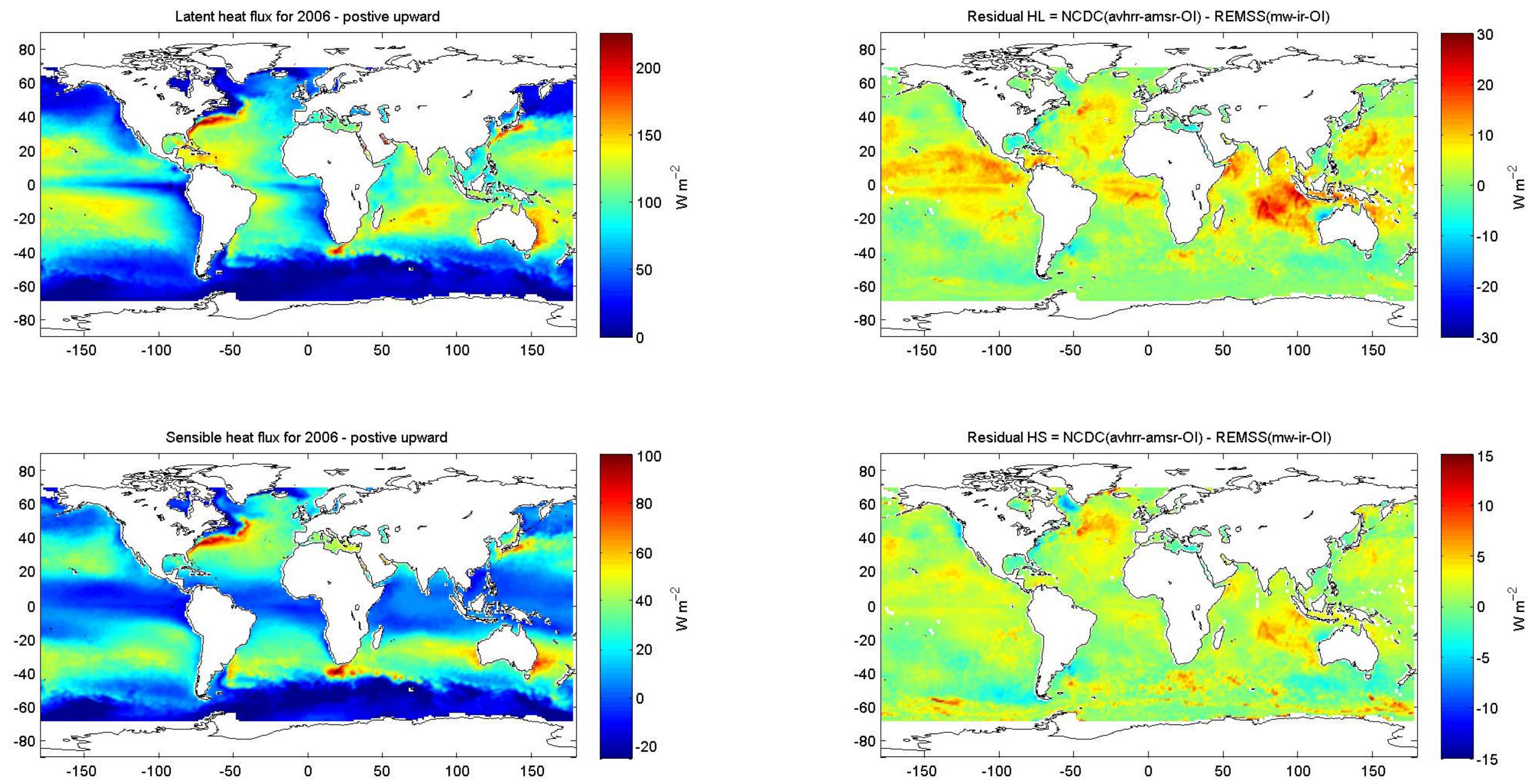
Seasonal latent heat flux



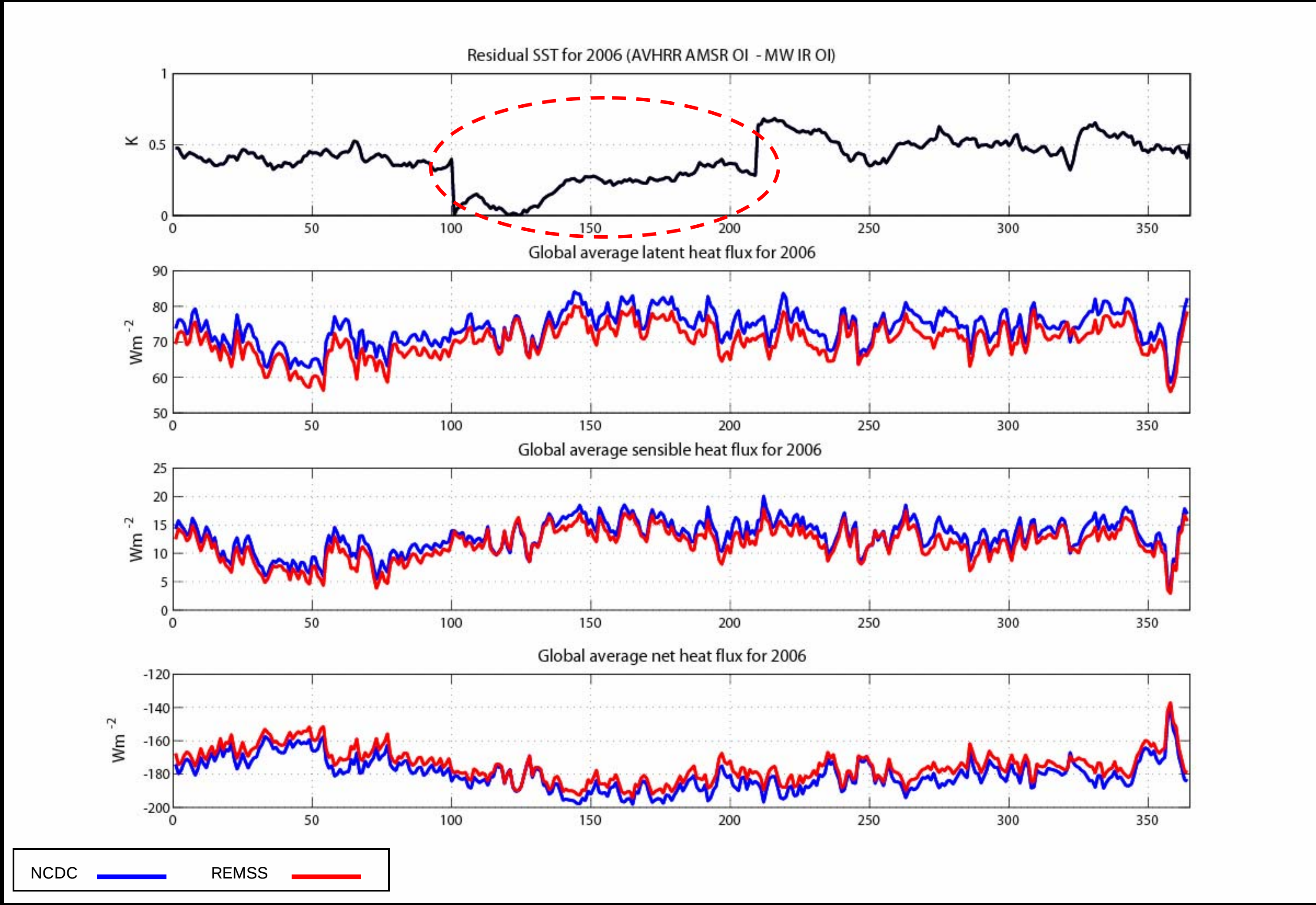
Seasonal sensible heat flux



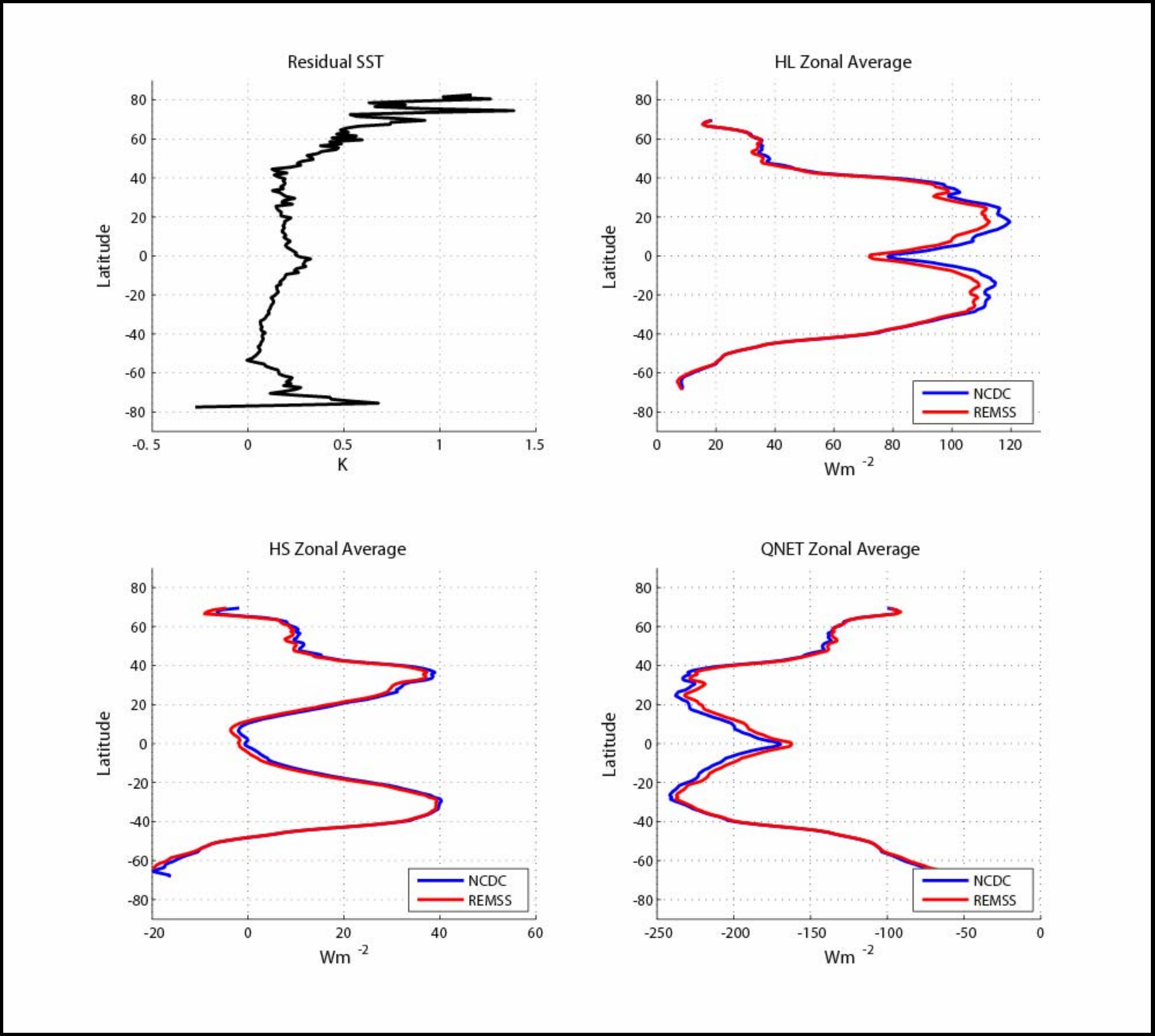
2006 Latent and sensible heat fluxes



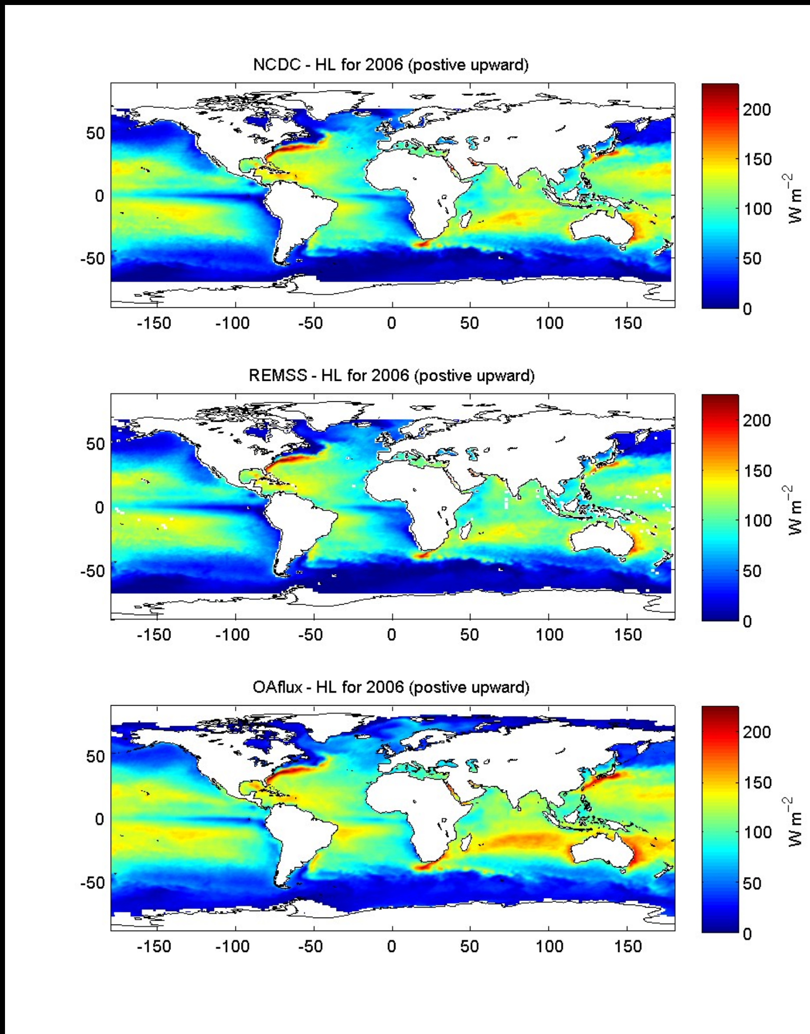
Daily global averages

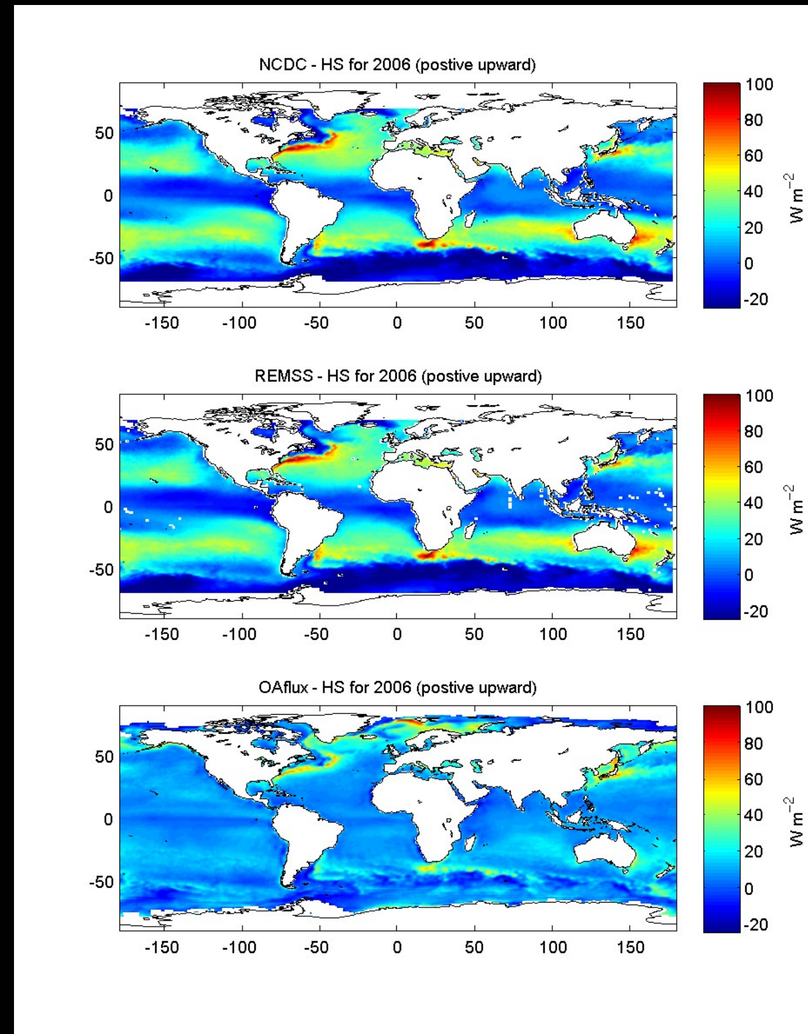


Zonal averages



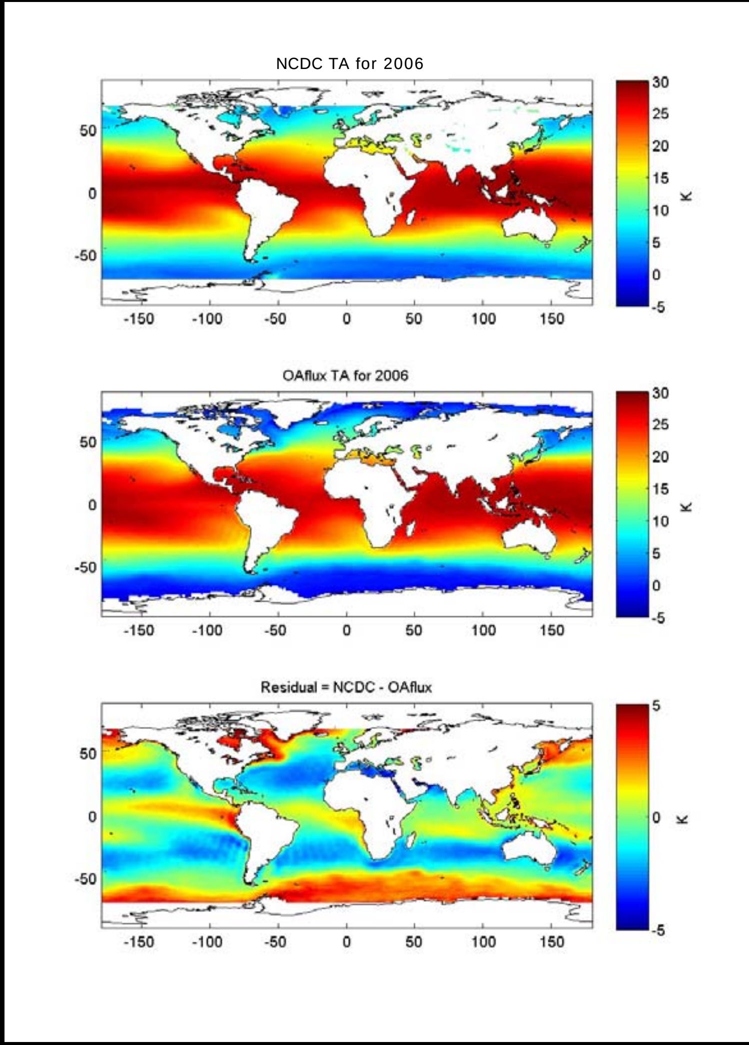
Comparison with OAflux data





Why the discrepancy in Hs?

- Latent heat (Hs) is dependent on the air-sea temperature difference.
- Look at input TA from OAflux and TA from NCDC.
- Some regions show large differences in TA up to 5 K.
- This translates into larger air-sea temp. differences >> larger sensible heat fluxes.
- Do we need to choose new TA input?



Future work

- In situ fluxes comparisons
  - TAO/PIRATA buoy calculated bulk fluxes
  - SEAFLUX validation dataset, contains direct obs. of turbulent fluxes [*Curry et al., 2004]*
- Further GHRSST L4 datasets for SST
- Other datasets for TA, QA, U10 etc...
- Additional years, different resolutions – sub-daily
- Regional validation study?
  - L2/L2P GHRSST data
- Links with international SOLAS project
  - E.g. CO2 fluxes, DMS fluxes

Selected references

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