Background
The ESA Support to Science Element (STSE) supports “Earth Science Flagship Projects”. e.g. GEWEX (WACMOS Land Flux), SPARC (SPIN), CLiC (North Hydrology), SOLAS (OceanFlux GHG, Seaspray, Upwelling), iLEAPS, ....

New opportunity for Ocean Heat Flux with CLIVAR
“Great opportunity for collaboration around the world to improve globally important data sets that are iconic for climate sciences”, Martin Visbeck

Participants
• 20+ across disciplines, world experts

Objectives
• Review existing activities, gaps & opportunities.
• Identify the scientific requirements for a CLIVAR/ESA activity this year.

Outcomes
• EO requirement document for ESA
• Roadmap document input for CLIVAR Community White Paper
Reconciling errors from independent measurements. e.g. altimetry, gravimetry, INSAR

Ice sheets have contributed to 11±mm global sea level since 1992 (1/5 total). 2/3 from Greenland. Recent acceleration of melting.

45 investigators, 26 partners
NASA / ESA

epoch I: overlap 2003-2008
epoch II: IPCC 2005-2010
Focus on Heat Budget

- Challenge of Closing the Planetary Heat budget,
- Key role of the Ocean, biggest heat reservoir.

Source: The Economist, scepticalscience.org, Trenbert et al., How Climate Deniers view global warming
New CLIVAR Research Opportunity

- NET RADIATION AT TOA: ASR - OLR
- GLOBAL ENERGY BUDGET AT THE SURFACE
- OCEAN: MAIN ENERGY RESERVOIR

MEAN EARTH'S ENERGY BUDGET

ENERGY BALANCE
\[ \text{ASR} - \text{OLR} + \text{G} = 0 \]

CLIMATE FORCING
ENERGY IMBALANCE
\[ \text{ASR} - \text{OLR} + \text{G} > 0 \]

CONSEQUENCES FOR EARTH'S CLIMATE

CHALLENGE:
COHERENCY ASSESSMENT OF I, II AND III: REDUCE UNCERTAINTIES TO BE ABLE TO INVESTIGATE INTERANNUAL TO LARGER VARIABILITY IN ENERGY OF THE CLIMATE SYSTEM

STATE OF THE ATMOSPHERE
- Temperature changes
- Radiation budget
- Circulation
- Extreme events

STATE OF THE OCEAN
- \( G \)
- Sea level
- Ocean mixing
- Circulation
- Extreme events

STATE OF THE BIOSPHERE
- Carbon cycle
- Ocean acidification
- Biodiversity

STATE OF THE CRYOSPHERE
- Surface temperature changes
- Ice melt
- Extreme events

CHANGES IN FLUXES OF MASS, HEAT AND MOMENTUM, E.G. WATER CYCLE, OCEAN-ATMOSPHERE, ICE MELT

Source: Karina von Schuckmann, clivar.rog

Sunday, July 7, 13
Specific focus on Air-Sea Heat Fluxes

Air-Sea fluxes are a key WCRP cross-cut focus of WCRP, across programmes (GEWEX, CLIVAR, SOLAS, iLEAPS, CLiC), and data (EO, in-situ, models),

• WCRP Working Group & GEWEX LandFlux - SeaFlux
• Action plan on Surface Fluxes (2012), WOAP meeting (Frascati, 2012)
• GSOP workshop in WHOI (Nov 2012), obs + synthesis for joint evaluation

Recommendations

• **Regional Heat/Salt budget analysis**
• Direct point wise comparison with OceanSITE
• Metrics for flux evaluation
• Requirements on Products
• Requirements on Infrastructure
• **Perspective of CAGE experiments** (Bretherton, 1986)
\[ Q_{\text{net}} = Q_{\text{LH}} \text{ (Latent)} + Q_{\text{SH}} \text{ (Sensible)} + Q_{\text{SW}} \text{ (Short Wave)} + Q_{\text{LW}} \text{ (Long Wave)} \]

\[ Q_{\text{net}} = F(p, x) \]

\[ x = dT[\text{air-sea temp diff}], q_a[\text{humidity}], W[\text{wind speed}], \text{SST}, \text{roughness / slope, Water Vapour, Clouds, Aerosols} \ldots \]

\[ p = C_p, C_e, C_h, \text{ +other parameterisations} \]

**Wealth** of flux data sets

- Atm Re-analysis (e.g. NCEP / CFSR, NASA / MERRA, ERA-CLIM, JRA)
- Ocean Synthesis (e.g. ECCO, Mercator)
- Empirical Bulk Formulas
  - in-situ (e.g. ICOADS NOCS)
  - EO (e.g. HOAPS [de], GSSTF [us], J-OFURO [jp], SeaFlux [us], ...)
  - Hybrid (e.g. CORE.2, DFS4, OAFlux, ...)

but **not** necessarily **consistent** with heat budget constraints!!

Use of **EO**, mainly non European, need for a “Flux Train”

e.g. \( T/a/q \) (SSM/I, AMSR-E), SST (reynolds, AVHRR..), \( W \) (SSMI, QuickScat,..),
Generating
- Need for new algo? parameterisations?
  e.g. probabilistic approach
- Need for new data?
  e.g. air-sea Temp

Validating
- Ground truth?
- Indirect measurement (issue of incest),
- In-situ (point-based),
- Poor Sampling:
  - Sparse (few buoys),
  - Uneven (better in the tropics!)
- Use of inter-comparison of products!

Quantifying Uncertainty
- Difference of Large Numbers
- Sampling issues,
- Representativity error,
- Empirical derivation.

Evaluating
- Need for new methodology?
- Reference data?
- Metric? Suitability? Usefulness?

Need to ensure **consistency**
with Heat Budget Constraints
Opportunities (from in-situ data)

BUOYS / SITES
- Idea of Super Sites, Reference Sites
- 85% buoys in tropical regions
- about 20 active full-flux buoys
+ OceanSITES

FLOATS
- 3000+ Argo floats for T/S profiles
- Sampling of upper ocean 2000m
- 7+yrs complete data
- **Focus on Argo period** 2004+

Source: GSOP report, Argo web site
Opportunities (from EO data)

**Missions**
- 20yrs archive ERS, Envisat + Explorers (SMOS, Cryosat, GOCE)
- 20yrs of data to come, e.g. Sentinels, Met missions

**Products**
- ESA Climate Change Initiative CCI (e.g. SST, OC, Aerosol, Cloud)
- GLOB products (e.g. current, wave) + STSE products
STSE study [400K, 2yrs]

- Be important for CLIVAR, complementary to other activities e.g. SeaFlux
- Exploit EO data, in particular from ESA missions and programmes,
  - ESA missions: Envisat AATSR, Cryosat Altimetry, SMOS L-band?
  - ESA projects / products: CCI SST, GLOBWAVE
- Produce Concrete Science Results
- Be realistic, Focus on topic / region

Big Opportunity here to shape this activity!
Possible STSE Ocean Heat Flux?

The overarching objective of **Ocean Heat Flux** is to **Develop a collaborative “Ocean air-sea Flux Laboratory Platform” to reconcile EO-based air-sea fluxes with heat budget constraints derived from EO and sub-surface data.**

In particular, to achieve this objective the project will aim to:

- **Gather** input data sets to derive air-sea fluxes from EO (e.g. W, SST, OC, Altimetry, Globwave, TOA..), ancillary data (Met data, Reanalysis, with associated meta-data), and ground truth (e.g. direct/indirect flux measurements), on one collaborative portal to enable easy inter-comparison of products.

- **Generate an ensemble of fluxes** based on existing data sets (e.g. HOAPS) and latest developments in algorithms and data, maximising the use of ESA data and products such as CCI. e.g. the ensemble would explore space of parameters and hypothesis, (e.g. wave/no wave, averaging SST), ..

- **Develop** a strategy to perform assessment of fluxes, at **regional** spatio-temporal scale, exploiting heat budget constraints.

- **Identify** “Reference” Regions (e.g. natural/pre-defined CAGES, Bubbles, Medsea) and time windows suitable to perform evaluation of flux (e.g. good signal to noise).

- **Quantify** Quality of fluxes, and parameterisations, through comparison with *in-situ* and regional constraints.

- **Provide** ESA with recommendations of future work and satellite missions useful to address the CLIVAR research opportunity on planetary energy budget.
Exploiting Heat Budget Constraints?

Bubble Analysis, identify adequate reference “CAGE” regions:
e.g. Pacific Warm Pool, Med Sea, Tropical Band, ..
e.g. closed regions where div F known or small ...
e.g. Time window, depending on events e.g. ENSO, availability of data

Ocean Synthesis
to enable optimal sampling of suitable reference regions

EO obs
Barotropic (RA)
SST (AATSR)
W (ERS)
Absorption (MERIS)

In-situ obs
OHC (Argo)
Q Fluxes (Buoys)

Surface Heat Transport

Change in Heat Content

Qa

div Fh

Advection Heat Transport

OHC

dt OHC

div Fz

Diffusive Heat Transport

Sunday, July 7, 13
**Test Bed Environment for Consistency Assessment**

- Input Data
  - SST, q, W

- SST CCI
- SST AVHRR
- W PMW
- W Scat

- Flux Data
  - ESA Ocean Heat FLux
  - SeaFlux
  - HOAPS
  - ERA-Interim

- Heat Budget Data
  - OHC Argo
  - Diffusive FLux
  - TOA
  - ERA-Interim

- \( \text{CAGE I} \)

- Test - benchmark flux algorithms & parameterizations
- Assess Consistency / Quality .. Heat / Freshwater ?
- Quantify sensitivity, perform effective inter-comparisons
- Recalibrate parameters regionally
- Flexible to integrate other layers e.g. land fluxes
Need for EO-ARGO Flux-type Product?

New flux retrieval algorithm based on a variational approach to partition fluxes components on the CAGES regions.