# Research Focus Name: CONCEPT-HEAT

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## Overview on CLIVAR Research focus CONCEPT-HEAT

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**CONCEPT HEAT**

**http://www.clivar.org/research-foci/heat-budget**

The CLIVAR research focus CONCEPT-HEAT (Consistency between planetary energy balance and ocean heat storage) is focused on Earth's Energy Imbalance (EEI) and its largest component, the changes in ocean heat content (OHC). CONCEPT-HEAT aims to bring together experts from ocean and atmospheric reanalysis, air-sea fluxes, OHC, atmospheric radiation, sea level, and climate models to better synthesize all the information available. A goal is to foster collaboration among these different communities and build up a multi-disciplinary community to promote progress and an integrated view.

There has been a change in the leadership of CONCEPT-HEAT in October 2017. Kevin Trenberth has stepped down as co-chair but will remain as a member of the RF. Tristan L'Ecuyer has replaced Kevin and is now the new co-chair, together with Karina von Schuckmann. Tristan is also co-chair of GDAP in GEWEX.

### Objectives of CONCEPT-HEAT.

I. Quantify Earth's energy imbalance, the ocean heat budget, and atmosphere-ocean turbulent and radiative heat fluxes, their observational uncertainty, and their variability for a range of time and space scales using different observing strategies (e.g., in-situ, satellite), reanalysis systems, and climate models.

II. Analyze the consistency between the satellite-based planetary heat balance and ocean heat storage estimates using data sets and information products from global observing systems (remote sensing and in situ) and ocean reanalysis. In addition, the results can be used to compare to outputs from climate models to facilitate validation.

**Implementation:** 21st CLIVAR SSG meeting: November 2014

**Planned ending date**? Research foci normally last for order 5 years. C-H began in 2014, and could evolve into a WCRP wide activity.A common CLIVAR/GEWEX workshop in the second half of 2018 is planned to further discuss this issue.

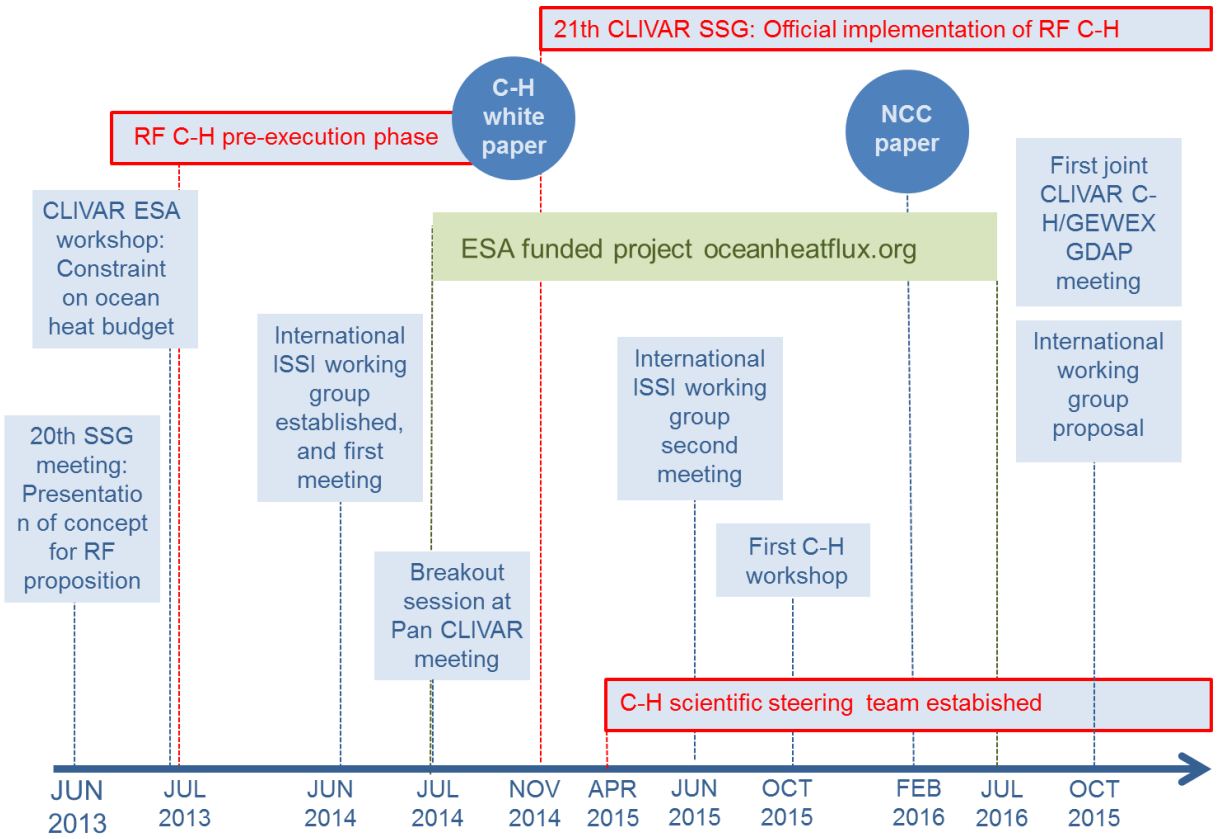


***Figure 1:*** *Schematic overview on milestones of the CLIVAR research focus CONCEPT-HEAT.*

## Achievements for 2016-2017

During 2016, the publication of the perspective paper on the Earth Energy Imbalance in Nature Climate Change was a fundamental step forward on knowledge exchange and scientific capacity building. Since the second half of the year 2016 up to now, strong achievements on knowledge exchange are under the way, particularly between CLIVAR (e.g. CONCEPT-HEAT) and GEWEX (e.g. GDAP). These discussions will fundamentally contribute to the main goal of C-H to build up a multi-disciplinary synergy community on the energy flow through the climate system, and the Earth Energy Imbalance. Intensive and various discussions had been performed, and a joint meeting of CLIVAR C-H and GEWEX GDAP has taken place on the 9$^{th}$ of October 2017 (host: NCAR, Boulder), agenda attached. Beside discussions on the scientific cross-link topics during this meeting, a specific discussion occurred on a common WCRP: CLIVAR/GEWEX workshop to take place during the second half of 2018, and funding appears to be available from WCRP (to be confirmed); see below.

A second discussion point included future collaborations between C-H and GEWEX to undertake an assessment of methods for assessing EEI and its variability with the aim of documenting uncertainties, assessing their implications for prediction, and identifying future observational needs. This may then develop into a community paper.
Several scientific sessions have been held: at AGU 2016, and planned for AGU 2017.

## Plans for 2018 and beyond

Plans for 2018 are:

1) Foster the collaboration of C-H with GEWEX related activities/topics. Milestones in 2018 for this objective will be the organization of one common workshop (see appendix) as well as a C-H session during the GEWEX science conference 2018
2) Establish the nature and scope of a community EEI assessment activity that integrates the mutual interests of relevant CLIVAR and GEWEX panels including C-H and GDAP.
3) A key outcome of C-H discussions during 2015/2016 was the proposed development of a new group project, estimating the net surface flux as a residual of the top-of-atmosphere (TOA) radiative fluxes (from CERES) combined with comprehensive estimates of the vertically integrated atmospheric divergence of energy (e.g., from ERA-interim reanalyses). The key point for C-H is that this approach can be used for all the surface flux datasets combined with any or all OHC datasets (in situ, ocean reanalyses), and it provides a metric of comparison and evaluation. The goal is to focus first on the Atlantic, and perhaps the North Atlantic in the form of a Cage experiment, i.e. an analysis of regional heat and mass budget closure. Another priority which has been mentioned is the analysis of ocean meridional heat transport (MHT) and its variability. For this analysis alternative estimates of MHT revealed by ocean reanalyses will be critically important. At present this activity has general support, but lacks funding and a group to lead it.
4) Organization of sessions at Ocean Science 2018 and the GEWEX Science Conference in May 2018 in Canada.
5) The CLIVAR/GEWEX/WCRP workshop is to take place during the second half of 2018, and funding appears to be available from WCRP (to be confirmed).

**The Workshop specifications:**

- open workshop, jointly with C-H RF meeting
- Invited key-note talks
- Reserved long time slots for coordinated common discussions
- Set up working groups to report back on last day
- Expected length: 3.5 days
- Scientific steering team: co-chairs of C-H, CLIVAR & GEWEX members, 1 scientist from CliC, ocean modeling/reanalysis, …. During the Boulder meeting, the following persons had been proposed: scientific and organization steering team: K. von Schuckmann (C-H), T. L'Ecuyer (C-H, GDAP), B. Meyssignac (Sea Level, C-H), R. Roca (GDAP).
- Location: Likely Toulouse, France.

**Proposed organization (see Fig. A.1 for an overview):**

- **Session 1: Estimate EEI globally**: Topics include OHC, ocean surface energy balance, land heat storage and energy balance, atmospheric heat storage, TOA net flux, EEI physical budget constraint.
- All topics should utilize results from observations, reanalyses and models. The synthesis and EEI assessment activity are included as well in this session, where future steps of these activities will be discussed.
- [1 day]

- **Session 2: Estimate EEI locally:** Cage experiments: comprehensive energy and water balances over specific regions: land, ocean, Arctic.
- Annual cycle, interannual variability, longer-term changes.
- ENSO: Recharge-discharge model; impact on OHC, SLR, GMST
- Cryosphere energy storage and balance, How much energy has gone into melting ice: Arctic, Antarctic, and what is the annual cycle in each hemisphere? (CliC)
- [1 day]
- **Session 3: Predictions:** Implications of anomalous heat storage for predictions, especially decadal and regional. [1/2 day]
- **Session 4: Cross WCRP interactions on the Earth's energy imbalance:** Objective is to strengthen and extend the community on the Earth energy imbalance, and is the key part of the workshop to achieve expected outcomes based on the gained knowledge from the previous sessions. It includes the need for different groups (e.g. within GDAP) to confront each other and enforce consistency (wrt energy and water).
- [1/2 day]
- **Session 5: Working Group outcomes and Wrap up.**

## Articles published in 2016/17 as part of RF activities


Bentamy, A., J. F. Piollé, A. Grouazel, F. Paul, H. Azelmat, P. P. Mathieu, K. von Schuckmann, S. Sathyendranah, H. E. King, R. Danielson, I. Esau, J. Johannessen, S. Gulev, C. A. Clayson, R. Pinker, S. Grodsky, M. Bourassa, S. R. Smith, K. Haines, M. Valdivieso, C. Merchant, B. Chapron, A. Anderson, R. Hollmann, J. Simon, 2016: Towards Improvement of the Estimation of Turbulent Heat Flux over Global Oceans, Remote Sensing of Environnement, 201 (2017) 196–218

Dieng, H.B., A. Cazenave, B. Meyssignac, K. von Schuckmann and H. Palanisamy, 2017: Sea and land surface temperatures, ocean heat content, Earth's energy imbalance and net radiative forcing over the recent years, International Journal of Climatology, DOI: 10.1002/joc.4996.

Chambers, D.P., A. Cazenave, N. Champollion, H. Dieng, W. Llovel, R. Forsberg, K. von Schuckmann, and Y. Wada, 2016: Evaluation of the Global Mean Sea Level Budget between 1993 and 2014, Survey of Geophysics, DOI 10.1007/s10712-016-9387-x.

Cheng, L., K. E. Trenberth, M. D. Palmer, J. Zhu, and J. P. Abraham, 2016: Reconciling observed and modeled ocean heat content changes since 1970. Ocean Sci., 12, 925-935, doi:10.5194/os-2016-16.

Cheng, L., K. Trenberth, J. Fasullo, T. Boyer, J. Abraham, and J. Zhu, 2017: Improved estimates of ocean heat content from 1960-2015. Sci. Adv. 3, 3, e1601545, Doi:10.1126/sciadv.1601545.

Cheng, L., K. E. Trenberth, J. Fasullo, J. Abraham, T. Boyer, K. von Schuckmann, J. Zhu, 2017: Taking the pulse of the planet. *Eos*, https://doi.org/10.1029/2017EO081839.

Liu, C. et al., Combining satellite observations and reanalysis energy transports to estimate global net surface energy fluxes 1985–2012, *J. Geophys. Res. Atmos*. **120**, doi:10.1002/2015JD023264 (2015).

Macintosh, C. R., C. J. Merchant and K. von Schuckmann, 2016: Uncertainties in steric sea level change estimation during the altimeter era: concepts and practices, Survey of Geophysics, DOI 10.1007/s10712-016-9387-x.

Mayer, M., J. T. Fasullo, K. E. Trenberth, L. Haimberger, 2016: ENSO-driven Energy Budget perturbations in observations and CMIP models. Climate Dyn. Doi: 10.1007/s00382-016-3057-z.

Kato, S., K-M. Xu, T. Wong, N. G. Loeb, F. G. Rose, K. E. Trenberth and T. J. Thorsen, 2016: Investigation of the bias in column integrated atmospheric energy balance using cloud objects. J. Climate, 29, 7435-7452; doi:10.1175/JCLI-D-15-0782.

Trenberth, K. E., J. T. Fasullo, K. von Schuckmann and L. Cheng, 2016: Insights into Earth's energy imbalance from multiple sources. J. Climate, doi:10.1175/JCLI-D-16-0339, DOI: 10.1175/JCLI-D-16-0339.1

Trenberth, K. E., and J. T. Fasullo, 2017: Atlantic meridional heat transports computed from balancing Earth's energy locally. Geophys. Res. Lett., 44, 1919–1927, doi:10.1002/2016GL072475, http://dx.doi.org/10.1002/2016GL072475

von Schuckmann, K., M. D. Palmer, K. E. Trenberth, A. Cazenave, D. Chambers, N. Champollion, J. Hansen, S. A. Josey, N. Loeb, P.-P. Mathieu, B. Meyssignac, and M. Wild, 2016: Earth's energy imbalance: An imperative for monitoring. Nature Climate Change, doi:10.1038/NCLIM-15030445C, 138-144.

## Budget and other needs for 2018

*See Annex A: "Proforma for CLIVAR Research Focus requests for SSG approval for meetings"*

**Annex A**

# Proforma for CLIVAR Research Focus requests for SSG approval for meetings

1. **Panel or Working Group: Research focus Concept-Heat**
2. **Title of meeting or workshop:** Joint WCRP/CLIVAR/GEWEX: "Synergy community on the Earth energy imbalance", and CONCEPT-HEAT RF meeting
3. **Proposed venue:** Toulouse, France
4. **Proposed dates:** during second half of 2018
5. **Proposed attendees, including likely number:** open workshop (C-H meeting is closed to RF members only)
6. **Rationale, motivation and justification, including: relevance to CLIVAR science & WCRP Grand Challenges, and any cross-panel/research foci links and interactions involved:** The Earth's energy imbalance is a topic developed by CONCEPT-HEAT, that has grown in scope to embrace most of the WCRP core projects, in particular between CLIVAR and GEWEX. It could evolve or graduate into a WCRP-wide activity. CONCEPT-HEAT is currently a CLIVAR research focus which normally last for order 5 years. C-H began in 2014. A workshop is planned in the second half of 2018 to further discuss these issues within the different core programs of WCRP, and is proposed to be commonly organized by CLIVAR (C-H) and GEWEX (GDAP).
7. **Specific objectives and key agenda items:** Overall goal: Strengthen and extend the synergy community on the Earth's energy imbalance aiming to discuss cross-links between the different WCRP core programs, in particular between CLIVAR and GEWEX, but also including CliC. Expected outcomes: The workshop will identify research goals and opportunities on the Earth's energy imbalance, and synthesize and focus the various aspects across WCRP. A main outcome may include the discussion and reporting on how the C-H topic could evolve into a WCRP topic.
8. **Anticipated outcomes (deliverables)**
   - Possible pan-WCRP projects, one related to the global aspects and a possible assessment, and one related to regional aspects on water and energy budget closure.
   - Report on identified cross-links between the WCRP core projects, in particular between CLIVAR and GEWEX.
9. **Format:**
   - open workshop
   - Invited key-note talks
   - Reserved long time slots for coordinated common discussions
   - expected length: 3.5 days (workshop) + 1 day dedicated RF meeting. But note that the workshop is essential part of the RF business.
   - 5 principal sessions (draft)

10. **Science Organizing Committee Members** of CLIVAR (e.g. Concept-Heat) and GEWEX (e.g. GDAP)

11. **Local Organizing Committee (if relevant)** Remy, Benoit, Karina

12. **Proposed funding sources and anticipated funding requested from WCRP:** Funding request: 10K. WCRP has proposed for Earth energy imbalance funding (~15K), but it is not clear if this funding will be restricted to the year 2017, or if it can be extended until the year 2018. Local funding for the venue from France (proposition: R. Roca). Proposals will be needed to garner other funding.

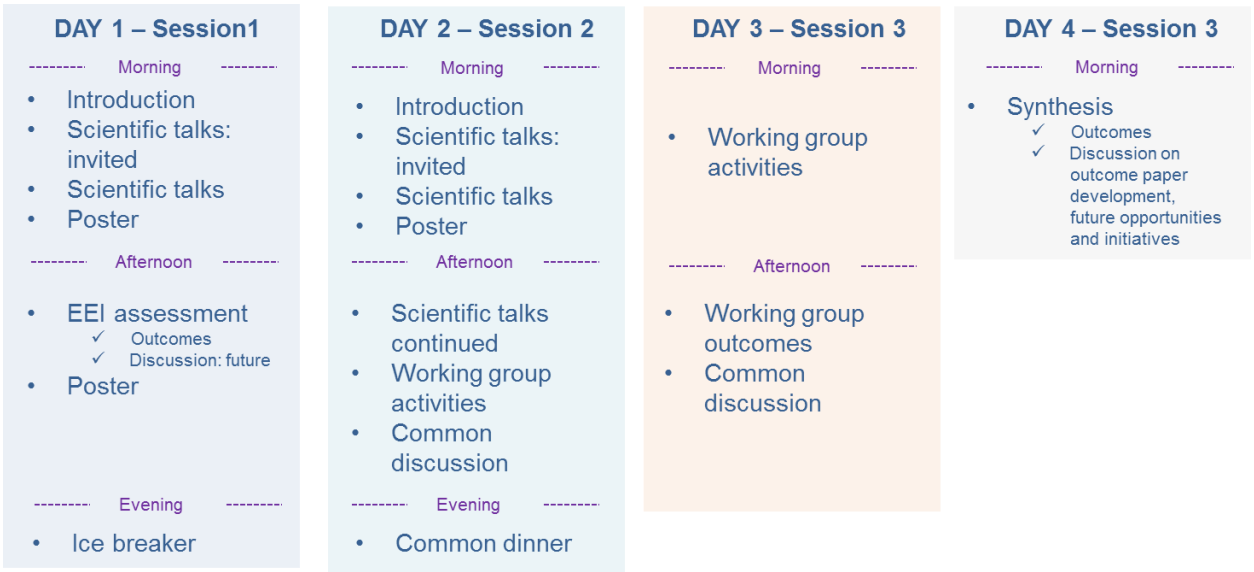


***Figure A.1:*** *Proposed first overview draft on workshop sessions.*

## Annex B

## GDAP meeting, NCAR, Boulder CO
## Damon Room, Mesa Lab
9 October 2017

**Topic: CONCEPT-HEAT: Interactions within WCRP**

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**Proposed agenda**

08:45 Opening remarks, welcome to NCAR, Jim Hurrell, Director
08:55 Round the room introductions

**Introduction**

| | |
|---|---|
| 09:00 C-H and past events | Kevin Trenberth/Karina von Schuckmann |
| 09:20 CLIVAR perspective | Detlef Stammer/Annalisa Bracco |
| 09:35 GEWEX perspective | Graeme Stephens/Sonia Seneviratne |
| 09:50 GDAP perspective | Tristan L'Ecuyer/ Rémy Roca |
| 10:05 Sea Level conference | Detlef Stammer |

10:15 Break

**Science developments**

| | |
|---|---|
| 10:40 Sea Level 1 | Steve Nerem |
| 10:50 Sea Level 2 | Benoit Meyssignac |
| 11:00 Discussion of perspectives | |
| 11:10 OHC | Lijing Cheng |
| 11:30 Establishing TOA radiation using CERES, ERBS | Seiji Kato |
| 11:50 Energy budget inventory methods | Kevin Trenberth |
| 12:10 Discussion | |

12:20 Lunch

| | |
|---|---|
| 13:30 Transport constraints on energy and water budget inverse model (U Reading) | Keith Haines |
| 13:50 Surface fluxes ocean | Carol Anne Clayson |
| 14:05 Surface fluxes land | Mathias Hauser/Isabel Trigo/Sonia |

14:20 How models do the energy balance Andrew Gettelman
14:40: High-latitude ocean heat uptake and cloud feedbacks in CESM Jen Kay
15:00: Skillful decadal prediction of upper ocean heat content Steve Yeager
15:20 Break
15:50: Ocean and models discussion Detlef; Frank Bryan, John Fasullo, Benoit, others?
Incl. reanalysis

**The future: where we go from here**
16:10 The transient Earth energy imbalance Karina von Schuckmann/Tristan
16:40 Possible workshop Trenberth and others
17:10 AGU/OS sessions Seiji Kato, Lijing Cheng
17:20 Discussion

18:00 **Reception**