

WCRP REPORT

World Climate Research Programme



ICSU
International Council for Science

Action Plan for WCRP Research Activities on Surface Fluxes

January 2012

WCRP Informal/Series Report No.01/2012

Action Plan for WCRP Research Activities on Surface Fluxes

10 October 2011

Purpose

The purpose of this report is to respond to a JSC request to WOAP to develop an outline of an action plan on surface fluxes and a timetable for its full development in collaboration with WCRP sub-programs. All relevant programs at the last JSC meeting (GEWEX, CLIVAR, CLIC, SOLAS, WGNE and GCOS Panels) expressed interest in the process and, together with a representative of IGBP and other experts, their representatives contributed to this report. The group involved in preparing this report is given in Appendix 1.

Background

Across WCRP and GCOS programs, surface flux observations are obtained both directly and indirectly, surface flux datasets are generated from both *in situ* and satellite-based data (as well as blended datasets from different sources), and model-based fluxes are generated. Fluxes are considered over land, ice and ocean, and the fluxes of both physical and chemical variables are considered. A number of groups have been carrying out inter-comparison studies of specific datasets which often identify some inconsistencies. Many of these issues will be resolved by the individual groups, but a number of problems may extend across domains. Moreover, some issues remain on the basic measurement of fluxes. Associated with the observation of fluxes has been the establishment of reference sites or super-sites at which comprehensive measurements are taken. A number of different networks of super-sites have been established around the world, and the relationships between these networks could also be considered.

It is recognised that surface fluxes are of interest because they represent exchanges across interfaces, and so they should not be considered in isolation from the state variables on both sides of the interface. For example, to properly understand the relationship between heat flux and SST it is necessary to know the character of the mixed layers in the ocean and atmosphere. Indeed the estimation of surface fluxes is often inferred from the state variables near the interface. The spatial and temporal variability of surface fluxes further highlights the need for careful consideration of their measurement and representation in models. The need to link fluxes with their associated state variables means that, when developing and evaluating global datasets, these inter-dependencies must be considered.

The group decided that the following issues need to be considered. Each issue is briefly summarised and recommended actions by WCRP to progress the issue are listed. These actions are finally summarised in overall conclusions to the report.

Issue 1. Common issues over land, ice and sea

While there has been much work in WCRP on physical fluxes at the sea surface (reflecting the work of the former Working Group on Surface Fluxes (WGSF)), some issues remain about land-based flux measurements especially about the links between physical and chemical (constituent) fluxes. This raises the question of whether there is a need for a process to consider the common interests on fluxes over land, ice and sea.

Comment

The group believes that, from a climate science view point, surface fluxes over land, ice and sea should be considered together as they represent equally important components of the climate system budgets of energy, water and carbon. De-emphasising any one component precludes its effective use in quantitative assessment of global and regional budgets (for example, Trenberth et al. 2011). It follows that there needs to be a process for dialogue between the experts dealing with fluxes over land, ice and sea. On the other hand, there are detailed requirements specific to each domain that mean that the interactions between experts need to be on topics of common interest, such as estimation of the accuracies of fluxes at different space and time scales, the evaluation of flux products, and the evaluation of model-based (including reanalysis) fluxes. It is noted that, through LandFlux and SeaFlux, GEWEX has had some experience in establishing a dialogue across domains, and this experience should be drawn on in developing a plan of action. A forum in which all relevant groups participate is provided by WOAP.

Action

It is **recommended** that dialogue should be facilitated by WOAP across the relevant programs (GEWEX, CLIVAR, CLIC, SOLAS, AOPC, OOPC, TOPC) to identify issues of common interest across the domains of land, ice and sea for joint consideration. These are expected to be associated with topics such as

- ⤴ estimation of the accuracies of fluxes at different space and time scales
- ⤴ the evaluation of flux products
- ⤴ the evaluation of model-based (including reanalysis) fluxes.

The agreed issues should be considered through specific meetings or workshops, that would produce reports on conclusions reached and future actions needed. The workshops could be held in conjunction with the regular meetings on one of the relevant groups (such as, GSOP or GRP), or they could be stand-alone meetings. The key point is that they need to be well focused and to attract the experts from all the domains. Relevant experts from IGBP programs should be invited to participate.

Issue 2. Distribution of reference sites

The issues about physical and chemical fluxes include the nature and extent of super-sites, which seem to be better organised over the ocean (through OceanSITES) than over the land. At its last meeting, WOAP identified a priority as the need to develop a strategy to optimise and justify the distribution of such multi-variable sites, with TOPC taking the lead. It would be important to recognise that the justification for the sites is often nationally based. The discussion should include consideration of regions that are currently poorly sampled; for example, the Arctic Ocean has been identified as poorly sampled. Thus there is a question of whether there is a need for a process to consider the distribution of super-sites, especially over the land.

Comment

The group believes there is a need to consider the somewhat sensitive issues associated with reference sites. The issues include the under-sampling of important geographical areas, the need for climate-quality instrumentation and data-handling systems, and the desirability of collocation of measurements of several variables (that is, multi-variable sites). The existing mechanisms for

managing OceanSITES and FluxNet account for these issues for each domain, but there may be value in taking a global perspective independent of domain. Moreover, especially over land and ice, there are independent networks, including GRUAN and GEWEX RHP. The scope of any discussion should be limited to sustained networks with global implications. Moreover, given that OceanSITES accounts for essentially all ocean-based reference sites, the focus initially should be on land-based networks. As with Issue 1, it would be appropriate to consider issues across all domains at some stage.

Action

It is **recommended** that the initial consideration of this issue should be focused on land-based reference networks, and that TOPC should be asked to summarise the characteristics of sustained networks with global implications and to recommend actions (such as focused workshops) that could be taken to optimise

- ⤴ the spatial distribution of reference sites
- ⤴ the consistency of measurements and data handling
- ⤴ the promotion of multi-variable sites.

Based on progress with land-based sites, it would be appropriate to consider the promotion of dialogue across domains as for Issue 1, led by TOPC and OOPC.

Issue 3. Flux measurement and data processing

The WGASF developed a guide on flux measurements over the ocean (Bradley and Fairall, 2006), and there has been a lot of work on the VOSCLIM system (Kent et al., 2007). Extended guidelines on instrumentation at flux buoys is provided by Weller (2008, Ocean Science Discussions). The CLIMAR and MARCDAT workshops have promoted improvements in measurement and data processing of flux-related data over the ocean. It has been suggested that there could be further work on consistency in the basic measurement of fluxes and the processing of the observed data, especially over the land. The issues include, not only instrumentation, but also visual observing practices and coding systems, data sampling, quality control and related topics. The relevant question is whether there is a need (including both land and sea sites) for a process to consider the consistency of flux measurement and data processing.

Comment

The group believes that these issues remain important for the continuing improvement of flux estimates. Over the ocean, there is a hierarchy of observing systems from high-quality measurements from buoys and research vessels, through VOSCLIM data to VOS observations. The science supporting these systems is provided through a number of agents, including JCOMM, OOPC, GSOP and SOLAS. Over the land, FluxNet provides a major mechanism for leadership, but there are other activities, such as the GEWEX RHP.

The need for standards and consistency considered for *in situ* measurements of fluxes also applies to satellite-based flux estimates. Concerns about the handling of fundamental climate data records (FCDRs) are being taken up by satellite agencies, but the estimation of surface fluxes are especially sensitive to inconsistencies in calibration and algorithms. The inter-dependence of *in situ* and satellite-based fluxes also needs to be taken into account when considering the spatial and temporal distribution of surface flux measurements. The GRP currently is promoting these issues through

SeaFlux and LandFlux, and WOAP has a continuing role in considering them with the space agencies.

The key consideration for flux measurement is whether there is an organisational gap that needs to be filled by WCRP. There is a view amongst the ocean community that a working group is needed to facilitate the interactions between the different observing platforms and to promote and assess the quality of measurements. A flux inter-comparison workshop is being held by GSOP in 2012, where the opportunity could be taken by the full community to delineate the responsibilities of the relevant groups and to identify any significant gap that should be filled by WCRP. Consideration should be given to whether the gap should be best filled by a long-term working group, a series of specific task groups, or a series of specific workshops.

Actions

It is **recommended** that GSOP in cooperation with OOPC, SOLAS and JCOMM should use their 2012 inter-comparison workshop (or another meeting of opportunity) to document and analyse the responsibilities of existing groups (such as GSOP, OOPC, SOLAS and JCOMM) and to identify any organisational gap that should be filled by a WCRP sub-program. If a gap is identified, then a report should be prepared that delineates the need for a new group, recommends the sub-program that should sponsor the new group, and identifies a funding mechanism for the group. It is further **recommended** that WOAP (in collaboration with WCRP programs and GCOS panels) should continue to liaise with space agencies (especially through CEOS and CGMS) on the requirements for satellite-based FCDRs, bearing in mind the particular needs for surface flux estimation.

Issue 4. Global datasets of fluxes

There has been progress in WGSF and GEWEX on the development and evaluation of global datasets of fluxes over the ocean and land, based on satellite measurements (eg SeaFlux and LandFlux (Mueller et al., 2011; Jimenez et al., 2011)); a flux inter-comparison workshop is proposed by GSOP in 2012. On the other hand, analyses such as Trenberth and Fusallo (2010) suggest that there remain significant uncertainties about the energy and water fluxes between the atmosphere and sea and land. Under the auspices of WOAP, ESA recently hosted a workshop in Frascati aimed at developing a consistent framework for the evaluation of global climate datasets; radiative fluxes were the only surface fluxes to be considered at that meeting. A question follows as to whether there is a need for further processes to promote the production and evaluation of global surface flux datasets.

Comment

It is appropriate to separate actions required to promote the production of datasets from those to promote their evaluation. The group believes that the production of datasets is generally done by individual agencies with the interest and resources to carry out the work. If gaps do exist in relation to ocean *in situ* datasets then they would be included in the recommended actions for Issue 3.

On the other hand, the group believes that the evaluation of global surface flux datasets is a significant challenge for the international community. The GRP has established the SeaFlux and LandFlux projects that have carried out formal evaluations of flux products over the ocean and land. However, major challenges continue to limit the usefulness of global flux products. These challenges include uncertainties in the closure of the surface energy budget, the expected applications of products, sensitivities to algorithms for both satellite-based and *in situ* data, and sensitivities to sampling errors including the validation of precipitation and the representation of

spatial and temporal gradients over the oceans. A particular application of global datasets is the estimation of variability and trends on decadal scales which requires the removal of sources of bias in both satellite and *in situ* data.

While GRP has shown that independent assessment of global datasets is a necessary and very worthwhile activity, the work is substantial and current policies do not seem to provide adequate support and recognition to allow a continuing process to be established. However, the recent promotion by WCRP and GCOS of the need for international collaboration on the evaluation of global climate datasets (through, for example, the release of the GCOS guidelines for evaluation and the Frascati workshop on dataset evaluation) is raising the awareness of the issue with space agencies and their international organisations (CEOS and CGMS).

Assuming the policy environment is favourable, the question is how best to fill the current gap in international arrangements to evaluate global surface flux datasets. The expertise and interest in the tasks extends across groups in CLIVAR, GEWEX, CLIC, SOLAS, AOPC, OOPC and TOPC, and so the creation of a new working group would lead to a group that could be quite large and have a charter that intersected with those of existing groups. An alternative approach would be to recognise that data-related groups of WCRP and GCOS participate in WOAP meetings, where priorities for the evaluation of flux datasets could be set. Based on the collaborative decisions for priority actions, task groups could be established to organise workshops or meetings to complete specific tasks. Of course, the initiative for an evaluation is likely come from an existing group and then WOAP would provide the forum for other groups to contribute and participate.

It is anticipated that task-related workshops will be more likely to attract the relevant experts as well as sponsorship, than annual working group meetings that could duplicate activities of existing groups. For these tasks groups to be effective and efficient, it will be important for WCRP to continue to promote the need for national support for research associated with systematic evaluation of global climate datasets.

One consequence of the establishment of broadly-representative task groups should be the promotion of data sharing across communities. Access to a range of data is essential for effective evaluation (and production) of flux datasets, and the trust developed through collaborative task groups should facilitate the required exchanges.

Action

Recognising that this is a very high-priority issue and that alternative arrangements could be argued, it is **recommended** that WOAP should be requested to set priority tasks on the evaluation of global surface flux datasets (for example, development of community guidelines on the evaluation of flux products) and to establish short-term task groups to organise workshops to complete these tasks. For these tasks groups to be effective and efficient, it will be important for WCRP to continue to promote the need for national and regional support for research associated with systematic preparation and evaluation of global climate datasets.

Issue 5. Evaluation of model fluxes

The SURFA project is using surface flux observations to assess NWP model output (over land and sea) on a day to day (rather than purely climatological) basis. The project is fairly small in scope and is using only buoy data for observational measurements. On the other hand, GSOP has developed guidelines for the evaluation of air-sea flux datasets (Josey and Smith, 2005), especially

for reanalysis datasets. GABLS and GLASS continue to work on surface fluxes, generally over the land. The question is whether the scope of SURFA should be extended to link with other related activities on comparison of flux observations with model output.

Comment

The group believes that model-based flux products are important for climate applications, and so their comparison with instrument-based products and direct observations should be seen as a significant aspect of the overall evaluation of flux datasets (Issue 4). Model-based products should include reanalysis and NWP output. The evaluation of fluxes should include comparison of observation-based (both *in situ* and satellite) and model-based state variables on both sides of the surface interface. It is recognised that the fluxes in models are determined by the overall system, rather than just the flux parameterisation, and so the modelling groups need to play a leading role in these evaluations. Special attention is needed in the evaluation of fluxes derived from ocean reanalyses that diagnose the net heat and fresh water fluxes and require particular care for evaluation. In the future, coupled reanalysis will be a further source of surface flux products.

While the initial focus may be on fluxes of physical variables, it will be important to collaborate with SOLAS and other groups in IGBP to promote the evaluation of datasets of fluxes of chemical constituents such as carbon. Biogeochemical fluxes will soon be diagnosed by ocean reanalyses, such as GECCO. It is also recognised that data assimilation systems now include chemical constituents, including CO₂ and CH₄, and flux products associated with these systems, including those from inversion methods, should be included in future evaluation programs.

The SURFA project is a valuable initiative of WGNE and it should continue to be supported. Extension of the activity could be promoted by WGNE inviting relevant experts to their meetings. Alternatively, the extension could be seen as an aspect of Issue 4 and WOAP meetings could be used to establish a cross-program task group to define and conduct the expanded activity.

Action

It is **recommended** that the evaluation of model-based fluxes (NWP, atmospheric and ocean reanalysis) should be seen as an aspect of the evaluation of global surface flux datasets, and handled through the establishment of specific task groups as for Issue 4. The continuation of the WGNE SURFA project is encouraged as a basis for any enhancement through collaboration with other groups.

Issue 6. Communication across the international research community

Surface fluxes are relevant to almost all sub-programs of WCRP, IGBP and GCOS. Moreover they involve a very broad range of scientists, including observations and modelling, physics and chemistry, as well as land, ocean and atmospheric domains. Unlike some cross-program issues that involve a common set of specialists, surface flux research may need specific consideration to ensure that appropriate communication is maintained across the whole community. The question is whether additional mechanisms needed to ensure that appropriate communication is maintained across the surface flux research community.

Comment

The group believes that because surface fluxes are important to most programs there should be a

special effort to ensure that communication on various levels is maintained across the programs. The communication needs to extend from information exchange on current and planned activities to consideration of priorities, standards and techniques. As all programs are represented at WOAP meetings, these forums should be used to ensure the required communication. The actions from Issues 4 and 5 would be a component of the communication. Another component of the communication strategy could be the development of an appropriate web site.

Action

It is **recommended** that WOAP should place a priority on the consideration of surface flux issues to ensure that priority activities are being planned and carried out collaboratively across WCRP and GCOS.

Conclusions

The group considered six topics seen to be important for the effective management of surface flux research across WCRP and GCOS. The topics are

- 1) Common issues over land, ice and sea
- 2) Distribution of reference sites
- 3) Flux measurement and data processing
- 4) Global datasets of fluxes
- 5) Evaluation of model fluxes.

Based on careful consideration of each issue, of existing organisational arrangements and of the current policy environment for support of international research, the group recommends the following actions:

Common issues over land, ice and sea (Issue 1)

Dialogue should be facilitated by WOAP across the relevant programs (GEWEX, CLIVAR, CLIC, SOLAS, AOPC, OOPC, TOPC) to identify issues of common interest across the domains of land, ice and sea for joint consideration. These are expected to be associated with topics such as

- ⤴ estimation of the accuracies of fluxes at different space and time scales
- ⤴ the evaluation of flux products
- ⤴ the evaluation of model-based (including reanalysis) fluxes.

The agreed issues should be considered through specific meetings or workshops, that would produce reports on conclusions reached and future actions needed. The workshops could be held in conjunction with the regular meetings on one of the relevant groups (such as, GSOP or GRP), or they could be stand-alone meetings. The key point is that they need to be well focused and to attract the experts from all the domains. Relevant experts from IGBP programs should be invited to participate.

Distribution of reference sites (Issue 2)

The initial consideration of reference sites should be focused on land-based reference networks, and TOPC should be asked to summarise the characteristics of currently-sustained networks with global implications and to recommend actions (such as focused workshops) that could be taken to optimise

- ⤴ the spatial distribution of reference sites
- ⤴ the consistency of measurements and data handling
- ⤴ the promotion of multi-variable sites.

Based on progress with land-based sites, it would be appropriate to consider the promotion of dialogue across domains as for Issue 1, led by TOPC and OOPC.

Flux measurement and data processing (Issue 3)

GSOP in cooperation with OOPC, SOLAS and JCOMM should use their 2012 inter-comparison workshop (or another meeting of opportunity) to document and analyse the responsibilities of existing groups (such as GSOP, OOPC, SOLAS and JCOMM) and to identify any organisational gap that should be filled by a WCRP sub-program. If a gap is identified, then a report should be prepared that delineates the need for a new group, recommends the sub-program that should sponsor the new group, and identifies a funding mechanism for the group.

WOAP (in collaboration with WCRP programs and GCOS panels) should continue to liaise with space agencies (especially through CEOS and CGMS) on the requirements for satellite-based FCDRs, bearing in mind the particular needs for surface flux estimation.

Global datasets of fluxes (Issue 4)

Recognising that the evaluation of flux datasets is a very high-priority issue and that alternative arrangements could be argued, WOAP should be requested to set priority tasks on the evaluation of global surface flux datasets (for example, development of community guidelines on the evaluation of flux products) and to establish short-term task groups to organise workshops to complete these tasks. For these tasks groups to be effective and efficient, it will be important for WCRP to continue to promote the need for national and regional support for research associated with systematic preparation and evaluation of global climate datasets.

Evaluation of model fluxes (Issue 5)

The evaluation of model-based fluxes (NWP, atmospheric and ocean reanalysis) should be seen as an aspect of the evaluation of global surface flux datasets, and handled through the establishment of specific task groups as for Issue 4. The continuation of the WGNE SURFA project is encouraged as a basis for any enhancement through collaboration with other groups.

Communication across the international research community (Issue 6)

WOAP should place a priority on the consideration of surface flux issues to ensure that priority activities are being planned and carried out collaboratively across WCRP and GCOS.

Appendix 1. Contributors to the report

Mark Bourassa
Andy Brown
Carol Anne Clayson
Han Dolman
Albert Fischer
Christoph Garbe
Sarah Gille
Sergey Gulev
Keith Haines
Elizabeth Kent
Eric Lindstrom
Michael Manton (Convenor)
Vladimir Ryabinin
Sonia Seneviratne
Adrian Simmons
Konrad Steffen
Toste Tanhua
Kathy Tedesco
Maciej Telszewski
Michael Tjernstrom
Kevin Trenberth
Brain Ward
Scott Woodruff