Summary of third meeting of ISSI team 7-8 December 2020

Attendies: S. English, J. Boutin, L. Labzovskii, L. Kilic, M. Anguelova, M. Matricardi, M. Kazumori, M. Bettenhausen, S. Newman, N. Nalli, A. Stoffelen, B. Johnson, C. Accadia, C. Prigent, C. Lupu, E. Dinnat, T. Meissner, F. Weng.

1. **Introduction**

   Participants were welcomed. As with the second meeting this virtual ISSI team meeting was opened to additional remote participations, and several joined. The agenda was agreed.

2. **Review Actions from Meetings-1 (20-22 November) and 2 (30 April)**
   - **A1_1: All** scientific papers to be shared amongst the group, as some are more difficult to obtain. These can be linked to from the ISSI web page.
     Status: A number of useful publications have been circulated in the team, it would be useful to accumulate a list on the webpage. A page has been created for this:
     https://www.issibern.ch/teams/oceansurfemiss/index.php/useful-references/
     Action remains open.
   - **A1_7: Fuzhong Weng**: The model will be compared to the model from Fuzhong Weng, who will also approach Ming Chen and Mark Liu to see if they wish to contribute to this effort.
     Status: CMA uses RTTOV and their own model. The CMA model is in β-version and it is too early for public release. The code has been optimized and it runs much faster now. A fast model for operational use is also being developed. It is being tested in an NWP environment in CMA. At this point there is no development that can directly input to the ISSI effort, so close action but revisit when there has been more progress.
     Action closed.
   - **A1_8: Stu Newman**: The two-scale model will also be used to calculate IR emissivities and compared to Stu Newman's results, to see how realistic this is.
     See Stu Newman presentation.
     Action closed.
   - **A2_1: Jacqueline Boutin**'s model will be made available once the paper is published. Matlab code is available on : https://owncloud.locean-ipsl.upmc.fr/index.php/s/ovhgqNazmMsEdna
     Jacqueline circulated the paper and other information. The citation has been added to the page mentioned under A1_1 and is given here :
     Boutin, J., J. L. Vergely, E. P. Dinnat, P. Waldteufel, F. D'Amico, N. Reul, A. Supply, and C. Thouvenin-Masson (2020), Correcting sea surface temperature spurious effects in salinity retrieved from spaceborne L-band Radiometer measurements, IEEE Transactions on Geoscience and Remote Sensing, doi: 10.1109/TGRS.2020.3030488
     Action closed.

     A2_2: Maggie Anguelova: The formula for the revised foam model will be sent to the group. Maggie Anguelova provided her foam emissivity model (in form of a report) in June 2020 to a few team members for initial review. See her presentation.
     Action closed.
   - **A2_3: Thomas Meissner**: The Zhou data is not available yet. More lab measurements to be done, but not possible due to the shut-down. Question about the possibility to have dielectric measurements from Zhou at L-band for pure water. Share update in group at next meeting.
     See Thomas Meissner presentation.
     Action closed.
   - **A2_4: Lise Kilic**: Some issues with the water vapor model and/or inputs at that stage in the comparison with GMI to be fixed.
     Fixed. See Lise Kilic presentation.
     Action closed.

3. Summary of progress since 2nd meeting

3.1. Status of code (lead: Emmanuel Dinnat, Ben Johnson) and discussion

- Sea emissivity model written in Fortran is now available on GitHub. Lise and Stuart already downloaded, compiled and run without any problems. Some documents are still in French but all that is required to run the code is now available in English. Furthermore Lise can provide comments about its user-friendliness from the perspective of a user. It can now be tested by the wider ISSI team.
- Link to the code: https://github.com/edinnat/Ocean-reference-model (invitation required).
- **Action 3_1: All to send an email to Emmanuel to get access to the code.**
- The Zhou sea water and distilled water dielectric constant measurement full dataset is available. Emmanuel to provide the link.
- Link to the dataset: https://podaac.jpl.nasa.gov/SMAP?tab=mission-objectives&sections=about%2Bdata
- More complete documentation is required, at present only a few pages are available.
- **Action 3_2: Emmanuel will make available a short user guide for the code.**
- Ben Johnson enquired about making the repository public. It was agreed for now to do more testing within the team, whilst we familiarize with the code and documentation is completed. It would be useful to give the code a name. As much of the code was pre-existing, it would be misleading to call it the ISSI model. It was noted the model was originally developed at LOCEAN and has been referred to as the LOCEAN model, but to retain this name would appear to undervalue the new contributions arising from the ISSI collaboration (e.g. from Thomas and Maggie).
- **Action 3_3: All to suggest suitable name for the model, that captures Emmanuel's massive contribution, the ISSI role and its LOCEAN beginnings.**
- The model can run from microwave to IR frequencies. It is a priority to further evaluate its IR capability (see talks by Nalli and Newman) and for radar. The model can also run in active and passive mode with the core basic calculations in common, before alternative paths to return either emissivity of basckscatter parameters. It is a priority to test active model
- **Action 3_4: Steve to identify a contact to discuss about wave models and active / passive remote sensing. [Post meeting note: Saleh Abdalla is testing the model in active mode at ECMWF].**

3.2. Dielectric Model (lead: Thomas Meissner)

- Thomas gave a broad overview reminder of the construction of dielectric models. He noted that whilst these models adopt a general analytic function they then fit this to observations so the calculations are implicitly empirical, except in the Somaraju & Trumpf model. As a consequence it is not correct, indeed dangerous, when they are used outside the range of values they have been done for. However, users are often tempted to do this. At L band, Somaraju & Trumpf and Meissner & Wentz show very small differences. Both models use lab measurements for the conductivity. Jacqueline argued that Somaraju & Trumpf model could be tuned to give reliable results for high frequencies.
- **Action 3_5: Jacqueline and Thomas decided they will test the S&T model at higher frequencies and will report to the group.**
- Jacqueline noted that, as with high frequencies, results are worse for low temperatures at very low frequency. This lead to a discussion on the relevance of work on supercooled water, where there has been significant effort on cold water dielectric properties for radiative transfer in clouds. RTTOV uses Rosenkranz for the supercooled droplets, Ben noted the paper by Turner, D.D., Kneifel, S. and Cadeddu, M.P., 2016. An improved liquid water absorption model at microwave frequencies for supercooled liquid water clouds. Journal of Atmospheric and Oceanic Technology, 33(1), pp.33-44 and Steve noted the work by Katrin Lonitz: https://amt.copernicus.org/articles/12/405/2019/. It was agreed that comparing these results for ocean surface emissivity model at very low temperature would be interesting.

- The Meissner and Wentz dielectric constant model is already available in the code on Github.
- **Action 3_6: Emmanuel to check if it is the very last version.**
- Steve reminded the team that a key goal of the ISSI team was to deliver a model with uncertainty estimates, so asked if an error model will be provided so the model can calculate emissivity and uncertainty in emissivity? Emmanuel suggested calculating uncertainty avoiding the outlying models for each frequency range. But then what is the reference? Catherine suggested the error model is too difficult to contemplate at this time, and should not be the priority until the system is more mature.

3.3. Foam models (lead: Maggie Anguelova)

- Maggie presented an overview of the foam models. The team agreed that at high wind speed sea foam is the main driver of model error. It is therefore a priority to test the model with the NRL foam formulation. Maggie showed differences calculated between the closed (analytically solved integrals) and the general (numerically calculated integrals) forms of the foam model equations. The differences are very small at the chosen environmental conditions (SST of 20 °C and SSS of 34 psu), but Maggie noted that the differences could be larger for different SST and SSS. In response to a question from Emmanuel Maggie noted that the general form of the code takes much longer to run.
- In the form of the foam fraction equation, $W(U)=aU^b$, wave modelers at ECMWF (Peter Janssen, Jean Bidlot, Saleh Abdalla) have advised b should be 3, because this is a strong constraint from the physics of breaking waves. So to reduce the number of degrees of freedom in the model, this will be adopted, at least initially.
- Emmanuel reported that he had tested Maggie's foam emissivity model at high frequencies using the parametrization by Yin et al 2016 for foam emissivity and fraction. It works, but results are poorer than at low frequency. Results are significantly improved when an alternate foam fraction model is used. A consistent physical model for both fraction and emissivity of foam valid across frequencies is needed.
- **Action 3_7: Maggie to provide numbers for the different parameters in the emissivity model.**
- **Action 3_8: Maggie to generate fortran-90 code for the close form and for the general one of the foam emissivity model, provide code to Github and team members.**

3.4. Comparisons update (Lead : Lise Kilic)

- Lise gave an update on her validation work with GMI. Firstly, this confirmed other work which shows models in general fit GMI better than older microwave imagers, consistent with a part of the bias against older imagers being instrument observation bias. Whilst biases are very different, and in general smaller, the results of dependence of bias on geophysical parameters (wind and SST in particular) is consistent with the AMSR2 study. However, Emmanuel's results look different, this needs to be checked, it may be arising from different sampling errors.
- **Action 3_9: Emmanuel and Lise to compare results and identify causes of differences**
- There followed a discussion on wind direction impact and errors arising from this aspect. Maggie agrees that we should separate the dependences on the wind between the Fc and the Ec. The Fc should not depend upon the frequency.
- Emmanuel and Jacqueline believe that the reference model formulation is consistent with the wind direction signal observed by SSMI. However, Thomas believes that 2 scale models have trouble to reproduce the wind direction. Thomas mentioned a Gene Poe paper about that some time ago. The RSS model shows good agreement with observations.
- **Action 3_10: Thomas to circulate Meissner and Wentz wind direction signal paper citation, to ISSI team members.**
- **The reference is: http://images.remss.com/papers/rsspubs/Meissner_TGRS_2002_wdir_signal.pdf. It includes citations of earlier papers (Poe and St. Germain, ref. 30 + 31).**

- **Action 3_11: The wind direction sensitivity in the reference model to be tested and compared to the RSS model.**
- The team noted that when using the model with a scattering atmosphere account needs to be taken of the construction of multiple streams (even in a simple approach such as delta-Eddington). The model needs to be able to interface to this type of atmospheric scattering model. Design implications need to be though through.
- **Action 3_12: More discussions needed about the reflection / scattering of the atmosphere. Emmanuel + Thomas + Lise + Catherine + Steve**
- Ad Stoffelen noted that cross polarization of the radar gives stronger sensitivity to high wind speeds. Co polarization is not very sensitive to high wind. ASCAT is calibrated to the Stepped Frequency Microwave Radiometer (SFMR) at high wind speed. It would be useful to test the model in radar mode to better understand the calibration issues.
- **Action 3_13: Similar to Action 3_4 above, Ad to test radar simulation mode and to discuss with team about radar issues.**

3.5. L-band dielectric model (Lead : Jacqueline Boutin)

- Following on from Thomas' talk Jacqueline presented work on the dielectric model at L-band, noting salinity accuracy requirements demand a very high degree of accuracy in this component. Using SMOS retrieved pseudo dielectric constant, she revisited the Somaraju and Trumpf model, which uses a physical basis with two parameters fitted on a large range of data (including Meissner et al, Ellison et al., Klein and Swift simulated data), up to 256 GHz (Saline water up to 90 GHz, pure water at higher frequencies). This model makes it possible to deal with the residual dependency in SST for the SMOS SSS retrieval and has been shown to work well simulating Aquarius data and also with the recent GWU laboratory measurements. She showed that at moderate SST, results are similar to Klein and Swift, but differences are larger at high and low SST
- **Action 3_14: A two-step comparison for the S&T model is proposed. Comparison between models first (Jacqueline,Thomas and Emmanuel). Then if OK, we can compare simulations with observations (Lise and Catherine).**
- It was also noted that operational monitoring of observations is carried out continuously by NWP centres, and whilst this does not do the in-depth studies available from detailed research, it can show very nicely whether the bias has changed seasonally or inter-annually. This can enable results from studies at different times to be compared. Steve noted that the NWPSAF maintains a one-stop page for monitoring of microwave and infrared radiances, and scatterometer data at https://nwp-saf.eumetsat.int/site/monitoring/nrt-monitoring/. The most complete set of monitoring plots, including long period time series from re-analysis (ERA-5, ERA-Interim as well as operations) is available from ECMWF: https://www.ecmwf.int/en/forecasts/quality-our-forecasts/monitoring-observing-system#Satellite.
- **Action 3_15: ISSI members to view operational monitoring sites and consider how this can be used to better understand differences between more detailed studies.**

3.6. IR emissivity models (Lead : Nick Nalli NOAA)

- It was noted in the second meeting in the spring that the team had not progressed far with testing models in the infrared, so it was pleasing to have talks from Nick Nalli and Stu Newman. Nick gave an overview of infrared ocean surface emissivity models, including physical model and fast models used in data assimilation. He noted that the geometric optics assumption can be applied in the IR. The Masuda model has been widely used and validated against in situ measurements.
- In most aspects the models in the infrared are not greatly different to the microwave. IR models generally use Cox and Munk or Ebuchi and Kizu slope variance model functions, and a specular reflectance for each facet. However, usually a specular or Lambertian reflectance is

also assumed for the ensemble surface reflectance, neither one being strictly correct. Nick suggests a calculation of an effective emissivity that accounts from the downwelling radiation, in a similar way to the approach generally used in the microwave. The global differences between obs and calculation show some temperature difference, related to the optical constants (Pinkley et al.,1977).

3.7. Initial MW/IR model comparison (Lead : Stu Newman Met Office)

- Stu followed Nick's presentation by doing the first validation of the reference model in the infrared. A key component is to have correct refractive index measurements across the infrared domain. E.g. Rowe et al., 2020 for permittivity of water with SST dependence (including 0°C). The SST dependence has to be accounted for and to date there is limited information available for both the SST and SSS dependence for the dielectric properties. It is generally assumed salinity can be ignored in the infrared, but this needs to be confirmed.
- **Action 3_16: Stu to circulate citation for Rowe (2020) paper to ISSI team.**
- **Action 3_17: Develop and test a unified dielectric model from MW to IR for pure water. Stuart and Nick, with support from ISSI team.**
- The model is run using geometric optics, and no foam. There was a discussion on how to setup and run the two scale model correctly for the infrared, for example is the same scaling for the two scale cut-off frequency applicable in the infrared and microwave?
- **Action 3_18: Emmanuel, Stuart, Lise and others interested to discuss optimal IR setup for two scale model**
- The wave slope model used is different to that considered optimal in the microwave. Can we adopt the same wave spectra model?
- **Action 3_19: Wave spectra sensitivity needs to be tested further. Stuart, Nick and others if interested.**
- As noted Stu's initial work ignored foam. Can we have a single physical framework for microwave and infrared foam? Maggie noted there is a paper about the foam effect on IR surface emissivity doi: 10.1029/2007JC004521 and Andy Jessup's group paper on foam in IR: doi: 10.1016/j.rse.2016.06.009
- **Action 3_20: Undertake a literature review and further test of sensitivity to different foam formulations. Stuart, Nick and others.**

4. Plan for the future:

Discussion by small groups to be initiated to carry forward the 20 actions listed above.
Action 3_21: Catherine and Lise to coordinate small groups to carry forward Actions from this meeting.

A remote meeting in Spring 2021 (assumption would be the dates provisionally set for the physical meeting previously planned. These were 13-14 April 2021. The plan would be to hold a very similar meeting with 3-4 hour meetings each day at the best time zone to enable maximum global participation.
Action 3_22: All to confirm if 13-14 April 2021 is still OK, or we should re-open to find optimal date.

A physical meeting in the fall 2021 (let's all cross our fingers!). Steve will circulate a doodle poll ASAP with dates in November 2021.
Action 3_23: Steve to setup doodle poll to find autumn 2021 date and confirm with ISSI for physical meeting