WG1	WG2	WG3
Chair: Mark Buehner Secretary: Steffen Tietsche	Chair: Anne O'Carroll Secretary: Tony Mc Nally	Chair: Chris Merchant Secretary: Phil Browne
Large Committee Room (We, Thu)	Meeting Room 1 (Wed, Thu)	Mezzanine Room (Wednesday) Council Chamber (Thursday)
Observations and Methods processing chains	Downstream Applications of SST and sea ice	Observations and Method processing chains
Frozen (Sea ice)		Unfrozen (SST)

- What are the possible visions (10 years) for SST and sea ice information at ECMWF?
- What recommendations would you make to space/observations agencies ?
- Which observations (& what level) should drive the evolution of our systems?
- What should be the next steps to improve SST and sea ice in NWP and reanalysis?
- What are the current gaps future barriers (observations, forward models, DA, etc)?

WG3: Observations and Methods. Sea Surface Temperature

Participants

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What different trajectories could be taken from this point?

0. Do what is done now – it's great.
1. Stick with L4 but "reformulate" it to be more in tune with (C)DA
2. Work with L2/3 SSTs
3. Directly assimilate L1 radiances.

Option 0 is not OK – delay in getting current L4 sst degrades forecast.

The SST observations have not changed as the forecasts evolve.

Considerations on L4 products

- Timeliness vs accuracy. What is the weighting needed between these for the best NWP forecast?
- Can you see the impact of the lag in later analysis cycles? Is 00Z analysis worse than 12Z, because it uses older L4 observations?
- Note that SSTs are used differently in ocean and atmosphere analyses
  - Directly inserted in atmospheric analysis
  - Nudged towards in ocean analysis
- What are the measures of impact of different L4 products? E.g. are processes like precipitation improved when using different SST products?
- Assimilation of L4 is generally a bad idea – better to get to lower levels as soon as possible
  - L4 error correlations are complex and hard to represent in DA. Are they even known?

Considerations on L4 products (continued)

- What is driving the move towards coupled DA for the analysis?
  - Coupled state needed for coupled modelling. Hopefully reducing shocks
  - Better use of observations – cross domain influences
- Wish for consistency with other (satellite) observations
- More control over operation chain and observation usage
- Sticking to L4 gives more exposure to outside changes
  - This is particularly a problem in reanalysis.
- Not taking someone else's L4 requires in house resources or wider collaboration

If we were to stick to L4, what could we change?

- **Forecast**
  - All forecasts are planned to be coupled to the ocean from Q2 2018.
- **Analysis**
  - The atmospheric analysis is driven by an atmosphere only model with prescribed SST.
  - Rolling time windows could be used with more frequent delivery
  - Shorter time windows in existing products with the increases delivery frequency.
  - Optimisation of the delivery time of the current product
  - Longer parallel dissemination and improved feedback from ECMWF to producers
  - Making use of diurnal cycle information on top of foundation temperature in the context of a shorter SST analysis window
  - Assimilate L4 into the ocean instead of nudging towards it.
- **Reanalysis**
  - Always have a ongoing new data that is compatible with the historic time series
  - Freezing L4 processing system and continue in future for ongoing reanalyses e.g. CDR + ICDR
  - In the long term, complete observational consistency is not possible in terms of temporal resolution
  - 24 hours latency for reanalysis is the goal
- **Product itself**
  - Are there additional fields useful for monitoring purposes?
  - Feature resolution within the L4 product.
    - What resolution is beneficial at different atmospheric resolutions?
    - What is the trade off between additional feature resolution and noise added?
  - Dynamical constraints on the product
  - L4 is relevant to validation of SST from a coupled system therefore consistent multiple depth SST analyses should be produced with appropriate time resolution

Considerations on L2/L3 assimilation

- Assimilation of L2/L3 observations implies changes to ECMWF ocean DA scheme
  - L2/L3 have to be assimilated in the context of the other observations.
    - All background and observational error structures need to be characterised
    - Engage with observational community for observation error structures
  - In extreme data sparse cases (pre 1979 all the time, certain circumstances now) model drifts can be issues.
    - Centennial scale analysis using in situ/L2 would require statistically based infilling of SST, eg large-scale EOFs done in the context of ERA-CLIM2
  - Geophysical meaning of L2/L3 products vary.
    - Obs can be treated at appropriate depth
    - The sensitivity to real SST change (across fronts, across the diurnal cycle) varies between 50-100% in L2 products.
  - L2/L3 allows use of observations for the period they were taken
  - L2/L3 has reduced latency compared to L4
  - Var conditioning issues are possible.
- L3 delegates cloud screening/averaging to someone else
  - The “advantage” of L3 is a reduction in data volume c.f. L2. Superobbing could be done in house.

Considerations on L2/L3 assimilation (continued)

- L2 activities that would have to move in-house include:
  - Cloud screening/averaging/thinning - Some QC information available but needs care to be used.
    - Category 2/3/4/5 data would vary between sensor/data producer
    - Time needs to be spend to consider these for each instrument
  - Bias correction
    - This applies to in situ at the level of individual platforms as well as satellites
    - Magnitudes are several tenths of a degree between sensors
    - Same magnitude biases for a given sensor in different synoptic situations
    - Can easily be confused with diurnal variability
    - Aliasing of bias estimates and model biases
  - Reference sensors are needed to be selected/assessed/maintained over all timescales
- Data volumes and maintenance of data streams increase compared to L4.
- Lack of an SST value from not using L4, in certain cases, is not necessarily a problem. i.e. tropical cyclones. A coupled model would dynamically interpolate here.

Considerations on L1 assimilation

- L1 assimilation likely implies coupled assimilation – development of assimilation system is required.
  - Consistent correction of atmosphere and ocean in a coupled DA context.
  - Need to assess whether this is possible in outer loop CDA or whether longer term fully coupled DA is needed
- Advantages of L2 apply for L1 also.
- In house requirements for L1 assimilation include
  - Data complexity increases. Is this an issue given the current systems for other products?
  - Forward modelling might require upgrades to radiative transfer and inclusion of aerosols, waves (for emissivity) in order to achieve comparable SST uncertainty levels
  - Calibration and orbit drift can be strong which L2/L3 producers should be accounting for.
  - There is a need to handle radiance sensor biases (see below)
  - GSICS provides real time calibration fields for geostationary sensors as an alternative to in house bias correction

Considerations on L1 assimilation (continued)

- Modern radiance sensors' (SLSTR, VIIRS) error characteristics are primarily uncorrelated noise plus a slowly drifting calibration error.
  - Older sensors have radiance error correlations between pixels and channels at a given pixel.
  - Older sensors error characteristics are highly temporally variable throughout the mission. Only Fiduceo products are attempting to provide this information.
  - Desroziers diagnostics are promising for estimating these.
- Microwave radiances have very particular bias issues including poorly understood surface emissivity at SST relevant channels.
  - RFI issues
  - Bias issues across swath
- L1 error structures are more simple than higher levels – reduced covariances
- Not valid for pre-satellite era reanalyses

Recommendations to ECMWF

- Actively engage with GHRSST to optimise the properties of SST observations for NWP applications. Feedback what uncertainty information would and/or could be used by ECMWF?
  - This applies to L1/L2/L3/L4
- Engage with historical SST observation community for centennial scale reanalyses
- Make use of diurnal cycle information on top of foundation temperature

- Uncertainty information with the L4 product is not necessarily being used
- Forecast SST validation should be done against foundation temperature, drifting buoy depth and skin temperature SST analyses.
- Develop DA algorithms that can exploit spatial and temporal observation error correlations

Recommendations to space/observation agencies.

Ongoing funding and support for reprocessing and understanding of observations of all kinds is needed to support Copernicus services

L2 products:

- Passive microwave:
  - Support the efforts to ensure continuity of 7Ghz SST or equivalent capability
  - Future missions should target the best feasible spatial resolution, 5km would make substantial impact on SST features in conditions adverse to IR
  - Radiometric specifications should target SST uncertainty better than 0.35K in order to significantly impact relative to current analysis verification statistics
  - The fundamental physics of the surface emission is not adequately constrained at 7-11Ghz and requires further study
  - Resilience to RFI is necessary
- Synergy with other near contemporaneous observations
  - Importance of proximate sea ice and SST information
  - Some added value in contemporaneous wind observations (for diurnal cycle and microwave emissivity)
- IR geostationary
  - Continuity of SST information over the Indian Ocean, with an impact on the ability to resolve the diurnal variability

Recommendations to space/observation agencies (continued)

L1 products:

- Per datum error characterisation and quality flags would be used within DA of L1 radiances. For SST the instrument radiance errors are the same order as the retrieval errors.
- Quantified uncertainties and error covariance information should be provided in L1 products
  - Engagement between assimilation agencies and observation agencies is required to establish the appropriate level of information
  - For the purpose of reanalysis this needs to be done historically
- Connection to L1 with respect to SST can be coordinated through GHRSST
- Efforts and methodologies developed for radiance validation and uncertainty characterisation in GAIA-CLIM should be taken forward to support L1 assimilation

Recommendations to space/observation agencies (continued)

In situ products:

- A climate quality data delivery system from extratropical moorings
  - This includes evaluation of their quality and adequate metadata
- In general, in situ data should be provided with uncertainties associated so that they can be used appropriately
- High accuracy trans-basin lines from research vessels are a good source of data and should be provided and managed in a more coordinated way.
- Different components of the in situ observing system are complementary. Experts in the different platforms and users of the observations need to get together.
  - Increased measurements for upper ocean profiles are required to support multi-layer assimilation
- Redundancy needs to be built into the design of in situ observing systems
- Multivariate observations in the same location (including flux measurements) as they are extremely valuable for evaluation of coupled systems
  - Efforts to identify the extent of such observations for maximum impact should be undertaken
- Full metadata should be provided within the BUFR formats to enable improved bias correction and extraction of maximum information from the observations
  - Data that are transmitted via the GTS should include quality information as they are frequently used in climate reanalyses
- Fiducial reference measurements should be continued and assesses as a reference for climate reanalyses

What should be the next steps to improve SST and sea ice in NWP and reanalysis?

- Quick wins – see earlier slides. Need to make a roadmap and identify collaborations.
- L1 assimilation could be compared with the L2 assimilation done at the UK Met Office
- L2 assimilation will inform L1 assimilation by developing methods for spreading information vertically and horizontally
- What form of pre-satellite era SST assimilation could smoothly transition to modern day assimilation of L1/2/3 SST data?
- Work towards a consistent DA methodology for the ocean and atmosphere (and land and waves and ice and aerosols)