Regional wave data assimilation, using NEMOVAR and a refined grid wave model

Presentation to 2nd INTERNATIONAL WORKSHOP ON WAVES, STORM SURGES AND COASTAL HAZARDS

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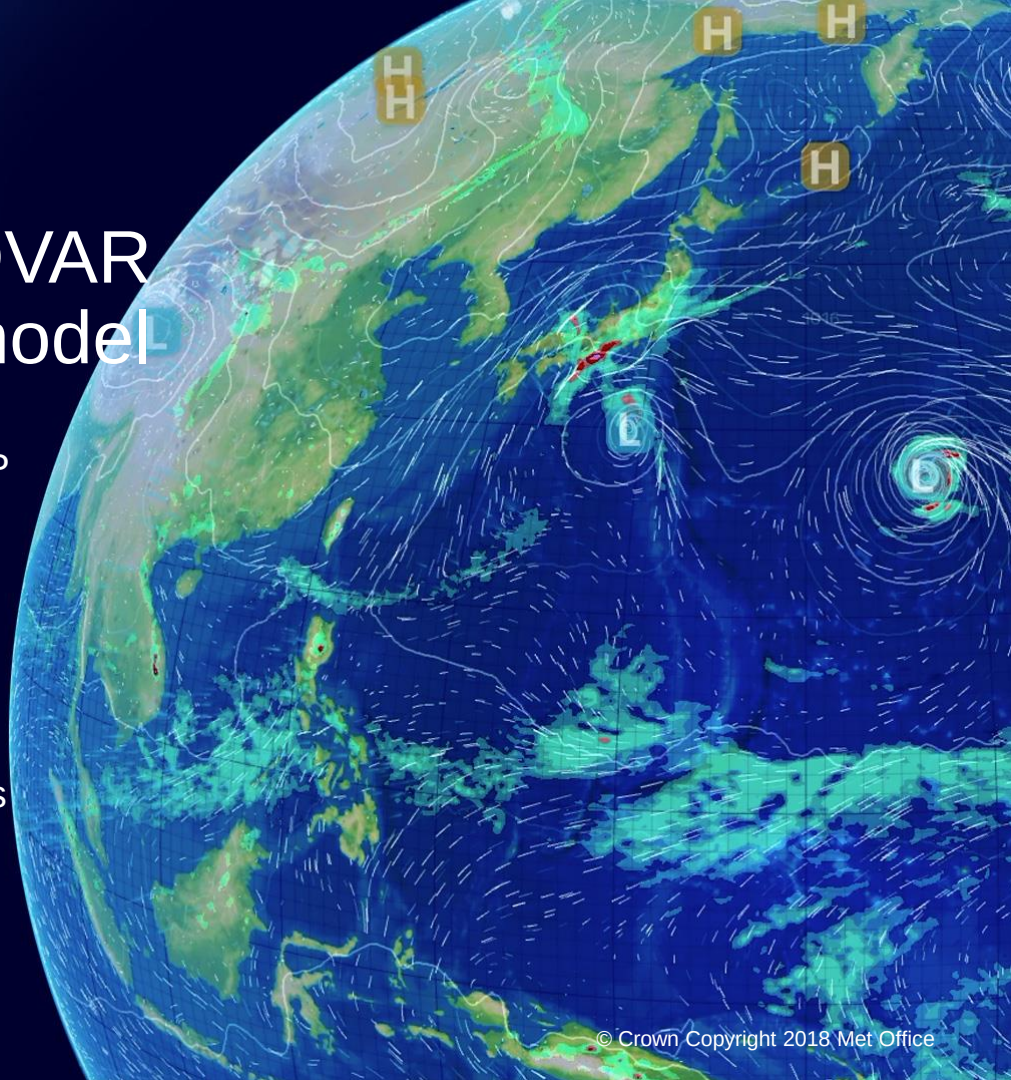

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Research conducted as part of the EU Horizon 2020 project ‘CEASELESS’

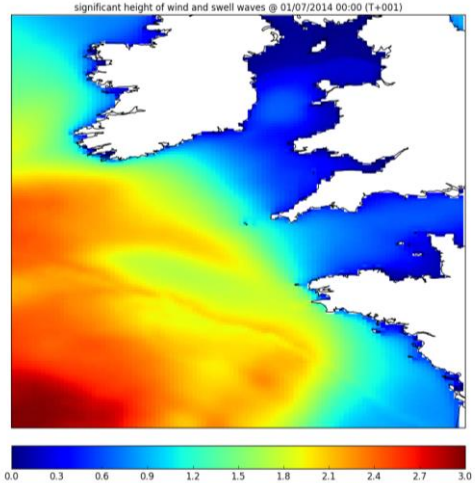
Summary

- NEMOVAR and Spherical Multiple-Cell grid WAVEWATCH III model run with assimilation via updates to the ww3_uprstr.ftn module
- In seas of the Northwest European Continental Shelf the assimilation benefits forecasts on 6-12 hour lead time-scales; this is rather shorter than Global model equivalents
- Inclusion of in-situ data in the assimilation makes a significant improvement relative to satellite-only DA, but only for the first few hours of forecast
- DA using observations in the offshore zone positively impacts coastal zone forecasts; coastal assimilation has higher impact but is extremely localised in space and time

The system: regional wave models for the Northwest European Shelf

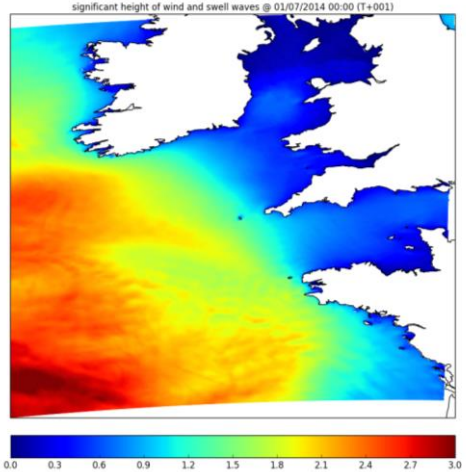
AMM7 – 7km regular grid

Used for DA configuration trials



AMM15S – 3-1.5km SMC grid

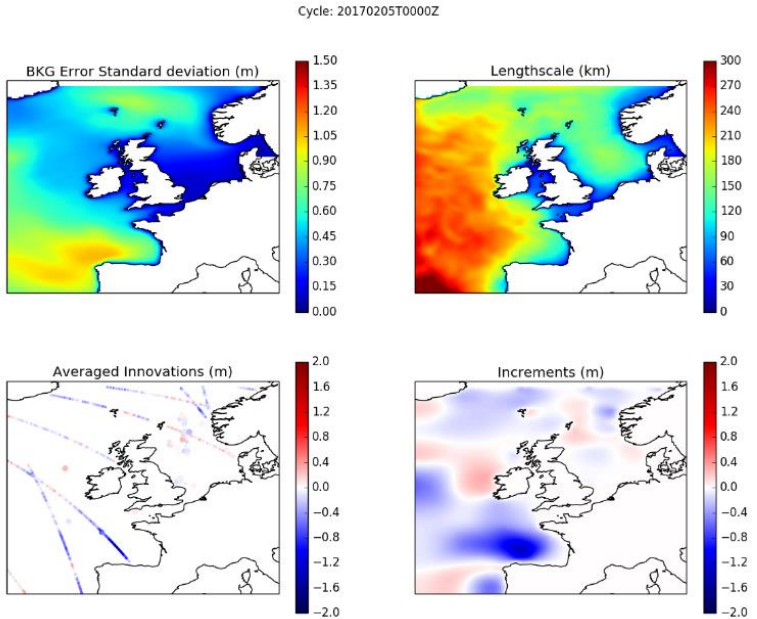
Used for DA impact trials



All trials forced using Unified Model global winds (17km) and surface currents from corresponding NWS physical ocean models (AMM7/AMM15)

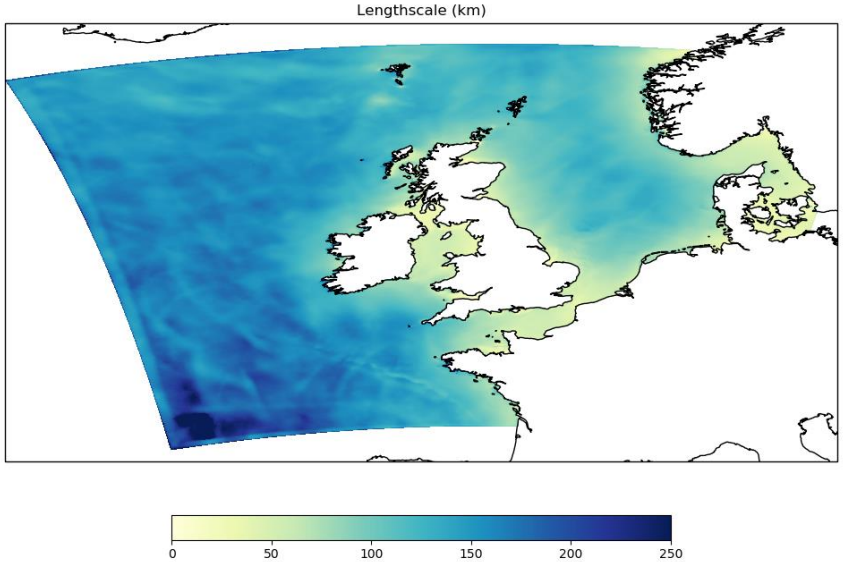
The system: Data Assimilation set-up (1)

- NEMOVAR 3DVAR, FGAT:
  - Observation operator uses nearest neighbour
  - Assimilation applied to regular gridded data
  - SMC girds mapped to regular grid and then back to unstructured sea-point arrays at update
  - 6-hourly update cycle using direct initialisation at end of analysis period
  - Significant wave height increments are applied to wave spectra at start point of next forecast/analysis cycle



The system: Data Assimilation set-up (2)

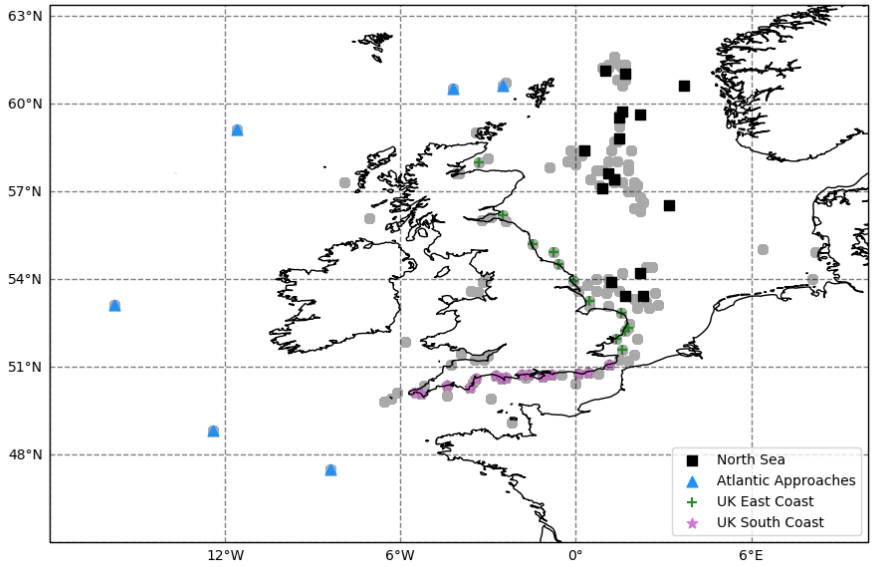
- NEMOVAR 3DVAR, FGAT:
  - Domain variant error covariance and lengthscales derived from Canadian Quick analysis of 2-year free run
  - Error standard deviations determined from percentage correction of model background (using Palmer and Saulter, 2013; 10% for obs, 15% for model)
  - Spectral update method following Lionello et al. (1992) and Toba (1973) – varying treatment of spectrum dependent on wind-sea or swell dominated conditions*



* Options available as extension to ww3_uprstr.ftn; wind correction component of Lionello et al. scheme to be added

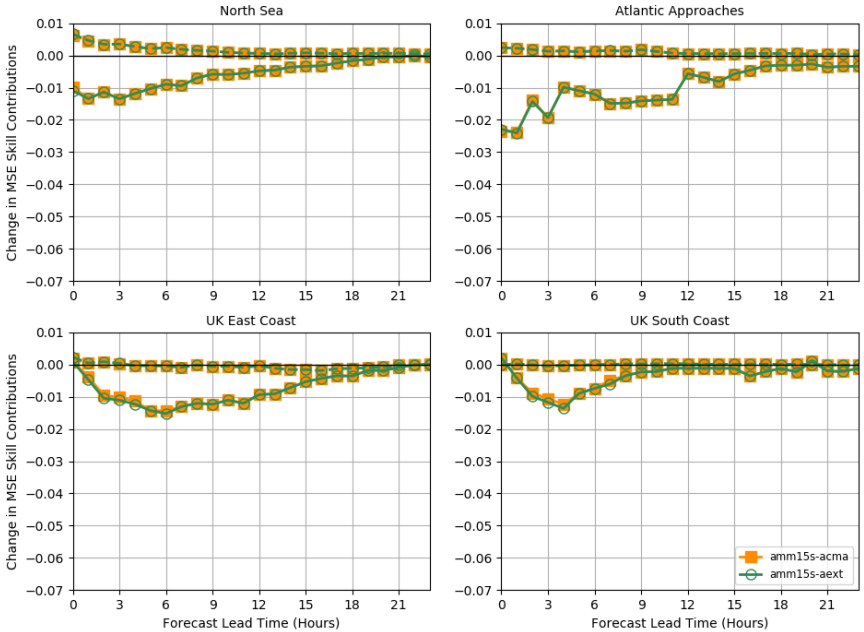
Experiments: Open waters and coastal impacts trials

- 2 month trials using AMM15S
- Measure bias and error variance contributions to change in $Skill_{MSE}$ relative to non-assimilative run
- $Skill_{MSE} = \frac{Bias^2 + Var[x_{model} - x_{observed}]}{Var[\bar{x}_{observed} - x_{observed}]}$
- Subset of in-situ platforms used to assess sub-regional variations:
  - Background wave climate
  - Open vs coastal waters
  - Availability of upstream observations



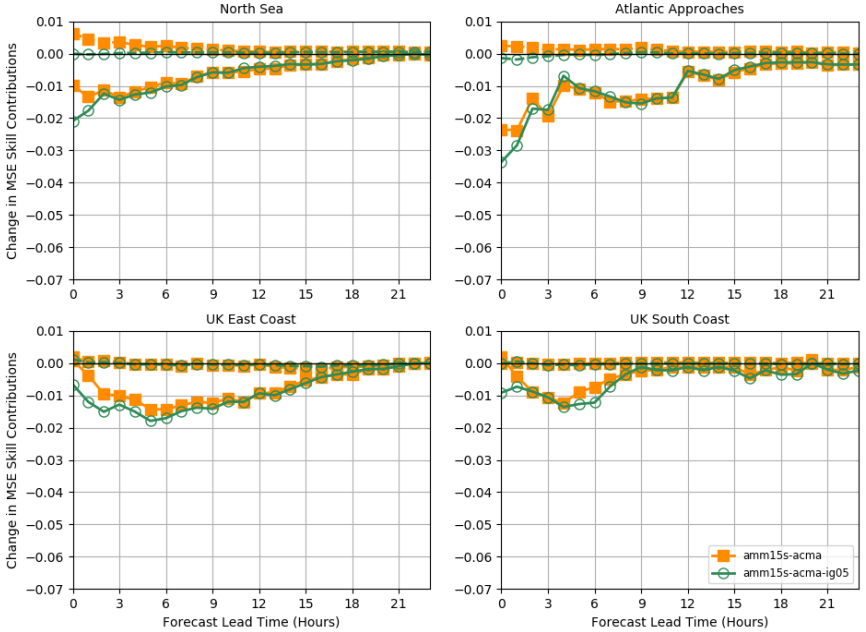
Experiments: Impact of altimeters and extending coastal coverage

- Altimeter only experiments:
  - ACMA: S-3, J-3, J-2, Cryosat, Altika masked within 40km of coast
  - AEXT: As above, S-3 and J-3 masked within 8km
- Using altimeters delivers a general improvement in random errors over lead times up to T+12
- Little impact from coastal extension



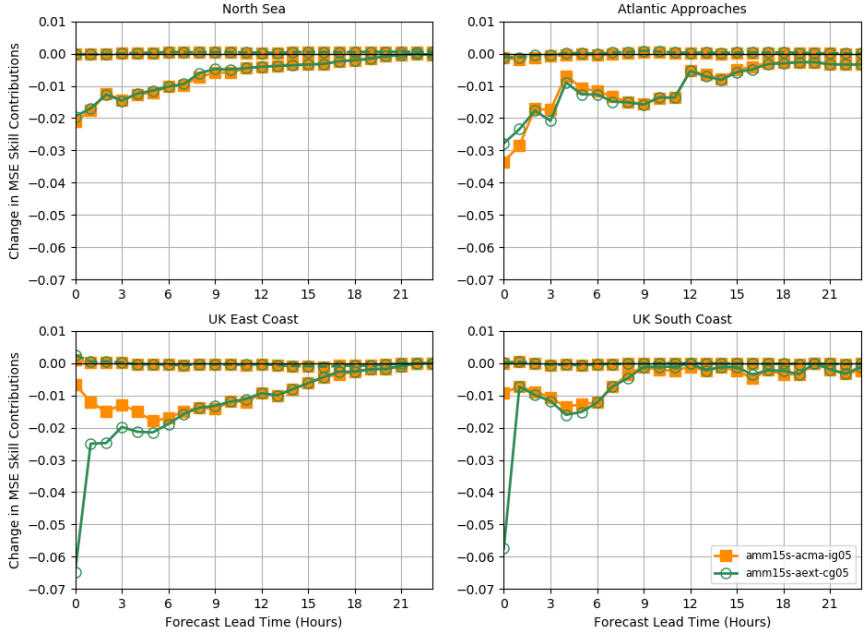
Experiments: Impacts of altimeter and offshore in-situ data

- Impact of including offshore in-situ observations alongside altimeter:
  - ACMA-IG05: In-situ observations ‘greylisted’ at 50% using random draw
- Additional value added in first 3-6 hours
- Corrects biases introduced by altimeter (or poor calibration of altimeter in these experiments)



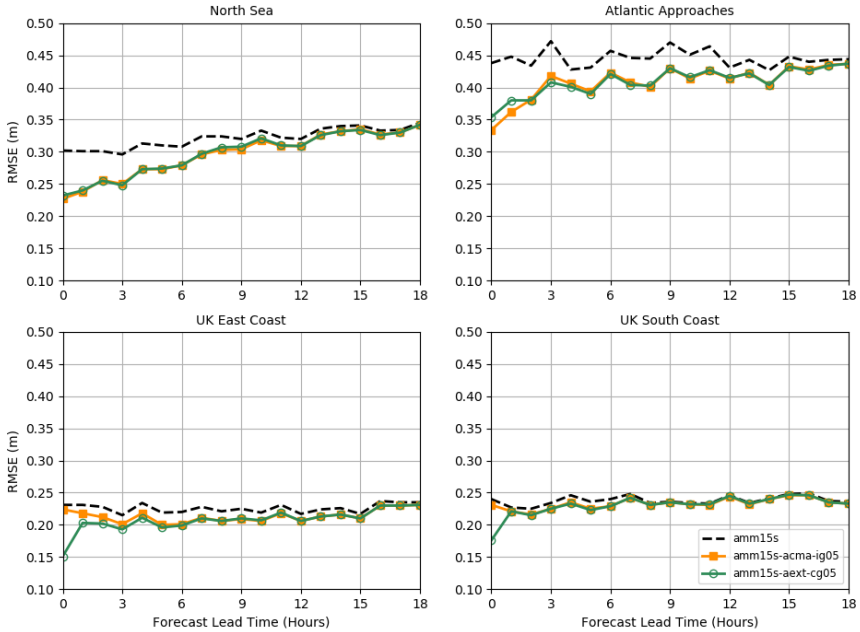
Experiments: Impacts of coastal in-situ data

- Impact of including offshore and coastal in-situ observations:
  - AEXT-CG05: Coastal in-situ observations ‘greylisted’ at 50% using random draw
  - *Potentially non-independent verification in open and coastal waters*
- Significant impact on random errors where verifying buoys are used in coastal assimilation – but only in first hour!
- Negligible effects thereafter



Discussion: Results in context

- RMSE for Hs, for a bit of context
- Although relative impact is similar in open waters and coastal zones the main practical impact (RMSE reduction 5-10cms) is in open waters
- Impactful system memory closer to 6-12 hours – vs global impacts of order 24 hours plus
- Tests on other parameters showed no significant improvements (consistent with other studies)



Discussion: Practical impacts of regional DA scheme

- For the NWS region, ‘system memory’ is of order 6-12 hours
  - Short correlation lengthscales versus data coverage
  - Forced-dissipative system, the model tends back toward forcing atmosphere and internal parameterizations quickly; particularly in high latitude regions
  - To improve this, we need to adjust the winds (atmosphere model!) as well as the waves – roll on coupled DA…
- Significant impact of assimilating local in-situ observations in first 3 hours
  - Non-independent verification – but users likely to want model results as close to in-situ observations as possible; so still ‘a result’ in practise
  - Very short lived effect – demonstrates the longer term, lower impact value of upstream observations
- In practise data delivery timescales suggest that regional DA best suited for nowcast and re-analysis applications
  - But likely to be worth trying this for global (longer lengthscales) and application of SAR spectra (improve wave periods, an Hs based assimilation does not tend to improve these parameters)

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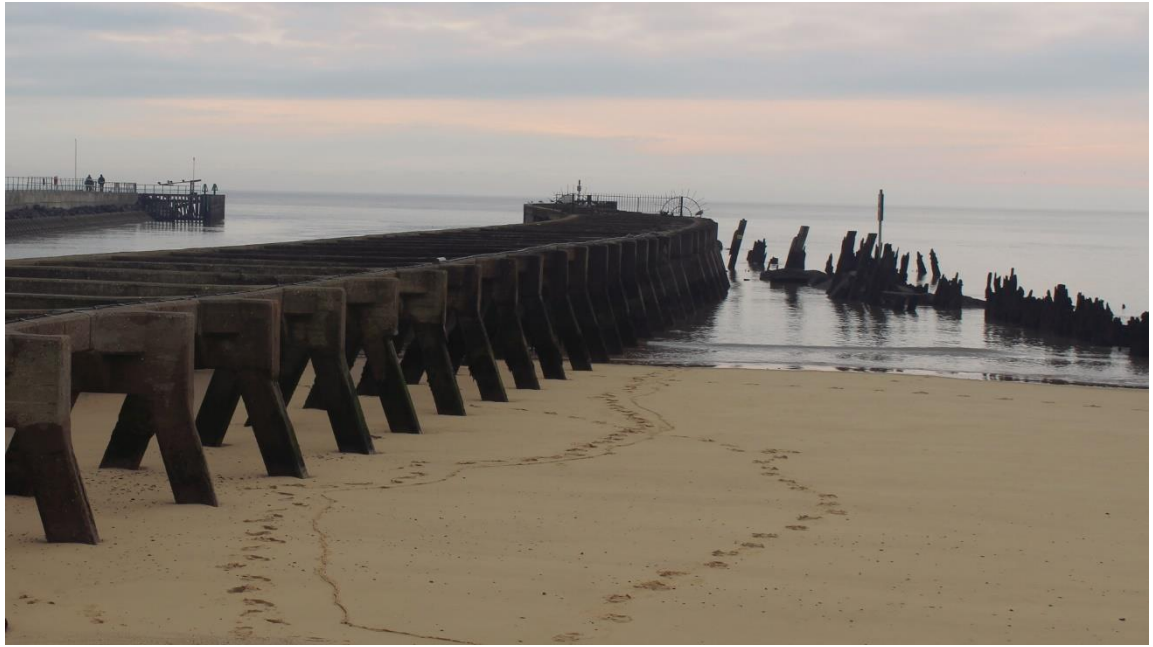
Thankyou for listening



Additional slides

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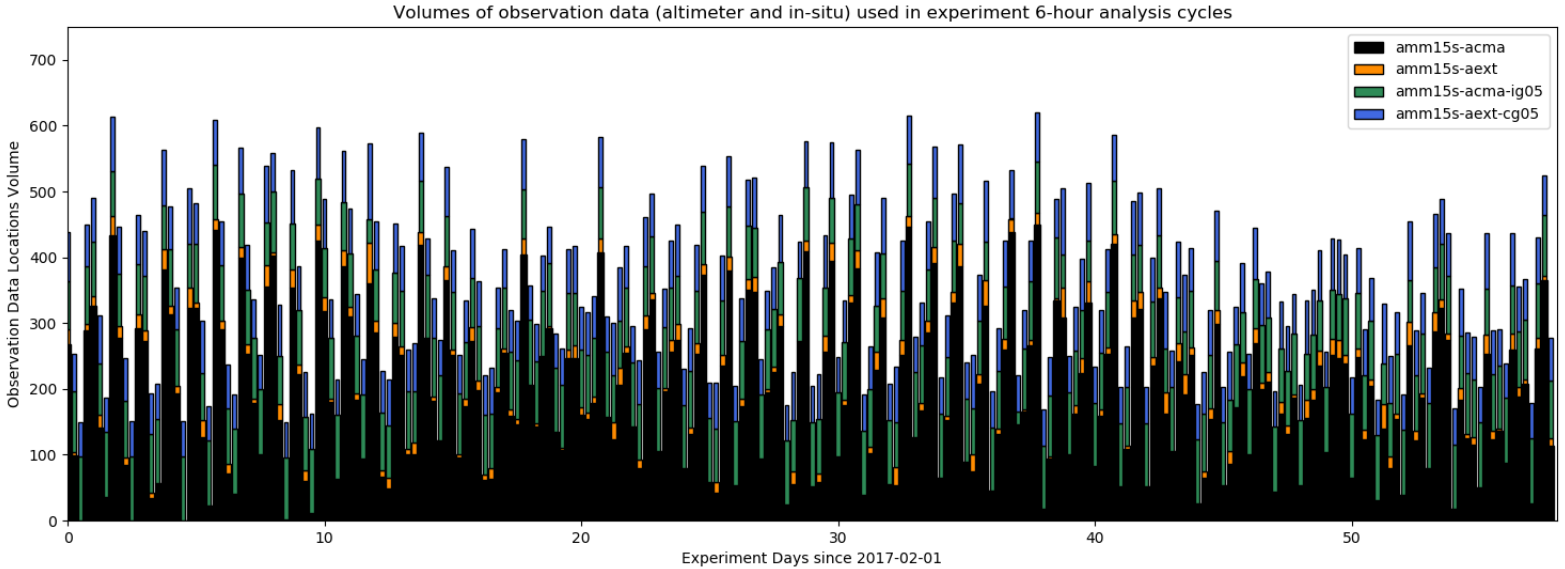
A quick diversion – MSE skill score

- Used as a basis for assessing assimilation impact versus a control (non-assimilative) run
- Relative metric, allows comparison of offshore and coastal zone impacts, which are otherwise related to background parameter variability (e.g. in RMSE)
- Using MSE allows simple decomposition of bias and error variance terms
- $Skill_{MSE} = \frac{MSE[model - observation]}{MSE[observed\ mean - observation]} = \frac{\sum(x_{model} - x_{observed})^2}{\sum(\bar{x}_{observed} - x_{observed})^2}$
- $Skill_{MSE} = \frac{Bias^2 + Var[x_{model} - x_{observed}]}{Var[\bar{x}_{observed} - x_{observed}]}$
- Scale of 0 (complete match to observations) to infinity; no skill versus observed climate at value of 1

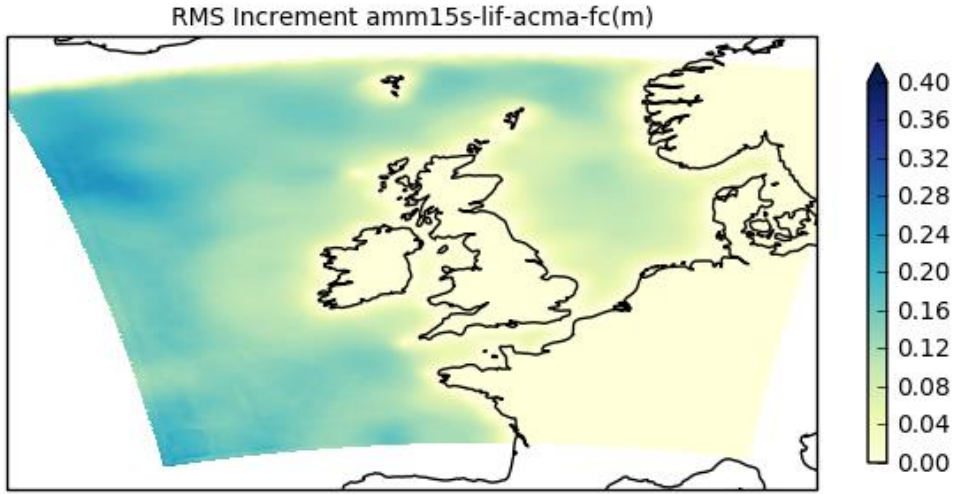
Experiments: Variation of data volumes

- Number of assimilated data at unique locations in domain



Experiments: Impact of altimeters and extending coastal coverage

- Estimate of ‘work done’ by altimeter only run with DA



Experiments: Impact of altimeters and extending coastal coverage

- Altimeter only experiments:
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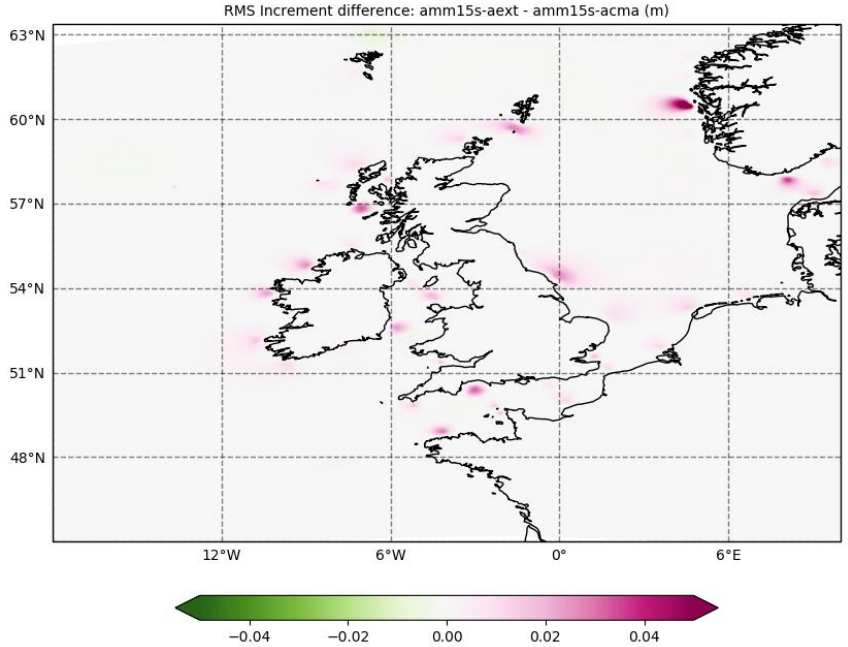
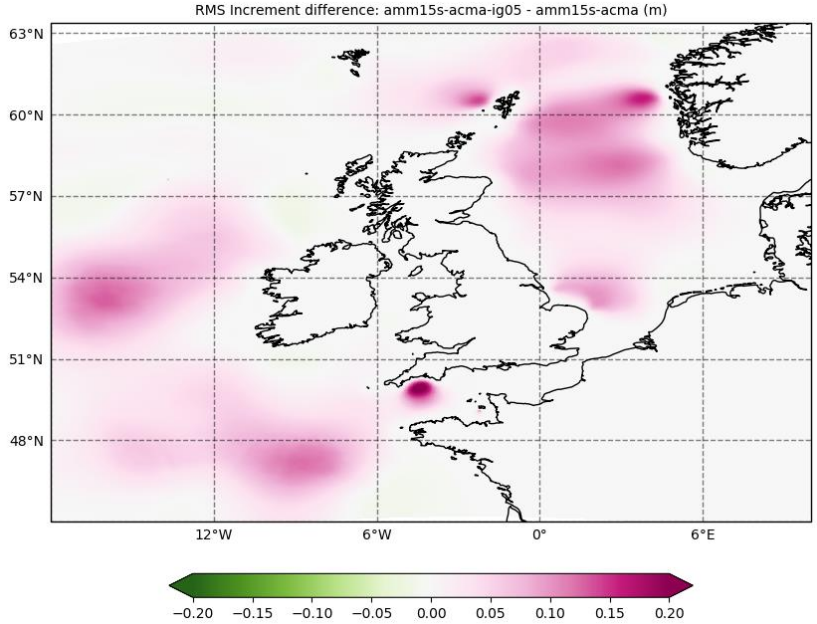
  - AEXT: As above, S-3 and J-3 masked within 8km
- Using altimeters delivers a general improvement in random errors over lead times up to T+12
- Little impact from coastal extension
  - Comparison of increments shows work is done by DA scheme, but not universally and RMS increment differences are limited (3-5cm) versus in-situ impacts (10-20cm)



Experiments: Impacts of altimeter and offshore in-situ data

- Difference in work done by altimeter DA run versus altimeter + offshore in-situ data run



Experiments: Checking impact of including verifying observations in DA scheme

- Impact of including offshore and coastal in-situ observations:
  - ‘Greylisted’ at 50% using random draw
  - Limited impact of removing verifying observations in open waters
  - *Potentially non-independent verification in coastal waters*