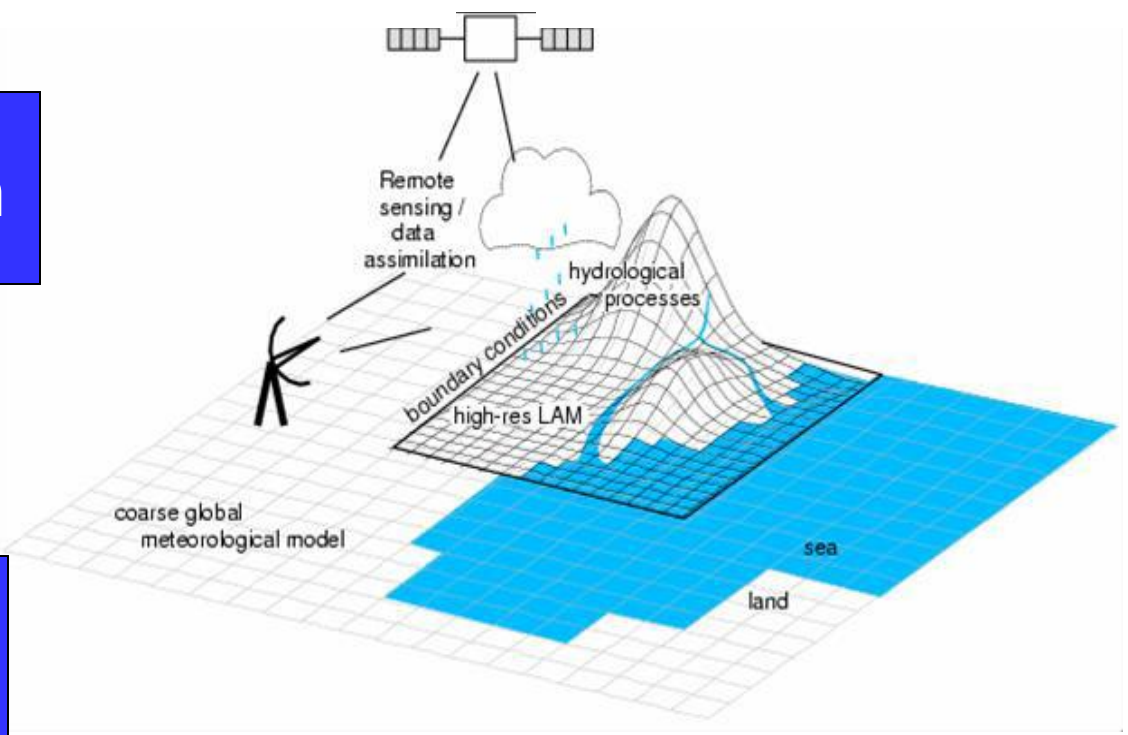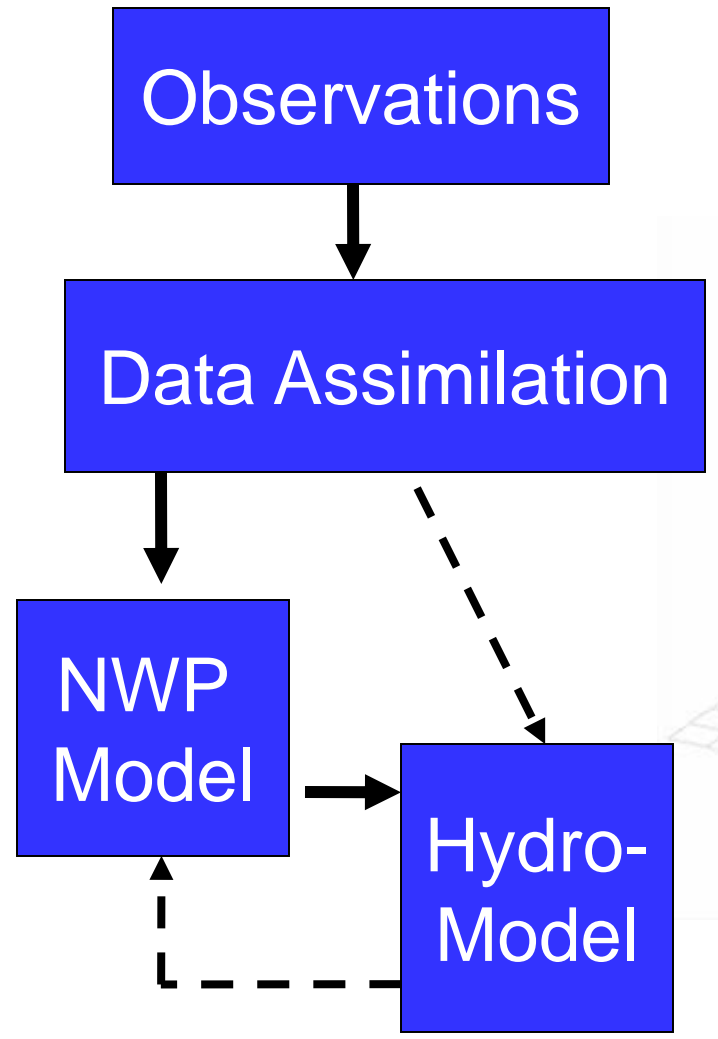# Data Assimilation for Coupled Systems

1. Hydro-meteorological

2. Ocean-atmosphere

Sarah Dance, Amos Lawless, Nancy Nichols et al
DARC Reading and NCEO

email: n.k.Nichols@reading.ac.uk

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

University of Reading

Hydrometeorological Forecasting

Picture by Ross Bannister

Applications of Data Assimilation

- Morphodynamic prediction - coupled hydrodynamic and sediment transport models of the evolution of coastal bathymetry – assimilates water line data from SAR data   (NERC Flood Risk from Extreme Events - FREE)
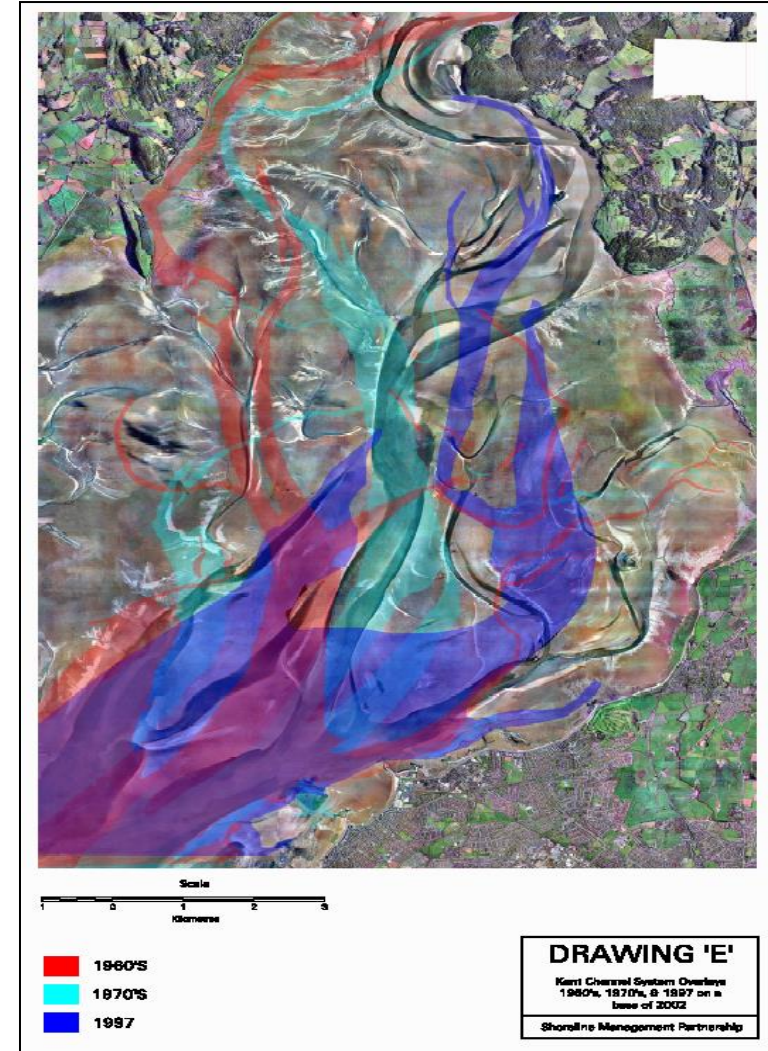
Channel movement

Applications of Data Assimilation

- River flood prediction - hydrodynamic flow in a digital terrain model of inundation - assimilates water line data from SAR data (NERC Demon Project/NERC CASE Award) to predict flood extent


Satellite SAR   Hydraulic Model   3D/4D Covariance   Flood Forecast
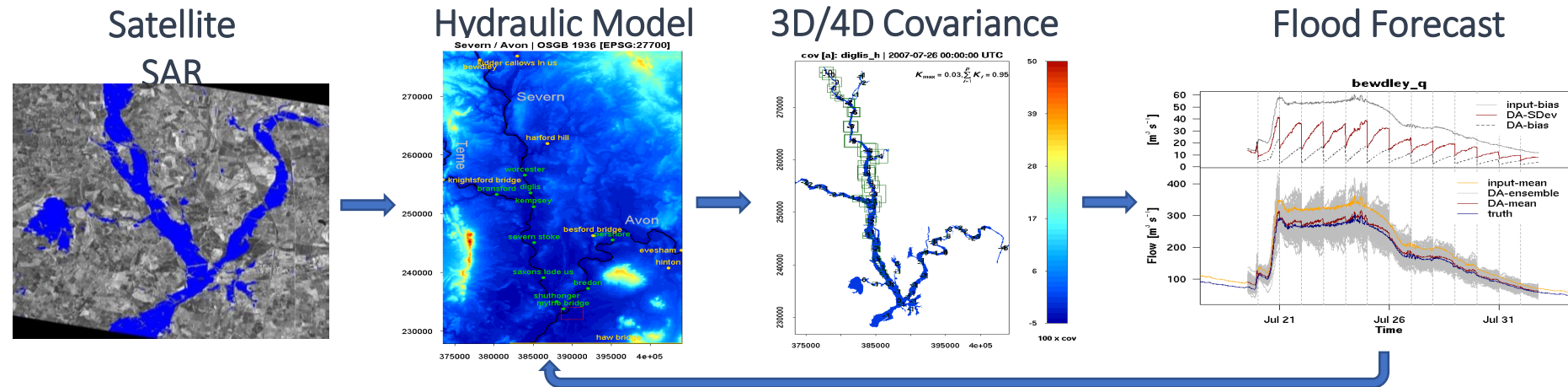
New Developments at Reading:

- assimilation of river camera images for flood forecasting
- machine learning to derive water level observations
- calibration of coupled NWP and hydrological models using data assimilation (EFAS)
- use of particle filters to assimilate satellite data for flood prediction (LIST)
- soil moisture in a hydrological model using SAR data (NERC FFIR)
- hydro-JULES project (CEH)

Coupled Atmosphere – Ocean Forecasting

- Assimilation in weakly / strongly coupled system (NERC)

- Error covariance estimation (NERC)

- Hybrid assimilation methods (Met Office)

coupled via SST and surface fluxes of heat, moisture & momentum
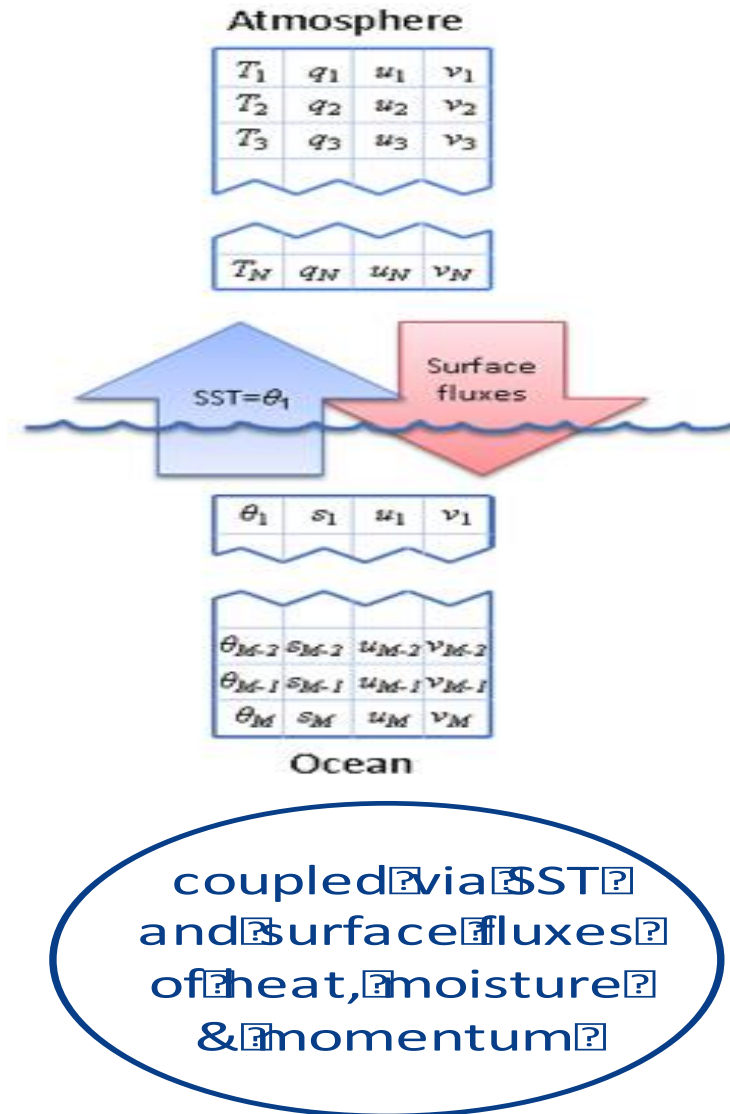
References

Coastal Morphodynamics:

- T.R. Scott, P.J. Smith, S.L. Dance, D.C. Mason, M.J. Baines, N.K. Nichols, K.J. Horsburgh, P.K. Sweby and A.S. Lawless, Data assimilation for morphodynamic prediction and predictability, *Coastal Engineering 2008*, Vols **1-5**, 2009, pp 2386-2398.   doi:10.1142/9789814277426_0197

- G.D. Thornhill, D.C. Mason, S.L. Dance, A.S. Lawless, N.K. Nichols and H.R. Forbes, Integration of a 3D Variational data assimilation scheme with a coastal area morphodynamic model of Morecambe Bay, *Coastal Engineering*, **69**, 82-96, 2012.   doi:10.1016/j.coastaleng.2012.05.010

- P.J. Smith, G.D. Thornhill, S.L. Dance, A.S. Lawless, D.C. Mason and N.K. Nichols, Data assimilation for state and parameter estimation: application to morphodynamic modeling, *Quarterly Journal of the Royal Meteorological Society*, **139**, 314-327, 2013.   doi:10.1002/qj.1944.

Flood Prediction:

- D. Mason, J. Garcia-Pintado, H. L. Cloke, S. L. Dance. J. Munoz-Sabatier Assimilating high resolution remotely sensed data into a distributed hydrological model to improve run off prediction. ECMWF Tech Memo 867, 2002, ECMWF

- Garcia-Pintado, J., Neal, J.C., Mason, D.C., Dance, S.L., Bates, P.D., Scheduling satellite-based SAR acquisition for sequential assimilation of water level observations into flood modelling, *J. Hydrology*, 495, 252-266, 2013. doi: 10.1016/j.jhydrol.2013.03.050

- Javier Garcia-Pintado, David C. Mason, Sarah L. Dance, Hannah L. Cloke, Jeff C. Neal, Jim Freer, Paul D. Bates, Satellite-supported flood forecasting in river networks: A real case study, *J. Hydrol*, 523, 706-724, 2015. doi: 10.1016/j.jhydrol.2015.01.084

- Mason, D. C., Garcia-Pintado, J., Cloke, H. L. and Dance, S. L. Evidence of a topographic signal in surface soil moisture derived from ENVISAT ASAR wide swath data. *International Journal of Applied Earth Observation and GeoInformation*, 45, 178-186, 2016.   doi: 10.1016/j.jag.2015.02.004

- E.S. Cooper, S.L. Dance, J. Garcia-Pintado, N.K. Nichols, P.J. Smith, Observation impact, domain length and parameter estimation in data assimilation for flood forecasting, *Environmental Modelling and Software*, 104, 199-214, 2018. doi: 10.1016/j.envsoft.2018.03.013

- J.A. Waller, J. Garcia-Pintado, D.C. Mason, S.L. Dance and N.K. Nichols, Technical note: Analysis of observation uncertainty for flood assimilation and forecasting, *Hydrol. Earth Syst. Sci*., **22**, 3983–3992, 2018. doi: 10.5194/hess-22-3983-2018

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

University of Reading

- E.S. Cooper, S.L. Dance, J. Garcia-Pintado, N.K. Nichols, P.J. Smith, Observation operators for assimilation of satellite observations in fluvial inundation forecasting, *Hydrol. Earth Syst. Sci*., **23**, 2541-2559, 2019. https://doi.org/10.5194/hess-23-2541-2019

- Hostache, R., Chini, M., Giustarini, L., Neal, J., Kavetski, D., Wood, M., et al. Near-real-time assimilation of SAR-derived flood maps for improving flood forecasts. *Water Resources Research*, *54*, 5516–5535, 2018. https://doi.org/10.1029/2017WR022205

- Di Mauro, C., Hostache, R., Matgen, P., Pelich, R., Chini, M., van Leeuwen, P. J., Nichols, N., and Blöschl, G.: Assimilation of probabilistic flood maps from SAR data into a hydrologic-hydraulic forecasting model: a proof of concept, *Hydrol. Earth Syst. Sci. Discuss*., published on-line https://doi.org/10.5194/hess-2020-403 , (***in review***).

- Vetra-Carvalho, S., Dance, S. L. , Mason, D. C., Waller, J. A., Cooper, E. S., Smith, P. J. and Tabeart, J. M. (2020) Collection and extraction of water level information from a digital river camera image dataset. *Data In Brief*. 106338. https://doi.org/10.1016/j.dib.2020.106338 (***in press***)

Ocean-Atmosphere:

- Smith, P. J., A. F. Fowler, and A. S. Lawless, 2015: Exploring strategies for coupled 4D-Var data assimilation using an idealised atmosphere–ocean model. _Tellus_, 67A, 27025, doi:10.3402/tellusa.v67.27025.

- P.J.Smith, A.S. Lawless and N.K. Nichols, Estimating forecast error covariances for strongly coupled atmosphere-ocean 4D-Var data assimilation, _Monthly Weather Review_, **145**, 4011 – 4035, 2017. doi: 10.1175/MWR-D-16-0284.1

- P.J. Smith, A.S. Lawless and **N.K. Nichols**, Treating sample covariances for use in strongly coupled atmosphere-ocean data assimilation**,** _Geophysical Research Letters_, **44**, 2017, doi:10.1002/2017GL075534.