Example utilization of simulation and assimilation residuals
Dimitris Menemenlis

Summary
There are many examples of utilization of simulation and assimilation residuals to drive the development of sub-grid scale parameterizations. I provide three recent examples, at different stages of completion.

Arctic halocline
A first published example (Nguyen et al., 2009, 2011, 2012) is that of improved representation of Arctic halocline in ocean-ice models. A more realistic representation of subgrid-scale brine rejection is key to preserving Arctic Ocean halocline. The above publications trace (i) identification and parameterization of problem, (ii) adjustment through ocean data assimilation, and (iii) utilization in a scientific application.

Tides and Antarctic Slope Front
Antarctic Slope Front (ASF) is a fundamental component of the MOC. It often has a characteristic V-shape caused by the presence of dense shelf water. It is particularly relevant in the Scotia Sea because of its role on ventilating intermediate depths of the ACC. In 2009, two moorings were placed over the southern slope of the Scotia Sea to study intermediate water ventilation. The data showed significant fortnightly signal down to 1800 m depth, with currents of up to 40 cm/s, for which there was no clear explanation. Numerical simulations without tides could not represent observations. Addition of tides drastically improved representation of ASF vs. observations.

Atlantic waters entering Arctic Ocean
The Nguyen, et al. (2011) optimized Arctic ice-ocean simulation was carried out on a model configuration with 18-km horizontal grid spacing. As model resolution was increased (from 18 to 9 to 4.5 km grid spacing) with same optimized model parameters, the Arctic Ocean warmed. Why and how to fix? There is indication that main culprit may be increased transport of heat from North Atlantic to Arctic through Fram Strait.

Key challenges and opportunities
Innovations, increments, and residuals include a lot of information about model biases caused by problematic representation of subgrid scale processes and boundary condition errors. Future Climate Process and Modeling Teams (CPTs) can and should be more directly motivated by innovations, increments, and residuals of current crop of ocean data-assimilating models. Can US CLIVAR help facilitate this?