DIRECT ASSMILATION OF SATELLITE SST RADIANCES

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ABSTRACT

A capability for direct assimilation of satellite sea surface temperature (SST) radiances has been implemented in the three-dimensional variational Navy Coupled Ocean Data Assimilation system (NCODA 3DVAR). The SST radiance assimilation operator uses both forward and inverse modeling based on radiative transfer. The operator uses an incremental approach and takes as input prior estimates of variables known to affect SST: (1) SST, (2) air temperature, and (3) water vapor. The priors are obtained from ocean and numerical weather prediction (NWP) model forecasts. The forward model uses the Community Radiative Transfer Model (CRTM) to simulate top-of-the-atmosphere (TOA) brightness temperatures (BTs) for the various SST satellites and channel wavelengths. The inverse model is forced by differences between observed and predicted TOA-BTs and uses CRTM Jacobians (radiance derivatives with respect to the priors) to retrieve information about the priors from the radiance measurements. The SST inverse model effectively partitions the observed change in TOA-BT into a change in SST that takes into account the variable temperature and water vapor content of the atmosphere at the time and location of the satellite SST radiance measurement. The change in SST is then input as an innovation in the NCODA 3DVAR minimization. Proper characterization of the prior errors is critical to the success of the method. For this purpose, atmospheric ensemble products are used to provide uncertainty of the NWP priors, radiometric noise estimates of the channels are obtained from satellite monitoring statistics, and SST prior errors are estimated from a time history of ocean model variability and model-data differences. The method is a true example of coupled data assimilation, whereby an observation in one fluid (atmospheric radiances) creates an innovation in the other fluid (ocean SST).

1. Introduction

Satellite derived SSTs are often generated using empirical regression models that relate cloud cleared radiances to drifting buoy measurements of SST. The regression models are global (or nearly global), calculated once, and held constant. The coefficients represent a very broad range of atmospheric conditions with the result that systematic errors are introduced into the empirical SST when the method is uniformly applied to new radiance data. In the direct assimilation method, coefficients that relate radiances to SST are dynamically defined for each atmospheric situation observed. As a result, the method explicitly corrects for the overlying atmosphere and produces a more accurate and time consistent estimate of SST. The direct assimilation method has multiple applications. In one application it is used to compute atmospheric corrections to an existing SST using collocated NWP fields. The correction is applied at the time the SST is assimilated. This approach is being used as a post-processing step in the NAVOCEANO SST retrieval processing. Alternatively, the method is integrated directly into a variational analysis scheme as an observation operator. In this mode there is no need for an empirical SST derived from buoy matchups. The SST prior comes from the ocean model forecast and is used with the atmospheric forcing in the radiance assimilation. Ideally the ocean and atmospheric models have evolved in coupled mode.

2. Progress

Figure 1 gives a schematic of the satellite SST radiance assimilation observation operator. The operator was validated using METOP-A data for 2008-2010 obtained from the ESA Climate Change Initiative project. Here, priors from ECMWF atmospheric model fields were used with collocated satellite SST radiances and drifting buoy SST measurements to calculate atmospheric corrections to the SST lower boundary condition used by the ECMWF model. The corrected and uncorrected SSTs were compared to the drifting buoy SST. Table 1 shows that the atmospheric correction resulted in an 80% improvement in the fit of the lower boundary SST to the drifting buoy SST. The operator has been successfully applied to cloud cleared radiances from NOAA-18, NOAA-19, METOP-A, GOES-13, GOES-15, and NPP-VIIRS using operational NAVOCEANO empirical SSTs and Navy NWP model inputs. It was found with global Navy NWP model priors that a bias correction step is necessary due to the model fields being too moist in what otherwise should be cloud free areas. Satellite SST radiance data by definition are cloud free but the NWP priors can be from areas that are both cloudy and clear. The bias correction uses a sliding time window of cloud cleared radiances from the drifting buoy matchup database maintained by NAVOCEANO. The bias correction is routinely updated in an automated scheme to capture changes in the Navy NWP model and its water vapor distribution over time.

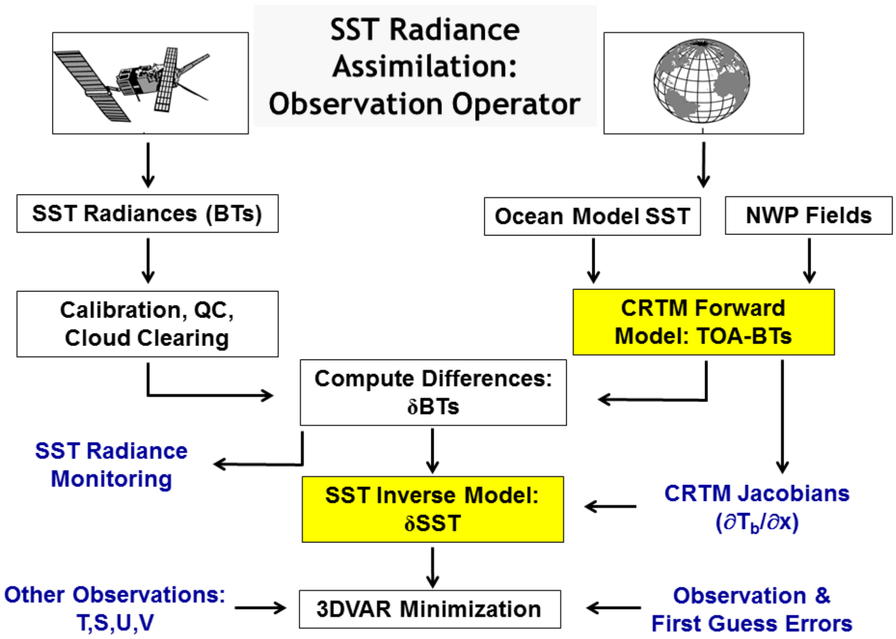

Figure 1. Flow chart of the SST radiance assimilation observation operator in NCODA. The CRTM forward and SST inverse models are highlighted in yellow.

Table 1. Verification statistics of SST radiance operator applied to METOP-A data using ECMWF NWP model priors.

METOP 2010 Data Count	Error Prior SST	Error Corrected SST	Per Cent Improvement
149,383	**-0.0314**	**-0.0062**	**80.2%**

3. Future Capabilities

The radiance assimilation operator is being evaluated in the NCODA 3DVAR analysis as part of the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS). Here, SST radiances are used in direct assimilation mode to correct the ocean model forecast SST using the coupled model state. In addition, SST lower boundary conditions derived from atmospheric corrected NAVOCEANO SSTs are being evaluated in the four-dimensional Navy Atmospheric Variational Data Assimilation System (NAVDAS). Here, the metric is fewer rejections of radiances from lower tropospheric channels that peak at or near the surface. Currently, these channels are rejected by the NAVDAS 4DVAR because of inaccuracies and unrealistic temporal variability in the empirical SST retrievals.

Work is underway to extend the radiance operator to ice covered seas to provide estimates of ice surface temperature (IST). The Navy global HYCOM ocean forecast system is coupled to a sea ice model (CICE), and the combination of SST and IST data will provide a seamless analysis of surface conditions for the coupled model. Finally, aerosol optical depth from the Navy Aerosol Analysis and Prediction System (NAAPS) will be added as a prior variable in the forward and inverse modeling. The presence of atmospheric dust is known to produce a cold bias in infrared radiances and needs to be taken into account.

4. References

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