Florida Bay Assessment Model Version 1.3 Update Notes

It has been noted that during the Florida Bay hypersalinity event in July 2015, BAM does not estimate the peak hypersalinities (above 50 ppt) well. In part, this is likely due to the large spatial scales and basin-wide averages inherent in BAM, whereas the observations are point measurements. Another potential issue is that ET is represented by a single timeseries derived from USGS GOES estimates in the southern EDEN domain (marsh).

In an effort to refine BAM salinity estimates, the update applies a temperature-based ET amplification. The idea is that observed water surface temperature can be used to estimate a ratio of increased equilibrium vapor pressure, and thus evaporation. This increased evaporation rate is then applied to specified basins. The vapor pressure change is quantified by the Clausius-Clapeyron relation:

$$\ln\left(\frac{P}{P_{ref}}\right) = \frac{\Delta H}{R}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)$$

where P is the vapor pressure, T temperature in Kelvins, ΔH the change in specific enthalpy (specific latent heat) and R the universal gas constant.

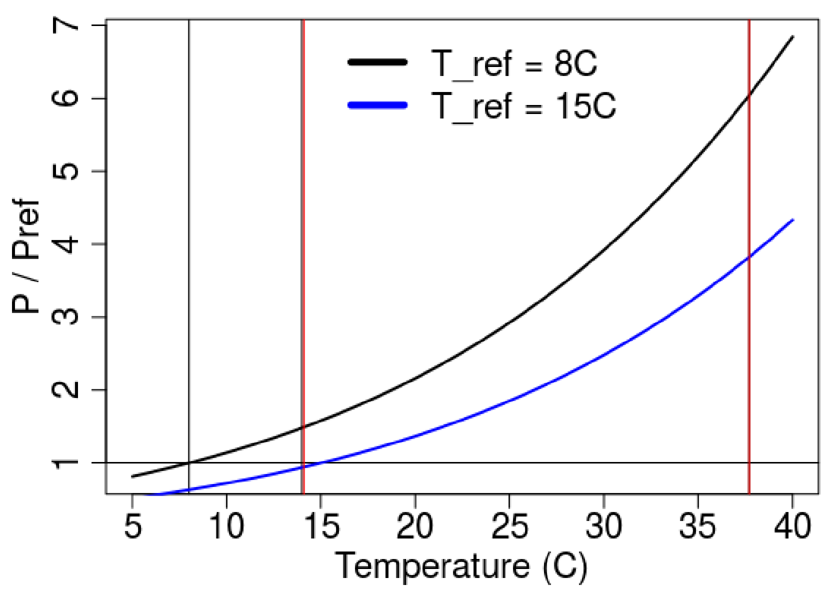


Figure 1.

Vapor pressure ratios for reference temperatures of 8°C and 15°C.

Vertical red lines demark the surface temperature range in BAM POR (1999-9-1 to 2016-12-31).

The addition of the ET Amplify physics in select basins improves model accuracy over the full POR (1999-9-1 to 2016-12-31) while allowing the physically reasonable global ET scale factor of 1.

Temperature Data

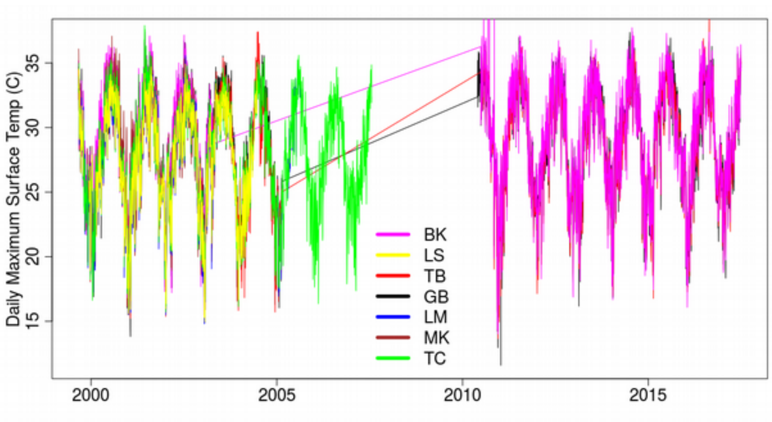


Figure 2.
Coastal water surface daily maximum temperature data available in Data4EVER over the BAM period-of-record.

Surface temperatures are largely coherent and similar in magnitude across basins.

The large gap will need data reconstruction.

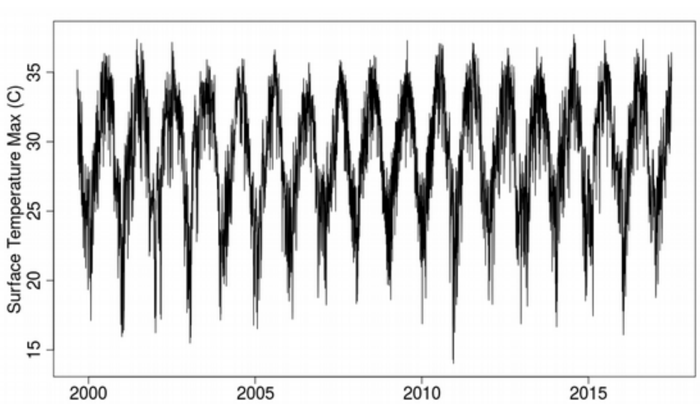


Figure 3.
Maximum daily water surface temperature data and reconstruction for BAM.

BK data was used where available. Where GB was available in the BK gaps, linear regression was used to estimate BK data. Where TC was available in the remaining gaps, linear regression was used to estimate BK data. The remaining gaps were filled with a Gaussian-based empirical resampling for equivalent year-days based on existing data.

Model Changes

BAM was modified with the addition of `GetTemperature()` and `VaporPressureRatio()` methods in the `model` object, and the `GetTemperatureData()` method in the `init` module. The temperature timeseries was added in the `data/Temperature` directory. Command line options to control these inputs are:

`-st --temperature` Temperature data file
`-ea --ET_Amplify` Apply basin ET amplification from vapor pressure ratio
`-rt --reference_temperature` Vapor pressure reference temperature

The ET amplification is only applied to basins in the basins parameter file (`-bp --basinParameter`) with the `ET_Amplify` field set `True` .

Model Results

Figure 4. Comparisons of model results with ET amplification to version 1.2 without ET amplification.

Red : With ET amplification at reference temperature of 20°C.
Green : Without ET amplification
Blue : Gauge point-measurements

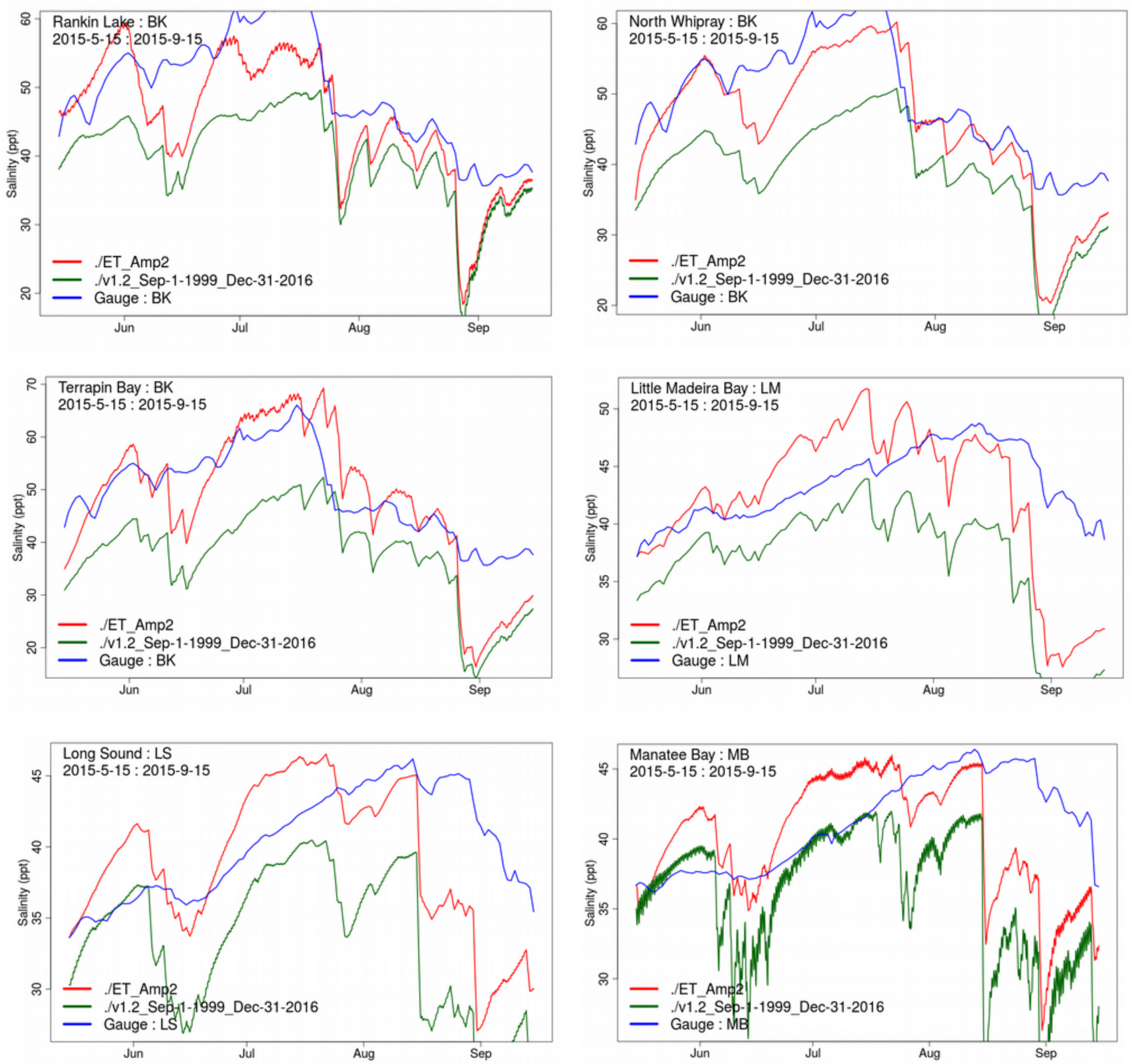
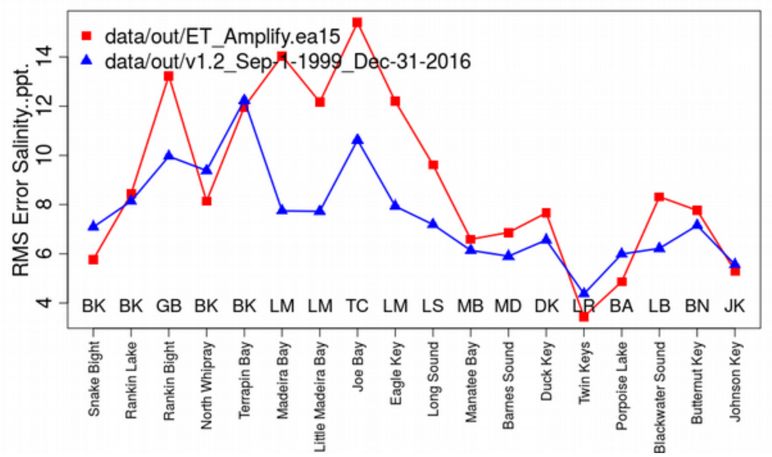
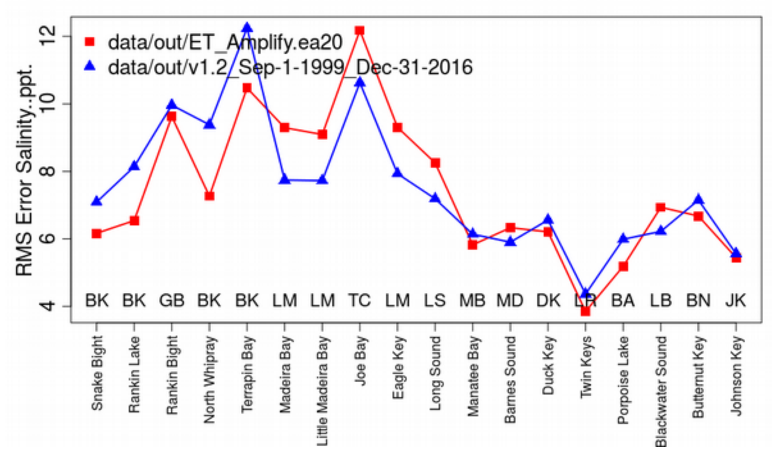


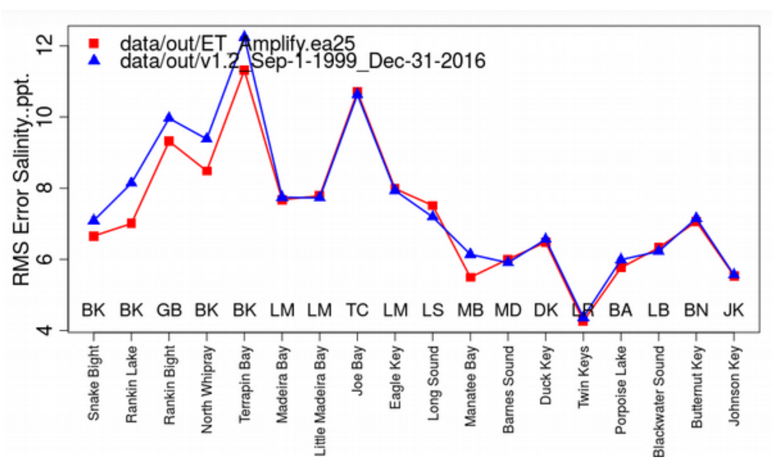
Figure 5. RMS Error (ppt) over the period 1999-9-1 to 2016-12-31 at basins in proximity to gauges. BAM was run with ET Amplify for basins: Terrapin Bay, North Whipray, Rankin Lake, Snake Bight. The default setting of ET scale (multiplier) of 2 (-es 2) was used.



a) Reference temperature 15°C.

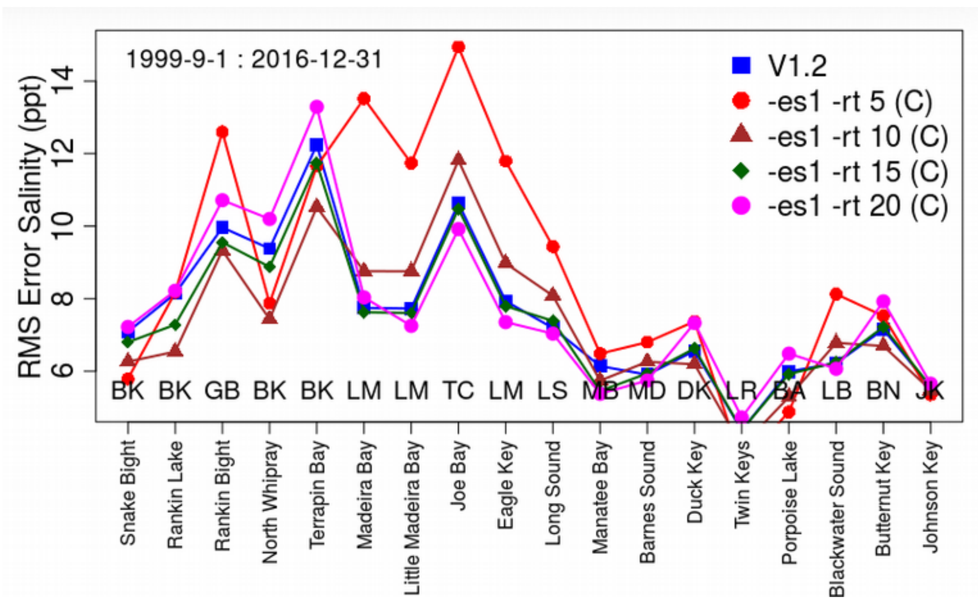


b) Reference temperature 20°C.



c) Reference temperature 25°C.

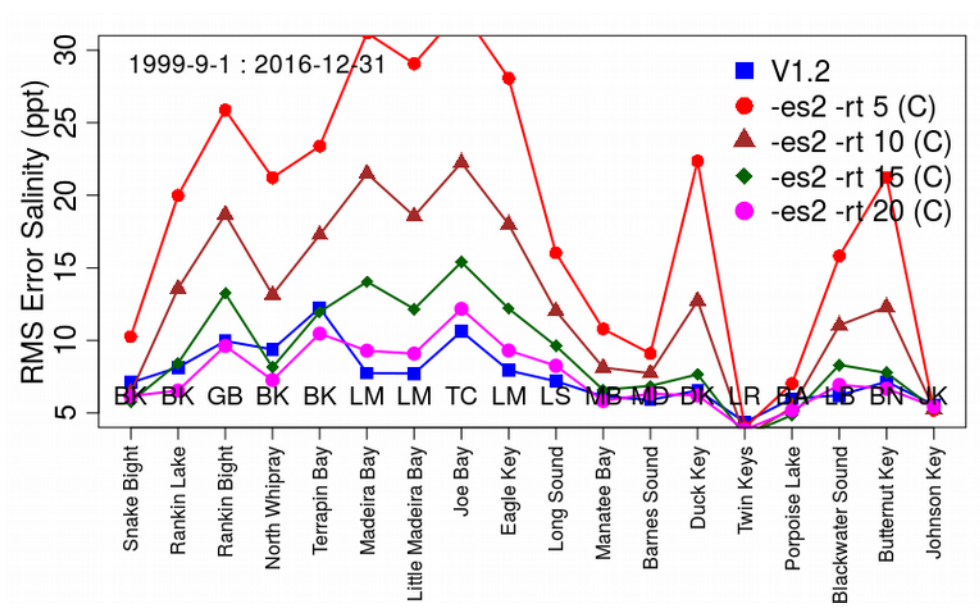
Figure 6. RMS Error (ppt) over the period 1999-9-1 to 2016-12-31 at basins in proximity to gauges. BAM was run with ET Amplify for basins: Terrapin Bay, North Whipray, Rankin Lake, Snake Bight.



a)

ET scale (multiplier) of 1 with varying reference temperature. V1.2 uses ET scale of 2, and no ET Amplify.

This suggests that the reference temperature (`-rt`) option be set to a default value of 15°C. The ET scale default set to 1.

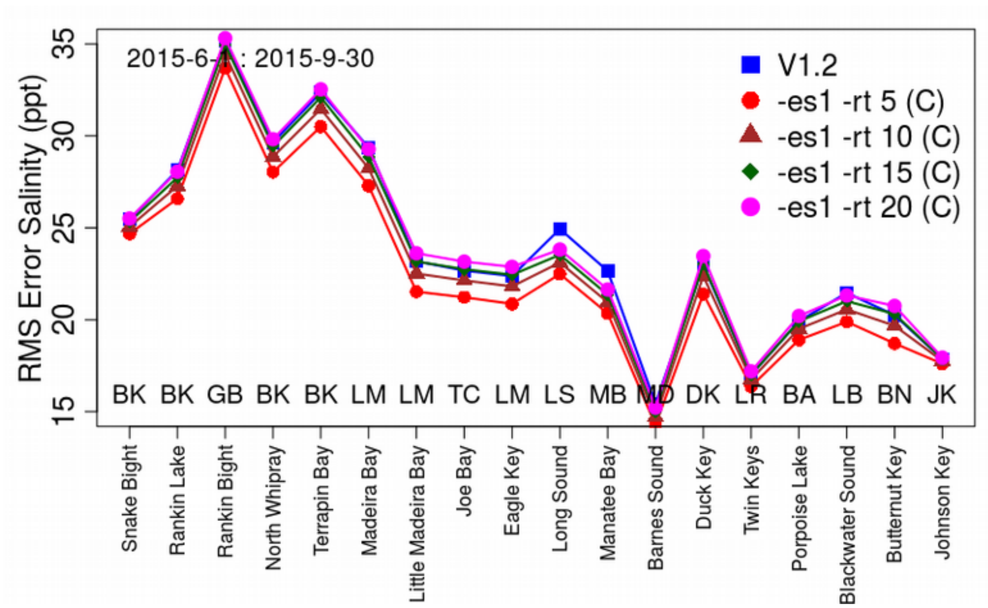


b)

ET scale (multiplier) of 2 with varying reference temperature. V1.2 uses ET scale of 2, and no ET Amplify.

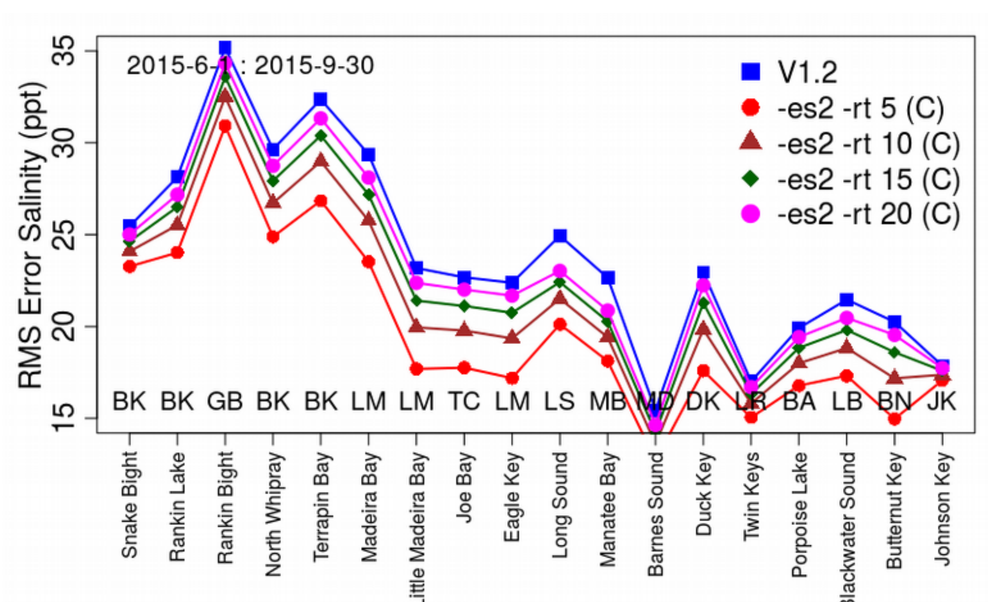
Figure 7. RMS Error (ppt) over the period 2015-6-1 to 2015-9-30 at basins in proximity to gauges. BAM was run with ET Amplify for basins: Terrapin Bay, North Whipray, Rankin Lake, Snake Bight.

However, these RMS errors can be misleading if model salinities oscillate. Selection of ET scale and amplify parameters should also consider the predicted salinity timeseries as in the following figures.



a)

ET scale (multiplier) of 1 with varying reference temperature. V1.2 uses ET scale of 2, and no ET Amplify.



b)

ET scale (multiplier) of 2 with varying reference temperature. V1.2 uses ET scale of 2, and no ET Amplify.

Figure 8. BAM model salinities for V1.2 and V1.3 from 2015-6-1 to 2015-9-30. Note the dissimilar salinity scales.   Top Left: Gauge Data. Top Right: BAM V1.2 with -es 2 and no ET Amplify.

Note that V1.3 with -es 2, -rt 5 creates salinity oscillations, but a lower RMS error than V1.2. The best V1.3 result is -es 2 -rt 20.

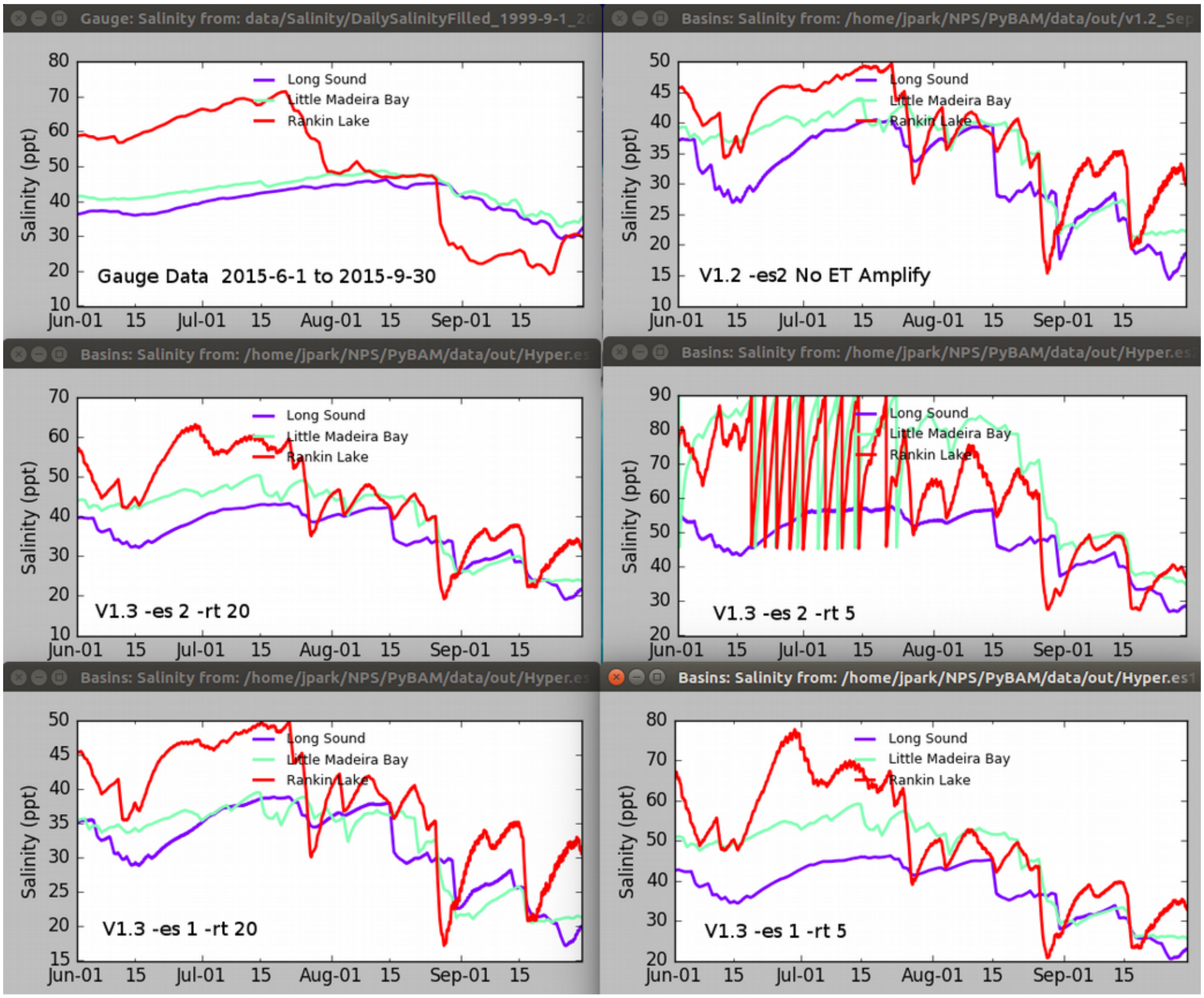
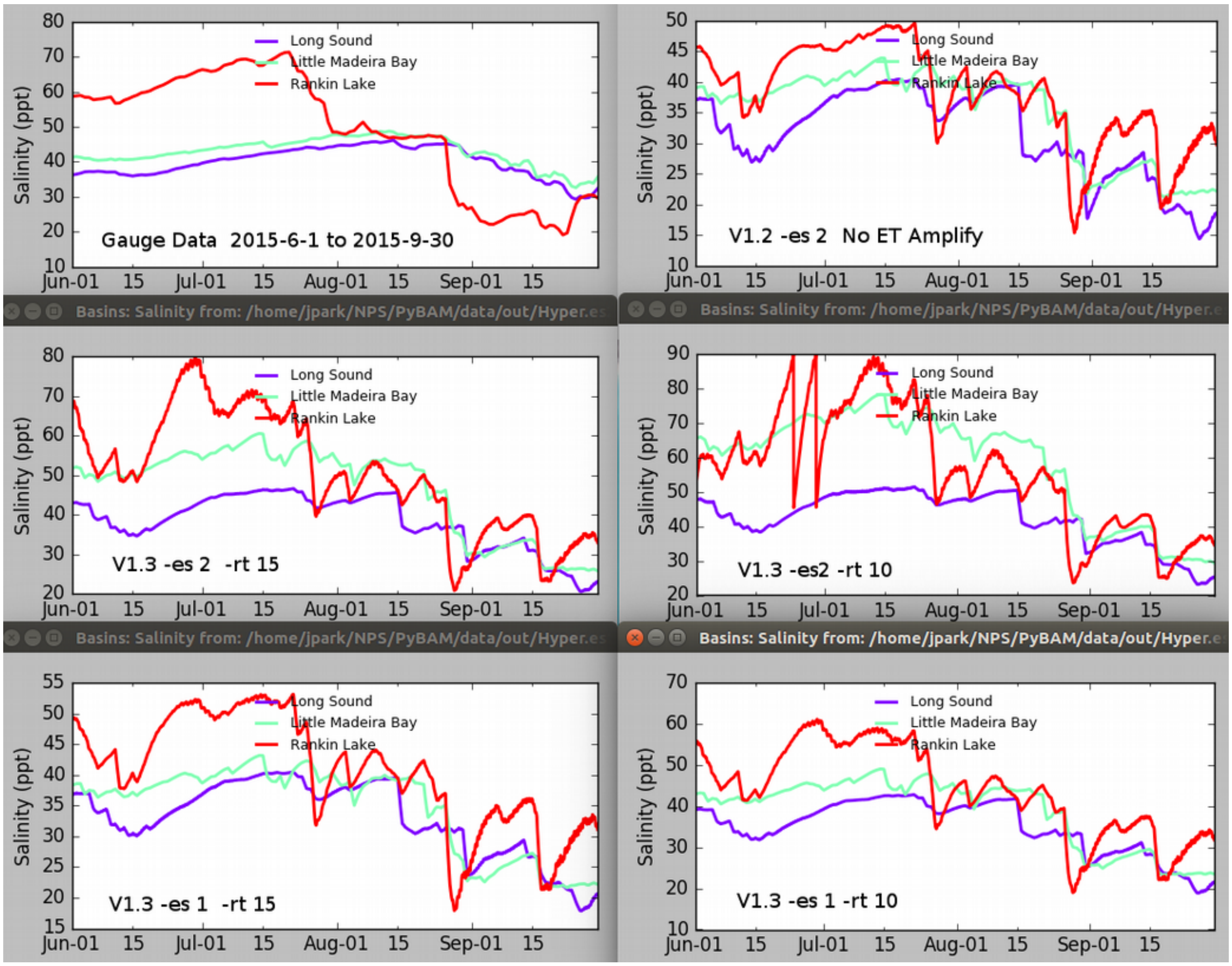


Figure 9. BAM model salinities for V1.2 and V1.3 from 2015-6-1 to 2015-9-30. Note the dissimilar salinity scales. Top Left: Gauge Data. Top Right: BAM V1.2 with -es 2 and no ET Amplify.

Note that V1.3 with -es 2, -rt 10 creates salinity oscillations, but a lower RMS error than V1.2. The best V1.3 result is -es 1 -rt 10.



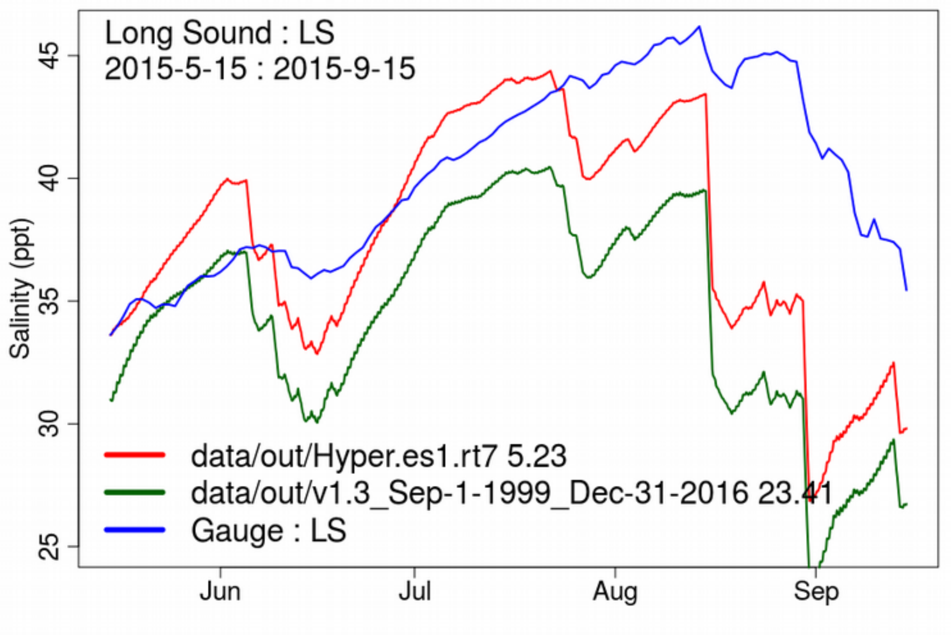


Figure 10.

Long Sound

Red : BAM v1.3 with a reference temperature of 7°C.

Green : BAM v1.3 with a reference temperature of 15°C.

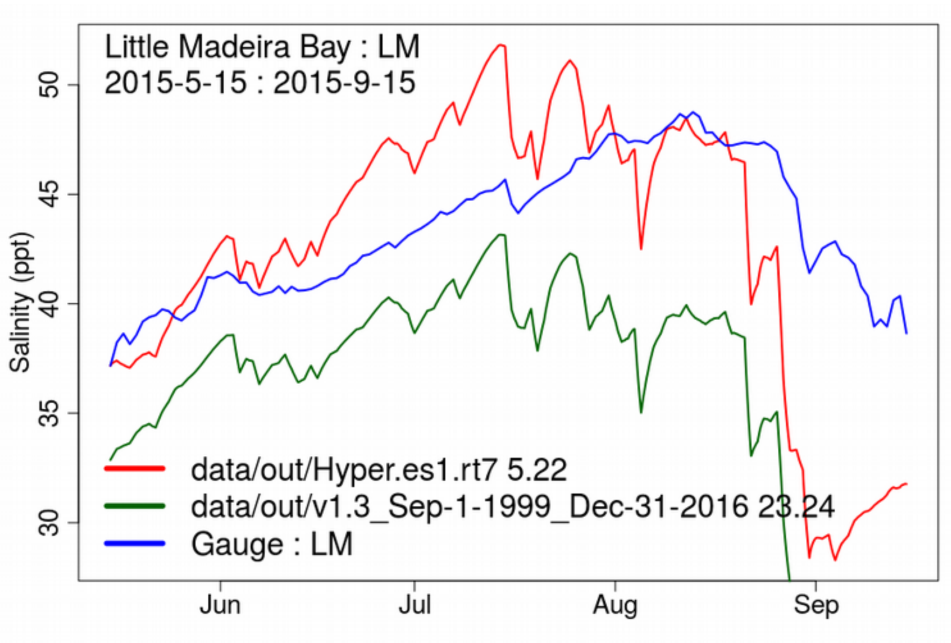


Figure 11.

Little Madeira Bay

Red : BAM v1.3 with a reference temperature of 7°C.

Green : BAM v1.3 with a reference temperature of 15°C.

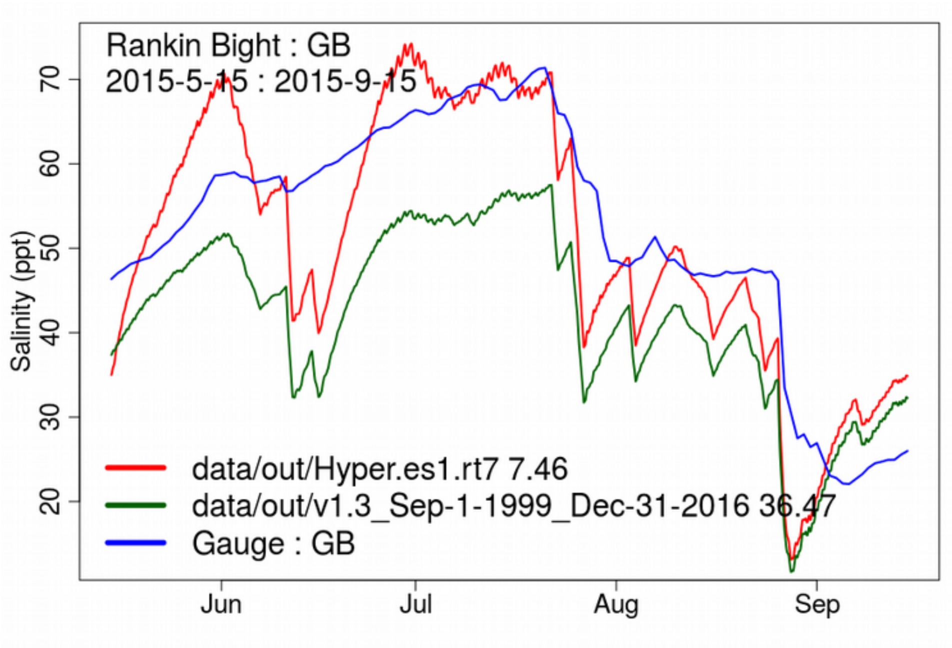


Figure 12.

Rankin Bight

Red : BAM v1.3 with a reference temperature of 7°C.

Green : BAM v1.3 with a reference temperature of 15°C.

Summary

The addition of the ET Amplify physics in select basins improves model accuracy over the full POR (1999-9-1 to 2016-12-31) while allowing the physically reasonable global ET scale factor of 1. The reference temperature (`-rt`) option should be set to a default value of 15°C for full POR runs.

In hypersaline events (July 2015), the ET Amplify physics can improve model accuracy with higher rates of ET, but should be used with caution to avoid salinity oscillations. In the 2015 event a global ET scale factor of 1 and reference temperature of 7 or 8°C improve model accuracy without stability issues as shown in Figure 13 and Tables 1 and 2.

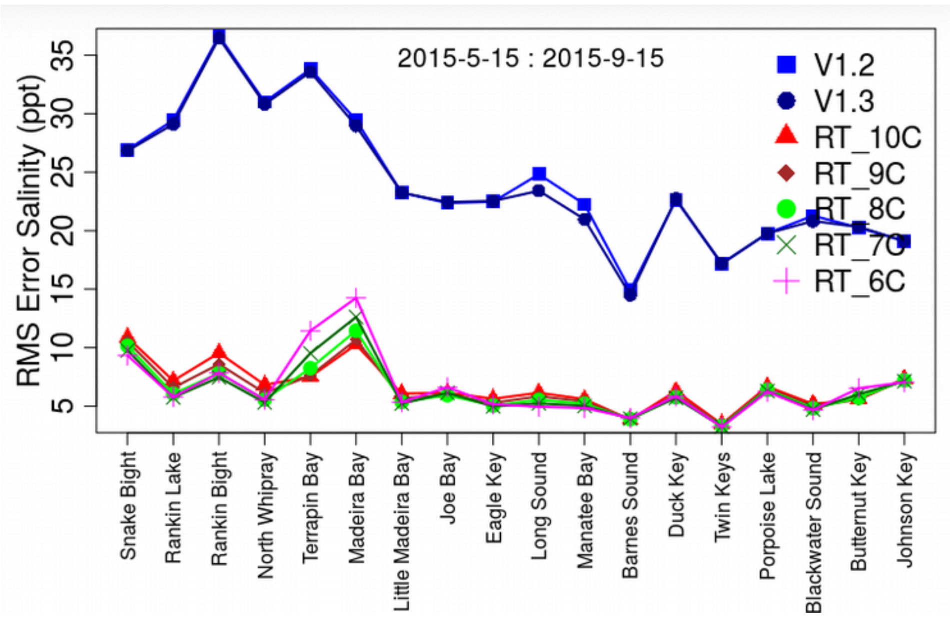


Figure 13.

Comparison of BAM salinity RMS errors for the period 2015-5-15 to 2015-9-15 at different reference temperature (RT). ET Amplify applied in: Snake Bight, Rankin Lake, North Whipray, Terrapin Bay.

V1.3 uses a reference temperature of 15°C.

Basin	V1.2	V1.3	RT_10C	RT_9C	RT_8C	RT_7C	RT_6C
Snake Bight	26.93	26.83	10.87	10.53	10.15	9.76	9.33
Rankin Lake	29.44	29.11	7.17	6.57	6.05	5.74	5.78
Rankin Bight	36.65	36.47	9.55	8.59	7.81	7.46	7.84
North Whipray	31	30.81	6.82	6.12	5.56	5.31	5.55
Terrapin Bay	33.81	33.57	7.52	7.6	8.24	9.52	11.44
Madeira Bay	29.45	28.96	10.26	10.68	11.45	12.62	14.25
Little Madeira Bay	23.24	23.24	6.07	5.67	5.36	5.22	5.34
Joe Bay	22.36	22.44	6.14	5.96	5.93	6.13	6.61
Eagle Key	22.47	22.54	5.63	5.28	5.05	4.98	5.16
Long Sound	24.82	23.41	6.14	5.84	5.53	5.23	4.95
Manatee Bay	22.25	20.97	5.59	5.4	5.2	5.01	4.84
Barnes Sound	14.91	14.5	3.84	3.86	3.89	3.93	3.99
Duck Key	22.64	22.71	6.29	5.98	5.76	5.7	5.84
Twin Keys	17.17	17.18	3.46	3.38	3.31	3.26	3.23
Porpoise Lake	19.77	19.77	6.67	6.53	6.4	6.29	6.22
Little Blackwater Sound	21.28	20.82	5.18	4.98	4.82	4.7	4.66
Butternut Key	20.25	20.32	5.58	5.57	5.71	6.02	6.53
Johnson Key	19.1	19.11	7.35	7.29	7.21	7.13	7.04

Table 1.

BAM RMS salinity errors (ppt) for the period 2015-5-15 to 2015-9-15 at different reference temperature (RT).

ET Amplify applied in: Snake Bight, Rankin Lake, North Whipray, Terrapin Bay.

V1.2	V1.3	RT_10C	RT_9C	RT_8C	RT_7C	RT_6C
24.31	24.04	6.67	6.43	6.30	6.33	6.59

Table 2.
Mean RMS Errors (ppt) versus reference temp.

Code Excerpts:

```
#----------------------------------------------------------------
#
#----------------------------------------------------------------
def GetTemperature( self, key ):
    '''Get water temperature for basin, but only if the ET Amplify
       option is specified (-ea) and the basin ET Amplify field
       is True in Basin_Parameters.csv'''

    if self.args.DEBUG_ALL :
        print( '\n-> GetTemperature', flush = True )

    if not self.args.ET_amplify :
        return

    temperature = self.temperature_data[ key ]

    for Basin in self.Basins.values() :
        if Basin.boundary_basin :
            continue

        if Basin.ET_amplify :
            Basin.temperature = temperature

#----------------------------------------------------------------
#
#----------------------------------------------------------------
def GetET( self, key ):
    '''Subtract ET volume from basin'''

    if self.args.DEBUG_ALL :
        print( '\n-> GetET', flush = True )

    if self.args.noET :
        return

    et_mm_day = self.et_data[ key ]

    for Basin in self.Basins.values() :
        if Basin.boundary_basin :
            continue

        kinetic_ET_factor = 1

        if self.args.ET_amplify :
            if Basin.temperature :
                kinetic_ET_factor = self.VaporPressureRatio( \
                                         Basin.temperature )

        et_volume_day = ( et_mm_day / 1000 ) * Basin.area * \
                        self.args.ET_scale * kinetic_ET_factor

        et_volume_t   = et_volume_day / self.timestep_per_day

        Basin.evaporation = et_volume_t

        Basin.water_volume -= et_volume_t
```

```
#-----------------------------------------------------------------
#
#-----------------------------------------------------------------
def VaporPressureRatio( self, temperature ):
    '''Return relative vapor pressure to amplify ET'''

    if self.args.DEBUG_ALL :
        print( '\n-> VaporPressureRatio', flush = True )

    if not self.args.ET_amplify :
        return 1

    dH = 44000 # enthalpy of vaporization J/mol @ 300 K
    R  = 8.314 # universal gas constant   J/(mol K)
    ref_temperature = self.args.reference_temperature

    # Clausius-Clapeyron relation:
    # ln( P2/P1 ) = ( dH / R ) * (1/T2 - 1/T1)
    P_Pref = exp( (dH/R) * ( 1/(ref_temperature + 273.15) -
                             1/(temperature     + 273.15) ) )

    # Limit ratio's less than 1 to 1 (when temp < ref_temp )
    return max( 1, P_Pref )
```