Impact of River Discharge on the California Coastal Ocean Circulation and Variability

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Abstract

A real-time California coastal ocean nowcast and forecast system is used to quantify the impact of river discharge on the California coastal ocean circulation and variability. River discharge and freshwater runoff is monitored by an extensive network of stream gages maintained through the U.S. Geological Survey, that offers archived stream flow records as well as real-time datasets. Of all the rivers monitored by the USGS, 25 empty into the Pacific Ocean and contribute a potential source of runoff data. Monthly averages for the current water year yield discharge estimates as high as 6,000 cubic meters per second of additional freshwater input into our present model.

Using Regional Ocean Modeling System (ROMS), we performed simulations from October 2015 to May 2016 with and without the river discharge. Results of these model simulations are compared with available observations including both in situ and satellite. Particular attention is paid to the salinity simulation. Validation is done with comparisons to sea glider data available through Oregon State University, which provides depth profiles along the California coast during this time period.

Discharge data collected by the USGS stream gages provides a necessary source of freshwater input that must be accounted for. Incorporating a new runoff source produces a more robust model that generates improved forecasts. Following validation with available sea glider and satellite data, the enhanced model can be transitioned into the real-time forecasting system currently in operation.

Background

Regional Ocean Modeling System (ROMS) is an ocean global circulation model developed through a collaborative effort amongst several bodies, including Rutgers University and UCLA, as a solution to a range of oceanographic and biologic applications. Remote Sensing Solutions, Inc. uses ROMS as an established tool to create real-time nowcasts and forecasts for ocean circulation along the coast of California. Currently, the only source of freshwater accounted for is precipitation; there is a need to incorporate river discharge in an effort to create a more robust model.

In order to test the effects of using California river data as an additional source of freshwater input, we aim to model a time period from October 2015 to May 2016 across an area of longitude 117°W to 128°W, and latitude 31°N to 43°N. The suggested time frame is advantageous due to a recent Seaglider™ dataset from Oregon State University collected during this period, which can provide a viable means of comparison and contribute a potential source of freshwater.

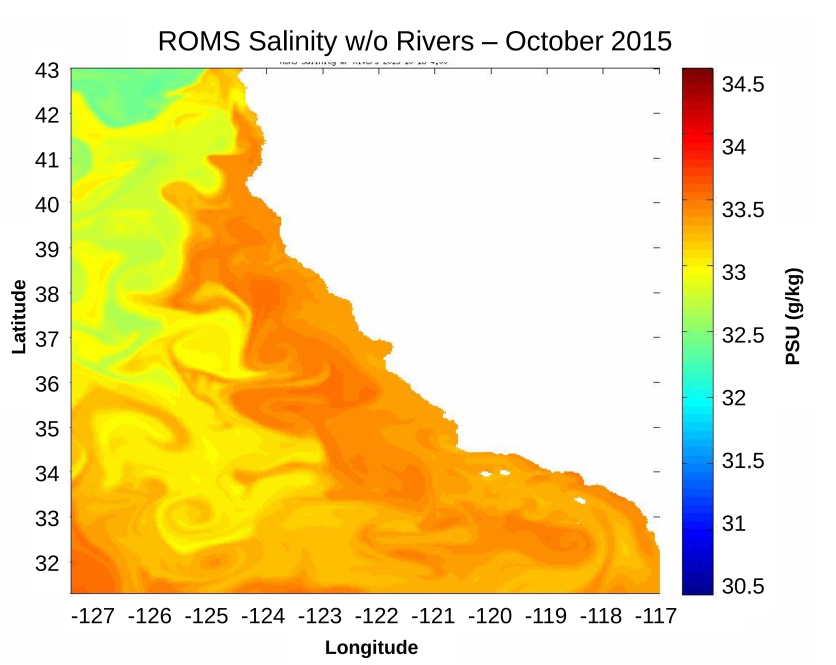


Fig. 1. Domain area for the California Regional Ocean Modeling System (ROMS)

Table 1. List of major California Rivers included as a new freshwater source in the ROMS model. Bolded river names are grouped under "San Francisco bay" or "SF bay" in Figure 2.

Major California Rivers	
1. Alameda River	**13. Petaluma River**
2. Carmel Creek	14. Redwood Creek
3. Coyote Creek	15. Russian River
4. Eel River	**16. Sacramento River**
5. Klamath River	17. San Diego River
6. Little River	18. San Gabriel River
7. Mad River	**19. San Joaquin River**
8. Mattole River	20. San Lorenzo River
9. Napa River	21. Santa Ana River
10. Navarro River	22. Santa Clara River
11. Noyo River	23. Santa Maria River
12. Pajaro River	24. Smith River

Research Questions

Currently, the California ROMS model predicts coastal salinity values that are higher than observed in regions known to be impacted by freshwater discharge from rivers.

- **What are the effects on California coastal salinity of the inclusion of new freshwater sources in the ROMS model?**
- **Will including these sources produce results that more closely match observations?**

River Data Analysis

River Selection

In order to incorporate California river data as a freshwater source into ROMS, the following information is required for our input file:

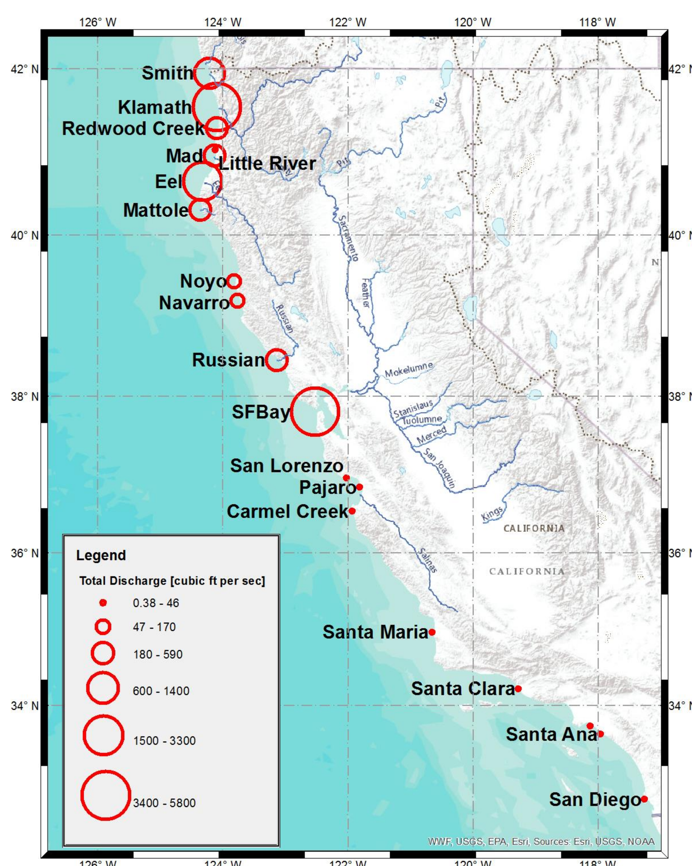
- Number of rivers
- Location of river mouth
- Flow orientation and direction
- Discharge
- Temperature
- Salinity

The process of selecting California rivers to use in our study was based on the availability and quality of data through the USGS National Water Information Services, which have real-time stream gage data. Efforts were made to use every major river; only in the event of an unusually great distance from the coast to the stream gage, or if no discharge was present, was a river disregarded. Using these criteria, 24 out of 30 possible rivers were included.

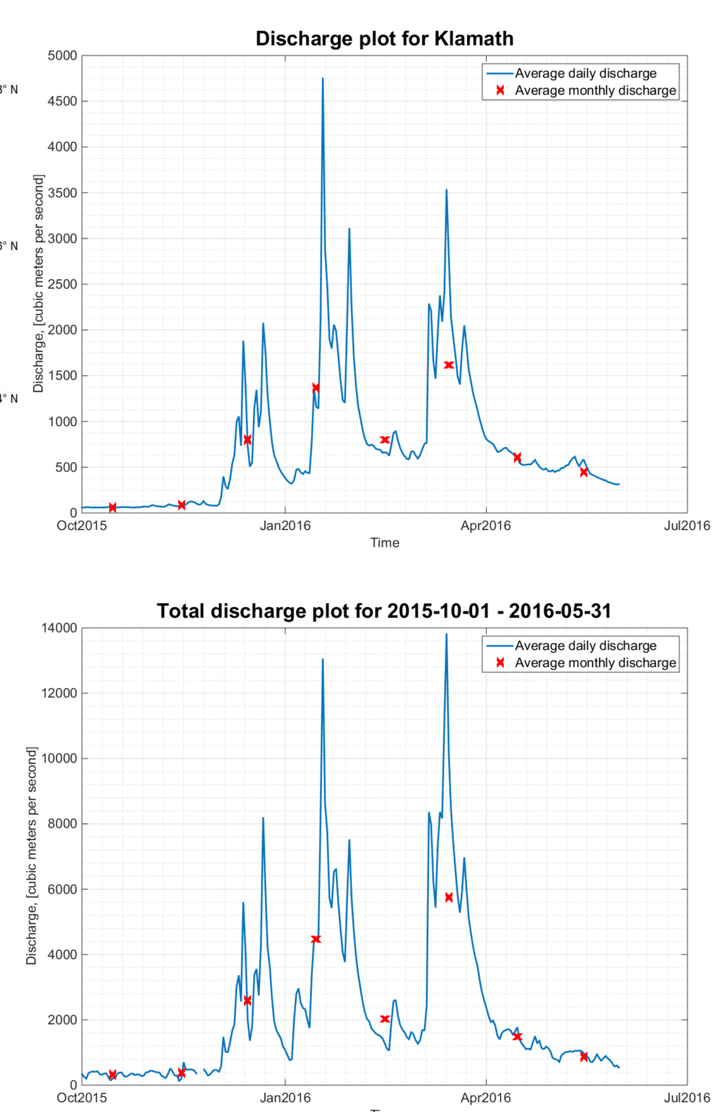
Averaged monthly values were used for discharge, temperature and salinity for eight months (October 2015 – May 2016). Table 1 lists the major California Rivers included in the new river input file.

Discharge Data

Presented as daily and monthly averaged values
October 2015 – May 2016



← Fig. 2. Map of monthly average discharge for California for February, 2016. Circle size is proportional to magnitude of mean river discharge.



→ Fig. 3. Discharge plot for Klamath River and total discharge across the 24 rivers used in this study. Three major discharge events are observed during December 2015, January 2016, and March 2016.

River Impact on Model

Sea Surface Salinity

04 UTC, 16 February 2016

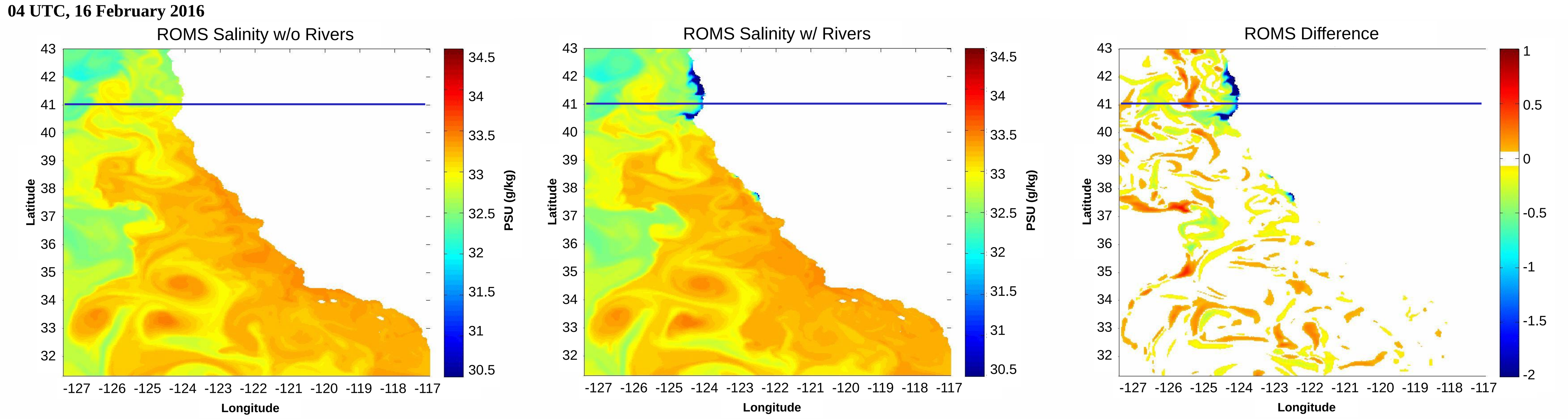


Fig. 4. Salinity measured at the surface for our domain region. LEFT: Model without river input file. MID: Model including rivers. RIGHT: Difference plot between both models.

Comparisons were made between the model run with and without the inclusion of river discharge data. The map view (Fig. 4) and cross-sectional view (Fig. 5) are shown for a time step in February 2016, during which a major discharge event occurred. Effects due to freshwater from rivers are observed close to the northern California shore (Fig. 4) and at depths shallower than 50 meters (Fig. 5).

SeaGlider™ Comparison

Comparison to OSU Dataset

04 UTC, 16 February 2016

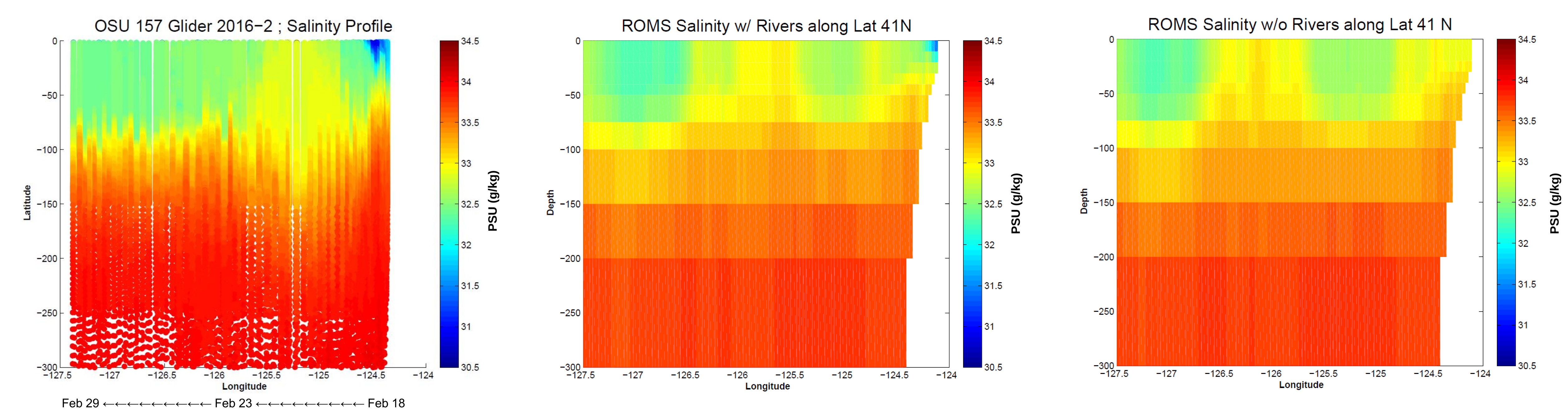


Fig. 5. Salinity measured with depth along 41°N for February 2016. LEFT: Dataset collected by OSU SG 157 between February 18 – 29, 2016. MID: Model including rivers. RIGHT: Model without river input file.

To test the robustness of the river model, we plotted data collected by Oregon State University's Seaglider™, SG157, which traveled approximately along 41°N from September 2015 to May 2016. We made comparisons for the full time period, and have plotted a time period in which the SG157 provided data within our domain range, February 2016 (Fig. 5).

For the month of February 2016, the impact of river discharge is most clearly observed at shallow near-shore environments, which more closely matches that seen in the SG157 salinity observations. A less obvious feature is a localized region of fresher water at the surface; the river model indicates a slight eastward shift of this region, which more closely matches that as shown from SG157.

Additional comparisons were made to Soil Moisture and Ocean Salinity (SMOS) mission datasets for the February 2016 time period. However, the presence of large nearshore errors and coarseness of spatial resolution prevented any clear conclusions to be drawn.

Conclusions & Future Work

- Successful for select time period, October 2015 – May 2016
  - Output from the model including rivers more closely matches the OSU SG157 salinity observations than the control without rivers for two time periods.
  - Including river discharge produced localized, shallow effects close to shore, which is beneficial to understanding near-shore ocean circulation.
- Future comparisons can be done to UC San Diego Seaglider™ data at other latitudes.
- After confirming the robustness of the new model, discharge data can be incorporated into the real-time nowcasts and forecasts that Remote Sensing Solutions, Inc. currently disseminates to the public.

References and Acknowledgements

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The authors would also like to thank Oregon State University's Glider Research Group for presenting the results of their current and archived SeaGlider™ deployments to the general public via < http://gliderfs.coas.oregonstate.edu/gliderweb/seagliders.php>.

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