Bridging satellite and in-situ scales of rain-induced near-surface salinity stratification

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Outline:

Goals: From two different perspectives (scales) of data, satellite vs. in-situ, better understand rain and rain-induced near-surface salinity stratification; report on best uses of satellite data

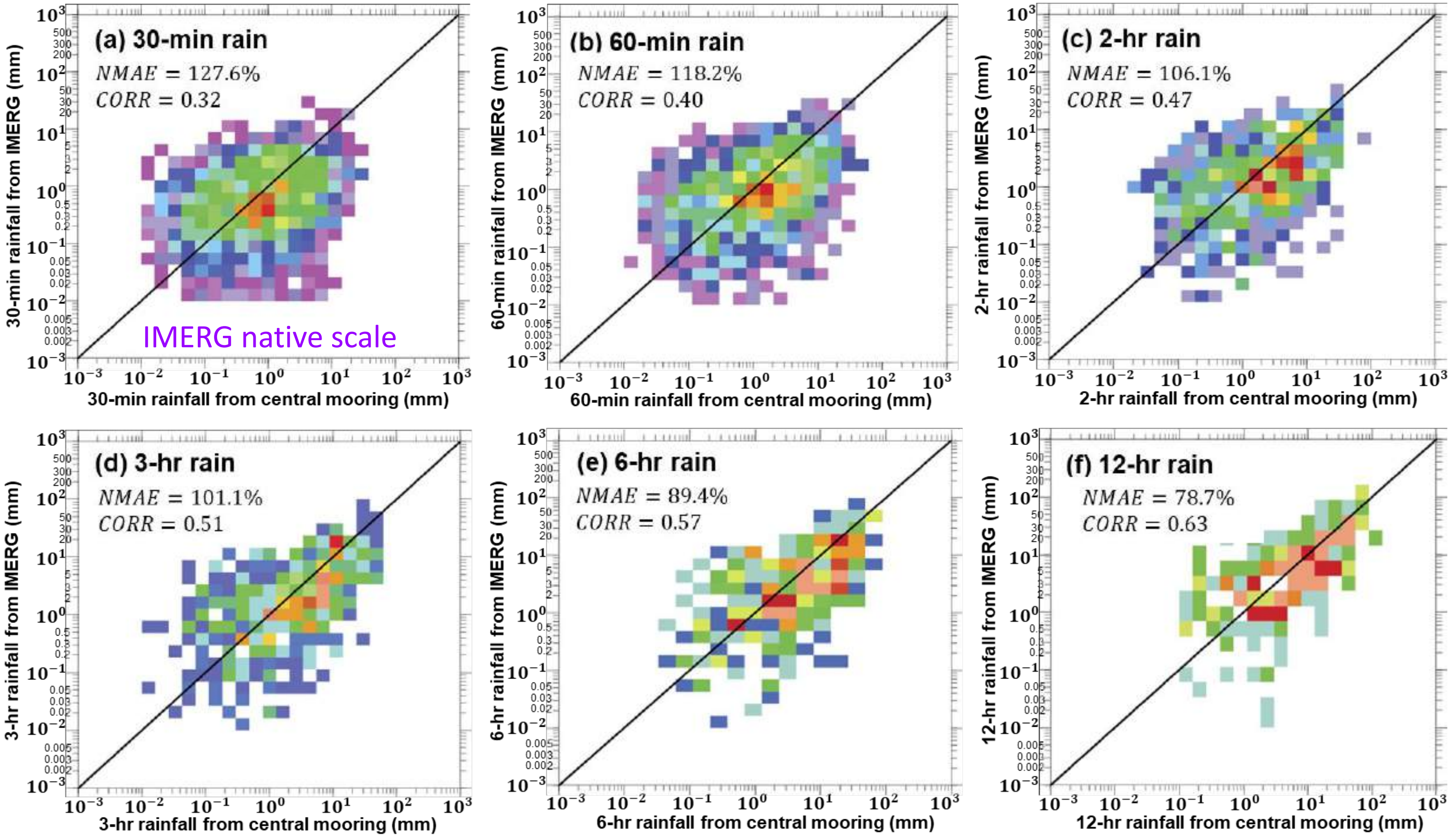
1. How well does the IMERG rain product perform as a function of rain type, size, duration, amount?
2. What are the ocean salinity impacts of rain events that are more/less well captured by IMERG?

Data and Methods:

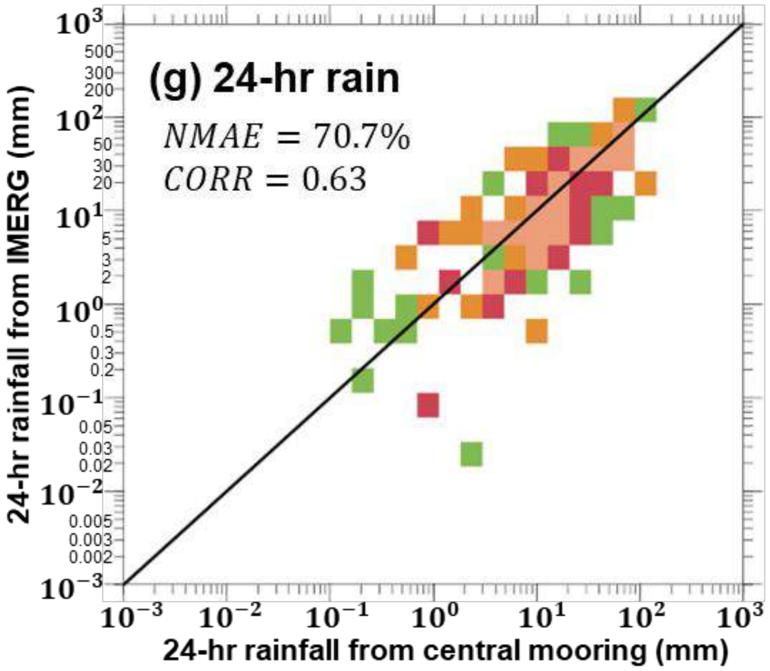
- SPURS-2 research ship and WHOI central mooring time series
  ℅ Jim Edson, Carol Anne Clayson … ℅ J. Tom Farrar
- SPURS-2 ship X-band navigation radar rain images
  Thompson et al. 2019. TOS
- IMERG rain rate v6 and SMAP SSS v4
- all data are used to compare rain and near-surface salinity stratification events

IMERG 30-min (native) rates and accumulations are biased low; agreement with in-situ is best at daily+ scales.

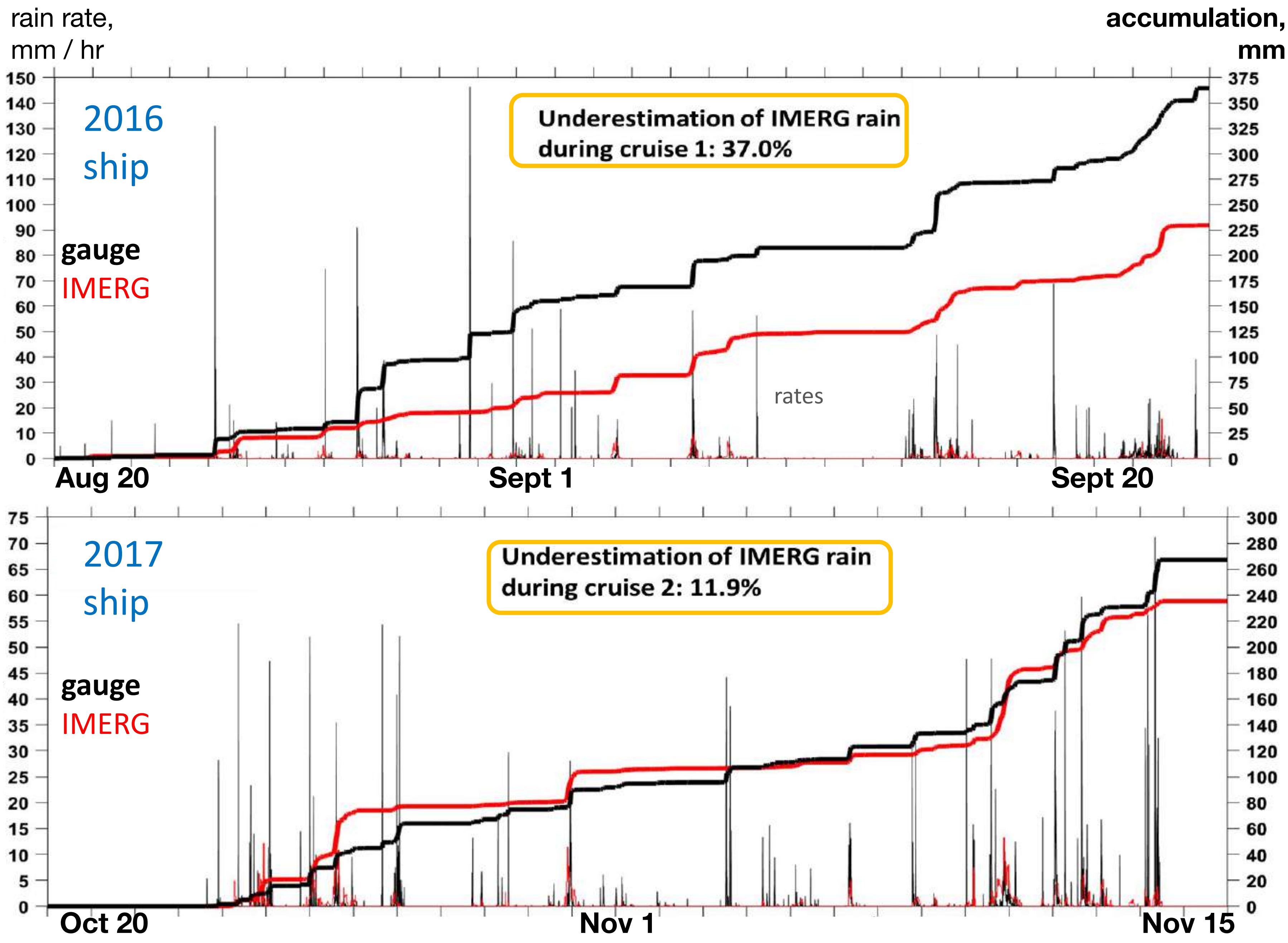
consistent results between ship optical gauge, mooring gauge, PAL, SEA-POL radar, all in-situ rain data



2D contoured normalized histograms



- Similar to prior studies (only extensively completed over land, *Tan et al. 2017, Bell et al. 2001*), satellite and in-situ rain rates agree more at longer time scales ~ 24 hr
  - error ↓, correlation ↑
- not helpful for minute-to-hour studies of salinity stratification
- downscaling IMERG hasn't been that fruitful (not shown)



Over entire months, or a year, IMERG +/- biases start to compensate and errors reduce

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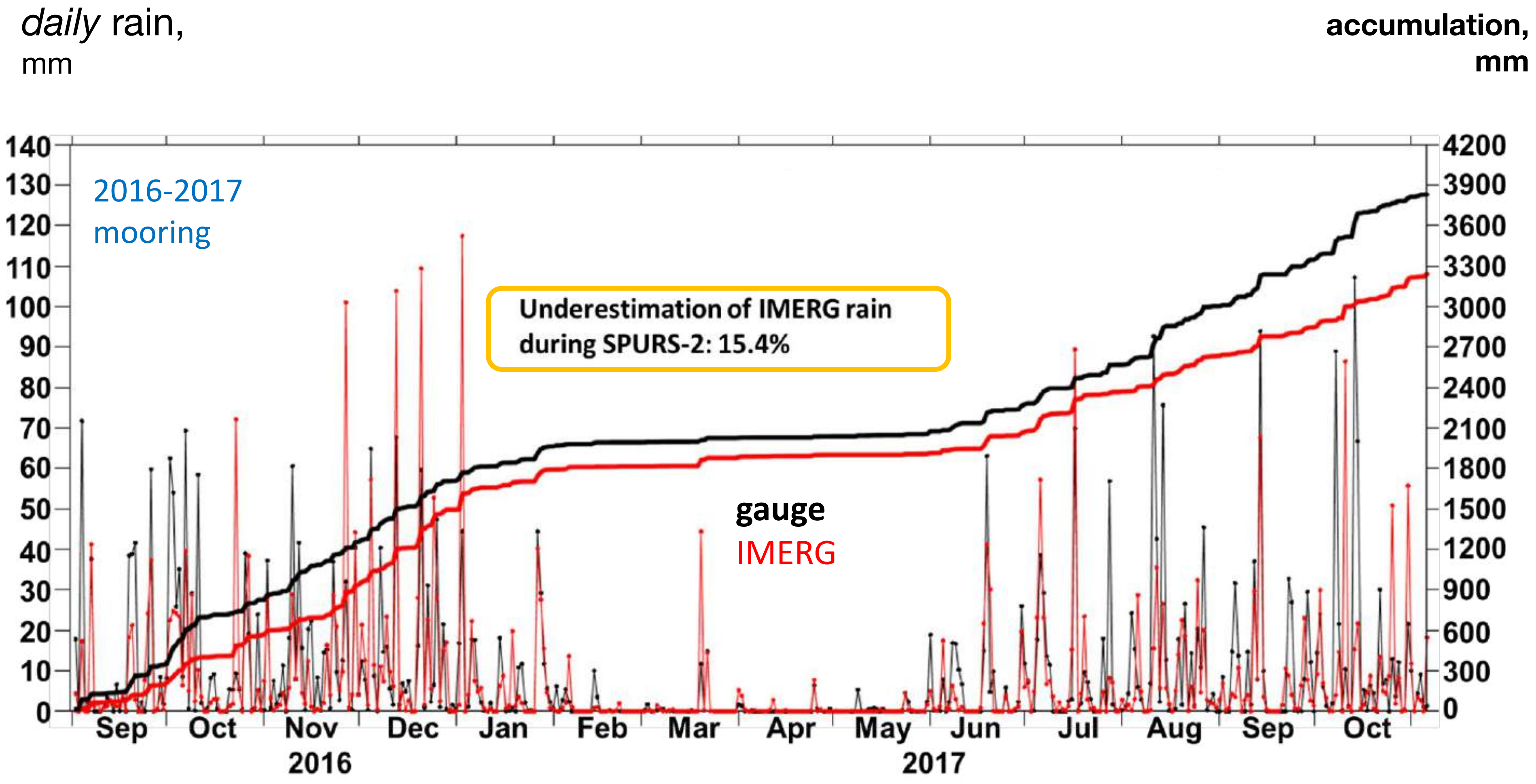
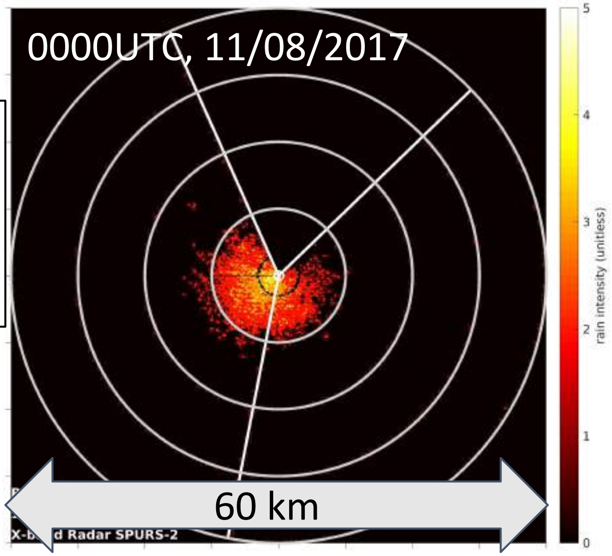
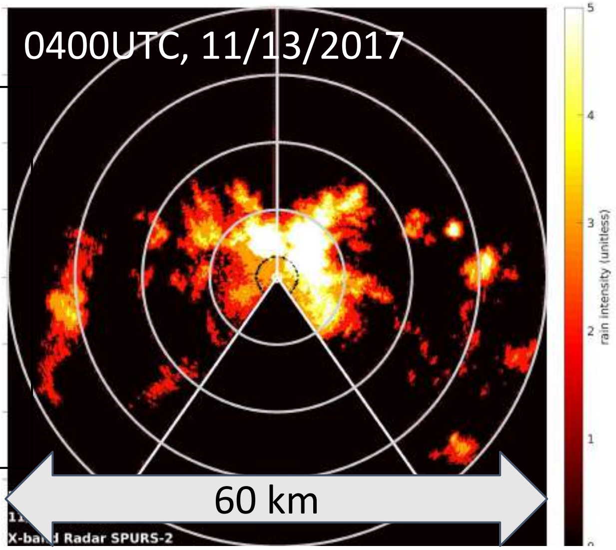


Categorized rain based on ship X-band radar spatial patterns

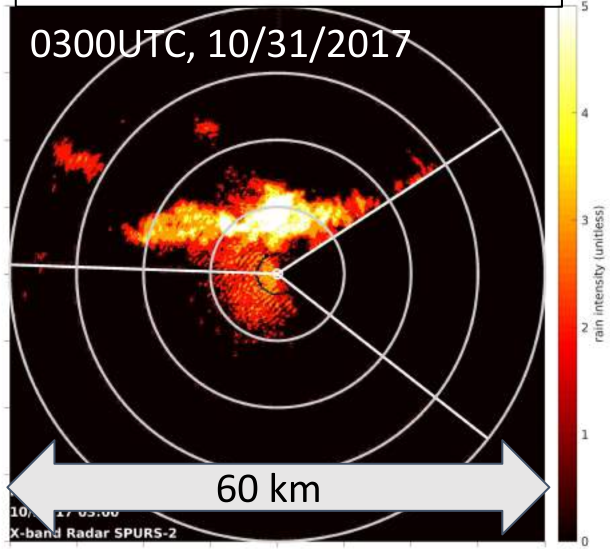
Category 1: Uniform echoes near radar or clear air



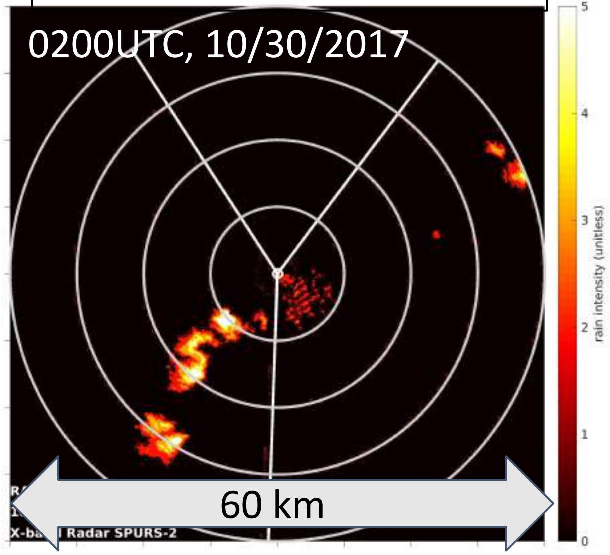
Category 2: Wide continuous echoes embedded with Isolated cells



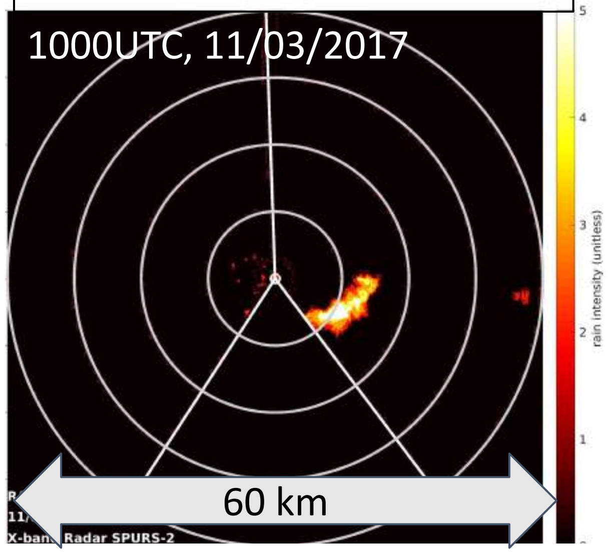
Category 3: Squall/narrow line with isolated cells



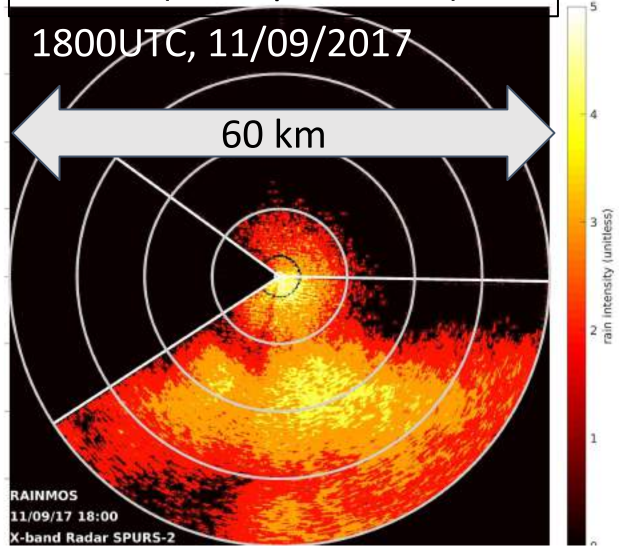
Category 4: Isolated cells



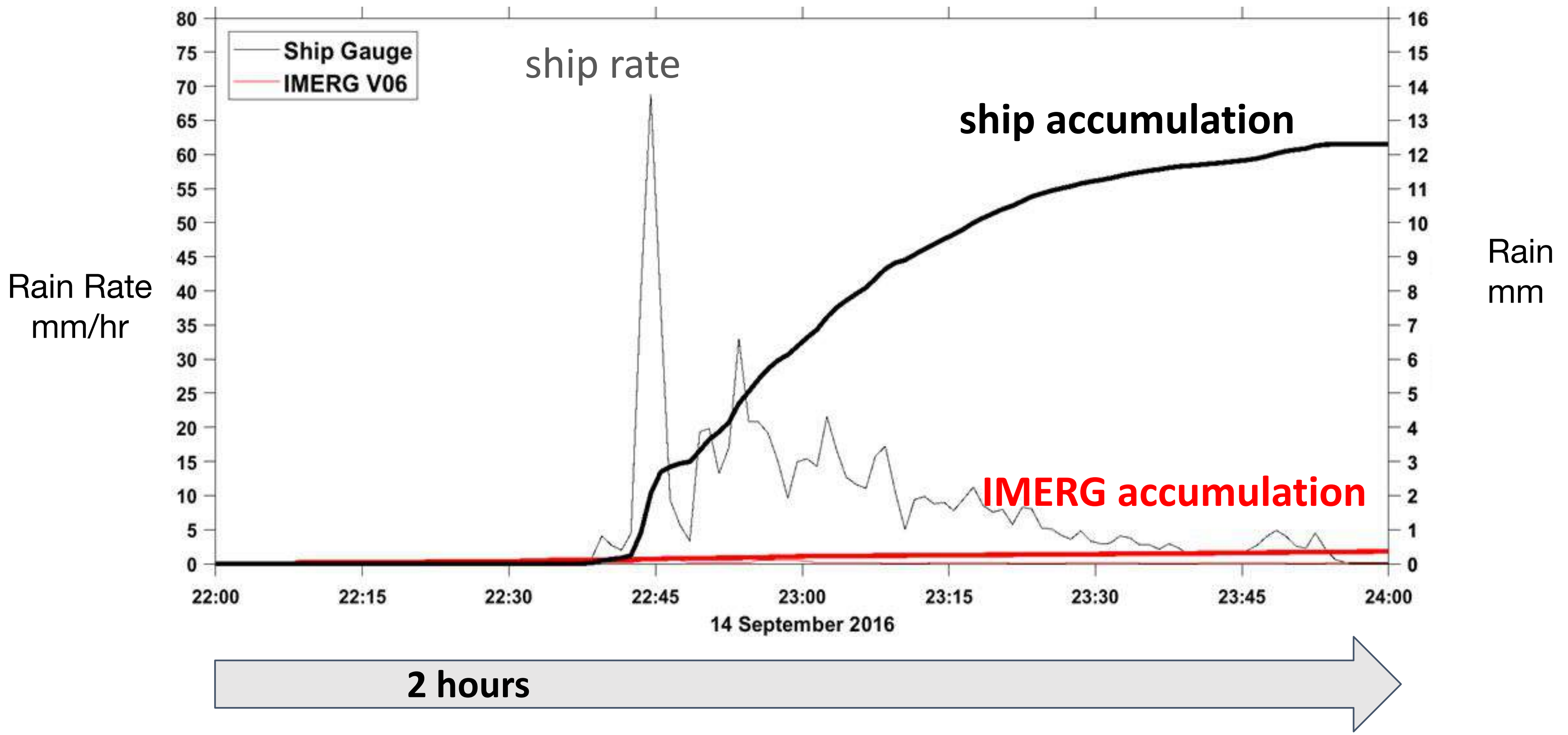
Category 5: Single/small cell



Category 6: Wide continuous echoes (widespread rain)



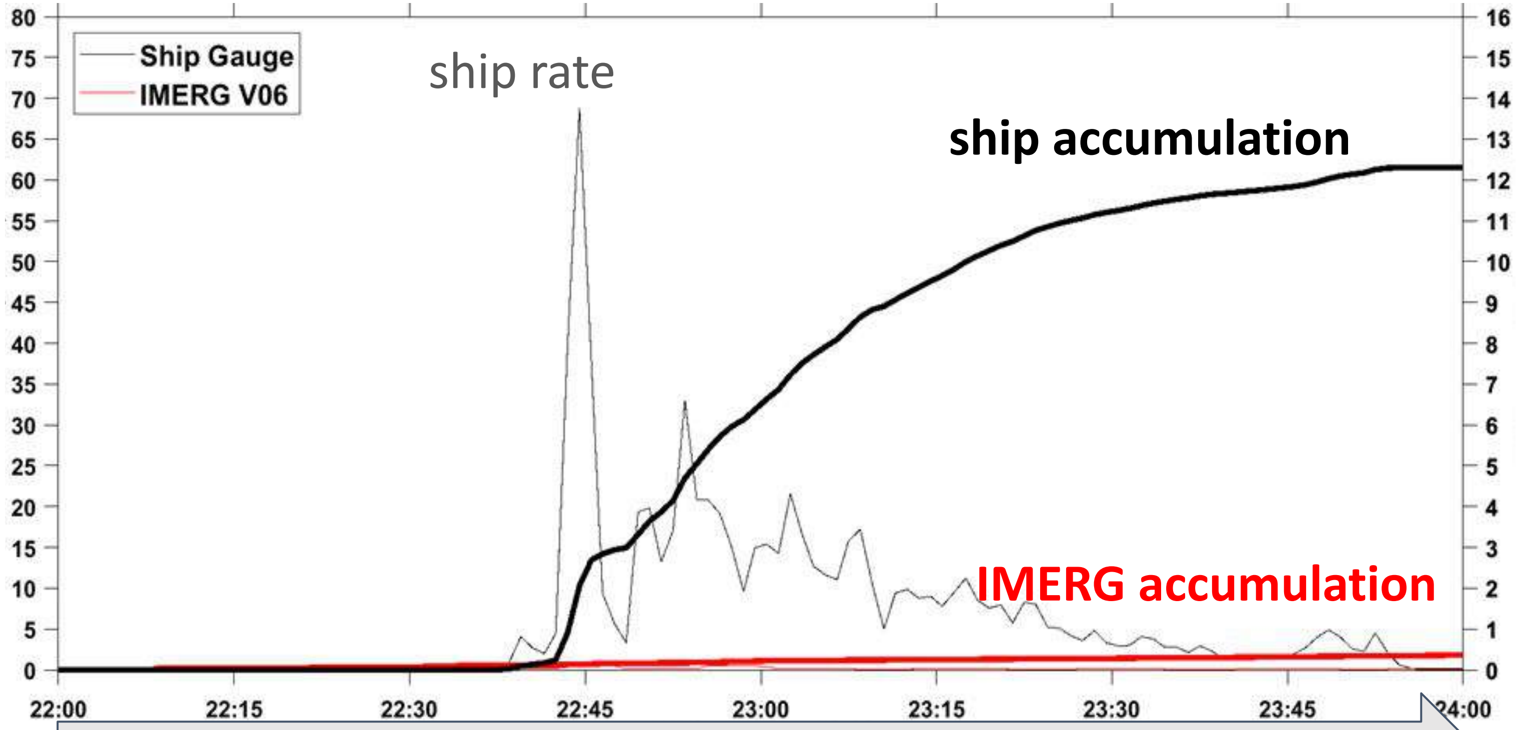
Case Study 1: Short-lived, fast-moving, small-area rain is not well captured by IMERG



No IR or PMW data were available to inform IMERG

Case Study 1: Short-lived, fast-moving, small-area rain is not well captured by IMERG

Rain Rate mm/hr



Rain mm

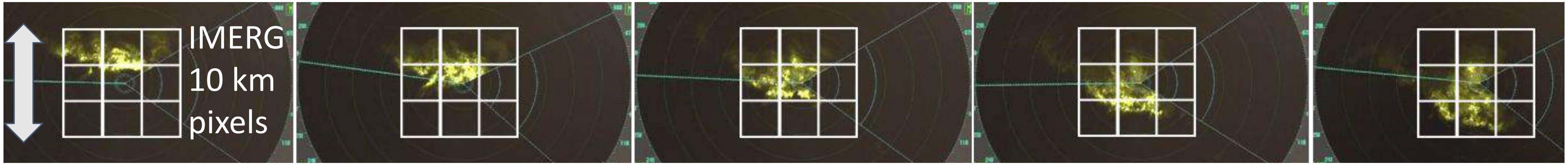
No IR or PMW data were available to inform IMERG

2 hours

Likely a non-uniform beam filling or location mismatch error

ship X-band radar reflectivity and IMERG grid boxes

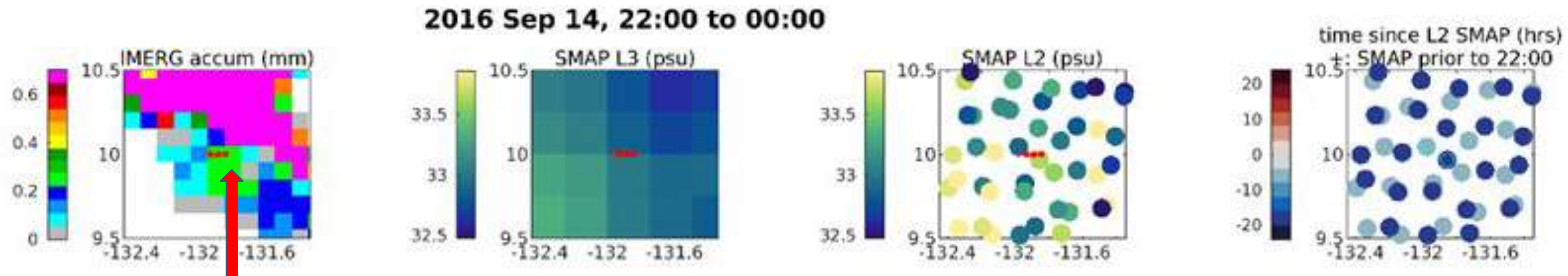
30 km



2230 2240 2250 2300 2310

30 min IMERG time step

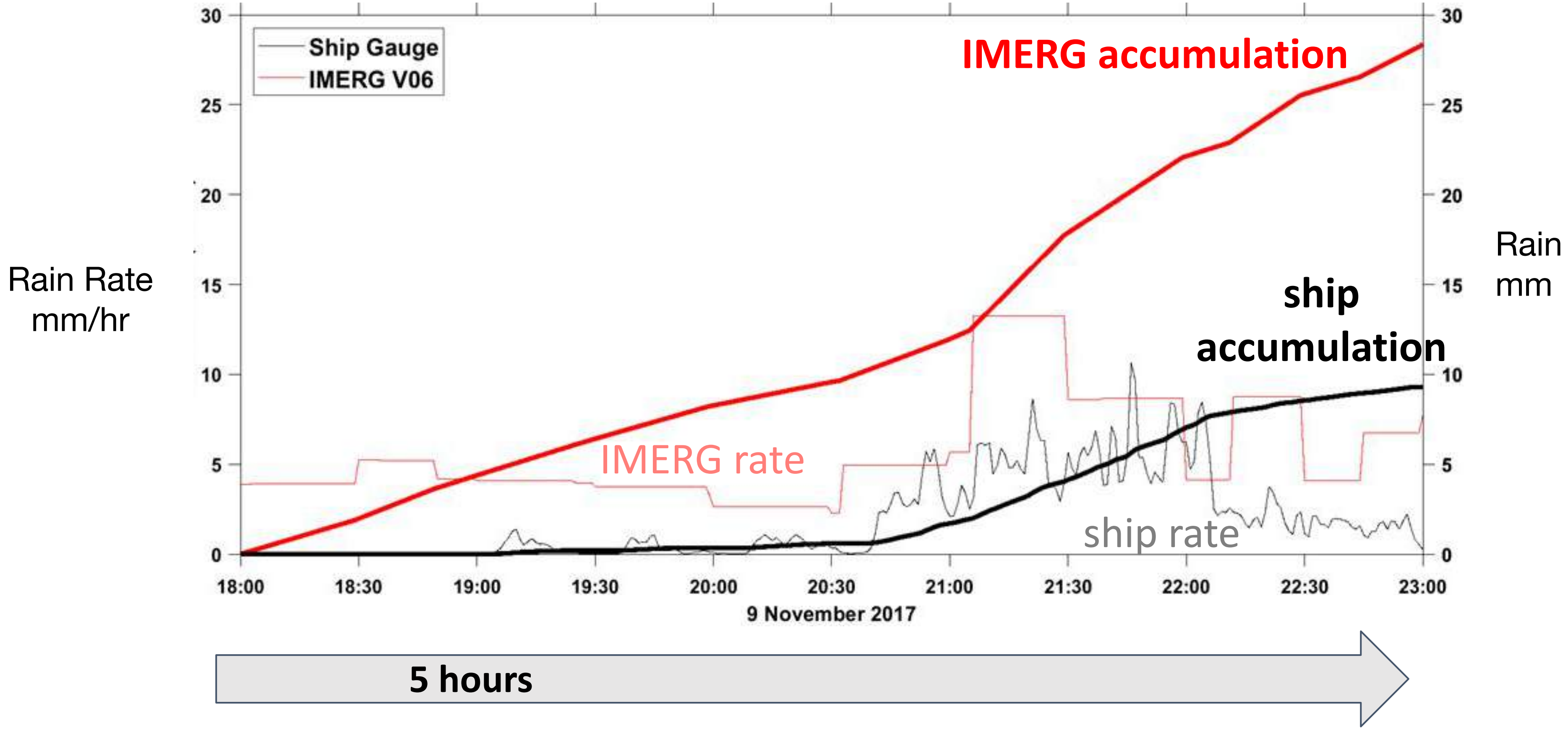
Case Study 1: Depending on timing of satellite overpasses and total rain area, satellite SSS can be a good indicator for fine-scale rain events



Ship path during case study, on each plot

2-hr rain event dimension was still large enough for satellite SSS to resolve ~ 40-70 km SMAP product

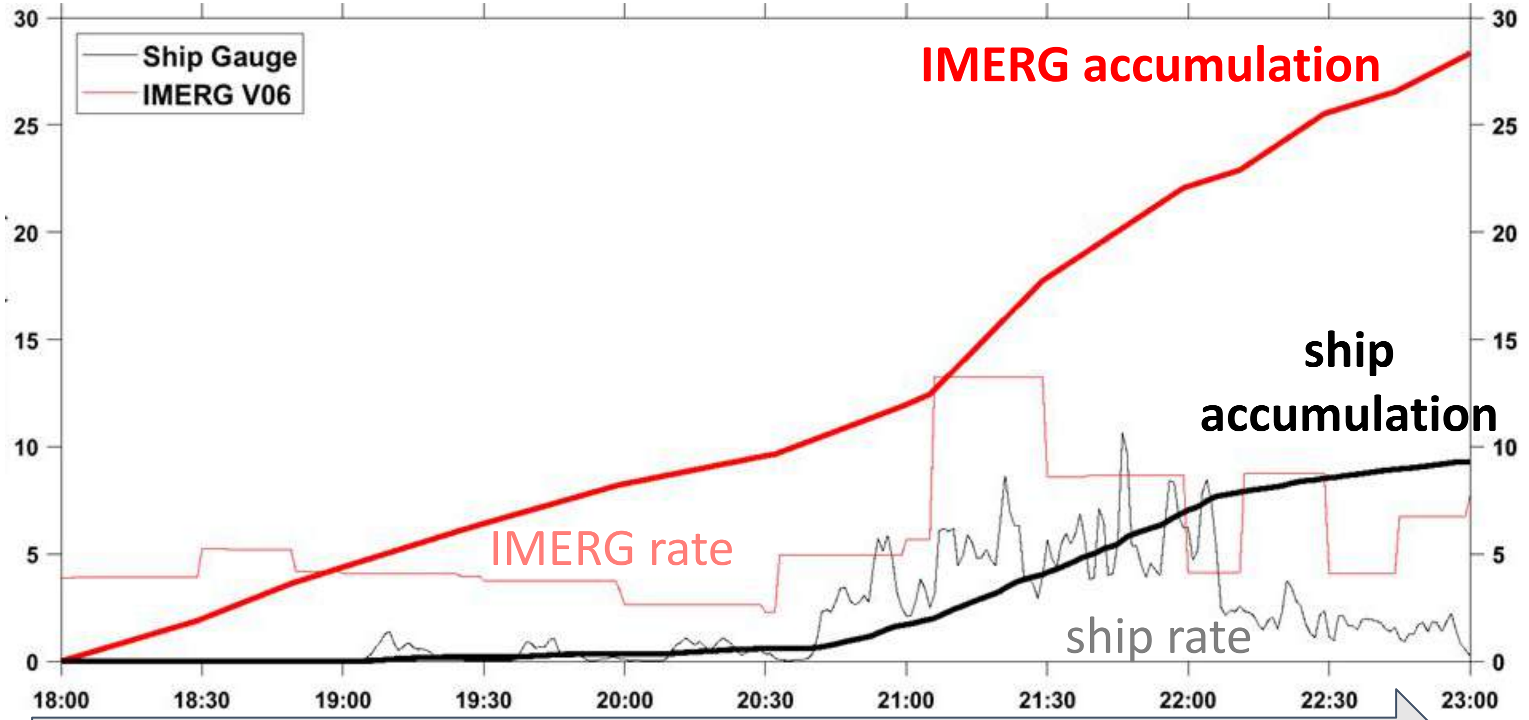
Case Study 2: Widespread, long-lived rain is relatively well captured but often overestimated by IMERG



IMERG information was all from IR during this case, not PMW *(PMW is more accurate)*

Case Study 2: Widespread, long-lived rain is relatively well captured but often overestimated by IMERG

Rain Rate mm/hr



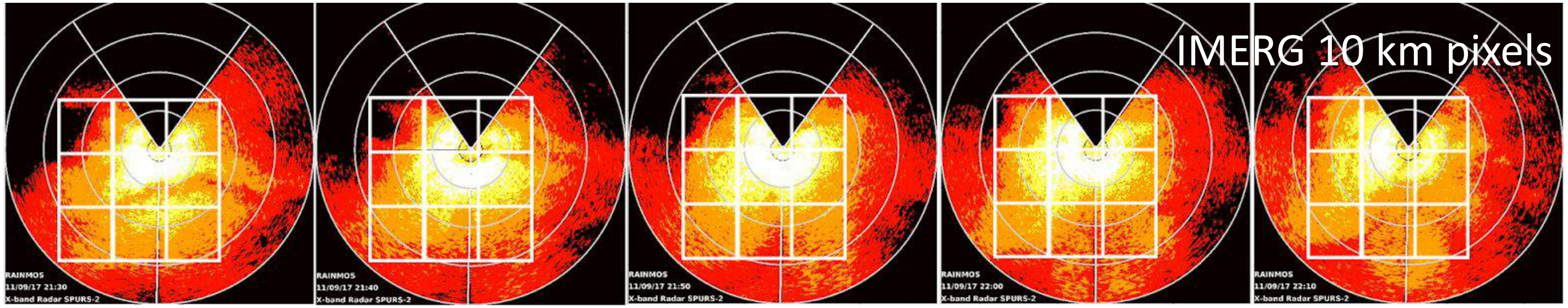
Rain mm

IMERG information was all from IR during this case, not PMW *(PMW is more accurate)*

5 hours

ship X-band radar reflectivity and IMERG grid boxes

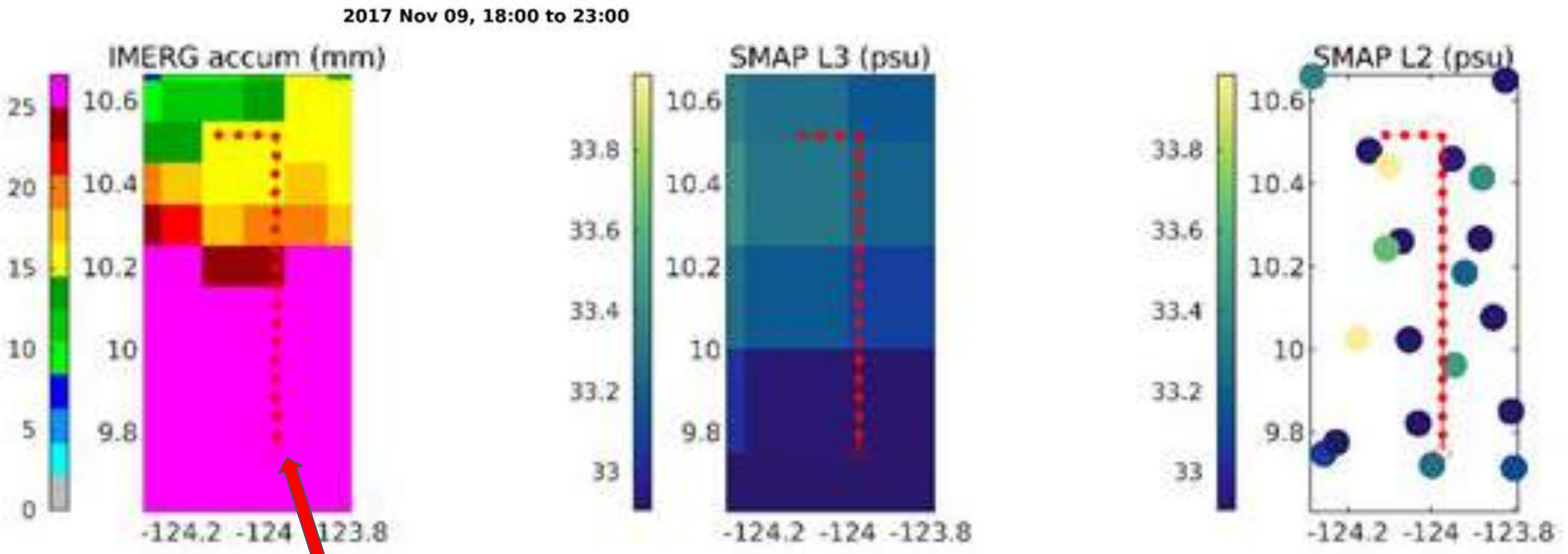
60 km



2130 2140 2150 2200 2210

Likely an algorithm accuracy error

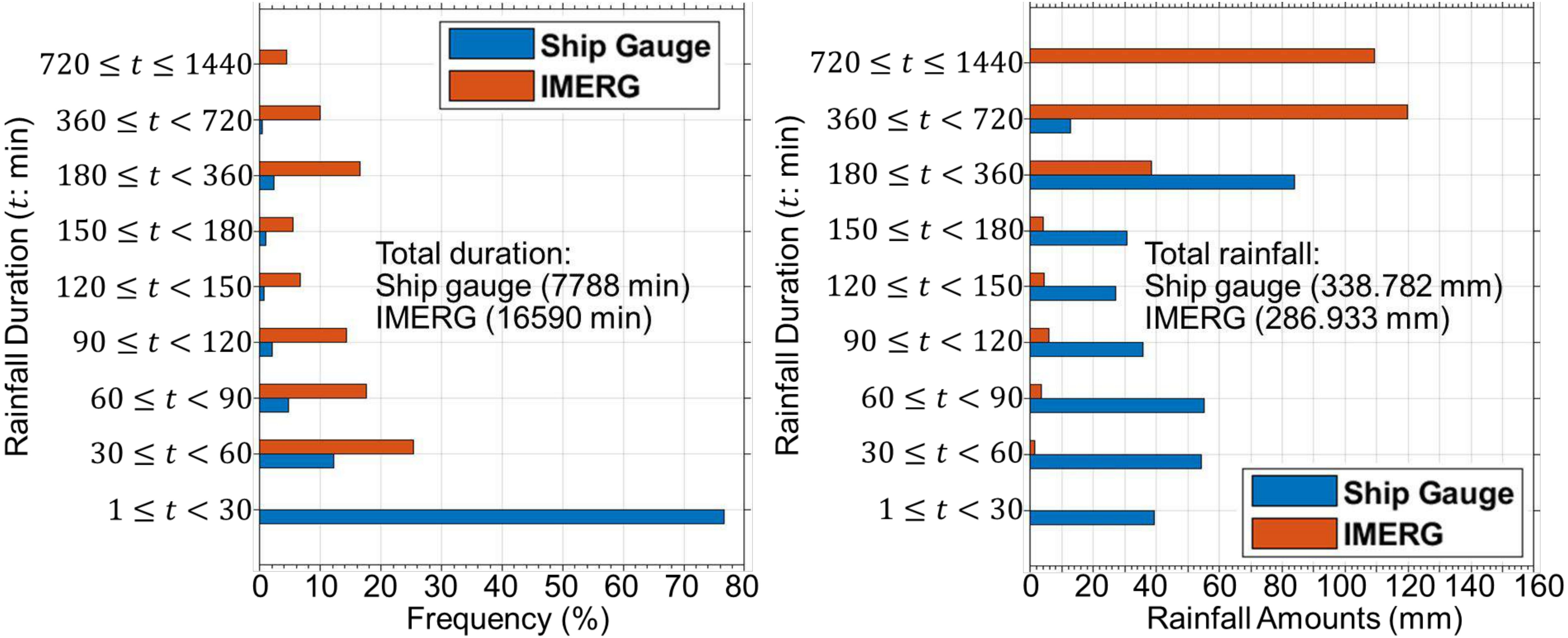
Case Study 2: Satellite SSS can capture ocean freshening by widespread, long-lived rain *(shown by many prior studies)*



Ship path during case study, on each plot

Should compare IMERG vs. SMAP accuracy
for these rain event accumulations

Compared to in-situ gauges, IMERG rain events are estimated to last longer, and rain more/less for long/short-lived events



Conclusions: SPURS-2 rain and its impacts on salinity

in-situ vs. satellite perspectives

- Compared to gauges, IMERG suggests that rain events are longer-lived and more/less rainy for long/short-lived events
- IMERG vastly underestimates instantaneous rain rate, +/- compensating errors lead to better daily+ accumulations
  - not necessarily helpful for minute-to-hour studies of ocean salinity stratification; downscaling IMERG didn't help
- IMERG error model is getting trained with the SPURS-2 in-situ rain rate database (not shown)

- **Short-lived, fast-moving, small-area rain events over the ocean are not well captured by IMERG**
  - < 30 km, < 30-60 min, non-uniform beam-filling or location errors
- **Depending on timing of satellite overpasses and rain area, satellite SSS can be a good indicator for fine-scale rain**
- **Widespread, long-lived rain over the ocean is relatively well captured but often overestimated by IMERG**
  - algorithm accuracy error, potentially more so for IR input data than PMW
- **Satellite SSS can capture ocean freshening by widespread, long-lived rain;**
  - Next: compare IMERG vs. SMAP accumulation accuracy for these events if overpass availability allows

- Next: for rain events not well captured by IMERG, how likely were they to stabilize the ocean?

From these analyses, we set quantifiable expectations for how best to use satellite precipitation and salinity products for studying rain's impact on the ocean.

Were conditions favorable for near-surface salinity stratification during/after rain events not well captured by IMERG?

- rain + wind + heat flux conditions were conducive for near-surface stable fresh layers to form during 28% of the central mooring record

friction velocity in water

stable layer depth $$\hat{h}_S = \frac{u_{*W}^3}{\kappa B}$$

buoyancy flux

wind limit for stable layers $$\hat{U}_S = \left(\frac{\hat{h}_S B}{C}\right)^{1/3}$$

where… $$C = \frac{1}{\kappa}\left(\frac{C_D \rho_{air}}{\rho_W}\right)^{3/2}$$

Thompson et al. 2019 JGR Oceans

- Near-surface salinity stratification by rain is expected when $U_{10} < U_S$

- Last step: test this condition for each rain event
  - *There should many salinity stratification opportunities because rainier events were not windier; rain and wind speed were not correlated*