Spatial and temporal patterns of rainfall, discharge, waves, and inundation in the Mekong Delta

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or...

WHEN IT RAINS,

LAND GETS WET

or...

WHEN RIVERS CREST,

LAND GETS WET

or... (final one!)

WHEN THE OCEAN SURGES,

LAND GETS WET

Drivers of delta surface inundation

- Rain in upstream basin → river network → fluvial flooding
- Local precipitation
- Offshore storms → storm surge → coastal inundation
- Irrigation
- Groundwater extraction
- Water management – dams, other engineering...

Drivers of delta surface inundation

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Importance of surface inundation data

- Surface water → related to flood risk
  - Soil moisture → ability of water to infiltrate rather than running off
- Surface water also an indicator of flooding itself, though not always
- Indicator of agricultural activity
- Indicative of wetland ecosystem processes, health
- Surface water dynamics also important for tracking long-term change in ecosystems, risk

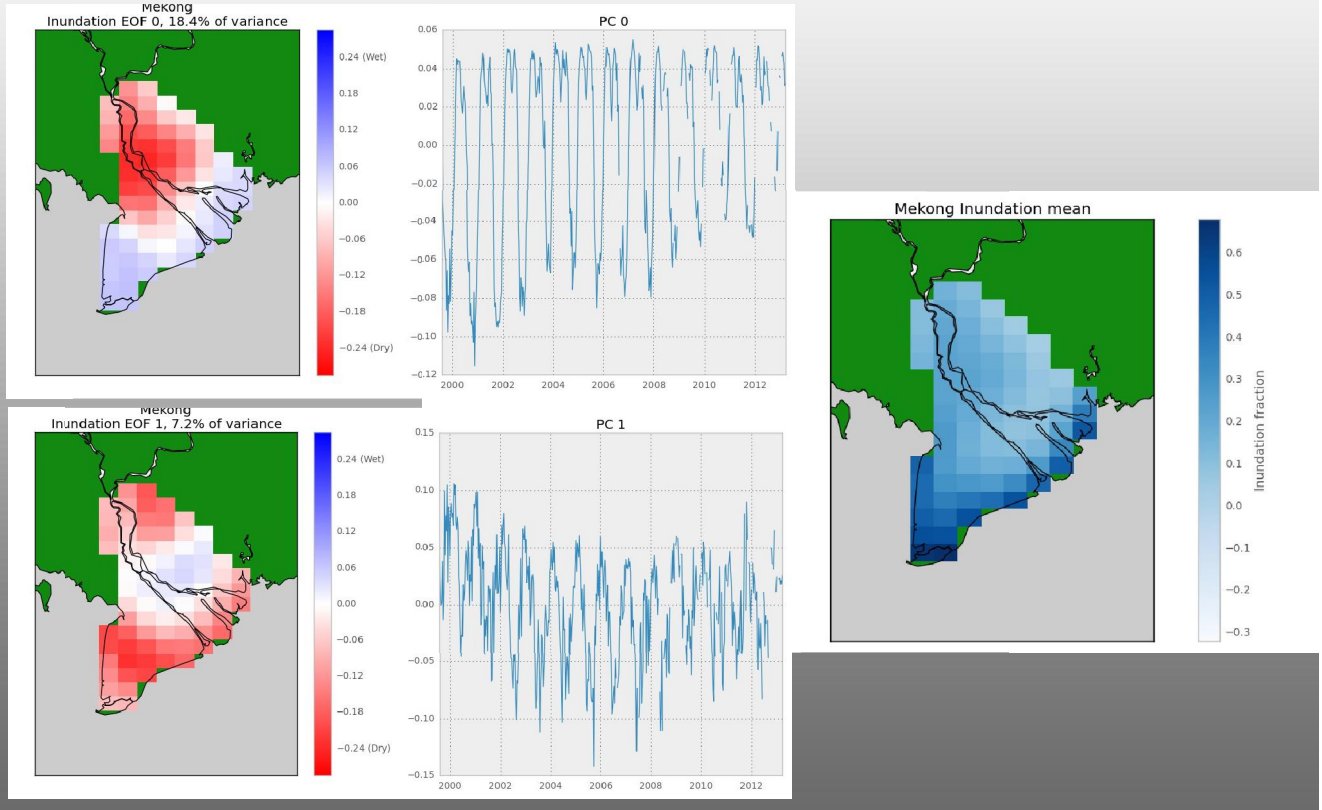
Questions

- How do precipitation, river discharge, and waves correlate with inundation over the delta?
  - What is the optimal temporal smoothing of higher sampling frequency data to match 10-day inundation data?
- Spatial patterns
  - How do these correlations and timescales vary spatially over the delta?
  - Is distance to coastline or major river branches important?
  - [How does this vary by delta?]

SSWAMPS Surface Inundation

- **S**atellite **S**urface **Wa**ter **M**icrowave **P**roduct **S**eries
- Developed at CUNY Environmental CrossRoads Initiative/City College of New York by Kyle McDonald and Ronny Schroeder
- V1: mid 1999 - mid 2009, SSM/I and QuickSCAT
- V2: late 2008 – end of 2012, SSMIS and ASCAT
- Coarse resolution: ~25km pixels (EASE Grid)
- Surface microwave signal is “shadowed” during active rainfall events, but clouds are no problem
- Daily, but very noisy due to variability in radar illumination footprint
  - Using 10-day averages

SSWAMPS Surface Inundation

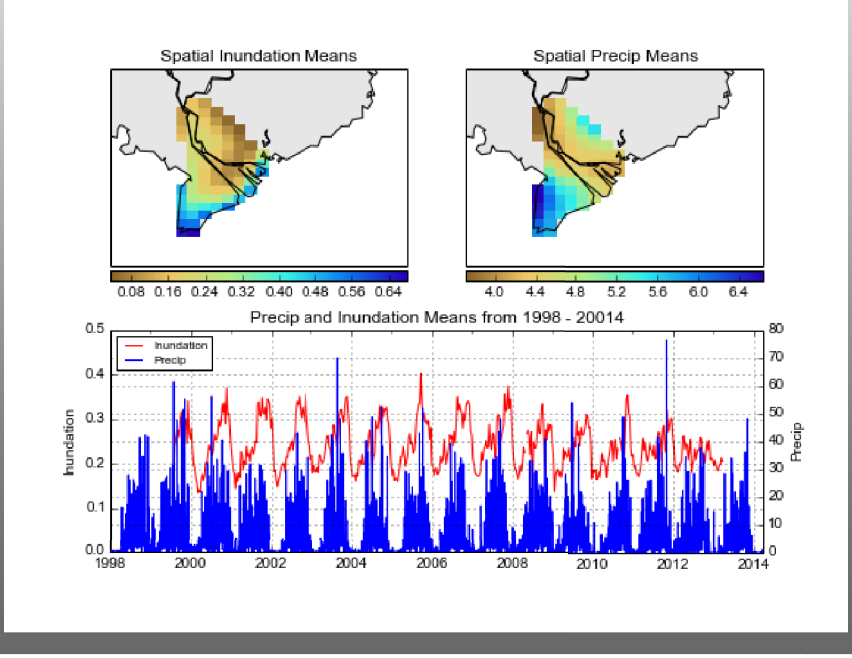


“Driver” datasets

- Precipitation
  - TRMM 3B42 satellite observations
    - 0.25 deg
    - 3hr, averaged to daily
- River discharge
  - Modeled, WBMplus, daily, 6 minute spatial resolution
  - Forced by precipitation, not fully independent
  - Correlation of ~.5 with precipitation data
  - Delta river network not modeled, using watershed input at delta apex
- Waves
  - WAVEWATCH III model, 0.75 degree spatial resolution, CSIRO hindcast
  - 3hr, averaged to daily
  - Coastline not well resolved, single spatial mean value per day

Spatial harmonization

- Precipitation regridded by averaging rainfall over each EASE grid cell

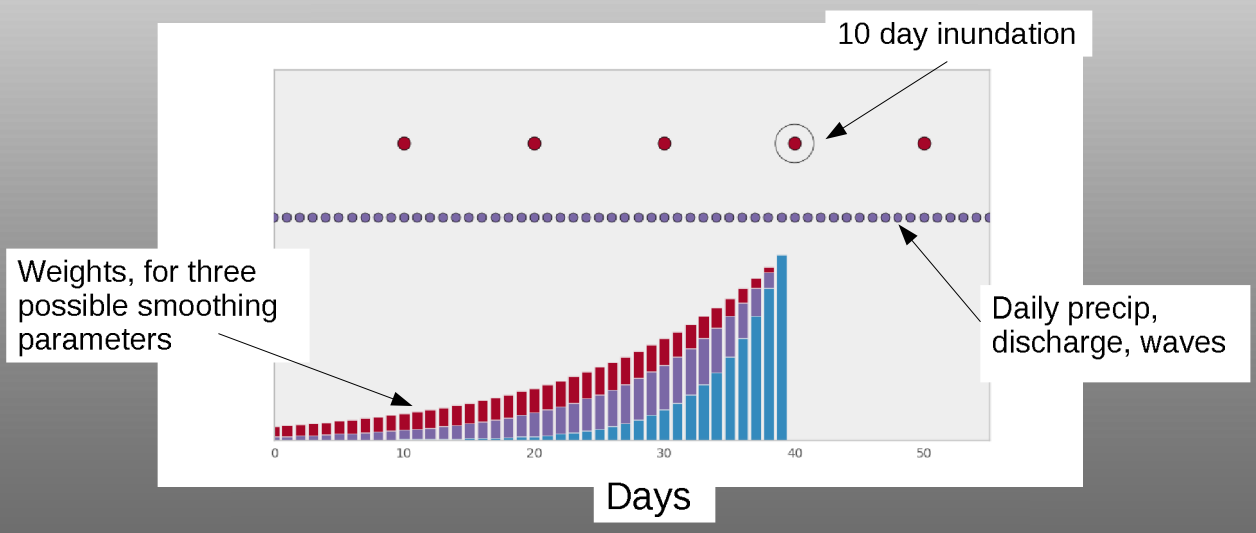


Temporal Harmonization

- What is the “period of influence” of rainfall (discharge, waves) on surface inundation?
- Apply smoothing kernel to precipitation (discharge, waves) time series, calculate correlation with inundation
- Search for optimal smoothing kernel parameters
- Two kernels tested – Gaussian and Exponential Weighted Moving Average (EWMA)
- Roughly similar results, EWMA shown here, only one parameter, simpler interpretation

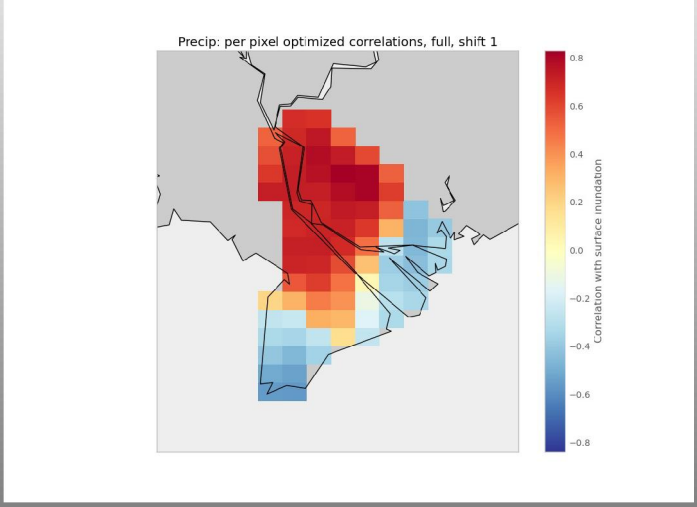
EWMA Smoothing

- 10 day inundation
- Daily precip/discharge/waves



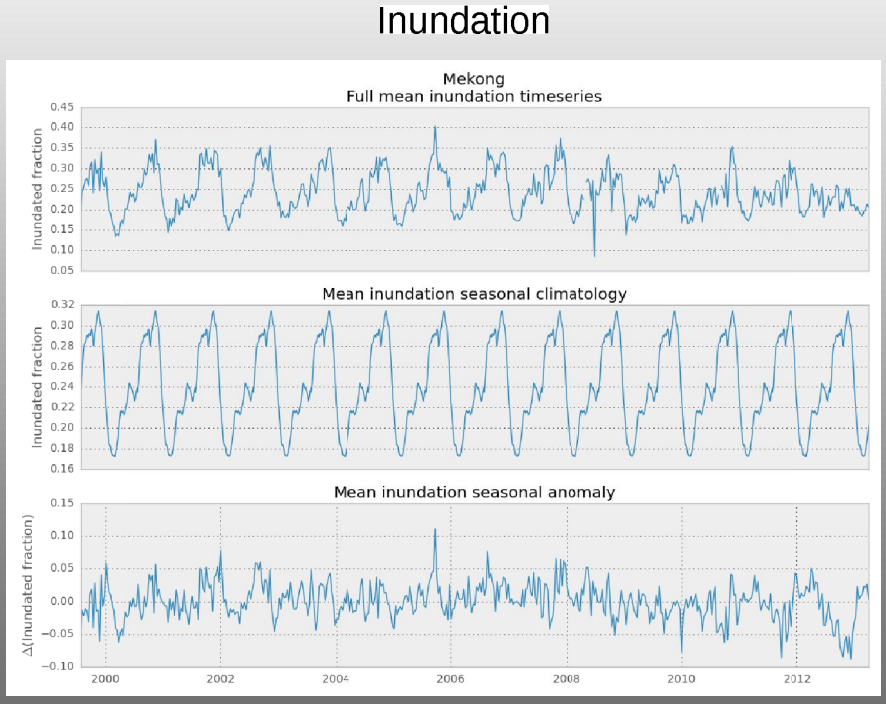
Optimized correlations - Precip

- Optimal smoothing calculated for each pixel
- Timescale for EWMA span is on the order of 100 days
- Picking up the seasonal cycle? Can we do better than discovering its wet during the Monsoon season?

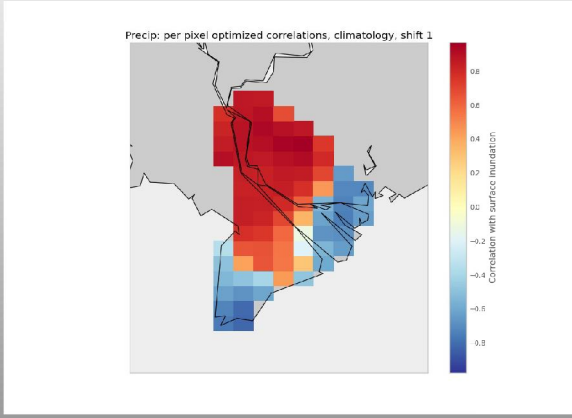


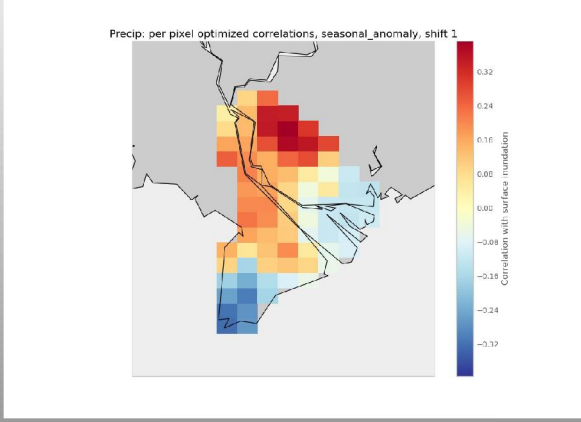
Seasonal influence - Mekong

- Decompose timeseries into climatological and anomalous components
- How much of these relationships is just seasonality?



Seasonality – Mekong, Precip

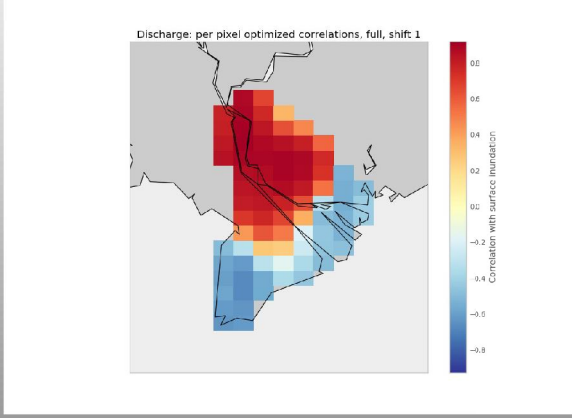


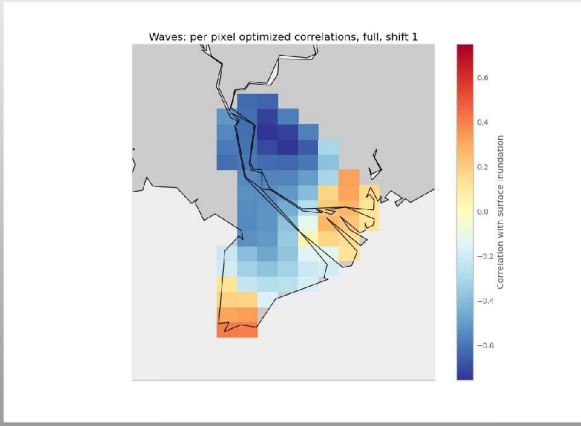


- Climatology – very similar to full timeseries, dominant signal
- Upland delta inundation most sensitive to precip

- Seasonal anomaly
- Weaker correlations overall, but northwest delta correlates better than other locations

Discharge, Wave correlations

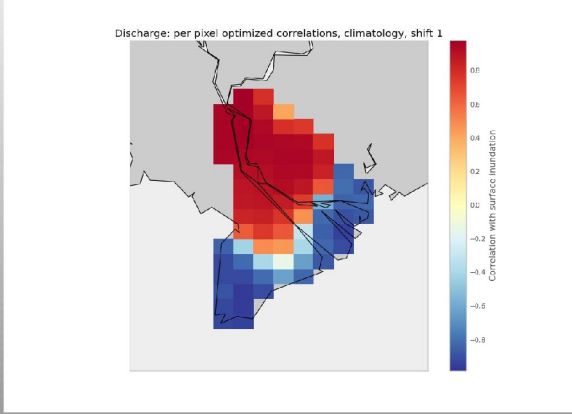


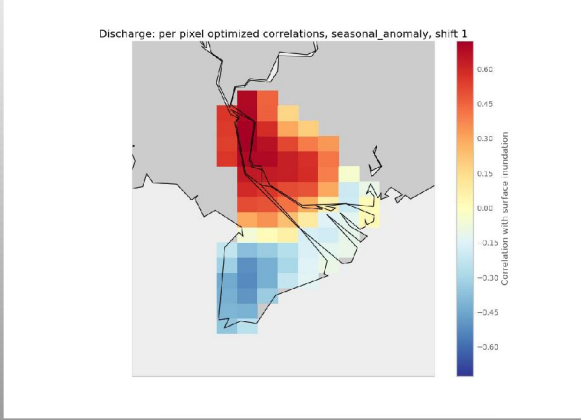


- Discharge well correlated in upper Mekong, ~.8, similar to precip

- Waves weakly correlated on coast, negative upland, most likely due to anti-correlated seasonality components

Seasonality – Mekong, Discharge

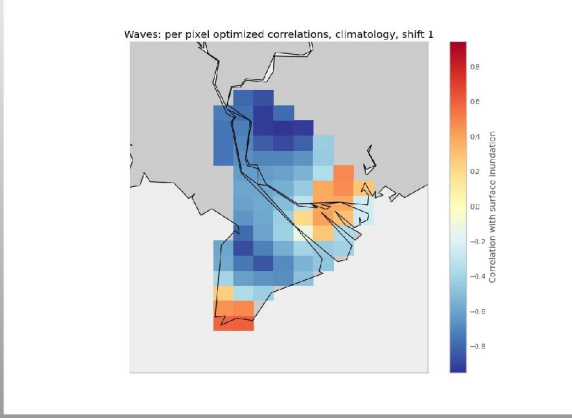


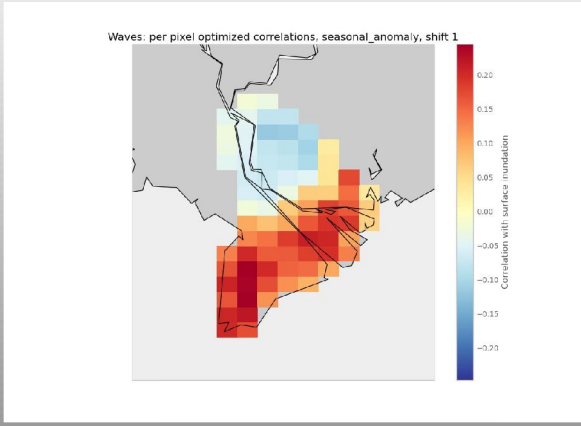


- Climatology – very similar to full timeseries, dominant signal
- Upland delta inundation most sensitive to discharge, correlations ~.8

- Seasonal anomaly
- Weaker correlations in upper delta, ~.6, but similar pattern

Seasonality – Mekong, Waves





- Climatology – very similar to full timeseries, dominant signal
- Very localized regions of positive correlation, ~.5

- Seasonal anomaly
- Weaker correlations along coast, ~.3, but clear spatial pattern

Simple linear model

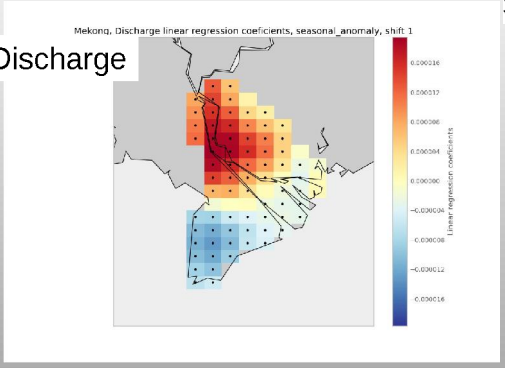
$$I_i = \beta_{1_i} P_i + \beta_{2_i} D_i + \beta_{3_i} W_i + \epsilon_i$$

- Fit data for each pixel to separate model
- Can't really compare the coefficient terms B1 to B2 to B3 meaningfully - “apples to oranges”
- Rather, compare all B1_i's to each other, “apples to apples”

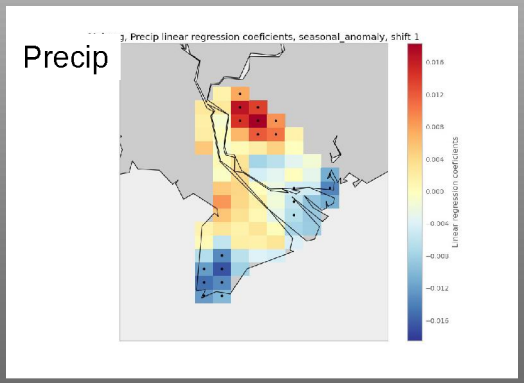
Linear coefficient spatial distributions

seasonal anomaly data

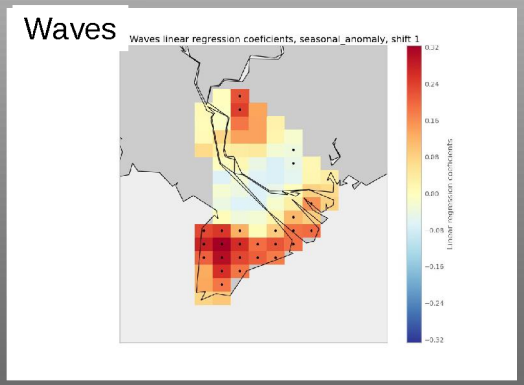
Discharge



Precip



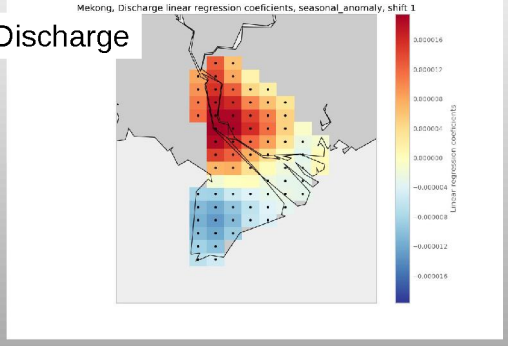
Waves



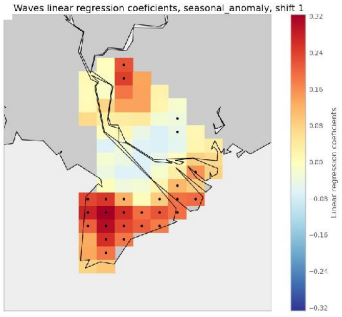
Linear coefficient spatial distributions

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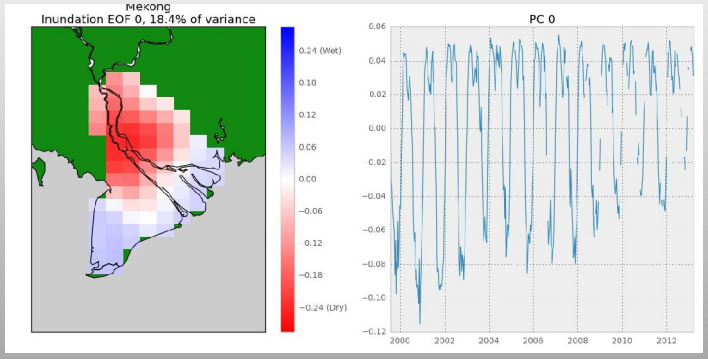
Discharge

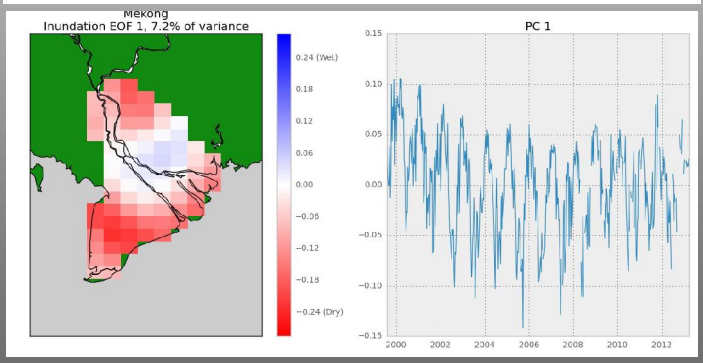


Waves

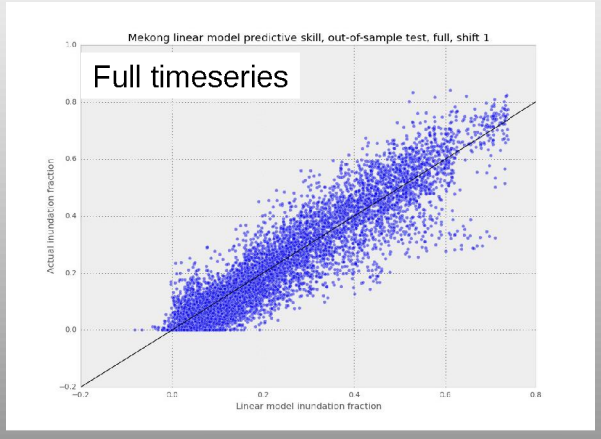


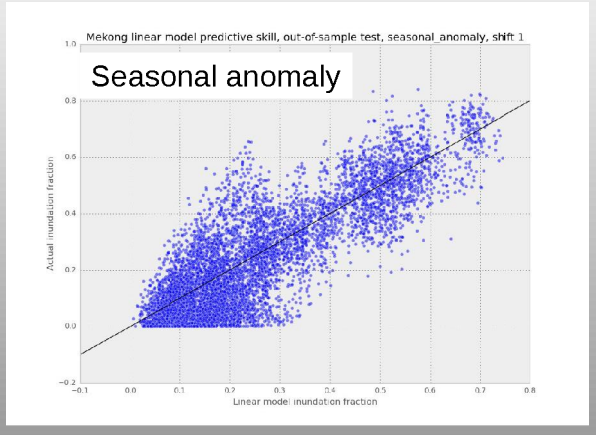
First two EOF/Principal Components





Linear model skill



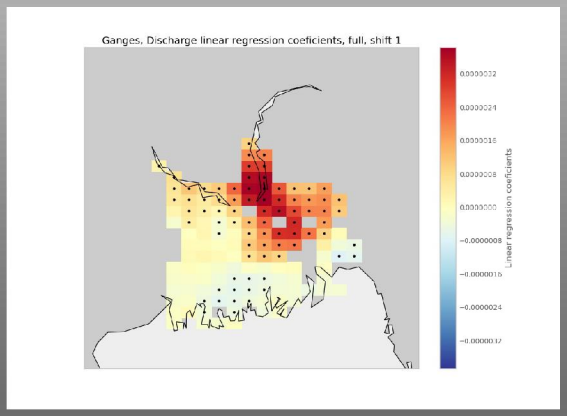


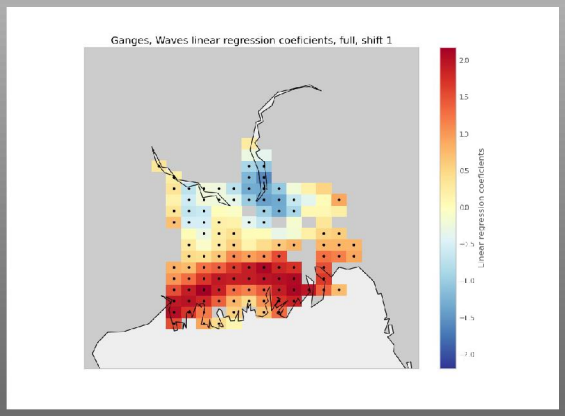
- Model fit to 80% of dataset, tested on 20%
- Test set , two contiguous time slices to avoid smoothing bias

- Seasonal anomaly is noisier
- High inundation skill is better

Comparative delta work

- All datasets here are global
- Analysis can be applied to other deltas
  - 25km pixel size means only large deltas
  - Ganges Discharge and Waves, full timeseries, linear coefficients:

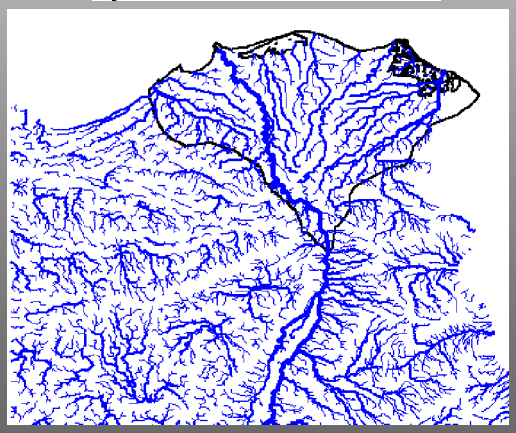




Modeling efforts

- Most numerical model river networks are derived from topographic flow directions grids
- Deltas are too flat for this method, and bifurcations are difficult
- IF this can be addressed, we can distribute discharge realistically through delta
- SSWAMPS as validation data

HydroSHEDS – Nile Delta



Summary

- Local precipitation and river discharge best correlate with Mekong surface inundation in the upstream delta, both on seasonal and shorter timescales
- Waves/storms important on short timescales, within ~50km of coastline
- Discharge and waves match well with first two EOFs, dominant sources of inundation variability
- Simple linear model appears to have some skill, on short timescales performs better at high-inundation levels
- Provides good observational basis for modeling efforts to separate out processes

A shameless plug!

- Deltas-in-Practice Workshop Friday 9am
  - Science-to-Action: Aligning science with stakeholder and community needs in the Mekong and other delta systems.
  - (Not “just” Mekong - all welcome!)

