# Seasonal forecasting with neural networks

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# Stacked LSTM for long-term predictions

## Inputs

Seasonal meteorological forecast up to 6 months:
- Precipitation
- Temperature
- Heat net flux
- Short-wave rad. flux
- Humidity
- Pressure

Land Surface:
- NDSI, NDVI
- Land surface temperatures
- Elevation, slope

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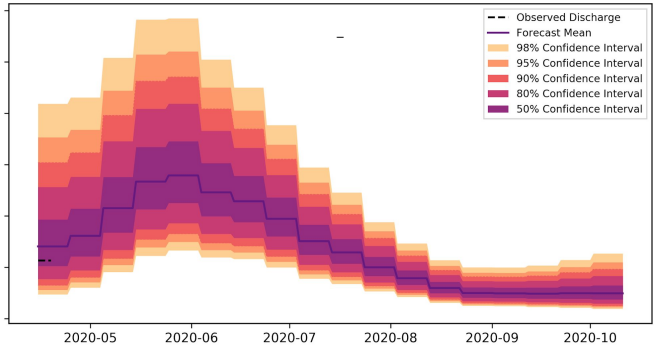
## Stacked LSTM Model

Historical LSTM:
- Uses land surface characteristics and weather data leading up to the forecast date to model the present hydrologic state (sequence to one mapping)

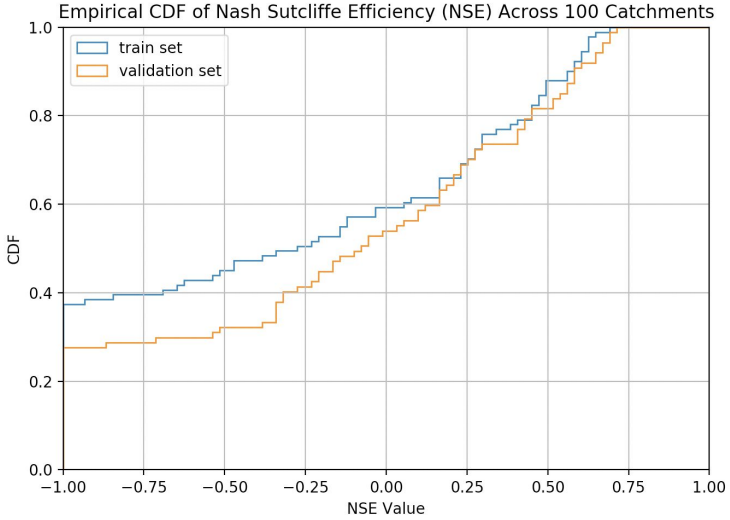
Forecast LSTM:
- Initialized with states of historic LSTM
- Uses seasonal weather forecasts to create seasonal flow forecast (sequence to sequence mapping)

## Output

Forecast with confidence ranges for the whole season and 10-day intervals



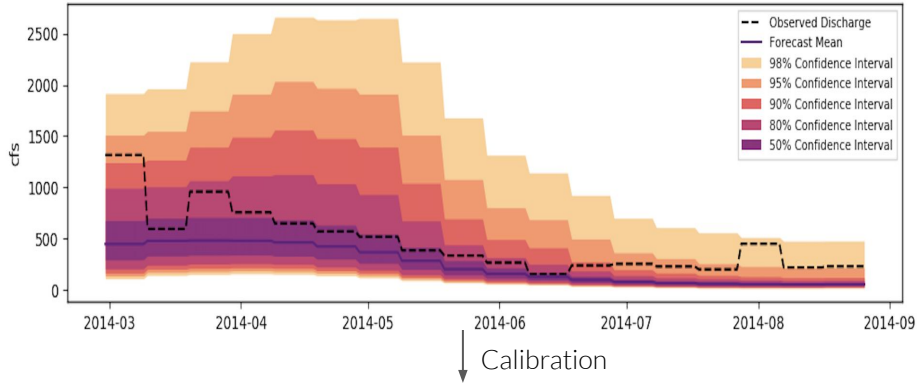
# General seasonal model




Ungauged basins have a median NSE value 0 on a sample of 100 basins from the CAMELS dataset.

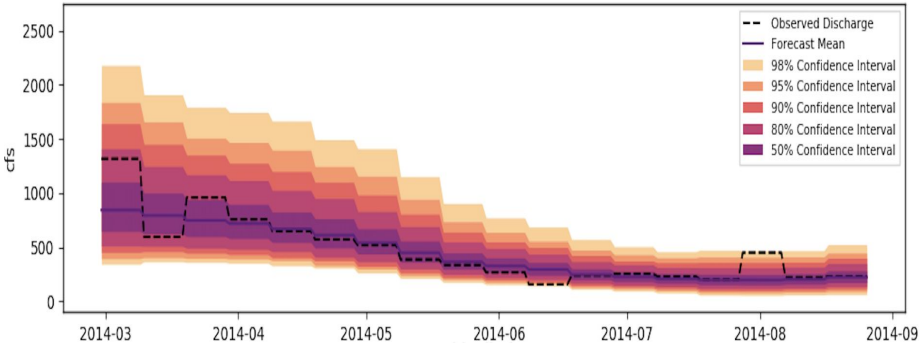
Calibrating to a specific catchment generally improves forecast accuracy.

**Ungauged** model forecast at a selected basin

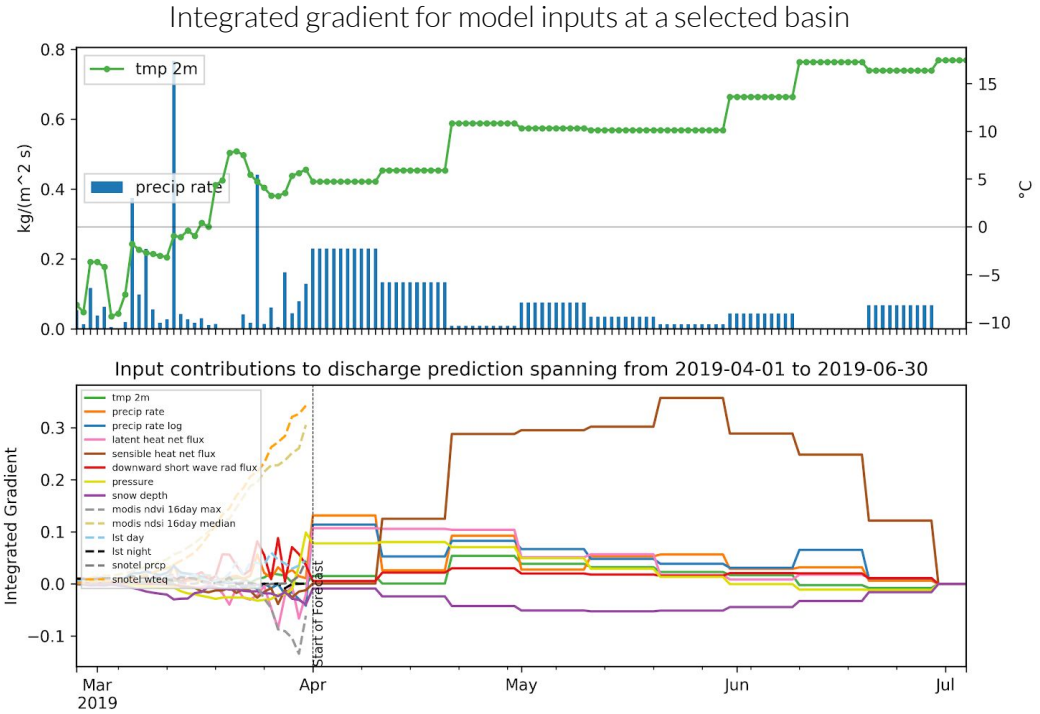



Calibration

**Gauged** model forecast at a selected basin



# Looking under the hood




Input importances for seasonal forecast created on April 1st forecasting April through June at a snow-driven basin

- Before the forecast date April 1st, the model learns that NDSI and SNOTEL SWE are most important features since they determine the amount of snow that can be melted over the coming months.
- After the forecast date the forecasted heat net flux determines the speed of snowmelt leading to discharge.

# Forecasting a distribution

- The model explicitly forecasts a distribution of outcomes. The distribution is a mixture with log-normal components.
- The chart on the right shows temporal dynamics of a log-normal mixture with two components at a selected catchment from February through July (top to bottom).
    - During the high flow period the model assigns a small weight to a distribution with higher mean and scale representing rare spikes in discharge
    - During the low flow period the model relies only on one components since the discharge is log-normally distributed