

Pelagic Fisheries Research Program

<http://www.soest.hawaii.edu/PFRP/>

From Light Measurements to Most Probable Track

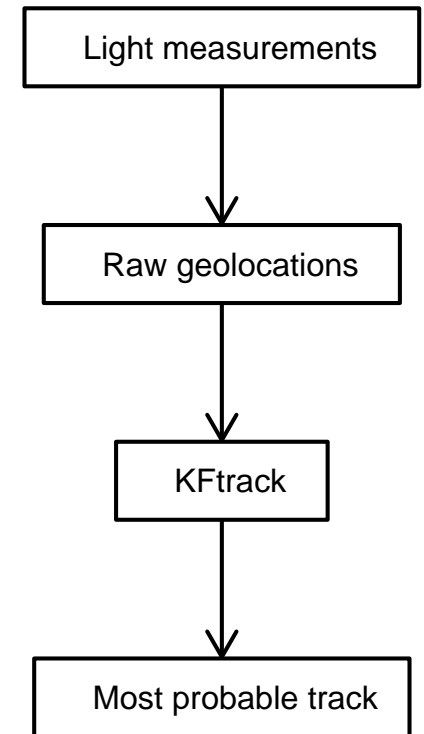
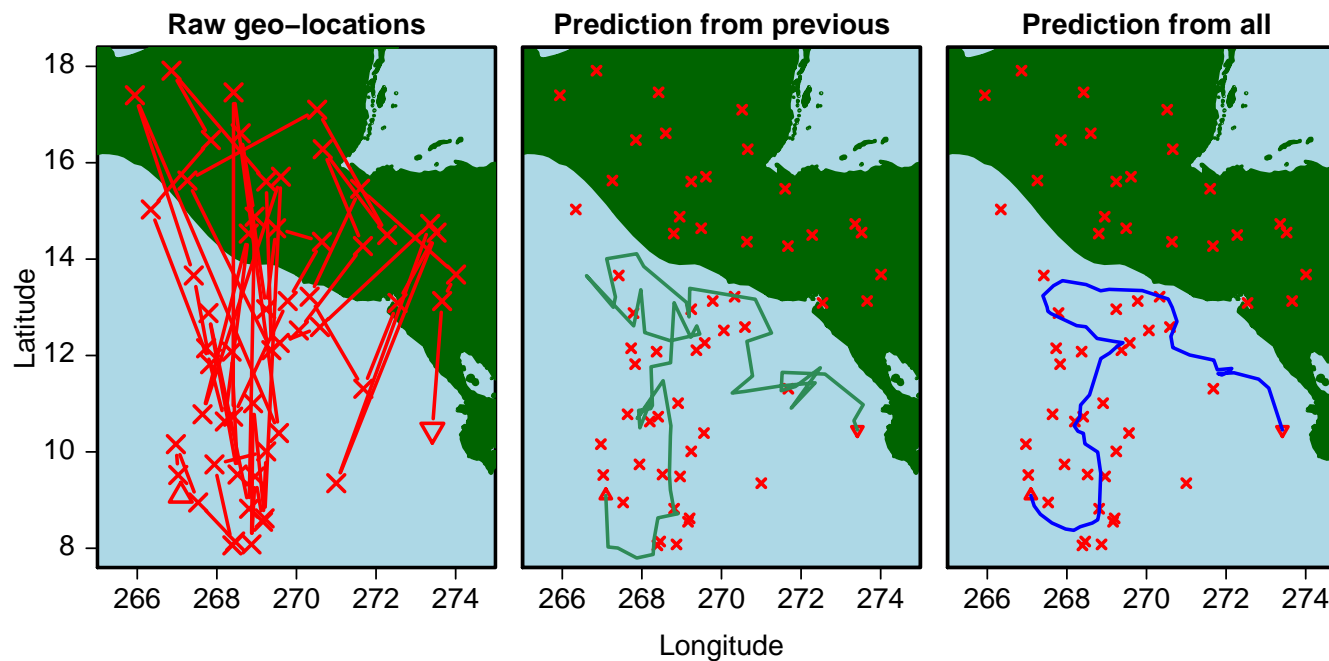
Anders Nielsen & John Sibert

anders.nielsen@hawaii.edu



Geolocation by light level

- Often a two step process is applied
 1. Get “raw daily geolocations” from tag manufacturer or via their software
 2. Try to reconstruct “most probable track” from raw geolocations

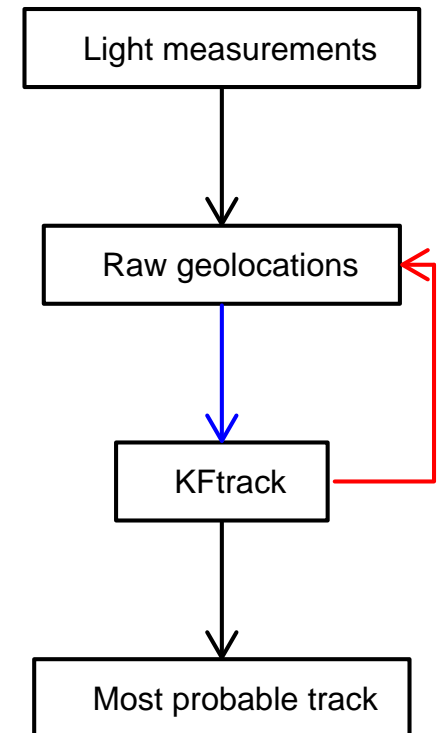


- Reminder: Light is not everything!



Why combine?

- With two step approach there is no **feedback** and not all is **carried through** to kftrack
- Kftrack assumes a fairly complex variance structure
- Kftrack estimates several (≈ 4) variance parameters
- Raw geolocations can sometimes contain extreme outliers, as the method has no knowledge of the entire track
- Extreme outliers can obstruct the final most probable track
- Frustrating to see patterns that can only be explained as artifacts of the unknown details of the raw geolocation

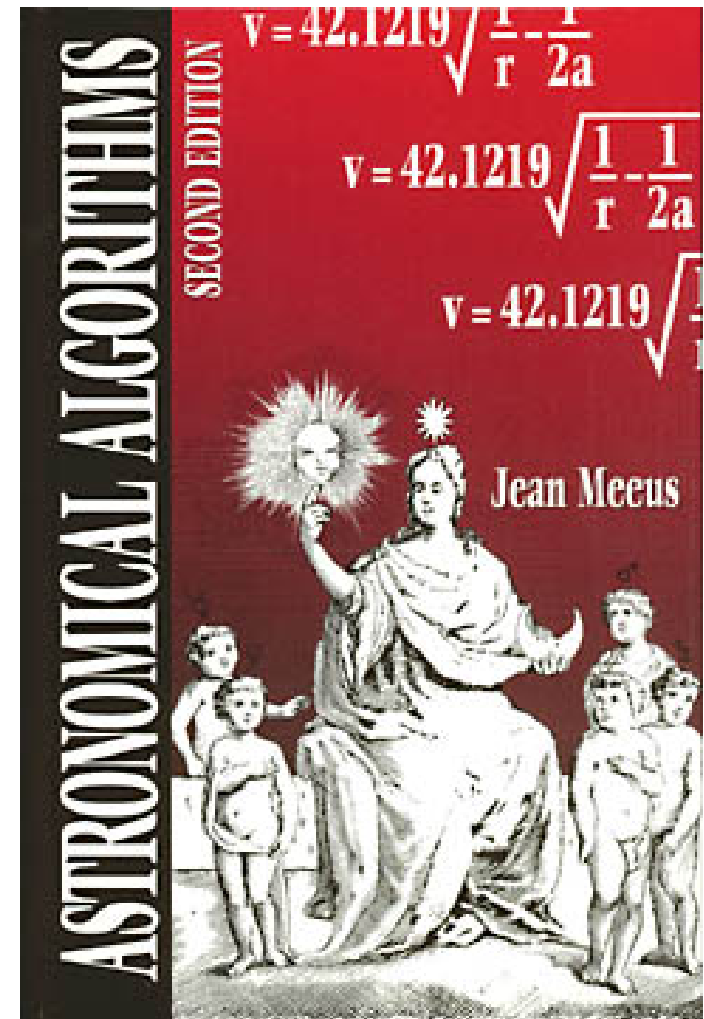


We aim to get one model that is transparent, statistically sound, and without ad-hoc solutions.



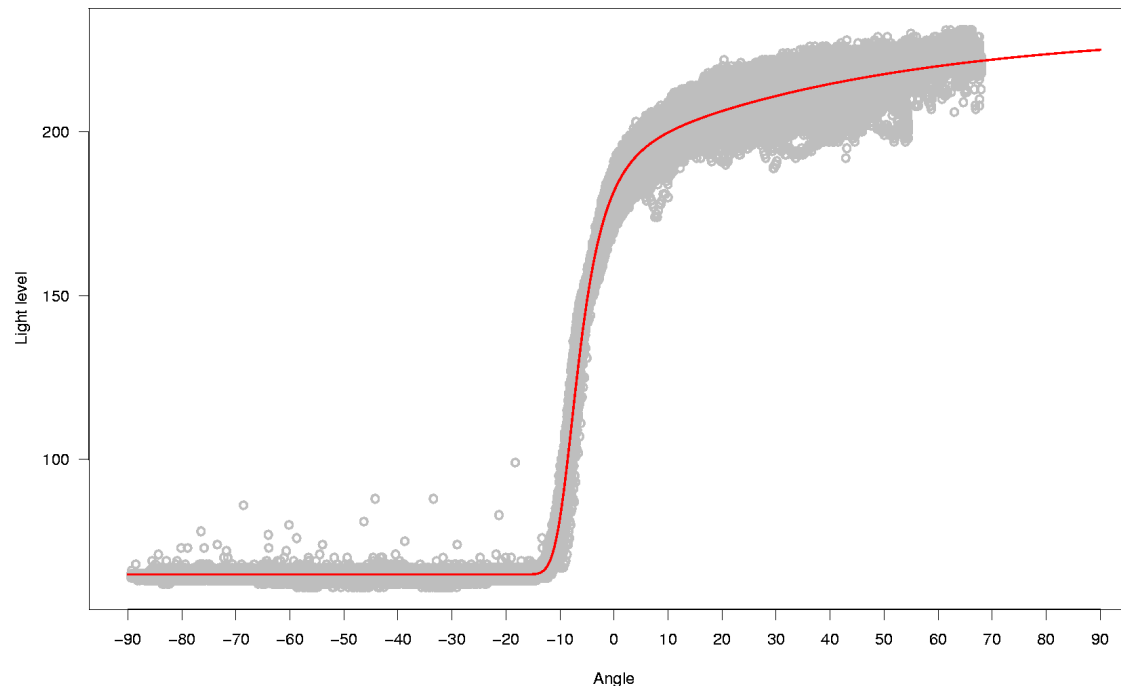
Astronomical algorithms are needed

- Universal time, dynamic time, position of the sun, position of the moon, position of the earth, rotation of the earth, ...
- In the end it all boils down to being able to calculate:
 - Altitude angle of the sun
 - Altitude angle of the moon
 - Fraction illuminated of the moonat any given time and position
- Algorithms are in: Meeus, J. (1998).
Astronomical Algorithms. Willmann-Bell.



Missing link – angle to sun-light $\varphi_s(\theta_s)$

- Have not been able find a parametric description of this relation
- Presently using a template estimated from mooring data (in periods without moonlight)
- If possible this template should be estimated within the model

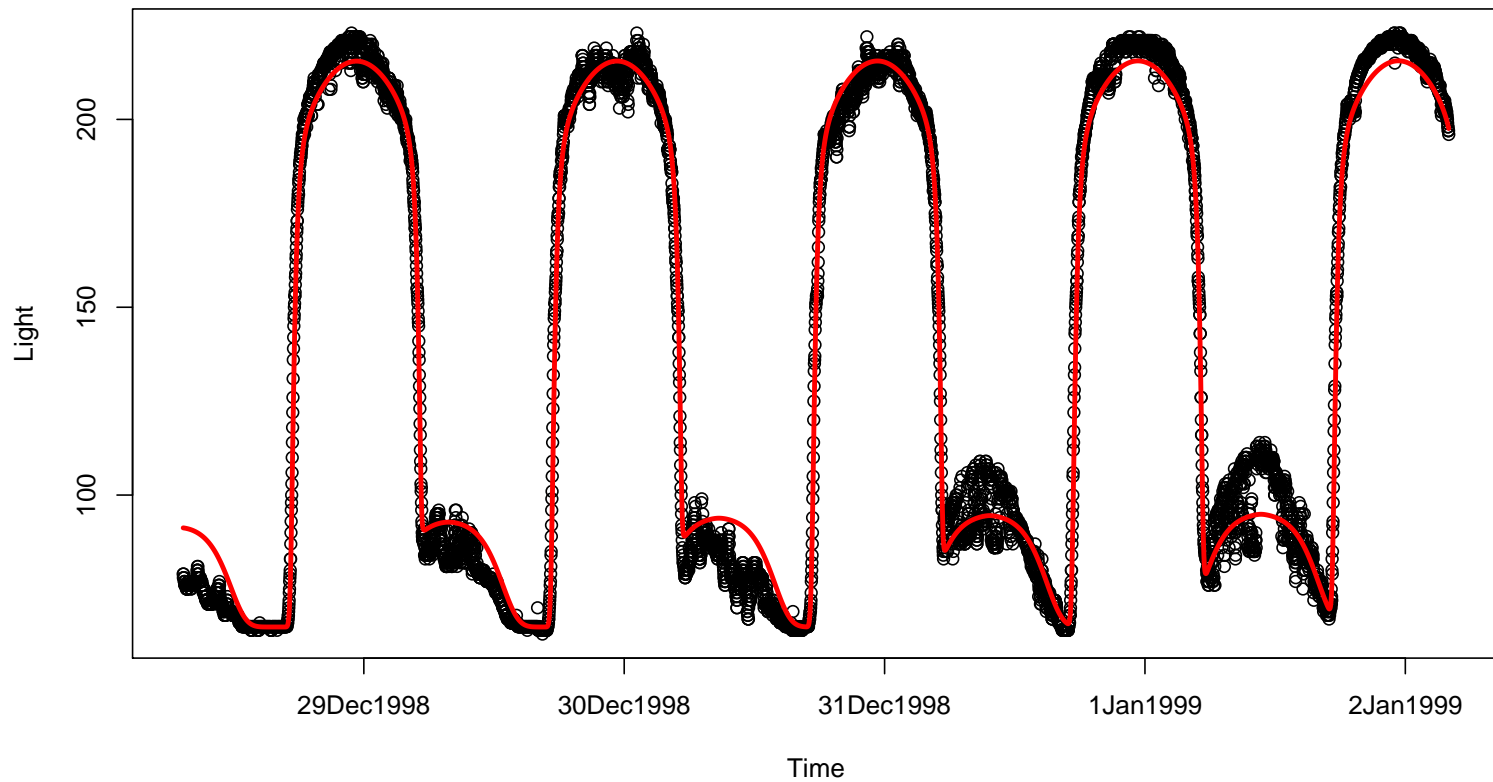


- Similar approach to estimate $\varphi_m(\theta_m)$



Fits the light measurements

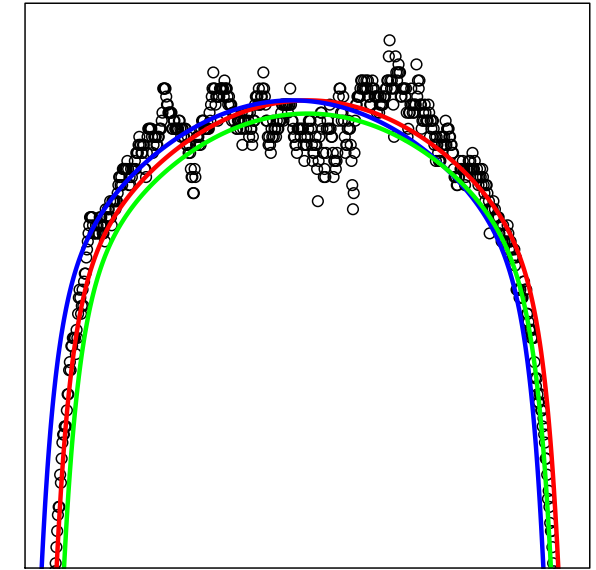
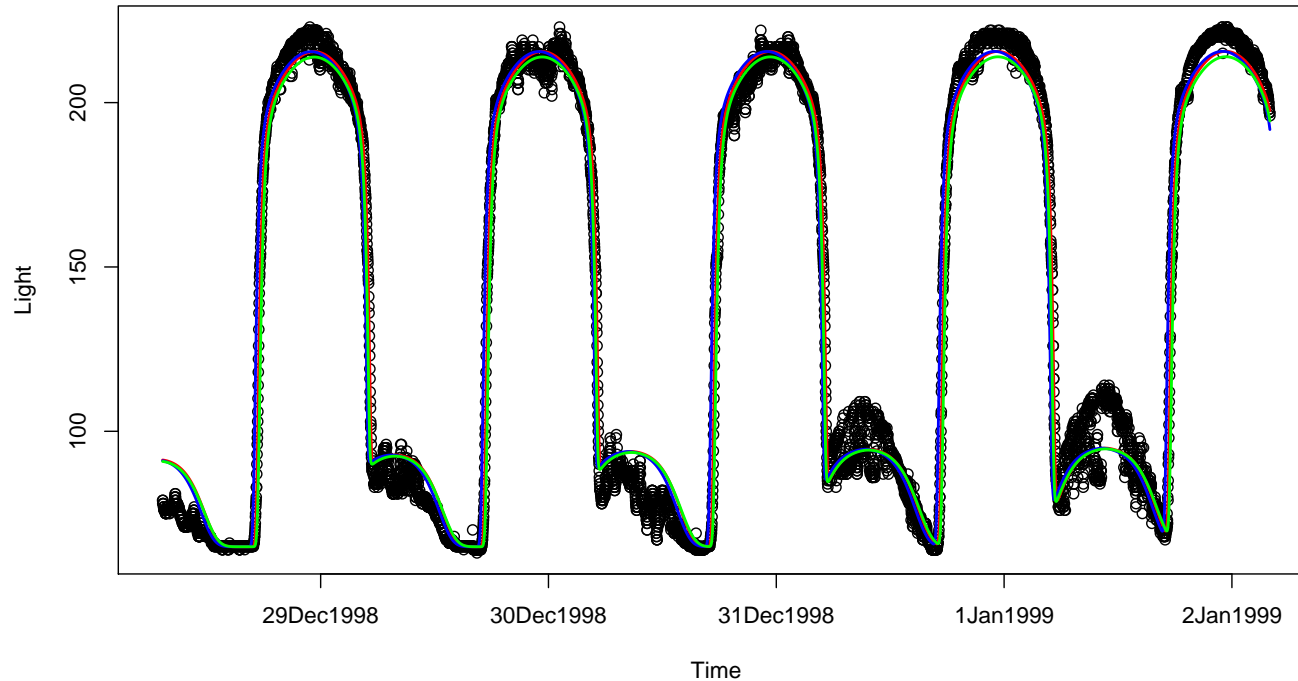
- Adding the three light sources “sun”, “moon”, and “background” it is possible to match the observations



- Clearly not independent observations



Why difficult?

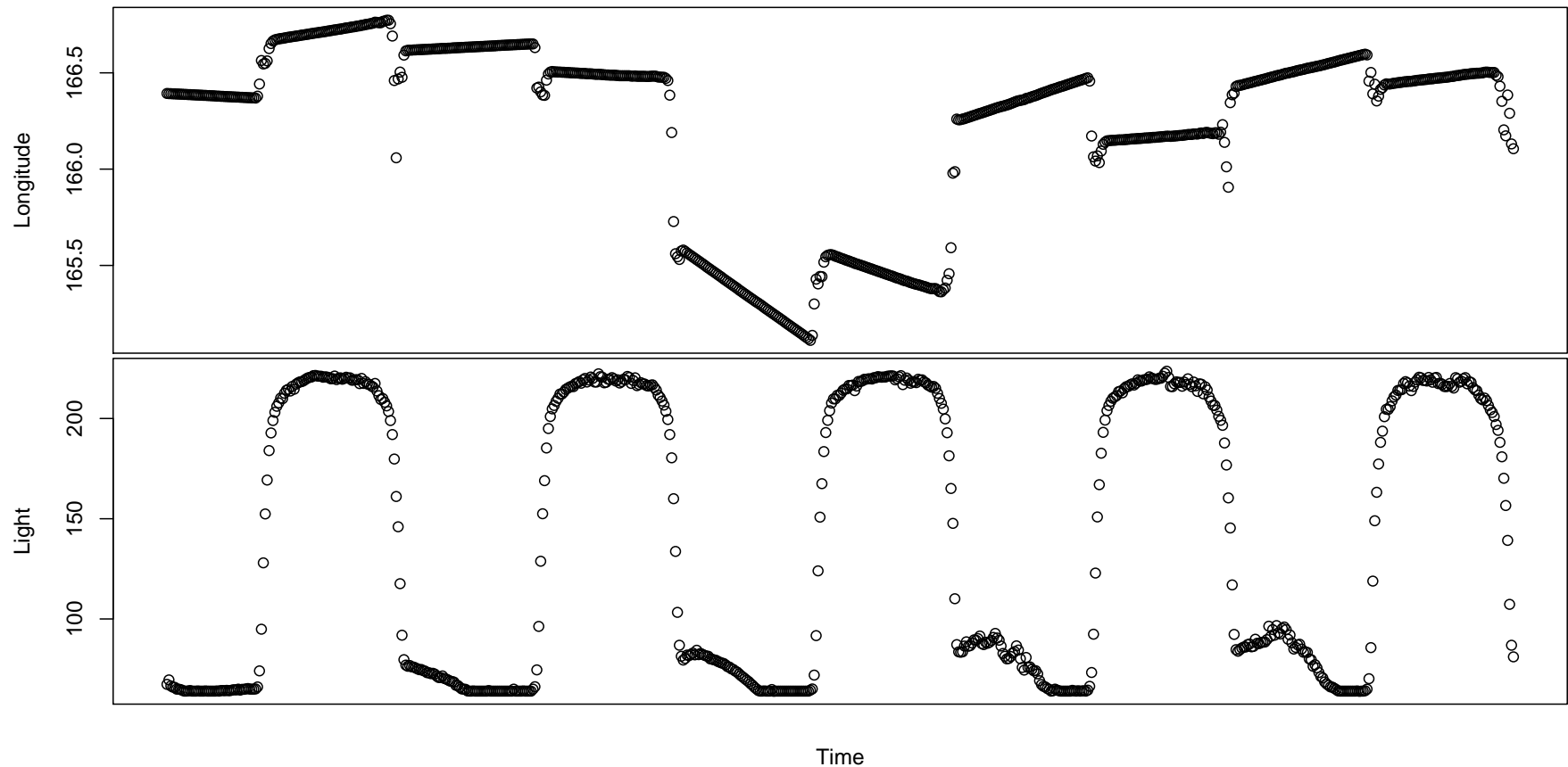


- Light curve at **correct position**, **5 degrees west**, and **5 degrees north**
- The amount of data is pretty big ($365 \cdot 1440 = 525600$)
- Highly correlated observations



Not all observations are equally important

- State space model (not really important here):
 - State: underlying movement model with random accelerations
 - Observation: at each time predicted light at current position is matched with observed



!



Current model of choice

- First an initial scan is carried out to select the data points close to sunset and sunrise
- State space model with semi-daily time steps

– State: $\psi_i = (x_i, y_i, \lambda_i)'$ follows a random walk

$$\begin{pmatrix} x_i \\ y_i \\ \lambda_i \end{pmatrix} = \begin{pmatrix} x_{i-1} \\ y_{i-1} \\ \lambda_{i-1} \end{pmatrix} + \begin{pmatrix} u \\ v \\ 0 \end{pmatrix} \Delta t_i + \eta_i, \quad \text{where } \eta_i \sim \mathbf{N}(0, \text{diag}(2D, 2D, \sigma_\lambda^2) \Delta t_i)$$

(x, y) is position in Nm from fix-point. λ is “light index” (weather)

– Observation: vector of light observations \tilde{L}_i at times \tilde{t}_i “near” time t_i

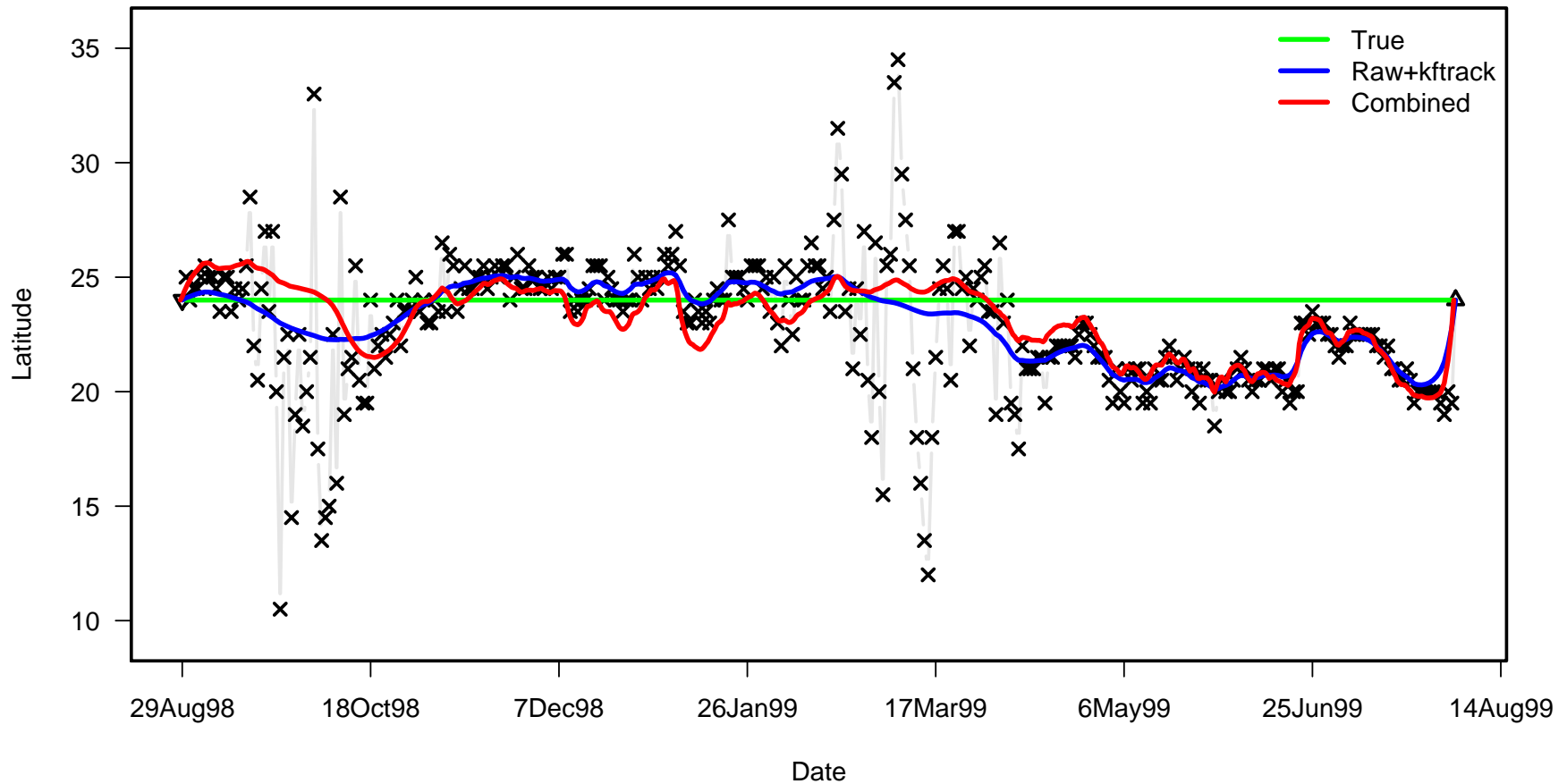
$$L_i = \mathcal{L}(\psi_i, \tilde{t}_i) + \varepsilon_i, \quad \text{where } \varepsilon_i \sim \mathbf{N}(0, V)$$

Covariance V is structured to give high correlation when time difference is small

- Notice two ways of handling correlations
- Model parameters estimated via the extended Kalman filter
 - First position is known without error (release position)
 - Predict next via model; calculate difference and its variance; update position; ...



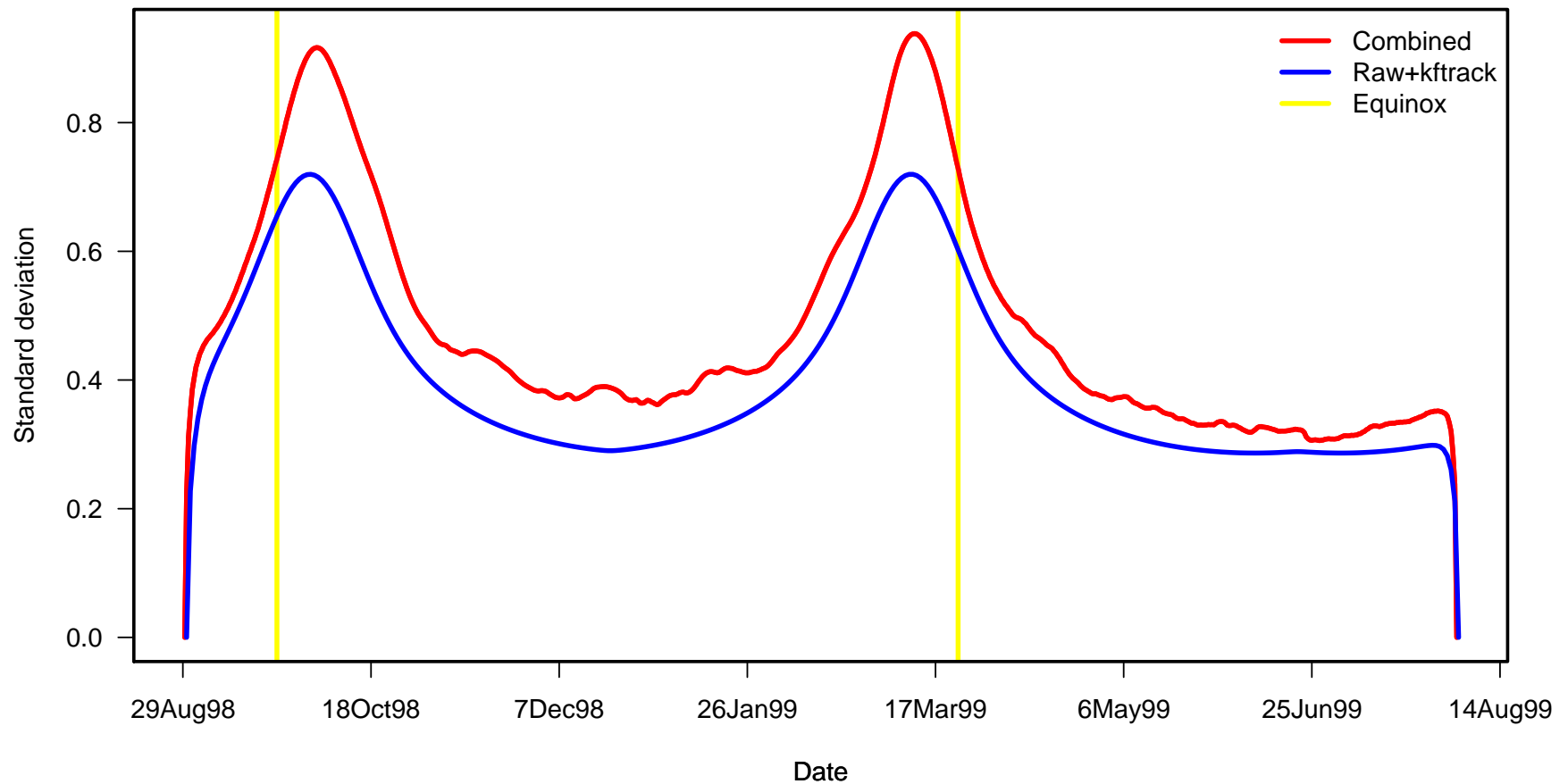
Example of reconstructed latitude



- Not very different
- Problematic bias near the end is present in both models
- Transparent approach gives us a chance of tracking it down



Estimated uncertainties



- Raw+kftrack has smaller uncertainty estimates, but maybe those from the combined approach are more realistic
- With combined approach we don't need to assume a parametric variance model



Summary, comments, and questions

Summary:

- A combined approach would be the better solution
- We are getting closer, but not quite there yet
- Important lessons are learned along the way
- Remember light is not everything

Comments and questions are very welcome both here and later on

Thank you for listening

