Previously, on Strateole-2...
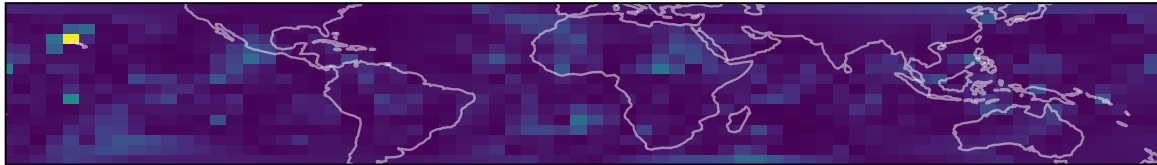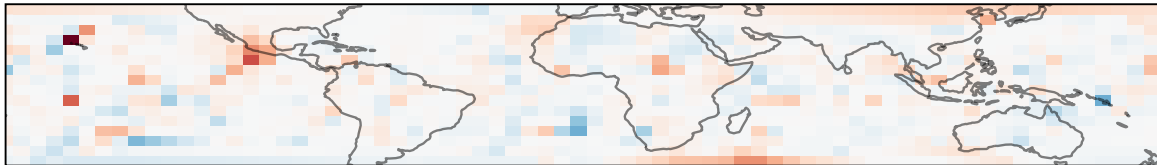
- Better estimation of k, l, v

- *Net* Momentum Flux from COSMIC2

(a) Absolute Momentum Flux @ 26 km, 31 Dec 2020

(c) Eastward Momentum Flux @ 26 km, 31 Dec 2020

(e) Northward Momentum Flux @ 26 km, 31 Dec 2020

Previously, on Strateole-2...

- Better estimation of k, l, v

- *Not* Momentum Flux from COSMIC2

Special thanks to
Hamid Pahlavan

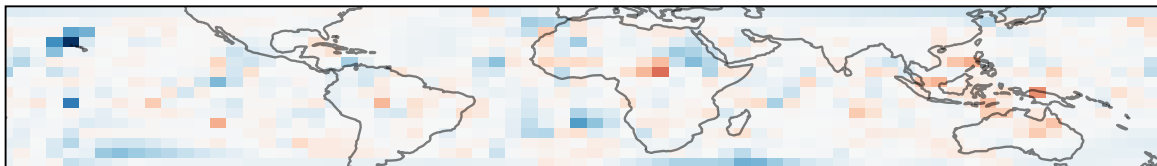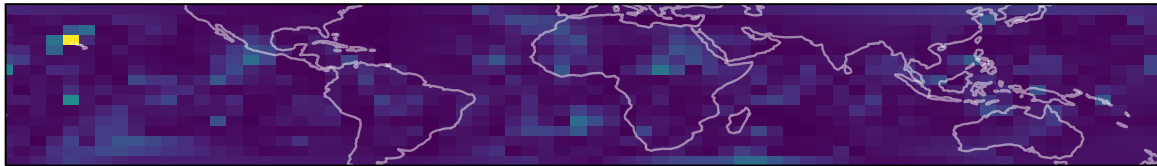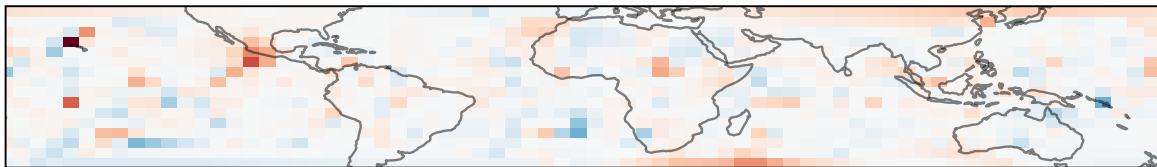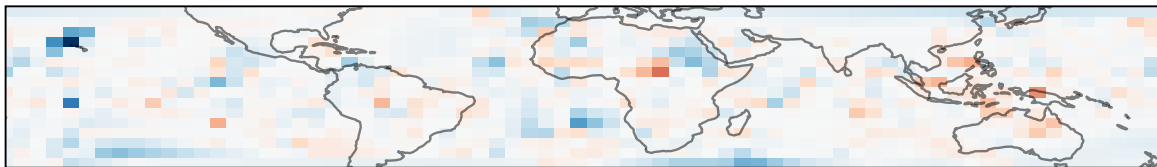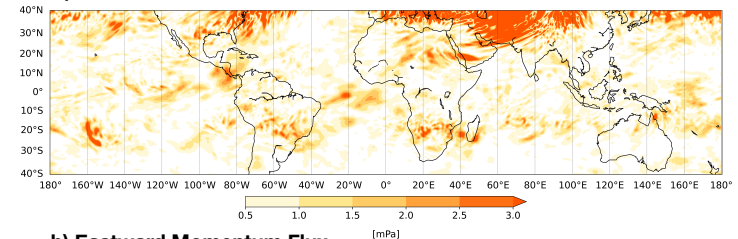(a) Absolute Momentum Flux @ 26 km, 31 Dec 2020

(c) Eastward Momentum Flux @ 26 km, 31 Dec 2020

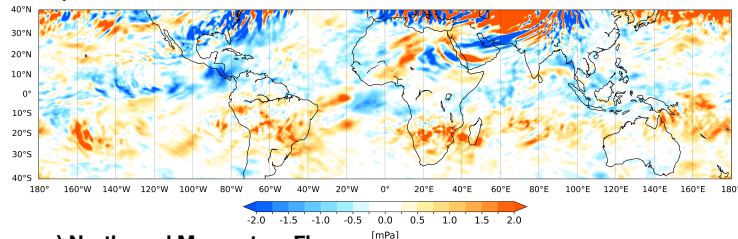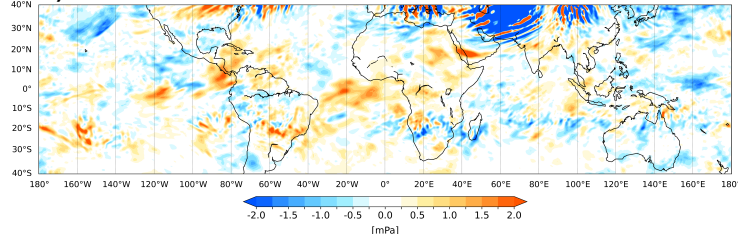(e) Northward Momentum Flux @ 26 km, 31 Dec 2020

a) Absolute Momentum Flux

b) Eastward Momentum Flux

c) Northward Momentum Flux

Today

- Review
  - The challenge with GPS RO
  - The usual approach

- Document
  - My new approach
  - Where I'm stuck

- Ideas where to go next

GPS RO is great at A, m, bad at k, l, v

- 2 profiles: easy
- 3 profiles: hard
- 4 profiles: impossible[*]

The usual approach to k, l

- S-transform on 3 profiles
  - A, φ vs m, z
- Assume $t_1 = t_2 = t_3$
- 3 estimates of λ_h projected onto 3 paths
  - k, l

$$\frac{\Delta\phi}{L}$$

$$\frac{\Delta\phi}{L}$$

$$\frac{\Delta\phi}{L}$$
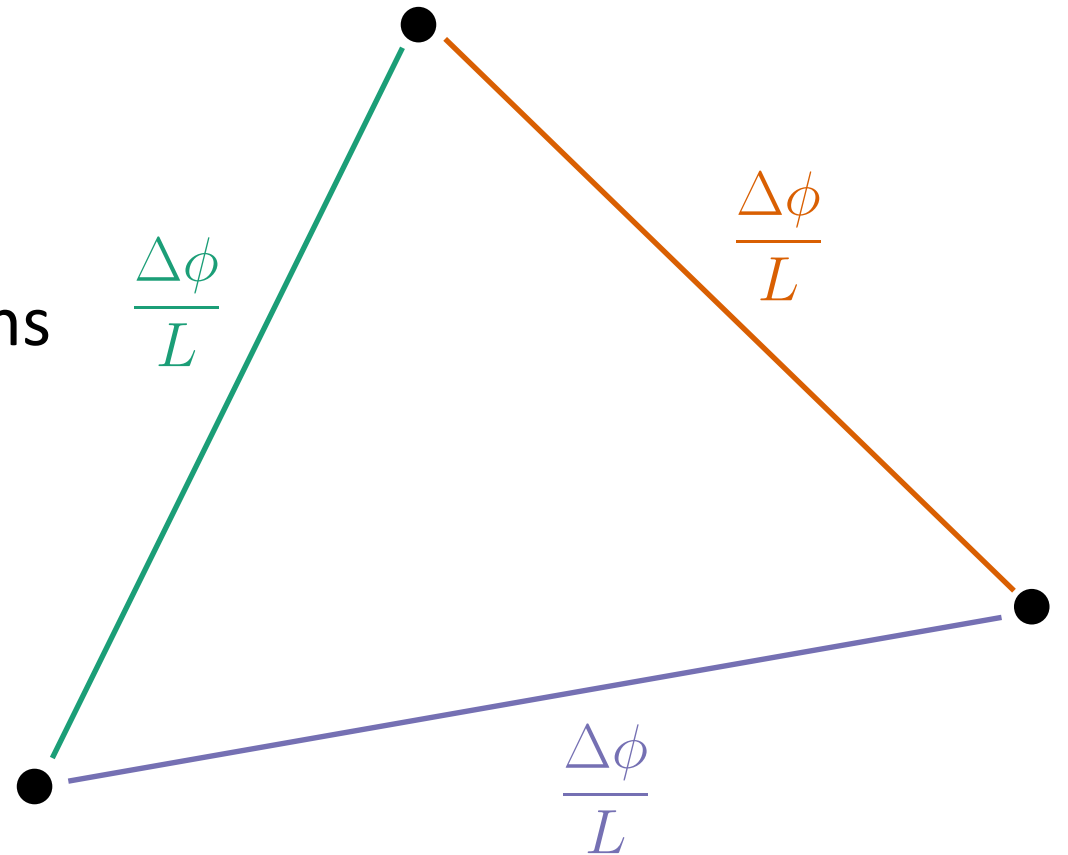
The trouble is...
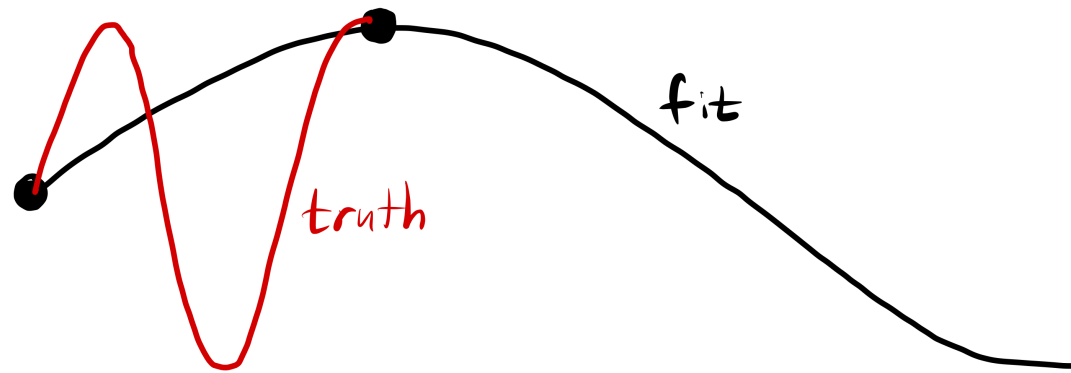
It requires small Δx...

fit

truth

...and small Δt.

t_0

t_1

fit

Alexander (2015)

2D

3D
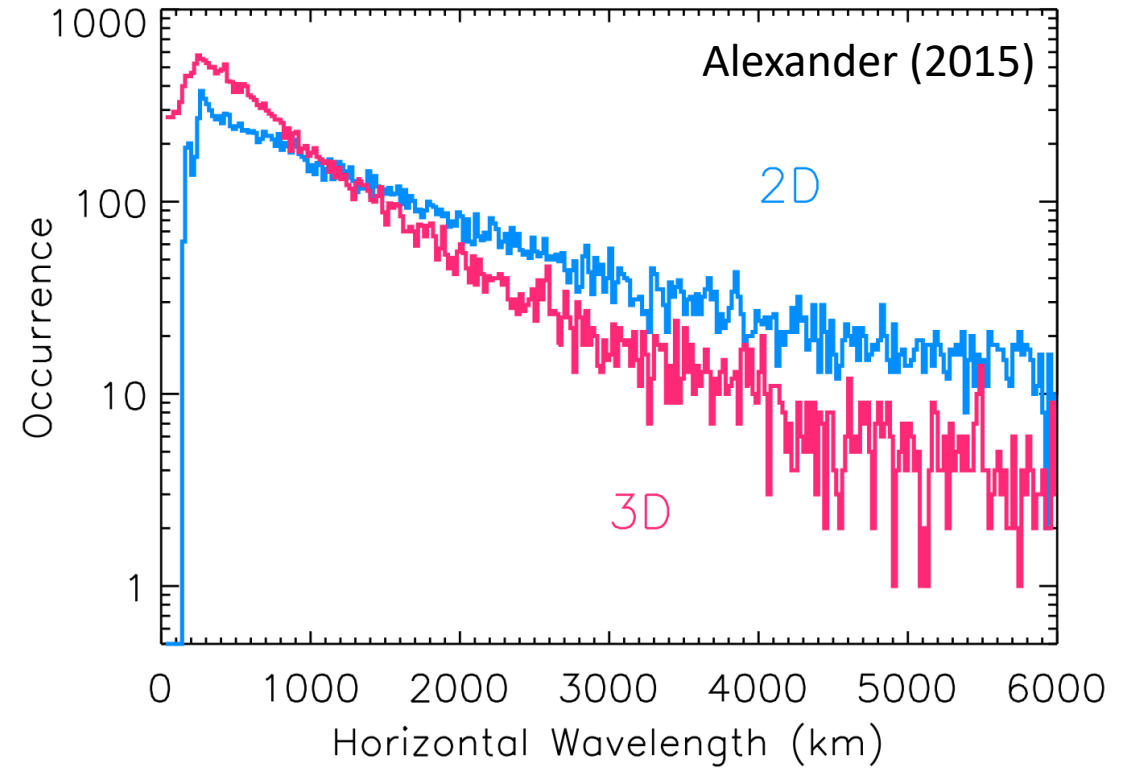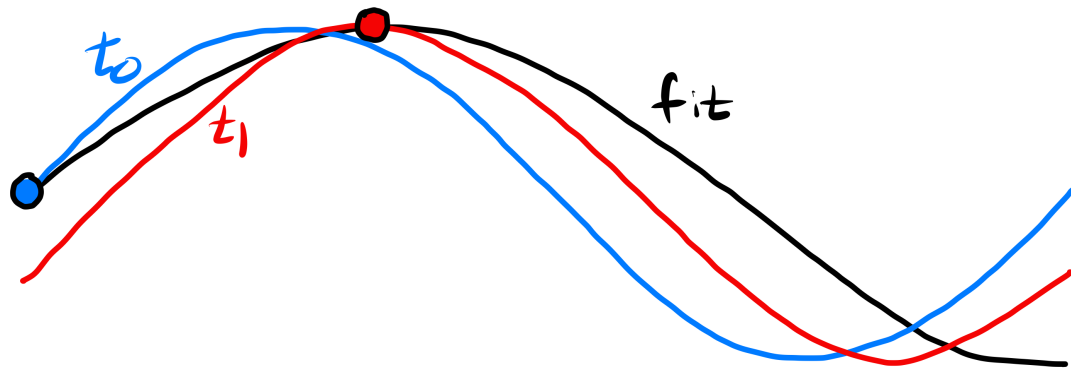
Schmidt et al. (2016) uses early COSMIC-2

P. Alexander et al. (2018) defer

Alexander (2015) takes it with a grain of salt

The minimization approach

- Define *T'=T*–background

- Assume $T' = A \cdot \Re\{\exp[i(kx + ly + mz - \nu t + \phi_0)]\} + \varepsilon$

- S-transform on dyads, *triads*, or tetrads
  - Determine A, m

- Let $\nu = \pm\sqrt{f^2 + N^2\dfrac{k^2 + l^2}{m^2}}$

- Run MCMC ensemble sampler
  - *Estimate k, l, φ_0 |*$_{v>0}$
  - *Estimate k, l, φ_0 |*$_{v<0}$

Why MCMC Ensemble Sampler?

- Fewer calculations per profile
  - 10 walkers, 1000 steps = **O**10^4 (×2)
  - 100 k_s × 100 l_s × 100 $\varphi_{0,s}$ = **O**10^6 (×2)
- Explicit prior
  - Currently uninformed,
    i.e., uniform over
    - $|\lambda_x|$ > 200 km
    - $|\lambda_y|$ > 200 km
    - $\varphi_0 \in [0, 2\pi)$
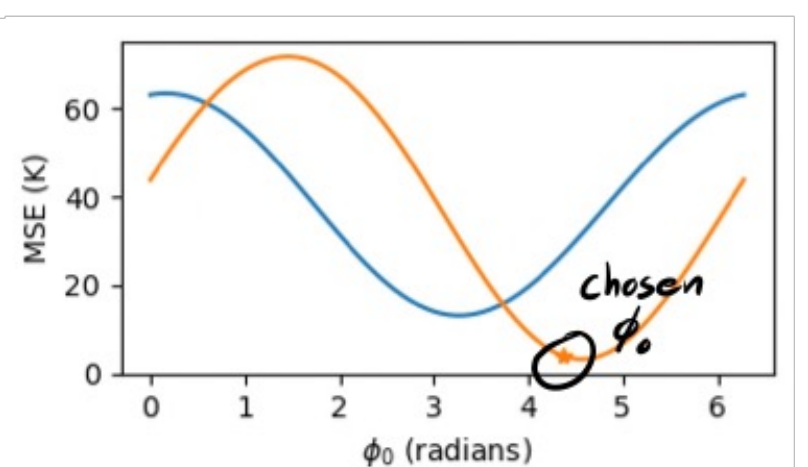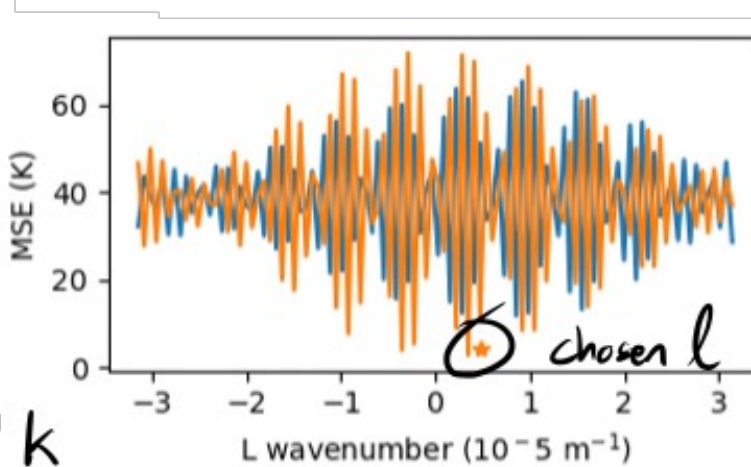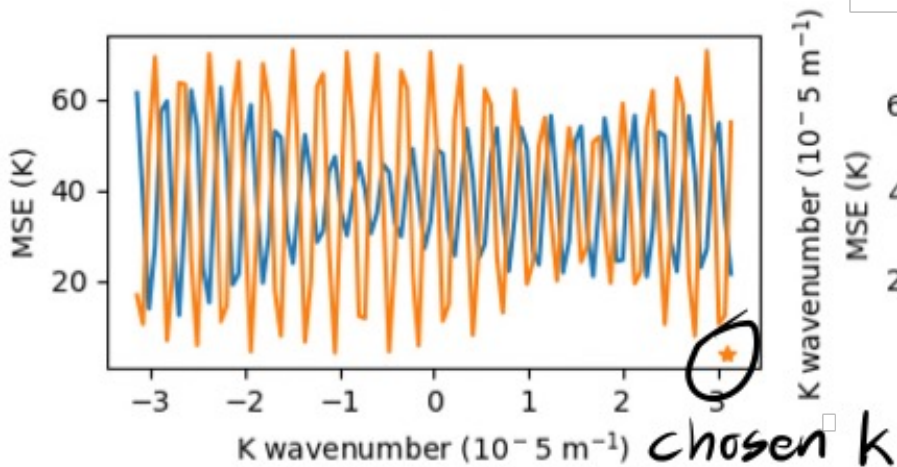
What to do with all those samples?

- Gaussian KDE, choose sample with largest density
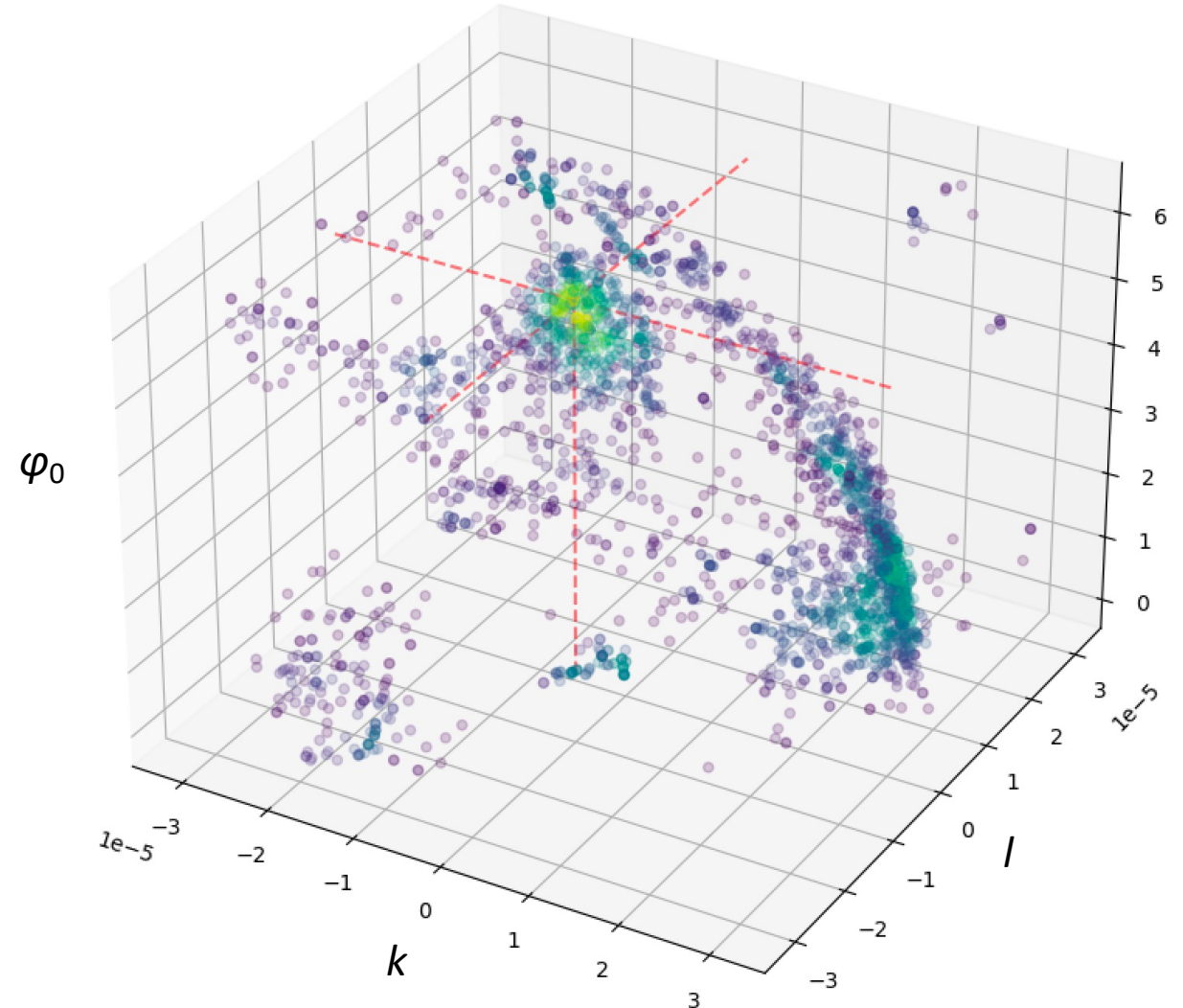
- Sometimes it works well…
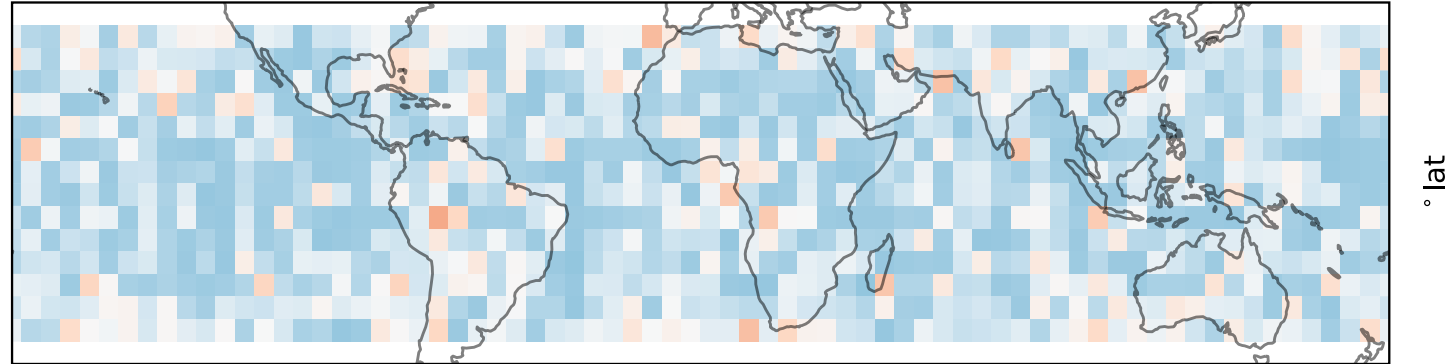
Sometimes it does poorly...
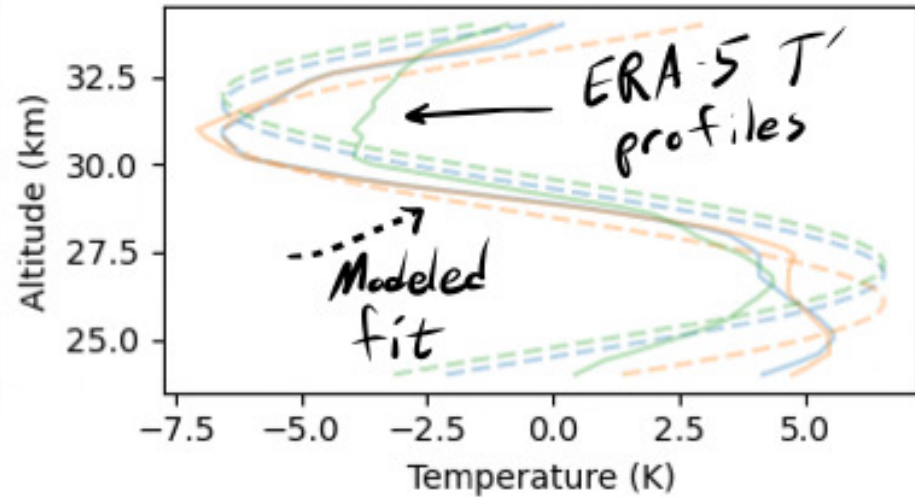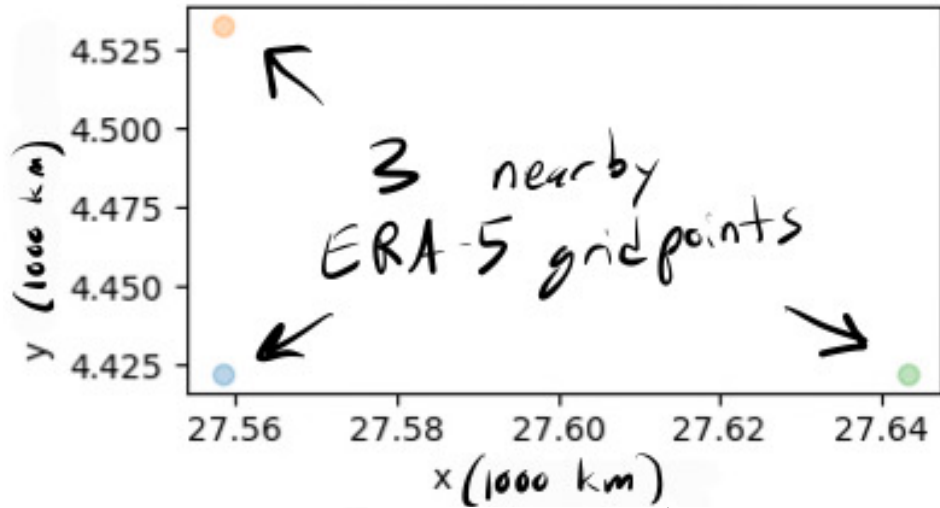
But...

- The magnitude and direction of the calculated momentum flux is not *completely* random.

Data replaced by single, initialized wave everywhere

Eastward momentum flux should be about -2.2 mPa everywhere

Northward momentum flux should be about -0.3 mPa everywhere

-40 mPa · 0 · 40 mPa
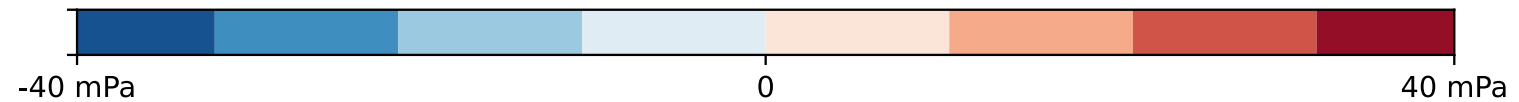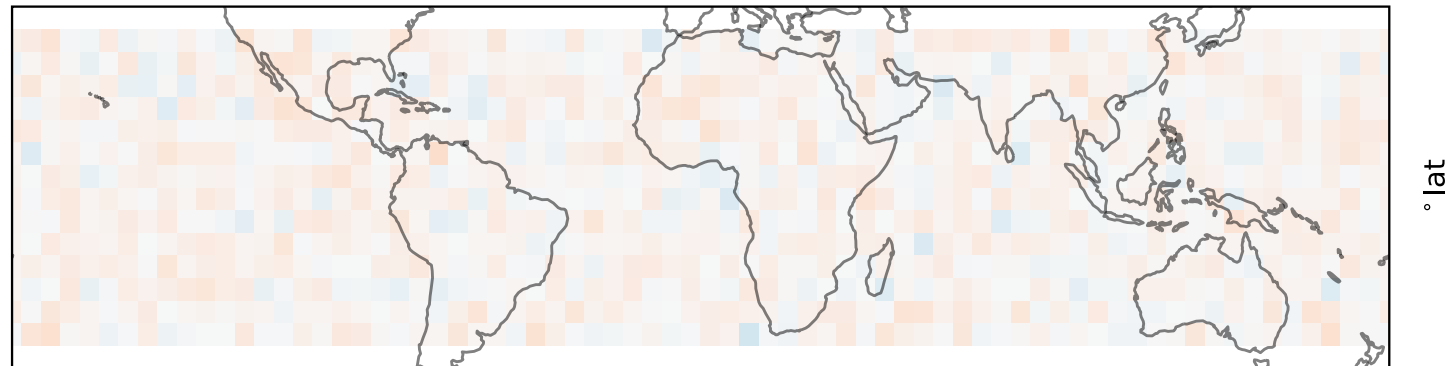
And...

- Magnitudes, though orders of magnitude too big, are *sometimes* big in the correct places.

ERA-*5* using minimization approach

(a) Absolute Momentum Flux @ 26 km, Dec 31 2020

0   80 mPa
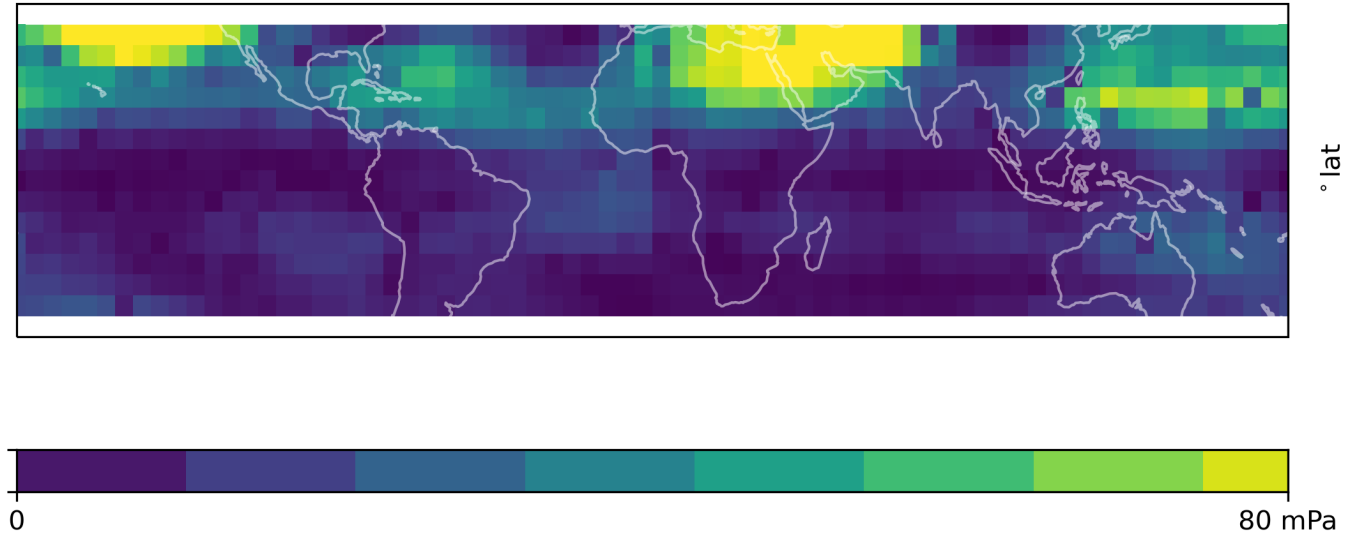
Direct calculation by Pahlavan

a) Absolute Momentum Flux
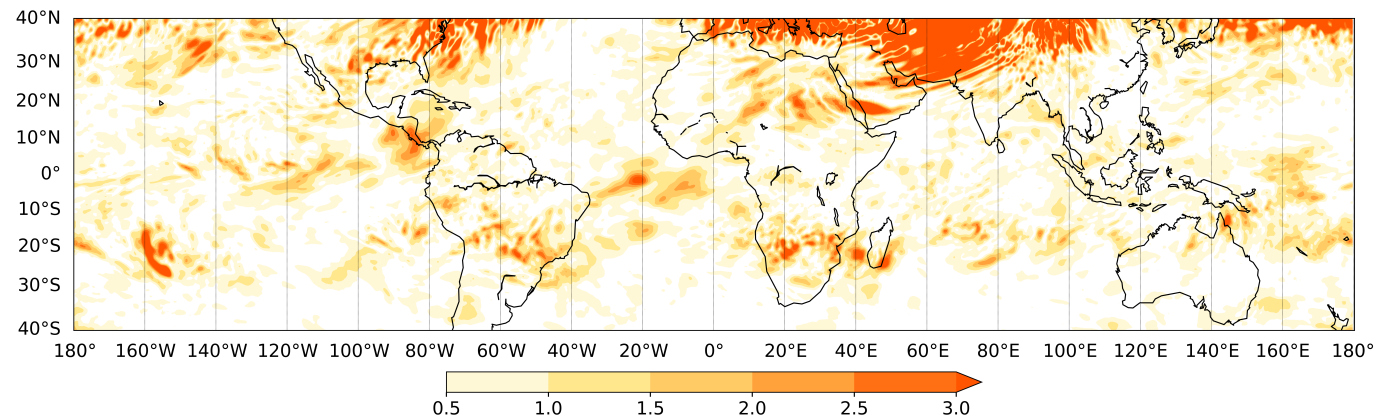
Sadly…

- Not ready for "prime time"

- Collocation requirements aren't as loose as I'd previously supposed

Flux calculated from GPS RO triads

0   80 mP
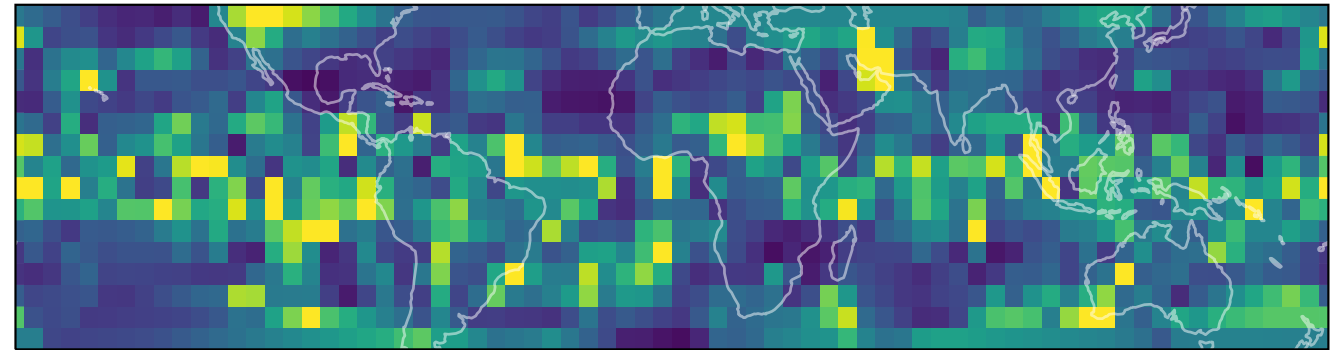
So far…

- 2 months ago, I got junk
  - Poor treatment of φ_0
  - Too-discrete S-transform
- Now I'm still getting junk
  - With some basis in reality
  - MCMC approach provides several ways forward

Ways forward

- Check again that pathological result isn't the result of a bug
- Analyze tetrads - perhaps feasible now
- Improving the prior
  - Explicitly favor lower k, l
  - Downward c_z
  - Upward c_{gz}
  - Incorporate ERA-5…
    - …just a little: c_x dependency on U_{trop}
    - …a whole lot: calculate prior distribution from surrounding ERA5 data
- Incorporate varying lon, lat, time versus height of RO profile
- Incorporate N' or background U (doppler shift) into objective function

What about balloons?

2 RO + 1 HVRRD

- Slow ascent rates are an advantage

- Wind profile can be incorporated directly into objective function

- Varying coverage, burst height

1 or 2 RO + 1 "Strateole"

- Horizontal flight path compliments GPS RO

- Winds, again, can be incorporated directly into objective function

- Rare

Thank you!

- Bill Randel
- Bill Kuo
- Bill Schreiner
- Fei Wu

- Joan Alexander
- Martina Bramberger

- Travis O'Brien
- Kaj Johnson

- Hamid Pahlavan