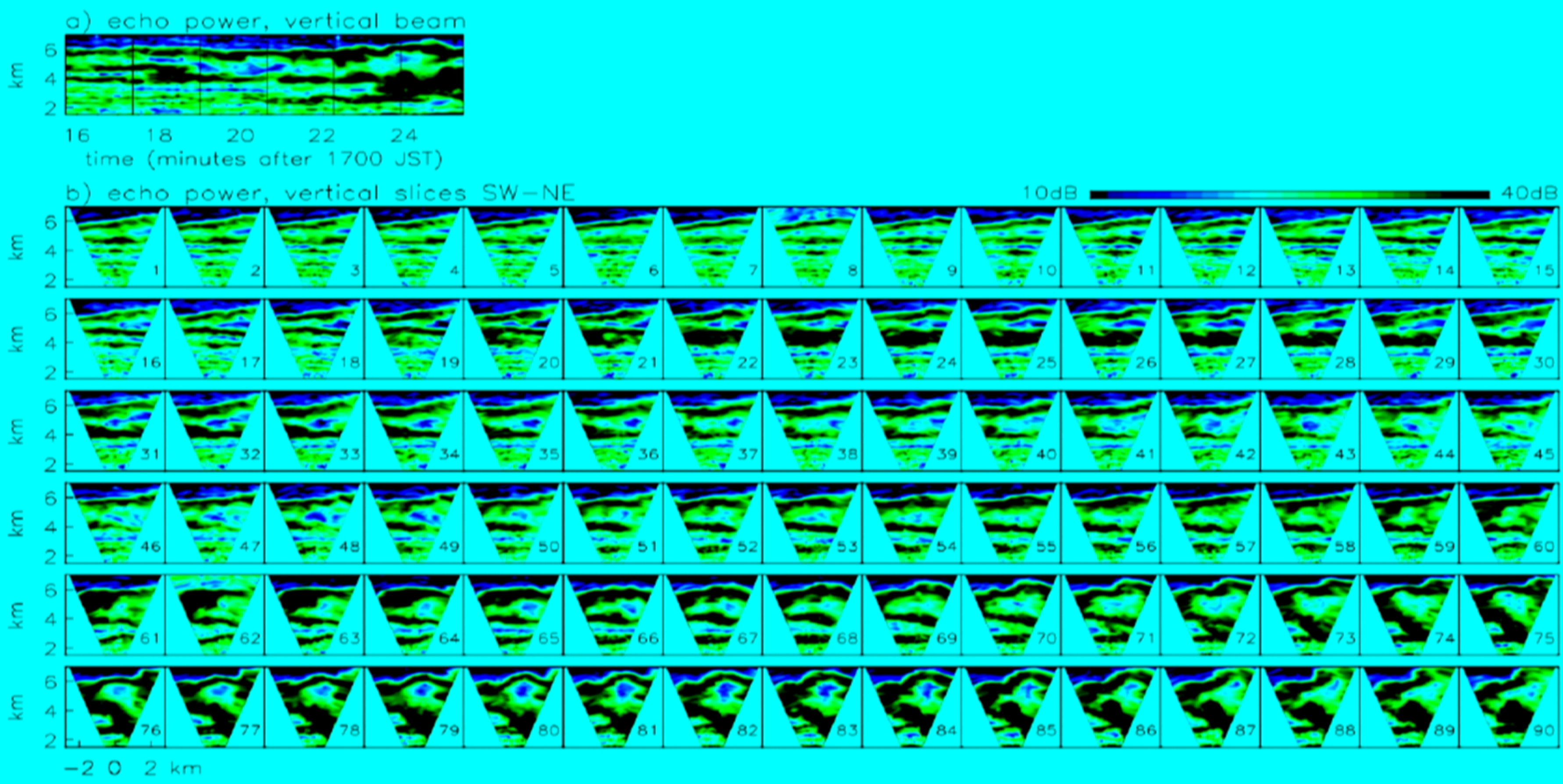
Title: Uses of HPC in radar data processing and analysis

Date: May 07, 2014 03:50 PM

URL: http://pirsa.org/14050056

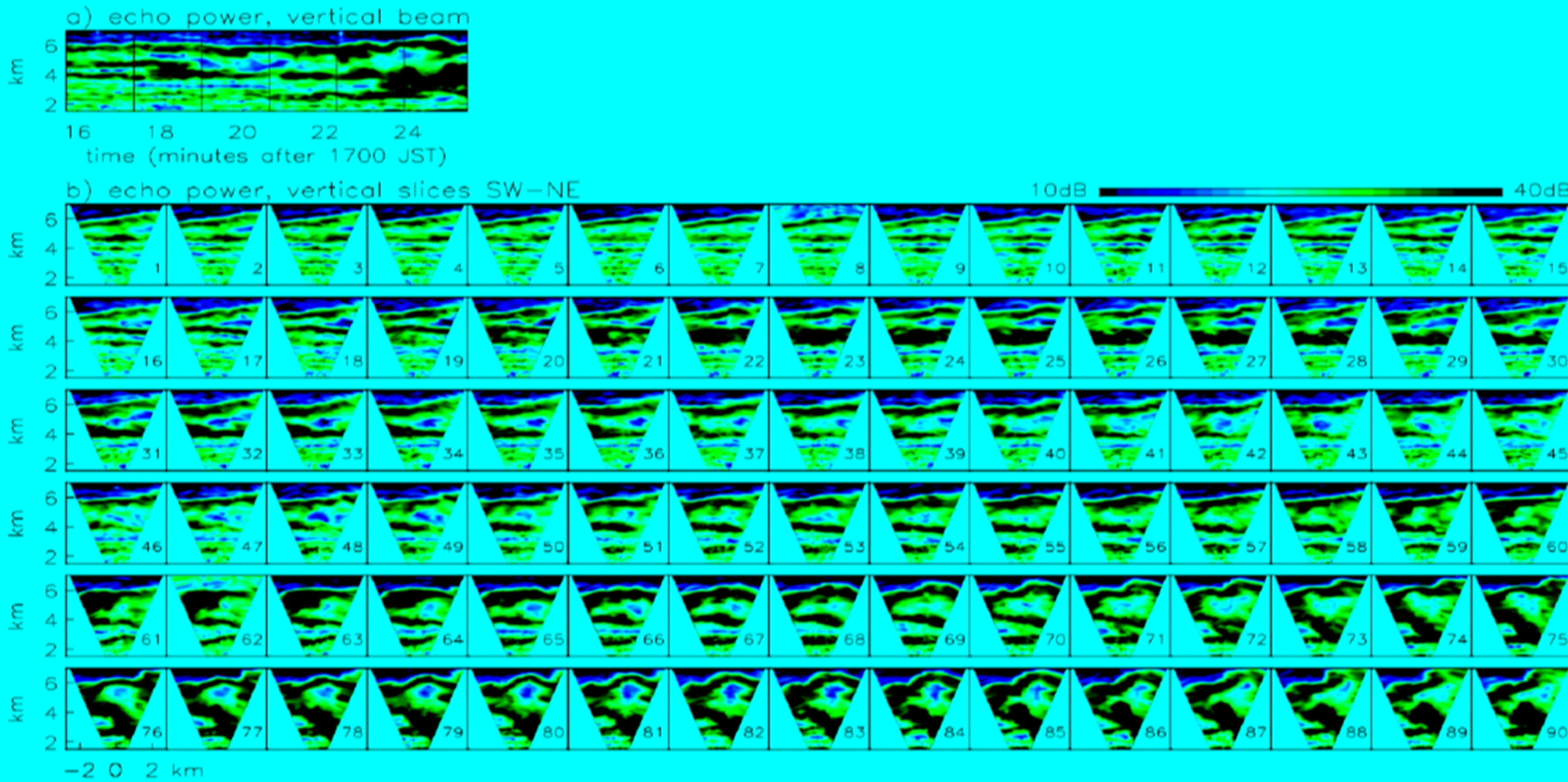
Abstract: A low troposphere MST type radar located in Costa Rica was used to gather information up to 6 km. With the digital radar technique used thousands of sweeps can be recorded every second. Challenges in processing spectral analysis and radar imaging were addressed with tools provided by HPC.

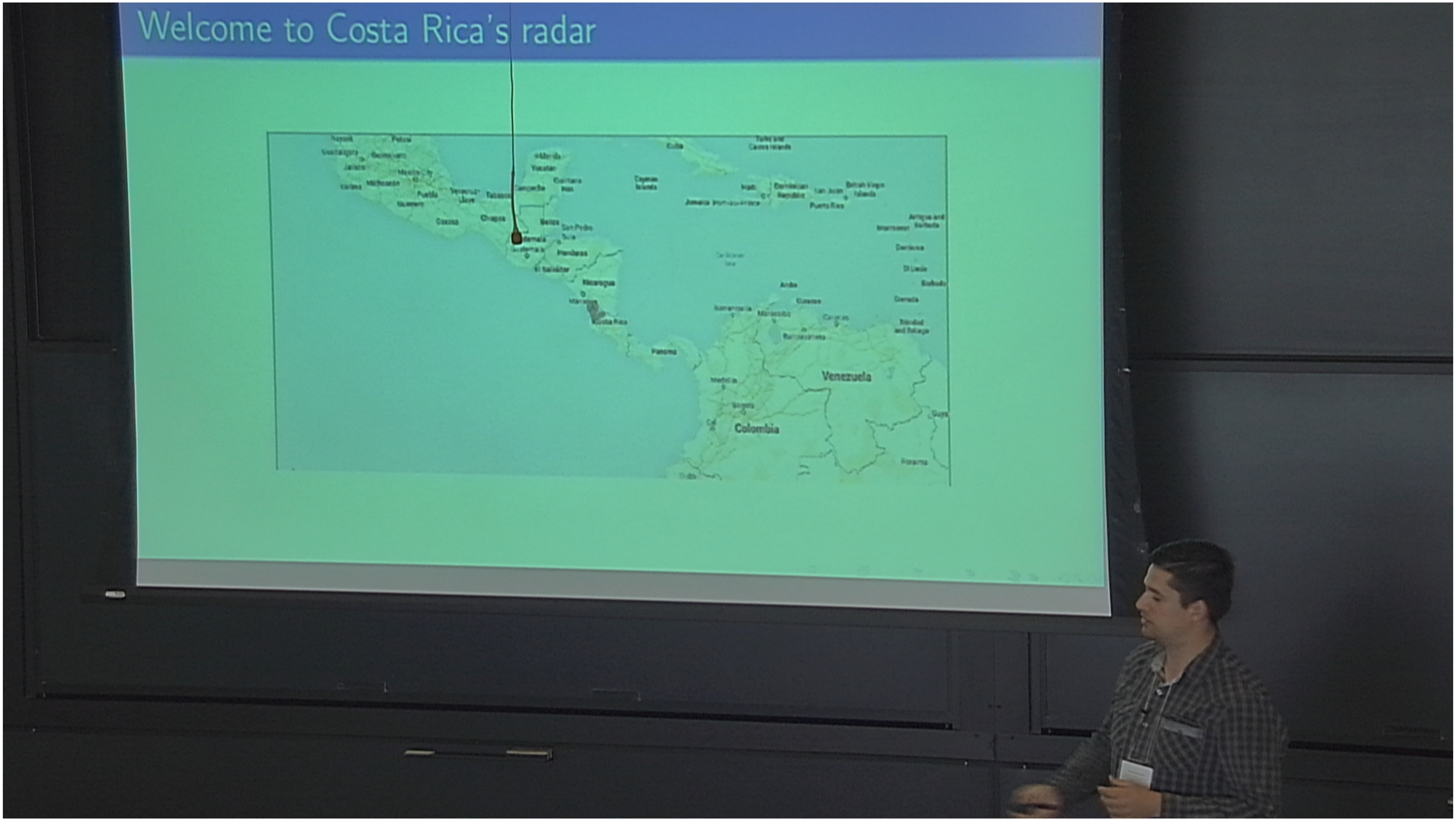
MU Radar



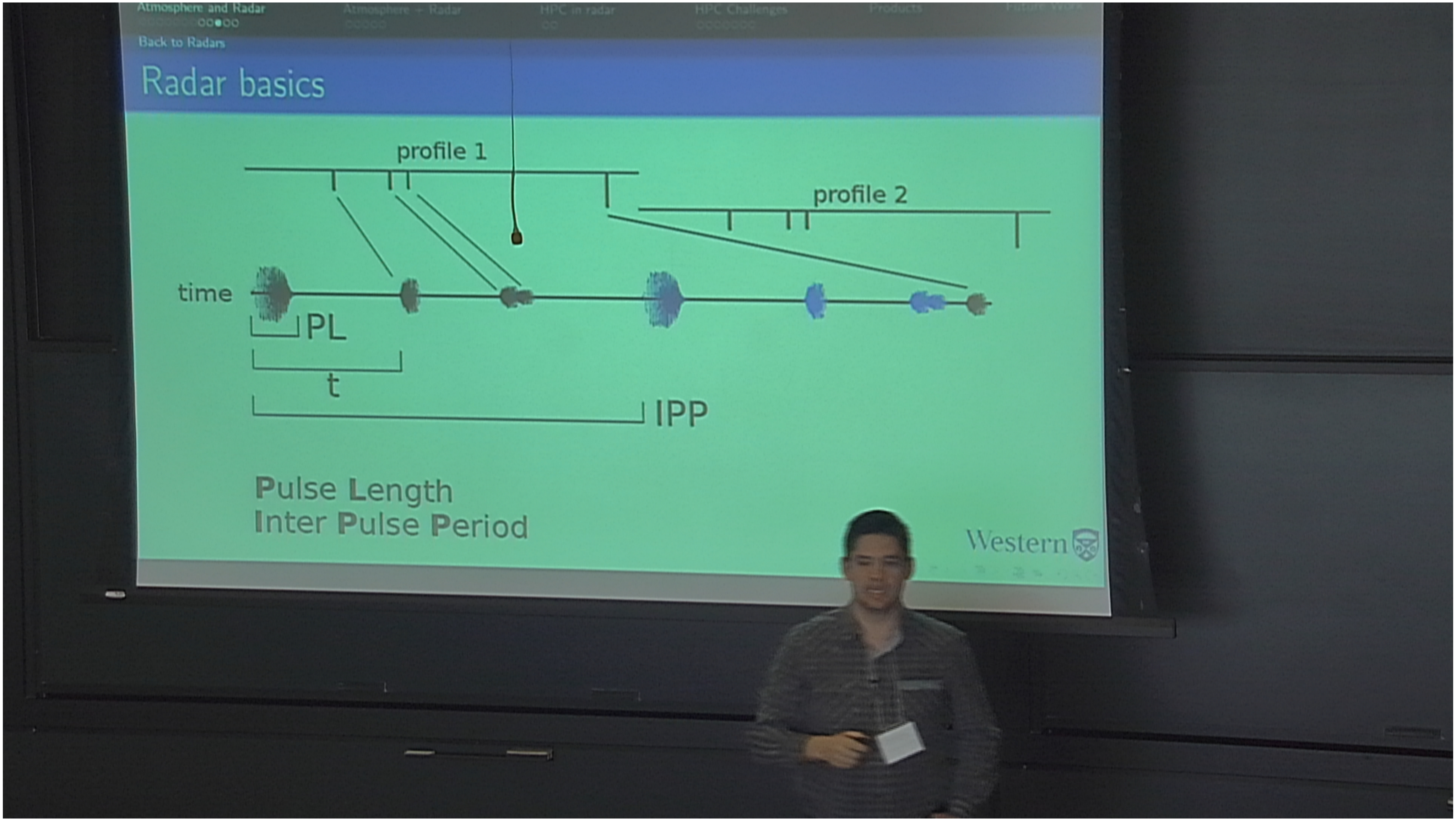
a) echo power, vertical beam
km
time (minutes after 1700 JST)
b) echo power, vertical slices SW–NE
10dB
40dB
−2 0 2 km

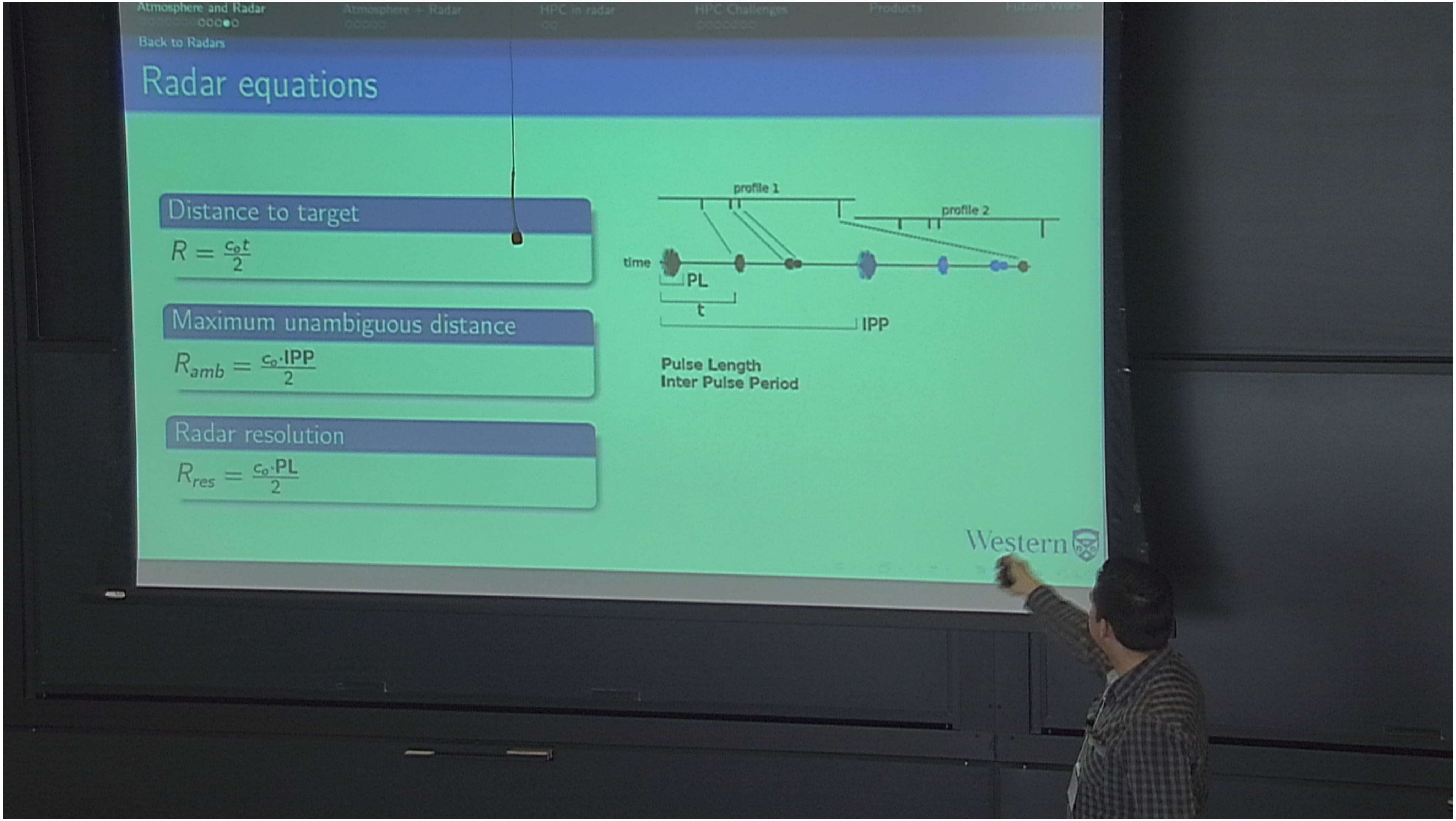
MU Radar

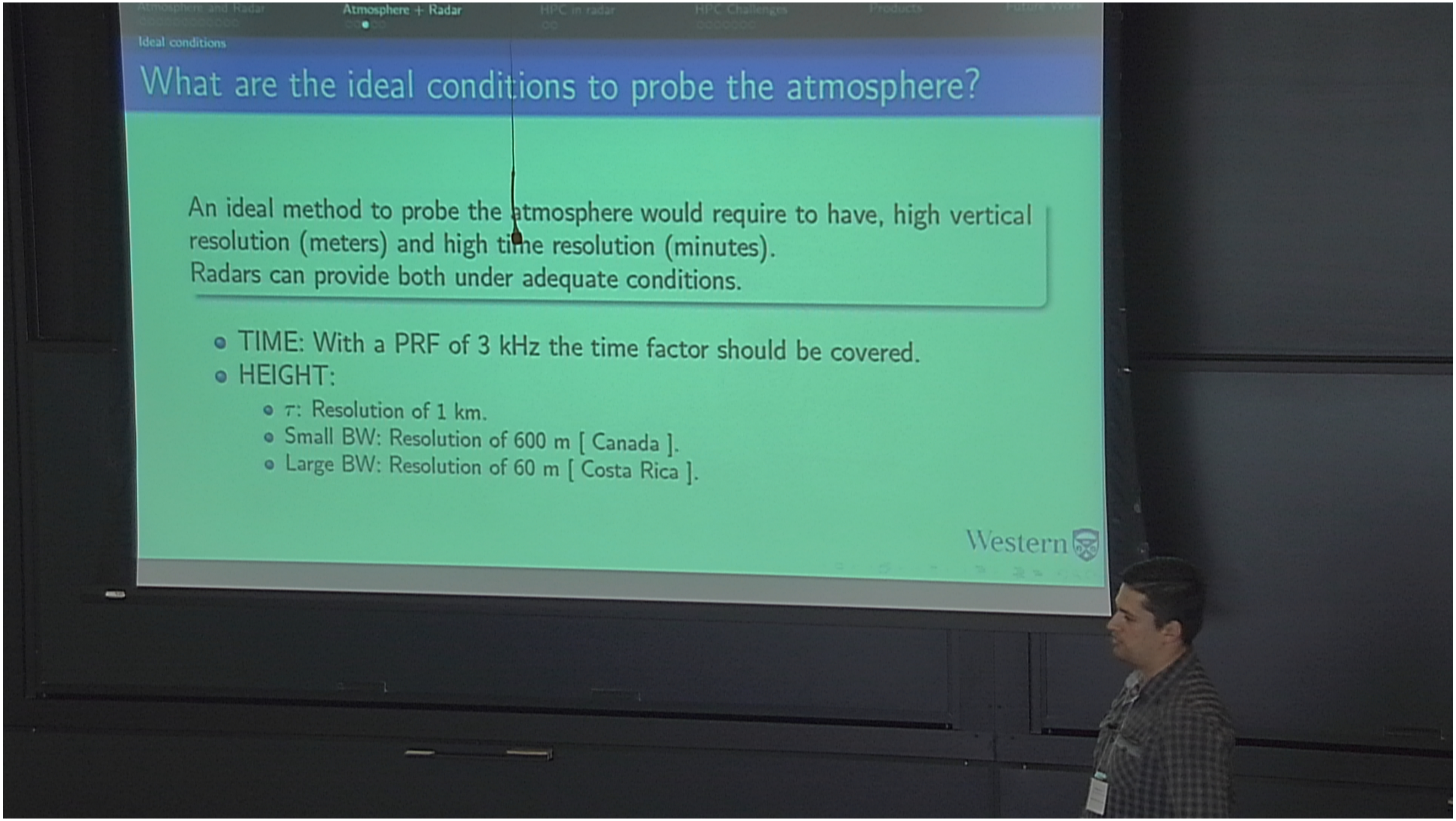

a) echo power, vertical beam
km
6
4
2
16 18 20 22 24
time (minutes after 1700 JST)
b) echo power, vertical slices SW–NE
10dB
40dB
-2 0 2 km

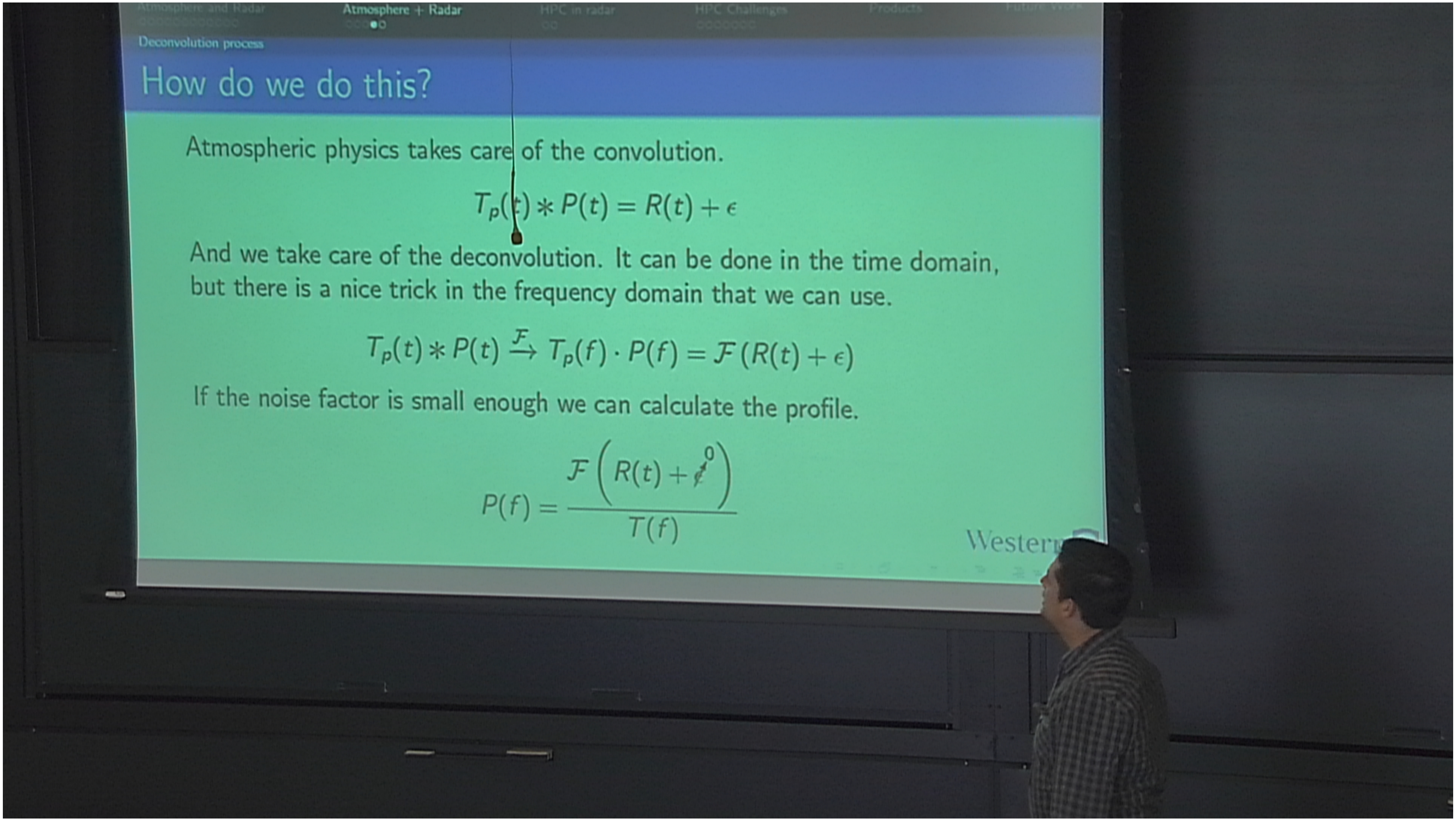

Welcome to Costa Rica's radar
Venezuela
Colombia

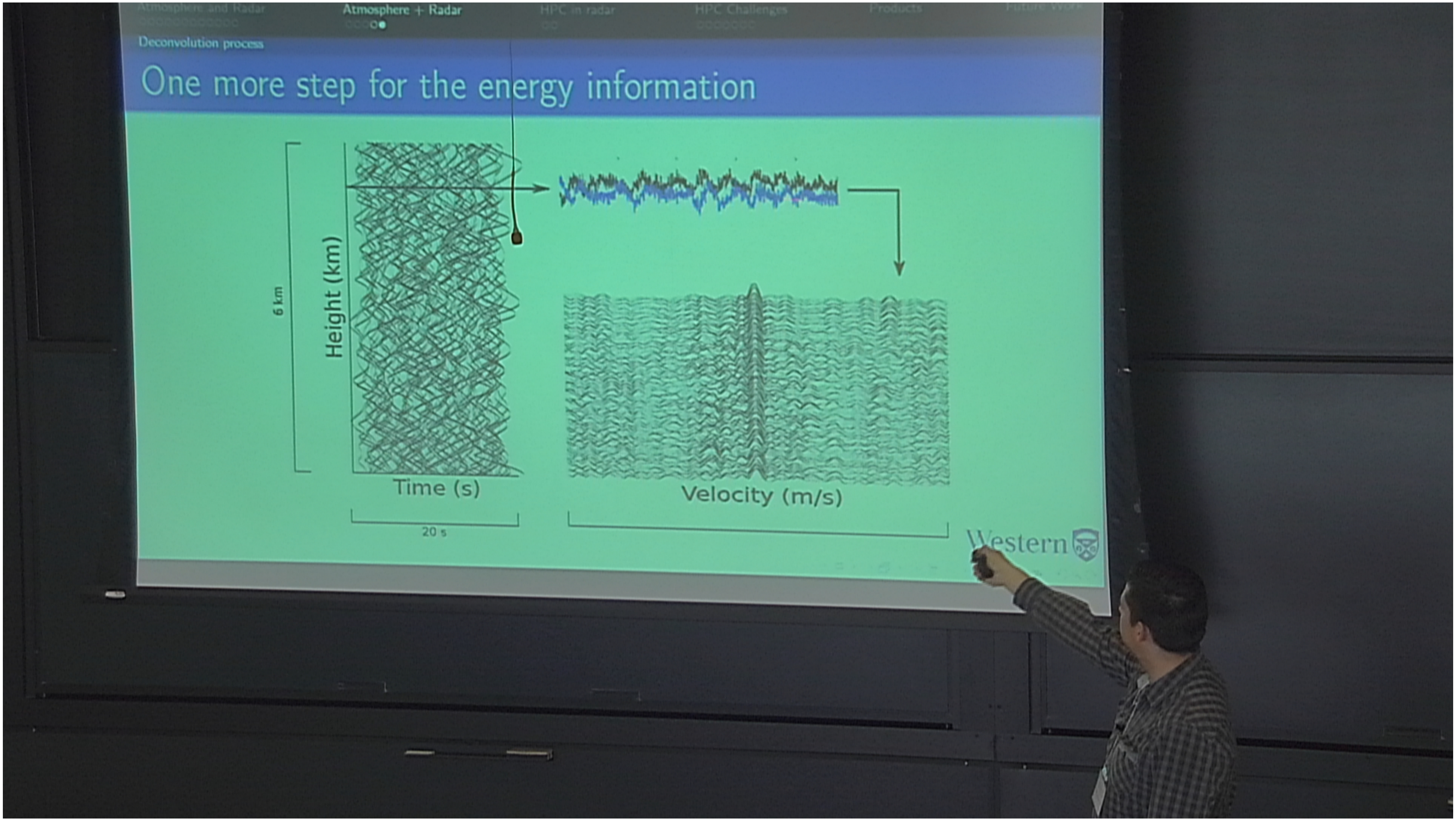

MST radar look


Atmosphere and Radar
Back to Radars
Radar basics
profile 1
profile 2
time
PL
t
IPP
Pulse Length
Inter Pulse Period
Western


Atmosphere and Radar
Atmosphere + Radar
HPC in radar
HPC Challenges
Products
Back to Radars
Radar equations
Distance to target
$R = \frac{c_o t}{2}$
Maximum unambiguous distance
$R_{amb} = \frac{c_o \cdot IPP}{2}$
Radar resolution
$R_{res} = \frac{c_o \cdot PL}{2}$
profile 1
profile 2
time
PL
t
IPP
Pulse Length
Inter Pulse Period
Western


Atmosphere + Radar
Ideal conditions
What are the ideal conditions to probe the atmosphere?
An ideal method to probe the atmosphere would require to have, high vertical resolution (meters) and high time resolution (minutes).
Radars can provide both under adequate conditions.
TIME: With a PRF of 3 kHz the time factor should be covered.
HEIGHT:
τ: Resolution of 1 km.
Small BW: Resolution of 600 m [Canada].
Large BW: Resolution of 60 m [Costa Rica].
Western


Atmosphere and Radar
Atmosphere + Radar
HPC in radar
HPC Challenges
Products
Future Work
Deconvolution process
How do we do this?
Atmospheric physics takes care of the convolution.
$T_p(t) * P(t) = R(t) + \epsilon$
And we take care of the deconvolution. It can be done in the time domain, but there is a nice trick in the frequency domain that we can use.
$T_p(t) * P(t) \xrightarrow{\mathcal{F}} T_p(f) \cdot P(f) = \mathcal{F}(R(t) + \epsilon)$
If the noise factor is small enough we can calculate the profile.
$P(f) = \frac{\mathcal{F}\left(R(t) + \not{\epsilon}^{0}\right)}{T(f)}$



Atmosphere + Radar
Deconvolution process
One more step for the energy information
Height (km)
6 km
Time (s)
20 s
Velocity (m/s)
Western

Here is where HPC comes in!

We gather 60032 sweeps of the atmosphere per measurement.

$$60032 sweeps \ \frac{1 measurement}{64 sweeps} = 938 profiles$$

$$60032 sweeps \ \frac{1s}{3071.76 sweeps} = 19.54s$$

Under optimal conditions we could gather more than 4×10^6 profiles per day. This becomes 6.5 Gb of RAW data. After the deconvolution process and the height analysis this becomes more than 50 Gb.

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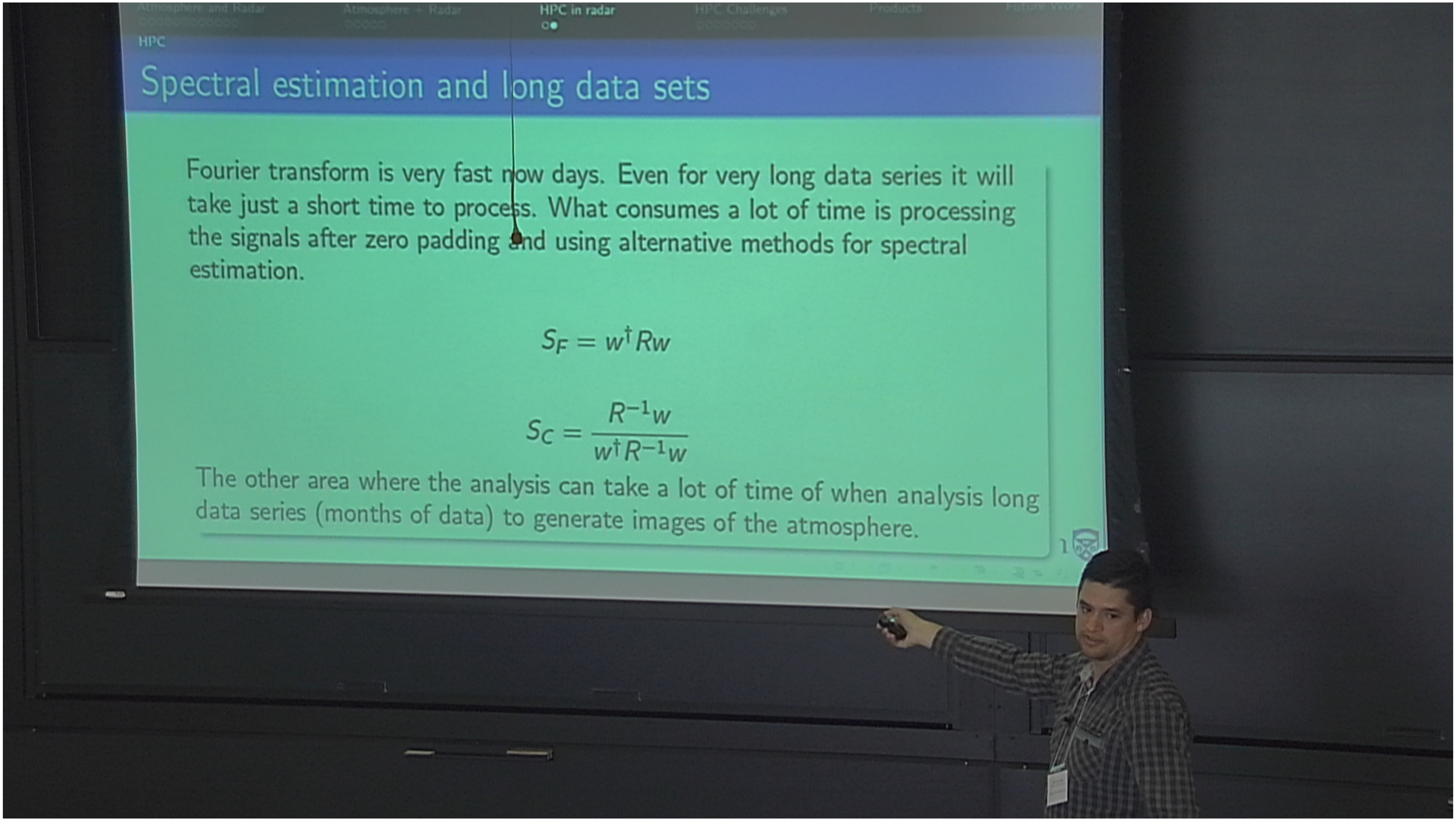
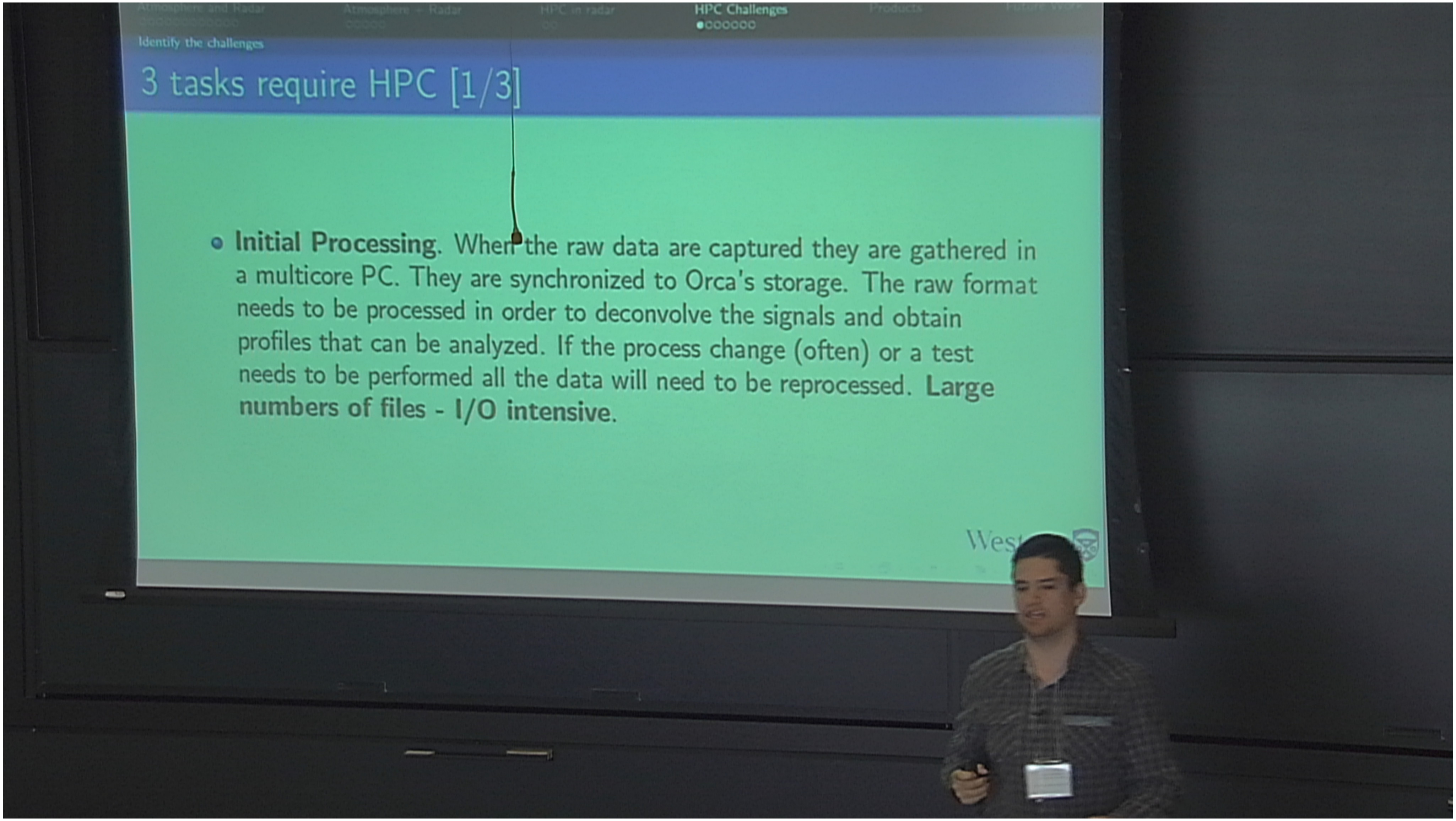
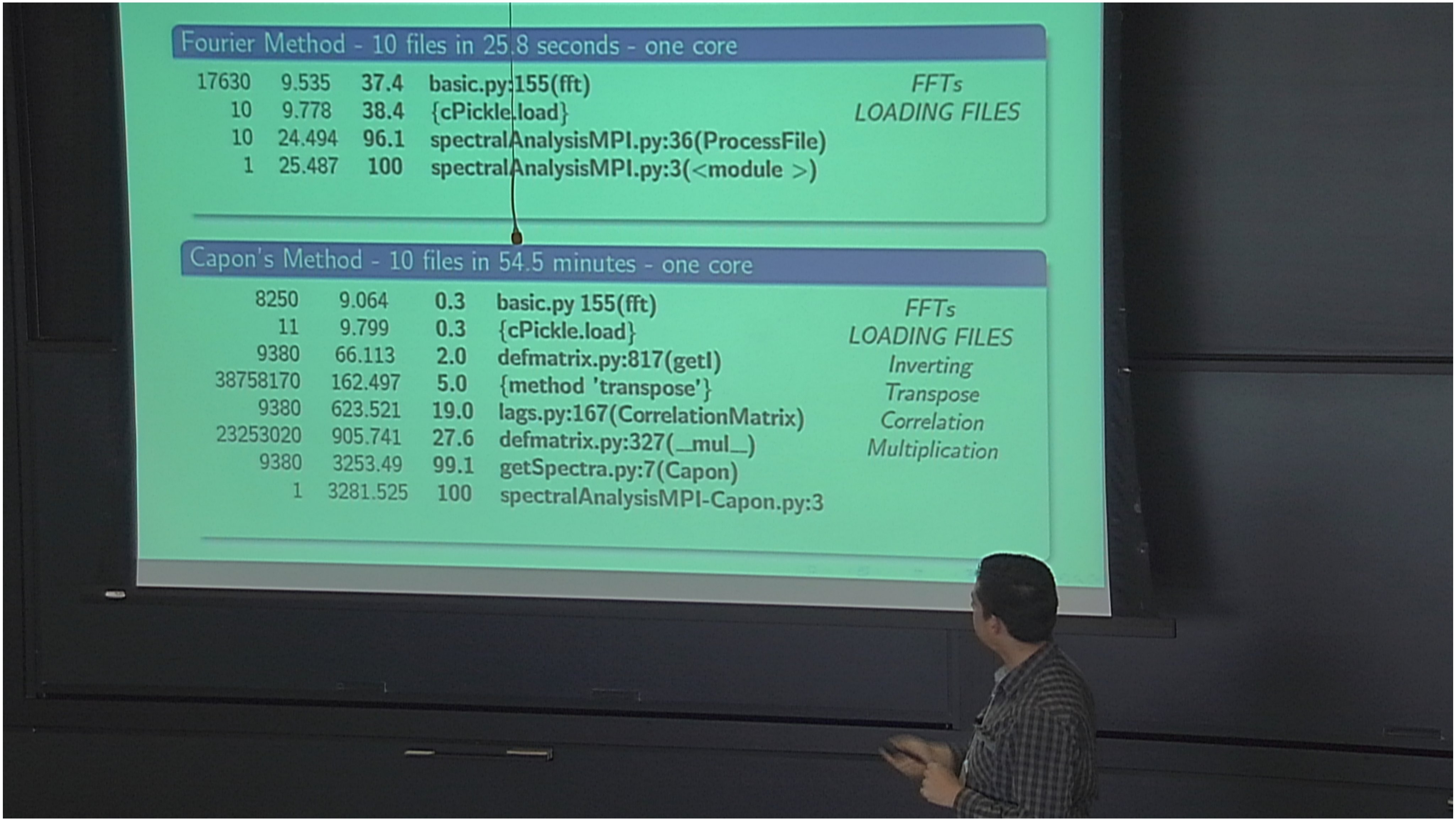
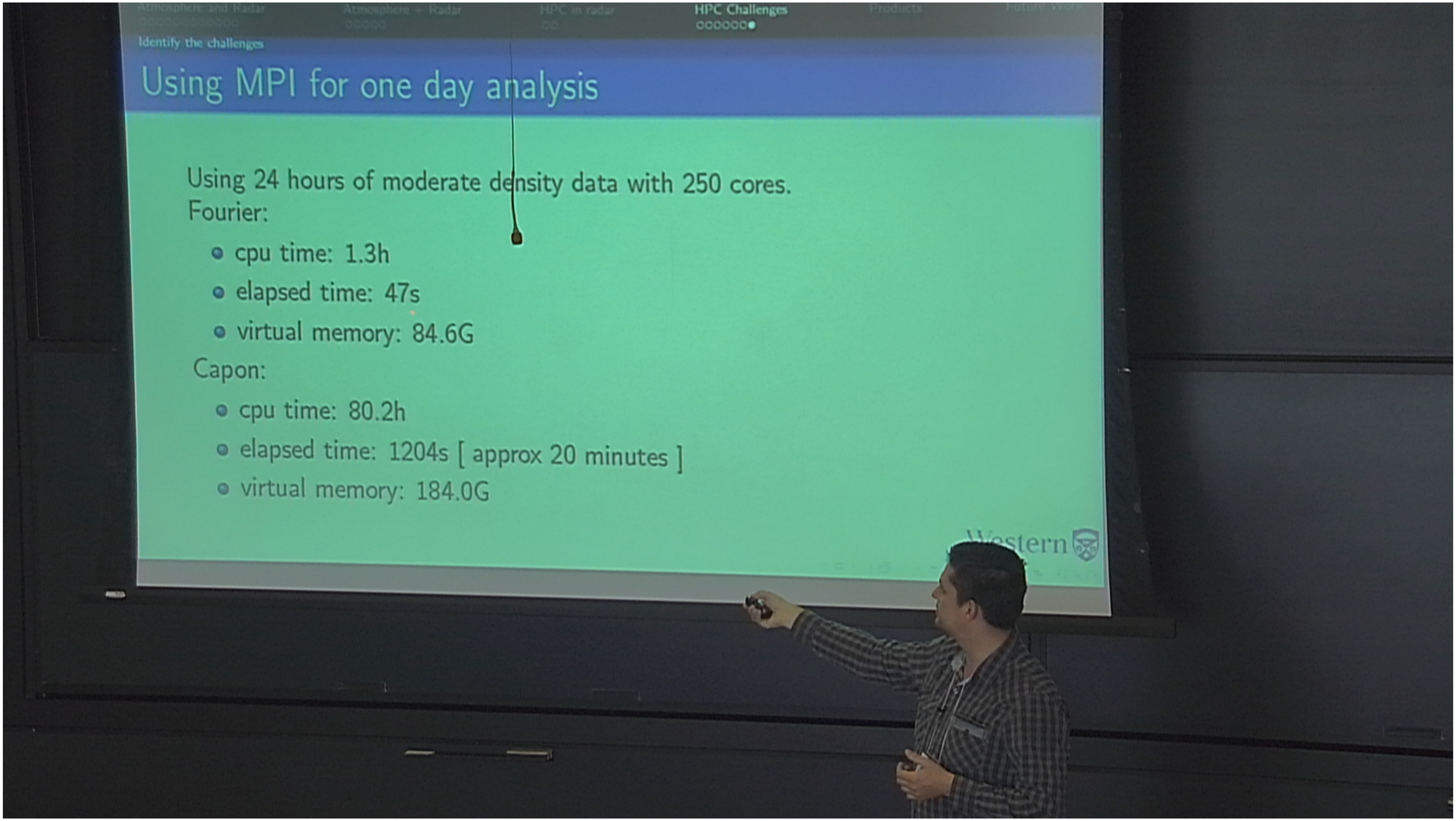
Western

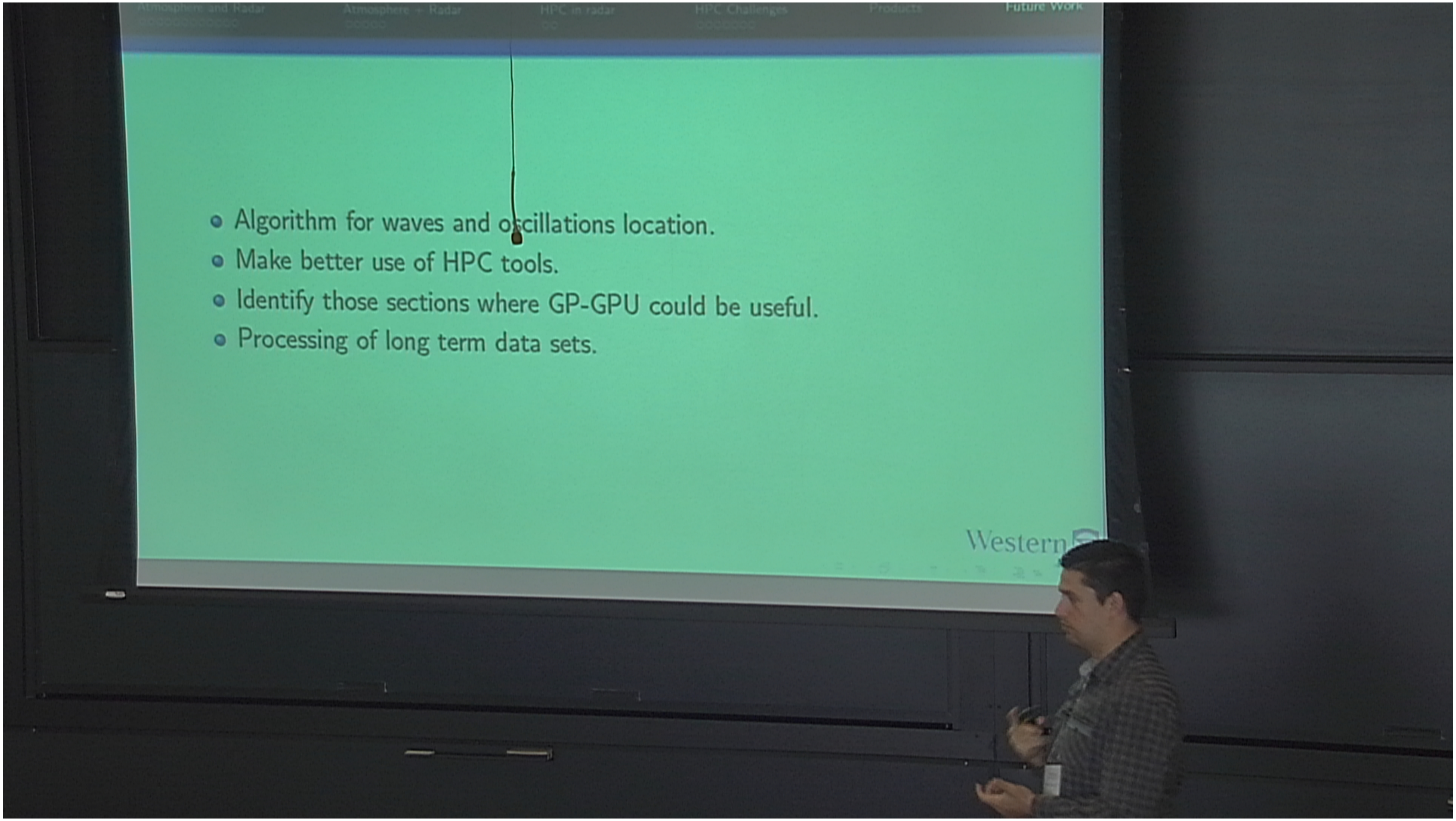

HPC in radar
HPC
Spectral estimation and long data sets
Fourier transform is very fast now days. Even for very long data series it will take just a short time to process. What consumes a lot of time is processing the signals after zero padding and using alternative methods for spectral estimation.
$S_F = w^\dagger R w$
$S_C = \frac{R^{-1} w}{w^\dagger R^{-1} w}$
The other area where the analysis can take a lot of time of when analysis long data series (months of data) to generate images of the atmosphere.


HPC Challenges
Identify the challenges
3 tasks require HPC [1/3]
Initial Processing. When the raw data are captured they are gathered in a multicore PC. They are synchronized to Orca's storage. The raw format needs to be processed in order to deconvolve the signals and obtain profiles that can be analyzed. If the process change (often) or a test needs to be performed all the data will need to be reprocessed. Large numbers of files - I/O intensive.


Fourier Method - 10 files in 25.8 seconds - one core
17630 9.535 37.4 basic.py:155(fft) FFTs
10 9.778 38.4 {cPickle.load} LOADING FILES
10 24.494 96.1 spectralAnalysisMPI.py:36(ProcessFile)
1 25.487 100 spectralAnalysisMPI.py:3(<module >)
Capon's Method - 10 files in 54.5 minutes - one core
8250 9.064 0.3 basic.py 155(fft) FFTs
11 9.799 0.3 {cPickle.load} LOADING FILES
9380 66.113 2.0 defmatrix.py:817(getI) Inverting
38758170 162.497 5.0 {method 'transpose'} Transpose
9380 623.521 19.0 lags.py:167(CorrelationMatrix) Correlation
23253020 905.741 27.6 defmatrix.py:327(__mul__) Multiplication
9380 3253.49 99.1 getSpectra.py:7(Capon)
1 3281.525 100 spectralAnalysisMPI-Capon.py:3


HPC Challenges
Identify the challenges
Using MPI for one day analysis
Using 24 hours of moderate density data with 250 cores.
Fourier:
cpu time: 1.3h
elapsed time: 47s
virtual memory: 84.6G
Capon:
cpu time: 80.2h
elapsed time: 1204s [approx 20 minutes]
virtual memory: 184.0G
Western


Products
Jan, 2014. 1st - 7th. cpu time: 16.4h. elapsed time: 269s. memory: 177.6G.
Height (km)
4
3
2
Jan/1
Jan/2
Jan/3
Jan/4
Jan/5
Jan/6
Jan/7
Jan/8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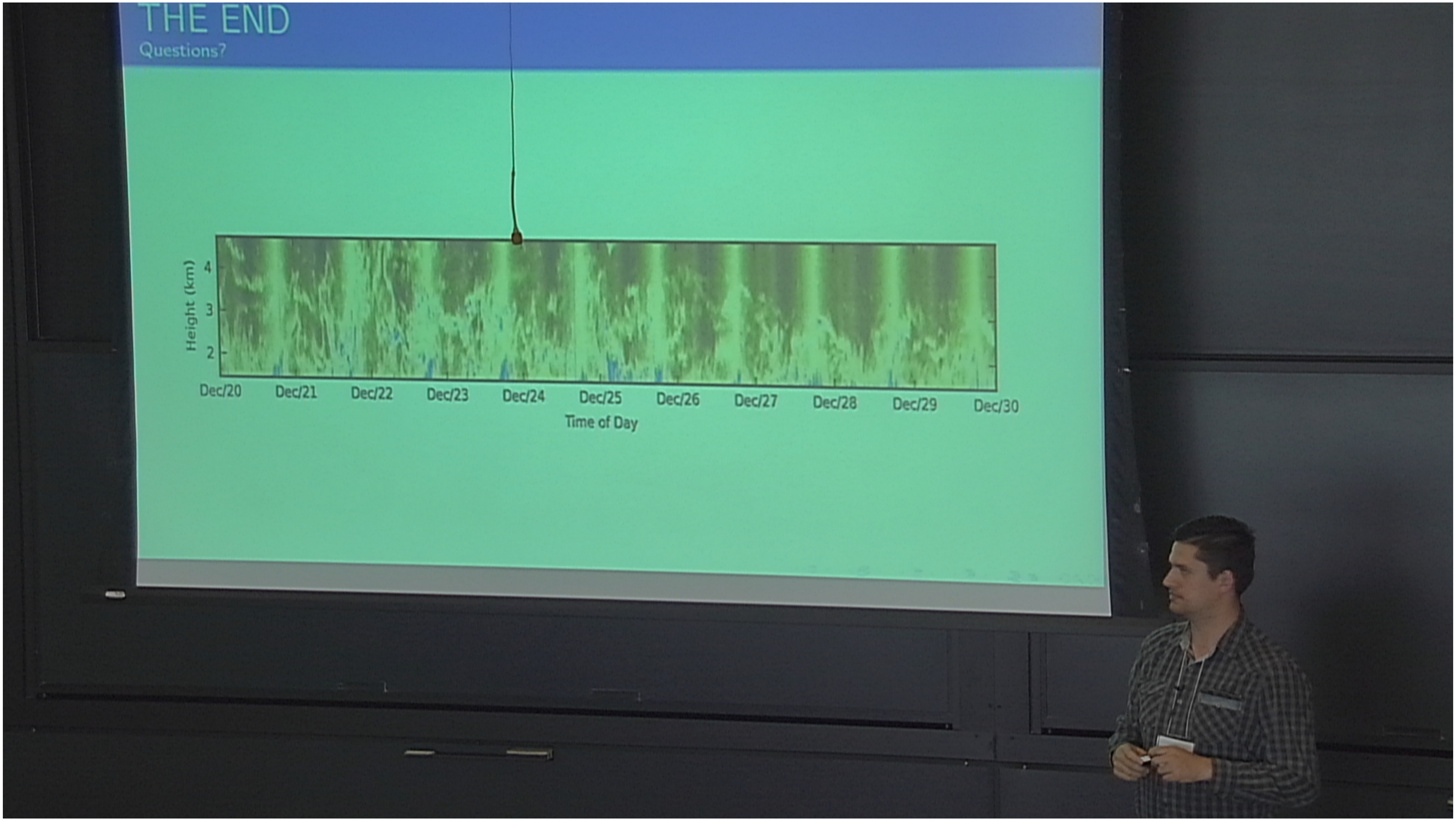
HPC Challenges
Products
Future Work
Algorithm for waves and oscillations location.
Make better use of HPC tools.
Identify those sections where GP-GPU could be useful.
Processing of long term data sets.
Western


THE END
Questions?
Height (km)
4
3
2
Dec/20
Dec/21
Dec/22
Dec/23
Dec/24
Dec/25
Dec/26
Dec/27
Dec/28
Dec/29
Dec/30
Time of Day