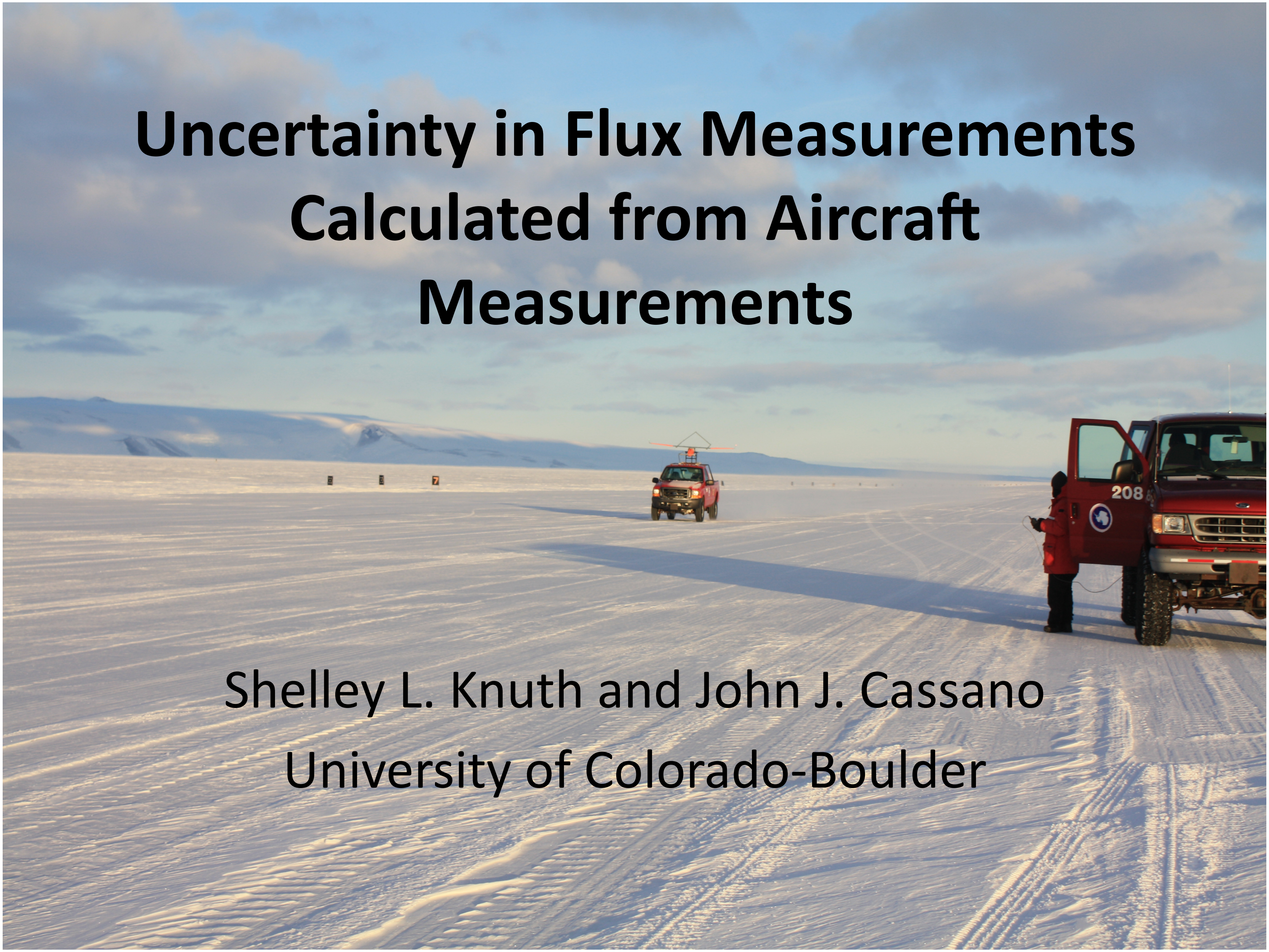

Uncertainty in Flux Measurements Calculated from Aircraft Measurements

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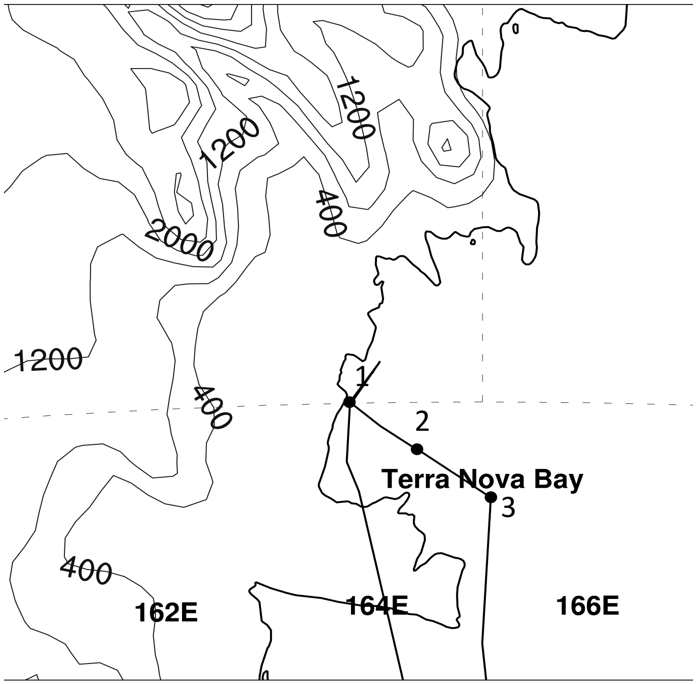
Purpose

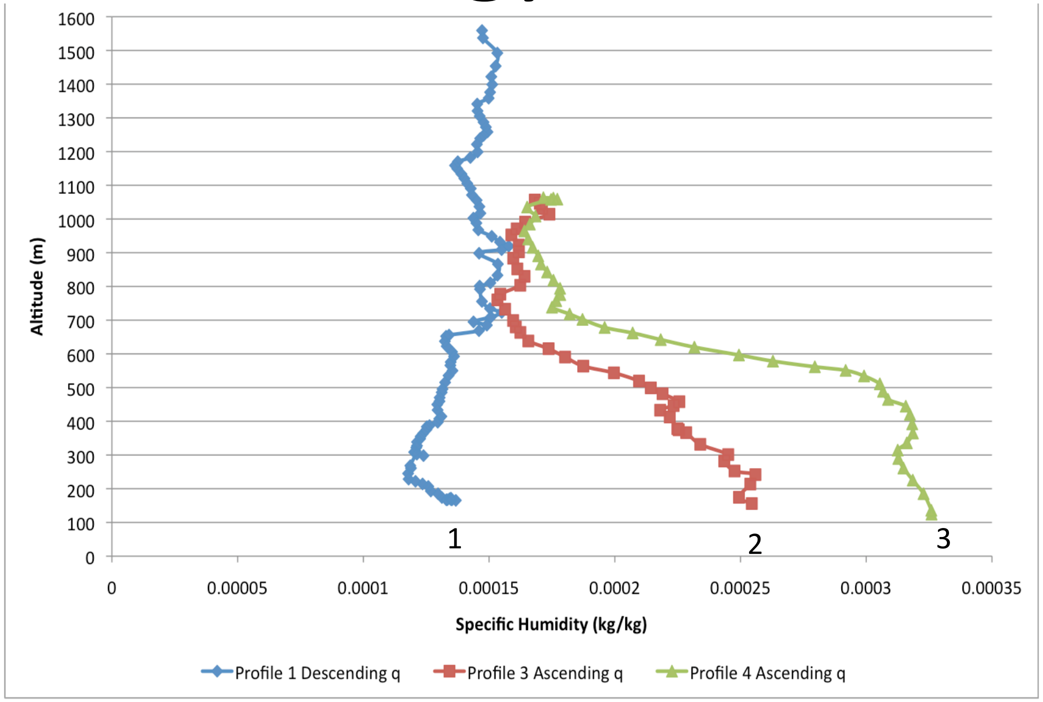
- Level of uncertainty with any kind of measurement
- In calculation of fluxes described earlier, there are two types of uncertainty
  - Scientific Method
  - Instrument error
- Question: What is the uncertainty associated with the sensible and latent heat fluxes calculated in Terra Nova Bay from the UAV data?

Scientific Method

- Several ways of calculating fluxes that are scientifically viable
- Depending on each situation and available data, one method might be more accurate than another
- Important to assess how the fluxes change depending on the method used

General Methodology

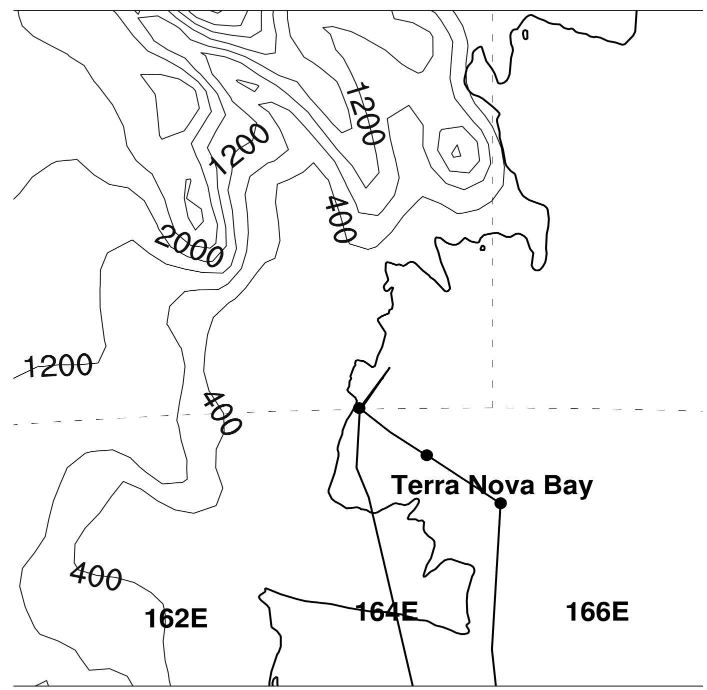




- Collect measurements from the downwind transect over polynya
- Consider how temperature, pressure, wind speed, and relative humidity change between vertical profile locations
- Examine how sensible, latent heat changed in the atmosphere between profiles

Alternatives to General Methodology

- The way we've set up our calculations are Lagrangian
- But the way we sample the atmosphere with the UAV is not
- Must correct calculation so that UAV is measuring the same air parcel in the downstream profile as it did in the upstream one
- Calculate fluxes incorporating non-Lagrangian processes

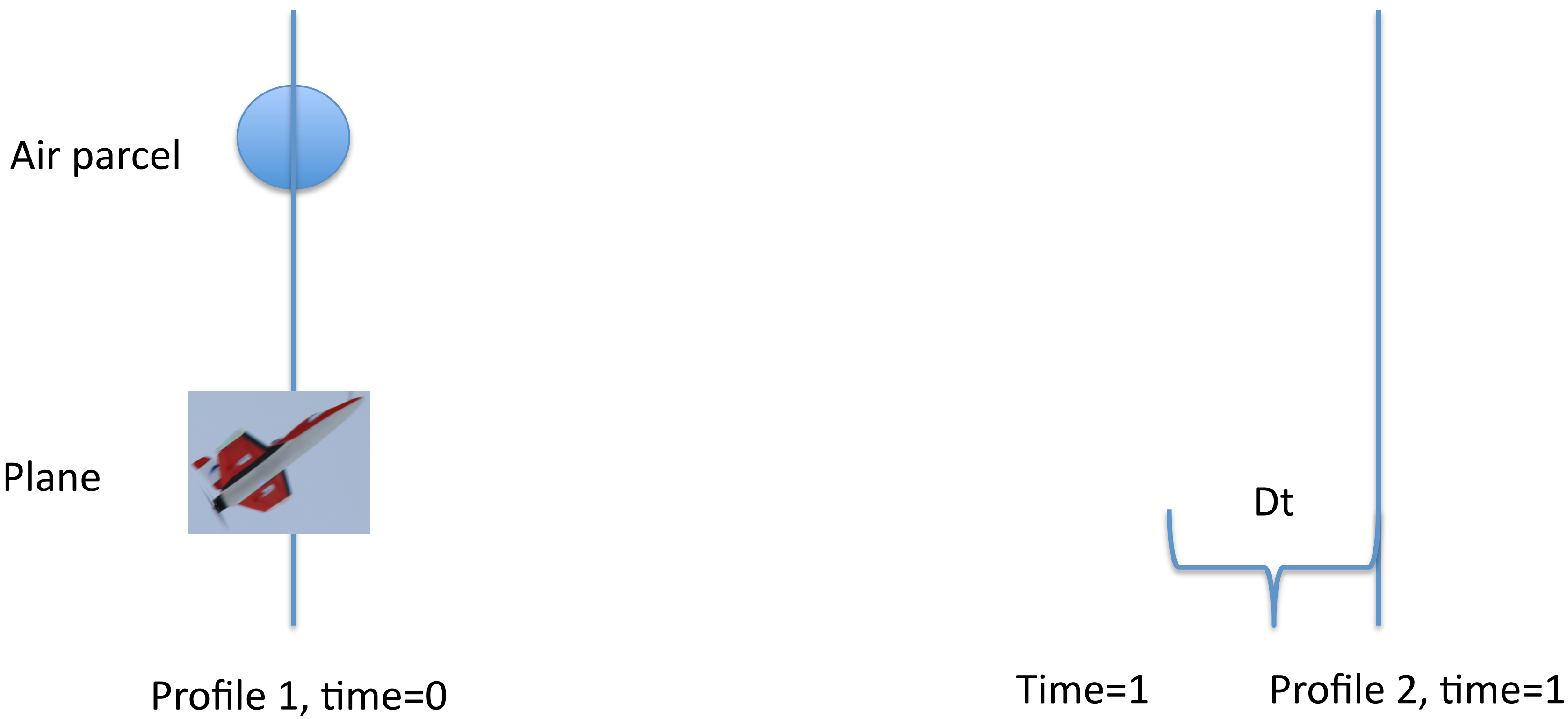


Non-Lagrangian Processes

- Two perspectives: time and space
- Time: the UAV measures the downstream profile at the same location as the original air parcel, but at the wrong time
  - Leave Profile 1 at same time, UAV measures Profile 2 at a different time than the air parcel (i.e., 10 minutes later)
- Space: the UAV makes a measurement at the same time as the air parcel, but isn't located in the same place

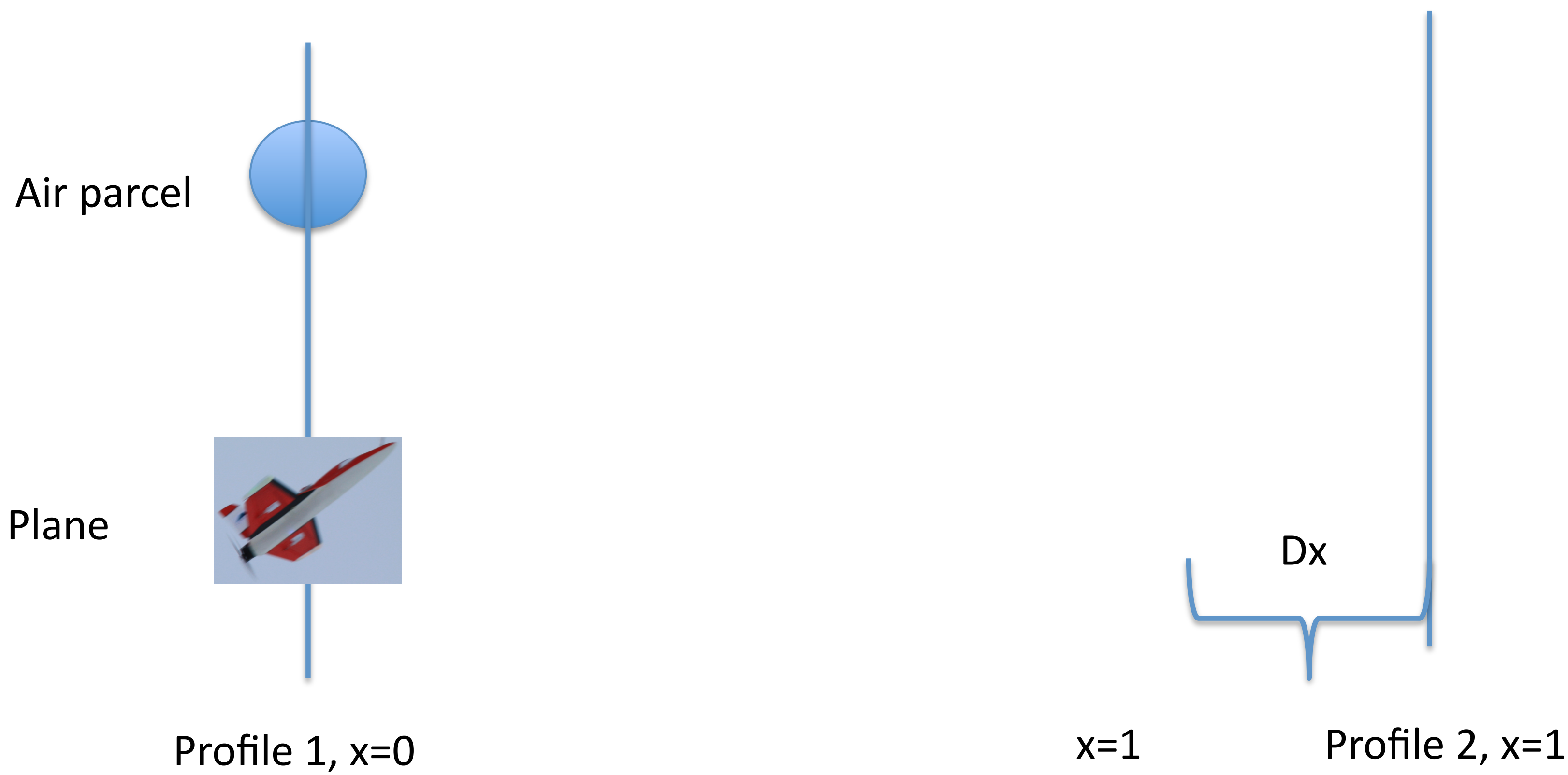
Time and Space Perspectives

- Time perspective:



Time and Space Perspectives

- Space perspective:



Time and Space Perspectives

- General methodology:

$$\frac{DT}{Dt} = \frac{\partial T}{\partial t} + \vec{u} \cdot \nabla T = Q + Ad$$

$$SHF = \frac{(\int C_p \rho T\, dz)_2 - (\int C_p \rho T\, dz)_1}{time_{21}}$$

- Correct atmospheric variable (i.e., temperature) to account for Dx or Dt
- Correction term:

$$\Delta T_{corr} = \left(\frac{\partial T}{\partial t} + u\,\frac{\partial T}{\partial x}\right)\delta t = Q\delta t + (Ad)\delta t$$

Time

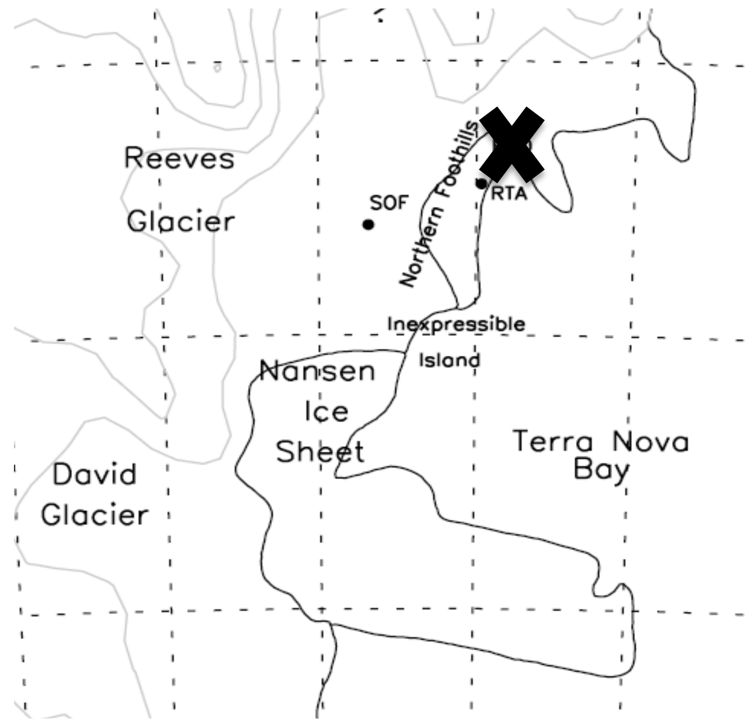
Space

Time and Space Perspectives

- Which one is more correct?
  - From a purely scientific perspective, neither
  - In the case of the UAV measurements, the space perspective

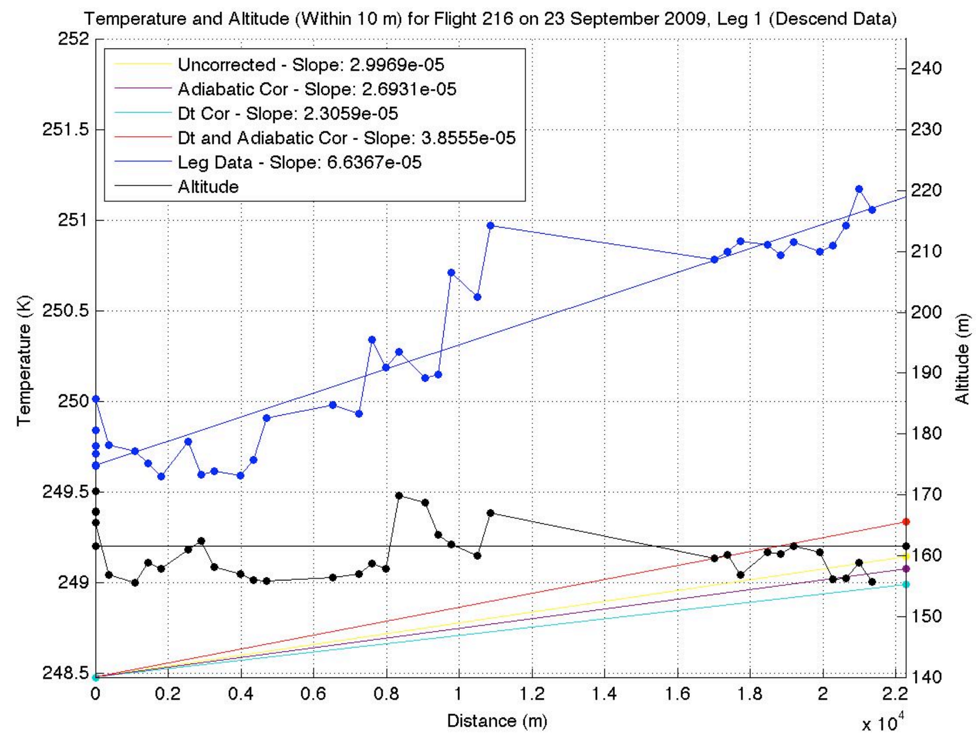
Why is Space more accurate?

- $\frac{\partial T}{\partial t}$ is only available from Eneide AWS
- Hourly readings
- Upwards of 50-60 km away from UAV measurements
- In a different atmospheric regime
- Not a good representation so do not want correction to rely solely on this term



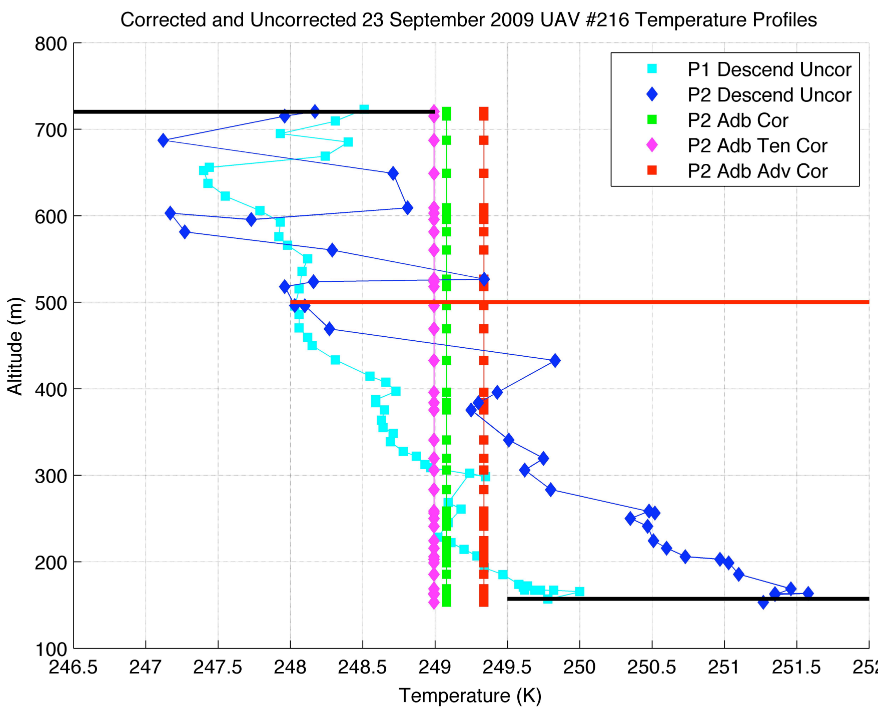
Why is Space more accurate?

- $u\frac{\partial T}{\partial x}$ is based on UAV readings between profile locations
- Much more accurate representation of atmospheric processes over TNB



Corrections to Flux Calculations

- Non-Lagrangian
- Adiabatic processes (SH flux only)
- Winds rotated along the flight path
- Same mass in both profiles
- Sensor lag



- Will present six different flux calculations
  - Uncorrected
    - Starting point to compare to
  - Incorporating changes due to adiabatic processes only
  - Incorporating time perspective changes only
  - Incorporating space perspective changes only
  - Incorporating time perspective and adiabatic changes
  - Incorporating space perspective and adiabatic changes
    - Most accurate correction
- Allows us to explore the impact of each correction on the fluxes

Uncertainty in Calculations, 23 Sept, Profiles 1-2

SH Fluxes	Values (Wm^{-2})	Correction Applied to Uncorrected Flux (Wm^{-2})	Percent of Space Perspective, Adiabatic Correction (%)
Uncorrected	403	0	77
Adiabatic Correction Only	361	(361-403)= -42	-8
Space Perspective Correction Only	563	(563-403)= 160	31
Adiabatic and Space Perspective Correction	520	(-42+160)= 118	23

- Shows how each correction contributes to the space perspective/adiabatic correction
- Adiabatic correction changes uncorrected flux by -42 Wm^{-2}
- Space perspective changes uncorrected flux by 160 Wm^{-2}
- Leads to a total flux change of 118 Wm^{-2}

Uncertainty in Calculations, 23 Sept, Profiles 1-2

SH Fluxes	Values (Wm^{-2})	Correction Applied to Uncorrected Flux (Wm^{-2})	Percent of Time Perspective, Adiabatic Correction (%)
Uncorrected	403	0	131
Adiabatic Correction Only	361	(361-403)= -42	-13
Time Perspective Correction Only	351	(351-403)= -52	-17
Adiabatic and Time Perspective Correction	308	(-42+-52)= -94	-31

- Shows how each correction contributes to the space perspective/adiabatic correction
- Adiabatic correction changes uncorrected flux by -42 Wm^{-2}
- Space perspective changes uncorrected flux by -52 Wm^{-2}
- Leads to a total flux change of -94 Wm^{-2}

Uncertainty in Calculations, 23 Sept, Profiles 1-2

SH Fluxes	Values (Wm^{-2})	Correction Applied to Uncorrected Flux (Wm^{-2})	Percent of Time Perspective, Adiabatic Correction (%)
Adiabatic and Time Perspective Correction	351	0	0
Adiabatic and Space Perspective Correction	520	169	48

- Here, compare the two perspectives side by side
- Have a flux change of 169 Wm^{-2}
- It is NOT accurate to say that we have an uncertainty of 169 Wm^{-2} however.
- This is because time perspective is not an appropriate flux calculation for 2009

Instrument Accuracy

- All instruments will operate with a certain degree of inaccuracy
  - Temperature, etc measurements might change only due to instrument fluctuations
- Assess how much fluxes change due to instrument fluctuations
  - Introduce random error to each observation within each instrument accuracy range

Instrument Accuracy

Time (s)	Old Temperature Value (C)	Correction Value	New Temperature (C)
0	-10	0.09	-9.91
1	-10.1	0.04	-10.06
2	-10.2	-0.0003	-10.2003
3	-10.3	-0.0222	-10.3222
4	-10.4	-0.1	-10.5
5	-10.5	0.012	-10.488

- Use the new temperature values in flux calculations
- Test changes only in temperature, only in RH, only in pressure, and only in wind speed, and then random corrections for all four values
- Allows us to assess the importance of each measurement

Instrument Accuracy – 23 September

	SH – Instrument Corrections Added	SH – No Instrument Corrections Added
Average	519.43	519.77
Max	567.31	
Min	470.61	
+/- 1 Std. Deviation +/- 2 Std. Deviation	+/- 9.89 +/- 19.79	

- Data shown for most correct values (space perspective, adiabatic correction)
- Can see that implementing an overall correction does not change flux much

Temp Corrections Only	SH – Instrument Corrections Added	SH – No Instrument Corrections Added
Average	519.63	519.77
Max	549.19	
Min	492.91	
+/- 1 Std. Dev. +/- 2 Std. Dev.	+/- 10.31 +/- 20.62	

RH Corrections Only	SH – Instrument Corrections Added	SH – No Instrument Corrections Added
Average	519.77	519.77
Max	519.77	
Min	519.77	
+/- 1 Std. Dev. +/- 2 Std. Dev.	+/- 5.82×10^{-4} +/- 1.16×10^{-3}	

- Data shown for most correct values (space perspective, adiabatic correction)
- Can see that implementing an overall correction does not change flux much
- Temperature and pressure have cause largest flux variability

Pressure Corrections Only	SH – Instrument Corrections Added	SH – No Instrument Corrections Added
Average	519.19	519.77
Max	549.11	
Min	484.18	
+/- 1 Std. Dev. +/- 2 Std. Dev.	+/- 10.58 +/- 21.16	

Wind Speed Corrections Only	SH – Instrument Corrections Added	SH – No Instrument Corrections Added
Average	519.52	519.77
Max	531.92	
Min	504.78	
+/- 1 Std. Dev. +/- 2 Std. Dev.	+/- 4.98 +/- 9.95	

Conclusions

- Uncertainty in flux values from TNB UAV calculations based on:
  - Scientific method
  - Instrument accuracy
- Varying perspectives show a difference in flux of 169 Wm^{-2}
- However, this isn't the true uncertainty because one perspective is not an appropriate measurement
- Instrument variability accounts for minor flux changes (<10 Wm^{-2})

Future Work

- Can more accurately assess the uncertainty from 2012 data
- Repeat sampling of the 2012 downwind TNB transect allows for better representation of local time rate of change of atmosphere
- Will also assess other areas of uncertainty in measurements

Questions?

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