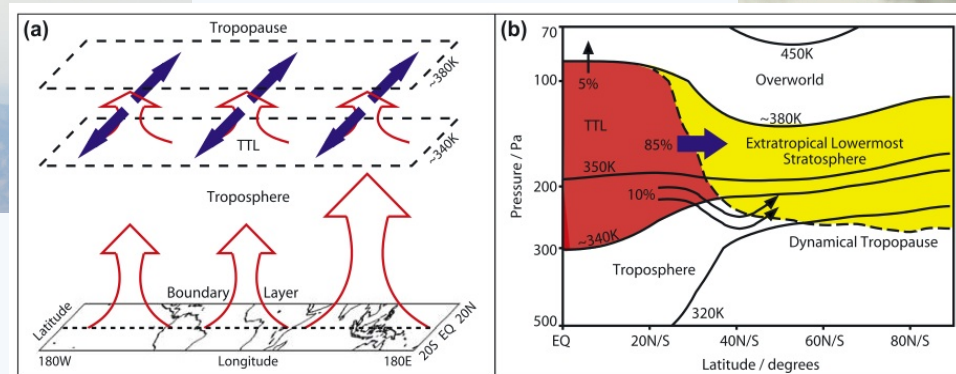
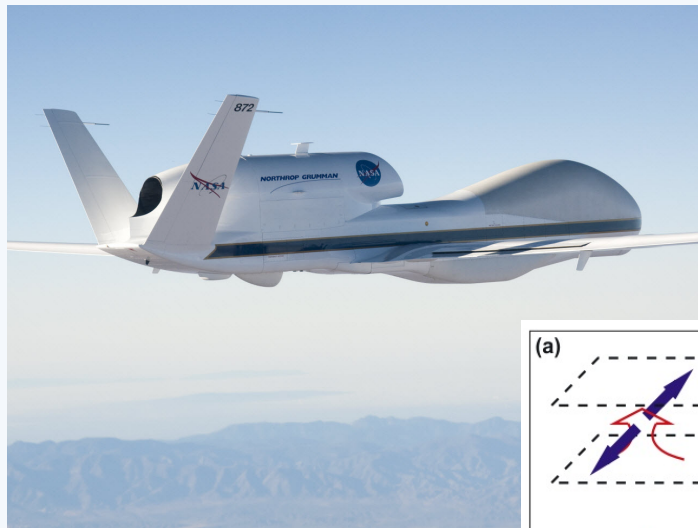


# CAST - Coordinated Airborne Studies in the Tropics

## Overview and aircraft planning

Neil Harris

University of Cambridge



## Outline

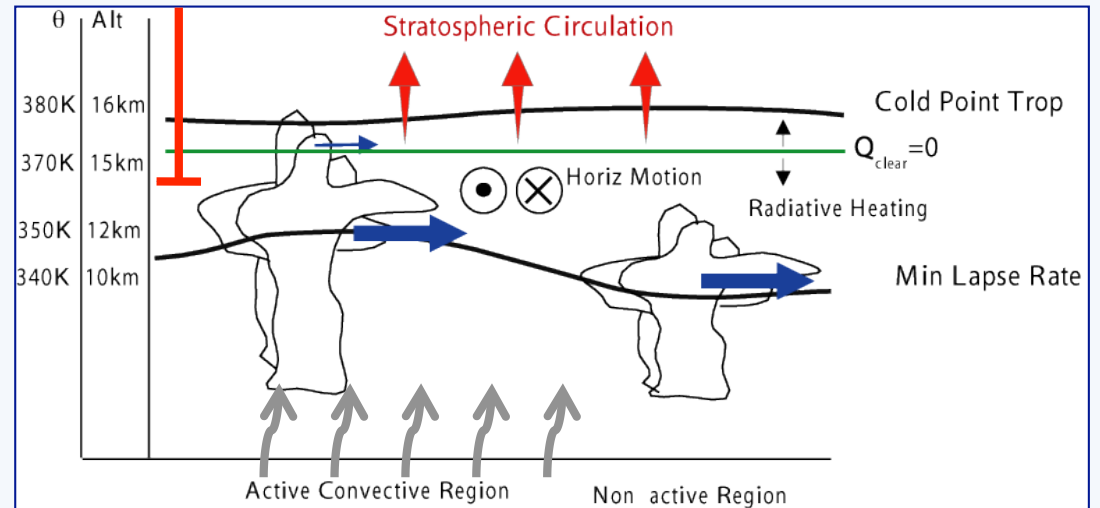
1. Rationale
2. Capability
3. Flight planning



# Collaboration with ATTREX

## Issues

- Tropical tropopause layer
- Transport pathways / convection
- Short-lived halogen compounds
- T & humidity
- TTL cirrus
- Effect of changing climate



## Approach

- Four ATTREX missions :

Fall 2011: integration & science flights from NASA Dryden (Dryden, California)

Jan-Feb 2013: Pacific deployment (Dryden)

★ Jan-Feb 2014: Pacific deployment (\*Guam) ★

Jun-Jul 2014: Darwin (or alternate)

- ATTREX: looking at warm pool and can reach it from afar
- Payload is mainly for tracers with some radiation and ice particles

Add ability for surface & low altitude measurements

# CAST

## Science focus: TTL composition and transport

1. Transport processes in the Tropical Tropopause Layer (TTL)
2. VSL compounds in the Tropical atmosphere
3. Role of cirrus (including SVC) in the Tropics

Measurements and modelling

*coordinated aircraft campaign (Global Hawk, **FAAM BAe-146**)*

***ground-based and sonde measurements***

*suite of models for interpretation of TTL measurement*

## Additional aims

4. Develop a UK measurement capability for use on the NASA Global Hawk

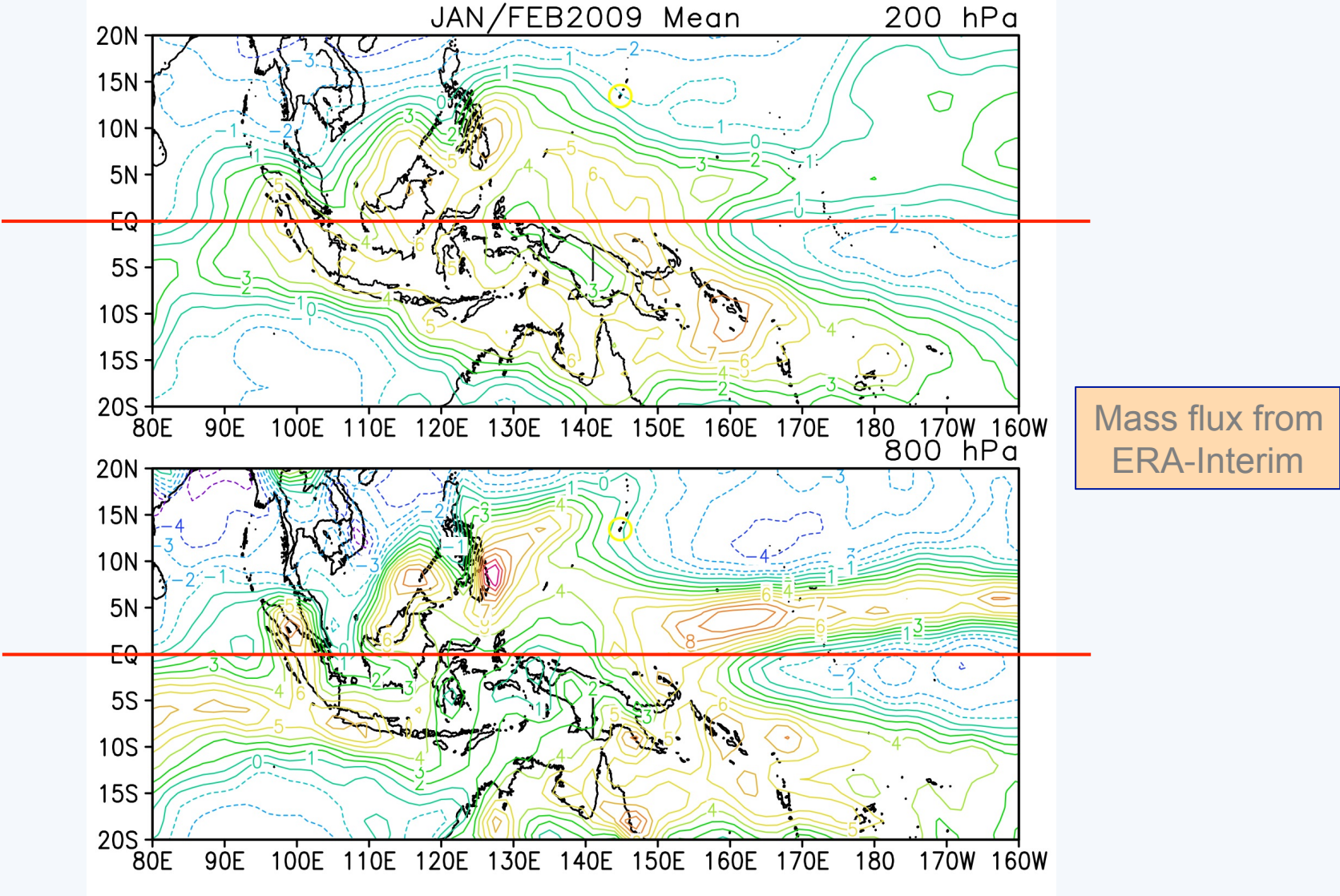
*in situ measurements of aerosol-ice transition (APC/AIITS)*

*below aircraft column measurements of CO<sub>2</sub> & CH<sub>4</sub>*

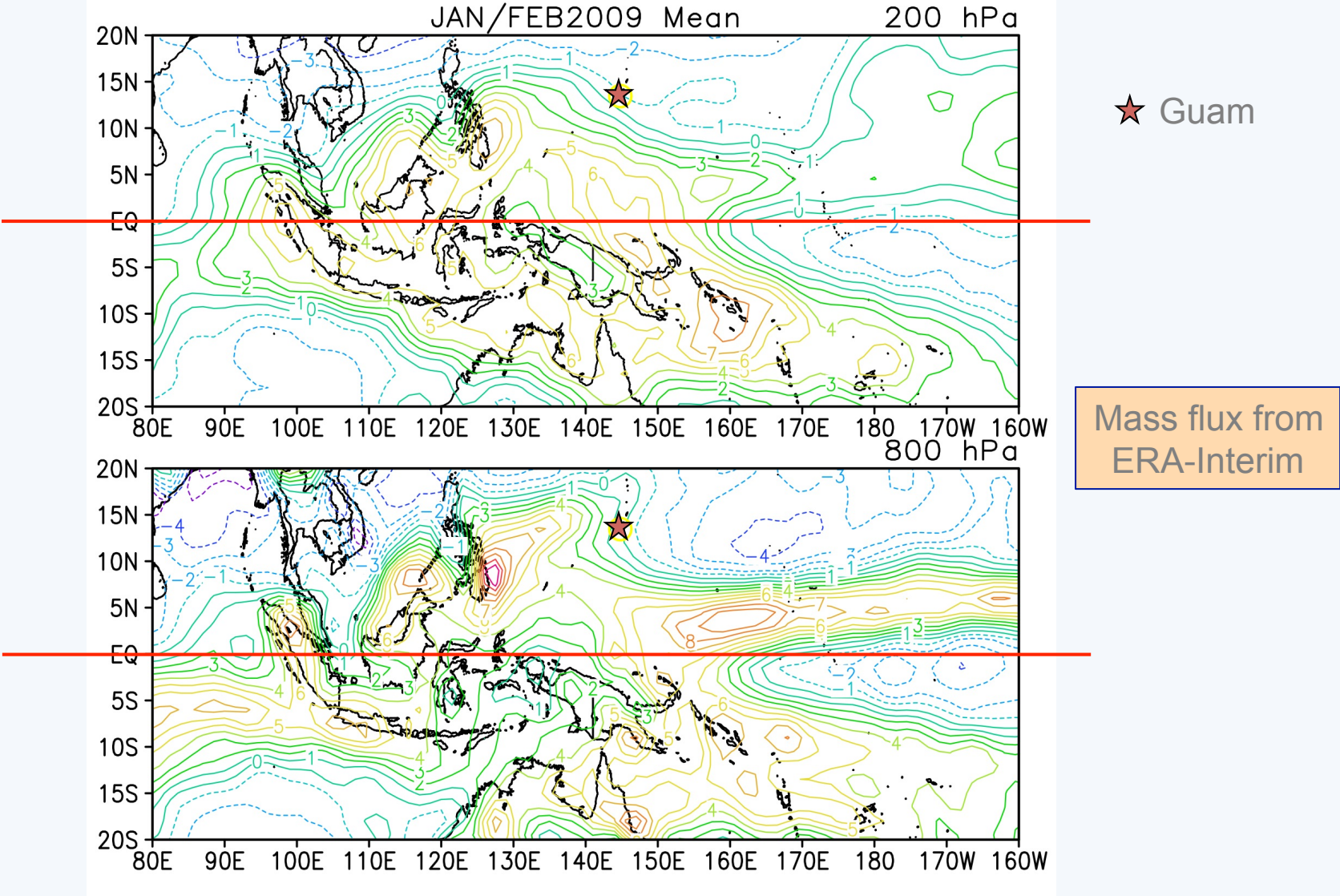
*software for real-time data analysis*

5. Build expertise / gain experience in creating and implementing Global Hawk flight plans

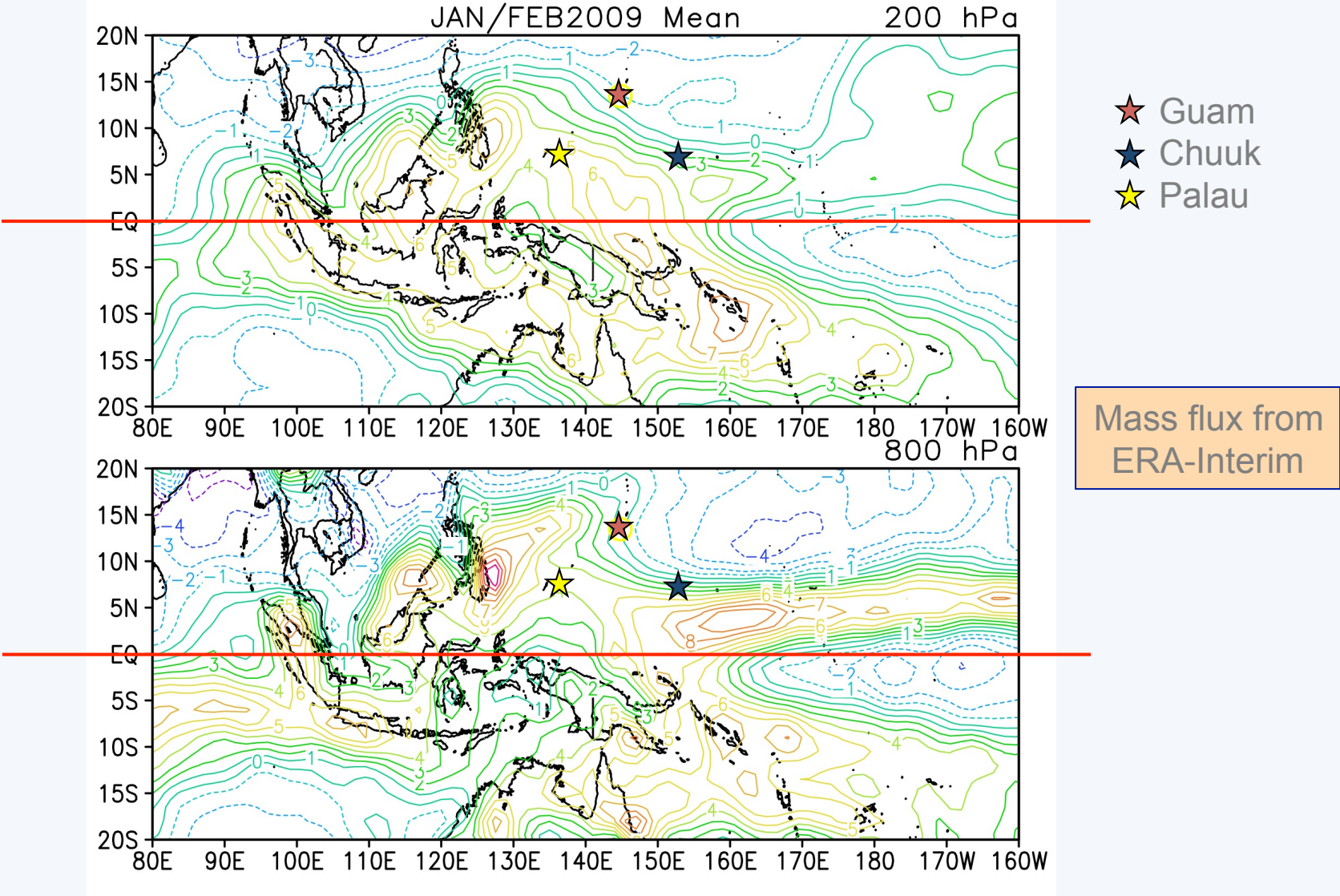
Guam: in downwelling region, but near strong upwelling region  
BAe-146 to measure across transition and into upwelling region



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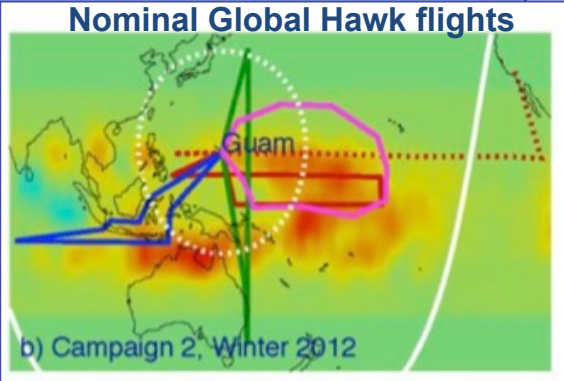
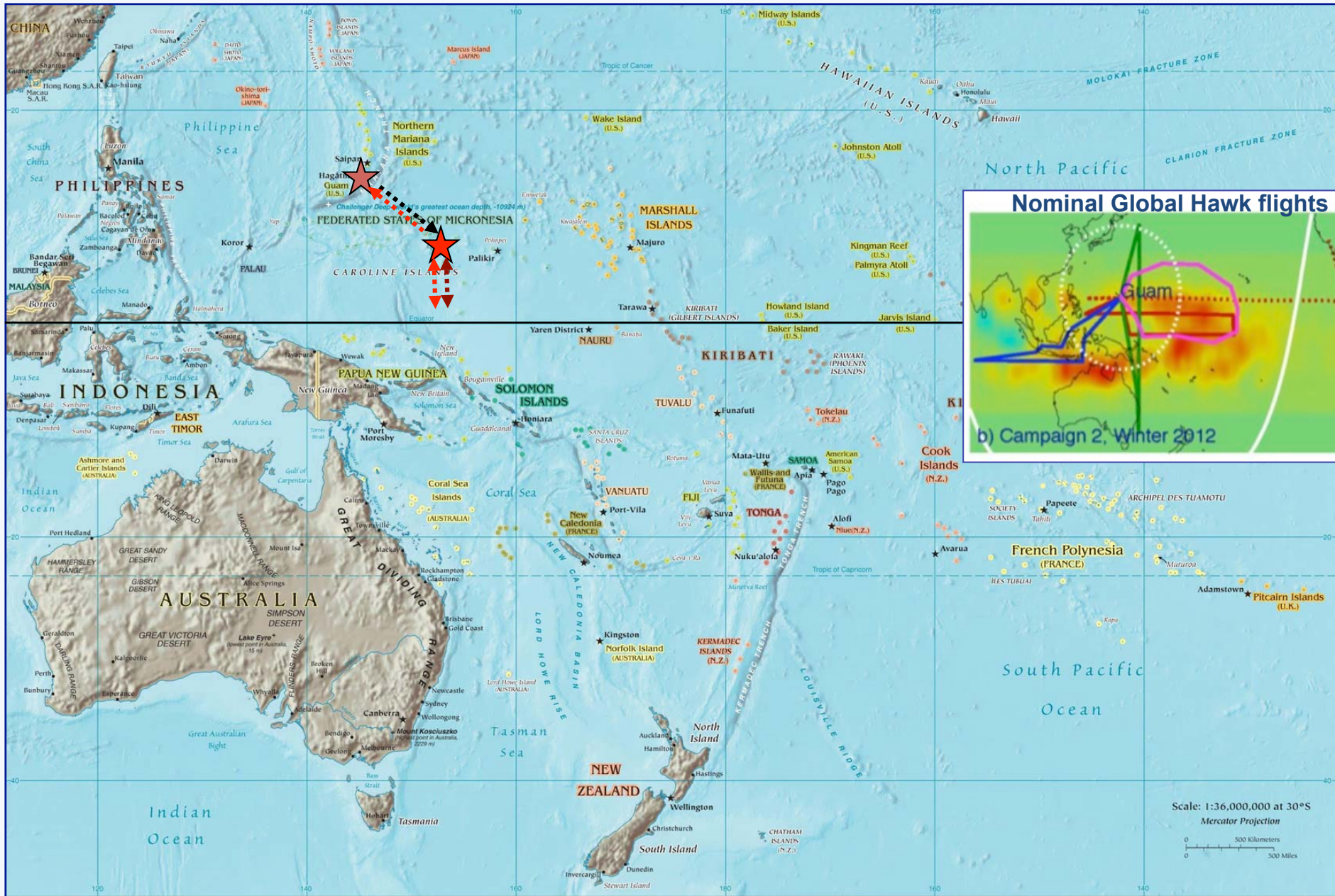


Guam: in downwelling region, but near strong upwelling region  
BAe-146 to measure across transition and into upwelling region



- ★ Chuuk (7.5N, 152E)
- ★ Guam

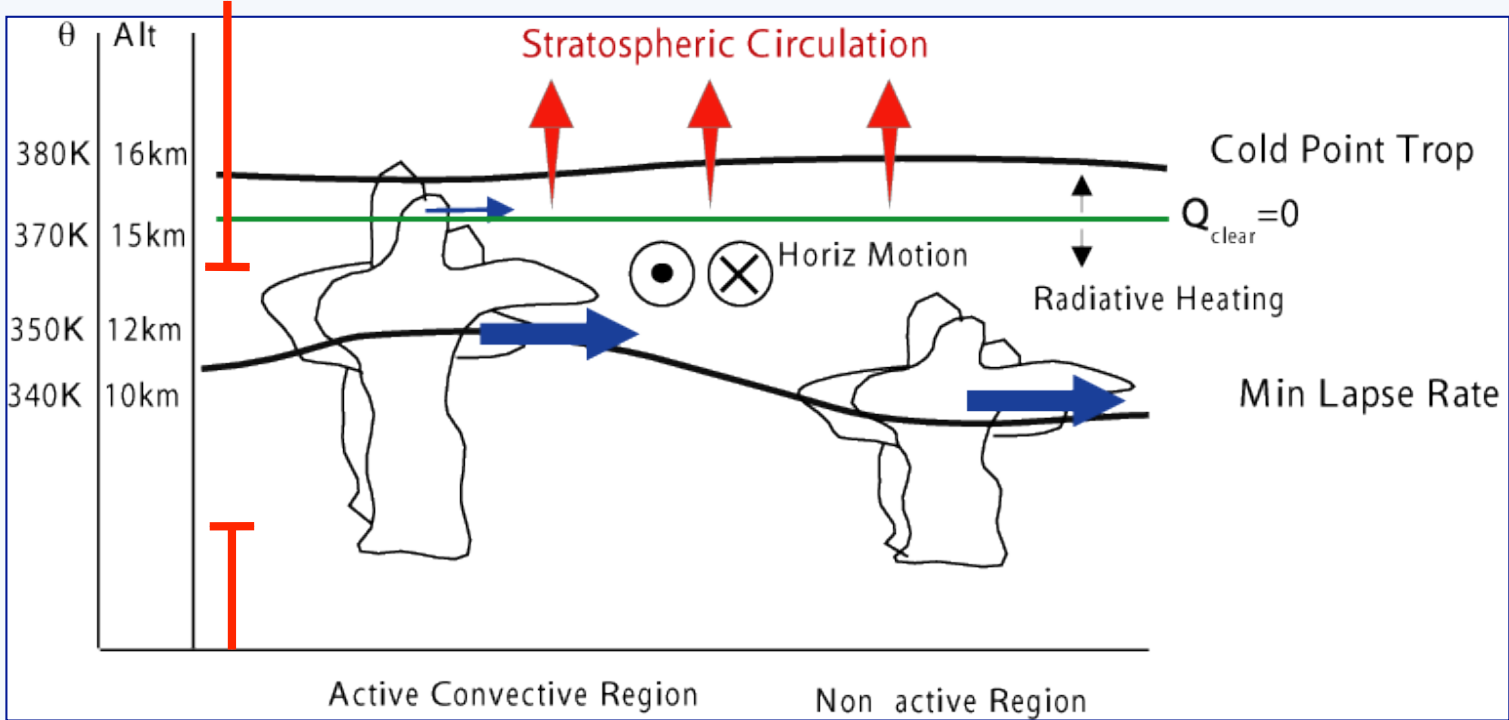
# Measurements



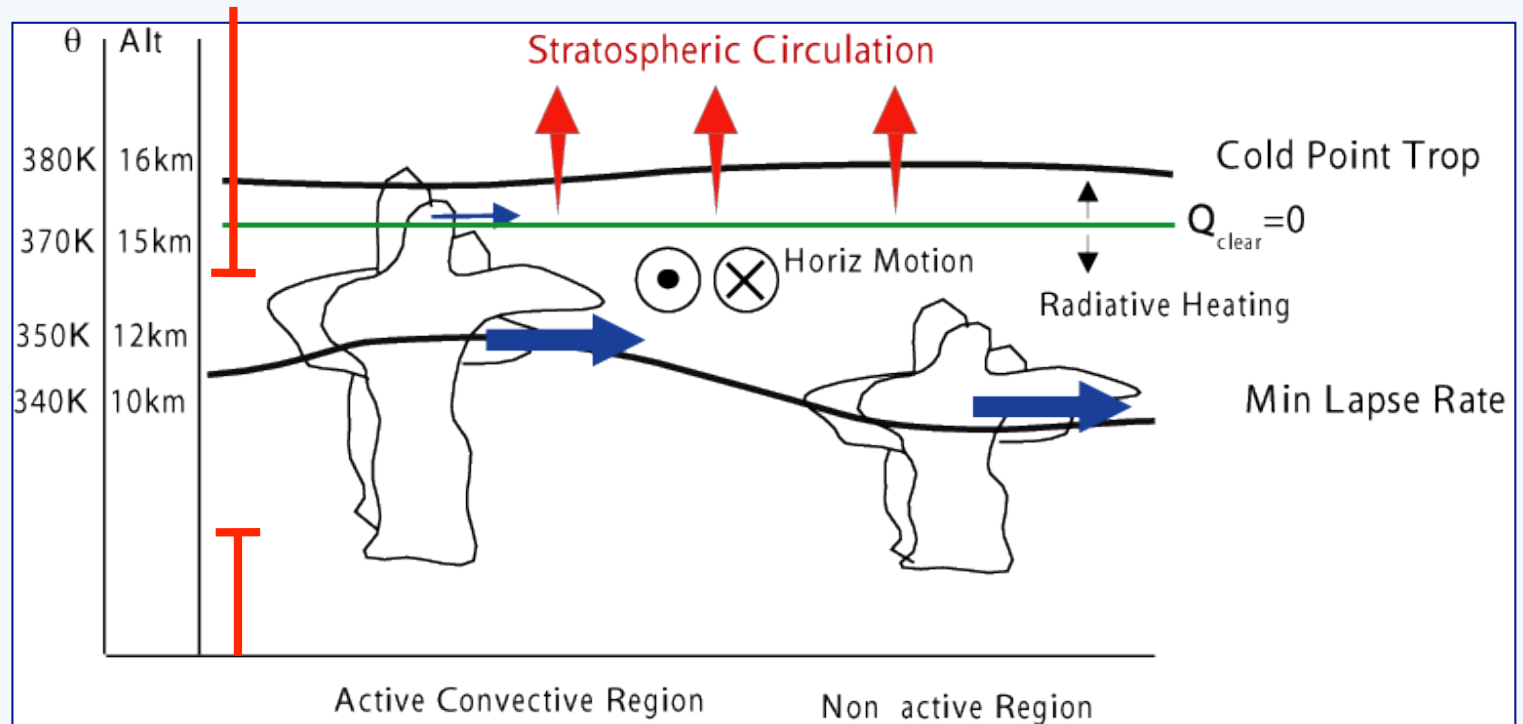
Scale: 1:36,000,000 at 30°S  
 Mercator Projection  
 0 500 Kilometers  
 0 500 Miles



# Measurements



# Measurements



? CONTRAST proposers should know in Dec/Jan  
So HIAPER could be based in Guam in Jan/Feb 2014

## BAe-146 Payload

Parameter	Instrument	Performance	Institution
Ozone	TE49C	1 minute integration time, 1ppb detection limit (dl)	FAAM
Water vapour	General Eastern 1011 & Buck CR2		FAAM
Carbon Monoxide	Aerolaser 5002	1 minute integration time, 2 ppb dl	FAAM
Nitrogen oxides	Air Quality Designs	1 Hz, dl is 10 pptv for NO and 20 pptv for NO <sub>2</sub>	FAAM + York
VSL Halocarbons: CHBr <sub>3</sub> , CH <sub>2</sub> Br <sub>2</sub> , CHBr <sub>2</sub> Cl, CH <sub>3</sub> I, CH <sub>2</sub> BrCl, CHBrCl <sub>2</sub> , C <sub>2</sub> H <sub>5</sub> I, CH <sub>2</sub> I <sub>2</sub> , CH <sub>2</sub> I <sub>2</sub> Br, CH <sub>2</sub> I <sub>2</sub> , CH <sub>2</sub> Cl <sub>2</sub> , CHCl <sub>3</sub>	In situ Agilent GC-MS with Markes dual TD	3-4 min sampling <i>in situ</i> , 2-3 min via WAS bottles < 0.01-0.05 ppt dl.	York
Whole Air Samples NMHC (C <sub>1</sub> -C <sub>6</sub> ), small OVOCS, DMS	Perkin Elmer GC-FID (WAS bottles, ~2-3 min sampling)	2-3 min sampling. 2.5, 1 pptv dl for C <sub>2</sub> -C <sub>4</sub> and >C <sub>4</sub> respectively	York
CO <sub>2</sub> , CH <sub>4</sub>	Los Gatos	5 sec integration precision ±σ CH <sub>4</sub> , 1.0 ppb; CO <sub>2</sub> , 200 ppb. Max rate 10 Hz.	FAAM + Manchester
N <sub>2</sub> O, H <sub>2</sub> O	Aerodyne QCLAS	N <sub>2</sub> O precision @ 1 Hz ±1σ, 0.2 ppbv. Max sampling rate 20 Hz.	Manchester
BrO	CIMS	2.6 pptv ± 3σ @ 4 s integration	Manchester
Black Carbon	SP2	Black carbon mass size distribution, 1 Hz	Manchester

*plus, hopefully, I<sub>2</sub> (IO, OIO) with BBCEAS*

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Whole Air Samples NMHC (C <sub>1</sub> -C <sub>6</sub> ), small OVOCS, DMS	Perkin Elmer GC-FID (WAS bottles, ~2-3 min sampling)	2-3 min sampling. 2.5, 1 pptv dl for C <sub>2</sub> -C <sub>4</sub> and >C <sub>4</sub> respectively	York
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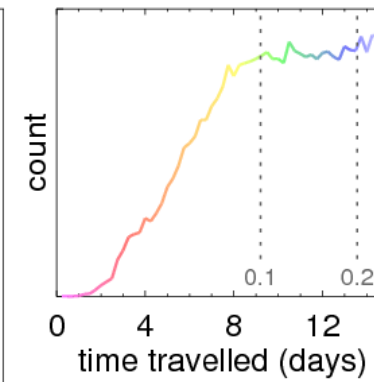
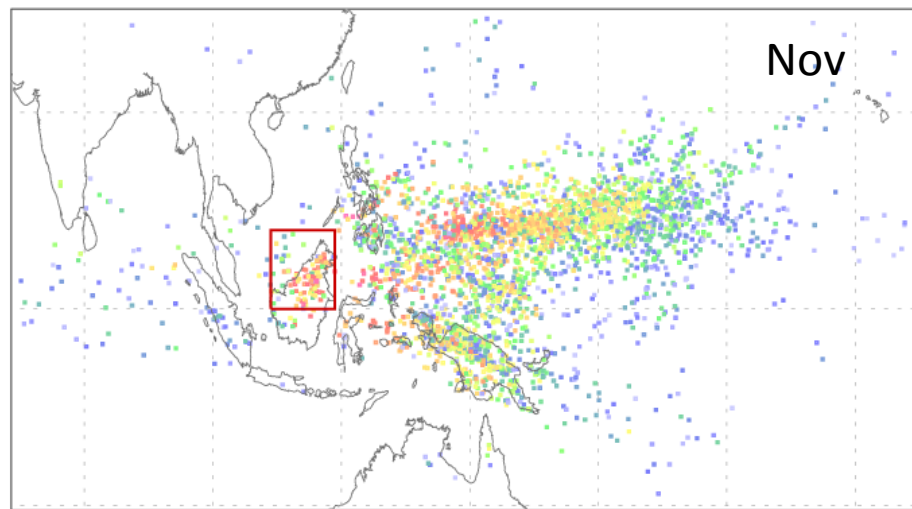
✓: Global Hawk

✓: HIAPER\*

But how can the measurements from different aircraft be linked?

12-13 km –  
cross 1 km?

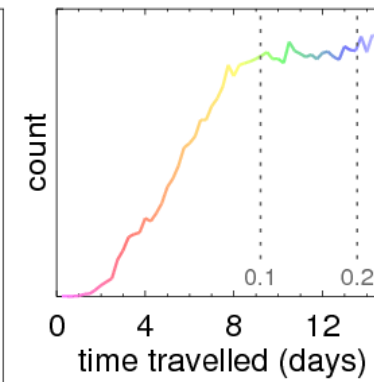
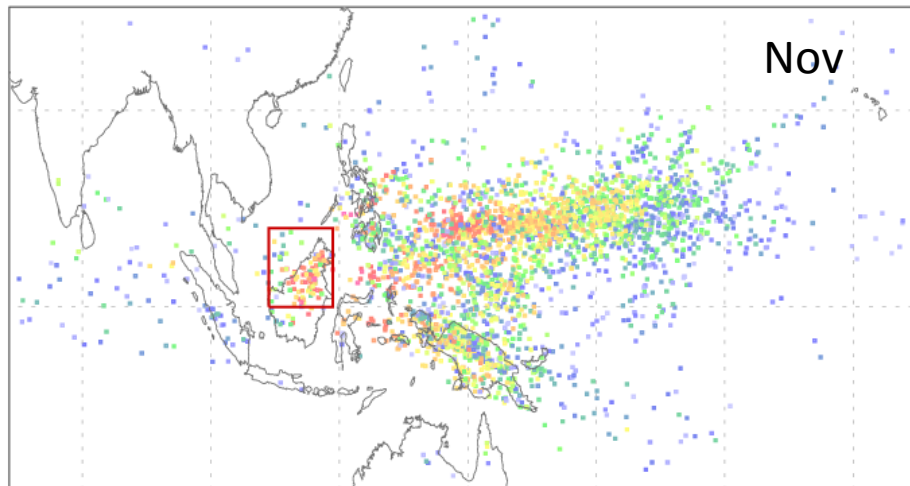
2006  
El Nino



month = 11/2006  
starting alt. = 12-13 km  
crossed 1 km = 0.216

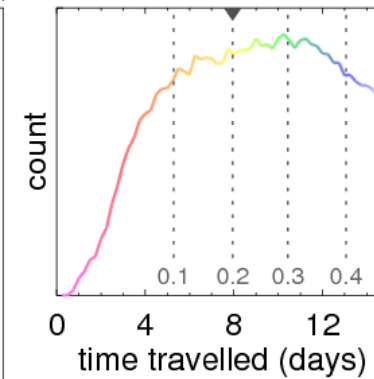
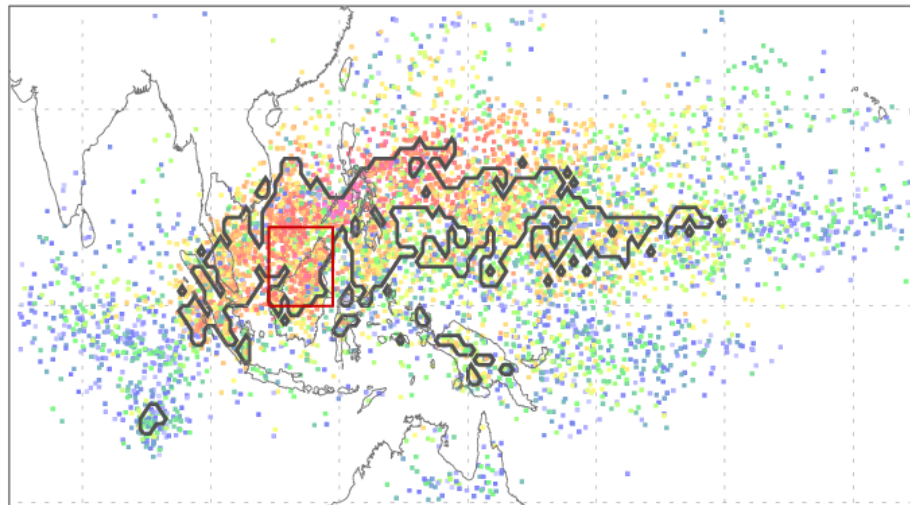
12-13 km –  
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2006  
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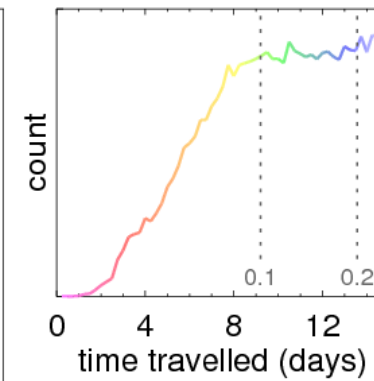
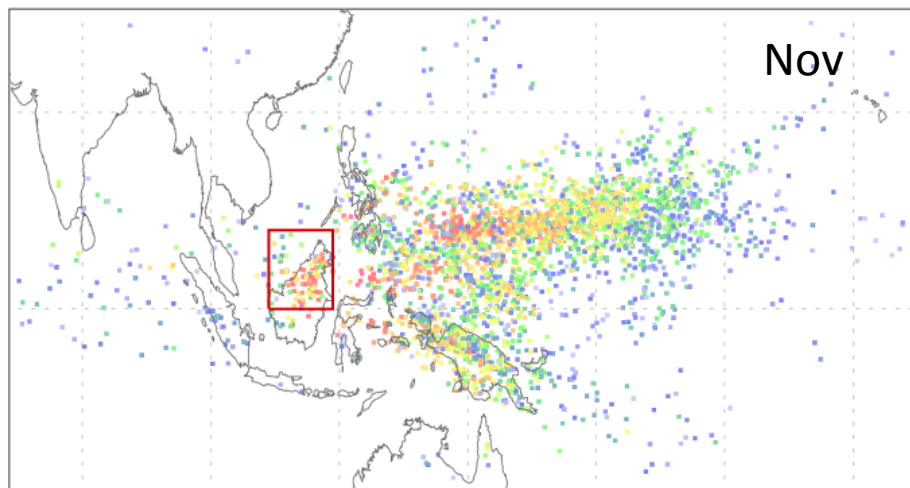
2007  
La Nina



month = 11/2007  
starting alt. = 12-13 km  
crossed 1 km = 0.439

12-13 km –  
cross 1 km?

2006  
El Nino

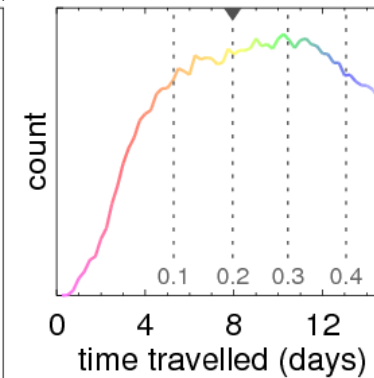
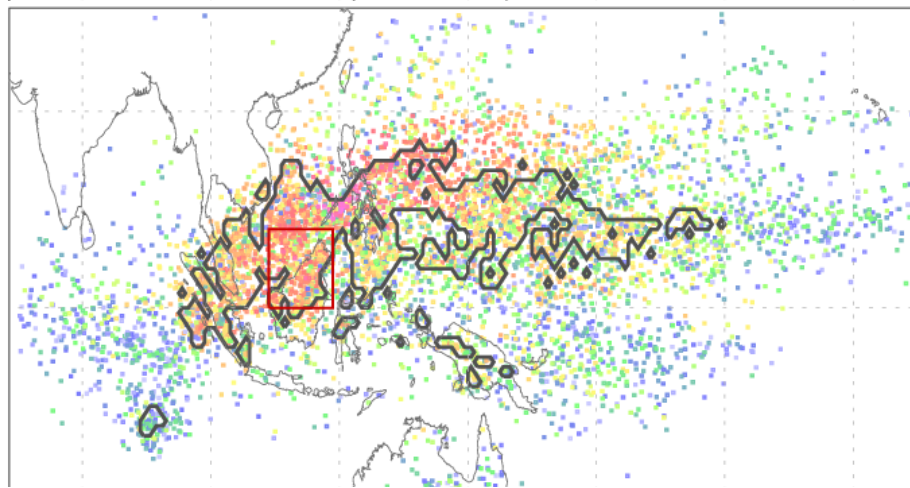


month = 11/2006  
starting alt. = 12-13 km

Below 1 km  
at start

22%

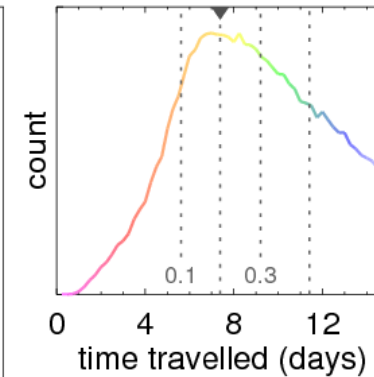
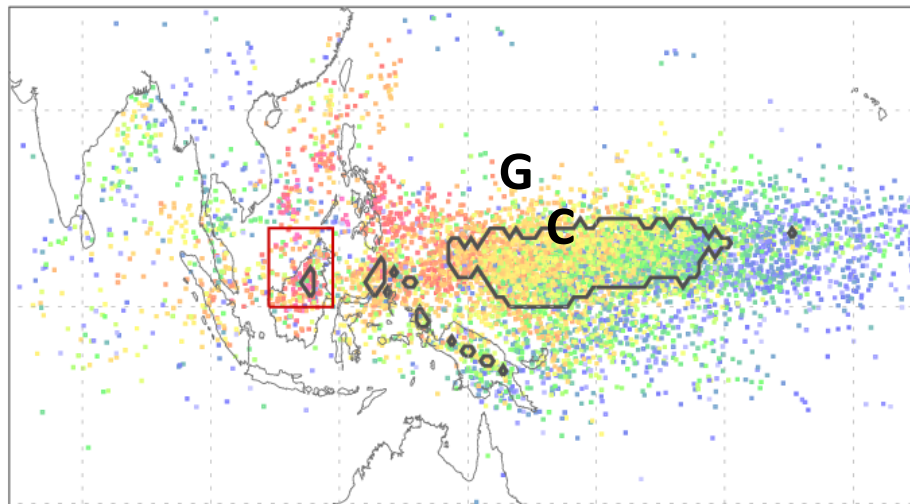
2007  
La Nina



month = 11/2007  
starting alt. = 12-13 km

44%

2008  
Neutral



month = 11/2008  
starting alt. = 12-13 km  
crossed 1km = 0.496

50%

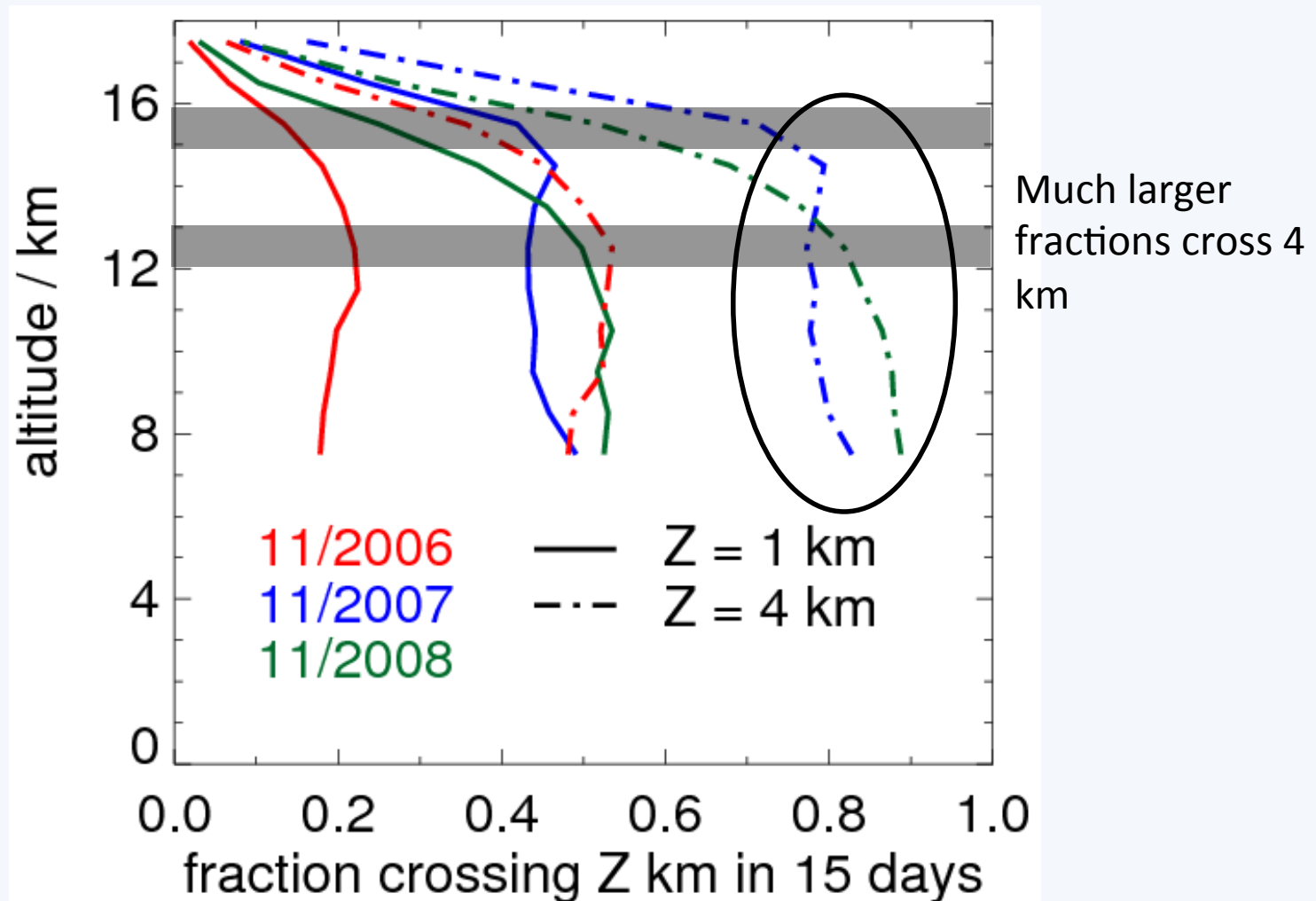
Ashfold et al,  
ACP, 2012

## Back trajectories from the TTL – how many reach 1 km within 15 days?

2006 (**El Nino**), relatively few trajectories reach 1 km

2007 (**La Nina**), more trajectories from upper TTL reach 1 km

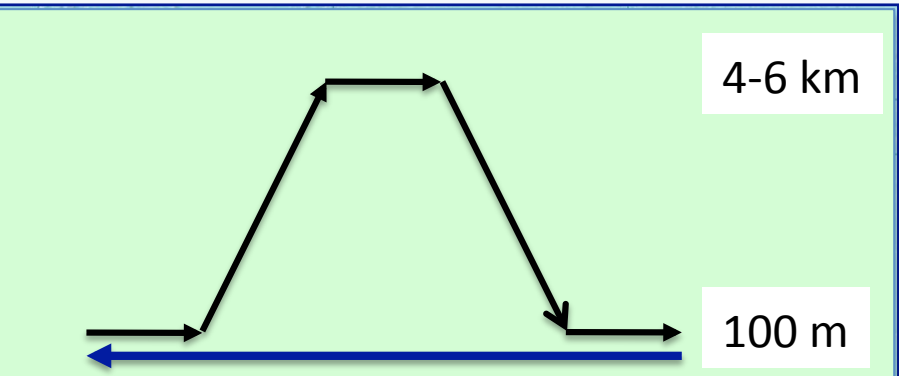
2008 (**neutral**), more trajectories from upper troposphere reach 1 km





- ★ Chuuk (7.5N, 152E)
- ★ Guam

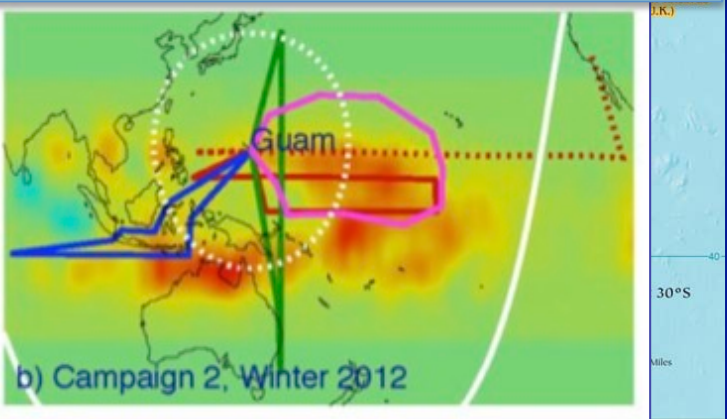
# Measurements



Sample:

- mixed lower troposphere
- coast / open water
- Regularly

Variant on this, but simple and regular  
A few 'flights of opportunity'



- ★ Chuuk (7.5N, 152E)
- ★ Guam

# Measurements

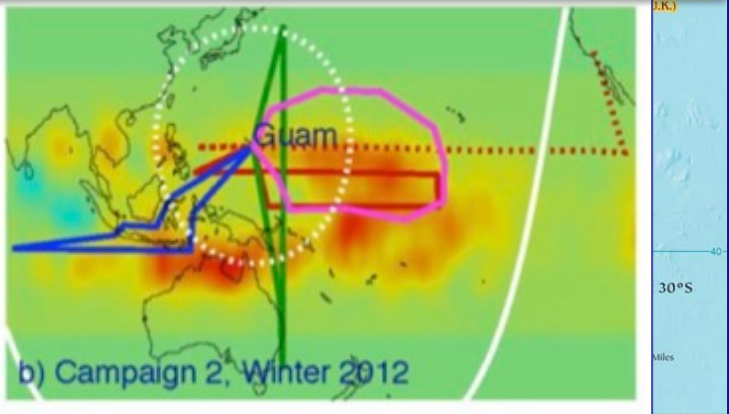
NAME starting grid



Sample:

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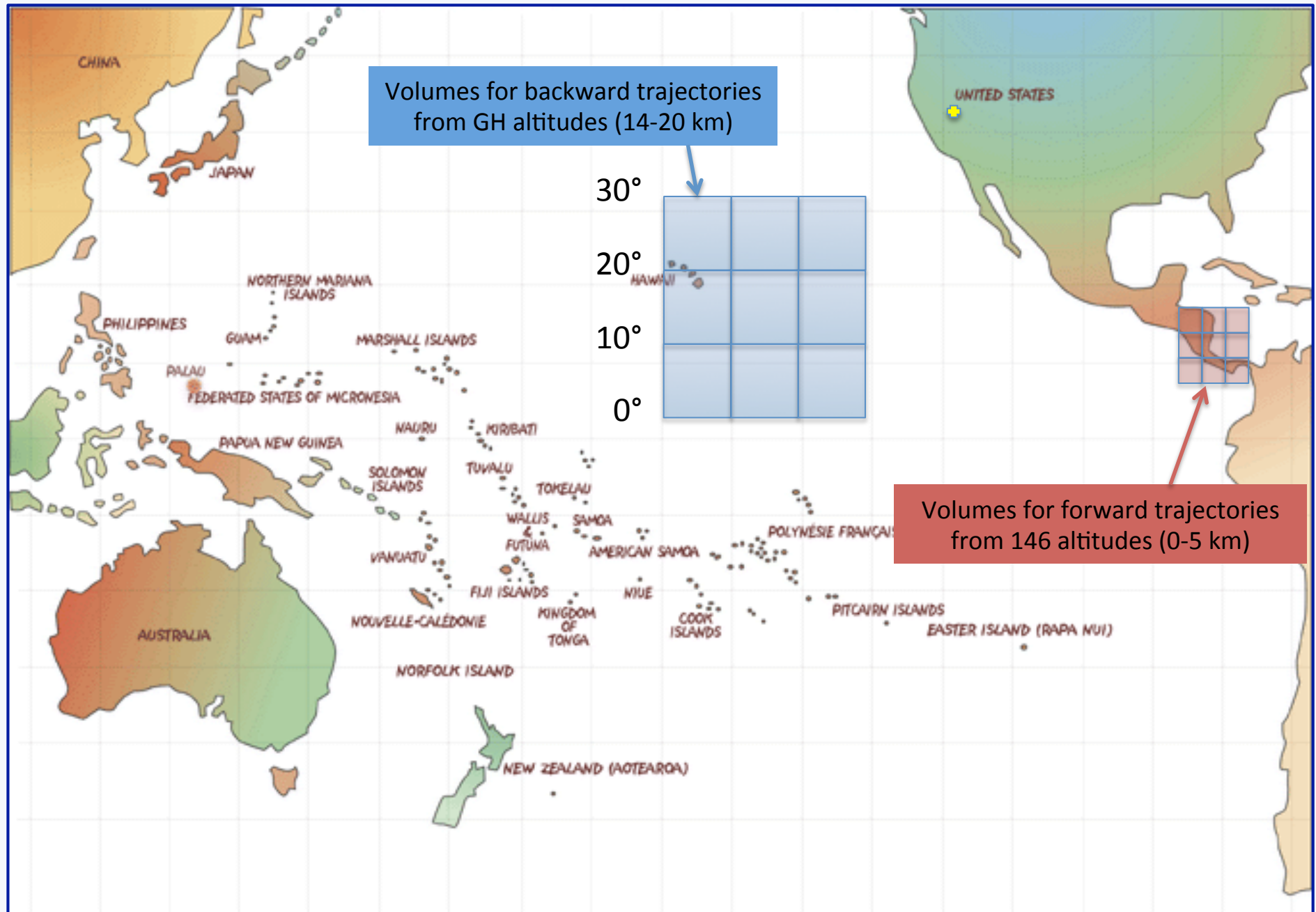
Variant on this, but simple and regular  
A few 'flights of opportunity'



## NAME with UK Met Office forecasts

- 5 day forecasts available with calculations in real-time
- Trajectories extended with analyses – up to 10 days
- Standard products (maps) where possible
  
- **Aim: Identify low altitude origin of air sampled by Global Hawk**  
Method: Run back-trajectories back from regions in GH flight zone
  - Day and night? - yes
  - Altitude regions? – how thin? – 14-16 km; 16-18 km; 18-20 km
  - Lat/long boxes? – define region of interest –  $9 \times 10^\circ \times 10^\circ$
  
- **Aim: Identify periods when air sampled by 146 would be in GH flight zones**  
Method: Run forward trajectories from regions in 146 flight zone
  - Day and night? – yes for trial (land convection)
  - Altitude regions? – 0-2.5 km; 2.5-5 km
  - Lat/long boxes? –  $9 \times 3^\circ \times 3^\circ$

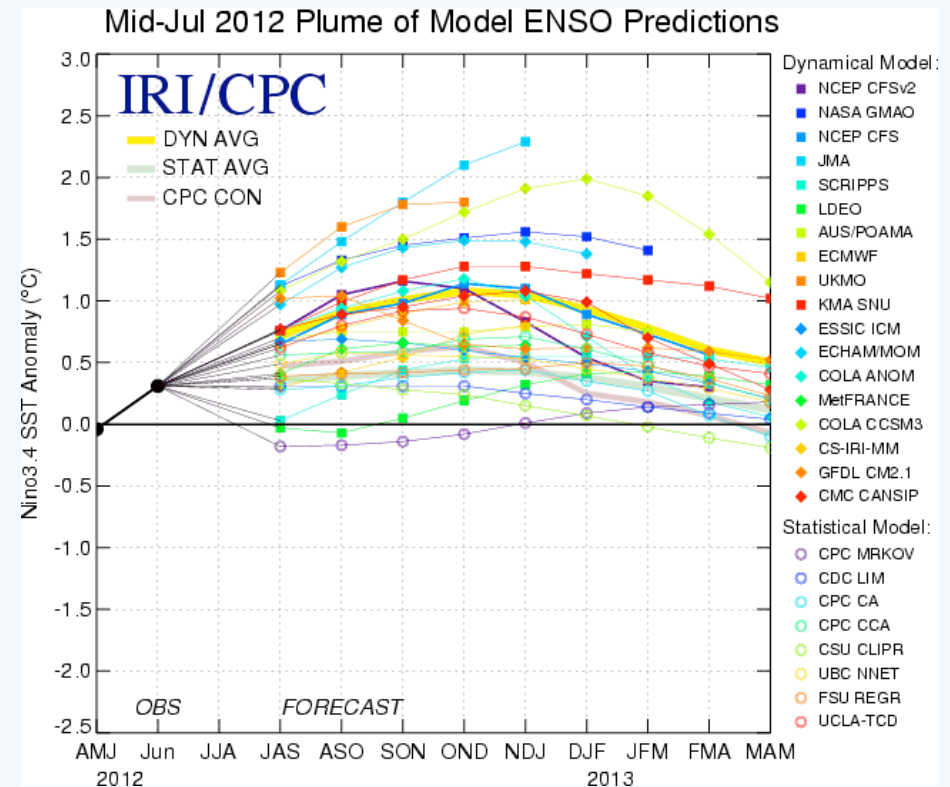
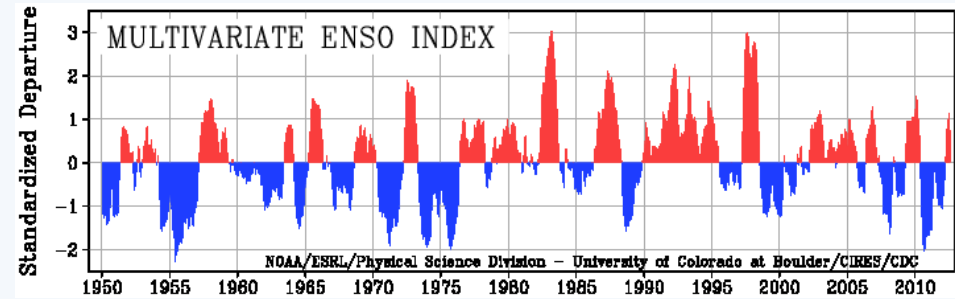
# Trial run for ATTREX in Jan/Feb 2013



## To shift or not to shift....

### ENSO (CPC/NCEP/NWS, Aug 2012)

- “Supported by model forecasts and the continued warmth across the Pacific Ocean, there is increased confidence for a weak-to-moderate El Niño during the Northern Hemisphere fall and winter 2012-13. El Niño conditions are likely to develop during August or September 2012”
- i.e. 6-9 months of forecasts
- Does this make one in 2013/14 less likely?
- Assume GH not likely to move; HIAPER may not, but could fly more out of Hawaii
- 146 would not not measure in main inflow region during ENSO
- Move East? But where?
- FAAM need > 6 months warning
- FAAM are looking at options

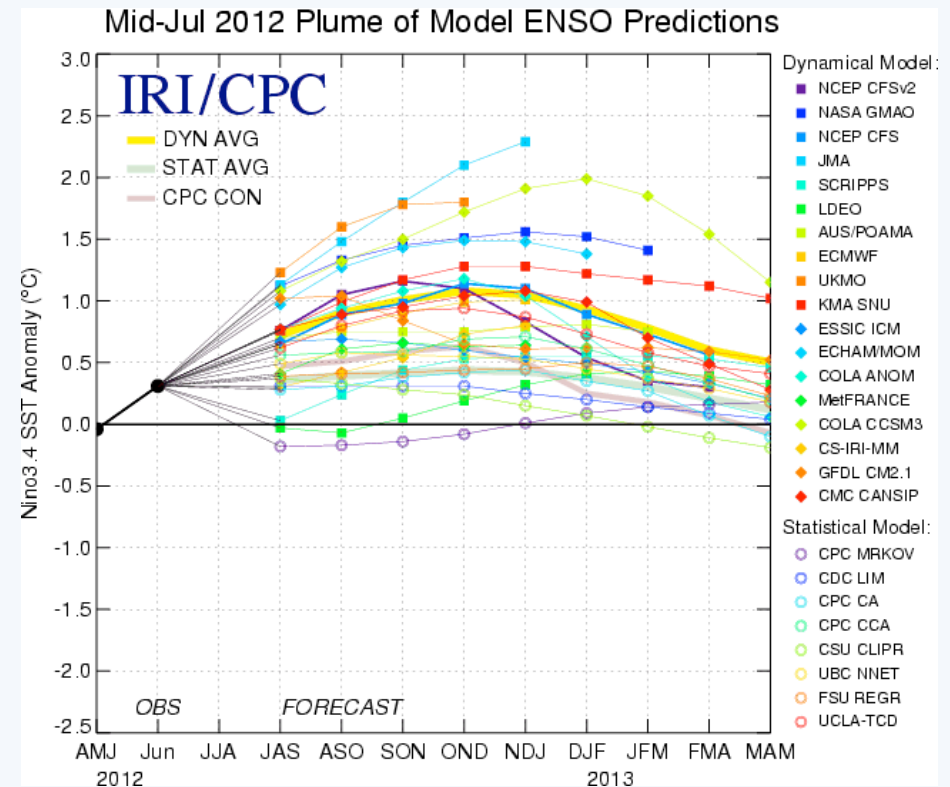
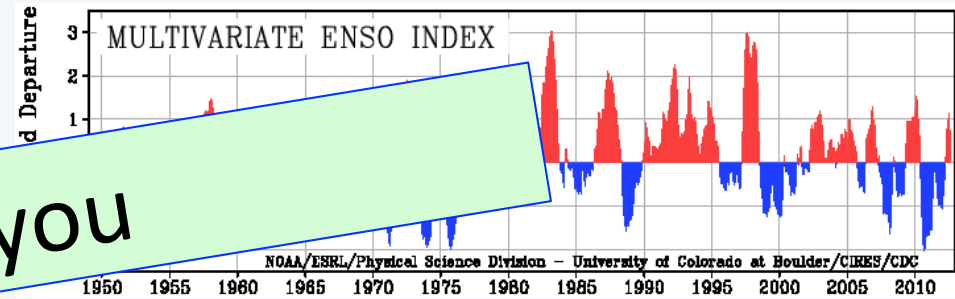


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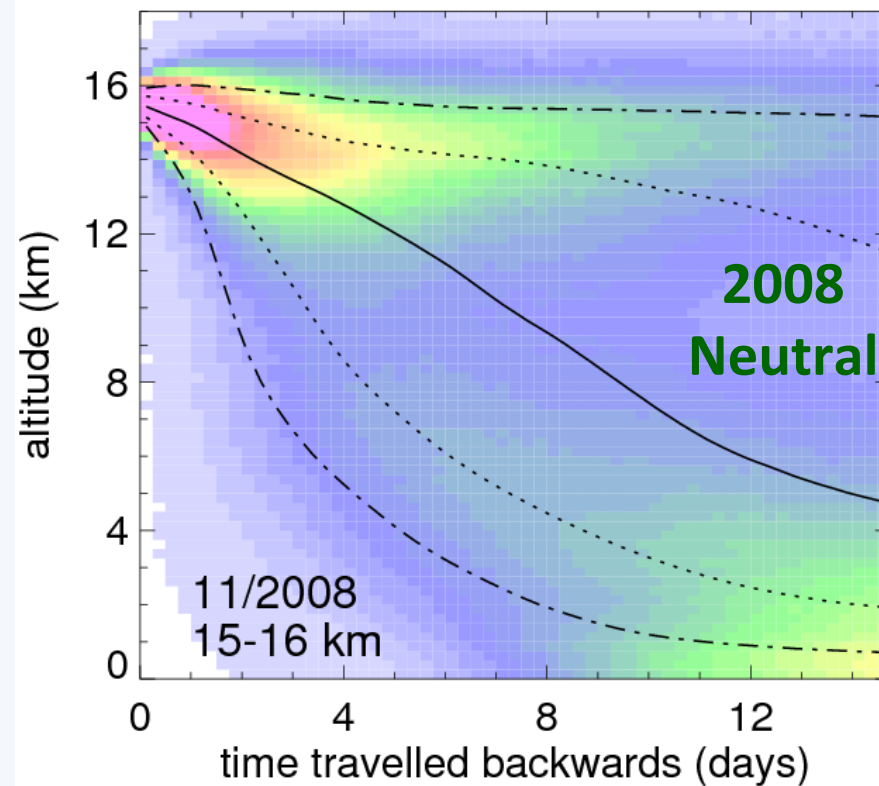
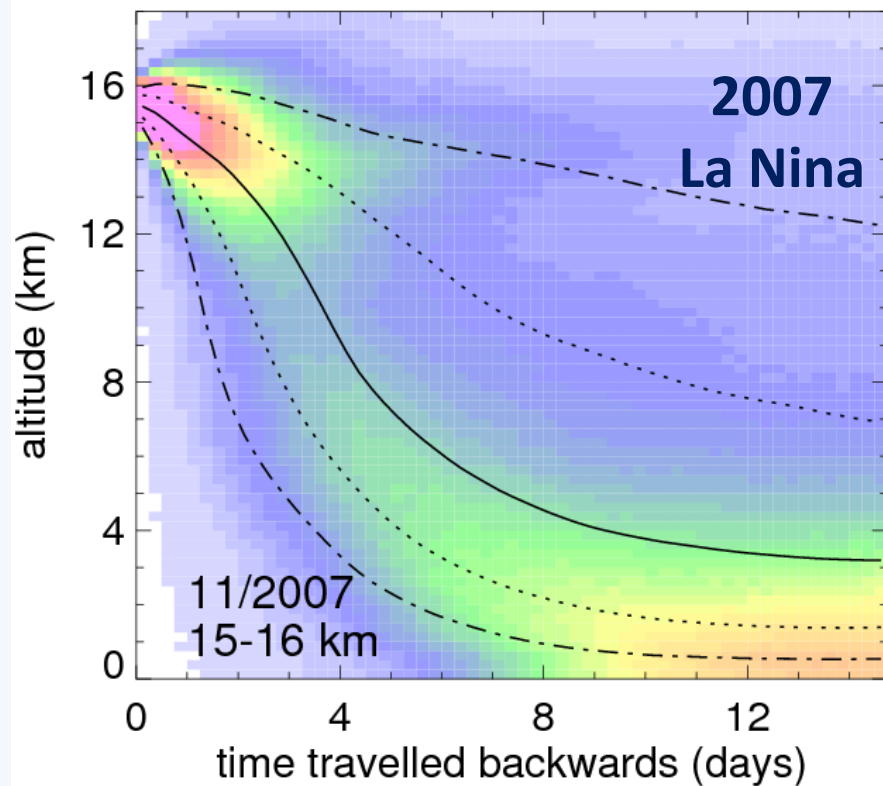
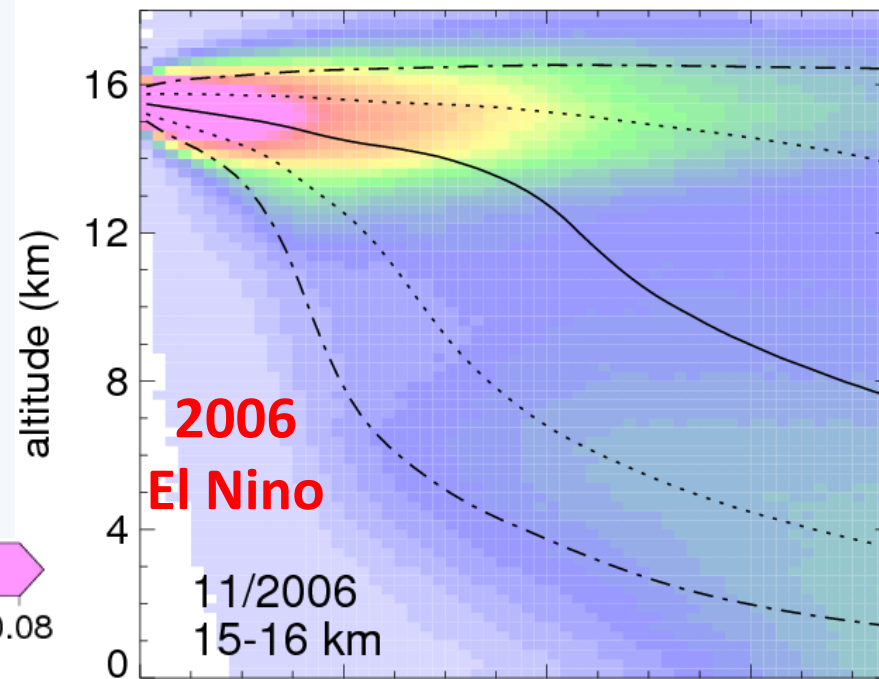
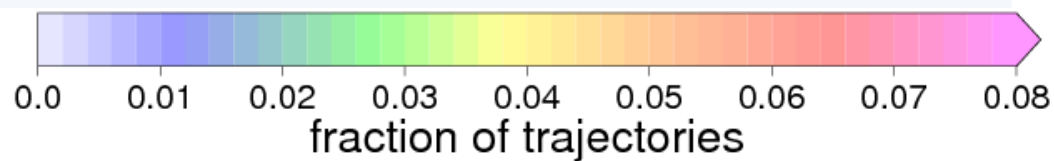
- “Supported by model forecasts and the continued warmth across the Pacific Ocean, there is increased confidence for a weak-to-moderate Niño during the March–April–May 2012–13 winter 2012–13. A moderate Niño is likely to develop during the summer 2012–13 (September 2012)”
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Thank you



# 15-16 km – probability of a trajectory being at a certain altitude as it travels backwards

Ashfold et al, ACP, 2012



# ATTREX

**Table 1.** *Global Hawk Payload*

Instrument	Measurements
Cloud Physics Lidar (CPL)	Aerosol/cloud backscatter
Ozone	O <sub>3</sub>
Advanced Whole Air Sampler (AWAS)	Tracers w/ varying lifetimes
Chromatograph for Tracers (UCATS)	O <sub>3</sub> , CH <sub>4</sub> , N <sub>2</sub> O, SF <sub>6</sub> , H <sub>2</sub> O, CO
Picarro Cavity Ringdown Spectrometer	CO <sub>2</sub> , CO
UAS Laser Hygrometer (ULH)	H <sub>2</sub> O
Diode Laser Hygrometer (DLH)	H <sub>2</sub> O
Hawkeye	Ice crystal properties
Solar, Infrared Radiometers	Radiative fluxes
Meteorological Meas. System (MMS)	Temperature, winds
Microwave Temperature Profiler (MTP)	Temperature profile
Absorption Spectrometer (DOAS)	BrO, NO <sub>2</sub> , OClO, IO



## CONTRAST (proposed)

<b>Observation</b>	<b>Requirement</b>	<b>Instrument Source &amp; Status</b>	<b>GH</b>	<b>BaE</b>
<b>O3</b>	1 ppbv; 10 s	Facility (Fast O3)	Yes	Yes
<b>H2O Vapor</b>	1 – 1000 ppmv; 1 s	Facility (VCSEL)	Yes	Yes
<b>CO</b>	5%; 10 s	ACD (VUV)	Yes	Yes
<b>CH4</b>	5 ppbv; 10 s	ACD (Picarro)	Yes	Yes
<b>CO2</b>	0.3 ppmv; 10 s	ACD (Picarro)	Yes	Yes
<b>H2CO</b>	25 pptv; 30 s	CU (Laser DFG?)	No	No
<b>NO, NO2</b>	5 pptv; 10 s	ACD (Chemiluminescence)	No	Yes
<b>BrO, HOBr, Br<sub>2</sub> (ins)</b>	2 pptv; XX s	Facility (CIMS)	No	Yes
<b>BrO, IO, H<sub>2</sub>CO (rm)</b>	2/1/100 pptv; 10 s	CU-AMAX (DOAS)	Yes	No
<b>Br, I</b>	2 pptv; 10 min	CIAC (Spain) (ROFLEX)	No	No
<b>NMHC VSLs+</b>	Various	Facility (AWAS)	Yes	Yes
<b>Oxygenated VOC</b>	Various	Facility (TOGA)	No	No
<b>Aerosol (no, size)</b>	Various	Facility (USHAS)	No	No
<b>Cloud detection</b>		Facility (CDP, 2D-C)	Remote	No
<b>MTP</b>	2 K; 6 km +/- a/c	Facility (MTP)	Yes	No
<b>Radiation (UV/VIS)</b>		Facility (HARP)	Yes	Yes