Observational evidence from Calipso for a Stability-iris effect

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The Stability-iris effect

Bony et al. 2016

Cloudy sky

Clear sky

Anvil

Conv

\[ T \]

\[ T_c \]

\[ |Q_r| \]
Cloudy sky

Clear sky

Conv

|Qr|
The Stability-iris effect

Cloudy sky

Clear sky

|Qr|

Fixed Anvil Temperature
(Hartmann & Larson 2002)
The Stability-iris effect

Conv = $\frac{\partial \omega}{\partial p}$

With

$\omega = -\frac{Q_r}{S}$

Propotionally Higher Anvil Temperature
(Zelinka & Hartmann 2010)
The Stability-iris effect

Bony et al. 2016

PHAT: nearly isothermal rise
Rise = increasing stability
⇒ Conv peak reduced

Conv = $\partial \omega / \partial p$
With
$\omega = -Q_r / S$
The Stability-iris effect

PHAT: nearly isothermal rise
+ Rise = increasing stability
⇒ Conv peak reduced
⇒ Anvils shrinkage

\[
\text{Conv} = \frac{\partial \omega}{\partial p}
\]

With
\[
\omega = -\frac{Q_r}{S}
\]
The Stability-iris effect

PHAT: nearly isothermal rise
Rise = increasing stability

⇒ Conv peak reduced
⇒ Anvils shrinkage = Stability-iris

Conv = $\partial \omega/\partial p$
With
$\omega = -Q_r / S$

In models (at least 3 GCMs and a CRM):

Anvil cloud fraction

Conv [d$^{-1}$]

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The Stability-iris effect

Bony et al. 2016

In observations (Zelinka & Hartmann 2011):

In models (at least 3 GCMs and a CRM):

\[ \text{Conv} = \frac{\partial \omega}{\partial p} \]

With \( \omega = - \frac{Q_r}{S} \)

PHAT: nearly isothermal rise

\[ \text{Rise} = \text{increasing stability} \]

\[ \Rightarrow \text{Conv peak reduced} \]

\[ \Rightarrow \text{Anvils shrinkage} = \text{Stability-iris} \]
Stability-iris in observations?

- **Accuracy of active sensors**: lidar (Caliop) measurements from Calipso to isolate anvilv and detect rise and shrinkage
  
  Monthly data
  
  - GOCCP Caliop product (Chepfer et al. 2010) for clouds
  - ERA5 reanalyses for clear-sky properties
  - HadCRUT4 for \( T_s \)

- **11 years** of data now available with Calipso to look at **interannual variability** (monthly data) [2006-2017]

- Analysis on the **whole tropical belt** to look at intrinsic cloud response to tropical \( T_s \) (not local)
STEP 1: PHAT in observations

**ERA5:**

![Graph showing radiative cooling and static stability](image)

- ΔTs ~ -0.22 K
- ΔTs ~ 0.31 K
STEP 1: PHAT in observations

GOCCP & ERA5:

\[ \Delta T_s \sim -0.22 \, \text{K} \]

\[ \Delta T_s \sim 0.31 \, \text{K} \]
STEP 1: PHAT in observations

GOCCP & ERA5:

⇒ PHAT confirmed based on 11 years of observations
STEP 1: PHAT in observations

GOCCP & ERA5:

\[ \Rightarrow \text{PHAT confirmed based on 11 years of observations} \]
Stability-iris in observations

GOCCP & ERA5:

Conv peak anomaly (day-1) vs. Anvil cloud fraction anomaly

r = 0.72
p-value = 0.0131
Stability-iris in observations

GOCCP & ERA5:

\[
\text{Conv peak anomaly (day-1)}
\]

\[
\text{Anvil cloud fraction anomaly}
\]

\[
\text{Stability anomaly at Conv peak (mK/hPa)}
\]

\[ r = 0.72 \]
\[ \text{p-value} = 0.0131 \]

\[ r = -0.81 \]
\[ \text{p-value} = 0.0023 \]
Stability-iris in observations

GOCCP & ERA5:

- Conv peak anomaly (day-1)
- Anvil cloud fraction anomaly
- Stability anomaly at Conv peak (mK/hPa)
- Ts anomaly (K)

Graphs showing correlations:
- Anvil cloud fraction anomaly vs Conv peak anomaly (day-1)
- Stability anomaly at Conv peak vs Ts anomaly (K)
- Stability anomaly at Conv peak vs Conv peak anomaly (day-1)

Correlation coefficients and p-values:
- r = 0.72, p-value = 0.0131
- r = 0.83, p-value = 0.0014
- r = -0.81, p-value = 0.0023
Stability-iris in observations

GOCCP & ERA5:

Strong / significant relationships supporting a thermodynamic Stability-iris hypothesis
At what scale do PHAT and the Stability-iris hold?

How far?
Tropical belt?
Anvil scale?

Cloudy sky
Clear sky

Conv

$|Q_r|$
Spatial scale of Stability-iris?

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Anvil scale

Tropical belt
Spatial scale of Stability-iris?

Anvil scale

Tropical belt
Spatial scale of Stability-iris?

Anvil scale

Tropical belt

![Graph showing correlations between temperature anomalies and convective peak anomalies, with different color lines indicating different scales and correlation coefficients](image-url)
⇒ Stability-iris mostly holds at the tropics-wide scale,
Spatial scale of Stability-iris?

⇒ **Stability-iris** mostly holds at the **tropics-wide scale**, Possibly has a **local component** too
Spatial scale of PHAT?

**Anvil scale**

![Graph showing relationship between Conv peak height anomaly (km) and Anvil height anomaly (km) with correlation coefficient r = 0.85 and p-value = 0.001.]

**Tropical belt**
Spatial scale of PHAT?

\[ \Rightarrow \text{PHAT at play at both the Anvil and Tropics scale,} \]
Conclusions

Analysis of interannual variability with 11 years of active lidar measurements from Calipso:

- **PHAT confirmed** on 11 years of observations

- Observational support for the stability-iris effect on the interannual scale

- **Stability-iris** mostly holds at the tropics-wide scale

⇒ At play on long timescales? (Climate change)

⇒ Radiative impact?
Conclusions

Analysis of **interannual** variability with **11 years of active lidar** measurements from **Calipso**:

- PHAT confirmed on 11 years of observations
- Observational support for the stability-iris effect on the interannual scale

**Thank you!**

- Stability-iris mostly holds at the **tropics-wide scale**

⇒ At play on long timescales? (Climate change)
⇒ Radiative impact?
Examples of two monthly grid-points: