Storm Top Processes seen from Concurrent Satellite and Aircraft Observations

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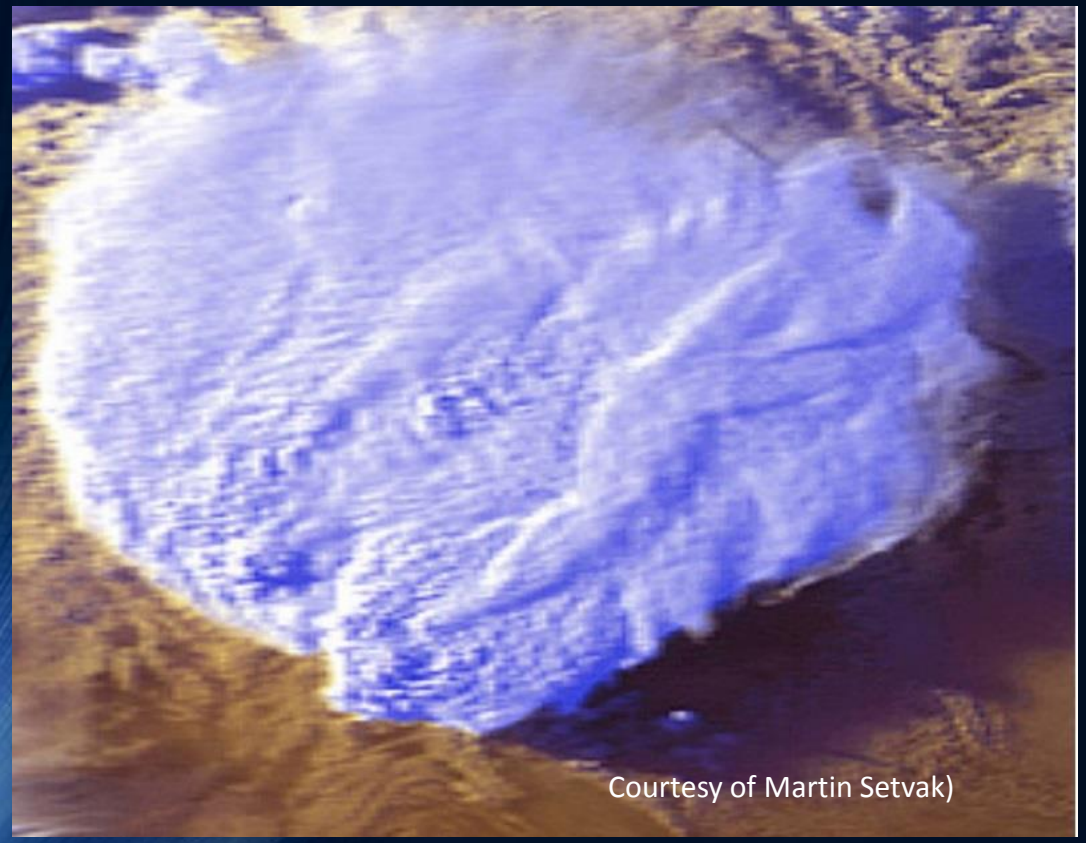
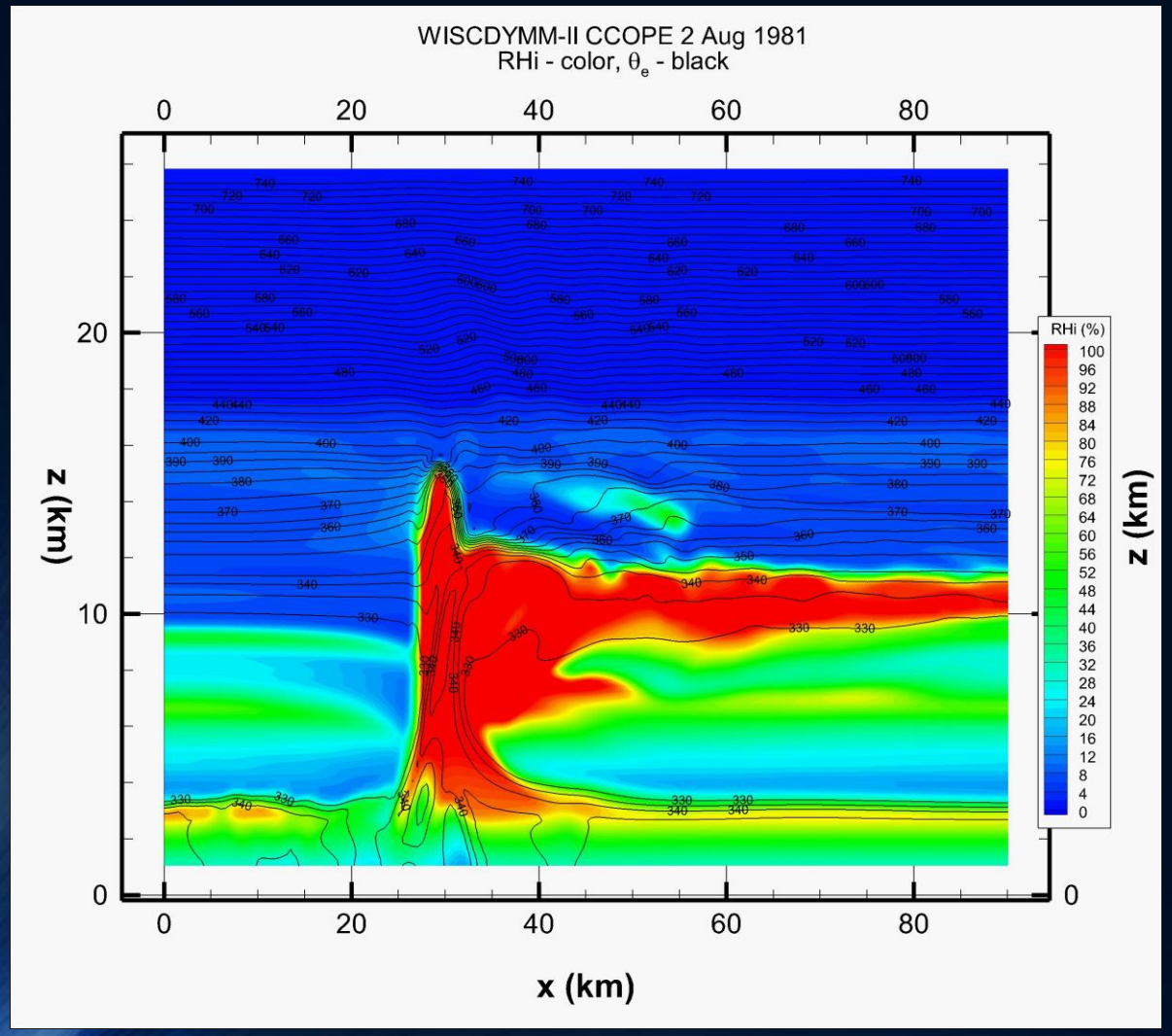
Above anvil cirrus plumes (AACP) that are now well-received by the scientific community



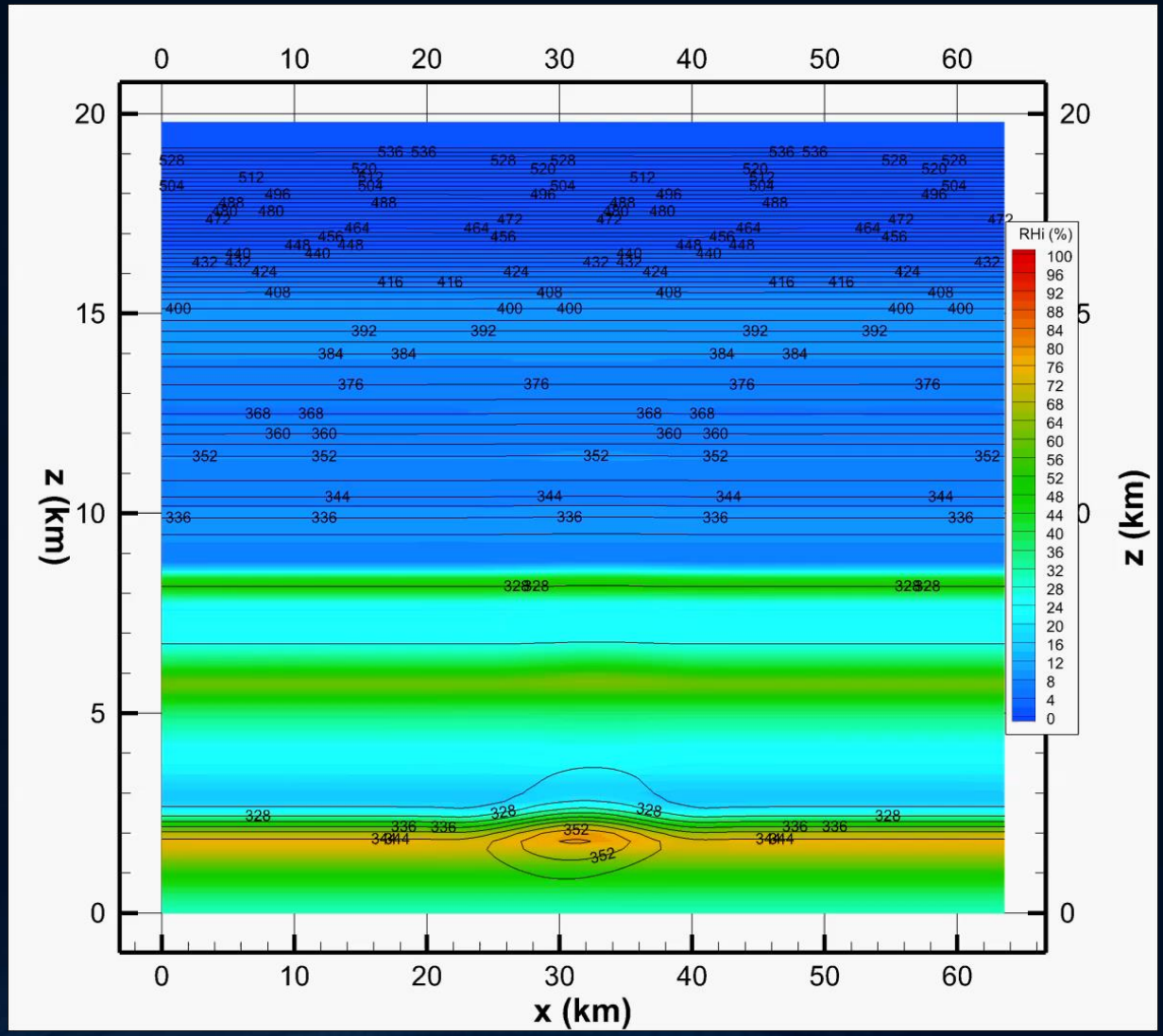
And jumping cirrus is related to AACP

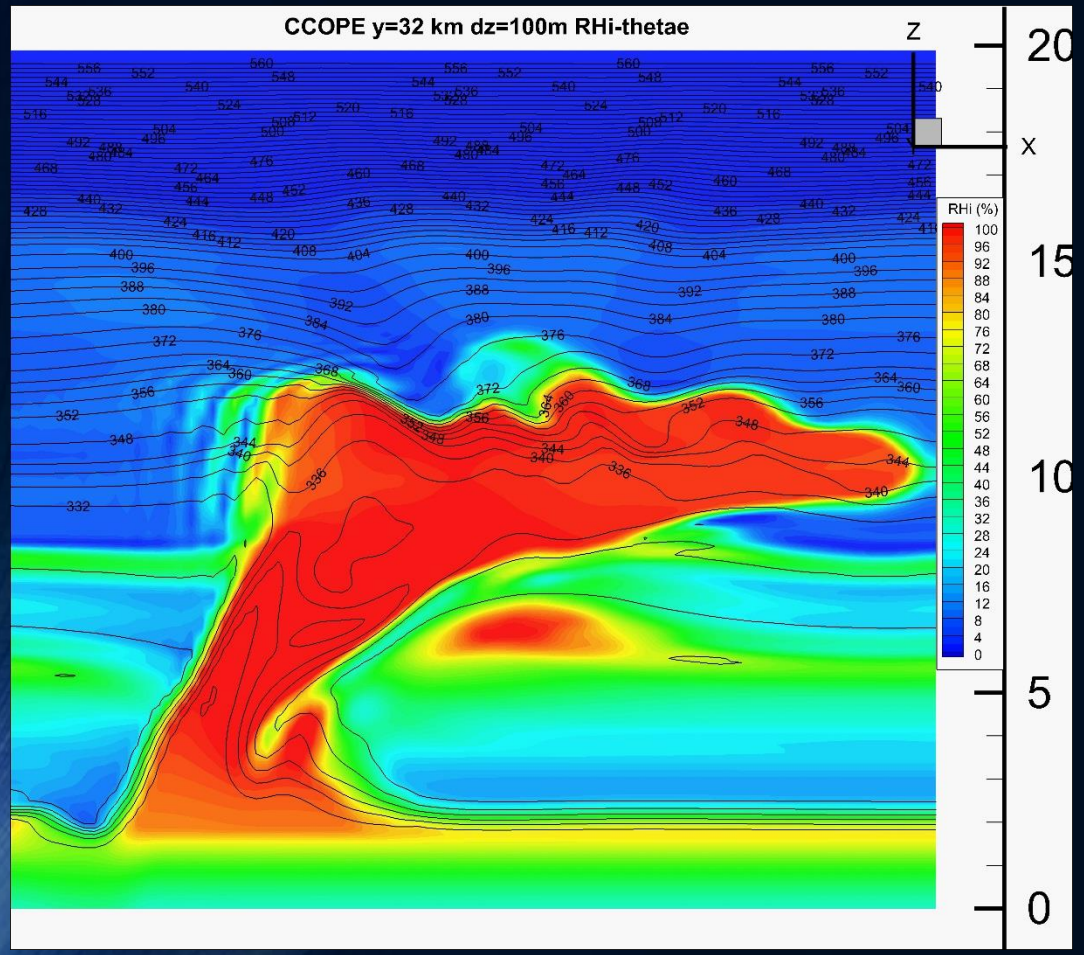
Model results show that the jumping cirrus is produced by internal gravity wave breaking (IGWB)



- Jumping cirrus (JC) in the stratosphere usually moves slower than the anvil, so it appears to take over the overshooting top (OT)
- …protrusions are often overtaken by the approaching cirrus, thus disappearing into the cloud. **We often got an impression that an advancing cirrus front chases protrusions until they are swallowed by the cloud.** (Fujita, 1974)

Model results show that the jumping cirrus is produced by the internal gravity wave breaking (IGWB)

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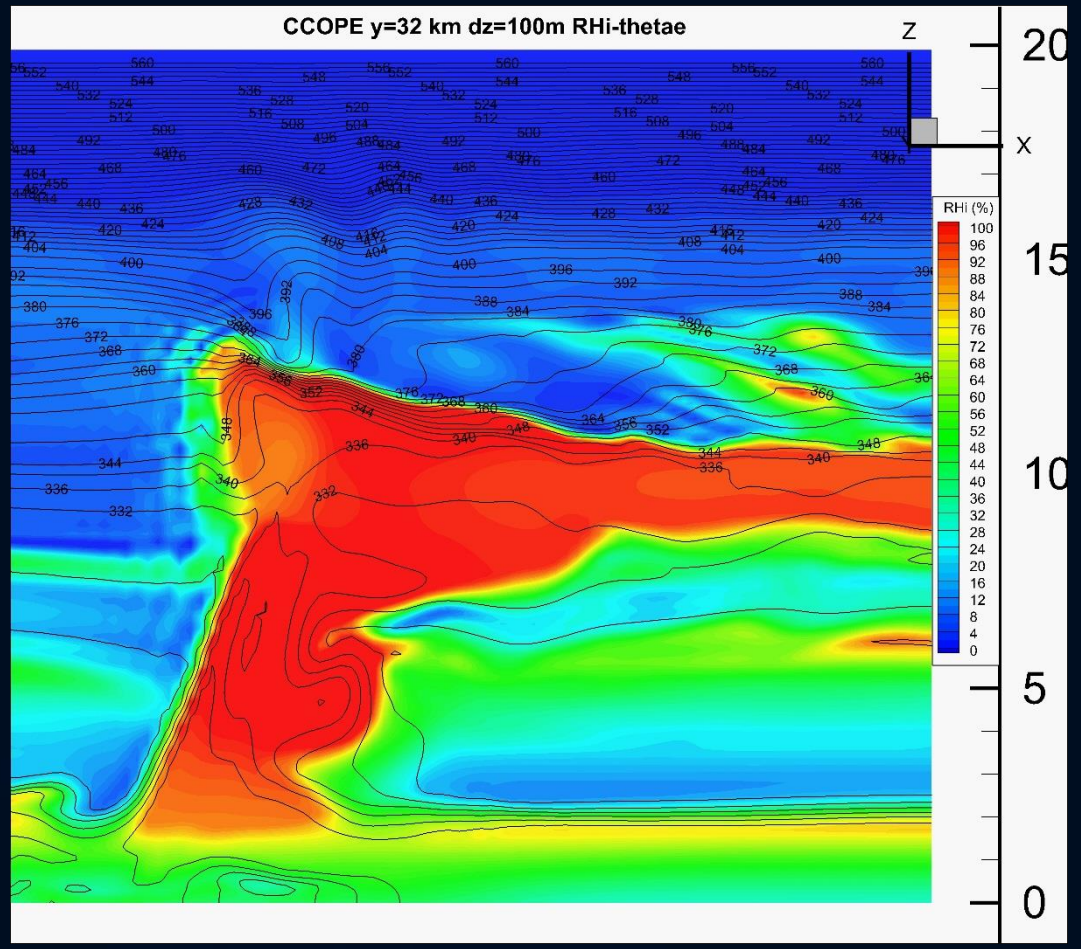
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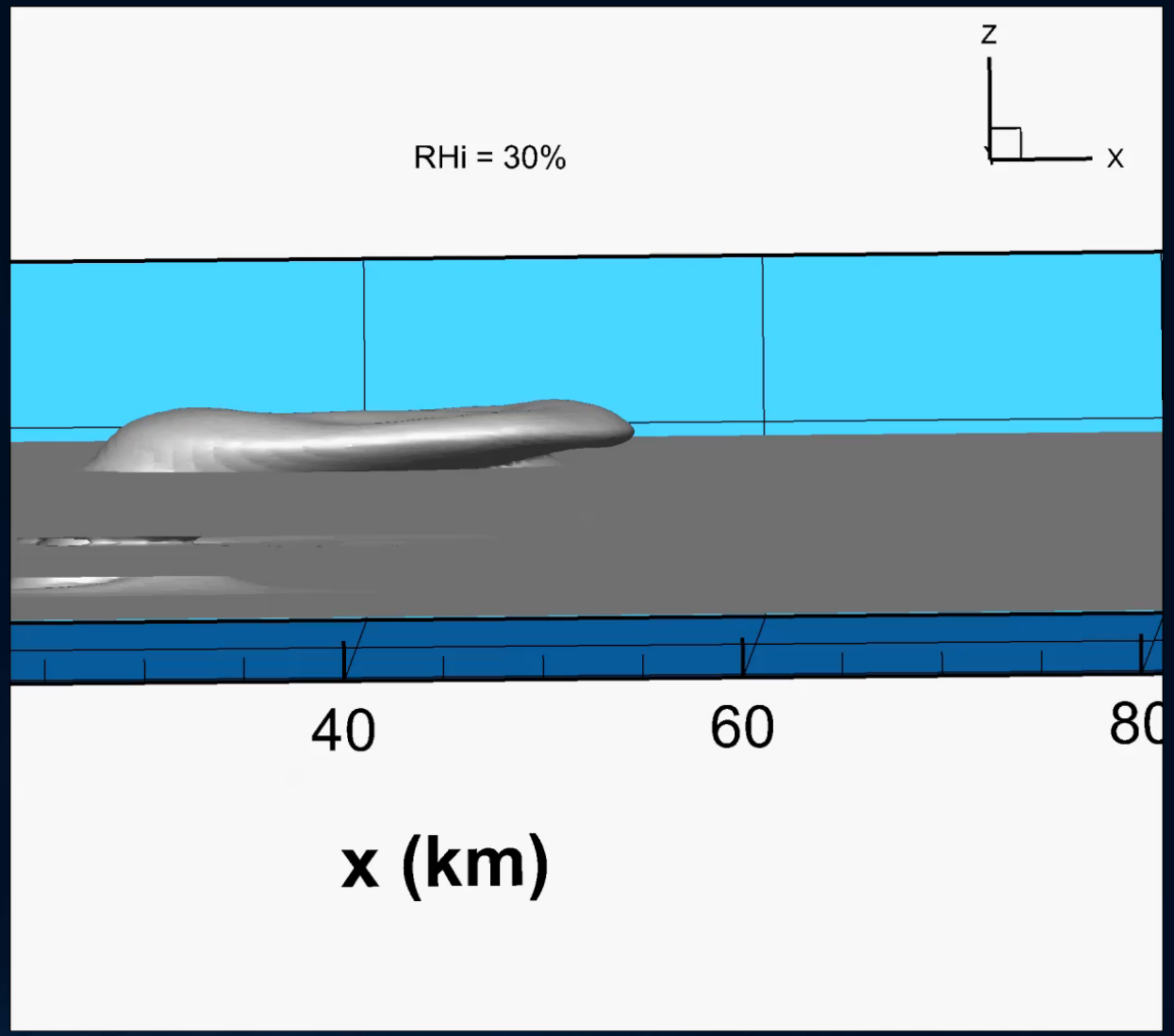
Missing link?

- The model predicts that the JC may eventually become AACP after the JC is blown and stretched along the wind direction to assume the chimney plume shape. Is this true?
- Ground based and most aircraft observations seem to see only JC
- Satellite images seem to show only AACP
- Are the two really linked?

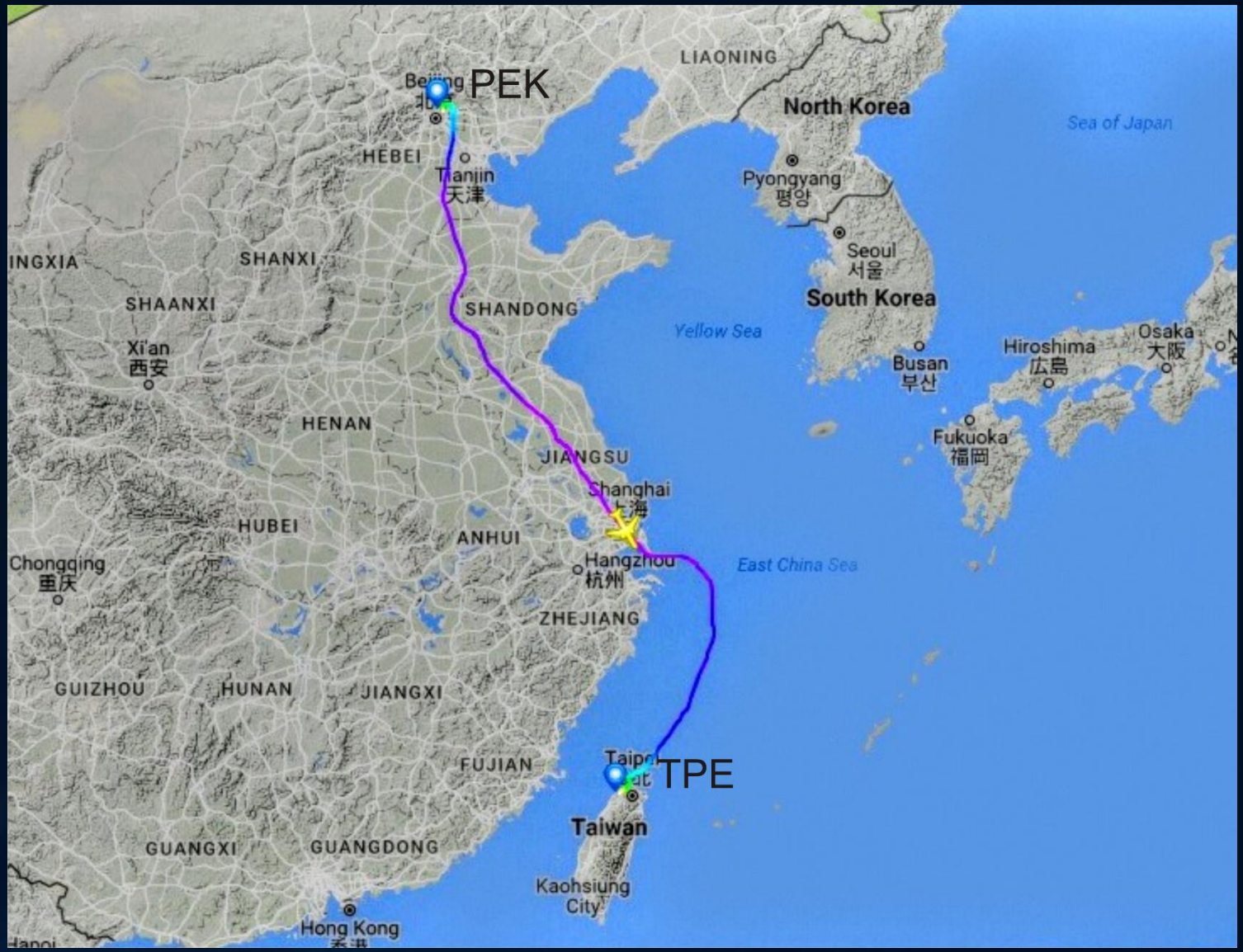
The good ol’ example of jumping cirrus

Courtesy of Willi Schmid

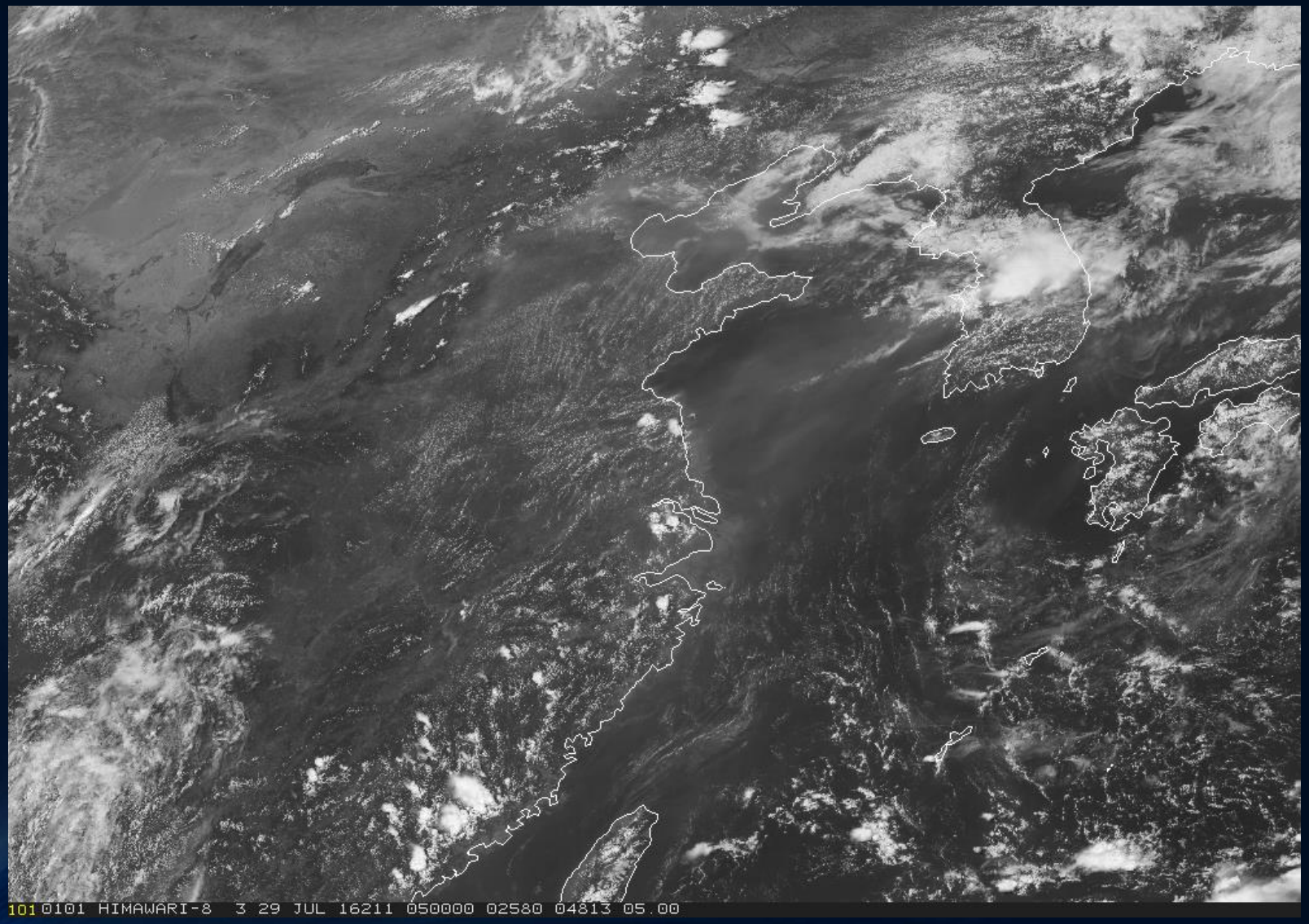
Model simulation of plume formation (2-momemt model)



July 29, 2016 flight from Beijing to Taipei



A line of sea breeze thunderstorms along coastal China



Courtesy of Dan Lindsey

Various stage of the AACP formation have been observed in aircraft photos

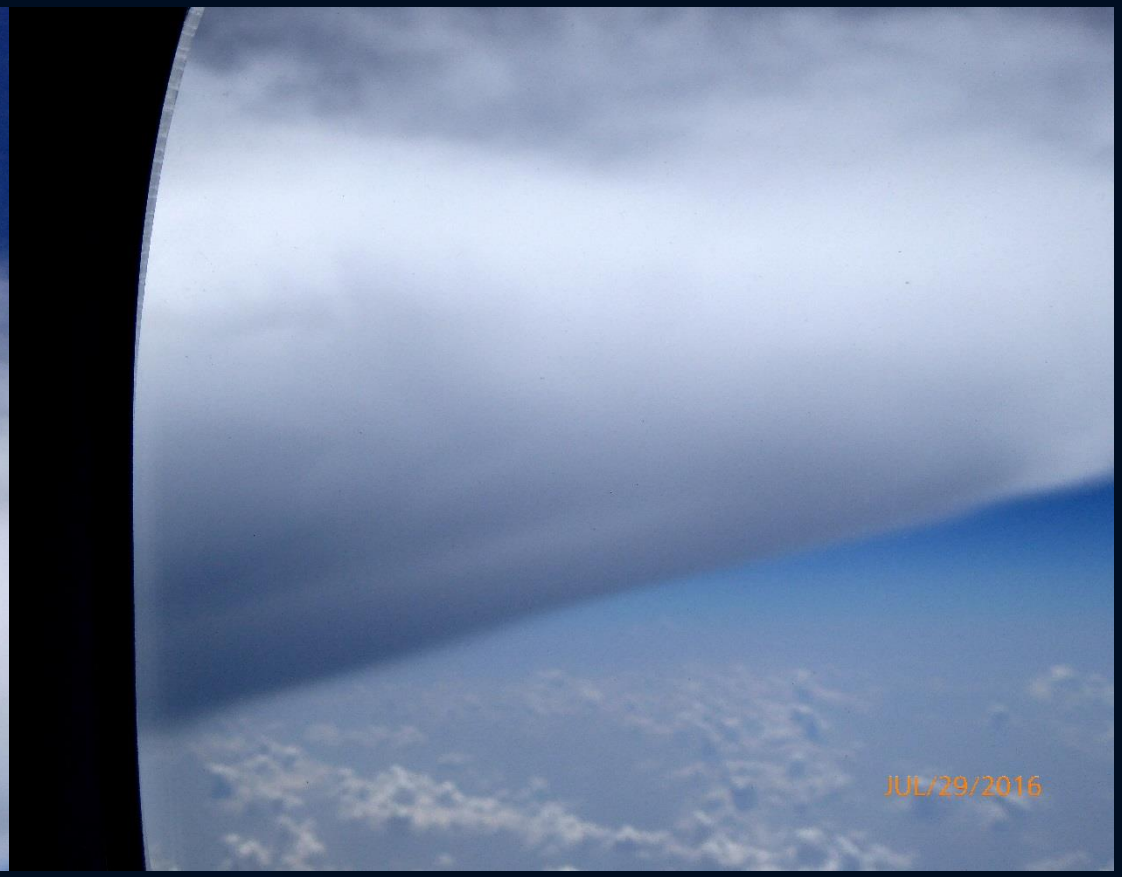
JUMPING CIRRUS STAGE

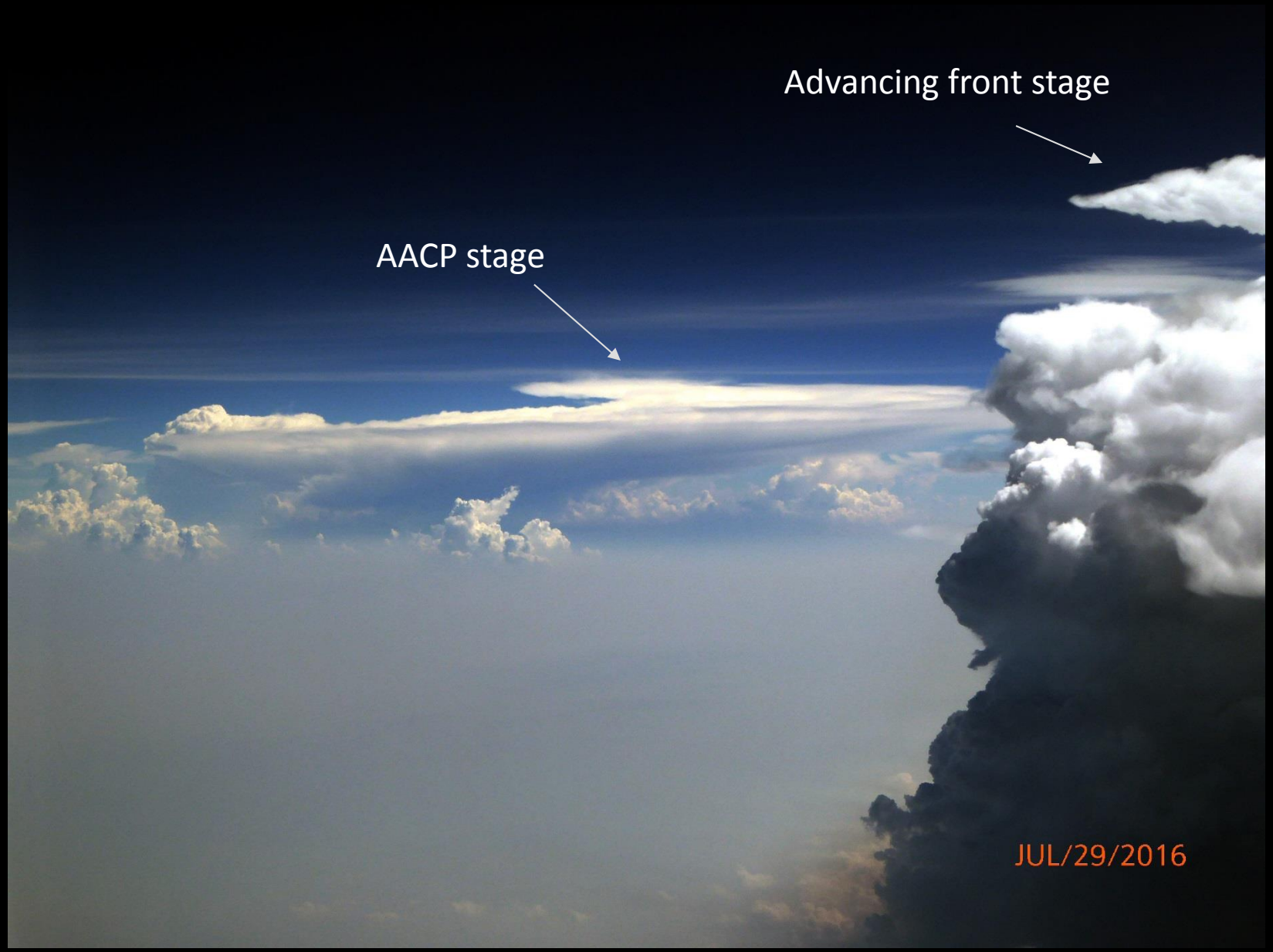
DEVELOPING STAGE

JUL/29/2016

JUL/29/2016

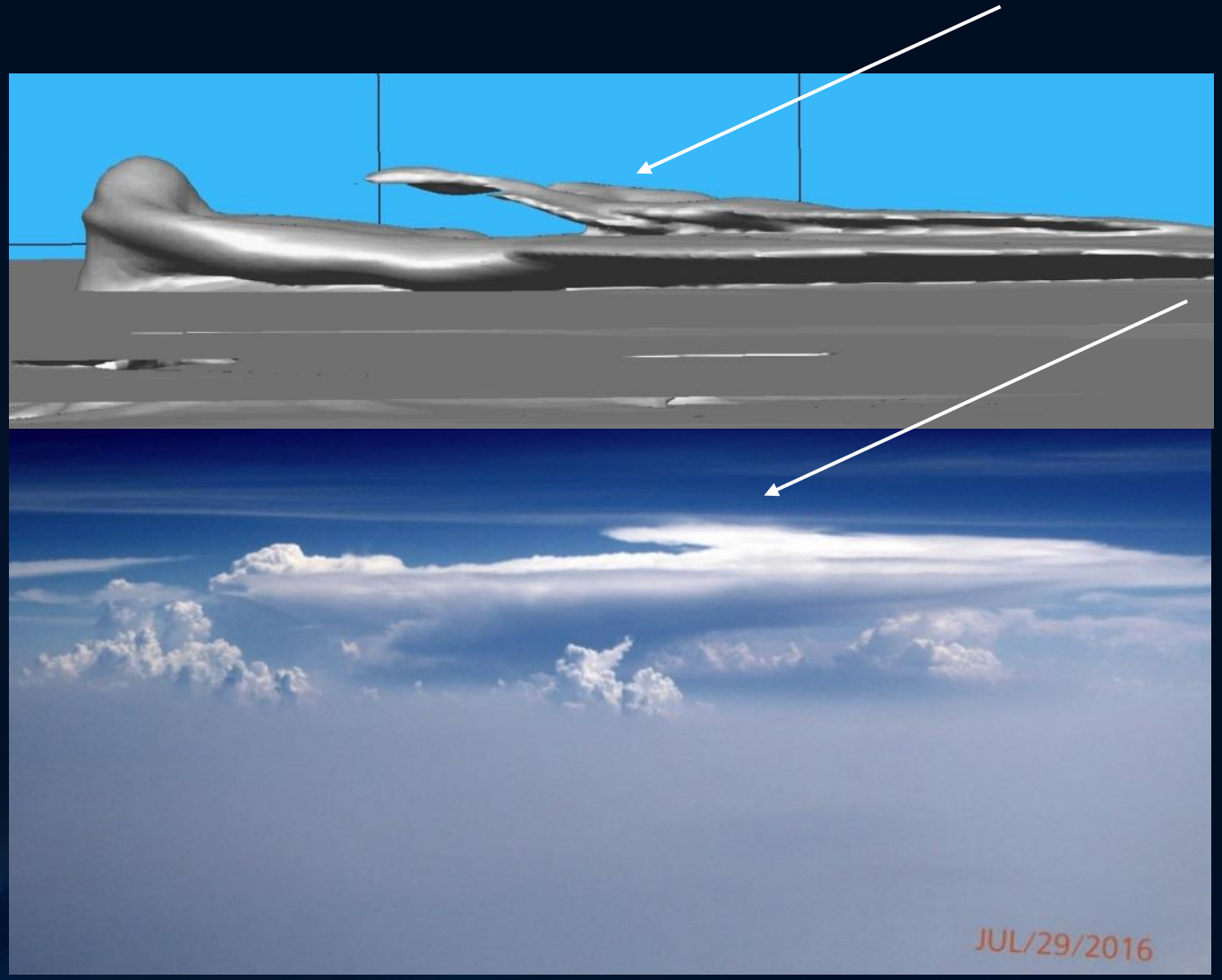
Turbulent top layer and laminar bottom layer



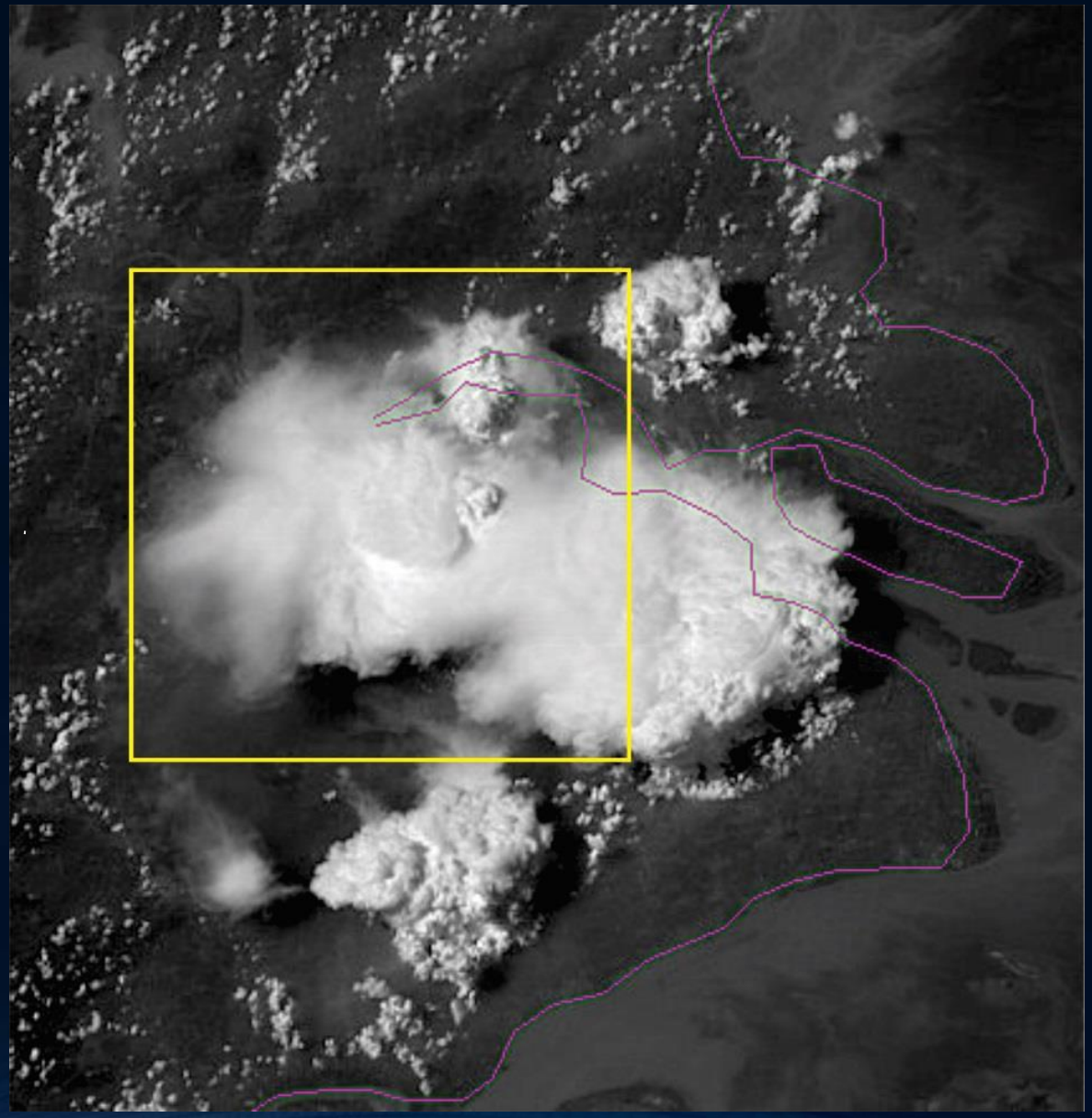

Advancing front stage
AACP stage
JUL/29/2016

Virtually every stage appeared in the model results also showed up in the aircraft observation

it is real—Jumping cirrus does turn into AACP !



The corresponding satellite image

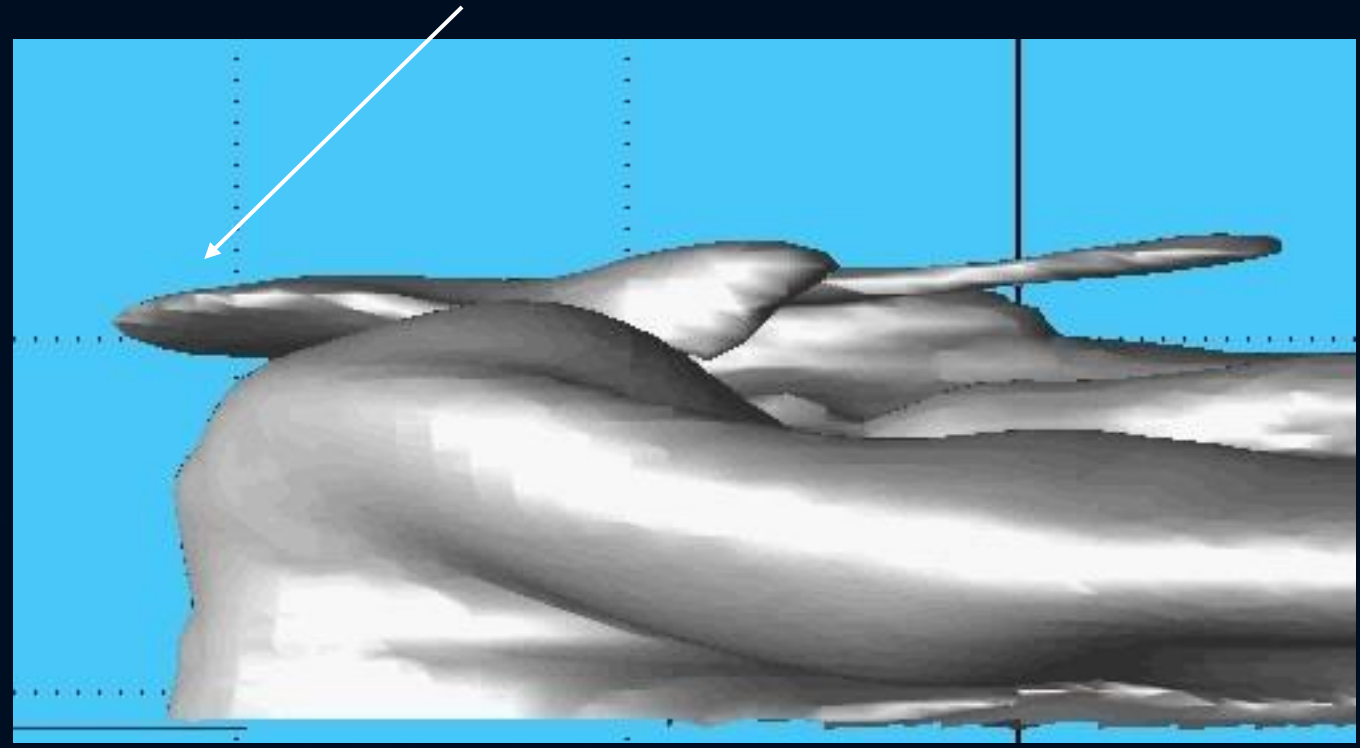


Advancing cirrus front-1

Advancing cirrus front-2

advancing cirrus front

…Model results show that JC often forms first and later may combine with other JC to form advancing cirrus front to become a forward cirrus plume… protrusions are often overtaken by the approaching cirrus, thus disappearing into the cloud. **We often got an impression that an advancing cirrus front chases protrusions until they are swallowed by the cloud.** (Fujita, 1974)

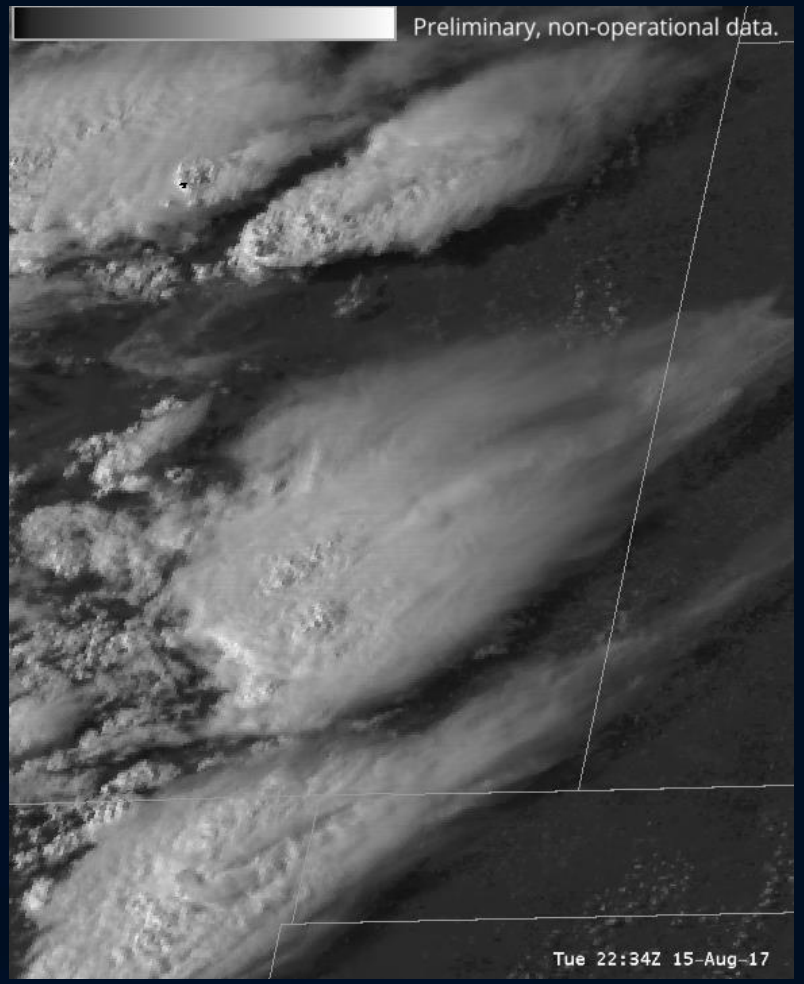


Physical mechanisms

- Updraft of the deep convection encounters the tropopause exciting internal gravity waves. They look like ripples on the anvil and can cause small scale jumping cirrus under suitable conditions. Ice particles in these JC may be detectable by satellites
- The updraft also behaves like an obstacle to the ambient wind that excites mountain waves in the lee side of the OT (so the OT is like a moving mountain). The wave breaking in the lee side causes the large JC to turn into an AACP. (The lee side wave breaking occurs often in the east side of Rocky Mountains).

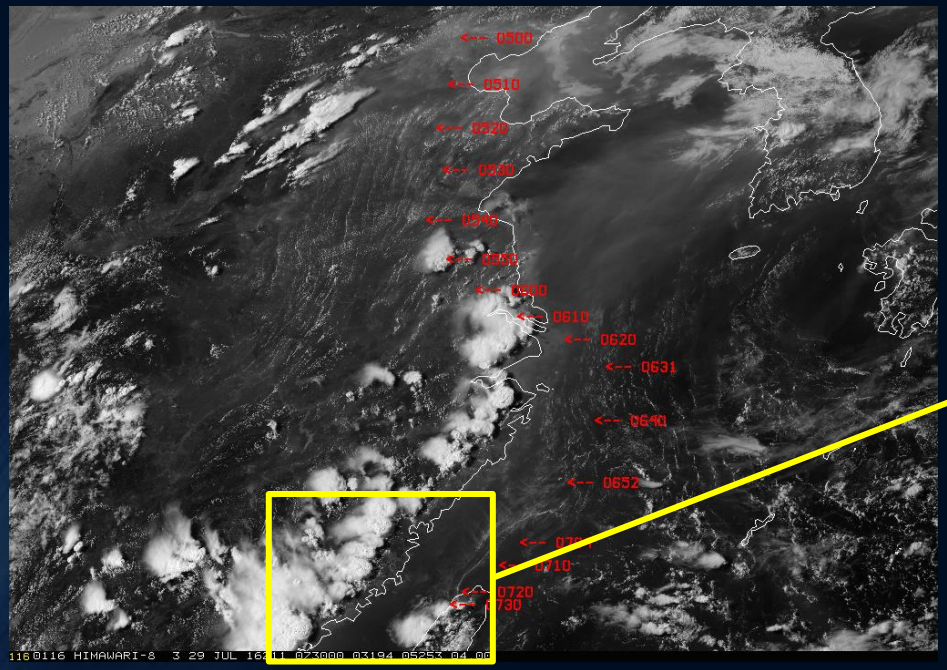
More recent examples by GOES 16

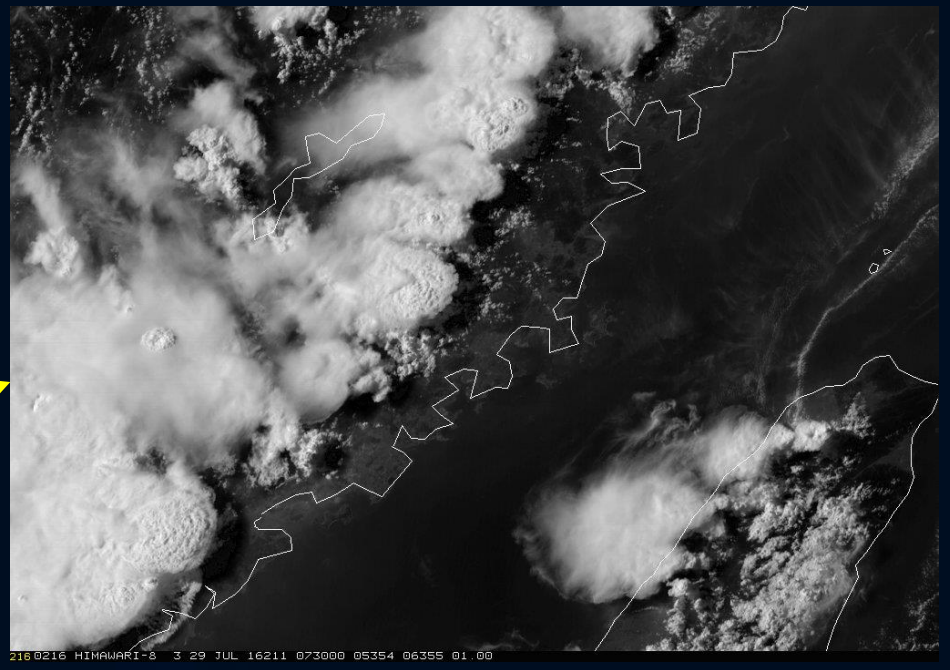
very vigorous AACP and tilted in the same manner



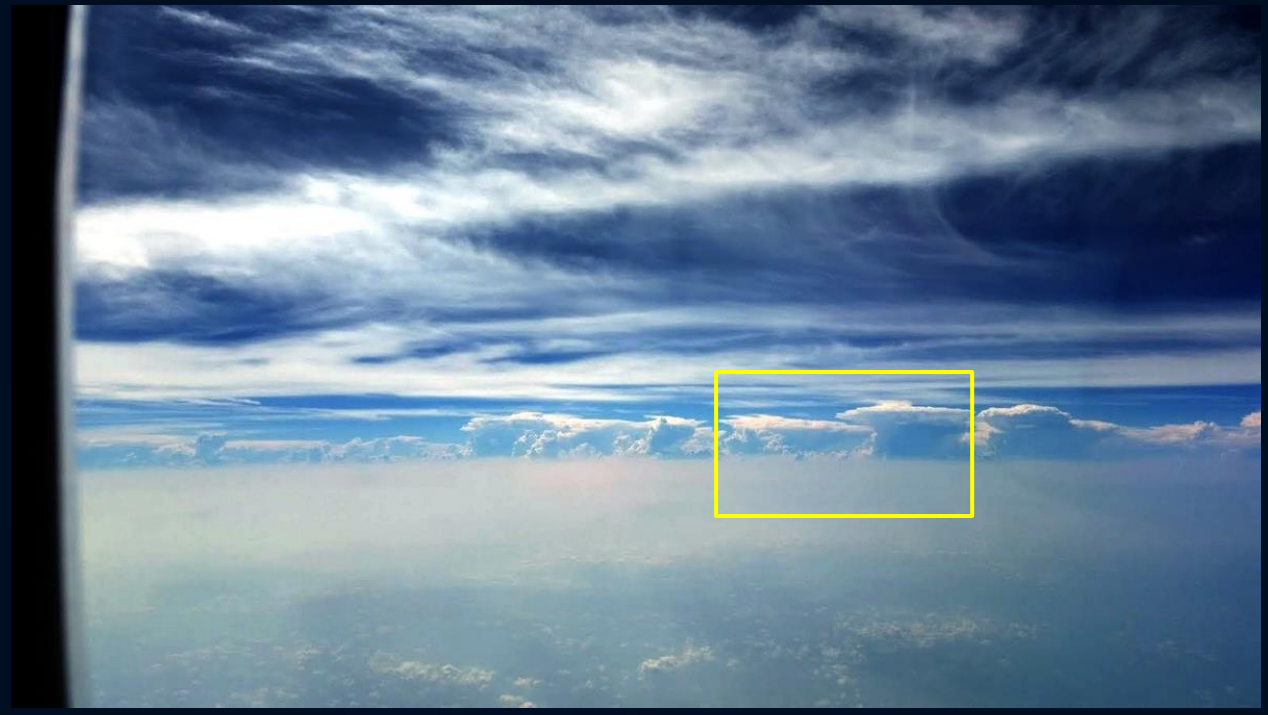
From: Satellite Liaison Blog by Bill Line

Is AACP a rare phenomenon?
Nearly all cells show AACP!





The line of thunderstorms in the previous satellite image. Not only that all cells have AACP, there are also extensive cirrus clouds above storms



Conclusions

Comparing aircraft and satellite observations and model results, we found that:

- Jumping cirrus can indeed turns into above-anvil cirrus plumes (AACP)
- Cloud resolving models can simulate storm top dynamics successfully
- AACP occurs very frequently
- All these features are caused by the interaction among the updraft, tropopause and ambient wind

The End

HVALA