Storm Top Physics and Dynamics

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Understand the storm physics

- Several storm top features in both visible and IR will be examined from the point of view of model simulations. The purpose is to understand the physics of the observed phenomena using the physics included in the model.
- The understanding of such physics is useful for forecasters who use these satellite observed features. The forecaster will be able to identify what was happening in the storm at the time the image was taken. That piece of information will enable the forecaster to project the future development of the storm.

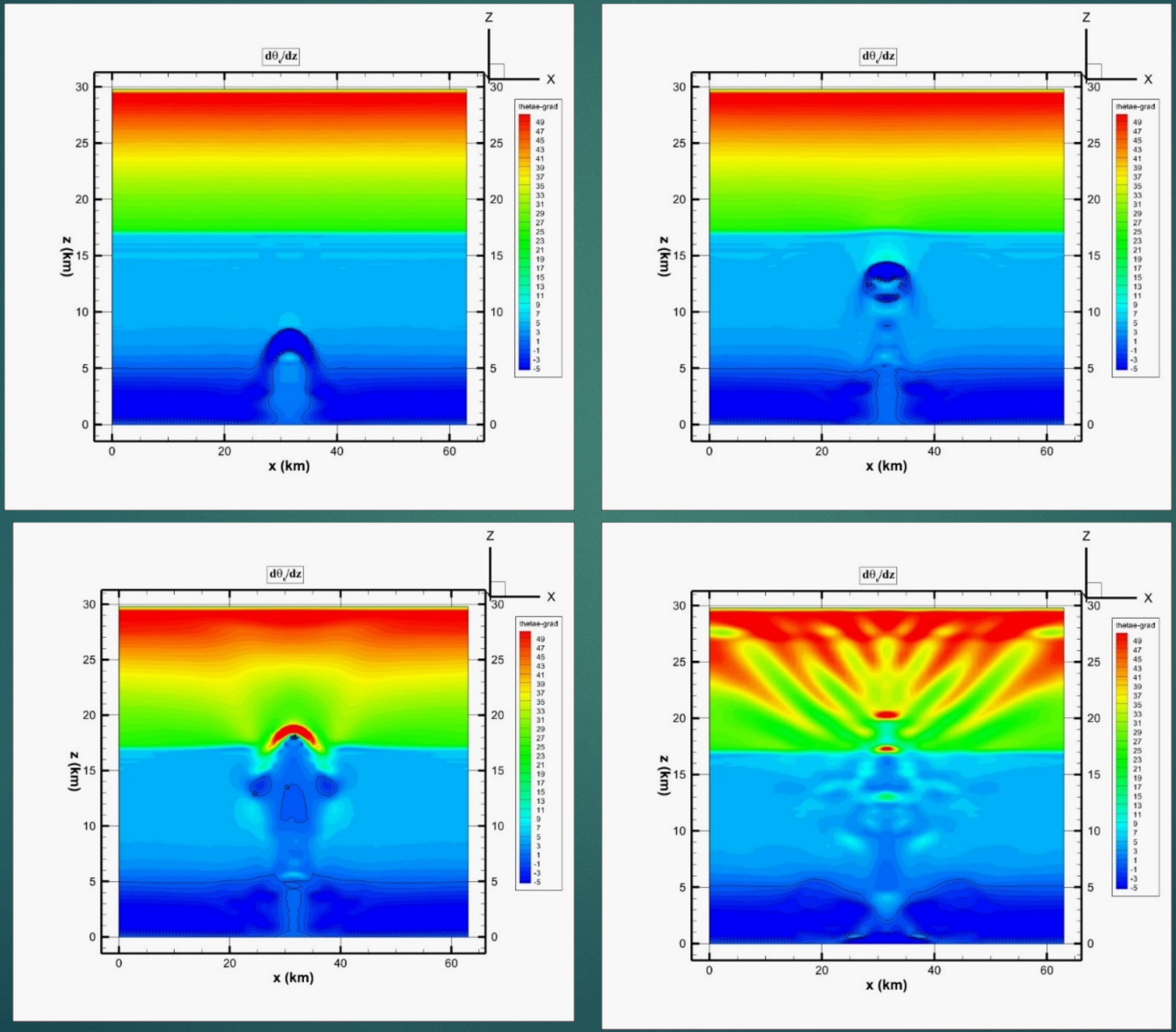
Internal gravity waves in the lab

University of Kyoto

Internal gravity waves in cloud model

Transport of instability ($d\theta_e/dz < 0$) from the surface to upper levels

what do you see from above?



Dynamic regimes of deep convective storms

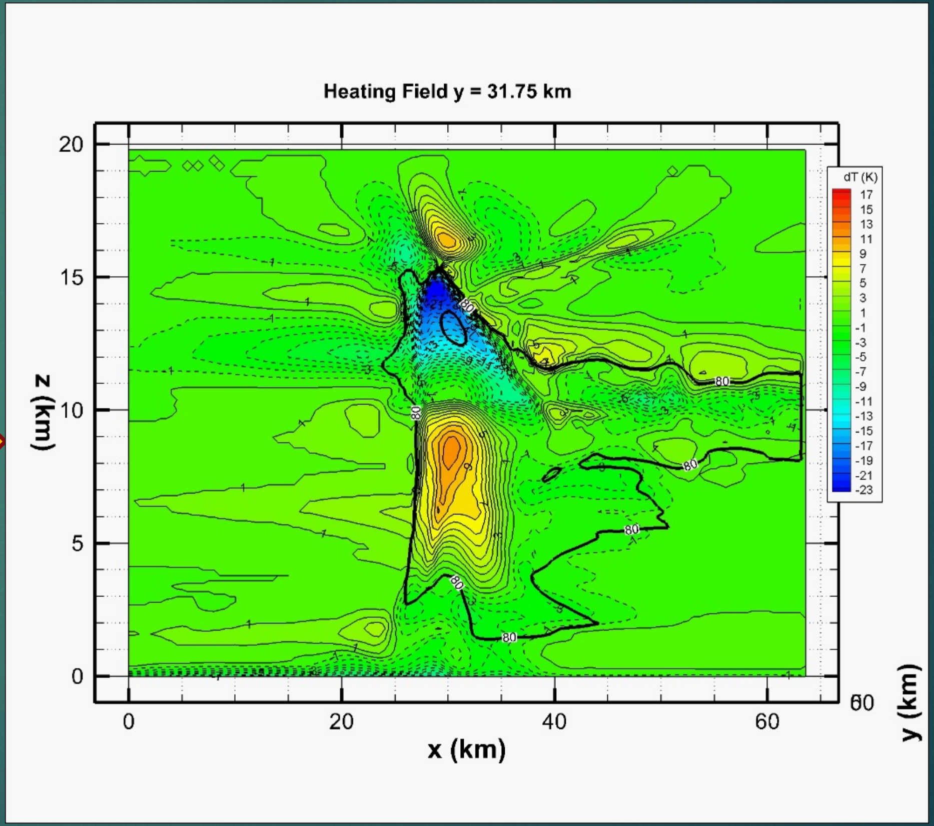
Wave physics dominated

Overshooting top (OT), Cold –U or V, close-in warm area (CWA), distant warm area (DWA), above anvil cirrus plumes, jumping cirrus (JC), ship waves, radial cirrus, gullwing cirrus (GC), etc.

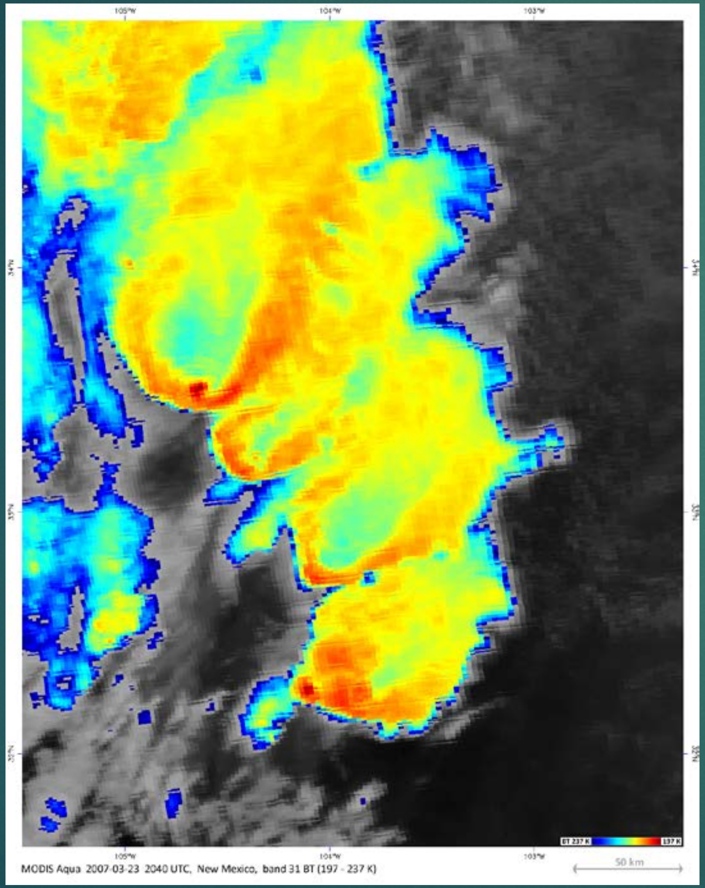
Transition layer ~ 8-10 km

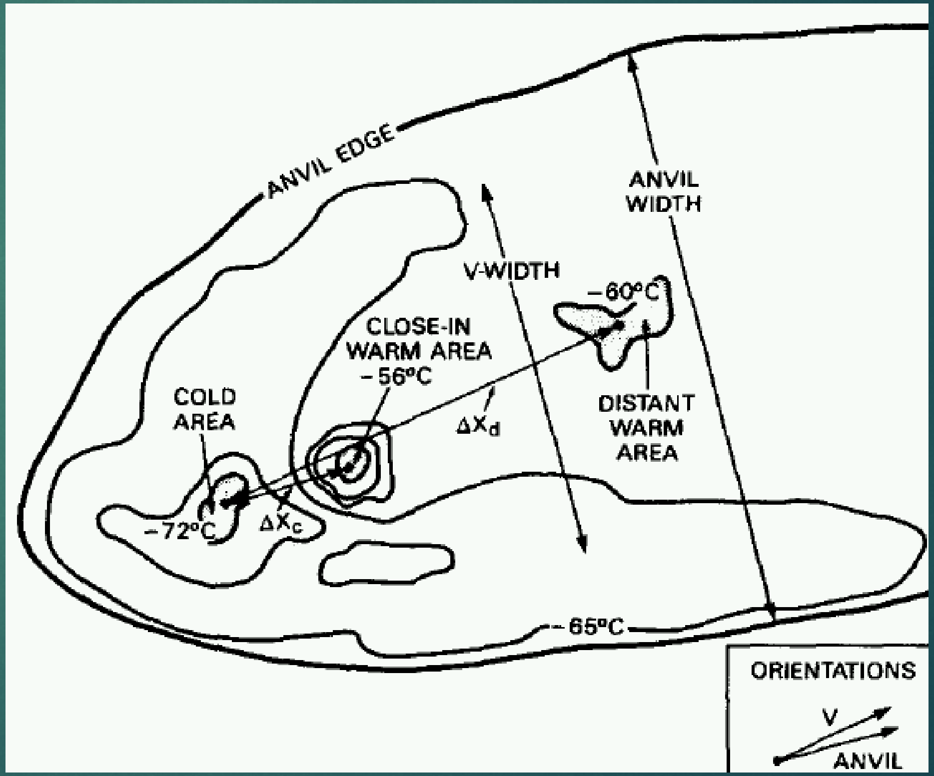
Instability physics dominated

Intense updraft, heavy precipitation, strong wind, large hail, hook echo, gust front, cold pool, thunder and lightning, tornado, etc.

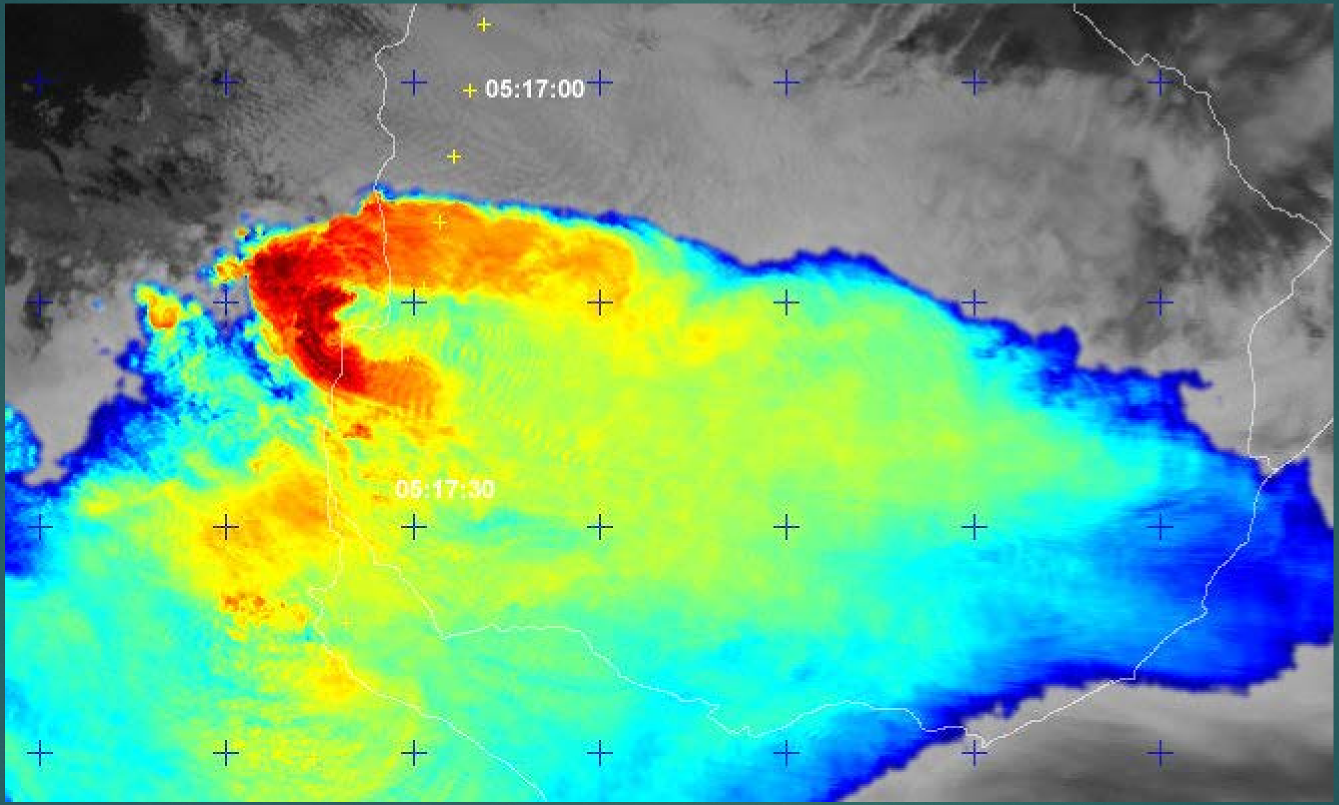


Cold-U or V(enhanced-U or V), CWA, DWA

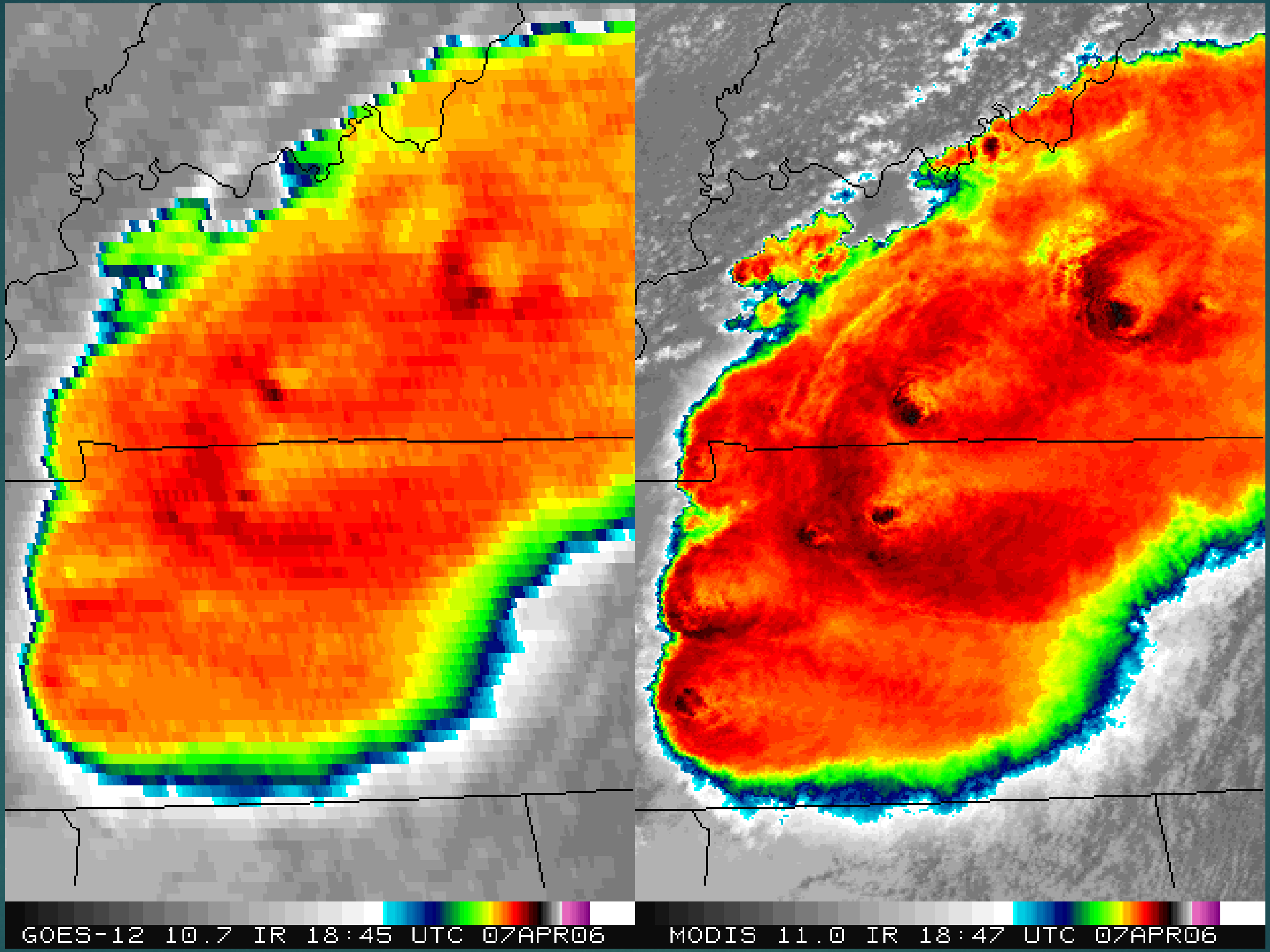




Cold-V : Argentina storm



Martin Setvak

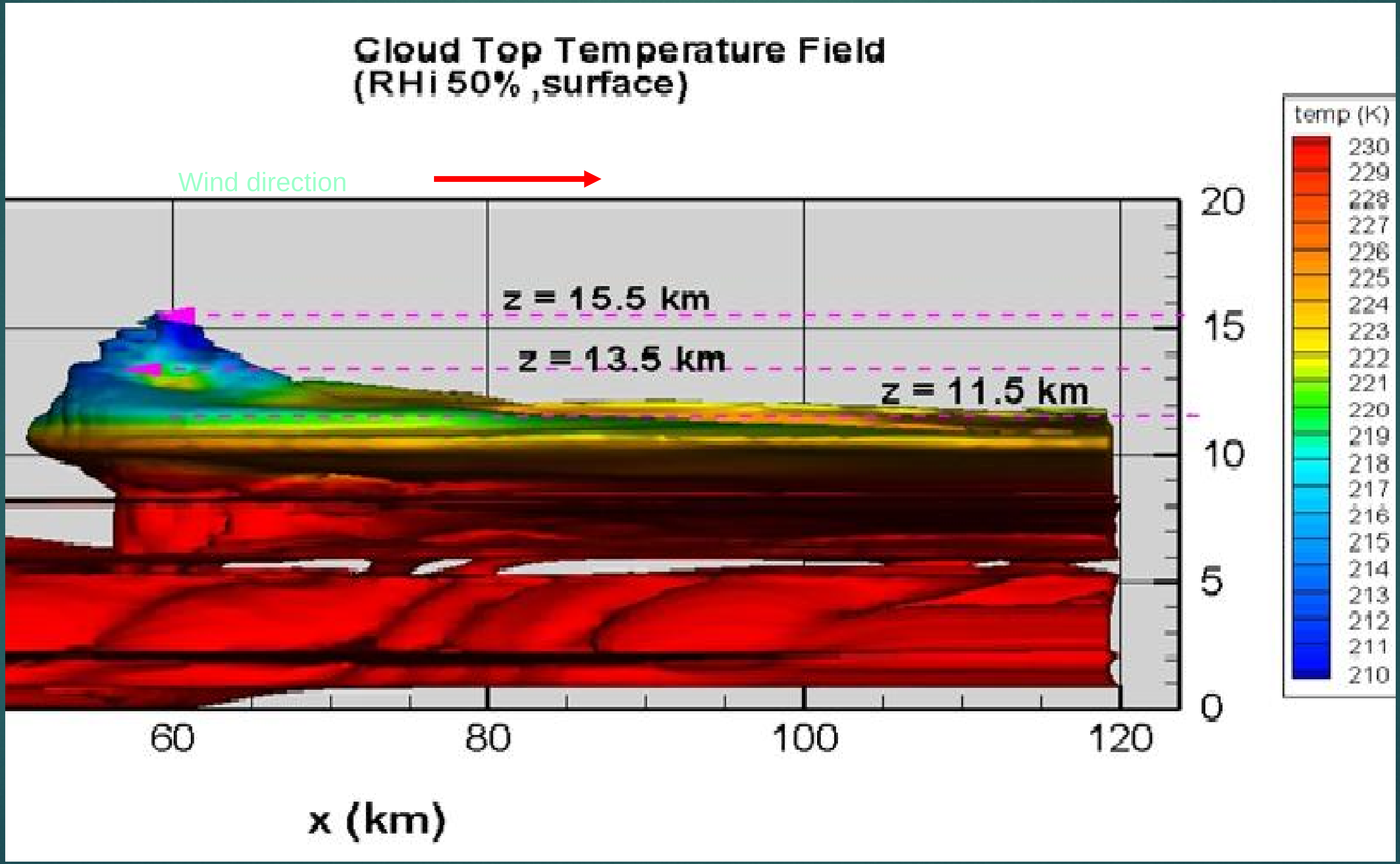


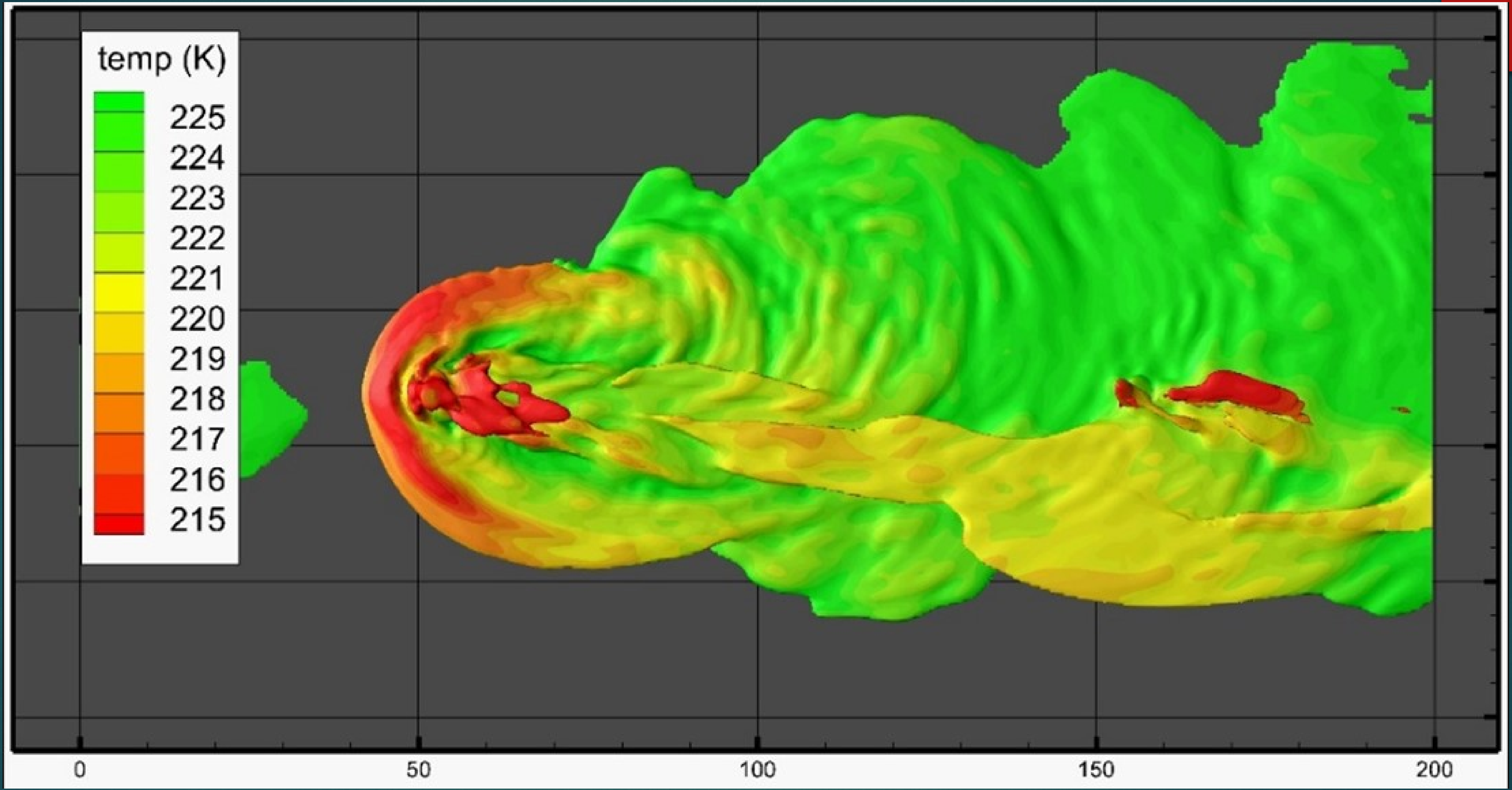
CIMSS/UW-Madison

Simulated CCOPE supercell cloud top temperature field

Interaction between the storm updraft core and ambient flow

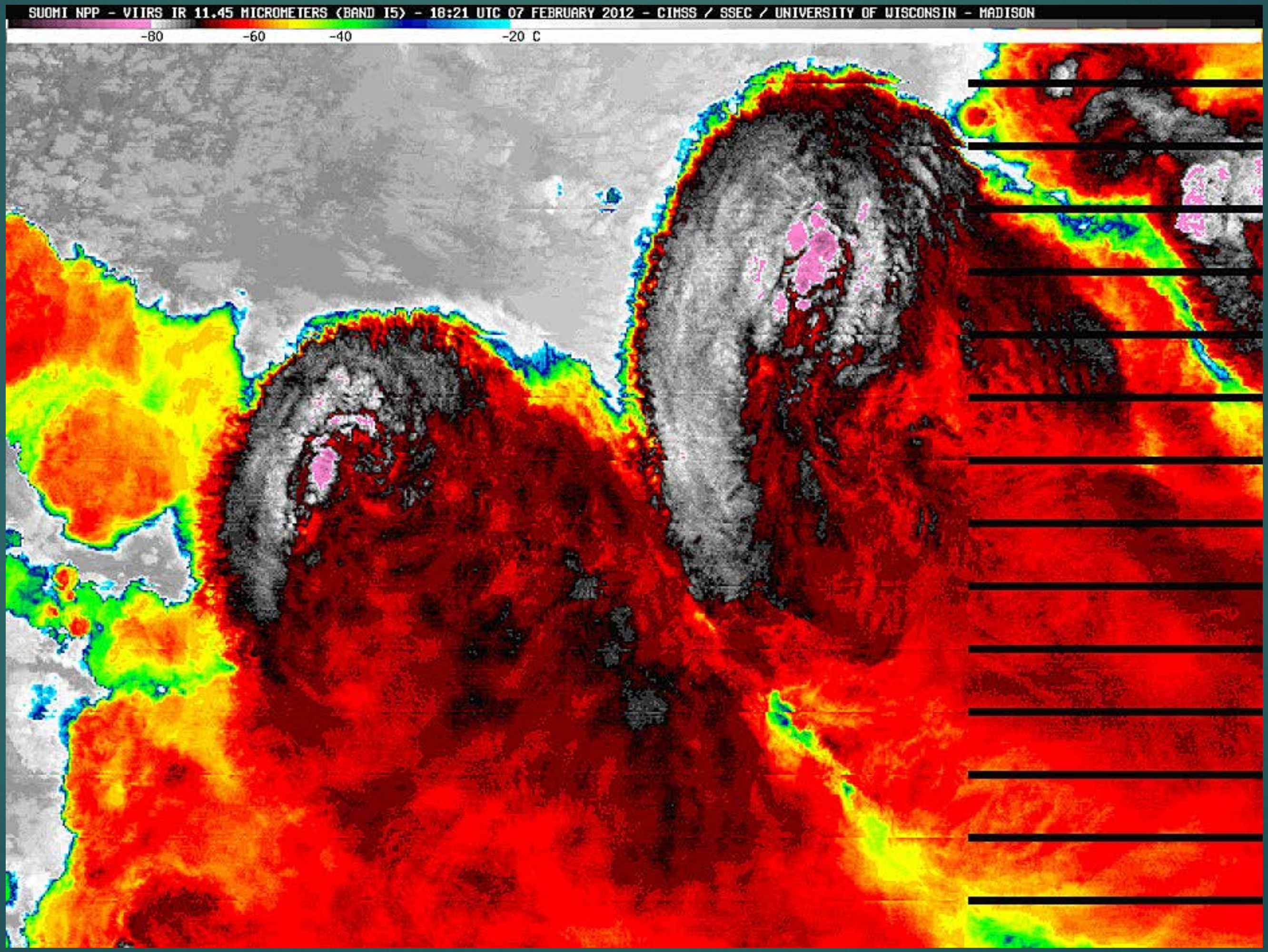
- General height difference Δz~ 2 km
- an adiabatic temperature difference ~ 13-20 K
- Other processes such as phase change and mixing may modify this difference.



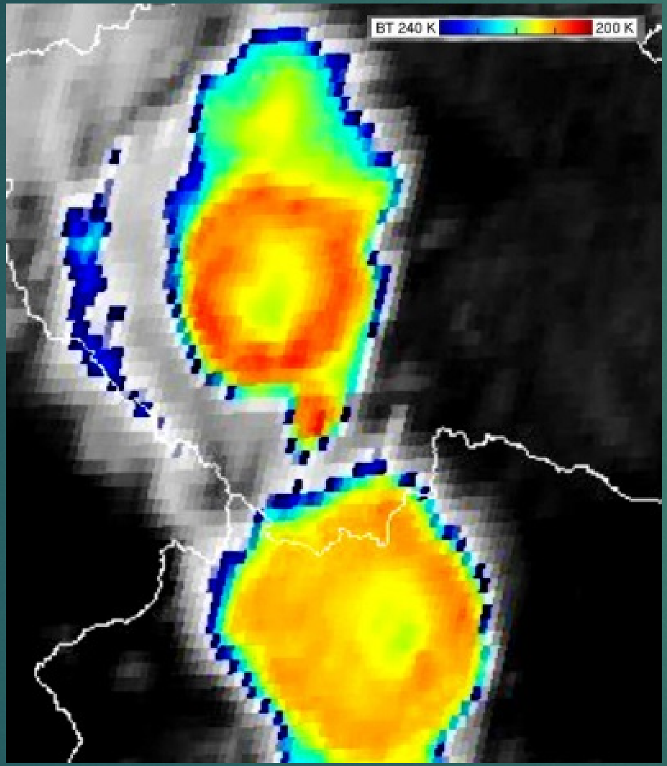


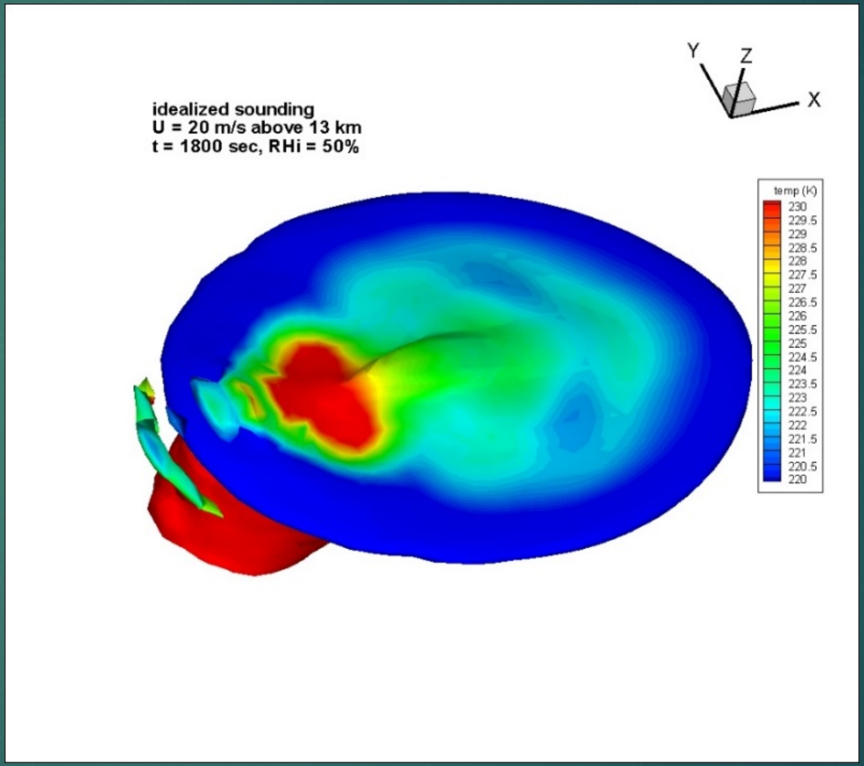
temp (K)
225
224
223
222
221
220
219
218
217
216
215
0
50
100
150
200

SUOMI NPP - VIIRS

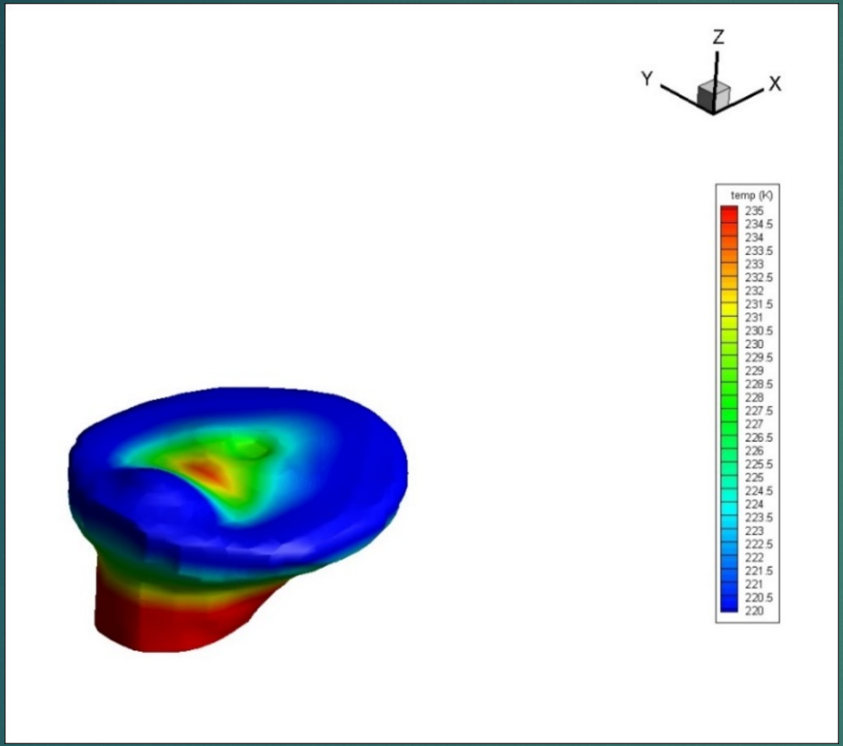


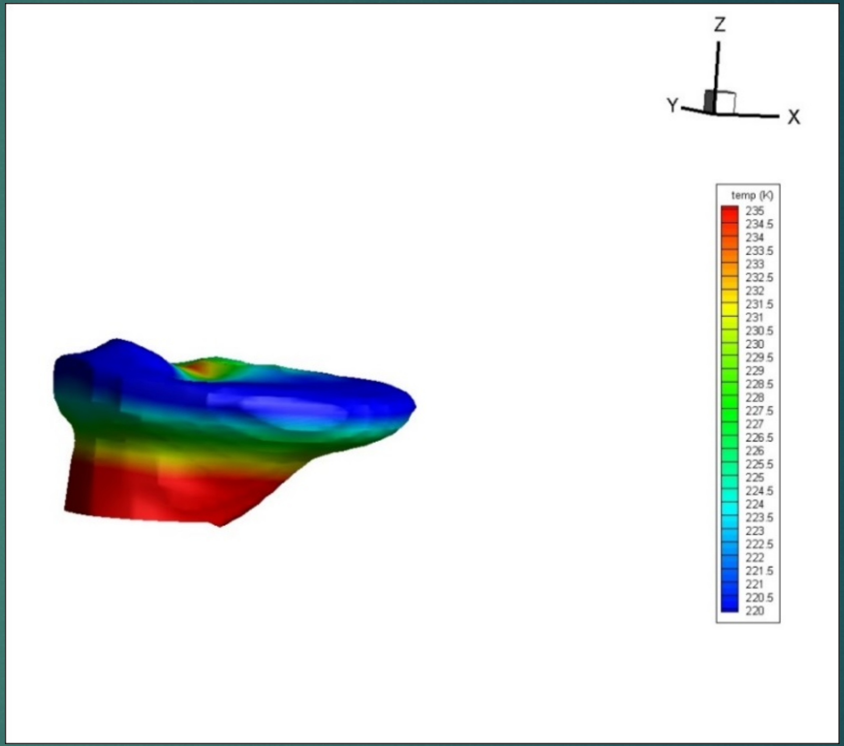
Weak wind shear – cold ring





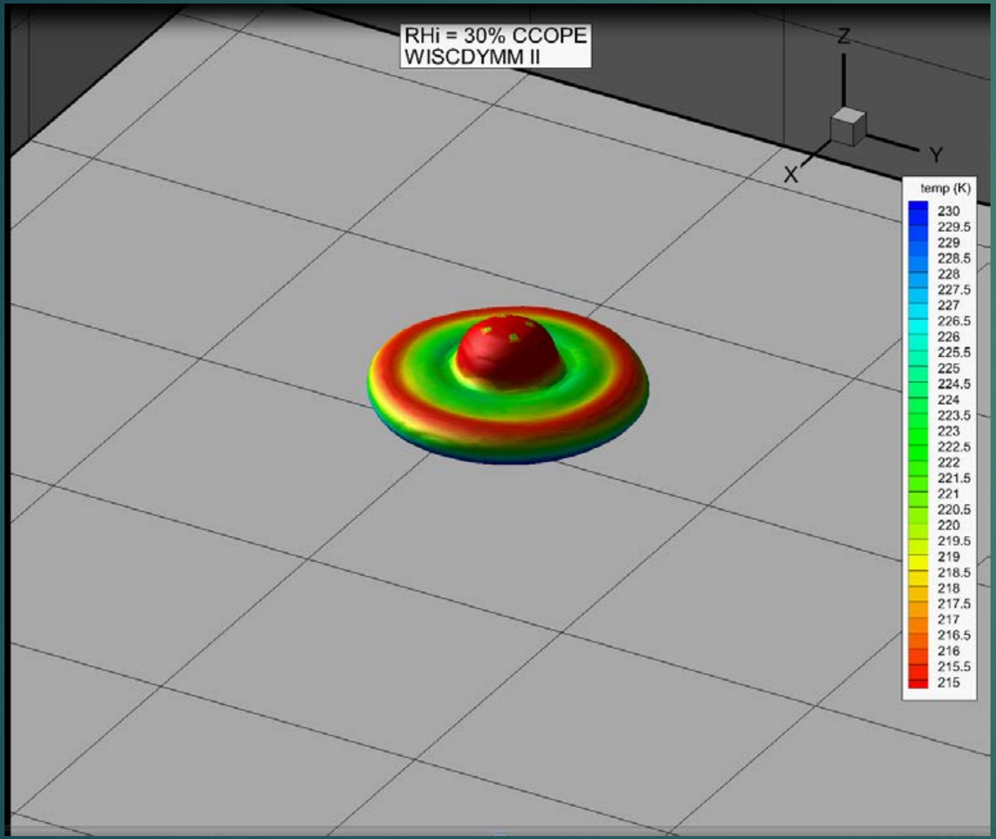
Simulated storm top temperature with weak shear

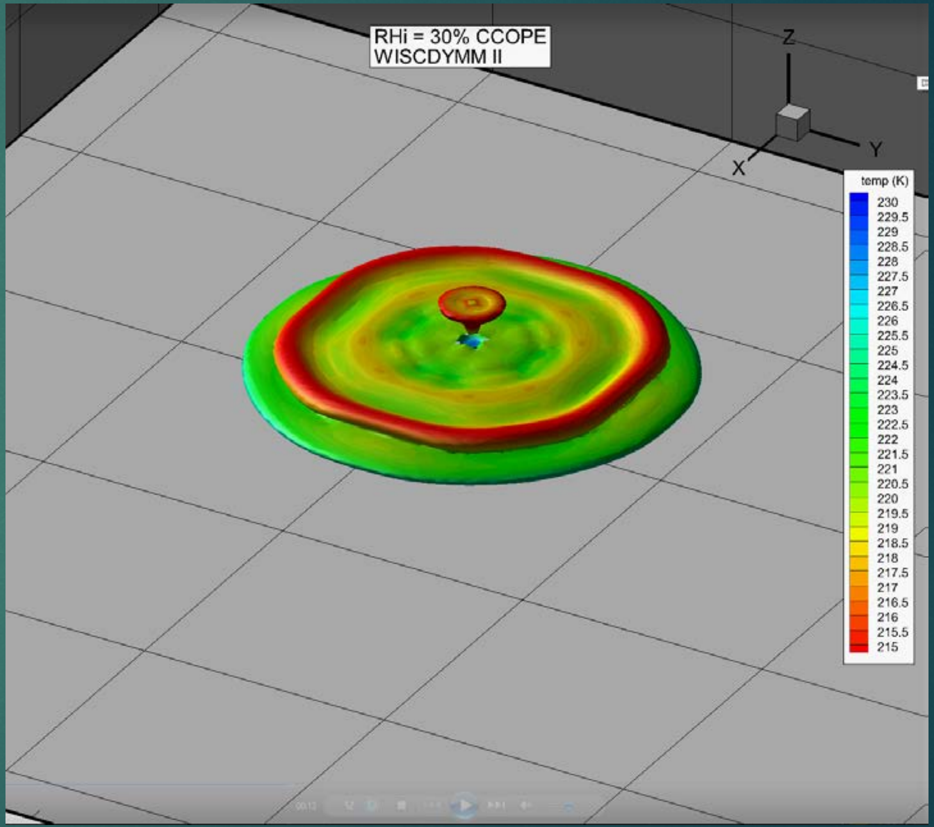




Cold ring – simulation

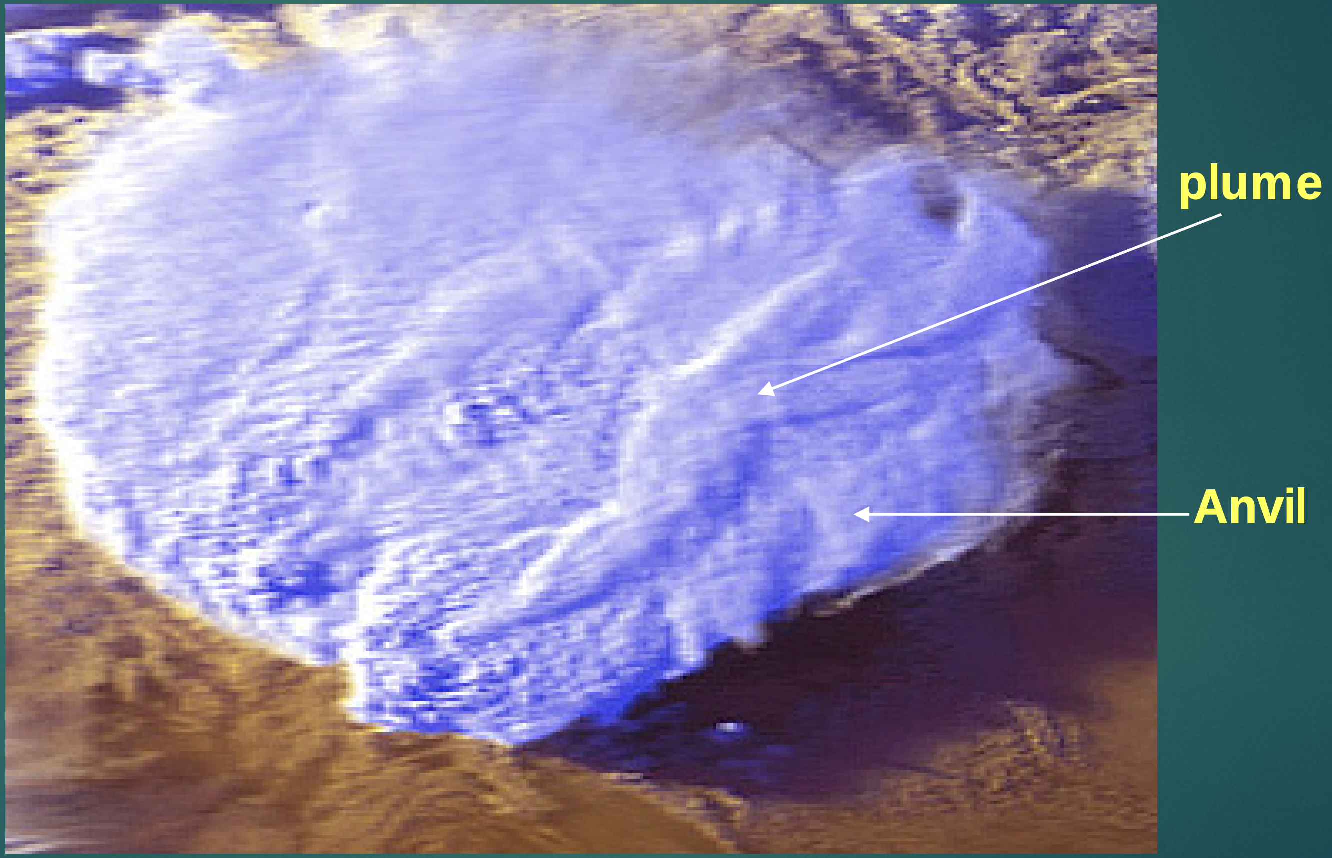
no wind shear





Above Anvil Cirrus Plumes (AACP)

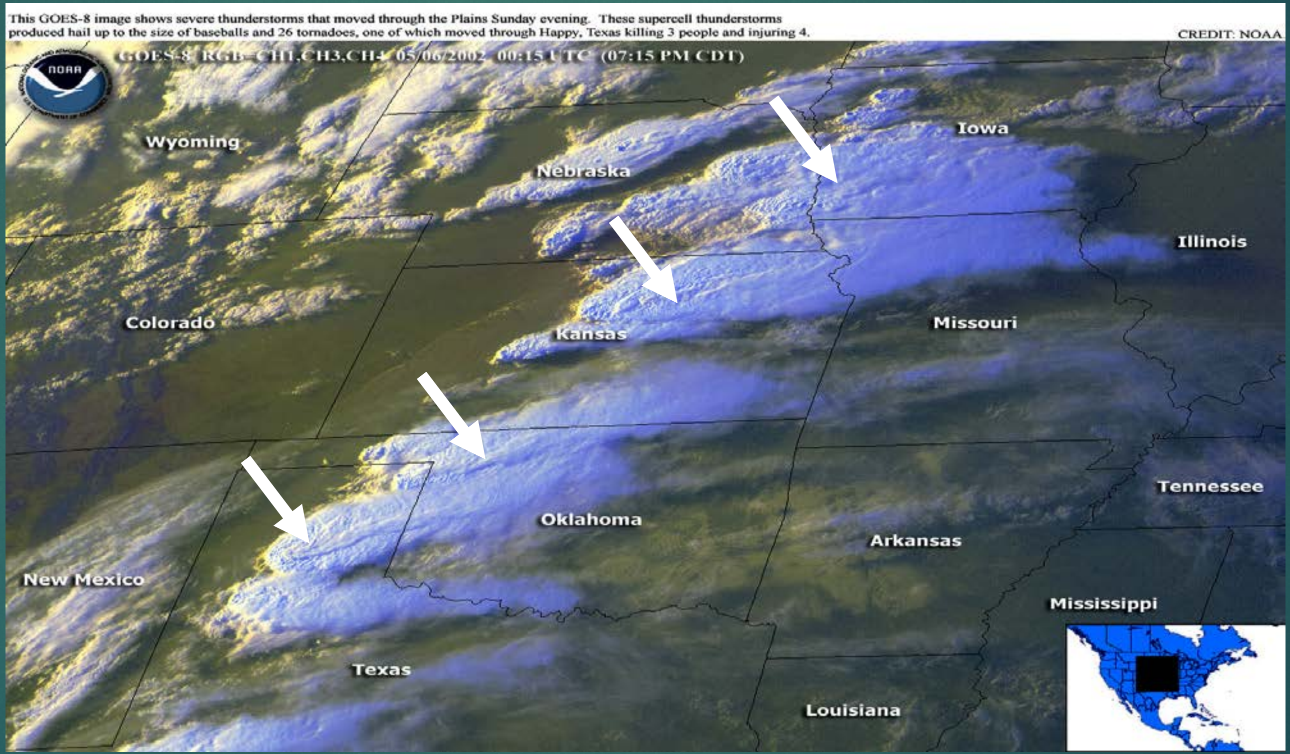
Satellite observation of middle latitude deep convective storms



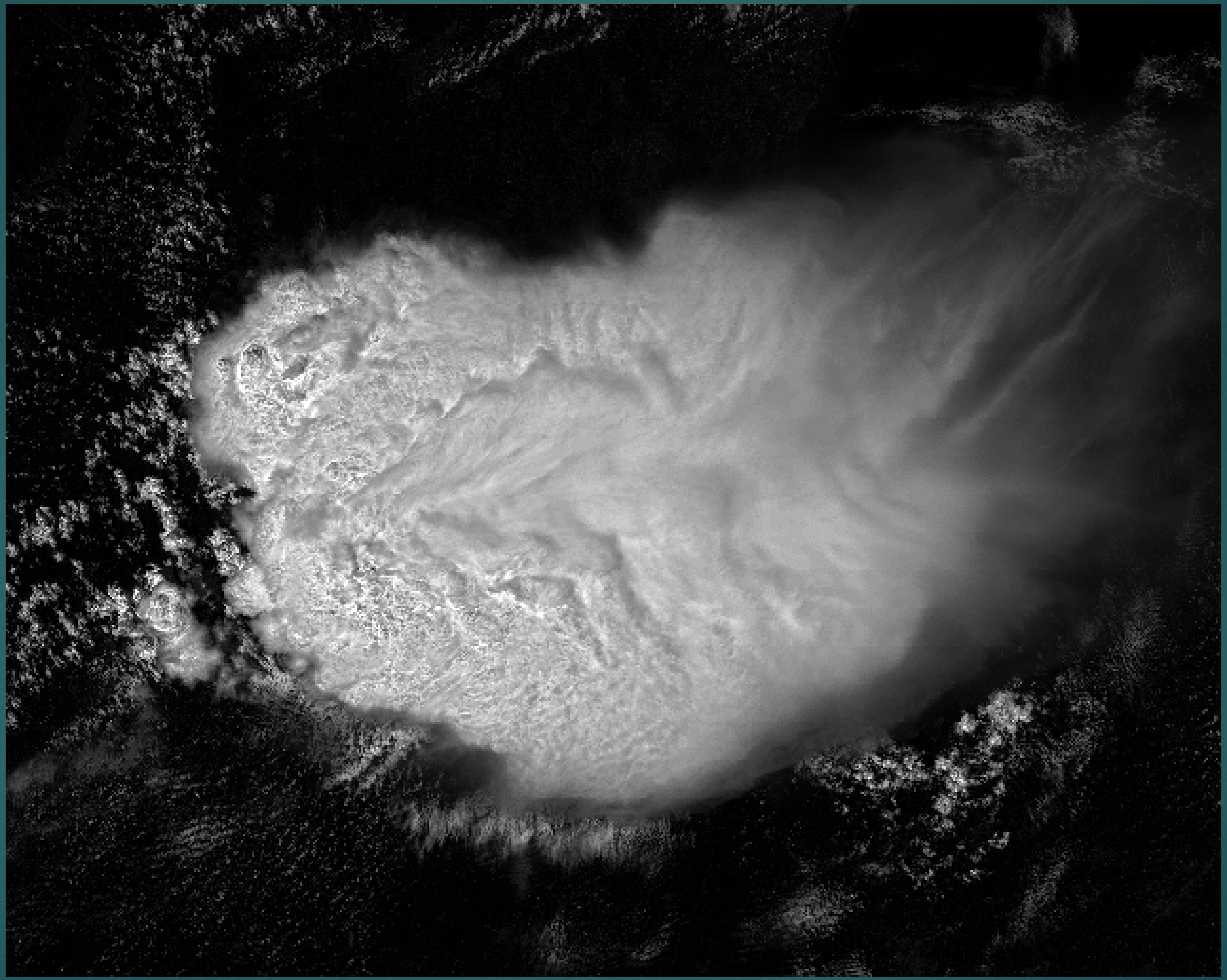
Storms over Balearic Islands

(courtesy of Martin Setvak)

GOES visible images—nearly every active cell is associated with plumes



MODIS examples



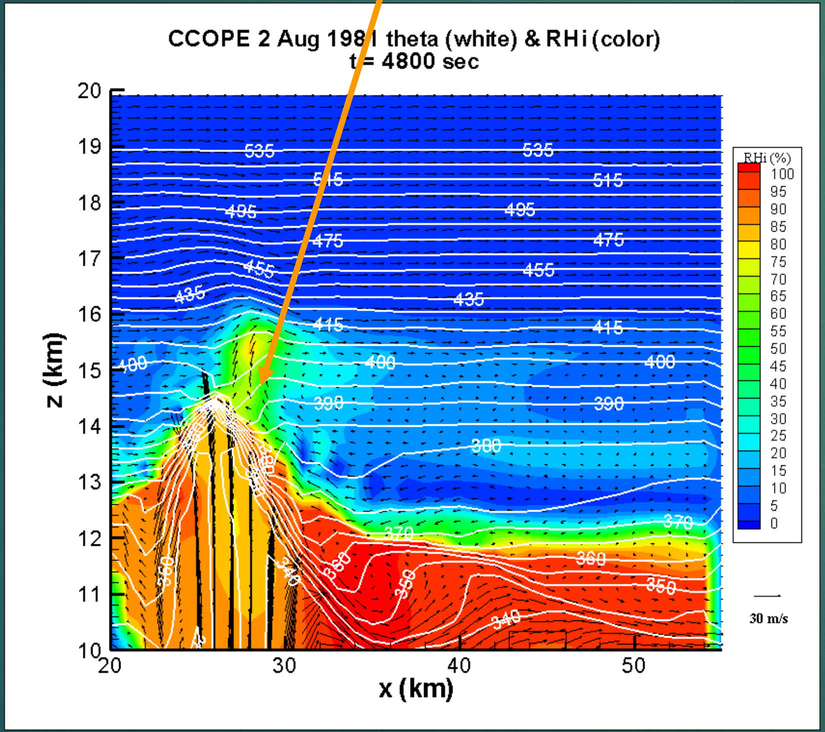
13 July 2004 MODIS Aqua band 1, Northern Illinois

Simulated plume formation

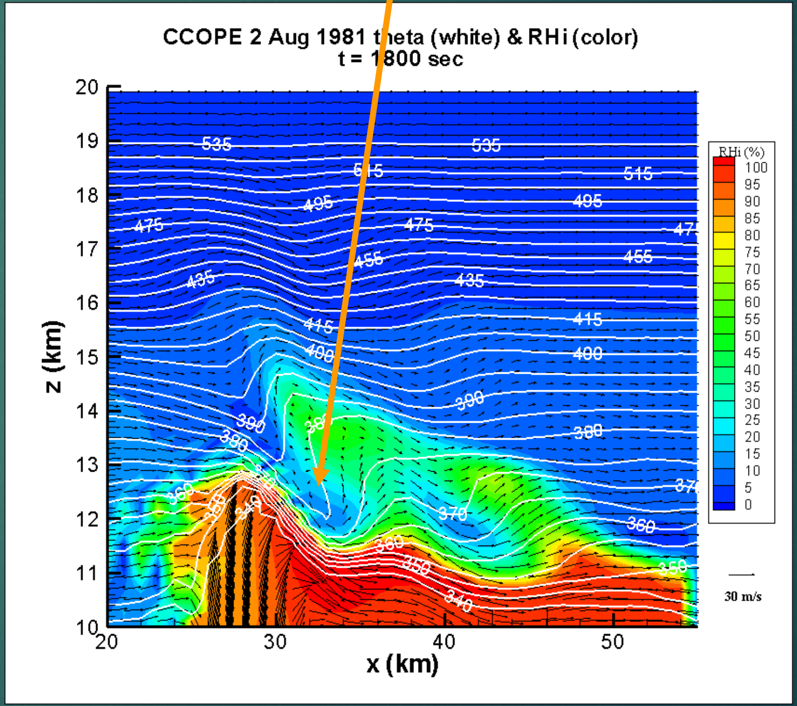
Instability and Wave Breaking

- Convection-induced instability and gravity wave breaking at the storm top send H_2O through the tropopause to enter the stratosphere.

Overshooting top plumes



Anvil wave breaking



Wang (2007)

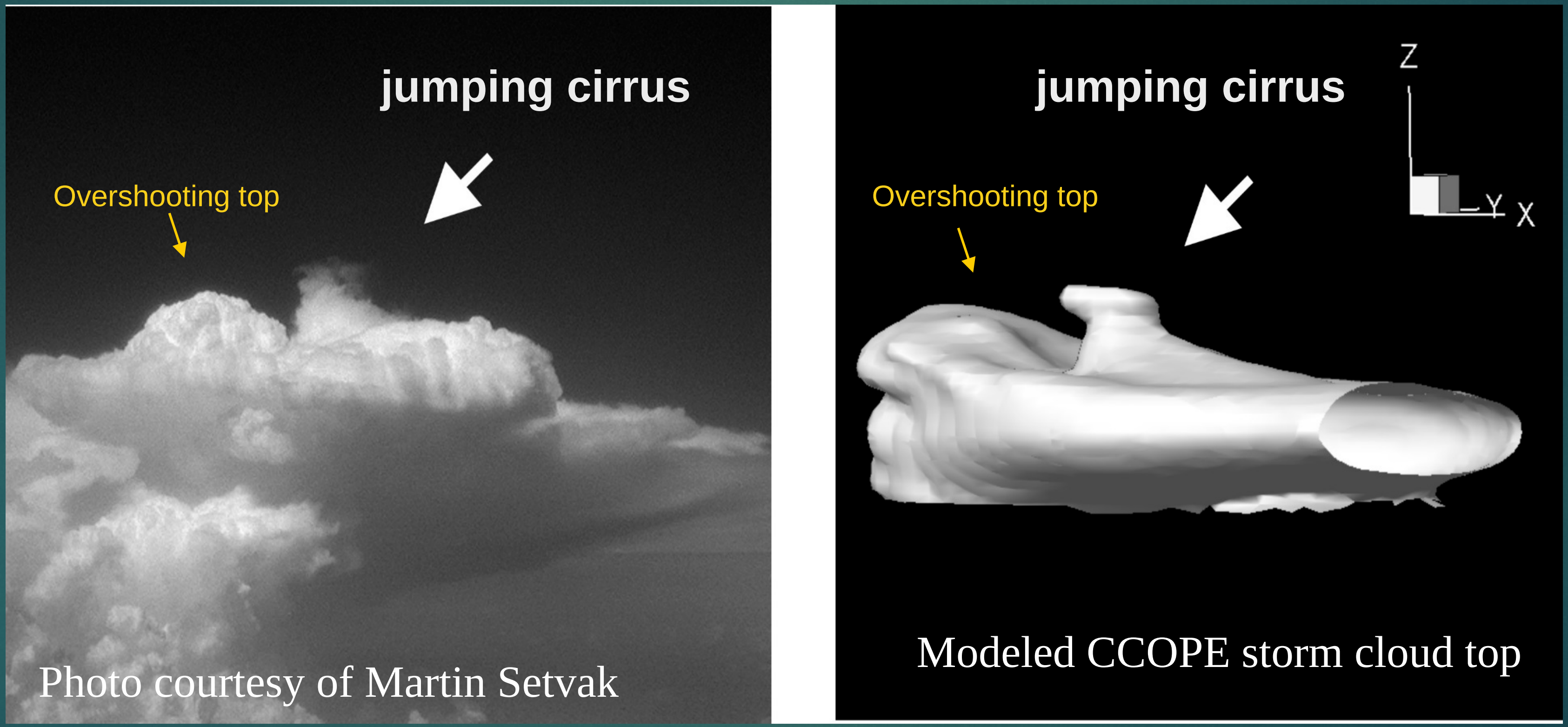
Fujita's Jumping Cirrus

- There were considerable cirrus clouds in the stratosphere above relatively old anvil clouds with active domes. Fly-by observations revealed that the stratospheric cirrus clouds originate when overshooting turrets or domes collapse rather rapidly. During such a colapsing stage, cirrus clouds literally jump up 5,000 to 10, 000 ft beyond the anvil surface.

The top of the stratospheric cirrus at about 50,000 ft was under the influence of, say, 50 kt westerlies. The time-motion analysis revealed, however, that the cirrus moves toward the turrets located to the west of the cirrus front. As seen in the example, 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)

Fujita (1982, 1989) observed jumping cirrus above severe storms – they are also due to wave breaking

Similar shape, size, orientation and occur at similar relative location



From: Wang (2004, GRL)

Courtesy of Willi Schmid

From youtube.com

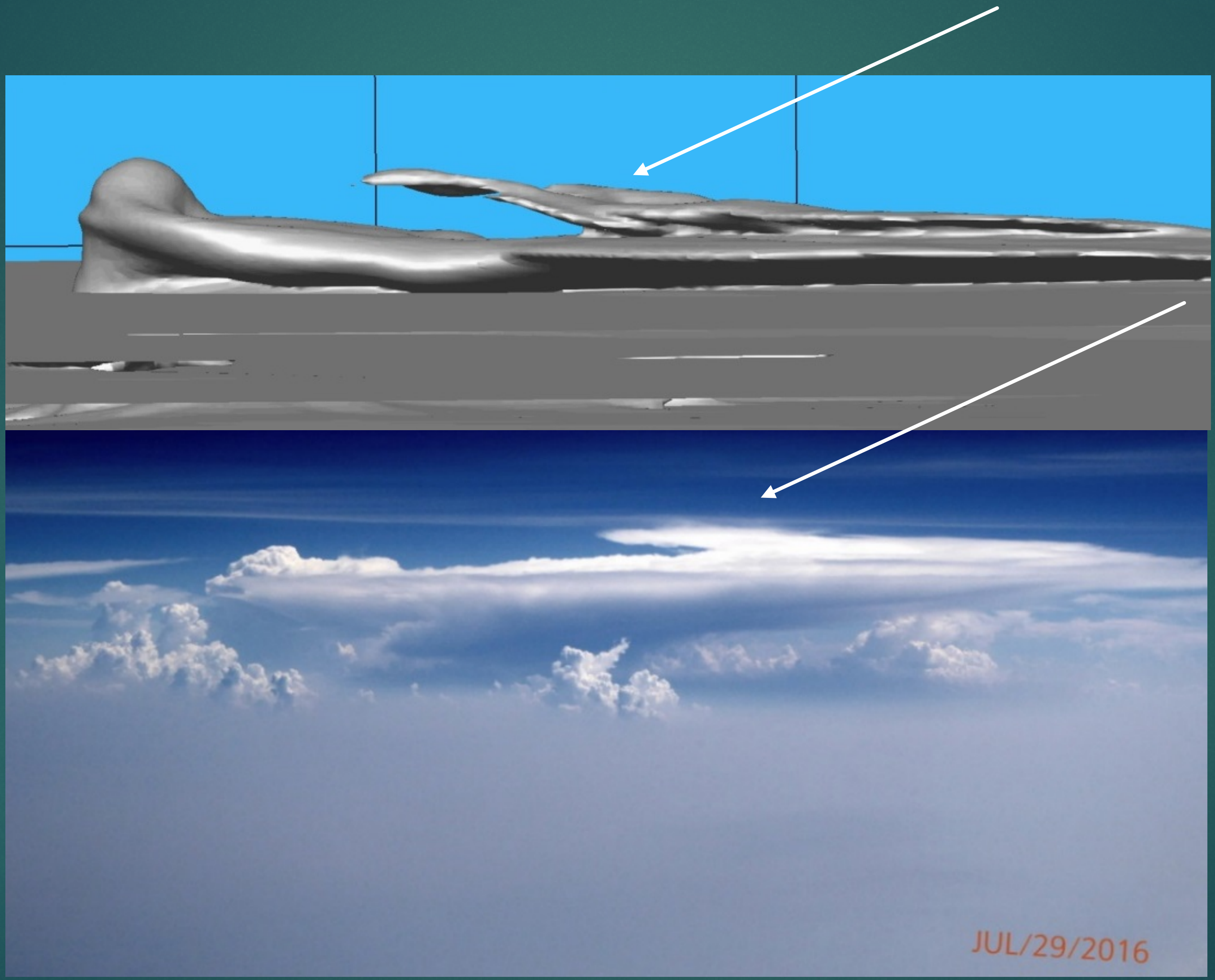
Do jumping cirrus really turn into above anvil cirrus plumes as observed by satellites?

WISCDYMM-2 Model simulation of plume formation

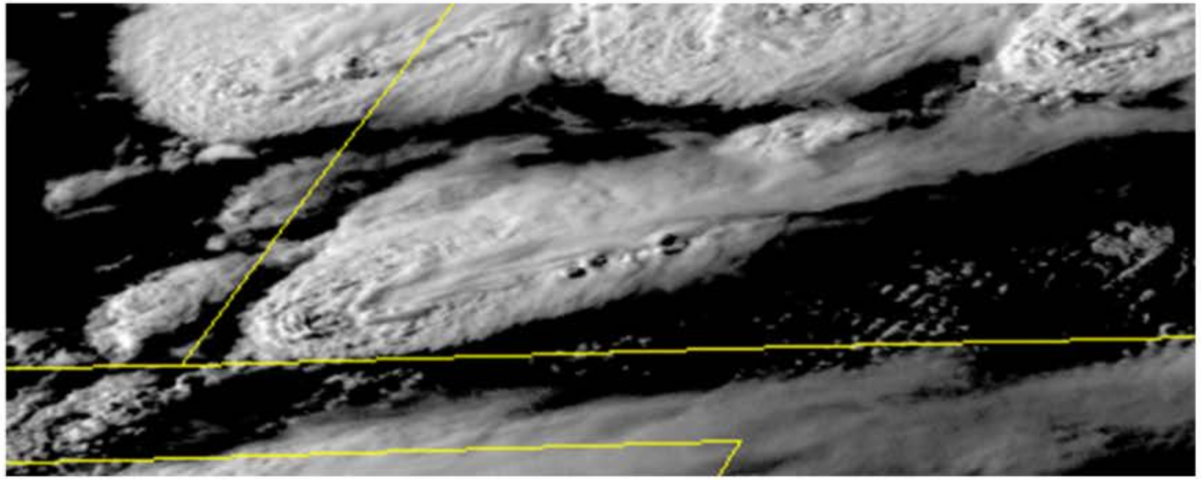
- Notice AACP formation
- Also, advancing cirrus front around OT area


JUL/29/2016

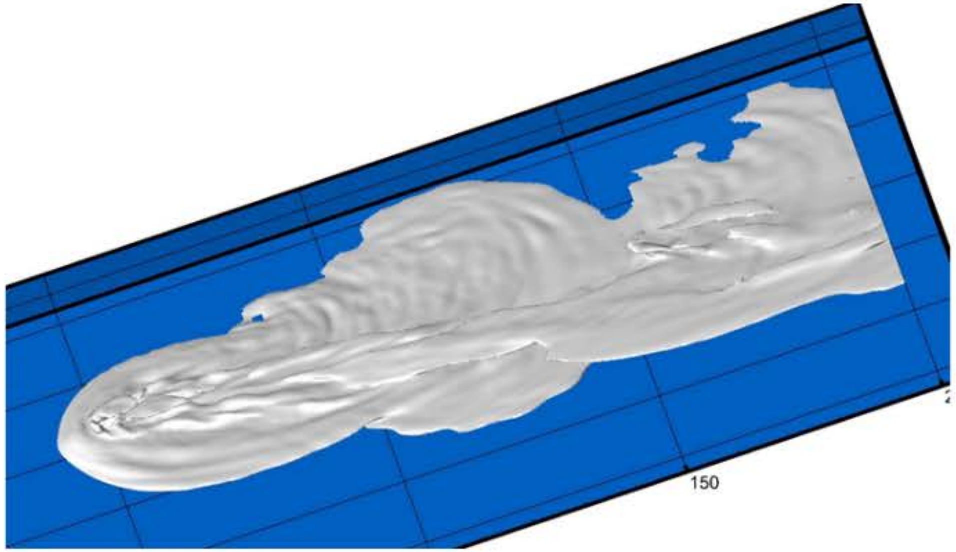
it is real—Jumping cirrus does turn into AACP !



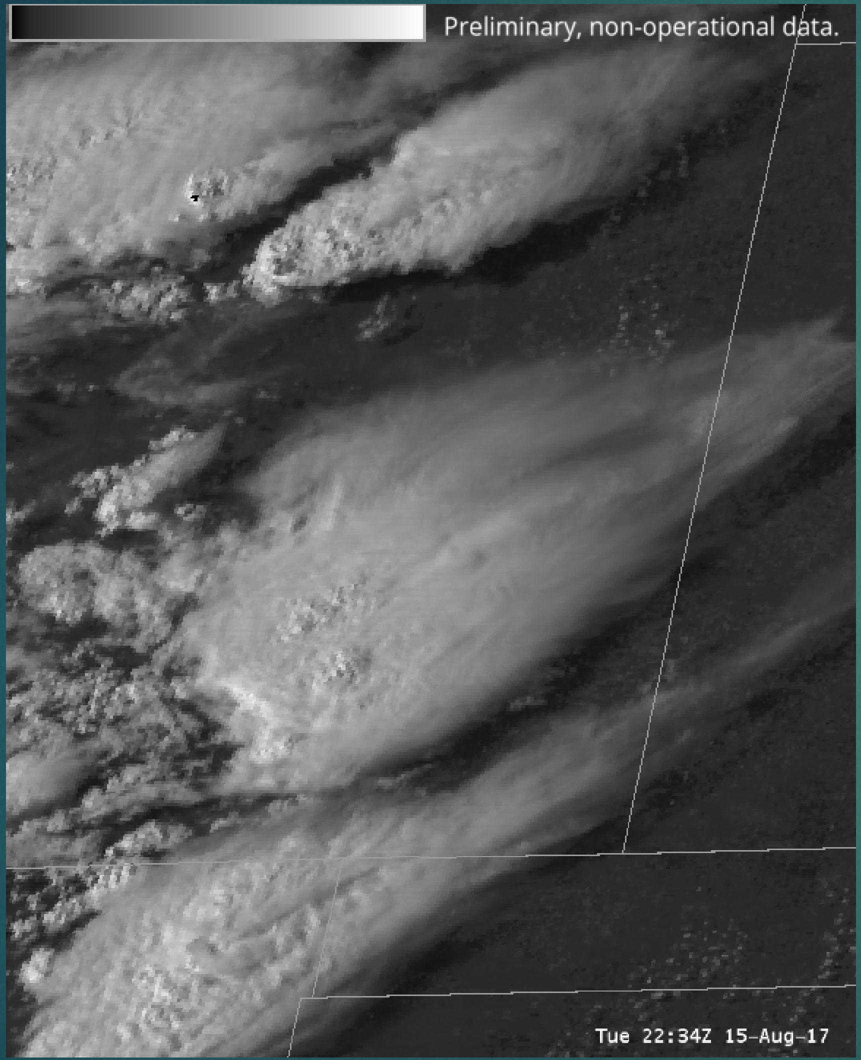
Observed above anvil plume



Simulated above anvil plume

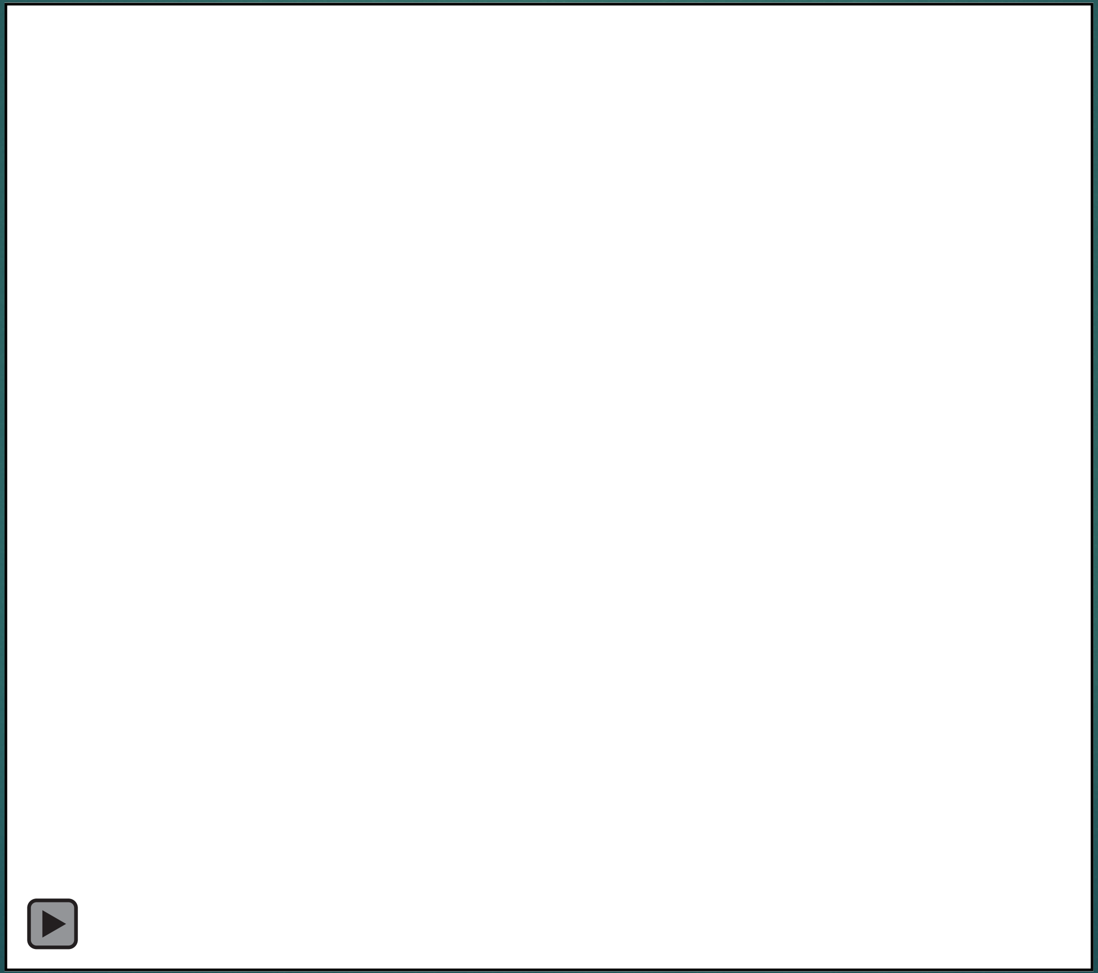


AACP occur everywhere all the time



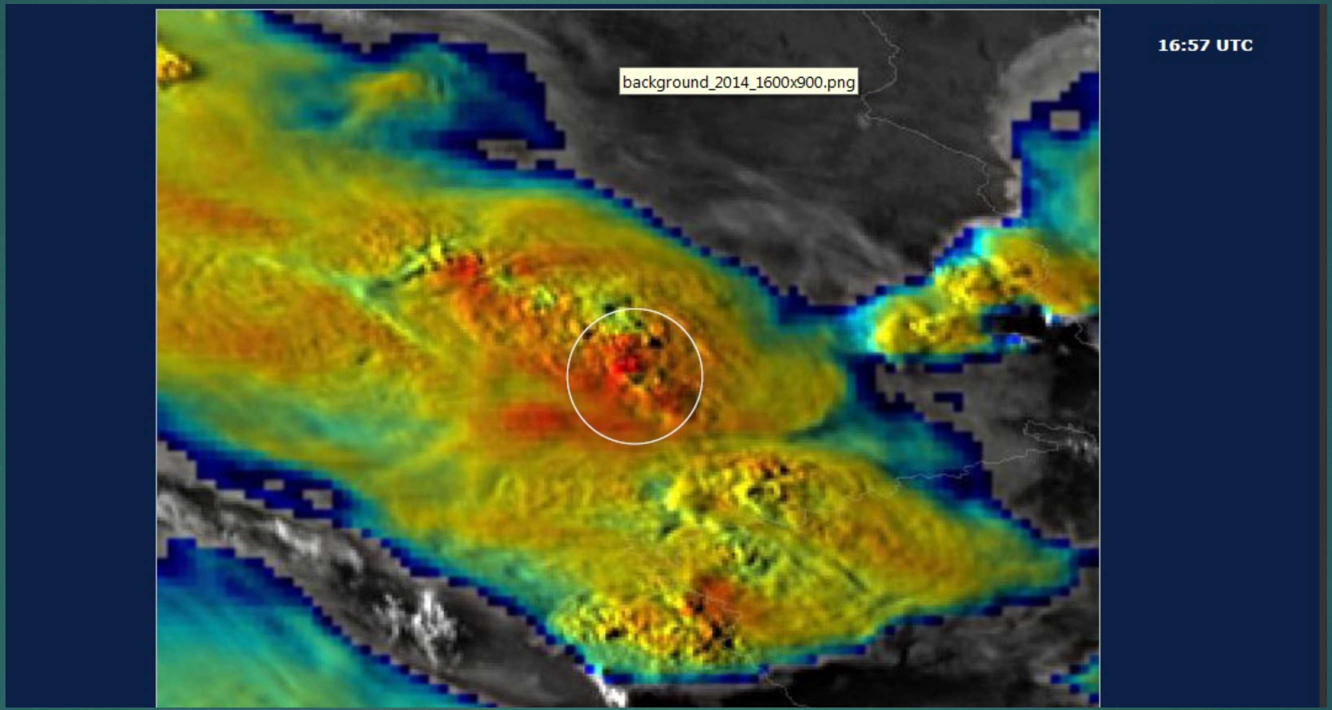
Courtesy of Bill Line and Dan Lingsey

Pancake cloud
(no wind shear)

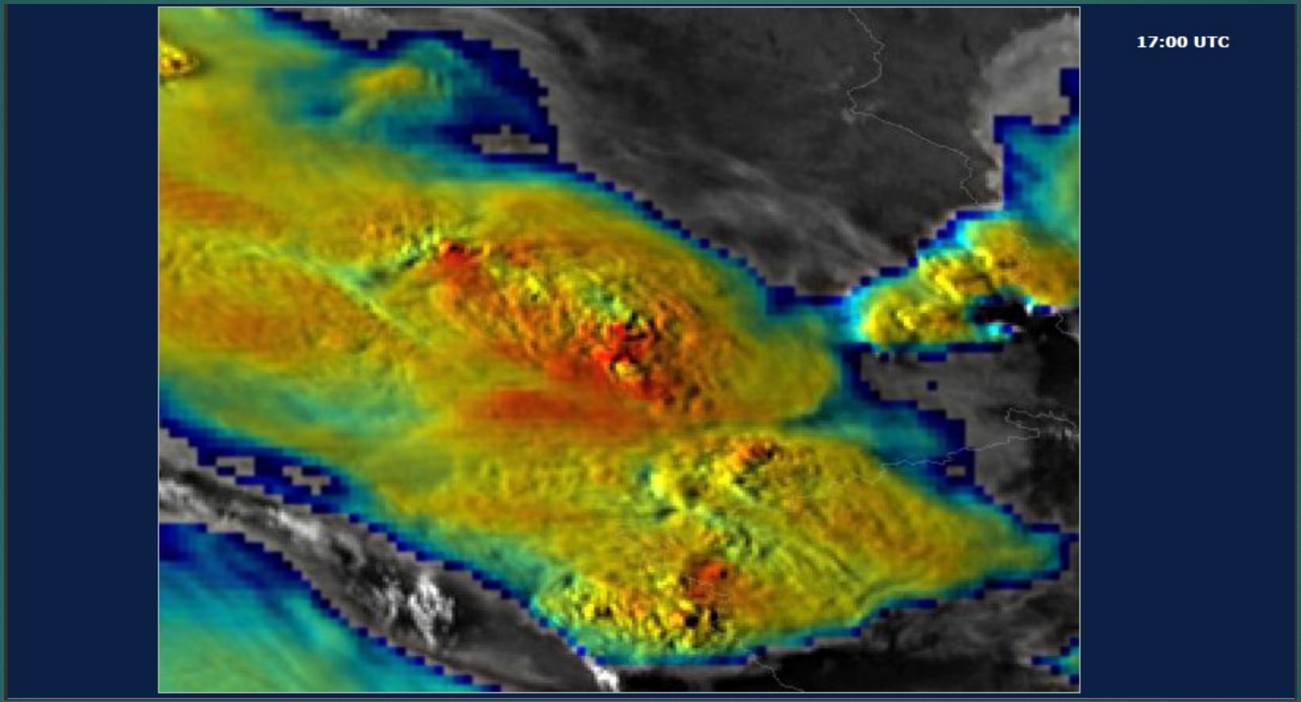


Pancake cloud (courtesy of Po-Hsiung Lin)

Low wind shear –cold-V not obvious



Courtesy of Martin Setvak



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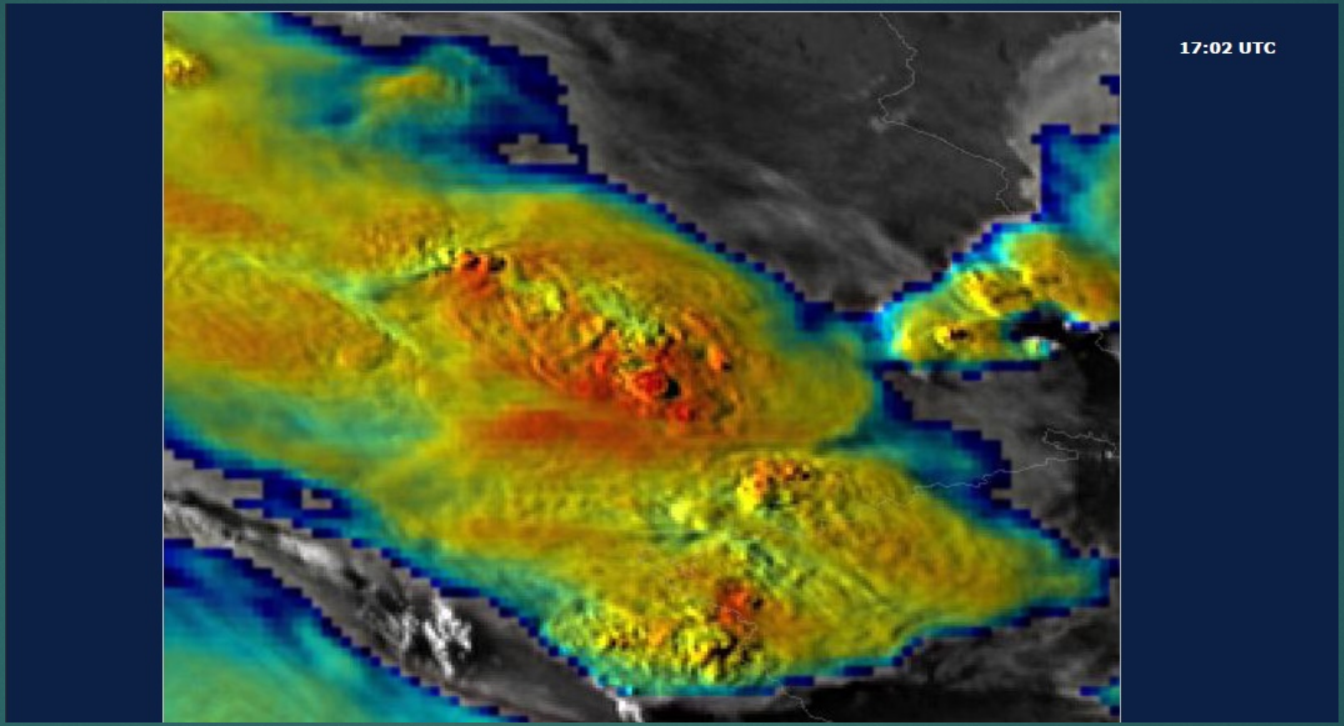
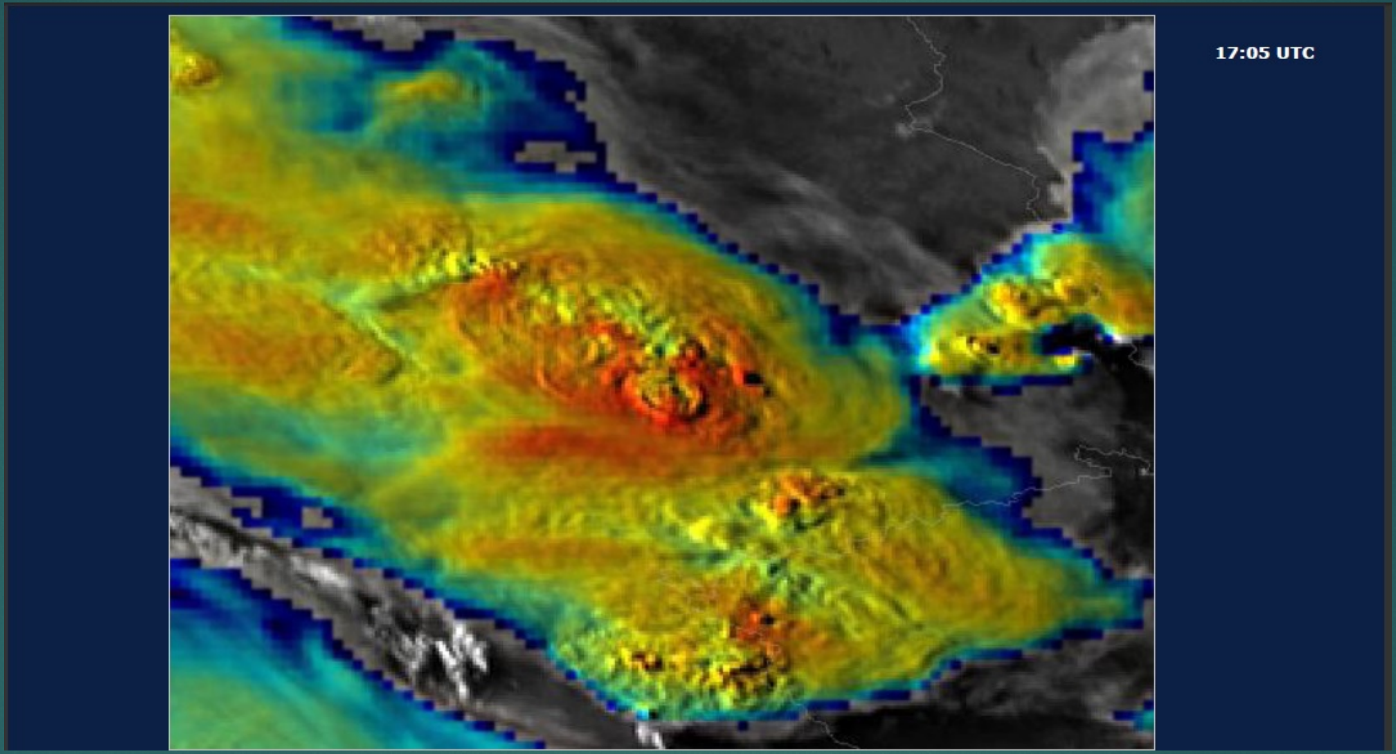
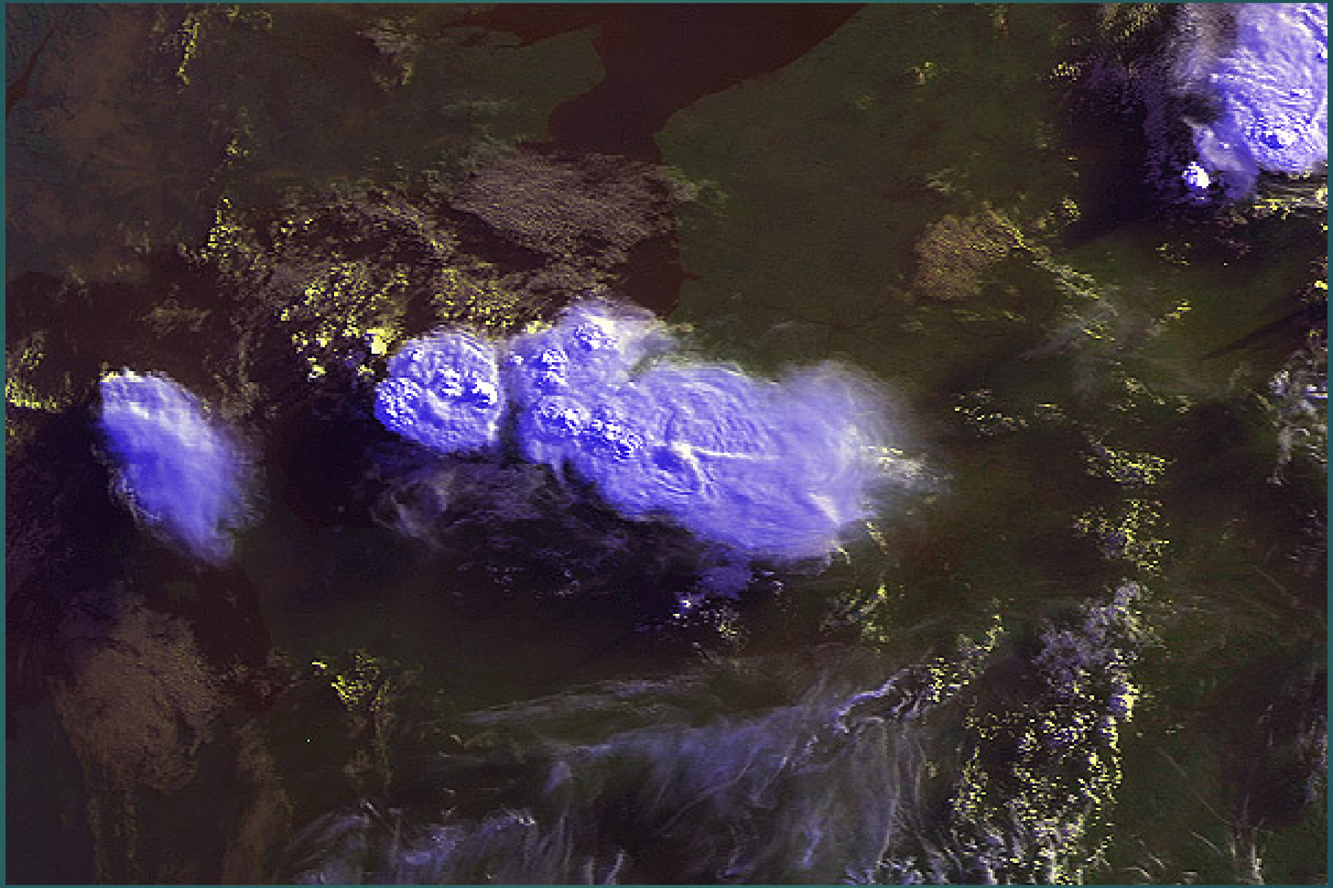


Courtesy of Martin Setvak



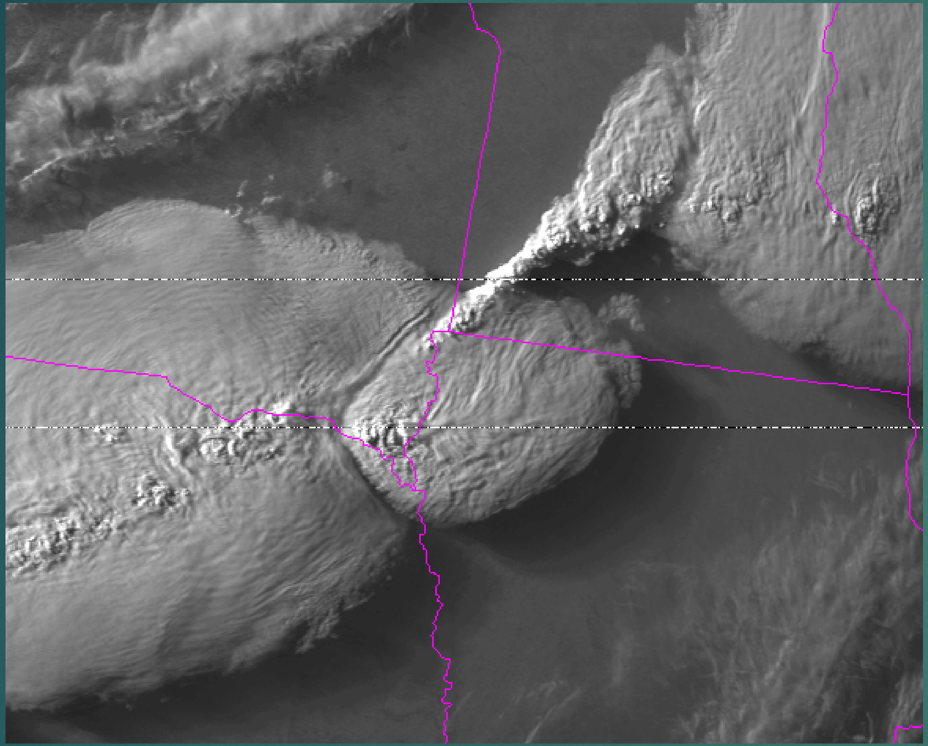
Courtesy of Martin Setvak

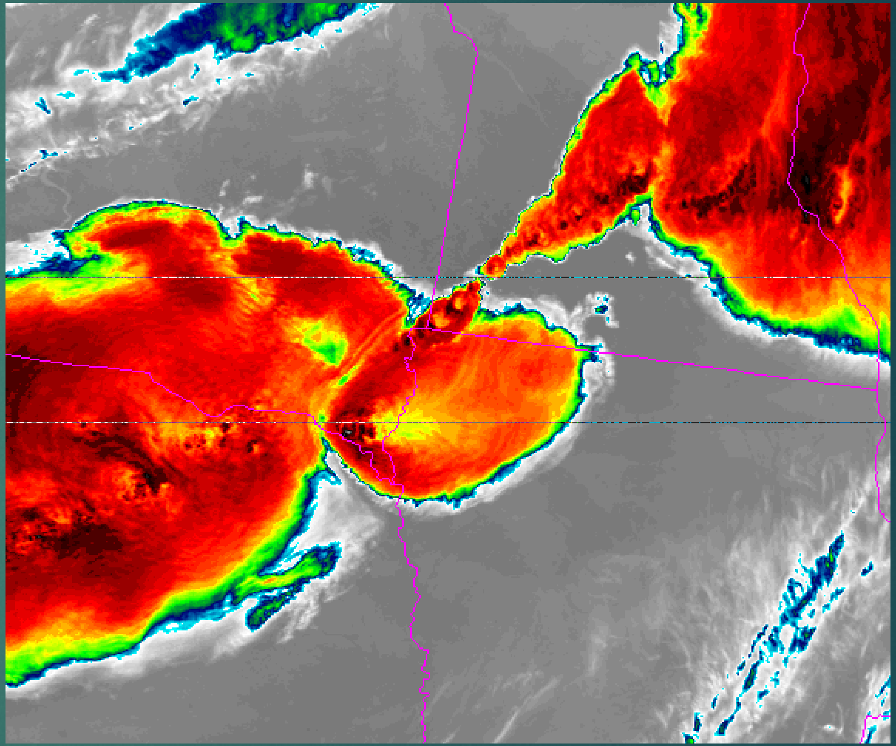
Storm top ship waves

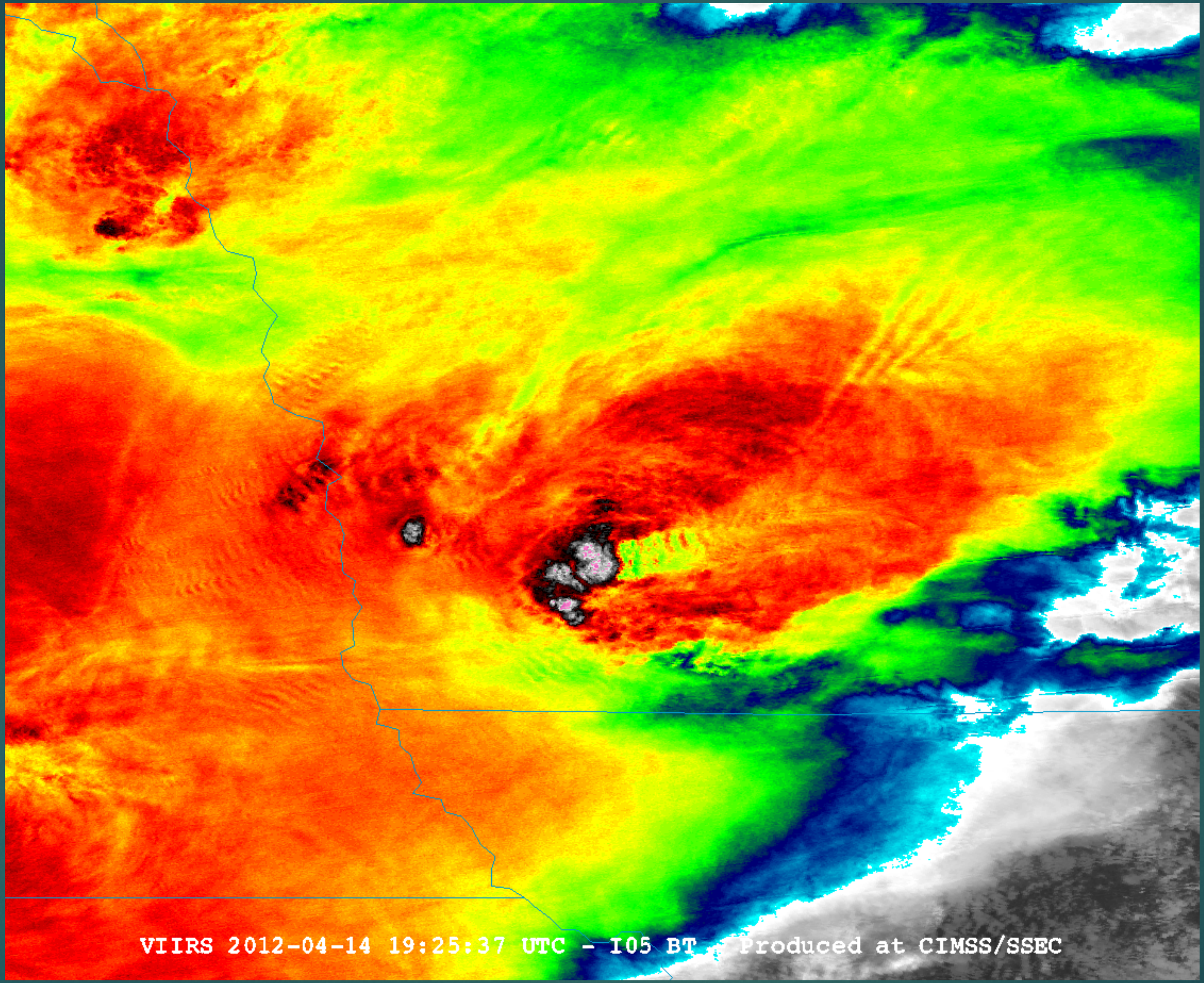


Levizzani and Setvak (1996)

Storm top ship waves

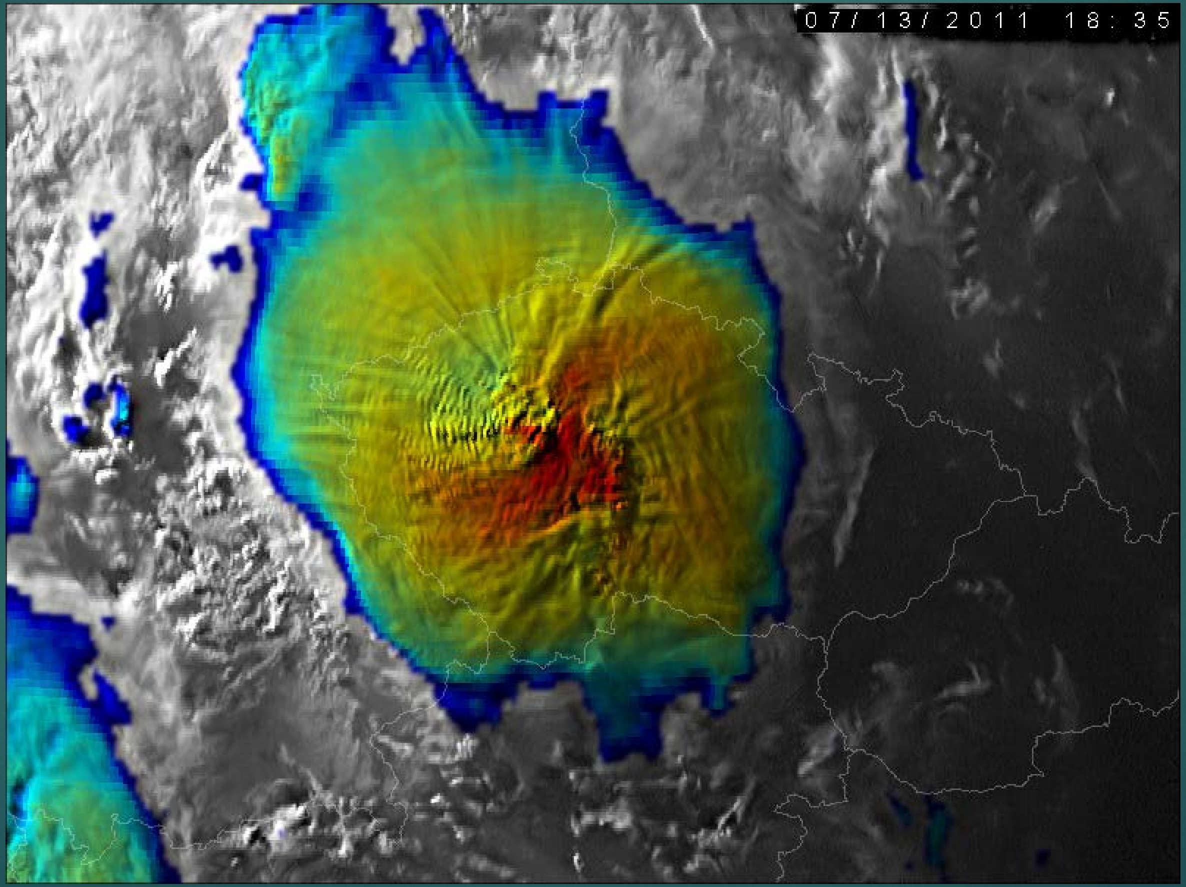






Courtesy of Kris Bedka

Courtesy of Martin Setvak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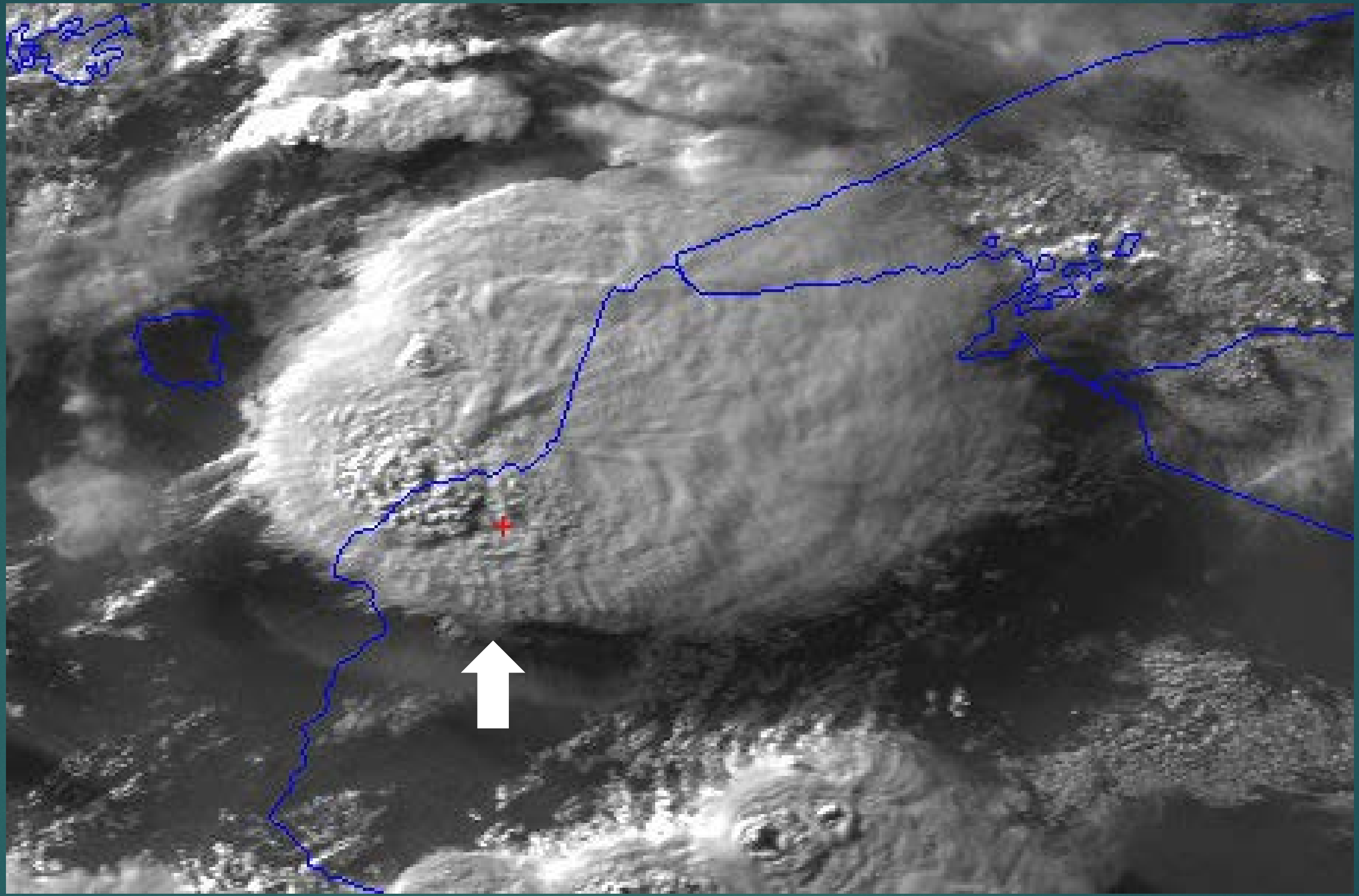

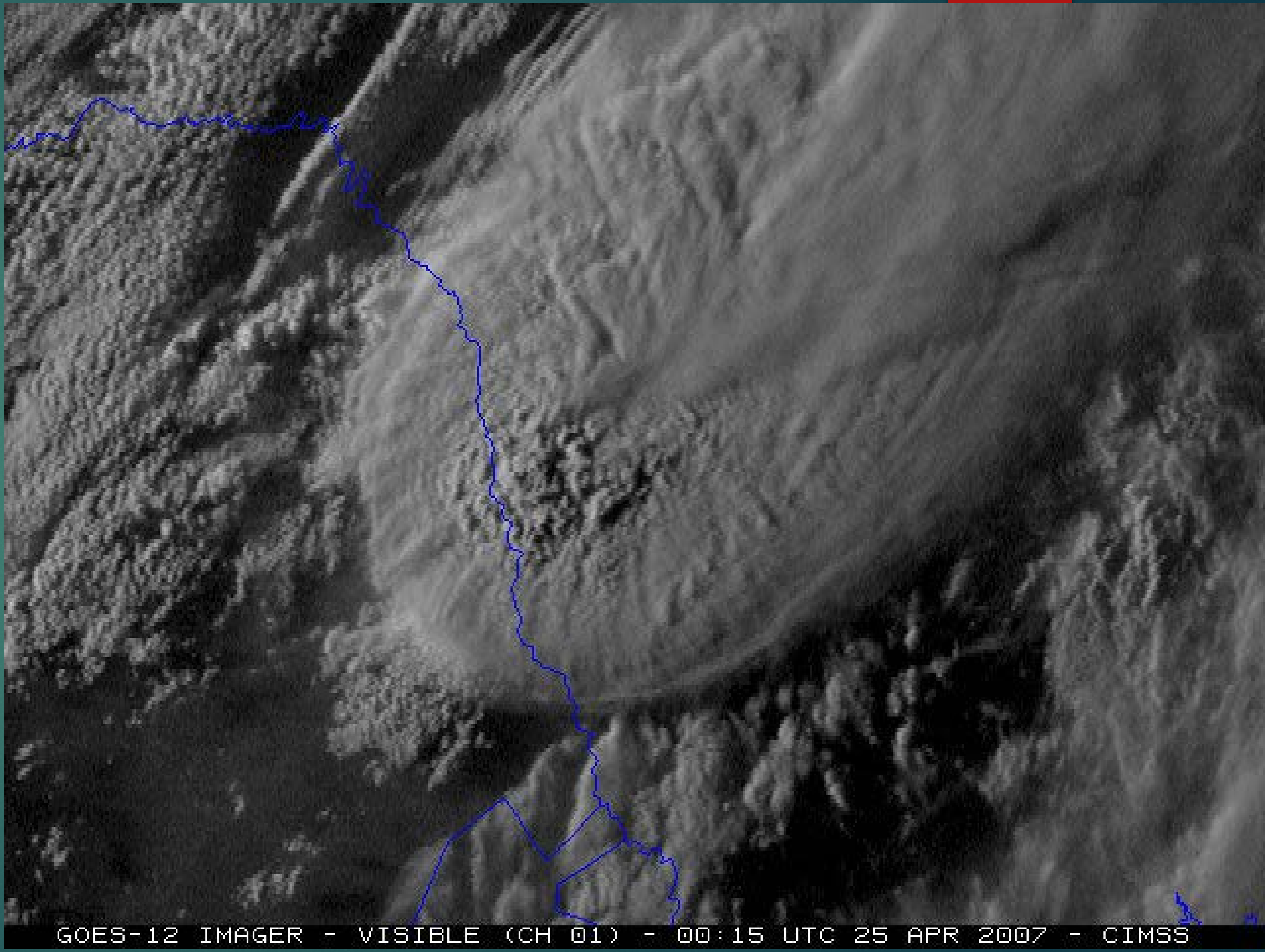
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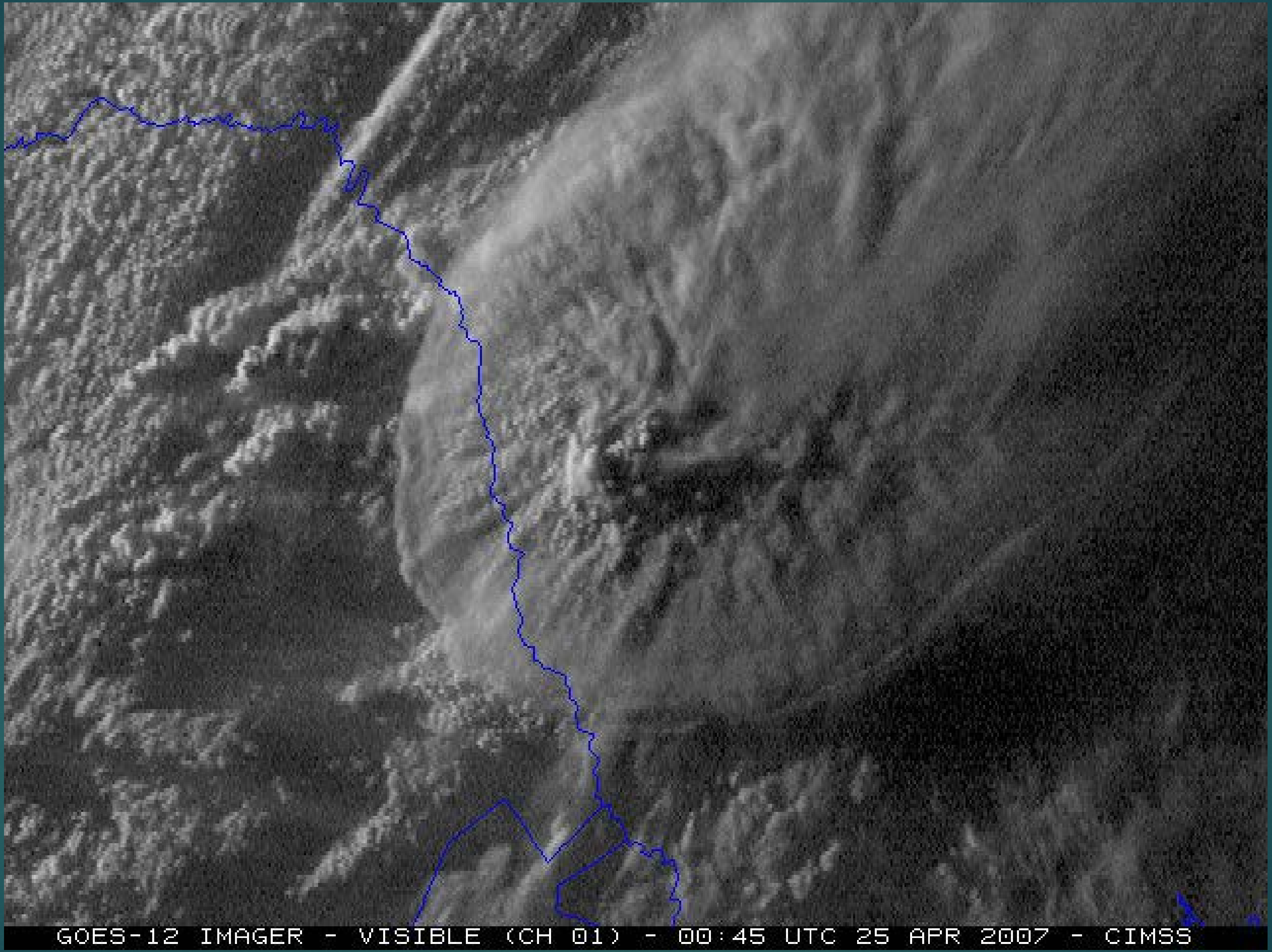
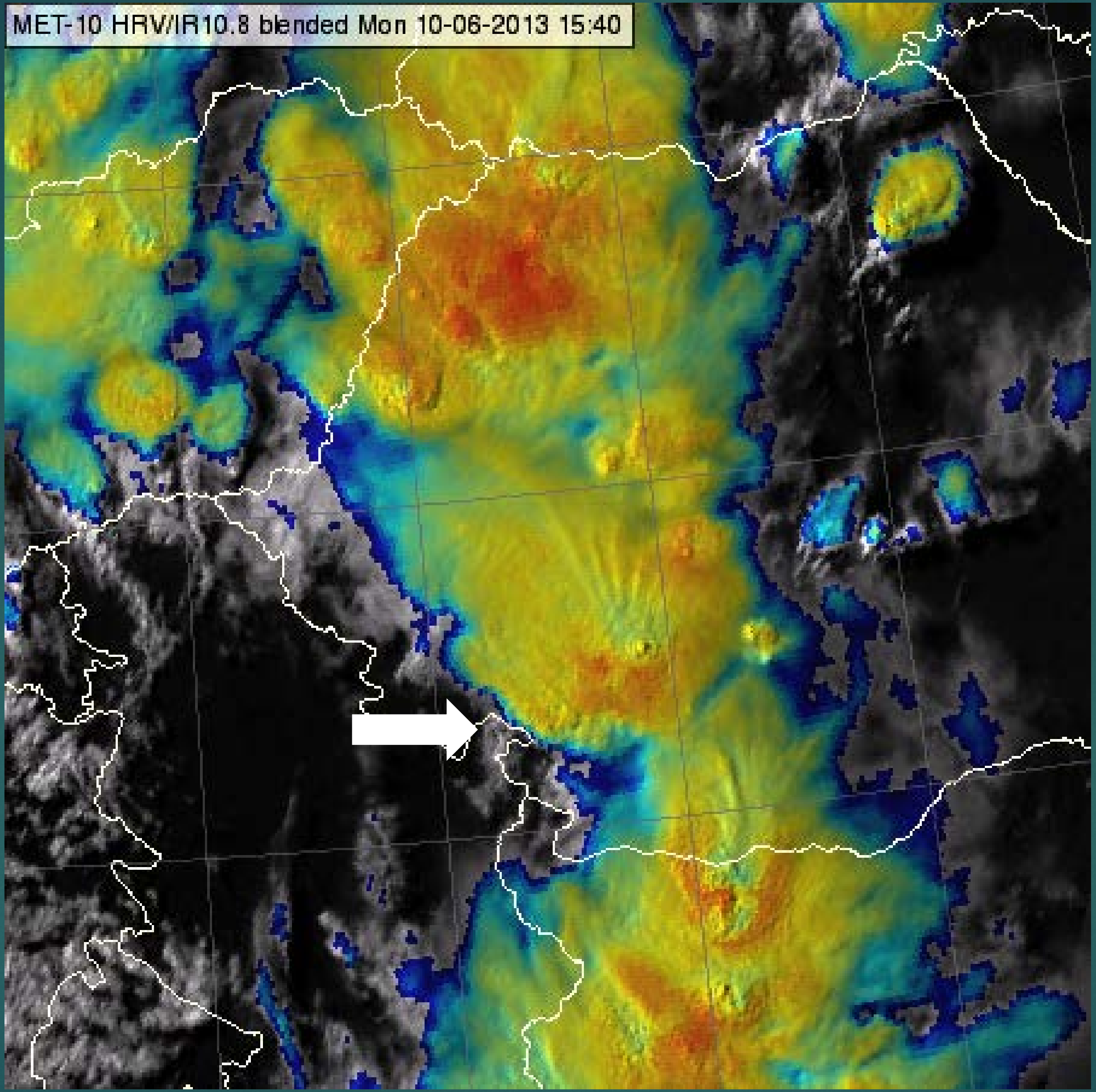
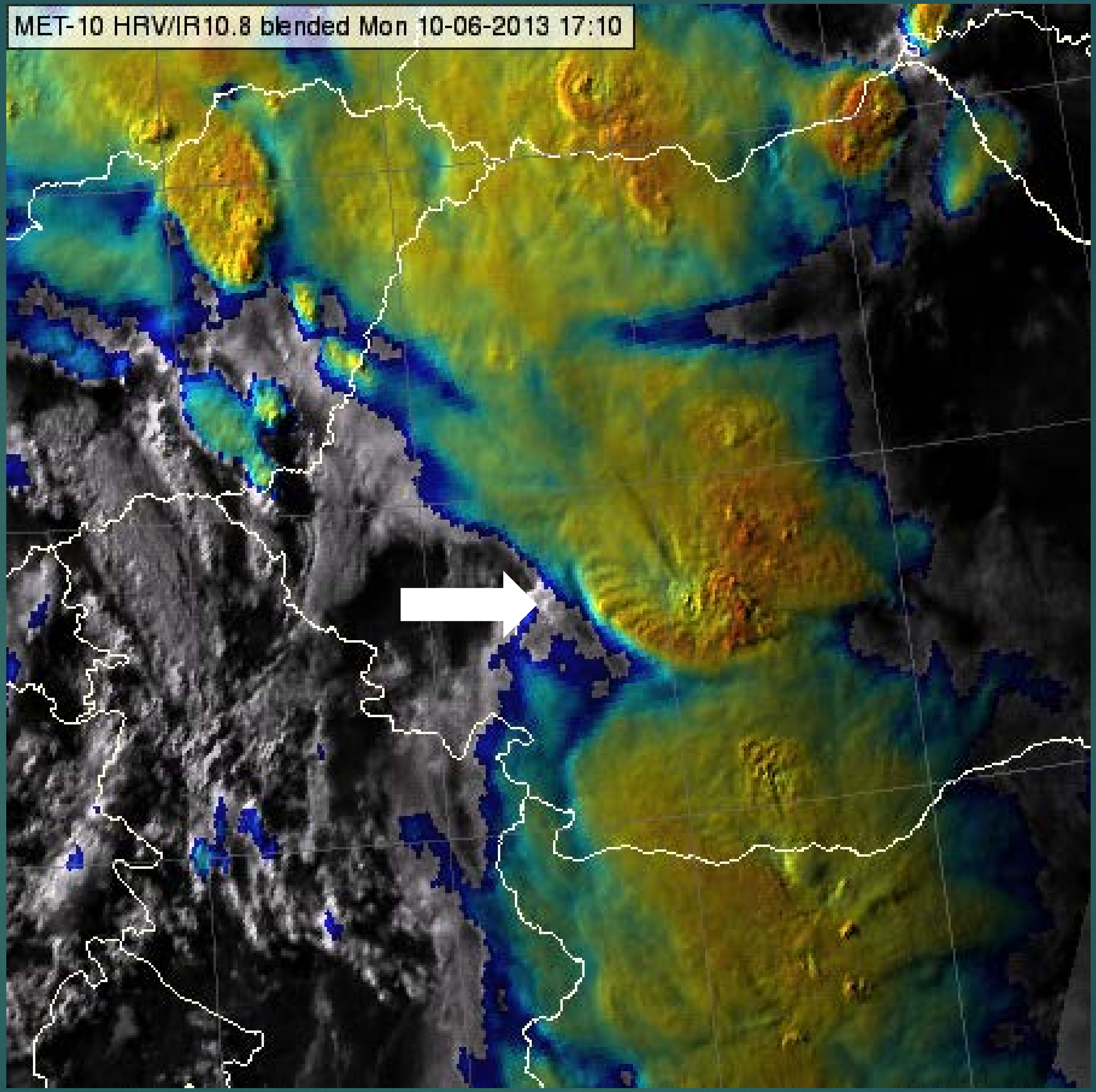

GOES-12 IMAGER - VISIBLE (CH 01) - 00:45 UTC 25 APR 2007 - CIMSS



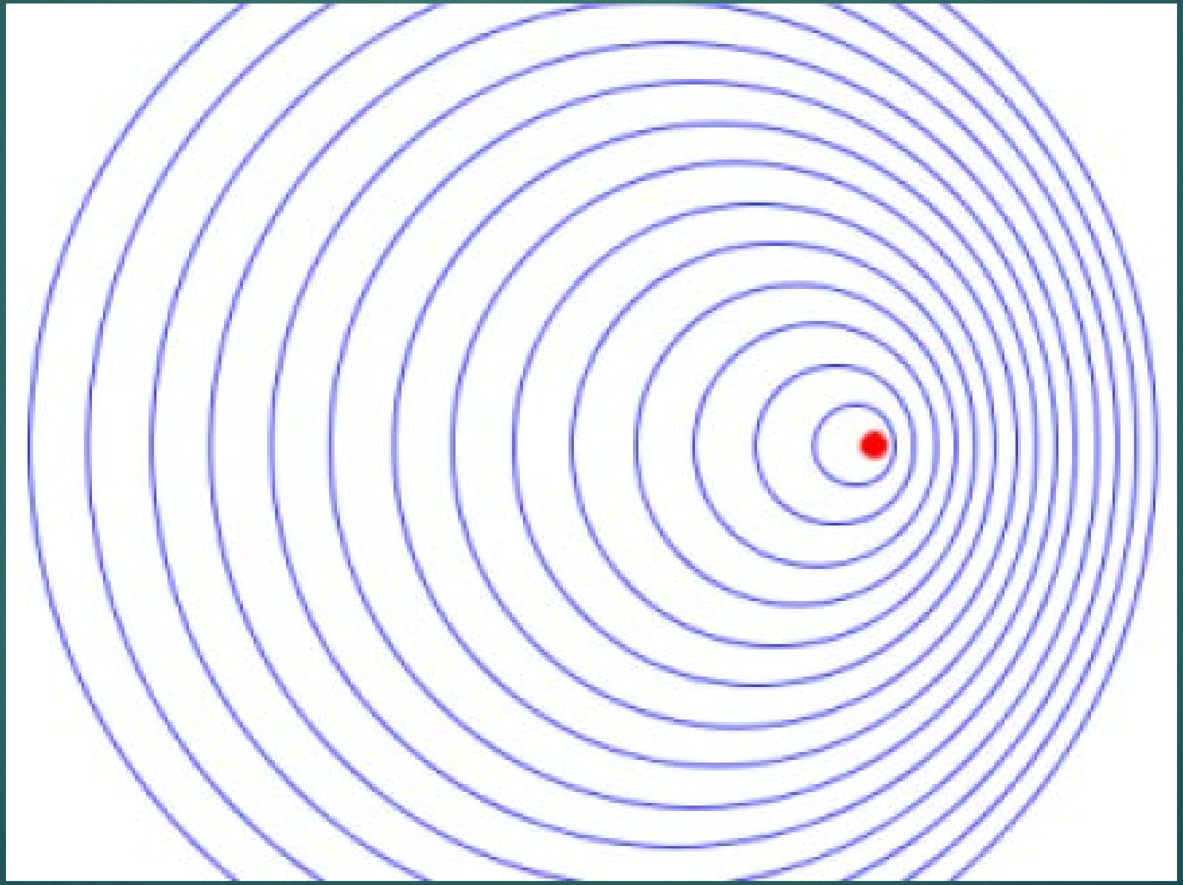
Courtesy of Maria Putsay

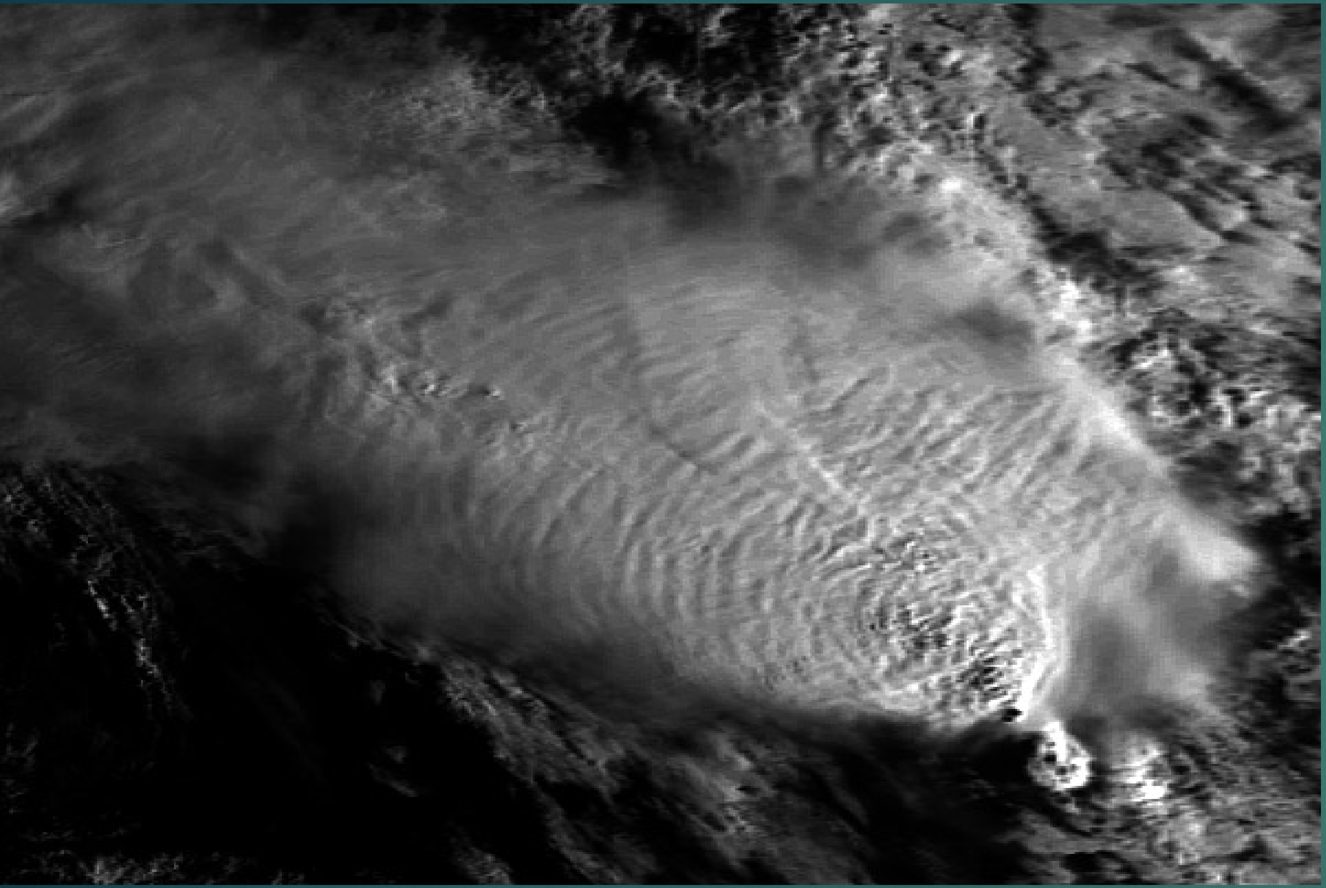


Courtesy of Maria Putsay

Wave in a moving fluid

wind

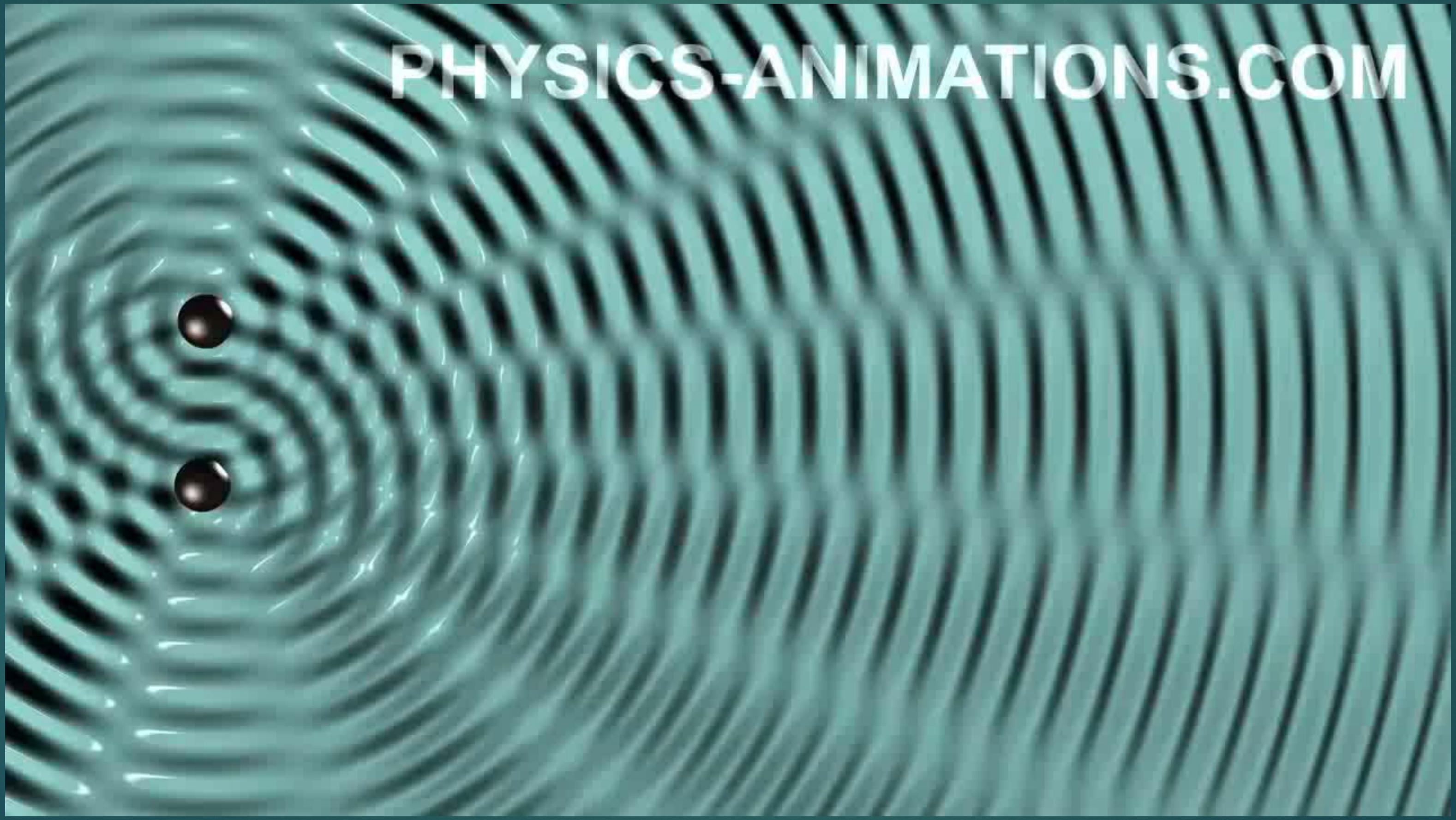




Courtesy of Martin Setvak

Interference of waves

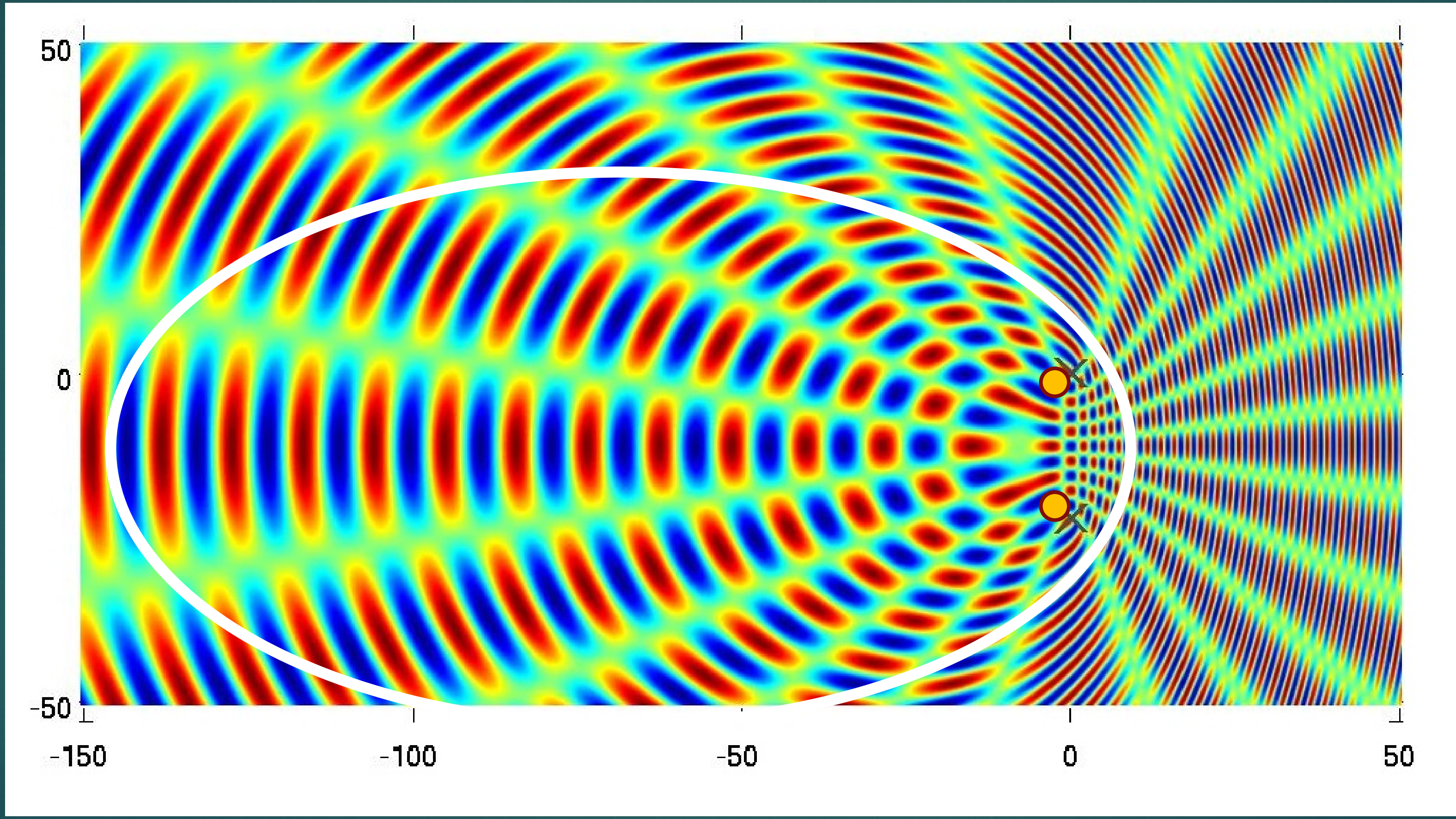
same phase, frequency, amplitude, no wind

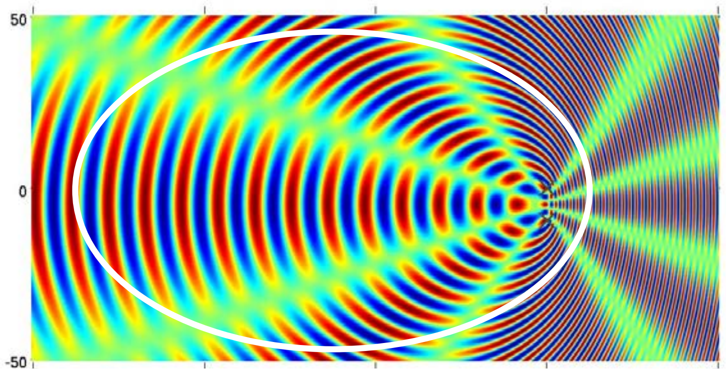


Now add fluid motion

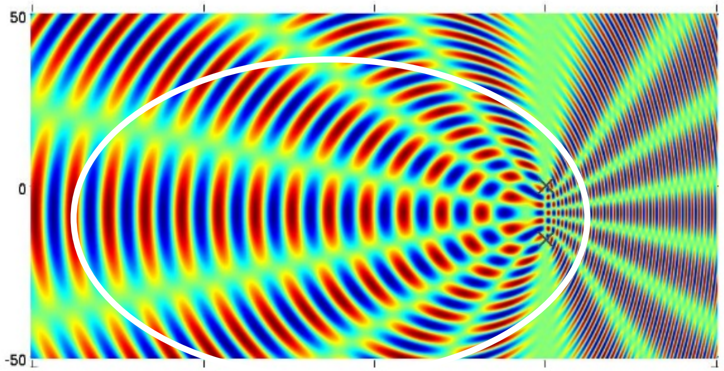
Same phase, frequency, amplitude, constant wind

2 point sources. D = 3.5 lambda

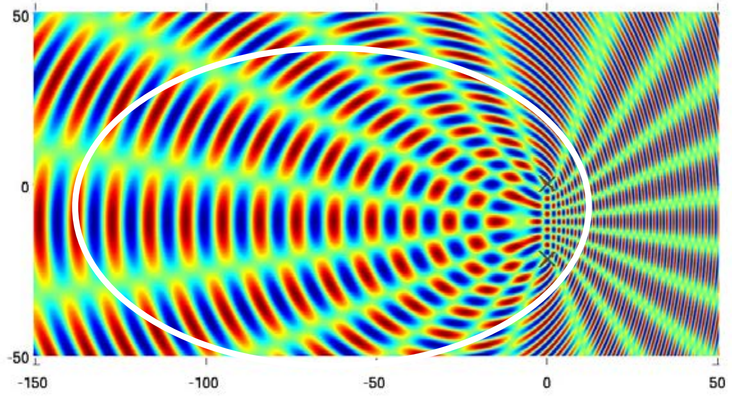




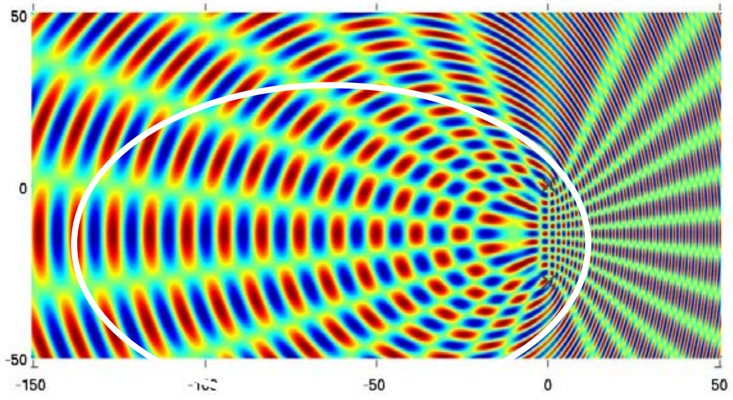
D = 1.5 lambda



D = 2 lambda



D = 3.5 lambda



D = 4 lambda

3 sources (i.e., 3 Ots)