Effects of Sea Breezes and Cold Pools on Convective Evolution during TRACER

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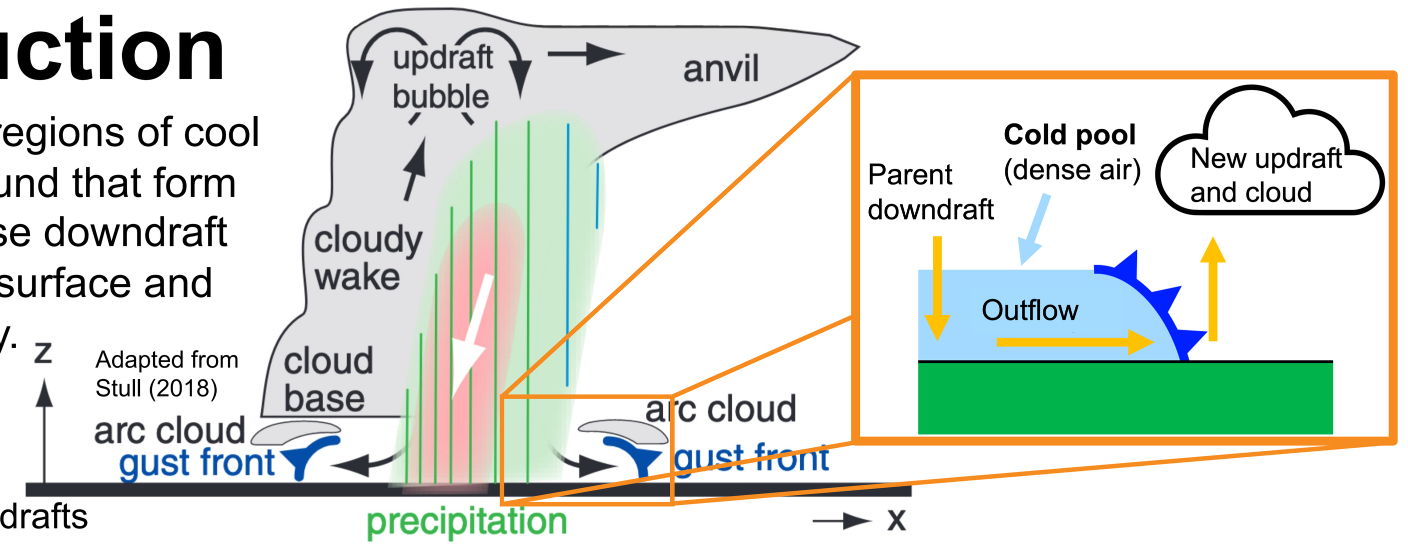
ASR Atmospheric System Research

Introduction



Cold pools are regions of cool air near the ground that form when cool, dense downdraft air reaches the surface and spreads laterally.

What can cold pools do?

- Trigger new updrafts
- Suppress convection within their stable interiors
- Promote storm organization and longevity
- Alter the thermodynamic and dynamic characteristics of the boundary layer (cool air, gusty winds, etc.)
- Transport aerosol particles and trace gases
- Prolong the diurnal cycle of convection (old storms can trigger new storms that would not otherwise form)
- Modulate processes such as convective aggregation, tropical cyclogenesis, and tornadogenesis

Why are cold pools cold?

Traditional explanation:

- *Phase changes in the rain shaft, such as* ***evaporation, melting,*** *and* ***sublimation,*** *cause* ***latent cooling*** *of downdraft air.*

This study asks: ***Do rainfall-land surface interactions help to fuel cold pools?***

- *How do interactions between rainfall, land surfaces, and near-surface air affect cold pool evolution?*
- *What are the downstream effects on convective organization and interactions with the sea breeze?*

What happens to rainfall after it reaches the land surface?

- Interception by vegetation
- Shedding and stemflow (plants → soil)
- Contributes to soil moisture
- Surface water
- Runoff

Consequences:

- Cools and moistens the near-surface air:
  - Alters the partitioning of surface fluxes, promoting latent heat fluxes at the expense of sensible heat fluxes
  - Increased evaporation (of moister soil and vegetation-intercepted rain)
  - Increased transpiration (reduced heat stress, increased soil moisture)
- Reduces surface temperature through direct cooling (cold rainwater)
- May also cause surface warming if soil moistening lowers the soil albedo

Mechanism-Denial Experiments

NOTE: As used here, "puddles" refers to *all* rainfall-land surface interactions.

Regional Atmospheric Modeling System (RAMS) simulations:

17 June 2022 case study (observed during TRACER)

Based on TRACER Model Intercomparison Project (TRACER-MIP) setup by Fan, Saleeby, and others:
https://arm-synergy.github.io/tracer-mip/Roadmap.html

Model grids shown at right ⟶

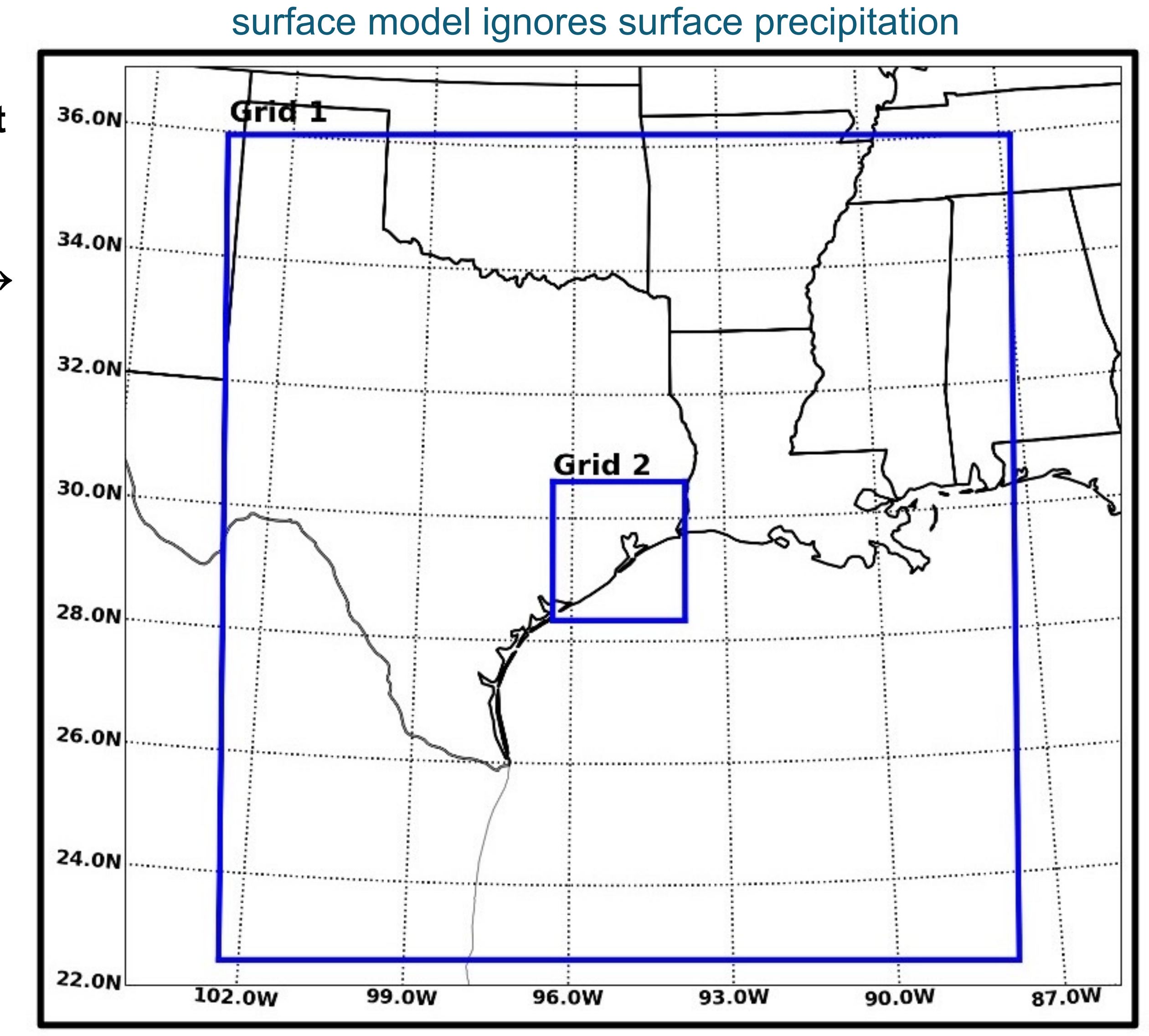
- **Horizontal grid spacing:** outer grid: 2 km, **inner grid: 500 m**
- **Vertical grid:** 95 stretched vertical levels (~50 m spacing near surface)
- **Initial and boundary conditions:** ERA5 (3-hourly)
- **Surface:** Land Ecosystem-Atmosphere Feedback model, version 3 (LEAF-3) with modifications
- **Microphysics:** RAMS two-moment bin-emulating bulk microphysics, 7 hydrometeor classes
- **Radiation:** Harrington (1997) two-stream scheme
- **Diffusion:** Modified Smagorinsky (1963) scheme
- **Aerosol:** TRACER-MIP setup; sources and sinks active; radiatively inactive

0600 UTC (start) → **1830 UTC (branching time)** → **...then continue for 2 hours**

Spin-up with "puddles" disabled: Uses a modified version of LEAF-3, in which the land surface model ignores surface precipitation

NO PUDDLES: Continue the original simulation

PUDDLES: Turn on puddles (revert to the standard version of LEAF-3)

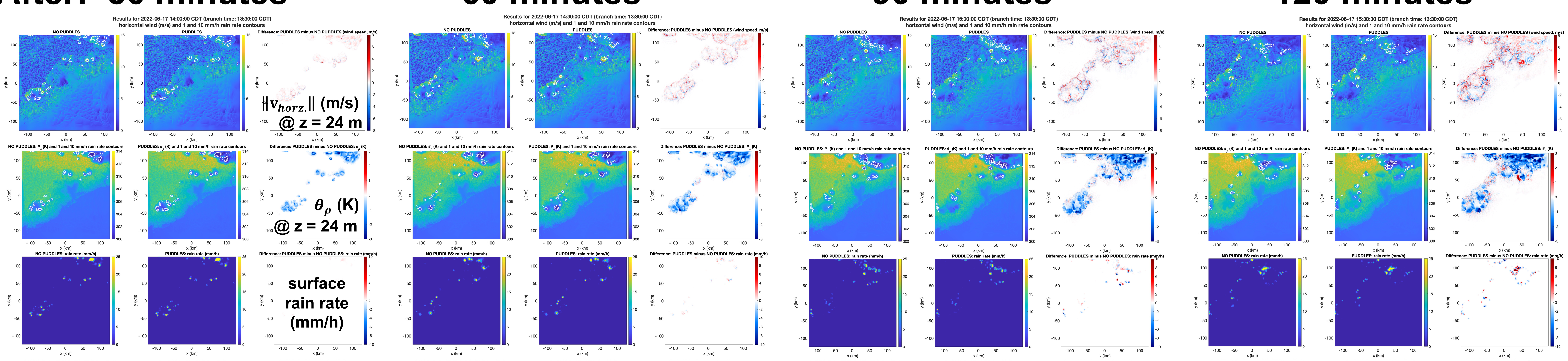


The "branching time" occurs after clouds have already begun to form and precipitate.

At the restart time, the existing simulation branches into two "parallel universes" in which rainfall-land surface interactions either remain disabled or are abruptly reenabled.

The differences that gradually emerge between these "parallel universes" (particularly within the first ~90 minutes) **reveal the impact of rainfall-land surface interactions on cloud and cold pool evolution.**

After: 30 minutes | 60 minutes | 90 minutes | 120 minutes



NO PUDDLES | PUDDLES | PUDDLES minus NO PUDDLES (for each of 30, 60, 90 and 120 minutes)

Acknowledgments

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Conclusions:

- Fallen rainfall invigorates cold pools in the coastal southeast Texas setting where TRACER took place
- Downstream effects on convection and precipitation are observed in these simulations
- Next steps: perform additional mechanism denial tests (rain shaft cooling, sea-breeze formation) and additional case studies

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