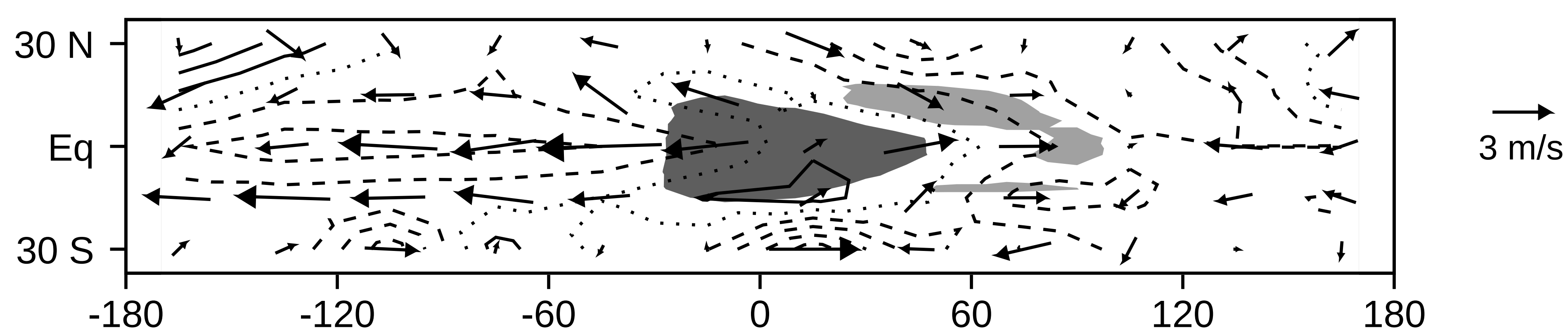
Transforming Circumnavigating Kelvin Waves that Initiate and Dissipate the Madden Julian Oscillation

Patrick Haertel

Yale University



Collaborators

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Andrew Budsock, Susquehanna University

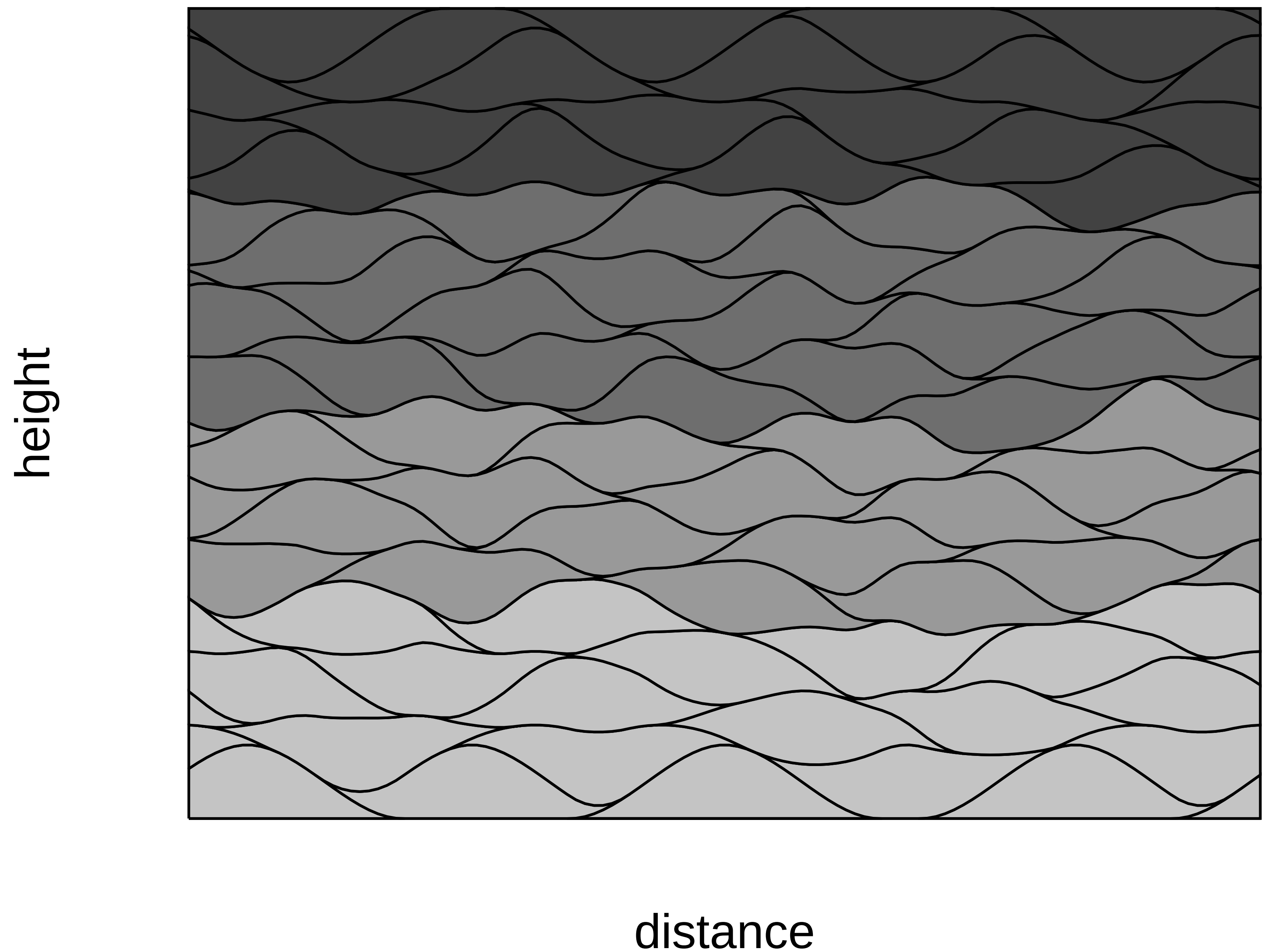
Supported by the National Science Foundation

Outline

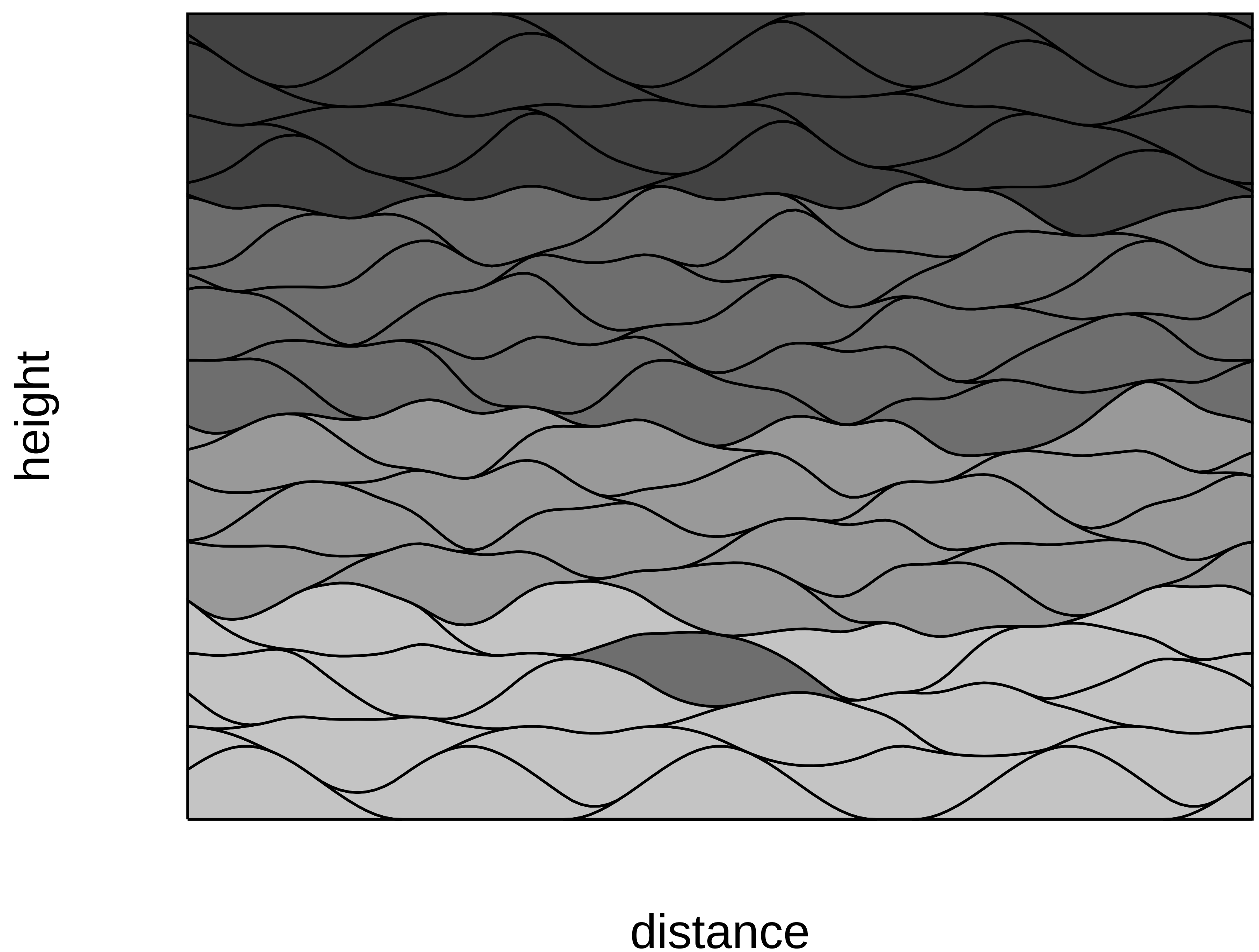
1. Lagrangian Atmospheric Model
2. Data and Methods
3. Observed and Simulated MJOs
4. Dynamics
5. Summary and Future Research

Lagrangian Atmospheric Model

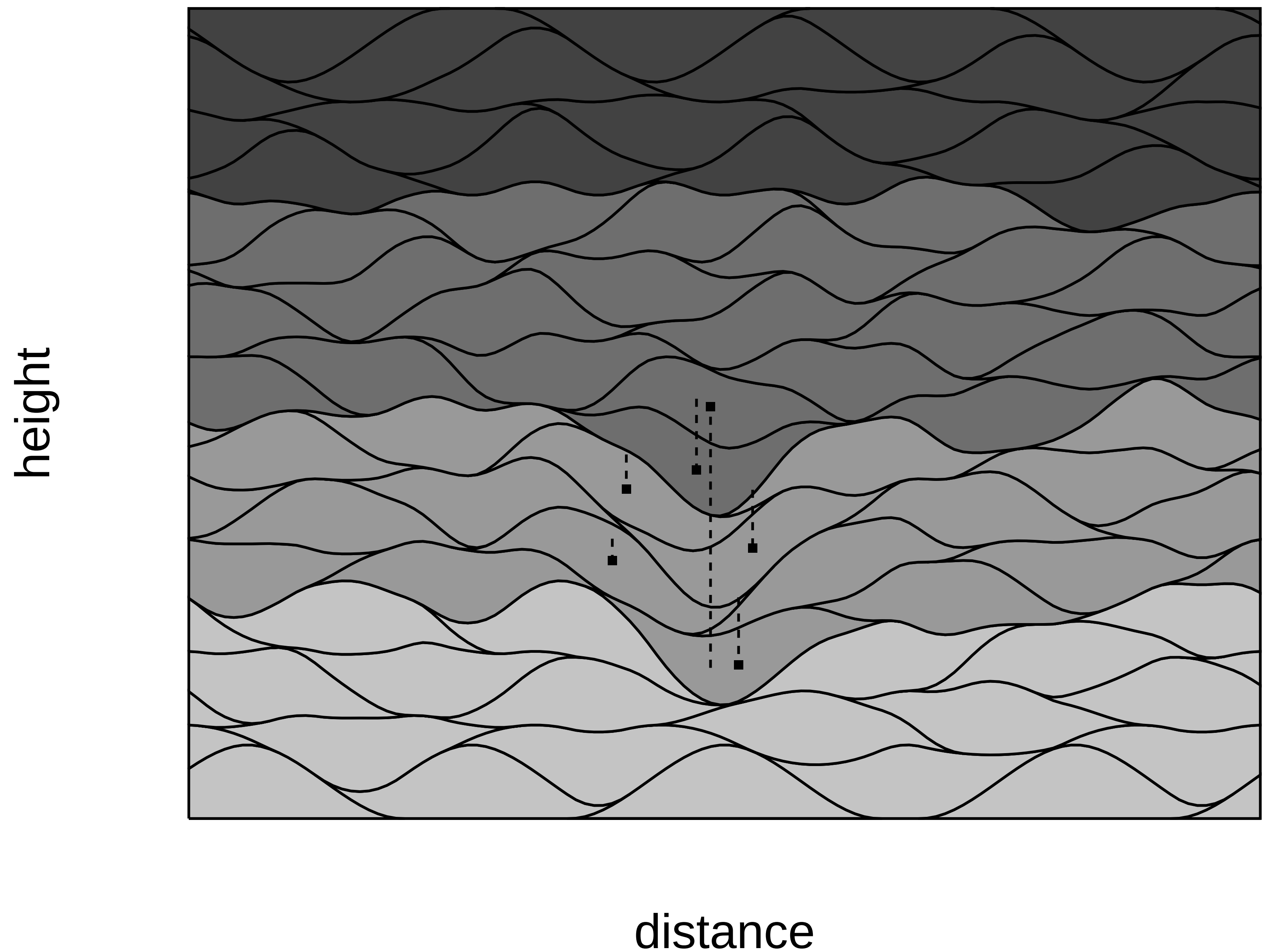
Conforming Parcel Concept



Lagrangian Convective Parameterization

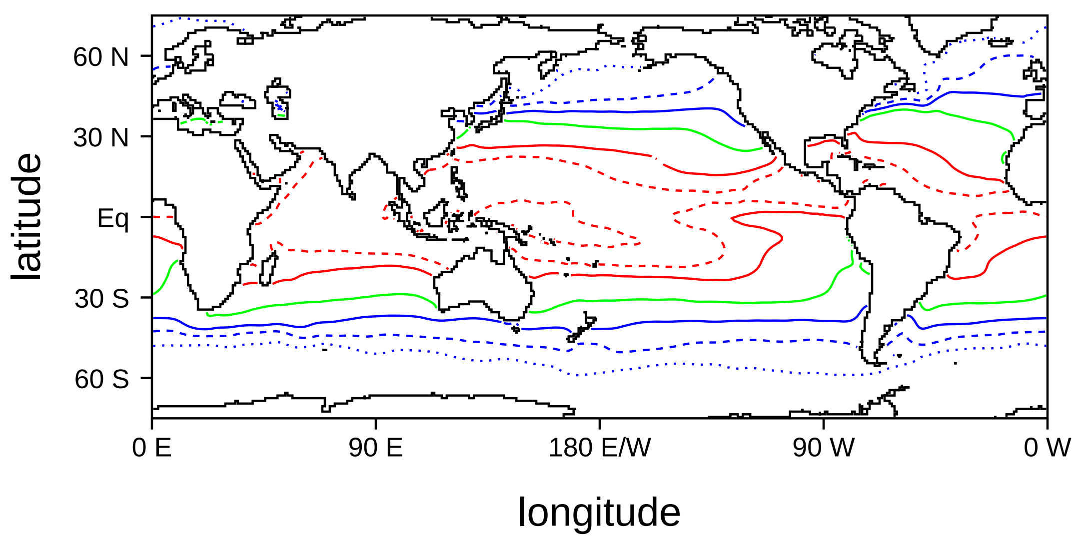


Lagrangian Convective Parameterization

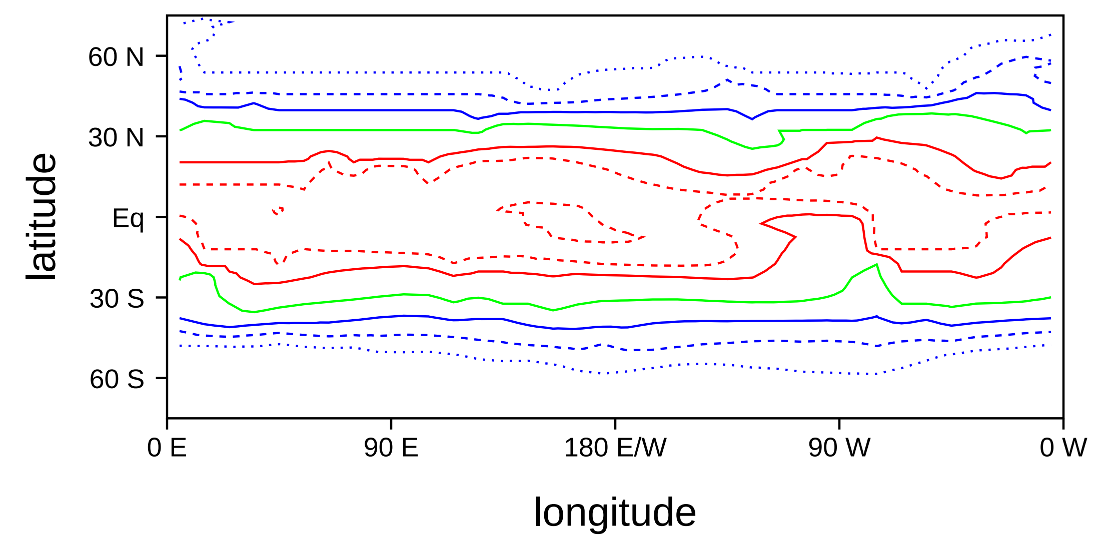


Sea Surface Temperature

Observed

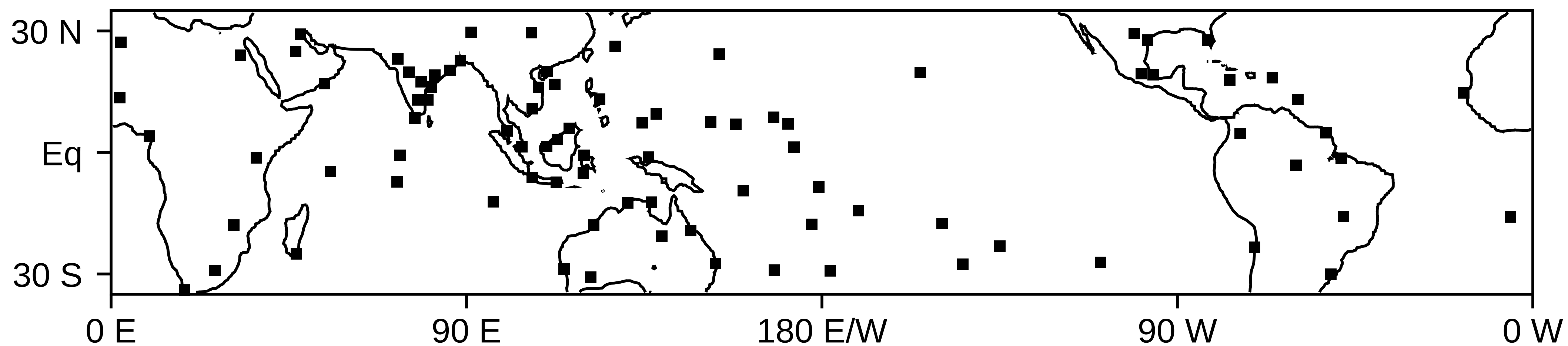


Prescribed for Model



Data and Methods

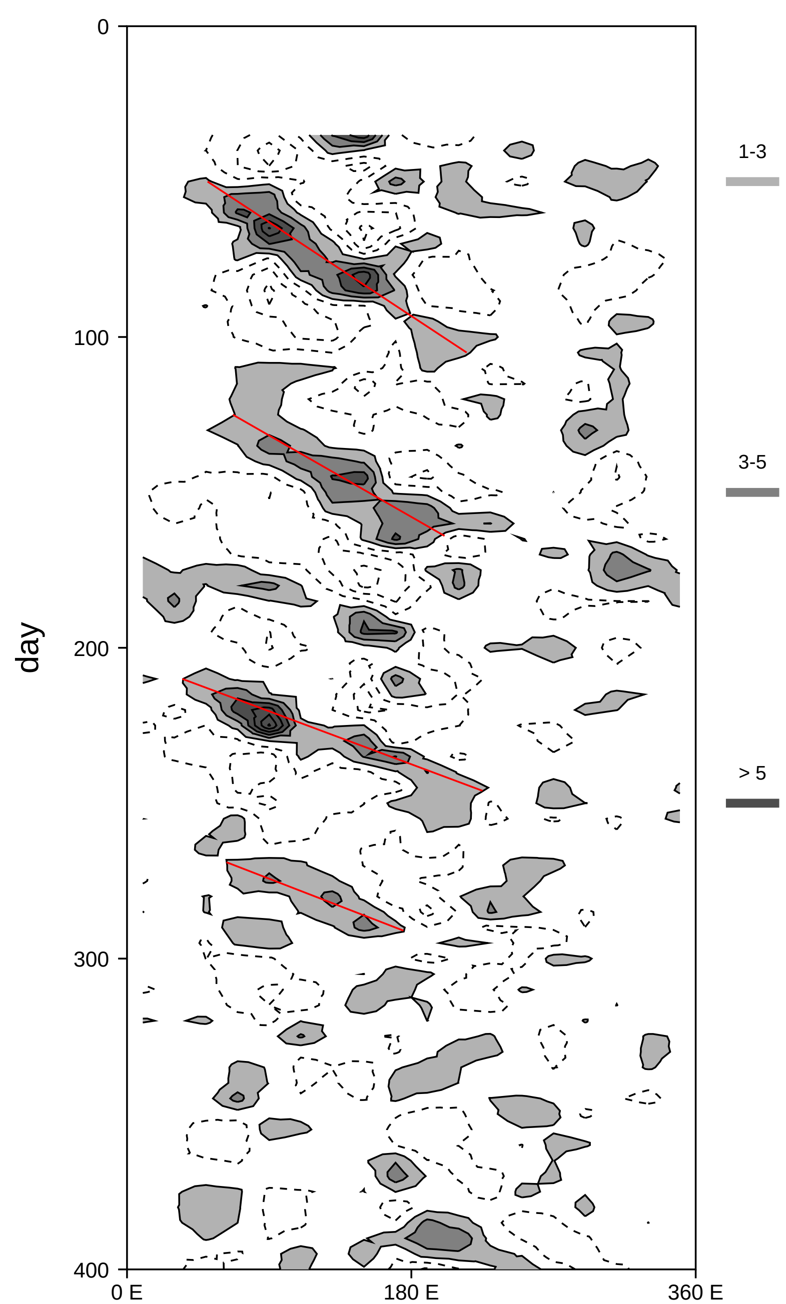
Atmospheric Sounding Stations



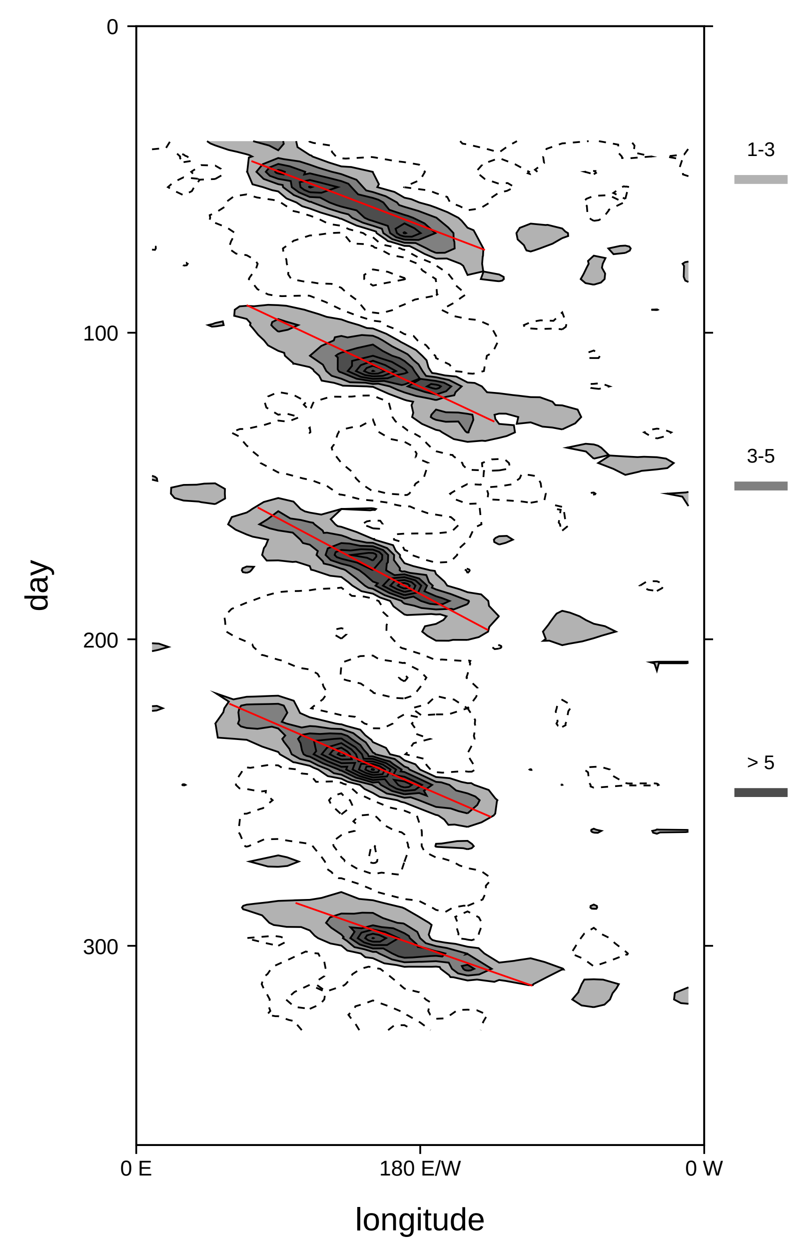
- 25 hPa resolution
- 7-70 day filter
- MJO relative coordinates

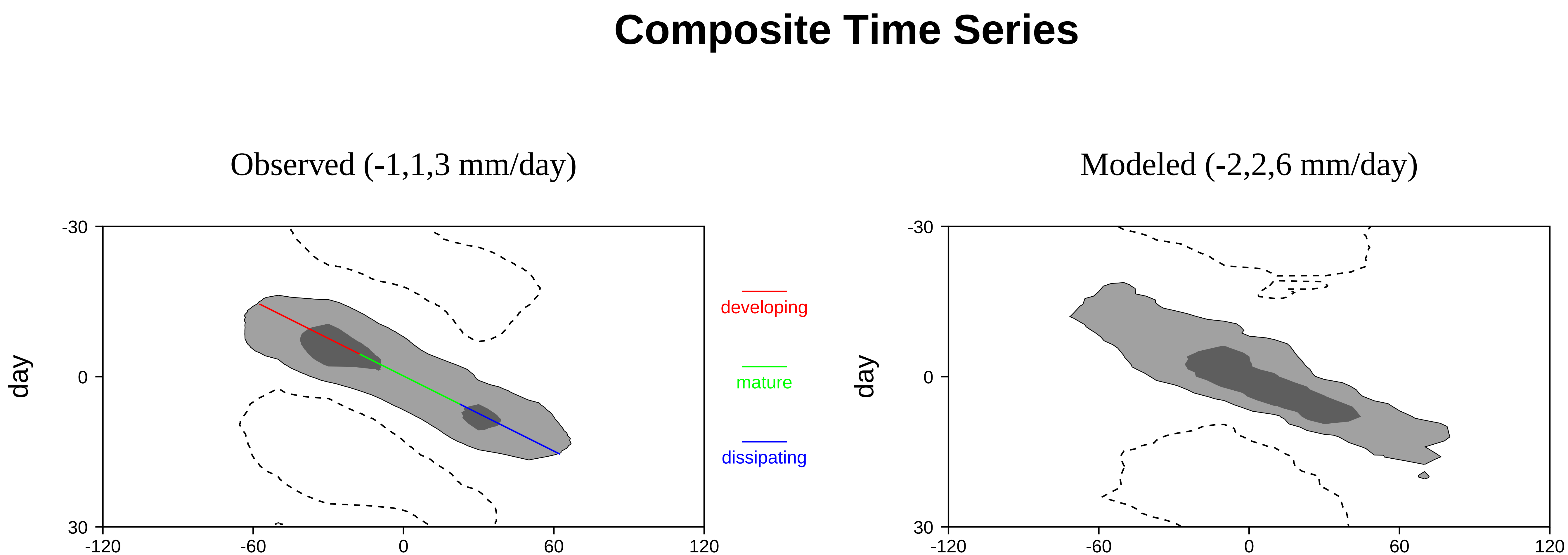
Determining MJO Paths

GPCP Rainfall (mm/day)



Model Rainfall (mm/day)

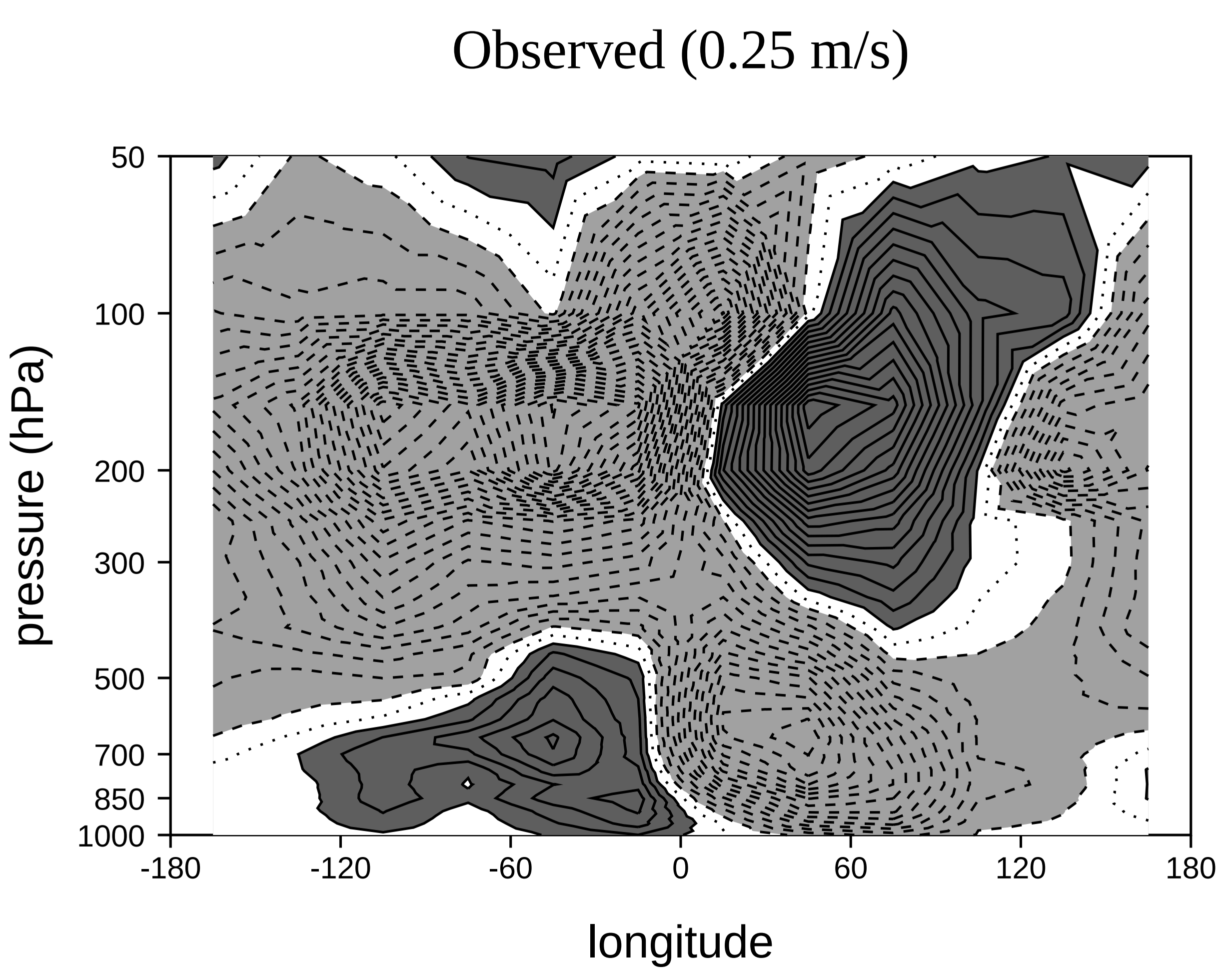


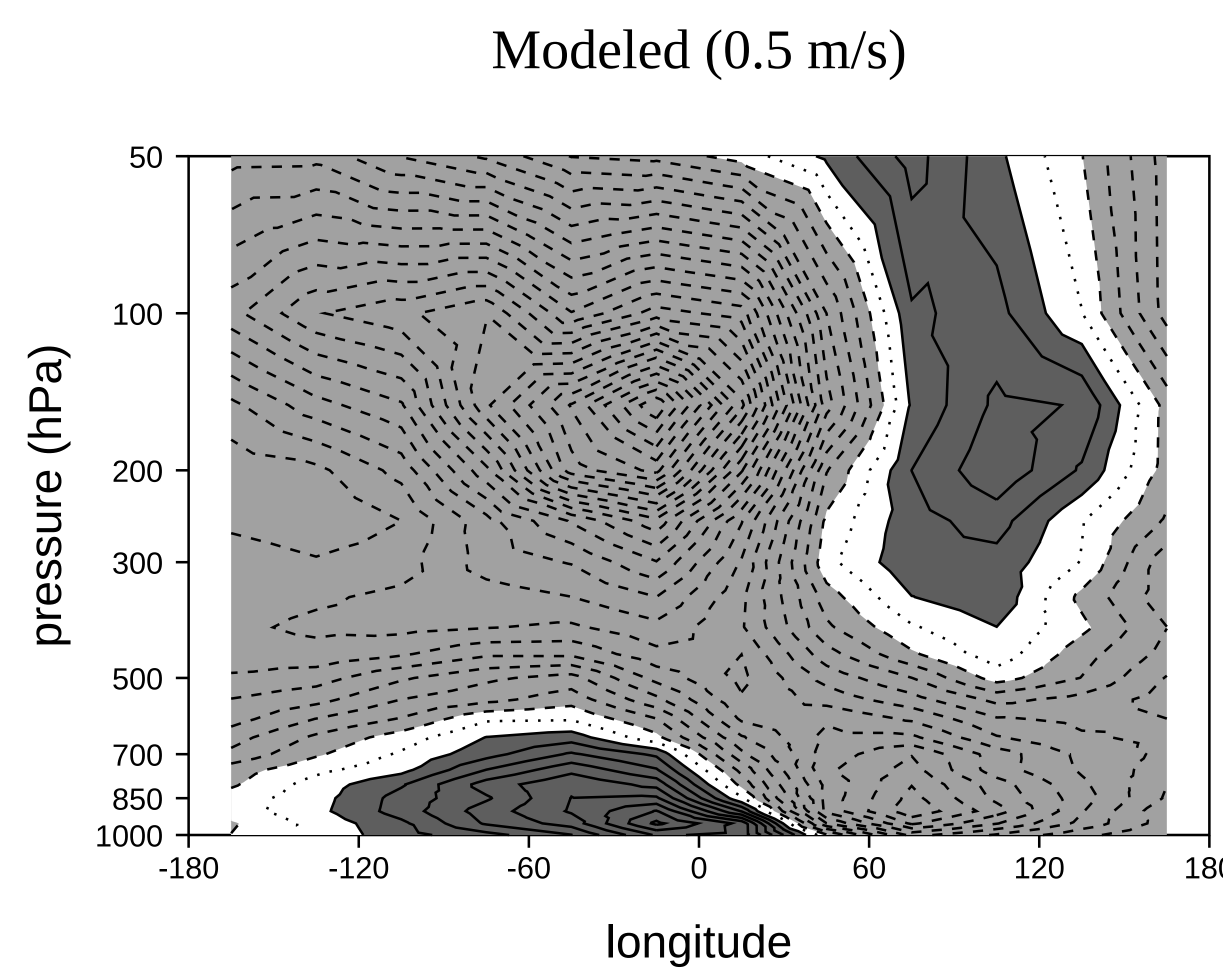

Composite Time Series
Observed (-1,1,3 mm/day)
Modeled (-2,2,6 mm/day)
day
-30
0
30
-120
-60
0
60
120
developing
mature
dissipating

Observed and Simulated MJOs

Composite Zonal Wind

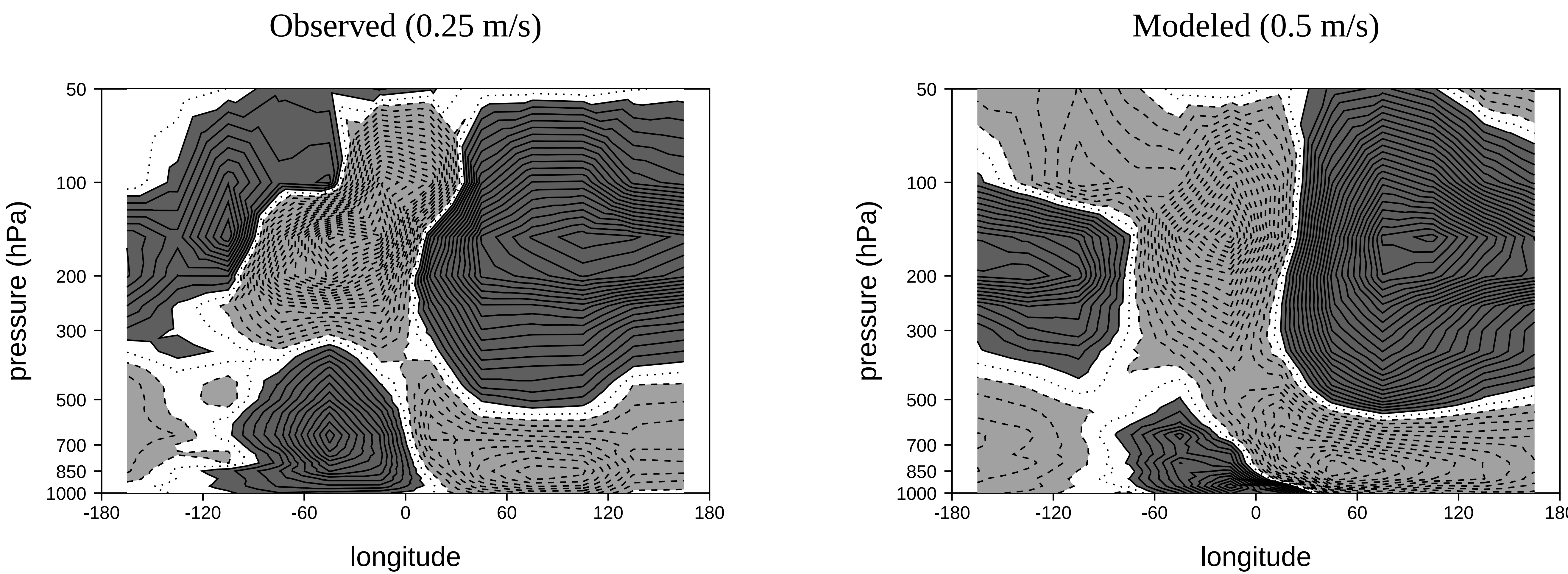
Developing Stage





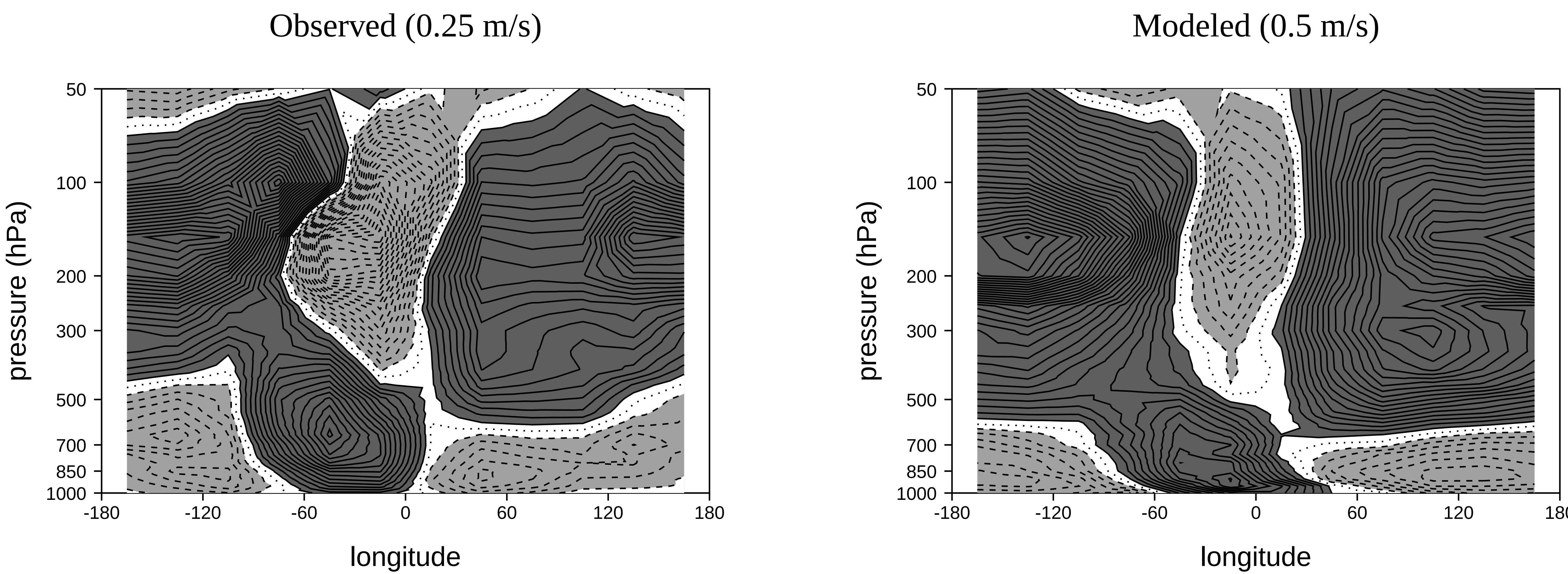
Composite Zonal Wind

Mature Stage



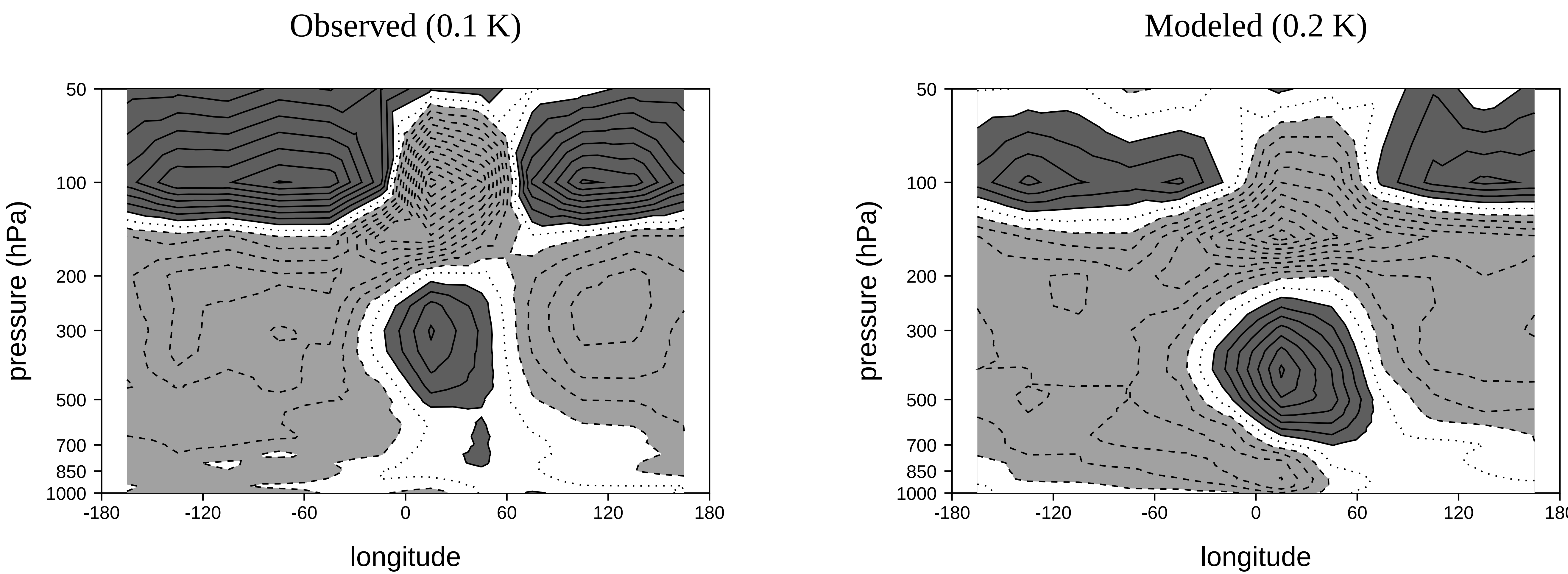
Composite Zonal Wind

Dissipating Stage



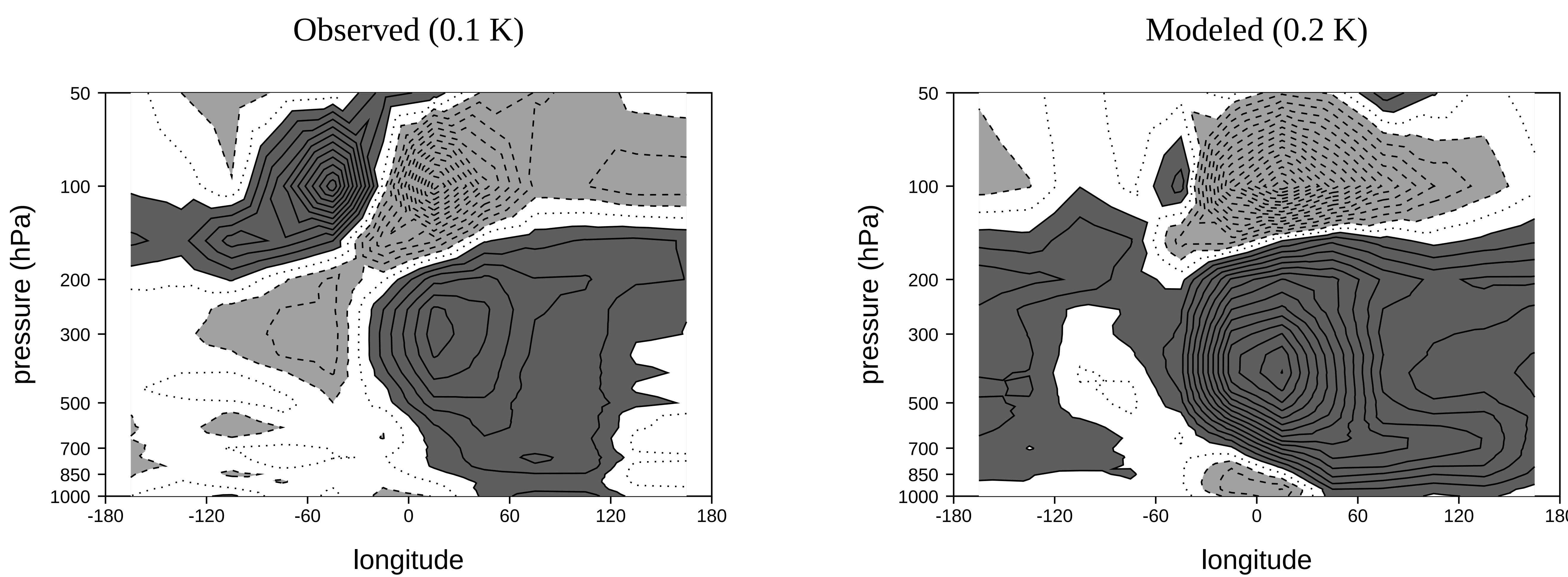
Composite Temperature Perturbation

Developing Stage



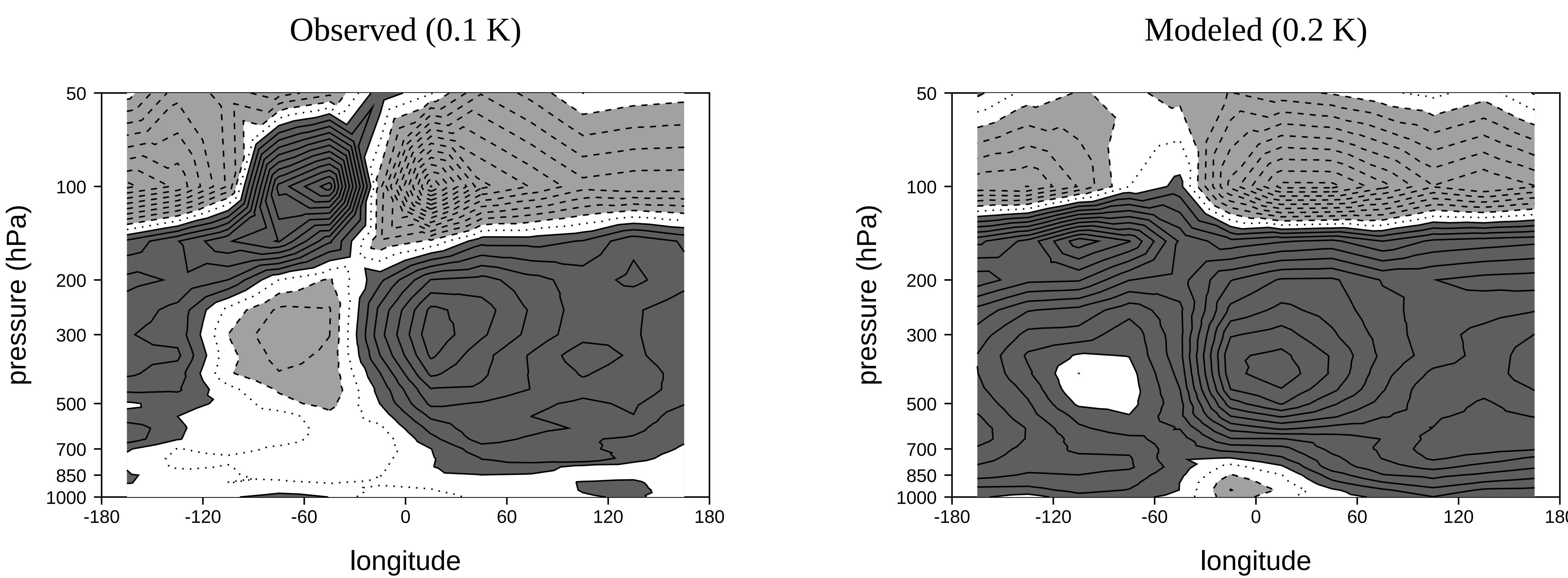
Composite Temperature Perturbation

Mature Stage



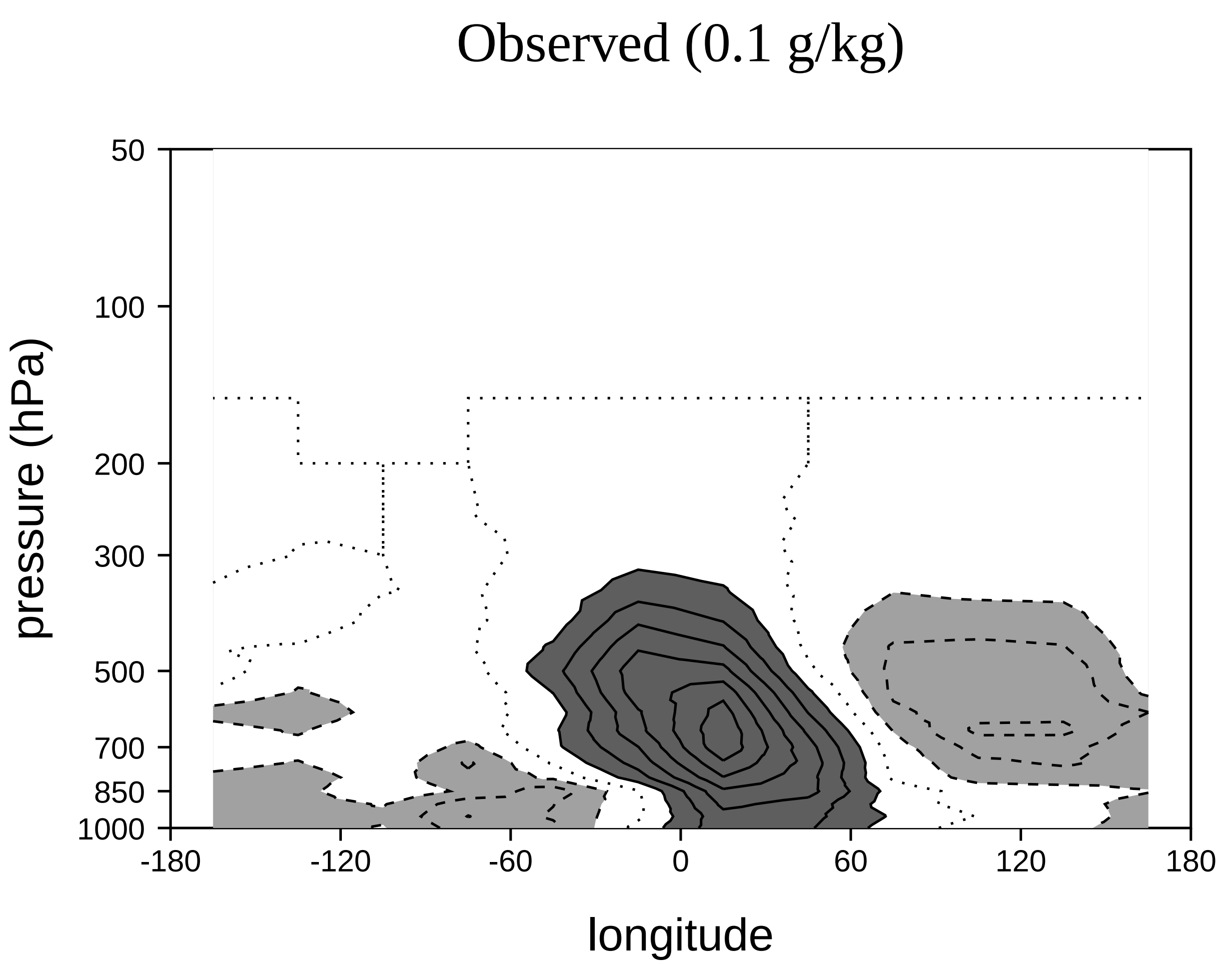
Composite Temperature Perturbation

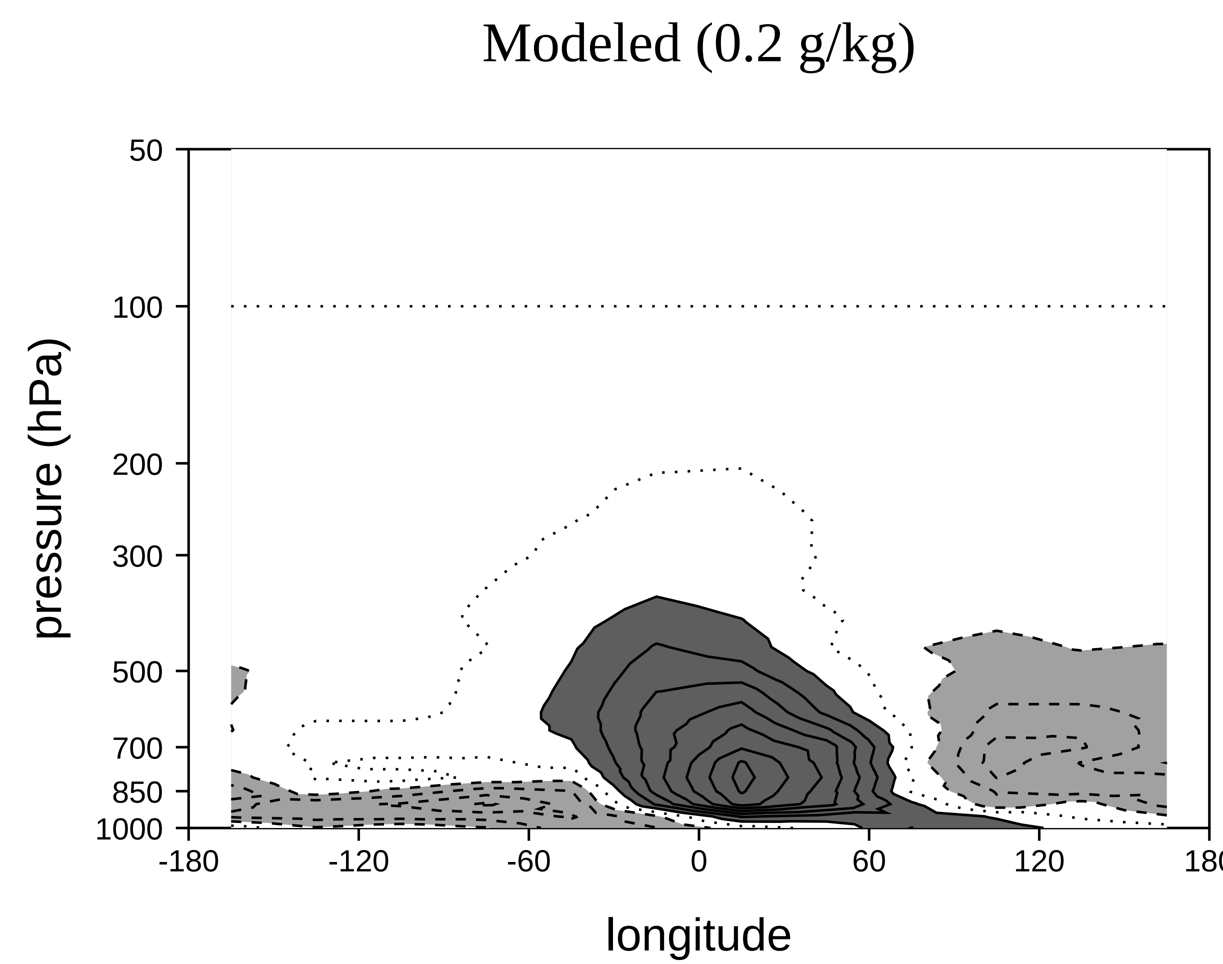
Dissipating Stage



Composite Moisture Perturbation

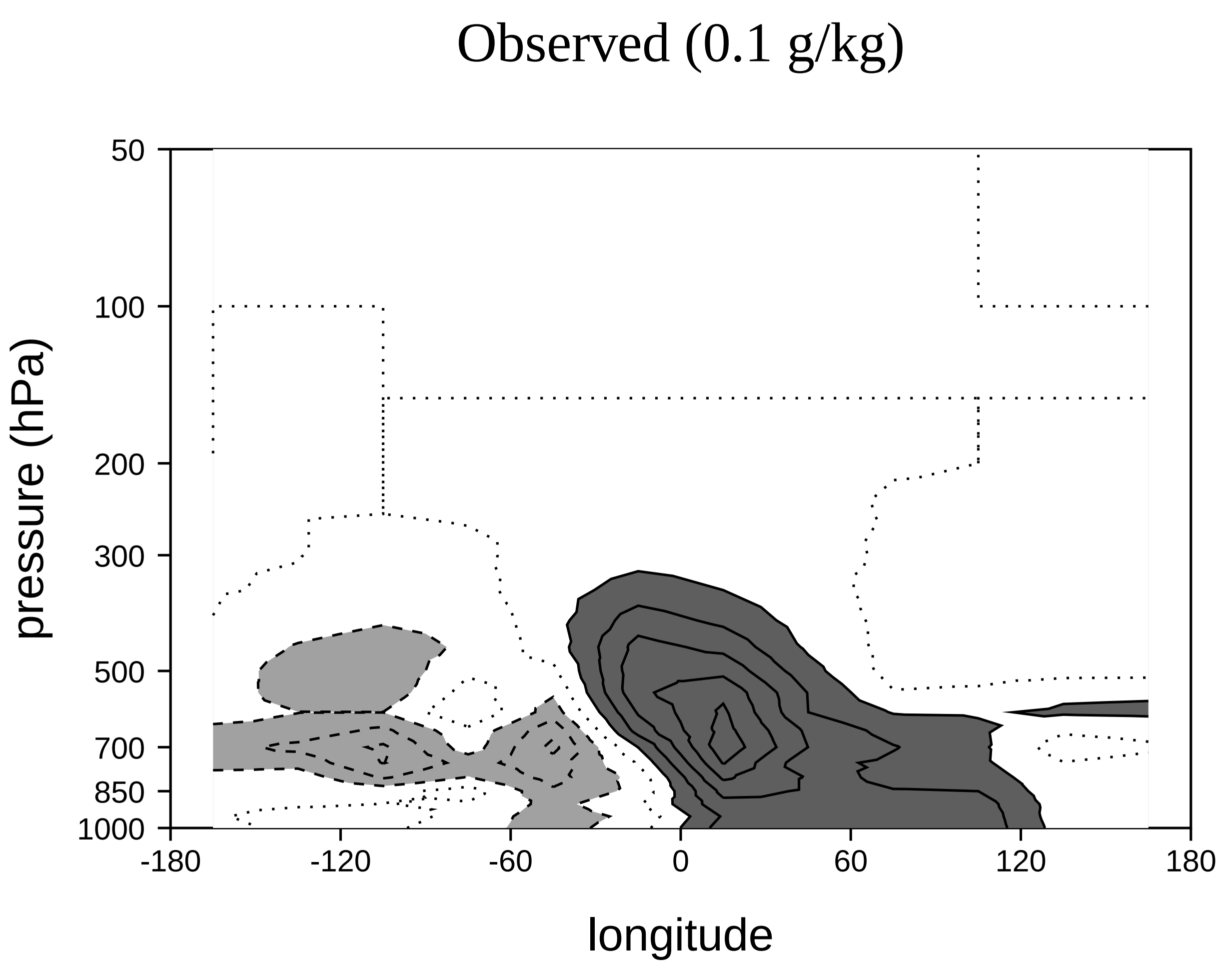
Developing Stage

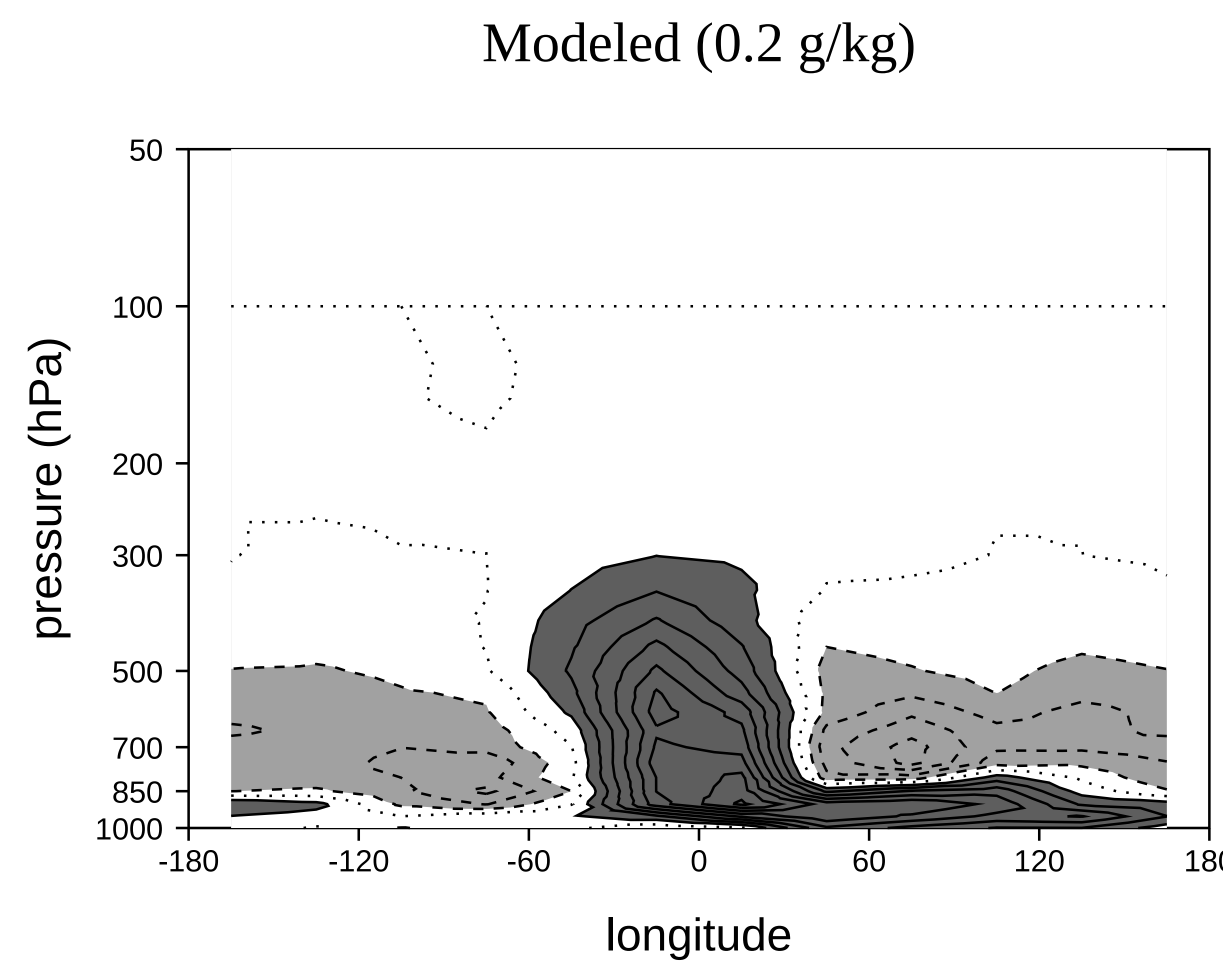




Composite Moisture Perturbation

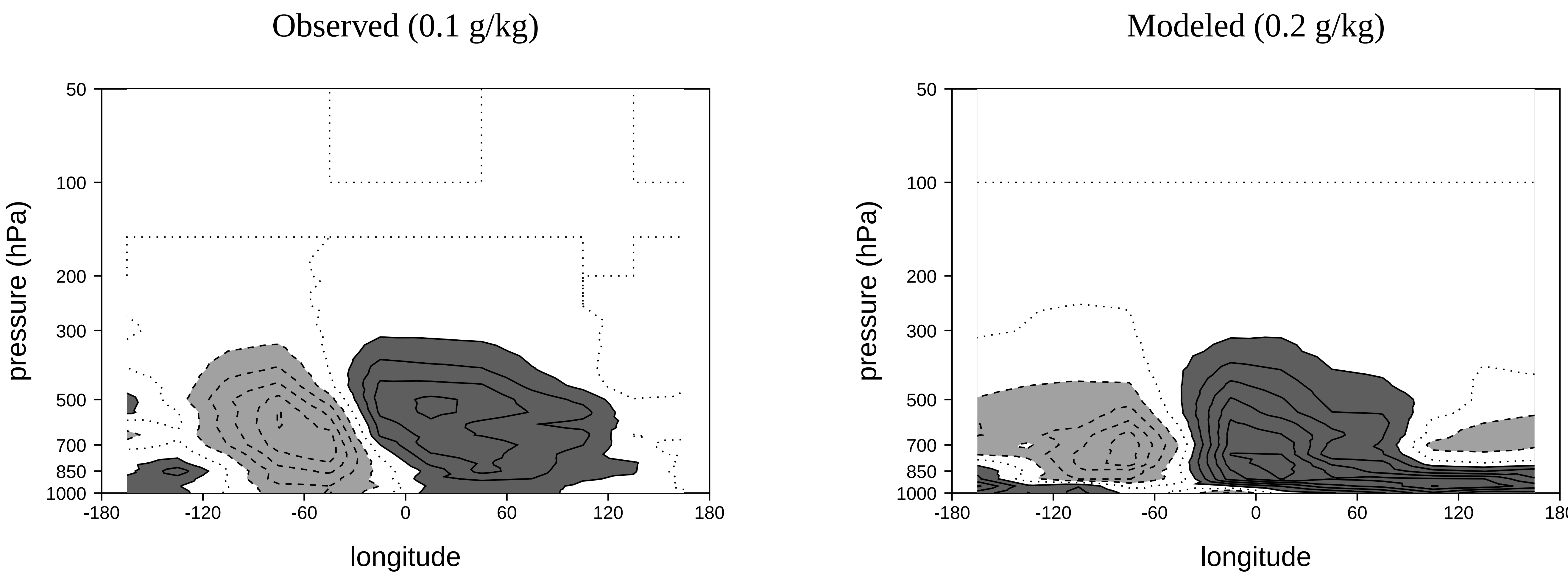
Mature Stage





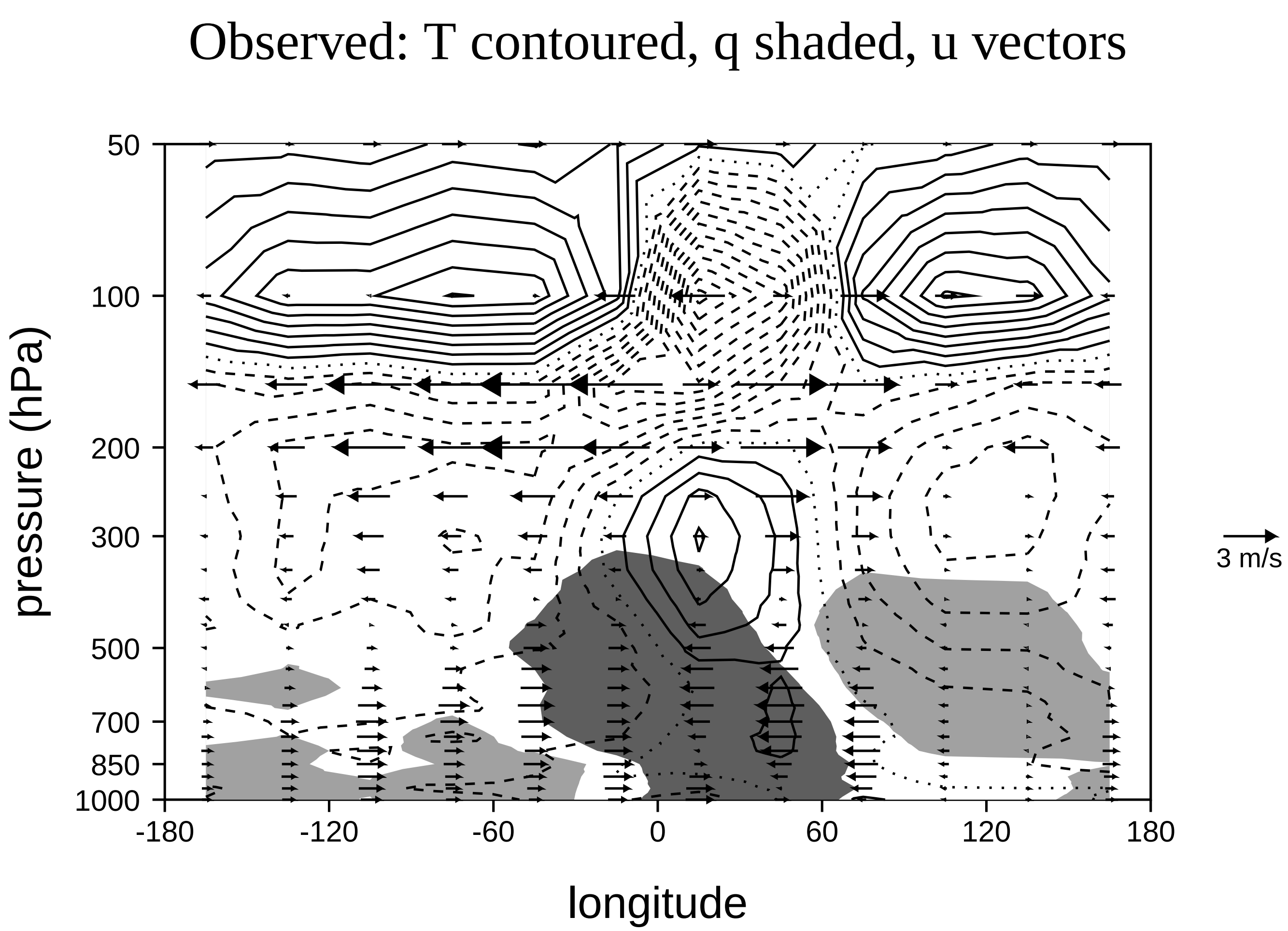
Composite Moisture Perturbation

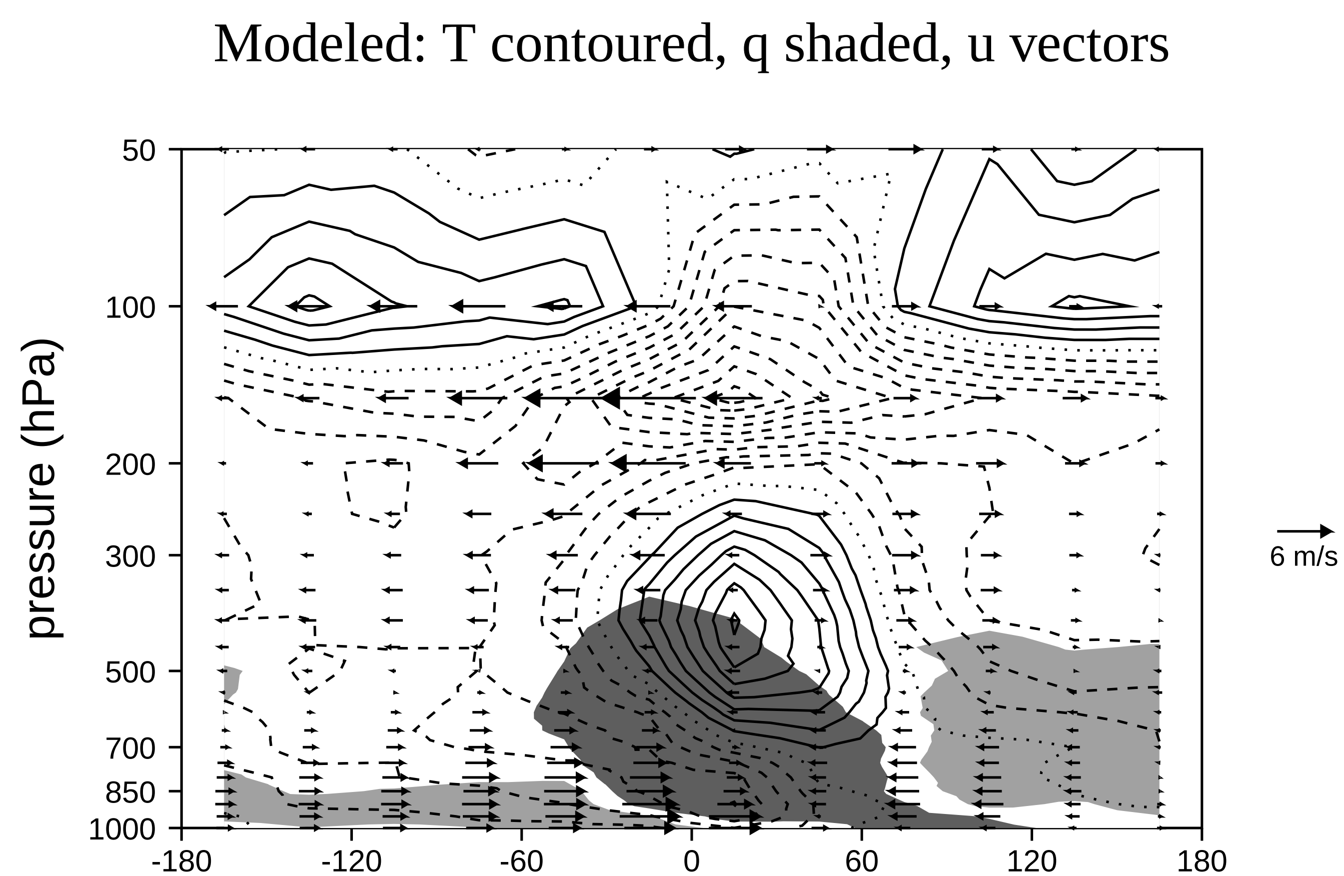
Dissipating Stage



Composite Vertical Structure

Developing Stage

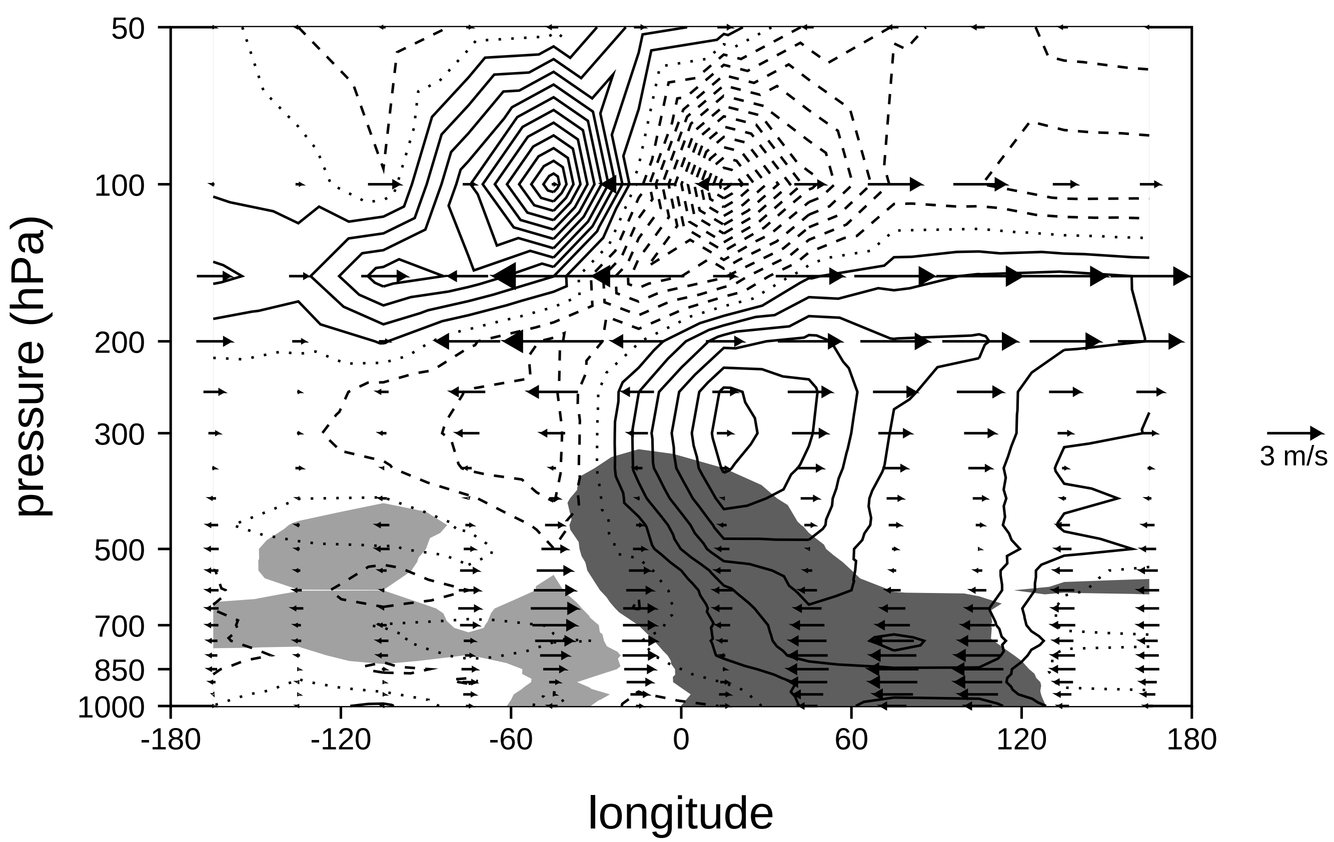




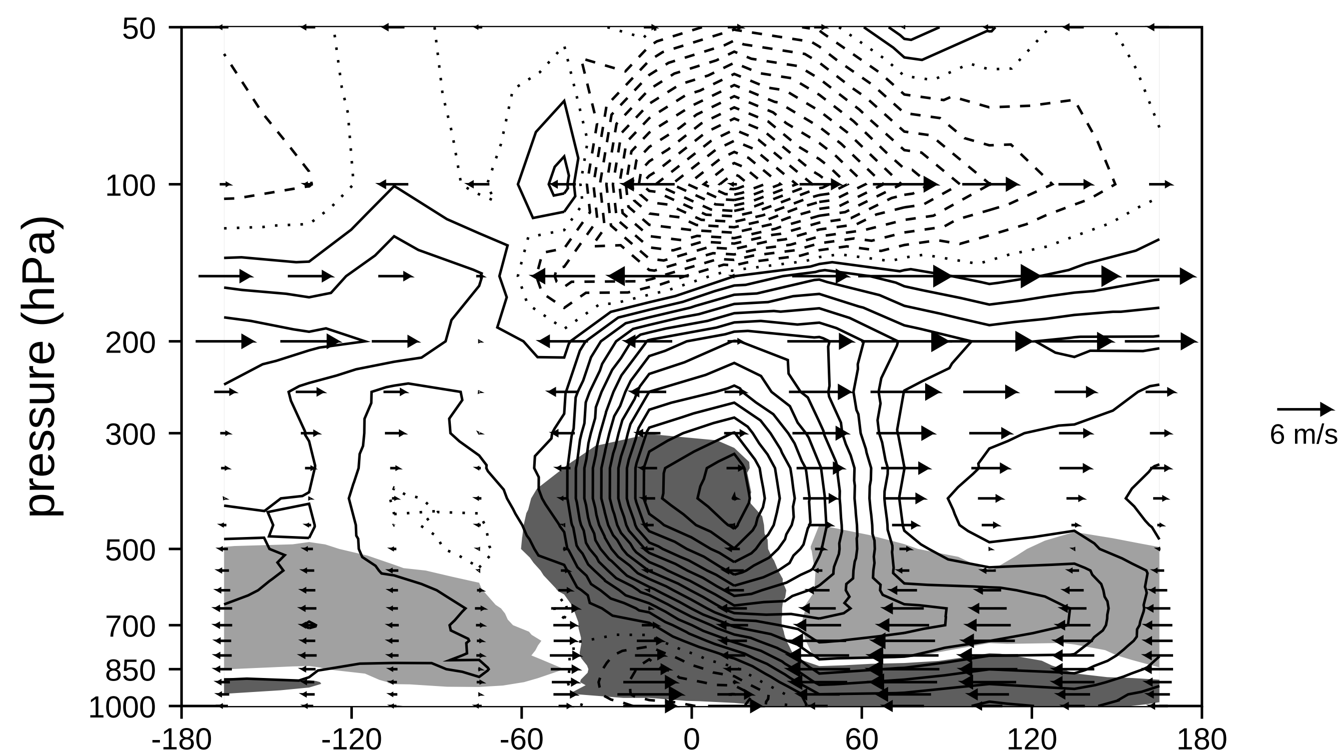
Composite Vertical Structure

Mature Stage

Observed: T contoured, q shaded, u vectors

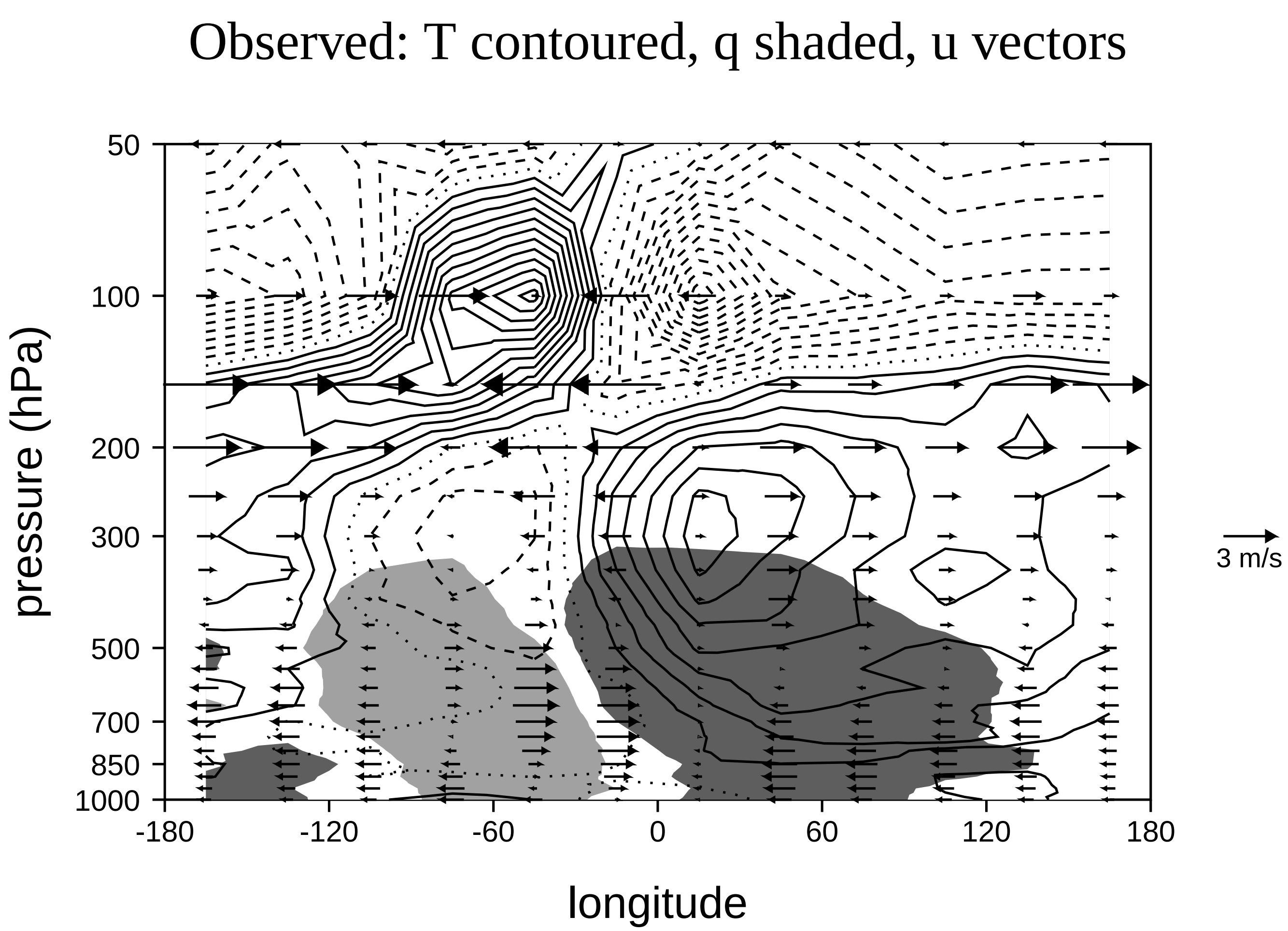


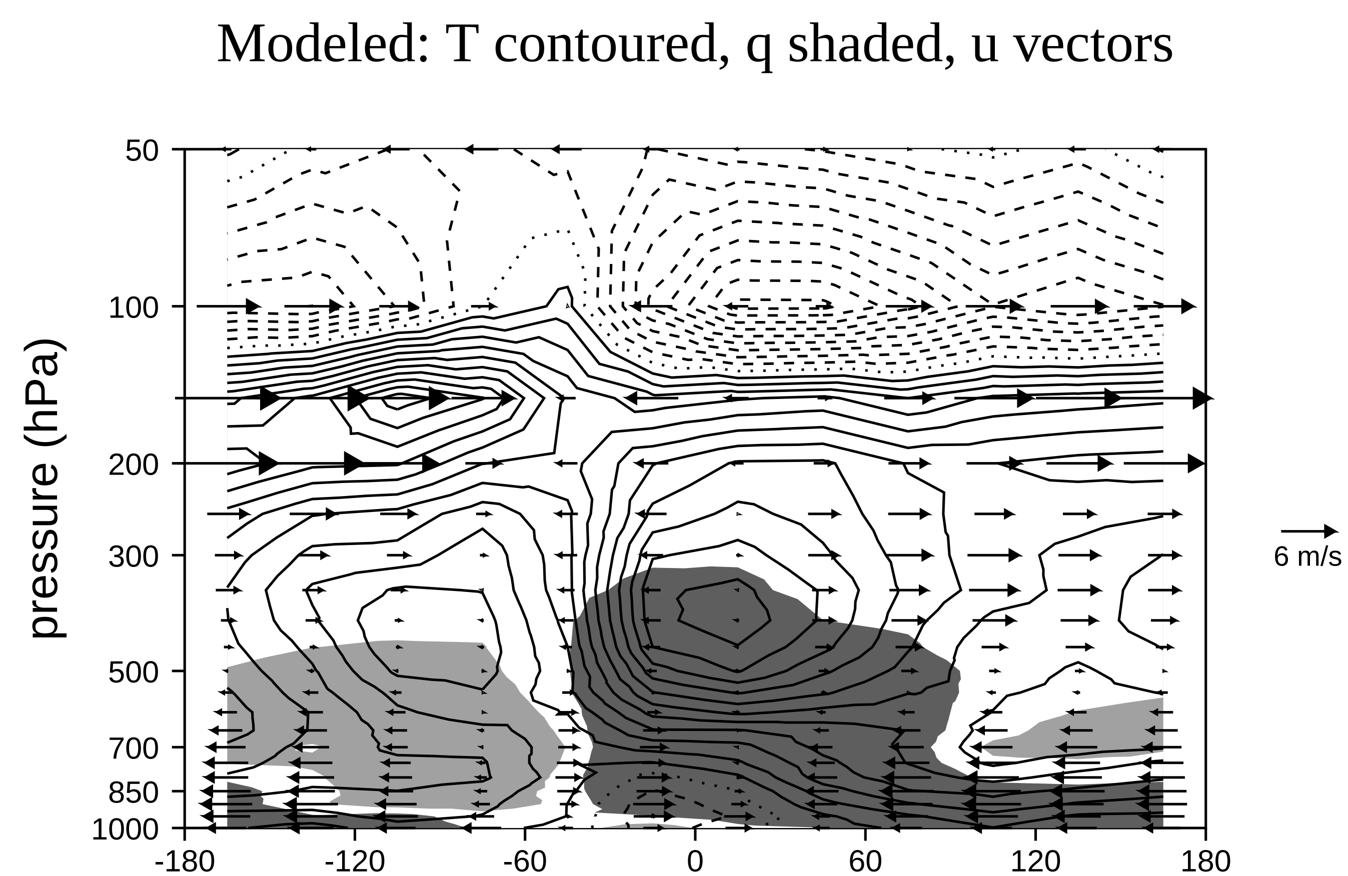
Modeled: T contoured, q shaded, u vectors



Composite Vertical Structure

Dissipating Stage

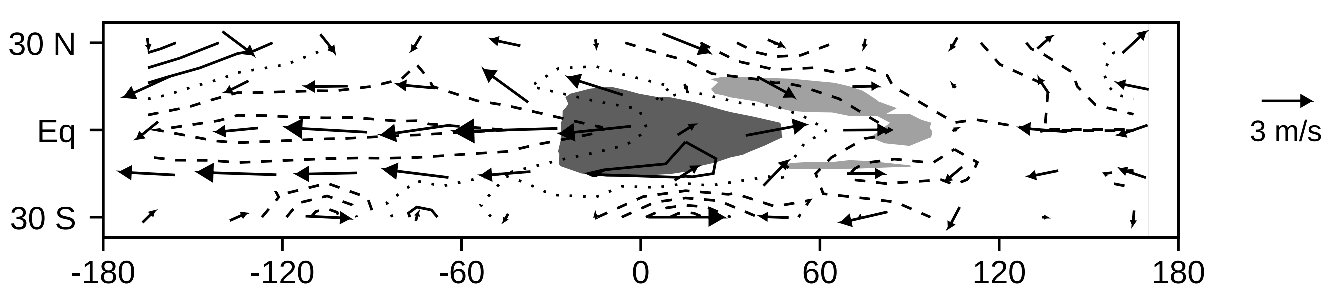




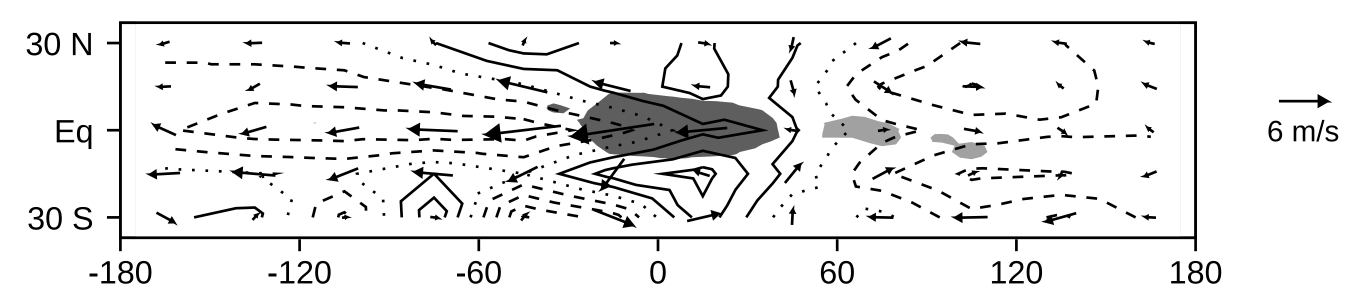
Composite Horizontal Structure

Developing Stage: T, rainfall, 200 hPa wind

Observed

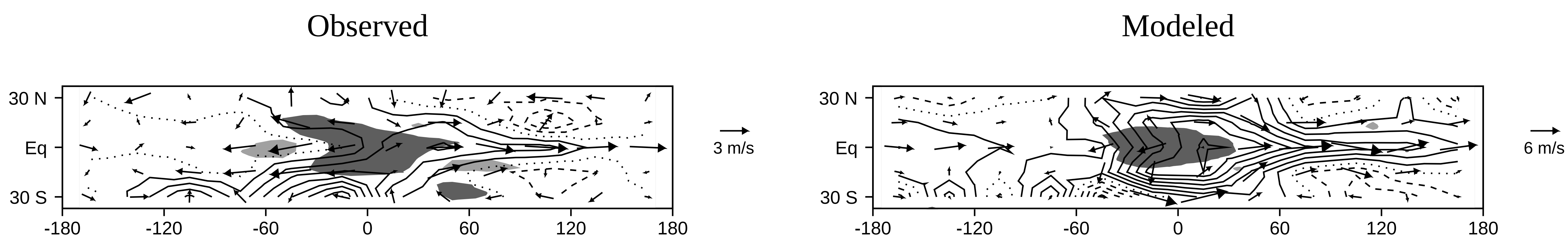


Modeled



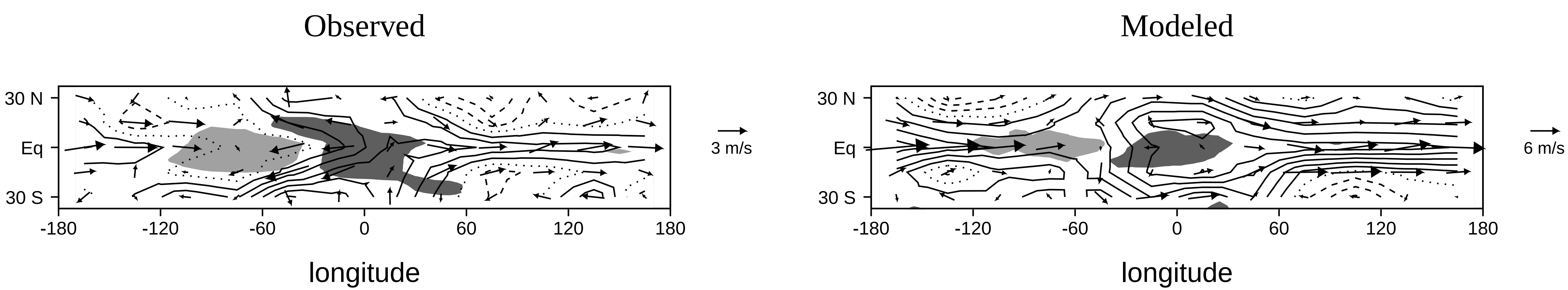
Composite Horizontal Structure

Mature Stage: T, rainfall, 200 hPa wind



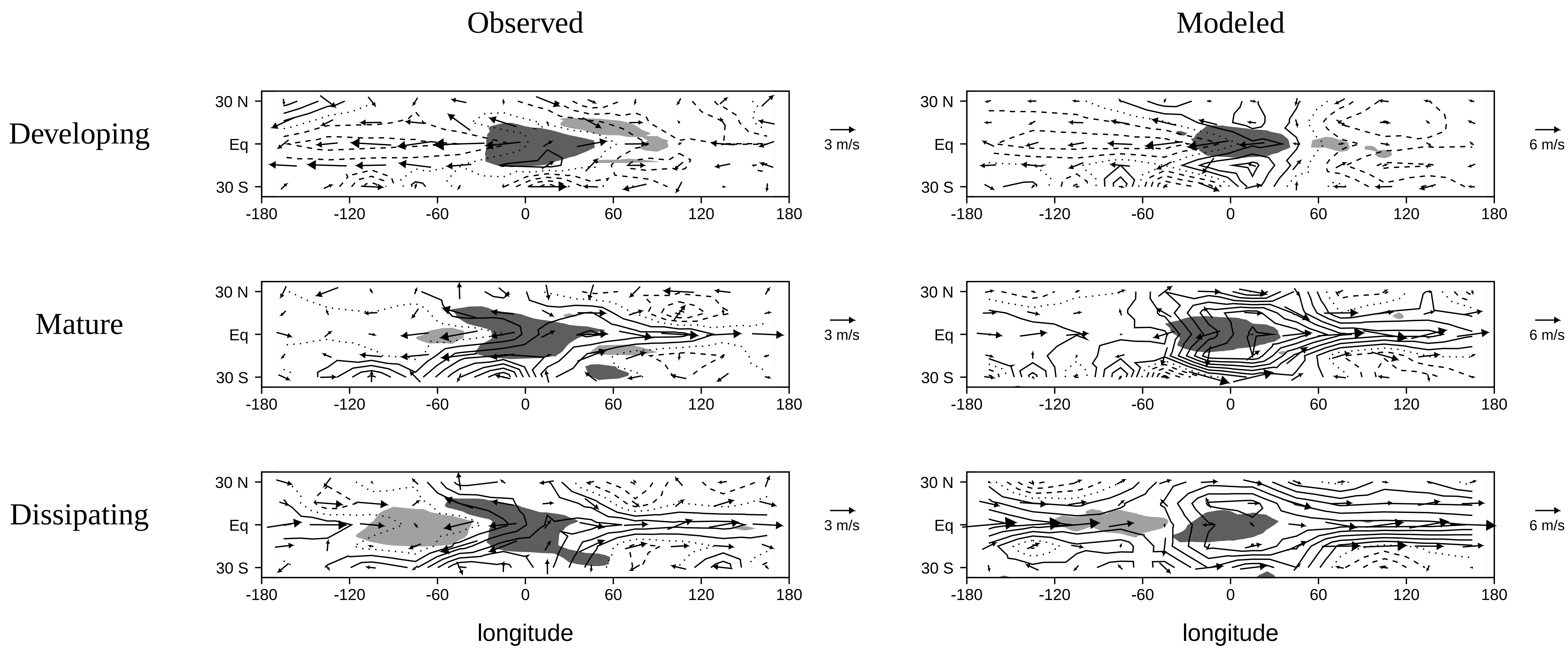
Composite Horizontal Structure

Dissipating Stage: T, rainfall, 200 hPa wind



Composite Horizontal Structure

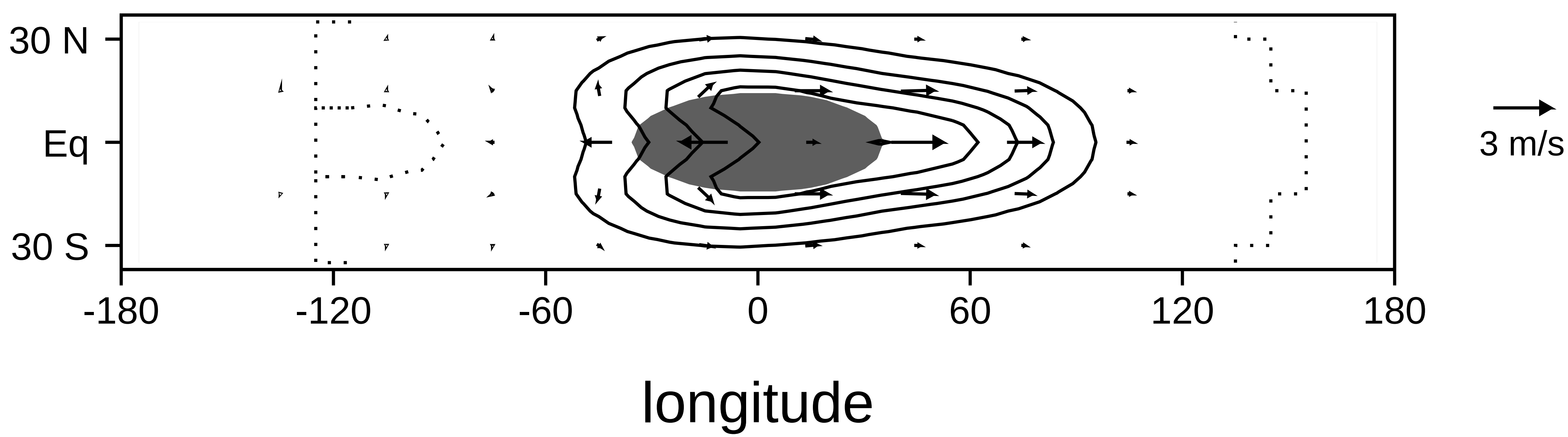
T, rainfall, 200 hPa wind



Dynamics

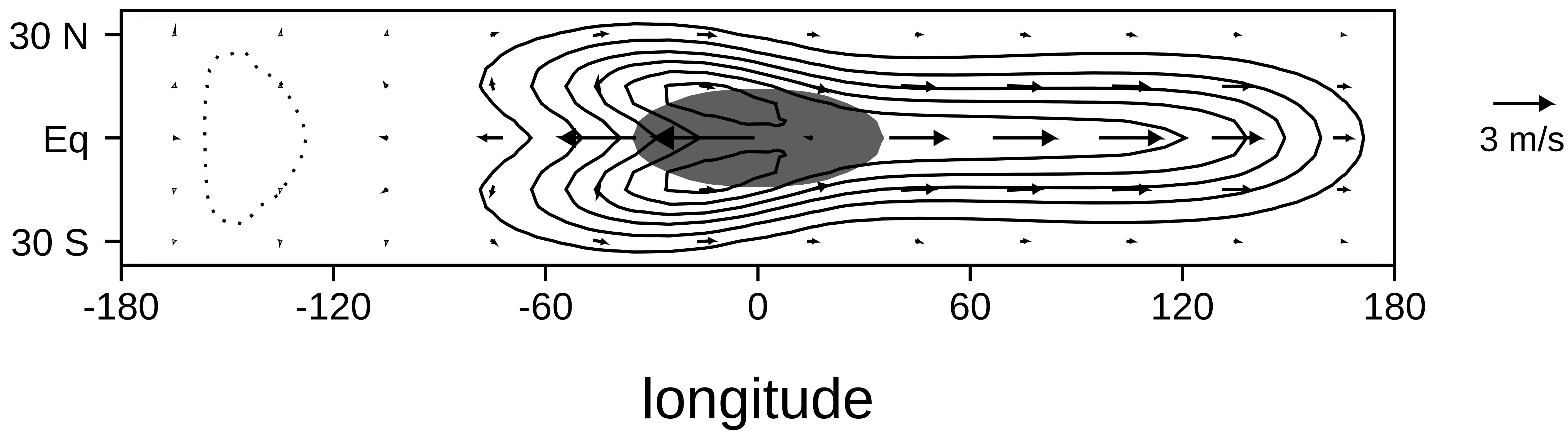
Inviscid Response to MJO-like Heat Source

T (contoured), Q (shaded), 200 hPa winds at 2 days



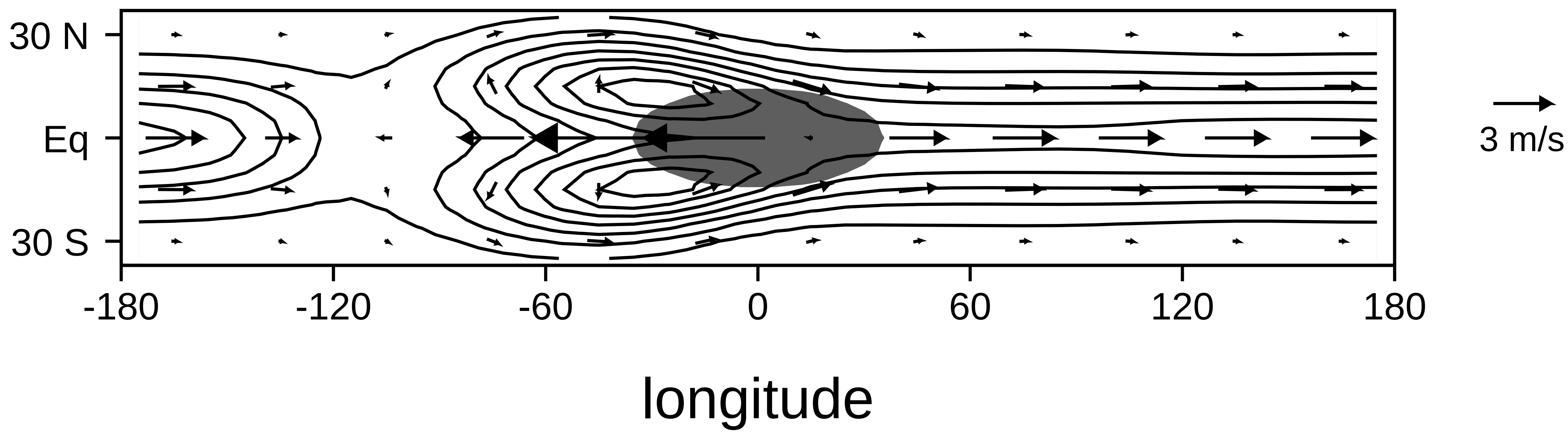
Inviscid Response to MJO-like Heat Source

T (contoured), Q (shaded), 200 hPa winds at 4 days



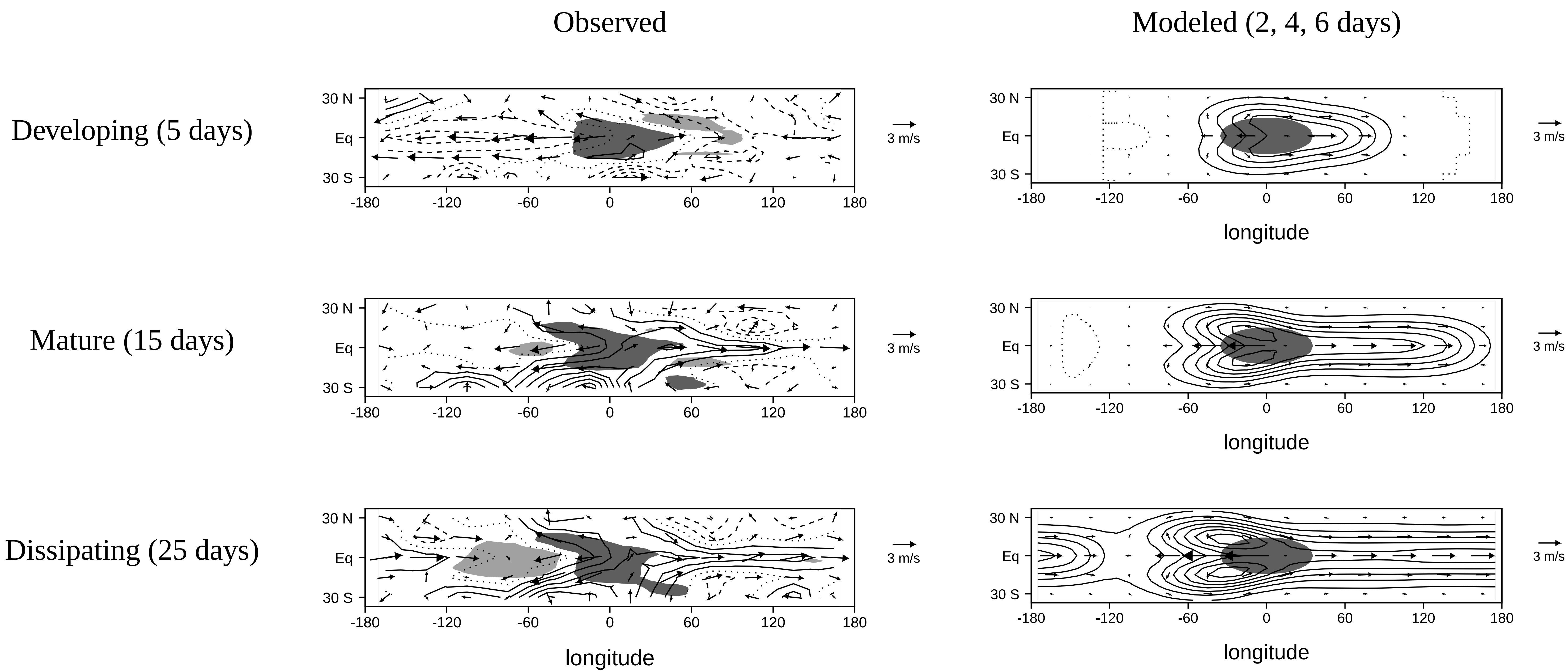
Inviscid Response to MJO-like Heat Source

T (contoured), Q (shaded), 200 hPa winds at 6 days



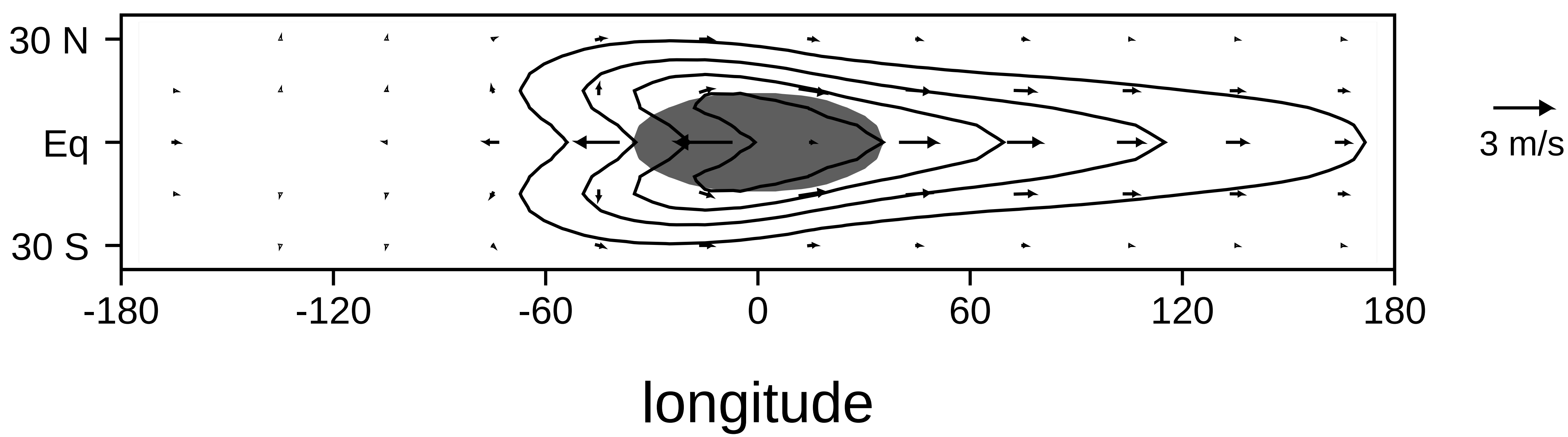
Observed MJO Structure vs. Inviscid Response to Heating

T contoured, Q/rainfall shaded, 200 hPa wind



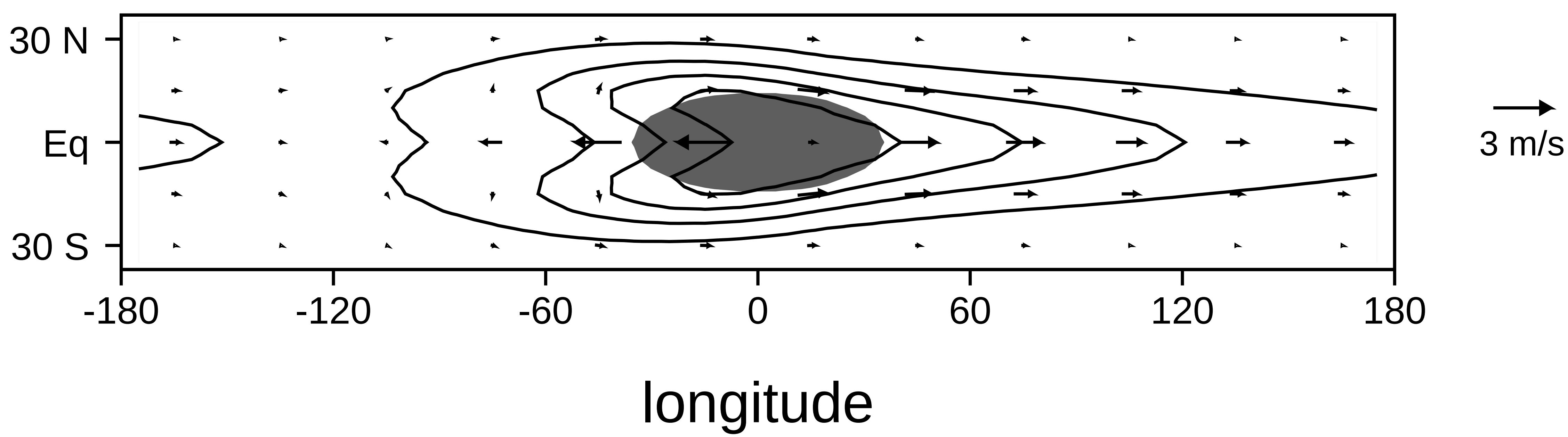
Damped Response to MJO-like Heat Source

T (contoured), Q (shaded), 200 hPa winds at 5 days



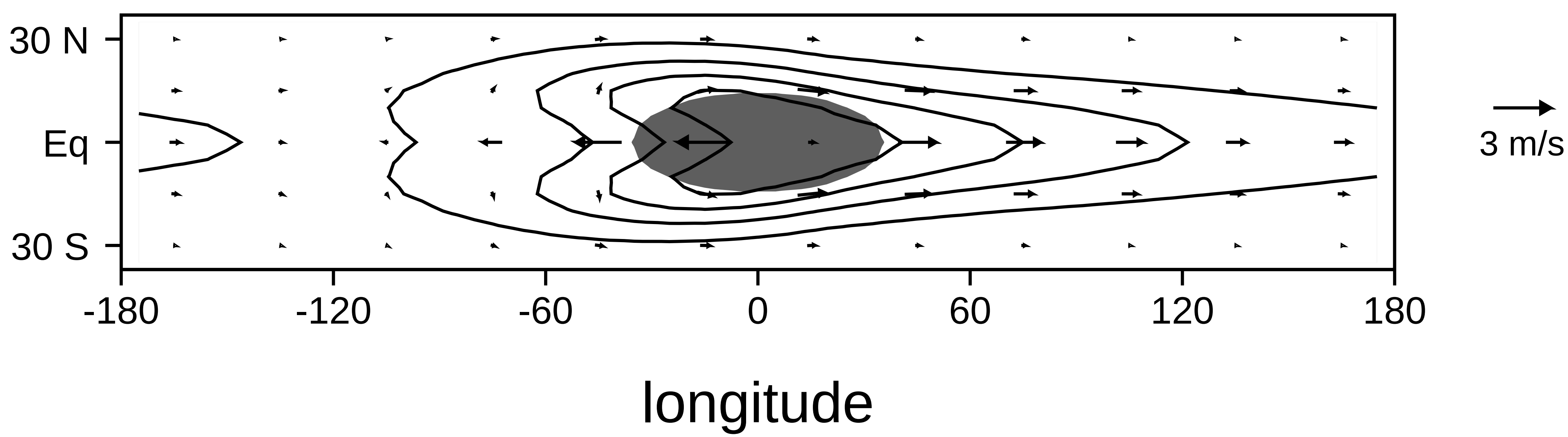
Damped Response to MJO-like Heat Source

T (contoured), Q (shaded), 200 hPa winds at 15 days



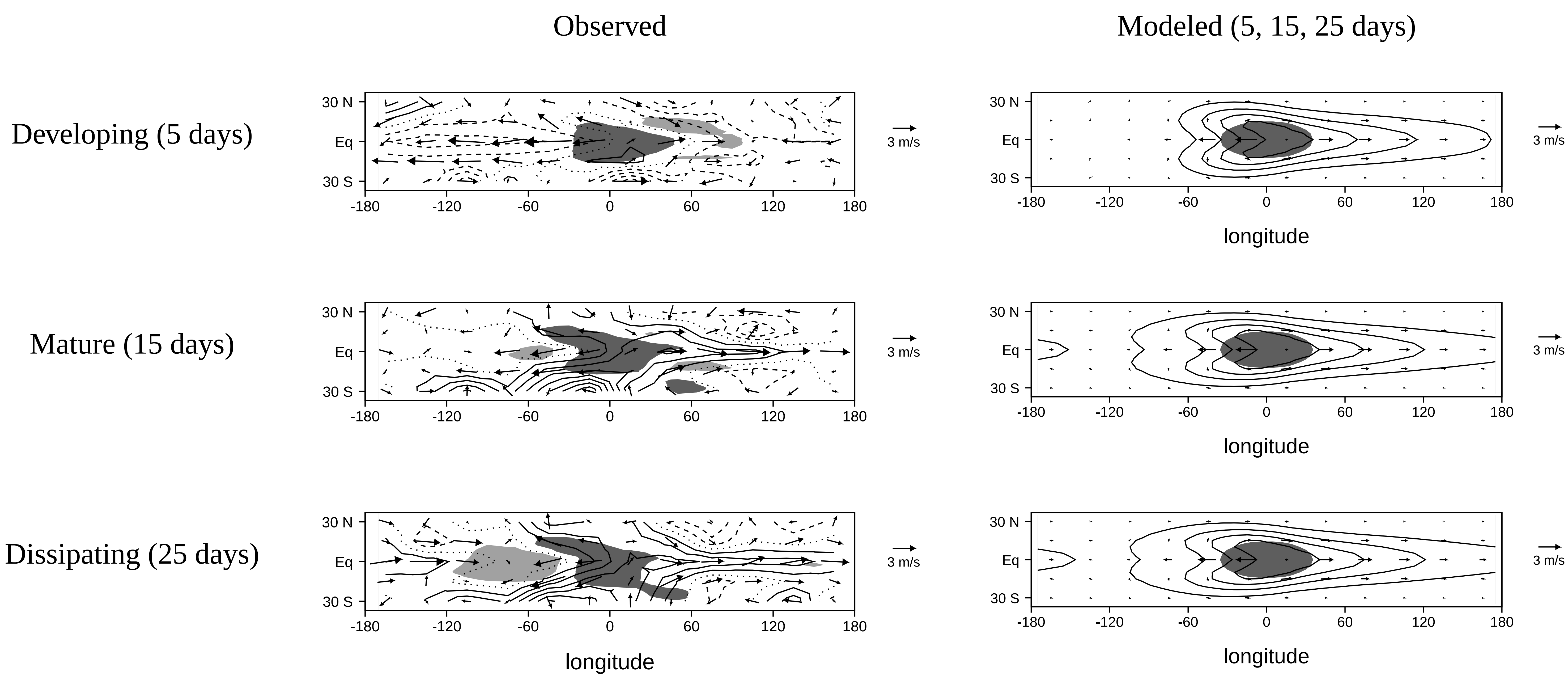
Damped Response to MJO-like Heat Source

T (contoured), Q (shaded), 200 hPa winds at 25 days



Observed MJO Structure vs. Damped Response to Heating

T contoured, Q/rainfall shaded, 200 hPa wind

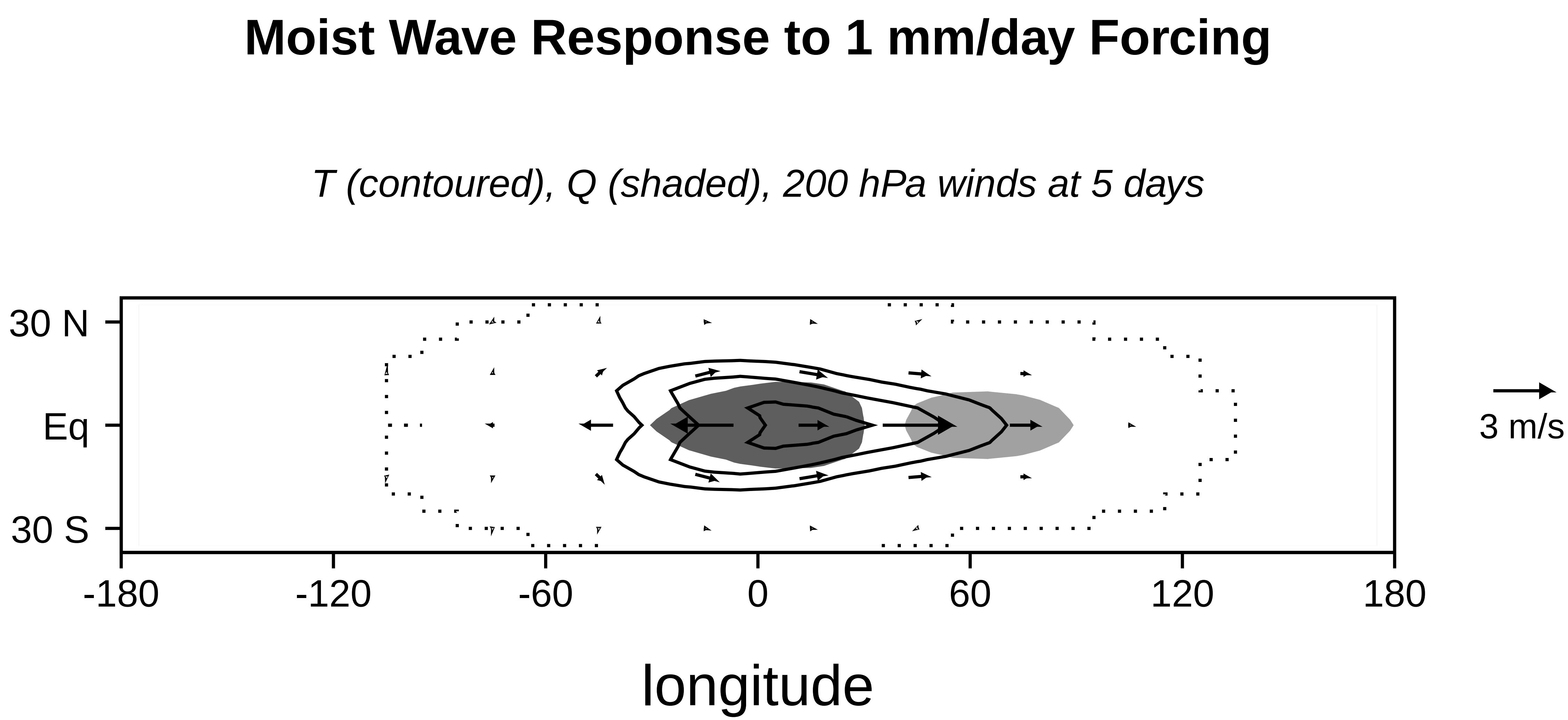


Moist Wave Response

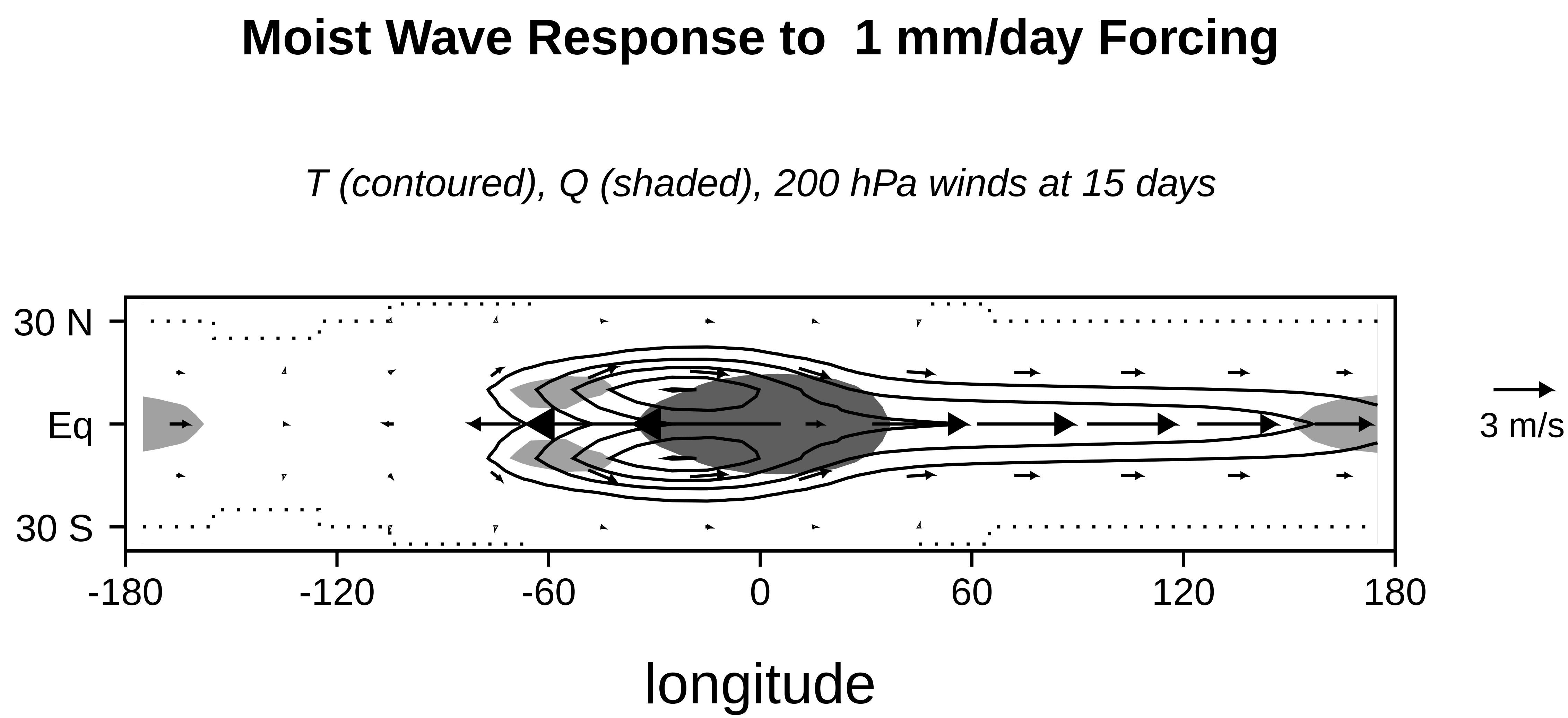
Modified Thermodynamic Equation

$$\frac{\partial T}{\partial t} = (1-\mu)S\ \omega + Q$$

μ : offset of adiabatic temperature change by convective heating

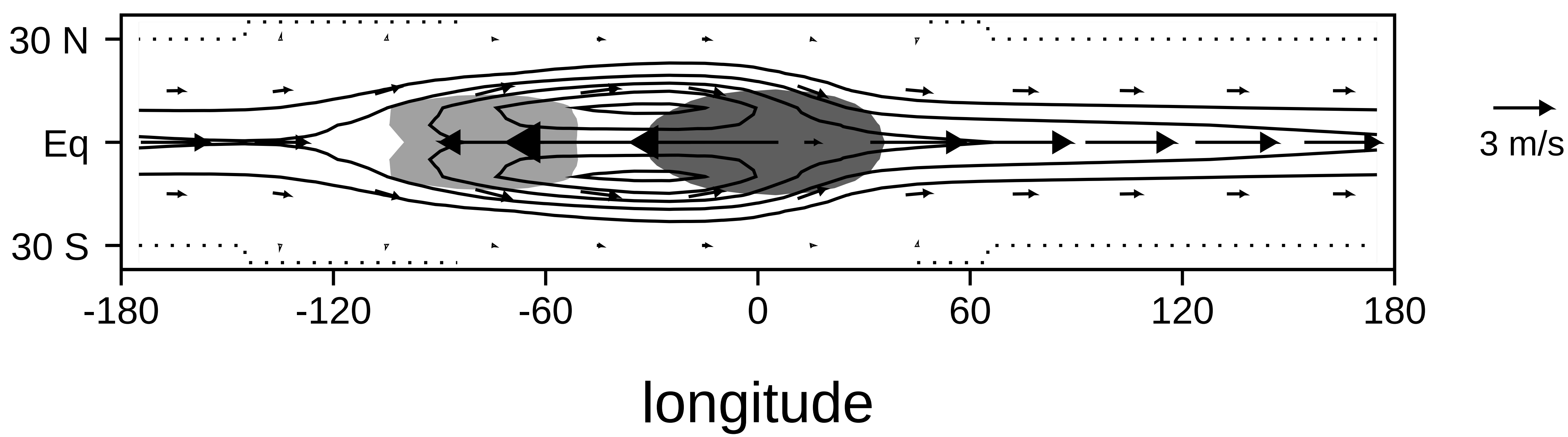


Moist Wave Response to 1 mm/day Forcing
T (contoured), Q (shaded), 200 hPa winds at 5 days
30 N
Eq
30 S
-180
-120
-60
0
60
120
180
longitude
3 m/s


Moist Wave Response to 1 mm/day Forcing
T (contoured), Q (shaded), 200 hPa winds at 15 days
30 N
Eq
30 S
-180
-120
-60
0
60
120
180
longitude
3 m/s

Moist Wave Response to 1 mm/day Forcing

T (contoured), Q (shaded), 200 hPa winds at 25 days



Observed MJO Structure vs. Moist Wave Response

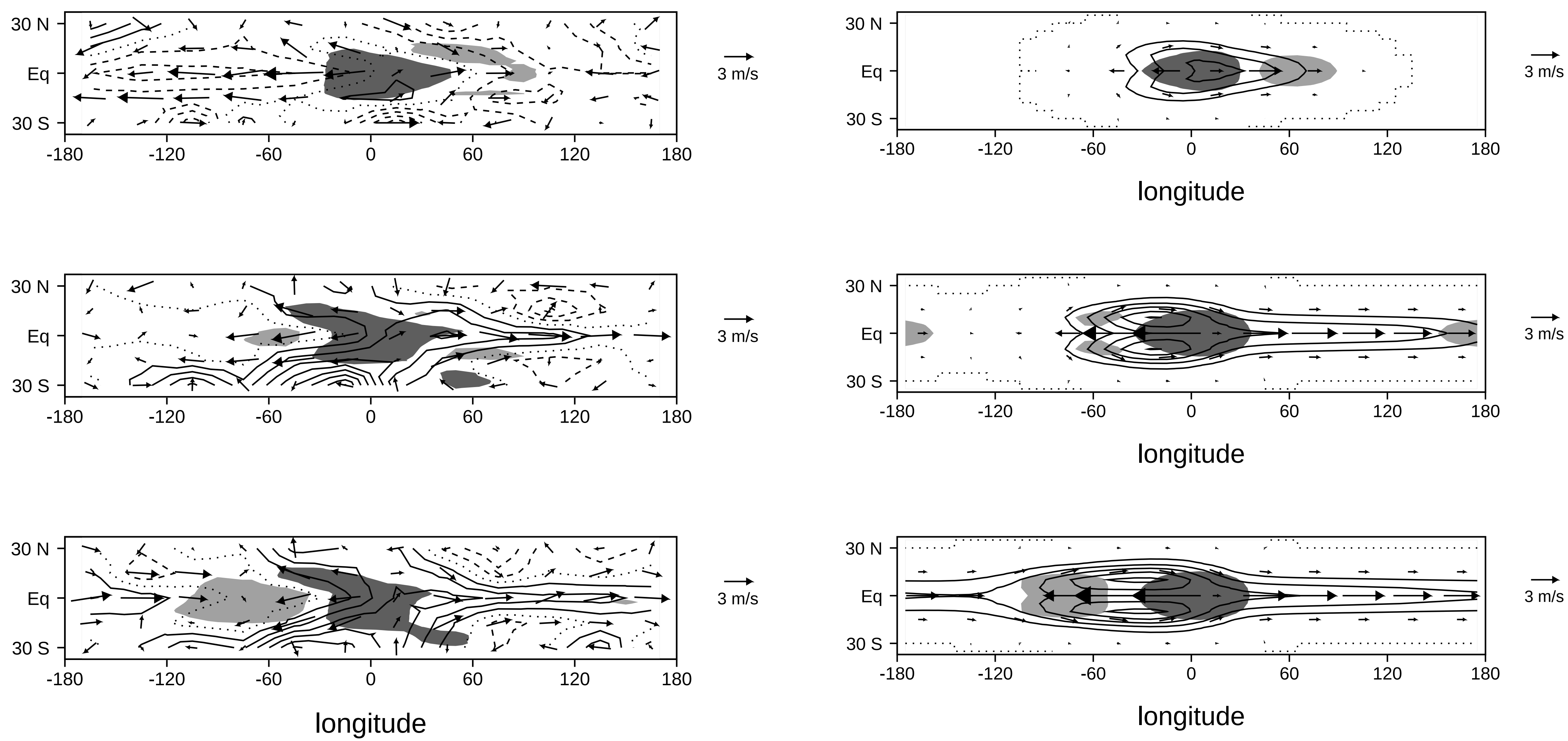
T contoured, Q/rainfall shaded, 200 hPa wind

Observed | Modeled (5, 15, 25 days)

Developing (5 days)

Mature (15 days)

Dissipating (25 days)

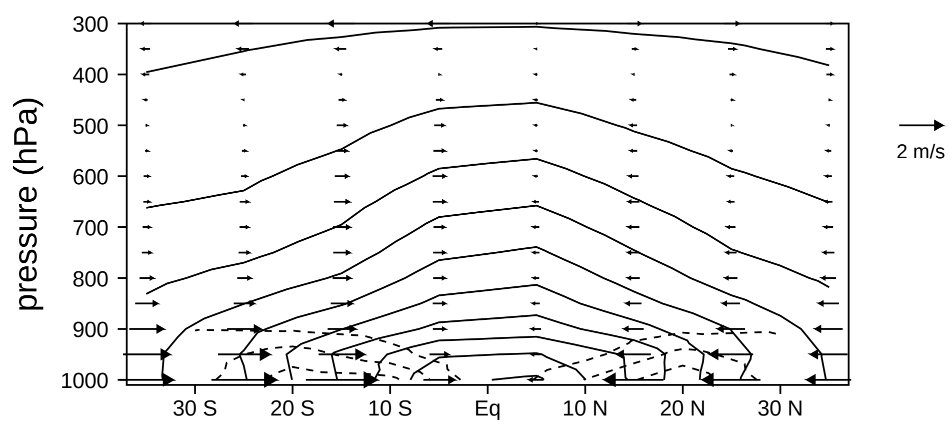


What’s the forcing?

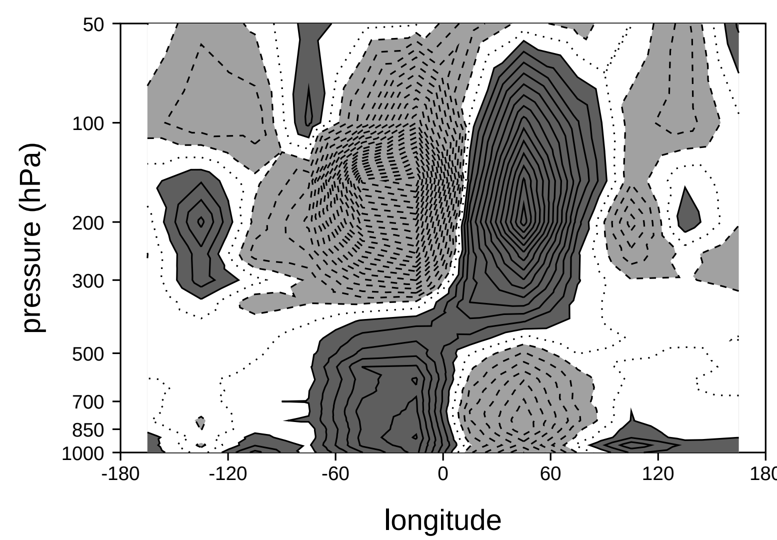
Meridional Moisture Transport

Mature Simulated MJO

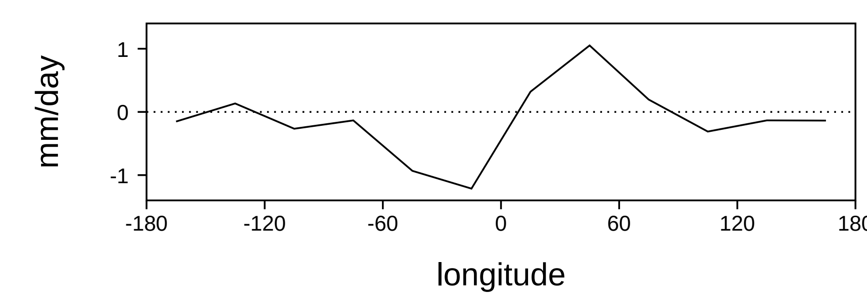
Basic State q, v, dq/dt



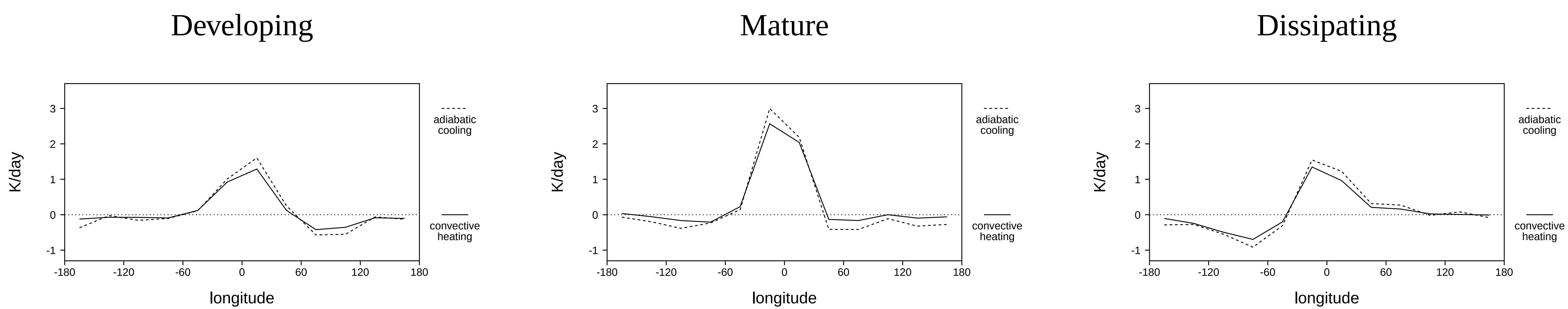
v_eq' at 15 N/S



dPW/dt at 15 N/S

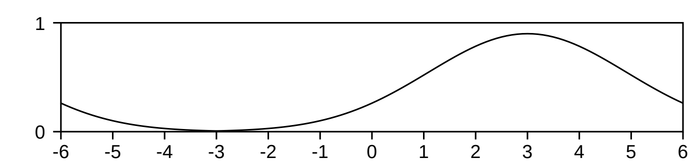


Offset Check: Simulated MJO

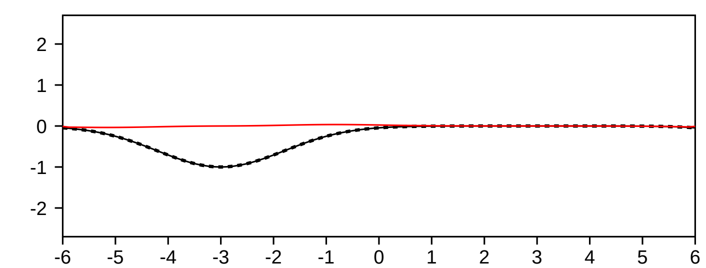


Effects of Variable Offset: Shallow Water Example

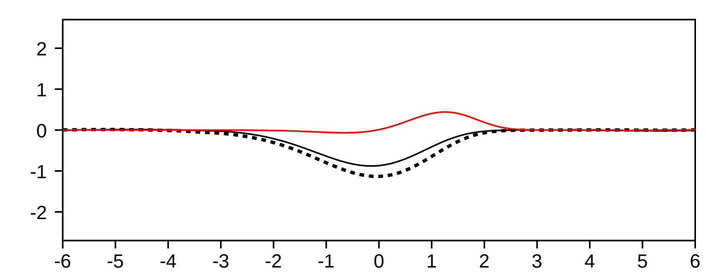
offset parameter μ



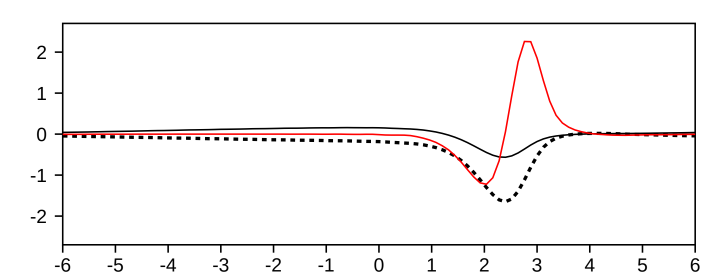
u,h,Q at t=0



u,h,Q at t=3



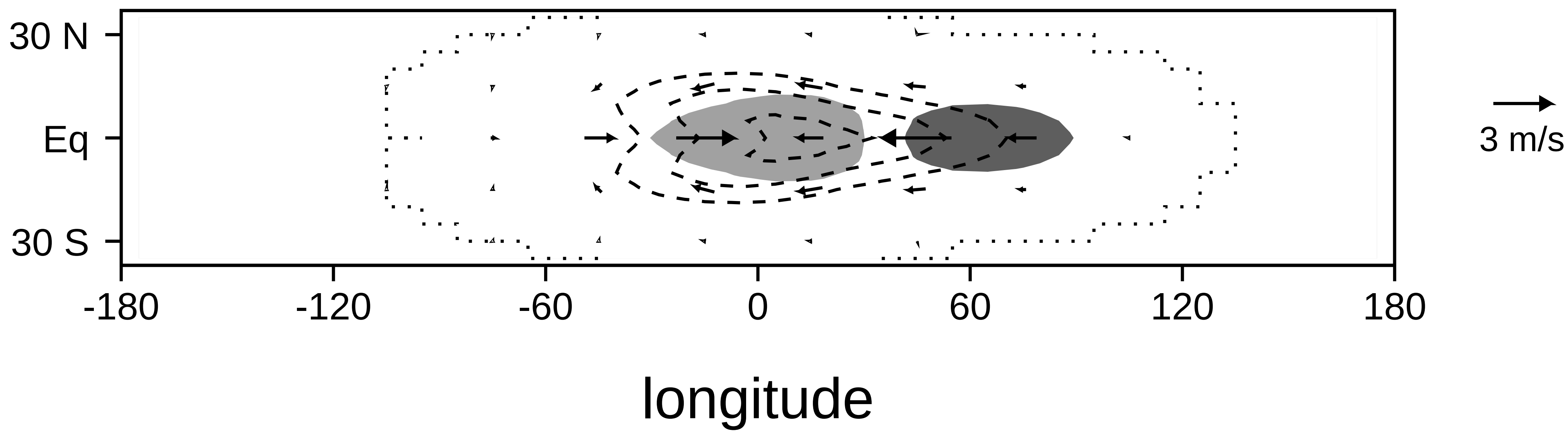
u,h,Q at t=7



Origin of Initiating Kelvin Wave

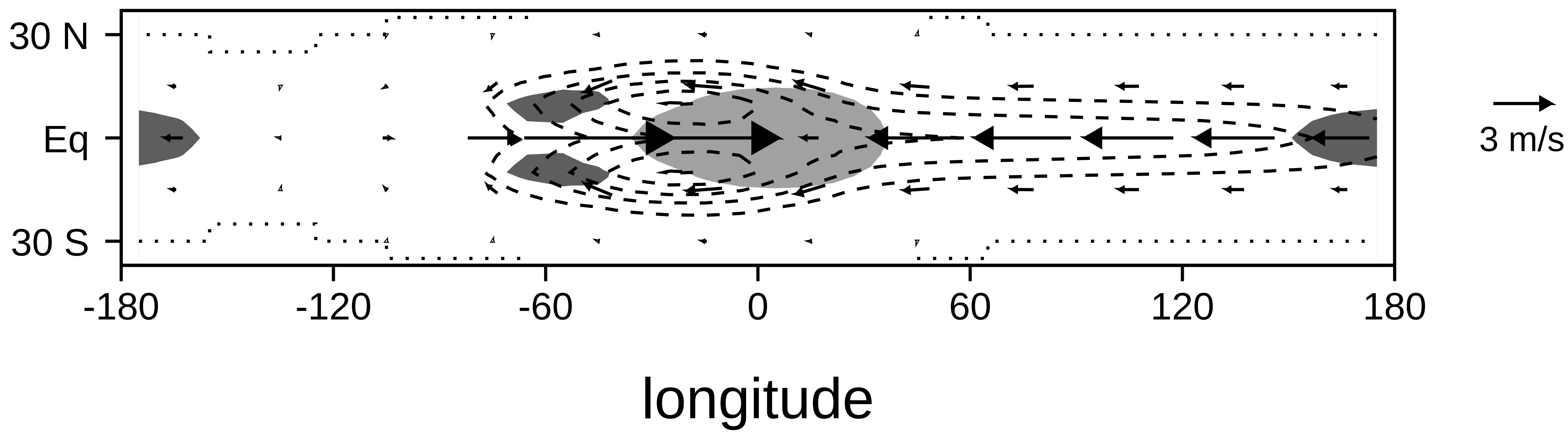
Moist Wave Response to -1 mm/day Forcing

T (contoured), Q (shaded), 200 hPa winds at 5 days



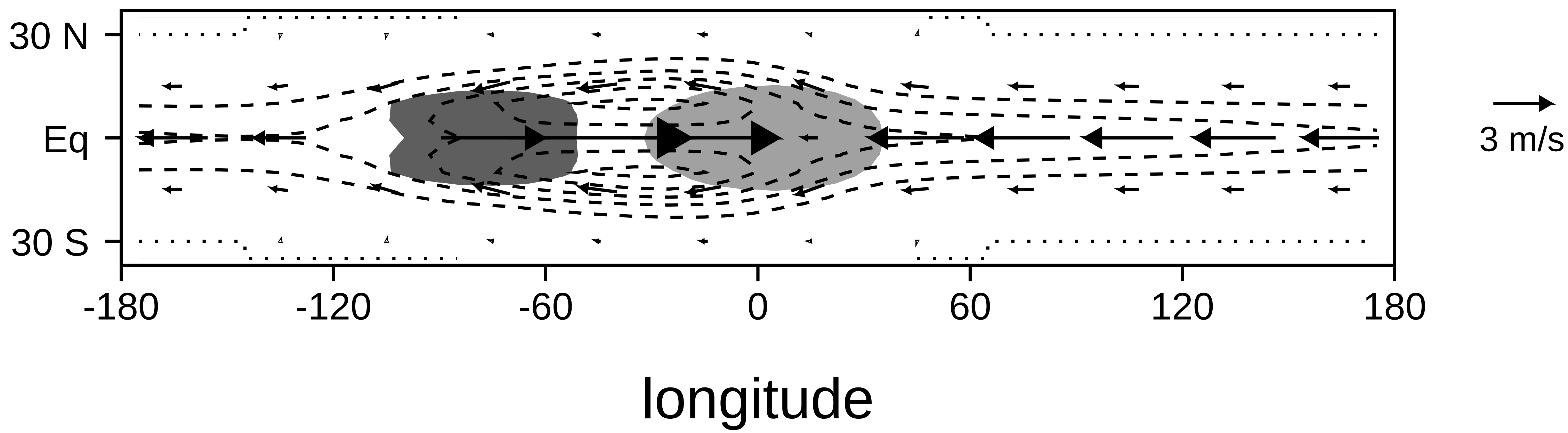
Moist Wave Response to -1 mm/day Forcing

T (contoured), Q (shaded), 200 hPa winds at 15 days



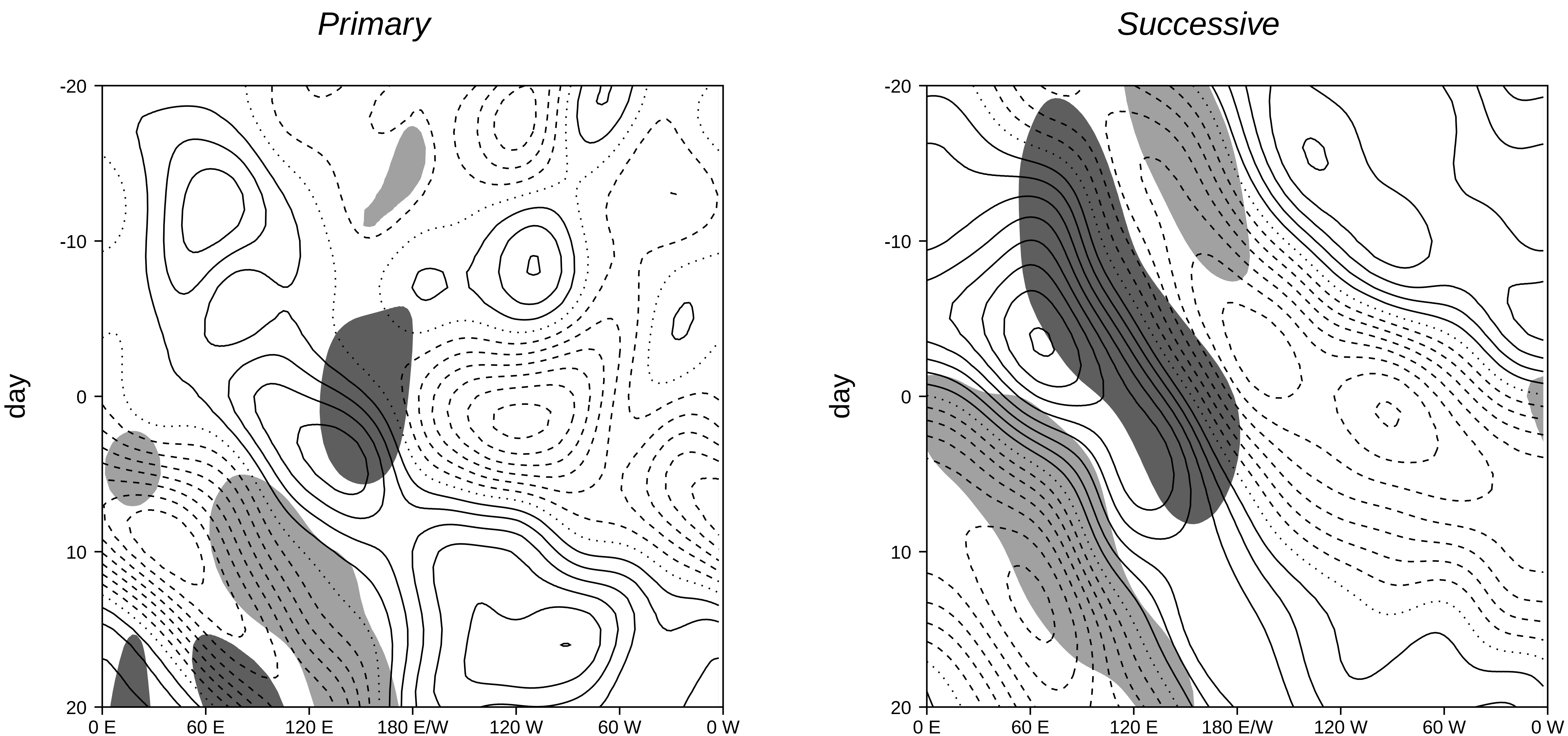
Moist Wave Response to -1 mm/day Forcing

T (contoured), Q (shaded), 200 hPa winds at 25 days



Role of Kelvin Waves in Primary and Successive MJOs

Straub (2013): MJO OLR (shaded), u_200 - u_850 (contoured)



Summary

- MJO convection is initiated and dissipated by planetary scale Kelvin waves

- Active and suppressed phases of the MJO excite the two phases of Kelvin waves

- Over the warm pool, convective heating mostly offsets adiabatic cooling due to vertical motion, but the offset is much weaker elsewhere

Possible Future Research

Spontaneous TC formation at 1^o *resolution*